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ORIGINAL ARTICLES.

I.—ON THE ODONTORNITHES, OR BIRDS WITH TEETH.¹

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(PLATE II.)

REMAINS of birds are among the rarest of fossils, and few have been described save from the more recent formations. With the exception of *Archæopteryx* from the Jurassic, and a single species from the Cretaceous, no birds are known in the old world below the Tertiary.² In this country, numerous remains of birds have been found in the Cretaceous, but there is no satisfactory evidence of their existence in any older formation, the three-toed footprints of the Triassic being probably all made by Dinosaurian reptiles.

The Museum of Yale College contains a large series of remains of birds from the Cretaceous deposits of the Atlantic coast and the Rocky Mountain region, thirteen species of which have already been described by the writer. The most important of these remains, so far as now known, are the *Odontornithes*, or birds with teeth, and it is the object of the present communication to give some of the more marked characters of this group, reserving the full description for a memoir now in course of preparation.

The first species of birds in which teeth were detected was *Ichthyornis dispar*, Marsh, described in 1872.³ Fortunately the type specimen of this remarkable species was in excellent preservation, and the more important portions of both the skull and skeleton were secured. These remains indicate an aquatic bird, fully adult, and about as large as a pigeon.

The skull is of moderate size, and the eyes were placed well forward. The lower jaws are long, rather slender, and the rami were not coössified at the symphysis. In each lower jaw there are twenty-one distinct sockets, and the series extends over the entire upper margin of the dentary bone (Plate II. Figures 1 and 2). The teeth in these sockets are small, compressed and pointed, and all are directed more or less backward. The crowns are covered with nearly smooth enamel. The maxillary teeth appear to have been numerous, and essentially the same as those in the mandible. Whether the

¹ From the American Journal of Science and Arts, vol. x. Nov. 1875.

² For some account of previously known Fossil Birds, see an Article on "Birds with Teeth," by H. Woodward, in the "Popular Science Review," No. 57, October, 1875, p. 337, pl. cxxv.

³ Silliman's American Journal, vol. iv. p. 344, and vol. v. p. 74.

premaxillary bones supported teeth, or were covered with a horny beak, cannot be determined from the present specimen.

The scapular arch and the bones of the wings and legs all conform closely to the true avian type. The sternum has a prominent keel, and elongated grooves for the expanded coracoids. The wings were very large in proportion to the legs, and the humerus had an extended radial crest. The metacarpals are coössified, as in recent birds, thus differing widely from those of *Archæopteryx*. The bones of the posterior extremities are slender, and resemble those of some aquatic birds. The centra of the vertebræ are all biconcave, the concavities at each end being distinct, and nearly equal (Plate II. Figures 3 and 4). The sacrum is elongated, and made up of a large number of coössified vertebræ. Whether the tail was elongated or not cannot at present be decided.

The jaws and teeth of this species show it to have been carnivorous, and it was probably aquatic. Its powerful wings indicate that it was capable of prolonged flight.

Another Cretaceous bird (*Apatornis celer*, Marsh), belonging apparently to the same order as *Ichthyornis*, was found by the writer in 1872 in the same geological horizon in Kansas.¹ The remains preserved indicate an individual about the same size as *Ichthyornis dispar*, but of more slender proportions. The vertebræ are biconcave, and there were probably teeth.

The most interesting bird with teeth yet discovered is perhaps *Hesperornis regalis*, a gigantic diver, also from the Cretaceous of Kansas, and discovered by the writer in 1870. The type specimen, which was found by the writer in 1871, and described soon after, consisted mainly of vertebræ and the nearly complete posterior limbs, all in excellent preservation.²

A nearly perfect skeleton of this species was obtained in Western Kansas by Mr. T. H. Russell and the writer in November, 1872, during the explorations of the Yale College party, and several other less perfect specimens have since been secured, and are now in the Yale Museum. These various remains apparently all belong to one species.

