

MEMOIRS OF THE PEABODY MUSEUM OF NATURAL HISTORY
VOLUME III, PART 3

A REVISION
of the
CERATOPSIA
OR HORNED DINOSAURS

BY

RICHARD SWANN LULL
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AND DIRECTOR OF PEABODY MUSEUM,
YALE UNIVERSITY



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1933

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A REVISION
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“So I prophesied as I was commanded: and as I prophesied, there was a noise, and behold a shaking, and the bones came together, bone to his bone.

“And when I beheld, lo, the sinews and the flesh came up upon them, and the skin covered them above: but there was no breath in them.”

EZEKIEL XXXVII, 7, 8.





RESTORATION OF PROTOCERATOPS WITH NEST AND EGGS.

From a painting by Charles R. Knight.

Courtesy of the Field Museum of Natural History, Chicago.

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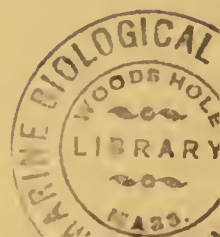


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INTRODUCTION

The Ceratopsia Monograph published in 1907 summarized our knowledge of this interesting group of dinosaurs up to about 1905, when the manuscript was completed. It was largely the work of John Bell Hatcher, who actually collected much of the material upon which the monograph was based. He utilized also the brief papers, mainly generic and specific descriptions, which had appeared from time to time under the authorship of Othniel C. Marsh, as well as the lithographic plates and other illustrations which had been prepared under Professor Marsh's direction in anticipation of the monograph which the latter had planned to write. It was fitting, therefore, that the names of Hatcher and Marsh should appear as co-authors of the completed work. When Mr. Hatcher died in 1904, several important sections still remained to be finished, including those on the phylogeny, taxonomy, distribution, habits, and environment of the Ceratopsia. He had said that only two weeks more of work on the manuscript were needed, but no notes or other writings regarding the unfinished sections could be found among his effects, and therefore, Professor Osborn, who had succeeded Marsh as the Vertebrate Paleontologist of the United States Geological Survey, assigned to the present author the task of completing the manuscript and seeing it through the press.

Since that time more material has come to light, largely from the older formations, such as the Belly River and Edmonton of Canada and the Cretaceous of Mongolia, and while new species have been described from these formations, the time seems ripe once more to coördinate and amplify our knowledge of this amazing group in the light of these discoveries. Some problems of generic identity cannot even now be solved in view of the inadequacy of material, especially that from the Judith River of Montana upon which the genera *Monoclonius* Cope and *Ceratops* Marsh were based; thus, it cannot now be determined definitely whether or not these genera are synonymous with the better known Belly River forms of equivalent age. Only more extended and detailed collecting of plesiotypes in the Judith River formation can solve these problems in any degree of finality. Enough is known, however, to warrant this study.

The research upon which this publication is based was rendered possible primarily through the research funds granted to the Sterling Chair of Paleontology at Yale University, which not only made possible the travel incident to the study of widely separated collections, but also provided for a research assistant to aid in the work.

I very deeply appreciate the generous aid given by the various museums and especially by the several individuals connected with each of them, all of whom were exceedingly generous of free access to the collections as well as of personal aid and advice. My especial acknowledgments are due to Mr. Charles W. Gilmore of the United States National Museum for facilities for study, for photographs and other illustrations, and for the reading and friendly criticism of the manuscript. I am also deeply indebted to Messrs. Barnum Brown and Walter Granger of the American Museum of Natural History for generous aid on several occasions as well as for extraordinary privileges in connection with the rich collections of ceratopsian material. Several photographs were especially taken and others freely furnished for this work. To the authorities of Yale University I am grateful for providing funds for the purchase of the *Monoclonius* (*Centrosaurus*) skeleton which forms the basis of our morphologic work and restoration, and to the members of the Peabody Museum staff who aided in the preparation, and in rendering permanent the results of our labors.

Two of the Canadian Museums have shown the friendliest courtesy, the Royal Ontario Museum of Palaeontology, in Toronto, through Professor Parks, and the National Museum of Canada, in Ottawa, through Messrs. Kindle and Charles M. Sternberg, who granted not only access to the collections but the use of several photographs which adorn this volume. The latter institution also aided us in securing through exchange a fine skull of *Chasmosaurus belli*, and gave the privilege of publishing the interesting restoration of that genus by L. S. Russell.

My gratitude is also due to President C. C. O'Harra of the South Dakota State School of Mines for measurements and photographs of his *Triceratops* skull, to Mr. H. H. Lane of the

University of Kansas for information concerning the *Triceratops* skull there, and to Mr. E. S. Riggs of the Field Museum of Natural History and Mr. F. W. Kohler of the Carnegie Museum for similar aid, as well as to the Field Museum itself for the privilege of reproducing Charles W. Knight's mural of *Protoceratops*, which forms the frontispiece. Mr. J. A. Allan of the University of Alberta has kindly furnished the photograph of *Chasmosaurus* reproduced in Plate VII B.

Messrs. T. W. Stanton and L. S. Russell furnished valuable information regarding stratigraphy, and Mr. Roy L. Moodie graciously diagnosed and described the diseased squamosal of *Torosaurus*.

Miss Clara M. LeVene has edited the memoir, and Miss Nelda E. Wright, Research Assistant, has aided most efficiently in every way, preparing all of the text figures, with one or two exceptions, and seeing the manuscript through the press.

HISTORY OF DISCOVERY

A brief résumé of discoveries prior to 1907 should be given, although set forth in detail in the *Ceratopsia Monograph*.

Horned dinosaurs were first found in North America in 1855, when Dr. F. V. Hayden made a geological reconnaissance on the Upper Missouri, around the mouth of the Judith River in Montana. The material then collected, among which was a characteristic bi-fanged tooth subsequently referred to *Monoclonius*, was described by Dr. Joseph Leidy in 1856 and 1859. In 1872, the form later described by Prof. E. D. Cope as *Agathaumas sylvestris* was discovered by Prof. F. B. Meek at Black Buttes Station on the Union Pacific Railroad 52 miles east of Green River, Wyoming. Cope himself visited the locality the same year and secured the remainder of the type. During the summer of 1873, Cope also discovered, somewhere in Colorado, the extremely fragmentary material which he called *Polyonax mortuarius*. This is clearly ceratopsian, but Hatcher considered it so undiagnostic that he rejected the genus and species as a nomen nudum, founded upon an insufficient type. Hatcher further considered it possible that some of the material collected by Dr. G. M. Dawson on Milk River, British America (?Alberta), should be referred to the Ceratopsia, although Cope himself referred it to the trachodont *Hadrosaurus*.

In 1876, Professor Cope, assisted by the veteran collector Charles H. Sternberg, explored the Judith River badlands of the Upper Missouri in Montana. Much of the resultant material was again too fragmentary for precise identification. It includes, nevertheless, the type of the ceratopsian *Monoclonius crassus*, as well as other specimens referable either to *Monoclonius* or an allied genus, and described in 1877. In 1890, after Marsh had made known the principal characters of the Ceratopsia from abundant material collected by Hatcher in Wyoming and Montana, Cope was able to describe three additional species from his Judith River collections. They were *Monoclonius recurvicornis*, *M. sphenocerus*, and *M. fissus*.

In 1887 Marsh described *Bison alticornis*, based upon a pair of horn cores found by Dr. George L. Cannon in the Denver beds on Green Mountain Creek, near Denver, Colorado. The form was subsequently referred to *Ceratops*, now *Triceratops alticornis*. For two or three years afterward, Cannon, George H. Eldridge, and Whitman Cross continued to find fragmentary ceratopsians in the Denver and Arapahoe beds, near Denver. This material has not yet revealed its true identity.

Hatcher's own collecting under Professor Marsh's direction began in 1888 when he made collections in the Judith River badlands, securing among other things the type of *Ceratops montanus*. He then went to the eastern part of Converse County (now called Niobrara County), Wyoming, where he was shown a massive horn core found on the ranch of Mr. Charles A. Guernsey by the ranch foreman, Mr. Edmund B. Wilson. The next summer, Mr. Hatcher returned and secured the remainder of the skull, which became his "skull number one," later known as the type of *Triceratops horridus*; it was also the beginning of his highly successful exploration in this famous Niobrara County locality, extending from 1889 to 1892, which yielded no fewer than 32 complete or partial ceratopsian skulls and other skeletal material, including the types of most of the species of *Triceratops*, two of *Torosaurus*, and one of *Diceratops*. All of these are now either in the United States National Museum or in the Yale Peabody Museum.

Another famous locality was in the region of the Milk, Red Deer, and Belly rivers of Alberta, Canada, which were long known to contain dinosaurian remains. The systematic exploration of this region was begun in 1897 by Lawrence M. Lambe and continued during the years 1898 and 1901.

Finally, in 1902, an American Museum party consisting of Messrs. Barnum Brown and R. S. Lull collected in Hell Creek, Montana, in Lance strata, a large *Triceratops* skull now in the American Museum.

RECENT DISCOVERIES

Since the publication of the Ceratopsia Monograph in 1907, an amazing amount of ceratopsian material has come to light, as the subsequent pages will show. This has added little to our knowledge of the younger Lance forms, such as *Triceratops*, other than to show the remarkable range of variation within the so-called species. But of the older forms, where fragmentary material only was known, we now have perfect skulls and, in several instances, more or less complete skeletons with occasional impressions of the external covering. Perhaps the most outstanding explorer of all is Barnum Brown of the American Museum, whose remarkable skill both in discovery and exhumation has enriched our collections amazingly, especially by forms derived from the Belly River beds of Alberta. Then that noted family of collectors, the Sternbergs, should be mentioned, headed by the veteran Charles H., and ably seconded by his several sons, Charles M., George, and Levi. They have worked collectively and individually, and some of the most remarkable of ceratopsians which adorn the museums, not only in America but also abroad, are due to their indefatigable labor and skill. Charles W. Gilmore of the United States National Museum, while working largely on other forms of bygone life, has also added some notable ceratopsians to that museum's collections.

Space will not permit a detailed account of the work of these collectors in the field, but some of the outstanding expeditions should be mentioned, of which Brown's expeditions to the Red Deer River region stand first. As we have seen, the exploration of this area was begun by Lawrence M. Lambe of the Geological Survey of Canada, but, as is frequently true of collecting in a virgin field, the material secured was extremely fragmentary; nevertheless, it gave to science indications of an extraordinary fauna. About 1908, a ranchman, John C. Wagner, who lived at Tolman, Alberta, called Mr. Brown's attention to the profusion of dinosaur bones along the Red Deer River, and for seven seasons, including his initial visit in 1909, Brown explored the region with surprising results, bringing to light not only horned dinosaurs but trachodons, carnivores, and other dinosaurs as well. Owing to the peculiar conditions—a more or less navigable stream flowing through the land of his exploration—Mr. Brown found that his work could best be done by boat. Accordingly, he and his assistants went to the town of Red Deer where the Calgary-Edmonton Railway crosses the river, and there built a scow, 30 by 12 feet, with a 22-foot sweep at either end for navigating it. Upon this they pitched their tent and stored their impedimenta, and then set forth on a current that averaged some four miles an hour, with placid areas interspersed by occasional rapids. On this craft the party lived, and from it they prospected, mooring ship when conditions were good and exploring not only the canyon walls but all of the tributary valleys as well, and storing the collected fossils on board until the boat was practically full. At the end of the season when the weather became too cold for effective work, the craft was hauled out, materials stored, and on the coming of the second season she was recommissioned to continue from the point where she ceased the year before. A canoe and an outboard motor boat added to the efficiency of the fleet.

This same method was afterward (1912-1916) used with admirable results by Sternberg and his sons while working for the Canadian Survey under the direction of Lawrence M. Lambe. The preparation and description of this material was well under way when it was halted by Lambe's sudden illness and death. Charles M. Sternberg is continuing to do effective work both in collecting and research but there is great opportunity for further trained workers in Canadian paleontology when conditions shall warrant it.

Mr. Sternberg senior has written two interesting books¹ which, aside from their value as human documents, recount in detail the collecting of some of the most remarkable of ceratopsian material such as the two mounted chasmosaurs, Pl. XIV, B; the skull of *Styracosaurus*, Pl. VIII; the *Pentaceratops* material from New Mexico, both at the American Museum, Pl. V, B, and at Upsala, Sweden, Fig. 40; as well as other type and otherwise interesting specimens.

¹ Sternberg, C. H., 1909, 1932.

Charles W. Gilmore of the United States National Museum explored for horned dinosaurs especially in the Blackfeet Indian Reservation in northwestern Montana in 1913. Here, exposures of the Two Medicine formation were found along the Milk River near the Canadian boundary. The collection was small, but of great interest since it contained several specimens of the only adolescent ceratopsian found in America, the type of *Brachyceratops* (Pl. IX, B), as well as other recognizable material. He also collected here the type of *Styracosaurus ovatus*.

The discovery of *Protoceratops* in Mongolia by the American Museum expedition of 1922 under Andrews and Granger has opened a new chapter in ceratopsian history, for it gives not only the first record of the group outside the limits of North America, but also for the first time an ontogenetic record of a ceratopsian genus. The collection includes eggs and all stages of growth from the newly hatched young to the old adults. Several skeletons and no fewer than 73 skulls were included in the finds.

The principal desideratum from the standpoint of ceratopsian study would be further exploration in the Judith River formation of northern Montana for the purpose of securing additional material to clarify our conception of the early Cope and Marsh genera, *Monoclonius* and *Ceratops*, of which our knowledge is so very imperfect owing to the fragmentary condition of the types. Another region deserving more exploration is New Mexico, which is sure to yield ceratopsians other than *Pentaceratops*, a genus which, with one authentic and another doubtful species, represents all that we know of the southern horned dinosaurs.

GEOLOGIC DISTRIBUTION

(Fig. 1)

The known Ceratopsioidea, both of North America and of Asia, are confined to the Upper Cretaceous (Senonian and Danian of European usage), and thus far have been found in non-marine strata only. In North America, they extend through several horizons, from the Belly River where they appear abruptly, to the very close of the Lance formation where, with equal abruptness, they disappear.

I am indebted to Doctors L. S. Russell¹ of the Geological Survey of Canada and T. W. Stanton¹ of the United States Geological Survey for information concerning the correlation of United States and Canadian horizons. The statements derived independently from these two high authorities entirely agree, and from the tables of correlation that they furnished, the combined one here published (Fig. 1) has been made.

In Alberta, two principal horizons have produced Ceratopsia. The first is the Belly River, in which the fossils are restricted to the Pale or uppermost beds of the series. Then, after an interval represented by the marine Bearpaw formation, these animals reappear in the Edmonton, above which there is no record of their occurrence in Alberta.

In Glacier County, Montana, the Ceratopsia-bearing horizon is the Two Medicine, the equivalent of the Belly River series of Alberta; but here again these dinosaurs, of which only a very few have been found, are known from the upper part alone. In central Montana, the Judith River, equivalent again to the upper half of the Two Medicine and to the Pale and Foremost beds of the Belly River series, has produced ceratopsians whose closest equivalents taxonomically seem to lie among those of the Belly River, although with curious morphological differences which will be discussed, p. 27. Ceratopsia from the Judith River are ill known, due largely to pioneer collecting, nor is their precise stratigraphic position within the formation clear. They do not seem to be limited to any part of the horizon as in the Belly River series, according to available evidence. Above the Judith River comes a longer interval of marine deposition than in Alberta, for the non-marine Lance (Hell Creek beds) is separated from the Judith River by both the Bearpaw and the Fox Hills formation, hence such annectant genera as those found in the Edmonton are entirely absent.

Niobrara County, Wyoming, contains the classic Lance locality, the so-called "Ceratops beds" of Marsh, out of which have come almost all of the principal types of the latest of the ceratopsians, *Triceratops*, *Diceratops*, and *Torosaurus*. The last genus, so far as we know, is found nowhere else.

In the Denver Basin of Colorado, the formations equivalent in time to the earlier Ceratopsia-bearing horizons are all marine, and hence it is only in the uppermost Cretaceous, in the Denver and Arapahoe beds, correlated with the Lance, that a few horned dinosaurs have been found, which are the generic equivalents of those of Wyoming and Montana.

A new locality, the Ceratopsia of which were unknown at the time of the publication of the Ceratopsia Monograph, lies in San Juan County, New Mexico. Here the non-marine formations are late in Cretaceous time and, as our table shows, are homotaxial with the Edmonton of Alberta and with the Lance of Montana and Wyoming. Of these, the Fruitland and Kirtland, equivalent to the Edmonton, have been the most productive, revealing a genus, *Pentaceratops*, which is morphologically older than *Triceratops* or *Torosaurus* but younger than the Belly River ceratopsians. Some material is also recorded as possibly from the Ojo Alamo; but one cannot be sure either of the generic identity or of the stratigraphic reference, for the term Ojo Alamo² is said to have been

¹ Letters to the author, 1933.

² Brown, B., 1910.

originally used to include the Kirtland and Fruitland as well. Were we to identify without question *Triceratops* itself, its reference to the McDermott or Ojo Alamo as now restricted would be expected, but all of the ceratopsian material from the Southwest other than the several recognizable *Pentaceratops* specimens is too fragmentary for certainty of generic reference.

The Mongolian *Protoceratops* from the Dja-doch-ta formation, has its nearest taxonomic equivalent in *Leptoceratops* of the Edmonton. Whether this one fact has correlation value without further evidence is open to question.

The geological sequence of the ceratopsian species is as follows:

JUDITH RIVER FORMATION

Ceratops montanus
Monoclonius crassus
Monoclonius recurvicornis
Monoclonius sphenocerus

BELLY RIVER FORMATION

Chasmosaurus belli
Chasmosaurus kaiseni
Chasmosaurus brevirostris
Monoclonius dawsoni
Monoclonius (Centrosaurus) apertus
Monoclonius (C.) flexus
Monoclonius (C.) cutleri
Monoclonius (C.) nasicornus
Eoceratops canadensis
Styracosaurus albertensis

TWO MEDICINE FORMATION

Brachyceratops montanensis
Styracosaurus ovatus

EDMONTON FORMATION

Anchiceratops ornatus
Anchiceratops longirostris
Arrhinoceratops brachyops
Leptoceratops gracilis

FRUITLAND AND KIRTLAND FORMATION

Pentaceratops sternbergii
Pentaceratops fenestratus

LANCE FORMATION

Torosaurus gladius
Torosaurus latus
Triceratops alticornis
Triceratops brevicornus
Triceratops calicornis
Triceratops elatus
Triceratops flabellatus
Triceratops galeus
Triceratops (Diceratops) hatcheri
Triceratops horridus
Triceratops maximus
Triceratops obtusus
Triceratops prorsus
Triceratops serratus
Triceratops sulcatus

DJA-DOCH-TA FORMATION, MONGOLIA

Protoceratops andrewsi

GEOGRAPHIC DISTRIBUTION¹

(Fig. 2)

The remains of *Ceratopsia* have been found in at least two continents, Asia and North America, and possibly in South America. So far, only one genus and species has been unearthed in Asia, while the remainder of the species have been located in North America, in a broad belt along the eastern slope of the Rocky Mountains, running from Alberta in the north to Mexico in the south.

The *Ceratopsia* Monograph by Hatcher, Marsh, and Lull, published in 1907, gave a complete list of all localities where horned dinosaurs had hitherto been found. Since that date, however, a number of additional regions have been discovered which, together with certain of those already known, have produced an amazing number of new and interesting forms.

A list of all geographic localities from which *Ceratopsia* have been collected or reported is as follows:

Alberta	New Mexico
Saskatchewan	Texas
Montana	Mexico
North Dakota	South America
South Dakota	Mongolia
Wyoming	British Columbia (footprints)
Colorado	

These will be discussed in the order mentioned.

ALBERTA

The Red Deer River region of Alberta has proved a wonderful field for ceratopsian discoveries, no fewer than five new genera having been recognized since 1910. This country was first explored by Lambe in 1897, 1898, and 1901. Since that time, it has been reworked largely by expeditions from the Geological Survey of Canada, the Royal Ontario Museum of Toronto, and the American Museum of Natural History. In vertical sequence, the fossils have come from two distinct formations, the Edmonton and Belly River series. Stratigraphically, the Belly River beds are older than the Edmonton, and separated from the latter by the marine Pierre and Fox Hills.

From the Edmonton formation on Red Deer River (Locality 1, on map of North America, Fig. 2), the following specimens have been obtained:

Anchiceratops ornatus, type, No. 5251 A.M.N.H., skull; paratype, No. 5259 A.M.N.H., frontal horns, part of skull; No. 5273 A.M.N.H., skull. Collected by the American Museum of Natural History in 1912, 7 miles below Tolman.

Anchiceratops ornatus, left half of posterior portion of skull, collected by G. F. Sternberg in 1916, 7½ miles southwest of Morrin. This specimen is now at Ottawa.

Anchiceratops ornatus, skull, collected by the Royal Ontario Museum in 1931, 6 miles west and 3 miles north of Munson on the west side of the river.

Anchiceratops ornatus, skull, collected by the Royal Ontario Museum in 1922, 6 miles west of Morrin.

