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OBSERVATIONS UPON THE DEVELOPMENT OF THE SKULL IN NEOTOMA FUSCIPES; A CONTRIBUTION TO THE MORPHOLOGY OF THE RODENTIA.

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While collecting in the vicinity of San Bernardino, California, during the spring of 1887, Mr. F. Stephens secured a female specimen of *Neotoma fuscipes* which was far advanced in pregnancy at the time of capture.

From this source I obtained an embryo of this wood rat, and am under great obligations to Mr. Stephens for the opportunity it has given me to record something in reference to its developmental anatomy, and my observations upon it will form the subject of the present paper.

Neotoma fuscipes is by no means a common species, being restricted in its geographical range to certain parts of the Pacific coast and northern Mexico. I have never personally taken this representative of the genus, but I have on numerous occasions secured its near relative, the form found throughout New Mexico, *Neotoma cinerea*, of which I have a series of skeletons at my hand, of my own preparing.

Just prior to birth, the embryo of *N. fuscipes* is quite hairless, and measures in its total length about 4cms. between vertex and tip of tail, presenting all the general characteristics of the embryo of this genus of the Muridæ. For its total length, the head measures 1 centimetre and some few millimetres and in drawing my plates which illustrate this account of its skull, I have enlarged these parts six diameters.

In working out the skull of this little rodent I have had to make constant reference to the following works, which, though the only ones available to me at the time, by no means pretend to be a complete bibliography of the subject, while, on the other hand, they constitute the best aids we possess to embryological research upon the mammalia:

Allen, Harrison, M. D. On a revision of the Ethmoid Bone in the Mammalia. Bull. Mus. Comp. Anat. Harvard College, Cambridge, Mass. Nov. 1882, pls. 1–7, pp. 135–164.

Balfour, F. M. A Treatise on Comparative Embryology. London, 1881.

Flower, W. H. An Introduction to the Osteology of the Mammalia, 1885. Article, "Mammalia" Encyc. Brit. 9th Edition, 1883.

Forbes, W. A. Coll. Scientific Memoirs.

Garrod, A. H. Coll. Scientific Memoirs.

Huxley, T. H. Elements of Comparative Anatomy. London. 1864. A Manual of the Anatomy of Vertebrated Animals, London, 1871.

Owen, Sir Richard. Comparative Anatomy and Physiology of Vertebrates.

Parker, W. K. The Morphology of the Skull. 1887.
On the Structure and Development of the Skull in the Mammalia. Phil. Trans. of the Royal Soc. 1885.

Parker, W. N. Wiedersheim's Comparative Anatomy of Vertebrates. 1886.

Parker, T. J. Zoötomy. London, 1884.

Besides numerous special memoirs of other authors and laborers in similar fields.

A general survey of the Skull and of the investing bones.

Professor Parker, I think, would say that the embryo before me was in the "fourth stage," inasmuch as endostosis has at many points invaded the cartilaginous parts, while ossification is more than apparent in such investing bones of the primordial skull as the interparietal and the supraoccipital, which latter is as yet in two distinct lateral moieties.

We might describe the form of the skull of this embryo as being subconoid, the apex being represented by the snout, and the hemispherical base by the region of the cranial vault and infraoccipital parts.

Judging from the skull of an adult of another species, *Neotoma cinerea*, this form materially changes by the time the animal arrives at maturity, for then the skull is quite flat for its entire superior aspect, and from incisor teeth to occipital condyles. Most of the structures of the basis cranii are to be found in a plane parallel to this superior surface. Then, too, frontal, parietal, and interparietal bones do not quite fulfil in the skull of the adult what they promise in the embryo; by this I mean that as growth proceeds the mesial portions gain area over the first and last mentioned elements, and come to be the chief agents in forming the cranial roof.

In our embryo the *nasals* have advanced to no inconsiderable degree of calcification after the manner of the membrane bones among the higher mammalia generally. By chafing their superior surfaces with the edge of the scalpel the grit of the ossificatory state can at once be detected, though they are yet thin and easily punctured. Each one is in contact, laterally, for its entire length with the premaxillary of its own side. In front they overlap the cartilaginous snout, while posteriorly they are separated from the frontals by a membranous suture, the coronal suture of anthropotomy. They curve downwards mesially, and are in contact with each other for their entire lengths.

A *frontal*, as another investing membrane bone, seems to be rather further advanced towards ossification than we found a nasal to be, and this pair of bones are, as before remarked, the chief roofing elements at this stage of the middle area of the skull. Behind and towards the middle line each one presents a rounded angle to the "fontanelle" (fig. 2, *fo.*), and is separated from the parietal of its own side by a membranous interval. Within either orbit a frontal is in contact with the nascent maxillary margin in front and below, while mesoposteriorly, and at the side, the bone is juxtaposed to the growing margins of the ali- and orbitosphenoids and the squamosal. (Plate I, Fig. 1).

