ART. XV—*Notes on the Armored Dinosauria;* by G. R. WIELAND.

[Contributions from the Paleontological Laboratory of Yale University.]

WITH the progress of exploration in many fields it becomes more and more evident that an interesting parallel must exist between the long-persistent Testudinata and the shorter-lived armored Dinosauria, a group which plainly constituted a numerous and varied cosmopolitan race with its dermogene bones always as distinctly ranged in keels as in any turtles. For, as insisted upon several years since,* not only is a primary comparison afforded by the keels, but secondarily as well. the lumbar-hip carapace, present in the Nodosauridæ though not in the Stegosauridæ, finds its analogy in the osteodermal mosaic of *Dermochelys.*

Nevertheless, despite the cumulative evidence for the existence of a race of keeled saurians of world-wide distribution, and despite the frequent occurrence of more or less isolated plates from these keels, only the median dorsal line of *Stegosaurus* and the lumbar-hip carapace of *Polacanthus* (with *Stegopelta* Willistont), are so far known with any degree of satisfying exactness. Indeed it appears that collectors, in both Europe and America, have been so little fortunate in finding the keeled Dinosaurs with their plates more or less naturally aligned *in situ* as to long leave the existence of such a great group obscure, although field work has but recently reached a far point in the collection of integumented skeletons of the unarmored, swift-footed Laramie Hadrosaurs. Nor was it known until three years ago that in that most explored of all vertebrate yielding horizons of North America, the Niobrara chalk, typical armored saurians occur. Then, as described in this Journal,‡ the plates assigned to the new genus *Hierosaurus* (with dermal plates characterized by deep and broad horn shield sulci), were found by the fossil hunter Sternberg.

As it transpired, the interest of these fossils had not been fully recognized by their collector. In consequence, as was later learned on the occasion of a visit by Mr. Sternberg at the writer's home, many much weathered and broken fragments of the type had been left behind. But fortunately, as found so desirable by us both, Mr. Sternberg was able to make the needed reëxamination of the locality before the frosts of another winter had set in, securing and sending every last remaining fragment.

*A new Armored Saurian from the Niobrara; by G. R. Wieland. This Journal, vol. xxvii, March, 1909, p. 230-232.

† A new Armored Dinosaur from the Upper Cretaceous of Wyoming; by S. W. Williston, Science, N. S., vol. xxii, No. 564, October 20, 1905, p. 503-540. [Preliminary note on *Stegopelta landerensis*, from the Frontier Benton. An illustrated description is not yet published.]

‡ Loc. cit.

And indeed from this second instalment of the type much more has been learned than might have been anticipated. In it, as enumerated below, nearly every part of the skeleton is represented. In fact, after careful search and reuniting of many separated fragments, it is found that although much of the new material, especially of the limb bones, is too much weathered and broken to permit restoration, there are present far more than twice as many complete elements as were first secured; while taking both collections together, quite one-third of the entire armor is directly indicated, and inferentially, more than half. To the description of this new material we may now turn with the remark that the recovery of such a large part of the armor in intimate association with the skeleton assures us that the Niobrara must in time yield finely conserved armored saurians.

Further Structures of Hierosaurus.

Figures 1–3a.

The additional portions of the skeleton of *Hierosaurus* described herein have the same general surface characters and features of weathering as the plates first collected, and are to be regarded as part of one and the same type. They come from the same locality, and so far as I can determine represent but a single animal, with the exception of the caudal bands shown in the first description (cf. figures 7, 7*a*, loc. cit.).

