

A P P E N D I X.

ART. LIII.—*Principal Characters of American Jurassic Dinosaurs*; by O. C. MARSH. Part V. With seven Plates.

IN previous articles, the writer has described the main characters of *Morosaurus*, *Apatosaurus*, *Diplodocus*, and *Atlantosaurus*, the best known genera of the *Sauropoda* hitherto found in American deposits.* The fortunate discovery of a nearly complete skeleton of *Brontosaurus* has added many new points to our knowledge of this group, and some of these are given in the present communication. A second species, equally gigantic in size, has since been found, and its distinguishing features are also here recorded.

Two new genera from the same formation are noticed, and an outline of classification of the best known American Jurassic Dinosaurs is proposed.

Brontosaurus excelsus Marsh.†

The present genus may readily be distinguished from all the other *Sauropoda* by the sacrum, which is composed of five ankylosed vertebræ, none of the other genera in this group having more than four. The sternum, moreover, consists of two separate bones, which are parial, and were united to each other on the median line apparently by cartilage only. In many other respects the genus resembles *Morosaurus*.

The present species, aside from its immense size, is distinguished by the peculiar lightness of its vertebral column, the cervical, dorsal, and sacral vertebræ all having very large cavities in their centra. The first three caudals, also, are lightened by excavations in their sides, a feature not before seen in this group, and one not shared by the other species of this genus.

* This Journal, xvi, 411, Nov., 1878, and xvii, 86, Jan., 1879.

† This Journal, xviii, 503, Dec., 1879, and xix, 395, May, 1880.

THE SCAPULAR ARCH.

The scapular arch in the present species is fortunately better known than that of any other Dinosaur hitherto discovered. In Plates XII and XIII the various bones are represented separately, and in figure 1 of the latter plate they are in position. The scapula resembles in general form the corresponding bone in *Morosaurus*, but the shaft is longer, and the upper end less expanded. The coracoid, on the other hand, differs materially from that of *Morosaurus*, and approaches more nearly that of *Apatosaurus*, which is sub-quadrate in outline. In Plate XII the scapula and coracoid of the present species are placed nearly in the same plane, and the space between them probably represents about the amount of cartilage which originally separated them. Both scapulæ were found in apposition with their respective coracoids.

The two sternal bones lay side by side between the two coracoids, and in Plate XIII they are represented nearly as found. They are sub-oval in outline, concave above, and convex below. They are parial, and when in position nearly or quite meet on the median line. Each bone is considerably thickened in front, and shows a distinct facet for union with the coracoid. The posterior end is thin and irregular.

THE PRESACRAL VERTEBRÆ.

The cervical vertebræ of the present species are quite numerous, thirteen at least belonging in this part of the column. All are strongly opisthocælian. The anterior cervicals are very small in comparison with those near the dorsal region. From the third vertebra to the middle of the neck, the centra increase in length and especially in bulk, but the posterior cervicals gradually become shorter. In Plate XIV the sixth cervical is represented, and this is typical for the anterior half of the neck. All the anterior cervicals have coössified ribs, as in Birds. In the posterior cervicals, the ribs become free. The articular facet for the head of the rib rises gradually on the side of the centrum, the tubercular articulation remaining on the diapophysis. None of the cervicals have a neural spine. The neural canal is comparatively small. The centra of all the cervicals have deep excavations in the sides, and the transverse processes are more or less cavernous. The posterior cervicals which bear free ribs are remarkable for the great size of the zygapophyses, which are here much larger than elsewhere in the series. The anterior cervicals have several lateral cavities, while those farther back have only one large foramen in each side of the centrum, as in the dorsals.

The dorsal vertebræ of this species have short centra, more or less opisthocælian. There is a very large cavity in each side which is separated from the one opposite by a thin vertical partition. The neural canal is much larger than in the cervicals. The anterior dorsals are distinctly opisthocælian. The neural spine has no prominence in this region, but rises rapidly further back. In Plate XV, figures 1 and 2, a posterior dorsal is represented which shows the peculiar character of the vertebræ in this part of the series. The neural spine is greatly developed and has its summit transversely expanded. The vertebræ in this region, as in all the known *Sauropoda*, have the peculiar diplosphenal articulation. This is shown in figure 2. In the vertebra figured, at the base of the neural spine, there is a strong anterior projection, which was inserted into the cavity between and above the posterior zygapophyses of the vertebra in front. There appear to be no true lumbar vertebræ, as those near the sacrum supported free ribs of moderate size. These vertebræ have both faces of the centrum nearly flat or biconcave.*

THE SACRUM.

