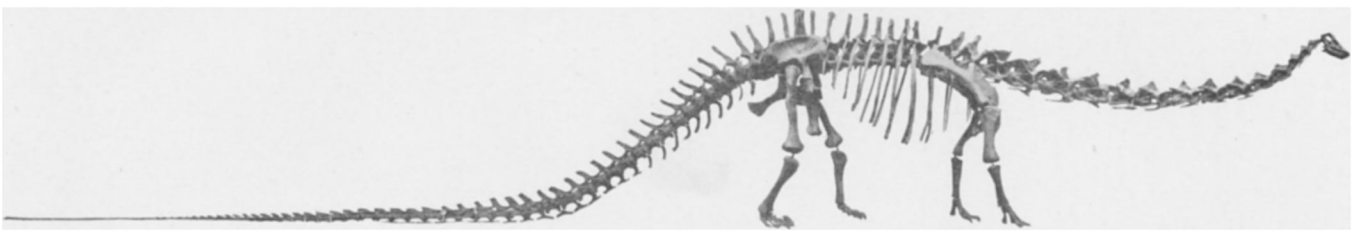

THE SKELETON OF DIPLODOCUS CARNEGIEI, MOUNTED IN THE CARNEGIE MUSEUM, PITTSBURGH

THE LENGTH FROM THE TIP OF THE NOSE TO THE END OF THE TAIL OVER CURVES IS 84½ FEET; THE HEIGHT AT THE HIPS IS ABOUT 14 FEET. REPLICAS THUS MOUNTED ARE LOCATED IN BERLIN, PARIS, VIENNA AND BOLOGNA

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A REVIEW OF SOME RECENT CRITICISMS OF THE RESTORATIONS OF SAUROPOD DINOSAURS EXISTING IN THE MUSEUMS OF THE UNITED STATES, WITH SPECIAL REFERENCE TO THAT OF DIPLODOCUS CARNEGIEI IN THE CARNEGIE MUSEUM[1]

DR. W. J. HOLLAND

CARNEGIE MUSEUM

ALL paleontologists are familiar with the figure of *Brontosaurus excelsus* Marsh, which was originally published in the *American Journal of Science* in August, 1883, and republished with modifications in the same periodical in 1895. This figure has since been frequently reproduced in text-books. Paleontologists are also familiar with the restoration of the skeleton of *Diplodocus carnegiei* Hatcher, which originally appeared in the *Memoirs of the Carnegie Museum*, and is reproduced in the second volume of the English translation of Zittel's "Text-book of Paleontology," by C. R. Eastman. Since the time when Mr. Hatcher made this restoration the acquisition of new material has thrown much light upon the subject, and certain changes in the pose have been suggested, which are reflected in the accompanying illustration (Plate I), which is taken from a photograph of

[1] The substance of this paper was communicated to the Annual Meeting of the Paleontological Section of the Geological Society of America on December 30, 1909. The paper at that time was freely illustrated by means of the stereopticon, and a number of the pictures and diagrams then used are herewith reproduced.

the splendid specimen in the Carnegie Museum, replicas of which have been generously presented by Mr. Andrew Carnegie to a number of the leading museums of Europe.

In *The Field* (London) of August 26, 1905, Mr. F. W. Frohawk, a well-known English illustrator, published a note, in which he said, among other things:

> The visitor to the Reptile Gallery of the Natural History Museum can not fail to be struck by the extraordinary pose of the gigantic skeleton. . . . It would be interesting to know the reason for mounting the specimen so high on its legs, like some huge pachyderm. As it is a gigantic lizard, why should it not be represented in the attitude usually assumed by such animals? . . . Doubtless there is some good reason for mounting it in such an attitude; if so, information on the subject would be welcome.

No reply was given to this query, except incidentally by Professor (now Sir) E. Ray Lankester, who said in a newspaper interview that "the laterally compressed form of the body, according to the opinion of American students, precludes the idea that the animal could have crawled upon its belly."

Shortly after the restored skeleton of *Brontosaurus excelsus*, which is one of the ornaments of the American Museum of Natural History, had been erected, Messrs. Otto and Charles Falkenbach, assistants in the paleontological laboratory of that museum, made a model, in

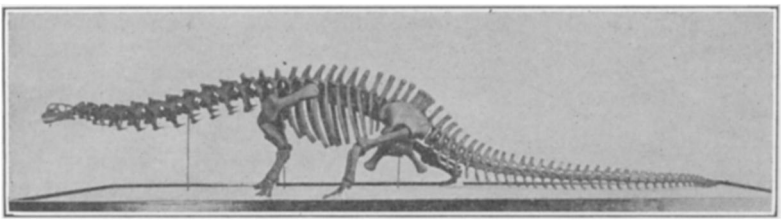

FIG. 1. Small Model of Skeleton of *Brontosaurus excelsus* Marsh, made by Messrs. O. and C. Falkenbach.

which they attempted to show the *Brontosaurus* in a crawling attitude. I am indebted to Dr. W. D. Matthew for an illustration of this model, which is herewith reproduced (Fig. 1). This model was discussed at the meeting of the American Society of Vertebrate Paleon-

tologists held at the American Museum of Natural History in 1906, and by common consent was judged for many reasons to represent the impossible.

In October, 1908, there appeared in Vol. XLII of THE AMERICAN NATURALIST an article from the pen of Dr. Oliver P. Hay, "On the Habits and Pose of the Sauropod Dinosaurs, especially of Diplodocus." Dr. Hay maintains that in assembling the fossil remains of these animals they should have been given a crocodilian attitude. At the conclusion of his article he sums up his views in the following words:

> It seems to the writer that our museums which are engaged in making mounts and restorations of the great sauropoda have missed an opportunity to construct some striking presentations of these reptiles that would be truer to nature. The body placed in a crocodile-like attitude would be little, if any, less imposing than when erect; while the long neck, as flexible as that of an ostrich, might be placed in a variety of graceful positions.

