XVIII. *Morphology of the Mammalian Ossicula auditûs.* By ALBAN H. G. DORAN,
F.R.C.S. (Communicated by Professor FLOWER, F.R.S., F.L.S., &c.)

(Plates LVIII.-LXIV.)

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AMONG John Hunter's original collection are some preparations in spirit, representing the tympanic region of mammals, with the small ear-bones *in situ*, but only a very few imperfect dry specimens of the internal ear-bones themselves, though those of man are better represented. Little was added to this department at the Royal College of Surgeons' Museum until 1866, when Mr. Toynbee's valuable pathological auditory collection showed the want of a corresponding series in the physiological department. Fortunately, about the above date, the nucleus of such a collection offered in that of Dr. Max Hübrich, of Munich, which the College authorities purchased. The Conservator, Prof. Flower, wisely availed himself of opportunities to increase this; and at the present date a very complete series of most of the genera of Mammalia is the result.

In drawing out a catalogue of these, I was led to study minutely and compare the various groups one with the other. I soon found that, excepting the labours of Prof. Hyrtl, of Vienna, on the osteology of the entire auditory apparatus in the Mammalia ('Vergleich. Anat., Untersuch. über das innere Gehörorgan des Menschen und der Säugethiere,' Prague, 1845), little or nothing in a connected form had been done to elucidate the characters of the small ear-bones of Mammalia. Occasional desultory remarks are to be found scattered in papers on human and comparative anatomy; but these in most cases are entirely lost sight of. This suggested to me, in preparing and arranging the Museum series, to take notes thereon and the critical comparison of the objects themselves and collation of the literature on the subject, have resulted in the following descriptive and comparative account of the *ossicula auditûs* in the class Mammalia.

In such small objects as the internal ear-bones it is at first difficult to apprehend the value that may be attached to them as regards physiological influence on audition, and still less as to their morphological importance; but if, for instance, those of man be compared with those of marsupials, the wide difference is at once apparent. Again, in such groups as the Carnivora or Cetacea, the family characters derived from these diminutive ossicula are in the main very distinctive.

As the small ear-bones of the human being, for various apparent reasons, have necessarily had most attention called to them, and moreover as man, in other respects, is considered by some a standard of comparison, I have consequently taken the human ossicula first into consideration. Moreover I have described their peculiarities in such a way that the homologies of the parts of each ossicle in the lower mammals may be more clearly understood.

The drawings forming the accompanying Plates are from nature, and in all cases enlargements. By their representation side by side in series a much better idea of the family and generic distinctions are obtained than by mere verbal descriptions. Indeed the latter have grown inordinately in my hands; and but for the circumstance that the full data whereon my conclusions are founded are absolutely necessary, pending the fact of this series of ossicula being unique, or certainly the most extensive now extant, I should gladly have dispensed with this portion of the labour, and curtailed my text accordingly.

In the Journal of this Society (Zool. No. 68, vol. xiii. p. 185) and in the Proc. Roy. Soc. (No. 172, vol. xxv. p. 101) I have already indicated briefly a few of my results, and in the latter referred to those gentlemen to whom I have been indebted for objects, advice, and assistance.

THE AUDITORY OSSICLES IN MAN.

The Malleus.—In the human malleus (Pl. LVIII. figs. 1 & 2, taken from a fully developed foetus) the portion of the head above the articular surface is prominent, smooth, and convex, projects more on the outer than the inner side, and is broadest in its lateral measurement. Posteriorly it bears the articular surface for the incus, which has very elevated borders and is about three times as broad as it is deep vertically. This surface lies very obliquely compared with the mallei of most mammals, so that its external extremity is much higher than its internal. It is generally described as “saddle-shaped,” though, from a functional point of view, Helmholtz † has objected to this expression. In most works on human anatomy it is regarded as if it were one single facet; but on comparing it with the same surface on the malleus of a Cat (Pl. LVIII. figs. 30 & 31), it will be seen that it should be considered as made up of two facets, much less distinct, it is true, than in *Felis* and most other mammals, but far better-marked than in certain monkeys. A very faint groove, more marked in some human mallei than in others, and not reaching either extremity, divides them, running in the very oblique long axis of the whole surface. The more internal and upper facet (Pl. LVIII. fig. 30, *a * a*), or portion of the articular surface *above* the groove, represents that facet which is almost completely superior in position in most lower mammals (fig. 31, *a * a*), the more external (*b * b*) below this groove corresponding to the lower facet in many other mammals. Both rise into a high vertical convexity about the middle of the whole surface, which is there much contracted; their planes slope downwards towards the groove, so that a concavity is formed, plainly visible when the articular surface is viewed sideways. Now it may be remarked that of all the portions of the three ossicula there is none that requires so minute and careful an investigation as the articular surface of the malleus; and although the results of such labour are often puzzling, and not invariably satisfactory, still, as a whole, many distinctive points of value will be found in this region among the different orders of mammals. It will be shown, when speaking of the ruminants, that the characters of this surface undergo

† See his remarks on the malleo-incudal articulation in his work, ‘The Mechanism of the Ossicles and the Membrana Tympani,’ translated by J. Hinton, New Sydenham Society, 1874.

conspicuous changes during growth in some genera, whilst in others no such alterations take place. Hence the advisability of procuring young as well as adult ossicula, before coming to conclusions with regard to peculiarities in any group, is manifest.

Between the head and the manubrium is the short, constricted "neck." This is rather flattened laterally, so as to be narrower in its vertical than in its horizontal measurement. On its external aspect is a sharp sigmoid ridge*, convex forwards at first, where it is near the anterior border of the articular surface, then concave forwards, where its anterior end loses itself on the root of the manubrium (Pl. LVIII. fig. 30). I call particular attention to this ridge, as it is almost constant in those animals where the malleus has a distinct neck, and is very plain in the mallei of the fissiped Carnivora and most Ungulates, appearing as the sharply curved compact neck itself, the remainder being a thin lamella of bone joining the processus gracilis. In the Common Badger (*Meles taxus*) it will be seen to curve so sharply as to form a distinct projection.

Observe that this sigmoid portion—evidently the essential part of the neck, if we give that name to the bony isthmus which seems made to unite the head to the manubrium—runs away from the processus gracilis, but is lost on the base of the manubrium. This is easily accounted for when we remember that the neck is originally developed from the incurved dorsal end of the mandibular arch, the apex of which forms the manubrium itself, Professor Parker has recently shown†.

On the anterior aspect of the neck, close to the root of the manubrium, is the root or place of origin of the processus gracilis. Now, after examining numerous mallei from human foetal and adult skulls, I have hardly ever found a trace of the wide lamina of thin bone filling up the angle that process forms with the neck as in the fissiped Carnivora. But as I believe the sigmoid posterior part of the neck in *Homo* to represent the similar curved isthmus which constitutes the whole neck (independently of the lamina) in these animals, I consider it correct to say that the stout compact portion of the "neck" of human anatomists in front of that sigmoid ridge is really the same ossification as the upper part of the lamina, when such exists—the lower being absent in any form, whether compact or papery. In good specimens from a foetus at full term, it will be seen that a little fringe of friable bone extends as far upwards as the front of the head, which latter, in these cases, sends forward a slight projection, identical with a far more developed process seen in some lower animals, especially in many of the Rodentia with laminated mallei, and notably in the Musquash (*Fiber zibethicus*); in these extreme cases that projection may readily be taken for the processus gracilis, if the anatomist overlook the fact that its root is not in the right position for the origin of the latter.

The form of the human processus gracilis is well known. It cannot be seen entire unless taken from a foetal or very young human skull, not only on account of its fragility, but also because it actually atrophies to a mere stump before adult life‡; so that after removing a malleus from the temporal bone of a full-grown subject, the anatomist,

* Henle describes this as "a sharp border" ("Kante"), but he does not mention its sigmoid form.

† "On the Structure and Development of the Skull in the Pig," Phil. Trans. 1874.

‡ See Helmholtz, *op. cit.*

unaware of this fact, has frequently searched in vain along the Glaserian fissure for this process supposed to have been broken off. It forms with the neck an angle of 125° , and runs almost horizontally forwards to the fissure. It is generally bowed regularly, and is concave forwards; sometimes it is somewhat wavy; but in all cases the degree of curvature is slight. When well preserved, the processus gracilis at birth is longer than the manubrium.

Below and internal to the processus gracilis the insertion of the tensor tympani muscle is sometimes marked by a faint elevation, close to or upon the manubrium representing the "processus muscularis" of Hyrtl, which attains a great development in some lower animals. In the human malleus, however, an elevation is occasionally seen as marked as its homologue in the Bears, presently to be described.

That important process the manubrium, or handle, now claims our attention. In *Homo* it is below the average length, far shorter than in ruminants or terrestrial Carnivora, though longer than in some Seals or Whales. It forms with the neck an angle of about 140° ; Hyrtl gives 150° ; but he must have taken the axis, not of the upper and greater part of the manubrium, but of the recurved portion at the tip, from strongly curved examples. It is of a stout make, and broader at the base than in the Simiidae; it is much flattened laterally, the sides looking respectively antero-superiorly or postero-inferiorly; they are slightly convex, notwithstanding their compression. The extremity is always slightly recurved, though more in some specimens than in others, and perceptibly spatulate and smooth towards the tympanic membrane. The edges of the manubrium are both thick and blunt; and the outer edge, though of a certain breadth, and giving attachment to fibres along its entire length, is rarely separated from each side by sharply defined borders, so as to constitute a true and distinct outer surface, as seen in many lower animals, and particularly in the Canidae*. This edge ends below in the spatulate dilatation, above in a very distinct sharp projection, well curved outwards. This is the "processus brevis:" its good development is a prominent feature in the human malleus; and it will be seen to be better marked in the higher than in the lower Quadrumana, though it occasionally reappears in the latter. In most mammals it is merely an angle at the outer aspect of the base of the manubrium; in many it does not exist even in that form, especially where the neck of the malleus is very short.

Such is the human malleus. It may be seen as a good central type of the bone in mammals, a type which very frequently reappears as we go downwards in the scale—a malleus characterized by a well-developed head, a moderately long, constricted neck, and a broad-based, stout manubrium. It holds an intermediate position between the almost or quite neckless type seen in the Cebidae, in *Tupaia*, and in the true Squirrels, and the broadly laminated form so well seen in the terrestrial Carnivora and the artiodactylate Ungulata. It will be seen to be repeated, with modifications, in the higher monkeys, reappearing among Carnivora in the Ichneumons, and certainly approached (with some important distinctions) in the Seals. It is also imitated in some of the Insectivora,

* In a recent contribution to the 'Archiv für Ohrenheilkunde,' Trautmann describes and figures this condition as if constant in *Homo*. It is only in a very few specimens of the human malleus, however, that I have distinguished two distinct borders running completely from the processus brevis to the tip.

Rodentia, &c. As for its comparison with the malleus of the Anthropomorpha, such a consideration may be more conveniently deferred until the latter have been described individually. The same remark applies to the other ossicula.

The Incus.—In the embryo this little bone holds a very prominent position, as the proximal end of the hyoidean arch. In comparative anatomy it has hardly as yet received the attention it deserves, on account of its having been supposed to vary less in different mammals than do the other ossicles. My own observations lead me to consider that in reality the chief objection to the incus as a distinctive feature in the skeleton is the frequency with which it varies in form in different individuals of the same species. Still it possesses important distinctive features in many orders of mammals. The incus of *Homo* is of even more central type than the malleus.

The “body” is well developed both in length and in height, and is considerably compressed laterally. Its posterior part, or that which lies over the processus brevis, is more developed than the anterior. The articular surface looks upwards and forwards, and is shaped to fit that of the malleus; its more external limit is on the posterior segment of the body, which is higher and more external than the anterior, in accordance with the high position of the external extremity of the opposing surface on the malleus, already described. On the other hand, that boundary of the surface on the incus opposing the inner, which is the much lower extremity of the corresponding area on the malleus, lies upon the lower and more internally placed anterior segment of the body. Into the deep groove between the two extremities fit the convexities of the two facets on the malleus. The very oblique position of the incus renders any purely verbal explanation of the relations of this surface somewhat confusing; and the difficulty is increased in this case chiefly because, in describing the malleus, I have acted in conformity with its condition in the lower animals, where, as I have already remarked, that which is almost the upper end of the articular surface in Man is in them rather the outer extremity, the boundary which lies almost quite superiorly in most mammals being almost internal in our species; hence the homologue of their upper facet in *Homo* has an interno-superior, and that of their lower facet an externo-inferior position.

Around the inner margin of this articular surface of the incus is a distinct groove, like that which is often so strongly developed in the Seals (especially in *Cystophora* and *Phoca*); and there is a distinct concavity on the inner surface of the body, at the bottom of which is a minute nutrient foramen, often, however, filled up, even in the incus of a new-born child.

The “processus brevis” of a human incus is, as a rule, not much shorter than the so-called “processus longus.” It may, with more reason, be called the “posterior crus.” In Man, however, it lies as much superior to the rest of the ossicle as posterior; and in some animals (the Dugong, &c.) it is almost absolutely superior; but the term given above is less clumsy than “postero-superior crus.” This posterior crus is broad at the base and blunt at the point, where, on the inner aspect, is a minute pit or concavity, generally admitted to be a true articular surface. It is moderately divergent from the body. The processus longus, or stapelial crus, is slender and slightly convex inwards at first, then forms a gentle curve, suddenly turning inwards at the extremity, which bears

a flat elliptical disk on a narrow pedicle. This is the "os orbiculare," better termed the "Sylvian apophysis"*. Among anatomists, Sappey gives reasons for considering it a separate bone; but as it is now recognized as being formed on the proximal end of the hyoidean arch, and, on the other hand, is separate from the long crus in an early stage of development, it would appear correct, on such premises, to consider it an epiphysis of the incus.

The Stapes.—Whilst the ossicles already described take, in *Homo*, a rather central type, this little bone assumes in the Bimana an extreme and highly developed form. The beautiful bicurrate stapes of Man differs strikingly from the simple columelliform representative of that ossicle in the *Ornithorhynchus*; and the study of the types intermediate between those two extreme forms is highly instructive.

The "head" is broad and shallow; its free aspect is elliptical and a little concave, to articulate with the os orbiculare. The crura are long and widely divergent, so as to leave a large aperture between them and the base. The anterior crus is the more slender and the straighter of the two; it is widely grooved towards the aperture in its upper half; but the channel generally narrows close to the base. The posterior crus has a curve or shoulder, often very marked, not far from the head; it is deeply channelled towards the intercrural aperture by a groove almost as deep near the base as near the head. This sulcus joins, under the head, that which exists on the opposite crus.

Sometimes the anterior crus is more curved than usual, but seldom so sharply as the opposite limb of the stapes. In such cases it is still the more slender, and the groove is less marked near the base than it is on the posterior crus. I have examined several specimens of short, stumpy stapedes, from both infants and adults, where it was found very hard to distinguish the anterior from the posterior crus by their own characters alone†.

The base, or foot-plate, is reniform, its upper border being a wide arch, its lower slightly concave in the middle. Its posterior extremity is always well rounded off; and its anterior is usually much sharper; but this distinction is often the least marked where the crura are most alike.

The base is slightly convex towards the vestibule. I have never seen a true umbo like that which is found on the stapes of many monkeys. On the tympanic aspect it is formed into a shallow tray by the prolongation along its margin of the high edges of the channel within the crura. This condition is very frequent in animals where that ossicle is well developed and lightly made. A bony ridge‡, traversing the long diameter of the tympanic aspect of the foot-plate, is sometimes seen, but is not constant. The aperture between the crura of the human stapes is larger, when measured vertically as well

* A beautiful description of this structure and the incudo-stapedial joint is to be found in Eysell's "Beiträge zur Anatomie des Steigbügels," Arch. f. Ohrenheilkunde, vol. v.

† But the straightness of the anterior crus is generally much more apparent in the stapes of an infant than in that of an adult. A specimen from an adult Bushwoman in the College collection is of a very marked infantile type in the form of its crura. This agrees with the characters of the rest of her skeleton, described in Flower and Murie's "Account of the Dissection of a Bushwoman," Journal of Anatomy and Physiology, vol. i.

‡ The "crista stapedis." See Eysell, *loc. cit.*

as horizontally, than in the lower animals, even including the Elephant, as Hyrtl justly observes; but in the Golden Mole (*Chrysochloris*) and a few other fossorial animals the width of the aperture at the base is proportionally greater, though the head is much nearer the foot-plate.

The presence of a minute tubercle on the inner side of the head of the stapes does not seem constant in our species. The occasional ossification of a part of the stapedius tendon in *Homo* is well known; it is a constant feature in many animals.

For the most recent minute observations on the anatomy of the human ossicula, the works of Magnus *, Helmholtz †, Eysell ‡, Rudinger §, Trautmann ||, Urbantschitsch ¶, and others should be consulted.

THE OSSICULA OF THE SIMIIDÆ.

In a set of ossicles from a large mature fœtus of a Gorilla (Pl. LVIII. fig. 3) the incus much resembles that of *Homo*, the stapes is not so large as in the human fœtus at birth, and the crura are a little more slender and straighter. The tympanic ring from the same fœtal Gorilla has a considerable part of the floor of the external meatus already developed, which is not the case in *Homo* at birth. Both rings are preserved in the College of Surgeons' collection.

I have examined a single malleus of the adult *Troglodytes gorilla*. It is above the average size of the same bone in Man. The free upper portion of its head is more developed than in *Homo* or *Simia*, and is somewhat flattened vertically, at the same time protruding considerably forwards, as in the Chimpanzee. The articular surface remains oblique, so that, as in our species, its outer extremity, or the homologue of that extremity in other animals, lies very much higher than does the inner. The outer and upper segment of the articular surface is far larger than the inner**—another point in which this genus differs from Man and the Orang. The upper and lower facets are saddle-shaped; the vertical convex ridge is very near the inner margin of the whole surface; and hence the external, concave, sloping portions of both facets are very wide. A very faint groove divides them, indeed, as in Man; it is only relatively that they can be spoken of as two separate facets. This is the case with the remaining Quadrumana.

The neck is rather short and very narrow; the size of the head and the length of the handle make it look less developed than it really is. The sigmoid ridge described in Man is well marked. In the mallei from a fœtal Gorilla the processus gracilis is very slender, especially at the root.

The manubrium is very long, resembling in that respect the Orang's, and differing from the rather shorter manubrium of the Chimpanzee and Man. It is somewhat narrow at the root, and well recurved at the tip, which is more thoroughly spatulate in *Homo* and

* "Beiträge zur Anatomie des mittleren Ohres," Virchow's Archiv, vol. xx.

† *Op. cit.*

‡ *Op. cit.*

§ 'Atlas des menschlichen Gehörorgans,' Munich, 1875.

|| "Der gelbe Fleck am Ende des Hammergriffs," Archiv f. Ohrenheilk. vol. xi.

¶ "Zur Anatomie der Gehörknöchelchen des Menschen," *Ibid.* vol. xi.

** This condition is not nearly so marked in specimens from new-born Gorillas.

the other anthropoid apes; but the processus brevis is quite as well developed as in our species.

In the Chimpanzee (Pl. LVIII. fig. 4) the malleus is much more human than in the Gorilla or Orang-utan, and is as big as most of the numerous mallei removed by me from adult male skulls in the dissecting-room of St. Bartholomew's Hospital. In the shape of its head, which projects markedly forwards, and in the nature of its articular surface, of which the outer segment is much the widest, it approaches *T. gorilla* more than *Homo* or *Simia*; but in neck and manubrium it is very human, the only difference being that the latter, in this ape, is rather narrower at the base, and more curved than in Man, and its well-developed processus brevis is directed upwards, and hardly outwards. In length the handle does not exceed that of our species—another prominent distinction from the other two apes.

The body of the incus resembles that of *Homo*; the processus brevis is more slender, and ends in a sharp point, with no trace of any depression on it. The processus longus is rather stouter and shorter than in Man; it forms, with the posterior crus, a right angle.

The stapes of an adult Chimpanzee is smaller than the smallest specimen of that bone from *Homo* in the College collection. The crura are almost equally curved; they are shorter and more slender than in Man, but wider apart at their insertion. They are well grooved towards the aperture, which is very wide. The base resembles that of *Homo*, though less distinctly reniform, and equally rounded off at both extremities.

In the Orang-utan (Pl. LVIII. fig. 5) the head of the malleus is rather less developed, and less regularly globular than in Man, and does not project conspicuously forwards as in *Troglodytes*. The whole bone, however, is of about the average size of its human representative. The articular surface is shaped as in Man, but is less extensive; it is hardly wider at its external or externo-superior extremity than internally. The neck is as narrow as in the last genus, but rather longer; and it seems as if the sigmoid ridge had become almost effaced in the process of elongation, being hardly perceptible, though so marked in *Troglodytes*.

The manubrium is as long and slender as in the Gorilla; but the processus brevis is very ill developed, though distinctly bent outwards. The extremity of the manubrium is less dilated than even in *Homo*.

In the incudes of *Simia*, in the College collection, removed from a young male Orang, the body is much more developed*, particularly behind, than in Man, though not as wide horizontally. Hyrtl asserts that the body is markedly smaller. The posterior crus is as small and pointed as in *Troglodytes*; but the processus longus is short and slender, and more incurved than in *Homo*; the crura too are more divergent.

The stapes has a very slightly developed head, and much more slender crura than in *Troglodytes*. The anterior is quite straight, the posterior slightly curved. The base is distinctly reniform, and equally rounded at each extremity.

* Less of the body is taken up by the articular area than in the incus of *Homo*, as that surface is smaller absolutely and proportionally in this ape.

In *Hylobates* (Pl. LVIII. fig. 6) the malleus (which is rather small even in a large Gibbon's skull) resembles in many respects that of the Chimpanzee. The upper part of the head projects forwards; its articular surface is very wide externally, after the *Troglodytes* type. From the fore part of the head projects a thin fringe of bone, which does not join the root of the processus gracilis as in the Cynomorpha, and is represented, as in this genus, in some mallei from new-born children. The neck is short and constricted; the manubrium is as short as in Man, and much curved; it has a very prominent, outwardly directed processus brevis, and a distinctly spatulate dilatation at the tips; the whole angle forms, with the neck, an angle about as wide as in *Homo*, not being so obtuse as in the Cercopithecidae. Moreover the neck, though short and constricted, is longer than in *Semnopithecus*, which has the most distinctly necked malleus of all the next group. Altogether the affinities of the malleus of a Gibbon tend more towards *Homo* than to the tailed monkeys.

In *H. syndactyla* and *H. leuciscus* (and probably in other Gibbons, only not constantly) a distinct "processus muscularis" for the attachment of the tensor tympani exists. In the latter it is seen as a distinct projection from the inner edge of the manubrium, at some distance from its root. In *H. syndactyla* it is reduced to a very small tubercle on the root, almost on the site of the attachment of the tendon in *Homo*.

The incus in the Siamang (*H. syndactyla*) has a body of the same form as in *Homo*; in a specimen of that ossicle from *H. leuciscus* the body is higher and narrower, whilst in an incus from another *Hylobates* the body is as narrow as in some of the Cebidae.

The stapes of *Hylobates* has always curved, divergent crura, and a wide aperture*. This is particularly marked in *H. syndactyla*. In this ossicle the Gibbons are allied to *Homo*, *Simia*, and *Troglodytes*, in a manner not nearly so apparent in the malleus, and still less in the incus. The very straight and not very divergent crura of the stapes in all the tailed monkeys, even *Semnopithecus*, distinguish that group of the Quadrumana not less from *Hylobates* than from *Homo*†. With regard to the ossicula of the Simiidae, in general, it may be briefly stated, in conclusion:—

I. That the ossicula of *Troglodytes niger* are, taken as a whole, most like those of *Homo*. *T. gorilla* closely resembles *Homo* in its incus and stapes, but less in its malleus; *Simia* more resembles *Homo* in the head and articular surface of the malleus.

II. Though the incus of some species of *Hylobates* exhibits a tendency to low type, in the malleus, and particularly in the stapes, this genus is quite anthropoid.

III. In their ossicula, but most markedly in the stapes, these apes are much more allies to *Homo* than to the lower monkeys.

* In the *Hylobates* of uncertain species just referred to, the stapes bore on its foot-plate a distinct umbo, or central convexity on the vestibular aspect.

† From want of a sufficient number of good specimens when I contributed the communication already quoted to the Royal Society, I was under the impression that the Gibbon's stapes was of a low type; but I am now, after more favourable opportunities, compelled to modify that assertion.

THE AUDITORY OSSICLES OF THE CYNOMORPHA, OR TAILED OLD-WORLD MONKEYS.

The study of the ear-bones of the Old-world monkeys yields interesting results; for they all possess certain types in common; but in comparing them with the Anthropomorpha we find definite grades of distinction, particularly between *Semnopithecus* and *Macacus*.

In examining the malleus of an *Entellus* (*Semnopithecus entellus*, Pl. LVIII. fig. 7), the free upper portion of its head will be seen to be well developed and globular, distinctly projecting forwards. In the majority of the mallei of this species and genus a distinct fringe of bone, of papery consistence, is found on the front border of the head, joining the root of the processus gracilis (which is stout, stumpy, and very brittle in the Cynomorpha). This (which is the exception in Man, and when existent the fringe never joins the root of our processus gracilis, and is as little indicated in the anthropoid apes, excepting, perhaps, *Hylobates*) is a clear approach to the laminated type of malleus seen in the Carnivora, &c. The articular surface is shaped much as in Man and *Simia*, and is as little divided into the two facets of the typical mammalian malleus as is the case in *Homo*. The neck is very short, but, being much constricted, is quite distinct. The manubrium forms with the axis of the neck and head an angle of at least 155° , distinctly wider than in any of the last family. This process is of moderate length, though the shortness of the neck makes it look rather longer than it actually is. It is almost of equal breadth laterally, till near the tip, where it turns up rather sharply, and is there discoidal rather than spatulate.

Immediately above this dilatation is a distinct convex projection, giving a wavy look to the manubrium seen in many lower monkeys. There is always a well-developed and everted processus brevis in this genus; and on the inner edge of the handle, above the projection just described, on the opposite or outer margin, is a distinct "processus muscularis" (as Hyrtl styles it, in describing the carnivorous malleus, and as it will be henceforward designated in this paper), to which, in the recent skull, the tensor tympani muscle will be found attached, as I have verified by dissection. Its position in this and in neighbouring genera, well down the manubrium, reminds the observer of the same process in *Herpestes* and in many Rodents.

In its very distinct though very short neck, and well-developed processus brevis, the malleus in the genus *Semnopithecus* resembles the Simiidae more than any of the following genera except *Colobus*, where we find similar characters; but there the form of the head is different. But the wide angle between the body and manubrium, the peculiar form of that process, with a tendency to a discoidal termination, and the presence of a distinct processus muscularis, as well as the trace of a lamina between the head and processus gracilis, are points that ally this genus far more closely to other Old-world monkeys.

The incus, on the other hand, in all the skulls of this genus which I have examined, more resembles that of the anthropoid apes than in the succeeding genera, being broad in the body, measured horizontally, and not very deep, with a considerable distance between the origin of each crus, which diverges as much as in Man.

But the stapes of *Semnopithecus* assumes to perfection the type almost constant in the lower monkeys. The head is deep rather than wide, the crura practically quite straight, the base rather broad and almost plane, and the aperture much smaller than in the Simiidae. Thus, when we take into consideration all three ossicula in this genus, we see at once that the majority of their salient features ally them, as a whole, to lower genera. The nature of the incus, and the few points given above regarding the malleus, show a decidedly high tendency in *Semnopithecus*, compared at least with *Macacus*.

In the malleus from a large skull of *Colobus satanas* (Pl. LVIII. fig. 8), proportionally smaller than the same ossicle in a *Semnopithecus* of the same size, the head is rather ill-developed and flattened laterally—a condition seen, but never to so marked a degree, in *Macacus* and *Cynocephalus*. But there is a distinct, short, constricted neck, very like that of the last genus, with a well-developed processus brevis; only the processus muscularis is abortive, and the tip only slightly spatulate. The incus is distinctly higher and narrower than in the genus *Semnopithecus*; and its crura arise nearer to each other. Hence, as to these bones, *Colobus* must take a lower place than *Semnopithecus*, the ill-developed head of the malleus being apparently a generic peculiarity, and the incus allying it decidedly to succeeding genera. But the well-developed processus brevis, and the still distinct neck, are marked affinities to the genera already considered.

Cercopithecus (Pl. LVIII. fig. 9) is central among these Old-world monkeys in its ossicula. The head of the malleus is fairly developed; the articular surface, though shaped as in *Homo*, assumes the position usually observed in lower animals, the outer extremity lying but little higher than the inner. A trace of lamination, as described in *Semnopithecus*, exists; the root of the processus gracilis is very thin and fragile. The neck is always extremely short (in *C. cynosurus*, however, I have found it nearly as long as in *S. entellus*); and the manubrium runs almost in its axis. This is similar in form to that of the last two genera, and bears a distinct processus brevis, never so well developed as in any higher monkeys, excepting *Simia*. In *C. diana* it is more prominent than in *C. cynosurus* or in *C. lalandii*. The extremity is always spatulate, often discoidal (as in a Diana-monkey, of which the ossicula are in the College collection). But there does not seem to be any convexity above the tip, as described with *Semnopithecus*. A more or less distinct trace of a processus muscularis is always seen upon the inner border of the manubrium*. The incus is very high and narrow in *C. cynosurus*, but in the other species resembles that of *Colobus*; the processus longus is very straight and slender. The stapes is as described with *Semnopithecus*; in one from a fine *C. diana* the base is so broad that the whole bone forms almost an equilateral triangle.

In *Macacus* (Pl. LVIII. fig. 10) the malleus assumes an extreme condition in this group. The head presents a surface flattened laterally, and projecting considerably forwards. This is best seen in *M. nemestrinus* and *M. erythræus*; in *M. cynomolgus* it is nearly as small as in *Colobus*. There is a trace of lamination and a stout processus

* This is represented in a sketch of the malleus of *C. sabæus* in Owen's 'Anatomy of Vertebrates,' vol. iii. fig. 177c.

gracilis, of which a great part is persistent in adult Macaques. Although the neck does exist, it is extremely short, especially its anterior wall, the manubrium running almost in its axis. The latter seems to spring from immediately below its articular surface; its extremity is often quite discoidal; the processus brevis may be completely obsolete, but it is fairly marked in some species; the processus muscularis is in the same position as in *Semnopithecus*, and is generally well developed.

The body of the incus is always either square or higher than broad; the anterior segment is nearly as high as the posterior. Hence it approaches (in the first peculiarity) the form seen in some specimens from *Hylobates*, and (in both the above points) many of the Cebidæ. Both processes are rather long and slender; the long crus is very straight till close to the tip. The stapes has straight crura and a broad base, as in all the past genera.

In *Cynopithecus* (Pl. LVIII. fig. 11) the head of the malleus is as ill-developed as in *Colobus*, the neck and manubrium closely resemble the same in the Macaques. The incus has an extremely stout square body; the anterior segment is very well developed. The crura are very much stouter and shorter than in any *Macacus* of the same size, and shorter, though of the same thickness as in *Cynocephalus*. This incus, with its square body and short stout crura, is as different from the anthropoid type, and as strikingly reminds the observer of the shape of the bone in *Cebus* and *Ateles*, as the high narrow incus of *Hylobates* and *Macacus* diverges from the type of *Homo* in a direction towards the form prevailing in *Myctes* and in other less typical Cebidæ.

The stapes, too, though very similar to the prevailing form in this group (see *Semnopithecus*), has a narrower base; nor are the crura so far apart as usual.

In *Cynocephalus* (Pl. LVIII. fig. 12) the characters of the malleus are like those of *Macacus*, but rather more marked. The head is not so developed in proportion to the size of the bone, is extremely flattened laterally, and projects very sharply forwards. The neck is also extremely shortened, especially in its anterior wall; the manubrium runs almost in its axis. This process has a very well developed processus brevis, and a sharp, extremely prominent muscular process almost halfway down the inner margin of the handle.

The incus has a rather shallow body, and very stout crura; the anterior is rather long. It is clearly of a higher type than in *Macacus*.

The stapes of the Baboons does not differ from the common type in this group, and is in outline almost an equilateral triangle.

In conclusion, it may be said of the Old-world tailed-monkeys:—

I. That they all depart from the apes and Man, and resemble lower monkeys and most other mammals in the straight and little-divergent crura of the stapes. A processus muscularis on the malleus is almost constant.

II. In the distinctly-necked malleus, with a well-formed head, and in the incus, broad between the crura, *Semnopithecus* approaches the Simiidæ, especially *Hylobates*; but the stapes is not at all anthropoid.

III. In *Cercopithecus* the malleus is nearly as high in type, but the incus is either square-bodied or high and narrow, as in lower monkeys.

IV. In *Colobus* (and *Cercocebus*) the head of the malleus is almost as ill-developed and sometimes more flattened than in *Macacus*, and the incus is of the same form.

V. In *Macacus*, *Cynopithecus*, and *Cynocephalus* the malleus has a very short and constricted neck; the manubrium, which bears a processus brevis and muscularis, forms a very wide angle with the rest of the bone; the incus and stapes exhibit constantly the tendency to low types, already seen occasionally in higher Quadrumana.

THE OSSICULA OF THE CEBIDÆ.

The ossicula of the Spider-monkeys (*Ateles*) present some singular peculiarities not observed in neighbouring genera.

The head of the malleus (Pl. LVIII. fig. 13) is extremely flattened vertically as well as laterally; seen from above it appears as a smooth, convex, almost quadrilateral surface. The articular area is very wide, far more extensive than in any higher monkey; the upper segment or facet is not so wide as the lower, and they meet each other at a very open angle without a trace of a groove. The upper lies almost vertically above the lower segment, so that the whole surface resembles the condition seen in the lower Mammalia, and is unlike the type of *Homo*. Anteriorly a little friable layer of bone fills up a part of the angle between the head and the processus gracilis, the stump of which is stout. This homologue of the lamina seen in some mammals is often broken off and absorbed in the mallei of old Spider-monkeys. The head never bulges prominently forwards.

So far the malleus bears characters common to the other Cebidæ; but it differs from them all in possessing a singular neck, quite unlike that of the Anthropomorpha, though almost as long. Through the kindness of Prof. Garrod I have been enabled to examine numerous skulls of *Ateles melanochir*, *A. hybridus*, and *A. ater*, from specimens once living in the Zoological Gardens; and I find these characters best marked in *A. melanochir*. Immediately below the articular surface the neck is very stout, and it becomes narrower close to the handle, though even there it is much less constricted than in the apes and Old-world monkeys. The very short and curious manubrium forms with the neck an angle often not more than 120° , though occasionally much wider. Constricted near the base and tip, it bulges in a conspicuous manner in the middle, and terminates in a wide discoidal enlargement. The processus brevis is represented by a prominent rounded knob. There is no processus muscularis; and the tendon of the tensor tympani muscle is inserted into the root of the manubrium close to the neck. This malleus is certainly the most specialized among all the Quadrumana.

The incus has a very well-developed and very square body; in a specimen from *A. hybridus* I find it slightly longer horizontally than vertically. The anterior segment is almost as high as the posterior; and the articular surface, looking rather outwards, appears unusually deep from the outer surface of the body, and unusually shallow from the inner aspect. The incus, on this account, will be seen to be most like that of *Cebus*, except in the last feature, not showing that tendency to great height and narrowness so frequent amongst other American monkeys.

The stapes has a well-developed head, and long slender crura, not very divergent, and

both inserted some distance from the extremities of the base, which is slightly convex towards the vestibule.

The crura are longer than in most Cebidæ, where the stapes closely resembles that of the Old-world monkeys, only differing from them, as a rule, in the greater length of their limbs; hence this distinctive feature of the entire family is best marked in *Ateles*.

In the Howlers (*Mycetes*) the head of the malleus is of the same form as in *Ateles*, but still more flattened vertically and still less developed, the height of its convexity hardly rising above the level of the upper border of the articular surface (Pl. LVIII. fig. 14). This latter is extremely wide in all directions and very shallow; both facets are very saddle-shaped. There is absolutely no neck; but immediately from below the articular aspect springs the manubrium, which is tolerably long, forms an even, rather wide curve, and becomes gradually narrower towards the extremity, which ends in a perfect disk. There is not a trace of a processus brevis; and the processus muscularis is almost obsolete. In *M. seniculus* the manubrium runs almost in the axis of the body; in *M. laniger* and *M. ursinus* it forms a distinct angle.

The malleus of *Mycetes*, so different from that of *Ateles*, where there is a thick neck and a manubrium bulbous in the middle and possessing a tubercular processus brevis, may be considered a good type of this bone among the Cebidæ, and to a certain extent among the less-typical Lemurs. It differs strikingly from the same bone in Man, Apes, Old-world monkeys, and the genus *Lemur*.

The incus is very deep vertically, and narrow horizontally, with thick and short crura arising close to one another. The articular surface has the peculiarity noticed in *Ateles*. This bone, too, is very typical among the Cebidæ.

The stapes is of the ordinary monkey type, the base concave laterally, with a trace of an umbo in a specimen of *M. laniger* in the College collection, but not in one of *M. ursinus*, where the crura are almost fused; a minute aperture which exists between them is, I have reason to believe, accidental*.

In *Cebus* (Pl. LVIII. fig. 15) the malleus differs little from that of *Mycetes*; the head is almost identical in form. The manubrium runs still more closely to the axis of the body; and no rudiments of a processus brevis or muscularis can be traced. The handle does not form the free and regular curve seen in most Howling-monkeys (*Mycetes*), but is slightly bent near its root, and straighter towards its extremity, which is a little turned up and almost a perfect disk.

The incus departs from the type of *Mycetes*, *Pithecia*, *Nyctipithecus* and the Marmosets, the body being generally longest horizontally, or quite square. The posterior crus is rather thick at the base; it diverges, as in most Cebidæ, very little from the body. The processus longus is often long and thin, and always divergent.

The stapes is of the usual monkey form; but in most specimens the posterior crus is always slightly bowed and thicker than the anterior.

In the Douroucoulis (*Nyctipithecus*, Pl. LVIII. fig. 16) I do not find any distinction

* "Bei den Brüllaffen ist die Basis konkav, aber in der Mitte als Umbo gegen das Vestibulum vorgetrieben. Bei einem Sapajou dessen Species unbestimmt ist, finde ich in beiden Ohren die Crura des Stapes verwachsen."—HARTL, *op. cit.* But I have noticed an Umbo in an ape (see *Hylobates*).

of importance in the malleus from the same bone in *Cebus*, except that a rudimentary processus muscularis is to be found halfway down the inner border of the manubrium in *Nyctipithecus*. The incus, on the other hand, is always high and narrow; the posterior crus hardly diverges from the body, the slender processus longus diverging considerably. The stapes has long slender crura and a comparatively narrow base.

In the Squirrel Monkey (*Saimaris sciurea*, Pl. LVIII. fig. 17) the malleus has the general characters described with *Cebus*; but the articular surface is still shallower, and the manubrium runs much less nearly in the axis of the body, often forming an angle of not more than 150° . The incus is higher than broad, resembling that of *Nyctipithecus* in its crura, as does the stapes.

In a single specimen of the malleus and incus of the Black Saki (*Pithecia satanas*, Pl. LVIII. fig. 18) the former ossicle has a manubrium rather thicker at the base, and more distinctly flattened laterally (as in most mammals) than in the above-described genera. This process, too, forms the same wide curve seen in *Myctes*; and the incus has the same extremely high narrow body as in the Howlers; the vertical measurement of the posterior segment is even greater than in those monkeys.

After careful observation, I consider that the malleus in the HAPALIDÆ (Marmosets) is intermediate between the same in the Cebidæ and in the Nycticeboid lemurs. The description given of the malleus in the genus *Cebus* will apply to *Hapale* with two important distinctions—namely, that the articular surface is always narrower and deeper in the Marmoset, and in that animal the whole body is bent more inwards on the manubrium, a character much more prominent in the Nycticebidæ, but in *Hapale* the head of the malleus is longer in its vertical measurement than in *Nycticebus*. The body of the incus is quite square in *H. jacchus*; but in a specimen of *H. melanura* in the College collection it is as high and narrow as in the Douroucoulis (*Nyctipithecus felinus* and *N. trivirgatus*). The stapes is of a different form from the type prevalent in the last family. The head is very long; or, more correctly speaking, the crura are fused halfway to their insertion, where they suddenly diverge towards the base. This is very like the condition seen in many of those marsupials where the crura are not fused throughout. Hence in the genus *Hapale* may be found the lowest type of ossicle seen in all the Primates (Pl. LVIII. fig. 19).

In *Midas* (Pl. LVIII. fig. 20) the malleus is of much the same form as in *Hapale*, the articular surface also is rather deeper and narrower than in the Cebidæ; but the tendency of the body to be bent inwards on the manubrium is not so plainly seen, at least in *M. ædipus*, *rufimanus*, and *geoffroyi*, as in *Hapale*. In all these species the incus is high and narrow. The stapes in *M. ædipus* has a small head with free crura and a wide aperture; but one from *M. geoffroyi* in the College collection has the peculiarities of that ossicle in *Hapale*.

The absence of a neck to the malleus of most of the New-world monkeys seems not to be due to an absolute suppression of that part, but rather to its being bent down below the articular surface, and lying actually in the axis of the manubrium. In many mallei from the genus *Cebus* a slight rounded projection may be detected high up on the outer edge of the handle. In such cases, if the small segment of the manubrium above that

prominence were raised to the exact axial line of the head (for even in these cases the manubrium is never literally in that axis, but always slightly bent on the head), the rest of the handle retaining its angle, we should have an ossicle almost exactly like the malleus of *Ateles*. The processus muscularis, placed so low down as the inner edge of the manubrium, would then be brought close to the neck, its normal or, at least, most usual position.

THE OSSICULA OF THE LEMURIDÆ.

In the genus *Lemur* (Pl. LVIII. fig. 21) the malleus has a well-developed head, rising considerably above the level of the articular surface, which is tolerably deep, and much like the same in the Old-world monkeys. A faint trace of a neck exists; the manubrium forms an angle of 150° with the rest of the ossicle, and ends in a broadly spatulate or discoidal termination. In the specimens of *L. varius* and *L. albifrons* in the College collection, the manubrium is much flattened near the base, as in *Homo*; and in *L. albifrons* a distinct processus brevis exists; but in *L. catta*, *L. nigrifrons*, and *L. xanthomystax* the base of the handle is narrow, and hardly perceptibly flattened; but probably in any species of this genus a processus brevis may be occasionally developed. A small area of lamellar bone is generally to be seen between the head and the stump of the processus gracilis. The malleus of *Lemur* bears more resemblance to the same in the Old-world monkeys than to the Ceboid type—not so, probably, from any nearer relation of the Lemurs to the Macaques &c., which is most unlikely, but rather from the fact that the malleus of the American monkeys is highly specialized, while it happens that the same in *Lemur* and the tailed Old-world monkeys is of a far more generalized type in all cases.

The incus decidedly varies in form in different species of *Lemur*. In the College specimens of that bone in *L. varius* the body is wide horizontally and shallow vertically, with stout widely divergent crura. In *L. nigrifrons* and *L. xanthomystax* the body is both shallow and narrow, the crura stout and but little divergent, so that the ossicle has a very tooth-like appearance. In *L. albifrons* and *L. catta* the body is square, and the processus longus is slender and very divergent.

The stapes has always long and extremely slender crura, very slightly bowed outwards, with a wide aperture. The base is invariably convex towards the vestibule, and rather narrow vertically. The space between the crura is in this genus *always* occupied by a bony canal, which runs between two projections of the petrous bone above and below the fenestra ovalis, and transmits a small blood-vessel—a frequent condition among some Insectivora and Rodents. The same condition is seen in a skull of *Hapalemur* in the Museum of the Royal College of Surgeons.

Among the Indrisinæ, *Propithecus* (Pl. LVIII. fig. 24)* has a malleus more like that of *Cebus* than *Lemur*. The head is of much the same shape, and the articular surface of the same depth, as in the latter; but there is the same absence of all trace of neck, so frequent in the American monkeys. The manubrium is sharply curved in the middle, and terminates in a very large disk. The incus is wide horizontally; the pos-

* Sketched from a young specimen. The presence of the processus gracilis, with some friable tissue between it and the neck, alters its aspect.

terior segment is much deeper than the anterior; and the crura are thick, and both divergent. The stapes resembles that of *Lemur*; but the crura are stouter. In both the skulls of *Propithecus* in the College Museum a bony canal passes between the crura of the stapes, as is the case in a skeleton of *Indris* (*Lichanotis*) *brevicaudatus*. In a skull of the Avahi (*Indris laniger*) I have found the trace of a bare vessel, not supported by bone, instead of an ossified intercrural canal.

The malleus of *Galago* (Pl. LVIII. fig. 22) strikingly resembles that of the Hapalidæ; but the upper part of the head is better developed, the articular surface is still narrower and deeper, and the head is much shorter vertically than in *Hapale* or *Midas*. It is quite neckless, and bent very much inwards on the manubrium—an exaggeration of a condition frequent in the mallei of Primates where the neck is suppressed. The manubrium is slender throughout, even at the base, and ends in a very distinct disk; there is a processus muscularis halfway down the inner margin. The incus is very high and narrow, as in *Nyctipithecus*, *Pithecia*, &c.; and the anterior segment is actually as high as the posterior, and projects forwards conspicuously. The processus brevis runs in the long axis of the posterior part of the body, with hardly a trace of divergence, the processus longus diverges extremely. This arrangement of the crura recalls *Nyctipithecus*, and is usual in the Lorises. The crura of the stapes are slender, and perfectly straight; the intercrural space is moderate; and no bony canal appears to occupy it in the recent skull.