The skull of *Hesperornis* has the same general form as that in *Colymbus torquatus*, Brün., but there is a more prominent median crest between the orbits, and the beak is less pointed. The brain cavity was quite small. The maxillary bones are massive, and have throughout their length a deep inferior groove which was thickly set with sharp, pointed teeth. These teeth had no true sockets, but between their bases there are slight projections from the sides of the grooves. (Plate II. Figure 6.) The teeth have pointed crowns, covered with enamel, and supported on stout fangs. (Plate II. Figure 9.) In form of crown and base, they most resemble the teeth of Mosasauroid reptiles. The method of replacement, also, was the same, as some of the teeth preserved have the crowns of the successional teeth implanted in cavities in their fangs. The

¹ Silliman's American Journal, vol. v. p. 74, Jan. 1873.

² Silliman's American Journal, vol. iii. p. 360, May, 1872.

maxillary grooves do not extend into the premaxillaries, and the latter do not appear to have supported teeth. The external appearance, moreover, of the premaxillaries seems to indicate that these bones were covered with a horny bill, as in modern birds.

The lower jaws are long, and slender, and the rami were united in front only by cartilage. The dentary bone has a deep groove throughout its entire length, and in this, teeth were thickly planted, as in the jaws of *Ichthyosaurus*. The lower teeth are similar to those above, and all were more or less recurved. (Plate II. Figure 5.) These grooves contain slight projections from the sides, but there are no true sockets. (Plate II. Figure 6.)

The scapular arch of *Hesperornis* presents many features of interest. The sternum is thin and weak, and *entirely without a keel*. In front, it resembles the sternum of *Apteryx*, but there are two very deep posterior emarginations, as in the Penguins. The scapula and coracoid are very small. The wing bones are diminutive, and the wings were rudimentary, and useless as organs of either flight or swimming.

The vertebræ in the cervical and dorsal regions are of the true ornithic type, the articular faces of the centra being quite as in modern birds. (Plate II. Figures 7 and 8.) The sacrum is elongated, and resembles that in recent diving birds. The last sacral vertebra is quite small. The caudal vertebræ, which are about twelve in number, are very peculiar, and indicate a structure not before seen in birds. The anterior caudals are short, with high neural spines and moderate transverse processes. The middle and posterior caudals have very long and horizontally expanded transverse processes, which restrict lateral motion, but clearly indicate that the tail was moved vertically, probably in diving. The last three or four caudal vertebræ are firmly coössified, forming a flat terminal mass, analogous to, but quite unlike, the "ploughshare" bone of modern birds. The anterior two at least of these caudals have expanded transverse processes.

The pelvic bones, although avian in type, are peculiar, and present some well-marked reptilian features. A resemblance to the corresponding bones of a Cassowary is at once evident, especially in a side view, as the ilium, ischium, and pubis all have their posterior extremities separate. The two latter are slender, and also free back of their union with the ilium at the acetabulum. The ischium is spatulate at its distal end, and the pubis rodlike. The acetabulum differs from that in all known birds, in being closed internally by bone, except a foramen, that perforates the inner wall.

The femur is unusually short and stout, much flattened antero-posteriorly, and the shaft curved forward. It somewhat resembles in form the femur of *Colymbus torquatus*, Brün., but the great trochanter is proportionally much less developed in a fore-and-aft direction, and the shaft is much more flattened. The tibia is straight and elongated. Its proximal end has a moderately developed cnemial process, with an obtuse apex. The epi-cnemial ridge is prominent, and continued distally about one-half the length of the shaft. The

distal end of the tibia has on its anterior face no ossified supratendinal bridge, differing in this respect from nearly all known aquatic birds. The fibula is well developed, and resembles that of the Divers. The patella is large, as in *Podiceps*, and in position extends far above the elevated rotular process of the tibia.

The tarso-metatarsal bone is much compressed transversely, and resembles in its main features that of *Colymbus*. On its anterior face there is a deep groove between the third and fourth metatarsal elements, bounded on its outer margin by a prominent rounded ridge, which expands distally into the free articular end of the fourth metatarsal. This extremity projects far beyond the other two, and is double the size of either, thus showing a marked difference from any known recent or fossil bird. There is a shallow groove, also, between the second and third metatarsals. The second metatarsal is much shorter than the third or fourth, and its trochlear end resembles in shape and size that of the former. The existence of a hallux is indicated by an elongated oval indentation on the inner margin above the articular face of the second metatarsal. The free extremities of the metatarsals have the same oblique arrangement as in the *Colymbidae*, to facilitate the forward stroke of the foot through the water. There are no canals or even grooves for tendons on the posterior face of the proximal end, as in the Divers and most other birds; but below this, there is a broad, shallow depression, extending rather more than half way to the distal extremity.