This article of Dr. Hay was followed by a paper from the pen of Dr. Gustav Tornier, who, taking his cue from Dr. Hay, has tried to show that American paleontologists have totally erred in their conception of the structure of the sauropod dinosaurs, and has given his views as to the manner in which the bones of the *Diplodocus* should have been assembled. His paper is embellished by a number of cuts. Professor Tornier's paper was followed in the popular scientific journal *Aus der Natur* by an article from the pen of Dr. Richard Sternfeld, in which he endorses the views of Tornier and endeavors to hold American paleontologists up to ridicule, asserting that they have "literally, from head to foot, misconstructed the *Diplodocus,* and probably also its near allies." Sternfeld enlarges upon Tornier's views and gives some illustrations of his own.

In the manner of a man who has made a wonderful discovery, Tornier announces at the outset of his paper that *Diplodocus* is a genuine reptile—"ein echtes Reptil." No student of the sauropoda has ever doubted this. But having predicated the genuinely reptilian

character of the animal, Tornier proceeds thereafter to speak of the *Diplodocus* as a lacertilian—"ein Eidechse." There are reptiles and reptiles. Having assured himself of the truly reptilian character of the animal, it was a bold step for him immediately to transfer the creature from the order Dinosauria, and evidently with the skeleton of a *Varanus* and a *Chameleon* before him, to proceed with the help of a pencil, the powerful tool of the closet-naturalist, to reconstruct the skeleton upon the study of which two generations of American paleontologists have expended considerable time and labor, and squeeze the animal into the form which his brilliantly illuminated imagination suggested. The fact that the dinosauria differ radically from existing reptiles in a multitude of important structural points seems not to have greatly impressed itself upon the mind of this astute critic. He intimates that the pelvis of *Diplodocus* is distinctly lacertilian. He states that the great trochanter of the femur, which he does not designate as such, articulated

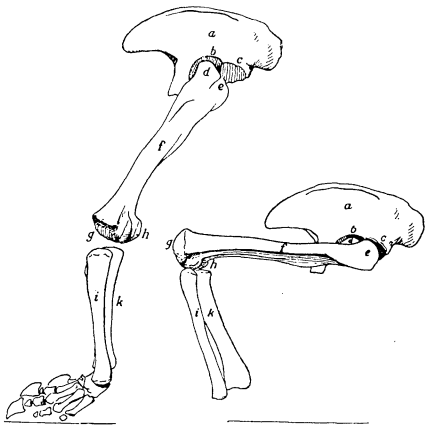

FIG. 2. Reproduction of figure given by Dr. Tornier in which he endeavors at the left to show the hind limb of *Diplodocus* as mounted, and at the right the position which he claims the limb should have.

with the ischial peduncle, and takes care to show the point of union by means of a lettered diagram, which I herewith reproduce (Fig. 2). He takes pains to show that (*e*) the great trochanter, articulates with (*c*) the

ischial peduncle. It may be said in passing that Dr. Tornier takes very great liberties with the outlines of the bones. His drawing is very far from accurate. Unfortunately actual experiment shows, *first,* that it is impossible except by smashing the ilium or breaking the femur to jam the head of the latter into the position demanded for it by the learned professor; but, *second,* this is the only time, it is believed, in the history of anatomical science that any one has discovered that the great trochanter of the femur ought to be and is by nature intended to be articulated with the ischial peduncle of the ilium, thus locking the femur into a position utterly precluding all motion whatsoever.

The next step taken by this wonder-working comparative anatomist was to dislocate the knee-joint. This he proceeds to do in a most nonchalant manner, and leaves the articulating end of the femur peering forth into space (see Fig. 2, *g*), while the tibia and the fibula are made to articulate with the posterior edges of the interior and exterior condyles of the femur. Having adopted this change, he succeeds in so lowering the hind quarters of the *Diplodocus* that they must rest upon the anterior extremity of the pubic bones, which, with the fragile ends of the ribs, not much greater in size than those of an ox, have thrown upon them the entire weight of the carcass. To obviate the inconveniences of this pose the lead pencil is again brought into requisition and the anterior vertebræ are hoisted into the air and propped up upon the scapulæ, the dorsal ends of which have been glued by a hypothetical suprascapula to the lateral processes of the last cervical vertebræ (see Fig. 3). This transference of the scapula to the Tornerian position is done in order to give, as the author says, an opportunity to so place the scapula that horizontal motion backward and forward may be allowed to the humerus, which he takes pains to inform us is strikingly like that of a *Varanus.* Upon the latter point it is quite possible to differ from the learned critic.

The anterior portion of the trunk having been thus

elevated, the fore legs are again dislocated at the juncture of the humerus with the radius and ulna and stuffed underneath the skeleton, while the great neck is thrown upward in the form of a reversed letter "S," the Hogarthian lines of which no doubt suggested themselves to the learned reconstructionist as possessing soulful grace. A reproduction of the skeletal monstrosity perpetrated by Tornier is here given (Fig. 3). As a contribution

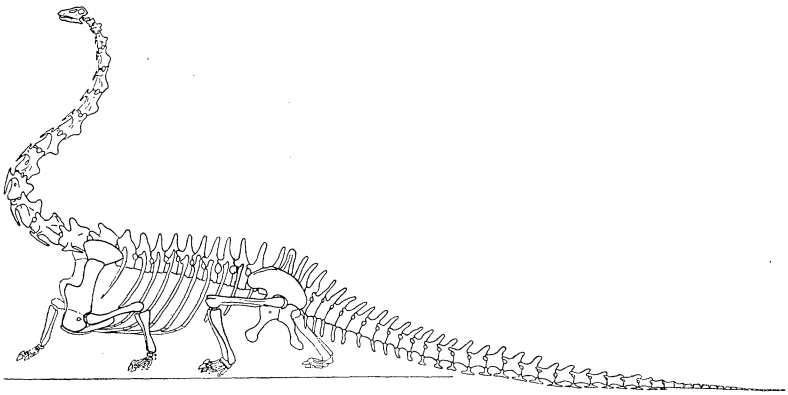

FIG. 3. The skeleton of *Diplodocus* mounted according to Tornier in the correct position "Richtige Stellung."

to the literature of caricature the success achieved is remarkable. It reminds us somewhat of those creations carved in wood emanating from Nuremberg, which were the delight of our childhood, and which came to us stuffed in boxes labeled "Noah's Ark," and stamped "Made in Germany."