As forwarded by Mr. Sternberg, this second instalment includes the following skeletal parts:

(*a*). One large flat caudal spine of isosceles triangular form 15 centimeters high with a base 13+ cm. long. Base somewhat crushed but showing clearly outlined surface of attachment about 4 cm. wide. (Cf. fig. 3, 3*a*.)
(*b*). Distal half of a somewhat lower spine than the preceding.
(*c*). Two portions of summits of spines of moderate to large size.
(*d*). A low set spine strictly intermediate in form between the preceding and following (fig. 1*b*).
(*e*). One elliptical and ridged dermal plate 10×15 cm. (fig. 1*c*).
(*f*). A subrhombic dermal plate like *e*, 9×15 cm.
(*g*). Four oblong elliptical elements ranging from 9 to 11 cm. long and from 3 to 5 broad, and having a submedian ridge varying from a shallow sigmoid (fig. 2*e*) to a crescent (fig. 2*f*, *g*), the latter form being doubtless one of the most anterior in which the tendency to form a posteriorly set spine is clearly marked.
(*h*). Three smaller oblong ridged elliptical elements about 8×3 cm. (fig. 2, *a*–*c*).
(*i*). Series of twenty-five incomplete plates like the two preceding groups. Length average 8 to 10 cm.
(*j*). About fifty additional fragments of smaller elongate ridged plates, less than 10 cm. in length. Some must be portions

of one and the same plate, the group doubtless representing about twenty-five plates. Average length under 10 cm.

(*k*). Six much crushed dorsal (?) centra 6 cm. long. Nearly platyan or slightly cœloplatyan.

(*l*). Four toe bones 4×2 cm. (may include a caudal vertebra).

(*m*). Fragments of ribs of T-shaped section with the top very heavy, breadth 3 cm.

FIG. 1.

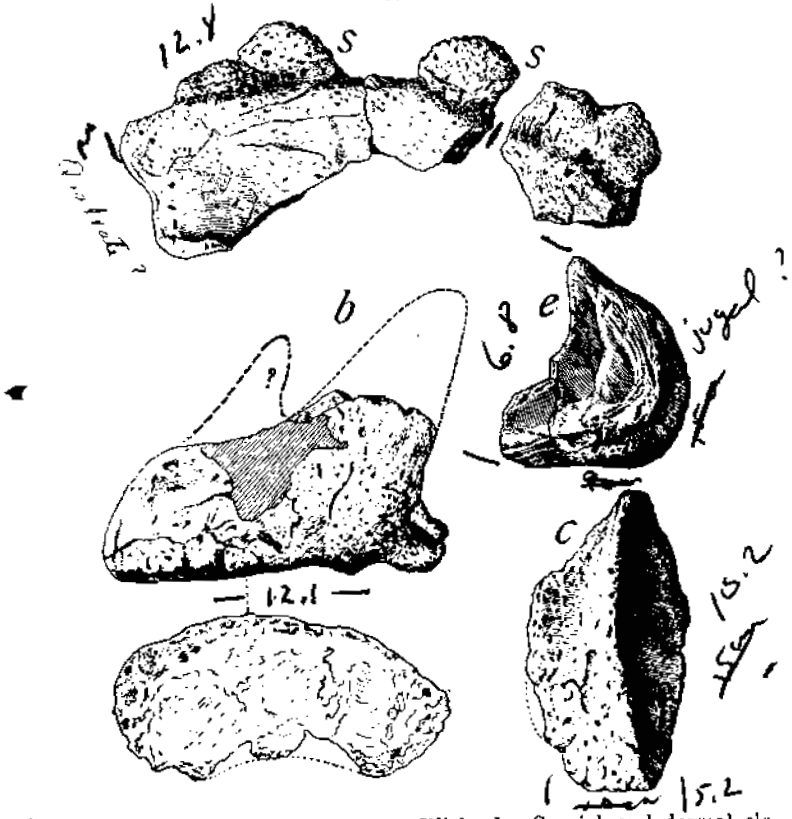


FIGURE 1.—*Hierosaurus Sternbergii* Wieland. Cranial and dermal elements referred to the original type. × 0·37.

s, *s*, lower outer portion of right squamosal with series of fused epijugals (*s*, *s*) indicating the presence of a Triceratops-like frill of considerable size if correctly identified (comparison is primarily to be made with the "posterauial scutes" of *Stereocephalus tutus* Lambe);—

e, inner side of a characteristic cranial element supposed to be the right jugal with the free concave side (at *e*) forming part of the orbital border;—

b, dermal element, rising into a large posterior spine with the suggestion of a possible bifid condition. (The rugose crescentiform base is shown below);—

c, dermal plate traversed throughout by a strong ridge not rising into a spine.