The sacrum in the present species consists of five well coössified vertebræ, and in the type specimen the centrum of the last lumbar is firmly united with it, as shown in Plate XVI. The striking feature about this sacrum is the large general cavity it contained. This was divided in part by a median longitudinal partition, as shown in Plate XV, figure 3. This septum, however, was not continuous the whole length of the sacrum, so that the two lateral cavities were virtually one. This extended even into the lateral processes. The transverse partitions formed by the ends of the respective centra were also perforate, so that the sacrum proper was essentially a hollow cylinder. This cavernous character of the sacrum is one of the peculiar features of the suborder *Sauropoda*, and was described by the writer, when the first species of this group was discovered in this country.† The statement that any of the group have the sacrum solid, like the caudals, is evidently based on erroneous observation.

Another peculiar character of the sacrum in the present genus is its lofty neural spine. This is a thin vertical plate of bone with a thick massive summit, evidently formed by the

* Prof. Cope, mistaking the character of these vertebræ in an allied form, described them as representing a new genus, *Amphicælias*, and even a new family, *Amphicæliidae*. (Proc. Am. Phil. Soc., xvii, 243.) All the known *Sauropoda*, however, have similar vertebræ, with opisthocælian centra in the cervical and anterior dorsal regions.

† This Journal, xiv, 87, July, 1877.

union of the spines of several vertebræ. In front, it shows rugosities for the ligament uniting it to the adjoining vertebra, and its posterior margin likewise indicates a similar union with the first caudal. In this genus, as in all the *Sauropoda*, each vertebra of the sacrum supports its own transverse processes. As shown in Plate XVI, the articulation for the ilium is formed by the coössification of the distal ends of the transverse processes. The neural canal is much enlarged in the sacrum, but proportionally less than in *Stegosaurus*.

THE CAUDAL VERTEBRÆ.

In the present species, the three vertebræ next behind the sacrum have moderate sized cavities between the base of the neural arch and the transverse processes. These shallow pockets extend into the base of the processes, but the centra proper are solid. All the other caudals have the centra, processes, and spines composed of dense bone. The fourth caudal vertebra, represented in Plate XVII, figures 1 and 2, is solid throughout, and the same is true of the chevron, figures 3 and 4. The neural spines of the anterior caudal vertebræ are elevated and massive. The summit is cruciform in outline, due to the four strong buttresses which unite to form it.

The median caudals all have low weak spines, and no transverse processes. The posterior caudals are elongate, and without spines or zygapophyses.

THE PELVIC ARCH.

The pelvic bones in the present species are shown in Plate XVIII. The ilium represented is not perfect on its upper margin, which extended higher originally than shown in the figure. Its anterior process for the support of the pubis is much larger than the posterior one which meets the ischium. The pubis is elongate and massive. It sends down a strong wing for union with the ischium, and has in front of this the usual foramen. The distal end is expanded, and has on the inner surface a rugose facet for union with its fellow by cartilage. The ischium is more slender than the pubis, and has its lower end expanded for symphysial union with the one on the other side. This pelvis is more like that of *Atlantosaurus* than any other of the known genera of the *Sauropoda*. The three bones shown in Plate XVIII were found nearly in the position represented.

Brontosaurus amplius, sp. nov.

A second species of this genus is from the same horizon, and is represented by the greater portion of the skeleton. In size, the two were very nearly equal, but they may be distinguished readily by the vertebræ. In the present species, the dorsal vertebræ are less massive, the differences being especially noticeable in the zygapophyses. The anterior caudals, moreover, are without the cavities noticed in the type species, and are likewise proportionally longer. The single sternal bone found near its coracoid is thinner, and has its anterior border less developed than the corresponding part in *Brontosaurus excelsus*. The metacarpals of the present species are more elongate than in the other known members of the group.

