Is the postulate of a dual heat supply a logical and legitimate proposition?

These and other problems of similar import are left untouched. Constructive criticism is always helpful; destructive criticism is less so. I asked for bread but thus far have received little but striated pebbles.

Art. XV.—*A Study of Diceratherium and the Diceratheres;*[1] by Edward L. Troxell.

[Contributions from the Othniel Charles Marsh Publication Fund, Peabody Museum, Yale University, New Haven, Conn.]

Table of Contents.

Introduction.

At present there are but two species of *Diceratherium*, *D. armatum* and *D. annectens*, which are accepted without reservation by students of paleontology; yet species from two continents have been referred to the genus, as well as all specimens from the John Day region of Oregon and those from the Lower Miocene of the Great Plains.

Our inability to classify harmoniously all the two-horned rhinoceroses under this genus does not tend to lessen its importance nor its distinction, and although there is a wide variation in John Day rhinoceroses, it is necessary to put them together into one group and at the same time separate that group from all others. Following is a list of the Oregon species of the true *Diceratherium*:

Diceratherium hesperium (Leidy) 1865. Inadequate. Figured heautotype, Cat. No. 10239, Y.P.M.
Diceratherium pacificum (Leidy) 1871. Inadequate. Figured heautotype, Cat. No. 10287, Y.P.M.
Diceratherium annectens (Marsh) 1873. Holotype, Cat. No. 10001, Y.P.M.
Diceratherium armatum (Marsh) 1875. Genoholotype. Holotype, Cat. No. 10003, Y.P.M.

[1] This is the last of the series of four papers on the American rhinoceroses. Three other parts appeared in this Journal for July, 1921. It is a pleasure to state that all of the drawings in these four papers were made by Rudolph Weber, whose work is so well known to scientists everywhere.

Diceratherium nanum (Marsh) 1875. Holotype, Cat. No. 10004, Y.P.M.

Diceratherium truquianum (Cope) 1879. Holotype, A.M.N.H. (Cope Coll.), Cat. No. 7333.

?Diceratherium oregonense (Marsh) 1873. Incertæ sedis. Holotype, Cat. No. 10002, Y.P.M.

Diceratherium lobatum, sp. nov. Holotype, Cat. No. 12487, Y.P.M. Fig. 6.

Diceratherium cuspidatum, sp. nov. Holotype, Cat. No. 12007, Y.P.M. Fig. 7.

The True Diceratheres.

Diceratherium Marsh.

The genoholotype, *D. armatum,* based on a large skull (Cat. No. 10003, Y.P.M., fig. 5) from the middle John Day beds of Oregon, has unusually simple teeth and enlarged broad nasals with rugosities not rounded, but elongated antero-posteriorly, separated and directed outward. Its size and the simple, primitive teeth make us think that the living conditions were not severe, that there was an abundance of nourishing food, and a moist climate. The molars resemble those of *Metamynodon.*

Diceratherine species from the Great Plains are here separated from *Diceratherium* Marsh and put under separate generic groups: *Metacænopus* Cook and *Menoceras,* gen. nov.

The species with simpler teeth, of larger size but with more subdued nasal eminences, belong with the genus *Metacænopus,* genoholotype *M. egregius* Cook. The smaller animals from the Agate Spring quarry, of slightly later age, with teeth more progressive in their subhypsodonty and in the development of additional folds of enamel, with horn rugosities even more prominent than in *Diceratherium,* are grouped under *Menoceras* nobis, the genoholotype of which, *D. cooki* Peterson, is defined later.

Diceratherium armatum Marsh.—The following points may serve in part to define this species: (1) males with well developed, widely separated, oval rugosities on the nasals in maturity; (2) moderate deepening of sinuses and pits of teeth, or increase in height of ridges, reaching an extreme in later rhinoceroses (*?D. oregonense*); (3) cingula broken on the molars, weak on the tetartocones, with a tendency toward elimination; (4) development of minute folds into a crochet, but virtual absence of a true crista; (5) moderate grooves on the protoloph of molars, separating the protocones from the protoconules, absent on premolars; (6) incisors and canines lost from premaxillary, except first and possibly second incisor; (7) milk dentition rather complex; (8) in size one of the largest rhinoceroses of the time; (9) geological age, middle John Day, corresponding to the Upper Oligocene or Lower Miocene of the Great Plains.

Fig. 1.