Anchiceratops longirostris, type, No. 8535 Geol. Surv. Canada, skull without lower jaws, collected by C. M. Sternberg in 1924, 12 miles northwest of Morrin.

¹ Compiled by N. E. Wright.

- Anchiceratops longirostris*, No. 8538 G.S.C., complete skeleton except skull, collected by C. M. Sternberg in 1925, 7½ miles southwest of Rumsey. Mounted in the National Museum of Canada.
- Arrhinoceratops brachyops*, skull, type No. 5135 R.O.M., collected by the Royal Ontario Museum in 1923, 6 miles west and 3 miles north of Munson, on the west side of the river.
- Arrhinoceratops brachyops*, skull, collected by the Royal Ontario Museum in 1931, 6 miles west of Munson on the west side of the river.
- Centrosaurus*, No. 5263 A.M.N.H., squamosal; No. 5265 A.M.N.H., lower jaw; No. 5267 A.M.N.H., scapula. Collected by the American Museum of Natural History in 1912, 3-10 miles below Tolman, on both banks of the river.
- Ceratopsian, No. 5244 A.M.N.H., brain case; No. 5246 A.M.N.H., frontal horn; No. 5260 A.M.N.H., maxillae and vertebrae. Collected by the American Museum of Natural History in 1912, 3-10 miles below Tolman on both banks of the river.
- Ceratopsian, incomplete skull, collected by C. M. Sternberg of the Geological Survey of Canada in 1925, southwest of Morrin.
- Leptoceratops gracilis*, type, No. 5205 A.M.N.H., incomplete skeleton, collected by the American Museum of Natural History in 1910, 3 miles above Tolman, 190 feet above the river on the left bank.

From the Belly River formation on the Red Deer River (Loc. 2, Fig. 2), we have the following material:

- Centrosaurus apertus*, type, No. 971 G.S.C., parietal crest, collected by Lambe in 1901, on the west side of Red Deer River, between Berry Creek and Dead Lodge Canyon.
- Centrosaurus apertus*, skull, collected by the Royal Ontario Museum in 1926, 2 miles south of Steveville, on the west side of the river.
- Centrosaurus apertus*, skull, less snout and part of crest, collected by C. M. Sternberg in 1919, from the south side of the west branch of Little Sandhill Creek. In the Carnegie Museum at Pittsburgh.
- Centrosaurus apertus*, No. 348 G.S.C., skull with lower jaws, collected by C. H. Sternberg in 1914, at the lower end of Dead Lodge Canyon, 15 miles east of Steveville. Mounted in the National Museum of Canada.
- Centrosaurus apertus*, No. 347 G.S.C., skull without lower jaws, collected by C. H. Sternberg in 1913, at Denhart Ferry, about 15 miles below Steveville. In the National Museum of Canada.
- Centrosaurus apertus*, skull less nasals, maxillae, and most of face, collected by C. M. Sternberg in 1921, 1 mile east of Denhart Ferry. In the National Museum of Canada.
- Centrosaurus* sp., skull without crest or lower jaws, collected by C. H. Sternberg in 1914, 2½ miles below Denhart Ferry. In the National Museum of Canada.
- Centrosaurus* sp., complete skull without lower jaws, collected by C. M. Sternberg in 1917, 1½ miles south of the mouth of Little Sandhill Creek. In the National Museum of Canada.
- Centrosaurus apertus*, No. 4519 R.O.M., skull and part of skeleton, collected by the Royal Ontario Museum in 1919, from Section 9, Township 21, Range 11.
- Centrosaurus apertus*, frill, collected by the Royal Ontario Museum in 1921, from Section 9, Township 21, Range 11.
- Centrosaurus* sp., skull and part of skeleton, collected in 1930 by the Royal Ontario Museum from the northwest quarter of Section 9, Township 21, Range 11.
- Monoclonius nasicornus*, skull with dentary and few bones of skeleton, collected by C. M. Sternberg in 1917, 1½ miles south of the mouth of Little Sandhill Creek. In the National Museum of Canada.
- Chasmosaurus kaiseni*, type, No. 5401 A.M.N.H., skull, collected by the American Museum of Natural History in 1913, 12 miles below Steveville in Township 21, Range 11.



FIG. 2.—Geographical distribution of the Ceratopsia in North America. Numbered localities described in the text.

- Chasmosaurus belli*, No. 5402 A.M.N.H., skull with jaw and parts of skeleton, collected in 1913 by the American Museum of Natural History, in Township 21, Range 12, about 1 mile below Steveville, on the left bank of the river.
- Chasmosaurus belli*, No. 5499, R.O.M., skull and complete skeleton, collected by the Royal Ontario Museum in 1926, 2 miles south of Steveville on the southeast side of the river. Mounted.
- Chasmosaurus brevirostris*, type, No. 5436, R.O.M., skull and part of skeleton, collected by the Royal Ontario Museum in 1926, 3 miles south of Steveville on the west side of the river.
- Chasmosaurus belli*, paratype, No. 2245 G.S.C., skull and most of skeleton, collected by C. H. Sternberg in 1913, $3\frac{1}{2}$ miles south of Steveville. Mounted in the National Museum of Canada.
- Chasmosaurus belli*, No. 2280 G.S.C., skull and most of skeleton, collected by C. H. Sternberg in 1914, $2\frac{1}{2}$ miles southeast of the mouth of Little Sandhill Creek. Mounted in the National Museum of Canada.
- Chasmosaurus belli*, type, No. 491 G.S.C., parietal, collected by L. M. Lambe in 1898, on the east side of the river, below the mouth of Berry Creek.
- Chasmosaurus* sp., skull and lower jaws, and a few bones of the skeleton, collected by C. M. Sternberg in 1928 on the west side of the river, 3 miles south of Steveville. In the National Museum of Canada.
- Chasmosaurus belli*, No. 2016 Y.P.M., skull without lower jaws, collected by C. M. Sternberg in 1919, on the south side of the west branch of Little Sandhill Creek, 60 feet below the overlying Pierre shales. At Yale Peabody Museum.
- Chasmosaurus belli*, skull, collected by the Royal Ontario Museum in 1930, on the southwest side of the river 6 miles north of Denhart. (Sent to Buenos Aires.)
- Chasmosaurus* sp., dentaries, maxillae, nose, right side of face nearly to orbits, and part of skeleton, collected by C. M. Sternberg in 1919 about 3 miles south of the mouth of Little Sandhill Creek. In the National Museum of Canada.
- Chasmosaurus* sp., 2 incomplete skulls, collected by C. H. Sternberg in 1915 from the lower end of Dead Lodge Canyon about 15 miles east of Steveville. In the National Museum of Canada.
- Ceratopsian, No. 5407 A.M.N.H., orbital horns; No. 5408 A.M.N.H., vertebrae; No. 5410 A.M.N.H., ilium; No. 5415 A.M.N.H., maxilla and jaw; No. 5416 A.M.N.H., jaw. Collected in 1913 by the American Museum of Natural History about 1 mile below Steveville on the left bank of the river.
- Ceratopsian, No. 5422 A.M.N.H., skull and parts of skeleton; No. 5425 A.M.N.H., skull; No. 5437 A.M.N.H., skull; No. 5439 A.M.N.H., brain case; No. 5342 A.M.N.H., fragmentary skull. The last was collected in 1914, the remaining specimens in 1913, all from the banks of Sand Creek about 12 miles below Steveville.
- Ceratopsian, No. 5374 A.M.N.H., frill of skull, collected by the American Museum of Natural History in 1915 from the "East Fork" of Sand Creek, about 12 miles below Steveville.
- Eoceratops canadensis*, type, No. 1254 G.S.C., skull, collected by Lambe in 1901 on the east side of the river, a short distance below the mouth of Berry Creek.
- Chasmosaurus*, No. 40 University of Alberta, nearly complete skull, collected by G. F. Sternberg in 1920, 2 miles southeast and 1 mile east of the mouth of Sand Creek.
- Monoclonius flexus*, type, No. 5239 A.M.N.H., skull, collected in 1912 about 1 mile below Steveville on the left bank of the river.
- Monoclonius dawsoni*, type, No. 1173 G.S.C., fragmentary skull, collected by Lambe in 1901 on the river, between Berry Creek and Dead Lodge Canyon.
- Monoclonius*, No. 5442 A.M.N.H., skull, collected in 1913 about 30 miles below Steveville, near the junction of the Pierre and Belly River formations (Section 15, Township 22).
- Monoclonius crassus*, central portion of crest, collected by C. M. Sternberg in 1917, 3 miles southwest of the mouth of Little Sandhill Creek. In the National Museum of Canada.
- Monoclonius flexus*, No. 5341 A.M.N.H. (No. 2015 Y.P.M.), skull and skeleton collected by the American Museum of Natural History in 1914, about 2 miles from the mouth of Sand Creek, 12 miles below Steveville. Mounted in the Yale Peabody Museum.

- Monoclonius cutleri*, type, No. 5427 A.M.N.H., posterior half of skeleton, collected in 1913 near the mouth of Sand Creek about 12 miles below Steveville.
- Monoclonius* sp., No. 5429 A.M.N.H., skull; No. 5430 A.M.N.H., part of skeleton; No. 5443 A.M.N.H., ulna; all collected in 1913 by the American Museum of Natural History, along the banks of Sand Creek about 12 miles below Steveville.
- Monoclonius nasicornus*, type, No. 5351 A.M.N.H., skeleton, collected in 1914 by the American Museum of Natural History, along Sand Creek, about 12 miles below Steveville.
- Monoclonius*, No. 5377 A.M.N.H., skull and jaws, collected by the American Museum of Natural History in 1915, on the "East Fork" of Sand Creek, about 12 miles below Steveville.
- Monoclonius*, No. 5372 A.M.N.H., skeleton without skull and jaws, collected by the American Museum of Natural History in 1915 on the "Middle Fork" of Sand Creek, 12 miles below Steveville.
- Monoclonius nasicornus*, No. 8897 U.S.N.M., skull, collected by C. H. and L. Sternberg in 1917, from Dead Lodge Canyon, 8 miles below Steveville.
- Chasmosaurus* (?), No. 5656 A.M.N.H., back of skull, frill including squamosals, collected by C. H. Sternberg in 1917, on Sand Creek.
- Styracosaurus albertensis*, type, No. 344 G.S.C., skull without lower jaws, collected by C. H. Sternberg in 1913, about 1½ miles southeast of Denhart Ferry. Mounted in the National Museum of Canada.

SASKATCHEWAN

The Lance formation in southern Saskatchewan has yielded two specimens of *Triceratops*, collected by C. M. Sternberg of the Canadian Geological Survey in 1929. The exact locality of the first specimen (Loc. 3, Fig. 2), which consisted of the posterior half of the skull, was 8 miles southwest of Eastend, in the lower Ravenscrag formation. The second individual included the posterior two-thirds of the skull and was found on the east side of Rocky Creek, south of Wood Mountain plateau (Loc. 4, Fig. 2).

MONTANA

Ceratopsia remains have been found in six different localities in Montana. The first (Loc. 5, Fig. 2) is situated on the north side of Milk River, in the Blackfeet Indian Reservation, in Glacier County. This is the locality for the type of *Brachyceratops montanensis*, No. 7951 U.S.N.M., consisting of a considerable portion of a disarticulated skull; also for the paratypes, No. 7952, consisting of a rostral and portions of the premaxillaries, No. 7953, which includes a sacrum, complete pelvis, and articulated caudal series of 45 vertebrae, and No. 7957, consisting of several tarsals and metatarsals. These were collected by Gilmore in 1913, from the Two Medicine formation.

At the same locality was found the type of *Styracosaurus ovatus*, No. 11,869 U.S.N.M., which consists of the posterior portion of the frill and numerous detached fragments. This specimen was collected by G. F. Sternberg in 1928. At the same time and place, he collected also a large nasal horn, recurved forward like that of *Monoclonius flexus*, parts of a skull, 2 ulnae, a tibia, scapula, coracoid, preclavicle, some ribs, and vertebrae. This material is catalogued as No. 12,745 U.S.N.M.

In 1916, Messrs. Brown, Kaisen, and Johnson of the American Museum collected from this region a skeleton of *Leptoceratops*, No. 5464 A.M.N.H., consisting of part of the skull, vertebral column including sacrum, pelvis, femora, tibiae, and foot bones. The exact locality was 3 miles west of Buffalo Lake, and 45 miles west of Sweetgrass, in the St. Mary formation.

The second Montana locality (Loc. 6, Fig. 2) is on Cow Creek, about 10 miles above the confluence of that stream with the Missouri River, in beds belonging to the Judith River formation. The following specimens have been found there:

- Ceratops montanus*, type, No. 2411 U.S.N.M., consisting of an occipital condyle and a pair of frontal horn cores, collected by Hatcher in 1888.

- Monoclonius sphenocerus*, type, No. 3989 A.M.N.H., consisting of nasals and left premaxillary, collected by C. H. Sternberg, on Missouri River near Cow Island, in 1876.
- Monoclonius recurvicornis*, type, No. 3999 A.M.N.H., portions of skull, including frontal and nasal horn cores, discovered by Cope in 1876, on the north side of Missouri River nearly opposite the mouth of Dog Creek.
- Monoclonius crassus*, type, No. 3998 A.M.N.H., teeth?, sacrum, anterior dorsals, and parietal; No. 3997 A.M.N.H., prefrontal and postfrontal with brow horn. Collected by Cope in 1876, opposite the mouth of Dog Creek.

Another important locality (Loc. 7, Fig. 2) is along the canyon of Hell Creek, about 30 miles above the mouth of Milk River, in the northern part of Dawson County. The following specimens were found here in the Lance formation:

- Triceratops serratus*, No. 970 A.M.N.H., skull, collected by Brown and Lull of the American Museum party of 1902, on the extreme point of the divide separating Hell Creek from a tributary which entered it from the west about 15 miles from the Missouri River.
- Triceratops brevicornus* (?), two skulls found by W. H. Utterback of the Carnegie Museum, Pittsburgh, in 1904, near Hell Creek.
- Triceratops prorsus* (?), skull with recurved nasal horn, collected from Hell Creek by F. B. Loomis in 1929. Amherst College Collection.
- Triceratops*, No. 5033 A.M.N.H., 2 cervicals, 14 dorsals, 17 caudals, 28 ribs, pelvis and sacrum, right hind limb and foot, and left femur; No. 5039, lower jaw; No. 5045, coössified cervical vertebrae. These were obtained by Brown and Kaisen in 1909, 16 miles southeast of Lismas. Mounted skeleton.
- Triceratops maximus*, type, No. 5040 A.M.N.H., 8 free vertebrae and 2 cervical ribs. Collected by P. C. Kaisen in 1909, 20 miles south of Lismas.

The fourth Montana locality (Loc. 8, Fig. 2) is the one referred to by Hatcher² on Willow Creek, about 13 miles north of Musselshell postoffice. In the same paper, Hatcher also reports having seen ceratopsian material on the west side of the Big Horn River, between Fort Custer and Custer station (Loc. 9, Fig. 2).

Locality 10 (Fig. 2) is in the Chalk Butte region, between Powderville and Ekalaka. Here, E. S. Riggs of the Field Museum, Chicago, found a skull of *Triceratops horridus* (No. 12,003), and associated with it were various skeletal parts and several pairs of horn cores. These fossils were included in the Lance formation.

NORTH DAKOTA

In the Little Missouri Badlands, in southern Billings County, A. G. Leonard collected in 1908, "various parts of the Cretaceous dinosaur *Triceratops*, 2 or more individuals being present; insufficient for specific diagnosis." The material was identified by Mr. C. W. Gilmore. It is from the Lance formation (Loc. 23, Fig. 2).

SOUTH DAKOTA

Two localities in South Dakota have produced ceratopsian remains. Both are in the Lance formation. Locality 11 (Fig. 2) is in the Short Pine Hills, Harding County, in the northeast quarter of Section 35, Township 17 N., Range 1 E. It has yielded a *Triceratops* skull of the species *horridus*. The specimen is No. P 271 South Dakota State School of Mines, Rapid City. From the same general locality, fragments of *Triceratops* skulls have been identified by Gidley.³

² Hatcher, J. B. 1896, p. 118.

³ Gidley, J. W., 1916, U. S. Geol. Surv., Bull. 627, p. 24.

Locality 12 (Fig. 2) is in the neighborhood of Watauga, Township 23 N., Range 21 E. Ceratopsian material collected here in 1922 by Philip Reinheimer consisted of "a considerable part of a skull, having the horns quite complete. The latter were not less than three feet in length. The frill had been eroded out and lay in many fragments upon the surface." There were also various skeletal parts that were quite disassociated.⁴

WYOMING

Locality 13 (Fig. 2) is in the Big Horn Basin. *Triceratops* bones were found here and identified by C. W. Gilmore.⁵ Hatcher also reports having seen ceratopsian material along the eastern flank of the Big Horn Mountains, about 40 miles south of Buffalo.⁶

Locality 14 (Fig. 2) comprises a large part of Niobrara County, formerly part of Converse County. This has been the most fruitful of all ceratopsian localities. Most of the collecting was done before 1907 by Hatcher, and by C. H. Sternberg, the account of which has been related in detail by Lull in the first monograph. However, a list of the specimens follows:

Triceratops obtusus, type, No. 4720 U.S.N.M., portion of skull, collected by Hatcher in 1890.

Triceratops elatus, type, No. 1201 U.S.N.M., skull; No. 5741 U.S.N.M.; No. 4708 U.S.N.M.; No. 2100 U.S.N.M.; No. 1829 Y.P.M. These were all collected by Hatcher.

Triceratops elatus, No. 5116 A.M.N.H., skull (on mounted skeleton), collected by C. H. Sternberg.

Triceratops brevicornus, type, No. 1834 Y.P.M., skull with lower jaw, a complete series of presacral vertebrae, a number of ribs, and portions of the pelvis; possibly, No. 1832 Y.P.M., both collected by Hatcher, Utterback, Sullins, and Bostwick in 1891.

Triceratops "ingens" (now referred to *horridus*), No. 1828 Y.P.M., skull, collected by Hatcher in 1891.

Triceratops calicornis, type, No. 4928 U.S.N.M., skull, and portion of skeleton, collected by Hatcher in 1889.

Triceratops horridus, type, No. 1820 Y.P.M., the greater portion of a skull, with portions of the lower jaws, collected by Hatcher in 1889.

Triceratops flabellatus, type, No. 1821 Y.P.M., a nearly complete but disarticulated skull associated with several vertebrae, and a few limb bones, collected by J. B. Hatcher in 1888.

Triceratops prorsus, type, No. 1822 Y.P.M., a nearly complete skull with lower jaw and six anterior cervicals, collected by Hatcher in 1889; No. 1205 U.S.N.M.

Triceratops serratus, type, No. 1823 Y.P.M., skull with lower jaw, collected by E. C. Beecher in 1889; No. 2416 U.S.N.M.

Triceratops sulcatus, type, No. 4276 U.S.N.M., fragmentary skull, and vertebrae, collected by Hatcher in 1890; No. 4286 U.S.N.M.; No. 1208 U.S.N.M.

Triceratops, found near Schneider Creek, Niobrara County, by C. H. Sternberg in 1908, and sent to the British Museum.

Triceratops undetermined, No. 1836 Y.P.M.; No. 1837 Y.P.M.; No. 1838 Y.P.M.; No. 2124 U.S.N.M.; No. 5738 U.S.N.M.; No. 5740 U.S.N.M.; No. 6679 U.S.N.M.; No. 7239 U.S.N.M.; 1833 Y.P.M.

Triceratops, tooth, identified by Gilmore,⁷ found in Section 30, Township 39 N., Range 62 W.

Triceratops (Diceratops) hatcheri, type, No. 2412 U.S.N.M., skull without lower jaw. Collected by Hatcher in 1891.

Torosaurus latus, type, No. 1830 Y.P.M., skull without lower jaw, collected by Hatcher in 1891.

Torosaurus gladius, type, No. 1831 Y.P.M., skull without lower jaw, collected by Hatcher in 1891.

⁴ Letter from J. D. Figgins, 1932.

⁵ U. S. Geol. Surv., Bull. 656, 1917, p. 28.

⁶ Op. cit., p. 118.

⁷ U. S. Geol. Surv., Bull. 471, 1910, p. 483.

Locality 15 (Fig. 2) is situated south of the Seminole Mountains, on the west side of the North Platte River, about one mile from that stream, and 40 miles below Fort Steele. Here, in 1888, Hatcher found considerable ceratopsian material consisting of parts of the skull, vertebrae, ribs, and other portions of the skeleton, all in such fragmentary and decomposed condition as to render their determination impossible. In the same general locality, from the Medicine Bow formation of the Hanna Basin, Carbon County, there have been found bones belonging to the ceratopsians but not sufficiently diagnostic for generic determination. This formation is best exposed along both sides of the North Platte River, at the mouth of the Medicine Bow River.