(*n*). A portion of post cranial band—cf. figure 1, *s*. *s*—as well as larger parts of same rugose surface character, with heavy sulci. All may be supra-cranial plates.

(*o*). A cranial element (jugal)—cf. figure 1*c*.

(*p*). Many fragments of limb bones and other parts of skeleton not determinable but bulking up as great as the parts determinable.

The principal anatomical features readily determinable from this type, as in part illustrated in my previous description (cf. loc. cit. figures 1–7*a*) and by the accompanying figures 1–3*a*, are:—

1. That the length of the animal was about four meters, being perhaps less than half the size of *Stegosaurus*, and distinctly smaller than *Stegopelta*;—whence the length of a spine series measured from near the skull over the lumbar-hip carapace, and including the anterior three-fourths of the tail, would be three meters more or less.

2. The dermal elements present in whole or part now number nearly 70. Hence if all were arbitrarily placed end to end with an allowance of say one-fourth their actual size as abutting space, a length of from 9 to 10 meters on keel lines or the equivalent of three full keel lengths is present. Or counting off space for the lumbar-hip carapace, fully four keels.

3. Since the dermal elements no doubt fairly represent all the keels and yet include no strictly bilateral members, it is not likely that there was a true median keel, whence five to six keels are arbitrarily demonstrated as present.

To make an estimate of the maximum number of keels is however seen to be impracticable. One can only say that there appear to have been at least as many as on the turtles with a neural, two pleural, two supra-marginal, and two marginal keels, or seven in all.

4. Since a few cranial bones are present, but no portion of the lumbar-hip carapace which was no doubt well developed, it is likely that the dermal elements recovered are mainly of the anterior dorsal region.

5. The complex character of the armor is striking, combining as it does a system of free keels which lose their identity in a lumbar-hip carapace and must then reappear in the caudal rings. No less too is the *tout ensemble* one of the most ornate that has ever been demonstrated. For as we see the elements of the keels vary regularly in shape from tubercles through rounded, oblong, elliptical, subrhombic and crescentic forms, with regularly increasing elevations passing from points to ridges both straight and sigmoid, low bifid, and at last huge caudal spines.

The specific isolation of *Hierosaurus Sternbergii* is believed to be clearly established, since the nearest form with which it can be compared is *Stegopelta* of Williston (loc. cit.) from a different horizon however, the Fort Benton. Not as yet clearly illustrated, that genus is described as having mainly rounded dermal elements, whereas those of the present fossil

Fig. 2.