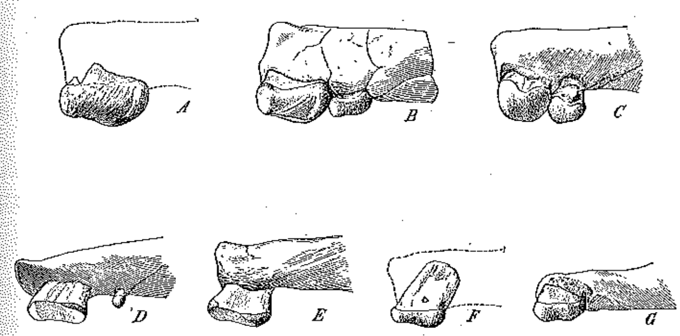

Fig. 1.—Premaxillaries showing the development of incisors in various species of *Diceratherium* in the Yale collections. All shown from the left outer side. × 1/3.

A, D. armatum. Cat. No. 10005. Second incisor unknown and bone restored in outline.

B, D. armatum. Cat. No. 11068. Two moderately large incisors present.

C, D. lobatum, sp. nov. Holotype. Cat. No. 12487. Lobate character of incisors and relatively large size of second one are unusual features. See figure 6 and the text description.

D, D. nanum. Cat. No. 11184. Drawn reversed. Note persistent small second incisor. In this old individual the prominent horn rugosities are wide spreading.

E, D. nanum. Holotype. Cat. No. 10004. See figure 2 and the text description. No second incisor present.

F, D. annectens. Holotype. Cat. No. 10001. See the text description following, and also figure 3.

G, D. annectens. Cat. No. 12019. A young specimen with premolars almost exactly like those of the holotype (fig. 3) but slightly smaller. Nasals broad but no prominences have developed.

Diceratherium annectens (Marsh) is a smaller species of rhinoceros, also from Oregon; it was named by Marsh from a specimen (Cat. No. 10001, Y.P.M.) consisting of the four upper premolars, the large upper incisor (see fig. 1 *F*), and the distal end of the tibia. The premolars (fig. 3) measure in length three fourths those of *D. armatum,* the incisor less than two thirds. The species differs so markedly from the type species of the genus that it might justly be put in some other group: (1) the crochet is almost lacking, possibly due to wear, the crista being much more distinct; (2) the cingula are entirely obsolete on the inner side of the deuterocone, but are strong around the tetartocone; and (3) the size is much smaller.

In certain features this species is more progressive: the deeper pits and sinuses, the cristæ, and the grooves marking off more distinctly the deuterocone in $P^{3.4}$. It has a close similarity to *Menoceras cooki* in its size, broken cingula, and the general form of the cross lophs; but the differences, especially the foldings of enamel, are greater and more fundamental.

Peterson (1920) is justified in putting *Diceratherium nanum* Marsh in a minor taxonomic position, because the type is so incomplete; there is, however, a difference from *D. annectens* of one fifth in the size of the incisors, the only parts duplicated. The worn teeth and broken skull of the holotype of *D. nanum* are nevertheless of value in showing the reduction of the incisors to the formula, $I\frac{1}{2}$, and in showing the long diastema between the incisors and premolars, and the true *D. armatum* type of horn cores. (See fig. 2.)

FIG. 2.

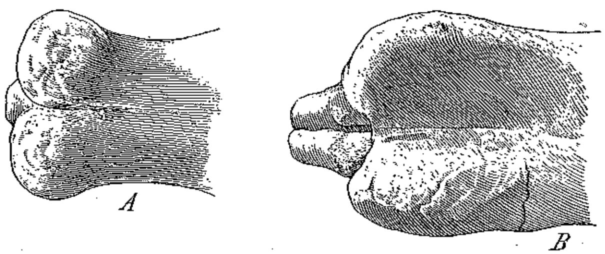

FIG. 2.—A comparison of the horn rugosities in (*A*) *Menoceras cooki* (Peterson), gen. nov., Cat. No. 10273, Y. P. M., where they are rounded knobs; and (*B*) *Diceratherium nanum* Marsh, holotype, Cat. No. 10004, Y. P. M., showing the broad nasals with elongated narrow ridges typical of all true diceratheres. × 1/3.

