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The Weights of Dinosaurs

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INTRODUCTION

One of the attributes of the dinosaurs that makes these fossils so interesting to scientist and laymen alike is their size. Of course not all dinosaurs are giants, indeed some of them are very small; yet by and large the two reptilian orders Saurischia and Ornithischia, which together are termed "dinosaurs," are typified by the large and even gigantic proportions of a majority of their constituent genera. Some of the dinosaurs were the largest animals ever to live on the land, and a very large proportion of them were greater and more massive than most of the land-living animals of the present day. It is a very human response to be interested in the extremes of size that occur in the world around us, either the very large or the very small, and consequently the dinosaurs because of their size are bound to be of more general interest than are most fossils.

It must not be thought, however, that interest in the dinosaurs as gigantic animals is a matter of idle curiosity. The general trend towards giantism, so characteristic of the dinosaurs of Jurassic and Cretaceous times, carries with it various evolutionary implications that have been vigorously studied in the past and offer the opportunity for much further investigation in the future. Such problems as the evolutionary growth rates in the dinosaurs, the structural limitations of size in land-living vertebrates, the relation of size to temperatures and other factors of the physical environment, giantism and competition, and many additional topics present challenging subjects for research by the paleontologist, anatomist, paleoecologist, and fellow students in related scientific disciplines who are concerned with the earth and its past life.

We know how big the various dinosaurs were from the evidence of their fossil bones, but how much did they weigh? Very little work has been done in answer to this question, and in truth most of the statements about the probable weights of the dinosaurs are educated guesses. There is a reason for this situation, namely, it is not easy to try to calculate the weights of animals long extinct, especially those of which no close relatives are living today. The determination of the weights of extinct animals such as dinosaurs must be carried out by methods that may be somewhat roundabout; nevertheless it can be done with a fair degree of accuracy.

One method is to find the volume of a good model of the animal in question and then to calculate the volume of the extinct form, the scale of the model used being known. With the volume of the extinct animal so determined, it is possible to calculate the weight by multiplying this volume by the assumed specific gravity of the extinct animal. It is apparent from this description that, given an accurate restoration of the extinct form (and a restoration usually can be made which approaches very near to the probable external form of the animal), a reasonably accurate calculation of its volume is possible. The only assumption of consequence that enters into this method is of the specific gravity of the extinct animal. Here a comparison with living related animals is of help.

A half century ago, William King Gregory calculated the weight of the giant sauropod dinosaur *Brontosaurus,* or more properly *Apatosaurus,* using essentially the method outlined above. His results, published in *Science* in 1905, are referred to below.

The present paper is an elaboration of Gregory's study, using models representative of the six suborders of dinosaurs. It was initiated as a project limited to the brontosaurs, a result of correspondence between the author and a colleague, Dr. Theodore White, Naturalist at Dinosaur National Monument, concerning the probable weight of some of the large sauropod dinosaurs. As work progressed, the project expanded, finally including dinosaurs belonging to all the suborders, as mentioned above. The method and the results are described on the following pages.

I wish to acknowledge the help of Mr. Gilbert Stucker, Specialist in the Laboratory of Vertebrate Paleontology at the American Museum of Natural History, who rendered invaluable assistance in determining the volume of the various models of dinosaurs. Also I wish to acknowledge the kindness of Mr. Charles M. Bogert, Chairman of the Department of Herpetology at the American Museum, for permission to obtain the weight and the volume of a live alligator and a live Gila monster

and for his assistance in the securing of these data. Help in these determinations was also given by Mr. George Foley of the Department of Herpetology.

DIRECT EVIDENCE AS TO THE WEIGHTS OF DINOSAURS

Of course some rather general ideas as to weights in dinosaurs can be obtained from the fossils themselves. For instance, one can look at a skeleton and make a rough estimate as to the probable weight of the animal in life on the basis of familiarity with living animals. Thus if a dinosaur skeleton appears to be about the same size as the skeleton of a modern elephant, one may assume that the dinosaur in life may have been comparable to an elephant in weight. Similar comparisons may be applied between various smaller dinosaurs and modern reptiles or mammals that are more or less equal to them in size. But many of the dinosaurs were considerably larger than the largest elephants (which are the greatest of modern land-living animals), so this method of visual comparison soon breaks down. We can only say that these dinosaurs were generally larger in life than elephants but generally smaller than the largest modern whales, which leaves much room for speculation.

