On the Classification of the Fossil Animals Commonly Named Dinosauria

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Proceedings of the Royal Society of London, Vol. 43 (1887 - 1888), 165-171.

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Proceedings of the Royal Society of London is currently published by The Royal Society.

November 24, 1887.

Professor G. G. STOKES, D.C.L., President, in the Chair.

In pursuance of the Statutes, notice was given from the Chair of the ensuing Anniversary Meeting, and the list of Officers and Council nominated for election was read as follows:—

President.—Professor George Gabriel Stokes, M.A., D.C.L., LL.D.

Treasurer.—John Evans, D.C.L., LL.D.

Secretaries.— { Professor Michael Foster, M.A., M.D.
The Lord Rayleigh, M.A., D.C.L.

Foreign Secretary.—Professor Alexander William Williamson, LL.D.

Other Members of the Council.—Sir William Bowman, Bart., M.D.; Henry Bowman Brady, F.L.S., F.G.S.; Professor Arthur Cayley, D.C.L., LL.D.; W. T. Thiselton Dyer, M.A.; Professor David Ferrier, M.A., M.D.; Edward Frankland, D.C.L.; Arthur Gamgee, M.D.; Professor Joseph Henry Gilbert, M.A.; Professor John W. Judd, P.G.S.; Professor Herbert McLeod, F.I.C.; William Pole, Mus. Doc.; William Henry Preece, M.I.C.E.; Admiral Sir George Henry Richards, K.C.B.; Professor Arthur William Rücker, M.A.; the Earl of Rosse, D.C.L., LL.D.; Sir Bernhard Samuelson, Bart., M.I.C.E.

The Rev. Octavius Pickard-Cambridge was admitted into the Society.

The Presents received were laid on the table and thanks ordered for them.

The following Papers were read:—

I. "On the Classification of the Fossil Animals commonly named Dinosauria." By H. G. SEELEY, F.R.S., Professor of Geography in King's College, London. Received August 31, 1887.

Three classifications of the Dinosauria have been proposed, which differ from each other in the principles on which their authors proposed to make the divisions.

First in time is Professor Cope's classification ('Philadelphia, Acad.

Nat. Sci. Proc.,' November 13th, 1866, and December 31st, 1867; 'Amer. Phil. Soc. Trans.,' vol. 14, Part I). He relied upon the characters of the tarsus and the ilium; and on their varied condition divided Dinosaurs into three orders named Orthopoda, Goniopoda, and Symphopoda. In the *Orthopoda*, the generic types associated are Scelidosaurus, Hylæosaurus, Iguanodon, and Hadrosaurus. And in this group the relations of the tibia and fibula are compared to those of modern Lizards, the proximal tarsals being distinct from each other and from the tibia. The ilium has a narrowed anterior prolongation.

The *Goniopoda* is so named from the abrupt flexure of the tarsus in the middle, which prevented the foot being extended in a line with the leg, so that the animals are plantigrade. The astragalus is distinct from the tibia, but embraces its distal end. The anterior portion of the ilium is dilated and plate-like. The genera in this group comprise Megalosaurus, Lælaps, Cœlosaurus, &c.

The *Symphopoda* comprises animals having the first series of tarsal bones confluent with each other and with the tibia. The anterior part of the ilium is dilated and plate-like. The type genera are Ornithotarsus and Compsognathus.

Professor Huxley rejected Professor Cope's groups because he considered that the relations of the tarsal bones to the tibia and fibula, which were supposed to characterise the Goniopoda, are also found in the Orthopoda. I am not concerned to inquire how far this criticism invalidates Cope's nomenclature, which does not rest wholly upon tarsal characters for definition; but it may be remarked that Professor Marsh subsequently obtained specimens which proved that there are many Dinosaurs in which the astragalus does not embrace the tibia. In place of Cope's three orders Professor Huxley offered a classification founded upon characters of the teeth, mandible, ilium, femur, and the absence or presence of dermal armour. He divided the order Dinosauria into three groups or families, named *Megalosauridæ*, *Scelidosauridæ*, and *Iguanodontidæ*. And it was further proposed to unite these families with Compsognathus into an order, Ornithoscelida ('Geol. Soc. Quart. Journ.,' vol. 26, February, 1870). The characters used for its definition are different from those relied upon by Cope. The Megalosauridæ is co-extensive with the Goniopoda. The Orthopoda is subdivided, chiefly on details of tooth character and the presence of dermal armour in the Scelidosauridæ, and its supposed absence in the Iguanodontidæ; but the grounds for the division became less evident when Mr. Hulke found dermal armour well developed in his *Iguanodon Seelyi* ('Geol. Soc. Quart. Journ.,' vol. 38, p. 144, May, 1882).