Of the six species of rhinoceros named from the John Day beds, *D. hesperium* (Leidy), *D. pacificum* (Leidy), *D. truquianum* (Cope), *D. nanum* Marsh, *D. annectens* (Marsh), and *D. armatum* Marsh, we agree with Peterson that only the last two constitute valid species, although some of the others may give valuable hints on the fauna.

FIG. 3.

FIG. 3.—*Diceratherium annectens* (Marsh). Holotype. Cat. No. 10001, Y. P. M. Premolar teeth with simple parallel lophs. × 1/3.

FIG. 4.

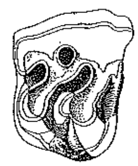

FIG. 4.—Restoration of *Rhinoceros* (*Diceratherium*) *oregonensis* Marsh. Holotype. Cat. No. 10002, Y. P. M. Probably the fourth premolar of an undetermined genus from the Mascall formation of the John Day Valley, Ore. × 1/3.

Rhinoceros (*?Diceratherium*) *oregonensis* Marsh, known only by the fragment of a tooth (Cat. No. 10002, Y.P.M., fig. 4), shows the presence of a large, much advanced genus in the Mascall beds of Oregon, comparable to the Miocene or Pliocene rhinoceroses elsewhere.

FIG. 5.

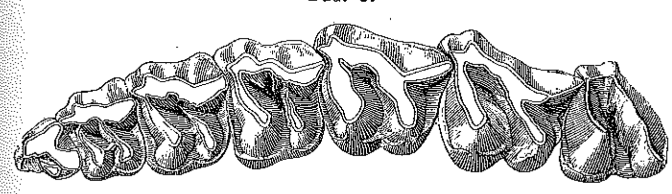

FIG. 5.—*Diceratherium armatum* Marsh. Holotype. Cat. No. 10003, Y. P. M. Crown view of molars and premolars. Note simplicity of the teeth, molar-like form of premolars, and large size. × 1/3.

Diceratherium lobatum, sp. nov.

(Fig. 6.)

Holotype, Cat. No. 12487, Y. P. M. Probably from the true Diceratherium zone, Turtle Cove, John Day River, Oregon.

The holotype consists of the anterior portion of a skull, collected in 1875 by William Day. Although slightly smaller than *D. armatum*, the new species shows a much greater complication of enamel, in which respect it is more advanced in its evolution; but it is more conservative in that it still possesses two incisors (see fig. 1 *A*, *B*, and *C*, comparing referred specimens of *D. armatum*).

Dentition.—The premaxillaries are quite slender, both laterally and vertically, and extend well beyond the premolars. The first or median incisors are smaller in antero-posterior dimension than even those of *D. annectens* (see fig. 1) and are rounded and lobate rather than elongated and pointed in front. I^2 is more than half as large as I^1, an unusual thing for this tooth is commonly very small or absent. Both teeth are rounded and lobate as viewed from the side and resemble the form of an elk tooth; it is this feature which suggests the specific name.

Fig. 6.

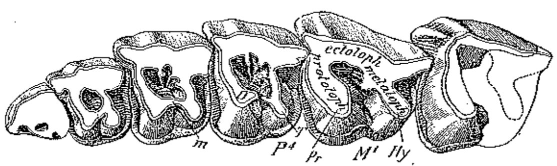

Fig. 6.—*Diceratherium lobatum*, sp. nov. Holotype. Cat. No. 12487, Y. P. M. Crown view of premolars and molars, excepting M^3, showing the complication of enamel and the cross ridges united by the "mure", *m*, a wall across the median valley. The designations of the ridges or lophs: ectoloph, protoloph and metaloph, apply both to molars and premolars; *D*, deuterocone, and *T*, tetartocone, to the premolars; *Pr*, protocone, and *Hy*, hypocone, to the molars. See also figure 1 *C* for premaxillary and incisors of the same specimen. × 1/3.

The premolars are distinctly bridged from loph to loph and united by a wall, which may be technically known as the *mure*, projected across the median valley effectively damming it up in such a way as to form the deep central pit completely surrounded by an enamel border.

The mure is entirely absent from P^4 of *D. armatum* and is incipient on $P^{2.3}$. It is a feature of varying development in *Cœnopus* and *Metacœnopus* of the Great Plains also but is not homologous with the encircling protoloph of more primitive forms.

Premolar teeth seem to reflect most quickly the evolutionary changes of a race. Here are shown the crista and crochet, supplemented by numerous small folds giving a distinctive air of advancement, features which were not simply lost by wear in *D. armatum* but which never existed.

