This reptile may be called *Sauranodon natans*, and the order it represents *Sauranodonta*. This genus bears a similar relation to the Ichthyosaurs that *Pteranodon* does to the true Pterodactyls, and it is interesting to find the two highly specialized forms preserved in the same region.

The geological horizon of the *Sauranodontidæ*, so far as now known, is in the Jurassic, immediately below the Atlantosaurus beds. The accompanying fossils are Ammonites and Belemnites, showing more distinctly marine deposits, which may be called the Sauranodon beds.

Yale College, New Haven, December 27, 1878.



ART. X.—*Principal Characters of American Jurassic Dinosaurs;* by Professor O. C. MARSH. Part II. With eight Plates.

IN a previous article (vol. xvi, p. 411, Nov., 1878), the writer gave a short account of the geological horizon and accompanying fossils of the Jurassic Dinosaurs recently found in the Rocky Mountains; and also stated the more important characters of the gigantic *Sauropoda*, as illustrated mainly by the genus *Morosaurus*. In the present communication, this group is further elucidated by a comparison of the structure in some other American genera, especially *Apatosaurus* and *Atlantosaurus*, to which belong the largest reptiles hitherto discovered. The carnivorous enemies of this group are also briefly described. The pelvis of Dinosaurians, hitherto so little known, is illustrated by new examples, and by the corresponding parts in some recent birds.

### *Apatosaurus* Marsh, 1877.*

The genus *Apatosaurus* may be readily distinguished from *Morosaurus* by the sacrum, which consists of only three vertebræ instead of four (Plates V and VI, figures 1 and 2.) The ischium, also, has its distal end expanded. The scapula, likewise, is quite different, its superior extremity, being without the anterior extension seen in *Morosaurus* (Plate IV.) So far as at present known, the latter character, together with the form of the sacrum, separates it from the allied genus *Atlantosaurus*.

The cervical vertebræ of *Apatosaurus* are strongly opisthocœlian, and of moderate length. (Plate III, figures 1 and 2.) The dorsals have their centra similar, and both have deep cavities in the sides and in the neural arch resembling those in the corresponding vertebræ of *Morosaurus*. The lumbar vertebræ have their articular faces more nearly plane, and the last lumbar

* This Journal, vol. xiv, p. 514.



is expanded transversely. The sacrum is characteristic of the genus, and quite unlike any hitherto known. The type specimen on which the genus was established is well shown in Plate VI, figure 1. It is short and massive, and the three vertebræ which form it are nearly equal in size and general proportions. They are firmly coössified, and their transverse processes are ankylosed to the centra. Those on each side are united distally into a solid mass, which rests on the short ilium. The articular faces of the sacral vertebræ are nearly plane. That of the anterior centrum is a transverse oval in outline, and the posterior face is more nearly round. The centra and their processes are somewhat lightened by cavities, as in the sacra of *Atlantosaurus* and *Morosaurus*. The sacrum of the latter genus, shown in figure 2 of Plate V, is built upon the same general plan, characteristic of the *Sauropoda*, but the transverse processes are less massive, and have a greater vertical elevation. The same sacrum is shown in position in Plate V, figure 1. A striking feature of this sacrum is seen in the large size of the neural canal (*nc*), which, strange to say, is here two or three times the diameter of the brain cavity. This is a most suggestive fact, and without parallel in known vertebrates.

The scapula of *Apatosaurus* is large (Plate IV), and has in its lower portion an anterior projection similar to that in *Morosaurus*.* Above this, the shaft continues about the same width to the upper end, which is comparatively thin. The coracoid is small in proportion to the scapula, and subquadrate in outline, thus differing in form from that of *Morosaurus*. The foramen is large, and near the superior border.

There is at present some difficulty in separating the limb bones and various other parts of the skeleton of *Apatosaurus* from the corresponding portions of *Atlantosaurus*, especially as the type species of each are nearly equal in size, and their remains are found in the same localities. The sacra show the genera to be quite distinct, and the abundant material now in the Yale Museum, when carefully collated, will enable other parts of the structure to be compared. The teeth in all the herbivorous genera of the *Sauropoda* from the Atlantosaurus beds, so far as now known, appear to be very similar, and hence do not afford generic characters.

The type species of the present genus is *Apatosaurus ajax* Marsh, and the known remains indicate a reptile at least fifty feet in length. A much larger species is indicated by various remains from the same locality in Colorado, among which is the huge cervical vertebra represented in Plate III, figures 1 and 2. This species had a short massive neck, and hence may be

* This Journal, vol. xvi, Plate VI.

called *Apatosaurus laticollis*. The size of the entire animal may be judged from this vertebra, which measures over three and a half feet (1·07 M) in width. This would imply a neck at this point not less than five or six feet wide,—a marked contrast to the long and slender neck of *Morosaurus grandis*, a vertebra of which is figured in the same plate for comparison. All the cervical vertebræ of the present species now known are unusually short, and the neural spine is rudimentary or wanting. With the exception of the articular faces of the centra, the resemblance of these cervicals to those in some birds is very striking.