I should prefer to end my communication at this point, commending the perusal of the articles by Hay, Tornier, and Sternfeld to the attention of those of you who are familiar with the osteology of the sauropoda as amusing illustrations of the manner in which it is possible for gentlemen possessing entirely inadequate acquaintance with a subject to "darken counsel by words without knowledge."

Inasmuch, however, as Professor Tornier's opinions and his misleading diagrams and figures have been given some currency in journals intended to popularize science,

it seems to the speaker that the present is a suitable occasion in which not merely to demonstrate the utterly absurd character of the opinions of Hay, Tornier, and Sternfeld, but also to bring out into clearer light the reasons why American paleontologists, and for that matter the leading paleontologists of Europe also, have concurred in regarding the sauropod dinosaurs as having possessed the power to assume the position which has hitherto been given them. At the risk, therefore, of occupying some of your precious time I wish to take up the subject a little more thoroughly and by the help of a series of illustrations to make my meaning clear.

I shall begin with the structure of the pelvis in the sauropod dinosaurs. I herewith give illustrations (Fig. 4) taken from the specimens in the Carnegie Museum of the pelves of *Brontosaurus, Diplodocus,* and *Haplocanthosaurus,* the last closely allied to *Cetiosaurus* of Owen.

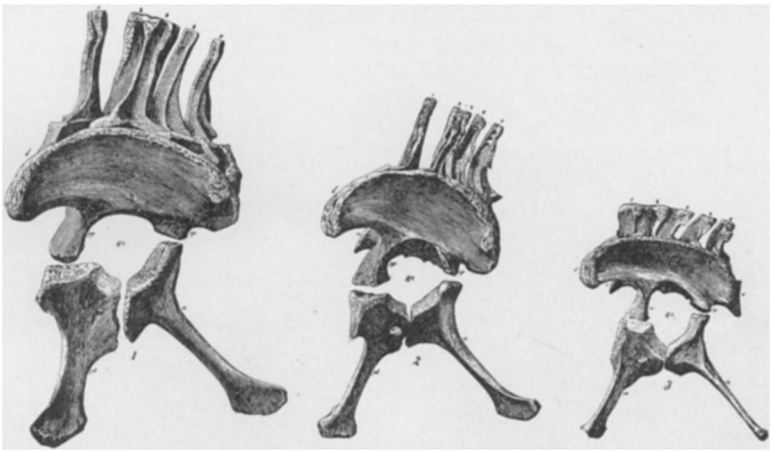

FIG. 4. 1, pelvis of *Brontosaurus;* 2, pelvis of *Diplodocus;* 3, pelvis of *Haplocanthosaurus.* From specimens in the Carnegie Museum.

Any one who has a merely rudimentary knowledge of the pelves of the dinosauria in general knows that they are distinctly ornithic in type, and not lacertilian, nor crocodilian, Professor Tornier to the contrary notwithstanding. Seeing is believing, and I also give illustrations of the pelvis of a crocodile, of *Varanus,* of *Iguana,*

and of *Uromastrix* (Figs. 5–8). Compare these for a moment with the pelves of the huge sauropod reptiles and you see immediately that there is an enormous dif-

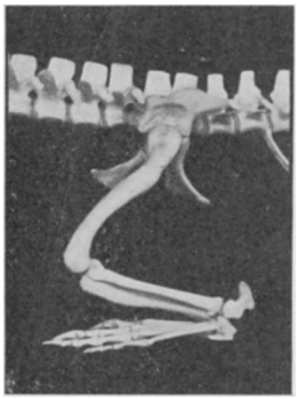

FIG. 5. Pelvis and hind limb of crocodile.

FIG. 6. Pelvis of *Varanus*.

ference in general, and in countless details, which it is not worth while to consume your time in describing.

Taking up now the articulation of the femur with the

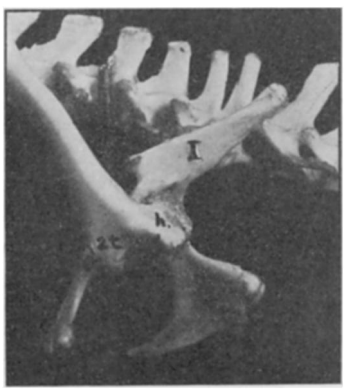

FIG. 7. Pelvis of *Iguana*. I, Ilium; *h*, Head of femur; *2t*, Second trochanter.

FIG. 8. Pelvis of *Uromastrix*.

acetabulum of the pelvis, we discover in the first place that the head of the femur in the lacertilia differs remarkably from the head of the femur in the sauropoda.

In the lacertilia the greater trochanter is reduced in size and in some genera is practically obsolete; when present and articulated it looks backward, downward, inward. On the other hand, the second trochanter in the recent lacertilia is enormously developed, looking downward, forward, and outward (see Fig. 7). In the sauropoda, as in the ratite birds, the second trochanter is obsolescent or wholly obsolete. The illustrations already given may help to make my meaning clear. In this connection it is well to study the head of the femur and the structure of the pelvis in the struthious birds. The analogy between these and the dinosauria has often been pointed out. The facts to which I have called your attention have great anatomical significance. A comparison of the head of the femur of the crawling reptiles of to-day with the femur of the sauropoda shows at a glance that in the latter the proximal end of the femur is more like that of birds than of recent lizards. It was, as we all know, in consequence of the recognized similarity of the pelvic girdle and the head of the femur to the corresponding structures in the ratite birds that Owen, Marsh and all other competent students have assigned the femur the position which has almost uniformly been given to it in restorations of the sauropoda, as well as of other dinosaurs.