Both molars and premolars of *D. armatum* have deep postfossettes. In the new species, these are shallow and narrow and the metaloph rises from the posterior cingulum direct. The teeth have the appearance of being slightly longer-crowned than usual, and they have decidedly straighter outer surfaces. In *D. armatum* there is a deep groove, especially on P^4 just in front of the paracone, and a second distinct ridge in the middle of the ectoloph.

The development of the crochet and antecrochet in the first molar results in a closing of the median valley and the raising of its floor a full centimeter above the deepest part. This is not homologous with the mure of the premolars. In M^1 of *D. armatum* there is scarcely a change of level of the valley bottom.

The cingula are almost obsolete on the outer side of all teeth, but one is present about the protocone of each molar. There is a coating of cement on the outer sides of the cheek teeth.

Whether or not this specimen had heavy nasals for the support of horns we have no way now of determining, but it is of minor importance since both types are well known among the John Day diceratheres and it is considered a sexual variation simply.

A very large antorbital foramen was traversed by the blood vessels and nerves to the lips and face; indicating that there may have been a large facile lip like that of the African black rhinoceros of to-day.

Diceratherium cuspidatum, sp. nov.

(Fig. 7.)

Holotype, Cat. No. 12007, Y. P. M. Middle John Day, near Bridge Creek, John Day Valley, Oregon.

The holotype of this new species consists of both maxillaries with all the cheek teeth save P¹. As compared with *D. armatum*, the smaller specimens seem generally to be more progressive in the development of enamel folds on the teeth, and this new species, especially, shows the complex pattern crenulations, together with additional cusps and irregularities of the cingulum to an unusual degree.

Fig. 7.

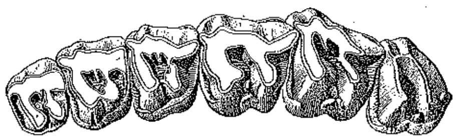

Fig. 7.—*Diceratherium cuspidatum*, sp. nov. Holotype. Cat. No. 12007, Y. P. M. P¹ is missing. The teeth have many folds of the enamel and there are strong internal basal cusps. × 1/3.

The species name is chosen because of the small conical tubercles arising from the floor of the median valley in the first and third molars, which in M³ come to be high cusps 6 or 7 mm. tall and 4 mm. broad at the base, a feature unique in the rhinoceroses. Except for this internal cusp and a short segment of the cingulum, the valleys of the molars are open; they are not obstructed by the crochet and antecrochet as in *D. lobatum* and the slender protocones are not set off by distinct grooves from the antecrochet.

A conspicuous style marks the outer end of the posterior cingulum on M³, but with the exception of M¹ neither molars nor premolars have a trace of cingulum on the outer side.

The size is approximately that of *D. annectens* (fig. 3), but a marked difference is shown on the premolars by the cristæ and crochets, the cingulum encircling the deuterocone, and the shape of the medifossette inclosed, in P³·⁴, by a mure. As in *D. annectens*, P² is subquadrate, but the protoloph is less prominent and does not extend beyond the metaloph. The anterior portion of the ectoloph is not so prominent on any of these premolars, but in P² it is unusually subdued. A small internal basal cusp may be seen on this tooth also. P³·⁴ each show the mure joining the two inner lophs. On these teeth the crochet is situated well out on the metaloph; it is not directed forward but inward toward the slender crista as though in anticipation of a continuous wall in later forms.

In each premolar the metaloph is compressed and very narrow between the central and posterior fossæ. The medifossette itself approaches a cylinder in form in that the sides are nearly parallel vertically; this marks a beginning of hypsodonty, and is a character to be noted in *Menoceras cooki* and other Miocene diceratheres.

In this species the posterior nares extend forward to the first molar.

Measurements of Holotypes.

	D. armatum No. 10003 Y. P. M. mm.	*D. lobatum* No. 12487 Y. P. M. mm.	*D. annectens* No. 10001 Y. P. M. mm.	*D. cuspidatum* No. 12007 Y. P. M. mm.
I¹, ant.-post. diameter	34*	20	21	
P¹, length, ant.-post.	29	24	20	?19
Width, transverse	27	21	18	
P², length	33	31	24	24
Width	39	36	29	30
P³, length	39	38	29	28
Width	47	47	35	36
P⁴, length	40	39	29	30
Width	51	52	37	39
M¹, length	52	53		39
Width	53	54		41
M², length	55			42
Width	57	54		43
M³, length	47			34
Width	50			37
Molar-premolar length	254			?190
Molar series, length	144			105
Premolar series, length	129			?97

* Measure of plesiotype, No. 10005, Y. P. M., fig. 1 *A*.