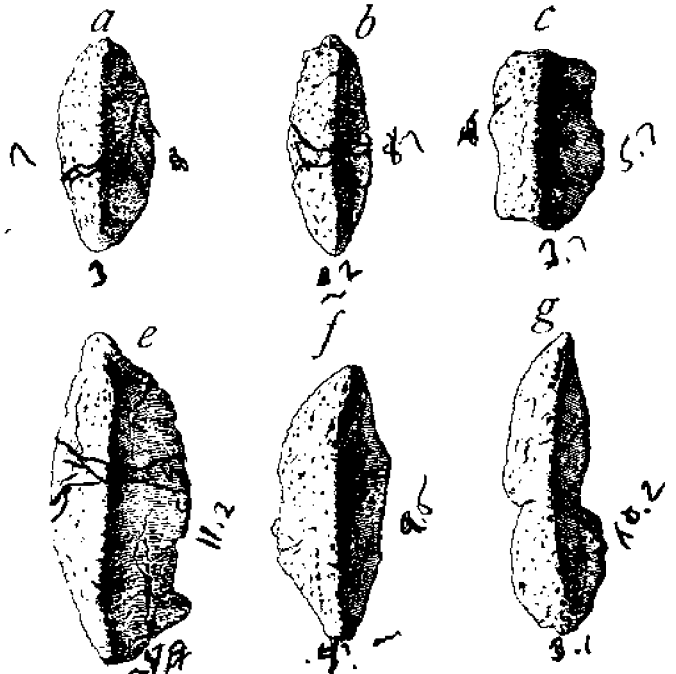


Figure 2.—*Hierosaurus Sternbergii* Wieland, × 0·37. Characteristic dermal elements showing variation from the straight keeled forms *a-c*, to the crescent keeled forms, *f*, *g*, and the sigmoid keel *e*. In all these instances (except *e*, incomplete) it can readily be determined by inspection of the specimen which is the anterior end. [That of *e* is below.]

cannot be so described. But in other respects these forms are so near as to make it possible that a fuller knowledge of both will warrant bringing the Niobrara saurian within the genus *Stegopelta*; while the next nearest relation is doubtless the slightly older *Stereocephalus* of Lambe* from the Belly River series of the Red Deer River, Alberta.†

*New Genera and Species from the Belly River Series (Mid-Cretaceous); by Lawrence M. Lambe. Contributions to Canadian Paleontology, vol. iii, Ottawa, 1902, p. 25.

†Since penning these lines I have shown the type material of *Hierosaurus* to Professor Williston, who says he believes the form generically distinct from *Stegopelta*, and calls attention to the fact that in the latter many of the dermal plates bear a large shallow pitting whereas no such markings are present in any of the *Hierosaurus* plates, though so many have been recovered.

Fig. 3.

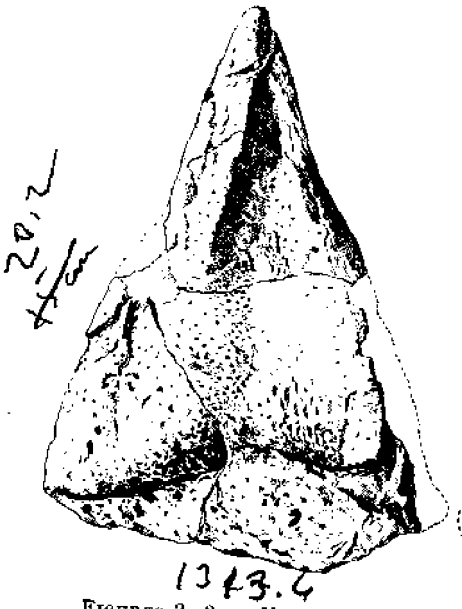
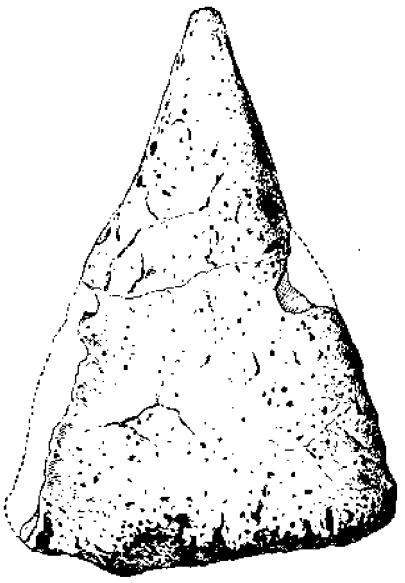


Fig. 3a.



Figures 3, 3a.—*Hierosaurus Sternbergii* Wieland, × ⅓. Large broad-based caudal spine of the type, 20 centimeters long. Figure 3 shows the slightly fluted intero-superior side, and figure 3a the rather flat extero-inferior surface. The base was broad and heavy, the apex ornately outcurved and sharp.

The family attribution of both genera along with *Polacanthus* Hulke, *Nodosaurus* Marsh, *Palæoscincus* Leidy, *Stereocephalus* Lambe, and *Ankylosaurus* Brown, we think surely lies within the Nodosauridæ of Marsh.

