

and a full list of Americans who studied under Bunsen could only be made from the official register of the university.

Of the charm of residence in the picturesque little city on the Neckar, with its magnificent ruined castle, its attractive forest-covered hills threaded by enticing paths, its historical associations, and its excellent beer, there can be but one opinion; but in winter we often felt the truth of the old couplet:

'Heidelberg ist eine schöne Stadt
Wenn es ausgereget hat!'

HENRY CARRINGTON BOLTON.

A SKELETON OF *DIPLODOCUS*, RECENTLY
MOUNTED IN THE AMERICAN
MUSEUM.*

IN the spring of 1897, one division of the American Museum exploring party was sent by the writer to the Como Bluffs of Wyoming, made famous by numerous discoveries of Dinosaurs. It was believed that this rich locality had been exhausted by the continuous excavations of the United States Geological Survey under the direction of Professor Marsh. The first prospecting, however, resulted in the discovery, by Mr. Barnum Brown and the writer, of a large femur, which guided us to a very remarkable skeleton of *Diplodocus longus* Marsh. Dr. J. L. Wortman joined the party later and superintended the work of excavation which occupied several months.

At one time strong hopes were aroused that the entire animal would be found together. The long tail stretched off parallel with the cliff, interrupted only by a narrow gully which

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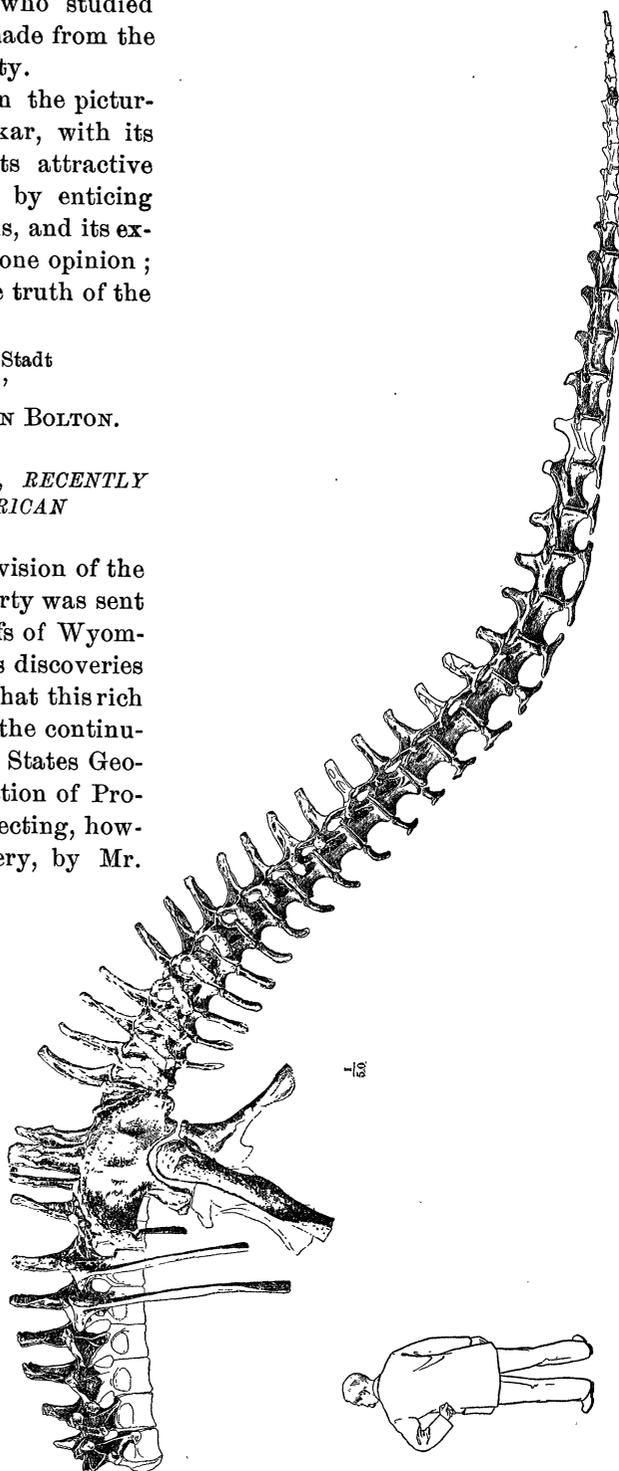