The Diceratheres of the Great Plains.

Menoceras, gen. nov.

Scarcely a more conspicuous or better known species of extinct rhinoceroses is mentioned in our literature than that which includes those specimens found and named by Peterson (1906) from the famous Agate Spring quarry on the ranch of Mr. Harold Cook at Agate, Neb. With the approval of Mr. Peterson, this species, *Diceratherium cooki*, is here made the type of a new genus, *Menoceras* (μένος, strength, κέρας, horn) and the following forms may be classed under this head, most of which Peterson considers invalid as species:

Diceratherium cooki Peterson 1906. Genoholotype.
Diceratherium arrikarense Barbour 1906.
Diceratherium schiffi Loomis 1908.
Diceratherium stigeri Loomis 1908.
Diceratherium aberrans Loomis 1908.
Diceratherium loomisi Cook 1912.

After a comparison with the genoholotype of *Diceratherium*, *D. armatum*, with which it has always been associated, it is very clear that *Menoceras* is probably the farthest removed from *Diceratherium* of all the Miocene-Oligocene rhinoceroses. This great difference was recognized by Peterson (1920), who calls attention to the features of *Menoceras cooki* here briefly enumerated: (1) form of the horn cores (fig. 2), (2) form of the muzzle and anterior nares, (3) expanded zygomatic arch with rugose angles, (4) complication of the cheek teeth and union of the crochet with the ectoloph. Other distinctive features, widely differentiating it from *Diceratherium*, are the smaller size, great geographical separation, unusual deepening of the pits and sinuses on both molars and premolars, almost complete absence of cingula, an extra transverse loph on the second deciduous premolar, and the closing of the external auditory meatus below.

It has been suggested by Peterson (1920) that *M. cooki* is derived from *Cænopus mitis*, a lower Oligocene species. *C. dakotensis* Peterson, also based on a lower jaw, but from the Protoceras beds, is considered by its author to be a connecting link because of the short symphysis and diastema, the curving of the lower border of the ramus,

and the everted angle. A comparison with *C. tridactylus proavitus* offers a further answer to the question of the ancestry of *M. cooki*, for in both we see the broad sagittal crest with converging straight lines, the heavy rugose angles of the temporal bone, and in the former an early stage of horn evolution.

Cænopus tridactylus in the Oligocene shows foldings of the enamel which may have given rise to the complex pattern of *M. cooki*, and it is reasonable to suppose that, just as favorable conditions must have influenced the opulent development of *D. armatum* in Oregon, so an unfavorable environment required a better dental mechanism and greater protection by the horns, at the expense of increased stature, on the Great Plains: *M. cooki* is scarcely two thirds as large as *D. armatum*.

Fig. 8.

Fig. 8.—Milk teeth, $Dp^{2,3}$, of *Diceratherium annectens?* Cat. No. 12003, Y. P. M. For comparison with those of *Menoceras cooki*, see Peterson 1920, pl. 65, fig. 2. $\times 1/3$.

The anterior portion of the skull and jaws (No. 12500, Y.P.M.) of a specimen of *M. cooki* was found by Professor Lull in 1908 near Rawhide Buttes, Wyoming, showing the distribution of the species in places other than the Agate Spring quarries.

Metacænopus egregius (Cook).

M. egregius (Cook) has for its holotype a fine skull and portions of the lower jaws in the private collection of its author. Although the species is considered by Peterson (1920) to be a synonym of *M. niobrarensis*, it seems to warrant the rank of a subspecies at least, and in any case should be retained as the type of the genus so happily named. Important features of the genus are: the larger size, smaller horn rugosities on the male skulls, the simpler teeth, and a distribution limited to the Great Plains. From the shape of the skull and the incipient horn rugosities one is led to believe that its ancestor was *Cænopus tridactylus* and therefore closely related to the true *Diceratherium* of Marsh.