Diracodon laticeps, gen. et sp. nov.

A new Jurassic Dinosaur of moderate size is indicated by various remains, among which are the two maxillary bones. These are unusually slender, and peculiar in the large number of teeth they contained. These teeth resemble in form those of *Echinodon*, Owen. They have compressed serrated crowns, sculptured on both sides. The base of the crown is expanded, and below this is a distinct neck, which will readily distinguish these teeth from any hitherto found in this country. The teeth are implanted in distinct sockets, and there were twenty-two in each maxillary. There is a foramen on the inner side, just below each tooth, and some large cavities on the outer side of each jaw. The teeth are very small.

The front of these jaws is edentulous, and this part curves inward so far that the snout must have been a broad one, almost batrachoid in form.

The following measurements indicate the size of these specimens:

Entire length of maxillary bone.....	170 ^{mm}
Space occupied by teeth.....	104
Space occupied by eleven anterior teeth.....	50
Length of anterior edentulous portion.....	62
Vertical diameter of jaw, above eleventh tooth..	27

The present species was probably ten or twelve feet in length. The vertebræ referred to this animal are biconcave, and the other characters known make it probable that the genus is most nearly related to *Laosaurus*. The known remains are from the *Atlantosaurus* beds of Wyoming.

Hallopus, gen. nov.

The specimen described by the writer as *Nanosaurus victor*,* proves, on investigation, to be distinct from the type of the genus to which it was referred, and presents some peculiar characters. Some of these characters are as follows:

- (1) There are but two vertebræ in the sacrum.
- (2) The femur is shorter than the tibia.
- (3) The metatarsals are one-half the length of the tibia.
- (4) The calcaneum is much produced backward.

The last character has not before been seen in Dinosaurs, and indicates a foot especially adapted for leaping. The species representing this group may be called *Hallopus victor*. The animal was about as large as a fox. The geological horizon of this specimen is near the base of the *Atlantosaurus* beds, in Colorado, and perhaps below them.

The collection of American Jurassic Dinosaurs now in the museum of Yale College includes the remains of several hundred individuals, many of them in excellent preservation. The completeness of this series renders it valuable as a basis of classification for the known American forms, and an outline of this classification may appropriately be presented in the present article. Most of the many genera and species represented in this series can be readily grouped in five suborders, as given below, two of which have already been defined by the writer. The details of the present classification, and its application to the Dinosauria from other formations in this country, as well as to those of Europe, will be reserved for a future communication. The outline of classification now proposed is as follows:

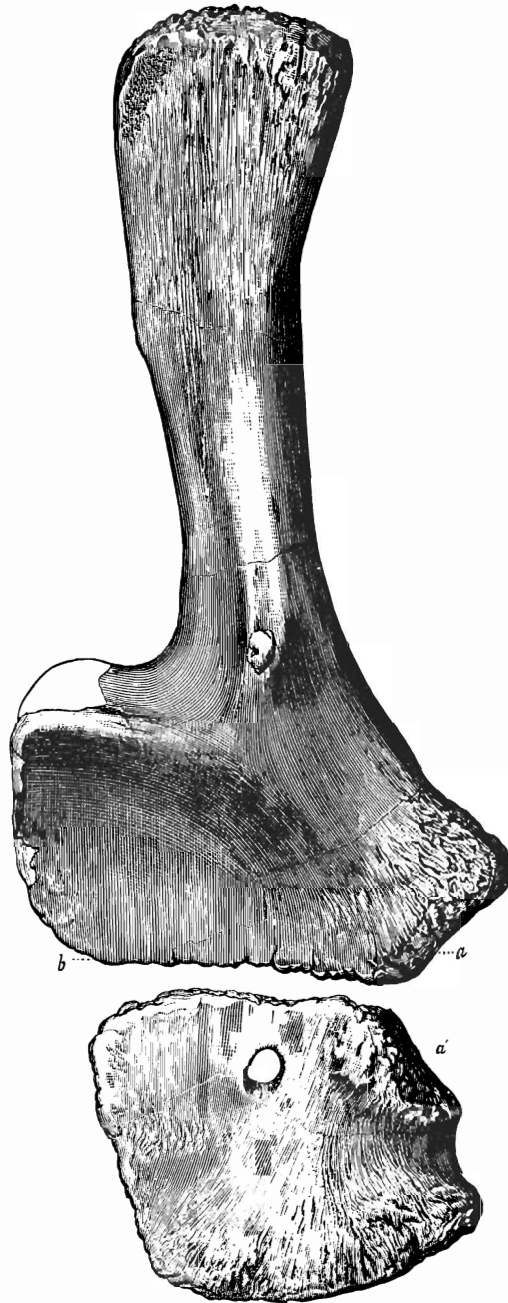
* This Journal, xiv, 255, Sept. 1877.