The phalanges are shorter than in most swimming birds. Those of the large, external toe are very peculiar, although an approach to the same structure is seen in the genus *Podiceps*. On the outer, inferior margin, they are all deeply excavated. The first, second, and third have, at their distal ends, a single, oblique, articular face on the inner half of the extremity, and the outer portion is produced into an elongated, obtuse process, which fits into a corresponding cavity in the adjoining phalanx. This peculiar articulation prevents flexion except in one direction, and greatly increases the strength of the joints. The terminal phalanx of this toe was much compressed. The third, or middle, toe was greatly inferior to the fourth in size, and had slender, compressed phalanges, which correspond essentially in their main features with those of modern Divers.

The remains preserved of *Hesperornis regalis* show that this species was larger than any known aquatic bird. All the specimens discovered are in the Yale College Museum, and agree essentially in size, the length from the apex of the bill to the end of the toes being between five and six feet. The habits of this gigantic bird are clearly indicated in the skeleton, almost every part of which has now been found. The rudimentary wings prove that flight was impossible, while the powerful swimming legs and feet were peculiarly adapted to rapid motion through the water. The tail appears to have been much expanded horizontally, as in the Beaver, and doubtless was an efficient aid in diving, perhaps compensating in part for want of wings, which the Penguins use with so much effect in swimming under water. That *Hesperornis* was carnivorous is clearly proven by its teeth; and its food was probably fishes.

The zoological position of *Hesperornis* is evidently in the *Odontornithes*; but the insertion of the teeth in grooves, the absence of a keel on the sternum, and the wide difference in the vertebræ require that it be placed in a distinct order, which may be called *Odontolcæ*, in allusion to the position of the teeth in grooves.

The two orders of birds with teeth would then be distinguished as follows :—

Sub-class, ODONTORNITHES (or AVES DENTATÆ).

- A. Teeth in sockets. Vertebræ biconcave. Sternum with keel. Wings well developed. Order, ODONTOTORMÆ.
- B. Teeth in grooves. Vertebræ as in recent birds. Sternum without keel. Wings rudimentary. Order, ODONTOLCÆ.

In comparing *Ichthyornis* and *Hesperornis*, it will be noticed that the combination of characters in each is very remarkable, and quite the reverse of what would naturally be expected. The former has teeth in distinct sockets, with biconcave vertebræ; while the latter has teeth in grooves, and yet vertebræ similar to those of modern birds. In point of size, and means of locomotion, the two present the most marked contrast. The fact that two birds, so entirely different, living together during the Cretaceous, should have been recovered in such perfect preservation, suggests what we may yet hope to learn of life in that period.

The geological horizon of all the *Odontornithes* now known is the Upper Cretaceous. The associated vertebrate fossils are mainly Mosasauroid reptiles and Pterodactyls.

A full description with plates of all the known *Odontornithes* is now being prepared by the writer.

YALE COLLEGE, NEW HAVEN, Oct. 18th, 1875.

EXPLANATION OF PLATE II.

FIGS. 1-4. *Ichthyornis dispar*, Marsh. Twice natural size.

- FIG. 1. Left lower jaw; top view.
- „ 2. Left lower jaw; side view.
- „ 3. Cervical vertebra; side view.
- „ 4. Same vertebra; front view.

FIGS. 5-9. *Hesperornis regalis*, Marsh.

- FIG. 5. Left lower jaw; side view; half natural size.
- „ 6. Left lower jaw; top view; half natural size.
- „ 7. Dorsal vertebra; side view; natural size.
- „ 8. Same vertebra; front view; natural size.
- „ 9. Tooth; four times natural size.

II.—CONTRIBUTIONS TO THE STUDY OF VOLCANOS.

By JOHN W. JUDD, F.G.S.

SECOND SERIES.—THE ANCIENT VOLCANOS OF EUROPE.

IN the preceding chapters we have endeavoured to throw light upon some of the more salient characters of volcanos—the features of their architecture, the nature of their products, and the peculiarities of their attendant phenomena. In doing so, however, we have preferred to select our illustrations from some of the less familiar, though, as we hope to have shown, by no means less interesting volcanos of our continent; and have of set purpose avoided the