Mesially, the *parietals* are well separated from each other by the intervention of the "fontanelle" (Plate I, Fig. 2, *fo.*). Here, they are at this stage antero-posteriorly rather narrow, but each one becomes gradually broader as it proceeds outwards and curves downwards towards the lateral aspect of the cranium, where the bone is separated by a considerable membranous sutural interval from the squamosal for its anterior marginal moiety; its posterior border jutting freely into the unossified tract above and behind the auditory bulla of the same side. Either parietal shows even better evidence of ossification than the frontal in front of it, being best marked at the middle of the bone, while the periphery is yet largely membranous, which fact no doubt allows the bones to assume the position they eventually attain to in the skull of the adult *Neotoma*.

There is a large and distinct *interparietal*, which the writer is inclined to think ossifies from *two* centres, one on either side of the middle line, though at the present stage it is one piece, and more thoroughly ossified than any of the elements described in the last few paragraphs (Plate II, Figs. 1, 2 and 4, *i. p.*). It has the

form of a lune, its straight edge being directed anteriorly, and the middle third of the same forming the hinder boundary for the "fontanelle," while its arc behind is juxtaposed to the non-united supraoccipitals, the extremities of the bone jutting at either lateral aspect into the unossified area above the auditory bulla. In an adult *Neotoma cinerea* the interparietal can be easily made out by its sutural margins, and it will be seen that it comes there more to contribute to the cranial roof, rather than to close in the back of the brain-case as it does in our embryo *N. fuscipes*.

Of all the investing bones of the outer surface of the cranium in our specimen none possess a greater interest than the *squamosal*. One of these (*sq*) stands between the frontal and parietal of the same side above, and the primary structures of the ear and associate parts below. Essentially, at this stage the squamosal is a flat bone of a pear-shaped outline, the smaller part being directed backwards, and the larger oval moiety forwards, which latter bears near its anterior periphery the forward-projecting zygomatic process. It articulates with the posterior extremity of the jugal of the corresponding side. Even in the adult *Neotoma*, the glenoid facette of the squamosal is not nearly as definitely marked as we find it in many other forms of eutherian mammals, so in this embryo the feature is still less pronounced at the stage of development in the specimen before us. In figure 1 of my plates I have intentionally slightly dislodged the mandible from its normal position the better to show the embryonic otic structures, which latter have to a less degree been similarly dealt with.

Apparently one of the scale-like, small, and fairly well ossified *lacrymals* presents a greater surface to the facial aspect of the skull than it does to the orbital, and at this stage the lacrymal canal (Plate I, Fig. 1, *l. c.*) may be seen just anterior to the slit-like and extensive infra-orbital foramen.

Professor Flower has said that this orifice "is always well within the margin of the orbit,"[1] but this wood rat undoubtedly constitutes an exception to the rule, for in the embryo it is found as I have just described it, and in the skulls of the adult specimens of *N. cinerea* at my hand, the lacrymal canal is found within that vertical fissure which in these rodents represents the infra-orbital foramen. It is here quite large, wedge-shaped, the edge being below, and its roof above formed by its maxillary, which base also forms the verti-

[1] Flower, W. H. Osteology of the Mammalia, 3d Edition, p. 181.

cal plate of its outer boundary, while its inner wall is formed chiefly by the lacrymal, and to a very small degree, posteriorly, by the frontal. The jugal takes no part in its formation in *Neotoma*.

Rodents are notorious for the large size of the premaxillary bones in their skulls, and to this rule the genus now under consideration forms no exception. Here a *premaxillary* of either side stands between the corresponding nasal and maxillary, preventing those elements of the face from coming in contact at any point. Superiorly, it sends backwards a lanceolate-shaped apophysis to overlap the frontal of the same side, and this feature is distinctly shown in Plate I, Figs. 1 and 2.

Laterally, it makes up the chief side-wall of the conical fore-part of the skull of this embryo, and rounds under to form the roof of the anterior part of the mouth, though here a mesially oval foramen largely prevents it from suturally uniting with the fellow of the opposite side down the middle line (Plate I, Fig. 3). Each one anteriorly and beneath shows a diminutive pitlet, in which the incisor tooth is budding out, the latter not quite filling the hole closely, and withal being yet in an elementary state. Either premaxillary in the oval foramen above referred to, and on the outer aspect of the nasal septum in front, send backwards a teat-like process, into the spinal space; and in the skull of the adult *Neotoma*, these processes seem to have finally each pressed down upon the vomer and fused with its infero-anterior part. A premaxillary articulates with a nasal, a frontal, a lacrymal, the vomer, the ethmoidal mass, and with the fellow of the opposite side, and at this stage it seems to have progressed in its ossification, about as far as the nasals have, already described above.

