

Article XVI. — CRITERIA FOR THE DETERMINATION OF SPECIES IN THE SAUROPODA, WITH DESCRIPTION OF A NEW SPECIES OF *APATOSAURUS*.

BY CHARLES C. MOOK.

The present paper is based upon studies made under the direction of Professor Henry Fairfield Osborn in connection with the latter's monograph on the Sauropoda now in course of preparation.

In this work the question of species and specific criteria has been a troublesome one. Marsh and others have used characters of size and slight differences in morphological structure, with little or no regard to their ontogenetic significance or their dependence on individual variation. In some cases authors have made generic descriptions answer for both generic and specific designations, leaving it for future revisers to select specific characters. A study of the value of various characters as specific criteria in the Sauropoda may perhaps be discussed advantageously at the present time.

Size has been used to a considerable extent both as generic and specific characters. If the size of two *adult* animals differs appreciably while their morphological structures remain practically the same, it seems reasonable to assign them to different species. If two individuals of the *same size* show considerable differences in their ontogenetic characters they may be considered as belonging to different species. If the larger of two animals, however, exhibits adult or old-age characters, while the smaller one possesses juvenile characters, it is by no means allowable to assign the two forms to different species on the ground of size alone, unless this difference is excessively great. In the case of reverse conditions, the smaller animal exhibiting characters of a later ontogenetic stage than the larger animal, it is certainly allowable to assign the two individuals to different species on the ground of difference in size. Size, then, is a reliable specific character when applied to individuals of the same ontogenetic stage, but may or may not be reliable when applied to individuals of different ontogenetic stages.

Ontogenetic characters have been used frequently as specific characters. Their use must be associated with that of some other kind of character, such as size, to be reliable. Ontogenetic characters which are frequently used are: union of neural arches and centra of vertebræ by suture or by complete coalescence; the presence of three, four, five, or six vertebræ in the sacrum, and the relative amount of coalescence of these with each

other; coössification or separation of scapula and coracoid, or scapula and suprascapula; thickness or thinness of bones which would be cartilaginous in young stages, such as the sternum; to a certain extent the degree of separation of processes of bones, such as vertebral laminae, zygapophyses, trochanters, etc.; the degree of development of rugosities for muscular and ligamentary attachment; perhaps the number of vertebræ bearing transverse processes; [this character must be considered as ontogenetic with caution as it may represent real morphologic difference]; relative differences in size and proportions between different bones or regions of the body; possibly in differences in the size of certain parts of the body only, which are similar in character; the degree of definiteness of outlines of bones, etc.

Slight morphological differences are often used as specific criteria in the Sauropoda. In order to be sure that these are not merely individual variations one must study all the material available, and determine, if possible, just what the range of variation is. Individual variation plays a very important part in sauropodan morphology, and if one were to consider all minor variations as having specific value, it is possible that every known sauropod specimen of any considerable degree of completeness would be considered as belonging to different species. By comparing a large amount of material, however, the range of individual variation can be determined with a reasonable degree of accuracy, and characters of this sort distinguished from characters definite and constant enough to have specific value.

The *order of differentiation of parts* may possibly be considered as a criterion for distinguishing species. The primary sauropodan sacrum, for instance, has three vertebræ, the typical adult sacrum five vertebræ, and occasionally an old individual has six. The order of addition of the extra vertebræ to the primary sacra, whether first the caudo-sacral and then the dorso-sacral, or the reverse, may perhaps have specific value.

A type of specific criterion which has considerable value when sufficient material is preserved in a skeleton to allow its use, is that of *acceleration* and *retardation*. It sometimes happens that a certain individual exhibits in general characters showing a certain stage of development, while some particular portion of the skeleton may belong to a stage much younger or older than that indicated by the rest of the characters of the animal. In the former case we have *retardation* which respect to the given portion of the body, and in the latter case *acceleration*. If we have two individuals which show by their morphological characters that they belong to the same genus, but with one having a greater degree of acceleration or retardation in respect to certain characters, or one individual normally developed and the other decidedly accelerated or retarded, the two individuals clearly belong to different species.