It is thus seen that the type of *Hierosaurus*, though promising but little of its true interest when first noted in fragments weathered, broken and scattered in the Kansas chalk hills, shows students as well as collectors that exhausted fossil-bearing horizons are as yet unknown. As enumerated, the elements recovered indicate that approximately an entire skeleton was present when erosion of the matrix began. Evidently future search in the Niobrara cannot fail to reveal other complete examples, mayhap with their keels fairly in place.

But for the present the evidence available for even tentatively illustrated restorations of mail-clad Dinosaurs remains too baffling. Perhaps if one were in ignorance of both *Polacanthus* and *Stegopelta* it would be possible to produce a plausible generalized restoration of the armor of our Niobrara form, seeing that it has quite the longest series of finely con-

served plates of any specimen so far obtained. Indeed Brown,* overlooking *Polacanthus* entirely, has attempted with far less material to restore the keels of his *Ankylosaurus*. But as Williston† has rightly said of this restoration, "It is based on too scanty material to serve as a satisfactory basis for a restoration * * since the form must be included in the same family as *Polacanthus* Hulke." Whence it is pertinent to remark that vertebrate paleontologists have reached the time when it is well to realize that even though what is more a surmise or a guess prove fortunate, its value both present and future must depend on the concrete evidence which lies behind it, as we have learned from severe experience.

We may pass on to a brief notice of some further structures of the mail-coated Dinosauria of much present interest.

Pleural Armor of Stegosaurus.

So far, the startlingly strange, complex, and ornate aspect at once indicated by even lesser portions of the mail-clad Dinosaurs, has naturally led to so called "new families." Not to mention a long series of genera of convenience, we thus have the Scelidosauridæ, Polacanthidæ, Stegosauridæ, Nodosauridæ, Ankylosauridæ, etc., etc.

Now while this nomenclature of expediency may really foreshadow the degree of complexity the mailed saurians will ultimately be found to exhibit, they are none the less to be regarded as a compact and homogeneous series. And in all likelihood this series displayed as much uniformity in the general alignment of its keels as might be observed in a similar array of Cretaceous Testudinate families. From our viewpoint we hence hold it safe to predict that buttressing pleural keels will certainly be found in addition to the two great and firmly set dorsal Stegosaurian keels recovered. On both anatomical grounds and relationship this must be the conclusion; though it is very clear that such pleural keels would be *low*, since the mid-line armor had become the dominant means of defense, or at least region of accelerated growth. Even so there is in the nearly rigid back a most curious parallel to the turtles, and we believe that restorations should take more cognizance of this fact in dealing with the leg flexion than they have so far.

That pleural keels have not been so far recovered, or recognized must be explained away as due to accidents of preservation and collection—even to paucity in field observations or notes. At best the chance to find more or less loose peripheral

* The Ankylosauridæ, a new family of Armored Dinosaurs from the Upper Cretaceous, by Barnum Brown. Bull. Am. Mus. Nat. Hist., vol. xxiv, Feb. 13, 1908, pp. 187–201.

† American Naturalist, vol. xlii, Sept., 1908, p. 629.

elements is always most precarious, as we know from the frequent dissociation of testudinate marginals.

Dinosaur Mail from the Ceratopsia Beds.

Figures 4–7.

There is strong reason to believe that owing to accidents of preservation, the course of erosion from their matrix, and even

FIG. 4.

