ON THE STRUCTURE OF THE EEL'S SKULL

THE skull of the Eel is much less specialised than that of most other Osseous (*Teleostean*) fishes. I was made aware of this many years since whilst preparing skeletons of the common kind (*Anguilla acutirostris*), and of the conger (*Muræna conger*). Afterwards, when Prof. Huxley's "Croonian Lectures" (Proc. Roy. Soc.) came into my hands, the importance of the aberrant structures of this type of skull was shown to me; and since that time I have been on the watch for further opportunities for dissecting and working out both this type, and also that of the Amphibia, which it serves to illustrate. In a few weeks' time I shall be able to make myself understood with regard to those morphological changes which take place in the vertebrate skull as it passes from a low Ichthyic into the higher Amphibian type. This will be done by the illustration and description of the frog's skull in the forthcoming part of the "Philosophical Transactions," an abstract of which paper has already appeared in these columns. At present the nomenclature of the parts of the cranium and face of the fish is in a state of painful confusion. I shall not, however, trouble the student with confusing references, but continue to use those terms which he will find in my other morphological papers. I may, however, remark that these differ in some instances from those used by Professor Huxley, for instance, his "squamosal" is my "pterotic" (see "Elem. Comp. Anat.," p. 188). This is a bone called "mastoid" by Cuvier, and this term was adopted by Prof. Owen. These anatomists came much nearer the truth than my friend; but the bone only represents *part* of the human "mastoid"—its antero-superior region. Again, the terms for the palato-pterygoid arcade are very confusing; Cuvier's "internal pterygoid," also called ento-pterygoid by Owen and Huxley, does not correspond to the internal pterygoid plate of man and the mammalia generally, but to a third piece, which I call meso-pterygoid, and which occurs in a young pig's and in a young fox's skull in my collection; I have also found it in the palate of all sorts of birds, except the fowls and Struthionidæ. The true representative of the human internal pterygoid is, in fishes, called "transverse" by Cuvier; most correctly the "pterygoid" by Owen; confusingly the "ecto-pterygoid" by Huxley. I drop the frequently misapplied terms, "ecto-" and "ento-pterygoid," altogether, and call the true "transverse bone" of the reptile—never seen in fishes—the "transpalatine." Most of the other terms used by me agree with those used by Prof. Huxley in his "Elements."

There is, however, in the hyoid arch one segment which requires its name,—that given to it by Prof. Owen—to be changed; I refer to that lump of cartilage which becomes segmented off from the lower part of the hyoid cornu by a joint cavity, and which has two ossific centres. This has been called the "basi-hyal;" but it is merely a distal and not a basal bone, the key-stone being the "glosso-hyal," which passes into the basi-branchial bar. I would call it the "hypo-hyal," as it is the manifest "serial homologue" of the "hypo-branchials." All these things I hope soon to make plain in a paper now in hand, on the "Structure and Development of the Salmon's Skull." My materials at hand, from which I have studied the eel's skull, are the adult conger's skull, that of a small *Muræna* (? species), and the heads of large and small common eels. The smallest of these are the gift of Mr. F. Buckland; they measure 2 inches 8 lines in length. The cranium of the eel is long, triangular, and depressed, the nasal region being very pinched and narrow, whilst the occipital is expanded, and sends out over-hanging outgrowths, — backwardly projecting crests, which are continuous in the conger, but distinct spurs in the eel.

These crests in the eel are formed by the super-occipital at the mid-line; then a pair from the epiotics; and below, and external to these a bilobate pair, belonging largely to the pterotics, but also to the ex-occipitals.

The flat top of the skull, up to the exit of the fifth nerve, is square, the top of the cranium then narrows suddenly to half the breadth of the square part.