The *maxillary*, on either side, is a very important, not to say interesting, investing bone of the face and roof of the mouth (*mx*). It sends backwards a delicate zygomatic process, which *underlaps* the jugal to complete the zygoma. To some extent anteriorly, it contributes to the formation of the bony walls of the orbit, especially where it articulates with the lacrymal. In front, just beyond the infra-orbital foramen, it articulates by a vertical suture with the premaxillary of the same side, while behind this it sweeps downwards and inwards, to complete the posterior moiety of its own side of the periphery of the incisor foramen, or "the anterior palatine foramen" of Flower, after which it contributes to the osseous oral roof, articulating by a transverse zigzag suture with the palatine, and

at the lateral aspect developing at this stage the elementary alveolar "process" for the lodgment of the molar teeth. These latter are now in a very primitive condition, though their form can be made out with no little distinctness. As in the case of the incisor teeth, their pristine sockets are larger than is necessary to lodge their dental occupants.

According to Wiedersheim, the *jugal* (Plate I, Figs. 1, 2 and 3 *j*) is considered to be one of the investing bones of the outer side of the mouth cavity, as the vomer is considered an investing bone of the mouth cavity proper. In *Neotoma*, as in some other rodents, the jugal has an uncommon disposition, as it is *overlapped* by the zygomatic process of the squamosal, and *underlapped* by the maxillary. For the most part it is to be found lying along on the superior aspect of the maxillary, while but a limited portion of it is to be seen upon a better view of the arch, at the middle of its continuity. In neither the embryo *N. fuscipes*, nor in adult specimens of the genus, does the jugal possess any salient characteristics, its sole function being to complete the slender zygomatic arch, and were it not that the demands of a universal law exacted its presence, its actual use might easily be dispensed with, for the zygomatic arch could just as well be completed by a meeting of the maxillary and zygomatic process. Indeed in some adult skulls of *N. cinerea*, it takes a good lens and careful observation to detect the presence of the jugal bone at all, so perfectly is it moulded to the conformation of this delicate osseous rod, which curves below and well out beyond the orbital cavity, in one way defining its limits, and lending to the skull of this species its well-known and characteristic form.

The *vomer* presents nothing peculiar, contributing as it does to the hinder moiety of the nasal septum, and ossifying rather late in the growth of the skull. We may refer to this bone further on, when we come to investigate the formation of the rhinal chambers.

We next pass to a brief consideration of some of the most interesting structures in this or any other mammalian skull; I refer to the mandible and those parts at its posterior extremity which are concerned in the elaboration of the auditory apparatus. Here, to some extent, we are upon debatable premises, and are brought face to face with yet mooted questions in morphology, and consequently must proceed with caution. Plate I, Fig. 1 shows very well the form of the *mandible* upon its lateral aspect. At this stage it is deep and thick, although the symphysis anteriorly has not as yet coössified, the

two halves here being held in juxtaposition by the not inextensive union between the fore ends of the Meckelian cartilaginous rod. Those toothsacs for the lower incisor teeth are about as far advanced as those described for the premaxillary bones, and this applies with equal truth to the molars of this lower jaw, though perhaps these are not quite as far advanced as the molars of the maxillary above.

For the most part the mandible has to no small degree ossified. We are to note, however, that the summit of the low and ill-defined "coronoid process" is tipped with nascent cartilage, and this state obtains also with the yet growing condyle, here harbored in the shallow glenoid cavity of the squamosal on either side. Below these protuberances a prominent angular process is to be observed, also cartilage-tipped as in the case of the condyle and coronoid. These several prominences of the posterior end of either ramus of the lower jaw in this embryo rodent, gives it a very marked vertical depth and a fan-like form, which renders it quite conspicuous. Through the ramus and thoroughly ensheathed by it, longitudinally courses the slender Meckelian rod of cartilage, to fuse anteriorly, as already stated, with its fellow of the opposite side.