But let us for the sake of experiment give the femur the same relative position which it has in the lacertilia, in which the second trochanter plays so great a part. To do this it is necessary to rotate the head of the femur in such a way that the great trochanter will point downward and backward. The accompanying diagrammatic illustration shows the femur of the *Diplodocus* adapted to the acetabulum after the analogy of *Varanus* and *Iguana* (Fig. 9). Of what earthly use the hind limb of the *Diplodocus* could have been to him in such a position I leave you to determine for yourselves. It has been suggested that kindly nature, to meet the requirements of the case, must have channeled the surface of the earth and provided the *Diplodocus* and its allies with troughs

in which they kept their bodies while the feet were employed for purposes of locomotion along the banks. The *Diplodocus* must have moved in a groove or a rut. This

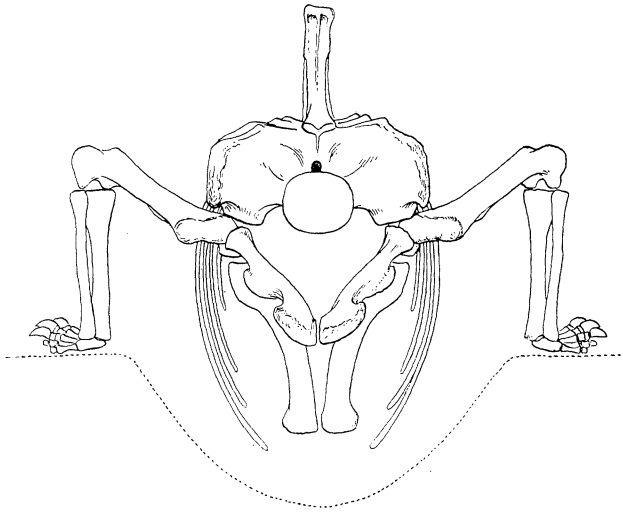

FIG. 9. The hind limbs of *Diplodocus* arranged after the analogy of the recent lacertilia.

might perhaps account for his early extinction. It is physically and mentally bad to "get into a rut."

Assuming that the articulation of the femur after all was not as it is in the lacertilia, and accepting, merely for the sake of argument, the pose of Professor Tornier, who, though contending that the creature was a lacertilian—"ein Eidechse"—nevertheless, constrained by obvious difficulties, in his drawings does not give the femur the characteristically lacertilian pose, I have taken pains to place the bones of the replica of the *Diplodocus* now in course of preparation for the Imperial Academy at St. Petersburg as nearly as is possible in the position which Professor Tornier demands that they should have. I have accepted Tornier's "richtige Stellung" for the time being, and have collocated the bones in the position which he demands for them, and I have the pleasure herewith of submitting to you photographs of the bones thus located (Figs. 10 and 11). In the first place you will observe that it is beyond possibility, when locating

the bones in this manner, to bring about anything like a plausible position of the head of the femur in the acetabulum. The ridiculous articulation of the great trochanter with the ischial peduncle demanded by Professor Tornier, who seems to have mistaken the ischial peduncle

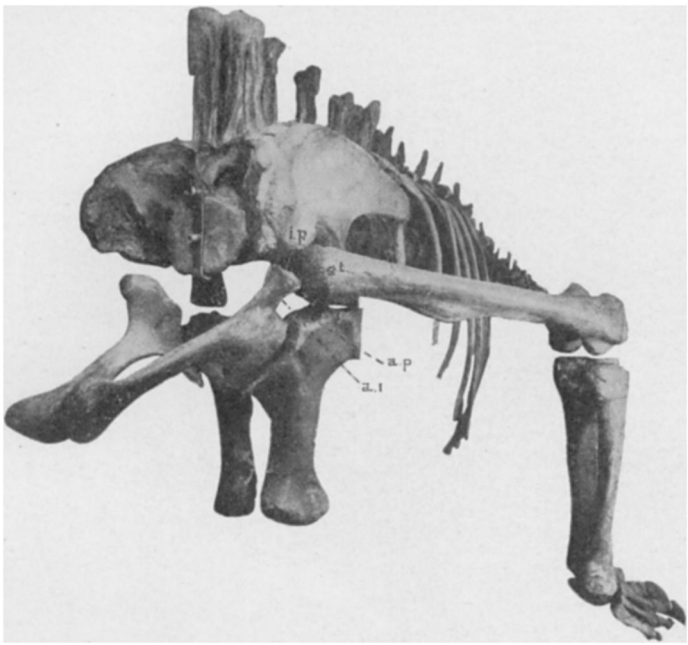

FIG. 10. View from behind of pelvis and femur of *Diplodocus* mounted according to the Tornierian prescription. *i.p,* Ischial peduncle; *g.t,* great trochanter; *a.p,* acetabular surface of pubis; *a.i,* acetabular face of ischium.

for an anti-trochanter, has already been alluded to. Of course we could not accomplish such an articulation, but we have come as near to it as the bones will allow. Placed as nearly as is possible in the situation in which Professor Tornier demands that the bones shall be put, the head of the femur stands in no relation whatever to the articulating surfaces of those portions of the pubis and the ischium (*a.p* and *a.i*) which enter into the composition of the acetabulum. The lower surface of the head of the femur is left out of all relation to these obviously articulating surfaces at a remove from them of at least six inches. Furthermore, in swinging the

bones into the acetabulum in such a way as to throw the distal end outward, the head of the femur necessarily enters and penetrates the opening of the acetabulum, invading the pelvic cavity and occluding the same. But this is not the worst. The distal end of the femur is left, as Tornier's figures themselves show, protruding into space without any surface whatever with which to artic-

