

No. 3. — *On a Revision of the Ethmoid Bone in the Mammalia, with special Reference to the Description of this Bone and of the Sense of Smelling in the Cheiroptera.* By HARRISON ALLEN, M. D., Professor of Physiology in the University of Pennsylvania.

IN the Bulletin of the Museum of Comparative Zoölogy dated February, 1880, I described briefly some peculiarities of structure I had detected in the ethmoid bone of the Cheiroptera.* It is my purpose in this communication to extend my remarks in the same direction, and by way of introduction to give a brief account of the ethmoid bone as it is met with in the mammals generally.

The ethmoid bone in mammals lies within the ethmoidal notch of the frontal bone, and is in all but a few groups (e. g. in Primates, Quadrumana, and some of the genera of Felidæ) protected laterally by the descending process of the frontal bone, the orbital process of the palatal bone, and the orbital process of the orbito-sphenoid bone. In the nasal chamber it is protected above by the nasal bone and in part by the vomer. Its several portions lie in the nasal chamber and in the frontal and sphenoidal sinuses. With a near approach to accuracy, it may be said that the ethmoid is included between the following openings: the optic, the ethmoidal and the sphenoidal foramina, and the lachrymal and the infra-orbital canals. The suture between the palatal bone and the superior maxilla in the roof of the mouth corresponds nearly to the anterior limit of the ethmoturbinals.

The Nomenclature of the Subdivisions of the Ethmoid Bone. — The ethmoid bone of the human subject is described by anatomical writers as composed of a pair of lateral masses, sponges, or labyrinths, united to a perpendicular plate by means of the cribriform plate, the projection of the former above the latter constituting the crista galli. Each lateral mass in turn is composed of ethmoid cells, and presents upon its median surface two scrolls. The "cones of Wistar" are a pair of symmetrical ossicles appended to the lateral masses posteriorly, and are not of olfactory significance.

* The prodrome of this memoir, as announced in the above-named paper, has not been followed in all respects. The points of difference, however, do not demand special attention.

The departures from this arrangement in the ethmoid of quadrupeds are so numerous and pronounced that an adherence to a similar plan of description is not satisfactory.

In proposing modifications, I will use the following language : —

The ethmoid bone is composed of the *meso-ethmoid* and two *ethmoturbinals*. The former includes the perpendicular plate and the crista galli; the latter, as in human anatomy, the lateral masses of the bone. These terms are in general use by English writers. The *nasoturbinal* is an ethmoturbinal plate projecting in front of the remaining plates, and forming the superior limit to the series, as seen on the median surface of a longitudinal (sagittal) section. — The “cones of Wistar” form the *sphenoturbinals*.

Each ethmoturbinal element is an *olfactory plate*. The space between any two plates is called an *olfactory interspace*.

Each olfactory plate is, as a rule, plicated, and each plication in turn forms an *olfactory fold*. The free projecting ends of the olfactory plates constitute the *olfactory lobes*.

The ethmoturbinal plates are divided into two groups, the *ectoturbinals* and the *endoturbinals*. The *ectoturbinal plates* are those which lie in a space defined by the frontal bone and the superior maxilla. This space communicates with the nasal chamber at the interspace between the nasoturbinal and the first endoturbinal, as well as by a large oval opening behind the maxillo-turbinal and the vertical plate lying between the superior maxilla and the ethmoid. The ectoturbinal plates are arranged on the lateral sides of the chamber, from which they project inward toward one another, but never to a degree to be seen on the median surface as this is seen in a longitudinal section of the skull.

The *endoturbinal plates* are arranged in a series lying beneath as well as medianly to the foregoing. They are placed in oblique parallel rows from above downward, and are best seen in a longitudinal (sagittal) section of the skull. Each ethmoturbinal plate has a base where it arises from the cribriform plate. The upper border of each plate is its *frontal border*, while its lower border is its *palatal border*.*

The space between the meso-ethmoid and the ethmoturbinal is the *septoturbinal space*. The lamina uniting the ethmoturbinals one with

* The terms ecto- and endoturbinal are named with reference to the relations they entertain to the nasal chamber. The ectoturbinals do not appear, with a few exceptions, on the lateral wall of the undissected nasal chamber (see Plate I. fig. 1), while the endoturbinals so appear, or can be made to do so, by producing the axes of the olfactory plates entering into them.

another constitutes the *transverse lamina*. Its posterior portion unites with the vomer, and may receive the name of the *turbino-vomerine lamina*. Its anterior portion lies in front of the last named. The sphenoturbinals are furnished with olfactory plates that join the vomer, thus crossing the septoturbinal space.

The surface of the ethmoid bone entering into the construction of the brain case is called the *encranial surface*. It exhibits a *perforate* or *cribriform plate*, and a *non-perforate plate* placed posteriorly to the foregoing. The perforate plate answers in position to the ectoturbinals, the endoturbinals in great part, and the septoturbinal space. The non-perforate space covers the sphenoturbinals and the lowest of the endoturbinals. The encranial surface may be subdivided, for convenience in description, into surfaces which correspond to the divisions of the ethmoid as seen from the nasal chamber. Thus the septoturbinal, the ectoturbinal, and the endoturbinal surfaces are easily distinguished.

The Literature of the Ethmoid Bone.—That the terminology of the ethmoid bone at present in use needs revision can be readily shown by a reference to the literature of the subject.

E. F. Gurlt (Handbuch der Vergleichenden Anatomie der Haus-Saugthiere, Berlin, 1843, Vol. I. p. 81) describes the ethmoid on the basis of the human bone. He identifies the nasoturbinal as the superior conch and the first endoturbinal as the middle conch: All parts not appearing on the median surface he groups under the head of the "Labyrinth."

H. Strauss-Durckheim (Anatomie Descriptive et Comparative du Chat, Paris, 1845, p. 385) gives the sphenoturbinals as equivalent to the "cornet de Bertin," and forming the third division of the bone. The second division is the group of plates seen only in the *cat* and its congeners. It is a development from the transverse lamina. All the remaining portion of the ethmoturbinal, comprising as it does the bulk of the bone, Strauss-Durckheim calls the first or superior division of the bone. The space between the two ethmoturbinals on a level with the lower border of the chamber of the ectoturbinals and the equivalent to the ethmoidal notch of human anatomy receives the name of the "écartement des anfractuosités supérieures." The mesoturbinal is named the "lame verticale moyenne."

Owen (Archetype and Homologies of the Vertebrate Skeleton, 1848) named the meso-ethmoid the prefrontal, and gave to the ethmoturbinals the name which they have since borne. In his elaborate work on the Anatomy of the Vertebrates, Owen restricts the term *ethmoturbinal* to

the lower plates only of the mass (the endoturbinals of this paper), as seen in the *hog*. In the description of the ethmoid in this animal the word "labyrinth" is also used, showing that the term had not, in the mind of the writer, supplanted that of "ethmoturbinal." — In the *tapir* the cribriform plate is said to be reticulate, with long radiating meshes. The ethmoturbinal in this animal consists of many convolute divisions, and each is perforated by many foramina. — In the *horse* the ethmoturbinal is separated from the nasoturbinal. The same language is employed in describing the ethmoids of other animals. — The *giraffe* exhibits the upper folds of the labyrinth coalescing in the moderately long and deep ethmoturbinal. — In the *dog* the horizontal folds of the "labyrinth" are four in number. Here by the word "labyrinth" the median surface of the ethmoturbinals (endoturbinals) is intended. Indeed, throughout the descriptions in this work, the term *ethmoturbinal* includes the periphery of the lateral mass, excepting that portion lying above the cribriform plate. Thus the os planum and the middle and lower plates of the median surface are ethmoturbinal, while the intervening structures and the superior division are vaguely included in the "labyrinth." This is evidently so in the account of these parts in the *giraffe*, where the upper folds of the labyrinth are said to coalesce and to be produced into the ethmoturbinal. In like manner, the ethmoturbinal forms the part identical with the transverse lamina.

J. Chatin (*Les Organes des Sens dans la Série Animale*, Paris, 1880, p. 241) describes each olfactory plate as it appears upon the median surface, where it is called a "cornet." The "cornet supérieur" is the same as the nasoturbinal; the "cornet ethmoidal," the equivalent of the endoturbinals. No attempt is made to describe the ethmoturbinal. It is simply stated to be most bizarre in its construction. In the *kangaroo* the maxilloturbinal is called the "volute ethmoidal."

Kitchen Parker ("On the Structure and the Development of the Skull in the Pig," *Philosoph. Trans.*, Vol. CLXIV. Part I., 1874) calls the first plate of the ectoturbinals the "upper turbinal"; the first endoturbinal, the "middle turbinal." The maxilloturbinal forms the "lower turbinal." The nasoturbinal is called the "nasal turbinal." In advance of the olfactory region Parker recognizes two turbinals, viz. the maxilloturbinal and the alinasal turbinal. The first of these has been already noticed. The last named is a ledge-like point within the nostril continuous with the ledge supporting the maxilloturbinal. A very good general view of the ethmoid as seen in the *hog* is shown in Plate XXXV. of the above memoir, — the ectoturbinals being as yet imperfectly developed.

Dr. Elliott Coues ("Osteology and Myology of the Opossum," Memoirs of the Boston Nat. Hist. Soc., II. 62) treats of the ethmoturbinal as synonymous with the lateral mass, and of the perpendicular plate as being probably homologous with a pair of coalesced prefrontals. He further ambiguously states that the "spongy convolutions" are borne on either side of the perpendicular plate. Respecting the arrangement of the olfactory plates, he remarks, "It would be difficult even if it were desirable (!) to describe the details of the spongy convolutions."

The description in Bronn's *Klassen und Ordnungen des Thier-Reichs* (Bd. VI. Abtheil. X. 52) embraces a general account of the bone. No attempt is made to discriminate between the olfactory plates. The ethmoturbinal mass is named the labyrinth, and composed of thin rolled plates of bone enclosing the ethmoidal cells.

The Method employed by the Author in studying the Ethmoid Bone. — The study of the ethmoid bone is greatly facilitated by immersion of the bone in an acid solution which is sufficiently strong to remove the bone-salts. When the bone is detached from the skull, the delicate folds are easily decalcified by a solution of nitro-muriatic acid of not greater strength than eight drops of the acid to an ounce of water. When the entire skull, say of an animal of the size of a horse or dog, is subjected to the acid solution, a strength from a half-drachm to a drachm of acid to the pint of water will be required. For small, delicate skulls, such as those of the bats, a fluid slightly acidulated, say two drops to the ounce of water, is sufficient. Immersion from six to twelve hours is needed for the smaller specimens, and perhaps a renewal of the fluid for a second period as long as the first for the larger ones. The specimen is next washed and soaked through several waters, and afterwards can be preserved in alcohol. The ethmoid bone thus prepared can be studied with signal advantage over the natural bone, since a dissection can be effected with ease, and without danger of mutilation. I think perhaps the best way to obtain a satisfactory preparation for general purposes of comparison is to secure a macerated skull* of the animal whose ethmoid is desired, and, after the bone-salts have been removed, to bisect the skull longitudinally at one side of the line of the vomer, and reserve one half of the specimen for study of the median surface of the ethmoid bone. The encranial

* Care must be taken to protect the freshly macerated skull from the attacks of a voracious dipterous larva, that is capable of destroying the delicate structures of the ethmoid in an incredibly short space of time.

surface will be seen in the same specimen. Next, to make a transverse (frontal) section of the opposite piece, in such a manner as to divide transversely all the parts of the ethmoid bone directly in advance of the cribriform plate. The section must be made concentrically to the plane of the cribriform plate, and of course to include the mesoethmoid. The proximal surface of such a preparation embraces a section of the ethmoturbinals and of the septoturbinal space, and gives at a glance the plan of the bone. The parts of both specimens can be handled with freedom, as the botanist can press aside the several parts of a flower, and afterward, without violence, return them to their natural positions.

