Cervical Vertebræ of Ichthyosaurus from the Lias of Lyme Regis and Street

XV.—*On certain peculiarities in the Cervical Vertebræ of the Ichthyosaurus, hitherto unnoticed.*

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SOME of the facts contained in the present Memoir, were announced to the Geological Society in a short notice, read May the 13th, 1835*. Since that period I have followed up the inquiry by the examination of a great variety of Saurian relics; and I am now enabled to enter more fully into the details of those facts, the bare occurrence of which was all I could safely offer in the former communication. By the aid of the illustrations given in Pl. XIV, the anatomical details will, it is hoped, be rendered sufficiently intelligible, to enable the reader to judge of the accuracy of the conclusions, which I have founded upon a consideration of them.

Atlas and Axis.

In the spring of 1835, I procured from Miss Anning (whose zeal and intelligence are well appreciated in the Geological community) a specimen from the lias of the neighbourhood of Lyme Regis, showing the atlas of a small Ichthyosaurus, apparently anchylosed to the second vertebra of the column. Having directed her attention to this circumstance, she informed me that though she had frequently found similar bones, yet it had never happened to her to see them disunited, even when a dislocation of every other bone of the animal to which they belonged, had taken place. In less than a week I received from her an atlas, seven inches and a half in diameter, corroborative in a remarkable degree of her former observations. The axis was firmly united to it, and she assured me that this was the only instance, in which any two bones had been found in contact, after she had collected a large portion of the skeleton to which it belonged. I have subsequently had opportunities of examining nearly thirty specimens of all sizes, and probably of several species, in various

* See Proceedings, vol. ii., No. 41, p. 192.

stages of growth, some in their natural position in the skeleton, others detached and rounded by attrition on the beach, all of which exhibited the same peculiar features. Two views of a very perfect specimen, from the collection of Lord Cole, which I have selected to illustrate the following details, are given at plate XIV., figs. 1 and 2.

Upon referring to fig. 2 it will be seen that the outlines of the two vertebræ are very clearly defined; I have found, however, by the examination of polished sections, that in the internal structure the bony texture generally extends without interruption from one to the other*. Once only have I succeeded, after the sacrifice of several specimens, in obtaining a forcible separation of the two vertebræ, and in this case I found that no intervertebral cavity existed, the bones articulating together by surfaces perfectly flat and even. (Fig. 3. A. B.) It is probable then, that in individuals of tender years the atlas and axis existed as distinct bones, but the extreme rarity of specimens in this condition, leads me to imagine, that the union between the two, took place at a very early period of the animal's life.

The atlas differs very materially from the other bones of the spinal column. It is furnished anteriorly with a semicircular cup (Plate XIV. fig. 1. *a*.) for the reception of the articulating tubercle of the basilar occipital, widely different from the conical cavities of the other vertebræ; for whereas in these the margin of each intervertebral cup is produced into a thin edge for articulation with its neighbour, in the atlas it is rounded into the form of a thick and solid lip, bounded on either side by a broad and rugged surface occupying the position of the costal articulation, which probably served for the insertion of the ligaments connected with the head. (Fig. 2. *a*.)

The axis, as I have already remarked, is flat anteriorly for articulation with the atlas. (Plate XIV. fig. 3. B.) It resembles the dorsal vertebræ in the form of the posterior cavity, as also in being furnished with bases for the attachment of ribs. (Figs. 2. *d*. and 3. *c*.)

Subvertebral Wedge Bones.

I now arrive at a very remarkable feature, at once distinguishing the first and second from the other bones of the spinal column, viz. the configuration of the inferior part of the vertebral body. On the under surface of each bone there exists an unusual enlargement in the form of a solid wedge-shaped process placed transversely to the smaller diameter of the vertebræ. By this arrangement four triangular planes are produced, disposed in the following order. The first and largest (Plate XIV. figs. 1 and 2. *b*.), is based upon the lower anterior margin of the atlantal socket, having its apex directed downwards and backwards until it meets the apex of a similarly shaped, though

* See a polished slab in the British Museum from the collection of the late Mr. Bullock.

smaller plane (fig. 2. *c.*) proceeding downwards and forwards from the posterior margin of the atlas. The third of like shape and size with the second, (fig. 2. *f.*), extends from the anterior margin of the axis, and joins the apex of the fourth (fig. 2. g.) which inclines forwards from the posterior portion of the same bone. This fourth plane is considerably smaller than the others, and corresponds in size with a fifth (fig. 11. *a.*), placed on the anterior border of the third cervical vertebra. When, therefore, the three anterior vertebræ are in their natural position, the arrangement of the five planes is as follows. The first and largest occupies the lower front of the atlas; the second and third, by the union of their bases, produce a triangular socket on the under surface of the atlas and axis; and a second smaller socket is formed between the axis and the third vertebra, by a similar disposition of the fourth and fifth planes. Having endeavoured to render intelligible the arrangement of these parts, I shall proceed to describe three peculiar bones which articulate with the above-mentioned planes, and which I propose, from their form and position, to designate *subvertebral wedge bones*.