In a specimen of the mallei (Pl. LVIII. fig. 23) and incudes of *Cheirogaleus cookii*, the malleus, although resembling *Galago* in its head and articular surface, has a manubrium which springs from immediately below the articular area of the head, yet bears a distinct projection corresponding to the processus brevis of Man. This peculiarity is seen in some squirrels, a family where gradations between the necked and the neckless malleus are as numerous as in the Primates. The handle, too, in *Cheirogaleus* is rather flattened naturally. This ossicle altogether is related not distantly to the same in the genus *Lemur*; but the incus assumes those conspicuous features seen in *Galago*; the divergence of the anterior crus is extreme. There appears to be no bony intercrural canal supporting the stapes in this genus.

In studying the Nycticebidæ or Lorisinæ, I find in the malleus of *Nycticebus* (Pl. LVIII. fig. 26) that the characters of the neckless type of that ossicle are all prominent. The head is very short in its vertical measurement, very much bent inwards on the manubrium, and bears a deeply cut but not very wide articular surface. All these features are seen in the Galagos, although the last two are approached in the Marmosets. The singular manubrium is long and very straight; its outer border is somewhat wavy; and there is a distinct projection and processus muscularis for the tendon of the tensor tympani halfway down the inner margin. The handle terminates in a large disk. The strong resemblance of the malleus of *Nycticebus* and of some other Primates to the same ossicle in the Tupaiidæ and Squirrels is interesting, especially as they are all small thickly furred arboreal animals.

The incus has a shallow body, quite unlike that of *Galago*; but the anterior segment is nearly as high as the posterior. Its articular surface is completely on the top of the

body (strictly expressed, on the antero-superior aspect), and does not lean outwards, as described in *Ateles*, and as found more or less in all the Cebidæ and Hapalidæ. Moreover this surface is in *Nycticebus* very saddle-shaped, indeed almost convex. The posterior crus is stout, short, and slightly divergent; the stapedial crus is stout, straight, long, and very divergent, supporting an "os orbiculare" or Sylvian apophysis, which is small as in all Lemurs.

The stapes has slender crura, not very divergent; the base is rather thick and almost plane. I have never found any intercrural bony canal in any skull of *Nycticebus*, *Arctocebus*, *Loris*, and *Perodicticus*.

In a malleus of *N. javanicus* the articular surface is deeper cut than in *N. tardigradus*. The characters of the ossicula of *Loris gracilis* are almost identical with those of *Nycticebus*; only the head of the malleus is even still shorter vertically, and the anterior part of the body of the incus projects forwards somewhat as in *Galago*. In *Arctocebus calabarensis* (Pl. LVIII. fig. 27) the extreme characters of the neckless malleus are even better-marked than in *Loris*; the head of the malleus is shorter than in any of the Platyrrhine monkeys, and the articular surface is far deeper cut than even in *Hapale*.

Perodicticus potto (Pl. LVIII. fig. 25) resembles *Nycticebus* in its malleus and stapes; but the incus is higher than broad, its articular surface being, however, similar in position to the same in the tardigrade *Loris*.

In *Tarsius spectrum* (Pl. LVIII. fig. 28 *) the malleus, which is quite neckless, has a head of square outline, not nearly so compressed vertically as in the last family, and projecting considerably forwards. The articular surface is deep and rather wide; the manubrium is slender, ending in a spatulate extremity; there is a trace of a processus brevis; and the tensor tympani is inserted into the inner border of the manubrium midway between the tip and the root. The incus has a square body; both crura diverge considerably. The stapes is small, even in proportion to the size of the animal; its crura are very thick, and its base almost plane.

Whilst the characters of the ossicula of the aberrant *Tarsius* are somewhat negative, the sole representative of the Chiromyidæ presents very salient features in its ear-bones.

All the ossicula of the Aye-aye (*Chiromys madagascariensis*, Pl. LVIII. fig. 29) are much larger in proportion to the size of the animal than in any tailed monkey. The mallei in the College collection are larger than any from *Ateles*, and as large as that ossicle in *Cynocephalus*. The head is much flattened vertically; its upper free surface is broad and concave, far more developed than in the other Lemures. The articular surface is deeply cut and wide vertically; the two facets are well-marked: the upper is very wide, and the lower is very small. There is a distinct short neck, twisted, together with the head, somewhat inwards; the manubrium is long, rather narrow laterally at the base, and forms a similar curve and angle to what is seen in the anthropoid apes. There is a small angle corresponding to the processus brevis, and a distinct processus muscularis

* Taken from a new-born *Tarsius*. The remark made in the foot-note to the description of *Propithecus* applies to this as well.

on the inner edge of the manubrium nearer the root than the tip. The outer aspect of the manubrium facing the tympanic membrane, though very narrow, is distinctly bordered off from both sides by sharp edges, till it dilates very gradually into the narrow spatulate, recurved extremity. This distinct outer surface to the manubrium is seen in the Carnivora, Ungulata, and many Rodents. As it is in the Rodentia that the processus muscularis is so frequently placed completely on the manubrium, the extensive lamina being generally absent in that order, it follows that the malleus of *Chiromys* is more allied to the Glires than to the flesh-eating and ungulate Mammalia.

The incus is remarkable for the sharp projection backwards of its posterior segments; the crura are stout, short, but neither are strongly divergent; the Sylvian apophysis is extremely elliptical, or rather key-hole-shaped in outline, being broad horizontally and very thin vertically. The crura of the stapes are stout, the posterior much bent, as in *Homo*; the intercrural space is wide, and not occupied by a bony canal in the recent skull.

The above researches into the ossicula of the Platyrrhini and the Lemuridæ will now be briefly summarized.

I. In *Ateles* the malleus is of peculiar shape. It has a short neck and a rounded prominence corresponding to the processus brevis. The articular surface is shallow, as in all the Cebidæ. The incus has not a very high body; the crura of the stapes are longer than in other monkeys.

II. In *Mycetes* and *Pithecia* the neck of the malleus is quite suppressed (together with the processus brevis), and the manubrium at its root runs in the long axis of the head. The incus has a very high narrow body. The stapes, in these and the genera of the Cebidæ yet to be mentioned, has not so long crura as in *Ateles*, but is of the same form as in the Old-world monkeys.

III. In *Cebus*, *Nyctipithecus*, and *Saimaris* the malleus much resembles that of *Mycetes*; but the head is bent on the root of the manubrium. In *Cebus* the body of the incus is not higher than in *Ateles*; but in the other genera it is almost as high as in *Mycetes* or *Pithecia*.

IV. In the Hapalidæ the malleus has a rather deeper articular surface than in the Cebidæ; it is quite neckless; and the head is bent on the manubrium. The incus is generally high in the body. In the Marmoset the crura of the stapes are often fused for some distance below the head, as in mammals of a very low grade.

V. Among the Lemuridæ, the Nycticebidæ, Galaginidæ, and *Propithecus* (at least in young specimens of *P. diadema*) much resemble the Hapalidæ and *Cebus* in the malleus; but the articular surface is deep, deeper than even in *Hapale*; the head is very short, and strongly bent on the manubrium. The incus has a very high body in the Galagos, but not in the Nycticebidæ. *Tarsius* and *Perodicticus* resemble *Nycticebus*.

VI. But in *Lemur* the malleus loses the specialized form common in the other Lemuridæ and the New-world monkeys. There is a constricted neck, and a more or less developed processus brevis; the manubrium forms a distinct angle with the neck, instead of the head being bent on it as in the Galagos &c. The incus is not high and

narrow. There is always a bony canal between the crura of the stapes. This is seen in the Indrisinæ as well, but does not appear to exist in *Galago*.

VII. In *Chiromys* the ossicula are large, and their affinities indistinct. The malleus has a much flattened head and a trace of processus brevis; in most respects it is of the rodent type. The incus is of a somewhat peculiar shape; the stapes has curved crura, a character seen in the higher monkeys, but also in many of the Sciuromorpha.

THE OSSICULA OF THE CARNIVORA.

The Fissipedia are almost as remarkable for the very trifling variations in the ear-bones of the different families, genera, and species as the Pinnipedia are for the boldly defined individual characters of all three ossicula in closely allied genera. The study of these bones in the latter suborder is rendered all the lighter on account of their great size. Yet while the Pinnipedia maintain, in the malleus at least, a certain adherence to the common and most typical form of ossicle, the Fissipedia possess a type of malleus unusual except among certain Ungulates and Rodents.

The Fissipedia must first be considered; and the study of their ossicula shows that distinctive features of any clear value in classification are chiefly confined to the malleus, the variations in the form of the incus being more limited, although of interest in some families.

The divisions of the suborder used here are those given by Flower* (P. Z. S. 1869, p. 4).

The typical malleus of a fissiped carnivorous mammal may thus be described:—It has a small head, with a deeply cut articular surface, of which the facets are divided by a deep well-marked groove; the neck is thin, long, cylindrical, and more or less sharply curved, bearing on its inner side a muscular process for the tendon of the tensor tympani. The manubrium forms with the neck an angle seldom over 100°; it has an angular projection at the outer side of its base, which may be dignified by the name of processus brevis, although never developed to the extent seen in Man. It is narrow laterally; but the side towards the membrana tympani is constantly separated from the two other sides by sharp borders, and is often very broad.

But the great and conspicuous feature is the broad lamellar expansion between the head and neck, on the one hand, and the very slender processus gracilis, which often appears as merely a thickened lower border of that bony lamina, undoubtedly a minor modification of the condition existing to an extreme degree in the Hedgehogs, Shrews and Bats. This is observed to a corresponding extent in the Ruminants and larger Muridæ.

The incus in the Fissipedia is always small in proportion to the malleus, directly contrary to what obtains with the Seals. Excepting extreme shortness of the processus brevis in some families, there are few distinctions of importance between the incudes of the various members of this group. The same applies to the stapes; and such slight differences as exist will be noted in the description of individual genera or species.

* In his paper "On the Value of the Characters of the Base of the Cranium in the Classification of the Order Carnivora, and on the Systematic Position of *Bassaris* and other disputed Forms."

In the FELIDÆ the malleus (Pl. LVIII. fig. 32), a bone of light construction, exhibits the general characters already described. The head is moderately developed; the articular surface is narrow vertically, but very deeply cut; the upper facet is nearly flat, the lower quite convex; they are separated by a groove, which is very sharply marked towards the inner limit of the articulation, but fades completely before reaching the outer border. In the characters of this surface the smaller Cats may be known from the Civets. The manubrium is not only narrow at the base, but its outer aspect, though sharply bordered anteriorly and posteriorly, is extremely narrow throughout; and the whole process, though well recurved at the tip, is not strongly bowed, with its concavity forwards. The last two points distinguish the feline malleus from that of the Dogs, the Hyæna, and *Proteles*. The extremity is only slightly spatulate, as in most Carnivora. From the inner side of the thin, curved neck proceeds a long sickle-shaped processus muscularis, as in the Canidæ and the Weasels, much more slender than in *Proteles* and *Hyæna*, and better developed than in *Cryptoprocta*, the Viverridæ, Procyonidæ, and Æluridæ; in the Bears it is absent. The lamina is well developed, though never as wide as in the smaller families; even in the largest Lions and Tigers it remains papery and semitransparent, not so compact as in *Hyæna*.

The body of the incus (Pl. LVIII. fig. 42) is deep; its posterior crus is always well-developed; the Sylvian apophysis is small.

The stapes (Pl. LVIII. fig. 56) has straight crura, with a wide aperture between them; and the thin but broad base is more or less convex towards the vestibule.

All the above characters are best seen in the Lion, where the lower facet of the articular surface of the malleus is unusually concave. In all the animals this facet lies rather external to the upper, the outer extremity of the articular surface is higher than the inner, but never to the extent seen in Man and in many monkeys. In the Tiger, the manubrium is rather more slender than in the Lion. In the Cat (Pl. LIX. fig. 1) the angle at the outer aspect of the base of the manubrium projects so much as to form a true "processus brevis." In the Leopard, the groove between the facets of the malleus almost reaches the outer border of the articular surface, and there is a distinct concavity of both facets external to the point where the groove ceases, an approach to the Viverrine type. In the Cheetah (*Felis jubata*) the manubrium is somewhat shorter than in the above cats, and more distinctly spatulate at its termination. The Serval has a stapes with long slender crura, much less divergent than in most Carnivora. In *F. lynx* and *F. caracal* the malleus has a stouter processus gracilis, and is altogether more solid than in other cats of the same size. This is not the case with *F. caligata*, which has a very broad lamina to the malleus, as in the European Lynx. These smaller Felidæ retain the characters of the articular surface of that bone as seen in the Lion.

In the HYÆNIDÆ (Pl. LVIII. fig. 34) the malleus is of stouter build than in any other family of the Fissipedia, excepting, perhaps, certain large Canidæ; the head is greater than in the Cats, yet not large in proportion to the development of the rest of the bone. The articular surface is wider than in *Felis*; and the groove, well marked internally, fades in the middle of the articulation; the facets it divides are flatter.

The neck is of the character seen in most Carnivora, but proportionally rather thicker. The manubrium is much thicker than in *Felis*, though not broad at the base laterally. Its outer surface is moderately broad above, but very broad towards the point; thus, lying exactly intermediate between *Felis* and *Proteles*, the whole process is rather more curved, with the concavity forwards, and less recurved at the tip than in the Cats. The great feature in this and the next family is the processus muscularis, which is very stout at the base, blunt at the tip, and almost straight. The lamina is denser than in the Cats and Dogs. The incus (Pl. LVIII. fig. 48) resembles that of a large *Felis*. The stapes (Pl. LVIII. fig. 58) is rather larger than in the other Carnivora; its crura are slender, as in the greater Felidæ, not thick, as in Wolves.

In the Aard-Wolf (*Proteles*, Pl. LVIII. fig. 35) the head of the malleus is smaller and less convex than in *Felis* or *Hyæna*; its articular surface approximates to the Viverrine type: both the facets are convex internally; but they run into one another, forming a marked concavity external to the point where the groove ceases, the latter only running half across the surface, as in *Hyæna*. The manubrium has its outer surface broad throughout, as in the Dogs; this character distinguishes it from *Hyæna*, which it resembles in having an almost equally straight and solid processus muscularis. The body of the incus is shallow, as in *Viverra* and *Canis*; both crura are very stout and well developed.

Among the Viverridæ two distinct varieties of malleus are to be found. One, unlike any other among the Fissipedia, is seen in *Herpestes* and *Suricata*, and in all probability in allied genera; the other, which will be described first, is found in the genera *Viverra*, *Paradoxurus*, *Nandinia*, *Arctictis*, *Cynogale*, and *Eupleres*.

The malleus of the Civet and its allies possesses very negative characters, or may be considered to present, together with those of the Cryptoproctidæ, Procyonidæ, and Æluridæ, a central type, from which those of the Cats, Dogs, and Bears are much specialized, the above-named families exhibiting in this bone very slight tendencies towards the modifications observed in those more important groups, which they respectively approach in their general anatomy. Taking the most prominent point of distinction between the mallei of terrestrial Carnivora, namely the form and development of the processus muscularis, we find that process long in the Cats, and absent in the Bears. Now, as it is of moderate length in the Civets and Racoons, from a quite natural modification of the characters of the bone in the two former families, it comes to pass that the latter animals, very different from each other in the whole skeleton, come close to each other as far as the malleus is concerned.

The head of this bone in *Viverra* (Pl. LVIII. fig. 37) is small, its free surface projecting but little above the upper margin of the articular area. The articular surface is narrow vertically and deeply cut; both facets are convex; the groove between them is very deep, and, as in the Cats, it runs from the inner border to the middle of the surface, where, however, it does not fade, as in *Felis*, but bifurcates; the two branches run to the outer surface, and enclose a triangular, somewhat concave space, which may be considered a third facet, and is clearly a further modification of the condition described in *Proteles*, where the two branch grooves do not exist, but the facets run, externally, into a concavity. In many faintly marked Viverrine mallei the bifurcation is

effaced; then the articular surface appears precisely as in *Proteles*. The neck is always thin, and much curved towards the manubrium, which latter process is very long and slender in all directions, even near the root; the angle corresponding to the processus brevis is blunt; the outer surface, though well bordered, is extremely narrow throughout, the terminal dilatation being almost imperceptible; and the point is little recurved. The whole manubrium is very straight, as in the Cats, never forming the curve seen in the Dogs and, to a less degree, in *Hyæna* and *Proteles*. The processus muscularis is a small mammillary projection, never quite absent. The processus gracilis forms a wide angle with the neck, so that the lamina is extensive.

The incus (Pl. LVIII. fig. 45) is a small bone with a shallow body, bearing a proportionally deep articular surface. Both crura are well developed; the posterior diverges little from the body.

The stapes (Pl. LVIII. fig. 60) has always very slender crura, with a large space between them, and a thin, broad base; the former are inserted close to each extremity of the latter.

The Viverrine malleus strikingly resembles that of certain ruminants; but the articular region in those ungulates is of a different character, and the other two ossicles are unlike those of the Carnivora.

Viverra civetta exhibits all these characters. The processus muscularis of the malleus is well developed, and, in a small way, approaches the straight conical type seen in *Hyæna* and in *Proteles*. In *V. malaccensis* that process is very short, and the manubrium is very slender and almost styliform at the tip. In *Genetta vulgaris* the processus muscularis is short, but still prominent; otherwise the malleus is as in *Viverra*; but the crura of the stapes, though very thin, are not so extremely slender in this animal and in the remaining Viverridæ as in the true Civet Cat. In *Nandinia binotata* and *Paguma grayii*, as well as in *Cynogale bennettii* (Pl. LIX. fig. 13 a), the processus muscularis is still short; but in *Paradoxurus bondar* and *musanga* it is reduced to a conical tubercle. In *Eupleres goudotii* (Pl. LIX. fig. 10) the head of the malleus is proportionally larger than in the Civet; but the processus muscularis is as long, and the neck as well developed, as in that animal. The incus has a slender and well-developed processus brevis, as in most of the Cats, Dogs, and Viverridæ. The stapes is larger in proportion to the incus than even in *Herpestes*. In *Arctictis binturong* (Pl. LIX. fig. 2) the malleus is much more distinct. The neck makes a very short curve before joining the root of the manubrium, so that the whole bone appears "hog-backed." The manubrium is much broader at the base and more recurved at the tip than in any of the preceding genera—a distinct approach to *Herpestes*; but the processus muscularis, a mere tubercle, as in *Paradoxurus*, still arises from the neck, and the lamina is well developed*.

One cannot fail to be struck by the great difference between the malleus of *Herpestes* (Pl. LVIII. fig. 38) and that of the preceding Viverridæ. The Ichneumons are the only Carnivora where that auditory ossicle approaches the somewhat central type seen in Man. The head is large, with a free orbicular surface; it bears an articular surface similar to that of the Civets. The neck is short and stout; the manubrium is much broader at the base, and more recurved at the extremity, than in any of the past genera

* The figure is from a specimen where the lamina was mutilated.

except *Arctictis*, and forms a very obtuse angle with the neck; the processus brevis is generally well marked. The short, stout, conical processus muscularis does not spring from the neck, but from the inner edge of the manubrium, a perceptible distance beyond its root, approaching a characteristic of some rodents. The lamina is very little developed, indeed is not perceptible until close examination.

The incus (Pl. LVIII. fig. 47) is rather larger than in the Civets; the stapes is large (Pl. LVIII. fig. 61), and resembles that of *Genetta* and *Arctictis*.

The species do not differ much in their ossicula. The head of the malleus in *Herpestes ichneumon* and in *H. paludosus* is particularly large. In the manubrium of the latter, Prof. Flower has detected a minute foramen which perforates it close to the root of the processus muscularis. In the above species and in *H. nepalensis*, where the head is smaller, the processus brevis is well marked; but it is much blunter in *H. griseus* and *H. pulverulentus*. In the latter (Pl. LVIII. fig. 38) the processus muscularis is a more considerable distance down the inner edge of the manubrium than in the malleus of any other ichneumon; its incus is proportionally larger.

In *Suricata zenik* (Pl. LIX. fig. 3) the ichneumon type of malleus is maintained. The head is large, the neck extremely short. The manubrium leaves the neck at a wider angle than in *Herpestes*, and is distinctly shorter, broader at the base, and more spatulate at the tip. The processus muscularis is situated on the inner side of the manubrium, a perceptible distance from the neck; and the lamina is very little developed.

In the *Cryptoprocta* the malleus closely resembles that of *Viverra*; the head is a little larger, the articular surface similar; the manubrium is even more slender; the processus muscularis is almost as short as in *Paradoxurus*. The incus (Pl. LVIII. fig. 44) is a larger bone than in the Civets; and the stapes (Pl. LVIII. fig. 59) has thicker crura than in *Viverra*.

Thus *Cryptoprocta ferox* is incontestably more allied, as far as its ossicula are concerned, to the Viverridæ than to any other family; and the latter are clearly more related to the Cats by the type of their ear-bones, as *Hyæna* and *Proteles* are related to the Dogs.

In the Canidæ the ossicula have far more marked distinctive features than they bear in the Viverridæ.

The malleus (Pl. LVIII. fig. 33, and Pl. LIX. fig. 5) often rivals that of the *Hyæna* in stoutness of build. The head cannot be said to be remarkably developed; the articular surface is narrow, and deeply cut; both facets are concave; the groove dividing them never bifurcates, as in well-marked viverrine mallei; but the facets join in a concave area external to the point where the groove fades, as in *Proteles*. The neck is only moderately curved; the manubrium, the most distinctive feature in the canine malleus, is long, rather thin at the root, and very strongly curved, with the concavity looking forwards. The outer aspect is a distinct surface, not only sharply bordered from the sides, as in all Carnivora, but likewise very broad throughout, though rather broader towards the extremity. Thus the Hyænidæ, as has been already remarked, resemble the Dogs in their manubrium; but *Proteles* is still more canine. On the other hand, the Canidæ have a long sickle-shaped processus muscularis projecting from the inner side of

the neck, as in the Felidæ; it is never straight and conical as in *Hyæna*. The lamina is broad, and bounded below by a well-marked splinter-like processus gracilis. The body of the incus (Pl. LVIII. fig. 43) is shallow; and the crura, which are both of nearly equal length, are conspicuously far apart, even at their origin. The stapes resembles that of the Cats. Hyrtl considers that the aperture between the crura is much smaller in the Dogs; but it is more correct to say that in the large Canidæ the crura are more massive than in the Lion or Leopard, and encroach more on that space, which, in small dogs, is often as wide as in the domestic cat. The anterior crus is often curved.

In large specimens of the Dog the outer surface of the manubrium is so expanded at its borders that the rest of that process appears as a sharp ridge springing from the inner side of that external aspect. In the Wolf the same surface of the manubrium is even broader than in the malleus of a Newfoundland or a Mastiff (although I have prepared a malleus from a small dog where it is nearly as broad); and the whole process is extremely curved; the extremity, however, is not much turned up, as in the straighter manubria of many other mammals. The crura of the Wolf's incus are extremely far apart; and the anterior crus of the stapes is always well curved, and thicker than the posterior. In the Dog the crura are far more similar in straightness and bulk. (See Pl. LVIII. figs. 33, 43, 57, & Pl. LIX. fig. 5.)

The other species in this genus have ill-marked specific characters. In the European Fox the neck of the malleus is shorter than in the Dog or Wolf; the outer aspect of the manubrium is nearly as broad as in *Canis lupus*; but in *C. vulpes* (Pl. LIX. fig. 6) it is nearly of equal breadth throughout. The crura of the incus diverge as much as in the Dog, and hence less than in the Wolf; the anterior crus of the stapes is slightly curved, but not much thicker than the posterior. In a specimen of *C. fulvus* I found the manubrium rather longer than in the Fox. The crura of the stapes were both straight, and the opening between them very small. In the Arctic Fox (*C. lagopus*) the malleus has a much longer neck than in the two foxes above named, and a longer processus muscularis than in any of the preceding Canidæ; the incus is wolf-like. In the Cape Hunting Dog (*Lycaon pictus*, Pl. LVIII. fig. 41) the processus muscularis is stouter and straighter, and proportionally larger than in any other of the Canidæ; it closely resembles that of *Proteles*; but the outer surface of the manubrium is quite canine, being very wide, and almost of equal breadth throughout; the incus is most like a dog's in aspect. In the Long-eared Fox (*Otocyon*) the neck and manubrium mallei are both rather short; and the processus muscularis is as long as in *Canis* (Pl. LIX. fig. 4).

In *Canis lupus* and *familiaris* the lamina of the malleus is wider than in the Foxes, *Lycaon* or *Otocyon*.

The MUSTELIDÆ possess auditory ossicles which are not so remarkable for any single distinctive feature or prominently developed process as for their very characteristic general appearance.

The malleus of the Glutton (*Gulo*, Pl. LVIII. fig. 39) has a rather elongated head; the free globular portion, fairly developed, projects considerably upwards. The articular surface is always wide, contrary to other land-Carnivora; but the facets are of the same pattern as in *Viverra*. The neck is long, and only slightly curved, except in the Badger; the manu-

brium is always short, broad at the base, much recurved at the tip, though not curved as a whole, with the concavity forwards, as in Dogs; and it forms an extremely obtuse angle with the neck. There is always a rudimentary processus brevis. The muscular process is always stout at the base, and tolerably long. The lamina is very long and narrow, owing to the very acute angle formed between the neck and the somewhat stout processus gracilis—a condition diametrically opposite to that seen in the Procyonidæ, and a great modification from most other Carnivora.

Careful comparisons seem to lead to the conclusion that the musteline malleus is intermediate between the typical carnivorous form and that seen in *Herpestes* and *Suricata*. By slightly enlarging the head in this family, and fancying the lamina absorbed, and shifting the processus muscularis to the root of the manubrium, we have an ichneumon's malleus without altering the manubrium or the angle it forms with the neck. But by widening the lamina, lengthening and thinning the handle, and placing it at nearly a right angle to the neck, the weasel's manubrium may be brought to the type prevailing in the other Carnivora already described. The thick curved processus muscularis reminds the observer of *Canis*, and completely separates it from the Procyonidæ and Ursidæ. In some foxes there is a marked tendency to shortening of the manubrium, and to a wide angle between that process and the neck; but it curves more, as a whole, with the convexity backwards, and less at the tip; then, on the other hand, the weasel's manubrium is never so broad at its outer surface as in these vulpine Canidæ.

It may seem at first remarkable that the malleus in the Mustelidæ is unlike that of the Bears, except perhaps in the head and articular surface; but after all, there are considerable differences in the tympanic bullæ beneath them. (See Flower, P. Z. S. 1869, p. 11, figs. 2 & 4.)

The incus (Pl. LVIII. fig. 55) is unusually distinctive in the weasels, having a very short, slightly curved processus brevis, as pointed out by Hyrtl, at least in *Mustela* and *Lutra*. The tendency to shortness of this process is as marked in most bears as in many weasels, and nearly as great in the Æluridæ and Procyonidæ, except *Nasua*. The processus longus stretches well forwards, and bears a rather large pedunculated Sylvian apophysis.

The stapes (Pl. LVIII. fig. 62) has straight crura and a stout base; the former are inserted each close to the extremity of the latter. The base is very bullate towards the vestibule in small weasels, as it is in *Hyrax*, *Geomys*, and *Phalangista cookii*.

In the Pine Marten (*Martes abietum*, Pl. LIX. fig. 7) all the above characters are well marked in all the ossicles. The outer surface of the manubrium is broad at the base and tip, which is well recurved and spatulate. The processus longus of the incus is shorter than in other weasels; the stapes is larger, with a well-formed bulla. In *Mustela vulgaris*, *M. putorius*, and *M. erminea* the neck of the malleus is generally rather shorter than in *Martes* and *Gulo*. The base of the stapes of the Mink (*Mustela vison*) is very bullate. In *Ictonyx zorilla* the malleus has a very stout deflected muscular process; the base of the stapes is slightly inflated (Pl. LIX. fig. 8). In the Glutton (*Gulo luscus*) the large malleus has a very elongated head and neck, a wide articular surface, and a short diver-

gent manubrium. The incus has a very short processus brevis, but a long, far-stretching processus longus; the whole bone is very like a Bear's. The stapes has thick crura; and the base is absolutely concave in the horizontal direction.

In the Badger (*Meles taxus*) (Pl. LVIII. fig. 40) the malleus is remarkable. The head is as long as in *Gulo*; the articular surface is even wider; and the facets are almost flat, whilst in the above-described genera of weasels they are both quite convex*. The most distinctive feature is a conical projection, formed by the neck making a sharp angular bend, instead of a curve, close above the manubrium. It appears at first sight to be the processus brevis, and thus makes the handle look longer than it really is. But on close examination, the true representative of the processus brevis may be seen, projecting outwards, a perceptible distance below the conical projection. The incus resembles that of *Gulo*. A very slight representative of the above-described projection exists on the neck of the malleus of the American Badger (*Taxidea americana*). As regards *M. taxus*, this process (Pl. LVIII. fig. 40) is equally prominent and well developed in five pairs of mallei from skulls in the College collection. Its evident relation to the orbicular prominence on the malleus of the Shrew (*Sorex*) and other mammals will be discussed later on.

The malleus of *Helictis nipalensis* resembles that of *Meles* in general aspect; but there is no projection from the neck; the muscular process is not as long as in *Mustela*.

In the Otter (*Lutra*) (Pl. LIX. fig. 9) the malleus resembles the Weasel's; the neck is much constricted close to the manubrium. The incus has an extremely small processus brevis; the processus longus is stout and divergent. This character is better seen in the Sea-Otter (*Enhydra*), where that crus supports a large flask-shaped Sylvian apophysis. *Aonyx* (Pl. LIX. fig. 13) closely resembles *Lutra* in its ossicles.

In the PROCYONIDÆ the malleus is devoid of good distinctive features, and is of slender make, with a broad lamina, as in the Civets. The head is not much developed; the articular surface is always narrow, and shaped very much like the same in the Viverridæ; the manubrium is generally long and slender, but the outer aspect, though narrow, is broader than in that family. The muscular process is always present and always short. The processus gracilis leaves the neck at a very wide angle, so that the lamina suddenly becomes broad to an extent seldom imitated in the Civets. In a well-preserved malleus of a member of this family this feature is very prominent; but the lamina is often mutilated.

The incus has generally an ill-developed processus brevis, never so small as in *Mustela*; the crura of the stapes are straight, and, together with the base, are thicker than in Cats, Dogs, and Civets.

In the Raccoon (*Procyon lotor*, Pl. LIX. fig. 11) these characters are well marked: the processus muscularis of the malleus is as large as in *Viverra*; the end of the manubrium is distinctly spatulate; and the whole process is long and slender. The lamina, too, widens suddenly from the great divergence of the processus gracilis. The processus brevis of the incus is very much more slender than the stapedia crus, which is very broad, and turns up sharply at the tip. The base of the stapes is very convex. In the Coati (*Nasua nasica*,

* In this and many other Mustelidæ the lamina is sometimes perforated, probably from atrophy or ill development. Owen describes such a condition in *Gulo* and *Lutra* (Anatomy of Vertebrates, vol. iii.).

Pl. LIX. fig. 12) all these features in the malleus and incus are very feebly marked: the neck of the malleus is rather short; the processus muscularis is a mere tubercle; the manubrium is very slender, and the lamina wide but not wider than in a typical Civet's ossicula. The processus brevis of the incus is more developed than in the Raccoon. The stapes is of stouter make than in *Procyon*, or in any *Felis* or *Viverra*; and its thick base is very convex. In the Kinkajou (*Cercoleptes caudivolvulus*, Pl. LIX. fig. 14) the malleus is much more distinct in type: the head is more developed upwards than in the other Procyonidæ, and resembles that in many bears and weasels; the articular surface is deeply cut and very narrow; the neck is long, the manubrium is rather short, broad at the base, and well recurved at the tips, as in the Mustelidæ; but it does not form nearly so wide an angle with the neck, and the lamina has the characters of the Raccoon's. The incus (Pl. LVIII. fig. 53) has a very small sharp-pointed processus brevis, and a stout processus longus, as in *Procyon*. It may be here noticed that, while the tendency to great shortness of the former process exists in the Mustelidæ, Procyonidæ, *Æluridæ*, and Ursidæ alike, in the first two families the processus longus is stout and short; in *Ælurus* and the Bears it stretches out far, as in Man. The base of the stapes in *Cercoleptes* (Pl. LVIII. fig. 63) is almost flat.

In the Cacomixl (*Bassaris astuta*) the malleus (Pl. LIX. fig. 15) more resembles that of *Viverra* and *Procyon*; but its head projects more than in either of those animals, and the processus gracilis is extremely divergent, so that the procyonine type of a wide lamina is best marked in *Bassaris*. This rare animal has a peculiarity already described and better marked in *Meles*. The neck of the malleus forms a sharp conical projection just above the manubrium (Pl. LIX. fig. 15, *a, n*), which being readily mistaken for the angular upper extremity of the base of the latter, representing the processus brevis, makes the whole manubrium look unusually long. In reality the handle is as short as in *Cercoleptes*, and nearly as broad at the base; the extremity is distinctly recurved and only slightly spatulate. The incus (Pl. LVIII. fig. 52) has a very small processus brevis; the stapedial crus is stout, and rather longer than in *Procyon*; it supports, as in the rest of the family, a sessile elliptical Sylvian apophysis.

In the Panda (*Ælurus fulgens*) the malleus (Pl. LIX. fig. 16), as a whole, somewhat resembles that of *Procyon*. The head forms a narrow projecting knob above its articular surface, which is broader than in the last family. The neck is rather short, and almost as sharply curved as in *Viverra*. The lamina has the same depth as in the Procyonidæ, owing to the divergence of the processus gracilis. The manubrium is rather short, not very broad at the base, and but little recurved at the tip; it does not form a very broad angle with the neck: thus it is intermediate in characters between those of the Weasels and the typical Procyonidæ, and resembles its representatives in most Bears. The processus brevis of the incus (Pl. LVIII. fig. 51) is very short and sharp-pointed; the processus longus is rather thin, and stretches forwards considerably, as in the Ursidæ; it bears at its extremity a distinctly pedunculated and discoidal Sylvian apophysis.

The URSIDÆ are the only terrestrial Carnivora where a large malleus is to be seen with an obsolete processus muscularis (Pl. LVIII. fig. 36). The head of that ossicle is well developed, often projecting considerably upwards; the articular surface is rather wide, as in the Mustelidæ; but the groove between the facets is generally faintly marked.

The neck is somewhat stout and boldly curved. The manubrium is not unlike the same in *Felis*, but generally shorter and broader near the base; it turns up at the tip, which is slightly spatulate; but the outer aspect is rather narrow. It never forms the bold curve seen in the *Canidæ*, *Hyænidæ*, and *Protelidæ*. The processus muscularis is a mere tubercle or almost imperceptible elevation close to the root of the manubrium. The processus gracilis always diverges considerably from the neck, so that the lamina is very broad, as in *Procyon*, whereas the same is narrow in *Mustela*.

The incus (Pl. LVIII. fig. 49) has a very small processus brevis, whilst the stapedial crus stretches far forwards, and supports a Sylvian apophysis in the form of a disk on a very narrow peduncle. The stapes (Pl. LVIII. fig. 64) has a well-formed head and rather slender crura.

In the Polar Bear (*Ursus maritimus*, Pl. LVIII. figs. 36, 49, & 64) all these characters are well marked. The neck forms a sharp curve close to the manubrium, rather approaching the condition described in *Cercoleptes*; but it is placed lower, and does not give an appearance of false length to the manubrium. This process is stout, sharply angled at the base, and well recurved at the tip. The processus muscularis is represented by a tubercle nearly as large as in *Paradoxurus*. The shortness of the processus brevis of the incus, and the length and divergence of the other crus, are very marked; the latter bends, forming a prominent knuckle, before contracting to give attachment to the peduncle of the Sylvian apophysis. There is a rather wide aperture between the crura of the stapes; the base is broad and plane.

In the Spectacled Bear (*Ursus ornatus*, Pl. LIX. fig. 17) hardly a trace of the processus muscularis can be found on the malleus; the manubrium is rather long and slender, little recurved at the tip, and not sharply angled at the base. In an incus in the College collection there is a slight tubercular projection close to the extremity of the processus longus, just above the Sylvian apophysis. The crura of the stapes are rather thick, with a small aperture between them.

The malleus of the Himalayan Bear (*U. tibetanus*) is more like that of *U. maritimus*, especially in the manubrium, which is not very long, and is broad at the root, sharply angular at the base and well recurved at the tip; but there is hardly a trace of processus muscularis. The anterior crus of the stapes is distinctly curved.

In the Sloth Bear (*Melursus labiatus*) the head of the malleus is less developed than in an *Ursus* of the same size. The manubrium is less stout and recurved than in the large species of the typical genus, but is as angular at the base. There is no trace of any processus muscularis; the lamina is very wide, and bounded in front by a prolongation of the head, which joins the processus gracilis, a condition seen less plainly in other Carnivora, but constant in some other mammals.

THE OSSICULA OF THE PINNIPEDIA.

The ossicula of the majority of the Seals and their allies are not only very large but also well-marked and readily distinguishable in the different genera or even species. The ossicles of the Otariidæ differ from those of the other families in their absolutely

and proportionally small dimensions. The ear-bones of an adult *Otaria jubata* are very much smaller than those of any small Seal, such as *Phoca hispida*.

The malleus from the skull of a Sea-lion (*Otaria stelleri*) (Pl. LIX. fig. 20) that measured 0·305 metre from the præmaxilla to the front of the foramen magnum, is itself only 0·008 metre in length from the summit of the head to the tip of the manubrium; but this and the other ossicles, though small in these eared-seals, are always of stout make. The head of the malleus, instead of projecting well above the articular surface, as in Man, or forming a smooth convexity in front of it, as in most of the Fissipedia, is hollowed out anterior to that surface, and forms a shallow pit as in all other Pinnipedia. The articular surface is very wide laterally and rather narrower vertically; each facet has so high a vertical convex ridge meeting its fellow that the whole area is quite convex, forming a prominent angle in a horizontal view, though, viewed perpendicularly, the planes of the facets do slope towards each other, and form a distinct concavity. The groove dividing these prominent facets is but faintly marked. The neck is thin, much constricted towards the manubrium, and never long. The manubrium is longer than in the true Seals, and shorter than in the Fissipedia; it is broad, and flattened laterally at the base, narrowing laterally, and turning well up at the point, which is only slightly spatulate; it does not curve as in the Dog and Hyæna. There is a sharp angle at its base; and its outer aspect forms a true well-bordered surface, very narrow, except at the base and at the slight dilatation near the extremity. There is no trace of a processus muscularis, nor of any lamina, the processus gracilis running close under the head and neck, to which it is fused by a medium of very compact, not lamellar, bone. All the characters of the Otarian malleus are thoroughly phocine, putting aside its small dimensions. Yet Hyrtl says,—“Bei *Otaria* ist er (der Hammer) nicht grösser als bei der Fischotter, und hat den gemeinsamen Typus aller Fleischfresser.” Had that distinguished anatomist said “common type of all *aquatic* Carnivora,” he would have been correct; but he means the reverse, as the context shows.

But the incus does not approach any of the singular forms observed in the other Fissipedia. It assumes very much the form seen in Man, though smaller in proportion to the malleus, having high compressed sides, a rather short, but stout, blunt-pointed and only slightly divergent processus brevis, and a long, slender, far-stretching stapedial crus. This is a modification of the forms seen in the arctoid Carnivora (compare figs. 49 & 50, Pl. LVIII.), where the posterior crus is short and not divergent. The extended or widely divergent character of the processus longus is, it will be remembered, very marked in *Ursus maritimus*, in *Ælurus*, and to a less extent in *Bassaris*. The little stapes has stout crura, often, but not invariably, fused; they are not inserted precisely into the extremities of the base, which is very thick, and quite concave horizontally.

In *Otaria jubata* the ossicula are largest: the incus is as large as in *Homo*, and similar in form; the posterior part is much higher than the front of the body; the sides are almost flat. The whole bone is wonderfully light in make compared with the incus in some true Seals.

In *Otaria stelleri* (Pl. LIX. fig. 20) the concavity on the front of the head of the malleus is very shallow, the neck and manubrium are moderately long; the posterior part

of the body of the incus is not much higher than the anterior, the latter being well developed; the anterior or long crus stretches well forwards, and supports, as in the other Eared Seals, a Sylvian apophysis in the form of a perfectly circular sessile disk. The crura of the stapes are quite fused, and the base is very thick; the bone strongly resembles the same in the Dolphins. In *Otaria falklandica* (Pl. LIX. figs. 18, 19) the depression in front of the head of the malleus is deep and well defined, the neck is very short and constricted, the manubrium shorter than in Steller's Sea-lion, though, from the ill-development of the neck, it looks as long. The body of the incus is not quite so broad as in the last two species, the posterior part is much higher than the front, the processus longus does not reach so far forwards as in *O. stelleri* and *jubata*. The two crura of the stapes are very thick and straight, with a distinct space between them, and a base like that in *O. stelleri*. It is more regular in form than in any true Seal; but a stapes of *Phoca grænlantica* in the College collection makes a near approach to it, excepting that the ossicle in the Greenland Seal is much larger.

In the Walrus (*Trichechus*) (Pl. LIX. figs. 21, 22) the malleus has a large broad head, of a rhomboidal form, its anterior and posterior aspects being very much flattened, and very wide in the middle, tapering at their upper and lower extremities. The former surface bears a deep concavity, as in *Otaria* and the Phocidæ; but, unlike either, there is a smooth rounded surface, of small extent, above the level of the articulation, representing the globular part of the head seen in other mammals. Posteriorly lies the articular surface, as broad horizontally and as narrow vertically as in the Seal, but concave in both directions; the facets are only slightly saddle-shaped, and divided by a very distinct but shallow groove. The neck is short, not broad near the head, and extremely constricted close to the manubrium; it is also flattened antero-posteriorly. It bears no vestige of a muscular process; and the root of the processus gracilis is very blunt. The manubrium, which forms little more than a right angle with the neck, is extremely short; it is proportionally broad at the base and at its outer aspect; there is a distinct everted processus brevis at its upper extremity. The whole bone is not so large in proportion to the whole skeleton as in the true Seals, but is larger than in any *Otaria*. It is plainly a mere modification of the Seal-type of malleus, the articular surface being the most distinct feature; the shortness of the malleus is only a slight exaggeration of the condition seen in *Stenorhynchus*, where, on the other hand, the neck is shorter than in *Trichechus*. It far less resembles the Otarian malleus.

The incus is a large bone, with the posterior part of the body well developed and bulging externally; the processus brevis is long, thin, and rather divergent. The processus longus is stout, stretches far forwards, and is broadest in the middle, without a trace of a groove on its broad inner aspect. It forms a gentle sigmoid curve, and bears on its extremity a thick, sessile, discoidal Sylvian apophysis. This bone, too, is very seal-like in the thinness of the processus brevis. The long, far-reaching processus longus allies it to *Otaria*; but I have examined one incus of *Trichechus* where that crus was rather short; and moreover divergence and length is seen in the same process in the Cystophorine Seals, but masked by the huge over-developed body of the incus.

The stapes is a high narrow bone, with a small head, thick crura, completely fused,

without a trace of an aperture between them in any specimen I have seen, and a narrow, rather thin base, concave horizontally. The whole is shaped like a bottle with a short neck, and very unsymmetrical on account of the outline of the anterior crus being by far the most convex. This stapes strongly resembles that of *Macrorhinus*, while *Otaria* closely assumes in its stapes the type of the Dolphin. These two animals approach, though less nearly, the Sirenian form of that bone.

The Cystophorina, the first subfamily of the PHOCIDÆ, are remarkable for the great difference between the auditory ossicles of two well-known species otherwise closely allied, and often included in the same genus, viz. the Hooded Seal (*Cystophora cristata*) and the Elephant Seal (*Macrorhinus proboscideus*). The latter most resembling *Trichechus* in its ear-bones, it will be described first.

The head of the malleus of *Macrorhinus proboscideus* (Pl. LIX. figs. 23, 24) is flattened laterally, as in the Walrus; it is still larger in proportion to the rest of the bone, but is rather triangular than lozenge-shaped, the upper aspect being rounded off and very broad, not produced to a blunt point. Anteriorly the head is marked by a deeply concave pit, quite triangular, its basal boundary being uppermost—that is, corresponding to the broadest or upper part of the whole head. The articular surface is very small, not extending to the periphery or upper part of the broad posterior aspect of the malleus. It exhibits the extreme of vertical narrowness and horizontal breadth so general among the Phocidæ. Both facets have a very prominent vertical convex ridge; so that the whole surface is horizontally quite convex, though laterally slightly but distinctly concave; the groove dividing them is extremely faint. The neck is very short; and the processus gracilis springs from it as a prominent splinter of bone, connected with the head by a thin and very brittle layer of compact, not lamellar bone. There is no trace of a muscular process. The manubrium is very short, though not quite as short as in *Trichechus* and *Stenorhynchus*; it forms almost a perfect right angle with the neck; the base is very broad; it is much recurved at the tip, which is spatulate; the outer aspect is very wide at the base, corresponding to the processus brevis; it widens again near the termination.

In general configuration the malleus of *M. proboscideus* closely resembles that of *Stenorhynchus*; indeed the only differences I can find are in the wider articular surface and the still shorter manubrium, forming a wide obtuse angle with the neck in the latter Seal. In *Trichechus* the articular surface is different from that of *Macrorhinus*, and the manubrium is still shorter. In *Cystophora* and *Phoca* the neck is long, and the manubrium forms a very wide angle with the rest of the bone.