At its hinder and free end, the Meckelian cartilage becomes clubbed and of a peculiar form; the extremity proper is cupped to receive in articulation the *incus*, while below this cup the rod sends forwards and downwards a very delicate, cylindrical spur of cartilage, here incorporated in the plane of the *membrana tympani*, within the semi-arc of the *tympanic annulus*. These parts seem yet to be largely performed in cartilage, and we see the *malleus* in the hinder end of this Meckelian cartilage, while the labors of Salensky, Fraser and Kitchen Parker seem to have at last definitely decided that "the *incus* is the upper element of the first or mandibular arch." Here in this embryo *Neotoma*, the incus develops an unusually long posterior crus, as shown in Figure 1, extending over towards the auditory bulla (*an*). As in the vast majority of the higher groups of the mammalia, the *stapes* is stirrup-shaped, and its foot-piece closes up the fenestra ovalis, and this stapes according to the most recent researches has been said to correspond with the hyomandibular of fishes, or in other words is the upper element of the hyoid arch, as the incus, as we have just said, is the off-constricted piece of the proximal extremity of the mandibular arch. Agreeing with the first two described auditory ossicles, the stapes at this stage in *Neotoma fuscipes*, seems yet to be wholly in cartilage. I failed to detect

the rudimentary *interhyal* in the tendon of the stapedius muscle, but might do so were additional material at hand. These wood rats have tympanic bullæ of no inconsiderable size, and in the dried skull of an old *N. cinerea* their lower surfaces are quite transparent, each being somewhat laterally compressed and inclined towards each other, so that were their imaginary horizontal long axes produced to the front they would intersect at a point just slightly anterior to the posterior narial aperture.

In form, then, these bullæ are subcompressed ovoid, where mesially they are moulded upon the bones they come in contact with at the base of the cranium at its infero-external aspect, which have to do with the auditory chamber.

Turning for the moment from our consideration of the proper "investing bones," I desire to pass a few remarks upon the "hyoidean apparatus." Essentially, this seems to be built up upon the plan of these parts as we find them in the more highly organized eutherian mammalia generally. In the specimen before us, however, ossification even at this stage appears but to have advanced slowly, the several segments of the arch yet being largely in cartilage.

All the elements of these parts seem to be present in this embryo, and the most notable feature to me is the form of the basi-branchial as I make it out. It is far more extensively curved than Parker found it to be in the hedge-hog, by which I mean the curved rod of cartilage composing it is longer (Plate I, *b. h. br.*). By examining the arch in an adult *N. cinerea*, the same feature seems to be present, for the "body of the hyoid" is there larger and curved. Another mammal, the dog, as drawn by Flower, also shows a curved basi-branchial, whereas in the armadillo it is a medium piece united apparently with the thyrohyals (Parker). The thyrohyals in the embryo *Neotoma* are but feebly developed (*t. hy*), and remain inconspicuous after ossification in them is completed. Agreeing with most ordinary mammals the three remaining pieces of the hyoid present nothing of marked peculiarity.

Returning to the investing bones of the skull, there yet remains two of them to be described in the present connection, viz.:—the palatine and the pterygoid.

If there be any superficial ossific deposit yet in either pterygoid (Plate I, Fig. 3, *pg*) the writer failed to discover it after a very careful investigation. We are aware that in the pig at the fourth stage of its development the pterygoids are somewhat advanced in

their ossification, but here in our specimen each pterygoid proper now consists in a well-pronounced subcylindrical cartilaginous rodlet to some extent centrally ossified, which, on either hand, projects out from behind the ossifying palatine of its own side. External to either one of these we observe the continuation of the bone in its 'external pterygoid plate,' which is also in cartilage, and arises both from the ali- and basisphenoidal regions. *Neotoma cinerea*, in the skull of the adult, shows well how the pterygoids are finally fashioned in bone at maturity, and if they represent the condition for the genus, we find that the external plate in each is nearly horizontal in position, and raised above the frontal and sphenoidal regions; the sutural traces remain quite distinct; the "hamular processes" have their extremities produced, and turned slightly outwards, while these apophyses are not far apart mesially, nor do their ends lack much of reaching the auditory bulla on either side, where the Eustachian tube opens.

Passing next to a *palatine* bone, we find it to be ossified to no inconsiderable extent, with the salient angles of its horizontal portion rounded off, its borders being yet membranous, or in an imperfect cartilaginous stroma, a tissue furnished by the epiblast during the growth of the embryo, and now taking on ossification.

The "posterior palatine foramina" are easily found, while the hinder margins of these bones unite to form the lower free edge of the posterior bases.

Having the most usual relations to the nasal septum and surrounding parts, the ascending lamina of a palatine is not so thoroughly ossified as the horizontal portion of the bone; and at this stage of its growth, this embryo *Neotoma* may be said to have a cleft palate, so wide are the medial sutures between the elements.

Of the endocranium, and the development of the cartilage bones.