Order DINOSAURIA, Owen.

- (1.) Suborder SAUROPODA (Lizard foot.) Herbivorous.
 Feet plantigrade, ungulate; five digits in manus and pes.
 Pubes united in front by cartilage. No post-pubis.
 Precaudal vertebræ hollow. Limb bones solid.
 Family *Atlantosauridæ*.
 Genera *Atlantosaurus*, *Apatosaurus*, *Brontosaurus*, *Diplodocus*, and *Morosaurus*.
- (2.) Suborder STEGOSAURIA (Plated lizard.) Herbivorous.
 Feet plantigrade, ungulate; five digits in manus and pes.
 Pubes free in front. Post-pubis present.
 Vertebræ and limb bones solid.
 Family *Stegosauridæ*.
 Genus *Stegosaurus*.
- (3.) Suborder ORNITHOPODA (Bird foot.) Herbivorous.
 Feet digitigrade; four functional digits in manus and three in pes.
 Pubes free in front. Post-pubis present.
 Vertebræ solid; limb bones hollow.
 Family *Camptonotidæ*.
 Genera *Camptonotus*, *Diracodon*, *Laosaurus*, and *Nanosaurus*.
- (4.) Suborder THEROPODA (Beast foot.) Carnivorous.
 Feet digitigrade; digits with prehensile claws.
 Pubes coössified in front. Post-pubis present.
 Vertebræ more or less cavernous; limb bones hollow.
 Family *Allosauridæ*.
 Genera *Allosaurus*, *Creosaurus*, and *Labrosaurus*.
- (5.) Suborder HALLOPODA (Leaping foot.) Carnivorous?
 Feet digitigrade, unguiculate; three digits in pes.
 Metatarsals much elongated; calcaneum much produced backward.
 Two vertebræ in sacrum. Limb bones hollow.
 Family *Hallopodidæ*.
 Genus *Hallopus*.

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- (6.) Suborder CÆLURIA (Hollow tail.) Carnivorous?
 Family *Cæluridæ*.
 Genus *Cælorus*.



Left scapula and coracoid of *Brontosaurus excelsus*, Marsh; one-twelfth natural size. *a*, scapular face of glenoid cavity; *b*, rugose surface for union with coracoid; *a'*, coracoidean part of glenoid cavity.