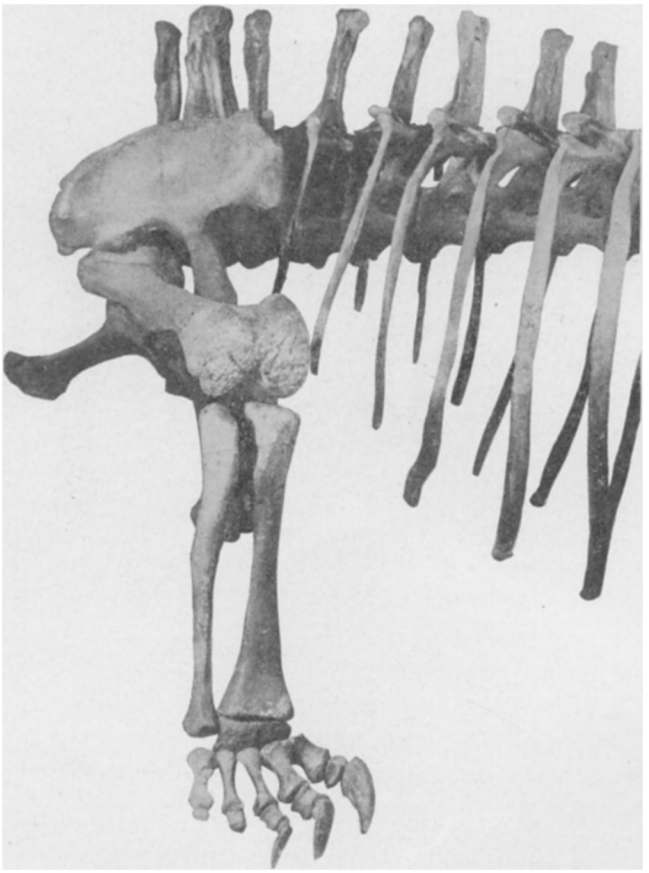

FIG. 11. View from side and front of femur and pelvis of *Diplodocus* mounted after the Tornierian prescription.

ulate. I am fully aware that in the lacertilia the joint made by the femur with the tibia and fibula, especially in young individuals, is provided to a high degree with cartilaginous connections, and the ends of the bones are covered

with great cartilaginous epiphyses, which in the bones of the fossil animals we are considering have not been petrified and preserved, but making all allowance for the existence of these cartilaginous masses at the points indicated, it is impossible to conceive that the broad expanded heads of the tibia and fibula should merely come in contact with the internal and external condyles of the femur at two small points, in each case not larger than a sixpence. The pose given to these bones by Dr. Tornier represents nothing else than the complete dislocation of the femur from the tibia and fibula.

Dr. Tornier labors long with the scapula and the humerus. As I have already stated, he claims that the humerus of *Diplodocus* is startlingly—"verblüffend"—like that of *Varanus*. It is wonderful what a man can see who has determined to see things! If you will simply take the trouble to compare the humerus of the sauropod dinosaurs with that of a *Varanus* I think you will be able without opening your eyes very widely to discover a number of startling differences. In addition to falling into error as to the startling likeness existing between the humerus in the sauropoda and the lacertilia, he makes a multitude of grossly inaccurate and misleading statements in uttering the special plea which he makes for his theory. It would be wearisome to recall them. One of the more noticeable misstatements is made when he declares that the coracoid bone belongs on the lower side of the belly—"Bauchunterseite." The coracoid, as we all know, is a sternal element and has nothing whatever to do with the "Bauch," or belly. He

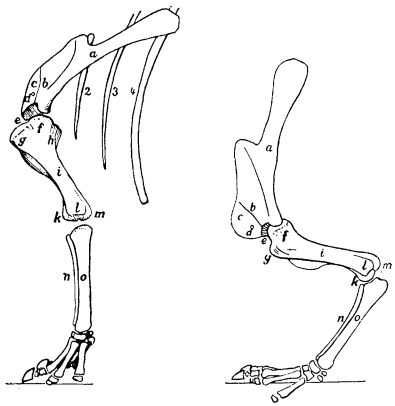

FIG. 12. Reproduction of figures given by Tornier showing the restoration of scapula and fore limb of *Diplodocus* as he alleges it to be (left figure), and as he claims it should be (right figure).

ignores the fact that the superior surfaces of the anterior ribs and the lateral processes of the anterior dorsal vertebræ unite to form a surface evidently adapted to the end of providing a field over which the long dorsal blade of the scapula can play. He demands for the scapula a vertical position so as to give to the humerus an opportunity, as he says, to move in a horizontal plane backward and forward. He states that a vertical position of the scapula is universal among recent reptilia, which is not the case. It is true of the lacertilia, but it is not true of the crocodilia. I herewith give a reproduction of a drawing copied from Blainville of a crocodilian skeleton, and another copied from Brühl (Fig. 13), both of which show that the scapula in the

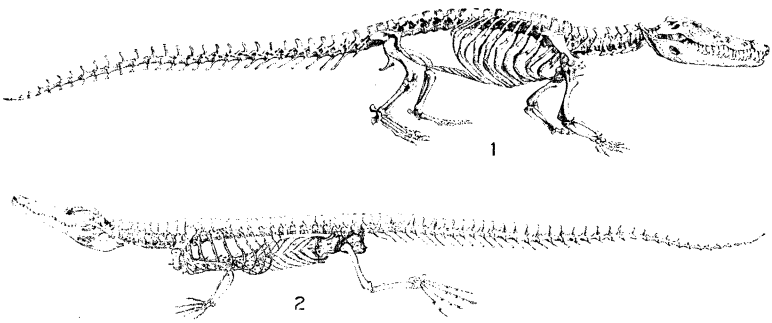

FIG. 13. 1, the skeleton of an alligator after Blainville; 2, skeleton of crocodile after Brühl, showing position of scapula.

crocodile has a position in the articulated skeleton similar to that which it has in the mammalia. But lest some one may say that the artists were mistaken, I am able through the kindness of Dr. Geo. C. Johnston, of Pittsburgh, the well-known radiographer, to exhibit a number of X-ray photographs showing the scapula in position in the common American alligator[2] (Fig. 14). These photographs show the entire accuracy of the drawings of Blainville and Brühl. And I am prepared to further verify the drawings by an example of an

[2] At this point the lecturer threw upon the screen a number of projections from X-ray photographs showing the limbs of the alligator in different attitudes. Only one of these is reproduced in the text.

alligator in the flesh, in which the parts surrounding the scapula have been dissected away, showing the scapula in the same position which is given by Blainville and Brühl. Any one who cares to verify the accuracy of my statements can easily do so. The scapula in the crocodile does not lie in the position which is given