In the Ferris formation of the Hanna Basin, there were obtained "indeterminable fragments of ceratopsians, and a few specimens that have been identified by C. W. Gilmore as *Triceratops*." The formation "is best exposed from the old Ferris ranch, on North Platte River, eastward to the top of the hill north of 'Middle Ditch' at its junction with 'Big Ditch'."⁸

Locality 16 (Fig. 2) is in Sweetwater County in southwestern Wyoming, not far from Black Buttes station on the Union Pacific Railroad. It was here, in 1872, that F. B. Meek discovered the type of *Agathaumas sylvestris* (No. 4000 A.M.N.H.) which consists of about 16 vertebrae, the sacrum, the right ilium, and fragments of ribs.

COLORADO

Locality 17 (Fig. 2) is on Green Mountain Creek, near Denver. It was here that George L. Cannon found a pair of supraorbital horn cores in 1887, first described by Marsh as *Bison alticornis*, but later referred to *Ceratops* and finally to *Triceratops alticornis*, type, No. 4739 U.S.N.M. From the same general locality, near Brighton, Messrs. Cross and Eldridge collected a considerable number of fragmentary dinosaur bones No. 1871, No. 6530 U.S.N.M. There was also a nasal horn core described by Marsh as the type of *Triceratops galeus*, No. 2410 U.S.N.M.

In 1931, a U. S. Geological Survey party collected what is probably ceratopsian material from the Dawson arkose, east side Section 9, Township 14 S., Range 62 W. (Loc. 18, Fig. 2).

NEW MEXICO

New Mexico has given us some of the most recent finds. Locality 19 (Fig. 2) is in San Juan County. The following material has been discovered there:

Pentaceratops sp., No. 12,002 U.S.N.M., a left squamosal, found by G. F. Sternberg in 1929, in the southwest quarter section, Township 24, Range 13 W.

Ceratops (?), No. 8604 U.S.N.M., the median bar of a fenestrated ceratopsian dinosaur, collected by Reeside and Clark, 3½ miles southwest of Kimbetoh, near the south side of Section 4, Township 22 N., Range 10 W., in the Kirtland formation.

Ceratops (?), Considerable portion of a right squamosal, collected in the southeast corner of Section 4, Township 22 N., Range 10 W., in the Kirtland formation.

Monoclonius (?), No. 5798 A.M.N.H., part of a supraorbital horn; and small sections of characteristic squamosal bones, not collected. From the Ojo Alamo sandstone.

Monoclonius (?), No. 7347 U.S.N.M., coössified atlas, axis, third and fourth cervical vertebrae, considerable portions of several dorsal and caudal vertebrae, parts of two pubes, and fragments of other bones, collected in the Fruitland formation in Amarillo Canyon, 10 miles south of San Juan River, and 2½ miles east of Chaco River.

Monoclonius (?), No. 8359 U.S.N.M., proximal portion of an ischium, found in the uppermost part of the Kirtland shale, about 4 miles west of Farmington, ¼ mile east of Mesa Point, and 1 mile south of San Juan River.

⁸ Bowen, C. F., 1918, p. 230.

Pentaceratops, No. 12,743 U.S.N.M., supraorbital horn and parts of squamosal, collected by G. F. Sternberg in 1929, from the Kirtland formation, in S. W. $\frac{1}{4}$, Township 24 N., Range 12 W., San Juan County.

Pentaceratops sternbergii, type, No. 6325 A.M.N.H., skull and skeleton (skeleton discarded), collected by C. H. Sternberg in 1922, 9 miles northeast of Tsaya, from the Fruitland formation.

Pentaceratops sternbergii, No. 1624 A.M.N.H., skull with half of frill gone, collected by C. H. Sternberg in 1923, from the Fruitland formation near Tsaya.

Pentaceratops fenestratus, types, (A) skull, without lower jaw; (B) skeleton almost complete, lower jaw; discovered by C. H. Sternberg in 1921, 1 mile south of Kimbetoh wash, on the south branch of Myers Creek, in the Kirtland shales. The material is now at Upsala, Sweden. Sent along with this material were two pieces of a squamosal and part of a parietal (*Pentaceratops*?) which were found on the south branch of Meyers Creek, 4 miles above Cattle Ranch, and also from the Kirtland formation. There was also included the lower part of a squamosal, the distal part of a quadrate, and the proximal part of a supraorbital horn about 35 cm. long. These latter bones were found in the Fruitland shales, by C. H. Sternberg, on the south side of Alamo Wash, 3 miles above Hunter's store.

Pentaceratops, No. 1625 A.M.N.H., rear part of crest, collected by C. H. Sternberg in the Fruitland formation in 1924.

Ceratopsian, No. 1622 A.M.N.H., skull, from the Fruitland shales, near Tsaya, collected by C. H. Sternberg in 1922.

The following ceratopsian material is in the U. S. National Museum:

Ceratopsian, a fragmentary skull, collected in Barrel Spring Arroyo, about 1 mile southwest of Ojo Alamo store in the Ojo Alamo sandstone.⁹

Ceratopsian, fragments of teeth, found in the Ojo Alamo sandstone,¹⁰ on the north side of Barrel Spring Arroyo, about 1 mile south of Ojo Alamo store.

Ceratopsian, fragments of a ceratopsian frill, not determinable, found on the north side of Barrel Spring Arroyo, about $1\frac{1}{2}$ miles southwest of Ojo Alamo store, in the Ojo Alamo sandstone.

Ceratopsian, fragments of a frill, found on the north side of Barrel Spring Arroyo, $1\frac{1}{4}$ miles southeast of Ojo Alamo store, in the Ojo Alamo sandstone.

Ceratopsian, fragments discovered by J. H. Gardner of the U. S. Geological Survey in 1908, near the head of Coal Creek, 1 mile southeast of Ojo Alamo.

Ceratopsian, teeth, found in 1915 on the north side of Barrel Spring Arroyo, $\frac{1}{2}$ mile west of the wagon road from Ojo Alamo, in the Ojo Alamo sandstone.

Locality 20 (Fig. 2) is situated in the Red Beds of the Rio Grande region, at Elephant Butte. The only record of Ceratopsia from here is of some *Triceratops* bones, consisting of a few fragmentary vertebrae identified by J. W. Gidley.¹¹

TEXAS

Locality 21 (Fig. 2) is in the Big Bend of the Rio Grande, near the Chisos Mountains. In the Upper Cretaceous Rattlesnake beds exposed here there was discovered the lower extremity of a tibia, which was identified by Williston¹² as ceratopsian, but considered by the author as scarcely sufficient for determination. However, it is indicated as a possible locality.

⁹ Gilmore, C. W., 1919, p. 65.

¹⁰ Gilmore, C. W., 1916, pp. 286-287.

¹¹ Jour. Geol., 1907, Vol. XV, p. 57.

¹² Williston, S. W., in Udden, J. A., 1907.

MEXICO

Locality 22 (Fig. 2) is in the state of Coahuila, north of Movano but south of the railroad running north from Soledad. The ceratopsian material found here consists of a right squamosal, a large and a small caudal vertebra, a large section of a femur, and two undetermined fragments. It was discovered by E. Haarmann in the Soledad layers, which he regards as contemporaneous with the Lance.¹³ Preserved in the University of Berlin.

SOUTH AMERICA

Von Huene gives us a possible ceratopsian locality in South America.¹⁴ In 1918, A. Tapia discovered a part of a mandible which Von Huene ascribes to the Ceratopsia under the name of *Notoceratops bonarelli*. It was found in the dinosaur layer, north of the outlet of Chico River, in the southeast angle of Lake Colhué Huapí, district of Chubut, Argentine. The stratigraphical level is below the upper marine Senonian. The actual specimen, however, seems too fragmentary for definite determination.

MONGOLIA

The genus *Protoceratops*, found in Mongolia, presents the most complete fossil series of all stages of a reptile's existence, from egg to adult and old age. The type specimen, No. 6251 A.M.N.H., was found in 1922 by Walter Granger and party, on the Kwei-wa-ting trail east of Artsa Bogdo, in the Gobi desert, Mongolia, Lat. 44° N., Long. 104° E. The horizon is the Cretaceous Shamo series, Dja-doch-ta formation. Since that time the locality has yielded about 80 specimens, many of them in almost perfect preservation of skull and skeleton, and grading from the very small and youthful animals to the old adults.

BRITISH COLUMBIA

During the summer of 1930, C. M. Sternberg collected from the Peace River Canyon in British Columbia a number of dinosaur tracks which correspond exceedingly well in size, posture, length of stride, and morphology, with the known anatomy of some of the Ceratopsia, *Monoclonius* (*Centrosaurus*), for instance. It seems possible, therefore, that the Ceratopsia had inhabited this region. There is, however, a marked time discrepancy. The horizon of the tracks is correlated with the lower Blairmore of about middle Lower Cretaceous age. The exact location of the footprints is in the "Peace River Canyon, north side, about 1½ miles upstream from Gething's mine, on a stratum 216 feet above Grant seam, Gething member of Bullhead Mountain formation."

The type, No. 8556 G.S.C., consists of a plaster cast¹⁵ of six tracks (two manus and two pes of the left side and one each from the right side), and has been called *Tetrapodosaurus borealis*, as described by C. M. Sternberg.¹⁶

¹³ See Janensch, W., 1926, pp. 192-197.

¹⁴ Huene, F. von., 1929, pp. 147-149.

¹⁵ Original could not be removed from the locality.

¹⁶ Sternberg, C. M., 1932, pp. 73-74.

ALPHABETICAL LIST OF GENERA AND SPECIES

For convenient reference, there is given below an alphabetical list of genera and species, with the author and date of original description, the horizon from which they came, and the page and plate of their description or illustration in this memoir.

- Anchiceratops longirostris*, Sternberg 1929, Edmonton, p. 104, Pl. X; Text fig. 3.
ornatus, Brown 1914, Edmonton, p. 103, Pl. XI.
- Arrhinoceratops brachyops*, Parks 1925, Edmonton, p. 106, Pl. XII; Text fig. 3.
- Brachyceratops montanensis*, Gilmore 1914, Two Medicine, p. 97, Pl. IX, B.
- Ceratops montanus*, Marsh 1888, Judith River, p. 96.
- Chasmosaurus belli*, Lambe 1902, Belly River, p. 92, Pls. VI; XIV, B; XVII; Text figs. 3, 30.
brevirostris, nov. sp., Belly River, p. 94, Pl. VII, A.
kaiseni, Brown 1933, Belly River, p. 94, Pl. V, A; VII, B; Text figs. 3, 38.
- Eoceratops canadensis*, Lambe 1915, Belly River, p. 91.
- Leptoceratops gracilis*, Brown 1914, Edmonton, p. 78, Text figs. 35, 37.
- Monoclonius crassus*, Cope 1876, Judith River, p. 82.
dawsoni, Lambe 1902, Belly River, p. 83.
recurvicornis, Cope 1889, Judith River, p. 83.
sphenocerus, Cope 1889, Judith River, p. 83.
- (*Centrosaurus*) *apertus*, Lambe 1904, Belly River, p. 84.
cutleri, Brown 1917, Belly River, p. 87, Pl. III, B.
flexus, Brown 1914, Belly River, p. 86, Pls. II, III, A; Text figs. 3-5, 7-10, 13-14, 16-29.
nasicornus, Brown 1917, Belly River, p. 86, Pl. IX, A; Text figs. 11, 12, 15.
- Pentaceratops fenestratus*, Wiman 1930, Kirtland, p. 111, Text fig. 40.
sternbergii, Osborn 1923, Fruitland, p. 108, Pl. V, B; Text figs. 3, 39.
- Protoceratops andrewsi*, Granger and Gregory 1923, Dja-doch-ta, p. 74, Pls. I, IV; Text figs. 32-34, 36.
- Styracosaurus albertensis*, Lambe 1913, Belly River, p. 87, Pl. VIII; Text fig. 3.
ovatus, Gilmore 1930, Two Medicine, p. 90.
- Torosaurus gladius*, Marsh 1891, Lance, p. 132, Pl. XVI; Text fig. 3.
latus, Marsh 1891, Lance, p. 130, Pl. XV; Text figs. 3, 42.
- Triceratops alticornis*, Marsh 1887, Denver, p. 128.
brevicornus, Hatcher 1905, Lance, p. 119, Text fig. 3.
calicornis, Marsh 1898, Lance, p. 123, Text fig. 3.
elatus, Marsh 1891, Lance, p. 122, Pl. XIV, A; Text fig. 3.
flabellatus, Marsh 1889, Lance, p. 121.
(*Diceratops*) *hatcheri*, Lull 1905, Lance, p. 126, Text fig. 3.
horridus, Marsh 1889, Lance, p. 116, Pl. XIII; Text fig. 3.
maximus, Brown 1933, Lance, p. 129.
obtusus, Marsh 1898, Lance, p. 125, Text figs. 3, 41.
prorsus, Marsh 1890, Lance, p. 117, Text fig. 3.
serratus, Marsh 1890, Lance, p. 120, Text fig. 6.
sulcatus, Marsh 1890, Lance, p. 128.

ECOLOGY, HABITS AND MANNER OF LIFE

ENVIRONMENT

One should visualize the known habitat of the horned dinosaurs in North America as a great belt of lowlying lands along the western border of a vast inland sea, which extended from what is now the Gulf of Mexico into northern Alberta and Saskatchewan. When these creatures first appear, in middle late Cretaceous, this sea had already dwindled from its former extent, and by Lance time, according to Schuchert's¹ maps, was merely a narrow vestige confined exclusively to the limits of the United States. To the west of the bordering lands, the great uplift of the Rocky Mountains was already in process of formation; the so-called Laramide revolution, which produced it, also brought about, at the close of the Age of Reptiles, the final drainage of the epeiric sea. The great area wherein the dinosaurs dwelt was for the most part so near the sea level that very slight vertical movements would either submerge it beneath the sea or drain it wholly or in part, thus producing at times a rapid change from land to shallow-water or marine conditions over relatively large areas. This would account for the alternation of marine and non-marine strata and the consequent occasional breaks in the continuity of the record of ceratopsian history. The actual habitat has been likened to such a region as the Florida Everglades, a vast swamp drained by small interlacing streams the course of which was continually changing. There must have been areas of firmer ground, for not all of the associated dinosaurs were adapted to swamp conditions. The entire region, swamp and drier areas, must have been covered with abundant plant life of an essentially modern aspect, and of sufficient profusion to form, in places, extensive beds of coal. The names of the recorded plants² are familiar—ferns, sequoia and other conifers, the ginkgo, and of deciduous trees, the poplar, beech, elm, sycamore, maple, willow, and oak. In addition to these forest trees there must have been an abundant underbrush and actual swamp vegetation. With the exception of the palms and sequoia, all of these plant genera now thrive in the vicinity of New Haven, and do not necessarily imply a tropical, but perhaps a warm temperate climate with more equable conditions the year round than in present-day Connecticut, for great reptiles could hardly survive a New England winter. The contrast of conditions in the same geographical area then and now is striking, for where vast swamps and deltas and heavily forested lowland formerly prevailed, there is now a great plateau, semi-arid to desert in character. The events which have produced this alteration of environment, largely elevation and consequent climatic change, erosion, and deposition, and which have made the area untenable to dinosaurian life, are among the fundamental causes of the passing of a great race.

There was a curious repetition of conditions at the close of the Jurassic and toward the end of the Cretaceous; for both periods saw the wide extent of what has been called the amphibious-aquatic environment and its peopling by dinosaurian forms. But in the Jurassic, the great amphibious and swamp-dwelling dinosaurs were the saurischian sauropods, such as the gigantic *Brontosaurus*, while in the Cretaceous, with one apparent exception,³ these had entirely passed away, at all events in the Northern Hemisphere, and their place was filled by Ornithischia, especially unarmored trachodons and Ceratopsia. Very comparable physical and climatic changes seem to have caused the final extinction of each of these amphibious assemblages. But the question of the origin of these Cretaceous forms arises, for, as Matthew has shown, neither the trachodons nor the ceratopsians had their initial evolution under such conditions and in such a habitat as that in which we find them, a fact which may account, in part at any rate, for the abrupt appearance, especially of the latter. Matthew says, "These Cretaceous giants . . . appear to have evolved, not from amphibious or aquatic dino-

¹ Schuchert, C., and Dunbar, C., 1933, p. 348, Pl. 31, maps 2, 3.

² Knowlton, F. H., 1930.

³ Gilmore, C. W., 1922, A.

saur of the Jura, but, in part at least, from small and little known forms, of more upland adaptation, which had been much more highly specialized for dry-land life than any of the Jurassic swamp dwellers, and had readapted themselves to the forest and swamp environment of the later Cretaceous."⁴ As heritages from this upland phase in their evolutionary history, Matthew stresses particularly the efficient grinding dentition and the compact feet with depressed hoofs, which characterize both the trachodons and ceratopsians, for these characters when found in modern mammals are especially associated with an upland habitat. As further evidence for this upland stage, he cites the rarity of very young animals among the thousands of dinosaurs which have been unearthed in the principal quarries. In *Protoceratops*, all stages from the egg to the old adult are known, but in America I know of but a single form which can really be called adolescent and that is Gilmore's *Brachyceratops*.⁵ All of the rest are fully adult, although not all are aged individuals. Hence, Matthew argues that the laying of eggs or bringing forth of young was done elsewhere than in the adult environment, probably in the upland regions where the periods of infancy and adolescence were passed, the creatures coming to the swamps on maturity when increasing size made the amphibious environment more suitable. It is well known that many animals today return periodically to their own birthplace to produce their offspring, but the final significance lies in the fact that the breeding or egg-laying place would be presumptively the ancestral habitat of the race.

While the trachodons, with their webbed feet and laterally compressed swimming tail, are clearly splendidly adapted to an amphibious life, fully as much so as a modern crocodile, I cannot see any character or group of characters in the ceratopsians which can be interpreted as in any sense aquatic in their adaptation. On the contrary, the low-carried head with the nostrils near the ground, the cumbersome limbs, and the relatively short tail as compared with that of other dinosaurs, all point to a terrestrial manner of life. Swampy areas, where the ground was sufficiently firm to bear their weight without miring, and perhaps an occasional water hole would be visited but never the actual aquatic environment. I would visualize their manner of life as somewhat similar to that of a modern browsing rhinoceros, which they resemble superficially in a number of ways, but I doubt whether submergence would be desirable either for coolness or for ridding the body of parasites, for modern reptiles bask in a scorching heat and it is difficult to imagine ticks or insect pests having any effect on the thoroughly protected hide of a ceratopsian.

FEEDING HABITS

There is no ambiguity about the mouth armament of a ceratopsian. It is clearly that of an herbivorous animal and is not in any sense fitted for the rending of prey. Anteriorly, there is a laterally compressed beak, while in the rear of the mouth, there is a splendid battery of successional teeth comparable to those of the trachodons; although the individual teeth are larger, and consequently fewer in number, and their mode of succession is different, they are fully as efficient. There is evidence that the masticating area of the jaws was enclosed by powerful muscular cheeks, formed largely of the masseter muscles, and the well-developed coronoid points to equally powerful temporal muscles. Altogether, the mouth, with its activating tissues, was fully as efficient as that of a modern rhinoceros, with this advantage, that the endless succession of teeth gave no limit to the expectation of life as compared with the very definite limit of a modern mammal whose permanent teeth, once worn out, cannot be replenished. The jaw movement was a vertical or chopping one through an arc the center of which lay in the articulation, with no indication either of lateral sway or of fore and aft motion; and the teeth met, not as in a modern ungulate with the horizontal surface of the crowns in contact, but shearing past each other so that the occluding surfaces were vertical, on the inside of the lower teeth and outside of the upper. They were in effect like two converging pairs of shears, one on either side of the mouth. Hence their mastication was not a grinding one, but a shear-

⁴ Matthew, W. D., 1915, p. 278.

⁵ Gilmore, C. W., 1922, B.

ing and chopping one, which is one reason for the need of muscular cheeks to retain within the mouth that portion of the food which would fall outside the teeth. A well-developed mobile tongue is also a necessary part of the buccal mechanism. The form of the muzzle varied somewhat in its degree of lateral compression, being very narrow and deep in *Monoclonius*, but broader and shallower in *Chasmosaurus*. Whether this indicates a difference of food and the manner of its prehension it is difficult to say. There is no marked specific distinction in the teeth themselves other than of size and a small variation in the number of vertical rows.

Tait and Brown⁶ have given us a vivid picture of a feeding ceratopsian, derived not only from a study of the mouth, but also from that of the ball and socket articulation of the skull and neck and the length of the unprotected area of the spinal cord. Of course, a ball and socket joint is a universal one in the mechanical sense, but whether it implied a ninety-degree rotation of the skull on its long axis, which their picture calls for, I seriously doubt. They say, "From its bodily configuration . . . it must have attacked the plants and plant stems near their base, and the wedge-shaped beak . . . was no doubt the instrument employed in seizing these stems. *Triceratops* is possessed of forward projecting horns, and it is conceivable that these may also have been used as an accessory mechanism in the process of food collecting.

"Throwing its beak laterally towards the cluster of vegetation, in which position it could seize and grip vertically growing objects, it picked, let us say, one of these stems, the recurved beak closing either lightly or firmly around the column. Next with violence it wrenched the selected stem towards the open. . . . A nasal horn such as *Monoclonius* possesses may have played some part."

