this delicate tapestry has been hanging and growing, and breaking and growing again, quietly in darkness, beneath the grind of our carriage wheels, and yet high in air, with the stream of human life flowing underneath it too. Alike in the pendant stalks, on the walls, and in the mounds on the floor, the prevailing colour of the crystalline incrustation is pure white. These caves in middle air have been shut up from the contamination from town smoke. Now and then, however, the dripping water has come upon soluble iron as well as lime. Hence the mounds on the floor are sometimes curiously coloured yellow, brown, and red.

"As the bridge is built of sandstone, wholly or almost wholly free from lime, it is evident that the material which has converted these vaults into such picturesque caverns has been derived from the mortar. All rain-water, as is well known, takes up a little carbonic acid from the air, and of that acid there is in the air of a town usually more than the normal proportion. Filtering through the masonry, it dissolves the lime, carrying it downward in solution, and, if made to halt and evaporate, depositing it again in the form of the white crystalline substance which we call spar. It would be a curious question for the architect how long his masonry could resist this action. Certainly, in spite of what these vaults in the North Bridge reveal, the masonry of that structure is to all appearance as solid and firm as ever. It is evidently impossible, however, that the mortar, if necessary at all, can be piecemeal removed without in the end causing the destruction of a building."

REPORT OF PROF. PARKER'S HUNTERIAN LECTURES "ON THE STRUCTURE AND DEVELOPMENT OF THE VERTEBRATE SKULL" *

III.

IN the types already considered, the exo-skeleton consists of small placoid scales having the structure of teeth, and imbedded in the skin, but being altogether irrelative to the true cartilaginous endo-skeleton. In the group of fishes which form so perfect a mean between these Elamobranchs and the osseous fish—the Ganoids—the body is covered with close-set "ganoid" scales, which consist of two layers, a deeper one of bone (dermostosis), and a superficial one of enamel, covered only by a thin layer of epidermis. In the head these scales pass insensibly into a set of bones in close relation with the chondro-cranium, and having the connections, positions, &c. which characterise the roofing-bones of one of the higher skulls (parietals, frontals, nasals, &c.). In many cases these bones are so deeply imbedded in the subcutaneous tissue as to deserve the name rather of parostoses than of dermostoses, but are always easily removed by maceration or boiling. They are evidently of an entirely different nature to another series found in the same skulls, but in intimate connection with the cartilage, and only separable by its entire destruction. These last are ossifications of the chondro-cranium, and are often spoken of as "cartilage-bones;" the former kind have only a secondary relation to the primordial skull, and are known as "membrane-bones."

In the osseous fish both these varieties of bone appear, but the investing or membrane-bones are all true parostoses developed in the deeper subcutaneous tissue, and the place of the ganoid dermostoses is taken by cycloid or ctenoid scales. Still the insensible gradation between scales and skull-bones is very apparent: along the side of the trunk passes a series of curious tubular or grooved bones containing mucous glands and known as the "lateral line series;" these, on reaching the head, branch out so as to produce a tree-like arrangement instead of a single row, and the burrowing is now, not in a set of modified scales, but in true cranial bones, some belonging to the opercular apparatus, some to the series above and below the eye.

IV.—*Skull of the Salmon* (Salmo salar).—In the Teleostean the investing bones attain a greater development than in any other group, and, in the description of the salmon's skull, will be considered before the cartilage-bones which they overlie, and from which they come away with great ease by maceration.

There are, in the first place, on the upper surface of the skull, three pairs of bones and a single median ossification. Of these, a pair of small bones, separated from one another by a considerable interval, and lying over the auditory region, answer to the parietals (Fig. 7, Pa); a much larger pair roofing over all the central portion of the brain case, from the parietals behind to the nasal region in front, are the frontals (Fr); and a very small and insignificant pair situated just above the nasal sacs the nasals (Na). All these are well known from their occurrence in the higher animals; but the bone marked S.Eth (super-ethmoid), which lies between the nasals and over the cartilage separating the olfactory organs, is peculiar to certain osseous fishes.

Above the eye is a small bone, known as the supra-orbital (S.Or), and below and at its sides a chain of bones, deeply excavated by slime-glands, the sub-orbitals (Sb.Or); the most anterior of these (Lch) seems to answer to the lachrymal bone of the higher animals. The gape of the mouth, instead of being formed, as in the shark and ray, by the naked pterygo-palatine and Meckelian cartilages, is bounded entirely by membrane-bones, three in the upper jaw, the pre-maxilla (Pmx), maxilla (Mx), and malar or jugal (Ju), and one in the lower, ensheathing Meckel's cartilage, the dentary (D). The maxilla, unlike that of most typical Teleosteans is dentigerous, and takes a large share in the formation of the gape. Immediately below the angle of the lower jaw is situated a small bone, the angular (Ang).