The incus is of unique form. It is more than double the bulk of its own malleus, and exceeds in size its representative in *Balæna* and in most specimens of *Manatus*. The great feature is the immense development of the posterior part of the body, which leans over to the outer side of the crura to an extraordinary degree. The anterior part projects forwards like a lip, and is also inclined somewhat outwards at its uppermost part. The articular aspect is very small, occupying, to an equal extent, both the projecting posterior and the more level anterior part of the body; internal to it is a deep pit, divided by a groove, which runs in a line with the ridge dividing the facets. This

latter peculiarity, also seen in *Stenorhynchus*, distinguishes the incus of *Macrorhinus* from that of *Phoca* and *Cystophora*. The processus brevis is a short process, very stout at the base and blunt at the tip; it does not diverge from the body; the long crus is short compared with the dimensions of the whole incus, rather thin, quite cylindrical, and stretches well forwards from the body, with a wide curve, as in the Bears, the Sea-lions, and the Walrus. This bone is only a caricature, so to speak, of the same condition seen in *Phoca* (compare fig. 23, with fig. 27, Pl. LIX.); but whilst the posterior part of the incus of *Macrorhinus* assumes and exaggerates the Phocine type, the long crus is, as just noticed, rather like the same in the last families, Otariidæ and Trichechidæ; so that the incus of *Macrorhinus* is a truly central form.

The stapes strongly resembles that of *Trichechus*, only it is of much stouter build; the head is even smaller; the crura widen close below it, and then slowly approximate to the base; they are entirely fused; but on the front aspect of the bone is a deep concavity, representing the normal aperture. The base is a thick bordered facet, and is quite saddle-shaped, being very convex vertically, though nearly plane horizontally.

In *Cystophora cristata* (Pl. LIX. fig. 25) the head of the malleus is flattened antero-posteriorly, and somewhat oval, being broadest horizontally; there is a concavity in front and a facet behind, convex laterally and concave vertically, as in *Phoca* and *Macrorhinus*, &c.; but it occupies nearly the whole of the posterior aspect, being far wider than in the latter, while the whole head is smaller. The neck is extremely long, more so than in any other Seal, and almost perfectly cylindrical, being but little constricted near the handle; it is, moreover, very straight. The manubrium is short, rather narrow at the base, well recurved and dilated at the extremity; it forms a very obtuse angle with the neck, and bears a prominent blunt processus brevis. Altogether this bone resembles the malleus of *Phoca*, from which it may at once be known by the length of its neck.

The posterior part of the body of the incus is well developed, and bulges internally, but not nearly to the extent seen either in *Stenorhynchus* or *Macrorhinus*. There is a shallow groove round the inner side of its facets, as seen in a more developed form in *Phoca*. The processus brevis is short and stumpy; the longer crus is shorter and stouter than in *Macrorhinus*; still it stretches well forward, and in that process alone the incus of this animal resembles that of the last-described species rather than *Phoca*.

The stapes has an ill-developed head and very thick crura, both crossed, but the anterior more so than the posterior. There is a considerable round aperture between them; the base is broader than in the last family, and slightly concave.

This stapes is truly intermediate between that of the Pinnipedia already noticed and those to follow. It differs from the former in having an intercrural space and a wider base, and from the latter in that the space between the crura is very much more limited, and, the crura being almost parallel, the base is therefore narrower.

In the STENORHYNCHINA (see Pl. LIX. fig. 26, *Lobodon carcinophaga**), the head of the

* Syn. *Stenorhynchus serripens*, Owen, P. Z. S. 1843, p. 131, & Cat. Ost. Mus. Coll. Surg. ii. p. 641.

malleus closely resembles that of *Macrorhinus*. The excavation in front of its large, flat, triangular head is deeper, the articular surface is similar but wider, the neck and the manubrium are even shorter; the latter differs from that of the Elephant-seal (*Macrorhinus*) in being more recurved and spatulate at the tips; its outer aspect is very broad.

There is no trace of a processus muscularis, or of the special articular process seen in *Phoca vitulina* and *hispida*; but I find the tendon of the tensor tympani is inserted in a depression on the exact site of the latter process in a malleus of *L. carcinophaga*. This would seem to indicate that the extra articulating process of some Seals is a modified processus muscularis, though nearer to the head than that process is usually placed; but, on the other hand, it will be seen that in *Phoca barbata*, where no trace of the second articulating process can be seen, there exists a sharp, tubercular processus muscularis in the exact position of the same in the Felidæ and Canidæ.

In the incus the posterior part of the body is more developed than in any Seal excepting *Macrorhinus*. Internal to the facets is a deep pit, with a deep groove, which runs in a line with the groove on the articular surface; this peculiarity is better marked in *Lobodon* and *Stenorhynchus** than in the Elephant-seal. The posterior crus is very short and stout; the processus longus is short, thick, and sharply curved; it is almost plane, not channelled, on its inner aspect, and the Sylvian apophysis is placed a little to the posterior side of its extremity.

Hence this bone resembles that of *Macrorhinus* in its peculiar depression internal to the articular surface, but *Phoca* in its processus longus, which, however, is not grooved as in that animal.

The stapes is rather aberrant. In the Crab-eating Seal (*L. carcinophaga*) it has long, very divergent, and much flattened crura, with or without an aperture. The base is wide, thick, and concave horizontally. In the Sea Leopard (*S. leptonyx*) the flattening of the crura is very marked; both limbs have rather crooked outlines.

Among the true PHOCINA, the ossicula are remarkable for marked differences in closely allied species. These will be enumerated after describing the ear-bones of the common Seal (*Phoca vitulina*) (Pl. LIX. figs. 27, 28, & Pl. LX. fig. 1).

The head of the malleus is flattened, as in the Seals already described; it is rather small, and nearly circular in outline. Its upper border, the site of the globular part of the head in most mammals, is quite thin and sharp. The anterior aspect is completely occupied by a deep concavity (Pl. LIX. fig. 27 c). The articular surface occupies more than half the posterior aspect; so that it is more extensive than in *Macrorhinus*, but not quite so large as in the other Seals already described. As in most of them, it is narrow vertically, and very broad horizontally; and from the sharp, perpendicular ridge on the facets, it is convex in the latter sense, though vertically it is distinctly concave; even the ridges slope downwards to meet each other, and are divided (or, rather,

* Prof. Flower informs me that Prof. Peters (Monatsh. Akad. Berlin, 1875, p. 393), in a footnote, has notified that the term *Stenorhynchus* applied by F. Cuvier (1824) to the Small-nailed Seal had been preoccupied by Lamarck (1819) for a genus of Crabs; hence Prof. Peters proposes to substitute the term *Ogmorhinus* for the Seal-genus in question. I have preferred, however, to use *Stenorhynchus* as that at present best known to naturalists.

merely indented) by a faint groove. The neck is thin and subcylindrical, rather long, but never so regularly cylindrical or so prolonged in this species and genus as in *Cystophora cristata*. Close to and a little below the articular surface there springs from the neck a little projection in the form of a much-truncated cone, directed inwards and slightly downwards and forwards; its extremity is quite plane and round, and articulates with a similar projection from the incus (Pl. LIX. fig. 28, & LX. fig. 1, *e a s*). This peculiarity, as well as the concavity in the head, is already well known to anatomists. The processus muscularis is absent. The manubrium closely resembles that of *Cystophora*, but is slightly longer; besides, it has a distinct processus brevis, which is curved upwards towards the neck in well-preserved specimens.

The incus closely resembles that of *Cystophora*; the articular surface is surrounded posteriorly and internally by a deep ear-shaped depression; the posterior crus is very short, and generally thick; the stapedia crus is short, rather thin, boldly curved inwards, and deeply grooved on its internal aspect, bearing on the outer and interior aspect of its base a projection as well developed and similar in form to that on the back of the neck of the malleus, with which it articulates (Pl. LIX. fig. 28). When these ossicles are articulated, a small foramen exists between the ordinary and the peculiar phocine articulations (Pl. LX. fig. 1). The extremity of the processus longus, which is rather thin, bears a Sylvian apophysis, happily compared in its form by Hyrtl to a house-fly's proboscis.

The stapes has very stout, rather short and crooked crura; the anterior is most bent; they diverge considerably towards the base, and have an almost circular aperture between them; the base is also thick, and quite concave in its long diameter.

Such are the ear-bones of *Phoca vitulina*; and no essential variations have been found in numerous specimens examined by me at the Royal College of Surgeons. In a specimen of the left ossicula of the Harp-seal (*Phoca grælandica*) (Pl. LIX. fig. 30) the neck of the malleus does not bear a trace of the singular extra articular process; but Hyrtl has observed such a projection in this species. There is a faint protuberance at the back of the neck, close to the manubrium, which may resemble the processus muscularis seen in *P. barbata*. The neck is nearly as long (though not nearly so regularly cylindrical), and the manubrium as short, as in *Cystophora*. The incus (Pl. LX. fig. 3) wants the extra articular projection, as might be expected; its crura are otherwise exactly similar to *P. vitulina*; the limbs of the stapes, though rather straighter, are quite as divergent.

In the Bearded Seal (*P. barbata*, Pl. LIX. fig. 29) the extra articular process of the malleus is quite absent; but on the back of the neck, near the root of the manubrium, is a distinct processus muscularis (absent in the *left* malleus of one specimen in the College collection, though present on the right side). In describing the Stenorhynchina, I discussed the relationship of the true processus muscularis to the extra articulating process and the deep depression found on its site in that Seal. The fact that in *P. barbata* there is a true processus muscularis much lower down the neck than the articulating process is placed in *P. vitulina*, is against the probability that the latter is a modification of the former; but the insertion of the tendon of the tensor tympani into a deep pit situated in

the malleus of *Stenorhynchus* and *Lobodon*, on the exact site of that articulating process, is in favour of that theory, which cannot be disproved till a malleus is found with both the processes coexisting.

The incus of *P. barbata* (Pl. LX. fig. 2) most resembles that of *P. grænlantica*, as both necessarily want the extra articulation; but the groove around the inner side of the facets is faint. The anterior crus of the stapes is very crooked.

In a complete set of the ear-bones of the Ringed Seal (*P. hispida*, Pl. LIX. fig. 31) the malleus and incus closely resemble those of *P. vitulina*, having the extra articular process on both bones; there is no trace of a processus muscularis. The stapes has a very large space between the crura, which are very divergent; and the anterior is much bent; the base is very broad; and, in fact, this bone in this little Seal has all the distinctive features of this subfamily well pronounced.

I have only procured a single incus of the Grey Seal (*Halichærus grypus*, Pl. LX. fig. 5); it resembles that of *P. vitulina*, except that the extra articulating process is much less developed.

The foregoing observations on the auditory ossicles of the Carnivora may be conveniently abridged in the following manner:—

I. The ossicula of the Fissipedia differ from those of the Pinnipedia very strongly, in type as well as in consistence.

II. The laminated form of the malleus prevails throughout the Fissipedia, excepting in *Herpestes* and allied genera, where the lamina is nearly obsolete.

III. The Felidæ possess a malleus which bears a long, curved, and slender processus muscularis, and a long manubrium, with a narrow, but distinct and sharply bordered outer aspect. The processus brevis of the incus is slender and rather long. The crura of the stapes, as in all these Carnivora, are straight and moderately divergent.

IV. In the Viverridæ the malleus (except in *Herpestes* and *Suricata*, whereof the peculiarity is mentioned above; moreover the processus muscularis is on the manubrium, away from the root, in these genera) has a very ill-developed processus muscularis, and the outer surface of the manubrium is even narrower than in the Cats, yet still distinctly bordered. The incus and stapes are very similar to those of *Felis*.

V. The extreme narrowness of the outer aspect of the manubrium and the very small processus muscularis of the tolerably large malleus, of *Cryptoprocta* ally it more closely to *Viverra* than to *Felis*.

VI. In *Hyæna* the processus muscularis of the malleus is very stout and straight. The outer surface of the manubrium is very broad near the tip.

VII. In *Proteles* the processus muscularis is as stout and as straight as in *Hyæna*; but the outer surface of the manubrium is very broad throughout, as in *Canis*.

VIII. In the Canidæ the processus muscularis of the malleus is as long, curved, and slender as in the Cats, but the outer surface of the manubrium is very broad throughout.

IX. In the Mustelidæ the handle of the malleus is much shorter, and forms a wider angle with the neck than in any of the above Fissipedia. The processus brevis of the incus is very short, as in the Bears.

X. In the Procyonidæ the manubrium of the malleus is long, its outer aspect as narrow as in the Viverridæ, and the processus muscularis as ill developed as in that family. The processus brevis of the incus is shorter (except in *Nasua*) than in the already named groups, excepting the Weasels.

XI. In *Bassaris* and *Ælurus* the malleus has the same characters as in *Procyon*. The lamina is very wide, as in most Bears; but the processus muscularis appears never to be absent. The processus brevis of the incus is very short.

XII. In the Ursidæ the manubrium is long, with a very narrow outer surface; the processus muscularis is very short, or quite obsolete, the lamina wider than in the Cats and Dogs. The processus brevis of the incus is very short, and the stapedia process long and divergent from the body. In the latter ossicle it is allied to the Weasels, Procyonidæ, *Bassaris*, *Ælurus*, and to the Eared Seals.

XIII. In all the Seals the ossicles are of very dense consistence; and in all but the Otariidæ they are very large, absolutely and proportionally.

XIV. In the Otariidæ the ossicles are small; the incus is of the ursine type, but the malleus and stapes decidedly phocine.

XV. In *Trichechus* the malleus resembles that of *Phoca*, excepting that the manubrium is extremely short. The incus is very like that of the Phocina, but the stapes like that of *Macrorhinus*.

XVI. In the Cystophorina, the ossicula of *Cystophora* are very similar to those of *Phoca*; but in *Macrorhinus* the malleus and incus more resemble those of the Stenorhynchina, whilst the stapes is of the Walrus type.

XVII. In the Stenorhynchina the malleus has a very large head, and a manubrium almost as short as in *Trichechus*; the body of the incus is very bulky. The stapes is of slender make compared with the same in the Walrus and *Macrorhinus*. *Lobodon* and *Stenorhynchus* are very similar in their ear-bones.

XVIII. In the Phocina the head of the malleus is excavated, and the articular surface of a distinctive form, as in all the Fissipedia. The neck is not as long as in *Cystophora cristata*, but longer than in the other Seals; the manubrium is of moderate length. The incus has often a special process, articulating with a corresponding development from the malleus. The stapes has rather stout crura; an aperture is constant, being never effaced as in *Trichechus* and *Macrorhinus*. Neither is that ossicle nearly so bulky as in those genera; but it is a little stouter than in the Stenorhynchina.

THE OSSICULA OF THE RODENTIA.

This order is remarkable for extreme variety in the form of the auditory ossicles in different families: nearly every type of malleus may be observed among Rodents; a peculiar kind of ankylosis between that ossicle and the incus is exclusively found in certain groups of this order; and there is likewise great variety in the form of the stapes.

To study the peculiarities of the ossicula of the SCIURIDÆ, a set should be selected from a skull of one of the fine large foreign species, such as the Malabar Squirrel (*Sciurus*

maximus, Pl. LX. fig. 6). The head of the malleus of that animal is large, rising well above the articular surface, but much flattened laterally. The articular area is deeply cut; each facet has a vertical ridge running down the middle, meeting its fellow at the groove of separation. Of the two segments thus formed in each facet the outer are most concave, the inner almost flat. There is absolutely no neck; and the manubrium runs almost in the axis of the body, and springs from close under the lower border of the articular surface. This process in *S. maximus* is narrow throughout, but flattened laterally, and terminates in a well-developed disk. Halfway down its inner border is a slight projection; this is the processus muscularis (Pl. LX. fig. 6, *pm*),—very frequently in that position among Rodents. The processus gracilis, which I have found entire in a large adult skull, is very long, thin, and straight; and a small area of friable opaque bone extends from the head to its root. The incus has a moderately developed body, a short, pointed, and non-divergent posterior crus; and the processus longus is broad at the root vertically, long, very straight, and widely divergent; it turns up very sharply at the extremity, which is tipped by a minute elliptical Sylvian apophysis. The stapes is large, with extremely slender crura; the anterior is the thinnest; both are slightly curved and very divergent. There was no bony canal between the crura in the skull whence the stapes was extracted for the College collection; but an intercrural canal was found in *S. vulgaris*, *S. bicolor*, and *S. carolinensis*. The base is thin and slightly bullate towards the vestibule; its extremities, especially the anterior, extend considerably beyond the attachment of the crura.

In the Jelerang Squirrel (*S. bicolor*) the ossicula are very similar, but the termination of the manubrium is spatulate rather than discoidal. This process, moreover, is broader at the root; and the processus muscularis, on the inner border, is very prominent. In the Common Squirrel (*S. vulgaris*) the manubrium mallei is even broader, but the termination is an almost perfect disk. The processus muscularis is in the same position as in *S. maximus*. In a young British Squirrel's skull I found the processus gracilis of the malleus nearly five millimetres in length, running free for two fifths of its length from the ossicle, beyond which it becomes a little dilated, and is fused by its inner border to the neighbouring bone; its extremity is a little rounded.

In *Tamias striatus* (Pl. LX. fig. 9) the malleus resembles closely that of *S. vulgaris* in every respect, especially in the manubrium; but at the point where that process leaves the body of the ossicle there is a blunt angular projection, a rudimentary processus brevis. The body of the incus is very shallow. The stapes has a bony canal between its crura*.

In the European Souslik (*Spermophilus citellus*, Pl. LX. fig. 10) the malleus, in general respects like that ossicle in *Sciurus vulgaris*, has a still more distinct trace of a processus brevis (*pb*) than has *Tamias*. The incus is of the *Tamias* form; and there is a bony canal between the crura of the stapes.

The malleus of *Anomalurus fraseri* (Pl. LX. fig. 8) is of about the same size as that of *Sciurus bicolor*; the manubrium is broader and more flattened laterally than in the true

* In the Bristly Ground Squirrel (*Xerus setosus*) the ossicula are very similar.

Squirrels, and ends in a very narrow, spatulate, and not discoidal termination. There is no trace of a processus brevis. The body of the incus is well developed, the anterior part as much as the posterior. The stapes differs from that of the true Squirrels; its crura are short, stout, and almost straight, not very divergent. There is no intercrural canal in the recent skull. The base is rather thick, quite flat towards the vestibule, and projects more than a millimetre beyond the insertion of both crura. In the general characters of its ossicula, *Anomalurus* is as nearly a true Squirrel as it has recently been shown to be, in its general anatomy, by Mr. E. R. Alston *.

In the Flying Squirrels (*Pteromys*, Pl. LX. fig. 7) the malleus, in general resembling the British Squirrel's, has a more distinct trace of the processus brevis on the manubrium even than *Spermophilus*. The termination of the handle is spatulate. The body of the incus is as shallow as in *Tamias*, *Spermophilus*, and many of the smaller species of *Sciurus*. The stapes is of the same form as in the above-named genera, and unlike that of *Anomalurus*, having slender, widely divergent crura, occupied in lifetime by a bony canal; the anterior crus is inserted into the base some distance from its extremity, the posterior joining the base almost precisely at the opposite end.

The above descriptions show that *Sciurus* is the most specialized of the genera already examined, particularly in the absence of any processus brevis to the malleus, which is not as broad as in most Rodents. The distinctions from *Sciurus* in the other genera already discussed will be seen to be truly transitional when allied families are considered.

In the Marmots (*Arctomys*, Pl. LX. fig. 11) the sides of the malleus are flatter than in *Sciurus*, and the head rises into a conspicuous blunt point high above the articular surface, which is extremely deep and narrow. All this gives a peculiar aspect to the ossicle. The manubrium is much broader at the base than in any true Squirrel, though otherwise of the same type; the extremity is very faintly spatulate, the inner border very angular. The neck is quite wanting; and there is hardly any trace of a processus brevis. The incus has a very wide shallow body; the crura are very similar to those in *Sciurus*. The stapes is a proportionally very large bone, with slender, bowed, and widely divergent crura. There is a dense bony canal between them during lifetime; and they are inserted almost exactly into the corresponding extremities of the base, which is very narrow vertically, and slightly convex towards the vestibule. The characters of the malleus and stapes separate *Arctomys* from the Squirrels: in the former bone this genus approaches the Beaver, where, however, there is a neck and a very prominent processus brevis. The Marmot's malleus, with its broad, flattened manubrium, is of the type most prevalent in this order.

In the Dormice, MYOXIDÆ (Pl. LX. fig. 13, *Myoxus glis*), the head of the malleus is as compressed laterally and as flattened at the top, above the articular surface, as in *Sciurus*, and the articular surface is as deep and narrow vertically. So far it differs from *Arctomys*, where the head rises high and the articular surface is wide and shallow. However, the malleus of *Myoxus* resembles families yet to be described in having a faint

* "On *Anomalurus*, its Structure and Position," Proc. Zool. Soc. 1875.

trace of a neck and a characteristic manubrium, very thin, very broad at the base, and still broader at the middle, where an angular projection from the inner border constitutes the processus muscularis. There is a distinct angle corresponding to the processus brevis; and the outer aspect of the manubrium, though very narrow, is distinctly bordered off from the sides, as in the Carnivora; the extremity is distinctly spatulate. The malleus of both *Myoxus glis* and *M. muscardinus* much resembles the same among certain Muridæ, where the lamina, conspicuous in *Mus*, is nearly suppressed.

The incus in the Dormice has a longer and more slender processus longus than in other families of Rodents; the posterior crus is short and very thick.

The stapes has very slender and straight crura, neither of which is inserted into the extremity of the base, which is quite plane. No bony canal exists between the crura in the two species above mentioned.

In the Beavers, CASTORIDÆ (Pl. LX. fig. 12), the head of the malleus is still large in proportion to the size of the whole ossicle, as in all the above families; it is also rather flattened laterally: the articular surface is very wide vertically, as in the Marmots; but the head does not rise high above it. There is a narrow lamina between the head and the processus gracilis, and a distinct, much constricted neck. The manubrium is very broad laterally; at the outer aspect of the base is a very prominent angle (*pb*); it is recurved and spatulate at the tip; but the processus muscularis (*pm*) is placed close to its root, so that there is no angular projection on the inner border. Such is the case in many Rats and Hares; but in the form of the head of the malleus the Beaver more resembles the Squirrels.

The processus brevis of the incus is very short and pointed, it diverges distinctly, as in most of the Muridæ. The body is square and well developed; the processus longus is rather long, and supports a well-developed Sylvian apophysis. The stapes of the Beavers is peculiar, it is large, with very slender, widely divergent, and rather short crura, both inserted some distance from the corresponding extremity of the base, which is very large, being long horizontally and wide vertically. There is no bony intercrural canal.

In the MURIDÆ, Rats and Mice, the malleus retains the singular form seen, with modifications, in *Arctomys*, *Castor*, &c., in its less typical genera; but in the genus *Mus* and allied genera the broad lamina seen in *Sorex*, the Carnivora, and the Ungulata reappears. Even in more aberrant genera the lamina is always developed, though to a less degree.

In *Mus decumanus* (Pl. LX. fig. 14) the head is little developed and deeply excavated by the articular surface; the neck is long, thin, and much curved, and, together with the head, is united to the processus gracilis by a broad area of lamellar bone (*l*); this lamina is bordered above by a linear prolongation of compact bone from the front of the head (*phm*), the processus gracilis bordering it anteriorly and below. From the outer aspect of the neck projects an orbicular apophysis (*oa*), a prominent spherical knob of bone, as seen in the Shrews. It displaces the manubrium considerably outwards; and, as in *Sorex*, it is probably an extreme development of the boss sent outwards from the shoulder of the incurved capitular portion of the first postoral bar*. The tensor tympani is not inserted into it, but into a minute tubercle close to

* "On the Structure and Development of the Skull of the Pig," by Prof. W. K. Parker, F.R.S., Phil. Trans. 1874, p. 301.

the root of the neck, and just below it. The relations of the processus muscularis to the orbicular apophysis will be considered when the ossicula of the Shrews are described, as certain interesting homologues are seen among the Insectivora, throwing much light upon the subject.

The manubrium is much flattened laterally, very broad at the base; and, as in *Castor*, the processus muscularis is at its root, not halfway down its inner margin. The processus brevis is an angular projection concealed by the orbicular apophysis, which lies above and internal to it.

The incus has an ill-developed, slightly divergent, short crus. The processus longus is stout, and projects far forwards.

The stapes, as in other Muridæ, has slender, long crura, not very divergent towards the base, which is thin and narrow; there is no intercrural canal.

Mus rattus closely resembles the above in its ossicles; in *M. musculus* the orbicular apophysis is very well developed, and was first described in that animal by Hagenbach.

In the Golden-bellied Beaver-Rat (*Hydromys chrysogaster*) the malleus, being larger, shows the murine characters very well (Pl. LX. fig. 16); the spherical knob of bone is proportionally less developed than in the smaller mice. Below this orbicular apophysis a tubercular projection can be detected; this is the real processus muscularis; I have seen the tendon of the tensor tympani still attached to it. The processus brevis of the incus is very short.

In *Hapalotis mitchelii* (Pl. LX. fig. 15) the orbicular apophysis is ill developed, and the tubercular processus muscularis, close to the root of the manubrium, is plainly visible with the aid of a pocket-lens. The manubrium itself is rather shorter than in *Mus*. The anterior crus of the incus is far stouter than the posterior. The stapes is of the same form as in the past genera of the Muridæ; and, as in them, there is no bony canal between the crura.

In the Water Voles (*Arvicola*, Pl. LX. fig. 17) the lamina of the malleus is less developed, the orbicular apophysis is quite absent, and the manubrium is rather short and very broad at the base. The processus muscularis is tubercular, and is placed on the inner side of the neck, close to the manubrium, as in *Mus*. In *A. amphibius* I have found a bony canal between the crura of the stapes, but not in *A. arvalis*.

In the Musquash (*Fiber zibethicus*, Pl. LX. fig. 18) the head and lamina of the malleus resemble those of *Arvicola*; but from the front of the head a very stout process of bone (ib. *p h m*) runs to join the upper border of the lamina: as the true processus gracilis is very slender, the former might, on hurried observation, be mistaken for it. This process from the head exists in the mallei of most mammals, but rarely to so highly developed an extent as in *Fiber*. Its homologue will be seen to form a conspicuous feature in the Cetacean malleus. The manubrium is extremely broad and flattened, even for a Rodent; the processus muscularis is at the root of the manubrium, as in *Mus*. The incus has an ill-developed processus brevis, and a long, divergent processus longus.

The stapes has the same form as in *Mus* and the other Muridæ, the crura being long,

slender, and not very divergent near the base. There is a bony canal between them in the recent skull.

In the Hamster (*Cricetus frumentarius*) the malleus has nearly as well-developed a lamina as in *Mus*; there is no orbicular apophysis; and the manubrium is not so broad at the base as in the other Muridæ. The processus brevis of the incus is very ill-developed, a character more pronounced in *Castor* and *Fiber* than in *Mus*. There is a bony canal between the crura of the stapes.

As an example of the Siphneinæ, the malleus of *Ellobius talpinus* is somewhat rat-like in form, having a small head and a distinct lamina; the manubrium bears a processus brevis close to its root. It is sometimes partially ankylosed to the incus. The incus itself has a very ill-developed body with well-developed crura, a feature seen in the fossorial rodent families distinct from the Muridæ, and about to be considered. The processus longus is much longer than the posterior crus. The stapes has very slender crura, between which runs a very dense bony canal in the recent skeleton.

Coming to the SPALACIDÆ, considerable variety will be found in the ossicula of prominent genera. In *Spalax typhlus* (Pl. LX. fig. 19) the head of the malleus is ill-developed and laterally flattened, with a very shallow articular surface, hardly any trace of a lamina, and a very constricted neck. The manubrium runs almost in the axis of the neck; it is short, and is very broad at the base, much laterally compressed; there is a prominent angle representing the processus brevis. In its malleus *Spalax* bears the same relation to *Geomys* that *Castor* does to *Arctomys*, the mallei in *Geomys* and *Arctomys* being quite neckless; otherwise, in the flattened heads, with wide and shallow articular surfaces, they all bear a certain relation to one another; and all seem intermediate between *Sciurus* and *Mus*.

The incus of *Spalax* much resembles that of *Ellobius*; but the body and articular surface are still shallower*; the crura are very similar in form and proportion. The stapes is of an extraordinary and quite unique type. It is very large, measuring from head to base two millimetres, the base of the skull measuring from the præmaxilla to the occipital foramen not quite five centimetres, whilst in a skull of *Capromys*, measuring over eight centimetres, the stapes is only a millimetre and a quarter in height. The head is a small narrow rod; the anterior crus is very straight, and runs forward at a great angle to the posterior, which is much bowed, and inserted into the corresponding extremity of the base almost vertically under its origin. The base is well developed, convex, both vertically and horizontally, and very reniform, its lower border being concave. There is no bony intercrural canal in the recent skull.

In the Bay Bamboo Rat (*Rhizomys badius*, Pl. LX. fig. 20) the head of the malleus is well developed and not much compressed laterally: the articular surface is much deeper than in *Spalax* or *Ellobius*; and the neck is long and constricted. There is a trace of a lamina; and the head is prolonged into a point forwards as in *Fiber*; near the root of the manubrium is a small tubercular processus muscularis. The manubrium is longer than in *Spalax*, and forms a sharper angle with the neck; it is of similar shape, and very broad laterally. The malleus of *Rhizomys* bears a strong resemblance to that of

* The posterior part of the body is much deeper than the anterior.

some of the less-typical Muridæ, especially *Fiber*. The ossicle is decidedly not so specialized as that of *Spalax*. The incus has a very shallow body; the posterior crus is less developed than in the other genera, though the processus longus is stout and long—a murine character. The stapes has straight crura, more divergent than in the Muridæ, and a very broad base; there is no canal between the crura in lifetime.

In the subfamily Bathyerginæ the genus *Bathyergus* exhibits in its ossicles a feature as distinctly allying it to the Cavies and Porcupines as the past fossorial rodents are allied by other peculiarities to the Muridæ, and more distantly to the Sciuridæ.

The head of the malleus (Pl. LX. fig. 22) is much elongated anteriorly, but not so much as in the Hystricidæ. The neck is thin and constricted; and there is a distinct laminar expansion beneath it. The manubrium is rather short; it is tolerably wide near the base, but gets very narrow towards the tip, and has a distinct processus brevis, and a small stout tubercle on its inner border, representing the processus muscularis, as in many Squirrels. The head of the malleus is completely fused to the body of the incus by their articular surfaces, the contour of which is deeply marked all round the seat of ankylosis; the bony union involves the neck and a part of the inner border of the manubrium, from the root to close above the tubercle for the tendon of the tensor tympani, the manubrium being fused to the processus longus of the incus nearly down to the point where it turns inwards towards the head of the stapes. This ankylosis was observed by Hyrtl. Whilst the malleus differs from the hystricine malleus in the head being less produced forwards, the incus is distinguished from that of the Porcupines in having the very shallow body and proportionally large crura seen in the rest of these fossorial animals. The posterior crus is particularly long. The processus brevis is as well developed as in *Spalax* or *Ellobius*, and hence different from the same in *Rhizomys*.

The stapes (Pl. LX. fig. 22) is a large bone, though not proportionally as great as in *Spalax*. Both crura are straight, not very long, and widely divergent. The base is very broad, and extremely convex towards the vestibule; the crura are inserted some distance from both extremities. There does not appear to be any bony canal between the crura; at least such does not exist in the skulls of *Bathyergus* in the College collection.

Among the SACCOMYIDÆ, in the Pouched Gopher (*Geomys bursarius*, Pl. LX. fig. 21) the malleus is much flattened laterally, and the articular surface is extremely shallow, long vertically and narrow in horizontal measurement; there is no lamina, no trace of a neck; and the manubrium, which runs almost in the long axis of the head, is little compressed laterally, and has no processus brevis. It more resembles the malleus of a Beaver or Marmot than the same in *Sciurus* or *Mus*.

The incus is of singular form; its body is extremely shallow; so is the articular surface; the processus brevis is very stout and blunt, and disproportionately large, whilst the anterior crus is very slender throughout, bearing a well-developed pedunculated Sylvian apophysis at its extremity. The stapes has rather stout well-diverging crura; the aperture is occupied, in the recent skull, by a very delicate ossified canal for an artery. On its base there projects towards the vestibule a very large bulla, better developed than in *Mustela* or *Hyrax*, and rivalling the same condition already described by Hyrtl as existing in *Phalangista cookii*.

It is evident that *Geomys* is more nearly allied to the families already described than to the Cavies, and is not in any way so related to the latter, in the characters of its otosteals, as is *Bathyergus*.

In the Jerboas, DIPODIDÆ, very interesting transitional characters may be observed.

In one adult skull of *Dipus ægyptius* I have found the malleus and incus unankylosed (see Pl. LX. fig. 23) on both sides; in other crania of this Jerboa these ossicles were firmly united. The head of the malleus is extremely small, and deeply excavated by its articular surface. The neck is slender and constricted; there is a broad and distinct lamina, along the front of which a portion of the head is prolonged as in *Fiber* (*p h m*). The manubrium is very thin and fragile; it is compressed laterally and broad at the base, which has a curved upper border, ending externally in a true processus brevis (*p b*). The outer aspect of the handle dilates into a very broad, spatulate, slightly recurved extremity; its inner border is stout, and has a sharp angle not far from the tip; but the tensor tympani muscle is not inserted into that projection, being attached to a little tubercular processus muscularis where that border joins the neck (*p m*). The incus of *Dipus* has a moderately developed body, a stout posterior crus, and a slender very divergent processus longus. The stapes has long, exceedingly slender crura, not widely divergent; the base is narrow horizontally. I have found a canal between the crura in some skulls of *Dipus*, but not constantly.

Altogether the malleus of *Dipus* approaches to that of the Muridæ, having a small head and wide lamina, as in *Mus*, and a very broad manubrium, as in *Fiber*. In its frequent fusion with the incus it allies itself to the Porcupines and Cavies, where, however, the head is always well-developed at the expense of the lamina.

The malleus of *Pedetes caffer* (syn. *Helamys capensis*) is more Hystricine, since the head is much developed at the expense of the lamina, and the bone is firmly fused to the incus. The stapes, too, has well-divergent crura.

Among the Porcupines, HYSTRICIDÆ, the fusion of the two outer ossicles is extreme, and the line of separation is barely perceptible externally, in *Hystrix*; but in none of the rodents to be described does this bony union extend beyond the normal articular area as in *Bathyergus*.

The malleus of *Hystrix cristata* (Pl. LX. fig. 24) has a very well-developed head, which projects very prominently forwards, taking the shape of a Phrygian cap, the convex border being above, the concave below; the blunt apex points forwards and downwards. In a perfect specimen the processus gracilis (*p g*) may be seen running close to the lower border of the head, a very limited area of lamellar bone (*l*) connecting them. The manubrium, much flattened laterally and very fragile, is trapezoidal rather than triangular, on account of the sharp angle on its inner border, which is here a true processus muscularis, the tendon of the tensor tympani being actually inserted into it. The broad upper border of the base, well-developed here, as in *Fiber* or *Dipus*, forms a very obtuse angle with the outer border, so that the site of the processus brevis (*p b*) is not so prominent as the angular processus muscularis which is readily mistaken for it in a detached bone. The outer border dilates very gradually into a narrow, spatulate, slightly recurved extremity. The incus, which is firmly ankylosed

to the malleus in quite young skulls, has a well-developed body and stout crura, the posterior diverging as much as the processus longus. The crura of the stapes are very straight, rather short, and very divergent; the posterior is inserted into the base at a marked distance from its extremity. There does not ever appear to be any bony canal between the crura, either in *Hystrix* or *Cercolabes*. The base is very broad vertically as well as horizontally, and rather convex towards the vestibule.

In *Hystrix javanica* the angular projection on the inner border of the manubrium mallei is even better-marked than in *H. cristata*. In the Guiana Tree-Porcupine (*Cercolabes insidiosus*, Pl. LX. fig. 25) the manubrium is like that of *Hystrix*; but the head is more massive than in the common Porcupine's, and still more than in the elongated mallei of *Cavia*, *Chinchilla*, &c. The stapes has a rather narrow but very stout base, convex towards the vestibule; and the crura, as in *Mus* and *Hydrochærus*, are not widely divergent. There is no bony intercrural canal.

Among those Rodents arranged by Mr. Alston (*l. c.*) under the family OCTODONTIDÆ, in the Ground-Rat (*Aulacodus swindernianus*, Pl. LX. fig. 27) the head of the malleus is still more produced forwards than in *Hystrix*, and there is as little trace of a lamina; but in the manubrium it differs from the Porcupine's in having no projection on the inner border, the processus muscularis being a prominent tubercle close to the root of that border. The outer aspect ends in a very broad spatulate dilatation. The fusion of the malleus and incus is complete; the line of junction is very faint. The processus brevis of the incus does not diverge so much as in *Hystrix*. The crura of the stapes are slender and very divergent; both are inserted into the base a distinct distance from each extremity; and there is no bony intercrural canal in the recent skeleton. The base is very broad vertically and horizontally.

In Fournier's Capromys (*Capromys pilorides*, Pl. LX. fig. 26) the head of the malleus is as much produced forwards as in *Aulacodus*; the manubrium, however, resembles that of *Hystrix*, as the processus muscularis (*p m*) is placed on the middle of the inner border*. There is the same obtuseness of the angle corresponding to the processus brevis (*p b*) as in all these Hystricomorpha. The fusion of the malleus and incus is so complete that the line of demarcation is often quite effaced, especially posteriorly. The stapes is very small in proportion to the other ossicles, as is seen in *Dasyprocta*; the crura are thick, short, and not widely divergent; the base is very broad; and an intercrural bony canal exists in some, but not all, of the skeletons of this rodent in the Museum of the Royal College of Surgeons.

Hyrthl states that in the Coypu (*Myopotamus*) the malleus and incus are not ankylosed; no ossicula of this animal have yet been prepared for the College collection.

In a skull of an *Octodon cumingii*, six weeks old, the author found the malleus and incus quite unankylosed (Pl. LX. fig. 28). The former ossicle is rather different from the same in the above animals. The upper part of its head is ill-developed, and hardly projects above the articular surface; the latter is narrow and deeply cut; the neck is very short; the manubrium is long, and not so broad at the base as in the Porcupines and Rats; it bears a trace of a processus brevis (*p b*); and the processus muscularis (*p m*) is halfway down the inner border of the handle. There is, as usual in this

* The letters *p m* in the lithograph are placed too near the processus longus of the incus.

section of the Rodentia, a narrow rudimentary lamina (*l*). The incus of *Octodon* has a well-formed body and slender crura. The crura of the stapes are very thin; its base is wide; there is a dense bony intercrural canal in the recent skull*.

In the CHINCHILLIDÆ, the malleus of *Chinchilla lanigera* (Pl. LX. fig. 29) has a head extremely produced, so as to look like a slightly flexed index finger, a very characteristic feature. The manubrium is very broad, resembling that of *Aulacodus* rather than that of *Hystrix*, the processus muscularis being on the inner border close to its root and not further down. This ossicle is very completely fused by its articular surface to the incus, of which the body is well developed; and both crura are stout and short. The crura of the stapes are very slender; and there is a distinct bony canal between them in the recent skeleton.

Among the DASYPROCTIDÆ, the Spotted Cavy (*Cælogenys paca*) has the malleus and incus completely fused. I have found, in a mutilated specimen prepared for the College collection, that the line of demarcation between the ossicula was best-marked above and internally; Hyrtl describes it as best-marked below and only partially indicated above. The head of the malleus is not so prominent forwards as in *Hystrix*. There is no canal between the crura of the stapes in the recent skull.

In the typical genus *Dasyprocta* (Pl. LX. fig. 30) the fused malleus and incus (ankylosed even in very young skulls) closely resemble the same in *Hystrix*. The head of the malleus, however, is less produced, and the two otosteals are more flattened than in the Porcupine. The stapes is small in proportion to the other ossicles; the crura are short, straight, and not widely divergent, so that the aperture is small. The base is very broad, projecting far beyond the insertions of each crus. In one out of three skulls of *D. aguti* I have found a bony intercrural canal; none existed in a cranium of *D. antillensis*.

In the Patagonian Cavy (*Dolichotis patachonica*, Pl. LX. fig. 31) the malleus and incus are completely ankylosed. The head of the malleus is stouter and straighter, and at the same time more produced than in *Dasyprocta*. The boundaries of the articular surface are clearly marked on the outer, but very faint on the inner aspect of the fused bones. The manubrium of this representative of the CAVIIDÆ is trapezoidal as in *Hystrix*. The angle at the outer aspect of the base is very obtuse, but still it represents the processus brevis (*pb*); the well-developed and tubercular muscular process (*pm*) is seated on a sharp angle on the inner border, which is very thick above and quite sharp below that process. The outer border broadens regularly from the processus brevis to the tip, which is slightly everted and spatulate, its edges spreading out widely from the thin compressed sides of the manubrium. The body of the incus is both broad and deep; and its crura are of almost equal thickness and length. The stapes is proportionally large, the crura very straight, rather long, and divergent; they are deeply grooved within; and in the recent skull a bony canal runs between them. The base is broad, extending considerably beyond the insertions of the crura; it is convex towards the vestibule; the convexity is separated from the periphery by a deep channel, so as to form a large umbo.

* In the figure of the malleus of *Octodon* the letters *pm* have been placed where *pg* should have been written; and *l* is marked too close to the head of the malleus.

In the Guinea-pig (*Cavia caprera*, Pl. LX. fig. 33) the malleus and incus, which are ankylosed in new-born specimens, resemble strongly those of *Dolichotis*; but the head of the malleus is more produced and more slender. The manubrium has the same general characters; only its thin flattened sides and spatulate extremity are much broader than in the Patagonian Cavy; there is a distinct trace of a processus brevis. The stapes has all the characters seen in *Dolichotis*; there is sometimes a bony canal between its crura.

In *Hydrochaerus capybara* (Pl. LX. fig. 32) the malleus and incus are ankylosed in the adult, but often free in young skulls. The head of the malleus is stout and less produced than in *Cavia* and *Dolichotis*; and the manubrium mostly resembles the same in the latter. The crura of the stapes are long, rather crooked, and slightly divergent; the base is somewhat narrow, stout, and extends beyond the insertions of the crura. No bony intercrural canal exists, or at least it is not constant.

Among the Glires Duplicidentati, the LEPORIDÆ possess a malleus which does not assume the extreme types seen in different Rodents, such as the Sciuridæ and the Hystricomorpha. It assumes the less-specialized characteristics of the Marmots, Bears, and some of the Muridæ.

In the English Hare (*Lepus europæus*, Pallas) the head of the malleus is ill developed, rising hardly at all above the articular surface; however, it sends a narrow projection towards the trace of the lamina. The articular surface is rather deeply cut, and rather narrow laterally; the facets have a vertical convex ridge across their middle as in many animals in other orders. Between the body and the processus gracilis is a very fragile and rather narrow bony lamina, generally damaged in the removal of the bone, but plainly visible if the malleus of a new-born hare or rabbit be prepared *in situ* with the tympanic bone. I have examined it in its natural position in the adult hare and rabbit, and certainly have found the lamina partially absent. That it should atrophy during adolescence is highly probable, seeing that the processus gracilis itself is partially absorbed in Man and in many lower animals.

The neck of the Hare's malleus is very distinct, being much constricted and rather short. The manubrium is of the sword-shaped form seen in the Beaver, being very thin and flattened laterally, broad at the base, and well recurved. There is a trace of processus brevis (Pl. LX. fig. 34, *L. cuniculus*, *p b*); the muscular process (*p m*) is situated on the inner border very close to the neck. The outer edge is very narrow, though distinctly bordered off from the sides and hardly dilated at the tip. This broad manubrium, without an angle on its inner margin, may be considered a central type among Rodents, differing, on the one hand, from the narrower manubrium of the typical Squirrels, and, on the other, from the trapezoidal handle of the malleus in the Hystricomorpha.

The incus has an ill-developed posterior crus and a very divergent stout processus longus, bearing a well-developed elliptical and pedunculated Sylvian apophysis. Of course the articular area is deeply cut; otherwise, particularly in the crura, this ossicle resembles the same in most Rats and Squirrels.

The stapes has perfectly straight and well-diverging crura; the base is broad, and projects beyond their insertions. There is no bony intercrural canal in the recent skull.

In the Rabbit (*Lepus cuniculus*, Pl. LX. fig. 34) the ossicles are identical in form with those of the Hare. In both these animals the processus muscularis may be situated absolutely on the neck of the malleus, and not at all on the inner edge of the manubrium as is usually the case.

The conclusions arrived at, after the study in detail of the ossicula of the Rodentia or Glires, is as follows:—

I. In the Sciuromorpha there is a tendency in the malleus to suppression of the neck and processus brevis. This is complete in *Sciurus* and *Anomalurus*; but the neck and the process are gradually developed in *Xerus*, *Tamias*, *Spermophilus*, *Pteromys*, *Myoxus**, and *Castor*, the process being perceptible as a slight projection in the first four genera, whilst it is well developed and there is a distinct neck in the Dormouse and Beaver. In *Arctomys* there is no neck, and the processus brevis is as ill developed as in the Ground-squirrels and *Pteromys*; the malleus is extremely flattened, and projects above the articular surface. As in all other rodents where the incus is free †, it has a rather square solid body, with the posterior crus but little divergent. The stapes is large, with wide, slender, divergent crura (least so in *Anomalurus*); a bony canal runs between the crura in lifetime.

The great breadth of the manubrium, so distinctive of Rodents, is well marked in *Castor* and *Arctomys*, least in *Sciurus*. The processus muscularis is situated on its inner border.

II. In the Myomorpha the laminated malleus reappears in its best-developed form in *Mus*, *Hydromys*, and allied species; in some of these Muridæ there is an orbicular apophysis, so frequent in the Chiroptera and the Shrews. In the less-typical genera the lamina is narrow, the manubrium extremely broad, with a prominent processus muscularis on its inner border. The stapes has long slender crura, little curved or divergent. A bony intercrural canal is rare.