The limb bones at present referred to this species have a general resemblance to those of *Morosaurus*, described by the writer in the previous article. The pelvic bones appear to be more like those of *Atlantosaurus*.

The more important remains of this genus now known were found in the Upper Jurassic of Colorado, by Mr. Arthur Lakes, of the Yale Museum, to whom science is indebted for other interesting discoveries.

### *Atlantosaurus* Marsh, 1877.*

The typical species of this genus is *Atlantosaurus montanus*, and the type specimen on which it was based is represented by the sacrum figured in Plate VI, and various fragmentary remains found with it, and pertaining to the same individual. This sacrum resembles that of *Morosaurus* (Plate V, figure 2), in having four vertebræ, but a comparison of the two shows many differences. The centra of the second and third vertebræ are deeply excavated below on each side, leaving a comparatively narrow keel on the median line. From each opening between the transverse processes, a large cavity extends inward and backward into the centra, greatly lessening the weight of the sacrum. These important characters were mentioned in the original description, (vol. xiv, p. 87, July, 1877), in which the discovery of these large reptiles was first announced.

The ilium in *Atlantosaurus* is comparatively short and massive, but its exact outline has not been fully determined. Its articulations resemble those in the ilium of *Morosaurus*, and in the pelvis represented in Plate VII, figure 2, the outline of this bone is restored from that genus. The pubis is somewhat like that in *Morosaurus*, and its position in the pelvis very similar. It has three distinct articular faces on its proximal end, and, below the ischiadic union, a post pubic projection indicated in the diagram by *p'*. The distal end is expanded, and rugose for union with its fellow on the median line, as shown in the pelvic

* This Journal, vol. xiv, p. 514. Also p. 87.



arch of *Morosaurus*, in Plate V, figure 1. The ischium is less massive than the pubis, and it is directed downward, backward and inward. The acetabular face is larger than that of the pubis. The shaft of the ischium is not curved as in *Morosaurus*, and the distal end is widely expanded, and unites with its fellow on the median line, in a strong symphysis. The difference in the pelves of the two genera are well shown by a comparison of the figures in Plate VII. The ischium of *Morosaurus* is somewhat more twisted in its distal half than the artist has drawn it in figure 1, where the three bones are represented nearly in the same plane.

The vertebræ referred to *Atlantosaurus* are opisthocœlian in the cervical region, and the caudals preserved resemble those in *Morosaurus*. The limb bones, so far as known, are similar in their more important characters to those in that genus.

The two species now placed in the genus *Atlantosaurus* are the type, *A. montanus*, and *A. immanis*, which contain the largest land animals yet discovered. The latter species may possibly belong to the genus *Apatosaurus*.

The genera of *Sauropoda* above described and figured, viz: *Morosaurus*, *Diplodocus*, *Apatosaurus* and *Atlantosaurus*, show this suborder to be a well marked and natural group, the most generalized of the Dinosaurs. Some other generic names have been given to members of this group by Cope, which I shall review at another time. He still places the horizon of these reptiles in the Cretaceous, although the evidence of their Jurassic age seems now conclusive. In one species which he calls *Camarasaurus supremus* (identical according to Professor Owen with his genus *Chondrosteosaurus* from the English Wealden),† he says, in the sacrum, "the centra are like those of the caudal vertebræ composed of dense bone,"‡ a statement wholly discordant with the known characters of the group. He likewise describes the diplosphenal articulation of the vertebræ as unknown, and states (page 76) that it "has not been observed in any other animals;" whereas it has long been known in *Megalosaurus*, one of the earliest Dinosaurs described, as well as in other genera. The pelvic bones of this species, he says, do not resemble those of *Dinosauria*, when, on the contrary, the pubis he figures is typical in the group. Conclusions based on such work will naturally be received with distrust by anatomists.

### *Allosauridæ.*

In addition to the huge *Sauropoda*, and the small species of the genus *Laosaurus*, described in the previous article, numerous

† Annals and Mag. Nat. Hist., vol. ii, p. 201, Sept., 1878.
‡ Am. Naturalist, vol. xii, p. 77.

remains of carnivorous Dinosaurs occur in the same beds, and indicate the natural enemies which kept in check their herbivorous cotemporaries. These carnivorous forms represent two very distinct families; the *Allosauridæ*, resembling in many respects *Megalosaurus* and its near allies; and the *Nanosauridæ*, a widely different group, which appears to have some affinities with *Compsognathus*. In the present article, the former group is briefly discussed, and both will be more fully described in a future communication.