To Professor Kitchen Parker are we indebted more than to any other single writer since the dawn of anatomical science to the present time for our knowledge of the morphology of the vertebrate skull, and from his recent writings, the mammalian skull in particular. Under the influence of his never weary hand, has this, one of the most difficult problems which man has ever investigated, grown out into the light with all the beauty associated with the budding of a complete flower. In reading his "Structure and Development of the Skull in the Mammalia" one loses himself as though he were

perusing pages of the most fascinating romance, and is led on step by step, as "the thing" grows, and shapes, and matures, with an almost irresistible passion for the marvelous story. Omitting those parts which I have referred to above, and confining ourselves to the structures which properly fall within the present section, we are clearly shown how in the endocranium in its pristine membranous condition there is laid down at its base in primitive cartilage the pair of rods which are the ground plan of the future brain-case, the harborage of that most powerful of all organs, the encephala. These rods of the *trabeculæ cranii*, which behind embrace the notochord (the parachordals), while anteriorly their segmentations become the *trabeculæ* proper and enclose the primitive pituitary space.

From these simple beginnings, part after part, grows and evolves, until in due time we have before us the mature skull with all its associated structures. At the appointed instant sense-capsules are born and elaborated *pari passu* as the cranial moulding proceeds; and nerves and vessels burrow with precision through tracts and by-ways long known to their kind in the ancestral types of the species, guided by the ceaselessly acting laws of variation and evolution.

Turning to the nether aspect of the basis cranii in our embryo *Neotoma fuscipes* we find the *foramen magnum* (Plate I, Fig. 3, *f. m.*) to be of a subelliptical outline, a form retained probably throughout life, as it obtains in the skulls of other adult Neotomas which I have examined. The *supraoccipital* is still in two parts, the medial vertical suture being very evident. It is, however, rapidly ossifying, bone having advanced to the superior arc of the foramen, and no doubt that early in the next stage the supraoccipital would be in one piece (*s. o.*).

The condyles show very prettily, and as structures developed by the *exoccipitals* (*e. o.*) they are well started in the process of ossification, though their ossific centres have not yet impinged upon either the supra or basioccipital. Much cartilage is still to be found, both above them and at their sides.

Embedded in this material below, we are to observe just in front of the occipital foramen the subquadrilateral form of the *basioccipital*, already nicely started in bone. This osseous part does not as yet reach the auditory bulla on either hand, though posteriorly it arrives at the margin of the foramen magnum. Anteriorly, a cartilaginous tract intervenes between the concave border of the basioccipital and the ossific centre which represents the future *basisphe-*

noid. This latter (*bs*) is at present but a small, squarish piece of bone occurring in the basic cartilage, just posterior to the pterygoid, which in the skull of an old *N. cinerea*, is wedge-shaped in outline for its exposed surface, and stands between the pterygoids, the narrow end to the front, separated by a distinct suture from the presphenoid, and the broad end behind, separated by a similar suture from the basi-occipital; the three bones, thus continuous, making a characteristic area having the form of an acute isosceles triangle. Nearly every trace of the notochord has disappeared in our embryo *Neotoma* at this stage, its former presence being but faintly indicated by a whitish line traversing the basi-occipital plate in a mediolongitudinal direction, and entirely disappearing near its middle. Beyond, the *presphenoid* shows commencing osseous deposit in a narrow line down its length, but is still chiefly performed in cartilage, the former being barely perceptible. Referring again to skulls of the *N. cinerea*, adult specimens, it becomes worthy of remark, that the supraoccipital region and the foramen magnum are both in nearly the same plane, it being quite vertical, and almost at right angles with the horizontal plane in which the interparietal and parietals lie. This part of the cranium in our embryo, as already stated above, is more or less rounded as shown in the figures. To the outer side of either exoccipital is seen a distinct and spine-like paroccipital, which feature I fail to find in so early a stage as the embryo before us represents.

Professor Parker in his famous work upon the 'Morphology of the Skull' in alluding to the development of the pig at its 'fourth stage,' contends that there the notochord is not yet quite obliterated in the basioccipital, though it is rapidly becoming so. He also points out that a separate ossific centre, in that animal, is to be found in either massive condyle, but they soon coalesce with the exoccipitals on either side. Agreeing with *Neotoma fuscipes*, the supraoccipital in the pig at this stage is in two pieces, or "patches" as Professor Parker expresses it, and they "run into one another in a day or two" (p. 288).

Of the three bones that unite to form the *periotic* ossification, I find but one that as yet appears in any way advanced beyond a cartilaginous condition; and this is the *opisthotic* (Plate II, Fig. 5, *o. p.*) After the membrane bones which form the vault of the skull have been duly removed, this auditory osseous element may be detected posterior to, and to the other side of the periotic capsule, which is

otherwise in nascent cartilage, though quite dense and on the verge of ossifying. This internal view of the cranial casket, reveals the fact that at this stage at least the periotic mass is but slightly elevated above the general level of the floor of the brain-case, and in no way as prominent as the external auditory bulla on either side. It still, however, is more or less rounded, and it is only later in life apparently that this projection becomes somewhat angulated as we see it in the adult skull. In this region in the cranium of the embryo *Neotoma* the usual vascular and nerve foramina can be easily made out.

