LXVIII.—*On the Extremity of the Tail in Ichthyosauria.*
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As early as 1839 Sir Richard Owen described the small laterally compressed ribless terminal caudal vertebræ which supported the caudal fin in the *Ichthyosaurus*; but the caudal fin itself remained unknown till figured by Dr. Eberhard Fraas. Owen also mentions, in his general account of the osteology of the Ichthyosaurs from the Lias, that these vertebræ are preceded by three or four with the centrums more compressed, and their margins raised, in the region where the abrupt bend or distortion of the tail usually takes place. That abrupt bend was formerly regarded as a postmortem condition produced by the weight of the tail-fin. The specimens available in 1839 were all more or less imbedded in slabs of Lias.

In 1869, in a short account of the Ichthyosauria of the Cambridge Greensand, I gave some particulars of vertebræ from the terminal part of the tail which are free from matrix. The specimens suggest that there were probably three vertebræ between the caudal series supporting short caudal ribs and the caudal fin-series from which ribs are absent. As in the Lias specimens, these pivot-vertebræ are distinguished by their antero-posterior measurement being slightly diminished; it is less on the ventral than on the neural border; the central pit is much less deeply impressed in the centrum than in the earlier caudals; the lateral margins of the articular faces of the centrums are convex, and so rounded as almost to meet and nearly obliterate the lateral surfaces of the centrum; but this condition is not seen on the ventral margin. The largest of these pivot-vertebræ are $2\frac{1}{2}$ to $2\frac{3}{4}$ inches wide, $2\frac{1}{10}$ to $2\frac{1}{4}$ inches deep, and $\frac{7}{10}$ inch from front to back. The measurements and conditions show that the vertebræ from this point are directed downward, and that the angular bend in the Ichthyosaurian tail is a natural condition of downward angular flexure due to wedge-shaped form of these centrums. The rounded lateral tumid borders of these vertebræ show that the movement was from side to side, and that the caudal fin could only be used as a rudder or steering-organ when moved upon these pivot-vertebræ.

In the Cambridge Greensand species the caudal fin appears to have been very short, for the centrums which support it decrease in size very rapidly in vertical and transverse measurements, though there is a slight increase in length. The contraction in width is more rapid than the decrease in

depth, so that the centrums speedily become deeper than wide. This indicates lateral movement within the caudal fin itself, and that inference is supported by the interarticular borders of the centrum continuing rounded in examples $1\frac{2}{10}$ inch deep and $1\frac{1}{10}$ inch wide. In all the earlier vertebræ of this series the measurement along the neural canal is rather longer than upon the ventral border.

In an associated series of seven (F. ii. 75–81 Sedgwick Museum) the antero-posterior measurement decreases from little more than $\frac{8}{10}$ to $\frac{6}{10}$ inch, the depth from $1\frac{1}{10}$ to $\frac{5}{10}$ inch, and the width from 1 inch to $\frac{4}{10}$ inch. In every vertebra the posterior articular surface is appreciably smaller than the anterior end. The rapid decrease in size appears to indicate that the caudal fin was short and supported by few vertebræ, perhaps fewer than twenty. Many of the smaller vertebræ have sharp margins to the centrum, as though the extremity of the fin was nearly rigid.

In these vertebræ the neural canal is at first defined by an elevated lateral border, but after a time this contracts from front to back into a median process which is directed outward and shows no indication of having supported neurapophyses.

Subsequently, in the 'Aves, Ornithosauria, and Reptilia' (1869), I gave some account of an Ichthyosaurian skeleton from the Oxford Clay of Woodstone Lodge, near Peterborough, in which seven caudal vertebræ are present with convex margins to the centrum (*f.* 13–19) rapidly diminishing in size. The rib-facet is last seen on *f.* 15 (p. 113), so that the last true caudal vertebræ appear to show more than usual flexibility before the caudal rib is lost, and the four flexible pivot-vertebræ occur which are anterior to the caudal fin. Only eleven of the fin series are preserved, which resemble compressed dorsal vertebræ of a Plesiosaur. The smallest is half an inch in diameter. In a well-preserved skeleton in the Sedgwick Museum from the Oxford Clay of Whittlesea there are four modified centrums anterior to the caudal fin, followed by fifty-one centrums with smooth rounded external surfaces which have the same generalized character as other examples. But the series is imperfect, and five or six or more may be missing.