I agree with Nopsca⁷ that the horns of the Ceratopsia could have had little or no part in food getting, but were offensive and defensive weapons, and I do not see why, with its great weight and widespread fore limbs, a horned dinosaur could not have ridden down the stems of desirable vegetation, in addition to that within easy reach, exactly as does a moose. This seems to me far more consonant with structural limitations than the remarkable cervical gymnastics postulated by Tait and Brown (see p. 73).

METHODS OF COMBAT

That the ceratopsians were pugnacious animals is attested first by their possession of horns and neck shield, and secondly by the injuries which they carried, such as puncture wounds and broken horns, all of which were premortem. These are in addition to the manifestations of bone tumors or other disease. (See *Torosaurus latus*, Fig. 42 and Pl. XV, which shows a puncture wound above and in front of the right orbit, visible in the plate, in addition to the diseased condition of the right squamosal.)

Nopsca⁸ stresses the heavy, broad-gauged position of the fore feet in contrast with the more movable hind limbs. This permitted a freer rotation about the fore limbs, the creature swinging the stern over to present the head to the enemy, rather than moving laterally the more cumbersome forward part. What it strove to do, I imagine, was to charge the enemy head on, and at the same time protect its own flank from attack. The long, more or less erect nose horn of *Monoclonius* must have implied a somewhat different mode of attack from that of *Triceratops* with its short nasal and long brow horns. The variation in curvature of the latter in the various species which possessed them implies either that some of the difference is due to postmortem conditions or that the individual tactics varied. The reinforcement of the skull, together with the powerful musculature of neck and shoulder, indicates a very decided survival value in these horns. There is never any evidence of immensely long spinous processes in the anterior dorsal vertebrae of these animals, however, such as certain horned mammals—the bison, titanotheres and rhinoceroses—possess. The great extent of the crest, together with the mechanical advantage of increased leverage of the head may have offset this in the ceratopsians.

⁶ Tait, J., and Brown, B., 1928.

⁷ Nopsca, F., 1929, A, pp. 69-70.

⁸ Op. cit.

On the defensive side, there is the crest itself, especially the squamosal area which would receive the brunt of the attack, and the thickened and highly rugose upper and anterior rim of the orbit, which was for the protection of the eye. I cannot think of the eye as protruding, as Hatcher believed, and hence the vision must have been limited to a lateral field with a blind area immediately in front, as with the sperm whale.

One has to consider not only combats with rival males but protection against such carnivorous enemies as *Gorgosaurus* of Belly River time and, above all, the huge *Tyrannosaurus* of the Lance. That the menace of these beasts of prey was real is attested by the facts that little or no sexual distinction is provable among ceratopsians and that apparently both males and females of a species possessed both the horns and crest in equal degree.

PROGRESSIVE EVOLUTIONARY CHANGES AND PHYLOGENY

(Fig. 3)

The recorded evolutionary history of the Ceratopsoidea opens abruptly, with several highly interesting early chapters not yet revealed, for when these grotesque animals appear in our records they are already ceratopsians with the essential features established. Not only so, but their differentiation into at least three phyletic lines has already been brought about.

The Protoceratopsidae end where they begin, for the two isolated genera, *Protoceratops* and *Leptoceratops*, each with its single known species, tell all we know of the group. With them there is no recorded phylogeny.

The Ceratopsidae, on the other hand, while established as such at their initial appearance, do nevertheless show a very considerable series of changes, some of which are common to all phyla, others peculiar to one or more. It is necessary, therefore, to give a "synopsis of preceding chapters," the details of which must be derived from comparative morphology and the known evolutionary trend of later forms, for the actual record of these chapters is as yet undiscovered. I should derive the Ceratopsia from some unarmored stock of ornithischian dinosaurs, probably bipedal in gait, although among those already discovered we know of none which could be considered ancestral, even in the structural sense.

The unrecorded changes have to do with the secondary assumption of the quadrupedal posture and with the increasing power of the fore limbs to carry the growing weight of the anterior part of the body, although the fore limbs never assume the rectigrade posture of the hind limbs. The increase in size of the head is correlated with a shortening of the neck and loss of motion, due to the condition of coössified immobility on the part of the three anterior cervical vertebrae. The postpubis shortens to a vestige and, on the part of the Ceratopsidae, the elongated ischia become curved downward, and the upper border of the ilium reflected so that the blade becomes horizontal as in certain of the Stegosauria.

The skull becomes more or less wedge-shaped when viewed from above, and in front of the laterally compressed premaxillaries there appears an additional bone, the rostral, which forms the opposing element to the prementary and, like the latter, is sheathed in a prehensile beak. The ancestral form was provided with premaxillary teeth, which persist in the Protoceratopsidae, but are lost in the Ceratopsidae.

The crest is composed of the squamosals and a median element which is variously interpreted, but is called here the parietal, and which is fenestrated on either side of the midline. The manner of origin of the fenestrae is clearly indicated in the genus *Chasmosaurus*, although not so evident in other contemporary genera, and it may possibly have arisen independently in more than one way. In *Chasmosaurus*, the squamosals are elongated and the median element consists of a keel-like, longitudinal portion, at the hinder end of which a transverse bar is extended to meet the end of either squamosal. Ancestrally, therefore, the outer limit of the fenestra must have been the squamosal. At the anterior end of the fenestra, behind the supratemporal openings, a plate of bone extends laterally to join the squamosal near its anterior end, and from these transverse portions of the parietal, branches developed forward and backward, as the case may be, extending along the squamosal until they met in an overlapping suture which, at any rate in *Chasmosaurus*, failed to fuse and in one case failed to meet. This now excludes the fenestra from contact with the squamosal and the aperture thus formed is persistent throughout the recorded history of the phylum. The other type of aperture, which disappears in evolution, seems to be merely a fenestration or perforation of the broad, plate-like parietals, and is associated with squamosals of short or intermediate length, for in the first records of this type, in *Protoceratops*, *Monoclonius*, or *Centrosaurus*, the fenestrae are some distance from the squamosals (toward the midline), with thin margins, somewhat variable in extent, even between the two of the same crest. There is no sign of sutural union in the bone forming the outer margin.

In the chameleon, the crest is formed by the middle parietal bar reinforced from below at its anterior end by the supraoccipital. Here, the parietal broadens out to meet the postfrontal or post-orbital, which in turn articulates with the jugal below, and the squamosal below and behind. The latter bone, passing backward, arches inward until it meets the hinder end of the parietal bar, thus enclosing an opening interpreted as the supratemporal fossa, but equivalent in position to the parietal fenestra of the Ceratopsia. In the latter, the supratemporal fossa is separated from the fenestra by a transverse portion of the parietal, but the two apertures may once have been confluent before the formation of the transverse portion, which in all large fenestrated forms still lies below the level of the remainder of the crest and forms the area for the origin of the temporal muscles.

In the Protoceratopsidae, a sagittal crest indicates that the origin of the temporal muscles overlay the greater part if not all of the dorsal surface of the parietal portion of the frill. In the Ceratopsidae, there are definite but limited areas in the wake of the supratemporal fossae which received the origin of this muscle. Thus, the frill had a dual function, mechanical and protective, for it formed the origin of the temporal muscles of the jaws on the upper aspect, while below it served for the insertion of the several neck muscles which wielded the head. It also formed a protective buckler to guard the otherwise unprotected portion of the spinal cord from the point of its emergence from the foramen magnum until it disappeared beneath the neural arch of the axis, a distance of several inches. Other vital portions of the neck, such as arteries and veins, were afforded protection as well. Initially, the formation of the frill was analogous to that of the chameleon; but whether the same elements enter into its formation in each instance is a matter of debate.

The dorsal surface of the cranium, while unmodified in the Protoceratopsidae, even in the adult, is altered in the Ceratopsidae through the formation of a false roofing analogous to that found in the Chelonina, and inclosing spacious sinuses between the roofing bones and the brain case proper. This is doubtless correlated with the evolution of the supraorbital horns, yet its development seems to have anticipated that of the horns, for it is well established, although not perfected, in genera in which these horns may be in an incipient stage, such as in some species of *Chasmosaurus* and in *Styracosaurus*. Another peculiar feature which is the outgrowth of this false roofing is the postfrontal fontanelle which lies in the midline of the dorsal aspect of the cranium, just above the level of the supratemporal fossae. This forms an opening into the sinuses from without and was supposed by Marsh to be the pineal foramen. This it clearly is not, for it does not communicate with the endocranial space, but what function it actually served we do not know. When I¹ gave the name of postfrontal fontanelle to it, I supposed that its presence was temporary and that it always closed over completely with age. But I find this is not true, for in but a single instance known to me, that of the type of *Triceratops prorsus*, is the closure complete. Moreover, there are always, so far as I know, two canals which radiate outward and backward from the fontanelle and of which vestiges are discernible even in the *prorsus* skull. This would seem to imply some sort of function, but not that of the emission of bloodvessels on the surface of the crest, for the vascular impressions emerge from the supratemporal fossae, but are not apparent until the margin of the smooth area for the origin of the temporal muscle is reached, where they are few and deep, ramifying into a countless number as they disperse over the crest.

Hay in speaking of the postfrontal fontanelle says, "Probably in all cases this postfrontal foramen divides below into two, one for each side," as Hatcher describes in *Torosaurus latus*. "It seems perfectly clear that the foramen in question represents the supratemporal fossae of the alligator and of various other reptiles. The bone rising up and dividing the fossa into two, either at the surface or deeper down, will almost certainly be found to be the true parietal. Through the enormous thickening of the postfrontals [our parietals] the parietal has been crowded from the upper surface of the skull of *Triceratops* and the two supratemporal fossae have been pushed into one at the midline."² But we recognize the supratemporal fossae as present and functional. Perhaps the canal-like depressions radiating from the postfrontal fontanelle represent old lines of communication

¹ Hatcher, Marsh, Lull, 1907, p. 24 (footnote).

² Hay, O. P., 1909, pp. 97-98.

between the fontanelle and the supratemporal fossae which at one time were confluent, and Hay was partially correct. At all events, the fontanelle and its canals represent a vestigial structure the function of which was apparently lost. Compare this area in *Styracosaurus*, Pl. VIII.

Another characteristic feature is the series of separate ossifications, one, the epijugal, at the lower end of either jugal, and a series, to which the name epoccipitals is applied, around the periphery of the crest. The Protoceratopsidae possessed the former, but apparently not the latter. In the first-appearing genera of the Ceratopsidae the epoccipitals are also present, and while seemingly absent in some later forms I seriously doubt whether they actually were missing during the lifetime of the animal, except perhaps in *Torosaurus*.

Of horns, the Protoceratopsidae possess none at all, for in the many skulls of *Protoceratops* itself there is not the slightest indication of their presence. *Leptoceratops*, on the other hand, while agreeing with *Protoceratops* in all essential details, except in the crest, is based upon so incomplete a skull that the areas where brow horns would naturally arise are missing, but the nasals are present and show no trace of a nasal horn. The inference is that the two genera agreed in hornlessness as in other ways. In the Ceratopsidae, horns are a very characteristic feature and are invariably present. The Belly River and Judith River genera had already developed the nasal horn; in fact, *Styracosaurus* has the largest one on record, with *Monoclonius* or *Centrosaurus* a close second. That of *Chasmosaurus*, however, is much smaller. Almost the entire progressive development of the nasal horn, therefore, lies within the unrecorded part of ceratopsian evolution. Of the brow horns, this is not true, for while *Chasmosaurus kaiseni* and *Ceratops montanus* possess fairly large ones, they are as a rule in an extremely rudimentary state in most species of each of the several genera which appear at the beginning of our record, especially in the Belly River series. This completes the tale of the missing chapters.

The actual recorded evolution, aside from the increase in size together with the mechanical adjustments of the skeleton necessary to carry the increasing weight, lies mainly in the head and more particularly in the horns and crest. As to size, the recorded increase in the over-all length is not very great. The length of the Yale *Monoclonius* (*Centrosaurus*) is 17 feet 4 inches, measured on the curve, and of the Washington *Triceratops*, 23 feet 6 inches; the larger *Chasmosaurus* at Ottawa is about 16 feet long, while *Torosaurus*, another long-crested form, probably did not exceed 21 feet. Of the skull alone, that of *Centrosaurus* is 4 feet 6 inches, *Triceratops* 8 feet 2 inches, *Chasmosaurus* about 5 feet, and *Torosaurus gladius*, as restored, 8 feet 10 inches (although the muzzle, which in the restoration looks disproportionally short, may have brought the actual length to over 9 feet). The living weight of a horned dinosaur has never been accurately estimated, but the percentage of increase can be roughly calculated, that of *Triceratops* over *Centrosaurus* being about one third.

The nasal horn seems to have reached its maximum size by Belly River time, for no subsequent short squamosal form, such as *Triceratops*, has a proportionately longer horn than *Centrosaurus*, and in several species it is much reduced, even to elimination. In this phylum, therefore, the recorded evolution of this horn is entirely retrogressive. In the long squamosal phylum, however, the nasal horn of *Chasmosaurus* is not as large as that of its Fruitland successor *Pentaceratops*, but in *Torosaurus* the horn has diminished so that in this phylum—if we are correct in assuming this generic sequence—the trend is first progressive and then retrogressive, the culmination occurring at a later date than in the other phylum.

Another interesting feature in connection with the nasal horn is its apparent shifting forward in evolution, and here the rate of movement is approximately equal in both phyla, for in Belly River genera it lies above the posterior limit of the nares, while in those from the Lance, it is over the anterior limit; the position of those of the Edmonton *Anchiceratops* and the Fruitland *Pentaceratops* is more or less intermediate. This shifting forward of the nasal horn results in a lengthening of the face, especially in the long-crested phylum.

The brow horns are always progressive in their evolution, regardless of phyla. In Belly River time they are incipient, sometimes a mere rugosity above the orbit, again a short pyramidal horn seemingly, sometimes at least, originating in a separate ossification which may be lost in macera-

tion as in the type of *Styracosaurus*. Very rarely, as in *Chasmosaurus kaiseni* and *Ceratops montanus*, are these horns of even moderate length. The subsequent forms are all well endowed with brow horns although these are not always equally long, as in *Triceratops brevicornus* and *Triceratops alticornis* by way of contrast; nevertheless, there is no evidence of retrogression.

There is a tendency in Belly River genera, but notably in the short-crested *Centrosaurus* and *Styracosaurus*, toward the development of peculiar horn-like excrescences around the periphery of the parietal. The former genus may be ancestral to such later Ceratopsia as *Triceratops*, the latter I think died without issue. At all events, these excrescences disappear with the Belly River-Two Medicine forms, for all of the Lance types are conservative in the ornamentation of the crest, if such it was. If, as I think, these growths were due to a sort of acromegalic response to the chemical environment, the altering of conditions might lead to a more normal racial health and hence their disappearance. With the long-squamosal types, the height of this ornamentation occurs in *Anchiceratops* of the Edmonton, lessens but is still apparent in the Fruitland *Pentaceratops*, but in *Torosaurus* of the Lance the crest is bereft of all appendages. Thus, in two details, in the length of the nasal horn, but not its position, and in the ornamentation of the posterior part of the crest, the long-squamosal phylum lags behind that of the short-crested types.

The closure of the parietal fenestrae is foreshadowed in the Belly River types and complete in the Lance in the short-crested phyla, while in the long-crested types the fenestrae never disappear. *Anchiceratops*, although with comparatively long squamosals, has relatively small fenestrae. It may be a precocious side line culminating in the Edmonton, although it is undoubtedly related to the *Chasmosaurus-Pentaceratops-Torosaurus* line.

The long crests seem to have been less closely invested in the horny covering than were the short crests, if one may judge by the vascular impressions. Although, if this means that the crest in the former was not free of the dorsal body musculature, the creatures must have had a singularly immobile head. It would seem, on the contrary, that when the fenestrae persisted there was a thicker, more fleshy covering over the crest both above and below, except perhaps at the periphery in *Chasmosaurus* and *Pentaceratops*. *Anchiceratops*, with its tendency to close the fenestrae, has deep vascular impressions in spite of its phyletic relationship. The variable extent of vascular impressions on the under side in the closely invested crests seems to indicate more accurately the extent to which the crest is free from the body.

As an outcome of the present study, I have attempted to present graphically, in Figure 3, certain conclusions in regard to the phyletic sequence of the Ceratopsidae. They are in no sense final, and the figure is to be regarded merely as a trial sheet which is imperfect, due perhaps to misinterpretation, but more, I hope, to the incompleteness of the record.

The two main phyletic lines, which may be of sub-family rank, are distinguished principally by the form of the crest, specifically in the length of the squamosal and its reaction upon the crest, and by either the persistence or closure of the parietal fenestrae.

The long-crested line, with persistent fenestrae, begins with the Belly River *Chasmosaurus*, of which *Chasmosaurus belli* is the most generalized form, while *Chasmosaurus kaiseni* is progressive in the development of its brow horns, although it may be an actual contemporary with *belli* of the rudimentary horns. In the Edmonton, this phylum is represented by *Anchiceratops*; but this genus, while showing certain characters comparable to those of *Pentaceratops* of the homotaxial Fruitland and Kirtland formations, seems to depart from the main evolutionary line, especially in the high degree of vascular impressions on both surfaces of the crest, and in the tendency toward the diminution of the fenestrae. According to available evidence, it seems to represent an abortive side line which left no descendants. This is not true of *Pentaceratops*, however, for the typical species *sternbergii* could be the lineal descendant of *Chasmosaurus kaiseni* with little alteration, other than of size and the more abundant vascularity of the squamosal. It is far removed in space from its predecessors and descendants, but otherwise fits into its place in the sequence admirably. *Arrhinoceratops*, also of the Edmonton, presents certain difficulties. It is clearly a long-squamosal form with vascular impressions on either side of the crest and rather small fenestrae. It may prove to be ancestral to *Triceratops* of the short-crested phylum and the resemblance is rather close, especially between

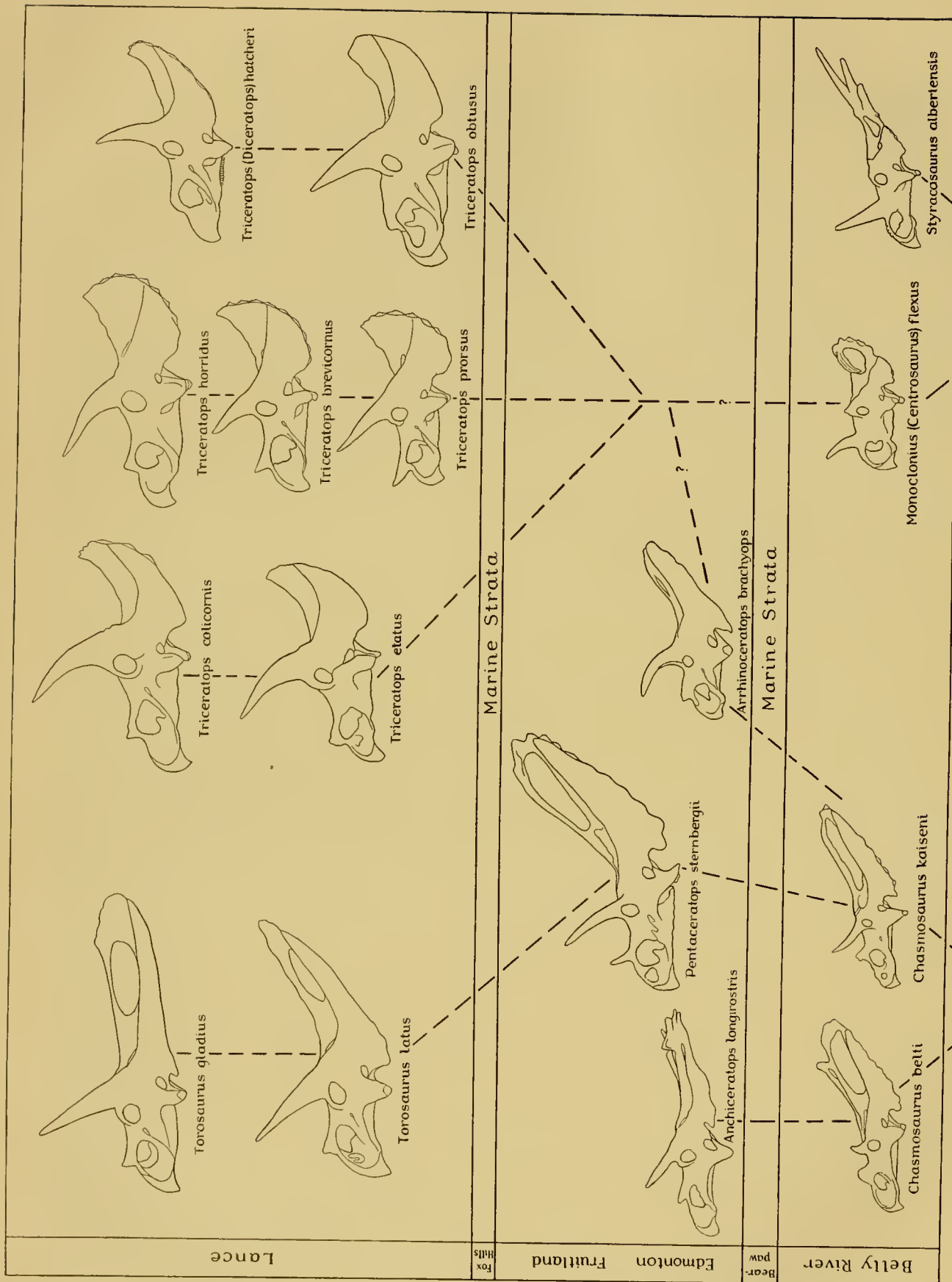


FIG. 3. Evolution of the horned dinosaurs, with tentative phylogeny. All drawn to approximate scale.