Subsequently Professor Marsh, in a series of memoirs dating from 1878 to 1884, proposed to divide the Dinosauria into four orders and

three sub-orders. The characters used in the classification are drawn from all parts of the skeleton. The chief orders are the *Sauropoda*, comprising the allies of Cetiosaurus; the *Stegosauria*, which includes the allies of Scelidosaurus; the *Ornithopoda*, formed for the allies of Iguanodon; and the *Theropoda*, which includes genera related to Megalosaurus. The sub-orders grouped under the Theropoda are named from their typical genera *Cœluria* and *Compsognatha*. The chief difference of Marsh's system from that of Huxley is that he separated the allies of Cetiosaurus from the Iguanodontidæ to form the type of a primary division of the group, as I had suggested ('Geol. Soc. Quart. Journ.,' vol. 30, 1874, p. 690), and named it Sauropoda. Otherwise the Theropoda is identical with the Megalosauridæ; the Ornithopoda is the Iguanodontidæ similarly re-named; while the Stegosauria is the Scelidosauridæ of Huxley, enlarged like the other groups by Professor Marsh's admirable discoveries, and re-named.

The characters on which these animals should be classified are, I submit, those which pervade the several parts of the skeleton, and exhibit some diversity among the associated animal types. The pelvis is perhaps more typical of these animals than any other part of the skeleton, and should be a prime element in classification. The presence or absence of the pneumatic condition of the vertebræ is an important structural difference. Differences in the construction of the base of the skull are indicative of affinities. The presence or absence of armour is less important, since it may show all grades of development from the perfect shield of Polacanthus to small granules in the skin; and the condition of the tarsus seems to me likely to be influenced by the habits of life of the animals. Yet the more general of these characters are morphologically preferable to slight differences in dental character, or digitigrade or plantigrade progression, or number of digits, or relative size of limbs. Many of the characters hitherto regarded as ordinal seem to me rather of a nature to distinguish families.

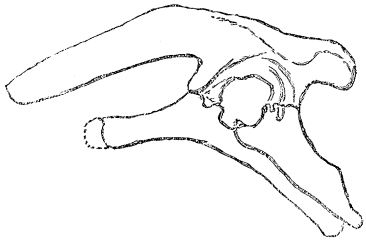
The ilium at first sight has the aspect of a distinctive character of the whole group, and has been regarded as Avian, because it extends both in front of the acetabulum and behind it. This character is common to birds; but it is also shared by the Ornithosauria, and to some extent by the Anomodontia. Hence this condition of the ilium does not necessarily imply that the Dinosauria is a homogeneous group. Professor Cope pointed out two distinct types of ilium which he regarded as ordinal. First, there is the ilium which is prolonged forward as a more or less narrow process which is typically seen in Iguanodon and less typically in Scelidosaurus. Secondly, there is the ilium which has its anterior process developed into a vertical plate. The bone varies a little in shape in every genus, but I

see no reason to doubt that these two types of iliac bones are available for purposes of classification.

The pubes also present two types. First there are genera in which the bones are directed anteriorly and meet by a median symphysis, and have no posterior extension except for the proximal symphysis with the ischium. This type is represented by Cetiosaurus, Ornithopsis, Megalosaurus, and many genera figured by Professor Marsh. The second form of pubis has one limb which is directed backward parallel to the ischium, and another limb directed forward. It is typically seen in Omosaurus and in Iguanodon. There are many variations in stoutness and details of form of the bones, but so far as I am aware these two plans comprise all the Dinosaurian genera.