In January 1889 Mr. A. N. Leeds, F.G.S., submitted to me the extremity of the tail of an Oxford Clay Ichthyosaurian which I believed to be *Ophthalmosaurus*. On that specimen I made the following note, which shows the vertebræ supporting the tail to be substantially similar to other specimens from the Oxford Clay:—

As the caudal vertebræ approach towards the extremity of

the region which carries caudal ribs the centrum rapidly becomes smaller, and the outline of its articular face is hexagonal. In the last three or four centrums the single rib-facet rises from the inferior position it has previously occupied towards the middle of the side of the centrum. It is a transverse tubercle extending between the anterior and posterior faces, with its articular portion towards the anterior margin. The neural canal remains large and wide, and, as in all other vertebræ, wider behind than in front. The margin of the intercentral articular surface is sharp anteriorly and convex posteriorly, and in harmony with this character the posterior surface becomes flattened, with a marked central concavity, very unlike the typical intervertebral cupped condition of an Ichthyosaur. Indeed, the facies of the centrum in the latest of these rib-bearing caudal vertebræ is essentially cetacean both in external form and in the manner in which the external lateral surfaces are perforated by innumerable close-set vascular foramina. In the last pivot-vertebra but one the base of the centrum develops on the anterior border, in the usual position of chevron bones in other animals, two tubercles which do not appear to be separate granules. In the centrum, which measures anteriorly 4·5 cm. deep, 5·2 cm. wide, and is 2·1 cm. from front to back, the transverse measurement over these granules is 2·5 cm. The last centrum of this series might almost be described as procœlous, the posterior surface being a well-rounded hemisphere with a small central pit. This ball is somewhat wider than deep, and occupies half the length of the centrum, which is 2·6 cm. long. The anterior surface is concave from above downward and less concave transversely, with a conspicuous central concavity which preserves the remnant of the Ichthyosaurian intervertebral type. This surface measures 4·7 cm. vertically, and 3·4 cm. transversely, so that the proportions of the centrum have now changed. This is chiefly owing to the development of the chevron granules into an inferior process. In the middle height of the sides are small facets adjacent to the posterior articular border, which, I suppose, supported the last pair of caudal ribs; they were probably very short.

The succeeding vertebra is of very irregular form, higher than wide, with the anterior surface flattened, with an elevated articular border and a central conical impression and a slight ridge midway between the central cup and the external border. The posterior surface is convex, but irregular and rugose. This is the pivot-vertebra of the caudal fin.

These vertebræ also make the joint in the tail at which the angular flexure commonly occurs in Lias specimens.

The remainder of the tail in *Ophthalmosaurus*, as preserved, comprises forty-one vertebræ, without any indication of the end being reached. These vertebræ are compressed from side to side and have the aspect of the bodies of dorsal vertebræ of Teleosaurs or Plesiosaurs, the antero-posterior measurement being relatively long compared with the transverse measurement. The centrum is free from lateral and inferior processes, gives a strong attachment to the neural arch, and has the articular faces moderately concave, but not approximating more than in many Plesiosaurs. Similar vertebræ support the caudal fin found in German specimens from the Lias.

The first of the Oxford Clay fin-series is about 3 cm. high, with a transverse width of about 2·6 cm. and antero-posterior extent of 1·7 cm. The size at first diminishes very slowly, but more by a decrease in the height of the centrum than by diminution in its length or width, though both of these vary. The measurements at the twenty-seventh centrum of this series are antero-posterior 1·5 cm., transverse 1·9 cm., and vertical 2 cm. The last vertebra preserved is 1·1 cm. long, 1·2 cm. wide in front and slightly less behind, and 1·2 cm. high to the neural canal ; its posterior surface has a tendency to convexity, and the process for the neurapophysis on the right side is divided into anterior and posterior facets, as though the nerve passed through the middle of the neurocentral suture. The same condition is found in several of the late vertebræ, sometimes on one side, sometimes on the other. Probably many vertebræ are missing from the extremity of this tail.

It thus appears probable that the number of vertebræ supporting the caudal fin in Oxford Clay types exceeded 50 to 60.

By the kindness of the late Professor Oscar Fraas I had the opportunity of detailed examination of specimens from the Lias of Germany in the Royal Stuttgart Museum. In the specimen 3775 there are 101 vertebræ in the tail; caudal ribs are only found in the first twenty-nine, so that 72 may be regarded as supporting the caudal fin. The neural arch is seen in all the caudals except the last twenty-two, though it becomes very small, and the neural spine is short.