Arrhinoceratops and the *Triceratops* species *obtusus* and *hatcheri*, in which the nasal horn is reduced. The closing member of this phylum is *Torosaurus*, which again fulfills the requirements in being just what one would be led to expect from the evolutionary trend established by its predecessors. It is strange that this genus should be so rare, with but two recognizable specimens found within a mile of each other at the very summit of the Niobrara County Lance. The contemporary *Triceratops*, on the other hand, is represented by hundreds of individuals³ of which comparatively few were collectable.

The initial short-crested form is *Monoclonius* (*Centrosaurus*), from the Judith River and Belly River formations, which may be the beginning of the entire line culminating in *Triceratops*, but the sub-genus *Centrosaurus* itself, with the high degree of ornamentation at the rear of the crest, seems too specialized. It may well be that the true ancestry lies in the ill-known forms of *Monoclonius* or even *Ceratops* of the Judith River which seem to be more conservative in this regard. The continuity through the Edmonton is not good, for *Arrhinoceratops* is the only known possibility and the objections to its inclusion in this phylum have already been given. *Styracosaurus*, with the riotous processes around the rear of the crest, is clearly derivable from the *Monoclonius* stock but not from any of the known forms, all of which are apparently too nearly contemporaneous. *Triceratops* is evidently a polyphyletic genus, and I have shown at least three descent lines, or rather groupings, within the genus. Of these, perhaps the most conservative is the *prorsus-brevicornis-horridus* phylum. The sequence, as I have shown it, is not actual, for the type of *horridus* is next to the lowermost of the Niobrara County series, although, if I am correct in referring the giant skull sometimes known as *Triceratops* "*ingens*" (No. 1828 Y.P.M.) to this species, it persisted until near the close of the Lance record. As the skulls are arranged, they show progressive increase in size, and reduction of the nasal horn. Of the *elatus-calicornis* group, the *elatus* type is somewhat the older, but here again *elatus* has a long vertical distribution and the single *calicornis* specimen may be merely a variant from the type, but actually conspecific. The great brow horns and curiously reduced nasal horn are the most outstanding features of this group. *T. obtusus*, with the nose horn nearly vestigial, is at the very beginning of the Niobrara County sequence; *T. (Diceratops) hatcheri* is two-thirds of the way up. Whether *obtusus* was actually ancestral to *hatcheri* is questionable, but except for smaller size, the latter seems to be the embodiment of the *obtusus* evolutionary trend.

³ Brown reports 500 in the Hell Creek region alone. 1933, A, p. 2.

GENERAL MORPHOLOGY

Mr. Hatcher's¹ study of the osteology of *Triceratops* leaves little to be desired. There have been, however, a few new elements discovered since his time, such as the hyoid, sternal, and sclerotic plates, which will be discussed in their proper place. In addition, studies have been made of the cranial musculature and a good deal of argument has arisen concerning the homologies of certain elements in the skull. Hatcher also discussed in such detail as was then possible the skeleton of Cope's type of *Monoclonius crassus*. Because of the abundance and perfection of material which has come to light in the Red Deer region of Alberta, including at least seven nearly complete skeletons representing four genera and two geological horizons, it is now deemed wise to describe anew the morphology of the genus *Monoclonius* (*Centrosaurus*), basing the description on the skeleton at Yale, recently purchased from the American Museum of Natural History (No. 2015 Y.P.M.).

MONOCLONIUS (CENTROSAURUS) FLEXUS² Brown

The animal was much smaller than *Triceratops* and the limb bones, especially, lack the robustness of that genus, although aside from the skull the skeletal elements are otherwise quite similar.

AXIAL SKELETON

SKULL

The skull (Fig. 4) of the Yale specimen resembles that of the type of *Centrosaurus flexus* Brown, differing only in minor details such as having two forwardly directed processes over the parietal fenestrae instead of but one, and in the nearer approach of the inwardly curved hook-like processes at the rear of the crest. These are shown to be matters of individual variation and apparently have little or no specific value.

In Brown's³ description of *C. flexus* the following points are noted for comparison: He speaks of the nasal horn being longer than in any other described species of the genus. This was true at that time, but his subsequently described *C. nasicornus* has a longer one although straight rather than curved forward. The nasal horn in the *C. flexus* type is described as ovate in section at the base with the broad end of the oval toward the rear, with which the Yale specimen agrees.

The horn arises from the nasals at their mid-length in both specimens so that its center lies directly above the posterior border of the nares. This is a character common to all early genera, in contrast with those of the Lance in which the horn lies over the anterior rim of the nares. In *C. flexus* the horn curves forward; in *Monoclonius dawsoni* Lambe it curves backward with about the same degree of curvature, while in *M. sphenocerus* Cope and *C. nasicornus* Brown it is straight and erect.

The supraorbital horns are rudimentary as compared with those of *Triceratops*. They are considerably larger than in *Monoclonius dawsoni*, and in both the type of *C. flexus* and the Yale specimen they are asymmetrical, that of the left side being in each skull considerably higher than the right. In the Yale specimen the left horn core is triangular, viewed from without, with a flattened outer face, and less rugose than in the type. On the right side there is only a rough, rounded area where the horn should be. Brown thinks it possible that the horns may have been derived from separate centers of ossification and that the right one has been lost, leaving only the rugose elevated portion of the postfrontal forming its base of attachment. In the type of *Styracosaurus albertensis* (Pl. VIII, B) in the Ottawa museum there are distinct sutural surfaces showing where the horn cores

¹ Hatcher, Marsh, Lull, 1907, Chapter III.

² For the sake of simplicity, during this chapter on morphology the term *Centrosaurus* will be used for all Belly River species under the genus *Monoclonius*.

³ Brown, B., 1914, B.

would have been attached were they present. This is apparently true also of a *Chasmosaurus* skull in the Yale collection, but not in either *Centrosaurus* skull under discussion. Hatcher states that in *Triceratops* the supraorbital horns are simple outgrowths of the postfrontals, whereas the nasal horn, like the rostral, prementary, epoccipitals, and epijugals, is to be considered a dermal or epidermal ossification. But no known *Triceratops* skull is individually young enough to prove the point, for the supraorbital horns are so large that coalescence with the postfrontals must have occurred at a very early age if they arose from separate centers of ossification. Brown expresses doubt as to whether the supraorbital cores bore a horny sheath in the rudimentary stage of their development in *Centrosaurus*. But judging from the abundance of vascular impressions, especially on the crest of older

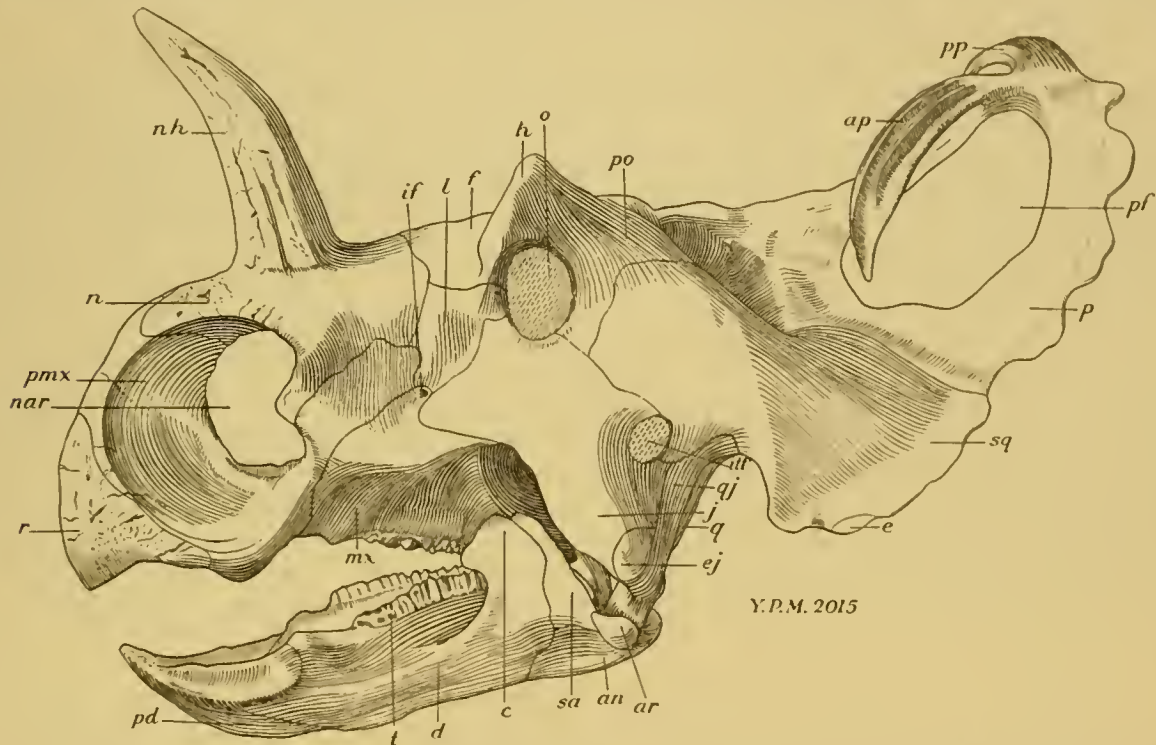


FIG. 4.—Left lateral view of skull of *Monoclonius* (*Centrosaurus*) *flexus*, at Yale Peabody Museum, $\frac{1}{8}$ natural size. *an*, angular; *ap*, anterior process of crest; *ar*, articular; *c*, coronoid process; *d*, dentary; *e*, epoccipital; *ej*, epijugal; *f*, prefrontal; *h*, supraorbital horn; *if*, preorbital fossa; *itf*, infratemporal fossa; *j*, jugal; *l*, lacrymal; *mx*, maxillary; *n*, nasal; *nar*, narial opening; *nh*, nasal horn core; *o*, orbit; *p*, parietal; *pd*, prementary; *pf*, parietal fenestra; *pmx*, premaxillary; *po*, postfrontal; *pp*, posterior process of crest; *q*, quadrate; *qj*, quadratojugal; *r*, rostral; *sa*, surangular; *sq*, squamosal; *t*, teeth.

individuals, the entire head except for muscle areas must have been clothed with a close-fitting resistant integument, leathery if not actually horny in texture. It is reasonable to assume that the areas of the horns were likewise so covered, and that, as in the horned lizard *Phrynosoma*, corneous horn-like prominences may actually have preceded rather than followed the development of an osseous horn core.

ROSTRAL

This bone is essentially as in *Triceratops* except for its smaller size relative to the entire face. The ascending process does not rise so high on the nose in *Centrosaurus*, and as a consequence the posterior margin of the rostral is straighter. The highly rugose and pitted character of the bone is characteristic of all ceratopsians. The muzzle of *Centrosaurus* is relatively deeper than in *Triceratops* and much deeper and shorter than in the contemporary *Chasmosaurus*.

PREMAXILLARY

This forms in a broad, smooth, vertical plate, the osseous septum, which divides the external nares. Above it meets an equivalent portion of the nasals. The septum differs from that of *Triceratops* in being thinner and in lacking the fenestration⁴ found in all Lance genera. This vertical plate is called the ? septomaxillary by Von Huene in his description of the skull of *Triceratops*. There is in no instance known to me any indication of suture between it and the premaxillaries proper. Here, again, however, the suture may have become obliterated at an earlier age than is represented by any known skull. One would expect to find it in the very youthful *Brachyceratops montanensis* type, as well as in the skull of *Triceratops flabellatus* in the Yale Museum in which the cranial elements are practically all isolated from each other, but the latter does not show it.

Anteriorly, the premaxillary is convex and broadened out to form the front of the nose, with an ascending process reaching nearly to the base of the nasal horn. This process is overlapped laterally and posteriorly by a downwardly curved process of the nasal which together with the latter forms the convex profile of the nose. The lower margin of the premaxillary is strongly convex downward, as viewed laterally, in all *Centrosaurus* specimens, while in *Triceratops* this margin is more nearly straight. The surface of this portion of the bone is smooth. The posterior process of the premaxillary, which is included between the nasals and maxillary, is relatively deeper and less slender than in *Triceratops*. Its form and extent, however, vary considerably. In some *Centrosaurus* skulls it reaches the preorbital fossa (lacrymal foramen of authors), in others it is widely separated from the fossa. Its contact with the lacrymal is also subject to variation although whether or not this is of specific value is not clear. In the two *C. flexus* skulls in the American and Yale museums there is such contact, but in the Ottawa one there is not, nor in the type of *C. nasicornus*, while the skull of *Centrosaurus apertus* No. 4519 R.O.M., which is very similar to *nasicornus*, shows such contact, as does skull No. 348 G.S.C. with a sharp forwardly curved nasal horn. In other words, the ascending process of the premaxillary meets the lacrymal in two out of three skulls identified as *C. flexus*, and in one skull of *nasicornus*, and in one with the forwardly directed nasal horn. The bones fail to meet in one *nasicornus* and in one *flexus* skull.

NASAL

The nasal of *Centrosaurus* is of very different proportions from that of *Triceratops*, due in part to the position of the erectly arising nasal horn which, as we have seen, lies over the posterior rather than the anterior margin of the nares. This makes the portion of the nasals anterior to the horn relatively longer in the present genus. Thus, in *Centrosaurus*, the nasals form nearly half the anterior profile of the muzzle, in *Triceratops*, little, if any. Posterior to the horn, the nasals of *Triceratops* are relatively longer. On account of the depth of the face in *Centrosaurus*, the nasals are also deeper than in *Triceratops*. Anterior to the horn, the nasals in *Centrosaurus* are divided, and are separated by the anterior ascending process of the premaxillaries, which apparently is not true of *Triceratops*. Posterior to the horn, on the other hand, the suture separating the right from the left nasal is obsolete and not discernible in any skull which I have studied. In *Triceratops*, the suture is, as a rule, clearly visible to the extreme posterior end except in very old individuals in which practically all of the sutures have been obliterated. The nasals in *Centrosaurus* thus form the top and sides of the nose to about halfway between the nasal and supraorbital horns, where they meet the prefrontals above and the lacrymals (and ? preorbitals) on the side of the face. Thus the bounding of the nasals is comparable to that in *Triceratops*, except that they never reach the preorbital fossa. The variable extent of the posterior ascending process of the premaxillary may exclude the nasal from contact with the maxillary as in the *C. flexus* type skull and the No. 4519 R.O.M. and No. 348 G.S.C. skulls. In the *C. nasicornus* type, on the other hand, the contact between nasal

⁴ This fenestration is not present in all *Triceratops* skulls, which leads to the supposition that it may not have been normally present in the living animal, but is merely an accidental post-mortem perforation through the thin septum.

and maxillary occurs. In *Centrosaurus* as we have seen, the nasal forms part of the septum separating the anterior nares. The extent of this septum area varies in the different *Centrosaurus* skulls. In *Triceratops*, the nasals have no part in the nasal septum.

LACRYMAL

The lacrymal is, comparatively, of about the same size as in *Triceratops*, but differs from the latter in being sometimes bounded anteriorly by the posterior process of the premaxillary. Below, it is bounded by the jugal and maxillary, and above, by the nasal and prefrontal.

MAXILLARY

This element has the same form and limitations as in *Triceratops*. It contains alveolar grooves for about 31 teeth, and on its inner face has a corresponding number of nutritive foramina in a horizontal row. The preorbital fossa is included within the maxillary though generally at the upper border. The maxillary is bounded in front and above by the premaxillary, above by the lacrymal and jugal, behind by the jugal, and on the roof of the mouth by the premaxillary, palatine, and pterygoid.

JUGAL

The form of this bone differs markedly from that in *Triceratops*, being broader and more rectangular, whereas in the latter the outer aspect of the bone is somewhat T-shaped. The area which overlaps the quadratojugal is much broader in *Centrosaurus*. Externally, the jugal is bounded by the maxillary and lacrymal, in front and above, and posteriorly by the postfrontal (postorbital) and squamosal. The epijugal is borne on the lower outer corner of the jugal as in all ceratopsians. Posteriorly, the infratemporal fossa is entirely surrounded by the jugal and squamosal, the quadratojugal not forming the lower border as it does in *Triceratops*. The jugal of *Centrosaurus* covers over more of the quadratojugal-quadrato complex than in *Triceratops*, when viewed squarely from without.

SQUAMOSAL

This is a most characteristic bone in the Ceratopsia, concerning which there has been little or no discussion, as all authorities agree as to its identity. Its form and development are of generic value. The squamosal of *Centrosaurus* is roughly quadrangular with the long axis running obliquely downward and backward. Its upper forward margin articulates with the postfrontal. Anteriorly, it meets the jugal, posteriorly the parietal. The outer free margin sends forward a short process which forms part of the lower border of the infratemporal fossa and unites with the jugal and quadratojugal. The anterior free border of the squamosal, together with the quadrato complex, forms a deep notch behind which the border of the squamosal is continued to form the lateral margin of the crest. This part of the border has five prominences which originally bore the epoccipital bones, of which two only are preserved on the right side and none on the left, where the margin is broken. In this specimen the remaining epoccipitals are fully coössified with the squamosal. In the type specimen of *C. flexus* there are three on the right side, one of which is represented by the base only. These squamosal epoccipitals in the type are much smaller than are those borne on the parietals, whereas in the Yale specimen they are nearly equal in size. The number of prominences is one greater in the type and the emarginations between them are not so deep. I find five to be the usual number of squamosal epoccipitals, not only in *Centrosaurus* but in *Styracosaurus* also. In *Anchiceratops* the number is six, while in *Triceratops* it is generally six with the seventh overlapping the squamoso-parietal suture. In long-squamosal forms, like *Chasmosaurus*, the number is naturally greater, and averages nine.

Vascular impressions are present but not very numerous on the upper surface of the squamosal in this adult specimen. This is true also of the type of *C. flexus*.

PARIETAL

About two-thirds of the area of the crest is formed by the coalesced parietals. Each incloses a large fenestra with a thin, somewhat variable margin. These have much the same extent in all *Centrosaurus* skulls. The margin is, however, practically never complete in any *Centrosaurus* skull as preserved, for its ultimate edges must have been extremely thin. The right fenestra of the Yale specimen is materially smaller than the left, although the width of the bone on the outer side is the same in each instance. The left fenestra is somewhat ovoid, with the apex pointing to the rear, and there is an angular prominence in the middle of the anterior margin, but slightly indicated on the right side. The bony edges may in life have merged into a cartilaginous or membranous sheet which covered the aperture, the evolutionary tendency in this *Monoclonius-Triceratops* phylum being toward the final closure of the fenestra by bone, as opposed to its persistence in the *Chasmosaurus-Torosaurus* group.

The supratemporal fossae are large, and open directly backward, due to the overgrowth of the false roofing of the skull. They are bounded by the postfrontals in front and above, and the parietals within and behind. In the rear of each there is a smooth area, depressed below the level of the postfrontal and squamosal bones, which must have formed the place of origin of the temporal muscles. The latter ran obliquely forward and downward beneath the facial bones to the coronoid process of the lower jaw. This is true of all Ceratopsia (see Lull⁵ on the musculature of the ceratopsian skull). Bloodvessels also doubtless emerged from the supratemporal fossae to deploy on the dorsal surface of the crest, especially on the anterior and outer portions, but not toward the middle of the crest.

The central portion of the parietals between the muscular depressions and the fenestrae forms a thickened bar, convex above and to a less extent concave below, which supports the median portion of the crest. Posteriorly, this bar increases in thickness and widens out into the marginal portion of the crest, thus forming the inner and posterior margins of the fenestrae. It terminates between the hook-like posterior processes.

The free outer margin of the parietals bore four epoccipital bones on either side, the curious inwardly curved hook-like processes constituting a fifth pair, if indeed they are homologous with the epoccipitals.

In several *Centrosaurus* skulls, notably in the one in Ottawa (No. 348 G.S.C., which I would also refer to *C. flexus*), there is a triangular bone filling a corresponding gap at the marginal end of the squamosal-parietal suture. This also seems to be in the nature of an epoccipital, or possibly two fused together, and corresponds to the epoccipital which overlies the end of this suture in *Triceratops*. In the Yale skull this element is not in evidence, but the space where it may have been is present in the type of the species (No. 5239 A.M.N.H.). The latter has the same number of parietal epoccipitals as the Yale specimen.