III. In the fossorial Rodents remarkable varieties are seen in all the ossicula, especially in the stapes, which is bullate in *Geomys* and of unique type in *Spalax*. *Ellobius*, *Spalax*, *Rhizomys*, and *Geomys* ‡ show distinct affinities to the Muridæ in the form of the malleus, whilst in *Bathyergus* we find that the malleus and incus are fused even to a greater extent than in the Hystricidæ.

IV. In the Hystricomorpha the malleus is almost invariably fused to the incus in the adults, but often free in young subjects. In *Dipus* § the malleus is more like those of some of the Muridæ than is that ossicle in the rest of the group. The head of the malleus is produced forwards moderately in *Hystrix* and its allies, also in *Cavia*,

* *Myoxus* is rather Sciuromorphic than Myomorphic in its ossicula.

† Excepting *Spalax* and its allies.

‡ The absence of a neck to the malleus in *Geomys* allies it to the Squirrels.

§ As the malleo-incudal ankylosis is frequent in *Dipus*, and probably constant in *Pedetes*, these genera are not placed here among the Myomorpha.

Dasyprocta, and *Hydrochærus*, but to an extreme degree in *Aulacodus*, *Capromys*, and especially in *Chinchilla*. The stapes is small, with well-developed crura, not very divergent. A bony canal runs between the crura in some specimens from several species, but is not constant.

V. In the Duplicidentati the characters of the ossicles are rather central. The malleus is of much the same form as in the less-typical Muridæ; but the head is less developed. There is never any fusion of the malleus and incus in *Lepus*.

THE OSSICULA OF THE UNGULATA.

The different families of Perissodactyla offer more sharply defined characters in their auditory ossicles than do the even-toed Ungulates.

Suborder PERISSODACTYLA.

Among the RHINOCEROTIDÆ, the ossicula are all very small in proportion to the size of the animal. In *Rhinoceros bicornis* (Pl. LXI. fig. 1) the malleus, from the top of the head to the top of its long manubrium, measures one centimetre, the incus is two millimetres high between the crura, and its body is barely four millimetres broad, all much inferior measurements to the same in a Horse, and hardly above the proportions in a Tapir.

The malleus has an extremely deep and wide articular surface, reducing the head to a mere cup-shaped process, with none of the free globular portion seen more or less in most mammals. The upper facet (very prominent from the ill-development of the head) is not as large as the lower; both are slightly saddle-shaped, and run into each other at the bottom of the deep excavation without any sharp dividing ridge. The neck is cylindrical, curved, and rather narrow, bordered anteriorly by the lamina. The manubrium is very long and slender: it is bent somewhat inwards as it leaves the neck, curving boldly outwards near the extremity, which is distinctly spatulate. It forms nearly a right angle near the neck; a well-rounded tuberosity occupies the site of the processus brevis; there is a small tubercular processus muscularis on the inner aspect of its root. The sides of the manubrium are flattened and narrow throughout, the inner border is rounded, not sharp; the outer angle is still bordered, though extremely narrow. In front of the neck is a laminar expansion (Pl. LXI. fig. 1, *l*), which is continued (rather than merely blended below, as in Carnivora and Ruminants) into a very large lamelliform processus gracilis (*pg*), shaped like a streamer or pennant, and measuring, in a specimen in the College, twelve millimetres, the manubrium being only nine millimetres long. A process from the head (*phm*) bounds the anterior and upper border of the lamina.

Comparing this bone with the corresponding ossicle in other Perissodactyla and Artiodactyla, the presence of a lamina might lead the observer to the assumption that the malleus of *Rhinoceros* is more like that of the Pigs and Ruminants than that of the Equidæ; the same remark applies to the very similar malleus of *Tapirus*. But a very little consideration must convince him that the lamina in the *Rhinoceros* is of a different type from that of the even-toed Ungulates. It is not, as in them, a broad lamella of bone

stretched from the root and adjacent part of the processus gracilis to the neck and head, but a narrow strip of lamellar bone running with that process far in front of the head into the Glaserian fissure. Indeed the thin sickle-shaped processus gracilis of *Equus* is probably a modification of it. The Rhinoceros's malleus approaches a type very frequent in the Insectivora, the Bats, the Marsupials, and some Edentata, as *Priodon*, where the processus gracilis is elongated in a very similar manner. But more will be said on the subject when the ossicles of the latter groups are discussed.

The incus of *Rhinoceros* is of a very peculiar form, the body being very broad and shallow, and the crura both widely divergent; the posterior is long, stout, and blunt-pointed; the processus longus is rather short, boldly curved, deeply grooved on its inner aspect, and bears on its extremity a greatly developed Sylvian apophysis, pedunculated with a slightly concave oval surface towards the stapes. It is absolutely and, as I believe, proportionally the largest Sylvian apophysis existing, greater than the same in *Galeopithecus*, to which Hyrtl gives the palm; but he does not describe the ossicula of the Rhinoceros.

The stapes has a very large head, slightly convex, to fit the apophysis; the posterior crus is quite straight, the anterior curved forward just before its insertion. In the specimen in the College collection there is a thin lamina of bone between the upper halves of the crura. The base is broad and convex.

The ossicula of *R. sondaicus* and *R. sumatrensis* are almost identical in character.

Among the TAPIRIDÆ, the malleus of *Tapirus bairdi* (Pl. LXI. fig. 2) resembles considerably that of the Rhinoceros, particularly in the large excavation for the incus, and the very slight development of the upper part of the head; but the neck is shorter, more curved, and not so closely defined in front from the lamina; the manubrium is not so much bent inwards, and is very little curved outwards at the tip, which is less broadly spatulate. Besides the processus muscularis there is a small tubercle on the inner side of the neck, not on the root of the manubrium as in *Rhinoceros*. The lamina is broad, and runs into a similar processus gracilis, which is slender and fragile.

The incus has a very broad body; its interior segment is much less developed than the posterior, by which it differs from *Rhinoceros* and approaches *Equus*.

In the EQUIDÆ, the typical *Equus caballus* (Pl. LXI. fig. 3) has a malleus with a well-developed globular head, exceeding, in that respect, other Ungulates, and a wide, deeply cut articular surface, whose edges are raised above the level of the rest of the head, upon which it encroaches very little. The facets are almost plane, but slightly saddle-shaped; the groove between them is not well marked. The neck is rather long, somewhat flattened, and twisted a little outwards near the root of the manubrium, which leaves it at a right angle, is long, but broader at the base than in the Tapir and Rhinoceros. The manubrium is only slightly spatulate and recurved at the tip, and has a narrow but well-bordered outer surface. The processus brevis is represented by a blunt tubercle, much bent forwards; the muscular process is a small tubercle on the inner side of the neck, close to the root of the manubrium. The processus gracilis is long and sickle-shaped, not nearly so broad as in *Rhinoceros*; and there is little trace of a lamina: hence the equine malleus is a less specialized bone than that of the other odd-toed

Ungulates, and far more removed from the Artiodactyle form. The incus is very much larger than that of the *Rhinoceros*, both absolutely and proportionally. Its body is rather broad, and cannot be distinguished posteriorly from the stout, short, and little-divergent processus brevis; the anterior part is very little developed; the processus longus is more slender than the processus brevis, though still rather broad at the base; unlike the posterior crus, it diverges considerably from the body. The stapes is quite triangular, has a well-developed head, with extremely straight crura, not very divergent towards the base, and inserted a perceptible distance from each extremity. The base itself is broad and almost plane.

In *Equus asinus*, and still more in *E. zebra*, the processus muscularis of the malleus is more developed than in *E. caballus*, appearing as a slightly curved blunt-pointed process. The incus in both the former has a slender and more divergent processus brevis; in the Zebra the whole body is more developed. The Sylvian apophysis is a flat sessile disk; in adults it fuses more or less completely with the processus longus, as in Man. The stapes of *E. zebra* is very horse-like, the head being very broad and stout, the crura straight, and the aperture triangular, with sharp angles; the base is thick, with an umbo towards the vestibule. The stapes in *E. asinus* has a smaller head; the anterior crus is distinctly curved; and the intercrural aperture is round rather than triangular. A tubercle, with an ossified piece of the stapedius tendon attached, is often seen in the stapedes of the Equidæ and also in many Artiodactyles.

SUBFAMILY ARTIODACTYLA.

This group is interesting for the frequent recurrence of the broadly laminate form of malleus which prevails among the fissipede Carnivora. The incus, as will be shown, is a bone of great interest and distinctive value in these animals.

In the Hippopotamus (Pl. LXI. figs. 4 & 5) the malleus has a large head, with a well-developed spherical upper aspect, and a very broad articular surface, of which the upper facet is of great breadth, almost plane, but has a vertical convex ridge near the outer border; while the lower facet is very narrow, and vertically much elongated, so as to be tongue-shaped and quite convex in both directions. They blend together undivided by any sharp groove; and the entire surface is somewhat shallow. The neck is short, very broad towards the neck, and constricted close to the manubrium; it is considerably flattened laterally; and from its inner aspect, a considerable distance from the root of the handle, springs a long, straight processus muscularis, of equal thickness throughout, and hence blunt-pointed. The manubrium is long, it leaves the neck at an obtuse angle, and is flattened laterally, but not very broad at the base. The processus brevis is a sharp angular projection bent rather backwards; the outer aspect of the handle is sharply bordered from the sides, and spatulate at its extremity, which is but a little recurved; the whole process is almost straight. The processus gracilis is very slender and united for some distance to the neck and head by spongy, not lamellar bone.

This bone is very like the same in the pig, the chief distinction being in the character of the articular surface; the spongy bone between the neck and processus

gracilis represents the lamina so marked in the other Artiodactyla; it exists in the same modified form in the still larger malleus of the Elephant.

The incus has a very high and rather narrow body; the upper part of the articular surface is very broad, the lower part forms a deep, narrow groove, to fit the lower facet of the malleus. Both crura are very short and divergent; there is a small tubercle over the outer aspect of the processus longus, which crus is concave on its inner side. This high-bodied incus is thoroughly porcine. The stapes has a comparatively small head, with a flat tubercle on its posterior side for the stapedius tendon. The crura are both straight, the posterior is much thicker than the anterior, and they diverge very considerably, leaving a large space between them. The base is thin, broad, and rather convex; the whole bone forms an equilateral triangle. Hyrtl considers the aperture between the crura to be small; but it is very wide in three stapedes of *Hippopotamus* in the College collection.

In the Wart-Hog (*Phacochoerus æthiopicus*) the malleus resembles that of *Sus*, about to be described; but the following distinctions exist: 1, the upper part of the head is narrower, and projects more prominently forwards; 2, the articular surface is wider and shallower, the lower facet is nearly as large as the upper, both are only slightly and evenly saddle-shaped, and the groove between them is very faint instead of being sharply cut. This is a distinct approach to the Hippopotamus. The manubrium is almost straight towards the extremity. The incus is like that of *Sus*, except that the processus "brevis" is absolutely longer than the stapedial crus, and is slender and blunt-pointed. The stapes is pig-like; its crura are extremely slender.

In the SUIDÆ (Pl. LXI. fig. 6) the malleus is of the broadly laminate type. The head is well developed, though not so large proportionally as in the Hippopotamus, and projects forwards rather than upwards; the articular surface is narrow and deep. The groove dividing the facets is very sharply defined; the upper is larger than the lower; and both are saddle-shaped, a vertical convex ridge running near their outer borders, leaving to each a very narrow outer segment,—a very different condition from that which exists the Carnivora, where the malleus is of a very similar form. The neck is very narrow, and boldly curved; a stout lamina connects it with the thin processus gracilis. From the inner aspect of the neck, a slight distance from the root of the handle, springs a long, stout, and straight processus muscularis, similar to that of the Hippopotamus. The manubrium leaves the neck almost at a right angle; it is not very broad laterally at the base, and has a sharp processus brevis pointing vertically upwards. Its outer aspect has well-defined borders, but is very narrow; the extremity turns up slightly, but distinctly, and is but little dilated.

The incus has a well-developed exceedingly square body, with short processes, as in *Phacochoerus* and *Hippopotamus*, and contrasts strongly with the incus of the Ox and Deer, and still more with that of the Perissodactyla. Its articular surface is deeply cut, to fit that of the malleus; the lower facet is narrow and shallow, a natural and necessary variation from the same in the Hippopotamus, corresponding to a similar difference in the malleus. The stapedial crus is scarcely longer than the processus brevis, and supports a small, discoid, pedunculated Sylvian apophysis. The stapes tends to the quadri-

lateral type frequent in the Ruminants, the head being very broad; the crura, wide apart at their origin, are slender, and diverge little towards the base; the aperture is large, and almost circular. The base is stout, with a very convex umbo towards the vestibule, as Hyrtl has previously observed.

In the genus *Sus* all the above characters are strongly marked; the lamina, however, is much encroached upon even in a foetal pig. In *Babirussa alfurus* the articular surface of the malleus has but a faint line between the facets, the lower of which is considerably narrower than the upper. This approaches the type of *Phacochærus*. The processus muscularis is very long and stout; the end of the manubrium is slightly but distinctly recurved.

In the Peccary (*Dicotyles tajaçu*, Pl. LXI. fig. 7) the malleus has a longer and a thinner neck than in *Sus*, much less abruptly curved, and a wide, perfectly papery lamina between it and the processus longus; the manubrium, which forms a more obtuse angle with the neck than in the other pigs, has a rather wider outer surface, and a distinctly broader and more spatulate extremity.

The more compact and less laminar expanse of bone between the neck and the processus gracilis in the Pig, as compared with the Peccary, might be explained by its greater size; and, indeed, in the larger animal in any Order there is often a tendency to such thickening of that area; still, in the large malleus of the Lion this lamina is as thin, in comparison with the rest of the bone, as the corresponding structure in the Cat and Genet; on the other hand, it is denser in the Hyæna, which is intermediate in size between them. Hence the degrees of density of the lamina constitute fair generic distinctions.

The incus of *Dicotyles* is even higher and narrower than in *Sus*; the processus longus is rather longer. The stapes has a broad head, very straight crura, and a very thick base, with an umbo convex towards the vestibule, as in *Sus*.

In the Chevrotains, TRAGULIDÆ (Pl. LXI. fig. 8), the head of the malleus is small; and the articular surface is deeply cut, with a sharp groove between the facets, which are both saddle-shaped, a sharp convex ridge running vertically down their surfaces, near the outer margin, as in the Pigs, whilst in most of the Bovidæ the facets are nearly plane. The lower facet is almost as wide as the upper. The neck is shorter than in *Sus*, and consequently much shorter than in most Ruminants; but the malleus resembles that of the latter group of Artiodactyla in the bluntness of the angle at the outer side of the base of the manubrium, which, moreover, forms a very obtuse angle with the neck; the processus muscularis is short, but stout. The incus invariably retains the solid square form seen in the Pigs; and the crura are as short. The stapes has a small head and more divergent crura than in *Sus*; the base is very thick and quite plane; the crura are both inserted a perceptible distance from its extremities. Hence this bone, with its divergent limbs, has the form of an almost equilateral triangle, as seen in some Antelopes, particularly in *Gazella*, differing from the almost quadrilateral stapedes of both *Bos* and *Sus*. The corresponding ossicle in the Cervidæ, having a narrow base, with straight, equal crura, is intermediate in form.

In *Tragulus javanicus* the manubrium does not form quite so obtuse an angle with

the neck as in *Tragulus napu* *. On the inner side of the neck of the malleus of *T. kanchil* is a small tubercle-like processus muscularis. The Sylvian apophysis on the end of the long process of the incus is a thick disk, wider in diameter than the end of the processus longus, and pedunculated.

In the CAMELIDÆ or TYLOPODA (Pl. LXI. figs. 10 & 11, *Camelus dromedarius*) the upper part of the head of the malleus above the articular surface is not much developed; and, as in the Pigs, it projects forwards, but does not rise above the level of the articular area in an upward direction. This surface is very wide vertically; its edges are much raised above the level of the rest of the head. The facets are almost plane; the lower is as long as, but narrower than, the upper; they run into each other without any trace of a groove. The neck is very short, rather broad towards the head, and very constricted near the manubrium; there is only a very small fragile lamina stretched between it and the processus grácilis. The manubrium is extremely long, rather slender even at the base, and does not form a very obtuse angle with the body; a bold rectangular projection corresponds to the processus brevis; the outer aspect is narrow, but sharply bordered, the extremity distinctly spatulate and only a little recurved.

The incus is very singular and distinctive in form (Pl. LXI. fig. 9, *Lama peruana*). It is extremely high and narrow; and the anterior part of the body is nearly as deep as the posterior—a rare condition in any Order†. The articular surface is equally distinctive; it is very wide, corresponding to that on the malleus, and absolutely convex from above downwards; its margins are very prominently raised above the level of the body; its lower and anterior extremity stops very far short of the root of the processus longus. Hence the incus in the Camelidæ is quite distinct from that of other even-toed Ungulates, even from those where it is high and narrow. The stapes has a small narrow head, long and rather slender crura, not very divergent; and both are inserted some distance from the extremities of the base, which is very thin, particularly in proportion to the same in other Ungulates; it bears a base of an umbo.

The malleus of the Camel and Llama are very similar, in the former the head projects more forwards than in its American representative. In *Camelus* and *Lama pacos* there is a small, tubercular processus muscularis on the inner side of the neck of the malleus, hardly perceptible in *L. peruana*.

In the Prong-buck, or American Antelope (*Antilocapra americana*, Pl. LXI. fig. 12), the head of the malleus is very little developed, the upper portion projecting neither upwards nor forwards; the articular surface is very wide and rather deep, its borders are much raised; both facets are almost plane; the upper is very broad; the lower is narrowed, and is sometimes prolonged into a short tail-like extremity, running onto the neck; but this feature is not constant. I have noticed the same peculiarity in individual mallei of Goats and Antelopes. The groove between the facets is distinct. The neck is very long, cylindrical, and only gently curved, it is joined to the slender processus gracilis by a well-marked lamina. From the inner aspect of the neck projects a very stout, straight, blunt-pointed processus muscularis. The slender manu-

* The processus muscularis is sometimes obsolete in these species.

† In *Camelus* the body of the incus is not so high and narrow as in *Lama*.

brium has a well-bordered outer aspect of almost equal breadth throughout; there is a sharp angular projection at its base; and it is but slightly recurved and very little dilated at the tip.

The incus is high and narrow; its articular surface is deeply cut; and when there is a tailed prolongation of the lower facet on the malleus, a corresponding peculiarity is seen on that facet on this bone. Both crura are very short; the lower is very divergent and boldly curved. The stapes is almost quadrilateral; the head is very broad, with a prominent process for the stapedius tendon; the crura are stout and almost parallel; the anterior, which is the thinnest, is inserted into the extremity of the base, which is rather thin and almost plane.

In general characters the ossicula of *Antilocapra* closely resemble those of the Bovidæ. The body of the incus is almost as stout and square as in the Pigs and *Tragulus*; but this feature is seen in *Gazella*.

THE BOVIDÆ.

In this family it is hard to find distinctive features in the auditory ossicles of different species, while, to add to the difficulty, in many instances these bones undergo considerable changes during the growth of the animal; so that little reliance can be placed on any conclusions based on the observation of one specimen alone from any species. It is necessary to examine duplicates as well as examples from different species of the same genus. Through the kindness of Sir Victor Brooke, Bart., the author has been enabled to collect a large series of the ear-bones of this order from the skulls in that gentleman's fine collection of skeletons of Ruminants.

Beginning with the Common Sheep (*Ovis aries*), it is highly important to select complete series of the ossicula from individuals of all ages, for reasons immediately to be explained.

Taking a set from the skull of an adult sheep (Pl. LXI. fig. 16), the malleus will be seen to have the upper and anterior part of its head ill developed, as in *Antilocapra*, and unlike *Sus* and its allies. The articular surface (a most important region to observe closely) is wide vertically as well as laterally, and also deeply cut; each facet is distinctly saddle-shaped, with a sharp vertical ridge down the middle. The neck is cylindrical and sharply curved, as in most mallei of this type; the lamina is of moderate breadth. The processus muscularis is curved and prominent, but not very long. The manubrium is long and slender, compressed laterally, but not broad even at the base, on the outer extremity of which is a rectangular projection, hardly to be called a processus brevis. The outer aspect is sharply bordered and extremely narrow, hardly dilating at the extremity, which is but little recurved.

From repeated observations, I find that the malleus of an adult domestic *Ovis* closely resembles that of a foetal *Bos taurus* of about the sixth week (Pl. LXI. fig. 15); but at birth the characteristic, extremely shallow articular surface, and strongly curved manubrium, are always found in the ox; the outer aspect of that process, too, is very broad in foetal calves, though never in adult sheep. The same articular surface is very deeply cut in the mallei of lambs.

The incus in an adult sheep has a well-developed body, which is by no means shallow, but never as square and solid as in the Pigs and their allies. The great development of the crura in *Ovis* makes the body look smaller than it really is. The processus "brevis" is very long and straight, and almost cylindrical in form, though a little compressed vertically. The processus "longus," well divergent from the other crus, is absolutely shorter; it bends very abruptly above its termination, which bears a very well-formed pedunculated and perfectly elliptical Sylvian apophysis. In the incus of a new-born lamb (Pl. LXI. fig. 17) the body is much shallower, as in many less typical Bovidæ; that part of the same ossicle in the adult sheep, on the other hand, clearly approaches the high well-developed type seen in adult oxen.

The stapes in a large adult skeleton is quite trapezoidal; the head is large and square, bearing a slight trace of a process for the insertion of the stapedius muscle on its inner aspect. The crura are thick and deeply channelled towards the aperture; they are wide apart at their origin and almost parallel; the anterior is the thinner and longer; so that base is further from the head in front than behind. The base is thick, its upper border is strongly arched, and both extremities project very perceptibly beyond the insertion of the crura.

But in the new-born lamb the stapes is generally quite triangular, the head being much less developed, and the crura close together at their insertion. It will be seen to retain features observable among many adult Antelopes—that ossicle in the Sheep, when full-grown, approaching, as does the incus, the type seen in *Bos*.

The Ox will now be considered; and it will be demonstrated afterwards how every grade of transitional features in all the ossicula, between *Ovis* and *Bos* compared, are seen in every kind of combination in Goats and Antelopes.

In a malleus taken from a large Ox's skull (Pl. LXI. fig. 14) the head appears no more developed above the facets than in *Ovis*; but the articular surface, wide horizontally, is very wide vertically, the facets gaping far apart. The upper is almost plane, though still slightly convex; the lower is more perceptibly elevated, and is divided from the upper by a very faint groove. The neck is short and very strongly curved; the lamina is moderately wide; the processus muscularis projects from the inner side of the neck some distance from the manubrium, and is rather short, almost straight, and blunt-pointed. The manubrium is boldly curved, with the concavity forwards; its outer aspect is rather broad and sharply bordered, dilating but little and very gradually towards the tip. The base projects upwards, outwards, and a little backwards, and may be said to bear a true processus brevis.

The malleus of a foetal calf at the sixth week (Pl. LXI. fig. 15), on the other hand, is much more like that of an adult Sheep, and is almost as large. The articular surface is wide and deep vertically, as in *Ovis*, but not so deep as in the adult *Bos*; and the facets are more perceptibly convex. The manubrium too is almost straight, and slightly recurved at the tip, instead of being well bowed forward. In the mature foetus the malleus has assumed the adult Ox's character.

The incus in the full-grown *Bos* has a very well-developed body, its outer and inner aspects both showing a wide, convex, bony surface; the postero-superior border over

the processus brevis is twice as long as the antero-internal; and the articular surface, well to the front, is of necessity wide. The processus brevis is as long and cylindrical as in *Ovis*, and much curved outwards; the processus "longus" is not so long, but it stretches out further than in the Sheep, and does not turn up so sharply near the Sylvian apophysis, which is similar in form. In the foetus of a calf at the sixth week the body is about as well developed, proportionally, as in an adult domesticated Sheep.

Taken as a whole, the Ox has the best-developed incus of all the Artiodactyla, inasmuch as the body is in all directions larger than even in *Sus*, where the crura are characteristically short, whilst those processes in *Bos* are even longer than in Sheep and Antelopes (where the body is shallower), and as long as in the Deer (where it is generally very shallow and broad).

The stapes of the adult Ox is absolutely oblong. The head is very broad, with a prominent tubercle for the stapedius tendon, which latter is partly ossified. The crura are quite parallel, or even nearer together at the base than the head in very large specimens; they are well channelled towards the aperture; the anterior is very thin and straight, and a little longer than the posterior, which is thicker; the base is very stout, and projects well beyond the crura. The whole bone is only an extreme modification of the form seen in *Ovis*; indeed in the foetal calf that bone is still trapezoidal, or almost triangular, the head being less broad, and hence the crura nearer together at their origin.

In the adult Zebu (*Bos indicus*) the ossicula are more slender than in the Ox; the manubrium of the malleus is not so boldly curved; the stapes is even more oblong than in *B. taurus*; its crura are very long and close together.

The ossicula of the Burrhel (*Ovis nahoar*) are more like those of a new-born lamb than those of a full-grown domestic sheep. The body of the incus is shallower, though the crura are as long; nor is the stapes so quadrilateral as in *O. aries*.

In the adult Goat (*Capra*) the malleus has an articular surface as wide as in *Ovis*, and hence not so wide or so plane as in *Bos*. The manubrium is distinctly curved, almost as much as in the Ox in *C. ibex*, less so in *C. hircus*, *C. megaceros*, and *C. ægagrus*, judging from specimens in the College collection. The body of the incus is sometimes shallow in this genus; but in the skulls of large goats it becomes as high as in the adult Sheep. The posterior crus is not very long; the anterior is sharply bent, as in *Ovis*. But even in large adults the stapes remains triangular, though the head is always thick, and the crura a distinct distance apart at their origin; they diverge considerably towards the base, which is very wide and thick, projecting beyond their insertions, and is quite plane towards the vestibule. The crura are almost of equal thickness; but the anterior is rather the longer.

In the Chamois (*Rupicapra tragus*, Pl. LXI. figs. 22-34) the articular surface of the malleus is wider than in *Ovis* or *Capra*, and almost as wide and as level as in *Bos*; but the manubrium is slender and almost straight, as in the Antelopes. The incus resembles the full-grown Sheep's in the development both of its body and crura; and the stapes is of the same trapezoidal form.

In the malleus of *Nemorhedus (Capricornis) sumatrensis* (Pl. LXI. fig. 29) the articular surface is as in *Ovis*; the manubrium is slightly curved; and the lamina is extremely wide. The stapes is, on the other hand, positively triangular, as in most Antelopes, the head being rather small, the crura close together at their origin, and very divergent; they are rather thick; the base projects but little beyond them, and is not very wide. In a single malleus of *Oreotragus saltatrix*, from an adult skull in Sir V. Brooke's collection, the articular surface is narrower vertically than in *Ovis*; the manubrium is long, straight, and very slender. The malleus in *Saiga tartarica* (Pl. LXI. fig. 23) is very sheep-like in the nature of its articular area and in the form of its manubrium; the incus (Pl. LXI. fig. 35) has a very shallow body, with widely separating and diverging crura; the stapes is quite triangular.

In *Gazella* (Pl. LXI. fig. 18) the malleus retains most of the characters of *Ovis*; but the articular surface is often wider, the processus muscularis is almost always shorter and smaller, the angle at the base of the handle is so prominent as to form a true processus brevis, and the extremity of the manubrium is well recurved and spatulate, the whole outer aspect of that process being rather wide. The body of the incus is always well developed in both directions, so as to take from the length of the crura (which, on actual measurement, are fairly long) and to make the whole bone resemble the same in the Pigs and Tragulinæ, where the processes are very short, especially the processus brevis. The stapes is a large bone, of very delicate make, and almost an equilateral triangle in form; the head is small, the crura very slender and divergent, the base very wide and plane, extending well beyond the insertion of the crura. The ossicula of *G. dorcas*, *G. lævipes*, and *G. bennettii* are very similar.

The malleus of *Antilope cervicapra* is of the Gazelle type; but the stapes has stouter and less-divergent crura. The malleus of *Procapra picticaudata* (Pl. LXI. fig. 27) is similar; the incus (fig. 38) has as large a body as in any *Gazella*. The same remarks apply to *Nanotragus pygmæus* and *N. montanus* (fig. 13), though even in adults of the latter species the body of the incus remains shallow; at least such is the case in the College series. The stapes approaches the quadrilateral form of that of *Ovis*, the head being larger and the crura more nearly parallel than in *Gazella*.

In *Cephalophus* (fig. 28) the articular surface is almost as wide on the malleus as on that ossicle in *Bos*, the processus muscularis is very short, and the manubrium is of the long, straight, and slender form frequent in Antelopes yet to be noticed. The incus (fig. 39) in *C. maxwellii* is very like a Sheep's; the stapes is triangular, though the crura are very divergent. The malleus of *Nesotragus moschatus* is of the *Cephalophus* type; in the incus from an adult *Tetracerus quadricornis* (fig. 37) the body is as shallow as in a lamb; the malleus (fig. 25) and stapes resemble those of *Cephalophus*; the same applies to the malleus of *Nemorhedus goral* (fig. 30), where, however, the processus muscularis is longer than in *C. mergens* or *C. maxwellii*; the incus has a shallow body and very long divergent crura. In the adult *Kobus ellipsiprymnus* (fig. 24) the articular surface of the malleus is quite as wide as in *Bos*, but the manubrium is well recurved and not very slender, altogether more like that of *Gazella* than of the other Antelopes. The incus has a very high body, quite as high as in the Ox; the crura are rather short. This ossicle

exceeds the incus of the Pigs in height as much as the incus of some other Antelopes exceeds that of *Sus* in breadth.

In the Harnessed Antelope (*Tragelaphus scriptus*) the malleus has a wide articular surface and a very long, slender manubrium, which is almost straight. In *Damalis lunatus*, *D. pygarga*, and *Alcelaphus bubalis* (Pl. LXI. fig. 19), the articular surface is always wide, as in *Bos*, but the manubrium is rather broad at the base and more curved than in *Tragelaphus*. In all these genera the incus has a very shallow body, with very large, thick, and long crura, somewhat as in the Cervidæ. The only stapes in the College collection (from *A. bubalis*) is triangular.

Catoblepas gnu and *C. gorgon* are remarkable for the great length and slenderness of the manubrium mallei, which is slightly turned up at the tip (fig. 26). The head is very small, the articular surface is wide and smooth, and the processus muscularis is moderately developed. The stapes of *C. gorgon* is triangular, of *C. gnu* more oblong from the crura being more parallel. In both the anterior crus is the thinner.

In the Musk Ox (*Ovibos moschatus*) the malleus (Pl. LXI. fig. 31) resembles that of *Bos*, but the manubrium is straighter, the body of the incus (fig. 40) is not so high, and the processus longus is as sharply curved as in the Sheep. As the crura of the stapes diverge a little, that ossicle takes the form of an isosceles triangle with a narrow base.

The left ossicula from an adult *Anoa* (figs. 32, 41) all resemble those of *Bos* in the broad articular surface and well-curved manubrium of the malleus, the high body and long crura of the incus, and the slender anterior crus of the stapes, which bone, however, is triangular from the divergence of the crura. The head bears a large tubercle for the stapedius.

In *Camelopardalis giraffa* the auditory ossicles (fig. 21) are remarkably like those of the Ox, and undergo similar changes in the growth of the young animal.

The articular surface of the malleus in an adult and a young male is still wider and more plane than the Ox; the manubrium is strongly curved. The incus is all but identical in form with the Ox's; the body is very well-developed; the stapes is almost rhomboidal; the anterior crus is much longer than the posterior, and more slender (fig. 21).

In the ossicula of a new-born or very young Giraffe, the articular surface of the malleus is deeper, and not so wide vertically nor so plane as in the adult, the manubrium is much straighter, the incus has a far shallower body, and the stapes is almost triangular. All these characters remind the observer of the changes which occur in the development of *Bos*.

The ossicula of the Deer are very small and light, a set from an adult *Cervus* (Pl. LXI. fig. 20) of large size being all smaller than a series from *Gazella dorcas*. The foetal type of *Bos* prevails more strongly and persistently among adult Deer than even in *Ovis*. The head of the malleus in the Red-deer is very little developed: and the articular surface is deep, very saddle-shaped, and narrow vertically; the manubrium is long and slender, only slightly bowed and recurved at the tip; the processus muscularis is a short stout tubercle; the lamina is very broad. The incus has a very shallow, ill-developed body, with a long, stout, diverging posterior crus, and a short processus "longus," sharply

curved, and bearing a distinct, pedunculated, elliptical Sylvian apophysis. The stapes is quite triangular, with a small head and slender crura, which are almost equal and not very divergent. There is generally a trace of a tubercle on the head of the stapes for the stapedius tendon.

There is no distinctive feature between any of the ossicula in *Cervus elaphus*, *C. axis*, *C. mexicanus*, *C. pudu*, *Dama vulgaris* or *Capreolus caprea*. In *Cervulus muntjac* the lamina of the malleus is very wide, and, contrary to Hyrtl's assertion, the stapes (in the College collection) is by no means thoroughly triangular; nor can any trace of the pear-shaped tuberosity described by that author be seen in the specimens examined by me.

In *Hydropotes inermis* the ossicula are identical in form with those of *Cervus*; the same applies to two sets of the ear-bones of *Moschus moschiferus* (figs. 33, 42) from two different skulls in the College collection. The shallow-bodied incus, with its long, stout, divergent processus brevis, is strikingly distinct from the square-bodied, short-limbed incus of *Tragulus* (Pl. LXI. fig. 8).

THE OSSICULA OF THE PROBOSCIDEA.

The malleus of *Elephas* (Pl. LX. figs. 38, 39) is the largest seen in any terrestrial animal, measuring nearly an inch in length from the head to the tip of the manubrium. The portion of the head above the articular surface is not much developed, either superiorly or anteriorly; it is smooth and globular, and widest from behind forwards. The articular area is shallow and wide vertically; its facets, which are only slightly convex, run into each other even more insensibly than in Man, not a trace of a groove dividing them. The neck is of a very peculiar form. It is very broad and flattened laterally, and bent strongly outwards on itself. The segment above the bend is formed of rather spongy bone, with a very irregular surface, generally marked with more than one nutrient foramen; posteriorly is a sharp ridge of the same sigmoid form as that seen in *Homo*; and anteriorly a thin splinter-like processus gracilis is given off without a lamina. The lower half of the neck is of very compact bone, smooth on the surface; it gives off the manubrium at a little more than a right angle. The handle is of the same stoutness as the lower portion of the neck; it is rather short, broad at the base which bears a prominent everted processus brevis, flattened laterally, and moderately recurved at the tip. There is a distinct sharply bordered outer surface to the manubrium; but it is narrow, and very little dilated towards the extremity.

This bone is the most distinctive by far of the three ossicula in the Elephant. The wide, shallow articular surface is seen among the larger Ruminants; but the breadth and shortness of the manubrium distinguish it from that of any Ungulate. There is no lamina; but the anterior part of the less dense upper segment of the neck probably represents it*, especially as the sigmoid ridge behind that part represents the entire neck of a laminated malleus. The manubrium recalls a form not rare in the Rodents; but in this great animal there is no trace of any processus muscularis, the tensor tympani being attached to a tubercular elevation on the angle formed by the bend of the neck. I had the advantage of dissecting the internal ear of the old female Indian Elephant that died

* See remarks on the malleus of *Sus*, *Phacochoerus*, and *Hippopotamus*.

in the Zoological Gardens in the summer of 1875. The tendon of the tensor tympani was on both sides attached to the elevation referred to above; yet a similar tubercle may be seen in other mammals where a processus muscularis also exists. The great size and peculiar development of this ossicle seems to mask all features which might relate it to any other Order in particular.

The malleus is as large in *E. africanus* as in *E. indicus*; but in the former it is of somewhat lighter make, and the neck is not so broad nor so abruptly bent, while the manubrium is longer.

The incus of the Elephant has a well-developed body, much deeper posteriorly than in front, where it is excavated for the articular surface. The crura are both short; the processus brevis diverges but little from the body, and is rather slender for the bulk of the whole bone; the processus longus is more divergent, and turns up very slightly at the tip, which bears a small, round, flat and sessile Sylvian apophysis. This bone, taking even its large development into consideration, cannot be referred to any type prevailing among the Ungulates. An approach to it is seen in many Rodents, especially as regards the much greater divergence of the processus longus compared with the posterior crus.

The stapes in *Elephas indicus* (Pl. LX. fig. 36) is quite triangular; the head is well developed, and bears a tubercle on its posterior aspect for the stapedius tendon; the posterior crus is quite straight the anterior is slightly curved; the base is broad, and convex towards the vestibule; it projects considerably in most specimens beyond the insertion of the posterior crus.

In a single specimen of the stapes of *E. africanus*, in the College collection, the head is broad, but shallow, and both crura are quite straight; the bone is triangular, but truncated at the apex (fig. 37).

The peculiarities of the Ungulate ossicula may thus be summarized:—

I. In this Order the central* laminated type of malleus is the rule; the processus muscularis is generally present, but is not often of any length; the incus is rather large, and variable in form; the stapes has a broad head, and is sometimes quadrilateral.

II. In the Equidæ the malleus is most generalized; the head is well developed, and the lamina almost obsolete. In the Rhinoceros and Tapir the malleus is of a very low type, almost recalling that of the higher Marsupials. The stapes in all Perissodactyla is triangular, with a wide head.

III. In the Tylopoda the malleus possesses characters seen both in the Artiodactyla and Perissodactyla, the incus is of peculiar form, the stapes is triangular.

IV. Among the Artiodactyla the Suidæ are distinguished by the production forwards of the head of the malleus and its deep articular surface, even in the larger species. The incus has a very square body, with short crura; the stapes is quadrilateral. *Hippopotamus* resembles the Pigs, excepting that the stapes is perhaps more triangular.

V. In *Tragulus* the incus precisely resembles that of *Sus*, but the malleus and stapes are like the same in the smaller Antelopes.

* My reasons for using this term when speaking of the laminated malleus will be found in the description of the mallei of the Marsupials.

VI. In the Bovidæ the head of the malleus is not produced forwards, as in the Pigs; the articular surface is wide and shallow in the *adults* of the large species. The crura of the incus are always long; the body is solid, and very high in the Ox, shallower in the Sheep: the stapes is quadrilateral in the larger members of this family. The foetal ossicula of the great Bovidæ much resemble the ear-bones of the full-grown smaller kinds. The gradations of type between *Ovis* and *Bos*, and the intricate distinctions between the ossicula of different genera of Antelopes, have already been discussed.

VII. The ossicula of the Giraffe are very similar to the same in the adult Ox.

VIII. In the Cervidæ the malleus is of the type seen in the Calf, or in the adults of smaller Bovidæ. The processus muscularis is stout, but short in the genus *Cervus*; the incus has a very shallow body, with very large crura, even in *Moschus*, which may thus at once be distinguished from *Tragulus*. The stapes is always triangular.

THE OSSICULA OF THE HYRACES.

In *Hyrax* (Pl. LX. fig. 35) the upper part of the head of the malleus is a wide, smooth, spheroidal surface; the articular area is extremely shallow, wide in both directions; and there is not a trace of any groove dividing the facets. The neck is narrow and rather long; there is no lamina. The manubrium is well recurved at the tip, which is slightly spatulate; close to its root a small tubercular processus muscularis is generally perceptible. The outer aspect of the whole manubrium is sharply bordered and narrow; there is a rudimentary processus brevis.

The incus is remarkable for a peculiarity already noted by Hyrtl: the body is extremely small, whilst the crura are both long and divergent. That anatomist describes those processes as thin; but in both *Hyrax dorsalis* and *H. capensis* they are stout and well-developed.

The stapes is perfectly triangular, with a small head and very straight crura. The base is thick and bullate towards the vestibule*.

The ossicula of the Hyraces recalls rather those of the Equidæ than their representatives in any Artiodactyle or Rodent. The malleus is not unlike that of *Equus*, where also the processes take considerably from the size of the body of the incus; the triangular form of stapes prevails, too, among the Perissodactyla.

THE OSSICULA OF THE INSECTIVORA.

In the different families that compose this Order we meet with great variations in the form of the ossicula, which are sometimes of almost as low a type as their representatives in the Marsupials; in other instances they assume characters seen even in the higher *Primates*. It is in the Insectivora that we so often find a bony canal between the crura of the stapes, giving support to a small vessel, the "Steigbügelarterie" of Hyrtl. This canal has already been described as existing in the genus *Lemur* and in some Rodents. It reaches, however, the highest degree of development in the Order now under con-

* According to Prof. Owen, "the base of the stapes is rarely ossified beyond the circumference." In the specimens in the College collection a bulla exists.

sideration; Hyrtl devotes a long and interesting chapter (*l. c.*) to the vessels of the mammalian tympanum, chiefly dwelling on the stapedia artery and its branches. According to that anatomist, this vessel seems, in *Erinaceus* and other Insectivora, to end ultimately in branches distributed to the orbit, whilst the homologue of the internal carotid is given off before the stapedia artery enters the canal between the crura of the stapes; but the distribution of these vessels, and the extent to which they are surrounded by bony canals, differ in certain families. Still that is a subject which does not pertain to the distinctions of the auditory ossicles in the same animals.

The ossicula of the Shrews (*Sorex*) are best studied in the crania of some of the large American species (Pl. LXII. figs. 1, 2).

The malleus is readily detached from the skull by maceration, together with the tympanic bone, which is almost identical in its ring-like undeveloped character to its homologue in the Marsupials. By the aid of a fine needle the ossicle may be separated from the tympanic without fracturing the processus gracilis.

The head is small, as in most laminated mallei. It bears a rather deeply cut articular surface, with two facets, of which the uppermost is the larger, and the lower the more convex. The neck is long and thin, and midway between the head and manubrium it is bent on itself, forming a sharp angular projection. At the point where it joins the manubrium is attached a prominent globular process of bone (Pl. LXII. figs. 1, 2, *oa*), which projects downwards and backwards in the natural position, and seems, as it were, to push aside the handle outwards and forwards. The manubrium itself is as thin and slender as in most Marsupials. A distinct angle, corresponding to the processus brevis, exists; it may be seen at the base of the manubrium, projecting anteriorly to the globular process. The extremity of the handle is almost styliform, although, with the aid of a strong lens, I have detected not only a slight spatulate dilatation, but also an outer surface to the manubrium, extremely narrow, yet sharply bordered from the very thin and compressed sides*.

The lamina is as wide as in a typical terrestrial Carnivore, and runs forward with the processus gracilis without receiving a thin process from the front of the head, such as is seen to join the processus gracilis in most laminated mallei. That process is flattened, narrow near the root, but wide in the middle, tapering to a point at the extremity; it is closely applied to the tympanic bone.

A very small tubercular elevation on the inner side of the neck, close to where it joins the manubrium, represents the processus muscularis. To study the relation between this process and the orbicular projection from the neck, a malleus of a *Sorex* should be placed side by side with one from a *Gymnura*, where both exist well developed † (Pl. LXII. figs. 2 *oa* & 14).

The exact morphological signification of the orbicular process is a difficult point to decide. It exists in many Insectivora and in many of the Muridæ. It clearly cannot be

* For a fuller explanation of this expression, "sharply bordered from the sides," see descriptions of the malleus in the terrestrial Carnivora.

† This elevation can only properly be seen by placing a very clean malleus of *Sorex* on a piece of black paper, and viewing it under the microscope with a 1-inch object-glass.

the processus brevis of Man, as the sharp angle at the base of the manubrium, which represents it in the Shrew, may be plainly distinguished (with the aid of a lens), and seen to be pushed outwards by this very orbicular apophysis under discussion. Nor is it the processus muscularis; for such a process exists in *Sorex*. In the Bulau (*Gymnura rafflesii*), as in the Shrew, a large, curved, and conspicuous processus muscularis exists, as well as a large, well-formed orbicular apophysis. The tolerably large malleus of this animal (fig. 14) is very favourable for examination to elucidate the question. I consider it highly probable that this orbicular process is the homologue of the sharp projection seen in the neck of the malleus of the common Badger, and already described in this paper. It is true that a sharp projection is also to be found on the neck of the malleus of *Sorex*; but in that little animal the projection lies midway between the head and the handle, whereas in *Meles* the sharp projection is placed close to the manubrium, in the exact position where the orbicular process is to be found both in *Sorex* and in all other animals where it exists.

Hence it is not the homologue of any named portion of the malleus in any of the Mammalia; nor is it represented, except as an orbicular process, in any member of that class, putting aside the angular projection on the Badger's malleus *. In all probability embryology will be able to show that it represents some part better developed in the homologue of the mammalian malleus among the Sauropsida and Ichthyopsida.

The incus of *Sorex* has a fairly developed body; the processus brevis is very short and non-divergent; the stapedial crus is rather long, and diverges considerably from the body; it supports a Sylvian apophysis, very minute (even proportionally), and mounted on a slender pedicle. Altogether this ossicle is of a type very frequent among the Marsupials; yet it will be remembered that extreme shortness of the processus brevis and marked divergence of the processus longus are seen in Mammals as high as *Ursus* and *Mustela*.

The stapes of *Sorex* has a minute vessel running between its crura in the recent skull, but unsupported by any bony canal; so that it drops out and is readily lost in maceration. The head is ill-developed, broad, and shallow; the crura are much curved, especially the posterior; and the aperture is very wide, as in *Homo*. The base is narrow horizontally, and very narrow vertically. The stapes of *Sorex* is evidently of a much higher type than are the two outer ossicles.

The malleus of the Daesman (*Myogale moschata*) must hold an important share of the anatomist's attention when he undertakes the study of the orbicular apophysis, so frequent in this Order (see Pl. LXII. figs. 3, 4).