In applying the above-mentioned criteria to the genus *Apatosaurus*, it appears that the well-preserved sacrum and pelvis of No. 675 of the American Museum collections belongs to a species of *Apatosaurus* which has not hitherto been described. This sacrum has been described and figured by Osborn in 1904. It consists of six sacral vertebræ (two dorso-sacrals, three primary sacrals, and a caudo-sacral). The size of both sacrum and pelvis is much smaller than that of the type specimen of *A. ajax*, or of *Brontosaurus excelsus*. All six vertebræ are coalesced by their centra, and all are attached to the ilia, otherwise the first and last of the series resemble a dorsal and caudal respectively, more than they do the primary sacrals. The first dorso-sacral is attached to the ilia by rather long ribs resembling those of the dorsal vertebræ. These ribs distinctly have shaft, tuberculum, and capitulum. The articulation of the tuberculum with the diapophysis is very distinct, and is well shown in the figure of the anterior end of the sacrum. The capitular articulation with the capitular facet is traceable, but less clearly so, and is not shown in the figure. The distal ends of the ribs are expanded; they attach with the ilia near the tips of the anterior processes of the latter. The second dorso-sacral is attached to the ilia in much the same way as the first. Its rib is much shorter and thicker, however, and the capitular attachment to the vertebra is not visible on the specimen. The union of the tuberculum of the rib with the diapophysis is still clearly visible. This rib is connected with that of the first dorso-sacral by a short, slender antero-posterior bar. The inferior portions of the articulations of the primary sacrals are not visible from above. The superior attachments in primary sacrals 1 and 2 are clearly of the dorsal type, with well-developed diapophyses. There appear to be very short ribs between the diapophyses and the ilia. This point requires further study, however. The 3rd primary sacral resembles a caudal in form, having a broad, thin plate for a transverse process instead of a diapophysis which is thick antero-posteriorly and thin vertically. This suggests that the ultimate origin of the three primary sacrals is from two dorsals and one caudal. The caudo-sacral is attached to the ilia by broad transverse processes which have no suggestion of division into diapophysis, parapophysis, and rib. They are supported posteriorly by a process which extends backward to the posterior border of the centrum. The sacro-costal yoke is made up of the coalesced inferior rib articulations of the second dorso-sacral and three primary sacrals, with which the lower part of the transverse process of the caudo-sacral is also united. Its inferior surface forms part of the acetabulum, a characteristic sauropodan feature which will be discussed by Professor Osborn in the paper on the *Camarasaurus* sacrum. The spines are rather slender compared with those of most *Apatosaurus*

sacra, such as the mounted specimen in the Field Museum. The spines of the second dorso-sacral and primary sacra 1 and 2 are firmly coalesced with each other, while that of primary sacral 3 is partially coalesced with that of the second primary sacral. The spines of the first dorso-sacral and the caudo-sacral are entirely free. The inferior portion of the sacral rib of primary sacral 2 has an oblique ridge on its inferior surface resembling those present in the types of *A. ajax*, *Brontosaurus excelsus*, and *B. amplius*. This is a characteristic structure in *Apatosaurus*. The inferior surfaces of the centra are broadly rounded, contrasting with those of *Diplodocus*. The inferior portions of the sacral ribs are not twisted as in *Camarasaurus*. These characters together with the tall spines which have the characteristic *Apatosaurus* lamination indicate conclusively that the specimen under consideration belongs to the genus *Apatosaurus*. Most or all of the other known sacra of *Apatosaurus* are much larger and have fewer vertebræ. That in the type of *Brontosaurus excelsus* has six, but the first is united by the centrum only, and the whole sacrum is much larger than the present specimen. Those of the types of *A. ajax* and *B. amplius* are both much larger than the present one and have four and five vertebræ respectively.

The present specimen, with its six sacra firmly attached to the ilia and its small size evidently belongs to a different species from the gigantic sacra of the species mentioned above, with their lesser, or at any rate not greater number of sacra. This species may be called *Apatosaurus minimus*, in allusion to its being the smallest known species of the genus. It may be characterized briefly as follows: small size, very strong sacrum, with six functional vertebræ in the adult, and also by the very slightly expanded distal end of the ischium.