Already in another paragraph, I have alluded to the state in which we find the basi- and presphenoid (Plate II, Fig. 6, *b. s.* and *p. s.*) and it will be seen that the anterior part of the cranial floor is fairly well-paved by two other ossifications of mammalian skull. I refer to the rather large and squarish *alisphenoids* (*al. s.*), one on either side of the first-named element, and the more oval *orbitosphenoids*, one on either side of the presphenoidal cartilage. These bones are already well-ossified and are pierced by the usual nerve foramina; the latter by the optic (II), and the former by the third branch of the fifth (V^3) through the *foramen ovale*. A slight *pituitary depression* is to be observed at its most usual site upon the presphenoid. The arrangement of these parts then, with its true stirrup-shaped stapes, indicates that *Neotoma* holds quite an exalted position, structurally, among the eutherian mammalia.

Beyond the sphenoidal region the endocranium gradually but rapidly narrows, and just posterior to the nasal structures and chambers we meet with a sub-vertical *cribriform plate* (*cr. p.*) showing minute perforations for the passage of the nerves. Mesially, a posteriorly rounded *crista galli* (Plate II, Fig. 5, *cr. g.*) is to be seen. These parts are as yet all performed in cartilage.

By carefully removing the investing bones from the fore part of the skull we at once bring into view the chondrified elements of the nasal organs. We have already alluded to the vomer, and now it can be easily detached from the cartilaginous lamina perpendicularis, with which it is articulated by a longitudinal median groove traversing its entire superior margin.

The base, for the vomer at this stage is entirely in bone, is some 3 cms. long, and sharp, or more or less sharp, along its inferior edge. As in most rodents the *lamina perpendicularis* is produced forwards

as the *septum nasi* (Fig. 6, *s. n.*). Cribriform plate and lamina perpendicularis together form the *mesethmoid.*

Jacobson's Organs, one on either side of the septum, are, as in the vast majority of the rodentia, well developed in this embryo; and as in the case of *Lepus* appear to be ensheathed by the backward, extending, posteriorly free terminating palatine processes of the snout, as seen in Figure 6 (*rc. c.*). These "organs" have been described by Prof. Wiedersheim (Parker's translation) as being "a paired accessory nasal cavity, which in an early embryonic stage becomes entirely separated from the nasal chamber, and which is supplied by the olfactory and trigeminal nerves." They are surrounded by the *cartilages of Jacobson*, likewise paired and of a scroll-like form. Uniting with the antero-ventral aspect of the septum nasi beneath, we are to note the *ali-nasal cartilage* on either hand, encircling the external nostrils (*e. n.* and *al. n.*), while the *ali-septal*, one on each side of the septum on the dorsal aspect, run the entire length and roof over the nasal chambers (Plate II, Fig. 5, *al. sp.*). Large and of peculiar form, the *aliethmoids* form a striking feature here, and may be seen both upon dorsal and ventral aspects. To some extent they form the roof of each rhinal chamber, as well as the sides and floor. Inferiorly, they become much expanded behind, rounded, encircling submesial vacuities, as shown in Figure 6, (Plate II, *al. e.*).

Finally, turning to the ventral aspect of this minute endocranium we see external to either recurrent cartilage, right and left of the median ossified vomer (*v*), the inferior turbinal proper (*i. tb.*), each one in addition to its usual attachments in mammals of this order is here connected with the septum nasi anteriorly, and terminates behind in a teat-like process, extending somewhat further in that direction than does the vomer. They swell at the middle of their continuity, being convex externally and concave upon their vomerine aspects. In a former paragraph, I have already alluded to the "recurrent cartilages," so designated by Parker (*rc. c*), and these may now be seen upon this view. Especial attention is invited to them as they are the essential capsules which enclose the organs of Jacobson. To study them properly it becomes necessary to gently press outwards the inferior turbinals. At present they are in cartilage entirely, thin, and of an elegant scroll-like form, being for the most part open superiorly, and in contact with the vomer, mesially, being in either case outgrowths of the *alæ nasi.*

With this I close the present account of the cranium in this embryo of one of our not abundant species of American rodents. Upon some future occasion I trust to compare it quite extensively with the development and morphology of the skull in other types of mammals of this country, especially the rodentia.

Explanation of Plates I and II.

Note.—The figures of these two plates were drawn and colored by the author directly from his dissections, and in them the membrane bones have been simply shaded; the cartilage bones colored orange; and the endocranium and other cartilaginous parts, purple.