Another clue as to the weights of dinosaurs is in their footprints. In Texas, for example, are found trackways made by a large sauropod of early Cretaceous age, each individual print being several inches in depth. Evidently the prints must have been made by very heavy animals, even if one assumes that the mud at the time was quite soft.

But these indications of the weight of certain dinosaurs are at best of a very general nature, and no exact information is to be had from them. Consequently it is necessary to turn to an indirect yet none the less valid method of getting to the heart of this problem, the method that involves the use of models.

THE METHOD

Some passages from Gregory's paper of 1905, in which the method used by him to determine the probable weight of *Brontosaurus* is described, are quoted here:

"From the model [made by Charles R. Knight], a number of plaster casts were made, and one of these was used in the following determination. The model was constructed as nearly as possible to the exact scale of one sixteenth natural size, hence the cubic contents of the model multiplied by the cube of 16 (4096) should indicate the probable volume of water which would be displaced by the animal in the flesh. One of the casts was cut into six pieces of convenient size, which were then made water-tight by a double coating of shellac. . . .

"The weight of the cast in air minus its weight in water would equal the weight of an equal volume of water. This differential weight was determined in grams. As a gram is the weight of a cubic centimeter of water the weight of the water displaced gave directly the cubic contents of the model" (Gregory, 1905, p. 572).

The advantage of the method described above is in the accuracy with which the weights of the model in the air and in water can be determined. Its disadvantage is the necessity of treating the model to make it impervious to water. Therefore it was decided in the present work to make a direct measurement of the volume of each model used and to use some dry material for this purpose. Sand was employed, because it is fine and can be packed around all the complex shapes of a model.

Some slight inaccuracies may have been introduced into the measurements by the use of sand. The volume of each model was determined at least twice, and an average was taken. Many of the models were attached to bases. With the use of sand, separate determinations of the volumes of the bases could be made, which would have been difficult if water had been used. Consequently the volumes of a valuable series of scaled models were obtained without any destruction or injury to the models. This is an item of importance, because of the cost of casting such models.

The method was simple. Three boxes were constructed, one for large models, one for those of medium size, and one for small models. In each instance the model was placed in its box and completely covered with sand, the box being tapped during the process so that the sand would settle in place and fill all the spaces. The box was filled with sand to its top, and the sand was leveled off. Then the model was carefully removed, without any of the sand being spilled. The box was again filled with sand, the amount of sand used being carefully measured. Thus the sand that went into the box the second time, after the removal of the model, indicated the volume of the model.

In the case of those models on bases, either of two methods was used. One was to place the model upside down in the box, with the base completely out of the box. When this method was not feasible, the volume of the model and that of the base were determined separately. In this latter method, the model was placed in a shallow tray, which was filled with sand, all around, to the upper surface of the base. The model was then removed, measured sand was again added, and the volume of the base was thereby obtained.

When the volume of the model had been obtained in cubic centimeters, it was multiplied by the cube of the linear scale to which the model had been made, which gave the volume of the dinosaur when alive. The metric volume of the dinosaur could then be converted directly into metric weight, based on an assumption of the specific gravity of the living animal.

Gregory wrote in his 1905 paper, "But as the animal was probably slightly heavier than the water displaced, in order to enable it to walk on the bottom along the shore of lakes and rivers, we may add about ten percent . . ." (Gregory, 1905, p. 572).

Probably Gregory erred in making such an assumption. Careful study of the Texas brontosaur tracks by R. T. Bird has shown that, where the water was deep, these animals did not walk along the bottom but rather floated, barely touching the bottom with one foot or another to propel themselves along (Bird, 1944, p. 66). That this is indeed the case among modern tetrapods has clearly been shown by under-water moving pictures of hippopotamuses made in recent years. These large mammals had long enjoyed the reputation of being able to walk on the bottoms of rivers and lakes. The pictures show that they do not walk in the true sense of the word; rather, they float at such a depth that they are able to push themselves along in great under-water "bounds." Consequently the hippopotamuses, so massive and clumsy on the shore, are transformed under water into beasts of true grace and agility, executing their aquatic leaps with the aplomb of a ballet dancer. Perhaps the same was more or less true for the large dinosaurs.