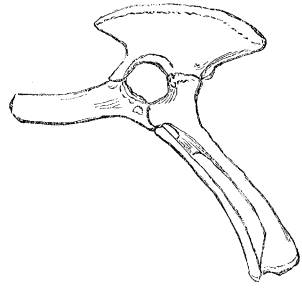
So far as can be ascertained by comparison of figures and specimens,

Stegosauria.



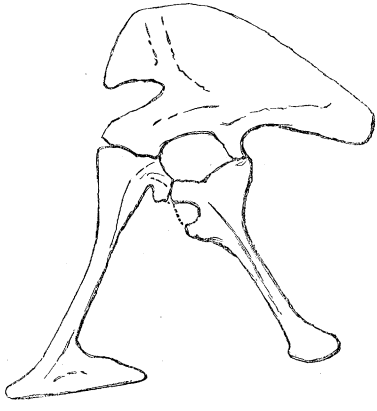
Stegosaurus.

Ornithopoda.



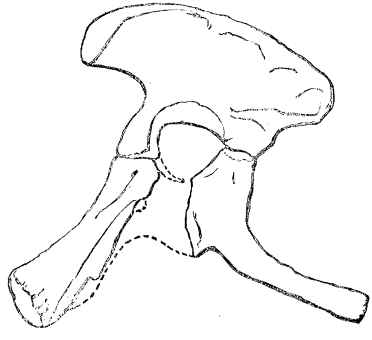
Camptonotus.

Theropoda.



Allosaurus.

Sauropoda.



Morosaurus.

there is no important difference of plan in the pelvis between the animals which have been referred to the order Stegosauria and those referred to the order Ornithopoda; and similarly, the plan of construction of the pelvis is essentially the same in the animals on which have been founded the orders Sauropoda and Theropoda. But there is as marked a difference between these two pelvic types as can be found in any part of the animal kingdom. These resemblances and differences are shown in the figures, which are copied from type genera of Professor Marsh's four orders.

The evidence concerning the penetration of air cells into the vertebræ has been less fully brought forward. But in the known genera which have been referred to the Stegosauria, the vertebræ are solid, and the like condition obtains in all the genera of Ornithopoda. The genera in Professor Marsh's list which are thus united are Stegosaurus, Diracodon, Omosaurus, Scelidosaurus, Acanthopholis, Cratæomus, Hylæosaurus, and Polacanthus, with Camptonotus, Laosaurus, Nanosaurus, Hypsilophodon, Iguanodon, Vectisaurus, Hadrosaurus, Agathaumus and Cionodon.

On the other hand, the precaudal vertebræ of Sauropoda are more or less hollow. This hollowness may amount to perfect excavation which leaves only an external investing film with a longitudinal median septum, or it may include a multitude of internal cells, or it may be limited to a pair of shallow impressed pits on the sides of the centrum. One of the characters by which Professor Marsh defines the Theropoda is: "vertebræ more or less cavernous." The animals included in the group appear to differ greatly in this condition. I have no evidence of presacral vertebræ of Megalosaurus being chambered, and the chambered condition of the caudal vertebræ rests upon a few specimens such as the types of Poikilopleuron. Professor Cope mentions that the tissue of the sacral vertebræ of Lælaps is so coarse as to resemble a mass of borings of the Teredo, but still the demonstration of the pneumatic condition has not been made. Nor is the evidence clearer with regard to Zanclodon. Professor Marsh figures deep pits in the sides of the dorsal vertebræ of Creosaurus. In Ceratosaurus, Marsh observes that all the presacral vertebræ are very hollow, and this is also true of the anterior caudals. The same condition is described in the cervical vertebræ of Labrosaurus, though the external foramina are small, while the Cœluria, if included in the order, would show a vertebral condition more perfectly pneumatic than in any of the Sauropoda. Hence, as the chambered condition of vertebræ is developed in most of the types of the group, it is possible that its absence in genera in which it is unrecorded may be due to the small size of the foramina having failed to indicate its existence, or to the air-cells having been so slightly developed that they did not penetrate the bones, as is the case with penguins among birds. But

the development of the pneumatic condition is sufficiently general among Sauropoda and Theropoda, to show that these groups are united together by a character which separates them from Stegosauria and Ornithopoda. It is not possible to form an opinion as to the inference which should be drawn from this character concerning the vital organisation of the animals in which it is found. For, many of the armoured genera have the neural arch much extended vertically, in the dorsal region, showing that the lungs were greatly developed. But since the difference in height between the carapaces of flat-shelled Emydian Chelonians and Tortoises, is chiefly due to differences in the volume of the lungs, it is quite possible that considerable variations in osteological character may occur in the vertebræ, without much difference in the vital organ which produces the change. On the other hand it must be remembered that among existing animals, the pneumatic skeleton is only found in birds.