In all the figures the structures are increased six times the size of life, and the following letters used as abbreviations:

ag. p.	Angular process.
al. e.	Aliethmoid.
al. n.	Alinasal.
al. s.	Alisphenoid.
al. sp.	Aliseptal.
a. ty.	Annulus tympanicus.
au.	Auditory capsule.
b. h. br.	Basihyobranchial.
b. o.	Basioccipital.
b. s.	Basisphenoid.
cr. g.	Crista galli.
cr. p.	Coronoid process.
cr. pl.	Cribriform plate.
d.	Dentary.
e. hy.	Epihyal.
e. n.	External nostrils.
f.	Frontal.
f. m.	Foramen magnum.
fo.	Fontanelle.
gl. f.	Glenoid cavity.
i.	Incus.
i. p.	Interparietal.
i. tb.	Inferior turbinal.
j.	Jugal.
l.	Lacrymal.
l. c.	Lacrymal canal.
mk.	Meckel's cartilage.

ml.	Malleus.
m. ty.	Membrana tympani.
mx.	Maxillary.
n.	Nasal.
nf.	Nasal floor.
n. v.	Nasial valve.
oc. c.	Occipital condyle.
op.	Opisthotic.
o. s.	Orbitosphenoid.
p.	Parietal.
pa.	Palatine.
p. e.	Perpendicular ethmoid.
pg.	Pterygoid.
ps.	Presphenoid.
pm.	Premaxillary.
py.	Pituitary region.
rc. c.	Recurrent cartilage.
s. n.	Septum nasi.
s. o.	Supraoccipital.
sq.	Squamosal.
st.	Stapes.
t. hy.	Thyrohyal.
v.	Vomer.

Plate I.

Fig. 1. Left lateral view of the skull of an embryo *Neotoma fuscipes*, with hyoidean apparatus attached; × 6.

Fig. 2. The same specimen seen from above; mandible removed.

Fig. 3. The same from below; mandible removed. Roman numerals indicate nerves or their foramina.

Plate II.

Fig. 4. Posterior view of the skull of an embryo *Neotoma fuscipes;* same specimen as figured in Plate I, (× 6); mandible removed.

Fig. 5. The endocranium of a specimen of an embryo of *Neotoma fuscipes;* the same skull as is figured in Plate I, fig. 1 (× 6). All the investing bones have been removed, and superfluous parts dissected away.

Fig. 6. The same specimen shown in Fig. 5, under view,

Fig. 1.

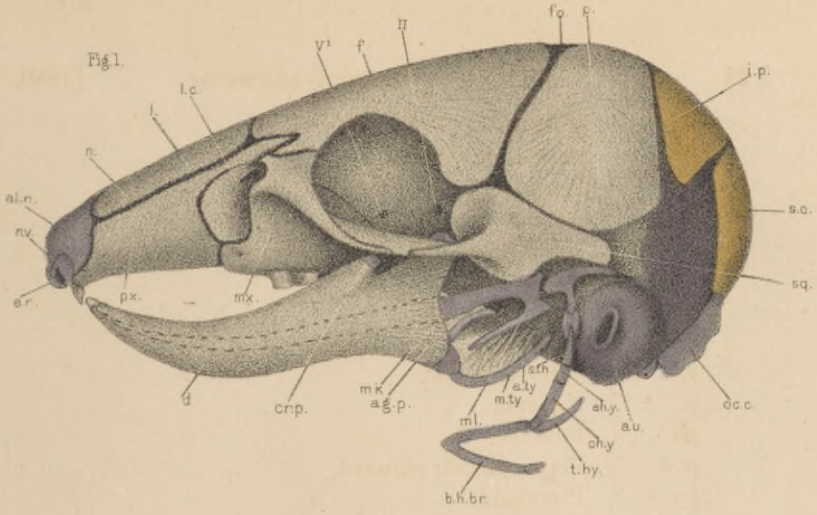


Fig. 2.