The fortunate acquisition of an Ichthyosaurus having the first subvertebral bone *in situ*, enables me to omit a series of arguments by which I was prepared to show, that a bone did exist supplementary to the atlantal socket, and that the specimen represented at Plate XIV. figs. 4, 5, 6. was to be ascribed to this position in the skeleton*. The second bone of the series is frequently found with the atlas and axis, and is not uncommonly fixed in its position by anchylosis. The third bone is of rare occurrence, in consequence of its diminutive size, and is probably in some species altogether wanting. Fig. 7. is an accurate representation of the cervical apparatus of the skeleton I have above mentioned, and shows the three subvertebral bones so far displaced as to allow their respective sockets to be seen. Fig. 8. *a. b. c.* is an enlarged view of the same bones seen from below.

First Subvertebral Wedge Bone.

This bone is of great strength and solidity. Its form triangular. The under surface is thickened into a central projecting boss, Plate XIV. figs. 5 & 6. *a.*, from which it spreads out anteriorly into two alæ, representing two angles of the triangle. (Figs. 4, 5, 6. *b.*) The base between these points is occupied by a smooth semilunar socket (fig. 4. *c.*) which receives the lower hemisphere of the articulating tubercle of the occiput. A rapid contraction of the bone posteriorly forms the apex of the triangle which is slightly truncated, (figs. 5, 6. *d.*) The upper portion of this

* I have just seen in the magnificent collection of Mr. Hawkins an Ichthyosaurus from the lias of Somersetshire, having the first and second bones in their natural position.

bone forms a rugose articulating surface, (fig. 4. *a*.) extending backwards from the semilunar socket until it meets at a considerable angle a smaller facet (fig. 4. *d*.), formed by the truncation of the distal extremity of the bone. The former corresponds in size with the plane on the front of the atlas, and articulates with it; the latter abuts against the anterior extremity of the second subvertebral bone. In order that the arrangement of this part of the skeleton may be fully understood it will be necessary to consider the nature of the connexion between the head and trunk of the animal. In the several species of Ichthyosaurus, the proportion of the head to the total length of the body varies considerably, but is in all very large. The articulation with the trunk is effected by a ball and socket joint, between the basilar* portion of the occipital bone and the atlas. How far the mechanism of this joint would have been complete without the aid of a supplementary bone will be immediately perceived by fitting the atlas to its corresponding occipital bone. By the application of this test I have invariably found the cup of the atlas incapable of receiving more than two thirds of the occipital condyle. In well-preserved specimens this portion of the articulating process is defined by a slight depression on its surface† (fig. 7. *m*.). This seeming deficiency in the socket of the atlas is more than compensated for by the supplementary bone I have above described; for the angle at which it unites with the atlas (fig. 6.) is so contrived that the semilunar socket on its proximal extremity does not coincide with the plane of the atlantal socket, but projects forwards in such a manner as to embrace the whole lower circumference of the occipital condyle. An universal joint is thus effected at the same time that the subvertebral bone affords by its form, solidity, and position, a most powerful fulcrum to restrain the downward pressure of the animal's head.

Second Subvertebral Wedge Bone.

This bone (Plate XIV. fig. 7. *h*.), like the one already described, is strengthened below by a boss of solid bone. It is generally lozenge-shaped, but variations occur both in its form and proportions, probably consequent upon the species and age of the animal to which it belonged. Above, it is divided by a transverse elevation (fig. 3. *b*.) into two facets articulating with those between the margins of the atlas and axis, and, in front, it impinges upon the extremity of the first subvertebral bone, affording it a strong basis of attachment, and greatly enhancing its power.

Third Subvertebral Wedge Bone.

This bone (Plate XIV. fig. 7. *i*.) resembles the second in form, but is considerably smaller. It is lodged in a depression between the axis and the third cervical vertebra, and imparts much firmness to these bones, at the same time that it does not materially affect the amount of motion between them. I have before stated that the third subvertebral bone occurs rarely, and is probably in some species altogether wanting. This may reasonably be inferred, if there be any truth in the argument, by which I shall endeavour hereafter to show the office, which I believe these bones were destined to perform.

Cervical Vertebræ.

The third cervical vertebra of those species of Ichthyosaurus which are

* This appears to have remained distinct from the other elements of the occipital bone in individuals of every age and species. Mr. Owen remarks that evidence is thus afforded of a languid circulation in this family of Saurians.