The upper portion of the head is even less developed than in *Sorex*, projecting but little above the upper edge of its articular surface, which is narrow in its horizontal, but extremely wide in its vertical measurement. The incus in the recent skeleton lies, I have observed, as much posteriorly as in the higher Primates. Both facets are of about the same size; hence the lower is proportionally larger than in most animals; they are nearly plane, and not divided by a sharp groove. The neck is short and curved. At a first glance the outline of the lower facet of the articular surface looks like a portion of

* And in the malleus of *Bassaris* and a few other animals.

the neck; and a sharp angle is seen where the latter commences, very like the projection which actually exists in the middle of the neck of the malleus of *Sorex*. But, by examining these ossicles in the Shrew and in *Myogale* by means of a lens, it will be seen that in the former the articular surface is not deep vertically, but the neck is long and sharply angled, whilst in the Daesman the articular surface is long, and the neck short. The lamina is wider than in *Sorex*; the processus gracilis is slender and partially ankylosed to the tympanic bone in the adult. Close to the root of the manubrium there springs from the inner side of the neck a round-headed process (Pl. LXII. fig. 3, *oa*) mounted on a long pedicel, to which I find that the tendon of the tensor tympani is attached in the recent skull.

The manubrium is long, and forms a very obtuse angle with the neck; it is much flattened laterally, and rather broad at the base, so as to be of the sabre-like outline frequent among Rodents. The outer angle of the base is blunt and slightly bent towards the neck; the same aspect of the rest of the manubrium is sharply bordered from the sides, and distinctly dilated at the extremity.

It is instructive to compare the malleus of *Myogale* with the corresponding ossicle in *Gymnura*, which possesses an undoubted orbicular apophysis homologous to that of *Sorex*, and an equally distinct processus muscularis. The latter process, moreover, actually coexists with the former in many Shrews, or at least is represented by a tubercle.

The attachment of the tensor tympani tendon to the single process in *Myogale* makes that projection a functional analogue of the processus muscularis; but since it projects *backwards*, as the orbicular apophysis does in *Gymnura*, where the muscular process points inwards and forwards, it seems to me that this solitary process of the Daesman must be considered as a homologue of the orbicular apophysis of the Shrew and *Gymnura*, serving functionally as a muscular process, the true representative of the latter being suppressed in this animal.

The incus much resembles that of *Sorex*; but the body is better developed, especially posteriorly. The processus brevis is very short and non-divergent; the stapedial crus is long, straight, and ends in a rather large discoidal Sylvian apophysis.

The stapes has a very wide aperture, occupied in the recent skeleton by a large bony canal. The head is broad and shallow; there is a small tubercle for the insertion of the stapedius tendon. Both crura are very slender and divergent; the anterior is considerably the more curved. The base is of necessity wide horizontally; it is distinctly concave towards the vestibule, without any bulla or umbo.

The ossicula of *M. pyrenaica* are very similar to those of the Russian *Myogale*. In this animal and in the skulls of the latter and larger species I have always found a very stout bony canal between the crura of the stapes. Hyrtl (*op. cit.*) observes:—

“In *Sorex* and *Myogale* the vessels run *exactly* as in *Talpa*, without, however, being enclosed within the tympanum in bony canals.” In describing the vessels of the tympanum in the Mole, he had previously remarked that “the bony canal does not fill the three-cornered aperture of the stapes; on that account the stapes can be moved up and down on the canal like a ring on the finger.” If this be “*exactly*” the case in spe-

cimens of *Myogale* examined by Hyrtl, or if the stapedial intercrural artery was not, in his examples, enclosed within the tympanum in a bony canal (whereas in the College specimens that osseous tube nearly blocks up the whole aperture), it follows that there is great variety among individual specimens in this respect, as I have actually observed in the crania of Squirrels and Cavies.

In the Mole (*Talpa europæa*, Pl. LXII. fig. 5) the head of the malleus is rather large for an ossicle of the laminated type; it forms a distinct globular prominence above the level of the articular surface, also projecting forwards. The area for articulation with the incus is wide laterally on account of the head being hardly flattened at all in that direction; but it is not long vertically; the facets form a sharp angle with one another, and the uppermost is the larger. The neck is short and curved, the lamina wide and rather opaque for so small a malleus; the processus gracilis is thin and very fragile. There is no orbicular process; and the processus muscularis is reduced to a scarcely perceptible tubercle.

The manubrium is short, and forms an angle of about 120° with the neck. The outer angle of the base, corresponding to the processus brevis, is considerably bent forwards; the whole manubrium is rather broad, laterally, at the base, but narrows rapidly, so as to be almost styloform at the extremity.

The incus of the Mole has an ill-developed body; and the processus brevis is almost obsolete. The processus longus is most characteristic, and has been long familiar to comparative anatomists. It is deeply channelled out on its front and inner aspect, and very long. It terminates in a proportionally small, pedunculated Sylvian apophysis.

The stapes is similar in form to that of *Myogale*; the crura are very slender and well arched. The intercrural canal is very small, and justifies Hyrtl's remark quoted in the above description of the Daesman's stapes.

The extreme difference between all the ossicles of this animal and those of the Golden Mole (*Chrysochloris*) is most instructive and significant; the great distinctions between the malleus of *Talpa* and that of *Condylura*, where the incus is very similar, are also interesting, but less to be expected.

The malleus of *Scalops* has a large head, as in the last genus; its lamina too is of the same form. There is a small tubercular processus muscularis close to the root of the manubrium, which latter fragile process is very readily broken in examining the attachment of the tensor muscle of the tympanum in the recent skull.

The incus (Pl. LXII. fig. 6) is more generalized than in either *Talpa* or *Condylura*, as the processus brevis is not so rudimentary; and though the stapedial crus is long, it is not so remarkably broad as in those animals. As in them, however, it is deeply channelled.

The malleus of *Condylura* (Pl. LXII. figs. 7, 8) is doubly interesting:—first, because it is so different from that of *Talpa*; secondly, because it possesses, like *Myogale*, a processus muscularis remarkably like the orbicular apophysis seen in the Shrew.

The head of the malleus in the Star-nosed Mole is very small; nor is the articular surface deep vertically; its upper facet is wider than the lower. The neck is very long and narrow, and is bent into a very sharply projecting angle midway between the head

and manubrium; the lamina is very wide and thin. Here it may be observed that in all the above characters this ossicle resembles the same in *Sorex*. It has not either the well-formed head of *Talpa* or the vertically wide articular surface and short neck of *Myogale*. The processus gracilis is broader at the root than in the Shrew; and in form, being of equal breadth for the greater part of its length, it resembles the same in the Phalangians and other Marsupials*.

The manubrium is rather short, it is broad at the base, with a very prominent external angle, not produced into a processus brevis. Its outer aspect, though extremely narrow, is nevertheless separated from the much-flattened sides by distinct borders; the extremity is very faintly dilated, so as to appear styliiform†. The whole manubrium is separated from the neck by a very deep constriction, so as to be readily broken off. From this constriction, on the inner aspect, arises a very prominent globular process, attached by a very narrow peduncle.

It is as difficult to decide whether in this animal the above is the analogue of the true globular apophysis of the Shrew and *Gymnura*, or whether it is the processus muscularis, as is the case in the malleus of *Myogale*. In *Condylura* the process certainly points backwards, as in *Myogale*, like the globular apophysis of *Gymnura*; but (likewise as in *Myogale*) the tendon of the tensor tympani is attached to the root of the process in the Star-nosed Mole, which may hence be either considered the homologue of the processus muscularis, or else as the homologue of the globular apophysis made use of, so to speak, by the tensor-tympani tendon as a point of attachment.

The incus in *Condylura* is almost identical in character with that of *Talpa* in the smallness of its body, the extremely slight development of its processus brevis, and the large deeply channelled processus longus.

Chrysochloris possesses a malleus of a perfectly unique pattern (Pl. LXII. figs. 9, 10). Otto and Rudolphi first appear to have observed the extraordinary development of the head of the malleus; but the former repeated the error of the latter, who took the enormously enlarged head for a fourth ossicle. Hyrtl discovered their mistake, and settled the true nature of the singular pear-shaped prominence from the malleus of the Cape Golden Mole. The error of the first two anatomists above named must have arisen from their having attempted to remove the ossicle by pulling at its manubrium with forceps without enlarging the aperture of the meatus; in doing so the bone is readily broken. If the malleus be extracted by chipping away some of the bone forming the prominent convexity in the temporal fossa behind which the enlarged head is lodged, then there is no fear of its breaking at the neck; but it cannot be drawn safely through the meatus. When removed entire, it may be examined separately with little fear of damage, as it is by no means fragile.

The head of the malleus of *Chrysochloris* is extremely elongated, so as to be over a quarter of an inch in length. Hyrtl describes it as pyriform, although, being rather thick and cylindrical at its root, convex behind, and slightly concave in front, it

* This process is united, partly by bone, to the tympanic ring in the adult *Condylura*.

† I have never found the extremity of the manubrium to be absolutely styliiform in any mammal except in its modified homologue in the Dolphins.

may be better compared in shape to a grenadier's bearskin. It is formed of dense and brittle bone, and lies in a concavity which bulges into the temporal fossa. There can be no doubt of its nature as a simple though extreme elongation of the ordinary caput mallei. On its root posteriorly is seated, very obliquely, the equally modified articular surface, which is long and narrow, slightly concave, without any indication of division into facets, and prominently raised above the level of the contiguous parts of the ossicle.

The neck is long, stout, and cylindrical; and a small depression on it extends towards the root of the head, and probably represents the site of the lamina, the ridge of bone below it being the root of the processus gracilis. I have found the ossicle slightly adherent to the tympanic bone at that ridge, and have reason to believe that part of the processus gracilis is modified and enlarged, and assists in forming a portion of the process chiefly developed from the head. The manubrium (*mn*) is very short, being hardly the length of the neck; it bears a very prominent processus brevis, and is scarcely dilated at the extremity. Hyrtl does not appear to recognize either neck or processus brevis in the Golden Mole.

I have detected a small tubercular processus muscularis in the neck of the manubrium of *C. trevelyani*, where the head does not form so great a prominence in the temporal fossa.

The incus of *Chrysochloris* is as modified in form as is its malleus. The body is of the long and narrow shape of the articular surface of the outer ossicle, and is much constricted before giving off its crura; its long axis intersects a line drawn from the tip of the long to that of the short process, instead of being parallel to the latter as in other mammals. Both crura are long, and stout, and rounded; the stapedial crus ends in a very minute Sylvian apophysis.

The stapes has a small head, and short, very divergent crura; a stout bony canal runs between them in the recent skeleton. The base is long horizontally, and very broad vertically in the middle; it is convex towards the vestibule without being bullate. In many respects this stapes resembles that of *Spalax*.

In the Hedgehog (*Erinaceus europæus*, Pl. LXII. fig. 13) and its allies the malleus assumes a very characteristic form. The head of that ossicle is very small, and bears a perfectly saddle-shaped articular surface, the two convex facets insensibly merging into each other, without any groove to separate them. The neck is extremely long, and forms a wide arch without any angular prominence as in *Sorex*. From its inner side, a perceptible distance from the root of the manubrium, springs a straight, narrow, and prominent processus muscularis; and nearer to the handle there projects from the neck a considerable prominence, not so large as in the Shrew, or even as in *Gymnura*, but clearly the homologue of the orbicular apophysis in those and in other Insectivora. The manubrium is slender, and but slightly dilated, and recurved at the tip; the angle corresponding to the processus brevis is very blunt, and pushed outwards and forwards by the rudimentary orbicular apophysis.

The lamina is wider than in any other animal; the processus gracilis is reinforced by a distinct process from the front of the head; and they together form an extremely

broad process, ankylosed to the tympanic ring in the adult. This process is broadest towards its extremity, which is well rounded; it is much flattened laterally; and as it stands at right angles to the plane of the lamina, it presents a very characteristic appearance. Close to its root, at about the point of junction of the processus gracilis with the process from the head, it is perforated for the passage of the chorda tympani nerve.

The malleus of *E. dealbatus* is very similar to that of the common British species. The prolongation of its processus gracilis is even wider and longer; but the lamina is not quite as broad.

That the rod-like projection from the inner side of the neck of the Hedgehog's malleus is the true processus muscularis there can be no doubt, as the tendon of the tensor tympani muscle will be found attached to it in the recent skull; nor, from the nature and position of the prominence nearer to the malleus, can it very well be otherwise than the homologue of the orbicular apophysis of *Sorex*, which is not utilized in this animal for the attachment of the muscle, a distinct processus muscularis existing as well. It seems extraordinary that the malleus of the common Hedgehog, broken in half, should ever have been taken for two ossicles; yet Hyrtl has corrected that erroneous opinion enunciated by a previous observer. Such a mistake could scarcely have been made if the homologies of the fragments of that or any other ossicle had been carefully made out.

The incus of the Hedgehog lies almost vertically above the malleus in the recent skeleton. Its body is wide and shallow; the processus brevis is very short, but stout, and pointed. The stapedia crus is long, stout, rounded, and very divergent from the body; near its root, to the inner side, it bears a small tubercle, and at its extremity a well-developed Sylvian apophysis on a narrow pedicle. In their general characters the incudes of the Hedgehog and of most of the musteline and arctoid Carnivora agree; but the remaining ossicles are totally dissimilar.

The stapes of the Hedgehog has a very small head, with a small tubercle for the stapediatus-tendon on its posterior aspect. Both crura are very slender, grooved towards the aperture, and much curved, so as to be furthest apart midway between the head and the base. The posterior is often the straightest. A large vessel passes through the wide aperture in the recent skull, not enclosed in a bony canal. The base is narrow and almost plane towards the vestibule.

In the Bulau (*Gymnura Rafflesii*, Pl. LXII. fig. 14) the head of the malleus is better developed than in *Erinaceus*, but still small; the articular surface is of similar character. The neck is much shorter and more sharply curved. From its inner aspect, near the handle, there projects a very conspicuous slightly curved processus muscularis; and closer behind the manubrium is a prominent, but sessile, convex process, evidently the homologue of the orbicular process in the Shrew. The presence of both these projections, equally well developed in this animal, is of great value in considering, by comparison, the homologues of the single process in *Myogale* and in other Insectivora. The manubrium is much laterally compressed, but not very broad at the root; the site of the processus brevis is rounded off, and not prominent. The lamina is much narrower than in

the Hedgehog; and the processus gracilis is produced into a much more slender appendage, which bears, however, a foramen for the passage of the chorda tympani.

In the specimen in the College series of ossicula, the incus of *Gymnura* is extremely like that of *Erinaceus*, but the processus brevis is longer.

The stapes in *Gymnura* has rather straighter crura and a broader base than in the Hedgehog. I have not found any bony canal between the crura in the skulls examined by me.

In the Tenrec (*Centetes ecaudatus*) the head of the malleus (Pl. LXII. fig. 11) resembles that of the Hedgehog; but the neck is shorter even than in *Gymnura*, and is bent on itself into a sharp angle, as in *Sorex*. It bears a short processus muscularis, and a very large, convex, but sessile, orbicular apophysis. The manubrium is quite hedgehog-like, the lamina still narrower than in Raffles's *Gymnura*; the processus gracilis is perforated near the root of its free part beyond the lamina by a foramen for the chorda tympani nerve. This ossicle in the Tenrec decidedly shows affinities to *Sorex*.

But the incus, otherwise like that of *Erinaceus*, has a well-developed and divergent processus brevis. This is not the case in the Shrews and Moles, though it is observed in *Ericulus* and, to a certain extent, in *Gymnura*. In the Macroscelidæ and Tupaiidæ this process is more developed than in the Hedgehog; but the body is higher than in that animal and in *Centetes*.

The stapes is of the *Erinaceus* type; the crura are slender and bowed, and not separated by any bony canal in the recent skeleton; the base is moderately broad.

In *Ericulus nigrescens* (Pl. LXII. fig. 12) the malleus is more like that of *Centetes* than that of *Erinaceus*, the neck being short and sharply curved, and the lamina narrow. The orbicular apophysis is not well developed; and the processus muscularis is reduced to a tubercle. The processus gracilis is perforated by a very distinct foramen for the chorda tympani.

The incus, as in *Centetes*, has a body and processus longus similar to that of the common Hedgehog; but, as in the former animal, the processus brevis is rather long, thin, and divergent.

The stapes has a very broad base compared with that of *Erinaceus*; the head and crura are very similar in character.

The malleus of *Solenodon cubanum* is much like that of *Centetes*; it has a prominent orbicular apophysis and a much more developed processus muscularis than has *Ericulus*. The free part of the processus gracilis is unfortunately broken off in the College specimen.

In the Macroscelidæ the malleus assumes a characteristic form widely differing from the types of *Erinaceus* and *Sorex*.

In the Elephant Shrew (*Macroscelides alexandri*, Pl. LXII. fig. 15) the caput mallei is ill-developed and much taken up by the articular surface, which is composed of two very distinct facets separated by a sharp groove. The lower is nearly the size of the upper and more anterior; both have a high vertical convexity running across them. The neck is rather short and curved; it is extremely constricted near the manubrium;

the constriction appears all the greater on account of the narrowness of the lamina. Close to the narrowest part, on its inner aspect, the neck bears a distinct, curved processus muscularis. I can detect no trace of any orbicular apophysis.

The manubrium is long and rather narrow at the base, which bears externally a trace of a processus brevis. Its outer aspect is not only sharply bordered from the sides, but remarkably and almost uniformly broad; the extremity is but slightly dilated and recurved.

The lamina is extremely narrow, owing to the processus gracilis joining rapidly a process from the head, and thus leaving little room for any area of lamellar bone. The processus gracilis thus reinforced forms a thin straight bar of bone, which runs half across the front of the tympanic cavity, to fit into the Glaserian fissure, quite different from what prevails in the preceding families of the Insectivora, where that process runs downwards at once, and is curved so as to fit accurately to the tympanic ring.

The incus lies almost vertically above the malleus in the recent skull; it has a well-developed square body; the part above the processus longus overhangs that process. The processus brevis is stout, blunt-pointed, and does not diverge from the body. The stapedia crus is straight and freely divergent; it supports a very small Sylvian apophysis.

The stapes has an ill-developed body, and long, slender, extremely straight crura. The aperture is wide and triangular, though not as wide as in the Shrews and Hedgehogs. A very stout bony canal fills it during lifetime. The base is rather broad, and convex towards the vestibule.

The malleus of *Rhynchocyon cirnei* (Pl. LXII. fig. 16) resembles that of *Macroscelides* in general characters, particularly in the narrow neck and singular processus gracilis; but the head is better-developed, and the processus muscularis is still stouter and more curved. The incus is very like that of the Elephant-shrew; its stapedia crus bears a fairly developed Sylvian apophysis. The crura of the stapes are very slender.

It is remarkable that in *Petrodromus* (fig. 19) (the ossicula of which I have been able to examine through the kindness of Dr. Günther) the malleus is much more Shrew-like than in the Elephant-shrew. The lamina is wider; and there is a trace of an orbicular apophysis. The processus muscularis and the manubrium are of the same form as in *Macroscelides*. As for the incus of *Petrodromus*, it is not only quite unlike that of *Sorex* or *Erinaceus*, but in its high and narrow body it diverges also from *Macroscelides* and *Rhynchocyon*, and tends towards *Tupaia*. The stapes has straight crura, with a bony canal between them in the recent skeleton.

In *Tupaia* the malleus differs from that of any other insectivorous mammal (Pl. LXII. fig. 17). The head of the malleus is broad antero-posteriorly, but flattened laterally. It supports a very shallow articular surface, saddle-shaped, and only indistinctly divided into two facets. There is not a trace of any neck or lamina; the tensor-tympani tendon is inserted into the root of the manubrium. This latter process arises from the head directly, and has no angle at the outer side of its base corresponding to the processus brevis. It is not very broad at the base, and is very little dilated at the tip; its outer aspect is distinctly bordered from the sides.

In being neckless and devoid of lamina, the malleus of *Tupaia* much resembles that of some of the lower Primates, especially *Midas* or *Hapale*, or certain Lemurs, the shallow articular facets being a Ceboid feature. It cannot be said to resemble the mallei of the Sciuridæ so closely; for though the latter have a similar head, and are neckless, the manubrium is of a different type.

The incus has a high and narrow body; the processus brevis is rather long, thin, and pointed, but hardly diverges from the body; the stapelial crus is scarcely longer than the short process; it is curved and divergent, and bears a very small Sylvian apophysis. In general characters this bone is very like the same in many Monkeys and Lemurs. The author has never seen the long process so divergent as to form (with the body and short process as the top-piece) a letter T out of the incus, as Hyrtl states of *Tupaia javanica*.

The stapes has a very small head and extremely slender, straight crura; the base is rather narrow. The aperture is filled by a thick bony canal in the recent skeleton, whence this frail ossicle can with difficulty be removed.

In the Colugo (*Galeopithecus volans*, Pl. LXII. fig. 18) the head of the malleus is much flattened antero-posteriorly, and is produced a little forwards and upwards above the articular area. The surface for articulation with the incus is of the type of *Homo* and the higher Primates, being narrow vertically and wide laterally; the outer extremity is placed much higher than the inner; and the two facets are faintly indicated, the upper lying rather internal to the lower; both have a vertical convex ridge internal to the middle line of the whole surface. The neck is very short and constricted; and a very narrow lamina (which seems to me to be absorbed in the adult skull, as the processus gracilis is in Man) connects it to the slender processus gracilis. It bears a small tubercular processus muscularis on its inner aspect.

The manubrium forms little more than a right angle with the neck, and is long, broad, flattened laterally, and recurved; it possesses a distinct trace of a processus brevis. Its outer aspect is distinctly bordered from the sides, but very narrow, and prominently spatulate at the recurved extremity.

The affinities of the malleus of *Galeopithecus* are puzzling. At first, judging from its articular surface, narrow neck, and large flattened manubrium, with a trace of a processus brevis, it seems allied to the highest Primates. But, on the other hand, in the *Manis* the articular surface is shaped much as in *Homo*; and in *Galeopithecus* the head is flattened, and the narrow lamina and slender processus gracilis connected with it also resemble the corresponding parts in the scaly Edentata; and the manubrium still more nearly resembles that of the *Manis* than that of Man, having an outer aspect separated by broad borders from the sides. It approaches the form of the malleus in *Lemur* more than that of any other of the Lemuridæ; but its head is not so well developed, nor of the form seen in any Lemur or Monkey, and its neck is more constricted and distinct than in any of these animals except the Apes and highest Cercopithecidæ. It differs widely from the malleus of the *Tarsius*, the Nycticebidæ, and Galagos; but it is more like that of *Chiromys*, where the head is better-developed, though the articular surface, neck, and manubrium are very similar.

It differs, comparing it with the other Insectivora, very completely from the Shrews' and Hedgehogs' in the smallness of the lamina and general form, and as widely from that of the Tupaiidæ in possessing a constricted neck and in other respects; but it certainly has points of resemblance to the malleus of *Rhynchocyon* and *Macroscelides*, the main distinctions being the form of the articular surface and the character of the lamina and processus gracilis, though the latter feature is not very different in this animal from that of the Elephant-shrew, except that the processus gracilis is more slender.

The incus is very high and narrow, especially over the short crus; in this respect it exceeds the *Tupaia* incus and approaches that of *Myctes* and *Galago*, though it does not project over the processus longus as in the latter. The processus brevis is very short, and curved backwards. The stapedia crus is stout, not very long, and bears a well-developed very elliptical Sylvian apophysis on a narrow pedicle; it does not diverge from the body so much as in *Tupaia*; but the incus altogether resembles that of the latter animal more than that of any other insectivorous mammal.

The stapes of a young *Galeopithecus* has an ill-developed head, with slender bowed crura, and a large aperture not occupied by a bony canal in the recent cranium. The base is broad and very convex; it projects far beyond both crura. In a pair from an adult skull in the collection the aperture is filled by a thin lamina.

In most respects both incus and stapes of this animal more resemble those of the Macroscelidæ and Tupaia than of the Shrews, Moles, and Hedgehogs. They are not strongly allied to the same ossicles in any definite group of the Primates, though strikingly like them in one or two characters above given. Hyrtl considers that the incus of *Galeopithecus* bears a larger Sylvian apophysis than in any other animal; but I find it larger in *Myogale*, *Rhinoceros*, *Ovibos*, and several other mammals.

The above researches on the ossicula of the Insectivora lead to the following conclusions:—

I. These bones all offer great variations in the different families of this Order; and there is no constant positive character to be found in any of the three ossicula. The stapes is never Sauropsidan or columelliform, as in *Manis* and the Marsupials; but the very frequent wideness of its intercrural aperture is perhaps not so much a sign of high type, as an accidental feature in relation to a bony canal passing through it, or, at least, on account of a large vessel, unsupported by such a canal, running between the crura*.

II. *Chrysochloris* has the most specialized ossicula in this Order. The extraordinary malleus appears as if rather modified from the highest or anthropoid type than from the more central laminated form of the ossicle. The almost equally peculiar incus, in the development of its body and short crus, must be considered as of rather high type than otherwise; and the stapes is quite the reverse of Sauropsidan in all its characters.

III. The ossicula of *Galeopithecus* are very generalized in character. The malleus has several characters seen in the highest Quadrumana and in some Lemurs, most of which, however, are reproduced in certain mammals as low as the Edentata. The incus

* More will be said, however, on this topic in the description of the stapes in the insectivorous Bats.

is of a type hardly seen except in certain Cebidæ and Lemuridæ; the stapes has no particularly high affinities. In the malleus *Galeopithecus* is decidedly allied to the Macroscelidæ among Insectivora, and to no other family in this Order; but in the incus it more approaches *Tupaia*.

IV. In the Tupaiidæ the malleus assumes to an extreme degree the neckless and non-laminated type common in most Cebidæ and some Lemurs, as well as in *Sciurus*; but the manubrium is rather of the form prevailing in the above-named Primates than of that seen in the Squirrels; and so in every respect is the incus. All the ossicula differ from the varied forms in other families of the Insectivora, except that the incus somewhat approaches in type that of *Galeopithecus*. Taken as a whole, the ear-bones of *Tupaia* are higher in type than in any other family belonging to this Order.

V. The Macroscelidæ have a more specialized malleus than can be seen in any other insectivore except *Chrysochloris*; the extremely constricted neck and the narrow lamina and processus gracilis running straight forwards to the Glaserian fissure are highly characteristic. The processus muscularis is well-developed. The head is better-developed in *Rhynchocyon* than in *Macroscelides*. In *Petrodromus* the malleus is far more like that of *Sorex* than in the two former genera; but the incus is not in any sense Shrew-like.

VI. In the Shrews, the Myogalidæ, Talpidæ, Centetidæ, and Hedgehogs proper one common feature exists—a malleus with a wide lamina and a processus gracilis united to the tympanic ring after the fashion of the Marsupials—in short, a low type of malleus. The processus brevis of the incus is always ill-developed except in the Centetidæ and *Gymnura*. The intercrural aperture of the stapes is always wide.

VII. In the Soricidæ the malleus has a moderately wide lamina, an orbicular apophysis, and a more or less distinct processus muscularis, to which, and not to the spherical protuberance, the tendon of the tensor tympani is inserted. As a whole the malleus is very much like that of a Marsupial. The stapelial crus of the incus is not very broad.

VIII. In the Myogalidæ the malleus differs in several respects from that of the Shrews proper: the manubrium is of stouter make; and an orbicular process exists, which probably is the homologue of that in the malleus of *Sorex*, but certainly functionally replaces the processus muscularis, absent in *Myogale*. The incus resembles that of *Sorex*.

IX. In the Talpidæ the malleus of *Condylura* most resembles that of *Sorex*, but has an orbicular process serving as a processus muscularis, as in *Myogale*; its incus resembles that of *Talpa*. In *Scalops* the incus has not the chief distinguishing feature seen in *Talpa* and *Condylura*; but its malleus is of the form seen in the common Mole, where the head is better-developed than in the Shrews and Hedgehogs, and the lamina not so broad. The incus of *Talpa* has a very broad and channelled processus longus.

X. The Erinaceidæ and Centetidæ have a more specialized malleus than the Shrews, Daesmans, and Moles. The great feature is the very broad processus gracilis perforated to transmit the chorda tympani nerve; the processus muscularis and an ill-developed orbicular process coexist; the lamina is very broad. In *Centetes* and *Ericulus* the pro-

cessus brevis of the incus is well developed; that crus is smaller in *Gymnura* and abortive in *Erinaceus*.

XI. The orbicular apophysis of the Shrews, Daemans, *Myogale*, and Hedgehogs allies them to the Muridæ, where also the malleus is laminated.

THE OSSICULA OF THE CHIROPTERA.

The malleus of *Pteropus* (Pl. LXII. figs. 26, 27) is attached to the ring-like tympanic bone much in the same manner as among the Insectivora and Marsupials. The anterior or upper extremity of that bone is fissured, and the processus gracilis fits into the cleft, beyond which is a flat surface, to which the extremity of the process is ankylosed. The portion of the tympanic external to the cleft is very thick, and it runs over the outer surface of the lamina and neck of the malleus, a distinctive feature not observed in the non-placental mammals or in the Insectivora, the tympanic ring reaching, in those animals, not further backwards than to the root of the processus gracilis.

The head of the malleus is small, and projects very little beyond the articular surface, which is placed as much posteriorly as superiorly, and is shallow, but deep vertically. It is distinctly divided into two facets, although they are not separated by a sharp horizontal groove; the upper is larger, and lies a little more internally than the lower, and both are faintly convex. The neck is narrow and well curved, as in most laminated mallei; the lamina is rather narrow, and formed of opaque and brittle, not semitransparent, papery bone: the processus gracilis is broad and thin at its root, the lower border being, however, well defined, and the lamina is prolonged upon it; this process ends in a point as in most Insectivora, not in a foliaceous dilatation as in many Marsupials.

I have found, in dissecting the ear of a fresh Bat (*Pteropus*), that the tendon of the tensor tympani is inserted into the point of junction of the neck and manubrium, at the most usual site, in fact, of the processus muscularis, which does not exist; but there is a distinct prominence close to the manubrium at the place where a large orbicular apophysis is seen in the Shrew (*Sorex*), Mouse (*Mus*), &c. The relations of that process to the processus muscularis have been already fully discussed in describing the ossicula of the Shrew and other Insectivora. Suffice it to say here, that in *Pteropus* the rudiment of the orbicular apophysis does not replace functionally the processus muscularis as in *Myogale* and *Condylura*. This rudiment is better marked in the College specimen from *P. hypomelanus* than in that from *P. edulis* in the same collection.

The manubrium is slender and rather long, broad at the base and flattened laterally; in fact, sword-shaped. Its outer and upper angle (not to be confounded with the rudimentary orbicular apophysis which pushes it aside) is somewhat blunt, so that no processus brevis exists; the outer aspect is very narrow, but bordered sharply from the sides, and ends in a distinct spatulate dilatation.

It is evident that a verdict of "low type" must be passed on the malleus of *Pteropus*. It has no anthropoid, ceboid, or lemuroid characters. It is not the typical laminated malleus of the Carnivora and the Ruminants. It is decidedly lower than the

malleus of the Muridæ, where the lamina is broad and semitransparent as in the Carnivora. Its general resemblance to the malleus of the Marsupialia is very evident.

The incus of *Pteropus* has a well-formed body, not deeply excavated. The processus brevis is distinct, but very short; the stapedial crus is rather long, and ends in a pedunculated almost discoid Sylvian apophysis. In relation to other animals its characters are negative.

The stapes has a small head with slender crura; the posterior quite straight, the anterior generally a little curved *. They do not diverge so much as in Man; but there is a free aperture not occupied in the recent condition by any intercrural canal. The base is rather narrow horizontally, and almost plane towards the vestibule; it projects but little beyond the insertion of each crus.

The stapes of *Pteropus* must be considered of rather central type, for it shows no sign of any tendency towards the columelliform stapes of most Marsupials; but its crura do not diverge as in the anthropoid Apes and Man, nor even to the extent seen in Ruminants and Carnivora. It most resembles the stapes of those Insectivora where the crura are not widely bowed to admit the passage of a bony canal, or the same ossicle in the Mice. This variety of stapes, with its straight crura, diverging but little, and its consequently narrow base and narrow but distinct aperture, lies between the carnivorous type, where the aperture is larger, but the crura as straight, and the form seen in *Didelphys*, where the crura are free throughout, yet leave a very narrow aperture between them.

I have experienced great obstacles in the study of the ossicula of the insectivorous Bats, as in museum specimens the bones of the auditory region are frequently lost in macerating the skull; still more generally are the incudes and stapedes wanting, and the delicate malleus is frequently mutilated. Nevertheless I have succeeded in procuring specimens of at least the latter ossicle from Bats belonging to all the chief divisions of the group, nor, judging from duplicates, does there seem to be great variety among them.

In studying the malleus of *Asellia tridens*, as an example of the RHINOLOPHIDÆ, a very strong general resemblance to the same bone in the Shrew (*Sorex*) may be observed at a glance. It is absolutely necessary, in studying the ossicula of the smaller Chiroptera, to place thoroughly clean white specimens upon a piece of black paper; they may then be viewed by direct illumination under the microscope. A 1-inch object-glass is sufficiently strong for this purpose.

The head of the malleus in *Asellia tridens* † (Pl. LXII. fig. 20), though small compared with the area of the entire ossicle, as in all laminated mallei, is well formed and convex. The articular surface is rather deeper cut than in *Pteropus*; but the facets are of similar character, the upper and anterior being the larger. The neck is narrow, longer even than in *Sorex*, and resembles its homologue in the Shrew in being sharply bent midway between the head and the manubrium. At the apex of this angle I find, projecting internally, a curved process (*pm*), remarkably like a second process (*acpm*).

* Hyrtl (*op. cit.*) states that the crura "in *Pteropus edulis* and *P. vulgaris* [*sic*] are convergent before their insertion into the base." This is not the case in the College specimens.

† In Mr. Dobson's 'Monograph of the Asiatic Chiroptera,' *Asellia* is reduced to a subgenus of *Phyllorhina*.

At first sight the anatomist may be inclined to consider that *pm* (fig. 20) is accessory, and *acpm* the homologue of the processus muscularis; for *acpm* lies in the usual position occupied by that process in laminated mallei; and though the muscular process is often found lower down, as in the Cavies, where it is seated on the manubrium, it is, on the other hand, rarely seen higher up than *acpm*. But whilst I have never found both processes coexisting in the malleus of any other Bat*, the upper of the two observed in *Asellia* (*pm*, fig. 20) is constantly observed in the remaining insectivorous Chiroptera (Pl. LXII. figs. 22, 24, 25, *pm*). As, then, the lower process, *acpm*, in *Asellia*, is the peculiarity of this (and probably of a few allied Bats), and the upper is the most frequent in others, it is reasonable to consider the latter, *pm*, as the homologue of the processus muscularis, so common in other orders, the lower *acpm* being an accessory process. From the base of *acpm* a sort of splint or buttress runs for a short distance across the lamina; it must not be mistaken for the thin processus gracilis below it, though it is most probably ossified as a part of that element.

Besides the structures just described, a large orbicular apophysis exists, identical in position to the same in *Sorex* and *Mus*, and as large in proportion to the entire bone as in those animals, but less conspicuous, because it is sessile, not pedunculated. It is far better developed than in *Pteropus*.

The processus gracilis is slender, and appears as the thickened free border of the lamina; it is joined by a process from the head, the homologue of what has been already very frequently described in this memoir; the two form a rather broad curved process, which fits into a cleft in the ring-like tympanic bone. The lamina is very broad, and formed entirely of semitransparent bone; a buttress from the lower processus muscularis runs across it, but is lost before the processus gracilis joins the process from the head.

The manubrium is slender and long, well compressed laterally, and narrow, in that sense, even at the root. It is not triangular, as is the case in most laminated mallei, but truly quadrilateral; for the inner aspect as well as the outer forms a narrow surface sharply bordered from the sides almost to the point. A tendency to this condition may be observed in the malleus of the Shrew and in some Carnivora, but never to so complete an extent; for in *Asellia* this inner surface is as broad as the outer. In the great majority of animals the inner aspect of the manubrium is a simple border, sharp or blunt as the case may be. The outer border or, rather, surface is very narrow, but ends below in a distinct spatulate dilatation†. Above it forms a rather sharp angle, slightly incurved towards the neck, in fact a rudimentary processus brevis.

In the well-formed lamina and orbicular and muscular process the malleus of *Asellia tridens* resembles that of certain Insectivora and Rodents, and differs from the less specialized type observed in *Pteropus*. It must be borne in mind that the characters of the malleus in *Asellia* and other insectivorous Bats almost coincide with the distinguishing features of the same ossicle in two tribes of mammals belonging to different Orders, but

* Excepting *Phyllorhina fulva* and *P. speoris*, where the malleus in all other points precisely resembles that of *Asellia tridens*.

† This dilatation is shown in fig. 21, the malleus of *Plecotus*.

alike remarkable for the small size of the species, namely the Muridæ and Soricidæ. There may be some functional explanation of this similitude.

Among the VESPERTILIONIDÆ, the malleus of *Plecotus auritus* (Pl. LXII. fig. 21) closely resembles that of *Asellia*; but the lower process (fig. 20, *ac pm*) is absent. The extremity of the manubrium is rather widely spatulate.

The stapes has long crura, both almost straight; unlike most Bats, they diverge but little; the aperture is on that account long and narrow; it is not occupied, in the recent skull, by any bony canal.

In *Vesperugo serotinus* (Pl. LXII. fig. 25) the malleus also much resembles that of *Asellia*; the upper or true processus muscularis alone exists, so that we miss the lower, which in *Asellia* sends a conspicuous buttress from its base across the lamina. The orbicular apophysis is smaller and more pointed in *Vesperugo*.

The incus of *Vesperugo* has a well-formed body, deeply excavated by the articular surface; the processus brevis is short, but stout; the processus longus is very long and divergent; it is slightly grooved on its upper and anterior aspect, and ends in an almost discoid Sylvian apophysis, mounted on a very slender peduncle. In general characters this incus is of a low type; the same form is frequent among Marsupials. In all the insectivorous Bats the body of the incus is deeper and better developed over the processus longus than it is over the shorter crus. The minute stapes of *Vesperugo* has a small broad head, with a tubercle on its posterior aspect. The crura are slender and very divergent; the posterior is quite straight, the anterior a little curved. The aperture is very wide; the base has a rather thick border, so as to be slightly concave towards the vestibule. It is much narrower anteriorly than behind—a well-marked feature here, seen to a less extent in the stapes of *Homo*, and still less distinctly in most mammals.

The completely bicurrate stapes of these small Chiroptera, with a moderate or wide aperture, is interesting when we consider the low type of the other two ossicula; but the wideness of the aperture may not so much indicate high type, but may be considered as merely due to the passage of an artery* between the crura; the same remark, as I have already observed, applies to many Insectivora where the stapes has a wide aperture. Whether a vessel passes through the opening free or unsupported by a bony canal is of small moment; still some may consider the wideness of the aperture as a sign of high type, since in *Lemur*, where a bony canal exists, the crura do not diverge widely; so that in the Bats and Shrews the wideness may not be entirely for the benefit of the canal or artery, especially as these structures do not always completely block up the aperture. In many Rodents I have found the blocking complete without the crura being much bowed or very divergent, as in some skulls of *Capromys*.

The malleus of *Vespertilio nattereri* (Pl. LXII. fig. 22) is very similar to that of *Vesperugo*. The processus muscularis, too, in this Bat, seems in position to be the homologue of the upper process in *Asellia*, especially as, in the place of the lower distinct process in the latter, I observe in *Vespertilio* a faint eminence which sends a pro-

* See Hyrtl, *op. cit.* pl. ii. fig. 13. This artery is given off from the carotid together with the occipital.

longation across the lamina. The processus longus of the incus is very long. The stapes is identical in form with that of *Vesperugo* *.

Among the EMBALLONURIDÆ *Molossus obscurus* shows in its malleus (Pl. LXII. fig. 24) all the typical appearances above described in *Asellia*; but the processus muscularis in *Molossus*, as in most Bats, represents the upper process described as existing in *Asellia*. The orbicular apophysis is not so large as in the last-mentioned genus. The quadrilateral condition of the manubrium is very well marked.

Among the PHYLLOSTOMIDÆ I fail to find any distinctive characters. In the malleus of *Chilonycteris osborni* the processus muscularis is very stout and long, and I have preserved the tensor tympani muscle actually inserted into it in a specimen in the College collection; but the process is the same in position as that in *Molossus*, hence corresponding to the upper process in *Asellia*. The reader is referred to the description of the malleus in the latter genus for arguments on the homologies of the two processes. The mere fact of the upper process being found the most constantly throughout the Chiroptera is, as already remarked, in favour of its being the true processus muscularis; the lower being so very rarely found.

The incus of *Chilonycteris* has an extremely long processus longus, but the processus brevis is much less developed than in the Bats already described; this in itself is decidedly a sign of low type.

In *Mormops blainvillii* the malleus has a similar character to that of *Chilonycteris*; the processus muscularis is in the same position (Pl. LXII. fig. 23).

I regret I have been unable to procure ossicula from the crania of Bats belonging to other genera. Sufficient material, however, has been examined to warrant certain definite conclusions on the characters of the ear-bones of the Chiroptera.

I. In all the Chiroptera the ossicula much resemble those of the Soricidæ and allied Insectivora, particularly in the malleus.

II. In the frugivorous Bats the malleus does not resemble that of *Sorex* so strongly as does the same ossicle in the remaining section of this Order; indeed it approaches the marsupial type in general characters, but bears a strongly marked rudiment of the orbicular apophysis seen in the Shrew.

III. In all the insectivorous Bats the malleus bears a long, curved processus muscularis, and in some genera (at least in *Asellia*) a process apparently accessory to it. A well-formed orbicular apophysis is constant, the lamina is always wide, and the manubrium is quadrilateral, the outer and inner aspects being sharply bordered off from both the sides.

IV. The incus in all the Chiroptera has a very short processus brevis and a very long divergent processus longus, as in *Sorex* and the Marsupials. In this point the Shrews and Bats differ from the Muridæ, where the malleus is similar in character to the same ossicle in the former animals.

V. The stapes is never columelliform, or even approaching that low type, but, on the contrary, the aperture is generally wide; this is partly necessary, at least, for the

* Prof. Owen describes in *Vespertilio noctula* "a retention of the columelliform confluence of stapes and incus" (Anat. of Verteb. vol. iii.).

transmission of an artery unsupported by any bony canal, but may be considered as well (for reasons given above at length) to indicate an approach to the Primates.

VI. Judging from their ossicles it may be said that the Chiroptera are very closely allied to the Insectivora far more than to any other order of mammals.

THE OSSICULA OF THE CETACEA.

The highly specialized tympanic and petrous bones of the Whales and Dolphins are now familiar, not only to the anatomist, who confines his studies to recent animals, but also to the student of palæontology, on account of their great density and consequent durability. The already known peculiarities of the soft parts in the auditory apparatus, as they exist in this Order, may be conveniently studied in the fine preparations made by Hunter, and now preserved in the Museum of the Royal College of Surgeons*. His observations, quoted in the Catalogue†, are full and satisfactory as far as concerns the common species described therein, but preparations of the tympanum and labyrinth of rarer types remain unrepresented in that series. Further researches in the anatomy of the cetacean tympanum and membranous labyrinth are much to be desired.

But, in accordance with the scope of this paper, the morphological characters of the ossicula must alone occupy our attention. I will describe them relatively, as touching the distinction of each ossicle in the different genera, and comparatively as regards the homologies of the several parts of the highly modified cetacean ear-bones to corresponding portions in the more familiar types of terrestrial or partially terrestrial mammalia.

In the College collection there is one fine specimen of the malleus of *Balæna mysticetus* (Pl. LXII. fig. 28), and another, precisely similar in character, attached to the tympanic bone (No. 2438, Osteol. Ser., Pl. LXIII. fig. 13), probably from *B. australis*. At the first glance, no part of this bone, as it is seen in other animals, can be distinguished in these specimens, excepting the articular surface; after a little observation, the processus gracilis will be recognized; and by further careful study of the specimen, the observer will find that the modifications are not quite so great as they at first appear.

The peculiarities of this ossicle may be rendered more intelligible by first examining it *in situ*, as in Pl. LXIII. fig. 13, which includes part of the (left) tympanic and petrous bones in *B. australis* and is viewed from in front. The malleus is seen to be firmly ankylosed to the tympanic (*tb*) by its processus gracilis (*pg*) and by certain appendages (*l.*, *phm*), presently to be explained. That ossicle is, in *Balæna*, anterior to the membrana tympani; and the processus gracilis runs, not forwards, but outwards, to a special projection of the margin of the tympanic bone to which it is attached. This projection probably represents the anterior extremity of the *annulus tympanicus* of other mammals, the part in front being an extension of that ossification to surround the beginning of the Eustachian canal. The petrous bone (*pet*) lies much above the tympanic; hence the unusual position of the articular surface of the malleus, as Cuvier has observed. It follows that the homologous parts of the malleus of *Balæna* and the same bone in an ordinary mammal will not be found in the same respective aspects of each bone.

* Nos. 1582-1598 B, Physiological Series.

† Physiology, vol. iii. p. 115.