Certainly there is good reason to think that these ancient reptiles had a specific gravity of less than one, as is the case among modern land-living animals.

During the course of the work it was decided to check the specific gravity of some modern reptiles. A young alligator (*Alligator*) and a Gila monster (*Heloderma*) were each weighed in air. Each was immersed in water, and the volume of water displaced was measured, thereby giving the volume of the animal. It was found that these reptiles had specific gravities considerably less than one, that of the alligator being about 0.9, that of the Gila monster about 0.8.

The low figure for the Gila monster is probably due to the fact that this lizard has a great deal of fat in the tail and in other parts of the body. The figure for the alligator is very likely closer to what was typical of most dinosaurs, this assumption being based in part on the close taxonomic relationships of crocodilians to the two dinosaurian orders. One might ask, of course, whether the figure of 0.9, which is the specific gravity of a very young alligator, can be taken as an index of specific gravity in the dinosaurs. What might be the specific gravity of a fully adult alligator, in which the ratio of heavy bone and muscle to total body weight is conceivably greater than in the young animal? For the moment this question will remain unresolved; the present author has no desire to struggle with a 10-foot crocodilian for the sake of a few percentage points of specific gravity. Certainly the figure of 0.9 should

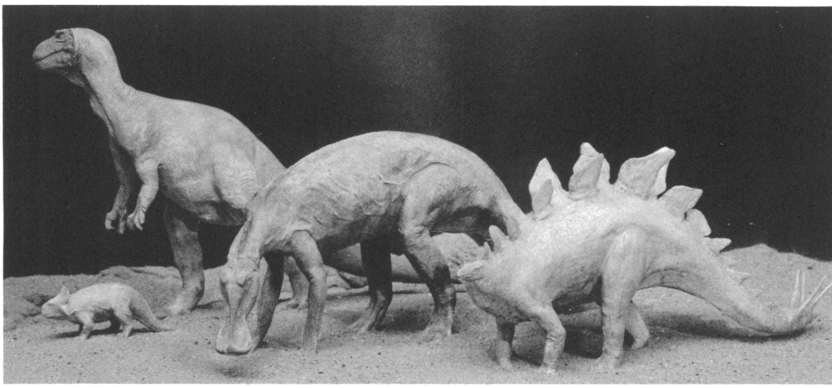

FIG. 1. Dinosaur models, scaled at one-tenth to one-twelfth natural size. Left to right: *Protoceratops, Allosaurus, Anotosaurus, Stegosaurus*. Figure not to scale.

not be far from the truth if applied in the calculations of the weights of dinosaurs.

Something should be said here about the models used and the determination of the scales of these models. As for the models themselves, it is highly important in a study such as this to have accurate restorations, made by competent artists under the supervision of experienced paleontologists, and executed with meticulous detail. Slight inaccuracies in small models will loom large when the volumes of such models are expanded to natural size. A list of the models follows, with the names of the artists and their supervisors, and remarks, where pertinent.

Allosaurus, or *Antrodemus*

Modeled by Charles R. Knight, under the supervision of Henry Fairfield Osborn and William Diller Matthew.

A very life-like model, except that the thoracic region is probably too thin. Consequently the weight of *Allosaurus,* as determined from volumetric measurements of this model, is slightly less than it should be.

Tyrannosaurus

Modeled by Vincent Fusco, under the supervision of Barnum Brown.

A good model, but a bit heavy in the thoracic region. The weight of *Tyrannosaurus,* as determined by use of this model, may therefore be somewhat on the heavy side.

Brachiosaurus

Modeled by Vincent Fusco, under the supervision of Barnum Brown.