On each side, there is, in the broad part of the skull, a large overhanging eave, below which is the double recess which forms the glenoid cavities for the hyo-mandibular. If the large parietals which meet at the mid-line were removed, we should see the "great upper fontanelle," bounded behind by the perfected occipital arch, and laterally by the cranial and auditory elements. Indeed, the term cranio-auditory elements would be a correct term for several of these bones, the auditory capsule coalescing very early with the rising crests of the investing mass, and the subsequent ossifications enclosing both the sense-capsule and the membranous cranium. Behind, the expanded occipital region is largely indebted to the "epiotics," and "pterotics," two pairs of which bones are really primarily related to the cartilaginous auditory sac. There is no opisthotic, and the large "pro-otic" is surmounted by a part of the posterior sphenoid, which is to be found in the bird, but not in the reptile or mammal. I allude to the post-frontal, a great outstanding projection from the "ala magna," a crested, fore-turned, supero-lateral element of the primordial skull. In front of the "foramen ovale," the "ali sphenoids" wall-in the skull; they are unusually large for an osseous fish; they rest upon an inverted "saddle" of bone, with a free fore-edge. This is the fish's basi-sphenoid, and corresponds to the pre-pituitary part of the human basi-sphenoid, and to its anterior clinoid region. In high-skulled fishes this bone is Y-shaped, the descent of its long crus showing that the "meso-cephalic flexure" of the embryo is never wholly recovered from in these fishes; and its slender size showing that the connective band which brought the investing mass into union with the "trabeculæ cranii," was a feeble strip of cartilage. Behind the saddled-shaped basi-sphenoid of the eel is the open pituitary space, which, as in birds, is merely closed below by the ossification of sub-mucous fibrous tissue, in the form of the para-sphenoid. The large basi-occipital, which encloses all the retiring notochord that belongs to the skull, helps to form an elegant tri-radiate synchondrosis in the floor of the skull; for all that part of the "investing mass" from which the notochord had retired, is invested, not by a basi-sphenoidal ossification, but by the huge "pro-otics" which meet at the mid-line, behind the open pituitary space. The structures of the skull that have morphological continuity with the vertebral column cease behind the optic nerves, and even the parts surrounding the pituitary body are of a secondary or connective character, bringing the true cranial structures into fusion with parts derived from the first or pre-stomal facial arch, the trabeculæ cranii. Now there comes in a most important condition of the skull of the eel; for the anterior sphenoidal region has no cartilaginous walls whatever; the roof is formed by the narrow frontals (frontal in the conger); the side walls are membranous, and the floor is that sub-mucous bone the para-sphenoid. In young eels, 5 in. long, the trabeculæ may be traced to their union with the "investing mass" in the pre-pituitary region; but there they unite with each other, and in the anterior sphenoidal region, instead of turning upwards to form a skull floor, they grow downwards, investing the convex upper face of the para-sphenoid (see Fig. B). Over the optic region the *pterotics* overlap, in the conger they nearly reach as far as the hinder end of the bony ethmoid; and here the frontal sends out a few post-orbital snags, and sends downwards on each side a thick post-orbital process, which articulates with the ali-sphenoid. At this part the narrow skull bends downwards in a Roman-nosed manner. The solid nasal region in front is of equal length with the long membranous interorbital space; these are separated by the large, thick,

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ear-shaped unossified pre-frontals, or lateral ethmoids. The median ethmoid is ossified entirely by the thick, bony bar, which commences as a knife-shaped vertical plate, or parostosis; here in the eel as in the Amphibia, the distinction between parostosis and endostosis at times breaks down. The long tooth-bearing vomer splits the parasphenoid with its long style, as far back as the pituitary space; it coalesces with the ethmoid when the eel is five or six inches in length. Where the bony ethmoid and vomer unite there is a groove; along this the olfactory crus runs, protected outside by the grooved, soft, lateral, ethmoidal wing, which arose as an outgrowth of the trabecular bar; the "cornua" of the trabeculæ (Fig. C) persist as filiform prolongations, continuous with the lateral ethmoids behind, and end in blunt points near the fore part of the ethmo-vomerine bony mass. In the conger, but not in the eel, the vomer sends out a wing on each side for the lateral ethmoids to rest upon. The parasphenoid is very deeply split at both ends, both for the vomer and the basi-occipital; it has large wings in the basi-temporal region, which underlie, in a squamose manner, the lower edge of the prootics. These latter bones divide the foramen ovale; behind and below the posterior opening there is a small passage evidently the distinct foramen for the "portio dura." The vomer and parasphenoid are azygous splints applied to the under surface of the coalesced and metamorphosed trabecular bars.