The malleus of *B. mysticetus* (Pl. LXII. fig. 28) measures about half an inch or a little more in length. The head is very large; its intero-inferior aspect is smooth and quite convex; externally and a little anteriorly it is very deeply excavated, the upper border of the cavity extensively overhanging it, especially towards the front, whilst behind there is a deep notch in that border. Hyrtl justly compares the excavation to that seen in the anterior aspect of the malleus of the Seal (*Phoca*); and from the extremely overhanging border, the bone assumes a form seen in certain shells, as Van Beneden has observed; indeed, putting aside the articular region and manubrium, the head much resembles the tympanic bone to which it is attached. On its upper aspect is situated the articular surface, which looks a little inwards and is deeply concave. It is made up of two facets, both of a semicircular form; the upper and external is almost plane, and by far the most extensive; it is separated from the lower, which is convex, by a sharp groove. In front of the head, on the outer aspect, is a deep channel, distinct superiorly, but absent below. This cuts off a portion of the malleus, which, close to the channel, is broad and flattened, bearing a distinct tubercle (Pl. LXII. fig. 28, & Pl. LXIII. fig. 13, *pm*), which projects upwards and inwards; but beyond the tubercle it gradually narrows as it runs forwards, ending in a hook-like point (*mn*), which curves downwards and outwards, and is longer and narrower in *B. australis* than in *B. mysticetus*. The tubercle (*pm*) is the processus muscularis, as may be seen in preparation No. 1598 B in the Physiol. Ser. Coll. Surg., where the tensor tympani muscle remains still attached to it. The hook-like process (*mn*) is without doubt the true manubrium; into it is inserted the apex of the curious prolongation of the membrana tympani characteristic in this Order.

The homologous parts of the malleus in *Balæna* (Pl. LXIII. fig. 13) may be compared with the same in the more familiar malleus of *Felis* (Pl. LXIII. fig. 14).

Cuvier states, in his 'Leçons d'Anatomie Comparée,' that in the Dolphin there is no manubrium, and that the malleus of the Whale "resembles it in every respect, but is double its size." Hyrtl (*l. c.*) correctly denies this assertion, and remarks of the Cetacean manubrium:—"It is only very short, and reduced to a rounded bony tubercle, separated by a deep incision from the head. . . . The processus minor [*sic*] is represented by two small pointed appendages, to which a triangular process of the membrana tympani attaches itself." But Van Beneden remarks* of *Balæna mysticetus*:—"The malleus possesses neither any distinct apophyses nor a manubrium." Lastly, Huxley † asserts, in describing the anatomy of the Porpoise:—"The tympanic membrane is concave externally; and, as is usual in the CETACEA, is connected by a ligament with the *handle* of the malleus." I cannot see how the curved process of the malleus of *Balæna* can represent any thing otherwise than the inflected splinter of bone on the blunt extremity of the malleus of the Dolphin ‡, which is the true manubrium of all other mammals; and, judging both by analogy and by the preparation above referred to, the

* 'Ostéographie des Cétacés,' Van Beneden and Gervais.

† 'Manual of the Anatomy of Vertebrated Animals,' 1871.

‡ Pl. LXIII. fig. 15, *mn*, from a *Globiocephalus*.

tubercle can hardly be fairly denied to be the homologue of the processus muscularis. Taking these assertions for granted, and recognizing henceforth in this treatise the curved process as the handle of the malleus, it will be shown that the manubrium is far better developed in *Balæna* than in the Dolphins or Sperm-whales, and still more than in the Ziphioid Physeteridæ.

From the malleus to the tympanic bone runs, almost directly outwards, a process over half an inch in length. It is made up of two stout splints or columns, one forming its posterior, the other its anterior border, and a broad flooring of thin bone connects them by their inferior borders; this latter is continuous with the floor of the excavation in the head of the malleus, the posterior raised and everted margin of that cavity running to join the posterior splint, the anterior coming distinctly from the corresponding margin of the depression in the malleus of *B. australis*; in that of *B. mysticetus* the anterior splint is given off in front of the groove, at least so I find it in the specimens I have examined; but this appears to be a trifling point, probably subject to variety.

The whole of this process, highly characteristic of the Cetacea, has for years been recognized by most authorities as the processus gracilis. One anatomist, Buchanan, who has carefully studied the anatomy of the ear in this Order, and written a most lucid description of the Whale's membrana tympani, represents this bony connecting medium in a Plate*, and there calls it "the long handle of the malleus;" whilst the process *mn* in Pl. LXII. fig. 28, & Pl. LXIII. fig. 13, at the end of this paper, is represented in Buchanan's illustration as very much longer than I can find it in any specimen in the College Museum, and styled "the short [*sic*], slender, or gracilis processus of the malleus." Here is a great confusion of terms, as other anatomists make the "long" and "gracilis" process synonymous; then, too, the expression "long handle" is very vague. Hunter (Phil. Trans. 1787) merely says that the process from the membrana tympani is inserted "into that bone" (*i. e.* the malleus), and speaks of the other process, that is the bony attachment of the malleus, without naming the homologies of those parts of the ossicle in question. Home (Phil. Trans. 1812) figures the ossicles very correctly, but calls the manubrium the "short handle," and the processus gracilis the "long handle."

But when we come to compare once more the process connecting the malleus to the tympanic bone in *Balæna* with the more typical malleus of *Felis* (Pl. LXIII. fig. 14), we shall find that, more strictly speaking, the anterior splint (fig. 13, *pg*) is the homologue of the processus gracilis, whilst the posterior (*phm*) is the prolongation towards it from the head of the malleus seen so frequently in terrestrial mammals; then the floor of thin bone between them (*l*) represents the lamina (fig. 14, *l*) of the Carnivora, Ruminants, &c. The whole of the above connecting process between the malleus and tympanic bone is rather longer in *Balæna*, and perhaps in *Balænoptera*, than in the Dolphins and Ziphioid Whales.

In its large excavated head and short curved manubrium, the malleus of *Balæna* bears a distant resemblance to the same in *Macrorhinus* and *Stenorhynchus* among the Seals.

* 'Physiological Illustrations of the Organ of Hearing.' London, 1828.

The incus of *B. mysticetus* (Pl. LXII. fig. 29) and of *B. australis*, which exactly resembles it, is more generalized than in any other cetacean (excepting, perhaps, *Megaptera* and *Neobalæna*). From the position of the articular surface of the malleus, the incus lies above and internal to it, with the corresponding surface downwards. The body is very solid and square. The posterior crus is short, stout, and recurved at its extremity. The processus longus, not so over-developed as in other Cetacea, is still very stout and broad to its extremity; it forms a bold sigmoid projection. A faint groove cuts off the Sylvian apophysis from the rest of the processus longus; it does not expand or project in any way from the crus itself. The articular surface on the body is very prominent; its upper facet is almost plane and larger than the lower, as in the malleus; a sharp ridge, which separates them, fits into the groove between the facets of the malleus.

The stapes (Pl. LXII. fig. 29) is nearly half an inch long and very narrow. The head is well developed, and bears a rough surface posteriorly for the insertion of the stapedius tendon. The crura are long, straight, and slender; they diverge but little, and are connected by a lamella, which has only a very small aperture in it; this lamella is evidently an ossification of the thin membrane thrown across the crura in the recent stapes of a typical mammal. The base is generally immovably soldered to the fenestra ovalis *. The stapes of *Balæna* bears a certain resemblance to that of *Stenorrhynchus*, and differs from all other Cetacea in the length and slenderness of its crura.

In describing the process which unites the malleus to the tympanic bone, the anterior column or border of that process (Pl. LXII. fig. 28, Pl. LXIII. fig. 13) was assumed to represent the true processus gracilis, and the posterior (*phm*) as homologous to the prolongation from the head of the malleus, which in other mammals generally joins it. This posterior column runs as an elevated ridge two or more inches over the outer surface of the scroll-like tympanic bone, ending in a broad lamina, which is closely applied to the upper part of the deep oblique groove which separates the anterior from the posterior portion of that bone, which would seem to indicate that the posterior column was the processus gracilis. But the anterior, which seems, from its position between the head and manubrium, to be the true processus gracilis, is soon lost on the *inner* side of the tympanic bone, where it makes a sharp ridge in some whales (*Physeter* &c.), as if the root of Meckel's cartilage had become embedded in that bone during ossification. Altogether, then, arguments are in favour of the anterior column being the homologue of the processus gracilis. This can alone be verified by the examination of very small fœtal Cetacea.

In the Pike Whale (*Balænoptera rostrata*) the auditory ossicles assume much more thoroughly the type most frequent in the Cetacea, excepting *Balæna*.

Indeed the malleus (Pl. LXII. fig. 30) is as extreme in its modifications as that of *Globiocephalus*, *Phocæna*, and *Delphinus*, being only exceeded in specialization by the Ziphioids. It is less like the malleus of *Balæna* than is the same ossicle in *Physeter* or even *Orca*.

* In *Balæna mysticetus*; but I have since found this not to be invariable, and in an adult petrous bone of *B. australis* in the College Museum the stapes has fallen out.

The head is less developed than in *Balæna*, especially below and internally*; it has a deep depression externally, of which the borders are elevated, but not nearly so overhanging as in the Greenland Whale. The articular surface is very similar, and the upper facet is the larger. In front of the head is a very prominent well-rounded tubercle, on the under and inner surface of which is a sharp splinter of bone (*mn*), with its point directed backwards; it lies flat against the malleus.

Hyrthl, in denying Cuvier's assertion that the manubrium is absent in Dolphins and Whales, continues:—"It is only very short, and reduced to a rounded bony tubercle, separated by a deep incision from the head." But in describing the tympanum of *Monodon* he remarks:—"The fleshy process of the membrana tympani is half an inch long, and attached to a ledge [*Leiste*] on the outer border of the malleus." Now the malleus of *Balænoptera* is very similar to that of *Monodon*, and still more to that of *Delphinus* and *Phocæna*. By carefully dissecting the tympanum of a *Monodon*, and examining the preparations of that cavity from all the remaining above-mentioned genera as seen in the College Museum (Nos. 1590-3 and 1596), I find that the tensor tympani tendon is almost invariably inserted into the most prominent and anterior part of the rounded tubercle of the malleus, whilst the process from the membrana tympani † is inserted, as Hyrthl says, into the splinter of bone described above; it is, however, on the under, not the outer surface of the malleus. Hence it must be correct to consider the bony splinter, Hyrthl's "*Leiste*," as the manubrium, whilst the bony tubercle ‡ should be considered the homologue of the processus muscularis of other mammals. The short curved process in the Greenland Whale, well divergent from the body, is evidently an intermediate condition between the long manubrium of terrestrial quadrupeds and the flattened splinter of *Balænoptera* and the Dolphins.

The process joining the malleus to the tympanic bone is very similar to that in *Balæna*, but shorter. The anterior pillar, or true processus gracilis, is very stout, and the lamina is rather denser than in *Balæna*.

The incus (Pl. LXII. fig. 31) assumes, like the malleus, the form prevailing in genera presently to be referred to. The body (which bears an articular surface similar to that of *Balæna*) is very ill developed, and the posterior crus is almost atrophied; it measures about a line in length, though tolerably stout. The processus longus is enormously developed, and incurved so abruptly as to present anteriorly a knee-like projection. On its broad extremity it bears a smaller and narrower, thick and elliptical Sylvian apophysis, of about the size and shape of the base of a Squirrel's stapes. Hence the incus of *Balænoptera* differs from that of *Balæna* more than the latter is different from that of most terrestrial Mammalia.

The stapes (Pl. LXII. fig. 31) is not so long as in the Greenland Whale, though its crura are longer than in the Dolphins. The head is well developed, and bears a rough

* It is much flattened on its outer and inner aspects.

† See Pl. LXIII. fig. 16, where the tendon of the tensor tympani and the process from the membrana tympani (in *Monodon*) are both indicated.

‡ The exact site of the insertion of this tendon is marked by a rough surface in *Balænoptera*, *Orca*, and most other Cetaceans.

tubercle for the insertion of the stapedius tendon. The crura are very stout, straight, and more divergent than in *Balæna*. The base was not soldered to the fenestra ovalis in the stapes removed from a skull of an adult male in the College collection, but could be displaced uninjured without any force being required to detach it; the same was the case with the stapes of an adult *Balænoptera* in the British Museum. The base is quite concave towards the vestibule. The aperture between the crura is small and circular.

The malleus of the small New-Zealand Fin-Whale (*Balænoptera huttonii*, Gray) in the British Museum almost precisely resembles that of *B. rostrata*; the tubercle is proportionately less developed, and the splint-like manubrium of the northern species is, in *B. huttonii*, reduced to a mere rough surface, as in many Dolphins.

A stapes from the gigantic Steypireythr (*Balænoptera sibbaldii*), kindly presented to the College by Professor Turner, has longer crura than that of *B. rostrata*, but is only half as large again*.

The malleus of *Megaptera novæ-zelandiæ* (Pl. LXII. fig. 32) has its head as flattened as in the last described genus; but in front, instead of a short round tubercle, is a stout, long, blunt-pointed process curved downwards. On the inner aspect of the latter is a sharp spine (*mn*), directed backwards, and representing, as in *Balænoptera*, the manubrium. The blunt tip of the process (*pm*) has a rough surface, evidently for the insertion of the tensor tympani; and posteriorly, close to the head, is a prominent tubercle, only faintly indicated in *Balæna* and *Balænoptera*, the analogies of which are not evident, though it decidedly is not a muscular process in the last-named genera, as preparations in spirit, already quoted, clearly show.

I have not had the fortune of examining the incus of a *Megaptera*, and cannot find a detailed description of it in any work on the Ear or on Cetacea. Van Beneden states that it is small, and that one of its articular surfaces is ill developed (in *M. boops*); in the illustrations to his work, that ossicle is represented with a body almost as well developed as in *Balæna*, and the "short crus" is depicted rather stout, long, and pointed, the "long" process not very thick.

The stapes of *Megaptera novæ-zelandiæ*, and also that of *M. longimana*, Gray, has as long crura and as wide an aperture as in *Balæna*; in a specimen of the former it was found ankylosed to the petrous bone; in the latter species (judging from an adult specimen in the British Museum) such ankylosis is at least not invariable.

In the greater length of the process bearing the homologue of the manubrium and the insertion of the tensor tympani, in the form of the stapes and probably of the incus, *Megaptera* tends more towards *Balæna* than to *Balænoptera*; but, on the other hand, the flatness of the caput mallei relates it very nearly to the latter; and the whole process from the head is produced and shaped not so much in the manner seen in *Balæna*, but rather as in *Platanista*.

The malleus of *Neobalæna marginata*† (Pl. LXII. fig. 33) is highly interesting, since,

* See Appendix to this section.

† Dr. Hector (Trans. N. Z. Inst. 1872) considers that this species, known to Dr. Gray under that name through

like that of *Megaptera*, it exhibits intermediate characters between *Balæna* and *Balænoptera*. It is larger than the malleus of an adult *Balæna*; its head is less flattened than in *Balænoptera*. The upper facet of the articular surface is extremely wide and almost plane; the lower is small, and as convex as in most Cetaceans; it must be remembered that in the Greenland Whale and Southern Whale the former facet is rather larger than in *Balænoptera*. From the front of the head a process projects, which bears on its inner side a sharp spine (*mn*), directed more downwards and less compressed against the body of the malleus than in the last-mentioned whale, but neither so long nor directed so much downwards as the stout curved manubrium of *Balæna*, which it represents (Pl. LXII. fig. 28, Pl. LXIII. fig. 13, *mn*).

In the plates illustrating Camper's 'Observations Anatomiques sur la Structure et le Squelette des Cétacés' the ossicula of *Physeter* are very correctly figured. He speaks of "la manche, ou l'apophyse de Rau" as if those terms were synonymous; the site of the insertion of the tensor tympani is not mentioned or indicated.

The malleus in the Cachalot and in the Ziphioid Whales possesses highly distinctive characters.

This ossicle in *Physeter macrocephalus* (Pl. LXII. fig. 34) is very small in proportion to the bulk of the animal. In general form it may be compared to a half-split pea, which it hardly exceeds in size. The head is small and convex; it does not bulge or rise high over the upper facet. The depression on its outer aspect exists, but is not so extensive as in any of the Balænoidea. The articular surface is very wide, considering the ill-development of most of the elements of the bone. Its upper facet is very broad and almost plane, the lower is much smaller, convex, and everted, like the mouth of a pitcher.

The process connecting the malleus to the tympanic bone is extremely short, but the same elements can be distinguished in it as in *Balæna*.

But the most distinctive feature in the malleus of *Physeter* is the suppression of the projecting tubercle which in other Cetacea bears the homologue of the manubrium and the insertion of the tensor tympani. On the anterior aspect of the head is a sharp, pointed tubercle (*pm*) looking directly upwards; directly below it is a very small blunt projection, pointing, in some specimens, a little forwards; in most examples it is hardly perceptible. This (*mn*) is the representative of the manubrium, and is much better developed in some of the Ziphioid Whales shortly to be described. In specimen No. 1584, Physiological Series, in the Museum of the Royal College of Surgeons, showing the auditory apparatus of *Hyperoodon*, where the malleus is very similar in form to the same ossicle in *Physeter*, the insertion of the membrana tympani to the tubercle (*mn*, Pl. LXII. fig. 35), and of the tensor tympani muscle into the upper process (*pm*), is well displayed. Hence *mn* in figs. 34 & 35 is the representative of the manubrium in *Physeter* and *Hyperoodon*, whilst *pm* is the homologue of the processus muscularis.

piece of whalebone only, is identical with the *Caperea antipodarum*, described in the B. M. catalogue from a solitary tympanic bone. Gervais and Van Beneden consider *Caperea antipodarum* to be the same as their *Balæna antipodarum*, which they distinguish from *B. australis*, and rightly, so far as the mallei are concerned.

The incus of *Physeter* has a much smaller body than that of *Balæna*; but this portion of the ossicle is, on the other hand, not so reduced in size as in *Balænoptera* and the Dolphins. The articular surface is very wide; the upper facet is the larger and planer, the lower is very concave, to fit the corresponding parts on the malleus. The ridge dividing them is most distinct anteriorly. The processus brevis is slender, but rather long; the processus longus is very stout, but not so big as in the Delphinoidea and in *Balænoptera*; it bears at its extremity a small, sessile, elliptical Sylvian apophysis.

The stapes has extremely stout crura, not so divergent as in the Dolphins; the aperture is sometimes obliterated. The footplate has a very thick border, and is a little concave towards the vestibule. I have never found this ossicle ankylosed to the petrous bone.

In the Ziphioid Whales the ossicula much resemble those of *Physeter*.

In *Hyperoodon rostratus* (Pl. LXII. fig. 35) the malleus has a larger head than in the Cachalot; that portion of the ossicle is also more convex, and rises a little above the upper border of the articular surface.

There is hardly any trace of a depression on the outer aspect of the head; it seems rather as if the bone above had grown into it, and reduced it to a horizontal slit. The process holding the malleus to the petrous bone is extremely short, but its homologues can be easily made out. The articular surface is, proportionately to the rest of the ossicle, considerably smaller than in *Physeter*, nor is the upper so much larger than the lower facet.

The processus muscularis (Pl. LXII. fig. 35, *pm*) is even less developed than in *Physeter*; the manubrium (*mn*) is a still more insignificant tubercle.

The incus also in general characters resembles the same in the Cachalot, but possesses a character which it shares with the two other Ziphioid Whales whose ossicula the author has examined, and in which it differs from *Physeter*. This feature is the long, flattened, and very divergent processus brevis, which is narrowest in the middle. The articular surface has its facets divided by a very sharp ridge, equally defined in its whole course; the upper facet is plane, the lower concave, as in *Physeter*, but consistently with the characters of the articular area in the malleus of *Hyperoodon* the upper facet is, in its incus, not so much larger than the lower, as is the case in the Cachalot. The body is developed to the same extent as in *Physeter*; the processus longus is as stout but shorter than its representative in that Whale.

The stapes in *Hyperoodon* (Pl. LXII. fig. 35) has very stout crura, with hardly a vestige of an aperture. The base is narrower than in *Physeter*, and not nearly so thick at its margin; towards the vestibule it is quite concave.

The stapes, but not the other ossicula, of *Ziphius cavirostris* is figured in a plate illustrating Prof. Turner's paper on that Cetacean *. It resembles, apparently, that of *Hyperoodon*.

The malleus from the fine adult specimen of *Berardius arnuxii* in the College Museum (Pl. LXIII. figs. 1 & 18) bears, to a well-marked degree, all the chief peculiarities seen

* Trans. Royal Soc. Edinb. 1872.

in *Physeter* and *Hyperoodon*. The head is better developed than in either of those Whales. It is half as long again horizontally as vertically, whilst in *Hyperoodon* this portion of the ossicle, though not more prominently convex than in *Berardius*, is almost a hemisphere. It rises very prominently above the facets. The depression on its outer aspect is small and slit-like; the process holding the ossicle to the tympanic bone is as short as in the *Physeteridæ* already described, and made up of the same elements (compare Pl. LXIII. fig. 1 with figs. 13 & 14). The specialized modifications in the processus muscularis and manubrium are very marked in the malleus of *Berardius*. The processus muscularis (fig. 1, *pm*) is nearly as long as in *Physeter*, so that it is better developed than in *Hyperoodon*. Here it may be observed that it is only in the *Physeteridæ* that the processus muscularis can be found as an actual process among the Cetacea, since in the Whalebone Whales and Dolphins its homologue is either a rough surface or a depression on the tubercle, from which also springs the manubrium; but it is this very tubercle which is wanting in the Cachalots and Ziphioid Whales, where the processus muscularis is distinct.

In *Berardius* the manubrium is much better developed than in *Hyperoodon* or *Physeter*. It is seen as a small, sharp spine*, arising close to the root of the processus muscularis, and running directly downwards, whilst the other process runs straight upwards. The two processes together lying close against the head, resemble the contrivance seen on board ship for belaying cable. The articular surface is extensive even in proportion to the rest of the malleus; its upper facet is of the same form as in *Hyperoodon*, plane, and very elevated at its margin; the lower is smaller and convex, everted as in the Ziphioid Whale just mentioned.

Hence, in its malleus, *Berardius* is more perfectly specialized than either *Physeter* or *Hyperoodon*. This ossicle is certainly, among these three Whales, largest and bulkiest in *Berardius*, smallest, proportionately, in *Physeter*, owing to the ill-development of the portion of the head external to the facets in that animal.

The incus (Pl. LXIII. fig. 1) resembles that of *Hyperoodon* rather than *Physeter*; the processus "brevis" is still longer, more divergent, and flattened and expanded at its extremity. Close to its root the body (as is the case in *Hyperoodon*) is not so reduced and shallow as in *Physeter*; the groove dividing the facets is not very sharp in *Berardius*. The processus longus is quite similar in character to that of *Hyperoodon*.

The stapes is longer than in the other *Physeteridæ* here described. In the *College* specimens there is a prominent tubercle on the inner aspect of the head for the tendon of the stapedius. The crura are long, stout, and straight, a slit-like but pervious aperture divides them. The base is narrow, its margin is rather thick, and it is quite concave towards the vestibule.

I have examined the malleus and incus from a skull of *Mesoplodon hectori* in the British Museum. These bones are much smaller than their representatives in the above-described *Physeteridæ*. The malleus has a head as small as in *Physeter*, moderately convex, and produced backwards to a prominent blunt point. The head projects slightly above the facets, as in *Hyperoodon*; the articular facets are proportionately still smaller

* Pl. LXIII. fig. 1, where this spine is lettered *hm* in place of *mn*, its true homologue.

than in that Whale, nor is the upper much larger than the lower. The processus muscularis is a short blunt point. I found a few shreds of the tendon of the tensor tympani adherent to it. The manubrium is represented by the faintest trace of a tubercle; there is a ridge above it, into which a part of the process from the membrana tympani is probably inserted as in *Platanista*.

The processus gracilis and its accessories connecting the malleus to the tympanic bone is extremely short, and the depression in the head above it almost effaced. See Pl. LXIII. figs. 19 & 19 a, where this bone in the closely allied *Mesoplodon grayii* is shown.

The incus is of the same character as in *Hyperoodon* and *Berardius*; it is rather smaller in proportion to the malleus. The ridge separating its facets is almost as sharp as in *Hyperoodon*.

Taken as a whole, and judging from the incus as well as the malleus, *Mesoplodon* resembles *Hyperoodon* rather than *Berardius*. In the ill-development of the head of the malleus we have a character which should place this Whale between *Physeter* and *Hyperoodon*. In the smallness of the articular surface of the malleus it differs alike from the Cachalot and *Berardius*, and approaches *Hyperoodon*.

The stapes has no aperture, and in form coincides with the same ossicle in *Hyperoodon*, confirming the remarks in the last paragraph.

In the Delphinidæ the ossicles may be said to be central in character among the Cetacea, the Balænoidea and Platanistidæ departing from them towards other mammals, the Physeteridæ diverging, on the other hand, from the Dolphins in the highly specialized characters of the malleus and incus. It is remarkable that among the Whales proper the genus *Balænoptera* should so closely resemble the Dolphins in its ossicula.

In *Delphinus* the malleus (Pl. LXIII. figs. 2 & 3) in general form reminds the observer strongly of the same in *Balænoptera* *. The outer aspect of the head is less flattened, the articular facets are similar, the upper being the larger and planer, the lower the most convex; but instead of the large rounded tubercle seen in the Whale just mentioned, a small, blunt, slightly excurved process projects from the head in *Delphinus*. On its inner surface may be observed a small spine (*mn*), directed backwards, hardly perceptible to the eye, yet readily detected by rubbing the finger forward over the internal aspect of the malleus. This represents the very perceptible homologue of the manubrium described as existing in the Pike-Whale, and equally or more developed in other genera of Dolphins †.

The body of the incus is very feebly developed, being, as it were, absorbed by the stapelial crus. Its articular surface has facets divided by a sharp ridge, as in the Balænoidea, and unlike *Physeter* and *Berardius*. The processus brevis is very slender and much shorter than in the Ziphioids; the processus longus is very stout, and shaped like its representative in *Balænoptera*; the Sylvian apophysis is of the same nature.

The stapes is about a line in length, with fairly divergent crura and a very thick base, quite concave towards the vestibule. The aperture is closed, but always represented in

* The ossicula of a foetal Dolphin, four inches in length, are all of precisely the same form as in the adult.

† The homologous parts of the malleus in the Dolphins are indicated in Pl. LXIII. fig. 15, representing that ossicle in *Globiocephalus* (see also figs. 3 to 12).

this genus by a minute pit; and in no specimen of any Dolphin of any age in the College Museum was it found ankylosed to the petrous bone, nor in any other Cetacean except *Balæna mysticetus*, and then not invariably. Hyrtl, who has described the ossicula of the Cetacea (*op. cit.*) far more extensively than any anatomist before him, states that all trace of the aperture is effaced "in *Delphinus longirostris*, *braziliensis*, *tursio* and *rissoii*;" but he asserts that it is also absent in *Monodon*, though a distinct trace is seen in the two College specimens from different skulls; and although he finds that the aperture "reappears in the Porpoise," it does not seem more distinctly indicated in the examples in the College collection than in *Delphinus*, and is decidedly not pervious. The distinguished anatomist continues:—"Possibly this depends on the age of the individual specimen; a conjecture, however, not justified by the persistence in all other animals of the form of the stapes in different degrees of age." I have not found the aperture more blocked up or less clearly indicated by a depression in adult than in young Delphinoid crania; and, on the other hand, a specimen of the stapes of *Bradypus tridactylus* in the College collection, from an adult Sloth, has a much smaller aperture than another stapes from a cranium of a younger animal of the same species.

In *Globiocephalus* (Pl. LXIII. figs. 4 & 15) the head of the malleus is rather larger than in *Delphinus*, and the projecting tubercle rather smaller; but it is marked at its apex by a distinct rough surface for the insertion of the tensor tympani tendon (*pm*), and the manubrium (*mn*) is represented by a very sharp spine pointing backwards and flattened against the inner side of the ossicle. The bony process connecting the malleus to the tympanic bone is rather long, and the same elements as described in *Balæna* may be observed in it; the processus gracilis (*pg*) or the anterior column is thick. The incus has the same characters as in *Delphinus*; the stapes, too, is very similar, but some specimens have a pervious aperture.

In a *Lagenorhynchus* in the British Museum the ossicula are of the same form as in the last genus, and the manubrium is as well developed (fig. 11). In *Phocæna* the malleus (fig. 5) most resembles that of *Globiocephalus*; the incus is very similar, and the stapes has generally a very minute but pervious intercrural aperture. The malleus is connected by bone to the tympanic, though by a somewhat thin processus gracilis, contrary to Hunter's experience.

In *Delphinapterus albicans* (Pl. LXIII. fig. 8), the Beluga or White Whale, the malleus much more resembles that of *Delphinus* than the same ossicle in *Globiocephalus*, the process in front of the head being rather long and curved outwards. The recurved splinter representing the manubrium in other Dolphins is quite absent, and represented by a rough ridge (*mn*), hardly visible except by aid of a lens*. There is no excavation on the outer aspect of the head of the Dolphins as in *Balæna*; it seems as if the edges so prominent in the Greenland Whale had rolled in and filled up a cavity, and to a less extent in *Physeter*.

The incus of *Delphinapterus* is of the form prevailing among the Delphinidæ. The stapædes in the College collection have neither so much as a trace of an aperture.

* As the malleus of this Dolphin is larger than that of most *Globiocephali*, the absence of the spine-like manubrium (as in the smallest *Delphini*) is not due to diminished proportions or development of the entire ossicle.

The malleus of a large *Orca* from Tasmania (Pl. LXIII. fig. 7) in general aspect appears like a magnified malleus of *Delphinus*; but some of its elements are proportionally more highly developed than in the typical genus. The head is large and convex; the depression on its outer aspect is very deep, and almost recalls *Balæna*. The size of the processus gracilis and the elements associated with it, connecting the ossicle to the tympanic bone, contrasts strikingly with the reduced proportions of the homologue of that process in the malleus of the *Physeteridæ*. The articular surface is as small as in *Delphinus*, and the facets are of similar type; but the tubercle from the head of the malleus is far larger than in any of the Dolphins of which the ossicula have been already described. It is much more prominent than in *Balænoptera*. At its upper extremity, looking forwards, is a conspicuous rough depressed surface for the insertion of the tensor-tympani tendon. Below is a sharp splinter-like process representing the manubrium. This is much more developed than in *Delphinus*, or even *Globiocephalus*; and instead of being directed backwards, and pressed, as it were, against the head, it is directed considerably in a downward direction. The whole tubercle assimilates to its homologue in *Balæna*, as the same in *Megaptera* recalls *Platanista* in general features.

The incus of *Orca* is quite Delphinoid; its short crus is thin and rather long, the stapedial crus very stout. The stapes is similar to that of *Delphinus*; it has a minute aperture.

In a smaller Grampus (*Pseudorca meridionalis*, Flower) all the ossicula much resemble those of *Orca*. The malleus has the tubercle bearing the manubrium a little less developed (fig. 6), so as to approach *Globiocephalus*.

The homologies of the splinter of bone inflected from the process projecting from the head of the malleus in most Cetacea, and of the rough surface or actual tubercle seen on the point of that process, have been discussed in the description of the ossicula of *Balænoptera*; and specimens in the College Museum illustrate the relations of the soft parts in Dolphins, Whales, and *Hyperoodon*. I have dissected several ears of Dolphins, Porpoises, and of a Narwhal, and the malleus from the latter dissection (Pl. LXIII. fig. 16) is mounted in the special collection of ear-bones on which this treatise is founded. The tendon of the tensor tympani is left attached to the apex of the process from the head; and the whole membrana tympani is also retained, dried and varnished; its broad, flat, and pointed process may be seen attached by the point to the splinter-like manubrium, Hyrtl's "Leiste." All the above preparations conform, on the whole, to the descriptions given by that distinguished anatomist, and by Buchanan, concerning the anatomy of the Cetacean tympanum. The dissection above described was suggested by a figure of the malleus of *Monodon* in Hyrtl's work.

The malleus of the Narwhal (*Monodon*, Pl. LXIII. figs. 9 & 16), though essentially the same in type as that of *Globiocephalus*, is much elongated antero-posteriorly, and the head merges into the broad process in front without any constriction or trace of separation. The articular surfaces are of equal size (as Hyrtl observes), the upper being not larger than the lower, as in all other Cetacea. The processus gracilis is of the same type as in *Balæna* and the rest of the Order; it is rather long. The incus has an even

thicker stapedial crus than in other Delphinoidea *; the posterior is short and small; and the facets are, of necessity, of equal size; they are divided by a sharp and prominent ridge. The stapes is of the ordinary Dolphin type, with a very thick base, generally (but not always) very concave towards the vestibule. It was found unankylosed to the fenestra ovalis in a large adult skull in the College Museum. The ossicle in this case had a minute almost perversive depression between the crura.

In the ossicula of the PLATANISTIDÆ we find interesting modifications. In the Gangetic Dolphin (*Platanista gangetica*) the head of the malleus (Pl. LXIII. figs. 12 & 17) is of the same form as in *Delphinus*, and the upper facet is larger than the lower; but the process in front is extremely elongated, so as to be longer than the head itself, from which it is hardly more distinct than in *Monodon*, except that a faint groove, generally observed in the true Dolphins, divides them above and internally. Instead of a rough and only slightly concave surface at the very extremity of the process, as is found in most Cetacea to mark the insertion of the tensor tympani, there is a very deep pit on the external aspect of the projection, actually nearer its root than its point; this is highly characteristic (fig. 17). The point itself is sometimes slightly hooked; and from it to close under the articular surface, all along the inner aspect of the process, runs a very distinct groove, ending posteriorly in a faintly marked tubercle representing the manubrium (fig. 12, *mn*). It seems as if the groove were homologous with the outer surface of that process in other Orders of the Mammalia, the hooked or blunt point corresponding to the processus brevis. Many of the fibres of the fleshy prolongation of the membrana tympani to the malleus are attached to the bottom of that groove, and are often seen still adherent in imperfectly macerated specimens. In *Monodon* and the Dolphins proper some of the fibres are in the same manner inserted along the back of the anterior projection from the head of the malleus, as well as to the splinter-like more definite homologue of the manubrium †.

The processus longus of the incus (fig. 20) is as thick as in *Monodon*, and the articular surface for the head of the stapes is as small; the posterior crus is even less developed than in *Delphinus*. The stapes is of the same form as in the smaller Dolphins, without a trace of any intercrural aperture; there is sometimes a large tubercle for the stapedius-tendon on the inner aspect of the head.

By the kind permission of Dr. Günther I have been enabled to examine the ossicula from the skull of *Inia geoffroyi* belonging to the British Museum. The general shape of the malleus (Pl. LXIII. fig. 10) reminds the observer more of *Delphinus* than *Platanista*. The head and facets resemble the same in the Gangetic Dolphin; but the process in front is not nearly so produced as in *Platanista*. The tensor tympani is inserted into a pit (at *pm*) as in the Gangetic genus, which, however, is seated in *Inia* quite at the tip of the process from the malleus, on the site of the same insertion in *Delphinus*. The manubrium is a very distinct reflected spine (*mn*); and there is a groove running

* Hyrtl (*op. cit.*) directs attention to the small size of the articular surface for the head of the stapes on the end of this process.

† In making a fresh dissection of the tympanum of *Platanista*, I found a strong band of fibres inserted into the groove, and the tensor tympani was inserted into the depression above described (Pl. LXIII. fig. 17).

forward from it. Hence the malleus of *Inia* allies it, on the whole, more to *Delphinus* than *Platanista*. The articular surface for the stapes on the stout processus longus is as wide as in *Delphinus*; the processus brevis is rather long, but slender. The stapes is of the type prevailing among all the Dolphins; it has an intercrural aperture. In a full-sized adult *Inia* these ossicula are less than half as large as their representatives in a *Platanista* of the same age and proportions.

In taking a general concluding view of the auditory ossicles of the Cetacea, it may be remarked :—

I. The ossicula of these animals differ from those of other Mammalia rather in their solidity than in any great size in proportion to the whole skeleton, and more in extreme modifications of detail than in solidity of composition; for in size they are exceeded by the Seals and Sirenia, in density by the latter, but in specialization of form by no other mammals.

II. The general diagnostic features are :—in the malleus, constant, firm bony ankylosis to the tympanic bone through the medium of the processus gracilis, with ill-development or complete suppression of the manubrium; in the incus, great development of the stapelial crus; in the stapes, thickness of the crura contracting or obliterating the aperture. This latter bone always fits firmly into the fenestra ovalis, to which, however, it is in no species constantly ankylosed.

III. The genus *Balæna* possesses undoubtedly the most generalized ossicula among all the Cetacea, particularly in the case of the incus. The malleus has the least-modified form of manubrium, the whole bone distantly resembling that of certain large Seals (*Macrorhinus*, *Stenorhynchus*), as does also the stapes.

IV. The malleus of *Neobalæna* is the next least specialized. That of *Megaptera* is much more modified in regard to the aborted condition of the manubrium.

V. Both in the malleus and incus *Balænoptera* is far more modified than any of the above genera*. The incus is quite Delphinoid, unlike either the *Balæna* or *Physeter* type. The malleus is even more modified than in the Dolphins; its manubrium is of more tubercular form, and the whole bone is more flattened.

VI. In the *Physeteridæ* the malleus is extremely modified. The tubercle projecting from the head in other Cetacea is here obsolete; the manubrium and processus muscularis are reduced to two small spines. That representing the manubrium is almost suppressed in *Physeter*, *Hyperoodon*, and *Mesoplodon*, but is well developed in *Berardius*. The head is largest in *Berardius*; in *Physeter* the articular surface is very extensive. The incus is intermediate in type between the same in *Balæna* and *Delphinus*. In the the Ziphioid Whales the short crus is long and of peculiar shape. The stapes differs a little in character from that of the true Dolphins.

VII. In the Dolphins the malleus is never so modified as in the Ziphioid Whales: the tubercle projecting from its head is pointed, not rounded as in *Balænoptera*; and the seat of insertion of the tensor tympani muscle is indicated by a roughened, depressed surface. The manubrium may be quite absent (*Delphinapterus*) or reduced to a small

* See Appendix to this section.

spine, depressed against the side of the ossicle (*Globiocephalus*, *Lagenorhynchus*, *Phocaena*); or the spine may be well developed and directed downwards, away from the rest of the malleus (*Orca*, *Pseudorca*). Part of the process from the membrana tympani is inserted along a narrow groove on the tubercle. *Monodon* differs from other Dolphins in the characters of its articular surface, and the length of the head and tubercle of the malleus.

VIII. All the Dolphins agree in the characters of the incus, which has an ill-developed body and processus brevis, but a very large stapedial crus. The stapes, too, is very similar in character in all these Cetacea.

IX. *Platanista* differs remarkably from the true Dolphins in the great length of the process from the head of the malleus, as well as in minor particulars. Such distinctions are hardly perceptible in *Inia*.

Appendix to Remarks on Cetacean Ossicula.—The malleus of a foetal *Balænoptera sibbaldii* in the Museum of the University of Edinburgh bears a long process in front of the head, with the same homologues, apparently, as are seen in *Megaptera*. Whether or not this process is arrested, whilst the head increases during the growth of *B. sibbaldii* is a question only to be solved by the examination of the malleus in an adult of this species. If the process remains long, then it is truly remarkable, since it allies this *Balænoptera* to the genus *Megaptera*, and separates it from *B. rostrata* and *B. huttoni*. The incus from the same foetus is of the *Balæna* type, as the body is very well developed, the long crus by no means so large as in *Balænoptera rostrata*. For this observation I am indebted to the kindness of Prof. Turner. I may further add that the malleus, in the skeleton of *Macleayius* (*Eubalæna*) *australis* at the British Museum, is of the *Balæna* type.

THE OSSICULA OF THE SIRENIA.

On account of their large size and conspicuous peculiarities, the ossicula of the Dugong and Manatee have already become familiar to most comparative anatomists; and, through their great durability, even the same bones in *Rhytina* and *Halitherium* have been described respectively by Claudius* and Krauss†; but the most prominent characters which have rendered them interesting to zoologists are due to their structure and consistence, the homologies of their various segments and processes being, on the whole, much easier to distinguish than is the case with the ear-bones of the Cetacea.

The malleus of the Dugong (*Halicore australis*, Pl. LXIII. figs. 26, 27) is a heavy bone, weighing on an average 40 grains, and measuring about an inch from the root of the processus gracilis to the tip of the manubrium; the largest specimen never attains the size and weight of the malleus of species of either *Manatus* or *Rhytina*, though, from Krauss's account, it appears to be longer than in *Halitherium schinzi*.

It is important to bear constantly in mind the position of this bone in the Sirenian tympanum. In ordinary mammals the head of the malleus lies far back in the tympanic cavity,

* "Das Gehörorgan von *Rhytina stelleri*," Mém. Acad. Imp. des Sciences de St. Pétersbourg, 1867.

† Leonhard u. Bronn's N. Jahrb. 1862, p. 385.

so as to be often invisible from the external meatus; the processus gracilis stretches well forwards from the rest of the malleus; and the articular surface is placed almost wholly posterior. In the Cetacea, on the other hand, the head of the malleus is much less posterior in position, the processus gracilis runs from it directly outwards to join the tympanic bone, and the facets look inwards. In the Dugong and Manatee the malleus holds an intermediate position, as may be seen by examining a skull of *Halicore* in the College Museum (No. 2633), where all the left ossicula are *in situ*. The head lies quite anterior to the posterior horn of the dense annulus tympanicus, its manubrium projecting directly outwards from it; the processus gracilis runs as completely forwards as in terrestrial mammalia; but, again, the articular surface is as internal as in the Whales and Dolphins.

The massive head of the malleus of *Halicore australis* is of irregular shape, about as long antero-posteriorly as vertically, and slightly flattened from within outwards. Its uppermost portion is wide, slightly convex, and does not project above the upper facet as in most Mammals. The articular region lies entirely on the very broad inner aspect of the ossicle. It is made up of an upper facet and two lower, which latter represent the single inferior facet in other mammals, the extero-inferior segment of the articular surface of the human malleus; they form almost a right angle with each other, and an obtuse angle with the upper facet, a very distinct groove dividing them. The superior facet is reniform, with its long axis vertical, and its concavity forward; its surface is distinctly convex from above downwards. The smaller inferior facets* are oval; and their edges generally coalesce along the high ridge which divides them, and whence they slope. On the outer aspect of the malleus is a very deep groove running forwards and slightly downwards; its upper border is thick and prominent; its lower is formed by the root of the manubrium. This projecting upper border is homologous with the sigmoid ridge on the neck of the human malleus, as may be seen by laying an ossicle of *Homo* and of *Halicore* side by side, with the manubrium forwards. Hence it must represent the solid curved neck of the laminar type of malleus in the Carnivora, Ruminants, and other Mammals†. Completely in front of the malleus of the Dugong is the processus gracilis (Pl. LXIII. figs. 26, 27), which is broad at its root, but narrows rapidly. Owing to the whole ossicle being placed unusually forwards this process is far shorter than in terrestrial Mammals. Its upper surface is smooth and convex, being continued from the upper surface of the head; its lower is flat and very short, separated by a deep horizontal groove from a prominent tubercle on the front of the head below it. The processus muscularis is a blunt tubercle, looking forwards from the inner aspect of the malleus, and is continued backwards and upwards as a very prominent convex ridge, which is lost on the head of the malleus behind the inferior facets, near the ridge on the anterior aspect already described. Strictly speaking, the whole must be considered as the processus muscularis, having its root on the true neck (the

* These evidently represent the inferior facet of other animals, the convex ridge being here much exaggerated, even to the point of dividing that facet into two.

† See the account of the human malleus, *anteâ*.

outer and anterior projection), as in many other animals. The manubrium stands out from the head completely external; and its point is directed rather backwards: it is separated from the rest of the malleus above by the groove on the outer aspect of the ossicle; below it is blended with the base of the ridge continued from the processus muscularis. It is wide at the root, and triangular in form; its upper border is very broad, particularly towards the groove, and sharply bordered from the sides; externally it runs into the outer aspect by forming a prominent bold convexity, instead of a processus brevis; the outer aspect is also sharply defined, its borders being continued from above, and towards the extremity it is spatulate: in some specimens this dilatation is very marked, in others hardly perceptible. The sides of the manubrium are flattened, and somewhat concave near the root; the inner border is rather sharp, and quite concave; it blends with the head as aforesaid below the processus muscularis. It is wide at the root, and triangular in form: its upper border is very broad, particularly towards the groove, and sharply bordered from the sides; externally it runs into the outer aspect by forming a prominent bold convexity instead of a processus brevis; the outer aspect is also sharply defined, its borders being continued from above, and towards the extremity it is spatulate; in some specimens this dilatation is very marked, in others hardly perceptible. The sides of the manubrium are flattened and somewhat concave near the root; the inner border is rather sharp, and quite concave, it bends with the head, as aforesaid, below the processus muscularis.

The incus of *Halicore* (Pl. LXIII. figs. 28, 29) is singularly placed, its "processus brevis" being absolutely superior in position to the rest of the bone, instead of being postero-superior, whilst the stapedial crus is equally inferior; the facets look directly outwards on account of the internal position of those on the malleus. The body is twice as wide as it is deep; its inner aspect, which is wide, smooth, and convex, fits into a depression in the petrous bone; its articular surface consists of a concave reniform facet, corresponding to the upper one on the malleus, separated by a sharp projecting angle from two oval lower facets, which look towards each other, and are divided by a deep groove, into which the projecting angle between the lower facets on the malleus is locked in the recent skeleton. The posterior of the two lower incudal facets is borne on a very prominent tubercle projecting from the outer and more posterior surface of the body of the incus—a most characteristic feature, by which this ossicle in *Halicore* may be at once distinguished from the same in *Manatus*, and apparently in *Rhytina* and *Halicore*.

The processus brevis is very short, and lies above and somewhat anterior to the rest of the ossicle; it is firmly ankylosed to the petrous bone; but being thin and brittle, the whole incus is generally detached if the skull is dropped on the ground, or struck violently after maceration. The processus longus arises far from the outer crus on account of the great width of the body, to which it lies inferiorly and slightly posteriorly. It is short, slightly curved, flattened extero-internally, and of almost equal thickness throughout; the oval disk at the extremity is generally separated from the rest of the crus by a faint groove, so as really to represent the *os orbiculare*, the existence of which in *Halicore* seems to be denied; as a rule, the larger the mammal the less developed is its Sylvian apophysis.

