proposing a *Bigelowia* on *Solea concolor*, of our own New England, as the Prodromus records, when he found that he had to refer it to *Noisettia*. Lastly, in 1836, DeCandolle bestowed the name of *Bigelowia* upon some golden-flowered Compositæ of the Southern United States, which had borne the name of an Old World genus, *Chrysocoma* (Anglice, Golden-tuft), and he added the complimentary phrase: "A Chrysocoma separatum dicavi cl. J. Bigelow qui floræ Americanæ auream coronam flora Bostoniensi et medica addidit." Although this genus was founded upon only two or three species, it has been vastly extended by the exploration of the western regions of our country, where it forms a conspicuous and characteristic portion of the low shrubby vegetation. More than thirty North American species of *Bigelovia*, besides one of Mexico and two of the Andes of South America, now commemorate our venerable late associate. Most of them were introduced to the genus by the present writer. A. G.

ART. XXXII.—*The Vertebræ of Recent Birds;* by Professor O. C. MARSH.

ONE of the most marked features in the skeleton of modern birds is the form of their vertebræ. This is so peculiar and so constant that it is considered by many anatomists to be the best distinctive character for the class. In no other group of animals known is there an approach to the saddle-shaped articulation of the centra seen in the vertebræ of birds.

Not only do the presacral vertebræ of all existing birds exhibit this structure, but the many extinct forms now known from the whole series of Tertiary deposits have the same articulation. If we knew only these fossil forms, in addition to the existing species of birds, the origin of this peculiar vertebral articulation would perhaps remain a mystery. Most fortunately, however, a few Cretaceous birds have been discovered which throw much light on this point, and virtually explain the difficulty.

In the toothed birds *Ichthyornis* and *Hesperornis*, we have two widely divergent forms. The latter was a huge swimming bird, without wings, and with vertebræ corresponding fully to the modern ornithic type. *Ichthyornis*, on the other hand, was a small bird, with great powers of flight, and with biconcave vertebræ, as in Fishes and Amphibians, and in a few Reptiles. The marked contrast between the shape of the vertebral articulation in these two genera is seen in the figures below, which show a characteristic cervical vertebra in each form.

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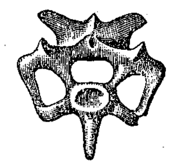
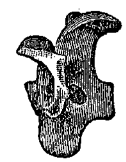
In the vertebra of *Ichthyornis* shown in figures 1 and 2, it will be seen that the articulation of the centrum is cup-shaped; while in the corresponding vertebra of *Hesperornis*, the ends of the centrum are saddle-shaped, as in ordinary birds. Thus the distinction between the two types in this part of the skeleton is as wide as between *Ichthyornis* and any living bird.

To the evolutionist, who believes that birds are all closely connected genetically, this difference in structure, at first sight, offers a most serious difficulty; since hitherto we have had no hint of a transformation from the one form to the other, and no explanation of the origin of the modern vertebræ of birds.

1.



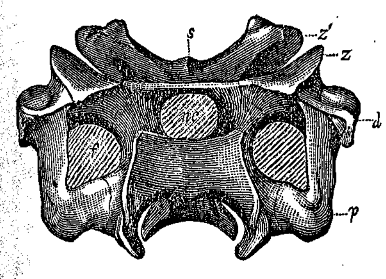
2.



3.

FIGURE 1.—Twelfth (?) cervical vertebra of *Ichthyornis dispar*, Marsh; front view; twice natural size.
FIGURE 2.—The same vertebra; seen from the left side.
FIGURE 3.—Third cervical vertebra of *Ichthyornis victor*, Marsh; front view; twice natural size.

4.



5.

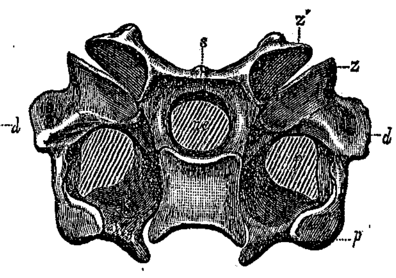


FIGURE 4.—Thirteenth cervical vertebra of *Hesperornis regalis*, Marsh; front view; natural size.
FIGURE 5.—The same vertebra; posterior view.
a. anterior articulation; *d.* diapophysis; *p.* parapophysis; *f.* lateral foramen; *nc.* neural canal; *s.* neural spine; *z.* pre-zygapophysis; *z'.* post-zygapophysis.