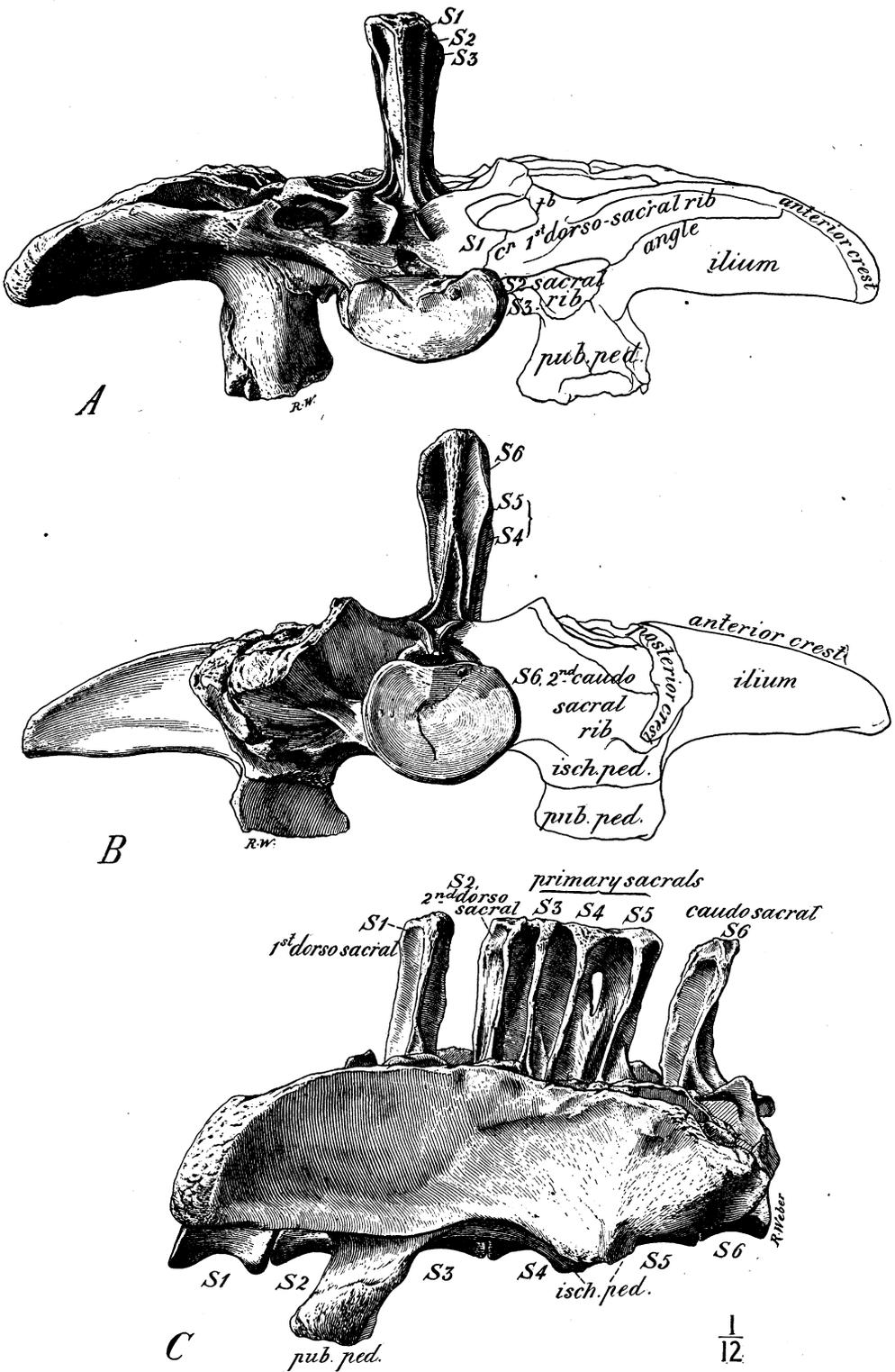


FIG. 1. A. Anterior view of sacrum and ilia of *Apatosaurus minimus*, sp. nov. $\frac{1}{2}$ natural size, after Osborn.
 B. Side view of the same, after Osborn.
 C. Posterior view of the same, after Osborn.

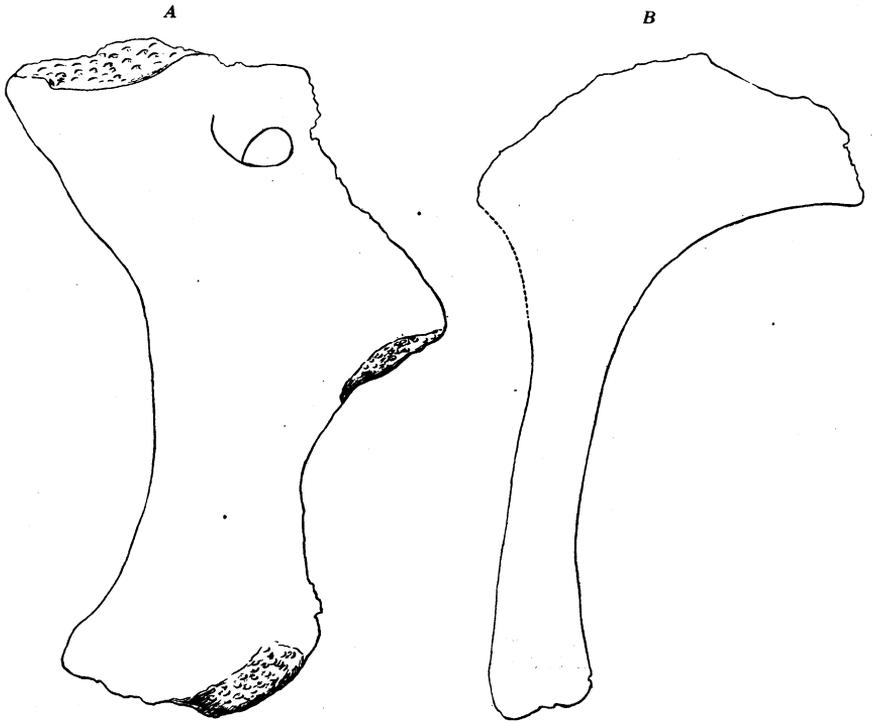


FIG. 2. A. Outline of right pubis of *Apatosaurus minimus*, $\frac{1}{12}$ natural size.
B. Outline of right ischium of *Apatosaurus minimus*, $\frac{1}{12}$ natural size.