The genus *Allosaurus* is typical of the family, which also includes *Creosaurus*, and *Labrosaurus*. The first named genus presents some very interesting features in the vertebræ, and pelvic arch. The vertebræ first described are remarkable for the reduction of the centrum by constriction, so that the requisite lightness is secured without cavities in the interior. This is shown in the lumbar vertebra represented in Plate X, figures 3 and 4. The diplosphenal articulation of the zyapophyses, seen in the corresponding vertebræ of *Megalosaurus*, and in some other Dinosaurs, is well marked in these vertebræ.

The sacrum in *Allosaurus* apparently contains four vertebræ only, and these have very short and stout transverse processes, not united at their distal ends. These processes are coössified with the sides of the centra, and their extremities are obliquely truncated for union with the ilia, which thus stand nearly vertical, or somewhat divergent above. The exact form of the ilium is not known with certainty, and in the diagram given in Plate VIII, figure 2, the outline is taken from the ilium of *Creosaurus*. The pubis is perhaps the most remarkable bone in the skeleton, and its determination and position solve many difficulties in the structure of the Dinosaurian pelvis, especially in the Carnivorous types. At its proximal end, this bone has four well-marked articular faces; one in front for the ilium; next the acetabular face; an oblique face for the ischium; and below this another, of about equal size, to which a separate bone was apparently articulated. Judging from the structure of the pelvis in *Laosaurus*, this bone should be the postpubis, and it is so indicated in the figure (Plate VIII, figure 2, *p'*). The shaft of the pubis is slender, and the distal end is expanded longitudinally, and firmly coössified with its fellow. The two seen from the front resemble an acute letter V. This type of pubic bone has long been a puzzle to anatomists, and portions of it have been referred to various parts of the skeleton. The ischia, also, are closely united on the middle line throughout the distal half, but are not ankylosed. This makes the entire pelvic arch a remarkably narrow one.



The large bones in *Allosaurus* are hollow, and the metatarsals slender. The terminal phalanges were armed with sharp claws. With the remains described above, a large spine was found, similar in general form to that of *Omosaurus armatus* described by Owen.

The type of *Allosaurus* is *A. fragilis*,* the remains of which indicate a reptile probably twenty-five feet in length, and of slender proportions.

The genus *Creosaurus* appears to be most nearly related in its vertebræ and ilium to *Megalosaurus*. It has apparently one less vertebra in its sacrum, and the ilium has in front of its pubic process an articular face which has not been observed in the latter genus. The position of this surface is indicated in Plate X, figure 1, *f*, and it may have supported a prepubic bone. The sacral vertebræ are elongated, and the transverse processes are placed higher up on the centra than those in *Allosaurus*. The teeth in both genera are of the *Megalosaurus* type, and in the whole group are so similar as to be of little value for the determination of species. The type of *Creosaurus*, is *C. atrox*,† a reptile about twenty feet in length.

A third genus of carnivorous Dinosaurs contains individuals of somewhat smaller size, and of this group the species named *Allosaurus lucaris*‡ is the type. The cervical vertebræ are short and strongly opisthocœlian, and the dorsals moderately so. All these vertebræ have very large cavities in the centra, which connect with the exterior by a comparatively small foramen on each side. The neural spines of the dorsal vertebræ are elevated and transverse, and the vertebræ now known do not show the diplosphenal articulation. The fore limbs in this genus are quite small, and the humerus is curved, and has a large radial crest. This genus is distinct fron *Allosaurus*, and may be called *Labrosaurus*, the type being *Labrosaurus lucaris*.

All of the carnivorous Dinosaurs known from the Atlantosaurus beds appear to have moved mainly on the posterior limbs. The large bones were hollow, and many of the vertebræ, as well as some of the feet bones, contained cavities, or were otherwise lightened to facilitate rapid movement.

The reptilian remains described in these two communications are preserved in the Museum of Yale College. In addition to these fossils, the collection contains a large quantity of similar specimens, from the same localities and horizon, some of which pertain to the same skeletons as those here illustrated. The careful investigation of this entire series will require much time, but promises important results.

* This Journal, vol. xiv, p. 515. † Ibid., vol. xv, p. 243.
‡ Ibid., vol. xv, p. 242.