The stapes of the Dugong (fig. 30) measures about half an inch in length, and is of very solid consistence; as the crura diverge but little, the base is narrow; the anterior extremity of the latter and of the fenestra ovalis is placed much lower than the posterior, although, after examining five skulls of *Halicore* in the College Museum, I do not find the long axis of the base of the stapes or of the fenestra vertical, as has been asserted; the same remark applies to *Manatus*. The head is well developed, and the articular surface is concave; the site of insertion of the stapedius is generally indicated by a slight depression. The anterior crus is half the thickness of the posterior, and both are rather crooked; the aperture is circular, generally just large enough to admit a small sewing-needle, but in some specimens it is of the calibre of a No. 1 English catheter. The base is convex, most so posteriorly, and is narrowest towards the front; it never appears to be ankylosed to the fenestra ovalis, or even tightly fitted into it, as in the Cetacea. The broad well-formed head and comparatively thin anterior crus somewhat remind the observer of the stapes of *Bos*; but in the other ossicula of *Halicore* and the other Sirenia few, if any, distinct analogies to the same bones in any particular order of Mammalia can be made out.

Since the extinction of the *Rhytina* the American Manatee (*M. americanus*) has borne the largest and heaviest malleus known in any animal, as Hyrtl has already stated. Indeed, to judge from Claudius's account of that ossicle in *Rhytina*, of which the head, he remarks, is of about the size of an ordinary hazel-nut, it hardly can have exceeded, as a rule, the malleus of a large Manatee, though I have never seen the processus gracilis of the latter "at least $1\frac{1}{2}$ " in diameter," which is the case in the specimen from the extinct Sirenian he describes. The specimen in the collection of ossicula in the College Museum (Pl. LXIII. figs. 21, 22), from a skull of *M. americanus*, in the Comparative-Anatomy series, measures over an inch in length, and weighs over sixty-one grains; the head is quite as large as a middle-sized hazel-nut. This bone, as well as the other ossicula, lies, in the recent skull, in the same position as has already been described in *Halicore*; but it offers many points of difference in its structure from the malleus of the latter animal.

The head is much longer antero-posteriorly than vertically. All the facets are larger; and the upper, though reniform, has its concavity backwards, and its surface is distinctly concave above. In the College specimen there is a prominent peg-like process (Pl. LXIII. fig. 21) projecting immediately below the inferior border of this facet, bearing superiorly another small facet; not a trace of this can be seen in any specimen from *M. senegalensis* in the same series. The lower facets in *Manatus americanus* are of much the same form as in the Dugong; but at the top of the prominent angle their borders do not blend, but are nearly a line apart. The outer aspect of the malleus is very wide and quite convex; the groove is very shallow anteriorly, and quite effaced behind, in which direction, however, is a very sharp and prominent ridge analogous to a similar projection in *Halicore*, the homologies of which have already been discussed. The processus muscularis is a stout incurved process, continued backwards as a conspicuous elevation towards the former ridge, precisely as in the Dugong.

The manubrium differs in form from that of *Halicore*. The upper border is very sharp and narrow; it forms a semicircle, and projects against the membrana tympani in the live subject; the outer border is short, and its margins, united above, diverge but little towards the extremity; its surface is concave vertically, and slightly convex horizontally. The inner border is much blunter than the outer in *Manatus*.

The processus gracilis is not relatively so well developed as in *Halicore*, and projects, as a fragile splinter of bone, from the massive head; it is firmly ankylosed to the tympanic ring; and, from its very nature, the whole malleus is easily broken off from the ring.

The incus (figs. 23, 24) is placed in the tympanic cavity precisely as in the Dugong, the processus longus lying above the body, and the other crus running downwards from it. The body is even shallower and wider between the crura than in *Halicore*; its inner surface is less extensive and less convex, and much overhung by the upper facet of the articular area, which facet is very wide, reniform, and faintly concave; the two lower facets look towards each other, and are separated by a deep groove, into which the corresponding prominence between the opposing surfaces on the malleus are fitted during lifetime. There is not nearly so marked a prominence behind the upper and more posterior of these facets in the Manatee, like that which projects so conspicuously on the posterior side of the Dugong's incus. The processus longus is rather long, slightly curved, and flattened extero-internally; it widens out towards the point, where it is ankylosed to the petrous bone. The processus brevis is very short, stout, and curved; the articular surface for the stapes is very wide, almost circular, and nearly plane; a faint trace of a rim can be seen above it, separating it from the crus, as the homologue of the os orbiculare.

No stapes of this Manatee exists in the College collection; but that of *M. senegalensis*, of which there are several examples, will be shortly described. The malleus from an adult of the latter species is rather smaller than in the American kind; the upper facet is not so wide, and there is no peg-like projection internal to it. The processus muscularis is extremely stout and prominent; but the manubrium is not so broad as in *M. americanus*.

The incus of *Manatus senegalensis* very closely resembles that ossicle in the American Manatee; the processus longus is of similar form and length; the articular surface is slightly different, in accordance with the characters of that surface on the malleus of the African species; hence the upper facet is smaller, and does not overhang the inner side of the body as much, and the two lower facets gape wider than in the American species. In none of the existing Sirenia does the incus reach the size of that of the Seal (*Macrorhinus proboscideus*), where it is larger than in any other animal.

But as is the case with the malleus, so is the stapes of *Manatus* (fig. 25) largest among mammalian stapedes. It is over an inch in length, and weighs about one drachm; it is of the dense consistence of the other ossicula in this Order. In shape it differs from the stapes of *Halicore*, being over twice as long as it is wide. The head is well developed, and bears an almost circular articular surface. Both crura are long and hardly

divergent; both are crooked; but the anterior is the thinner and straighter; the posterior is very broad inferiorly, often bulging prominently just above the base. The aperture appears as an oblique slit, a quarter of an inch long from above; but on the lower aspect it is more circular: in a large specimen it is of the calibre of a darning-needle. The sides of the crura bounding it are slightly concave, but not absolutely grooved. The base is rather narrower than are the crura a little above it, but it is wider than the head; it is convex towards the vestibule; and its margin is generally rather concave above, in accordance with the form of the fenestra ovalis in this animal.

According to Claudius*, the malleus and incus of *Rhytina* closely resemble those of *Manatus*. In the work already referred to, these ossicles are figured and described; and that anatomist does not name any point in which the extinct differs from the above-named existing Sirenian as far as these bones are concerned. The inner border of the manubrium, he says, is shorter, narrower, and sharper than the outer (that is, the upper and outer surface of our description); but he does not state whether the latter is broad, with sharply defined margins, as in the Dugong, or sharp and narrow, as in the Manatee. The incus is placed, according to his account, precisely as in the existing species; and the short crus is ankylosed to the petrous bone; the processus longus is described as long and strong, though in the plate it does not appear to be longer than in *Manatus*.

Dr. Krauss† has had the good fortune of procuring and examining all three ossicula of *Halitherium schinzi*, which he figures both separate and articulated. From the letterpress and the plates it appears that the malleus is intermediate in form between the Manatee's and Dugong's. The body is figured as short antero-posteriorly, as in *Halicore*; but the manubrium is represented more of the *Manatus*-type; the articular surface though not distinctly described or figured, must, judging from the incus, be as in the latter animal; the processus gracilis is rather long, thin, and brittle. As for the incus, it is both described and figured as much more like that of *Manatus* than *Halicore*; the articular surface is represented as large as in the Manatee, and similar in its facets; moreover there is no prominent tubercle on the outer aspect of the body, backing up one of the facets, as I have observed and described in *Halicore*. The stapes is described as very similar to that of *Halicore*, "whilst that of the *Manatus* is much larger, thicker, and rounder." The illustration confirms this statement, but represents the crura as rather longer than in the Dugong; the anterior crus is much the thinner; the head is broad; and the whole bone decidedly, as far as one can judge from a plate, approaches the quadrilateral type of the larger Ruminants.

In conclusion, it may be said of the ossicula of the Sirenia:—

I. That their dense structure and clumsy form, consistent with the characters of the whole skeleton, distinguish them at a glance from their homologues in all other Orders.

II. That their modifications lie much more in their peculiar general conformation than

* Mém. Acad. Imp. des Sciences de St. Pétersbourg, 1867.

† As already quoted in the Jahrb. 1862.

in the suppression or peculiar development of any of their processes, which are so remarkable in the Cetacea.

III. Not only do they differ clearly from the Cetacean ossicula, but their modified general structure may be said to mask or obliterate any homologies to the ossicula in other mammals, which otherwise might be observable—the only exception being the approach to a quadrilateral type of stapes in *Halicore*, apparently more marked in *Halitherium*, which, whatever be its value, cannot fail to remind the anatomist of the bovine form of that ossicle.

IV. *Halicore* differs distinctly from *Manatus* in the antero-posterior shortness of the body of its malleus, in the smallness of its articular facets, in the form of its manubrium, in the tubercle on the outer and posterior aspect of the body of the incus supporting the articular surface, and in the shorter incus with more divergent crura.

V. In *Rhytina* the malleus and incus appear very like those of *Manatus*. But in *Halitherium* the characters of the ossicula are extremely intermediate—the incus being most like that of *Manatus*, the stapes like the Dugong's, and the malleus possessing features seen in both.

VI. The distinguishing feature by which *M. americanus* may be known, by its ossicula, from *M. senegalensis*, is a slight difference in the characters of the malleo-incudal articulation.

THE OSSICULA OF THE EDENTATA.

As is the case with the rest of the skeleton, the ear-bones in this Order exhibit considerable variety of type; the characters of the malleus and incus are very general; whilst the stapes assumes the Sauropsidan form in one group, and approaches it in several others.

In the two recent genera of the PHYTOPHAGA the malleus offers points of difference too marked to be overlooked. This ossicle in the Aï, or Three-toed Sloth (*Bradypus tridactylus*, Pl. LXIV. fig. 1) has a rounded, well-developed head, projecting a little upwards, but more forwards, and rather flattened laterally. The articular surface is deeply cut, the facets lying almost at right angles to one another; they are narrow horizontally; the upper is almost plane, the lower perceptibly convex; the neck is long, slender, and almost straight. By laying the malleus of *Homo* by the side of one from this Edentate, the identity of the sigmoid ridge of the former with the much less curved neck, just described, in the latter will at once become very evident. The processus gracilis forms a very acute angle with the neck, leaving a narrow space between them, homologous with the lamina, but filled up with thick and friable rather than lamellar bone. There is no trace of any processus muscularis, either on the neck or the handle. The manubrium forms an angle of over 150° with the rest of the malleus; it is of medium length, very thin, and compressed laterally, and broad at the base, where, externally, is seen a sharp angle, representing the processus brevis. The external aspect is bordered from the sides by sharp edges, as in the Carnivora, &c., but very narrow; the extremity is slightly spatulate, and perceptibly recurved.

Thus the malleus of *Bradypus* has very general characters. It cannot be considered a low type, like that of any marsupial; but its affinities are rather in the direction of Mammals undeniably higher than the Edentata, such as the higher Primates, the Ichneumons, and the Horses, not from any positive characters, but rather from the absence of salient modifications so prominent in animals much nearer to them in other respects.

The incus (Pl. LXIV. fig. 1) has a rather shallow body, with proportionally large crura. The processus brevis is very stout and rather long, sharply pointed and very divergent from the body; the processus longus is well developed and broad. I have not observed any bifurcation on its inner surface in three incudes from different individuals in the College Museum, although Hyrtl names that peculiarity in describing the incus of *Bradypus*. The Sylvian apophysis is small, but very distinct, being attached to the crus by an extremely narrow pedicle. The affinities of this ossicle are very uncertain; the stout divergent processus brevis recalls the type of medium-sized Bovidæ; but in the Sloth the incus is smaller in proportion to the malleus than is the case with the Ungulata.

The stapes in *Bradypus tridactylus* (fig. 1) is a very interesting bone, remarkable for having occasional (not constant) features which relate it very decidedly to the Didelphia and Sauropsida. In one pair belonging to the College series the head is moderately developed, the crura are stout, rather long, and but little divergent, leaving between them a narrow but very distinct aperture. In another pair in the same collection the right stapes has no aperture, whilst the left has a minute foramen between its crura. In all, the base is very broad, recalling its form and proportions in the Marsupial stapes.

Yet Hyrtl remarks (*op. cit.*), "It is most remarkable that *Bradypus tridactylus* has only one crus, which is broad; *Bradypus didactylus* (*sic*), on the other hand, has two very thick crura, which, on that account are separated by a space hardly the width of a hair. The simple crus of the stapes of *B. tridactylus* is very thin and transparent, whilst the stapes in *B. didactylus* is massive and conical." He then remarks that he has only examined the stapes of *B. tridactylus* in an embryo.

From Hyrtl's observation, and from the distinct and complete fusion of the crura in the stapes on one side only in the specimen already referred to, we see in the Aï a singular wavering between the higher and lower type of this ossicle in the Vertebrata that possess it. The intercrural aperture in none of the College specimens is as large as it is in the columella of the Golden Eagle (*Aquila chrysaetos*), so that the presence of that space must not be considered unreservedly as a tendency to higher type.

The ossicula of the Unau (*Cholæpus didactylus*) differ from the above in some respects (see Pl. LXIV. fig. 2). The head of the malleus is even more developed, and is somewhat produced forwards, as in the Hystricidæ. The articular surface is similar; the neck is rather longer, but more curved, assuming the sigmoid form of the ridge on the human malleus. The lamina is similarly represented by a narrow tract of rather thick bone. Indeed the malleus of both the Sloths is distinctly intermediate between the non-lami-

nated form of *Homo* and the broadly laminated type of the Carnivora and Artiodactyla*. The manubrium of *Cholæpus* is longer than in *Bradypus*, and forms little more than a right angle with the neck; this alone gives the whole malleus a different aspect from that of the Ai. The processus muscularis is represented by a distinct tubercle on the inner side of the root of the manubrium; the latter is even broader than in *Bradypus*.

The incus of *Cholæpus* does not differ from that of the Ai; the Sylvian apophysis is of the same character.

The stapes of the Unau has even less divergent crura than that of *Bradypus*; the aperture is either very small or quite obliterated: these two conditions may be seen in different examples in the College collection.

Turning to the ENTOMOPHAGA, the ossicula in the genus *Dasypus* are larger than in the Sloths. In the College collection all three in *Dasypus villosus* are absolutely larger than in *Bradypus*.

In the fine malleus of the 6-banded Armadillo (*Dasypus sexcinctus*, Pl. LXIV. fig. 4) the head is well formed and globular, without being produced forward or in any particular direction. The articular surface is deeply cut, the facets lying at right angles to each other; the upper is very wide and nearly plane, the lower is barely half its area and more convex. The neck is short and bent; the processus gracilis is arched towards the body of the ossicle, and then curved downwards and forwards; the space thus formed is narrow, and occupied by a true lamina of really lamellar bone. The processus muscularis is a bony tubercle on the inner side of the neck, close to the root of the handle.

The manubrium is long and straight; it forms an angle of about 140° with the neck; it is compressed laterally, but not very broad at the base. A true processus brevis exists—the angular projection at the external aspect of the base being considerably everted, and hence is not merely the simple apex of an angle formed by the upper edge of the base and the outer side of the manubrium. This outer aspect, as in *Bradypus*, is very narrow, yet distinctly bordered from the sides; the extremity is very slightly spatulate and but little recurved. In the well-formed head, decurved processus gracilis, narrow lamina, and long manubrium this malleus recalls that of the Horse (*Equus*).

The body of the incus (Pl. LXIV. fig. 4) is shallow and broad; the processus brevis (which lies much more superiorly than posteriorly) is short and sharp-pointed, it diverges very little. The processus longus is thin, long, and very divergent; the processus Sylvii is absolutely sessile, and hardly separated in the adult by any trace of a groove; but a distinct channel is to be seen in incudes from new-born Armadillos. The characters of the crura very plainly and completely divide *Dasypus* from the Sloths.

The stapes is a large bone of very light and elegant form (fig. 4). The head is long and flattened, with a small tubercle for the insertion of the stapedius. The crura are long, straight, and conspicuously slender; they are well grooved towards the aperture, which is very wide. The base is broad horizontally, but not very deep vertically; it is distinctly convex towards the vestibule.

* Refer to the remarks on the human malleus (*antèa*), particularly the description of the sigmoid ridge and its homologies.

In every respect this stapes approaches the type of the higher Mammalia, as does that ossicle in the Ant-eaters and *Orycteropus*, contrasting strongly with the Sauropsidan stapes of *Manis* and the tendencies in that direction already described in the Sloths.

In *Dasypus villosus* and *D. minutus* the ossicula are almost identical with the same in *D. sexcinctus*. The stapes in the Hairy Armadillo is even more slender than in the six-banded species; the processus muscularis is more prominent in the malleus of *D. minutus* than in the larger species.

In the Pebas Armadillo (*Tatusia peba*, Pl. LXIV. fig. 3), the ossicula resemble greatly those of *Dasypus*. The processus muscularis mallei is obsolete in the College specimens; the crura of the incus are of similar character; the stapes is of slender form with a wide aperture. I have not found the head of this ossicle to be unossified in any young or adult *Tatusia*, as Hyrtl asserts of *T. hybrida*; but that portion is readily broken off from the fragile crura. The malleus in the new-born *Tatusia* (fig. 7) has an ill-developed head and a similar manubrium to that of *Priodon* (fig. 5). It is remarkable that whilst the malleus of the adult *Tatusia* or *Dasypus* resembles that of *Equus*, the same ossicle in the young of those genera or in the adult *Priodon* reminds the observer of *Rhinoceros*. This is at least remarkable when we remember the relationship of the ossicula of the adults in some of the Ungulata to those of the young in others.

In *Priodon gigas* (Pl. LXIV. fig. 5) the malleus has a much less developed and less globular head than in the above-described Armadillos: the articular surface is of similar form; the neck is thinner, longer, and straighter. The lamina is rather wide, and prolonged a little on the strongly decurved processus gracilis, which is joined by a styloform process from the front of the head, which has its homologue in the Carnivora, Rodentia*, Ungulata, Cetacea†, and most other Orders. The processus muscularis is wanting. The manubrium forms little more than a right angle with the neck; it is much more slender than in *Dasypus*, and bent outwards on the rest of the malleus; there is no processus brevis, but, on the contrary, a very blunt projection at its site. The ill-developed head, peculiar lamina, and the form of the manubrium give it a general resemblance to the malleus of *Rhinoceros*.

The incus of *Priodon* (fig. 5) has a shorter processus brevis than in *Dasypus*; the long crus is much stouter, and has a notch or fork on its upper margin. Hyrtl has observed a similar appearance in the Sloths. The processus longus bears a distinct, sessile, and very elliptical Sylvian apophysis.

The stapes (fig. 5) has much stouter crura than in *Dasypus* or *Tatusia*, with a small intercrural aperture. The base is rather narrow; and in no wise does this ossicle bear any resemblance to that of *Bradypus* or *Manis*.

In the Three-banded Armadillo (*Tolypeutes tricinctus*, fig. 6), the malleus of the adult much resembles that of *Priodon*; but the lamina is very wide, so that the ossicle is modified from a low type in the same direction as in the Carnivora, Artiodactyla, and Muridæ. The neck remains straight, and the outer angle of the base of the manubrium

* See remarks on the malleus of the Musquash (*Fiber*).

† Description of the malleus of *Balæna, antea*.

blunt, as in the Giant Armadillo; but there is a distinct tubercular processus muscularis in the same position as in *Dasypus*.

The incus of *Tolypeutes* resembles that of *Dasypus* and *Tatusia* much more than *Priodon*, the processus longus being long, slender, straight, and very divergent.

But the stapes from the adult specimen in the College Museum is of more Sauropsidan type than in any other Edentate except *Manis*. The head is long and narrow; and the slender crura keep together till close to the foot-plate, where they diverge, leaving a small aperture between them. The base is broad vertically as well as horizontally. It is the manner of divergence just described, and not merely the smallness of the aperture, which relates this stapes of *Tolypeutes* to obviously lower forms. As *Manis* in its stapes with absolutely fused crura allies itself to *Dasypus*, *Phalangista*, *Perameles*, the Ornithodelphia, and most of the Sauropsida, so does *Tolypeutes* tend, in the character of the aperture in that ossicle, to *Macropus*, *Didelphys*, and some Birds.

In the squamate Edentata all three ossicles present positive points of peculiarity.

The malleus of *Manis dalmanii* (Pl. LXIV. fig. 8) has a large head, much flattened antero-posteriorly; the front is but slightly convex, and it does not project beyond the upper margin of the articular surface. This latter has a very prominent border, and in form is not unlike the same articular surface in Man and the Anthropoid Apes. It is placed very obliquely, so that its outer extremity* lies much higher than the inner (fig. 10); it is also divided into two facets, one superior and internal, the lower being the more external. Each presents a vertical convexity; and they slope towards each other, so that the whole articular surface appears concave when viewed laterally. But this surface is far wider in proportion to the entire head than it is in *Homo*, nor does the head in *Manis* project prominently above it as in Man; moreover the division into facets is even less distinct†. The neck is very short and curved; the lamina is of medium width, and formed of not very thin or transparent bone; there is no processus muscularis. The manubrium forms an angle of about 130° with the neck, and resembles that of *Dasypus*; a distinct processus brevis exists; the manubrium is rather broad at the base, and much flattened laterally; the extremity is distinctly recurved. The character of the articular surface and the form of the head distinguish the malleus of *Manis* alike from the same in the Sloths and the Dasypodidæ.

The incus (fig. 8) lies in the skeleton with its articular surface looking directly forwards; it is rather broader than deep in the adult *Manis dalmanii*. The postero-superior part of its body (which is really absolutely superior in *Manis*) is well developed and bulging, but not so markedly deeper than the other part of the body over the processus longus as is the case in some species of *Manis*. The crura are very short, and diverge but little; the stapedia crus bears an ill-developed elliptical Sylvian apophysis, which is pedunculated.

The stapes of the Pangolin (*Manis*) is most remarkable, being absolutely Sauropsidan;

* This is actually the *upper* extremity in *Manis*; but being the homologue of the outer in most mammals, that term is retained, as in describing a similar condition in the human malleus.

† On the subject of the facets, I must again refer to my observations on the homologies of the articular surface in the human malleus.

the head is very ill developed ; the column does not exhibit the least trace of any division into crura ; the foot-plate is almost circular, and in diameter almost equals the length of the column. A tendency to this form of the base has already been described in *Bradypus* ; and the gradations from the completely bicurrate stapes of *Dasypus*, through the form seen in *Tolypeutes*, to that in *Manis* are most instructive to observe.

In *Manis tricuspis*, *M. longicauda*, and *M. pentadactyla*, the malleus is identical in form with that of *M. dalmanii* ; but in the incus (Pl. LXIV. fig. 9) the portion of the body over the processus brevis is extremely high, so that the whole ossicle assumes a form seen in *Mycetes* and *Pithecia* ; the processus brevis is thinner and slightly more divergent than in *M. dalmanii*, though both processes are as short. The stapes has a shorter column, without any trace of division into crura, and it is absolutely shorter than the diameter of the foot-plate, which is not so circular as in the species first described.

In the Great Ant-Eater (*Myrmecophaga*, Pl. LXIV. fig. 11) the malleus has a large head, very much flattened laterally and produced forwards ; its upper portion, very wide antero-posteriorly on account of the lateral flattening, does not project at all above the level of the articular surface, which is rather deeply cut, and much wider vertically than from without inwards. The lower facet is the most concave, and is divided from the upper by a very faint groove. The neck is long and almost straight ; there is a very narrow lamina ; the manubrium forms an angle of about 150° with the neck. The handle is long and slender ; there is no processus brevis, but a very blunt angle in its place ; the extremity is very slightly spatulate and scarcely recurved. The sides are flattened, and not broad near the base ; there is no trace of any processus muscularis. This malleus of the Great Ant-eater bears a certain resemblance to that of *Priodon*, from which it may at once be distinguished by the form of the head.

The body of the incus of *Myrmecophaga* (fig. 11) is almost square, although rather broader than deep. The processus brevis is moderately long, divergent, and blunt-pointed ; the processus longus is well developed without being very stout, and bears a distinct elliptical Sylvian apophysis on a broad pedicle. The whole bone is large in proportion to the malleus.

The stapes (fig. 11) has an ill-developed head and long very slender crura, with a wide aperture between them. The base is thin, but very broad vertically as well as horizontally. Thus this bone in the Great Ant-eater approaches the type of *Dasypus* rather than *Bradypus*, *Tolypeutes*, or *Manis*. The vertical breadth of the foot-plate (that is to say, the tendency to roundness in that portion of the ossicle) is the only approach towards the Sauropsidan columella, the crura tending towards much higher types.

In *Tamandua tetradactyla* (Pl. LXIV. fig. 12) the head of the malleus, though flattened laterally, projects much more above the upper margin of the articular surface than in *Myrmecophaga*, so as to be very convex above. The neck is a little more curved, and the lamina wider ; the manubrium is very similar in form. The incus has an even squarer body ; its processus longus bears a similar Sylvian apophysis.

In *Cyclothurus didactylus* (Pl. LXIV. fig. 13) the head of the malleus is as prominent above as in *Tamandua* ; the neck is shorter, and the manubrium is much broader at the

base, than in the two larger Ant-eaters. The whole bone somewhat resembles the same ossicle in *Bradypus*. The incus has a shallow body; and the end of its stapedial crus bears a very elliptical and sessile Sylvian apophysis, so narrow vertically as to be almost rod-like. The stapes in a young specimen in the Collection has no trace of any division between the crura, and in general resembles that ossicle in the Sloths.

In the Ant Bear (*Orycteropus æthiopicus*, Pl. LXIV. fig. 14) the head of the malleus is ill-developed, the articular surface is shallow and wide vertically, both facets are but faintly convex. The neck is long and curved; it bears internally and nearly one line distance from the root of the handle a prominent tubercular processus muscularis. There is a wide and transparent lamina. The manubrium is very long, and forms a right angle with the body; it is rather broad at the base, and presents an angle corresponding to the processus brevis; the extremity is very little dilated or recurved. In the characters of the head the malleus of the Aard-vaark (*O. capensis*) resembles *Priodon*; but the greater length of the manubrium, the broad lamina, and the very distinct processus muscularis distinguish it readily from the latter.

The body of the incus is shallow; both crura are long and divergent; the Sylvian apophysis is almost obsolete, being only separated from the long crus by an indistinct groove.

The stapes has an ill-developed head, and two long slender crura bowed outwards; a thin bony lamina is spread between them below, closing the lower part of the aperture, which otherwise would be wide. The foot-plate is not very wide horizontally, and is narrow vertically. Hence the stapes of *Orycteropus*, on account of the latter feature, is of a still higher type than that of *Myrmecophaga*.

Reviewing, then, the ossicula of the Edentata as a whole, it may be asserted:—

I. That in the Bradypodidæ the characters of the malleus and incus are fairly generalized, whilst the stapes assumes to a certain extent, though never completely, Sauropsidan characters. *Choloepus* differs from *Bradypus* in the form of the malleus.

II. That in the Loricata the genera *Dasypus* and *Tatusia* present much higher characters in their ossicula than are found in *Priodon* and *Tolypeutes*. In the first two genera the stapes is of a high type, both as to its crura and its base; in *Priodon* that ossicle is more Sloth-like; in *Tolypeutes* it resembles that of the Kangaroos and other Marsupials, or even some Birds, but not the complete columelliform type of *Manis* and most Aves.

III. *Manis* has the most positive characters of interest to be found among all Edentata: the malleus is more specialized than in the other groups; the incus has peculiar though less unusual characters; and the stapes is more absolutely Sauropsidan in every respect than in any other placental mammal.

IV. In the Ant-eaters the malleus may be known from that of other Edentata by the form of its head. The stapes is of as high type, as to the free separation of its crura, as that of *Dasypus*; but the base has a tendency to assume the circular rather than oval form seen in the columella of Birds. *Cyclothurus*, in its malleus, tends more towards

Bradypus and *Dasypus* than do *Myrmecophaga* and *Tamandua*; and its stapes, in one young specimen at least, approaches much more to the Sloth type.

V. In *Orycteropus* the malleus, quite unlike that of any Ant-eater, Sloth, or Manis, approaches to a certain extent that of *Priodon*, from which it has, on the other hand, very distinctive features. The stapes is of as high a type as in *Dasypus*.

VI. That many instances are observed in this Order of the ossicula of the adults of some genera resembling those of the young of others; especially does the malleus of *Priodon* or *Tolypeutes*, however old and well developed the specimen it be removed from, remind the observer of the malleus of a new-born or foetal *Dasypus* or *Tatusia*. The highest degree of development is not necessarily seen in the largest species, as is at once evident on comparing the malleus of *Priodon gigas* with that of *Dasypus minutus*.

THE OSSICULA OF THE DIDELPHIA.

The study of the ear-bones of the Marsupials is of necessity peculiarly interesting, as it is on them that we must depend to a great extent for elucidation concerning the obscure homologies of the proximal elements of the mandibular and hyoidean arches in the Mammalia and Sauropsida. Considering how undoubtedly inferior these animals are to placental mammals, it must be clearly understood that their auditory ossicula are, on the whole, of *proportionally* high type; for though these little bones in adults of this subclass resemble, as a rule, their representatives in the foetus of many higher animals, still hardly one persistent embryonic feature observable in any Order of the Didelphia is not also to be found in many highly organized Monodelphia. Indeed, in large Orders, as the Ruminants, or smaller ones with families very specialized and different in important features from each other, as the Edentata, certain genera, as already shown, retain in a most remarkable and instructive manner characters which disappear during advance to maturity in genera closely allied to them, where the species may be either larger or of distinctly higher conformation.

Those families will first be described where the stapes has divergent crura, as this character is manifestly a high one. But it must here be remarked that the divergence is slight, and only commences a little above the base-plate; never has any Marsupial been found to possess a stapes with a wide aperture extending freely in the direction of the head as in Man, most Insectivora, and many Rodents; nor can examples be found where, as in the Cetacea, the smallness of the aperture is due rather to thickness and over-development than to non-divergence of the crura. On the other hand, the intermediate condition seen in this section of the Marsupials exists already in many monodelphous mammals, as in *Priodon*, *Tolypeutes*, and to a certain extent in *Rhinoceros* and the Marmosets, as the author has already indicated. The families where this type of stapes is found are the Macropodidæ and the Didelphyidæ.

Secondly the ossicula of those families will be described where the stapes is absolutely columelliform, without any aperture or any indication of divergence of crura. Even this still lower type is represented in higher mammals, namely in *Manis*. The stapedes of

many Cetaceans and Seals are in no way homologous with that of this section, for a reason given in the last paragraph. This group will include the remaining families of the Didelphia—to wit, the Peramelidæ, Phalangistidæ, Dasyuridæ, and Phascolomyidæ. Among the larger species in these groups a small aperture occasionally exists.

The malleus of an adult Kangaroo (*Macropus major*, Pl. LXIV. fig. 31) is of light construction, though in no wise so thin and papery as in the Bandicoots. The head is small, and only moderately developed, as in the majority of laminated mallei in the Monodelphia; though much flattened laterally, it is not broad in that sense, nor does it project in any direction beyond the articular surface. This latter is placed more superiorly than behind, as in most Edentates, owing to the position of the incus. It has a raised and prominent border; owing to the lateral flattening of the head, it is rather narrow, but deeply cut. Its facets are of the character seen in most of the higher Mammalia, and hence differ from the type of Man, Monkeys, and *Manis*. The upper or, rather, the anterior is wide and almost flat; it is twisted a little more inwards than the lower, which is narrow and convex; the groove between them is well marked. The neck is rather short and slightly curved; the lamina is very narrow. The long and slender manubrium forms a right angle (or even a few degrees less than 90°) with the neck; the site of the processus brevis is very obtuse; and the sides are compressed, though not broad even near the root; there is a distinctly bordered outer surface, as in Carnivora, Ruminants, and others, very narrow, and but slightly spatulate near the tip, which is hardly perceptibly recurved. A very slight trace of a tubercle at the junction of the neck with the root of the manubrium represents the processus muscularis.

From the front projects the remarkable processus gracilis, already well known to anatomists*. It is much longer than the manubrium, and curved downwards and backwards, and also somewhat outwards. It is attached by membrane (or, in some individuals, actually ankylosed) to the tympanic ring, and is flattened and papery in character, rather broader below than at the root, but ending in a point; near the body of the malleus it is separated from the lamina by a thin ridge; and the narrow lamina itself is prolonged on the anterior edge of the processus gracilis. The anterior part of the head of the bone is not prolonged on to the front of the lamina, as in most laminated mallei; on the contrary, it is separated from the lamina by its very high border†.

Such is the malleus of *Macropus*. Let us review its peculiarities, and compare them with those of the same ossicle in higher mammals; for the more the latter possess characters in which the Macropodian malleus differs from that of the Primates, the lower, in that respect, must such Monodelphia be considered.

In the lateral flattening and general form of the head the mallei of Carnivora and Ruminants, and other Monodelphia where the lamina is well developed, all resemble the malleus of *Macropus*; so does that of *Myrmecophaga* and *Tamandua*; only in the Ant-

* See Hyrtl, *op. cit.*; Peters, 'Berichte der Berliner Academie,' 1867; his conclusions in his paper for that year on this subject were admitted to be incorrect by himself in an article in the same publication, 1868. See also, on the latter, Huxley, Proc. Zool. Soc. 1869.

† This high border is most marked on the external aspect of the malleus. It is very distinct in all the Kangaroos and Wombats. (See Pl. LXIV. fig. 31.)

eaters just named the flattening is greater and the head itself larger. In the narrow curved neck the same animals resemble the Kangaroos rather than Man and the higher Monkeys, and differ in having a distinct neck from the Cebidæ. But as to the lamina, which is absent in *Homo* and the *Quadrumana* and *Lemures*, it is well developed in the small-headed malleus of a Carnivore or Ruminant, but ill developed, though existent, in *Macropus*. A similar degree of partial development has already been noted in some Edentata, as in *Cholæpus* or *Myrmecophaga*; and it is to be remembered that the same condition may be said to exist in *Priodon*, whilst *Tolypeutes* possesses a lamina as wide as in many Carnivora; so that the latter genus differs from *Priodon* in one way, as *Dasypus* does in a much higher direction, the head of the malleus being almost anthropoid in development. On the other hand the lamina is again suppressed in *Manis*, and the articular surface is singularly like that of *Homo*, though the head is ill developed, and the stapes of a lower type than in *Macropus*, much lower than in *Dasypus*.

From the above facts, it appears to me to be justifiable to consider that the narrow-necked and narrow-laminated type of malleus, as seen in *Macropus*, is the lowest form, which has become developed, in higher mammals, into two higher forms:—one where the lamina is more developed, as in the Carnivora; the other where the neck is stouter or even merged into the head, as in *Homo* and the *Quadrumana*. The latter form must be considered the highest, not only because it exists in Man, but also because the former, or laminated type, most resembles the Kangaroo's malleus in the form of the head, and in the neck being equally long, narrow, and slightly curved; indeed, in the very Orders where the laminated type prevails, the occasional partial or complete suppression of the characteristic lamina is often associated with an increased development of the head, and a greater stoutness or shortness of the neck, as I have already observed in *Herpestes* and *Suricata*.

On the other hand, a form of malleus exists in other Monodelphia where not only are the head, neck, and even the manubrium strikingly like the same in *Macropus*, and the lamina of like small development, but the latter is prolonged upon a well-developed process gracilis in a similar manner. This is the case in *Rhinoceros* and *Priodon*.

Hence not only is the *Macropus* type of malleus the lowest of the three, but the laminated type is clearly the second or the intermediate form, the large-headed and thick-necked form being, therefore, unquestionably the highest; indeed it is almost as much above the laminated as it is above the Macropoid variety. These observations suggest an easy test of the grade of any mammal when judged by its malleus; and, as a rule, the other ossicula agree with it.

In a young *Halmaturus*, measuring two inches without the tail, I have found the malleus of similar form; but the head is much larger in proportion to the body than in *Macropus**; the lamina is the same in character and similarly prolonged on the process gracilis.

Supposing, then, that both head and lamina, as existent in the young *Halmaturus*, remain in a comparatively arrested state of development, the adult must necessarily

* The same, it is worth recording, is the case in the malleus of the adult Phalanger (*Phalangista*).

have a malleus of the type of *Macropus*, *Priodon*, or *Rhinoceros*; let the head remain undeveloped, and the lamina take an extra growth, then the laminated type will be seen in the full-grown animal; but if the head and neck grow, they must necessarily encroach on the lamina, and the adult will have a malleus like that of Man.

The foetal malleus of *Dasypus* or *Tatusia*, very Macropoid in character, undergoes the latter change, whilst in *Tolypeutes* it grows into a laminated hammer, and in *Priodon* remains unchanged in the adult. Almost similarly the mallei of the adult *Rhinoceros* and *Equus* differ, whilst that of the foetal Horse is remarkably like the adult *Rhinoceros*'s. Again, the mallei of foetal Ruminants ultimately overshoot the latter animal in type, but do not ultimately reach the high form of *Equus*.

The incus of *Macropus* (Pl. LXIV. fig. 27) lies in a very similar position to that of many Edentates, the processus brevis being almost superior; and the stapedia crus is directed rather backwards as well as inwards. The body is very small in proportion to the crura, and deeply excavated by the articular surface. The processus brevis is stout and blunt-pointed, rather long, and little divergent from the body. The processus longus is long, and rather slender, it is not much curved, and supports a very distinct almost circular Sylvian apophysis on a narrow pedicle; altogether it more resembles the singular incus of *Perameles* than that of any Monodelphian mammal.

The stapes (figs. 27 & 42) has a small head and two slender crura united for halfway towards the base, where they suddenly diverge, leaving a distinct triangular aperture; the outline of the crura is slightly concave. There is frequently a spur-like process for the insertion of the stapedius-tendon, rather on the inner crus than on the head. The base, which projects considerably beyond the insertion of the crura, is much more nearly circular than in most placental mammals; the upper border particularly is very much curved.

All these characters are seen almost literally imitated in *Tolypeutes*. I deem it hardly necessary to waste time in showing at length how this type is intermediate between the bicurrate stapedes, with large apertures, as in *Homo*, and the columelliform type of the Ornithodelphia; still less is there any occasion to demonstrate which is the lowest, and which the intermediate form, that being seen at a glance if a Man's, a Kangaroo's, and an Echidna's stapedes be put in a row. The Macropoid type of stapes is approached, it must be remembered, in animals as high as the Marmosets.

All the ossicula of other species of *Macropus*, as well as those of *Hypsiprymnus* and *Lagorchestes*, resemble the same in *M. major*. The crura of the stapes divide in a similar manner, and the base is broad and flat; nor has it the least tendency to become bullate in the smaller Kangaroos, such as *Hypsiprymnus murinus* (Pl. LXIV. figs. 27, 28, 29, & 30).

The DIDELPHYIDÆ will now be described, as they resemble the Kangaroos in that the stapes is not completely columelliform.

The malleus of the Opossum of the United States (*Didelphys virginiana*, Pl. LXIV. fig. 15) is a little smaller than the same ossicle in a small *Hypsiprymnus*; in its characters it closely resembles that of *Macropus*. The head is ill developed, and the articular surface deeply cut, with facets of the same character as in the family just described. The neck is of the

same slender build; it is very straight until close to the manubrium, where it curves suddenly. The lamina is decidedly wider than in any Kangaroo, and prolonged upon the processus gracilis, forming a curved process applied, as in other marsupials, to the tympanic ring very closely, though readily detached from the latter even in the oldest male specimens, without the aid either of a lens or of any great skill in dissection. This process is of more regular form in *Didelphys* than in *Macropus*, being of nearly equal breadth throughout except at the extremity, which is slightly dilated. No foramen can be detected in it, as in *Erinaceus*, which possesses a somewhat similar but still more uniformly broad processus gracilis.

The manubrium is even more slender and straight than in *Macropus*; but at the outer angle of its base, the site of the processus brevis in *Homo*, it is peculiarly broad and flattened, projecting towards the neck on the outer aspect. The extremity is almost styloid; still there is a distinctly bordered though extremely narrow outer surface*, which may be seen by a magnifying glass to be slightly dilated towards the tip. This malleus may be said to be a trifle higher in type than that of the Kangaroo, exhibiting certain affinities to some Insectivora.

The incus of the Virginian Opossum has a deeper body than in the Kangaroo, with the articular surface as deeply cut; the processus brevis is thin, long, and rather divergent from the body, lying almost vertically above the latter in the recent skeleton. The processus longus is very long, and bears at its extremity a circular Sylvian apophysis on a very long peduncle, which is broad, and flattened where it joins the extremity of the apophysis†. A high development of this process is frequent among the Insectivora; but it is also seen in other families of the Marsupialia, where the peduncle is of similar form.

The stapes has a small head, sometimes bearing a tubercle for the stapedius-tendon. The slender crura diverge rather higher than in *Macropus*, so that the aperture is more distinct and more triangular. The base, which is thin and flat, projects far beyond the crura, is more oval, and hence not so deep vertically as in the Kangaroo (Pl. LXIV. figs. 15 & 41).

The stapes of *Didelphys* is certainly of a higher type than that of *Macropus* or any other marsupial, both in the greater divergence of the crura and in the characters of the base. It much resembles that of some small American Monkeys and of certain Rodents and Insectivora. Classifying the different types of stapes on the same principle upon which the mammalian malleus was classified after describing that ossicle in *Macropus*, it may be asserted that we find two extreme types:—on the one hand the stapes of *Homo*, the Simiidæ, and some Rodents (as *Arctomys*) and Insectivora‡, where the crura are freely divergent and curved with a large aperture; and on the other hand the completely columelliform stapes of the Ornithodelphia, Phalangistidæ, and Manidæ.

* See the description of the ossicula of the Carnivora, *antè*.

† This apophysis is, of necessity, very easily broken off in preparing the ossicula for anatomical observation.

‡ The stapes in these latter and clearly inferior animals has a much less-developed head than in *Homo*; and the wideness of the aperture is necessary for the transmission of a bony canal. It may be said to constitute another and a rather high type.

Between these extremes will be found:—first, the stapes with straight crura and a moderate aperture, as in the Carnivora and Muridæ, including the Cetacean form, where the opening is filled more or less by the thickness of the crura; then the stapes, with thin straight crura and a very small aperture, as in *Bradypus*; and lastly the variety seen in *Midas*, *Didelphys*, *Tolypeutes*, and *Macropus*, where the crura are fused for a considerable way from the head, diverging near the base, the separation beginning much earlier in the first two than in the last two genera just named, so that the former possess a subvariety of higher type; from this last we find examples, in several Orders, of insensible gradations towards the still higher straight-limbed type, with a free aperture, as in the Carnivora.

In *Didelphys opossum* all the ossicula are of very similar character; the lamina of the malleus is even wider; and there is a little tubercle on the inner side of the neck, representing the processus muscularis, very feebly indicated in *D. virginiana*. In both species the processus gracilis is held in a chink between two forks of the tympanic ring during lifetime, as in most of the Marsupialia.

In the remaining families of marsupials the divergence of the crura is either completely absent in the stapes or exceptional and inconstant.

In the ossicula of the Tasmanian Wolf (*Thylacinus cynocephalus*) (Pl. LXIV. fig. 17), so like a *Canis* in its external appearance, there is hardly one point to be found in which they resemble the ear-bones of a dog.

The head is very ill-developed, though not much flattened laterally, and distinctly convex upwards. The articular surface is deeply cut, with prominent margins; the lower facet is very narrow. The neck is very thin, long, and narrow, forming a very prominent humplike bend midway between the head and the handle. The lamina is very broad and prolonged upon the processus gracilis, to form with it an extremely long process, which is very narrow, except near the club-shaped, curved, and flattened extremity. The processus muscularis is indicated by a very faint elevation on the inner side of the neck. The manubrium is slender, and very similar in character to that of *Macropus**.

Altogether, even in the character of the lamina, the malleus of the Tasmanian Wolf more resembles that of certain Insectivora than that of any Carnivorous mammal.

The incus has an ill-developed body with a very short processus brevis; the stapedial crus is long and very divergent; it bears a small elliptical Sylvian apophysis on a rather long pedicle.

The stapes (figs. 17 & 43) is absolutely columelliform. The head is very small, and the column long, and rather broader near the base; there is not a vestige of an aperture. The base is wide horizontally, but shallow vertically, with the upper border well curved, contrasting with the almost circular base of the Ornithodelphia and Sauropsida, and constituting a higher type of the columelliform stapes, in that the footplate assumes the same form as is observed in the higher mammals, where that ossicle is bicurrate.

* The front and lower part of the head ends in a point, and is not prolonged on to the lamina joining the processus gracilis in the Carnivora &c. With regard to the manubrium in *Dasyurus*, consult my observations on *Myrmecobius* further on.

In the smaller species of Dasyures, as, for instance, *Dasyurus maugæi* (Pl. LXIV. fig. 16), the malleus is of very similar character to that of *Thylacinus*, though the neck is not so boldly curved, and the lamina is narrower. The incus and stapes are identical with the corresponding ossicles in the Tasmanian Wolf. Not a trace of any aperture exists in the stapes.

In *Dasyurus ursinus* the malleus has a larger and rounder head, a much narrower lamina, and, in particular, a much stouter and stronger manubrium, than in the above-described species; its sides are of considerable breadth near the root. The processus longus of the incus bears a small Sylvian apophysis on an extremely thin and fragile pedicle. The stapes is absolutely columelliform. The two inner ossicles are smaller in an adult *D. ursinus* than in a full-grown *Thylacinus*; but the malleus of the former is of nearly the same size and of more solid make than in the Tasmanian Wolf.

The malleus from a small *Phascogale* (Pl. LXIV. fig. 18) in the collection resembles that of *Dasyurus* in every respect; the lamina is wide. The processus brevis of the incus is very short; the stapedial crus bears a similar but proportionally larger Sylvian apophysis compared with the same in *Thylacinus*. The little stapes is columelliform without an aperture; the stapedius-muscle attached to it is very large, as in most of these animals.

