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COURSE OF LECTURES ON THE ANATOMY, PHYSIOLOGY, AND DISEASES OF THE EAR.

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LECTURE V.

BEFORE proceeding to the examination of the organ of hearing in the superior *osseous fishes*, the general statement may be made, that it presents no very obvious differences as regards the number and disposition of its parts, from that state under which we found it in the cartilaginous division. Like the latter class, the higher organised bony fishes present the auditory apparatus in a condition of comparative simplicity, composed only of semicircular canals and vestibule. The sacular projection from the *sinus communis*, constituting, according to some anatomists, the rudiments of the future cochlea, forms the transitional grade from the uncomplicated labyrinth of fishes to that of amphibia and reptiles, in which the cochlea appears.* In a preceding lecture it was incidentally observed, that Treviranus, Weber, Monro, and some others, among whom Hunter may be ranked, had positively described pouches in the skin and integument over the situation of the ear, which they conceived to stand in that relation to the labyrinthine apparatus in the cartilaginous fishes, which the fenestra ovalis occupies, in reference to the vestibule of the higher animals. But in the rays and sharks, in which they can most readily be demonstrated, the counter-opinion of Blainville, Bell, Scarpa, and Müller, that they cannot,

from their anatomical arrangement, and remoteness from the internal ear, fulfil the purposes of an auditory meatus, may be very conclusively verified. It appears the more important to impress you with a right notion upon this disputed question, since it affects a fundamental principle in acoustics, that solids offer conditions more favourable for the conduction of sound than liquids or aeriform fluids.

It has already been noticed, however, that in the skates and rays, and others of the plagiostomatous fishes, there is an elongation which projects from the inner and upper corner of the vestibule, and rises into contiguity with the common integument, covering the interval between the two eyes. The extreme end of this prolongation is supposed by some writers to represent the fenestra ovalis. Notwithstanding the apparent affinity in structure, there are objections raised by Müller, to considering this as designed to perform the part of an external communication. It is obvious, he states, from the strength and thickness of the integument of which it is composed, that the vibrations of the surrounding water could not be conveyed with any greater force through its medium than that of the cranial bones. The supposed analogous structure with which the amphibia, living for the greater portion of their existence in the water, are provided, is a moveable operculum, covered with muscles and skin, and incapable, according to the experiments and imitative contrivances of this physiologist, of assisting hearing in *water*, but calculated materially to improve it in *air*. If this be the case, it may be thought that the arrangement of this part in cartilaginous fishes cannot add much to the intensity of audition.

In *osseous* fishes there is no fenestral communication with the external surface; nor is there any trace of a vestibular opening. There are, however, one or two exceptions to this general law of structure. The information is given us on the authority of Otto and Heusinger, that in the ear of two species of the lepidoleprus, of which little is known, diverticula of the vestibule are observed to be conducted through corresponding apertures in the cranial bones into contact with

* An opinion, the incorrectness of which will be afterwards proved.

the integument. It has been remarked, that in the higher genera of cartilaginous fishes, these productions of the vestibule are so obvious, as to have been by Weber compared to external auditory canals. This unquestionable distinction between the disposition of the auditory organ in the two classes, must be associated with some equally distinct physical law.

In the soft material of which the skeleton of cartilaginous fishes is composed, it is manifest that sonorous undulations conveyed to the ear can undergo but little increase, by resonance and reflexion, from one wall of the acoustic chamber to another; additional contrivances become, therefore, necessary, to produce the perfection of hearing. In the plagiostomatous fishes this is realised in the arrangement, by which the auditory sac is prolonged into more or less immediate communication with the integument of the head. It is evident that the inferior and imperfect power of conduction enjoyed by the cartilaginous skeleton of these fishes, renders a provision necessary for bringing the internal ear into advantageous communication with the vibrating element. It is on this account, probably, that the fenestral-like prolongation of the labyrinth exists in the shark and rays. In the cyclostomatous fishes, as the myxine and lamprey, the acoustic sacculus, with its rudimentary canals, it was formerly stated, is wholly imbedded in the cranial cartilage; a circumstance which obviously renders the organ of hearing with difficulty influenced by the vibrations propagated to the body and head of the animal, and therefore explains their imperfect hearing.

In osseous fishes, however, these auditory passages are superseded by the intensity with which vibrations are communicated through the solid structures of the body. The resonant properties of bone, likewise, by the reverberation and echo which occur in the labyrinthine chamber, reinforce the sound, and consequently impress with augmented effect the auditory nerve.

It was stated in the preceding lecture, that the semicircular canals in fishes attained a considerable size, exceeding those of mammalia and man, alike in length and breadth. The external superficies, however, of the cartilaginous or osseous canals, form a very fallacious gauge for determining the admeasurements of the membranous canals. In the class of fishes the proportional dimensions of the containing and contained canals discover few variations; the diameter of the membranous being one-third that of the cartilaginous or osseous, in which they are lodged: thus leaving a very considerable interval for occupation by the labyrinthine water, or perilymph of Cotunnus. Prosecuting the examination towards the interior, it will be discovered further, that the measure of surface offered by the membranous canals externally, forms no correct index of

the capacity of the channel within, in consequence of the disproportionate thickness of their walls.