The descriptions and illustrations given in this and the preceding article make clear the general structure of the Dinosaurian pelvic arch, which has so long been in doubt. In the *Sauropoda*, the elements of this arch are seen united in forms that admit of direct comparison with other more typical reptiles, each genus of the group having its own special features. In the smaller, more specialized, herbivorous forms, exemplified by *Laosaurus*, an advance is seen, especially in the pubic elements, where the long rod-like avian bone is fully developed, and the anterior part, or true reptilian pubis, is still prominent. In the Carnivorous forms represented by *Allosaurus*, a more complicated structure is seen to exist, but additional material will be necessary to elucidate it fully. In the pelves of the recent birds, given in Plate IX, the remnant of the reptilian pubis is still plainly to be seen, especially in *Geococcyx*. It is not improbable that the retention of this process may be due in part to the habits of certain species, as it seems to be best developed in running birds, and those that especially use the posterior limbs. The same process, apparently, is seen in some mammals, where it may serve a similar purpose. The ilium and ischium undergo but comparatively little change from the *Sauropoda* to recent birds. The sacrum, however, is gradually strengthened by the addition of vertebræ, and their more perfect coössification.

Yale College, New Haven, December 27, 1878.

[To be continued.]



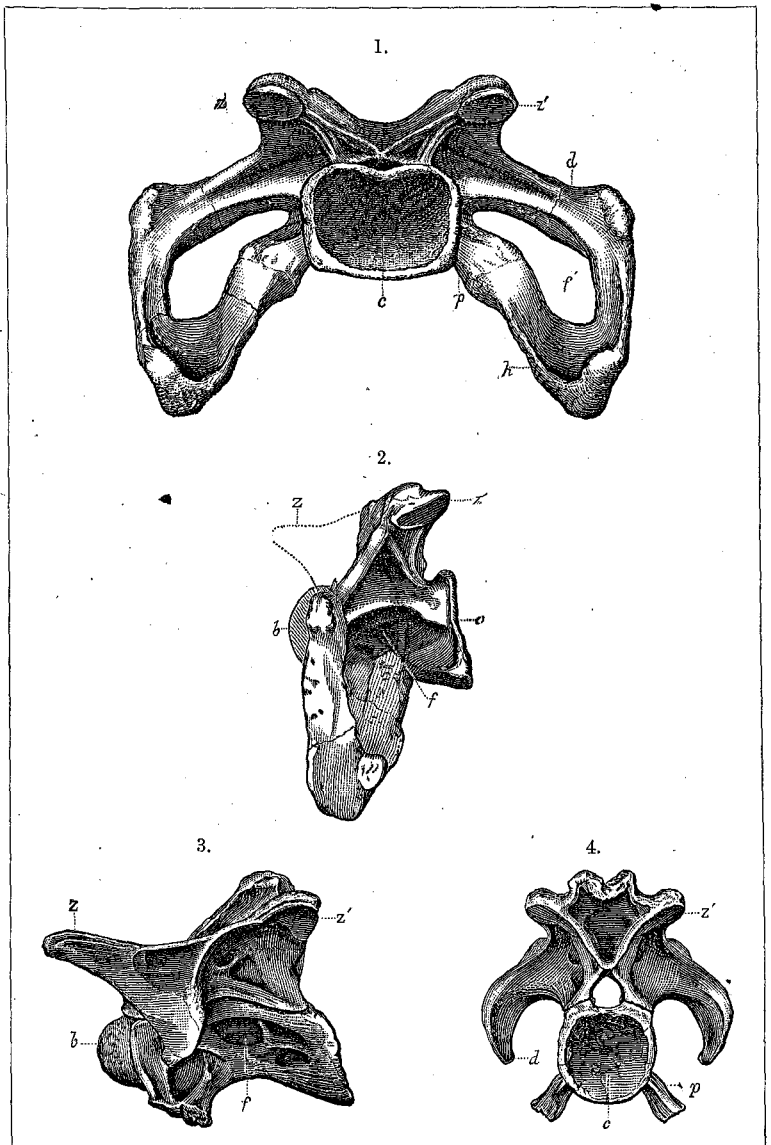
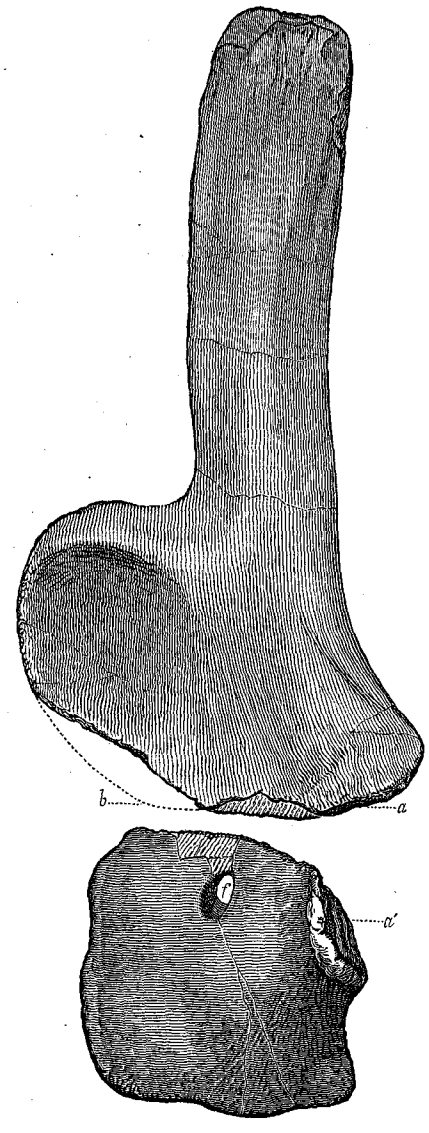