There is little to criticize in this model, except that again the thoracic region is

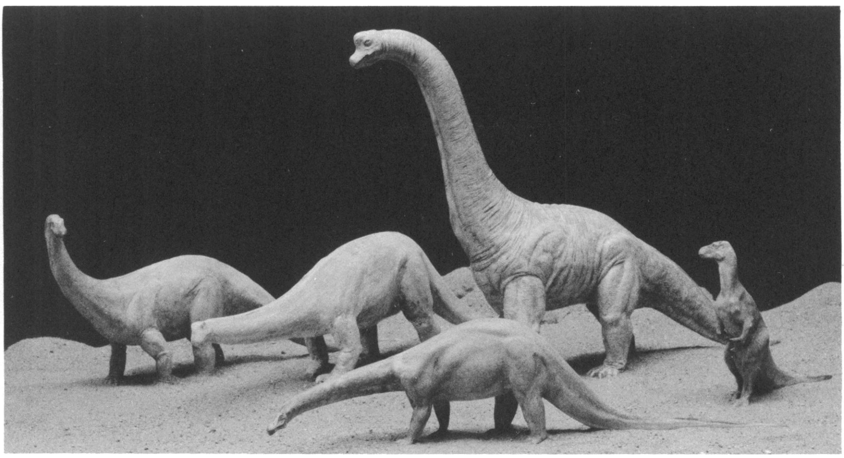

FIG. 2. Dinosaur models, scaled at one-twenty-fourth to one-twenty-seventh natural size. In front, *Diplodocus.* Back row, left to right: *Brontosaurus* (Allen), *Brontosaurus* (Knight), *Brachiosaurus, Iguanodon.* Figure not to scale.

well rounded—as indeed may have been the case.

Brontosaurus, or *Apatosaurus*

Modeled by Charles R. Knight, under the direction of Henry Fairfield Osborn and William Diller Matthew.

An excellent model by Knight. It can be criticized as having the base of the tail somewhat too thin. There was heavy musculature behind the pelvis in the great sauropods.

Brontosaurus, or *Apatosaurus*

Modeled by J. E. Allen, under the supervision of Barnum Brown.

This model is superior to the Knight model in that the tail is restored in what seems to be its more correct proportions, which accounts for the difference in the calculated weight of *Brontosaurus* as derived from the two models.

Diplodocus

Modeled by Joseph Pullenberg.

A good model, needing no comments.

Camptosaurus

Modeled by Vincent Fusco, under the supervision of Barnum Brown.

A good model. No comments necessary.

Iguanodon

Modeled by Joseph Pullenberg.

A good model, needing no comments.

Corythosaurus

Modeled by Vincent Fusco, under the supervision of Barnum Brown.

A good model. No comments necessary.

Anatosaurus

Modeled by Charles R. Knight, under the supervision of Henry Fairfield Osborn and William Diller Matthew.

A model with the display of the usual Knight skill. No comments necessary.

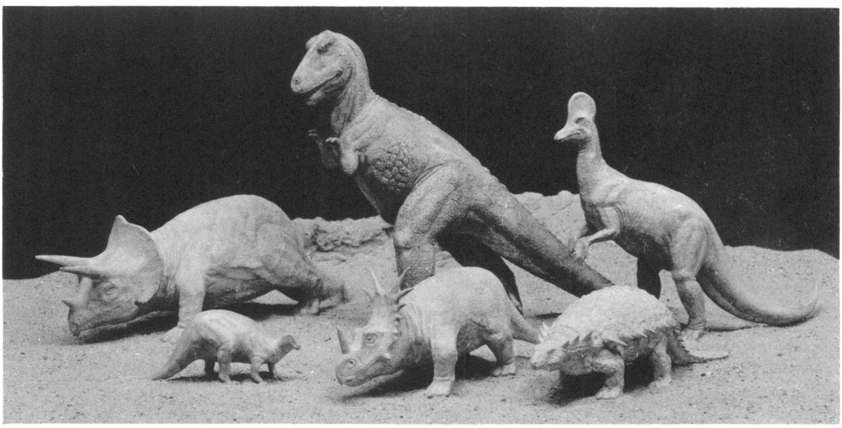

FIG. 3. Dinosaur models, scaled at one-fifteenth to about one-sixteenth natural size. Front row, left to right: *Camptosaurus, Styracosaurus, Palaeoscincus.* Back row, left to right: *Triceratops, Tyrannosaurus, Corythosaurus.* Figure not to scale.