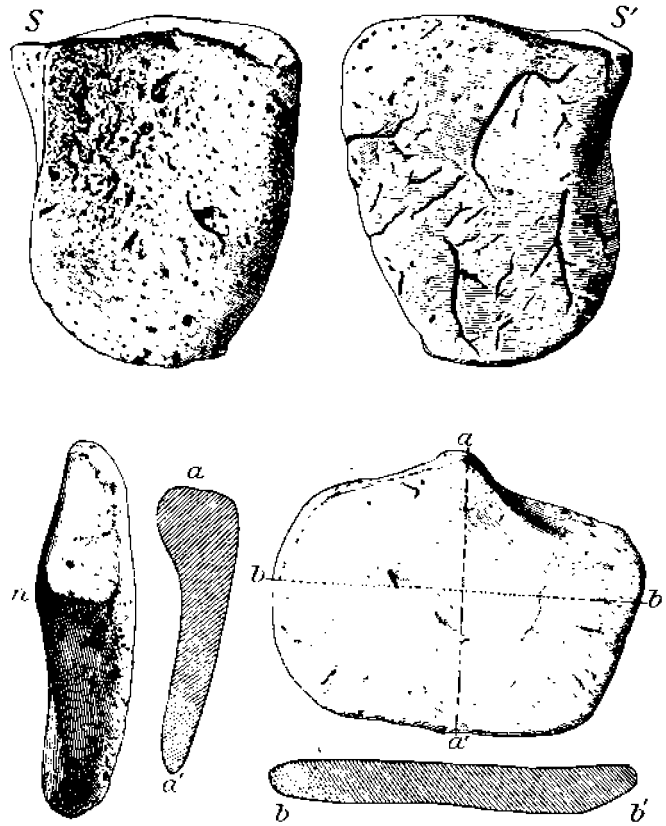


FIGURE 4.—Oblong dermal plates of Nodosauridæ or Ceratopsidæ from the Ceratops beds of Converse County, Wyoming. ×⅓. Forms illustrating extreme displacement of the spinal node. In the upper figure *s* is the inner, and *s′* the outer view of a plate, the inner left basal angle of which rises as a distinct triangular spinal elevation *ss′*, 3 centimeters high. Which is the major axis, remains uncertain.

In the lower figures, the spinal node is at the middle of the upper edge at the end of the transverse axis *aa′*, although the trifaced feature is as distinct as before. The entire form is shown by the transverse and longitudinal sections *aa′* and *bb′* respectively, *n* being the upper inner face of the plate, and its node.

to the fortunes of collection, the bony plates thus far found more or less closely associated with the reptiles of the Ceratops beds do not represent the true abundance and proportion of

FIG. 5.

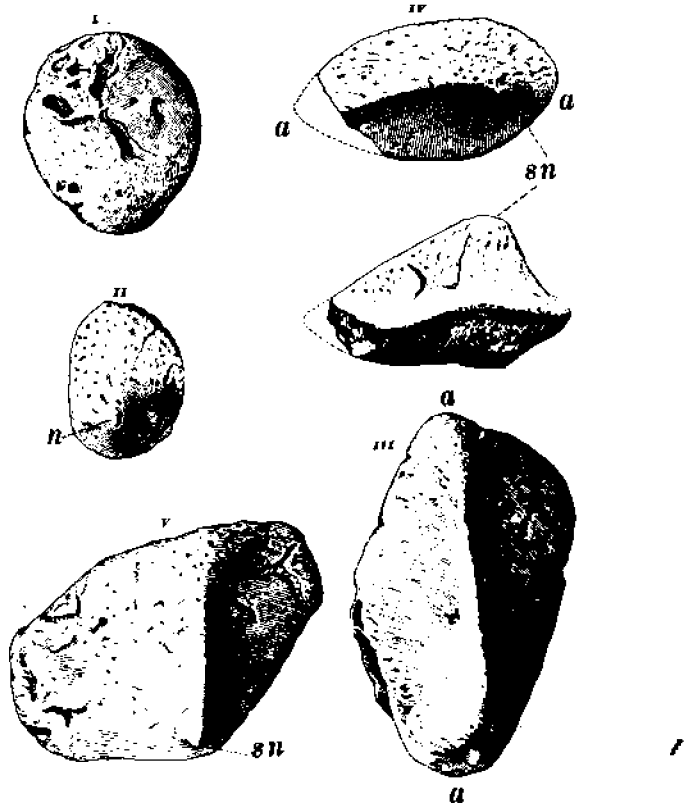


FIGURE 5.—Rounded, elliptical and subrhombic dermal plates of Nodosauridæ or Ceratopsidæ, further illustrating the great variety of form and the changing development and position of the spinal node. All are from the Ceratops beds of Converse County, Wyoming, and at least in part from the same individual as the plates shown in figure 4.