Figure 1.—Cervical vertebra of *Apatosaurus laticollis* Marsh; back view.
Figure 2.—The same; side view. Both one-sixteenth natural size.
Figure 3.—Fourth cervical vertebra of *Morosaurus grandis* Marsh; side view, one-eighth natural size.
Figure 4.—The same; back view.
The signification of the letters is the same in all the figures, viz: *b.* ball; *c.* cup; *d.* diapophysis; *p.* parapophysis; *h.* hatchet bone; *f.* foramen in centrum; *f'.* lateral foramen; *z.* anterior zygapophysis; *z'.* posterior zygapophysis.




Left scapula and coracoid of *Apatosaurus ajax* Marsh; one-fourteenth natural size. *a*. scapular face of glenoid cavity; *b*. rugose surface for union with coracoid; *a'* coracoidean part of glenoid cavity; *f*. foramen in coracoid.

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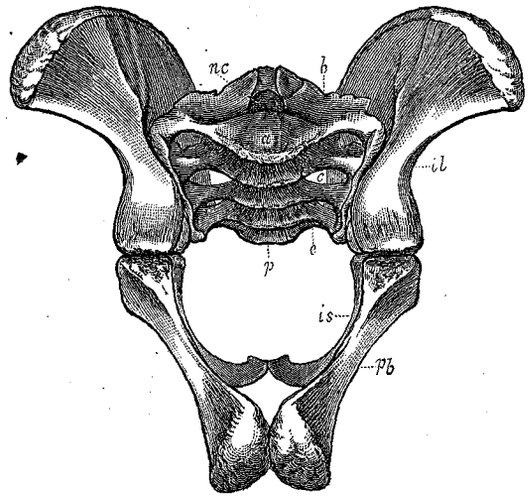


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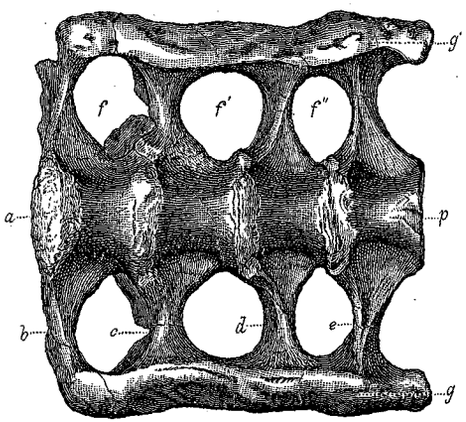


Figure 1.—Pelvic arch of *Morosaurus grandis* Marsh; seen from in front. One-sixteenth natural size.

Figure 2.—Sacrum of *Morosaurus grandis;* seen from below. One-tenth natural size.

*a*. first sacral vertebra; *b*. transverse process of first sacral vertebra; *c*. transverse process of second vertebra; *d*. transverse process of third vertebra; *e*. transverse process of last sacral vertebra: *f*. foramen between processes of first and second vertebra; *f'*. foramen between second and third processes; *f''*. foramen between third and last process; *g*. surface for union with right ilium; *g'*. same for left ilium; *p*. fourth, or last, sacral vertebra: *nc*. neural canal; *il*. ilium; *is*. ischium; *pb*. pubis.

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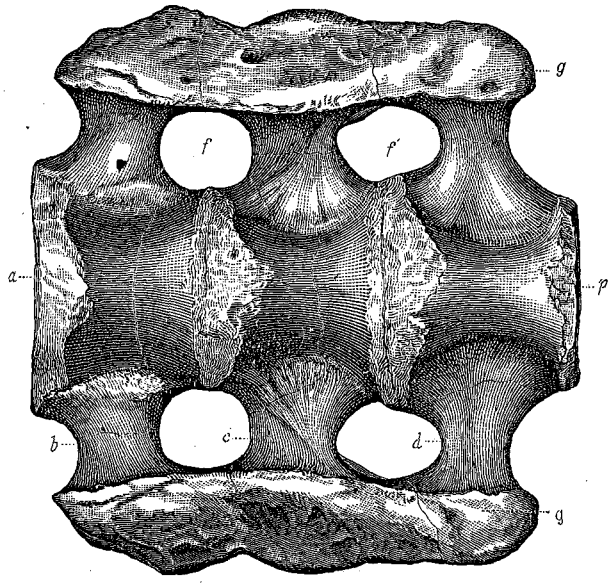