Stegosaurus

Modeled by J. E. Allen, under the supervision of Barnum Brown.

A good model. No comments necessary.

Palaeoscincus

Modeled by Vincent Fusco, under the supervision of Barnum Brown.

A good model. No comments necessary.

Protoceratops

Modeled by Vincent Fusco, under the supervision of Barnum Brown.

The smallest of the models in the series. Good, but because of its size the details are somewhat generalized.

Styracosaurus

Modeled by Vincent Fusco, under the supervision of Barnum Brown.

In general, a good model, but the base of the tail is thinner than it should be.

Triceratops

Modeled by Vincent Fusco, under the direction of Barnum Brown.

A good model. No comments necessary.

The determination of the scales of the models used is particularly important and should be done very carefully. Wherever possible the measurements were made on the original skeleton, and the same measurements were made on the model, even though most of the models had the scale indicated on them. As will be seen in table 1, a few of the models came out at rather odd scales, in relation to the skeletons measured. Nevertheless, this procedure gave a feeling of assurance concerning the results. The one large question as to the weight of a dinosaur in this series concerns *Brachiosaurus*, as is discussed below, and in the case of this reptile the scale had to be determined from published plates.

Those dinosaurs of which the scale of the model was checked against a mounted skeleton are *Allosaurus, Tyrannosaurus, Brontosaurus, Corythosaurus, Anatosaurus, Stegosaurus, Palaeoscincus, Protoceratops, Styracosaurus,* and *Triceratops*.

Those dinosaurs of which the scale of the model was checked against published figures and plates are *Brachiosaurus, Camptosaurus, Diplodocus,* and *Iguanodon*.

THE SPECIFIC GRAVITY OF TWO RECENT REPTILES

On page 5 there is a brief discussion of the specific gravity of two modern reptiles, namely, a young alligator and a Gila monster, particularly as these specific gravities bear on the problem of the estimating of the weight of dinosaurs. The complete measurements are:

Alligator (*Alligator mississipiensis*)	
Weight in air	280.1 grams
Volume	315 cubic centimeters
Specific gravity	0.89
Gila monster (*Heloderma horridum*)	
Weight in air	864 grams
Volume	1055 cubic centimeters
Specific gravity	0.81

CALCULATION OF THE PROBABLE WEIGHTS OF CERTAIN DINOSAURS

Table 1 presents the data obtained by the method described above. As can be seen, each model and each skeleton were measured in the pelvic region—from the crest of the ilium or the tips of the sacral spines to the base, except in the case of *Brachiosaurus*, of which a shoulder measurement was made. In some genera additional measurements were obtained, in order to check on the accuracy of the scales established by pelvic or shoulder heights. Such was the case particularly for *Brachiosaurus, Corythosaurus, Palaeoscincus,* and *Styracosaurus*. The skeletons