In *Myrmecobius* the malleus is of the same light build as in the Thylacine. The head projects considerably above and in front of the lamina. The neck is very long, but not more curved than in *Dasyurus*. The lamina is as wide and smooth as in the Tasmanian Wolf, and hence more extensive than in the Dasyure and Phascogale; it joins the processus gracilis to form the usual long curved process applied to the tympanic ring. The manubrium is of the same form as in the other Dasyures; but its outer angle (which in this family is generally sharper than in the Kangaroos) is conspicuously bent outwards so as to form a genuine processus brevis. The incus has an extremely short processus brevis, a deeply cut articular surface as in other Dasyures, and a distinct Sylvian apophysis on a long pedicle. The stapes is perfectly columelliform.

Among the PHALANGISTIDÆ the malleus of *Phalangista vulpina* (Pl. LXIV. fig. 20) may be selected as a typical example. The head, though small, is better developed than in the Dasyures; and though it does not rise high above and in front of the facets, its upper surface is wide antero-posteriorly, projecting backwards over the articular surface. This latter is rather deeper cut than in the Dasyures; and the upper facet is very wide, especially vertically. The neck is rather short, but curved, the lamina rather narrow; and the processus gracilis is of equal or almost equal breadth throughout, so as to look like a curved piece of steel ribbon. This is much more like the form of that process in the Didelphyidæ than in the Dasyures. The manubrium is almost straight, and is slender and little recurved at the tip, as in the Kangaroos; the angle corresponding to the processus brevis is rather obtuse.

A notable feature in this family is the large size of the incus. In *Phalangista vulpina* it is decidedly slightly larger than in *Macropus major*, and larger than in any Dasyure, nearly twice the size, in fact, of the same ossicle in *Thylacinus*; yet the malleus of an adult Vulpine Phalanger is hardly larger than that of *Dasyurus maugæi*, where the incus

is hardly ever one third the size. The body of the incus of *P. vulpina* is well developed and not much encroached upon by the articular surface, which has well-defined edges. The processus brevis is stout and blunt-pointed; it diverges little from the body. The processus longus is long, rather straight and divergent; it bears a small pedunculated Sylvian apophysis.

The stapes in large well-formed skulls of this species has a small aperture as in *Macropus*; its base is much longer horizontally than vertically; and there is a small umbo on the centre of the base.

In *Phalangista cookii* the distinctive characters above given are still better marked. The upper part of the head is well developed in the malleus, projecting well backwards over the articular facets. The lamina is very narrow, but produced on to the processus gracilis; they together form a curved ribbon-like process of very even breadth throughout. The incus is as large and well-developed a bone as in *P. vulpina*. The stapes (Pl. LXIV. fig. 21) is most remarkable for a character already noted by Hyrtl (*l. c.*): the crura are united throughout without a trace of any aperture, forming a stout pillar, much shorter than in any other Marsupial; and the base is inflated into a large bulla projecting prominently into the vestibule. I have not found this peculiar feature in any other Phalanger; and since Hyrtl represents it precisely as it appears in a specimen recently procured from a Cook's Phalanger preserved in spirit in the store-room of the College of Surgeons, it may be concluded that the bulla is a constant feature in this species. Its morphological value does not appear to be great, as a bullate stapes occurs sporadically, so to speak, among higher mammals—for instance, in animals not closely allied to each other, such as *Mustela*, *Geomys*, and *Hyrax*.

In *Petaurus* (Pl. LXIV. fig. 22) the malleus has even still more pronounced features than in *Phalangista cookii*. The head is markedly of the form already described in *Phalangista vulpina*; the neck is shorter, and the lamina rather wider; but in the Flying Phalanger the manubrium is of stouter make in the above-described species, and in the larger species (as in the fine and typical malleus of the Taguan, *Petaurus taguanoides*, Pl. LXIV. fig. 23) it ends in a very marked spatulate dilatation*.

The incus of *Petaurus* is a large bone with similar characters to that of *Phalangista*. The stapes often has a distinct perforation, though otherwise it is columelliform; the base is much wider horizontally than vertically.

In the characters of the malleus and of the large incus, the Flying Phalangers show certain affinities to the Sciuromorphic Rodents.

In the Koala (*Phascolarctos fuscus*, Pl. LXIV. figs. 24, 34) the malleus does not possess the distinctive features so well marked in other Phalangers.

The head is very small and ill-developed, projecting little either upwards or backwards; it is not much flattened laterally; the articular surface is rather wide; and the upper facet is planer but much larger than the lower. The neck is long, thin, and curved, the lamina rather narrow; and the processus gracilis forms with it a similar process to that in *Phalangista*, but more prolonged. The manubrium presents a great peculiarity

* This dilatation is marked in *Phalangista cookii*, though the end of the manubrium is almost styiform in *P. vulpina*.

(fig. 34): it is rather broad at the base and flattened laterally, very slightly curved, and dilated at the tip; but above, at the site of the processus brevis, it is not only broad, but presents a distinct concavity; the raised margins (of which the outer appears continued from the neck), very wide apart above, almost coalesce below, but keep slightly apart towards the extremity, forming a very narrow outer surface to the manubrium *. The incus of the Koala is smaller in proportion to the malleus than in the *Phalangista*; and the processus brevis is very short and ill-developed; the stapedial crus bears a pedunculated Sylvian apophysis.

The stapes is absolutely columelliform, without any trace of an aperture; it bears a small bony process for the attachment of the stapedial tendon.

Hence in all three ossicula *Phascolarctos* exhibits characters in which it differs from *Phalangista*, and resembles rather more the majority of Marsupials.

In the Wombat (*Phascalomys vombatus*, Pl. LXIV. figs. 32, 33) the most interesting feature is the enormous development of the processus gracilis of the malleus.

The head of the malleus is even less developed and more compressed laterally than in the *Dasyuridæ*; it is much encroached upon by the articular surface, which is both deeply cut and wide; the lower facet, though more convex, is not much narrower than the upper, from which it is divided by a well-marked groove. The neck is thin and curved, as in the Kangaroos and *Dasyures*; and the lamina is narrow. The manubrium, as in most Marsupials, is slender, and forms little more than a right angle with the neck. The outer aspect of the base is very broad, though not so modified as in the Koala. The extremity of the handle is narrow but distinctly spatulate. The processus gracilis, joined by the narrow lamina, forms a curious process three times as long as the manubrium, which is closely applied to the tympanic bone, and can readily be detached from it even in the adult. At first it is narrow and almost of as even breadth as in the *Phalangers*; but its distal two thirds form a broad sabre-like or leaf-like process, sharp-edged, much flattened, and ending in a tapering point. The whole processus gracilis is only an extremely developed form of the type seen in the *Rhinoceros* and in many of the *Insectivora* and Marsupials. The foliaceous extremity is readily broken off if the specimen be not carefully prepared.

In the incus the body is fairly developed, especially above the processus brevis, though the whole bone is not so large in proportion to the malleus as in *Phalangista*. The processus brevis is rather short, but stout at the base; it diverges but little from the body. The stapedial crus is long and thin, and supports a large elliptical Sylvian apophysis on a slender pedicle. The stapes is quite columelliform; the head forms a narrow elliptical capital to the fused crura; just beneath it is a spur-like process, to which the tendon of the stapedius may be found attached in the recent or even in the imperfectly macerated skull. The base is not of the *Sauropsidan* character, being as narrow vertically as in *Homo*.

The ossicula of *P. latifrons* are very similar in character. They are all rather larger in the Wombats than in the largest *Dasyures* (such as *D. ursinus*) or *Thylacinus*.

* The blunt outer aspect of the base of the manubrium in the mallei of large *Dasyures* and other Marsupials exhibits an approach to the above-described peculiarity in the Koala.

In the PERAMELIDÆ the malleus is of light and fragile construction, although wholly osseous and not very different in character from the same ossicle in many older Marsupials (Pl. LXIV. fig. 25).

The head is very small, with a deeply cut articular surface, which has two facets, the upper and anterior being the widest and plainest of the two. The neck is long and thin; it forms, by suddenly bending on itself midway between the head and manubrium, a sharp projecting angle, as in the equally fragile malleus of the Soricidæ. The slender manubrium is rather broad and flattened at the base, and is blunt externally at the point corresponding to the processus brevis. It ends in an almost styliform extremity. The lamina is narrow, and joins the processus gracilis to form a curved process slightly broad near the tip, as in the Dasyuridæ; this is fitted into the tympanic bone as in other Marsupials.

The incus of *Perameles* has a rather high and narrow body. The processus brevis is rather long and thin, and not divergent from the body. The processus longus is thin, long, and very divergent; it ends in a very conspicuous and perfectly elliptical Sylvian apophysis, supported on a pedicle which is extremely thin at its attachment to the stapedia crus, but becomes broad and flattened before it ends in the extremity of the apophysis. This is but an extreme development of the condition so frequent in the Didelphia.

The stapes is completely columelliform; and the column is as short as in the Passerine birds; the base, too, is rather wide vertically. This ossicle is generally imperfectly ossified even in the adult Bandicoot.

In *Chaeropus* all the ossicula are of the type seen in *Perameles* (Pl. LXIV. fig. 26).

All the ear-bones of this family must be considered as of a very low type, the fragile malleus of the adult recalling that ossicle in the fœtus of higher mammals. The ill-development of the processus brevis incudis and the persistent distinct character of the Sylvian apophysis, as well as the perfectly columelliform stapes, combine to force upon the observer the conclusion that, in respect of the ossicula, the Peramelidæ are the lowest of the Didelphia; for in no other family are the little bones to be found all three so thoroughly of low development in every detail.

In concluding this review of the Ossicula of the Marsupialia, it may be said, by way of a summary:—

I. That the ear-bones in this subclass are always of a low type, yet not as a rule so inferior to those of the Monodelphia as might be inferred, judging from the rest of their skeletons.

II. That no point showing a low grade of development in any ossicle in any Marsupial is not occasionally met with in higher mammals, excepting that in the latter the ear-bones are never seen to retain to so high a degree the fœtal consistence as may be observed in the adult *Perameles*.

III. That the Bandicoots or Peramelidæ are, in respect of their ossicula, the lowest family in the whole subclass, both in the type of all three bones, and in their frail papery consistence compared with the rest of the cranium.

IV. That in the same respect the American Opossums or Didelphyidæ must be considered the highest of the Marsupials. The malleus is, in type and consistence, similar to that of many Insectivora; the incus has the body and *short* crus as well as the processus longus well developed; and the stapes is more perfectly bicurrate than in any other allied family.

V. The Macropodidæ are very central among Marsupials in their ossicula. The malleus is of low type, but tolerably firm osseous consistence; it bears the peculiar highly-developed foliaceous processus gracilis also seen in the Wombats; the incus is fairly developed; and the stapes is always partially bicurrate.

VI. The Phalangistidæ come next in order. They are decidedly inferior to the Kangaroos in that the stapes is generally (though not invariably) columelliform; moreover the malleus is of the form seen in a new-born *Macropus*; but in the size and good development of all parts of the incus they are as high or even higher than the American Opossums. *Phascogale* is lower in all respects than *Phalangista*; its malleus is of a very distinctive character.

VII. The Wombats are slightly lower than the last family, the stapes being always columelliform, and the incus having a rather short processus brevis, but a stapelial crus rather of the *Perameles* type. The malleus is not so much of high type as an extreme form of the specialized corresponding ossicle in *Macropus*, the processus gracilis being very large, curved, and flattened.

VIII. The Dasyures have the stapes invariably columelliform, and the incus of low type; but all their ossicles are of more solid consistence than in the Bandicoots (*Peramelidæ*).

THE OSSICULA OF THE MONOTREMATA.

Next to the ear-bone of Man, those of *Echidna* and *Ornithorhynchus* are of all other mammalian ossicula the best known to the anatomist. From the conformation of the base of the skull in the Monotremata, the malleus cannot fail to obtrude itself on the glance of the student cursorily examining the cranium. Then these little bones are of profound interest to the morphologist when studying this subclass, which is so undoubtedly allied in many respects to the Sauropsida, where two out of three ossicula are suppressed. Good general descriptions of the ear-bones of the Monotremata, with clear figures, are to be found in the works of Huxley *, Hyrtl †, Peters ‡, and others.

I leave such important questions as What bones are the homologues of the mammalian malleus and incus in the Sauropsida? to distinguished authorities in the united branches of morphology and embryology. Next, I need hardly remind the anatomist that, as far as the ossicles are concerned, the Monotremata wear a perfectly mammalian uniform, having malleus, incus, and stapes. If any theorist consider this Order more Sauropsidan than mammalian, on account of the most marked feature in the first two

* Proc. Zool. Soc. 1869; see woodcut, p. 404.

† *Op. cit.*

‡ "Ueber das os tympanicum und die Gehörknochen der Schnabelthiere &c." Monatsberichte der Akad. der Wissensch. Berlin, 1867.

bones, he must, for the same reason, place the Porcupines and Cavies nearly as low in the scale, and decidedly in an inferior position to the Marsupials; and as for the stapes, it is of a type precisely imitated in the placental *Manis*.

It remains for me to describe the ear-bones of this Order as I have detailed the same in higher milk-secreting vertebrata, investigating carefully their exact homologues in the former.

In *Echidna hystrix* the two outer ossicula are proportionally much larger, better developed, and more firmly osseous than in *Ornithorhynchus*. It is on that account advisable to commence with the description of the ear-bones of the so-called Porcupine Ant-eater.

Let the united malleus and incus of an *Echidna* be removed from the skull. In so doing observe that the processus brevis of the incus lies anterior as well as superior to the stapelial crus in the natural condition, an exaggeration of what is seen in the Sirenia, Marsupials, and other mammals. Even in *Homo* the short crus is almost as superior as it is posterior to the rest of the incus. Observe also, if the skull be imperfectly macerated, how large the tensor tympani muscle is, as Professor Huxley* has already remarked. Were it attached to the inner edge of the manubrium, as in the Rodents, it would require still greater care and preparation, to remove the malleus entire, than even is necessary in those animals. Now let the united malleus and incus be examined from the inner aspect (Pl. LXIV. fig. 36), and the complete outline of the incus may plainly be seen. The inner aspect of its body is free, square, and faintly concave, whilst antero-inferiorly it is limited by a convex border fitting into a concavity in the malleus. The whole, at this region, has precisely the same appearance as may be seen in articulating the incus and malleus in a Marsupial, or in any mammal where the latter ossicle has a small ill-developed head.

But view the bones from without (fig. 35), and it will then be observed that the malleus encroaches on the whole of the outer surface of the body of the incus, so that only the processus brevis (*pb*) and the tip of the processus longus (*pl*) can be seen. As it covers the greater part of the long process, on turning to the inner aspect of the ossicles the singular appearance of a lamina of bone, reflected from the outer border of the stapelial crus towards the manubrium, is at once accounted for, that lamina being simply an integral part of the malleus appearing from behind at the point where, from this aspect, the incus ceases to cover it.

Hence the incus is articulated to the malleus by its whole inner surface, including the greater part of its long crus, and also by its convex inferior border. It is firmly ankylosed to the malleus; and even in a young skull the ossicles cannot be separated uninjured without difficulty.

Bearing in mind the above remarks, the description of the malleus by itself will now be more comprehensible. The head is narrow and concave; externally it is prolonged upwards into a thin scale (Pl. LXIV. fig. 35, *shm*), of which the wide convex free border reaches to the base of the short crus, and conceals still more of the long process

* Proc. Zool. Soc. 1869, "On the Representative of the Malleus and Incus of the *Mammalia* in the *Sauropsida*."

of the incus. This scale hides the concave excavation of the head, which, on the other hand, is plainly visible from the inner aspect of the united bones (fig. 36, *hm*).

From the inner aspect, too, it may be seen that the head sends forward a long, prominent, and very straight process to join the processus gracilis *. The analogue of this is already familiar to us in most laminated and in other mallei. The neck is rather long, and not strongly curved; its free border appears from in front of the incus when the bones are viewed from within, as just described; in the opposite direction it blends insensibly with that part of the bone representing the lamina in higher mammals. From the outer aspect the neck is more clearly defined. Close to the root of the manubrium a small tubercle rises from the inner side of the neck, to which the tensor tympani muscle will be found attached in imperfectly macerated specimens. Hence this tubercle is the processus muscularis.

The manubrium of *Echidna* is of a type very frequent among the lower mammalia. It is of moderate length, compressed laterally, but not so thin and broad at the root as in some Rodents. The outer angle of its base (the site of the processus brevis, which is absent) is very blunt, broad, and well rounded; the outer aspect is very narrow, though sharply bordered from the sides, and ending in a narrow but distinct spatulate dilatation. The entire process, in slenderness, bluntness of its outer angle, &c., recalls the same in *Rhinoceros*, *Priodon*, and the Marsupials. It cannot be said to bear any close resemblance to any process of the os quadratum or any neighbouring bone in the Sauropsida.

The processus gracilis is readily distinguished, as it starts off from the malleus, forms a deep curve, and joins the process from the head, to form the long straight splinter of bone which articulates with the tympanic. This condition is well known; but anatomists hitherto have described the united part as if it were solely and entirely the processus gracilis, ignoring the process from the head, which I have frequently described in animals where it is well marked, notably in *Fiber*. Whilst this latter process, as above stated, is traced along the united portion from the inner aspect, the continuation of the processus folianus proper must be looked for in viewing the malleus from without; then it can be seen to terminate in a broad lamellar expansion, on which the process from the head loses itself posteriorly.

Between the neck and the free curved portion of the processus gracilis (and hence best seen from the outer aspect of the ossicle) the analogue of the lamina so frequent in the higher mammals may be distinguished; it is neither broad nor thin, and runs on towards the united processes, with which it blends insensibly. This, it may be remembered, is the same as in the Marsupials.

The body of the incus has already been referred to, and the free inner aspect described, as well as the manner in which it is wholly covered externally by the malleus †. The processus brevis is short and flattened extero-internally; it projects from the outer

* See Pl. LXIV. fig. 36. The process from the head (*phm*) is here distinguished from the processus gracilis (*pg*).

† Excepting its anterior edge, which is just left uncovered.

aspect above the scale-like process from the head of the malleus, which covers the body. The processus longus is not much longer than the short crus; it is straight and flattened, and wholly concealed from without by the malleus, except its extremity, which is bent inwards, and bears a very small but distinct Sylvian apophysis.

It will be seen at a glance that the kind of ankylosis between the two outer ossicula in *Echidna* is totally different from their mode of union in Porcupines and Cavies, where the malleus and incus are joined on the same level externally as internally; and, besides, there is always in the latter animals a peculiar development of the head of the malleus forwards, *away* from the incus, instead of the scale-like prolongation of the head *on to* the outer side of the latter ossicle.

The incus of *Echidna* is, after all, not so very much smaller in proportion to the malleus than in many Marsupials; only it is more flattened; flatness is also seen in the same ossicle in those Rodents where it is fused with the malleus. I have never found it to be so loosely attached to the malleus as in young skulls of the Duck-bill.

The stapes is absolutely columelliform. Its head is very small, with no trace of any tubercle for the stapedius-tendon, which does not appear to exist in this animal*. The column bears not a trace of any subdivision into crura; it is rather long, and the foot-plate is almost perfectly circular.

What relation does the stapes of this avowedly low mammal bear to the columelliform representative of the same in higher animals on one hand and in the Sauropsida on the other? Is the column of the stapes of *Echidna* formed of the same element or elements as in Aves?

By referring to the description of the stapes in the Marsupialia, it will be seen that this bone is of the same perfectly columelliform type in the Dasyures, Wombats, Bandicoots, and most Phalangers, as in the *Echidna*; and among the Edentata, *Manis* has a similar type of stapes. In some of the above animals the base of the ossicle in question is less perfectly circular than in *Echidna*, and hence more like the foot-plate of the bicurrate stapes of *Homo*. Then the column is shorter in some of these animals than in the Porcupine Ant-eater.

But it happens that all the above characters rather strengthen the alliance between Marsupials, the Manidæ, and the Monotremata, than show that those animals are particularly ornithic or reptilian.

In some birds where the column is almost as short as in these mammals, it divides distinctly into two crura, as distinctly as in *Macropus* and *Tolypeutes*. This is the case with the Nightingale (Pl. LXIV. fig. 45) and Redstart; or at least it is so in the specimens in the College collection. In others, where the column is very long, it may also divide into two crura near the foot-plate, as is very clear in the Eagle (*Aquila*, Pl. LXIV. fig. 46). Besides, the foot-plate in many Finches and other birds, and in Crocodiles and other reptiles, is not of the circular outline seen in the *Echidna*, but as long horizontally, and narrow vertically, as in the stapes of the highest mammals.

Then, without plunging into unsettled questions of development, does the column of

* Huxley. I have never seen a vestige of any representative of that muscle.

the stapes of these inferior mammals represent the same or only a part of the elements making up the column of a bird's columella?

In all these mammals we have an incus with a processus longus and Sylvian apophysis articulating with the stapes, which is columelliform; but the column is clearly identical with the two crura of the higher Mammalia, as the transitional condition seen in *Macropus* &c. clearly proves.

In birds the column of their stapes or "columella" is certainly the same, whether short (as in the Finches, Pl. LXIV. fig. 44) or very long (as in the Eagle, Albatross, &c., figs. 46, 47); for the same "extrastapedial" and "suprastapedial" elements are found attached to its outer extremity in the same manner in both varieties. But at least part of the column is recognized by the latest investigators into embryology* as the "mediostapedial" element which represents the long crus of the incus in mammals, and begins as the proximal incurved extremity of the hyoid arch in both the Mammalia and the Sauropsida.

Now, this long crus of the incus always existing in mammals, it follows, if the most advanced embryologists have not erred, that the column of the Marsupial and Monotrematan stapes (as well as that of *Manis*) represents only a *part* of the columella in Aves. It is evidently formed entirely from the mass of cells which grow from the periotic capsule to meet the proximal end of the hyoidean arch (Parker, *l. c.*); for since that end becomes the processus longus of the incus and its Sylvian apophysis in these mammals (identical with the mediostapedial element in birds), no segment of that arch can take any share in the formation of their stapes, as it is seen to do in the Sauropsida.

In examining the ear-bones of *Ornithorhynchus paradoxus*, the first thing that strikes the observer is the relatively small size of the malleus and incus compared with those bones in *Echidna*, and their imperfectly ossified semimembranous texture, in which they exceed those of any other mammal. The stapes in the Duck-bill is nearly as large as in the Porcupine Ant-eater (Pl. LXIV. fig. 37).

If the united malleus and incus of *Ornithorhynchus* be more closely investigated, it will be found that in ossicles from young skulls they may be readily disarticulated; but in specimens from the adult this is not invariably the case. Professor Peters† asserts that these bones remain free throughout life in this animal; but in a set which I prepared for the College collection, from a full-grown skull, the malleus and incus remained ankylosed on the right side.

The manner of union between these two ossicula is precisely the same as in *Echidna*. The incus is seen from the inner aspect (Pl. LXIV. fig. 38), but almost completely concealed in viewing the malleus from without (fig. 37)‡.

The portion of the malleus representing the head in higher mammals (*hm*) is ex-

* Consult summary at the end of Professor Parker's memoir "On the Structure and Development of the Skull of the Pig," Phil. Trans. 1873.

† *Loc. cit.*

‡ In Pl. LXIV. figs. 37 & 38, the same abbreviations are used as in the figures of the corresponding ossicles in *Echidna*.

tremely small; and hence the greater narrowness of the malleo-incudal articulation, as seen from within, compared with *Echidna*. But it sends up from without a scale-like process (*shm*), as in that animal, which conceals the body of the incus and the root of its long process; so that on viewing the bones from within, the same appearance of a lamina of bone, reflected from that process to the malleus, may be noted. When the incus can be detached, a smooth slightly concave space on the process from the head comes into view. This has been already figured in Peters's memoir already quoted.

From the head a very stout and straight process is sent forwards, blending with the very thin papery processus gracilis. The neck is longer, and much better defined than in *Echidna*, and forms a very wide curve. The true processus folianus is merely the slightly thickened free border of the narrow but distinct lamina; it joins the well-developed process from the head. It is only by a careful comparison of these elements in *Ornithorhynchus* with the same in laminated mallei of placental mammals that the error can be avoided of taking the process from the head for the processus gracilis*.

The processus muscularis is of a unique form. It is a wide angular projection from the inner side of the neck above the manubrium. The processus gracilis (and its adjunct just referred to) is united with the tympanic bone in the same manner as in *Echidna*. This bone is here less developed and more sharply curved than in that animal. Hence, united with the malleus, it bears a very characteristic distinctive appearance.

The manubrium is short, ill developed, and so imperfectly ossified, as to shrink when the malleus is dried. Its outer angle is blunt, very broad, and slightly concave, somewhat as in *Phascolarctos*. Its shank is very slender, and slightly dilated at the extremity; the outer aspect is excessively narrow, but distinctly bordered from the sides.

The incus is small and flattened, as in *Echidna*. Its inner surface is more concave, and narrower where it joins the malleus. The crura are short, stout, and straight, and almost of equal length; the stapedial crus bears a very faint indication of a Sylvian apophysis.

The stapes is absolutely columelliform, and not so firmly osseous as in *Echidna*; the column is rather longer, the head broader, and the almost circular footplate is not quite as large. As a processus longus of the incus exists, the column must be the exact homologue of the same in *Echidna*, and of the two crura of the stapes of the higher mammals, and, for the same reason, represents only part of the column of the Sauropsidan columella. In fact the presence of the processus longus of the incus throws the stapes of the Monotremata both towards other mammals, and away from the birds.

The result of the above considerations shows:—

1. That, in their ossicula, the Monotremata are as low as in the rest of their skeleton, yet, as might be expected, thoroughly mammalian.
2. That their distinguishing features are a peculiar form of articulation between the malleus and incus by means of a scale-like development from the head of the former, and the presence of an absolutely columelliform or unicurrate stapes. Otherwise the three ossicula are not much modified from their representatives in the lower Marsupials.

* Compare *phm* and *pg* in Pl. LXIV. figs. 36 & 38, with the same in Pl. LXIII. fig. 14.

3. That a definite incus has long been admitted to exist, articulated, as above noticed, with the malleus, and ankylosed in the *Echidna*, and generally in the adult *Ornithorhynchus*. The method of ankylosis is quite different from that seen in certain Rodents.

4. That as a processus longus of the incus exists, and hence in all probability is the proximal end of the second postoral arch, it follows that the column of the stapes of these animals (and of all other mammals where it is of similar shape) represents the two crura of the stapes of higher mammalia, but only a part of the column of the Sauropsidan columella, which is generally admitted to be formed partly from the "mediostapedial" element of the hyoid arch. But a further careful study of the embryo of these animals is necessary to settle this point otherwise than by analogy.

5. That the malleus and incus of *Ornithorhynchus* differ from those of *Echidna* in matters of detail, but in no essential features which might ally either animal more or less than the other to higher mammals or to the Sauropsida, excepting, some might say, the semimembranous consistence of the malleus of the Duck-bill.

DESCRIPTION OF THE PLATES.

PLATE LVIII.

Throughout the Plates the *left* malleus and incus are represented as viewed from the inner side, that position being the most convenient for displaying the homologous elements. The "natural position," *i. e.* that in which the manubrium of the malleus is turned towards the observer, is objectionable, because foreshortening of the ossicles interferes with a ready comparison of their various processes and relative dimensions as seen in different animals. The ossicula are enlarged 3 times natural size, unless otherwise specified. The letters used in the various figures bear the following signification:—*as*, articular surface of malleus; *n*, neck; *pb*, processus brevis; *pg*, processus gracilis; *a*, *a**, upper facet, and *b*, *b**, lower facet of malleus; *sr*, sigmoid ridge of malleus; *emn*, external surface of manubrium; *pl*, processus longus; *c*, concavity head of malleus; *eas*, extra articulating surface on malleus and incus; *gr*, groove on incus; *an*, angular projection on neck of malleus; *oa*, orbicular apophysis; *mll*, malleus; *lm*, fig. 22, Pl. LX., in error for *pm*; *pm*, processus muscularis; *hm*, head of malleus (fig. 1, Pl. LXIII., lettered wrongly for *mn*, see footnote p. 458); *pg*, processus gracilis; *l*, lamina; *phm*, process head of malleus; *acpm*, accessory processus muscularis; *mn*, manubrium; *pet*, petrous bone; *tb*, tympanic bone; *shm*, scale head of malleus; *ms*, medio-stapedial element.

Figs. 1–17. Left ossicula: 1, 2, *Homo* *; 3, *Troglodytes gorilla*; 4, *Troglodytes niger*; 5, *Simia satyrus*; 6, *Hylobates syndactylus*; 7, *Semnopithecus entellus*; 8, *Colobus satanas*; 9, *Cercopithecus cephus*; 10, *Macacus erythræus*; 11, *Cynopithecus niger*; 12, *Cynocephalus anubis*; 13, *Ateles melanochir*; 14, *Mycetes ursinus*; 15, *Cebus*; 16, *Nyctipithecus trivirgatus*; 17, *Saimaris sciurea*.

Fig. 18. Left malleus and incus: *Pithecia satanas*.

Figs. 19–22. Left ossicula: 19, *Hapale jacchus*; 20, *Midas ædipus*; 21, *Lemur albifrons*; 22, *Galago crassicaudata*.

* The remaining figures of the left ossicula show the malleus placed as in fig. 2, and the incus as in fig. 1. I had intended that the human malleus and incus should be placed together in the desired position in the same group—namely, fig. 2; but by an oversight the object was not reversed on being drawn on stone.

- Fig. 23. Left malleus and incus: *Cheirogaleus cookii*.
 Figs. 24–26. Left ossicula: 24, *Propithecus diadema* (young); 25, *Perodicticus potto*; 26, *Nycticebus tardigradus*.
 Fig. 27. Left malleus: *Arctocebus calabarensis*.
 Figs. 28, 29. Left ossicula: 28, *Tarsius spectrum* (young); 29, *Chiromys madagascariensis*.
 Figs. 30, 31. Articular surface of right malleus: 30, *Homo*; 31, *Felis*, much enlarged; *a*, *a**, upper facet; *b*, *b**, lower facet.
 Figs. 32–41. Right mallei of various Carnivora, arranged so as to show the principal distinguishing features seen in the different families, more especially the processus muscularis and the relative breadth of the outer aspect of the manubrium: *as*, articular surface of malleus; *n*, neck; *l*, lamina; *pg*, processus gracilis; *pm*, processus muscularis; *pb*, homologue of processus brevis; *emn*, external surface of manubrium:—32, *Felis leo*; 33, *Canis lupus*; 34, *Hyæna maculata*; 35, *Proteles cristatus*; 36, *Ursus maritimus*; 37, *Viverra civetta*; 38, *Herpestes ichneumon*; 39, *Gulo luscus*; 40, *Meles taxus*, showing angular projection on neck; 41, *Lycaon pictus*.
 Figs. 42–55. Left incus: 42, *Felis domestica*; 43, *Canis familiaris*; 44, *Cryptoprocta ferox*; 45, *Viverra civetta*; 46, *Paradoxurus musanga*; 47, *Herpestes pulverulentus*; 48, *Hyæna*; 49, *Ursus maritimus*; 50, *Otaria falklandica*; 51, *Ælurus fulgens*; 52, *Bassaritis astuta*; 53, *Cercoleptes caudivolvulus*; 54, *Lutra vulgaris*; 55, *Mustela erminea*.
 Figs. 56–64. Left stapes: 56, *Felis domestica*; 57, *Canis lupus*; 58, *Hyæna*; 59, *Cryptoprocta ferox*; 60, *Viverra civetta*; 61, *Herpestes pulverulentus*; 62, *Mustela erminea*; 63, *Cercoleptes caudivolvulus*; 64, *Ursus maritimus*.

PLATE LIX.

- Figs. 1–3. Left ossicula: 1, *Felis domestica*; 2, *Arctictis binturong*; 3, *Suricata zenik*.
 Fig. 4. Left malleus and incus: *Octocyon lalandii*.
 Figs. 5–12. Left ossicula: 5, *Canis familiaris*; 6, *Canis vulpes*; 7, *Martes abietum*; 8, *Ictonyx zorilla*; 9, *Lutra vulgaris**; 10, *Eupleres goudotii*; 11, *Procyon lotor*; 12, *Nasua nasica*.
 Fig. 13. Left malleus and incus: *Aonyx indigitata*.
 Figs. 13a–16. Left malleus: 13a, *Cynogale bennettii*; 14, *Cercoleptes caudivolvulus*; 15, *Bassaritis astuta*; *an*, angular projection on neck; 16, *Ælurus fulgens*.
 Figs. 17, 18. Left ossicula: 17, *Ursus ornatus*; 18, *Otaria falklandica* (*c* in this figure and in the mallei of others of the Pinnipedia, represents the concavity on the anterior surface of the head of the malleus).
 Fig. 19. Right ossicula: *Otaria falklandica*.
 Fig. 20. Left ossicula: *Otaria stelleri*.
 Fig. 21. Right ossicula: *Trichechus rosmarus*.
 Fig. 22. Left ossicula: *Trichechus rosmarus*.
 Fig. 23. Right ossicula: *Macrorhinus proboscideus*; *c*, concavity of malleus.
 Fig. 24. Left ossicula: *Macrorhinus proboscideus*.
 Fig. 25. Right ossicula: *Cystophora cristata*; *c*, concavity of malleus.
 Fig. 26. Left ossicula: *Lobodon carcinophaga*.
 Fig. 27. Right ossicula: *Phoca vitulina*; *c*, concavity of malleus.
 Fig. 28. Left ossicula: *Phoca vitulina*; *eas*, extra articulating surface on the malleus and incus; *gr*, groove on the incus.
 Figs. 29–31. Left malleus: 29, *Phoca barbata*; 30, *Phoca græntlandica*; 31, *Phoca hispida*.

* The processus muscularis was broken off in the specimen from which this figure was taken.

PLATE LX.

Fig. 1. Left malleus and incus: *Phoca vitulina* (articulated).

Figs. 2-5. Left incus: 2, *Phoca barbata*; 3, *Phoca grælandica*; 4, *Phoca hispida*; 5, *Halichærus grypus*.

Figs. 6-35. Left ossicula: 6, *Sciurus maximus*; 7, *Pteromys nitidus*; 8, *Anomalurus fraseri*; 9, *Tamias striatus*; 10, *Spermophilus citullus*; 11, *Arctomys marmotta*; 12, *Castor fiber*; 13, *Myoxus glis*; 14, *Mus decumanus* (oa, orbicular apophysis); 15, *Hapalotis mitchellii*; 16, *Hydromys chrysogaster*; 17, *Arvicola amphibius*; 18, *Fiber zibethicus* (p.h.m, process from head of malleus); 19, *Spalax typhlus*; 20, *Rhizomys badius*; 21, *Geomys bursarius*; 22, *Bathyergus maritimus*; 23, *Dipus ægyptius*; 24, *Hystrix cristata*; 25, *Cercolabes insidiosus*; 26, *Capromys pilorides*; 27, *Aulacodus swindernianus*; 28, *Octodon cumingii*; 29, *Chinchilla lanigera*; 30, *Dasyprocta aguti*; 31, *Dolichotis patagonica*; 32, *Hydrochærus capybara*; 33, *Cavia caprera*; 34, *Lepus cuniculus*; 35, *Hyrax capensis*.

Figs. 36, 37. Stapes: 36, *Elephas indicus* (adult); 37, *Elephas africanus*.

Fig. 38. Right ossicula: *Elephas indicus*.

Fig. 39. Left ossicula: *Elephas indicus*.

PLATE LXI.

Fig. 1. Left ossicula: *Rhinoceros bicornis*.

Fig. 2. Left malleus and incus: *Tapirus bairdi*.

Figs. 3, 4. Left ossicula: 3, *Equus caballus*; 4, *Hippopotamus amphibius*.

Fig. 5. Right ossicula: *Hippopotamus*.

Figs. 6-9. Left ossicula: 6, *Sus scrofa*; 7, *Dicotyles tajaçu*; 8, *Tragulus javanicus*; 9, *Lama peruana*.

Fig. 10. Right malleus: *Camelus dromedarius*.

Fig. 11. Left malleus: *Camelus dromedarius*.

Figs. 12-21. Left ossicula: 12, *Antilocapra americana*; 13, *Nanotragus montanus*; 14, *Bos taurus* (adult); 15, *Bos taurus* (foetus 6th week); 16, *Ovis aries* (adult); 17, *Ovis aries* (foetus, at birth); 18, *Gazella dorcas* (adult); 19, *Alcelaphus bubalus*; 20, *Cervus elaphus* (adult); 21, *Camelopardalis giraffa* (adult).

Figs. 22-33. Left mallei of various Ruminants* (young): 22, *Rupicapra tragus*; 23, *Saiga tartarica*; 24, *Kobus ellipsiprymnus*; 25, *Tetraceros quadricornis*; 26, *Catoblepas gnu*; 27, *Procapra picticaudata*; 28, *Cephalophus maxwellii*; 29, *Nemorhædus sumatrensis*; 30, *Nemorhedus goral*; 31, *Ovibos moschatus*; 32, *Anoa depressicornis*; 33, *Moschus moschiferus*.

Figs. 34-42. Incudes of various Ruminants (left): 34, *Rupicapra tragus*; 35, *Saiga tartarica*; 36, *Kobus ellipsiprymnus*; 37, *Tetraceros quadricornis*; 38, *Procapra picticaudata*; 39, *Cephalophus maxwellii*; 40, *Ovibos moschatus*; 41, *Anoa depressicornis*; 42, *Moschus moschiferus*.

PLATE LXII.

As many of the ossicles are here represented much magnified, a smaller figure is, in all such cases, placed to the left of the greater, the smaller being drawn on the same scale as in all the other plates, *i. e.* three times the natural size.

Fig. 1. Right ossicula of a large American *Sorex*: oa, orbicular apophysis; pb, processus brevis.

Fig. 2. Left malleus from the same *Sorex*.

Fig. 3. Left malleus: *Myogale moschata*.

Fig. 4. Right ossicula: *Myogale moschata*.

Fig. 5. Left ossicula: *Talpa europæa*.

Fig. 6. Left incus: *Scalops aquaticus*.

Fig. 7. Right malleus: *Condylura cristata*.

Fig. 8. Left malleus and incus: *Condylura*.

Fig. 9. Right malleus: *Chrysochloris capensis*.

* The laminæ were more or less mutilated in the originals from which several of the figures in this group were taken.

- Figs. 10-18. Left ossicula: 10, *Chrysochloris*; 11, *Centetes ecaudatus*; 12, *Ericulus nigrescens*; 13, *Erinaceus europæus*; 14, *Gymnura rafflesii*; 15, *Macroscelides alexandri*; 16, *Rhynchocyon cernei*; 17, *Tupaia tana*; 18, *Galeopithecus*.
- Fig. 19. Left malleus: *Petrodromus*.
- Fig. 20. Right malleus: *Asellia* (*Phyllorhina*) *tridens*; *acpm*, accessory processus muscularis.
- Fig. 21. Right malleus: *Plecotus auritus* (outer aspect).
- Fig. 22. Left ossicula: *Vespertilio nattereri*.
- Fig. 23. Right malleus: *Mormops blainvillii*.
- Fig. 24. Left malleus: *Molossus obscurus*.
- Fig. 25. Left ossicula: *Vesperugo serotinus*.
- Fig. 26. Right ossicula: *Pteropus edulis*.
- Fig. 27. Left ossicula: *Pteropus edulis*.
- Fig. 28. Left malleus: *Balæna mysticetus*.
- Fig. 29. Right incus and stapes: *Balæna mysticetus*.
- Fig. 30. Right malleus: *Balanoptera rostrata*.
- Fig. 31. Right incus and stapes: *Balanoptera rostrata*.
- Fig. 32. Left malleus: *Megaptera novæ-zelandiæ*.
- Fig. 33. Right malleus: *Neobalæna marginata*.
- Fig. 34. Left malleus, right incus and stapes: *Physeter macrocephalus*.
- Fig. 35. Left ossicula: *Hyperoodon rostratus*.

PLATE LXIII.

- Fig. 1. Left malleus and incus: *Berardius arnuxii*.
- Fig. 2. Left ossicula: *Delphinus*.
- Figs. 3-12. Right malleus: 3, *Delphinus*; 4, *Globiocephalus*; 5, *Phocæna*; 6, *Pseudorca meridionalis*; 7, *Orca*; 8, *Delphinapterus albicans*; 9, *Monodon*; 10, *Inia geoffroyii*; 11, *Lagenorhynchus*; 12, *Platanista*.
- Fig. 13. Left malleus: *Balæna australis*, *in situ* (*pet*, petrous bone; *tb*, tympanic bone).
- Fig. 14. Left malleus: *Felis*, for comparison of the homologous parts in figs. 13, 15, 16, 17, 18, &c.
- Figs. 15-17. Left malleus: 15, *Globiocephalus*; 16, *Monodon* (with tendon of tensor tympani and process from membrana tympani attached); 17, *Platanista*.
- Figs. 18, 19. Left malleus: 18, *Berardius arnuxii*; 19, *Mesoplodon* (*Oulodon*) *grayii*.
- Fig. 19a. Right malleus: *Mesoplodon grayii* (inner aspect, showing the facets, the groove for the process from the tensor tympani, and the pointed posterior extremity of the head).
- Fig. 20. Right incus: *Platanista*.
- Fig. 21. Left malleus: *Manatus americanus*.
- Fig. 22. Right malleus: ditto.
- Fig. 23. Right incus: ditto.
- Fig. 24. Left incus: ditto.
- Fig. 25. Stapes: *Manatus senegalensis*.
- Fig. 26. Left malleus: *Halicore australis*.
- Fig. 27. Right malleus: ditto.
- Fig. 28. Right incus: ditto.
- Fig. 29. Left incus: ditto.
- Fig. 30. Stapes: ditto.

PLATE LXIV.

- Figs. 1-6. Left ossicula: 1, *Bradypus tridactylus*; 2, *Cholæpus didactylus*; 3, *Tatusia peba*; 4, *Dasyurus sexcinctus*; 5, *Priodon gigas*; 6, *Tolypeutes tricinctus*.
- Fig. 7. Left malleus: *Tatusia hybrida* (new-born).
- Fig. 8. Left ossicula: *Manis dalmanii*.
- Fig. 9. Left incus: *Manis tricuspis*.
- Fig. 10. Left malleus: *Manis dalmanii*. Head, much enlarged, to show articular surface.
- Fig. 11. Left ossicula, *Myrmecophaga jubata*.
- Fig. 12. Left malleus and incus: *Tamandua tetradactyla*.
- Figs. 13-22. Left ossicula: 13, *Cyclothurus didactylus*; 14, *Orycteropus capensis*; 15, *Didelphys virginiana*; 16, *Dasyurus mauçæi*; 17, *Thylacinus cynocephalus*; 18, *Phascogale*; 19, *Myrmecobius fasciatus*; 20, *Phalangista vulpina*; 21, *Phalangista cookii*; 22, *Petaurus flaviventer*.
- Fig. 23. Left malleus: *Petaurus taguanoides*.
- Figs. 24-27. Left ossicula: 24, *Phascolarctos fuscus*; 25, *Perameles*; 26, *Chæropus castanotis*; 27, *Macropus laniger*.
- Fig. 28. Left malleus: *Halmaturus Bennettii* (in situ).
- Fig. 29. Left malleus and incus: *Lagorchestes*.
- Fig. 30. Left ossicula: *Hypsiprymnus*.
- Fig. 31. Right malleus: *Macropus major*.
- Fig. 32. Left ossicula: *Phascalomys vombatus*.
- Fig. 33. Right malleus: *Phascalomys vombatus*.
- Fig. 34. Right malleus: *Phascolarctos*, showing great width; upper portion of the manubrium.
- Fig. 35. Right malleus and incus: *Echidna* (*Tachyglossus*) *hystrix*, from without; *shm*, scale-like process from head of malleus, concealing body of incus; *pb*, *pl*, processus brevis and longus of incus.
- Fig. 36. Left malleus and incus: *Echidna*, from within; *hm*, head of malleus; *pg*, processus gracilis; *phm*, process from head of malleus, blending with processus gracilis.
- Fig. 37. Right malleus and stapes: *Ornithorhynchus paradoxus*.
- Fig. 38. Left malleus: *Ornithorhynchus*.
- Figs. 39-48. A series of stapedes of mammals, "columellæ" of Sauropsida, displaying the gradations of type in the Mammalia of the occasional reappearance of the bicurrate stapes in Aves: *ms*, medio-stapedial element in columella of Sauropsidan, equivalent, according to Professor Parker, to the processus longus of the mammalian incus.
- Figs. 39-43. STAPES: 39, of Man; 40, White Bear; 41, Virginian Opossum; 42, Great Kangaroo; 43, Tasmanian "Wolf" (*Thylacinus*).
- Figs. 44-48. Columella: 44, of House-Sparrow; 45, Nightingale; 46, Golden Eagle; 47, Wandering Albatross (*Diomedea exulans*); 48, Nilotic Crocodile (adult).

N.B. The stapes of *Homo*, 39, is drawn on the scale maintained as the rule throughout these plates; so likewise are 46, 47, and 48. The remaining stapedes are represented of the same size as fig. 39, for a better comparison of their general forms.

OSSICULA AUDITUS.
BIMANA, QUADRUMANA, LEMURIDAE & CARNIVORA.

OSSICULA AUDITÛS.
PINNIPEDIA, RODENTIA, HYRACES & PROBOSCIDA.

OSSICULA AUDITUS.
INSECTIVORA, CHIROPTERA, & CETACEA.

OSSICULA AUDITÛS.
EDENTATA, MARSUPIALIA & MONOTREMATA.