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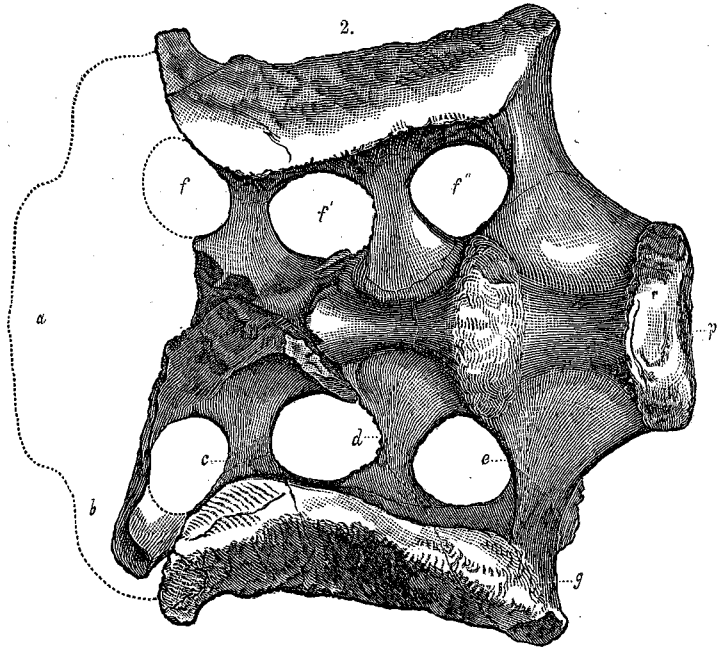


Figure 1.—Sacrum of *Apatosaurus ajax* Marsh; seen from below.
Figure 2.—Sacrum of *Atlantosaurus montanus* Marsh; seen from below; both one-tenth natural size.

*a*. first sacral vertebra; *b*. transverse process of first vertebra; *c*. transverse processes of second vertebra; *d*. transverse process of third vertebra; *f*. foramen between first and second transverse processes; *f'*. foramen between second and third processes; *p*. last sacral vertebra; *g*. surface for union with ilium.