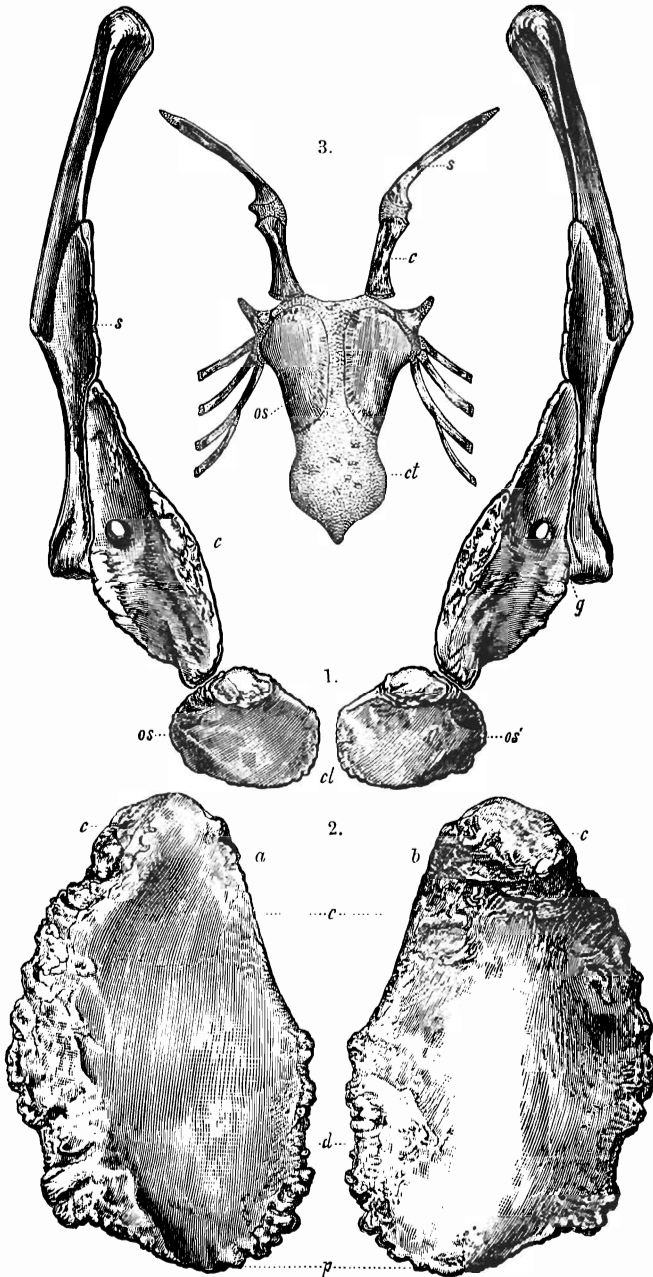


FIGURE 1.—Scapular arch of *Brontosaurus excelsus*, Marsh, front view; one-sixteenth natural size; *s*, scapula; *c*, coracoid; *g*, glenoid cavity; *os*, right sternal bone; *os'*, left sternal bone; *cl*, cartilage.
 FIGURE 2.—Left sternal bone, one-eighth natural size; *a*, superior view; *b*, inferior view; *c*, face for coracoid; *d*, margin next to median line; *e*, inner front margin; *p*, posterior end.
 FIGURE 3.—Scapular arch of young *Rhea Americana*, Lath; (after Parker); three-fourths natural size; seen from below. Letters as above.