If it be desired to retain the mucous membrane in connection with the olfactory plates, the superficial parts, together with the temporal and masseter muscles and the eyes, should be first removed to enable the acidulated fluid to act directly upon the bony surfaces. After the bone-salts have been dissolved, a saw may be employed to sever the denser surrounding structures, such as the frontal bone, the zygomata, the hard palate, etc., reserving the interior parts to be divided by the scissors or the knife. By this means irregular laceration of the plates and membranes is avoided, and the parts are kept free from bone-dust.*

A GENERAL ACCOUNT OF THE ETHMOID BONE.

At the risk of repeating here and there a fact already incorporated in the above list of terms, I will now give a succinct account of the ethmoid bone, as studied in a number of well-known mammals other than the bats.

The Encranial Surface.—The cribriform plate is divided into two portions, one lying over the septoturbinal space, and the other answering to the ethmoturbinal spaces. The latter is again divided into two portions, a superior and an inferior, which correspond to the ectoturbinal and endoturbinal spaces respectively. In the Carnivora,† so far as examined, these divisions are abruptly angulated one to the other. The line

* I desire to return my acknowledgments to the Academy of Natural Sciences of Philadelphia for the use of crania from its collection. When it is seen that a decalcified skull subsequently subjected to the making of sections of the ethmoidal region is one practically expended in the cause of science, it will be conceded that no inconsiderable privilege was accorded me.

† For purposes of comparison, the ethmoid bone of the dog and otter are figured side by side in Plate I. But the bone of the otter is not separately described.

separating them is distinctly ridged, and is conspicuous in the *raccoon* and the *dog*, but inconspicuous in the *sloth*. This ridge is the basal encranial aspect of the first endoturbinal, and the foramina ranged on the sides and at the tip of the ridge afford openings of exit to the olfactory nerves supplying the sides of the plate. Indeed, all the olfactory nerves excepting those of the septoturbinal spaces are similarly placed with respect to basal lines of the ethmoturbinal plates. The first endoturbinal, being the largest of the series, secures for its base a more decided line than is the case with the others. The septal openings are arranged in a single straight line parallel to the crista galli.

The simplest arrangement of foramina is seen when a row of openings lies parallel to the median border of the encranial surface, and another is seen similarly disposed along the lateral border. The successive degrees of complication on the surface are dependent upon the extent that the basal ridges extend medianly from the last-named row.

A general idea of the plan of the ethmoidal plates can be thus formed by the study of the encranial surface. The number of the foramina present, the size of the basal ridges, the extent of the non-perforate space, will be found to hold an exact relation to the number and size of the olfactory plates, and indirectly to the functional importance of the olfactory region.

As a rule, the encranial ectoturbinal surface is rounded in form, and of greater diameter than the surface for the endoturbinals. In the *cat* the cribriform plate is everywhere narrow, the ectoturbinal surfaces being separated by a median frontal process, on either side of which septal foramina are arranged. The crista galli is not developed at the anterior third of the endoturbinal region. The ridge for the first endoturbinal is scarcely longer than the width of the septoturbinal space at its side. The second endoturbinal closely resembles the first. The foramina of the last-named plates are continuous at the lateral border of the cribriform plate. The ridge of the third plate is indeterminate, the foramina being large and clustered.

In the *dog* (Plate I. figs. 1, 2) the ectoturbinal surface is subrounded, higher than it is broad, with the septoturbinal space widened superiorly. The ectoturbinal ridges and foramina are displayed laterally, and lie on the level of the descending portion of that portion of the frontal bone articulating with the orbitosphenoid. The first endoturbinal ridge is three times the width of the related septoturbinal space. The second is two thirds the length of the first. The third ridge is, as in the *cat*, indeterminate, and the foramina are clustered.

In both the *cat* and the *dog* the non-perforate space is exceedingly small. In the former it is reduced to a mere elevated rim, and in the latter it is concealed by the anterior edge of the presphenoid. The non-perforate space is well seen in the seal, *Phoca vitulina*, the *opossum*, and the *peccary*. In the *otter*, the *bear*, and other Carnivora, it is nearly absent, so that the posterior border of the cribriform plate is also the posterior border of the bone. The non-perforate space is in close relation with the orbitosphenoid and the presphenoid, so that the sphenoidal sinuses may be occupied by the lowest of the endoturbinals.

As is well known, the sphenoidal turbinals in *man* are distinct ossicles, lying between the ethmoturbinals and the presphenoid. In some mammals, as the sloth, the presphenoid has a group of plates which closely resemble an olfactory plate of the ethmoturbinal, but differing therefrom by the fact that the plates unite with the crest at the basal surface of the cranio-facial axis, instead of being separated by an intervening space, as in the ethmoturbinals. A slight tendency in the same direction is seen in the *peccary*. Is this group of plates homologous with the sphenoturbinals of man?

In the *otter* (Plate I. fig. 4), the *mink*, the *weasel*, and the *bear*, the frontal sinuses are occupied by the ectoturbinals. When such frontal development is pronounced, the ectoturbinal division of the ethmoid is of a circular form in transverse section and on the encranial surface, while the endoturbinal division is longer than wide.

The Nasal Surfaces.— Each ethmoturbinal plate is attached to the cribriform plate proximally, to the os planum laterally, and, it may be, to an associate-turbinal distally. Upon the median surfaces the plates remain free, and either end simply, or exhibit a tendency at their ends to form two revolute parts, the convex surfaces of which appear upon the superficies of the lateral-wall of the nasal chamber. In a longitudinal section of the nose the median aspect of the ethmoturbinal is thus made up, in the last-named variety, of the rounded convexities of the plates and the spaces between them. The uppermost of the plates is much longer than the others. . . . The lateral aspect of the nasal chamber at the ethmoturbinal region is, therefore, made up simply of those plates which have a common plane. The surface gives no impression of the number of the plates present; for some may not reach the median surface, and from this circumstance be not seen or accounted for. Neither is the surface a guide to the length of the plates, since, as the reader has already seen, the cribriform plate is wider above than below,

so that a plate extending from the last-named to the median surface is of necessity longer than one extending between similar points below.

In the transverse section it will be seen that a number of the plates have failed to reach the median surface. In the *dog* (Plate I. fig. 1), for example, the ectoturbinals are four in number. The first is obliquely placed from above downward, and within outward. Two conspicuous convolutions are present at the distal end, the lower one of which alone lies toward, but not on, the median surface. The second plate possesses a single convolution, which is directed outward. The third and fourth are very short, biconvolute, and directed upward and forward. None of the ectoturbinals appear on the longitudinal surface of the nasal chamber. The first endoturbinal is long and complex. It is directed forward and upward, and nearly touches the median convolution of the first ectoturbinal. It is biconvolute, but the parts are short and not incurved. Three secondary convolutions are seen on the sides of the plate, — one on the upper, and two on the lower aspect. Both of the latter reach the surface of the longitudinal section. The second endoturbinal is the longest of the series, and touches the septum. A single primary convolution is directed upward, and much convoluted. A single upper and two lower secondary convolutions are seen, as in the first plate, but they are less conspicuous. The third and remaining plate is the smallest of the endoturbinals, and arises from the os planum, as this structure is seen in the section. It is directed upward and inward, to appear on the longitudinal section. It presents a single convolution. Immediately beneath the last plate, the transverse plate or lamina is seen. The nasoturbinal is seen in the section as a minute non-convolute structure, intermediate between the two sets of plates.

The endoturbinals are always arranged in tiers one above another. All originate from the lateral surface. In the *dog* (Plate I. fig. 2) the second of the plates descends, and may follow the curve of the sides and the bottom of the nasal chamber as far as the meso-ethmoid, along which it ascends a short distance. The plates in this portion of the ethmoturbinal in the *dog* are from three to four in number. The olfactory plates tend to unite anteriorly. Thus two to three plates unite to form the nasoturbinal in the *dog*. The lower endoturbinal plates unite in front by broad, thin plates. These, taken collectively, constitute the transverse lamina of Strauss-Durckheim. It is constantly present, stretching across the septoturbinal space to the vomer, against which it rests.

The ectoturbinal plates may be rudimentary or absent. They would

appear to be absent in the *ape*, at least in the adult. In *man* they are also absent. The *opossum* has two ectoturbinals; the *cat*, two to three; the *hog*, five; the *ox*, eight. In the *seal* the ectoturbinals are developed to a greater degree than the endoturbinals.

The olfactory plates are either simple at their ends or convolute. Their anterior ends are often produced forwards in a series of tongue-like projections, which have received the name of the olfactory lobes. The projection known as the nasoturbinal is the most conspicuous of these. The lobe on the first endoturbinal is always well developed. The endoturbinals of the *hog* are without marked lobulations. The Carnivora and the Rodentia, as far as examined, possess lobes on all the folds. In the *opossum* two of the plates are simple, the remainder are convolute. Occasionally a convolute fold arises from the side of a plate instead of from the end, as in the larger plates of the Carnivora and the Ruminantia. The arrangement of the endoturbinals, as seen in the median surface of the ethmoturbinals, is much the same as in other Carnivora.

The septoturbinal space is in all mammals narrow, and indeed may be obliterated here and there where the endoturbinal plates lie in contact with the septum. Such a point of contact is evident in the *macaque*, *M. nemestrinus*, where a depression is seen on the septum answering in position to the first endoturbinal plate. Similar depressions are seen in the *bats*, as in *Antrozous* and *Corynorhinus*.

In *Cebus* (Plate II. figs. 1, 2) the absence of an ectoturbinal series, and the endoturbinal series being restricted to a single plate bearing incisures upon its posterior border, and retaining upon its anterior surface a deflected and abortive nasoturbinal (uncinate process), an example is afforded of the manner after which the ethmoid bone is modified in passing from the quadrupedal form to the primate. In man the interval between the endoturbinal series and the lateral aspect of the bone is occupied by a number of cellules. These being absent in *Cebus* and *Macacus* (the only genera examined), it would appear as though the chief difference between these forms and the human ethmoid lay in the development of the ethmoid cells.

The human ethmoid bone (Plate II. fig. 3), viewed from beneath, furnishes, as in *Cebus*, an aborted nasoturbinal in the "uncinate process," and the rugose under surface of the single endoturbinal plate in the "middle turbinated bone."

A Special Account of the Ethmoid Bone in the Horse, the Peccary, the Sloth, the Cat, the Seal, and the Mole.—I have thus endeavored to

sketch the general plan of arrangement of the ethmoid bone in the mammals, and to indicate the relations that the several parts hold one to another. Before describing the bone in the Cheiroptera, I propose giving detailed accounts of the ethmoid in the cat, the seal, the peccary, the sloth, and the mole; with the object of bringing together some widely diverse examples, and presenting descriptions which will be sufficiently detailed to permit of comparisons being made with those which will follow in the concluding portion of this paper.