Of late years the Dinosaurian skull has become well known. Mr. J. W. Hulke, F.R.S., described the brain-case of Iguanodon in 1871 ('Geol. Soc. Quart. Journ.,' vol. 27, p. 199), and in 1874 I described the base of a cranium ('Geol. Soc. Quart. Journ.,' vol. 30, p. 690) which was named *Craterosaurus Pottonensis*. In the former the brain-case is closed in front, and the basi-sphenoid has a comparatively slight downward development, while in the latter the base of the skull is much more like that of Hatteria than it is like Iguanodon. These types include so far as the evidence goes all the forms of skull hitherto discovered. On the plan of Iguanodon are shaped the skulls of Hypsilophodon and apparently Diclonius, while the skulls of Diplodocus and Ceratosaurus have much in common with Craterosaurus in having the deep pituitary depression, the anterior part of the brain-case open, &c. The evidence concerning the skull is very imperfectly known, but, so far as it goes, points in the same direction as the other characters in indicating that there are probably only two types in the group. Any classification must necessarily be provisional until the skulls and skeletons which exist are adequately described. The considerations adduced appear, however, to show that the Dinosauria has no existence as a natural group of animals, but includes two distinct types of animal structure with technical characters in common, which show their descent from a common ancestry rather than their close affinity. These two orders of animals may be conveniently named the Ornithischia* and the Saurischia, and defined by the following characters.

Ornithischia.

In this order the ventral border of the pubic bone is divided, so that one limb is directed backward parallel to the ischium as among birds,

* "Ischia" is used by Aristotle for the pelvis.

and the other limb is directed forward. Neither of these limbs of the pubis appears to form a median symphysis. The ilium is prolonged in front of the acetabulum as a more or less slender process or bar. The vertebræ are solid, and the skeleton is not pneumatic. The basi-cranial structure is distinctive, differing from that of Crocodiles and Lizards. The body and limbs are frequently covered with scutes which may form a complete shield or be reduced so as to be unrecognisable. The digits vary from three to five.

Saurischia.

In this order the pubis is directed forward from its symphysis with the ischium, and no posterior limb of the bone is developed. Both pubis and ischium appear to meet by a median symphysis, so that the arrangement and relations of the bones are Lacertilian. The anterior prolongation of the ilium has a vertical expansion. The vertebræ are more or less pneumatic or cavernous; and in the dorsal region the neural arch is commonly elevated. The basi-cranial structure is sub-lacertilian. No armour has been found. The digits vary in number from three to five.

I see no ground for associating these two orders in one group, unless that group includes Birds, Crocodiles, Anomodonts, and Ornithosaurs; for differences of pelvic structure have been as persistently inherited as any condition of the vertebrate skeleton.

The classification may be summarised in the following table:—

Cope, 1866.	Huxley, 1870.	Seeley, 1874.	Marsh, 1878–84.	Cope, 1883.	Seeley, 1887.
Orders.	Families.	Order.	Orders.	Orders.	Orders.
Orthopoda ...	Scelidosauridæ Iguanodontidæ	... ...	Stegosauria ... Ornithopoda ...	Orthopoda ...	Ornithischia.
Goniopoda .. Symphopoda	Megalosauridæ Compsognatha	Cetiosauria	Sauropoda ... Theropoda ...	Opisthocœla* ... Goniopoda ... Hallopoda.	Saurischia.

* Sir Richard Owen grouped Cetiosaurus and Streptospondylus in an extinct sub-order of Crocodilia named Opisthocœla in 1859; while Megalosaurus and Iguanodon were united to form the Dinosauria in 1841. This is the earliest and most definite reference of these animals to separate ordinal groups.