This principle of construction, by sensibly narrowing the cubic surface over which the nerve is spread, and correspondently limiting the extent and amount of the vibrating materials, obviously has for its object to subdue the intensity of the rougher undulations. In speaking of the membranous labyrinth of fishes, it should be recollected that the cochlea cannot be anatomically included; for it will be subsequently shown, that the supposition of Breschet and Cuvier, which establishes an analogy between it and the sacculus, as exhibited in the diagram of the *lophius piscatorius*, is erroneous. The cochlea is an appendage to the cartilaginous or osseous, and possesses, in its structure, nothing in common with the membranous labyrinth.

The bony labyrinth may have arrived at comparatively advanced perfection, as presented in the classes of fishes now under examination, without the formation of an unequivocal cochlea. The membranous vestibular sacs, ampullæ, and semicircular canals, continue likewise as separate elements of the auditory apparatus, in reptiles, birds, and mammalia; for in the former, as well as in the latter, the cochlea may be determined as a chamber superadded to the *osseous*, and not to the membranous labyrinth. The incorrectness of the analogy, therefore, sought to be instituted between the sacculus vestibuli of fishes, and the cochlea in its rudimentary form, is contradicted by the fact of their anatomical independence. From this it is evident that the pouch sometimes observed upon the *sinus communis canaliculi semicircularium*, or the sacculus vestibuli, or any other diverticulum of the *membranous* labyrinth, cannot represent the future cochlea, since the latter belongs to the osseous or cartilaginous labyrinth. The cochlea, and its specific organisation, will, however, be subsequently considered.

The humours of the labyrinth in fishes require separate attention. In mammalia, it is known that the chambers of the labyrinth are partitioned off in such manner as to be capable of containing two liquids, of which one occupies the interspace between the membranous and osseous canals, and the other fills the *interior* of the former. The analogy furnished us in the mechanism of the *higher ears*, has induced the supposition that in fishes, likewise, a similar arrangement must exist: the grounds of the comparison, however, are imperfect. In fishes, for the most part, the membranous labyrinth constitutes exclusively the auditory apparatus, for the cavity of the cartilaginous or osseous labyrinth communicates freely with that of the cranium, apparently removed from each other only by the intervention of the arachnoid tunic, or, in some instances, the dura mater. It is thus that anatomists have been

led to the incorrect comparison of what Breschet has denominated the *endolymph* contained in the membranous labyrinth, and the liquid of *Cotunnus*, which in the higher animals De Blainville and Breschet have called the perilymph. The anatomical construction of the ear in fishes, however, explicitly points to the encephalic liquid, as the counterpart of the perilymph of mammalia. It is an opinion, which has long been expressed by Weber and Breschet, that the lining of the cartilaginous and osseous labyrinth is derived as a prolongation from the dura mater and arachnoid; the former of whom further remarks, that even in mammalia the delicate vascular lining of the labyrinth is originally, in the earlier stages of embryonic existence, continuous with the cranial meninges.

This statement, however, must be received with caution, since it has been already observed, that the organs of sense are formed in instances in which no trace of brain is present. The lining membrane of the aqueducts of the more perfect organs, in their mode of formation, have been thought by Meckel to resemble that of the labyrinthine membrane: an account supported by Mr. W. Jones, who believes likewise that the interior of the osseous labyrinth owes its lining membrane originally to a production of the dura mater and arachnoid; which may be illustrated by the example of the processus vaginalis peritonei, when prolonged as a covering to the testicle.

Ear of the Lophius Piscatorius.

Fig. 4.

- (a) Sinus communis.
- (b) Sacculus rotundus.
- (c) Posterior canal.
- (d) Anterior canal.
- (e) External canal.
- (f) Ampullæ.
- (g) Utricle.
- (h) Nerve.

The *acoustic nerve* presents no peculiarity in its distribution in fishes, excepting that in the instances of its continuation by means of slender filaments, inwards as far as the surface of the otolithic mass. It proceeds in a separate form from the medulla oblongata,

at its posterior and inferior portion, emerging evidently by that sulcus on the lateral part of the medulla which intervenes between the olivary and restiform bodies, and which, if traced inwards, would lead into the fourth ventricle; thus corresponding, in its anatomical characters, with the portio mollis in the human subject.* In proportion as it approaches the ear, the nerve undergoes division into branches, of which some, reduced in size, proceed towards the ampullæ of the semicircular canals, the remaining being seen to spread themselves over the sacculus and vestibule.