† See a gigantic vertebral column in the British Museum.

furnished with three subvertebral bones, is characterized by an articulating facet on its anterior margin. (Plate XIV. fig. 11. *a*.) Certain modifications appear also to have obtained in the form of the intervertebral cavities in this region of the spine, producing a diminution of capacity to a greater or less extent as compared with those more distant from the head. A remarkable instance of the contraction of the cavity, combined with other striking peculiarities is shown at figs. 9 & 10. The vertebra there represented is seven inches in diameter, and was probably the fourth. It belonged to the same animal as the large atlas already mentioned. The anterior cavity is here reduced to a small cylindrical depression, not larger than a shilling in circumference. (fig. 9. *a*.) The remaining surface is nearly flat for articulation with the antecedent vertebra. The fifth vertebra resembles the fourth, but is somewhat smaller. Both are furnished behind with conical cavities of no great depth, for the reception of intervertebral matter. These bones exhibit a remarkable contrivance, by which the security of their articulation was much increased, although at the expense of a small amount of flexibility. In front of each, near the lower margin, a depression is so situated as to receive a corresponding eminence projecting from the contiguous vertebra (figs. 9, 10. *b*.), whilst on the upper margins similar depressions and projections are placed in the inverted order, affording twofold checks against the danger of dislocation. (Figs. 9, 10. *c*.)

The combined result of this construction, and of the reduction of the intervertebral cavities, must have been a considerable increase of power in this part of the spinal column. I shall only further remark that, proceeding from the lumbar vertebræ towards the head, the column attains its minimum diameter about the fifth cervical vertebra, from which point to the occiput it increases in size very rapidly.

Having concluded the anatomical details, I now proceed briefly to examine how far the structure I have endeavoured to describe agrees with the design of the other parts of the animal fabric, in adapting the Ichthyosaurus to the peculiar conditions under which it was destined to exist.

Whether we consider the osteological characters which I have detailed individually, or collectively, in their most contracted, or in their most extended state of development, we see in them provisions well calculated to increase, to a greater or less amount the power of the cervical region. We also see that this increase of power, is combined with only a slight decrease of the flexibility, so admirably provided for in the other parts of the spinal column. Let us now inquire, how far this combination of motion and strength in the neck of the Ichthyo-

saurus, is compatible with the ideas we may have formed of the exigencies of the animal, from our previous knowledge of its structure and habits. It has been established, upon evidence the most conclusive, that the Ichthyosaurus was a carnivorous reptile, inhabiting the sea, and breathing air, and the more we study its organization the more we see the beautiful adaptation of all its parts to such a mode of life. The lengthened snout, capacious jaws, and prehensile teeth, enabled it to seize and retain its slippery prey; while the broad expanse of tail, and the fish-shaped vertebræ, afforded a powerful apparatus for progression through the fluid that it is supposed to have inhabited, in pursuit of the finny tribes, which, principally, constituted its food. This combination of organs of pursuit and prehension for the capture of its prey, would have been of little avail, without the power of control and direction; consequently we find in the thoracic region, a powerful apparatus connected with the anterior extremities, to regulate and govern the movements of the body.

Mr. Conybeare, speaking of this structure, says*, "The form of the sternal arch, and the broad surfaces of the clavicles is such as to impart great strength to the chest, enabling the animal to breast the most disturbed waters, and affording an extensive surface for the attachment of powerful muscles to assist in moving the anterior extremities." It was further necessary that the head, constituting one-fourth of the entire length of the animal, should be furnished with adequate powers to enable it, not only to cleave the waves with steadiness and ease, but to obey each impulse, in directing the pursuit, with quickness and precision. If we examine living structures, we find in the whale, a fulcrum for the support of the ponderous head in the anchylosis of the cervical vertebræ. In fishes we find provisions for rapid progression in the construction of the spinal column. The Ichthyosaurus required a combination of the two powers; and as former observers† have demonstrated most clearly the beautiful adaptation of the animal's organization for progression through the waters, so I trust I may no less clearly have established, by the foregoing details, the existence of contrivances in the cervical vertebræ, fully sufficient to have afforded that enlarged amount of power, which the habits of the animal, and the proportions and arrangement of its parts would seem to suggest to have been almost necessary to its existence. Doctor Buckland, when speaking of the "Ossemens Fossiles," and of the author of that work, in his Bridgewater Treatise, says‡ "Nothing can exceed the accuracy of the

* Geol. Trans. 1st Series, vol. v. p. 578.

† Geol. Trans. 1st Series, vol. v. p. 559 et seq. 2nd Series, vol. i. p. 103 et seq.

‡ Vol. i. p. 140.

severe and logical demonstrations, that fill these volumes with proofs of wise design in the constant relation of the parts of animals to one another, and to the general functions of the whole body. Nothing can surpass the perfection of his reasoning in pointing out the beautiful contrivances, which are provided in almost endless variety, to fit every living creature to its own peculiar state and mode of life." If I have succeeded in adding one instance to those amassed by the illustrious Cuvier of "conformity of design," I trust the imperfections of the foregoing memoir may be pardoned.

Since this paper was written, I have received from Mr. Hawkins (whose splendid collection of Lias Saurians far exceeds any I believe in the world) the atlas and axis of an *Ichthyosaurus tenuirostris* found near Street. (Plate XIV. fig. 12.) The bones are firmly anchylosed together. The articulating facet on the front of the atlas is large. The second subvertebral bone is *in situ*, and is much smaller in proportion to the first than those I have before seen. The third subvertebral bone is entirely wanting. This interesting specimen confirms the statement I have before ventured, that modifications in the forms and proportions of the cervical apparatus, would probably be found in animals of different species and age.