In the *horse* (Plate II. figs. 4, 5) the endoturbinial aspect of the encranial surface is concealed from the brain case at its upper third by a transverse plate apparently of the frontal bone, but which in reality is an ossification of the ethmoid. The foramina of the endoturbinial surface are arranged elaborately in a crescent extending across the anterior end. The foramina of the ectoturbinial surface are seen in five transverse triangular or clavate clusters.

The ethmoid, studied from its lateral aspect, exhibits a trenchant distinction between the endoturbinals and the ectoturbinals by a thin septum extending across the great cranio-facial sinus. Both the turbinal sets lie in this sinus, connected by a thin papyraceous lamina, save at the anterior fourth of the ectoturbinial series, where it is firmly connected by the ends of the olfactory plates to the descending process of the frontal bone, as well as with the line of junction this process effects with the orbitosphenoid and the frontal bones.

Seen in transverse section, the turbinal mass exhibits sharply the division between the two sets of plates. The ectoturbinals are eight in number, including the nasoturbinial. The endoturbinals are five in number, and preserve the order already described as existing in the hog. The last plate sends backward a single folium within the sphenoidal sinus, so that the olfactory apparatus extends a short distance posterior to the encranial surface.

Seen from the median aspect, the nasoturbinial is seen to assume enormous proportions, being much wider than any of the endoturbinals. Four of the endoturbinals are visible, and all are markedly biconvolute, the convexities of the scrolls alone appearing on the general surface. Anteriorly each plate is seen ending simply at the bases, but toward the apices they are more or less lobate. The first and second plates project beyond the transverse lamina.

A small but distinct plate crosses the septoturbinial space obliquely at the orifice of the sphenoid sinus. The septum is distinctly foliated opposite the third, fourth, and fifth plates.

In the peccary,* *Dicotyles torquatus* (Plate III. figs. 1–3), the encranial surface is uniformly concave, and presents scarcely any angulation inferiorly. Hence, the indications of separation of the ectoturbinals from the endoturbinals are indistinct. The basal aspects of the endoturbinal plates form well-defined lines on the cribriform plate, about which are arranged a number of little pits. From the bottom of these lie the foramina of the olfactory nerves. The most conspicuous of these is the one for the first endoturbinal plate. The septoturbinal surface is on a higher plane than that of the ethmoturbinals. The crista galli is distinct throughout. The non-perforate space is nearly one third the length of the cribriform plate. Of the nasal surfaces, it is seen on the frontal section that the divisions between the ectoturbinals and the endoturbinals are well defined. The former are seen to have a less complicated structure, and are arranged as converging radii from the upper and lateral walls. The endoturbinals are arranged in tiers, and constitute, with the median exposure of the nasoturbinal, the entirety of the median surface.

The ectoturbinals are nine in number. The first ectoturbinal and the nasoturbinal are confluent. The former presents a convex uniform surface above. The nasoturbinal is distinct from the meso-ethmoid. The second ectoturbinal is of the same size as the first, but more distinctly biconvolute at the base. The third is the longest of the ectoturbinal series, and reaches the centre of the ectoturbinal space. Three additional plates, rudimental in character, are seen on the lateral aspect of the section. The endoturbinals are also nine in number, four of them only reaching the median surface. They are much more convolute than in the ectoturbinals, and present a number of secondary folia.

The sphenoturbinal is seen distinctly united to the meso-ethmoid.

In the two-toed sloth,† *Choloepus didactylus* (Plate III. figs. 5, 6), the cribriform plate is without angulation, as seen in the skull of the young of this species, and the entire surface which answers to that for endoturbinals is marked by four plates and associated foramina. The plates are all united anteriorly into a single transverse lamina. The posterior non-perforate space equals in longitudinal diameter one third of the area of the cribriform plate. The septoturbinal space is scarcely raised above the plane of the turbinal spaces. The crista galli answers in

* For purposes of comparison, the encranial surface of the ethmoid bone of the hog is figured (Plate III. fig. 4), but not described.

† For purposes of comparison, the encranial and the nasal surfaces of *Bradypus* are presented in figs. 1 and 2 of Plate IV., but not here described.

position to the anterior two-thirds of the same. No separate arrangement for ectoturbinals appears to exist. On the nasal surface the endoturbinals are, with the exception of the first, without lobes, and the nasoturbinal and the ectoturbinals are absent. The sphenoturbinal is united to the septum by three distinct laminae.

In the *cat* * the nasal surfaces are much compressed medio-laterally. With the exercise of a little care, the parts can be analyzed without resorting to a transverse section. The first ectoturbinal is excessively short, and presents biconvolute folia directed upward. The second, third, and fourth ectoturbinals are slight, and are biconvolute their entire length. The plates and the convexities of the convolutions are distinctly visible on the lateral surface of the ethmoturbinal mass. The nasoturbinal is biconvolute, the median convolution being the larger anteriorly. The lobule of this turbinal is in height equal to one half the length of the nasoturbinal, and is crescentic in outline. The nasoturbinal and all the ectoturbinals are united anteriorly by a transverse lamina.

The endoturbinal plates are five in number. The first is the largest of the series. It is obscurely convolute, while the lobule is as long as the plate. It is obliquely placed from above downward, and before backward, lying in front of the second and third endoturbinals, and composed of a number of closely-set convolutions. It is the anterior division of Strauss-Durckheim. The second plate also possesses a distinct foliated lobe. The second and third plates are united on the lateral surface by a common lamina. The third plate is small, concealed from the median surface, without lobes, and partly concealed on the lateral surface by the above-named lamina. The fourth plate closely resembles the second. Its lobule is nearly the length of the plate. The fifth is without a lobe, and convolute medianly, the convex surface of this convolution appearing for its entire length on the free median surface of the ethmoturbinal mass.

In the seal, *Phoca vitulina* (Plate IV. figs. 3-5), the encranial surface presents a narrow septoturbinal surface. It lies on the same plane with that of the turbinal surfaces, extends over less than one third the width of the encranial surface, and terminates anteriorly by an enormous foramen. The rounded surface answering to the ectoturbinal space is bordered by an elliptical row of foramina. The ridges for the endoturbinals are inconspicuous and short, not extending, even for the first endoturbinal, more than one third of the diameter of the cribriform plate.

* Elaborate figures of the ethmoid of the *cat* are contained in the work of Strauss-Durckheim, *loc. cit.*

The crista galli is robust, and extends the entire length of the cribriform. The non-perforate space is one third as long as the cribriform, thus presenting a striking contrast with the same plate of the other Carnivora mentioned in this paper. It is concealed in part by the frontal bone in articulation of the bone with the cranium, but in the disarticulated bone it is convex or rounded in outline and nearly equal to the ectoturbinal surface in diameter. From it the ectoturbinal plates in part arise. These last-named plates, with their accompanying convolutions, are well seen on the lateral surface.

As in the *dog*, the *cat*, the *otter*, and other carnivores, the nasoturbinal, as in the *seal* in part, arises from the meso-ethmoid. It is held to the meso-ethmoid one half the length of the latter, at its upper margin. The union does not interfere with free access of air to the olfactory plates.

Huxley makes a statement, in his "Anatomy of the Vertebrated Animals," to the effect that the ethmoturbinals in the seal are small and flattened, and that the latter are *anchylosed with the vomer on each side*. In a single specimen examined I did not find this to be the case. (See Plate IV. fig. 3. The position of the arrow indicates the septoturbinal space.) It is true that the mass is, on the whole, flattened; but the frontal portion of the mass is more than usually well developed, and at no point did ankylosis exist. The remarkably thickened transverse lamina was probably in this statement mistaken for an exceptional layer of union.

In the star-nosed mole, *Condylura cristata*, the ectoturbinals advance forward as far as the anterior end of the transverse lamina. The nasoturbinal extends as far as the third premolar. The first endoturbinal reaches to the last premolar; the second and third are of nearly equal size; all the endoturbinals presenting uniformly broad contiguous median surfaces, the first and third not connected below the cribriform plate. In transverse section the ectoturbinals are seen to be four in number, the last being the largest. It would here seem that the last is the one retained in the Cheiroptera.

THE ETHMOID BONE IN THE CHEIROPTERA.*

Enough has been said, I trust, of the general plan of arrangement of the several parts in the ethmoid bone of mammals, to serve as an introduction to the description of the bone in the Cheiroptera. It was, indeed, in attempting to describe the bone as found in the bats that the necessity of a revision of the subject became evident. It is not to be

* The crania furnishing the basis of this study were, with few exceptions, furnished by the Museum of Comparative Zoölogy.

inferred from this statement that the ethmoid bone in the bats differs in any essential feature from the bone as above described. In the more generalized forms, as the Pteropines and in most of the Phyllostomines, the ethmoid, while simple in construction, is in general appearance much the same as in other mammals. But in the more specialized genera, the details are so strongly contrasted with those of the mammalian type, (presenting a number of characters, which it is thought may be of value in classification,) that the special attention of the reader is invited to their consideration.

DESCRIPTIONS OF THE ETHMOID BONE, INCLUDING ALL ITS PARTS.

Pteropus medius. — The encranial surface presents a small ectoturbinal space, which, however, is as wide as the union of the septoturbinal and endoturbinal spaces farther backward. The cribriform is thus narrowed, and without conspicuous ridges or other markings than the median and lateral rows of foramina. The non-perforate surface is a mere narrow rim.

The ethmoturbinal mass is much compressed laterally, and composed of a single ectoturbinal and a series of four endoturbinal plates, which are united anteriorly and laterally. The tendency for the endoturbinal plates to form parts of one functional surface recalls the disposition of the parts in the *Quadrumana*. The opening above the endoturbinal series is distinctly median. The first plate lateral to this opening would be the nasoturbinal, which here does not appear to be different from the usual disposition of an ectoturbinal, and I have concluded so to name it.

The ectoturbinal extends as far as the plane of the anterior border of the first molar. It is higher at its origin from the cribriform plate than at its anterior free end. It is curvilinear and convolute outward. It is attached its entire length to the lateral surface of the ethmoturbinal mass, and anteriorly to the endoturbinal transverse lamina.

The endoturbinal series of plates are united by a broad transverse lamina, which anteriorly (i. e. beyond the point of its union with the vomer) is deeply concave on its free under surface, so as to cover in the maxilloturbinal.

In a profile view of the median surface of the ethmoturbinal series the vertical aspect of this concave surface is distinctly seen, and closely resembles a lobe; but it is not traceable to any one olfactory plate. The transverse lamina is traceable backward to the anterior ends of all the olfactory plates, including the ectoturbinal. The lower anterior half of the median surface of the plate is emarginate. The anterior

end of the lamina reaches as far as the canine tooth. Of the endoturbinal plates themselves it may be said that the first endoturbinal plate is nearly simple, and reaches the transverse lamina at the plane of the anterior border of the first molar. The second endoturbinal plate arises in common with the preceding, and ends at the same point. It is biconvolute. The third plate reaches as far as a point between the first and second molars. It is convolute, but permits a small portion of the plate to be seen anteriorly.