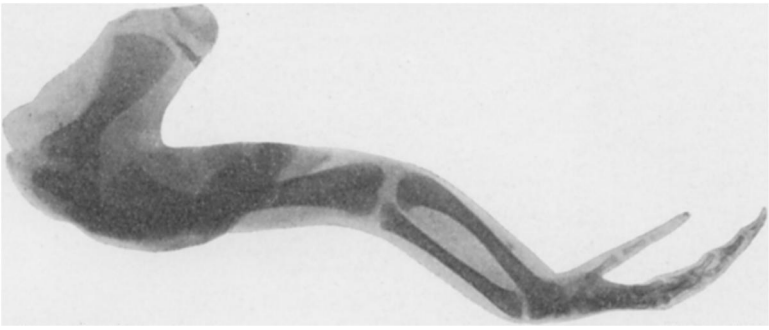

FIG. 14. X-ray photograph of scapula and humerous of alligator in position with foot thrown backward as far as possible. (Photographed by Dr. Geo. C. Johnston, Pittsburgh, Pa.) The scapula is not vertical.

to the scapula by Mr. Tornier in his restoration and it certainly did not so lie in the *Diplodocus,* but the lateral processes of the anterior dorsal vertebræ as well as the upper external faces of the anterior ribs united to form a surface to which the scapula manifestly conformed itself when in position. Any one who carefully studies the vertebræ and the proximal ends of the anterior ribs will see that there is here provided by nature a plane adapted to the inner surface of the scapula.

For the sake of experiment I have placed the scapula in the position demanded for it by Mr. Tornier, and have swung the fore limbs into place as he demands that they shall be put (Fig. 15). The result is in every way amusing. It leads in the first place to the entire disarticulation of the humerus from the radius and ulna. But as a secondary consequence it leads to a rather remarkable result, which the Berlin critic did not think of. In the position which Professor Tornier demands for the elements of the fore limb, the foot must fall into a position with the toes turned inwardly, while put into the

position which he demands for the hind limbs the toes of the latter necessarily point outwardly. The accom-

FIG. 15. 1, rear view of scapula and fore limb of *Diplodocus* mounted according to the Tornierian prescription; 2, side view of ditto.

panying diagram (Fig. 16) shows you the position which the hind feet and the fore feet assume when placed as Professor Tornier demands they shall be placed. Now, attributing to the humerus backward and forward motion in a horizontal plane, you will see, as the dotted lines in the diagram show, the result which is reached when the humerus is thrown into a line parallel with the line given to the femur. The toes of the manus point inward and backward. The animal was "pigeon-toed" in front, while its hind feet were planted like those of a grenadier. The animal moved forward with the hind-feet, moved backward with its fore feet. If Tornier is right it must necessarily have been somewhat "balled up."

The Berlin critic denies the possibility of a backward and forward movement of the humerus in the scapula in a vertical plane. As an actual fact, in the judgment of

competent American investigators, the articulating surface of the humerus did thus move in the scapula, and the great projection on the outer side of the proximal end of the humerus, showing every evidence of having been provided with enormous muscular attachments, gave the animal the power to move the limb in the direction indicated, this projection being strictly analogous in function to the great trochanter of the humerus as it exists in the mammalia to-day. The statement that the downward pro-

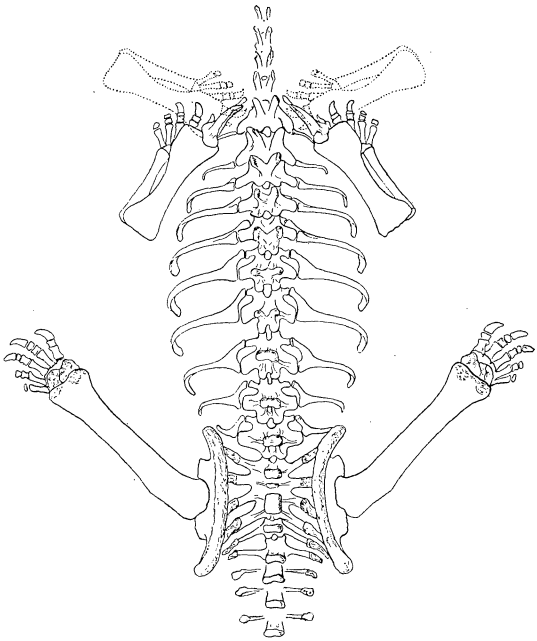

FIG. 16. Diagram showing position of the foot of *Diplodocus* when mounted and moved according to the Tornierian prescription.

jecting angle of the coracoid at its union with the scapula to form an acetabulum for the humerus precluded backward and forward motion in a perpendicular plane, as Tornier avers, is not borne out by an examination of the skeleton *in situ*. The humerus was capable of thus moving through a very long arc.

Professor Tornier utterly ignores in his discussion a very important point, and that is, the structure of the ribs of the *Diplodocus* as compared with the structure

of these parts in the recent reptilia. I throw upon the screen for purposes of easy comparison views of the ribs as they are arranged in recent crawling reptiles and of the ribs as they exist in the sauropoda, and more particularly in *Diplodocus* (Fig. 17). A glance at this dia-

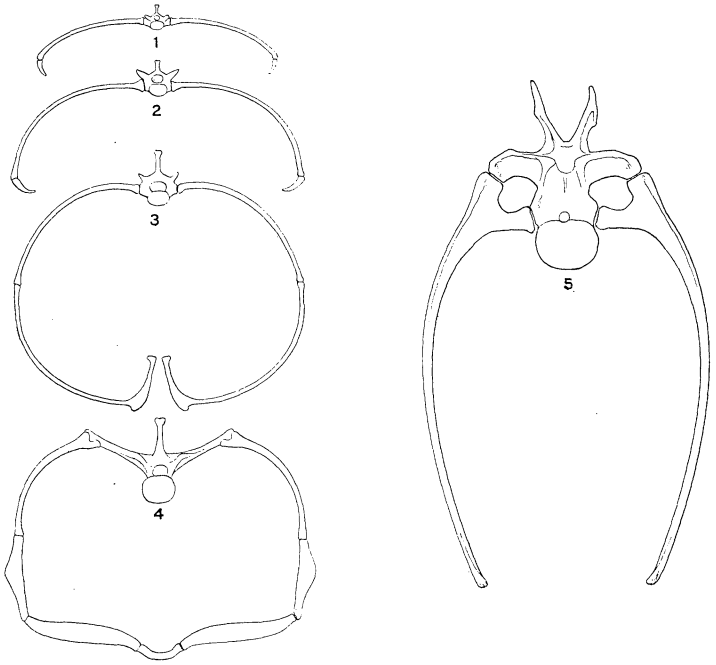

FIG. 17. Seventh dorsal rib articulated in 1, *Uromastrix;* 2, *Varanus;* 3, *Iguana;* 4, *Crocodilus;* 5, *Diplodocus.*