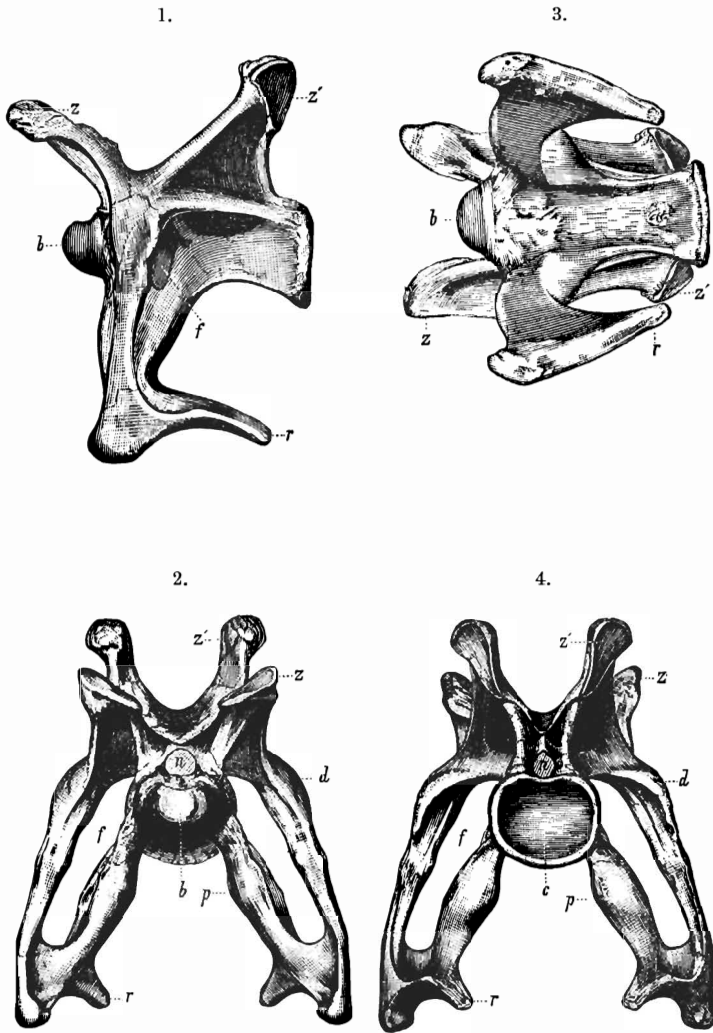


FIGURE 1.—Sixth cervical vertebra of *Brontosaurus excelsus*, Marsh, side view.

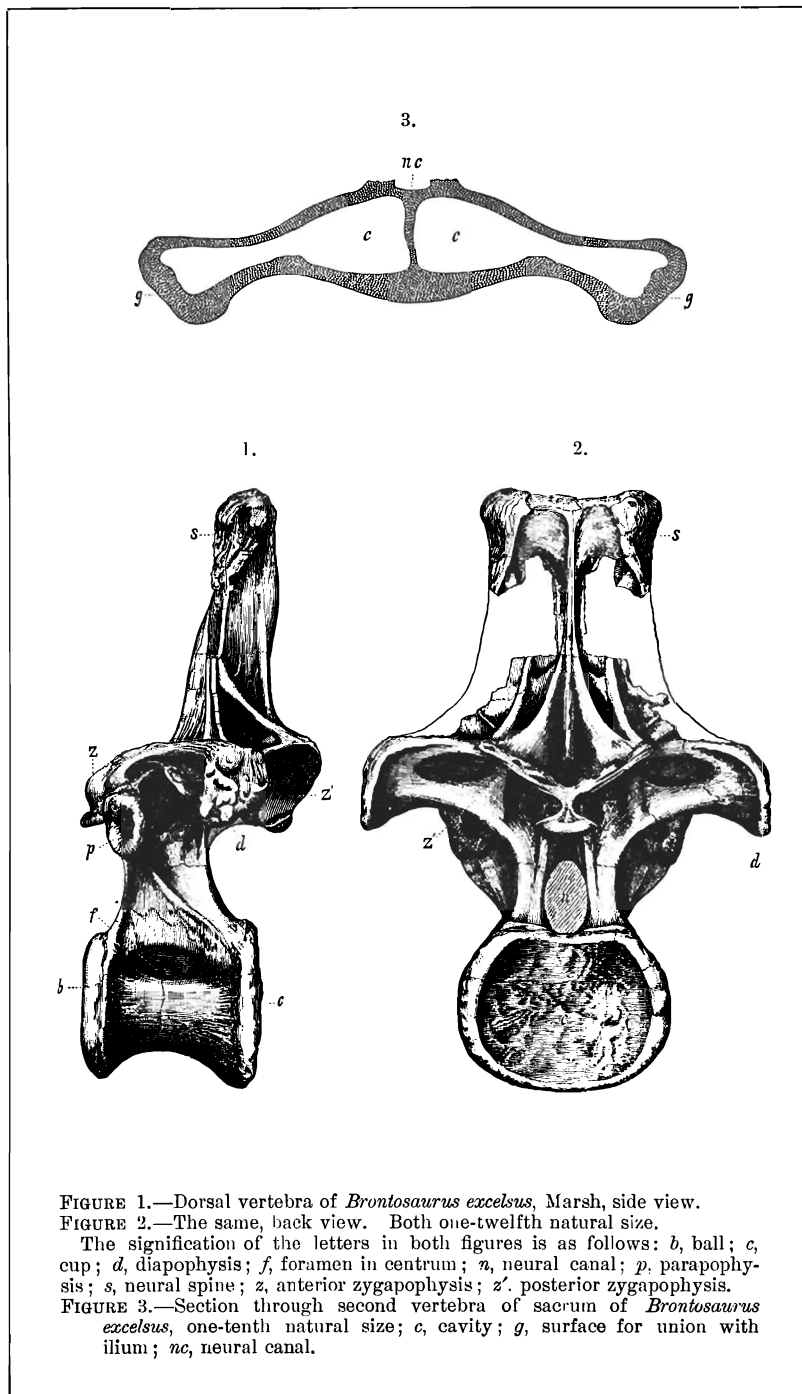
FIGURE 2.—The same vertebra, front view.