Two very important parostoses occur on the under surface of the skull, where they clamp and strengthen the cartilage; these are the vomer (Fig. 8, Vo), which bears a few teeth, and the para-sphenoid (Pa.S), the enormous development of which is so characteristic of the bony Ichthyspsida.

Lastly there are the bones supporting the gill-cover, or operculum proper, and branchiostegal membrane, each of which has its own set of osseous strengthenings. In the first set are included the opercular (Op), sub-opercular (S.Op), pre-opercular (P.Op), and inter-opercular (I.Op); in the second, the branchiostegal rays (Brs.R). The opercular are also divisible into two categories; two of them—the pre- and inter-opercular—are developed in the fold of skin growing from the mandibular arch, which covers the cleft (existing only in the embryo) between it and the hyoid (Fig. 1, p. 425, Ty.Eu), while the remaining two belong in like manner to the operculum of the hyoid arch covering the branchial slits (Fig. 1, Cl^1). The pre-opercular is interesting as being the homologue of the lower part of the mammalian squamosal, and the inter-opercular as representing the tympanic, the two membrane-developed ossifications of the complex temporal bone of human anatomy. The branchiostegal rays are flat sabre-like bones, twelve in number, attached to the hinder edge of the hyoid apparatus. In most Teleostei these bones are seven slender terete rays, the four upper of which are attached to the outer and the three lower to the inner side of the hyoid. At the point where the branchiostegal membranes of opposite sides meet below the throat a median ossification is developed in the subcutaneous tissue; this is the so-called uro-hyal, or basi-branchiostegal (B.Brs).

* Continued from vol. ix. p. 468.

When all the foregoing bones are stripped off, the salmon's skull is far more comparable than in its perfect state with that of an Elamobranch, being reduced to the chondro-cranium, a cartilaginous structure, with certain endogenous ossifications, but retaining to a remarkable extent the characters of a "primordial skull." A side view of the chondro-cranium is shown in Fig. 9: viewed from above it presents, like that of the ray, expanded sense capsules, and a narrowed inter-orbital region; the walls of the brain-case are, however, much thicker, and its cavity relatively smaller than in the preceding type (see Fig. 8); the rostrum also is short, and the roof of the skull or tegmen cranii produced into a strong ridge (culmen cranii). The end of the snout divides into two short processes (hypo-trabeculars, H.Tr), on each of which two labial cartilages are borne (l^1, l^2).

The bones developed in the chondro-cranium of the salmon very rarely come together so as to form sutures, but are usually separated by considerable tracts of cartilage or synchondroses. Ankylosis only takes place in the case of a single pair of bones—the orbito-sphenoids—which are fused together in the mid-line, so as to form a structure not unlike the "girdle-bone" of the frog.

Fig. 7.

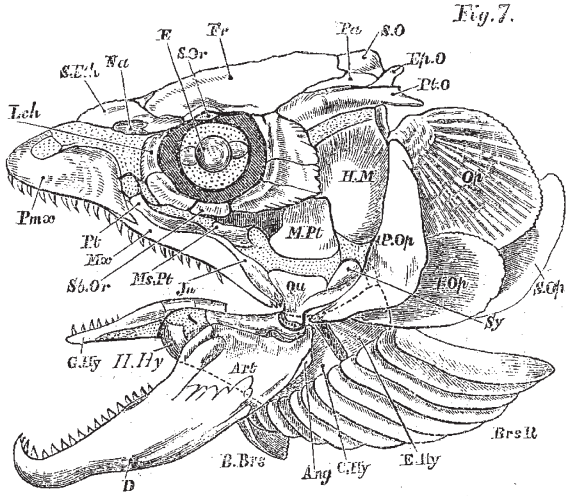

Fig. 7.—Skull of Salmon. Pa, parietal; Fr, frontal; Na, nasal; S.Eth, supra-ethmoidal; S.Or, supra-orbital; Sb Or, sub-orbitals; Lch, lachrymal; Pmx, pre-maxilla; Mx, maxilla; Ju, jugal; D, dentary; Ang, angular; Op, opercular; S.Op, sub-opercular; I.Op, inter-opercular; P.Op, pre-opercular; Brs.R, branchiostegal rays; B.Brs, basi-branchiostegal; S.O, supra-occipital; Ep O, epiotic; Pt.O, pterotic; Pl, palatine; Ms.Pt, meso-pterygoid; Art, articular; Sy, symplectic; G.Hy, glosso-hyal. The cartilaginous parts are dotted.