When the membranous cranium dips downwards in front (mesocephalic flexure) then the trabeculæ are not only parallel with the base of the first cerebral vesicle, but also nearly so with their immediate successors, the mandibular bars; whilst thus contiguous they form a *secondary connection*, which, of course, lengthens as the trabeculæ ascend with the cranial sac, and thus enlarge the mouth cavity. This bar is well chondrified in fishes

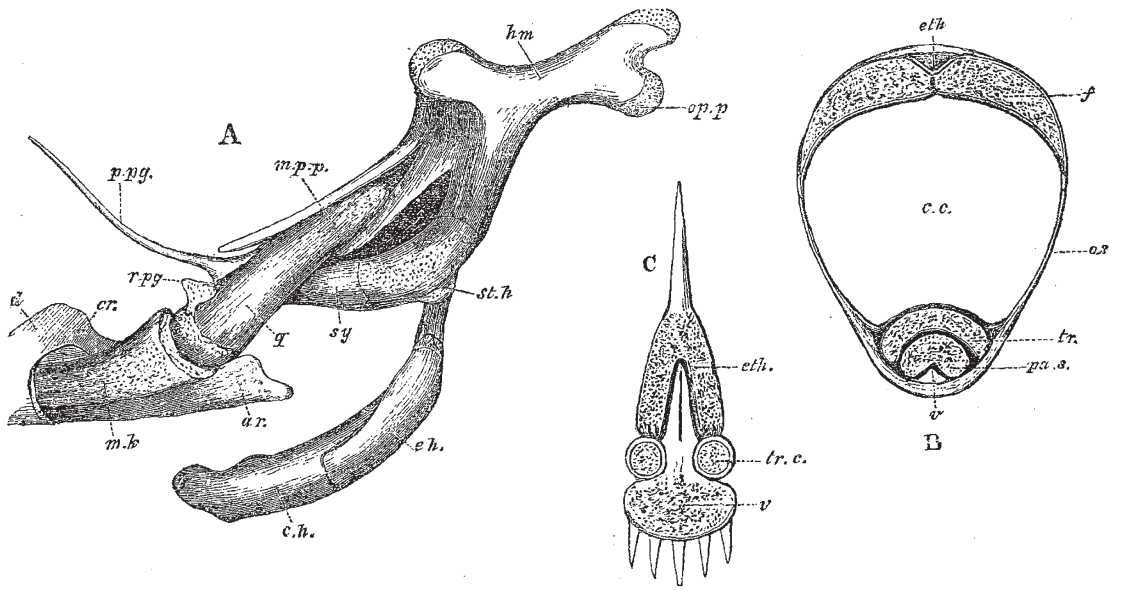

FIG. A.—INNER VIEW OF MANDIBULAR AND HYOID ARCHES OF A YOUNG EEL, 2⅜ inches long: *r.pg.* rudiment of cartilaginous pterygoid; *p.pg.* pterygo-palatine; *q.* quadratum; *ar.* articulare; *d.* dentary; *cr.* coronoid; *mk.* Meckel's cartilage; *hm.* hyo mandibular; *sy.* symplectic; *st.h.* stylo-hyal; *e.h.* epi-hyal; *c.h.* cerato-hyal; *op.p.* opercular process; *mp.p.* metapterygoid process.

FIG. B.—SECTION OF ANTERIOR SPHENOIDAL REGION IN A YOUNG EEL, 5 inches long: *eth.* ethnoid; *f.* frontal; *o.s.* orbito-sphenoidal region; *tr.* trabeculæ: *pa.s.* parasphenoid; *v.* vomer; *c. c.* cranial cavity.

FIG. C.—SECTION THROUGH THE NASAL REGION OF THE SKULL OF A YOUNG EEL, 5 inches long: *eth.* ethnoid; *v.* vomer; *tr. c.* trabecular cornu.

All the figures are magnified about 25 diameters.

generally, and in the tailless Amphibia. In the tailed Amphibia it is abortively developed, and no solid hyaline cartilage is found in this part in Sauropsida and Mammals. (See "On Skull of Fowl," Phil. Trans., 1869, pl. 81, figs. 1, 3, 6, 10, and 11, p. 767.)