Cyoncteris. — The general plan of the plates is the same as in *Pteropus*. The median vertical aspect of the concavity of the transverse lamina is one fourth the length of the second endoturbinal plate. The anterior margin is concave.

Epomophorus gambianus (Plate V. fig. 1). — The general plan of the plates as in *Pteropus*. The produced end of the transverse lamina reaches the plane of the anterior edge of the second premolar.

Cyanopteris. — The general plan of the plates as in *Pteropus*. The anterior margin of the median vertical aspect of the transverse lamina is straight (that is, not concave), and less oblique than in *Pteropus*.

Phyllorhina tridens (Plate VI. fig. 5). — The olfactory plates two in number. They are apparently the first and second endoturbinals. Each plate ends anteriorly in a clavate median process or lobe. The two are separate from each other, and nearly vertical in position. The encranial surface is of extreme simplicity.

Rhinolophus ferro-equinum (Plate VI. fig. 4). — The first ectoturbinal arched, long, reaching as far as the plane of the anterior border of the first molar. The first and second endoturbinals are horizontal, simple, not contiguous. They are without lobes, and are non-convolute. They do not advance beyond the vomerine portion of the transverse lamina. The encranial surface is slightly inflated over the cribriform plate. The ectoturbinal space is absent. The non-perforate space is scarcely at all raised.

Megaderma frons (Plate VI. fig. 2). — The ectoturbinal absent. The endoturbinals two in number, as in *Phyllorhina* and *Rhinolophus*. Both of these possess small swollen lobes, but are both confined within the limits of the vomerine portion of the transverse lamina. The lobes, as they appear on the median surface, are nearly vertical. Projecting in advance of the plates as far as the level of the last premolar is a lobule, which may be said to represent the produced transverse lamina, although in this genus it more closely resembles a septum defining the outer wall of the nasal chamber. The encranial surfaces were not examined.

Megaderma spasma (Plate VI. fig. 1). — The ectoturbinal a minute tubercle, lying above and to outer side of first endoturbinal. The ethmoturbinals four in number. The first endoturbinal is separated by a short interval from the remaining two. It is but slightly lobulated, extends as far as the level of the anterior border of the second molar, and is obliquely placed from above downward and from behind forward. The second and third endoturbinals are parallel, nearly contiguous, the second scarcely exceeding the third in length. The first is lobed for one third its length.

Nycteris thebaica (Plate VI. fig. 3). — The plates are three in number, one ectoturbinal and two endoturbinal. The first of these answers in position to the nasoturbinal, since it bounds posteriorly the opening leading outward from the nasal chamber. Its frontal surface is furnished with a clavate swelling, which is slightly projected as a small lobe. The first and second endoturbinals are smaller than the nasoturbinal, and are so arranged as to permit the second to conceal the third. The latter is, indeed, the only one of the two seen in profile, the former lying between it and the nasoturbinal. The first endoturbinal is slender pedunculated, and bears a small bifid lobule. The second endoturbinal is almost as stout as the nasoturbinal, and its lobule projects forward for a distance equalling one half of the plate itself. The lobe is obscurely clavate.

In the *Vespertilionidæ* the arrangement of the plates is more simple than in the *Pteropidæ*, but more complex than in *Rhinolophus* and the allied genera.

Vesperus. — The openings of the septoturbinal space are confined to a large foramen placed just in advance of the non-perforate space. Near to the septum, at the anterior portion of the space, is seen a group of foramina advancing well to the front. Directly opposite the beginning of this series to the lateral side is the group of foramina for the first endoturbinal plate, while in front of the latter lie the two foramina for the single ectoturbinal plate. The arrangement is the same in *Vesperugo*.

Seen from the nasal aspect in *Vesperus noctula*, the ectoturbinal is two thirds the length of the first endoturbinal. It is thickened above and convolute laterally at the summit. The lateral surface is concave. The entire plate rests on the concave lateral surface of the first endoturbinal. The last-named plate is very broad above, and expands laterally and in front of the ectoturbinal. It is narrower at the base than at the tip, where it is prolonged slightly along the median border into a slen-

der process. The lateral border of the portion in advance of the transverse lamina extends as far as the anterior edge of the second premolar. It is concave to receive the convex maxilloturbinal. The second endoturbinal is slightly narrower behind than in front. It is twice the size of the third endoturbinal, which is subrounded.

Vesperus fuscus. — The ectoturbinal is as in *V. noctula*, with the exception that it is deflected a little more outward. The first endoturbinal is acuminate, with a uniformly sloping border. On the median surface the plate is not visible below the second and third plates. The second plate is as in *V. noctula*. The third is longer than wide.

Scotophilus Temmincti. — The ectoturbinal is compressed medio-laterally, without lateral concavity, and is deflected slightly outward. It is a little more than one half the length of the first endoturbinal. The latter plate is much as in *V. noctula*. Its lateral border extends a short distance beyond the ectoturbinal. The end of the free portion is a narrow point, and lies at the level of the premolar. The median surface bears a general resemblance to the same part in *V. noctula*.

Vespertilio (Plate VII. fig. 6). — The encranial surface in all essential features as in *Vesperus*. The single ectoturbinal one third the length of the first endoturbinal plate. As seen from above, the ectoturbinal is lodged in a concavity in the lateral surface of the preceding plate. The first endoturbinal is produced as far as the first premolar. The plate is of a pyriform figure as seen from above, and presents a truncate apex. The portion in advance of the transverse lamina is deeply concave below, and overlies the maxilloturbinal. The second endoturbinal is of a triangular figure, with a rounded apex. It appears to be lodged, when the parts are viewed superficially, on the median surface of the endoturbinal series. The third endoturbinal is the smallest of the three, and is continuous with the upper portion of the first endoturbinal.

All the preceding genera of the Vespertilionidæ, as contrasted with the genus next to be mentioned, have the first and third endoturbinal plates united above the second plate.

Atalapha. — In *A. noveboracensis* the encranial surface presents the septoturbinal foramina placed in a row along the anterior half of the space of the same name. The openings of the ectoturbinal surface are in a direct line with the foregoing, and both are depressed below the general surface. The foramen for the first endoturbinal is seen lying at the bottom of the conspicuous depression near the crista galli. The foramina are everywhere at the sides of the encranial surface. Seen from the nasal aspect the ectoturbinal seems to be nearly the length of

the first endoturbinal, and is compressed medio-laterally. It is slightly convolute outward at its base, and concave on its lateral surface. The first endoturbinal is abruptly acuminate anteriorly, and straight on its median, lateral, and under free surfaces, the last named being concave inferiorly. The second endoturbinal plate is oblique, and slightly inflated at its anterior end. Its lower border forms the inferior edge of the median series of plates. The third endoturbinal is triangular in shape, and is one half the size of the preceding.

In *A. cinereus* the general plan resembles that of the foregoing species. The parts are, however, of greater height, the interval between the first and second endoturbinals being wider. The second endoturbinal is relatively larger, and curved outward. This arrangement causes the plate to present a concave surface outward, which receives the swollen lower border of the third plate. The median aspect of the first endoturbinal is straight; but the lateral surface is deflected outward, and is impressed on its entire surface by the ectoturbinal which rests upon it, leaving only a raised rim of the endoturbinal round its anterior half. The median surface of the produced portion of the first endoturbinal is nearly as high as it is long. The concave under surface embraces securely the maxilloturbinal.

Nycticejus crepuscularis. — In this genus the encranial surface is about one third the area of the entire region, the cribriform plate marked as follows: first, a single opening is seen on the sphenoturbinal surface; second, two openings on the ectoturbinal surface; third, a relatively large depression on the endoturbinal, containing two openings, well to the lateral aspect, for the first endoturbinal plate.

The nasal surface exhibits a single ectoturbinal plate. It is a little less than one half the length of the first endoturbinal, is directed almost vertically downward, the swollen upper border looking outward. The lateral surface is concave, deflected outward as far as the tip of the first endoturbinal. It is slightly concave above. The free portion is acuminate, reaching as far as the level of the canine tooth. The second plate is as in *V. fuscus*, but not so much narrowed at the base. The third is a mere rounded nodule.

Lasionycteris noctivagans. — The septoturbinal space extends a little in advance of the septal line. There is but a single opening for the ectoturbinal. The main plate is marked by a relatively small opening, behind which extends a row of three small foramina. The non-perforate space is as in the preceding forms. On the nasal surface the endoturbinal series is inflated, and does not exhibit the lateral concavity seen in other

Vespertilionidæ. It is directed downward and forward. The first endoturbinal is as in *V. fuscus*. It reaches a point as far as the canine tooth, is slightly depressed above, and presents a uniformly sloping surface laterally. Its lower edge forms the lower border of the median surface. The second endoturbinal is of uniform width, longer than high, and equal in length to the free portion of the first endoturbinal. The third endoturbinal is smaller than the preceding.

Antrozous pallidus. — The ethmoid bone in this genus closely resembles that of other Vespertilionidæ. The ectoturbinal is compressed medio-laterally.

Mollosus obscurus. — The ectoturbinal is biconvolute, slightly acuminate in front, and subequal in length to the mesoturbinal. The endoturbinal is somewhat broader in front than behind, straight on its median surface, concave on its lateral surface to receive in a measure the ectoturbinal. It is apparently without an olfactory plate, which being understood to be present the entire endoturbinal forms a summit thereto with two convolutions which make up the median and lateral surfaces respectively. The concavity thus opening downward receives in part the maxilloturbinal. The second endoturbinal is absent. The third and fourth closely resemble the same plates in the Phyllostomididæ, and do not demand any special description. The transverse lamina is apparently absent.

M. perotis. — The ectoturbinal is compressed from side to side, and is one half the length of the first endoturbinal. The first endoturbinal is acuminate as it is seen from the median surface, the portion projecting in advance of the third endoturbinal being slightly convex inferiorly. The third endoturbinal is received in a depression on the lateral surface of the first, the second being absent. It in turn receives the fourth. Both these turbinals as seen *in situ* are longer than wide.

Natalus stramineus. — The ectoturbinal is absent. The second is slender and acuminate, the convolutions uniting inferiorly at the anterior two-thirds. The lower border of the free part is straight. The third endoturbinal is globose, and one third the length of free portion of the preceding. The fourth is exceedingly minute, being about one third the length of the third. It is somewhat rounded in form.

Taphozous (Plate VII. figs. 2, 4). — The ectoturbinal somewhat broader than the first endoturbinal, but of the same length. The transverse lamina deeply concave, completely concealing the small maxilloturbinal. The under portion of the free portion of the first endoturbinal is traceable as far back as the end of the endoturbinal series. The median aspect of the concavity not projected, as in most genera, but appears as a

rounded convexity of equal width with the exposed portions of the endoturbinals. The second endoturbinal appears as a nodule between the transverse lamina and the second endoturbinal; the third and fourth much as in other genera, the lower border of the third plate being visible from the lower edge of the series.

Rhynconycteris naso. — The ectoturbinal absent. The remaining three endoturbinals closely resemble one another. The first projects in advance beyond the third no more than the third projects beyond the fifth. The free portion of the first small, yet reaches the level of the anterior of the second premolar. The plates on the median surface while contiguous leave exposed a larger surface than is the case in any other genus of the Molossi.