The hinder or occipital region of the skull is ossified by four bones, which surround the foramen magnum, and together form the "occipital segment;" these are the basi-occipital (Figs. 8 and 9, B.O) below, the exoccipitals (E.O) at the sides, and the supra-occipitals (S.O) above. The first of these bears a concave surface or condyle (O.C) for articulation with the first vertebra, the space between the two being filled up with the remains of the notochord. The auditory capsules are strengthened by no less than five bones: the prootic (Pr.O) formed in the anterior part of the capsule; the opisthotic (Op.O) over the ampulla, and the epiotic (Ep.O) over the arch of the posterior semicircular canal; the pterotic (Pt.O) over the arch and ampulla of the horizontal, and the sphenotic (Sp.O) over the ampulla of the anterior canal. The prootics of opposite sides meet in the mid-line (Fig. 8), and form a bridge of bone on the base of the skull, in front of the basi-occipital. Anterior to this "prootic bridge," and completing the basis cranii, is a small bone, Y shaped in section, the basi-sphenoid (B.S), which, curiously enough, has no cartilaginous predecessor, but is ossified directly from membrane. Above this bone, and in front of the sphenotic, the ali-sphenoids (As) are found in the side-walls of the brain-case, and, together with the basi-sphenoid below and the parietals above, form the "parietal segment" of the skull. The "frontal segment" has no basal element, the pre-sphenoid being absent, but its side-pieces are represented by the coalesced orbito-sphenoids (O.S) The only remaining bone in the skull proper is the large lateral ethmoid (L.Eth), which occurs immediately behind the depression for the nasal sac (Na).

Certain very constant relations exist between these bones and the cranial nerves. The trigeminal (V.), for instance, always determines the prootic, as its third division makes its exit just in front of that bone, or, in other

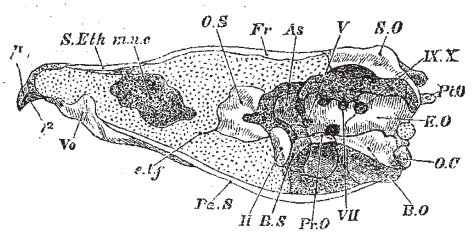

Fig. 8.—Longitudinal section of Salmon's Skull. Pa.S, para-sphenoid; Vo, vomer; B.O, basi-occipital; E.O, exoccipital; Pr.O, prootic; B.S, basi-sphenoid; As, ali-sphenoid; O.S, orbito-sphenoid; O.C, occipital condyle; l^1, l^2, labial cartilages; m.n.c, middle nasal cavity; e.t.f, ethmo-trabecular fissure.

words, between the anterior boundary of the auditory capsule and the parietal segment. The glosso-pharyngeal and vagus (IX. and X.) in like manner limit the posterior boundary of the ear capsule, passing out either between it and the exoccipital, or through the front part of the latter. The optic nerve (II.) passes between the parietal and frontal segments, usually being bounded in front by the orbito-sphenoid, and behind by the orbito-sphenoid. In the salmon a bar of bone grows across the trigeminal notch of the prootic, so that part of the nerve passes through a complete foramen.

An interesting instance of the retention of embryonic characters is seen in the slit marked e.t.f in the sectional view, Fig. 8. This is a fissure in the otherwise solid cartilage running forwards for a short distance from the lower anterior angle of the orbito-sphenoid, and indicating

Fig. 9.

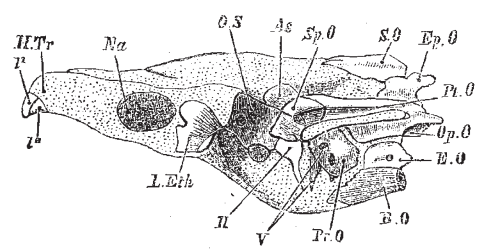

Fig. 9.—Skull of Salmon, with investing bones and facial arches removed. Op.O, opisthotic; Sp.O, sphenotic; L.Eth, lateral ethmoid; H.Tr, hypo-trabecular.

the line of separation between the trabecular portion of the skull and the part produced by the chondrification of its originally membranous walls; this structure is called the ethmo-trabecular fissure. In front of and above this fissure is a large cavity (m.n.c) filled with fat, and opening on the surface of the chondro-cranium beneath the supra-ethmoidal bone; there is no doubt that this seemingly useless space represents the single nasal chamber of the lamprey or hag.

The structure of the facial arches, and the chief points in the development of the salmon's skull, will be considered in the next paper.

(*To be continued.*)