TABLE 1
Calculation of the Probable Weights of Certain Dinosaurs

	Skeleton Height at Pelvis, in Mm.	Model Height at Pelvis, in Mm.	Linear Scale	Linear Scale Cubed	Volume of Model, 1 in Cc.	Volume of Model, 2 in Cc.	Volume of Model, Average in Cc.	Volume of Model × Linear Scale, Cubed, in Liters	Volume of Model, × 0.9 (Specific Gravity), in Kilograms	Weight of Dinosaur, in Metric Tons (or Kilograms)	Weight of Dinosaur, in U. S. Tons (or Pounds)
Theropods											
Allosaurus (1)	2510	250	10/1	1000	2294	2344	2319	2319	2087	2.09	2.30
Tyrannosaurus (2)	3600	246	15/1	3375	2239	2294	2266	7661	6895	6.89	7.60
Sauropods											
Brontosaurus (1)	4550	190	24/1	13824	2240	2246	2243	30966	27869	27.87	30.80
Brontosaurus (3)	4550	167	27/1	19683	1860	1800	1830	36020	32418	32.42	35.80
Diplodocus (4)	3600	150	24/1	13824	850	848	849	11736	10562	10.56	11.65
Brachiosaurus (2)	6090[a]	250[a]	24/1	13824	6310	6270	6290	86953	78258	78.26	85.63
Ornithopods											
Camptosaurus (2)	1300[b]	83	16/1	4096	104	104	104	426	383	383[c]	842[d]
Iguanodon (4)	2400[b]	95	25/1	15625	342	340	341	5016	4514	4.51	5.00
Corythosaurus (2)	3010	182	16.5/1	4492	950	940	945	4245	3820	3.82	4.21
Anatosaurus (1)	2800	244	11.5/1	1521	2090	2396	2243	3412	3071	3.07	3.38
Stegosaurs											
Stegosaurus (3)	2100	204	10/1	1000	1968	1982	1975	1975	1777	1.78	1.96
Ankylosaurs											
Palaeoscincus (2)	1800[e]	111	16/1	4096	943	942	942	3858	3472	3.47	3.82
Ceratopsians											
Protoceratops (2)	750	63	12/1	1728	114	114	114	197	177	177[c]	389[d]
Styracosaurus (2)	1955	122	16/1	4096	1000	1000	1000	4096	3686	3.69	4.08
Triceratops (2)	2300	154	15/1	3375	2800	2782	2791	9420	8478	8.48	9.35

1 Knight; 2 Fusco; 3 Allen; 4 Pullenberg.

[a]Measured at shoulder. [c]Kilograms. [e]Estimated.
[b]Large specimen. [d]Pounds.

of *Corythosaurus* and *Styracosaurus* at the American Museum of Natural History are set up as plaque mounts, not free mounts, and thus the pelvic heights had to be obtained by our measuring the various elements involved (ilium, leg bones, and foot bones) and working out the heights from these measurements with the bones posed in their correct positions. It is felt that the margin of error was small—certainly no more than would be involved in varying poses of free mounted skeletons. The

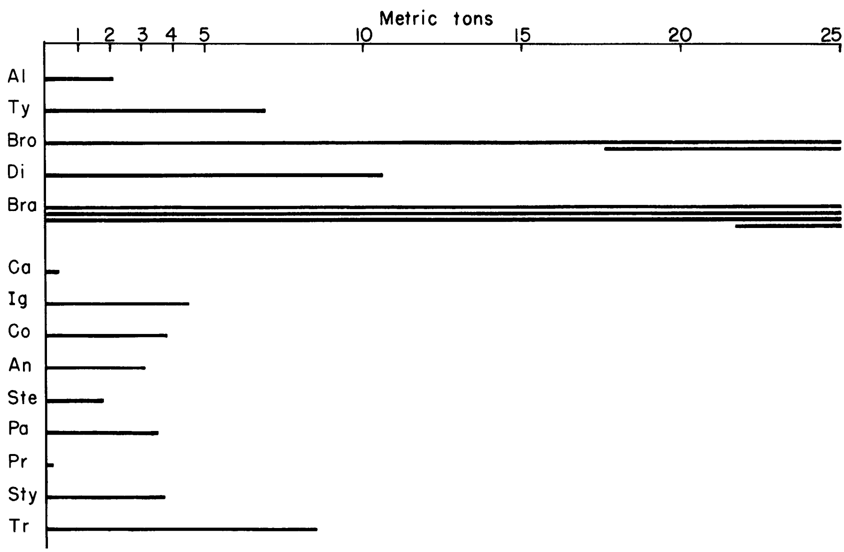

FIG. 4. Weights of saurischians (top five) and ornithischians (bottom nine). Abbreviations: Al, *Allosaurus;* An, *Anatosaurus;* Bra, *Brachiosaurus;* Bro, *Brontosaurus;* Ca, *Camptosaurus;* Co, *Corythosaurus;* Di, *Diplodocus;* Ig, *Iguanodon;* Pa, *Palaeoscincus;* Pr, *Protoceratops;* Ste, *Stegosaurus;* Sty, *Styracosaurus;* Tr, *Triceratops;* Ty, *Tyrannosaurus.*

pelvic height of *Palaeoscincus* had to be estimated, partly from the known elements of this genus and partly from close comparisons with *Ankylosaurus.*