This genus may include the following species:

Metacænopus niobrarensis (Peterson) 1906.
Metacænopus petersoni (Loomis) 1908. Inadequate.
Metacænopus egregius (Cook) 1908. Genoholotype.
Metacænopus gregorii (Peterson) 1920. Of doubtful validity.

M. petersoni Loomis, whether or not it is specifically distinct from *M. niobrarensis* or *M. egregius*, is of importance as showing that the Agate Spring quarries have a variety of rhinoceroses, and not *Menoceras cooki* alone.

M. gregorii Peterson is specifically indistinguishable from *M. egregius*; it is unfortunately based on a fairly complete skull but with characterless teeth; however, it is of interest in so far as it shows the spread of *Metacænopus* into the region of South Dakota.

SUMMARY.

In restudying the American horned rhinoceroses of Oligocene-Miocene time, one is impressed with the need of a systematic grouping which, first, will distinguish those of the Great Basin of Oregon, *Diceratherium* Marsh, from those of the Great Plains; second, will differentiate that well known group of animals from Nebraska and Wyoming, here designated *Menoceras cooki* (Peterson) gen. nov. from *Metacænopus* Cook; and third, will separate all from *Aceratherium* Kaup of the Old World.

In the present paper, all the known species of diceratheres are classified, the more important ones are redescribed, and two new species are proposed from the abundant material collected by Professor Marsh. From this study the conclusion is reached that in the light of our present knowledge it can not be reasoned that a hornless rhinoceros is of an aceratherine species, for the adult male may have been well armed.

ART. XVI.—*Fossil Vertebrates and the Cretaceous-Tertiary Problem;* by W. D. MATTHEW.

Recent contributions to *Science* by Professor Schuchert, Dr. Cross and Dr. Knowlton[1] have brought up again the old controversy as to the dividing line between Cretaceous and Tertiary formations in America. As the fossil vertebrate faunas afford an important part of the evidence on this dispute, very considerably increased by collecting and research in recent years, I have been asked to give a brief résumé of this evidence and of the conclusions to which my interpretation of it has led.

Recent Additions to the Vertebrate Evidence.

When the problem was discussed in 1913 by the Geological Society of America I contributed a paper[2] setting forth the data up to date especially as regarded the Paleocene formation. Since then considerable advances have been made in the study of the Vertebrata. I have been engaged jointly with Mr. Walter Granger upon a revision of the Lower Eocene mammals, now mostly published, and of the Paleocene mammals of New Mexico, still in progress.[3] Mr. Gilmore has contributed two most valuable memoirs, one on the vertebrates of the Ojo Alamo formation, the other upon the reptiles of the Puerco and Torrejon formations of New Mexico.[4] A very large amount of new information is now at hand as to the faunas of the late Cretaceous vertebrates of Alberta, partly in the published contributions by the late Mr. Lambe,[5] Mr. Barnum Brown,[6] Professor Osborn[7] and

[1] Schuchert, 1921, Science, **53**, p. 45, Jan. 14; Cross, 1921, ibid., p. 304, April 1; Knowlton, 1921, ibid., p. 307, April 1.

[2] Evidence of the Paleocene Vertebrate Fauna on the Cretaceous Tertiary problem, Bull. Geol. Soc. Am., 25, pp. 381-402.

[3] See various articles by Granger, Sinclair and the writer, in Bull. Am. Mus. Nat. Hist., 1914-1919.

[4] Gilmore, 1916, U. S. G. S. Prof. Pap. 98 Q, pp. 279-302; 1919, idem, Prof. Pap. 119, pp. 1-68.

[5] Lambe, 1914, Ottawa Naturalist, vol. **27**, pp. 130-135, 145-155; vol. **28**, pp. 13-20; 1915, Can. Geol. Sur., Mus. Bull. No. **12**, pp. 1-49; 1917, Ottawa Nat., vol. **30**, pp. 117-123, vol. **31**, pp. 65-73; Can. Geol. Sur., Mem. No. **100**, pp. 1-84; 1920, Can. Geol. Surv., Mem. No. **129**, pp. 1-79.

[6] Brown, 1914, Bull. Am. Mus. Nat. Hist., vol. **33**, pp. 539-548, 549-558, 559-565, 567-580; 1916, idem, vol. **35**, pp. 701-708, 709-716; 1917, idem, vol. **37**, pp. 281-306.

[7] Osborn, 1917, Bull. Am. Mus. Nat. Hist., vol. **35**, pp. 733-771.