The eel also has no solid cartilage in this bar, save a slight rudiment behind, as in the "Urodela" (Fig. A), and the three ectostal plates that invest the large cartilaginous bar in most osseous fishes—the palatine, meso-pterygoid, and pterygoid—are represented by a needle-like, solid style of bone, pointed in front, and pedate behind where it attaches itself to the inside of the front edge of the quadrate. In old eels this style becomes a flattened bar, articulating by a squamose suture with the quadrate, and loosely attached to the lateral ethmoid and the maxillary in front. This bone is the counterpart of the single plate in the Lepidosiren's mouth (see Huxley's Elem., Figs. 84 and 85, D, pp. 208, 209); but the pterygo-palatine of that fish is applied to a thick cartilaginous connective that fills in the whole sub-ocular region. As in the Lepidosiren and the Amphibia, tailed and tailless, the eel has only one ossification on the pier of the mandibular arch, and the generalised nature of the fish is shown in the partial coalescence which takes place between this and the succeeding (hyoid) pier. In the Lepidosiren, as in the Chimæra, the coalescence is entire between all but the free segmented rays of the first and second post-stomal arches; in the Urodelæ we have a similar state of things, but in the Anoura coalescence only takes place in the lower half of the pier. In all these it is cartilaginous confluence, but in the eel it is merely the anchylosis of the bony symlectic (Fig. A, *sy.*, *q.*) with the quadrate. Although there is no metapterygoid perched upon the quadrate, yet that element sends upwards a meta-pterygoid process which runs between and within two large denticulations of the hyo-mandibular. This latter bone (*hm.*) is very massive, and being most strongly united both by synchondrosis and deeply serrated suture to the quadrate, the suspensorium of the eel is exceedingly strong, quite as strong as, and more elastic than,

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the quadrate of the Sauropsida. It forms an acute angle with the basi-cranial line, as in most other fishes, but in *Muræna helena* (see Huxley, Croon. Lect., p. 34, and Osteol. Catal. Mus. Coll. Surg., vol. i., p. 14), the suspensorium is very frog-like, forming an obtuse angle. The well-developed heads of the hyo-mandibular fit into proper glenoid cavities, the foremost of which is made in the post-frontal and pro-otic, and the hinder pit is in the pterotic. The knob for the opercular is very large in the adult, and in eels five or six inches long the only sign of the separateness of the symplectic is the transverse cartilaginous tract which connects it with the hyo-mandibular; but in my youngest specimen it can be seen separate, with its own ectosteal sheath (Fig. A, *sy.*); it is very short, and the cartilaginous interspace above is very large. From the middle of that synchondrosis there arises a small semi-segmented bud of cartilage, the "stylo-hyal" (*st. h.*); this becomes ligamentous in the adult; in other Teleostei it forms a rather small cylinder, completely segmented off, and it acquires a bony sheath. The rest of the descending hyoid cornu is a thickish arcuate rod of cartilage ossified by two ectosteal sheaths, the "epi"- and "cerato-hyals." In Teleostei generally, the distal end is cut off by a joint cavity, and ossifies from two more ossicles, forming the "hypo-hyal" segment; this structure is not attained in the less specialised eel. The arch is finished by a long and stout glosso-hyal. Even the free bar of the first post-stomal arch—the mandible—has its peculiarities, for, contrary to rule, it has no angular splint—and the "coronoid," so seldom present in Teleostei, and so constant in Sauropsida, is well developed in the eel; it is very small in old individuals of the cod-fish. The dentary alone is dentigerous, and is very large and strong, with a large coronoid process; the "articulare" is short and massive. In the upper part of the face the specialised subcutaneous bones (*parastoses*) are very instructive; several belong to the lateral-line series, but, modified and broken up into two rows in the head, they form tubular mucous bones; these are the nasals and "sub"- and "pre-orbitals." Another facial series, which may run obliquely from the snout to the hinge of the lower jaw, has only two on each side,—the pre-maxillary and maxillary. Here we have, contrary to rule, the short pre-maxillary edentulous and the maxillary bearing teeth. The specialised bones of the back-face and throat are worth mention; the pre-opercular is oblong, twisted, strongly convexo-concave, and burrowed by mucous glands. The opercular fits by a deep cup to the knob on the hyo-mandibular; like the feebler sub-opercular, it is strongly falcate; the latter fits by a sliding joint to the pedate upper end of the wedge-shaped large inter-opercular. The long, thick-based, slender-pointed "branchiostegals" are eleven in number on each side in the common eel; the basal bone of this wondrously specialised series of dermal bones is the so-called "uro-hyal;" it is knife-shaped behind, and in front terminates in a massive head, facetted for the cerato-hyals. I call this bone the "basi-branchiostegal;" for the "uro-hyal" of the bird is the remnant of the basi-branchial bar. The student can easily obtain both the gigantic conger and the larger specimens of the common eel, and, having become familiar with the parts of the skull and face of such an ordinary teleostean as the cod, and of the larger amphibian types, both tailed and tailless, he will then be able to gain a much clearer idea of the fundamental harmony existing between such diverse types, if this intermediate eel-type be once well understood.