Fig. 1. Posterior half of Vertebral Column of the Diplodocus Skeleton with Pelvis and Femur in Position. The figure is of a man of the average height. $\frac{1}{30}$ nat. size. Parts missing in contours.

had cut through a small section of the caudals. In front of the sacrum the dorsals stretched forward in a promising way, but the centra were wanting, and finally nothing but the neural arches remained. The left side was found most deeply imbedded and most completely preserved in the region of the sacrum. The bones recovered, with the exception of three cervical vertebræ and the complete right scapula, are shown in the accompanying restoration. Not only the relative completeness of this skeleton, but the highly skillful manner in which it was taken out, render it unique. Upon arrival in the Museum, the reconstruction of the pelvis and sacrum proved especially difficult, but was completed successfully.

The points of greatest novelty are found in the vertebral column, since the only portions of this region described by the late Professor O. C. Marsh are a single cervical, an anterior dorsal, three sacral centra, and one caudal with chevrons. In order to understand the general structure of the posterior half of the column, that is from the 8th presacral backwards, the reader is referred to the restoration, Fig. 1. A remarkable *balance between the opisthocœlous presacrals and proœlous postsacrals* is observed. Vertebra for vertebra they correspond very nearly in size, with a slight advantage in favor of the presacrals. The balance was completed by the ponderous tail stretching out to a length of 30 feet. Between these balanced dorsals and caudals are the excessively rigid sacrals, coalesced with each other and with the ilium. Thus a long balanced vertebral lever is established with the acetabulum as a fulcrum, with opisthocœlous vertebræ in front and proœlous vertebræ behind. The dominating principle in construction of the backbone is maximum strength with minimum weight. The ingenuity of sculpture by which this is brought about, every single vertebra differ-

ing from its fellow, baffles the Lamarckian as well as the Darwinian, and tempts us to revive the old teleological explanation. The neural spines, arches and centra are constructed in such a manner as to connect all the principal points of stress and strain, and at the same time reduce the weight to the last degree. They are proportioned in each vertebra to meet its peculiar conditions, no two vertebræ being alike.

Presacrals 2 and 1 are of great interest because, as in the Struthious birds, the ribs they bear lie behind the ilium, the 14th being still free, the 15th having coalesced with the ilium. The analogy with *Apteryx* is very striking.

The *three anterior sacrals*, constituting the primitive Dinosaur sacrum, are firmly united together by their neural spines. These spines coalesce into a single very robust spine, showing the diapophysial laminæ separate; the antero-posterior diameter of this spine is far less than that of the three coalesced spines of *Brontosaurus* or *Morosaurus*.

The sacrum of Sauropoda is reinforced by the addition not of dorsals, but of anterior caudals. The third sacral was probably the first of the anterior caudals to be added in an ancestral stage of evolution. The fourth sacral is still more conspicuously a modified caudal.

This is the first instance among the Sauropoda in which a nearly complete sacrum has been found attached to the ilium. This fortunate circumstance determines the *correct position of the ilium with relation to the sacrum*, and shows that the entire pelvic girdle has been incorrectly placed hitherto; Marsh's error consisted in his placing the anterior and posterior acetabular borders, or pubic and ischiac peduncles, of the ilium upon the same horizontal plane, thus directing the superior iliac crest backwards; and altering the natural angle of the entire pelvis. The second point of great interest

is the marked elevation of the sacral spines above the ilium and the uniquely extensive and powerful union between the sacrum and ilia. The sacral spines are not only the highest spines in the vertebral column, but, as in the birds, the sacro-iliac junction is the center of power and of motion, and is of the most rigid character.

The completeness of the tail with its chevrons is of great moment; 37 caudals is the number estimated; 29 is the number fully or partly preserved; 26 chevrons are preserved. The length of the tail is estimated at 9 meters, or about 29 feet—this estimate is obtained by the addition of the actual lengths of the centra.