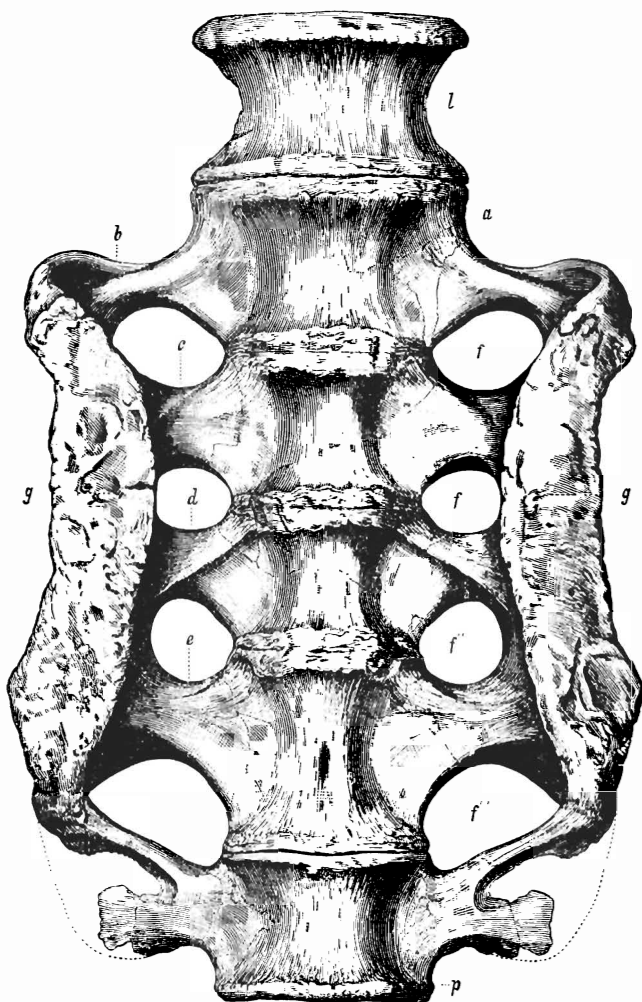
FIGURE 3.—The same, bottom view.

FIGURE 4.—The same, back view.

The signification of the letters is the same in all the figures, viz: *b*, ball; *c*, cup; *d*, diapophysis; *f*, lateral foramen; *n*, neural canal; *p*, parapophysis; *r*, cervical rib; *z*, anterior zygapophysis; *z'*, posterior zygapophysis.

All the figures are one-twelfth natural size.





Sacrum of *Brontosaurus excelsus*. Marsh, seen from below; one-tenth natural size; *a*, first sacral vertebra; *b*, transverse process of first vertebra; *c*, transverse process of second vertebra; *d*, transverse process of third vertebra; *e*, transverse process of fourth vertebra; *f*, *f'*, *f''*, foramina between processes of sacral vertebrae; *g*, surface for union with ilium; *l*, last lumbar vertebra; *p*, last sacral vertebra.