gram must be sufficient to show you the enormous differences which exist, and to reveal to one who has the least mechanical aptitude that the body, or "barrel," of the *Diplodocus* was constructed upon an ornithic rather than upon a lacertilian model. The articulation of the ribs does not lend itself to the idea that the animal progressed upon its belly.

Professor Tornier says that the long tail of the sauropod dinosaurs was intended to be carried at full length upon the ground, to stiffen and guide the movement of the anterior portion of the body. He speaks of it as intended for anchoring the body, describing it as "ein

Verankerungsmittel." No doubt it did to a certain extent so function, but to regard it as having been an instrument for promoting, as Sternfeld indicates, a wriggling motion—"schlängelnde Bewegung"—is to attribute to the organ properties which it hardly possessed. The tail, while capable, no doubt, when the animal assumed a crouching position, of functioning as Tornier demands that it shall, must nevertheless have been to a very large degree used also as a support upon which the animal could when necessary prop itself, as upon one of the legs of a tripod, as undoubtedly was the case with the carnivorous dinosaurs, to which the sauropoda are not so very distantly related.

The theory, which has been proposed by Dr. Hay, that it was impossible for these huge sauropods to rear upward, seems to me to be one that any one who has carefully studied the movements of animals, and especially of reptiles (turtles excepted), must repudiate. We know that certain of the smaller lacertilia to-day, when in rapid motion, assume a bipedal pose. Professor Osborn in one of his papers has given us a reproduction of the figure of *Chlamydosaurus* in a running attitude, taken from an instantaneous photograph by Saville-Kent (Fig. 18).

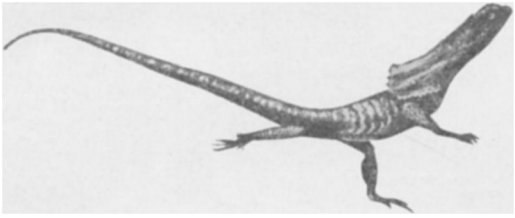

FIG. 18. *Chlamydosaurus* running. After Saville-Kent. Copied from Osborn.

Even more striking than the posture shown in this picture is the position constantly assumed by a well-known lizard of our southwestern and western country, *Crotaphytus collaris* Say. I regret that although I have had a number of these animals in captivity at our museum I never took the pains to have photographic snap-shots made of them when rapidly running across the floor. They assume when so doing a position in which the body

is far more perpendicular than is the case in the picture before you, and they carry the tail even higher. Ordinarily these lacertilians crawl, trailing the tail behind them, but when alarmed they rise upon their hind feet and throw the tail upward, moving along with great speed. I do not advocate such a position for the tail of *Diplodocus*, but, simply because it is long, to declare therefore that it must have necessarily trailed with its whole length upon the ground, does not appear to me to be reasonable. Animals with tails relatively quite as long, and even longer, are known to-day to hold them elevated, and there was proportionately as much muscular power, as shown by the muscular attachments, in the tail of *Diplodocus*, as there is in the tail of a *Crotaphytus* or a *Chlamydosaurus*. To declare as Mr. Hay does, that these animals must have moved as crocodiles and could not by any possibility have raised themselves from the ground, does not appear to me to be logical. In fact, those of us who have hunted alligators know that in life even alligators raise themselves high upon their legs when running, and get away like a dog at a sort of a trot.

Tornier indulges in a lengthy criticism of the pose given to the feet in recent reproductions of the *Diplodocus* and demands that they shall be placed in a plantigrade position. He thus takes issue with Mr. Hatcher and with others who have carefully examined the subject. Professor Abel, of Vienna, in criticizing Dr. Hay's article, has very aptly pointed out that the manner in which the metacarpals articulate in the pes and manus indicates a more or less digitigrade position. Those of us who are familiar with the feet of the sauropod dinosaurs know very well that in their structure, as indicated by the facets of both the proximal and distal end, there is strong evidence that they were not plantigrade in the sense in which the feet of existing reptiles are plantigrade. I throw upon the screen a diagram showing the proximal ends of the metacarpal and metarsal elements (Fig. 19). They arrange themselves in a semicircle

both in the hind foot and fore foot. This is less marked in the hind foot than in the fore foot. Such an arrangement of the metacarpals and metatarsals is significant, as has been pointed out by Hatcher and Osborn and is clearly shown by Abel. Sternfeld brushes Abel's criticism to one side, stating that it can be easily got rid of because the same arrangement exists in the feet of animals which are plantigrade. I would recommend Dr. Richard Sternfeld to more carefully study the anatomy of plantigrades. The structure of the feet of the sauropod dinosaurs differs immensely from that of the feet of all recent plantigrades and all the recent reptilia. We have evidence of a rather conclusive character as to the fact that the sauropod dinosaurs were decidedly digitigrade in the one existing specimen of a sauropod footprint, which is happily preserved, a figure of which I throw upon the screen (Fig. 20). You will see as you examine it that the animal must have been provided, as Professor Hatcher long ago pointed out, with a very large foot-pad, and that its track is not at all like the track of any of the recent lacertilia. The evidence of this footprint is impressive and ought to go a long way toward confirming the view, which I believe is the only view which we can maintain, that these animals were more or less digitigrade in the pose of their feet.