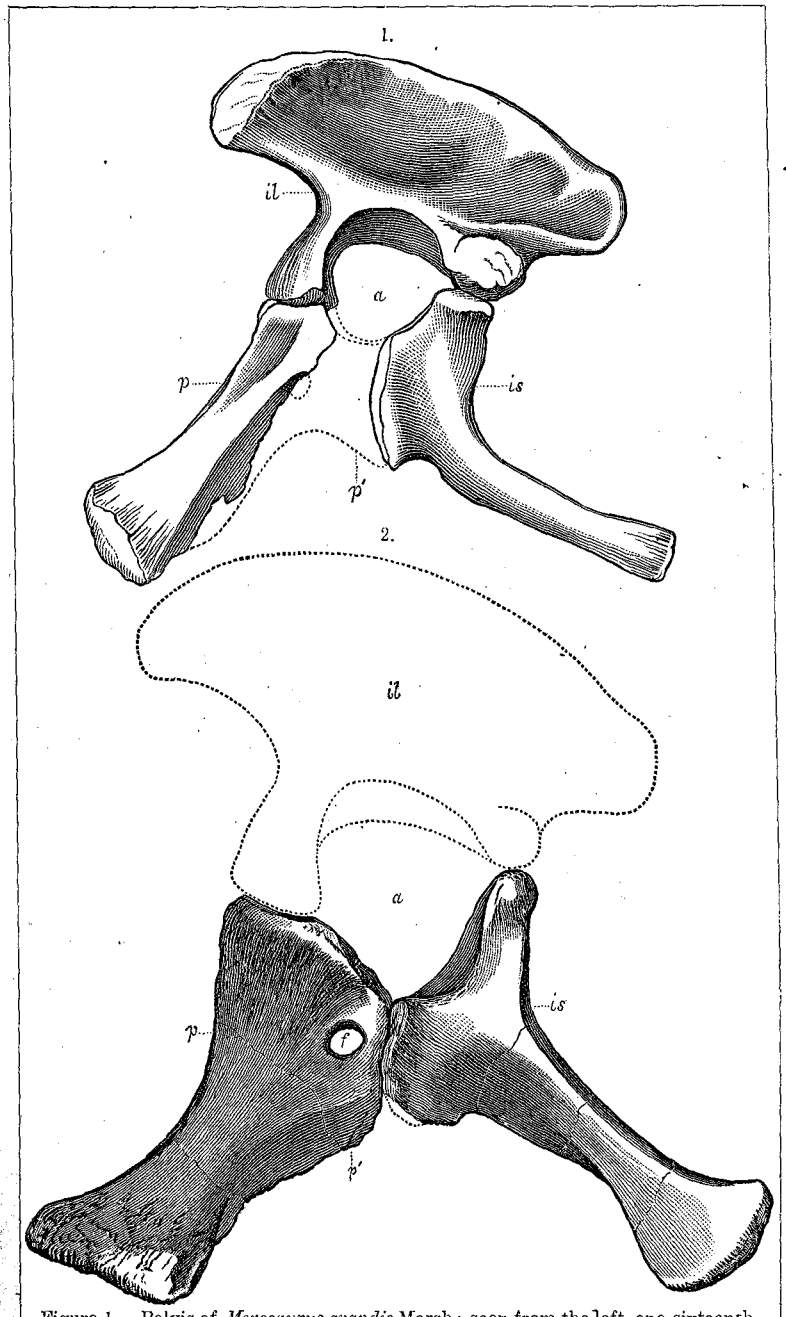


Figure 1.—Pelvis of *Morosaurus grandis* Marsh; seen from the left, one-sixteenth natural size.

Figure 2.—Pelvis of *Atlantosaurus immanis* Marsh; seen from the left, one-twentieth natural size. The signification of the letters is the same in both figures, viz: *a.* acetabulum; *f.* foramen in pubis; *il.* ilium; *is.* ischium; *p.* pubis; *p'.* post-pubis. In these and the following diagrams of Dinosaurian pelves, the three bones of each are represented nearly in the same plane.

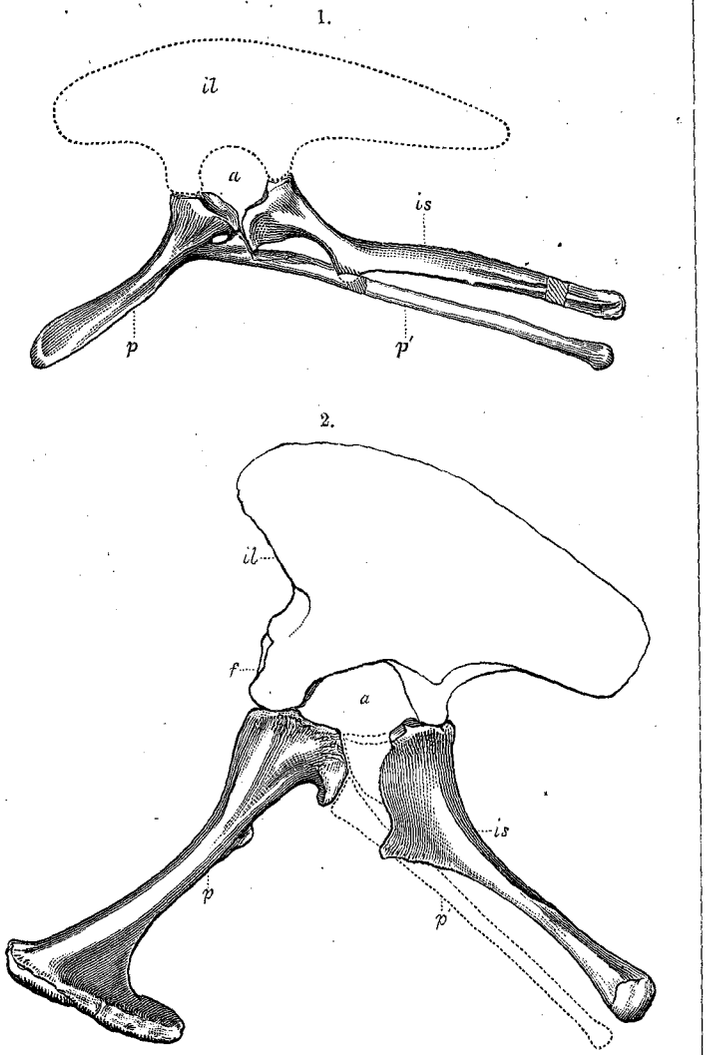


Figure 1.—Pelvis of *Laosaurus altus* Marsh; seen from the left, one-sixth natural size.

Figure 2.—Pelvis of *Allosaurus fragilis* Marsh; seen from the left, one-twelfth natural size. The outline of the ilium is taken from *Creosaurus atrox* Marsh.

The signification of the letters is the same in both figures, viz: *a.* acetabulum; *il.* ilium; *is.* ischium; *p.* pubis; *p'.* post-pubis; *f.* articular facet on front of pubic process of ilium.