Noctilio leporinus (Plate VII. fig. 5). — The ectoturbinal inflated nearly twice the thickness of the first endoturbinal, and nearly equalling it in length. The median aspect of ethmoturbinal closely resembling *Molossus*. The free portion of each plate of about equal width. The nasoturbinal of great width anteriorly, and almost entirely concealing the maxilloturbinal.

Mormops megaphylla. — The encranial surface presents the following features. The single ectoturbinal foramen is small. That for the first endoturbinal is conspicuous. The extent of the non-perforate space appears to be enormous as compared with the same space in other genera. The ectoturbinal is a mere rounded point at the base of the first endoturbinal. The endoturbinal series closely resembles the same in the *Vespertilionidæ*. The first endoturbinal is without the lobe present in *Chilonycteris*. Its under surface is concave at the free produced portion, and conceals the unusually long maxilloturbinal. The second ethmoturbinal is very slender and oblique. It is continuous above with the first thus differing from the arrangements seen in *Vespertilionidæ*. The third plate is obscure, if not absent. It is apparently continuous with the crista galli.

Chilonycteris rubiginosa. — The first ectoturbinal subglobose, one fourth the length of the first endoturbinal. The free projecting portion of the first endoturbinal is deeply concave beneath, and completely covers in the maxilloturbinal, as in the *Vespertilionidæ*. It reaches as far as the first premolar. This plate bears upon its summit a lobule, as in the *Phyllostomidæ*. The second and third endoturbinals are simple, non-revolute, nearly vertical, the third being the broader.

Desmodus rufus (Plate VII. fig. 1). — The ectoturbinal is inflated, and nearly the length of the first endoturbinal. The first endoturbinal is

compressed, and reaches the plane of the anterior border of the single molar. A lobule in the position of the basal convolution of other Phyllostomines lies between the first and the third plates, and resembles in general appearance a separate endoturbinal. The second endoturbinal is small and concealed. The third and fourth plates are in general appearance much as in other Phyllostomines. The lobes of the first and third endoturbinals are conspicuous.

Carollia brevicauda (Plate V. figs. 3, 5). — The first ectoturbinal is inflated, with no trace of the concavity marking the plate in the *Vesperilionidæ*. It is two thirds the length of the first endoturbinal. The last-named plate is narrowed anteriorly, but not acuminate, since the tip is truncate. Its lower border is concave. The lobule at the summit of the plate is broader in front than behind, and equals the free portion in length. The third plate is concealed. The fourth is of the same size and shape as the foregoing. The fifth is triangular in form, open beneath, and presents the appearance of having a large lateral convolution equal in length with the main plate. The maxilloturbinal is rudimentary and free from the ethmoturbinal.

Lonchoglossa. — The general plan in this genus is as in other Phyllostomines. The ectoturbinal is minute, compressed, not more than one half the length of the first endoturbinal. The latter is thin, straight, with a long falciform lobe, which is concave inferiorly. The basal lobule is well developed, and lies at the lower border of the median surface of the ethmoturbinal. The remaining endoturbinals as in other Phyllostomines, but less obliquely inclined.

Phyllostoma hastatum (Plate V. fig. 2). — The foramina of the septoturbinal and the ectoturbinal surfaces on the encranial aspect form a continuous arch. The depression for the main plate is large, and the space behind it is occupied by numerous openings arranged without apparent order.

Schizostoma. — The ectoturbinal is moderately inflated, but less so proportionally than in *Dermanura*. The narrow and acuminate first endoturbinal projects about one third of the length of the ectoturbinal. Its lobule is inconspicuous. The second endoturbinal is concealed, and presents a slightly inflated upper border. The third plate possesses a large anterior lobule, which is convex forward. The parts are contiguous upon the median surface.

Macrotus Waterhousii. — The ectoturbinal is small, a little less than one half the length of the first endoturbinal. Its upper border is horizontal, and its lower concave. The extreme tip of the lobule extends as

far as the anterior border of the first molar. The second plate is concealed, and the third and fourth are arranged much as in *Vampyrops*, which this form in great part resembles. The lobule on the first endoturbinal is small, but readily discernible. The plates below their inflated summits are not clearly seen. The parts on the median surface are contiguous.

Vampyrops. — The ectoturbinal extends the entire length of the inner wall of the orbit, and is inflated. The first endoturbinal is concealed between the last named and the second endoturbinal. It is a simple inflated plate, without convolutions. It is in intimate association with the region of the second plate, with which it may be confounded. If the first endoturbinal plate be counted as a lobule upon the base of the second, the series will lack the number five which all other genera of this group possess. Assuming, therefore, that the concealed plate is the true second endoturbinal, the one below it becomes the third. The last-named third plate is the largest of the series, and resembles the second of the *Pteroderma* related forms. It is broad, non-convolute, and ends in a narrow tongue that reaches a point as far forward as the anterior border of the first molar tooth. The fourth endoturbinal is a nearly simple plate, having a thickened free upper border. Its free surface is entirely median, and almost linear. The fifth endoturbinal is exposed on the median surface for its entire extent; its anterior border is thickened, and convolute upwards. The frontal section of the ethmoturbinal presents the ectoturbinal and the first endoturbinal in close juxtaposition and assuming a medio-lateral relation, while the remaining plates are arranged nearly at right angles to them. There appear to be no plates comparable to the sphenoturbinals.

Pteroderma (Plate V. fig. 6). — The ectoturbinal of a triangular form, whose base is forward and advances as far as the ends of the olfactory plates of the endoturbinals minus the lobules, and nearly to the hinder border of the orifice of the maxillary sinus.

The first endoturbinal is convolute laterally, and possesses an acuminate lobe directed forward that equals the plate itself in length. The free end of the olfactory plate is distinctly seen beneath the level of the lobe. Lying at the level of the lobe just described, behind the free portion of the plate, is a small nodule, which may receive the name of the *posterior lobe*, as opposed to the preceding, which is as compared to this an anterior lobe. The second endoturbinal plate is free inferiorly, but is biconvolute above for the greater part of its length. The last-named portions are concealed by the lobes of the adjacent plates. The third

endoturbinal plate is free beneath, and possesses a broad fleshy lobe directed forward. The fourth plate, unlike the preceding, is not free at its base beneath, and is the smallest of the series. It presents a concave border in front, and is furnished with a fleshy lobe which is directed backward. The surfaces of all the olfactory plates are separated by appreciable intervals.

Artibeus (Plate V. figs. 4, 6). — The parts in this genus closely resemble those of *Pteroderma*. The ectoturbinal is exceeding slender, and is furnished with a fleshy summit, which is convolute outward. Its upper portion alone is seen from the median surface. The first endoturbinal is free below, but fleshy above. It is produced forward one half its length beyond the end of the ectoturbinal in the form of a lobule, is acuminate, and possesses as in *Dermanura* a small posterior lobe. The second endoturbinal is concealed by the third. When the latter is pressed aside at its upper part the small biconvolute plate of the second plate is seen in position. The third endoturbinal possesses a large lobule, which lies upon the median surface. The lobule is subrounded in form, completely occupying the upper edge of the plate, so that it appears to arise from the cribriform plate by a pedicle. The fourth endoturbinal presents an exposed plate on the median surface. It is beneath the convex non-perforate space, and yields a single large convolution, which is turned outward. Although this plate lies back of the cribriform plate, the absence of any connection between it and the vomer would seem to show that the arrangement met with in many mammals is departed from.

Dermanura. — In this genus the ectoturbinal is inflated, and is projected beyond the first endoturbinal one half its length. The first endoturbinal is concave outward, is without a lobule, and in a measure embraces the last-named plate. The remaining plates are arranged as in *Pteroderma*. On the encranial surface the depression for the main plate is without associated foramina, but in their stead three openings are seen, ranged transversely. The ectoturbinal opening is single.

THE PHYSIOLOGICAL ANATOMY OF THE OLFACTORY SENSE IN THE MAMMALIA.

The olfactory organ in the mammalia is an appendage to the respiratory tract. It depends upon the direct contact of the odoriferous particle upon the specific cell fixed upon the olfactory surface, and united with a terminal filament of an olfactory nerve. The olfactory plates upon which the cells lie are composed of two sets, an ectoturbinal and

an endoturbinal, the space between them being defined on the median aspect by the nasoturbinal. In advance and beneath these plates, as well as being more or less embraced by the endoturbinals, the maxilloturbinal lies.* This bone acts as a sieve to warm the current of air entering the olfactory region, and to exclude extraneous particles. The particles which pass through the upper half of the maxilloturbinal pass directly to the ectoturbinals and the plates of the endoturbinals for the distance from their lateral attachments to the primary terminal convolutions or endings. The current passing through the lower half of the maxilloturbinal is received within the space below the level of the ethmoturbinal, and is chiefly respiratory. A large opening exists between the nasal chamber and the superior maxillary sinus, partly within which the ectoturbinal plates lie. The lower current may be deflected in part laterally through this opening or drawn upward between the lobes of the endoturbinal plates. Direct contact of the inspiratory currents through the space between the maxilloturbinal and the septum must be inconsiderable, by reason of the close relation, if not contact, existing between these parts. A small passage between the nasoturbinal and the septum would permit some to pass. It will be seen that all the currents above indicated are directed immediately inward, or inward and upward. In these directions no continuity with the air-passage exists. The currents in time must impinge upon the sides and roof of the nasal chamber above the level of the transverse lamina, and lie against the cribriform plate. Within this restricted area the currents may be assumed to cease, and their odor-bearing particles to fall gently upon the olfactory surfaces. This condition of rest doubtless goes on while ordinary respiration continues. So it is conceivable for a gentle respiratory current to be passing in and out along the lower portion of the nasal chamber, while the air is at rest unloading itself of its odoriferous particles above the transverse lamina. When the air is sniffed, the invitation for its ascent into the olfactory chambers is marked, — an act probably accompanied by partial elevation of the soft palate, by which means the respiratory current through the nose is suspended, and the air compelled to ascend to the olfactory level. The transverse lamina, therefore, has great functional significance. The parts contained above this

* The maxilloturbinal is continuous forward through the means of a well-defined crest into the snout, where it ends in the prominent swelling at the upper lateral border. Near its end it is concave outward, the concavity receiving a little crest-like fold on the outer side of the snout. The above description applies to the parts as seen in *V. noctula*, but is probably true of all mammals.

lamina would appear to have the most strongly localized olfactory significance, and the projected parts or lobes to be in part protectors of the maxilloturbinals, or highly specialized portions of the olfactory apparatus, in animals remarkably endowed with the sense of smell.*

CONCLUSIONS.