Most of the measurements of volumes ran surprisingly close, which indicates that the method of making these measurements was a good one. The greatest difference was in the measurements of *Anatosaurus*—13.6 per cent of the mean; the next greatest was in those of *Stegosaurus* —7.1 per cent of the mean. All the other measurements varied by only a few percentage points or by fractions of a per cent, the greatest of the remainder being in those of the Allen model of *Brontosaurus* (3.3% of the mean) and the least being the volumetric measurements of *Camptosaurus, Protoceratops,* and *Styracosaurus,* in which there were no differences in the two determinations. In five models (the Knight *Brontosaurus, Diplodocus, Brachiosaurus, Iguanodon,* and *Palaeoscincus*) there were differences of less than 1 per cent. In the remaining models (*Allosaurus, Tyrannosaurus, Corythosaurus* and *Triceratops*) the variation was between 1 per cent and 3 per cent.

DISCUSSION

Perhaps the chief value of this paper is its attempt to give some substance to a problem that has been largely in the field of speculation. Table 1 may not be completely accurate, but it is believed that the figures probably approach the truth with a reasonable degree of validity, particularly when one considers the range of individual variation among adult reptiles.

Certain elements in table 1 are rather unexpected, at least to the author. For example, the living *Allosaurus* and *Stegosaurus* were lighter than I would have expected them to be. Conversely, *Brachiosaurus* was seemingly much heavier than was expected.

The calculated weight of *Brachiosaurus* is the one worrisome figure in the table. It has been generally supposed that 40 to 50 avoirdupois tons constitute about the upper limit for the weight of a land-living vertebrate, the assumption being that greater weights would exceed the limitations of the supporting strength of bone, ligament, and muscle. Yet here is a dinosaur that, on the basis of the calculations, weighed as much as a large whale. Extra volumetric measurements of the model were made, and linear measurements of the model and of Janensch's figures of *Brachiosaurus* were checked several times. After all possible checks of method and measurements had been made, the figure still held. Therefore, unless one is prepared to reject the Fusco model of *Brachiosaurus* as being completely inaccurate, a proposition that I for one cannot accept, it appears that *Brachiosaurus* was indeed a gigantic sauropod, in weight almost two and a half times the size of *Brontosaurus.*

When a visual comparison is made of the models of *Brachiosaurus* and *Brontosaurus* (using the Knight interpretation of the latter, which is to the same scale as the Fusco *Brachiosaurus*), this differential is easy to believe. *Brachiosaurus* was indeed gigantic in comparison with other sauropods. Much of its great size can be attributed to the tremendous development of the shoulders and forelimbs, the massive neck, and the huge body. Certainly no other land-living vertebrate ever approached it in massiveness and weight.

All in all this study points up the well-known fact that giantism was advantageous to the dinosaurs of middle and late Mesozoic times, in spite of the many inherent disadvantages that accompany giantism. The Jurassic and Cretaceous periods were times of world-wide tropical conditions, when temperatures were at an optimum for the great growth of reptiles, plant life was luxuriant, and food was plentiful. It was the age when there were giants on the earth.

These giants came in assorted sizes, and, while it is evident that the big sauropods were giants in every sense of the word, many of the other dinosaurs were giants of moderate dimensions, which poses problems concerning giantism among the dinosaurs and their life habits, specifically the problem of first- and second-class food consumers and predator-prey relationships.

An overwhelming majority of the dinosaurs were first-class consumers, living on the abundant vegetation of middle and late Mesozoic times. It was obviously a good living, for the herbivorous dinosaurs, especially the ornithischians, developed in great variety along numerous lines of adaptive radiation. As can be seen from figure 4, the ornithischians that roamed Mesozoic landscapes varied from very small dinosaurs to ponderous animals weighing as much as 8 or 9 metric tons. The carnivorous theropods of the Cretaceous period, the time when the ornithischians were at the climax of their evolutionary radiation, were likewise large, the greatest of them, *Tyrannosaurus,* being some 7 metric tons in weight. Evidently this giant predator made his way in life by feeding upon a variety of dinosaurs that were considerably smaller than himself; thus *Tyrannosaurus,* in attacking one of the hadrosaurs or perhaps one of the ankylosaurs, would have had a great advantage because of his gigantic size. Even when he attacked *Triceratops,* a dinosaur larger than himself, his chances were good, because the size differential between them was not very great. The same considerations obtained for the earlier dinosaurs of the upper Cretaceous—*Gorgosaurus* and its contemporaries. Only the lingering sauropods were appreciably larger than these Cretaceous predators.