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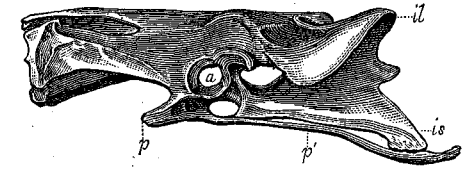


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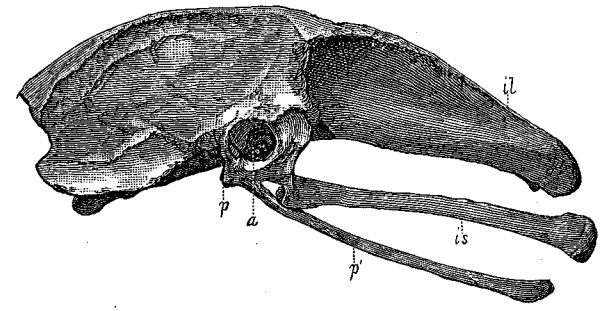


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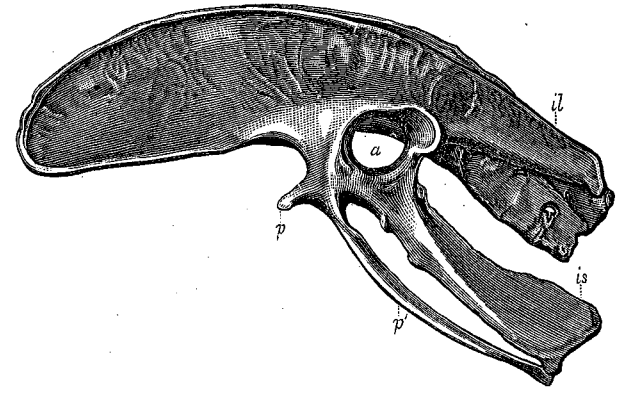


Figure 1.—Pelvis of *Geococcyx Californianus* Baird; seen from the left, natural size.
Figure 2.—Pelvis of Emeu, *Dromaius novæ hollandiæ* Lath; one-fifth natural size.
Figure 3.—Pelvis of *Apteryx australis* Owen; three-fourths natural size.
*a.* acetabulum; *il.* ilium; *is.* ischium; *p.* pubis; *p'.* post-pubis.

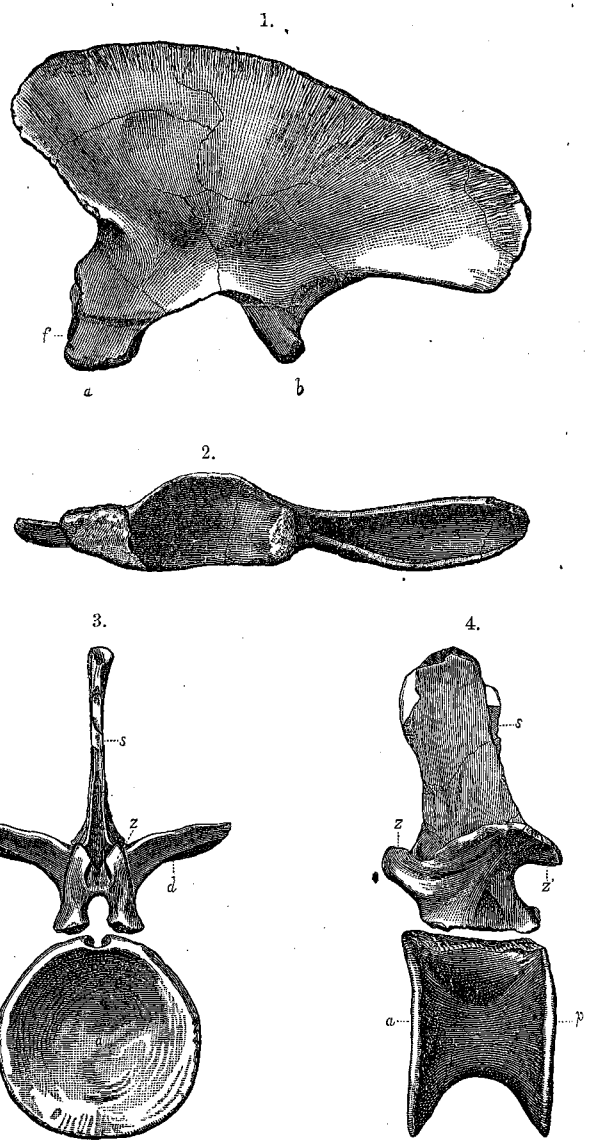


Figure 1.—Left ilium of *Creosaurus atrox* Marsh; seen from the left.
Figure 2.—The same; seen from below. Both one-tenth natural size.
*a.* anterior, or pubic, articulation; *b.* posterior, or ischiadic, articulation; *f.* articular facet on front of pubic process.
Figure 3.—Lumbar vertebra of *Allosaurus fragilis* Marsh; front view.
Figure 4.—The same; side view, from the left. Both one-sixth natural size.
*a.* anterior articular face; *p.* posterior articular face; *s.* neural spine; *d.* diapophysis; *z.* anterior zygapophysis; *z'.* posterior zygapophysis.