From the foregoing statements it is evident that the ethmoid bone varies greatly in its details in the Mammalia. While these variations may not have yielded any clues to relationship of genera in addition to those already entertained, they may nevertheless be said to present new evidence by which old claims can be strengthened. It has been seen that generalized forms, such as *Sus*, *Equus*, or *Dicotyles*, are related to more specialized forms, such as *Bos* or *Ovis*, not only by the characters yielded by the foot, the teeth, and the placenta, but by the ethmoturbinal bones as well. In like manner, in a generalized genus of the Carnivora, as *Ursus* or *Procyon*, the ethmoturbinal bones possess a less degree of specialization than in *Felix* in one direction, and in *Phoca* in another. If the testimony in confirmation of such relations of these genera were lost, it could be restated from the data obtainable from a study of the ethmoidal plates. — In the *bats* a plan similar to the one existing in the majority of the mammals is recognized in the Pteropidæ and Phyllostomididæ (groups already known to be generalized), but which is strangely departed from in highly specialized forms, as the Megadermatidæ and the Rhinolophidæ, and in a widely different way in the Vespertilionidæ. — It has been found that in many of the Cheiroptera, generic and even specific characters can be found in the ethmoid bone; and, on the whole, it is temperate to affirm that a comprehensive account of any species of *bat* would be imperfect which omitted an account of this bone. It is probable that a similar statement might with propriety be made for all mammals. Certainly it may be said that, in the study of those genera

* The relation borne by the ectoturbinals to the frontal sinus, by the sphenoturbinals to the sphenoidal sinuses, and by the passages of access to the lateral part of the ethmoturbinals to the maxillary sinuses, suggests the probability that the primary significance of these chambers is to accommodate the olfactory plates; and that in the human subject, where they are empty and not held subservient to the sense of smelling, the original conception has been lost, owing to the stunted condition of the olfactory apparatus. Until elaborate studies of the development of the mammalian head are instituted with the object of confirming such a suggestion, but little can be said about it in this connection. It must be remarked that the labors of Kitchen Parker (*loc. cit.*) have not led to any affirmative answer to such a line of inquiry.

of whose affinities the zoölogist remains in doubt, a careful examination of the ethmoid bone should be made. — Much might be said of the relation existing between the size of the olfactory bulb and the degree of development attained by the ethmoturbinal plates, — the bulbs, as has been found, being well developed in animals having large ethmoturbinals, and being small in others having small endoturbinals, — and of the mechanism of the act of smelling, and the significance, in a word, of the function of smelling in connection with habit. But any such extended discussion would be out of place in a communication planned as this has been, and would in no way strengthen the proposition which it was the original object of the paper to demonstrate.*

* I may here add, that a careful microscopic study of the cells of the olfactory plates, and a comparative study of the olfactory sense, and the tactile sense of bats as developed in the external nasal appendages, yielded at the hands of my friend, Dr. Francis X. Dercum, a negative result. The forms that were taken for study were *Phyllostoma hastatum* and *Nycteris Thebaica*.

EXPLANATION OF THE ABBREVIATIONS EMPLOYED IN DESCRIBING THE FIGURES.

<i>m. t.</i>	Maxilloturbinal.	<i>sp. t.</i>	Septoturbinal.
<i>n. t.</i>	Nasoturbinal.	<i>fr.</i>	Frontal.
<i>tr. l.</i>	Transverse lamina.	<i>op. f.</i>	Optic foramen.
<i>ect. t.</i>	Ectoturbinal.	<i>cr. gl.</i>	Crista galli.
<i>end. t.</i>	Endoturbinal.	<i>orb. sph.</i>	Orbitosphenoid.
<i>ect. sp.</i>	Ectoturbinal space.	<i>n. p. s.</i>	Non-perforate space.
<i>end. sp.</i>	Endoturbinal space.	<i>l.</i>	Lobule.
<i>s. t. sp.</i>	Septoturbinal space.	<i>ol. pl.</i>	Olfactory plate.
<i>m. e.</i>	Meso-ethmoid.	<i>orb. pl.</i>	Orbital plate.

EXPLANATION OF FIGURES.

PLATE I.

- Fig. 1. Sagittal section of head of the dog, showing the oblique position of the encranial surface of the ethmoid bone, with the median aspect of the lateral mass of the same bone. A portion of the septum has been included in the section at the transverse lamina. The horizontal line between the asterisks represents the dividing line between the olfactory and the respiratory regions of the nasal chamber. — It is probable that some variation will be found to exist in the turbinals of the domestic dog. Natural size.
- Fig. 2. Frontal section of the nasal chamber of the dog, a short distance in advance of the encranial surface. Natural size.
- Fig. 3. Diagrammatic representation of the encranial surface of the dog. Natural size.
- Fig. 4. Encranial surface of the otter. Natural size.
- Fig. 5. Diagrammatic frontal section of the turbinals of the otter. Natural size.

PLATE II.

- Fig. 1. Median surface of lateral mass of ethmoid bone of *Cebus capuccinus*. Natural size.
- Fig. 2. The under surface of same. Natural size.
- Fig. 3. The under surface of lateral mass of the human ethmoid bone. Natural size.

- Fig. 4. The encranial surface of the ethmoid bone of the horse. The dotted line, as it extends across the surface, represents the lower limit of the plate of bone described in the text as covering in the ectoturbinal subdivision of the surface. Natural size.
- Fig. 5. Frontal section, diagrammatically treated, of the turbinals of the horse. Natural size.

PLATE III.

- Fig. 1. Encranial surface of the ethmoid bone of the peccary. Natural size.
- Fig. 2. The isolated ridge of the first endoturbinal plate. Natural size.
- Fig. 3. Frontal section of turbinals of same, made close to the encranial surface. Natural size.
- Fig. 4. The encranial surface of the ethmoid bone of the hog.
- Fig. 5. The under nasal surface of the ethmoid bone of the two-toed sloth (*Cholapus didactylus*). Natural size.
- Fig. 6. The encranial surface of the same. Natural size.

PLATE IV.

- Fig. 1. The anterior aspect of the ethmoturbinals of the ethmoid bone of the three-toed sloth (*Bradypus tridactylus*).
- Fig. 2. The encranial surface of the same.
- Fig. 3. The ethmoid bone of the common seal (*Phoca vitulina*).
- Fig. 4. The encranial surface of the same.
- Fig. 5. The under surface of the same.

The figures are all of natural size.

PLATE V.

- Fig. 1. Median sagittal section of nasal chamber of *Epomophorus gambianus*. Slightly enlarged.
- Fig. 2. The same of *Phyllostoma hastatum*.
- Fig. 3. The same of *Carollia brevicauda*.
- Fig. 4. The same of *Artibeus* (slightly distorted).
- Fig. 5. Dorsal aspect of the turbinals in *Carollia brevicauda*.
- Fig. 6. The sagittal section of nasal chamber of *Pteroderma* (slightly distorted).
- Fig. 7. The dorsal aspect of turbinals of *Artibeus*.

Figs. 2-7 enlarged one half.

PLATE VI.

- Fig. 1. A median sagittal section of the nasal chamber of *Megaderma spasma*.
- Fig. 2. The same of *Megaderma frons*.
- Fig. 3. The same of *Nycteris Thebaica*.
- Fig. 4. The same of *Rhinolophus ferrum-equinum*.
- Fig. 5. The same of *Phyllorhina tridens*.

Figures enlarged one half.

PLATE VII.

- Fig. 1. A median sagittal section of the nasal chamber of *Desmodus rufus*. Figure enlarged two thirds.
 Fig. 2. The same of *Taphozous*.
 Fig. 3. The dorsal aspect of the turbinals of *Vespertilio subulatus*.
 Fig. 4. The same of *Taphozous*.
 Fig. 5. A median sagittal section of the nasal chamber of *Noctilio leporinus* (somewhat distorted, the nasoturbinal elevated).
 Fig. 6. The same of *Vespertilio subulatus* (somewhat distorted, the first endoturbinial elevated).

Figs. 2-6 enlarged one half.

PHILADELPHIA, November 4, 1882.

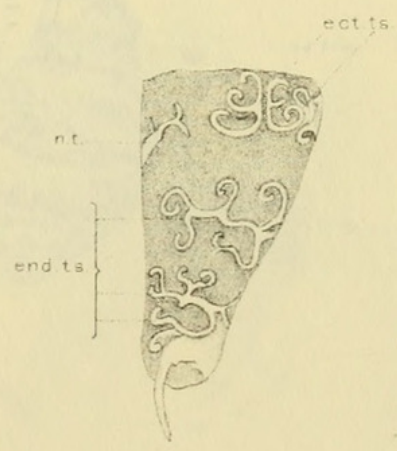
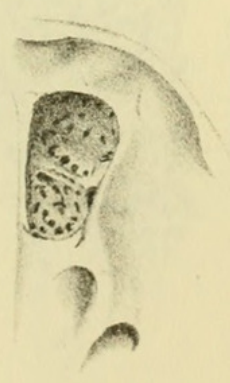
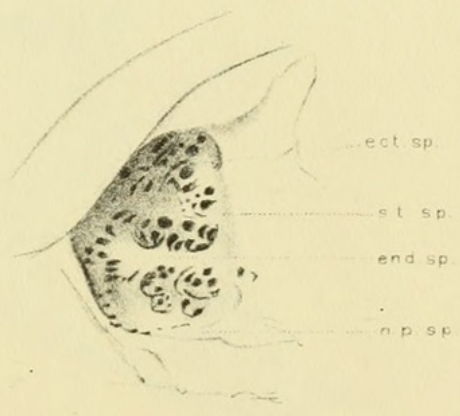
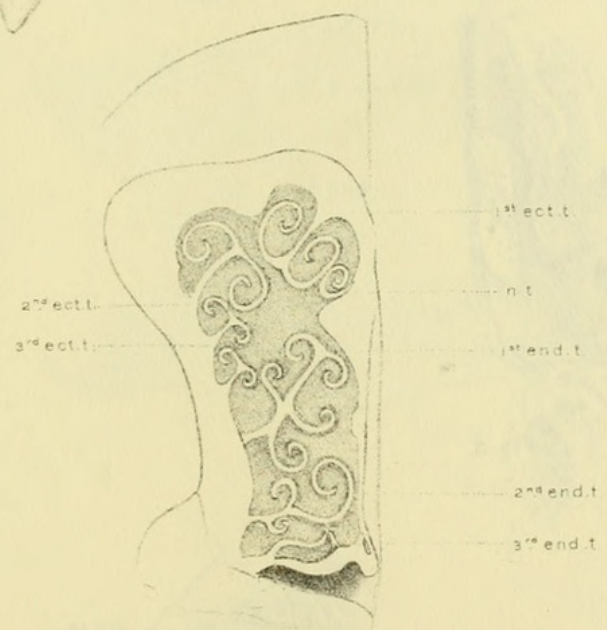
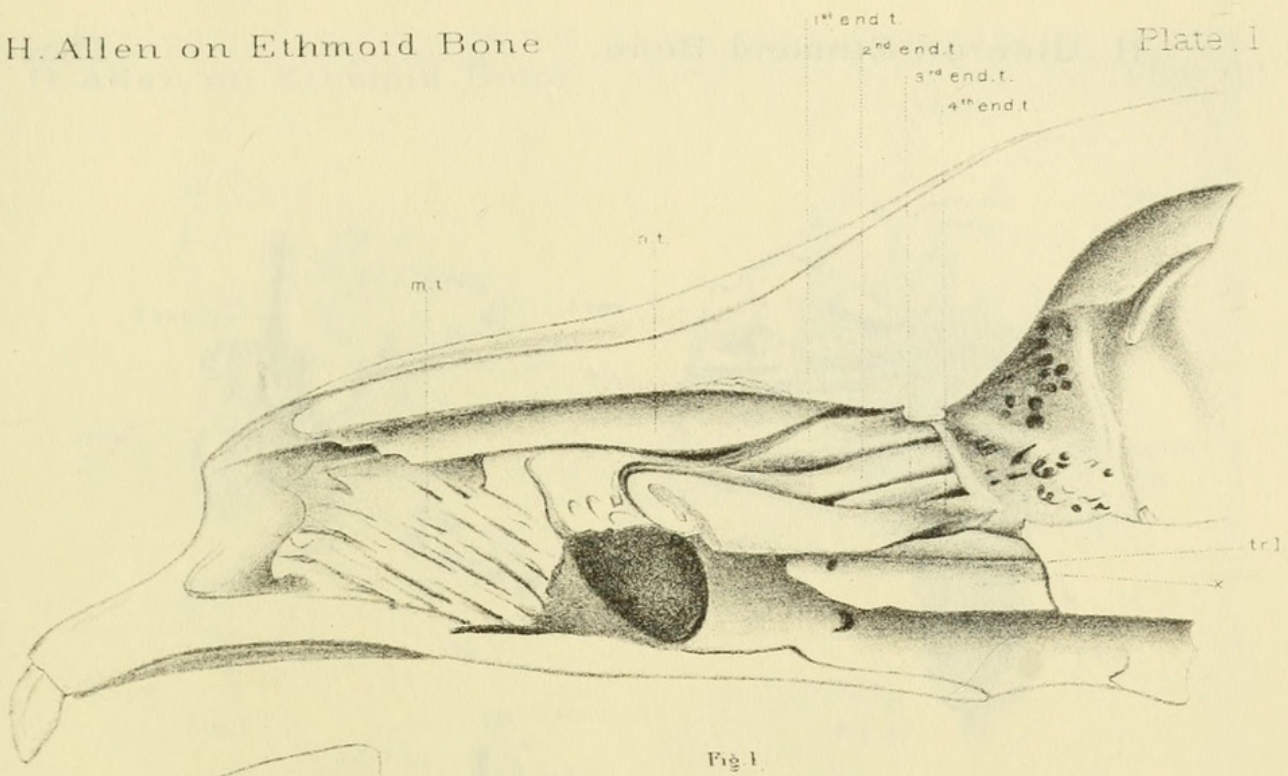