CREST

The crest or frill differs from that of *Triceratops* in several important details. Its general form is more highly arched transversely when viewed from the rear; the squamosals form a smaller portion of the entire area; there are large fenestrae through the central parietal bone; and normally there are two pairs of curious processes arising from the rear of the crest. Of these, the posterior two are small and hook-like, lie in the plane of the crest, and point toward each other, curving forward toward their tip. These are seemingly constant in occurrence but variable in form. The area of the crest which lies between them is smooth and rounded. The larger anterior processes are

⁵ Lull, R. S., 1908, pp. 388-389.

variable in occurrence as well as in form. Generally, there are two, but the type of *Centrosaurus flexus* has but one, that on the left side. In Lambe's type of *Centrosaurus apertus*, the right process only is preserved. This was detached at the time of Lambe's first description and, as it was an unknown element, he very naturally mistook it for a nasal horn and so described it. Later, it was fitted into place. The Yale specimen has the normal two anterior processes. These arise from the rear bar of the crest on its dorsal aspect and project forward and slightly downward over the fenestrae. They taper to a point, are somewhat curved, and are irregularly grooved or sulcated on their upper surface. Where the right process is missing in the type, the point where it would normally have arisen is smooth and shows no evidence of former attachment. Brown speaks of these processes as being of the nature of the ossified tendons which occur in this group of dinosaurs. The fractured end of these processes does not seem to bear this out. Compared with sections of the nasal horn core, the structure revealed is essentially the same, cancellous bone within and a denser outer layer. In the nasal horn are occasional larger canals which doubtless contained bloodvessels, for the vascular grooves on the outer surface begin abruptly proximally, branching distally as though the bloodvessels carrying nourishment to the horny sheath penetrated from within the bone outward, there to run their course in the external grooves. These are not apparent in the processes, but this is the only histological difference which I can discern. On the other hand, ossified tendons from the dorsal region of *Triceratops brevicornus* type (No. 1834 Y.P.M.) are of a very different character, far denser and with a more or less fibrous outer surface. Brown also suggests that the forwardly directed processes may have been for muscular attachment. If so, I cannot see what muscles these could have been, especially as the ends of the processes point downward toward the two large fenestrae through which no known muscle could have passed. Nor is their direction right for a possible prolongation of the temporal muscles, which have been shown to have their origin on the upper surface of the crest just behind the supratemporal openings and, passing through the latter, to go downward and forward within the jugals to be inserted into the coronoid process of the jaws.

These processes constitute a sub-generic character, although as we have seen, their degree of development varies with the individual, and the forward processes may be asymmetrical to the extent of total absence of one, or possibly both.

PALATAL ASPECT

The Yale skull (Fig. 5), while admirably preserved on the whole, is somewhat obscure in the region of the occiput, especially in the lack of clarity of the sutural limitation of the various elements. The narrowness of the *Centrosaurus* skull is especially marked in contrast to its contemporary, *Chasmosaurus*. Anteriorly, the rostral is well preserved, together with the maxillaries and their contained teeth, the last somewhat of a rarity especially in the various skulls of *Triceratops* known to science. The precise limitation of the individual teeth is at present obscure, so that the number may not be told with exactness. There seem to be about 31 vertical rows, as compared with 35 in the type of *C. flexus*.

The teeth of *Centrosaurus* are described by Brown as differing from those of *Triceratops* in that the central carina of the enameled crown in the middle rows is relatively higher and the outer curvature of the rows consequently greater.

The rostral, seen from below, is V-shaped, and the sharp, cutting edge is prolonged backward by the downwardly curved margins of the premaxillaries, although the actual edge is here somewhat rounded. No trace of the rod-like vomers is present, although, as Brown says, they must have been similar to those of *Triceratops*. These elements are so extremely fragile that they are preserved in but two ceratopsian skulls so far as I know. One case⁶ is that of *Triceratops serratus* No. 970 in the American Museum of Natural History, and the other a skull of *Chasmosaurus* at Yale (see Fig. 29). In the *C. flexus* type the maxillaries are notched for articulation with the anterior ends of the missing vomers. Were they present, the latter would form "a long narrow bridge dividing the space between

⁶ Lull, R. S., 1903, Pl. LIX, and Hatcher, Marsh, Lull, 1907, Fig. 26.

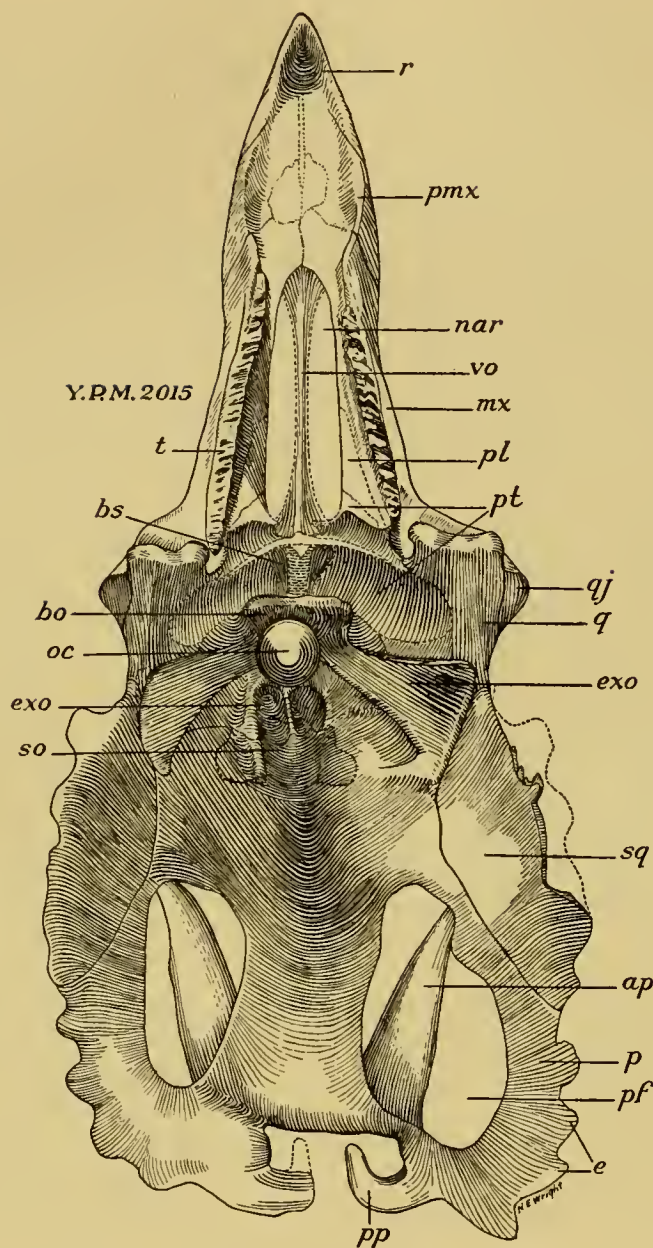


FIG. 5.—Palatal view of the skull of *Monoclonius* (*Centrosaurus*) *flexus*, 1/8 natural size. *ap*, anterior process of crest; *bo*, basioccipital; *bs*, basisphenoid; *e*, epoccipitals; *exo*, exoccipital; *mx*, maxillary; *nar*, narial vacuity; *oc*, occipital condyle; *p*, parietal; *pf*, parietal fenestra; *pl*, palatine; *pmx*, premaxillary; *pp*, posterior process of crest; *pt*, pterygoid; *q*, quadrate; *qj*, quadratojugal; *r*, rostral; *so*, supraoccipital; *sq*, squamosal; *t*, teeth; *vo*, vomer.

the maxillaries into two large vacuities as in *Triceratops*.⁷ The region of the palatines and pterygoids is defective, as they seem to be entirely lacking in our skull, but in the type specimen they resemble those of *Triceratops*.

The basi- and exoccipitals, together with the condyle, are fairly well preserved, but are deficient in the clarity of their outlines. This is especially true of the limitations of the supraoccipital. From the ventral aspect of the skull of the Yale specimen, the exoccipitals appear as wing-like

⁷ Brown, B., 1914, B, p. 557.

processes extending outward and backward from the occipital condyle, and bounded posteriorly by a suture crossing from wing to wing about midway along the length of the latter. Just posterior to the exoccipitals is a small bone called by Marsh and Hatcher the supraoccipital (see Fig. 5). Beyond this the parietal extends to the posterior end of the crest, at first broad and concave, but flattening toward the rear. Brown interprets these structures differently, making the supraoccipital a bone bounded by the foramen magnum, the wings of the exoccipitals, and a line drawn transversely between the expansions of the exoccipitals. Behind this is his small parietal, with what he terms the postfrontal (our parietal) forming the remainder of the middle portion of the crest. Our nomenclature, however, is based on the following points: the apparent lack of a suture across the foramen magnum defining an extra bone here; furthermore, it has always been held that the parietal should form part of the roof of the brain case, which Brown's so-called parietal does not do.

LOWER JAW

(Fig. 4)

The jaws in *Centrosaurus* are more slender and less massive than in *Triceratops*. Posteriorly, there is a high coronoid process which curves forward toward its summit into a hook-like process more marked in *M. sphenocerus* than in the Yale specimen. The main portion of the mandible, as usual, is formed by the dentary, on the lower and inner surface of which is a large splenial extending to the hinder end of the mandible. Externally, the angular forms a triangular plate of bone rising to about half the depth of the mandible, exclusive of the coronoid, hence relatively larger than in *Triceratops prorsus*. Above this lies the surangular, which forms the rear margin of the jaw except where it meets the articular below. The articular is well developed although its external limits are not very clearly defined. Externally, the modeling of the jaw is characteristic. There are two longitudinal hollows, separated by a rounded horizontal ridge. Of these, the upper one is much the deeper and runs within the coronoid process toward the rear of the jaw. Vascular impressions, well shown along the inferior margin of the dentary and angular in the *M. sphenocerus* type, are only faintly indicated in the Yale specimen, evidently that of a younger animal. This is in harmony with the general surface of the skulls as well. The type of *C. flexus* does not possess a lower jaw.

PREDENTARY

This bone in *Centrosaurus* resembles that of *Triceratops* except for one detail. The upper surface which is defined by two longitudinal ridges is horizontal in *Triceratops*, but in *Centrosaurus* is inclined outward at an angle of about 45°. Externally, the predentary resembles the rostral in its vascular surface.

HYOID

(Fig. 6)

The final preparation of the wonderfully preserved type skull of *Triceratops serratus* Marsh in the Peabody Museum of Yale University has brought to light a bone hitherto unknown among the horned dinosaurs and rarely observed in the entire dinosaurian order.

The hyoid, if such it is, lies nearly *in situ* alongside of the right ramus of the lower jaw, opposite its hinder end. It is of very peculiar form, being sharply curved so as to form a nearly complete semicircle, and having a thin, blade-like expansion set at an angle of about 35° with the main mass of the bone. The general form, seen from below, is shown in Figure 6, together with its position relative to the adjacent jaw. The bone is evidently one of a pair, the articulating surface being at the end opposite the blade. This articular surface thins out to a moderately sharp edge but is slightly roughened. As it lies, the bone extends toward the left beyond the median line of the head. It seems, however, to have been rotated through an angle of 90° rather than actually displaced. With

the conjectural position of the pair of hyoids relative to the jaws, it will be seen that the bones enclose a space within which the vocal apparatus may have been situated. If so, the latter must have been very large, implying on the part of these animals a voice commensurate with their bulk and—judging from their armament—general aggressiveness.

The curved body of the bone, which is unlike any other that I have seen, is provisionally referred to the basihyal and may constitute half of the first branchial arch.

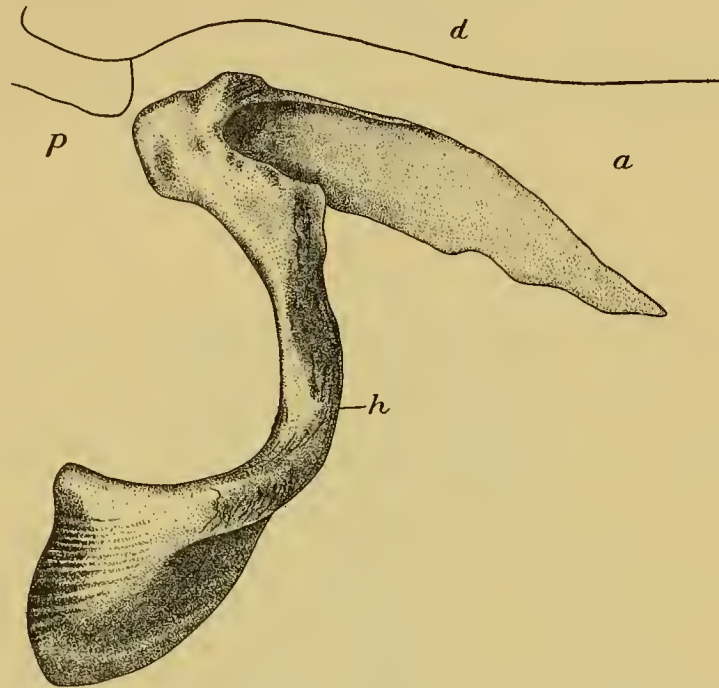


FIG. 6.—Hyoid of *Triceratops serratus*, No. 1823 Y.P.M., $\frac{1}{2}$ natural size. *d*, dentary; *h*, hyoid; *a*, anterior; *p*, posterior.

Compared with the so-called thyrohyals of *Centrosaurus*, the two elements have nothing in common other than being in each instance portions of the hyoid complex which can be known in its entirety only through future discovery.

Hyoid elements in the skull of *Centrosaurus apertus* No. 4519 R.O.M. have been described by Parks⁸ as follows: "Both these elements were discovered in the present specimen with their anterior ends touching the internal surface of the maxillaries near their posterior extremities, and the posterior ends almost meeting in the midline. The bones are long and slender, the right measuring 168 mm. and the left (slightly broken anteriorly) 162 mm. in length. The anterior end is somewhat expanded, the upper surface flattish and the posterior end inflected slightly outwards. The under surface is more convex in its anterior portion and this convexity rises into a distinct ridge near the outer side of the bone less than half way down. This ridge crosses the bone diagonally and terminates on the inner edge at the posterior extremity, thus giving a twisted appearance to the bone when viewed from the ventral side. The width at midlength is 16 to 18 mm. and the thickness (dorso-ventral) about 12 mm." These bones are comparable to the thyrohyal preserved in a *Camptosaurus* skull, No. 1887 Y.P.M.⁹ The chief difference seems to lie in a decided curvature in the *Camptosaurus* bone. Doubtless these bones were homologous elements; they cannot have been the same as the peculiar hyoid of *Triceratops*.

⁸ Parks, W. A., 1921, p. 57.

⁹ Gilmore, C. W., 1909, p. 224, Pl. 9.

VERTEBRAL COLUMN

The vertebral formula agrees with that of *Triceratops* in that there are 21 presacral and 10 sacral vertebrae. In *Centrosaurus* the number of caudals has been determined by Brown¹⁰ to be 46. The exact number is apparently unknown in *Triceratops*. Of the presacrals 7 have heretofore been described as cervicals and 14 as dorsals. To this Brown takes exception, however, claiming 9 as belonging to the cervical series and 12 to the dorsal. His arguments will be discussed later.

VERTEBRAL FORMULAE

	Cervicals	Dorsals	Sacrals	Caudals	Total
<i>Triceratops</i>	7-9	14-12	10	45 ?	76
<i>Centrosaurus</i>	7-9	14-12	10	46	77
<i>Anchiceratops</i>	7-9	14-12	10	38	67
<i>Brachyceratops</i>	8 ?	14 ?	6	50	78
<i>Protoceratops</i>	7 ?	13	7-8	45	72
<i>Chasmosaurus</i>	7-9	14-12	10	45	76
<i>Pentaceratops</i>	7-9	14-12	10	28+	59+

COALESCED CERVICALS

(Fig. 7)

Centrosaurus conforms with the rule in the Ceratopsia, in having the three anterior cervicals coalesced into a single mass. Each of these vertebrae bears a neural arch and the second and third

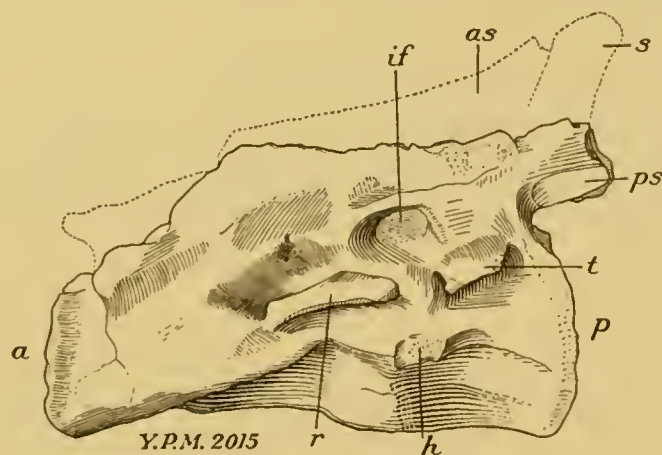


FIG. 7.—Anterior cervicals of *Monoclonius* (*Centrosaurus*) *flexus*, $\frac{1}{4}$ natural size. *a*, anterior; *p*, posterior; *as*, spine of axis; *h*, capitular facet; *if*, intervertebral foramen; *ps*, posterior zygapophysis; *r*, rib; *s*, spine of third cervical; *t*, tubercular facet.

a spine which as in *Triceratops* is bent sharply backward. The axial and third spines, although fused throughout, are distinctly defined in the distal half, and their summits are broadened transversely.

In the Yale *Centrosaurus* the neural arch of the atlas arises as a rather heavy plate a little forward of the center; in *Triceratops* it is seemingly lighter and arises farther back. The upper outline of the neural spines is lost, but the intervertebral foramen between the axis and the third

¹⁰ Brown, B., 1917, p. 289.

vertebra is elliptical in shape and is relatively longer and lower as compared with its nearly circular form in *Triceratops*.

Contrary to the descriptions of Marsh and Hatcher, Lull¹¹ recognized a suture apparently dividing the atlas, on the strength of which he described four coalesced vertebrae instead of three. To this Brown takes exception, claiming that the four *Monoclonius* specimens in the American Museum collections, and also a specimen of *Triceratops*, show only three vertebral divisions clearly marked by the point of union of the vertebrae, neural arches, and spines. I am now also in agreement with Marsh and Hatcher as well as with Brown. Nevertheless, the sutural marking is visible not only in the *Triceratops prorsus* type at Yale, but also in the Yale *Centrosaurus* specimen. It has been suggested that the portion of the atlas in front of this suture may represent a proatlas, which would then not increase the number of vertebrae in the coössified part beyond the generally accepted three.

The neural canal cannot be traced at its anterior end, as it is filled with matrix practically indistinguishable from the bone. Posteriorly, however, the outline is clear. Here the canal has a triangular section, broader at the base than on either side.

The articular face for the reception of the occipital condyle is a hemispherical cup, practically circular in outline, as in *Triceratops*. There is little if any flattening above or below until near the point where the axis and atlas meet, where the former is flattened. In *Triceratops* there is a distinct, median, fore and aft groove on the inferior face of the axis which is not evident, or very slightly so at the anterior end, in *Centrosaurus*. Laterally, the lower half of the centra of the axis and third cervical in *Centrosaurus* is constricted, much more so than in the axis of *Triceratops*, cervical III in each being more alike. The junction of the second and third is narrower below than in *Triceratops*, and, if one may judge from Hatcher's figure,¹² than in *M. crassus* also. There are slight prominences on either side of the atlas in the Yale specimen suggestive of those in *Monoclonius crassus*, but there is no real evidence of an atlar rib such as Hatcher assumes for the latter. These prominences, or at any rate the inferior ones, are lacking in the *Triceratops prorsus* type, which is exceptionally well preserved.

The posterior face of the centrum of the third cervical is concave in the Yale *Centrosaurus* and its transverse diameter exceeds the vertical, the reverse being true in *M. crassus*, according to Hatcher, although, as he says, the proportions have been much altered by crushing.

Cervicals I-III of the Yale *Centrosaurus* as well as of a specimen of *Centrosaurus apertus*, No. 4519 Toronto, are very different in general appearance from those of the *M. crassus* type, especially in the greater elevation of the neural spines, the fore and aft length of the third cervical, and the general proportions of the entire mass.

CERVICAL IV

As it is now preserved, the centrum is opisthocoelous with the anterior face flat, the posterior one concave. The anterior aspect is almost pentagonal, but the ventral angle fades out posteriorly. The lateral sides are concave. Part of the right rib is present, consisting of both capitulum and tuberculum. The cervicals differ only slightly from those of *Triceratops*, except for size.

CERVICALS V AND VI

Cervicals V and VI (Fig. 8), evidently pathologic, are coössified, with no visible sign of division between the centra. The neural arches are, however, normally distinct. The centra have a flattened lower aspect and no decided constriction on their lateral faces. The articular face of the fifth is hexagonal while the posterior face of the sixth, as preserved, is nearly quadrangular.

¹¹ Lull, R. S., in Hatcher, Marsh, Lull, 1907, p. 47.

¹² Hatcher, Marsh, Lull, 1907, Fig. 78.