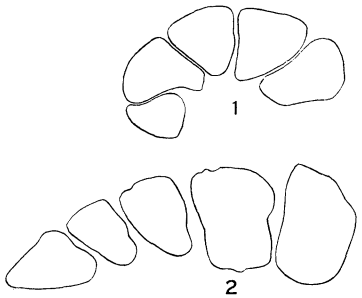

FIG. 19. Diagram showing arrangement at proximal end. 1, of metacarpals; 2, of metatarsals of *Diplodocus*.

The form of the limbs, long, straight and pillar-like, in this respect differing vastly from the limbs of the creeping lacertilia and crocodilia, suggests that they were intended to support a weight thrown upon them from above. The femur of the crocodile, as you know, is bent, and the femora of many of the recent lacertilians likewise show a distinct curvature of the axis. The same thing is true of the fore limbs, notably in *Varanus*.

The axis of the proximal end of the humerus in *Varanus* lies in a plane differing as much as forty-five degrees from the plane of the axis at the distal end. This is not true in the case of the sauropod dinosaurs. The limbs were intended to bear a burden placed mainly above, and

FIG. 20. Footprint of sauropod dinosaur. Specimen in the Carnegie Museum.

their structure seems to plainly indicate this. It is in short impossible to articulate the limbs in such a position as to impart to the animal a crawling attitude. We have experimented a score of times and have tried different poses, only to come back again to the position which we have given to the reproduction of *Diplodocus* and which is the position that has generally been accepted by osteologists as the correct position for such animals when standing or moving forward. Our reproductions may be, as they have been contemptuously styled by Hay, "light-legged and straight-legged," but no one who has had the matter practically in hand has yet been able to suggest any way of escaping the conclusion that these creatures were at all events more or less "straight-

legged." For their "light-legged" qualities nature is solely responsible, though I fail, standing before these huge bones, to see why anybody should so describe them. Students of the lacertilia and of the testudinata may sneer, but it is beyond possibility to adopt the suggestions which they from time to time make, that those of us who are engaged in studing the dinosaurs shall squeeze these creatures into the forms with which they are familiar. The critics possibly do not realize that weeks and months and years of study have been spent by those who have been charged with the task of assembling these remains, and that the prescriptions, which they now furnish, have been already tried without their suggestion, and have for good reasons been found wanting. It is easy for a knight of the quill, who has never practically attended to the matter, to find fault. The latest attack upon those who have been making a special study of the sauropod dinosaurs has only served in the mind of the speaker to prove the correctness of the careful work which has been done in the past by students on both sides of the Atlantic. Evolution has had something to do since the sauropod dinosaurs walked the earth, and to say simply because the lacertilia of the present day creep and crawl that in Mesozoic times there were no reptiles which walked, is to go further than the facts seem to warrant. The pinnipedia and the cetacea live in the waters: it does not necessarily follow that their ancestors were aquatic in their habits and that their limbs were like those which they possess. Because snakes are to-day without feet or with only vestigial feet, it does not follow that the ancestral forms in remote antiquity moved as they move. Because a *Varanus* crawls to-day it does not necessarily follow that a sauropod dinosaur crawled. There is every evidence that they did not crawl, but that the restorations of Marsh, Osborn, and others are substantially correct in many important particulars. It is "a far cry" from the crocodilia, which, by the by, existed contemporaneously

with the sauropoda, and the genera *Brontosaurus, Morosaurus,* and *Diplodocus.*

The Tornierian hypothesis may be dismissed, I think, as not within the range of the possible. It has, as one of my learned paleontological friends in Europe jocosely remarked to me, "only this feature to recommend it, that it accounts for the speedy disappearance of the sauropoda, because if true, their lives must have been spent in indescribable agony, every joint being dislocated."

Both Dr. Hay and Professor Tornier indulge in speculation as to the food of *Diplodocus.* Tornier emphatically repudiates the idea that the animal was herbivorous and suggests that it was piscivorous. Sternfeld pictures it as squatting on the banks of streams and feeding on snails, bivalves, and amphibians. Hay approves of the suggestion of the present speaker, that *Diplodocus* may have fed upon algæ. In this field we are all more or less left to our imaginations, and one man's guess is as good as another's. In view of the fact that cycads were numerous at the time when the *Diplodocus* and its allies lived and died, it may not be improper to renew the suggestion that possibly these plants furnished the food of the sauropod dinosaurs. However the terminal buds would have been poor fodder, being woolly and harsh, and the leaves are as stiff as wires and could not have been masticated by such teeth as the *Diplodocus* possessed. On the other hand the interior of the stems of the cycads, "sago-palms," is in all recent species a veritable mine of nutritious food, and was presumably the same in the ancestral forms. While the comparatively feeble dentition of the Sauropoda would not have been of much use in getting at these supplies of starchy food, the heavy claw-like armature of the feet was quite equal to the task of ripping open the thin outer bark of the stems, and this accomplished, a single cycad stem of some of the larger species would have furnished a good meal of soft food capable of satisfying the hunger even of a *Diplodocus.* This suggestion has been freely discussed by the speaker with Dr. N. L. Britton of the

New York Botanical Garden, and seems plausible. It is thrown out as a hint worthy of consideration. If the terminal end of a cycad could have been torn away this also would have given access to the mass of food in the stem. The feeble dentition hardly seems equal to the task of tearing away this upper growth, but if it was, we then might have a reason for the great elongation of the neck.

Before I conclude these remarks I desire to say that I am not without hope that recent discoveries made by the Carnegie Institute will tend to throw a flood of light on the whole subject. We have found what paleontologists have been searching for for forty or fifty years, three skeletons of sauropod dinosaurs lying articulated where they died. They are imbedded in hard sandstone, the work of removing which from the bones must involve a vast expenditure of time and effort; but in one case at least we know already that the vertebral column lies in position, articulated from end to end. Apparently hardly any disturbance has occurred and the bones even to the minutest tuberosities and rugosities are as perfect as when the animal died. The sternal ribs are present. When we succeed in carefully working out these huge skeletons from the surrounding matrix we shall probably be able to clear up some of the disputed points in the osteology of the sauropod dinosaurs.