The caudals thus steadily increase in length from the first to the 18th and then steadily diminish toward the extremity. Totally dissimilar from the caudals of other reptiles, and even from those of other Dinosaurs, the caudals of Sauropoda or Cetiosauria are distinguished by profound changes in different regions. In proportions the anterior caudals are *short*, relatively *broad*, and spreading with heavy rugosities, as the seat of the powerful musculature of the tail, sacrum and femur. The median caudals (of the type first described by Marsh) are *long*, *narrow* and contracted, as the seat of the propelling fin; the posterior caudals are long, slender cylinders. There are no less than five types of chevrons.

The *ilium* is finely preserved; the superior crest is perfect, but the anterior border is flattened or crushed inwards instead of turning sharply out to allow space for the two posterior ribs which lie in behind it. The superior crest, is directed mainly upwards, the rugose border of the crest is surmounted by five diapophysial rugosities, that is those springing from the first pre-sacral vertebra, and from the four sacrals. The function of the heavy pre-acetabular bar appears to have been to support the

weight of the body when the anterior portion of the trunk was raised and the tail depressed.

Of the shoulder girdle only the *scapula* is preserved. Singularly enough this is the right scapula, for most of the skeleton represents the left side. The *femur* is a highly characteristic bone. It is distinguished by a prominent trochanter placed on the posterior border, near the middle of the shaft, which apparently corresponds with the *fourth trochanter*, *tr⁴*, of Dollo. This is for the insertion of the great *femoro-caudal* muscles of birds and Dinosaurs. This femur is much more slender than that of *Brontosaurus* and has rather the proportions of the *Amphicebias altus* femur described by Cope.

The greatly extended and revised knowledge afforded by this specimen may now be summarized.

Dorsals.—The neural spines arise from the convergence of paired cervical spines. There are no nodal or broad-spined dorsals as in *Brontosaurus*. The rib articulations are greatly elevated in the posterior dorsals. The two posterior dorsals are placed behind the ilium and bear one free and one coalesced or vestigial rib. *Sacrals*.—There are four sacrals, three of which exhibit a complete coalescence of the spines, the fourth being more free and like a caudal. The sacro-iliac union is by means of sacral ribs and diapophysial plates. Additions to the sacrum are made from the caudal series.

Caudals.—All the anterior caudals have broad diapophysial laminæ. These plates were first observed by the writer in *Brontosaurus* or *Camarasaurus*. There are five distinct types of chevrons. One of these, belonging to the 18th or 19th caudal, is the type to which Marsh assigned the name *Diplodocus*. *Ilium*.—The superior crest of the ilium is directed upwards, and the coalesced sacrals form the center of motion and the highest portion of the vertebral

column. There is a balance of weight between the dorsals and the anterior caudals. The laminar construction of the dorsals, sacrals, and caudals is shown to exhibit a unity of type, with local differences adjusted to special stresses and strains.

RESTORATION AND HABITS OF DIPLODOCUS.

We must await the discovery of the complete limbs and neck before *Diplodocus* can be wholly restored. Yet a number of important points regarding the general structure of the animal can be established now. The length of the entire skeleton was considerably greater than estimated by Marsh. The known and estimated linear measurements are as follows :

	Feet.	Meters.
Caudals	30	
Sacrals	2	.60+
Dorsals (estimated).....	12	3.65
Servicals (estimated).....	12	3.65
Skull.....	2	61
Total.....	58	8.51

The animal was about 60 feet in length and relatively more elevated and more slender than *Brontosaurus*. The proportions of the shafts of the femora, namely *Diplodocus* 5, *Brontosaurus* 7, probably give us an approximate idea of the weight ratio—that is, *Diplodocus* had about five-sevenths the bulk of *Brontosaurus*.

We observe in Marsh's restoration of *Brontosaurus*, a pioneer work of very great difficulty, that the mid-dorsal region is made the highest point in the backbone; that the sacral region is subordinate; that the tail (in which 8 or 10 anterior caudals are now known to be omitted) is an *appendage* of the body instead of an important locomotor organ of the body. In all these points Marsh's restoration is probably incorrect.

We must consider therefore as three of the most important advances in our general knowledge of the structure of these animals; first, the establishment of the sacral spines

as the highest point in the backbone; second, of the sacrum and ilium as a center of power and motion; third, of the balance between the dorsals and caudals.

Diplodocus gives us a new and different conception of the Cetiosaurs or Sauropoda, one which increases their ability as aquatic reptiles, and specializes the functions of the tail. The tail constitutes one-half the length of the animal, and was of immense service as a propeller in enabling it to swim rapidly through the water, the broad anterior portion being provided with very powerful lateral muscles, and the compressed posterior portion being controlled by tendons and made effective by a vertical fin.