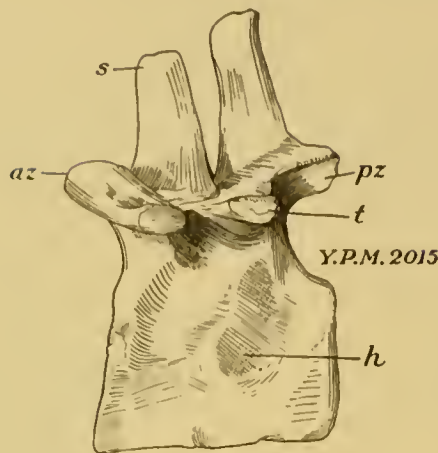


FIG. 8.—Cervicals V and VI, coalesced (pathologic), of *Monoclonius* (*Centrosaurus*) *flexus*, $\frac{1}{4}$ natural size. *az*, anterior zygapophysis; *h*, capitular facet; *pz*, posterior zygapophysis; *s*, neural spine of 5th cervical; *t*, tubercular facet.

MEASUREMENTS OF CERVICALS

	IV	V	VI	VII
Length of centrum	68.6 mm.	127.0 mm. ¹³		58.0 mm.
Height of centrum	101.0	96.5	88.0	80.0
Breadth of centrum	125.0	173.0	120.0	120.0
Breadth over diapophyses	168.0	220.0	220.0	220.0
Height over all	164.0	213.0	235.0	235.0

CERVICAL VII

In this bone the pedicels are longer, so that the diapophyses are higher with relation to the centrum. All of the cervicals are simple in form, with a rather large neural canal.

CERVICAL VIII

The eighth presacral vertebra, in the Ceratopsia, has always been designated the first dorsal, because of the change here in the length and character of the rib. Brown,¹⁴ however, has used a new system for differentiating the cervical from the dorsal region, contending that "in the cervical series throughout the Dinosauria the capitular facets are invariably located on the centra of the vertebrae, the change from the cervical to the dorsal series being marked by the rise of this facet from the centrum to the neural arch. In *Monoclonius* the last vertebra having a capitular facet on the centrum is the ninth."

Cervical VIII still has a very large neural canal to accommodate the brachial enlargement of the spinal cord. The canal here has nearly twice the diameter of that of vertebra XV. The centrum of VIII is somewhat biconcave and comparatively short, with a flattened lower surface and deeply constricted lateral ones. It corresponds fairly well with the "anterior dorsal" of *M. crassus*, figured by Hatcher,¹⁵ although the diapophyses are relatively longer and more slender, and the neural canal larger. They are equally simple in construction, but the Yale specimen is lighter in build.

¹³ Length of the coössified mass.

¹⁴ Brown, B., 1917, p. 288.

¹⁵ Hatcher, Marsh, Lull, 1907, Fig. 80.

CERVICAL IX

(Fig. 9)

Cervical IX corresponds more nearly to Hatcher's figure. In this bone the centrum is still biconcave, with the sides more deeply constricted than in *M. crassus*. The centrum is more evenly rounded, lacking the flattened lower surface seen in cervical VIII. The neural canal is still large

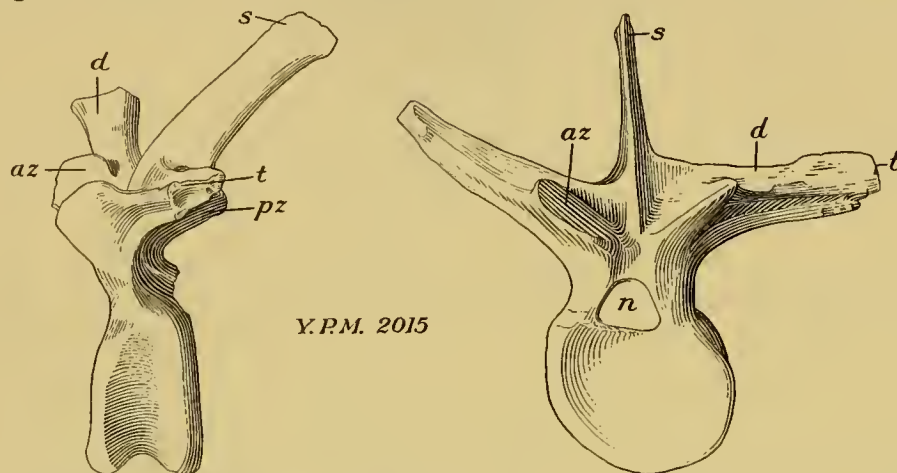


FIG. 9.—Cervical IX of *Monoclonius* (*Centrosaurus*) *flexus*. Left lateral, and anterior views, $\frac{1}{4}$ natural size. az, anterior zygapophysis; d, diapophysis; n, neural canal; pz, posterior zygapophysis; s, neural spine; t, tubercular facet.

and somewhat triangular in section except for a rounded apex. The capitular facet is hardly visible but is still borne on the centrum, while the distinct tubercular facet lies at the end of the diapophysis.

DORSAL VERTEBRAE

One marked peculiarity of the dorsal vertebrae (Fig. 10) of this specimen, which may be a specific character, is the more backward slant of the spinous processes as compared either with *M. crassus* or *C. nasicornus* (Figs. 11, 12) in which they are more nearly erect. This involves the entire neural arch and becomes more marked in the posterior vertebrae, especially in dorsal VI (see Fig. 13). In the Yale specimen the lateral constrictions are also deeper. The diapophyses are triangular in section, with the base of the triangle uppermost and the other sides concave.

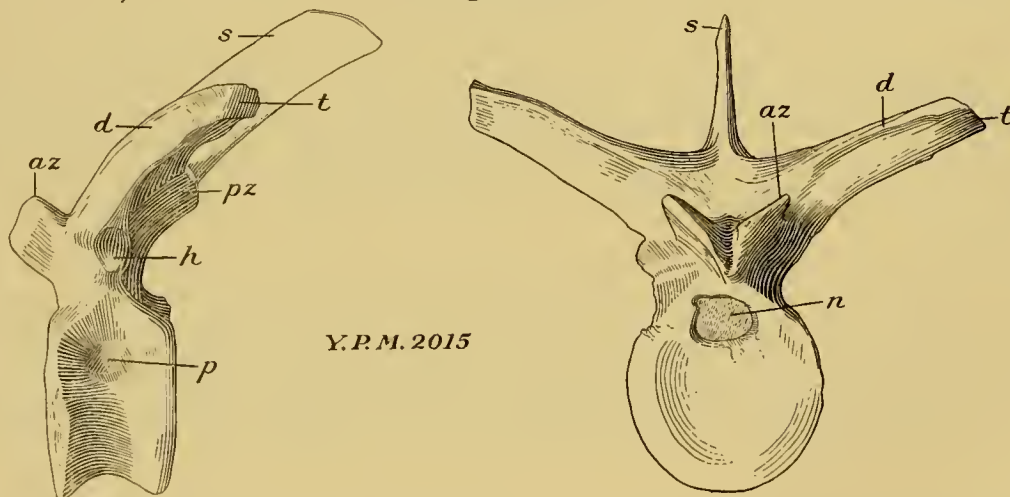


FIG. 10.—Dorsal II of *Monoclonius* (*Centrosaurus*) *flexus*. Left lateral, and anterior views, $\frac{1}{4}$ natural size. az, anterior zygapophysis; d, diapophysis; h, capitular facet; n, neural canal; p, pleurocoele; pz, posterior zygapophysis; s, neural spine; t, tubercular facet.

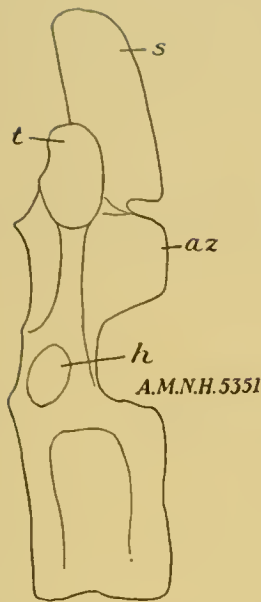


FIG. 11.—Right aspect of cervical IX of *Monoclonius* (*Centrosaurus*) *nasicornus*, $\frac{1}{4}$ natural size. *az*, anterior zygapophysis; *h*, capitular facet; *s*, neural spine; *t*, tubercular facet.

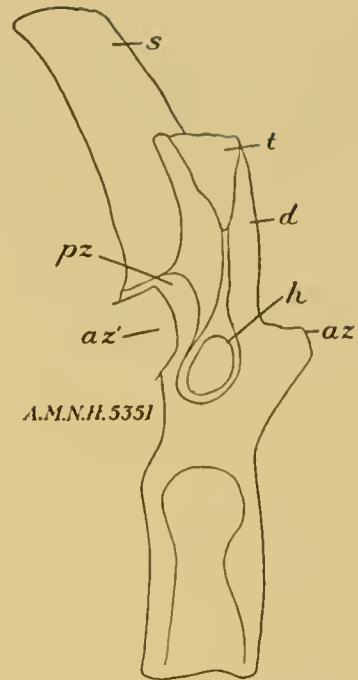
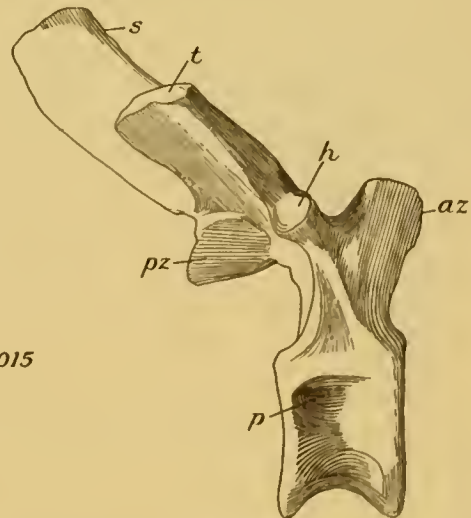
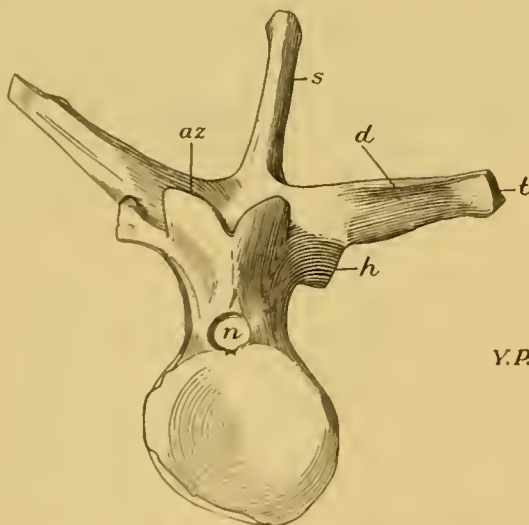


FIG. 12.—Right aspect of dorsal II of *Monoclonius* (*Centrosaurus*) *nasicornus*, $\frac{1}{4}$ natural size. *az*, anterior zygapophysis; *az'*, anterior zygapophysis of succeeding vertebra; *d*, diapophysis; *h*, capitular facet; *pz*, posterior zygapophysis; *s*, neural spine; *t*, tubercular facet.

DORSAL VI

(Fig. 13)

This vertebra differs greatly from that figured by Hatcher as a posterior median dorsal vertebra of *M. crassus*. The centrum has flattened articular faces but, viewed laterally, is deeply constricted and in addition has deep pleurocoeles in the upper half of each side. The capitular facet is now on



Y.P.M. 2015

FIG. 13.—Dorsal VI of *Monoclonius* (*Centrosaurus*) *flexus*. Anterior and right lateral views, $\frac{1}{4}$ natural size. *az*, anterior zygapophysis; *d*, diapophysis; *h*, capitular facet; *n*, neural canal; *p*, pleurocoele; *pz*, posterior zygapophysis; *s*, neural spine; *t*, tubercular facet.

a level with the zygapophysis at the base of the diapophysis. The latter is strong and well developed, and the spinous process is flat, narrow, but of considerable fore and aft extent, and slightly expanded distally. The lateral aspect of the bone is peculiar as the entire complex of processes arises above or behind the pedicels in marked contrast to any other *Centrosaurus* species. The zygapophyses are large and strongly buttressed while the neural canal is much smaller than in cervical VIII, so that behind the brachial enlargement the spinal cord was slender, in fact very slender for an animal of this size. In *Monoclonius crassus* the equivalent vertebra is more erect and lacks the backward offset and angulation of the processes. The zygapophyses are confluent as in *M. crassus*. The neural arch is higher than in presacral VIII and is somewhat constricted above the neural canal. In its anterior aspect the Yale vertebra resembles that of *M. crassus* but differs markedly when viewed from the side.

MEASUREMENTS OF DORSAL VI

	<i>M. crassus</i> No. 3998 A.M.N.H. ¹⁶	<i>C. flexus</i> No. 2015 Y.P.M.
Height of centrum, anterior face	97.0 mm.	97.5 mm.
Width of centrum, anterior face	100.0	98.0
Length of centrum	69.0	68.0
Width across pedicels	52.5	50.0
Vertical height over all	336.0 ¹⁷	270.0
Width across diapophyses	252.0	270.0
Length of spinous process	125.0 ¹⁸	152.0
Neural canal height, anterior end	25.0	15.0
Neural canal width, anterior end	22.0	20.0
Length over zygapophyses	100.0	118.0

DORSAL IX

(Figs. 14, 15)

In this vertebra the centrum is somewhat wedge-shaped, when viewed from the side (possibly due in part to crushing, although otherwise there is no evidence of it). The anterior face is nearly plane (but the rim is partly eroded), the posterior face concave. Lateral pleurocoeles are present in

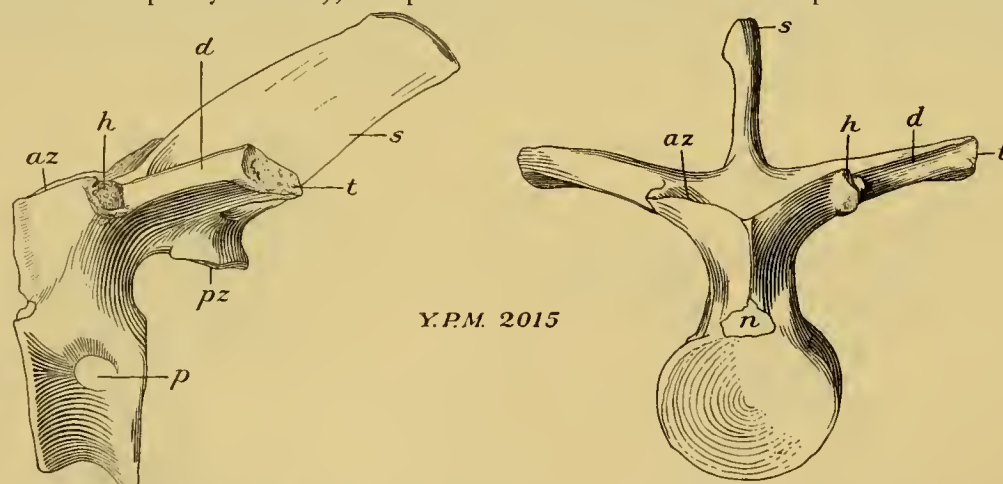


FIG. 14.—Dorsal IX of *Monoclonius* (*Centrosaurus*) *flexus*. Left lateral and anterior views, $\frac{1}{4}$ natural size. az, anterior zygapophysis; d, diapophysis; h, capitular facet; n, neural canal; p, pleurocoele; pz, posterior zygapophysis; s, neural spine; t, tubercular facet.

¹⁶ Calculated from Hatcher's figure.

¹⁷ Difference due in part to inclination of spinous process.

¹⁸ Estimated length.

the upper part of the centrum. The zygapophyses are confluent, the anterior pair forming a V-shaped surface which looks upward and somewhat backward. The posterior surfaces are smaller and nearly horizontal, with a slight division between the two halves, which look slightly outward as well as downward. The diapophyses are broad fore and aft and flattened. The capitular facet, one-third of the way out on the anterior border, is buttressed by the prezygapophysis. The tubercular facet is

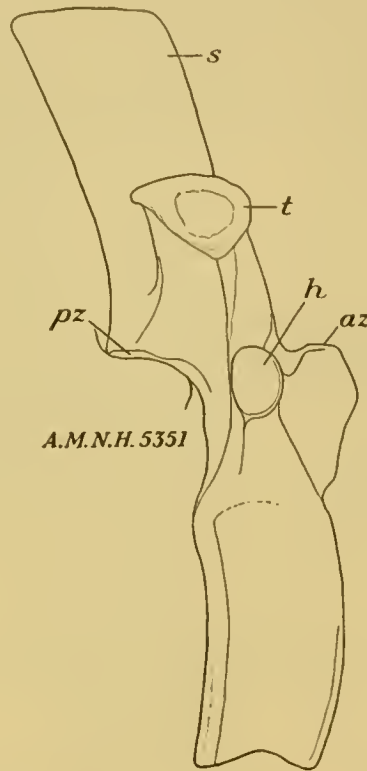


FIG. 15.—Right lateral view of dorsal IX of *Monoclonius* (*Centrosaurus*) *nasicornus*, $\frac{1}{4}$ natural size. az, anterior zygapophysis; h, capitular facet; pz, posterior zygapophysis; s, neural spine; t, tubercular facet.

terminal. The spinous process arises behind the pedicel so that its anterior edge is about over the posterior margin of the neural arch. It is flattened and its antero-posterior diameter is nearly twice that of the diapophyses. The thickness of each is about equal. A median ridge rises from the neural canal to the junction of the zygapophyses. In this, as in the general form of the latter, the offset to the rear of the base of the spinous process, and the depth of the lateral pleurocoles, the vertebra differs markedly from that of *M. crassus* figured by Hatcher.¹⁹

MEASUREMENTS OF DORSAL IX

Centrum, length at top	71.0 mm.
Centrum, width of anterior face	97.5
Centrum, height of anterior face	79.5
Width over diapophyses	244.0
Width over capitular facets	114.4
Length of spinous process	166.0
Neural canal, height of anterior end	25.0
Neural canal, width of anterior end	13.0

¹⁹ Hatcher, Marsh, Lull, 1907, Fig. 79.

DORSAL XI

(Fig. 16)

This vertebra shows the following characteristics: centrum constricted at mid-length; pleurocoeles fairly deep; anterior face nearly plane, posterior one deeply concave; prezygapophyseal facets confluent and nearly horizontal; postzygapophyseal facets forming an angle of 90° with each other. The latter are well below the former, and well behind the centrum as in the preceding vertebrae. The capitular facets are situated about one-third of the way out on the anterior edge of the zygapophyses. From them a groove extends outward on the anterior edge to the end of the diapophysis for contact with the rib. The spinous process is plain, slightly tapering, and slanting well backward.

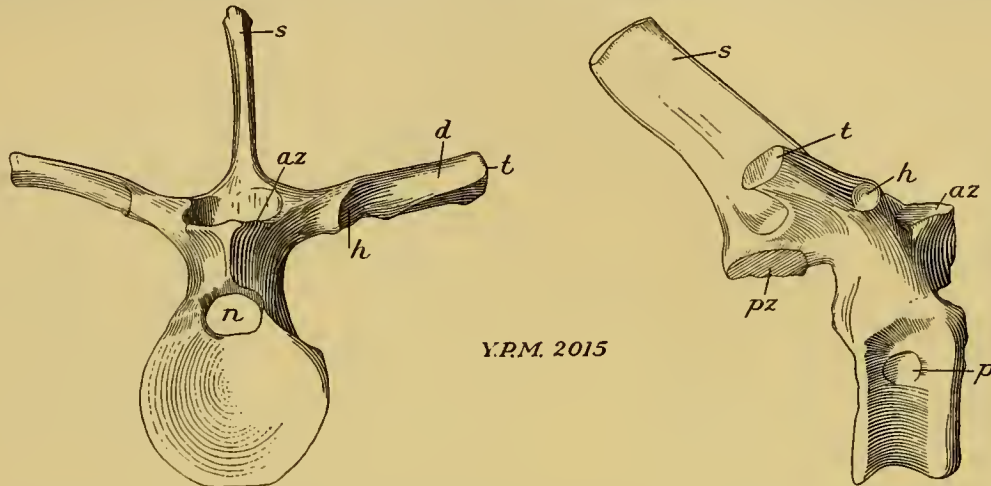


FIG. 16.—Dorsal XI of *Monoclonius* (*Centrosaurus*) *flexus*. Anterior and right lateral views, ¼ natural size. az, anterior zygapophysis; d, diapophysis; h, capitular facet; n, neural canal; p, pleurocoele; pz, posterior zygapophysis; s, neural spine; t, tubercular facet.

Compared with *Triceratops*, the vertebra in question differs in the shape of the centrum, when viewed from the end, that in *Centrosaurus* being more nearly circular and that in *Triceratops* somewhat pear-shaped. In *Triceratops* there is less slope to the neural arch and spinous process. The general proportions of the zygapophyses and spinous process are somewhat similar, but the surface for contact with the rib between capitular and tubercular facets is much less marked in *Triceratops*. The latter has no pleurocoele.