When we look at the late Jurassic scene a different situation is apparent. In the Morrison fauna of North America, for example, or in the roughly correlative Kimmeridge fauna of Europe or the Tendaguru fauna of Africa, there were no great hosts of ornithischians, these dinosaurs being limited to a few early types. Thus a less varied food supply was available to the carnosaurs of that age, such as *Allosaurus* (or *Antrodemus*). It has been very generally supposed, therefore, that the carnosaurs of the upper Jurassic were predators on the contemporary sauropods, apparently the most abundant of the herbivores. How valid is such an assumption?

A glance at figure 4 will show that *Diplodocus,* one of the lightest of the giant sauropods, was about five times heavier than *Allosaurus,* while *Brontosaurus* exceeded the carnosaur by as much as 13 times. The differential between *Brachiosaurus* and the largest of late Jurassic carnosaurs must have been exceedingly great. Would one expect these predators to have attacked intended victims that outweighed them by such great margins?

Perhaps they did. The series of dinosaur trackways mentioned above, discovered at Glen Rose, Texas, in sediments of lower Cretaceous age, give clear evidence that a large sauropod comparable to *Brontosaurus* in size was followed or trailed by a carnosaur of *Allosaur*-like proportions. Here is what seems to be the evidence of an ancient hunt.

But when we turn to a consideration of modern animals, we find that generally there are no extreme differences between the weights of the predator and those of its prey. Among the mammals, for example, a North American mountain lion, commonly weighing about 150 pounds (about 70 kilograms), preys extensively upon the mule deer, an animal the average bucks of which are of about the same weight. The mountain lion may attack the American stag or wapiti, which may be three or four times its weight, but the lion is not likely to make such an attack if the smaller deer are available. An African lion, weighing about 300 pounds (about 135 kilograms) habitually preys upon zebras, which exceed it in weight by about two to three times. It seldom attacks larger herbivores and very commonly kills smaller ones. In short, these more or less solitary hunters prey upon animals that they can "handle," by virtue of their speed and strength.

It is difficult to visualize an allosaur "handling" a sauropod many times larger than itself.

To extend the comparison, it should be remarked that the alligators and crocodiles, the arch predators among modern reptiles, at times kill animals that are considerably larger than themselves. The success of a large crocodile in killing a large mammal, however, usually rests upon its ability to drag the victim under water and drown it. Certainly no such behavior pattern would have been involved in the case of an allosaur, a thoroughgoing terrestrial animal and a brontosaur, an aquatic type.

There is a possibility that the carnosaurs hunted in groups or "packs," like wolves, but of course on a much lower level of organization. A pack of wolves, the individual members of which might weigh about

75 pounds (27 kilograms), will attack a caribou (300 pounds, 135 kilograms) or even a moose (1000 pounds, 450 kilograms). Yet even these highly intelligent and intrepid carnivores would, in the old days of the great bison herds, shy at attacking a full-grown bison. The disparity in weight and strength was too much, even for the combined efforts of the pack.

From these comparisons it is reasonable to think, therefore, that the giant carnosaurs of the Mesozoic preyed largely on dinosaurs that were not overwhelmingly larger than themselves, were of the same size as or were smaller than the hunters. Perhaps their consumption of giant sauropods was largely in the role of scavengers or carrion eaters.

Various other aspects of the problems of giantism in the dinosaurs might be discussed at this place. It is, however, a large subject, and can best be considered elsewhere. The foregoing remarks may indicate the manner in which so simple an exercise as an attempt to calculate the weights of living dinosaurs, rather than to resort to speculation, can throw light on various aspects of the lives of these long-extinct reptiles.

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