In many fishes it is not difficult to show that delicate fibrillæ from the nerve continue inwards, to connect themselves to the calcareous otolites, by means of a groove, provided on the convex surface of these bodies. There is some ambiguity in the signification of this arrangement. Roget exemplifies the principle of its operation in the work of hearing by the clapper of a bell, to which he supposes them to perform an analogous office. The acoustic purpose of this peculiar contrivance, however, is rendered still more obvious, by an experiment of great simplicity performed by Camper: he filled a small bag with water, and placed within it a small globular body, which, of course, from its unattached freedom, was capable of rolling in any direction, according to the force of an external impulse. Sustaining the apparatus in the hand, he found that the slightest agitation given to the bladder was *repeatedly* felt by the reaction of the body within. The vibrations, then, of these masses existing in the ear of fishes, probably augment the intensity of hearing not so much by reverberating from wall to wall in the labyrinthine cavity, as by direct propagation along the filaments of the auditory nerve attached to the surface of the vibrating body. The masses of *calcareous matter* contained in the interior of the labyrinth, surrounded by the endolymph, of which we have spoken, according to some, are discoverable in all classes of animals, from the vestibular ear of crustacea and fishes, to that of the human subject. These cretaceous substances amount, for the most part, to *three* in number, and are found within the vestibular sacs, and its communicating smaller sacculi. In density they present variations according to the class of fishes in which they are examined. In the cartilaginous, as formerly stated, they assume a pulverulent, and sometimes crystalline, appearance, and are soft and pulpy in consistence.

In the osseous fishes they acquire a petrous density proportionate to the perfection of the ossific structure of the animal's skeleton, that is, the more complete the transformation of the cartilaginous into the bony skeleton in the series, the greater the density of these

* See diagram.

otoliths. In figure and size they also vary, according to the species. In some, as the *salmon*, they are incurvated like the valve of a shell. The chemical constitution of these substances, as conveyed by the terms, calcareous and osseous, so frequently employed, appears to be made up of common components; differing from that of ordinary bone in the proportion of phosphate of lime, which in these bodies is small. The analyses of Huschke and Barruel determine their ingredients to be, carbonate and phosphate of lime and mucus, in addition to which a little animal matter was made out. These concretions, when discovered in the semicircular canals, are confined to the ampullæ. In fishes it is plainly shown, by the accompanying sketch of the labyrinth and otocories,* that the proper situations for the lodgment of the latter are the common sacculus, the utriculus of the sinus canalium communis, and the pouch of the vestibular sac called the cysticule. With these situations

Membranous Canals of Lophius Piscatorius.
Fig. 5.

- (a) Ampullæ.
- (c) Cysticule.
- (s) Sacculus rotundus.
- (n) Branches of nerves.
- (o, o, o) Otoliths shown in outline by dotted lines.

a coincident disposition of the branches of the nerve is remarked, a considerable division being implanted on the external surface at points corresponding to the resting-places of these otolithic masses. The error has been committed of comparing these substances in acoustic properties to the tympanic ossicula. From the peculiar principle of adjustment, however, evinced in these delicate elements of the auditory apparatus, floating as hydrostatic balances in the humour of the cavity, they are admirably calculated to reinforce the sonorous undulations within the acoustic chamber. The office of the tympanic chain of bones, is the conduction of the sonorous undulations from the external to the internal ear.

It is to Professor Weber that we are indebted for the discovery of a *communication between the air-bladder and the labyrinth* in

bony fishes. From this statement it is not to be inferred, however, that the aeriform contents of the swim-bladder have a free and undivided communication with the cavity and contents of the labyrinth. This, indeed, were to make grounds for the revival of an exploded and antique *theory* of audition, propounded and recognised in the days of Fallopius, Eustachius, and Duverney; according to which the faculty of hearing was dependent upon the agitations of some occult principle, or subtle and innate air, *aer ingenitus*, that pervaded the various windings of the labyrinth. Diogenes, and even the observant Aristotle, gave their admission to the existence of this *aer ingenitus*; and it was not until the more enlightened labours of Dominico Cotugno that the precise mechanism of the labyrinthine chambers, with their separate humours, was conclusively shown.*

The orders of animals to which our ascensive method of study leads us next to examine, are the *Amphibia* and *Reptiles*.

* [The connection which exists between the air-bladder and the ear is established, in the greater number of instances, by the intermedium of a chain of small bones. This bony junction is seen in all the species of the genus *cyprinus* or carp; in the *silurus*, including some electric varieties; and likewise in the *cobitis fossilis*, or loache. In these examples the communication is established by means of a series of ossicula, articulated, according to Weber, with the three first vertebræ, and in contact posteriorly with the air-bladder. They are so definitely arranged between the labyrinthine membrane at one extremity, and the air-bladder at the other, as to have suggested a comparison between them and the tympanic ossicles of mammalia. The analogy has been extended into the supposition, that the air-bladder performs the same part to the ear of these fishes, with that which, in the higher animals, devolves upon the membrane of the tympanum. The first vertebra is situate in close approximation to the ear, and presents on its transverse process a foramen or sinus, in which the ossicle, corresponding to the stapes in mammalia, is lodged; the malleus, at the other extreme of the chain, being in contact with the air-bag. In other fishes, however, the communication between the auditory organ and the air-bladder is accomplished without the intermedium of bones. The herring presents us with an example, in which the bladder is prolonged anteriorly into a tubular sac which bifurcates, and extends into contact with the labyrinth through appropriate apertures in the occipital bone. In some genera of fishes, the connection is established indirectly through the intervention of the encephalic liquid. Other differences are found in the mode in which the ear is made to communicate with the air-bladder.—T. WILLIAMS.]

* ὠτος, auris; κορυς, pulvis.