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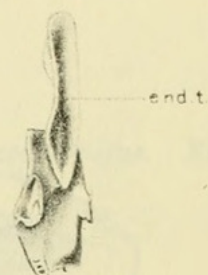


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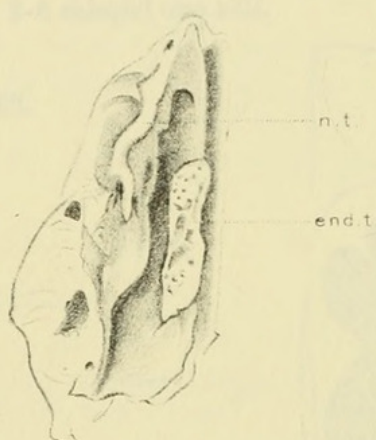


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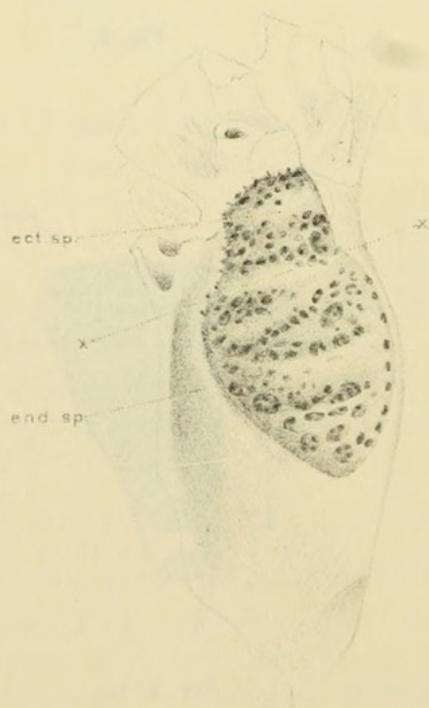


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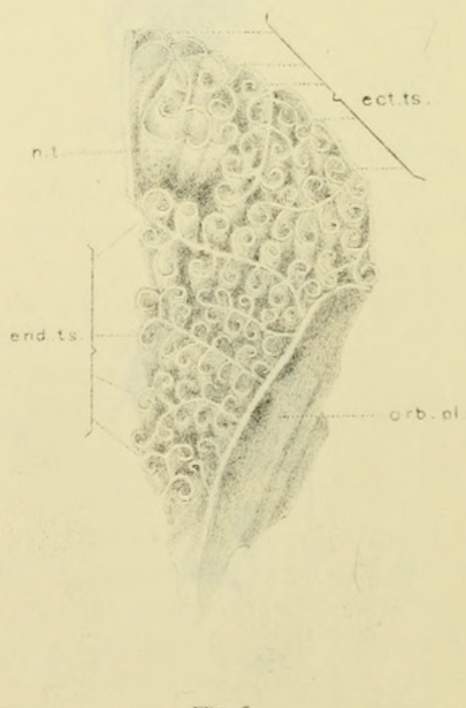


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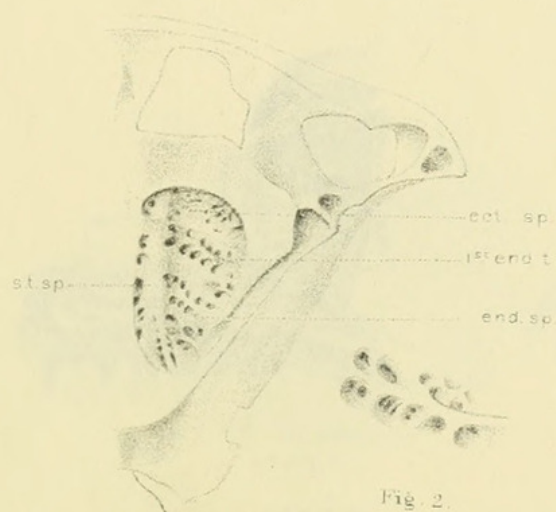


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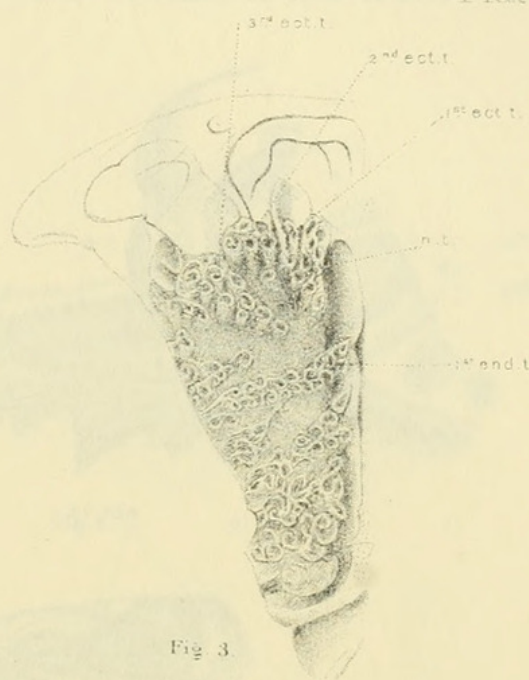


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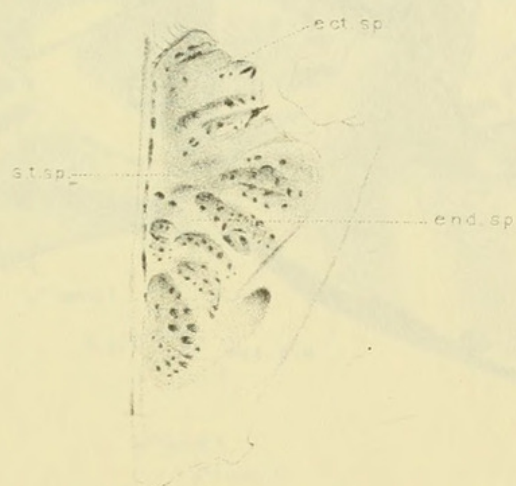


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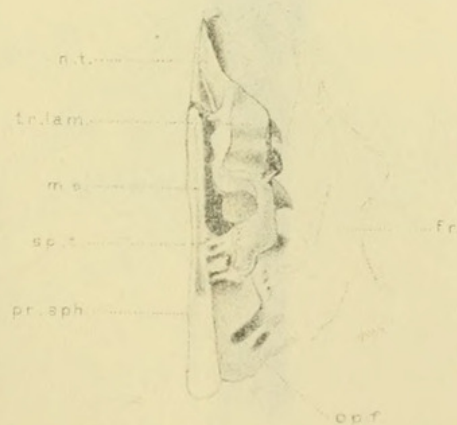


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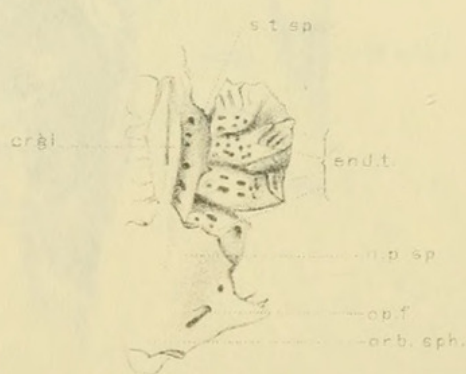


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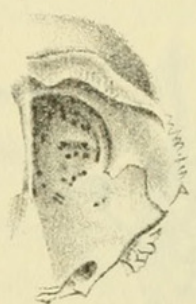


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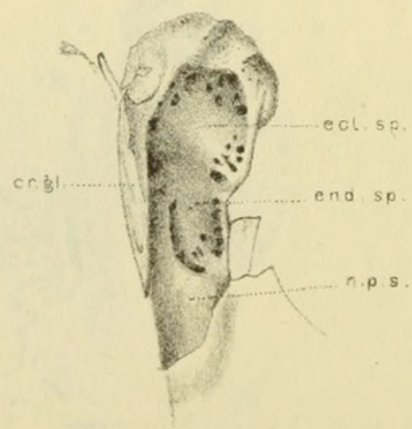
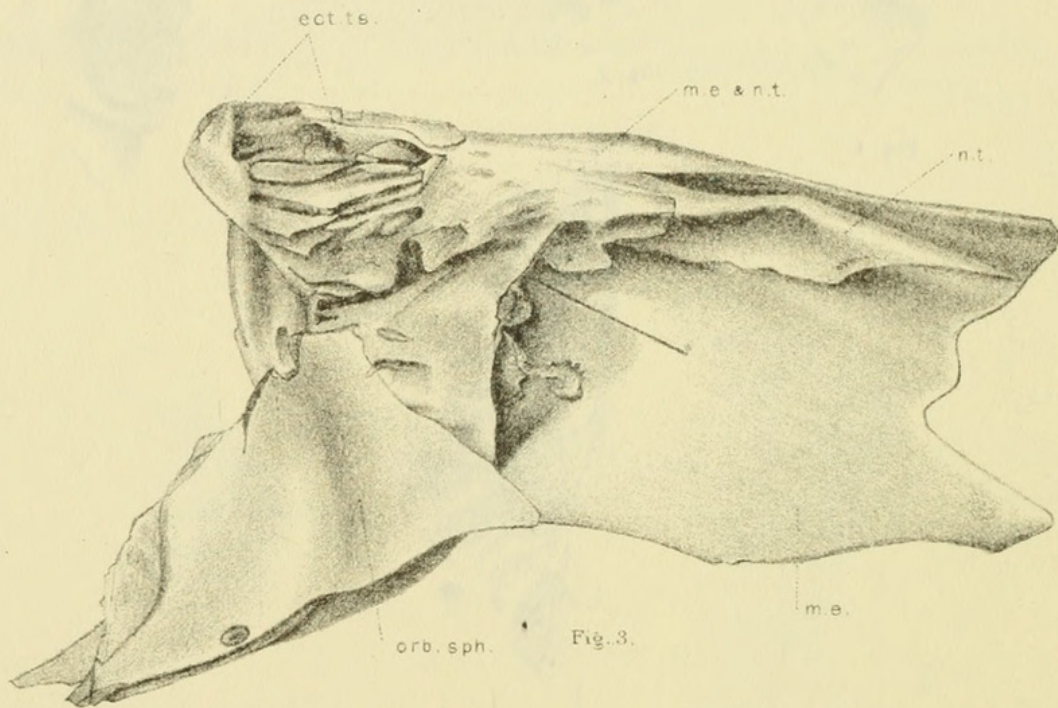