In no. 846 there are 115 caudal vertebræ. Of these 68 are posterior to the angular bend in the tail, and presumably supported the caudal fin.

No. 5792 is the *Ichthyosaurus multiscissus* (Quenst.). The tail is 4 feet 9½ inches long and includes 108 vertebræ, of which the last 75 appear to have supported the caudal fin.

In no. 5093, 127 caudal vertebræ are preserved, somewhat scattered towards the terminal end, but upwards of 90 appear to have supported the caudal fin.

The specimen 5094, named *I. tenuirostris,* which is only 3 feet 10 inches long, has 100 vertebræ in the tail, of which the last 70 supported the caudal fin.

I have a note of a specimen at Tübingen in which the first thirty caudal vertebræ have a length of less than 3 feet, and the remaining eighty-three vertebræ a length of 2 feet 8 inches in the region of the caudal fin.

In the Tübingen specimen 10,999 about 70 vertebræ support the caudal fin in a length of 2 feet.

In *Ichthyosaurus triscissus* there are 83 vertebræ in the tail, of which fifty are without ribs and appear to have supported the caudal fin ; and in no. 7532 there are 105 caudal vertebræ, but only twenty-two are posterior to the angular bend in the tail.

In 1881 Sir Richard Owen counted 60 vertebræ in the deflected part of the tail in *Ichthyosaurus tenuirostris.*

One of the most interesting specimens is in the Leicester Museum marked 1892/4765, from Barrow-on-Soar. It is the detached whip-like termination of the tail of an Ichthyosaur which appears to be perfect, though the vertebræ are not absolutely free from a little matrix, which slightly masks their articular edges. The vertebræ are all exceptionally short. The first three are relatively large and appear to be from the position of the usual angular deflection. They are followed by eighty vertebræ, which progressively decrease in length and size and diminish till they become like coarse granules which still retain the vertebral form. The terminal vertebræ are smaller than in any other example of the caudal fin series.

The caudal fin series appear to be exceptionally long in the British Museum specimen from Würtemberg, which contains several embryos.

It is thus evident that the number of these tail-fin vertebræ is variable in the different species from the Lias. On the whole the evidence appears to indicate that the caudal fin was longer in most of the Liassic than in the Lower Oxfordian types; and although the fragmentary remains from the Cambridge Greensand do not give any definite information, they suggest the inference that in the Cretaceous types the

tail-fin became shorter still. It is not without interest to find the extremity of the tail presenting so little variation in essentials of structure, as the order of animals is traced through the secondary strata.

LXIX.—*On the Interlocking of the Neural Arches in Ichthyosauria.* By H. G. Seeley, F.R.S., F.G.S., King's College, London.

The neural arches in Ichthyosaurs are never closely united with the centrums. When the centrums are isolated the arches are commonly lost. The characteristics of the arch are imperfectly known. They are illustrated by Cuvier in plate cclvi. Oss. Foss., but the figures are indefinite as to the interlocking of the arches, though the text indicates that Cuvier had seen and knew the structural relations of the bones. The excellent preservation of the vertebral column, with the vertebræ in natural sequence in skeletons imbedded in Lias slabs in the museums of this country and the Continent, is unfavourable to demonstration of the mutual relations of the neural arches. Exposed in side view they have a general resemblance to those of porpoises, for there is a manifest contact between them above the region of the neural canal by surfaces which enable the arches to support each other. But in *Ichthyosaurus* this zygapophysial surface does not project laterally, so that the lateral aspect of a neural arch is smooth and slightly concave from above downward, or only slightly tumid in the zygapophysial area. I have never seen any trace of laterally developed zygapophyses except in the cervical region.

It would appear that the cervical vertebræ is the part of the column most easily observed. Sir Richard Owen, in his 'Report on British Fossil Reptiles,' 1839, p. 100, speaking generally, states that "the neurapophyses are interlocked together by means of coadapted oblique processes." This is true for the neck, but not for the later vertebræ. In the account of *Ichthyosaurus platyodon* it is remarked in the same memoir: "the articular processes for mutual interlocking are well developed, especially at the anterior part of the spine." Forty-two years later lateral zygapophysial facets in *Ichthyosaurus* were figured by Owen in the Palæontographical