I-V form a series passing from a rounded flattened tubercle (I) to a form with a low node (II), to a ridged form (III), and then a form with a heavy spinal node *sn* (IV). In V the spinal node *sn* lies near to the posterior border.

All are of heavy and comparatively dense bone, upper surfaces usually showing nutrition canals.

armored saurians in that horizon. Such armor is as a rule found at some distance from the skeletons to which it belongs, and yet it cannot serve as a satisfactory basis for new species. There may, therefore, be far more of it in the various collections than one might suppose from the minor mention it receives in all accounts of Dinosaurian material from the Ceratops beds of the Laramie and Belly River series.

The plain fact is that we have been entirely misled by a seeming paucity of such armor not in accord with the existence in the Laramie of numerous representatives of the armored race, each bearing, as one may readily calculate, anywhere from 200 to 300 dermal elements varying from mere tubercles up to huge staked plates. Indeed it would be of very considerable interest to know the actual number and proportion of these

FIG. 6.

FIGURE 6.—Subrhomboidal Nodosaurid or Ceratopsid dermal element from the Ceratops beds of Converse County, Wyoming. × ½. (Thickness 1·5 centimeters.)

The upper surface, showing the large nutrition canals radiating from the subcentral and little elevated nodal area. The under surface is distinctly convex and shows the *Nodosaurus textilis* type of striated surface. A frequent and typical form.

elements in the collections, and especially their associations; though it is, we repeat, greatly to be feared that field notes sufficient to reveal the full cumulative value of this evidence may be lacking. The more are we impressed with this idea because of the fact that the discovery of the armored saurians has been late, is only beginning now. Furthermore we can add very tangible evidence to these views, having but recently secured from Mr. Sternberg a collection from the Laramie of some thirty most interesting dermal elements, the chief forms of

which are figured herewith. These are supposedly from two individuals and may represent *Ankylosaurus*, or an ally; though it is, as we must insist, by no means proven that some of these forms did not pertain to Ceratopsia, just as Professor Marsh supposed they did. Forms like these were found near Ceratopsians by Hatcher, and Sternberg says he found one of these plates accompanying the *Triceratops* skull he sent to the British Museum two years ago.

As readily seen from inspection of the figures, these elements present far more variety of form than do those of *Hierosaurus*. They also vary all the way from tubercles to plates of large size, and from mere knots of bone to armor with the most ornate ridging. Taking the elements as a whole there is in fact a notably small number with flat upper surfaces, the tendency being to rise first as a point, then as a more or less rounded elevation, and more often into a keel. Finally, there is the backward projection and elevation into a free spine.

FIG. 7.

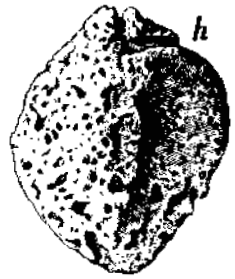


FIGURE 7.—Thick strongly rugose Ceratopsid or Nodosaurid dermal element from the Ceratops beds of Converse County, Wyoming.

At *h* a strong hornshield groove appears, not to be confused with the nutrition canals, and showing further evidence of a high development of hornshield systems in many of these forms.

The figures 4–7 taken in conjunction with those illustrating *Hierosaurus* give a fair idea of form-range in Dinosaurian dermal armature where passing beyond the stage of minor patternless ossifications such as may have been present in various heavy-skinned Dinosaurs and have been pointed out to me as accompanying *Pelorosaurus*. But they by no means show the range in these types characterized by a dominant linear arrangement of the elements, on which these studies are based. In particular one notes that the spinal node, as we term that point, line or area which tends to project, whether pronounced or not, may occupy any portion of the face. Usually the spine once it becomes pronounced of course rises from the posterior half. But as a ridge the node may even rise to form the edge of a plate as in figure 4.