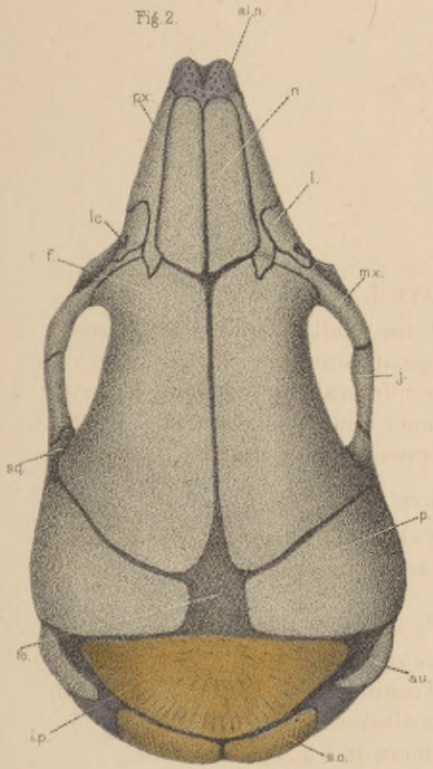
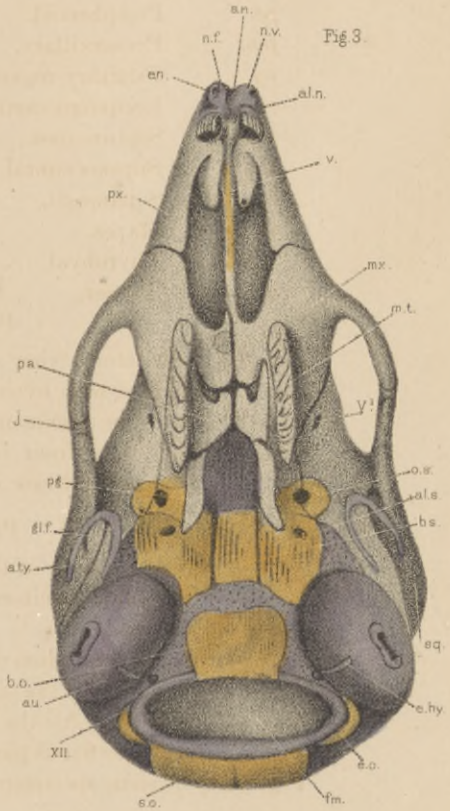


Fig. 3.



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SHUFELDT ON NEOTOMA FUSCIPES.

(Embryo ×6).

Fig. 4.

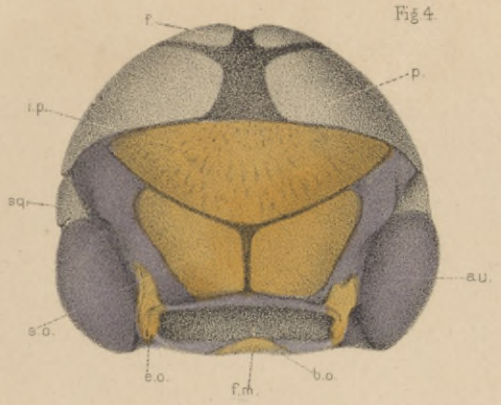


Fig. 5.

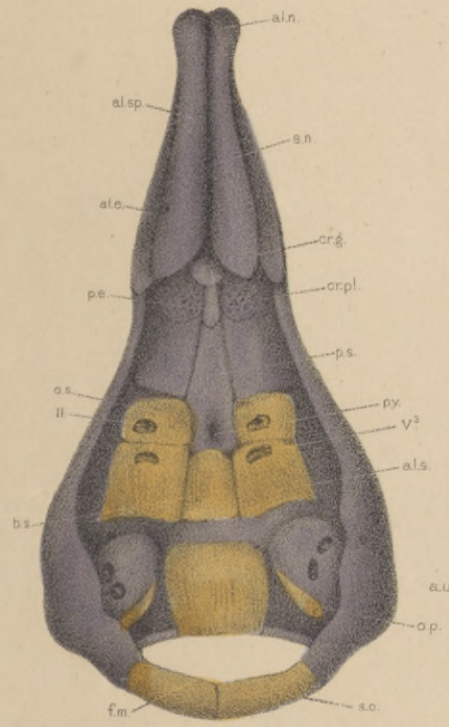
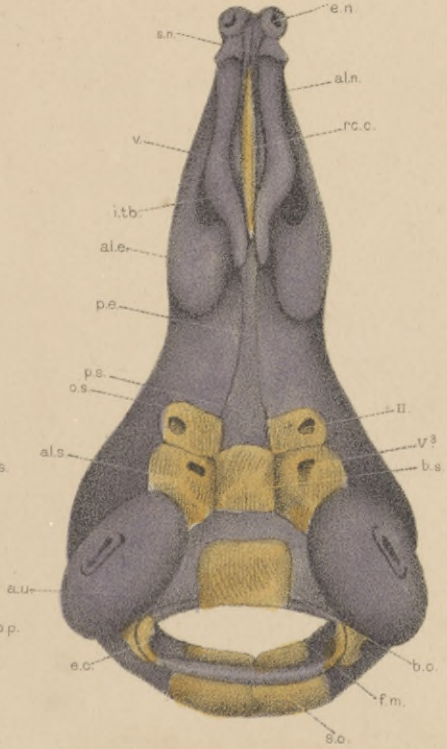


Fig. 6.



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SHUFELDT ON NEOTOMA FUSCIPES.

(Embryo ×6).