The development of the skull in the culminating amphibian, the frog, has yielded me already such satisfactory results that I am somewhat restless to know the early conditions of that of the fish: then whole groups of low vertebrate types will begin to be seen in harmonious relation.

W. K. PARKER

NOTES

THE following is a list of the Presidents of Sections nominated by the Council of the British Association for the approaching meeting at Edinburgh:—Section A, Prof. P. G. Tait, of Edinburgh; Section B, Dr. Andrews, of Belfast; Section C, Prof. Geikie; Section D, Prof. Allen Thomson; Section E, Alex. Keith Johnston, sen.; Section F, Lord Neaves; Section G, Prof. Fleeming Jenkin. The Evening Discourses will be delivered by Prof. Abel and Mr. E. B. Tylor.

IT is stated that the labours of the Royal Commission on Coal, appointed a few years ago by Sir George Grey, are on the point of completion, and the result is the demonstration of the fact that, assuming a certain annual increase in the rate of consumption, sufficient economically gettable coal exists in Great Britain and Ireland to last from 800 to 1,000 years. We shall be very glad to see such an important fact demonstrated.

WE have to record the death of Mr. George Grote, Vice-Chancellor of the University of London, whose serious illness we mentioned a fortnight since. He died on Sunday last, after a long illness, in his seventy-seventh year. We can ill afford to lose men who have so long and so ably thrown their influence and their abilities into the cause of the higher education of all classes of the community.

WE regret to announce that Mr. Numa Edward Hartog, Senior Wrangler of the University of Cambridge in 1869, died on Monday last of smallpox. Mr. Hartog was still, in common with other Nonconformists, excluded from the substantial reward of his exertions; but in the present Session he gave important evidence before the Lords' Committee on University Tests, and it is due perhaps to the sympathy which his exclusion excited that the Lords proposed a measure which would have admitted him to a Trinity Fellowship. Before, however, he could take advantage of the passing of the University Tests Bill the man who was expected to be the first to reap its fruits had passed away.

AT the recent examination for the newly-established Diploma in State Medicine given by the University of Dublin, the first place was taken by Mr. J. W. Moore, ex-scholar Trinity College, Dublin; the second by Dr. A. W. Foot, Junior Physician to the Meath Hospital and County of Dublin Infirmary; the third by Mr. Yeo, who obtained the Junior Medical Exhibition in 1864, and the Senior Medical Exhibition in 1866; and the fourth by Mr. Todhunter, a gentleman already well known in certain circles for his literary abilities.

THE new museum and library at Clifton College were inaugurated on Saturday last by a *conversazione*. There was a good collection of objects of interest contributed by gentlemen of the neighbourhood; some music, and a speech from the Rev. Principal of the College, interested the large company, and Prof. Church delivered an address on "Colour."

THE new buildings of St. Thomas's Hospital on the southern Thames Embankment, opposite the Houses of Parliament, were opened yesterday by the Queen in person.

THE Victoria Institute concluded its fifth session on Monday. Its members are now 305 in number, seventy having joined since February; the papers for the coming session include two on subjects connected with the vegetable kingdom.

THE managers of the London Institution, in accordance with the recommendation of the annual meeting of proprietors, have resolved to afford opportunities during the ensuing season for the reading and discussion of papers on subjects of special interest in science, literature, commerce, and the arts, provided they receive such offers as will insure a succession of suitable communications. It is believed that this proposed extension of the use of the Lecture Theatre in Finsbury Circus will produce a series of attractive meetings similar in character to those of the Society of

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