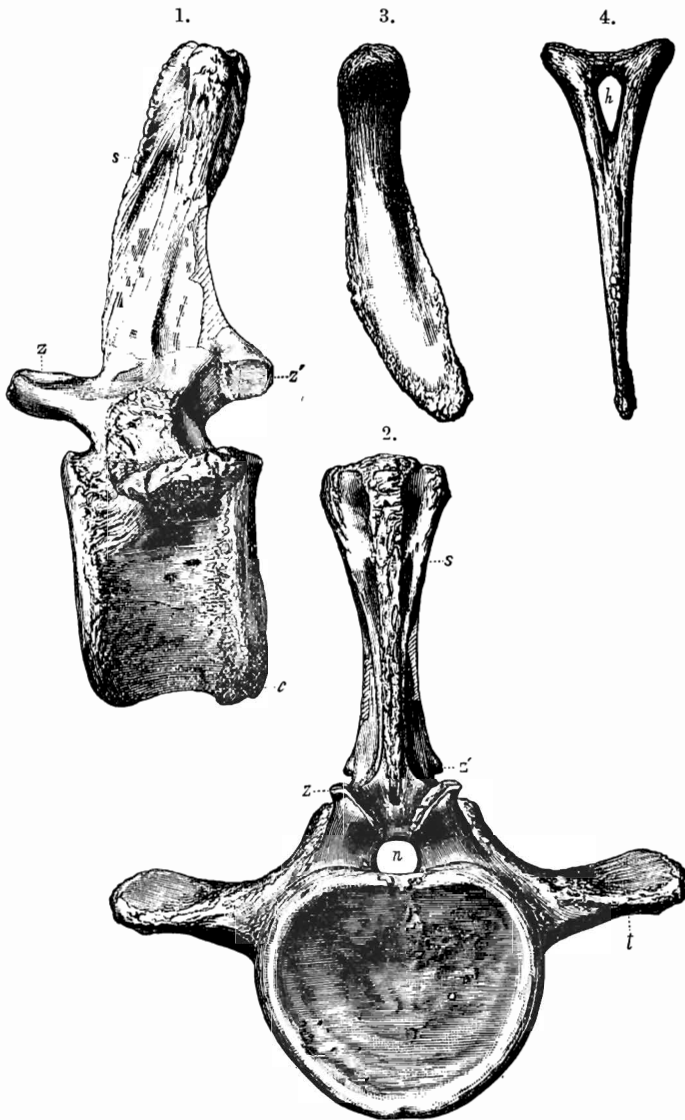


FIGURE 1.—Fourth caudal vertebra of *Brontosaurus excelsus*, Marsh, side view.

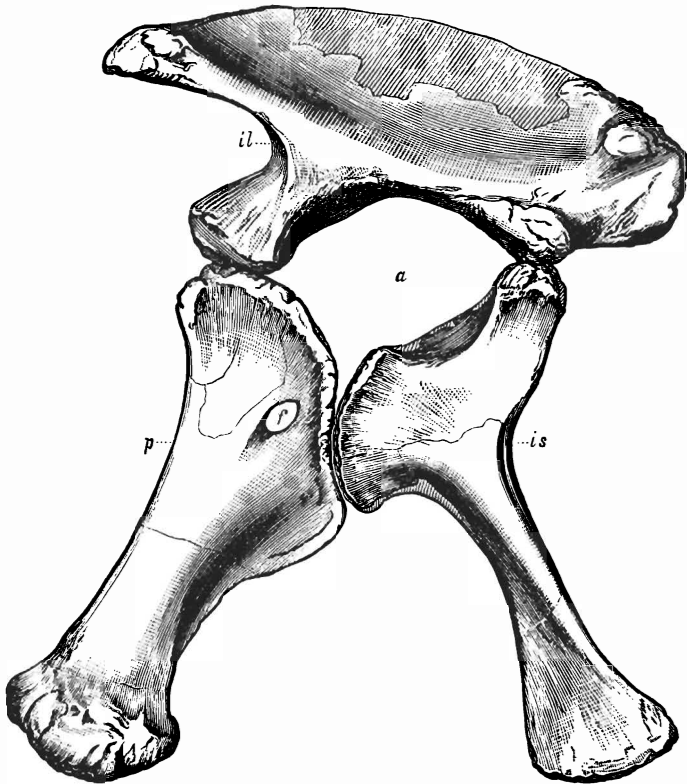
FIGURE 2.—The same, front view.

In both figures the signification of the letters is as follows: *c*, face for chevron; *n*, neural canal; *s*, neural spine; *t*, transverse process; *z*, anterior zygapophysis; *z'*, posterior zygapophysis.

FIGURE 3.—Chevron of *Brontosaurus excelsus*, side view.

FIGURE 4.—The same, front view; *h*, hæmal canal.

All the figures are one-eighth natural size.



Pelvis of *Brontosaurus excelsus*, Marsh, seen from the left; one-sixteenth natural size; *a*, acetabulum; *f.* foramen in pubis; *il.* ilium; *is.* ischium; *p.* pubis.

In this diagram, the three pelvic bones are represented nearly in the same plane.