In the third cervical vertebra of *Ichthyornis*, however, we catch nature in the act, as it were, of forming a new type; by modifying one form of vertebra into another. Following this hint, the connection between these widely divergent types of structure soon becomes apparent; and the development of the modern style of avian vertebra from the fish-like, biconcave form finds a ready solution. In the anterior articulation of

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this vertebra of *Ichthyornis* (figure 3), the surface looks downward and forward, being inclined at an angle of nearly 60° with the axis of the centrum. In vertical section, it is moderately convex, while transversely it is strongly concave; thus presenting a near approach to the saddle-like articulation. None of the other known vertebræ of *Ichthyornis* possess this character.

This highly specialized feature occurs at the first bend of the neck, and greatly facilitates motion in a vertical plane. If, now, we consider for a moment that the dominant motion in the neck of a modern bird is in a vertical plane, we see at once that anything that tends to facilitate this motion would be an advantage, and that the motion itself would tend directly to produce this modification. With biconcave vertebræ, the flexure in any direction is dependent on the elasticity of the fibrous tissue that connects them, as the edges of the cups do not slide over each other. An increasing movement in the neck of *Ichthyornis* in a vertical plane would tend to deflect the upper and lower margins of the circular cup, and to produce a vertical constriction, and at the same time to leave the lateral margins projecting; and this is precisely what we have in the third vertebra.

This modification of the vertebræ would naturally appear first where the neck had most motion, viz: in the anterior cervicals, and gradually would be extended down the neck; and, on to the sacrum, if the same flexure was continued.

Behind the axis, or where the vertical motion prevails, we find in modern birds no exception to the saddle articulation in the whole cervical series.

In the dorsal vertebræ, this cause would be less efficient, since the ribs and neural spines tend to restrict vertical motion, and hence to arrest this modification. This region, then, as might be expected, offers strong confirmatory evidence of the correctness of the above explanation; for here occur, among modern birds, the only true exceptions known in the presacral series to the characteristic saddle-shaped articulation. In *Strigops* and a few other land birds; in the Penguins, the Terns, and some other aquatic birds, one or more vertebræ in the dorsal region are without the saddle-shaped articulation, and are either opisthocœlian, or imperfectly biconcave. In such instances, we can usually, if not always, detect evidence of an arrest of vertical flexure. This may lock together the posterior dorsals by their neural-spines, as in *Strigops*, leaving the power of lateral flexure: or several vertebræ may be coössified, as in *Accipiter* and some other *Raptores*, in which a stiff back is a positive advantage.

In the coössified sacral series of many birds, one or more of the anterior vertebræ have the saddle-shaped articulation. This, however, is no valid objection to the above explanation, since these vertebræ are really dorsals, and have evidently gradually coalesced with the true sacral vertebræ.

In the caudal vertebræ of recent birds we have, in a measure, the original biconcave structure preserved, for here the motion in every direction was much restricted. The caudal vertebræ of these birds, even in the most aberrant forms, are essentially the same, and in the fossil species the articulations at least appear to follow the general rule. In *Pavo* and *Geococcyx*, the caudal vertebræ exhibit a tendency to a procœlian union. Some other forms also show unimportant modifications of the normal type of caudal articulation, but nothing to suggest a real objection to the explanation now proposed of the origin of the vertebræ characteristic of Birds.

In bringing together the above facts, and others suggested by them, the classification and development of the various forms of vertebræ appear to be somewhat as follows:

(1.) *Biconcave vertebræ* (Fishes and Amphibians); the primitive type; a weak articulation, admitting free, but limited motion. From this form, have been directly derived the other varieties, namely:

(2.) *Plane vertebræ* (Mammals); affording a stronger joint, with motion still restricted.

(3.) *Cup-and-ball vertebræ* (Reptiles); a strong and flexible joint, well fitted for general motion, and evidently produced by it. The vertebræ are procœlian when lateral motion is dominant (Serpents); opisthocœlian with varied motion (Dinosaur cervicals).

(4.) *Saddle vertebræ* (Birds); the highest type; a very strong and free articulation, especially adapted to motion in a vertical plane, and mainly due originally to its predominance.

This subject will be more fully discussed and illustrated by the writer in a future communication.

Yale College, New Haven, Conn., Feb. 25th, 1879.