* * * * * * * *

In all the armored saurians there is the constant variation in general form of the plates and spines suggesting close abutment to suit the different body areas, but yet producing no doubt a rigidity of body in most of the later forms approaching that of testudinates. Indeed these animals in the larger sense started in the direction of testudinate armoring but ran off to bizarre

patterns. As a rule, however, the transition from low, flat or erect plates to large spines does not appear so abrupt as in the case of the more or less fluted caudal spines of *Stegosaurus*; but taken all in all, it is evident enough that there was present throughout an entire armored race a most ornate keeled armorial pattern. And while the complexity of this pattern as yet baffles exact restoration, it is now seen to be most likely that forms with their armor in place will soon be discovered, revealing in full the structure and number of the keels, the degree of carapacial and hornshield development, the extent of possible comparison with the armor of the Testudinata, the correlated skeletal structures, and finally following anatomical features, the extent and the nature of the antithetic course of evolution which must be involved in the development of the late Cretaceous carnivorous and mailed and horned Dinosauria.

Indeed so extended has already become the evidence here added to, that a further brief word of interpretation is pertinent. At first sight all development of dermal armature may appear to be mainly a senile feature, due even to inertia—the general life movement of the individual and the race.* But it is also evident that the development of dermal ossicles in series finally resulting in a protective osteodermal armature or carapace is a most profound change coördinated with striking endoskeletal alteration. Used with less success by the Dinosauria, as already much specialized, the accomplishment of this change however appears to have given the Testudinata an exceedingly long lease of life.

It is hence in our view most probable that not so much bathmic courses and tendencies as ordinary exigencies of life and environment were really primary factors in the origin of armored reptilian races. At least ever since the discovery that races of formidable carnivores like *Megalosaurus* and *Lælaps* developed side by side with such strongly armored herbivores as *Scelidosaurus*, *Hylæosaurus* and *Stegosaurus*, it has seemed reasonable to believe that a completer knowledge of Dinosaurian faunæ must finally reveal some of the modes of adjustment to a life of attack and defense in these dominant but comparatively short-lived apposite lines. For if ever the vertebrate paleontologist might hope to detect boundaries between the direct origin of organs to meet obvious necessities, and their appearance with the aging of races as secondarily used senile features, here where all the characters are writ large

* On page 106 of this Journal, Aug., 1902, the parallel modification of cervicals in long separated Testudinate races was cited by the writer as a case of evolutionary inertia. It is a conspicuous one, and is correctly named inertia, whereas the term momentum, now used by some, implies a knowledge of rates of evolution we do not as yet possess. The general term is certainly preferable.

must be the point. Though in the simple relations of attack and defense involved in spines, bony plates, horns and teeth, nothing we can to-day observe in the reptiles or the mammals of the land or sea could have quite prepared us for that veritable apotheosis of force finally involved in *the* juxtaposition of *Tyrannosaurus* with the Ceratopsia as justly included members of the great group of keel-armored saurians here hypothesized.

Certainly then one can not bring himself *to* seek an explanation of the evident parallel development of these structurally antithetic series, and their brief culmination in the latest Cretaceous, as a chronological accident, explicable in terms of senility and bathmism, or of mere developmental inertia.

That one or the other of these opposed series could so arise as an aging race during continental and climatic evolution is thinkable. But that both the carnivorous and horned and mail-coated herbivorous Dinosaurian lines so developed their formidable array of structures of attack and defense synchronously, appears improbable. Such equal rates of evolution have never been demonstrated; though in any alternative one is surely led to believe that when once the Dinosaurian lines are known in approximate paleontologic totality, the sequence and cause of complementary development in these groups, whether simple as it now seems, or obscure, may not only be largely understood, but that the facts will aid us notably in gaining very definite conceptions of fundamental biologic factors involved. Indeed it is most evident that any idea that the study of the Dinosauria can be in the least barren must be wholly erroneous, and that contrariwise, this group is destined to yield in *largesse* evolutionary testimony of everyday bearing that can be learned nowhere else.