The tail, secondly, functioned as a lever to balance the weight of the dorsals, anterior limbs, neck and head, and to raise the entire forward portion of the body upwards. This power was certainly exerted while the animal was in the water, and possibly also while upon land. Thus the quadrupedal Dinosaurs occasionally assumed the position characteristic of the bipedal Dinosaurs—namely, a tripod position, the body supported upon the hind feet and the tail.

Thirdly, the *supporting function* of the posterior half of the tail is indicated by the sudden change in the shape of the chevrons at the 13th caudal; the chevrons of caudals 13 to 19 indicate the region to which part of the main weight of the body was transmitted; these chevrons are powerful and broadly spread out at the bottom. The 18th chevron is firmly ankylosed with the centrum; the 19th, 20th, 21st, 23d, 24th, 25th, are firmly connected with the centra by sutural surfaces, though not ankylosed.

What may be termed the 'supporting and balancing' tail of the Hadrosaurs, Iguanodonts and Megalosaurs is of a much simpler type than this 'balancing, supporting and propelling' tail of the Cetiosaurs.

There is a traditional view that these animals were ponderous and sluggish. This view may apply in a measure to *Brontosaurus*. In the case of *Diplodocus* it is certainly unsupported by facts.

As compared with the Crocodilian or Cetacean type, the axial skeleton of *Diplodocus* is a marvel of construction. It is a mechanical triumph of great size, lightness and strength. Judging by the excessive rugosity of the vertebrae and limbs, the powerful interspinous ligaments attached to the pre- and post-spinal laminae, the backwardly directed rugosities at the summits of the diapophysial laminae in the dorsals, and of the postzygapophysial laminae in the caudals, the animal was capable not only of powerful but of very rapid movements. In contrast with *Brontosaurus* it was essentially long and light-limbed and agile. Its tail was a means of defense upon land and a means of rapid escape by water from its numerous carnivorous foes. Its food probably consisted of some very large and nutritious species of water-plant. The anterior claws may have been used in uprooting such plants, while the delicate anterior teeth were employed for prehensile purposes only. The plants may have been drawn down the throat in large quantities without mastication, since there were no grinding teeth whatever. It is only by some such means as this that these enormous animals could have obtained sufficient food to support their great bulk.

HENRY FAIRFIELD OSBORN.

THE NOMENCLATURE OF THE NEW YORK
SERIES OF GEOLOGICAL FORMATIONS.

THE prime outcome of the work of the four geologists, Mather, Emmons, Vanuxem, Hall, engaged upon the original survey of the State of New York, was the promulgation of a series of terms designating and classifying the rock formations. Many of the terms adopted in the final reports issued in 1842-1843 had been previously introduced

in the annual reports of one and another of the geologists, but that finally announced was the mutual agreement of the four. Tradition and contemporary record have given us some evidence that differences of opinion as to the merits of various terms erected during the progress of the survey were not wholly reconciled by the final pronouncement which rejected a goodly number of provisional names. It was clearly the purpose of the geologists to institute and defend a classification of the older rocks, the stratigraphic units of which were to be of approximately equal value. In several instances subdivision of such units was recognized; thus Hall and Vanuxem especially added the term *group* to some units as indicative of a minor subdivision of the strata. Emmons avoided this term wholly and Mather seldom employed it.

The geologists also made use of a broader assemblage of the units into associations termed by some of them *groups*, by others *divisions*. These were four in number, namely, beginning at the bottom: Champlain, Ontario, Helderberg, Erie, and a fifth, Catskill, was employed by Mather. There was pretty uniform agreement in the use of these broader terms and such slight discrepancy as became apparent in their application was no more than an expression of imperfect knowledge and of personal equation. It was a genuine misfortune to the New York nomenclature that disturbed and drove out these terms which are supremely adapted to the unequalled paleozoic succession from which they emanated. In many respects they meet the actual conditions far more satisfactorily than the European terms which we are now carrying. They are entitled to respect for their venerableness and, where consistent with the present state of knowledge, to recognition for their merit.

It will be observed that the classification proposed by the four geologists was wholly