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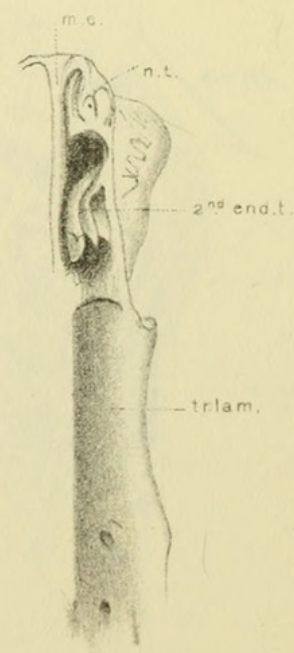
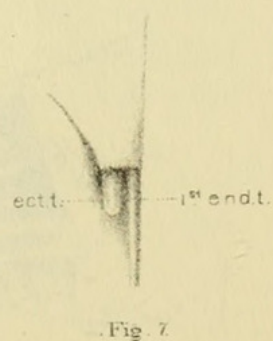
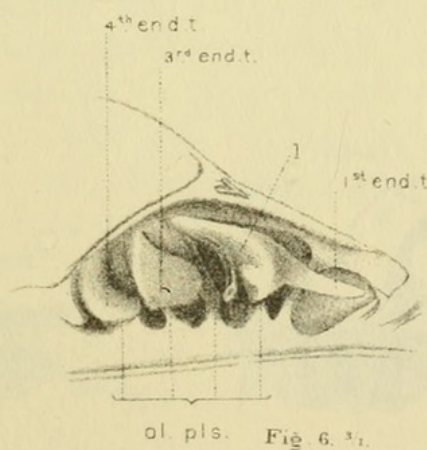
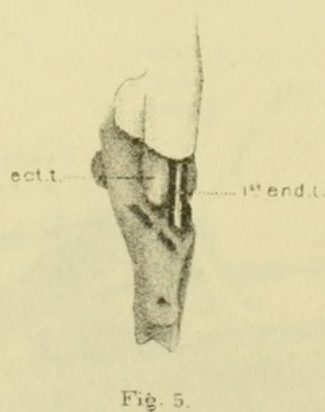
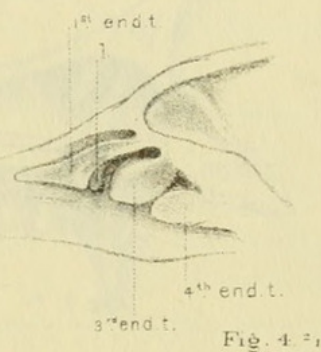
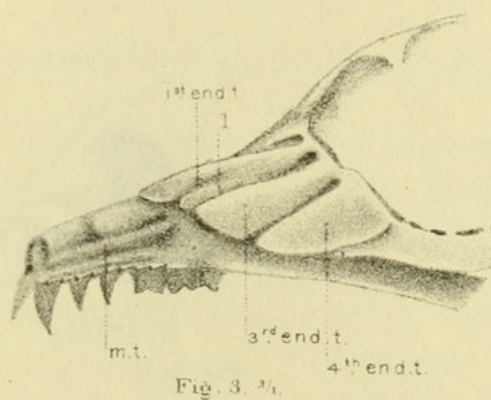
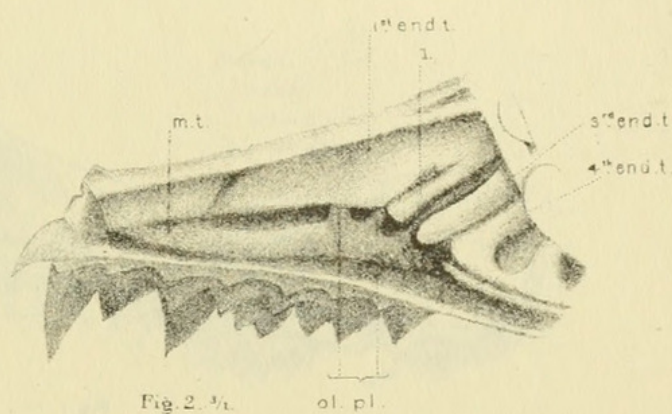
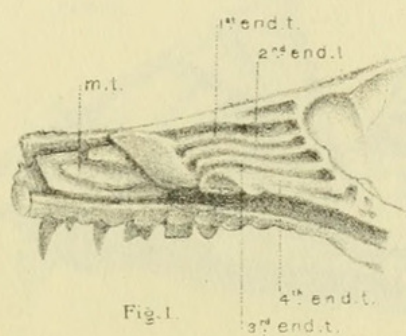


Fig. 5.



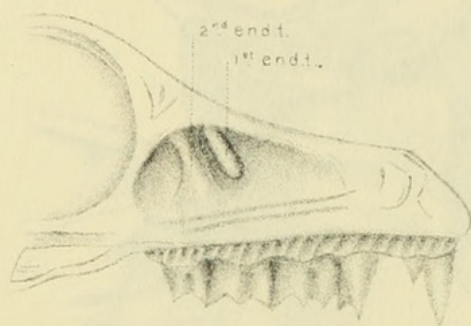
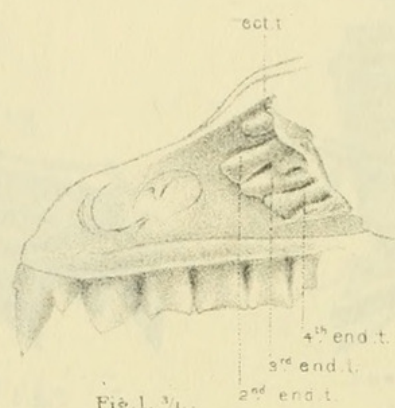


Fig. 2. $\frac{3}{4}$



Fig. 3. $\frac{3}{4}$

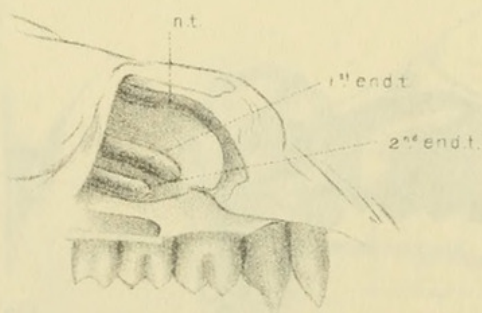


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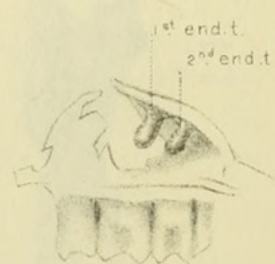


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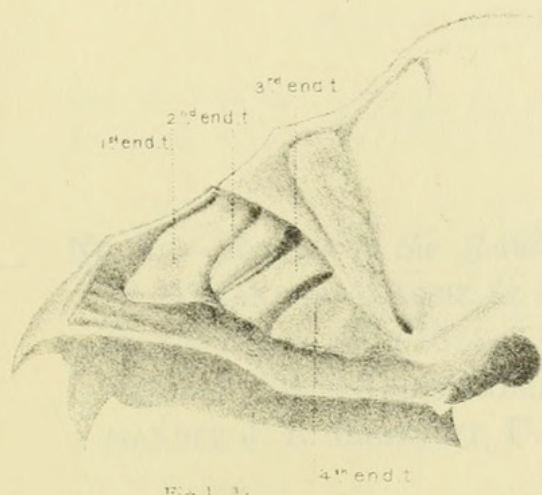


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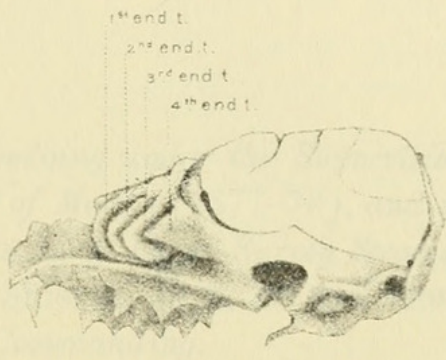


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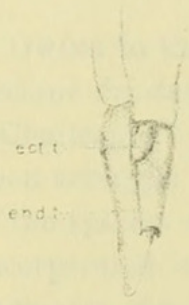


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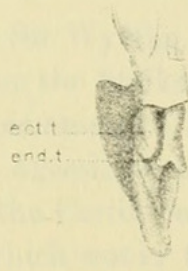


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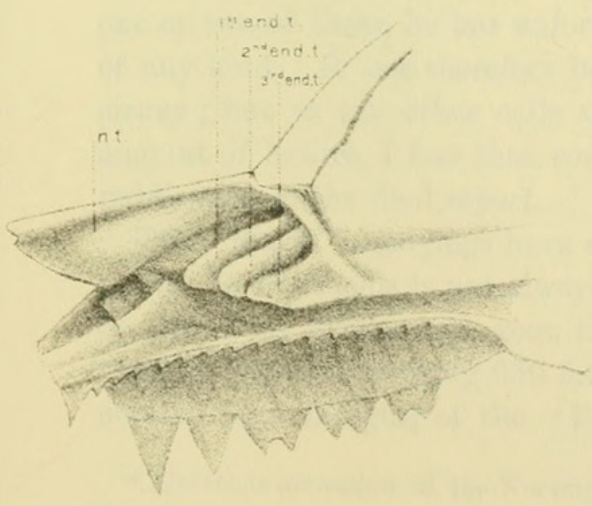


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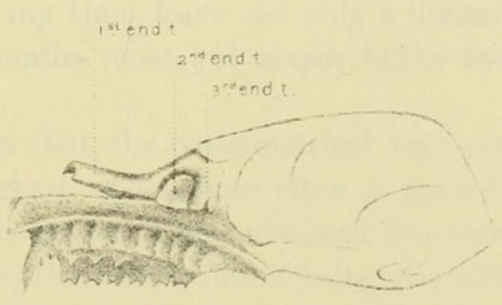


Fig. 6. 3/4.



Allen, Harrison. 1882. "On a revision of the ethmoid bone in the Mammalia, with special reference to the description of this bone and of the sense of smelling in the Cheiroptera." *Bulletin of the Museum of Comparative Zoology at Harvard College* 10(3), 135–164.

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