MEASUREMENTS OF DORSAL XI

Centrum, length at top	67.5 mm.
Centrum, width of anterior face	100.0
Centrum, height of anterior face	78.0
Width over diapophyses	253.0
Width over capitular facets	115.0
Length of spinous process	140.0
Neural canal, height of anterior end	16.0
Neural canal, width of anterior end	29.3
} ill preserved outline	

SACRUM

(Fig. 17)

The sacrum in *Centrosaurus*, as in all of the later Ceratopsia, consists of ten coalesced vertebrae. To these is added a dorso-sacral, coössified with the sacrum above but free below. The spinous processes, including that of the dorso-sacral, have become fused into a solid bar, the original limits of

the individual processes being for the most part indistinguishable in the present condition of the Yale specimen. The spinous processes are low and their superior margin is essentially straight throughout the first five sacrals, beyond which the individual summits are restored in such a way as to give a saw-tooth outline, as viewed from the side. Whether or not this restoration is correct is difficult to determine, for in the *C. nasicornus* sacrum the spines are entirely obscured by the ossified tendons;

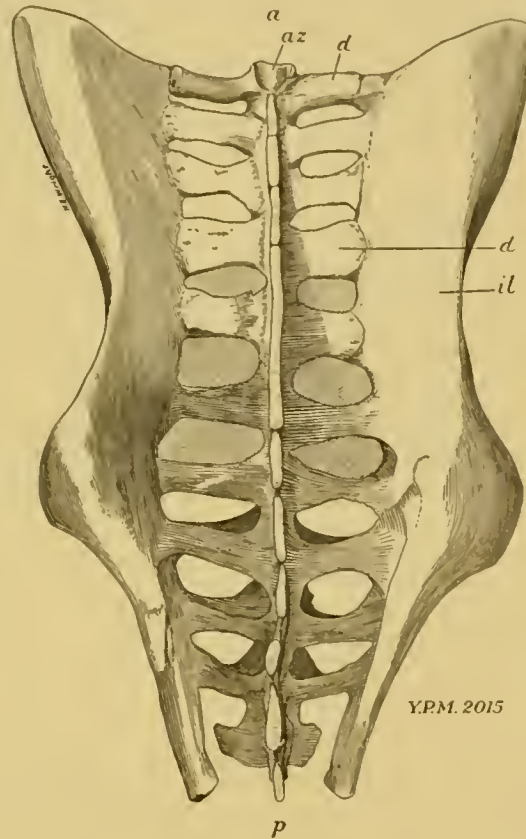


FIG. 17.—Sacrum and ilia of *Monoclonius* (*Centrosaurus*) *flexus*. Dorsal view, $\frac{1}{8}$ natural size. *a*, anterior; *p*, posterior; *az*, anterior zygapophysis of dorso-sacral vertebra; *d*, diapophysis; *il*, ilium.

in the *M. crassus* type the summits of the spines are broken away; and in *C. cutleri* the posterior summits are separate, but in line. In the Yale specimen, the zygapophyses and spinous process of the last sacral are distinct, the latter being isolated. The zygapophyses are well indicated only between the last two sacrals; otherwise, except for the prezygapophyses of the dorso-sacral, they are thoroughly fused. The diapophyses slope slightly upward (from the horizontal) from the neural arch outward, the angle of slope being highest at sacral IV, and least at X. The diapophyses of the dorso-sacral are heavier than the two immediately following and the anterior edge is deflected sharply downward. Diapophyses of sacrals I and II are rather narrow and flat, but reach the blade of the ilium, whereas that of sacral III is wider and heavily buttressed below to meet the pubic peduncle. This lower buttress is the parapophysis, which in *Triceratops* arises from the third sacral although bearing also against the second, is deflected backward, and is not fused with the diapophysis above. In *Centrosaurus*, the parapophysis seems to arise from the second sacral and sweeps backward so that the pubic peduncle is opposite the centrum of sacral III. Contrary to *Triceratops*, para- and diapophyses are fused in sacrals III-IX. The type of *M. crassus* agrees with the Yale specimen in this respect. Dia- and parapophyses of III-VI form the acetabular bar which abuts against the acetabulum, agreeing with *Triceratops*. The parapophyses in the rear of the acetabular bar are thin

buttresses of bone which, together with the diapophyses, form a T- or L-shaped cross section. All of them meet the ilium except those of sacral X.

The sacrum of *C. cutleri* type differs from that of the Yale specimen mainly in the forward extension of the ilia in front of the sacrum. In both, the rib of the dorso-sacral is a slender bone fused with the under side of the blade of the ilium near its anterior end; these ribs in *C. cutleri* also curve forward much more than they do in the Yale specimen, which seems to show that the ilia in both specimens are essentially complete. In the Yale specimen the diapophyses of sacral X do not meet the ilia, in *C. cutleri* they do, as seen from below. The visible differences between the pelvises of the Yale *Centrosaurus* and *C. cutleri* are slight. To what extent they are due to preservation is not clear. They are otherwise perhaps accountable as individual, perhaps sexual variations, and are hardly of specific value.

MEASUREMENTS OF THE PELVIS

	<i>C. flexus</i> Y.P.M.	<i>C. nasicornus</i>
Length of entire sacrum over zygapophyses, including dorso-sacral	840 mm.	800 mm.
Width over anterior diapophyses	252	—
Width over diapophyses of IV	237	—
Width over diapophyses of VII	276	—
Width over diapophyses of X	226	—
Width across ilia, anterior end	753	—
Width across ilia, over ischiac peduncle	630	—
Width across ilia, posterior end	190	—
Length of right ilium, as preserved	960	1060
Length of left ilium, as preserved	968	—
Length of ten sacral centra	703	—
Width across acetabular bar at pubic peduncle	322	—
Length of ilium in <i>C. cutleri</i> (estimated from photograph).....	1124	

It is only from below (Fig. 18) that the dorso-sacral is clearly differentiated from the sacrum proper, for here the centrum is free from the following ones, being separated from sacral I by at least 16 mm. of matrix at its lower margin. There are normally ten sacral centra, although the line of demarcation between the ninth and tenth is not clearly indicated in the present condition of the Yale specimen. In the *C. cutleri* type all are distinct.

The centrum of the dorso-sacral is constricted medially but possesses no pleurocoeles. Ventrally it is flattened and but slightly concave fore and aft. The parapophyses are distinctly indicated and are fused with the horizontally flattened diapophyses which, at their distal ends, are coössified with the ilia. In addition, the dorso-sacral bears a pair of slender, slightly curved ribs which proximally abut against the slightly dilated end of the parapophyses, with which they are in line. Distally these ribs curve slightly forward and unite with the ilia below and a little behind the anterior margin of the latter as preserved. On the left side, the rib extends to the outer margin of the ilium, but the tip is not present and may have jutted slightly beyond the limit of the ilium. The centra of sacra I-III are broad, and flattened inferiorly, being somewhat trihedral in cross section. Numbers V-VII are distinctly narrower and are constricted medially. Sacra VIII-X widen again, the median constriction disappearing in the last. Beginning about the middle of centrum III is a deep median groove which is deepest in the anterior part of IV. It soon fades out, however, but can still be seen at the union of VI and VII. In *Triceratops* this groove begins with centrum II and extends the entire length of the sacrum, being widest in II-IV, where it is also most marked in the Yale *Centrosaurus*. In *M. crassus*, commencing with the fourth and terminating with the ninth, the inferior surface of the sacrum is broad and shows a median shallow groove somewhat more marked at the junctions of the several centra. The Yale specimen, therefore, differs from both *Triceratops* and *M. crassus* in the fore and aft limits of the ventral median groove, which is noticeably shorter. The *C. cutleri* type is more like *M. crassus* in this respect.

The heavy parapophyses which support the pubic peduncle arise on the side of centrum II, but bear equally on II and III in the form of a triangular web of bone which covers the entire length of each vertebra. The second, third, and fourth parapophyses arise at the junctions of centra III to VI inclusive. The second and third sweep backward to join the acetabular bar while the fourth buttresses the ischiac peduncle and is perpendicular to the axis of the sacrum. This is especially true

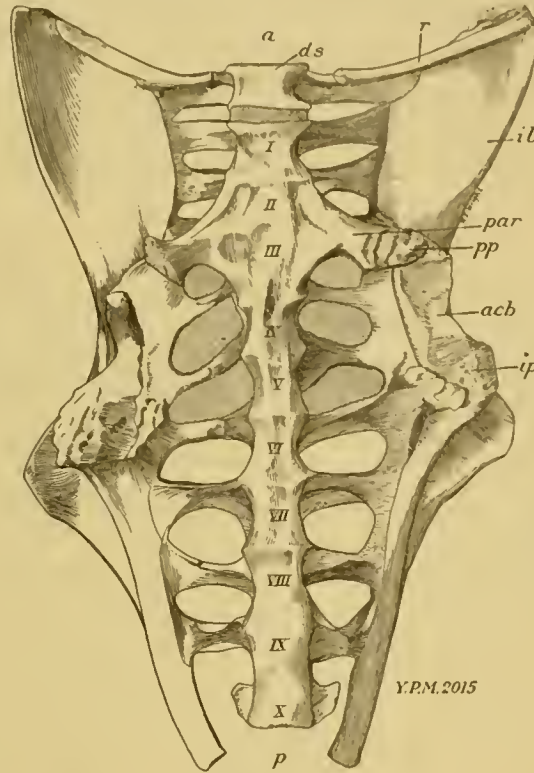


FIG. 18.—Sacrum and ilia of *Monoclonius* (*Centrosaurus*) *flexus*. Ventral view, $\frac{1}{8}$ natural size. *a*, anterior; *p*, posterior; *acb*, acetabulum; *ds*, dorso-sacral vertebra; *il*, ilium; *ip*, ischiac peduncle; *par*, parapophysis; *pp*, pubic peduncle; *r*, rib of dorso-sacral vertebra; I-X, sacral vertebrae.

of the right half of the sacrum, as Figure 18 shows. In all of this, the Yale specimen agrees essentially with *M. crassus* and to a less extent with *Triceratops*. In the last, the form of the first parapophyses differs in that they arise almost entirely from centrum II and do not have the triangular shape as seen from below, being more nearly cylindrical and somewhat dilated distally. The parapophyses of V to VII in *Centrosaurus* arise opposite the junctions of centra VI to IX. Number V is narrow fore and aft and forms a triangular buttress to the diapophysis. Number VI is somewhat less deep but wider, while number VII is the widest. Parapophyses of VII to IX are broadened distally and fuse with the ilia. That of sacral X arises apparently in the middle of the centrum instead of at the junction with the one before, and does not reach the ilium. This is in agreement with *Triceratops*. The acetabular bar, formed by the fusion of parapophyses I to IV, unites with the ilium, but with a distinct suture, and forms part of the acetabulum. Both pubic and ischiac peduncles are thus formed in part by the sacral and in part by the iliac elements.

CAUDALS

Except for a few proximal vertebrae and other scattered centra, the caudal series and their chevrons in the Yale specimen of *Centrosaurus* have been restored from the type of *C. nasicornus* of the American Museum. Brown's description of the latter follows: "The caudal series is complete

and is composed of 46 vertebrae including the minute terminal centrum. 23 of the anterior caudals bear transverse processes. The centra and spines of the caudal series decrease in size uniformly from the last sacral vertebra down to the 45th. The 46th apparently does not have a spine. The centra of the last 12 caudals are proportionately longer than high, slightly cupped on the anterior end with a corresponding ball on the posterior end and the spines of these last 12 vertebrae are likewise elongated anteroposteriorly. The spines in the caudal series are in height equal to the length of the corresponding chevrons.²⁰

APPENDICULAR SKELETON

CORACOID

(Fig. 19)

Both coracoids are present, the left being somewhat crushed so that the transverse diameter is lessened and the bone is more concave than normally. In the Yale specimen the coracoids are not fused with the scapulae as they would be in an older individual such as the *Monoclonius crassus* type

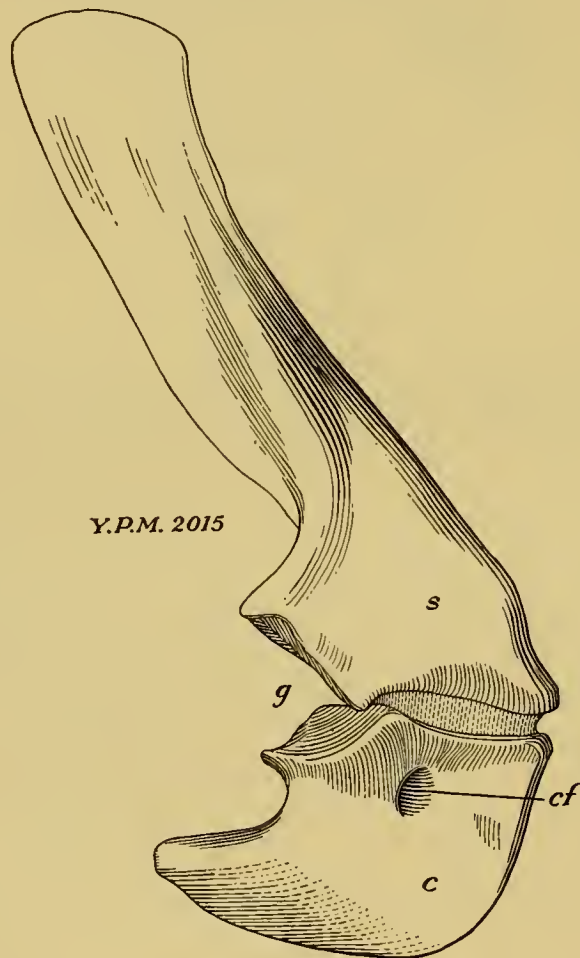


FIG. 19.—External view of right scapula and coracoid of *Monoclonius* (*Centrosaurus*) *flexus*, 1/6 natural size. *c*, coracoid; *cf*, coracoid foramen; *g*, glenoid fossa; *s*, scapula.

²⁰ Brown, B., 1917, p. 289.

figured by Hatcher.²¹ There, the fusion is complete although the suture is still visible. The form of both coracoids and scapulae in the two species is very similar and the size approximately the same.

The external surface of the coracoid is somewhat convex except toward the scapular surface and that of the glenoid fossa, where the bone thickens rapidly and as a consequence becomes concave. The internal surface is concave throughout. The outline agrees with that of *M. crassus*, having the same posterior hook-like process. Hatcher describes the coracoid foramen as midway between the anterior and posterior borders, directly opposite the point where the coraco-scapular suture joins the glenoid surface. Internally, the foramen opens at the coraco-scapular suture. Externally, the coracoid of the Yale specimen agrees; internally, however, the right coracoid (restored) shows the foramen about 20 mm. away from the suture. The left coracoid is more in agreement and is probably the more correct. There is no essential disagreement with *Centrosaurus nasicornus*.

SCAPULA

(Fig. 19)

The scapulae agree with Hatcher's description of *M. crassus*. The external surface is convex longitudinally, although tending to straighten toward the distal end. The inner surface, concave longitudinally, is deeply so transversely, especially at the proximal third. Hatcher says that the coraco-scapular suture just about bisects the glenoid fossa; with our specimen the greater part of the fossa is formed by the scapula, the lesser by the coracoid. The scapula dilates at the fossa, and is heavy at the proximal end, thinning out at the distal end of the blade. There is in each case a slightly rugose area just above the glenoid fossa from which a low (Hatcher says prominent²²) ridge extends obliquely outward toward the anterior edge at the distal end. In *Triceratops*, this ridge arises in the same manner, but curves at about one-third of its length in such a way that it terminates at the middle of the distal end of the blade instead of toward its anterior edge. The scapula of the contemporary *Chasmosaurus* agrees with that of *Centrosaurus* in this respect, whereas the ridge in the Edmonton genus *Anchiceratops* does not reach the anterior border and tends toward the condition found in *Triceratops*, thus showing an evolutionary trend.

DIMENSIONS

Coracoid	<i>C. flexus</i> Y.P.M.	<i>M. crassus</i>
Antero-posterior diameter	365 mm.	336 mm.
Transverse diameter	217	176
Coraco-scapula		
Over-all length	810	840

STERNUM

Additional morphological data concerning *Triceratops*, learned since the writing of the *Ceratopsia Monograph*, include but three items, the sternal plates, a hyoid element and the complete pes. The first were actually made known before the publication of the *Monograph* but the description of them was not included. Our knowledge of these elements is based upon the discovery of a very imperfect *Triceratops* skeleton, without skull, found by the American Museum of Natural History expedition of 1902 in the Hell Creek region of Montana, about a mile from the locality of the *T. serratus* skull (No. 970 A.M.N.H.) described by the author²³ in 1903.

²¹ Hatcher, Marsh, Lull, 1907, Fig. 84.

²² Hatcher, Marsh, Lull, 1907, p. 79.

²³ Lull, R. S., 1903.

These sternal plates have been figured and described by Brown.²⁴ They "are paired, elongate, and symmetrical except where distorted by crushing. One end terminates in a point which is restricted and enlarged with the rough portion most extensive on the visceral surface, and stands away from the body of the plate. The opposite end is thickened and rugose at the outer angle but thins rapidly toward the inner border which is very thin and nearly straight. The outer border is thickened, smooth and slightly concave. The ventral surface or outside of the plate is convex transversely while the dorsal or visceral surface is concave. Both are smooth. A deep incision on the visceral surface near the broad end of each plate may represent a foramen or a deep ligamentous attachment." Apparently "the pointed end extended forward with the enlarged point attached to the terminal curved portion of the coracoid. When placed thus with the thin inner borders meet-

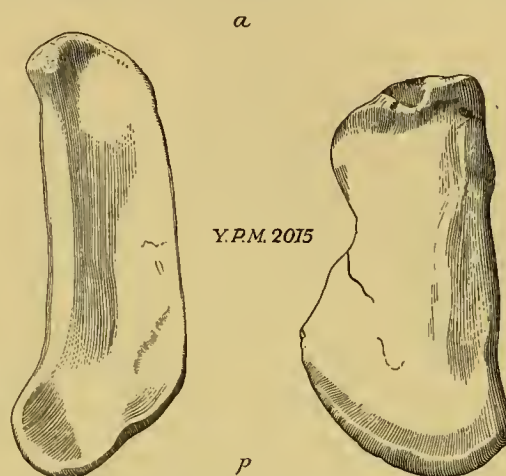


FIG. 20.—Sternals of *Monoclonius* (*Centrosaurus*) *flexus*. Ventral view, 1/6 natural size. *a*, anterior; *p*, posterior.

ing in the median line the width of the body cavity is determined at this point and the position of the coracoids is approximately fixed. . . . In the Jurassic Dinosaurs, *Brontosaurus*, *Morosaurus* and *Diplodocus*, the sternal plates were firmly united in the median line by cartilage as indicated by the long straight rugose inner border. But *Triceratops* presents an entirely different type of sternum in which the median borders of the sternals as well as the body of the plate are extremely thin and not coössified. . . . The deep anterior emargination of these plates indicates the presence of an inter-clavicle." Subsequent, very complete ceratopsian skeletons have not, however, disclosed this element. "The external third of the plate is thick and formed its chief strength, while the uniformly smooth surface shows that there was no lateral attachment of cartilaginous ribs as in the Ratitae. This rib attachment was clearly formed at the posterior end of the plate, probably direct without the intervention of a xiphisternum, for the thick posterior end seems subdivided as for rib attachments."

The two sternal bones of *Centrosaurus flexus* (No. 2015 Y.P.M.) (Fig. 20) do not appear to be mates, as they differ so markedly in contour, and in color and general appearance, doubtless as a result of conditions of preservation. The left, which is much the shorter of the two, retains apparently more of the original form, as there is little restoration on it. To what extent its outline is eroded away can not be determined. It is in essential agreement with the sternal in *Triceratops* and in *C. nasicornus* except for an emargination of the inner border, where the bone is extremely thin and may therefore have lost some of its former extent. The right, however, is relatively longer and narrower and lacks the emargination, so that in this latter respect it is in closer agreement with Brown's figures. It resembles that of *C. cutleri* except that the distal end is not so wide.

²⁴ Brown, B., 1906, pp. 297-300.

The sternals of *C. nasicornus*, according to Brown,²⁵ consist "of two broad flat plates, each plate having a thick external border and a thin internal border for articulation with its mate. The anterior end is thickened on the external border for articulation with the process of the coracoid, while the distal end is thick and shows on the ventral surface indentures for the attachment of the cartilaginous ribs." These indentures are not recognizable in the Yale specimen. "The dorsal surface of each plate is flat and the ventral surface is marked by a low ridge that extends from the proximal to the distal end near the outer border. There was probably no intermediate cartilaginous element."

DIMENSIONS OF STERNALS

	<i>C. flexus</i> No. 2015 Y.P.M.		<i>C. nasicornus</i> No. 5351 A.M.N.H.	<i>C. cutleri</i> No. 5427 A.M.N.H.	<i>Triceratops</i> No. 971 A.M.N.H.
	left	right			
Length	318 mm.	354 mm.	330 mm.	450 mm.	580 mm.
Greatest width					
Proximal end	129	107	110	110	—
Distal end	159	140	160	180	220 (at middle)

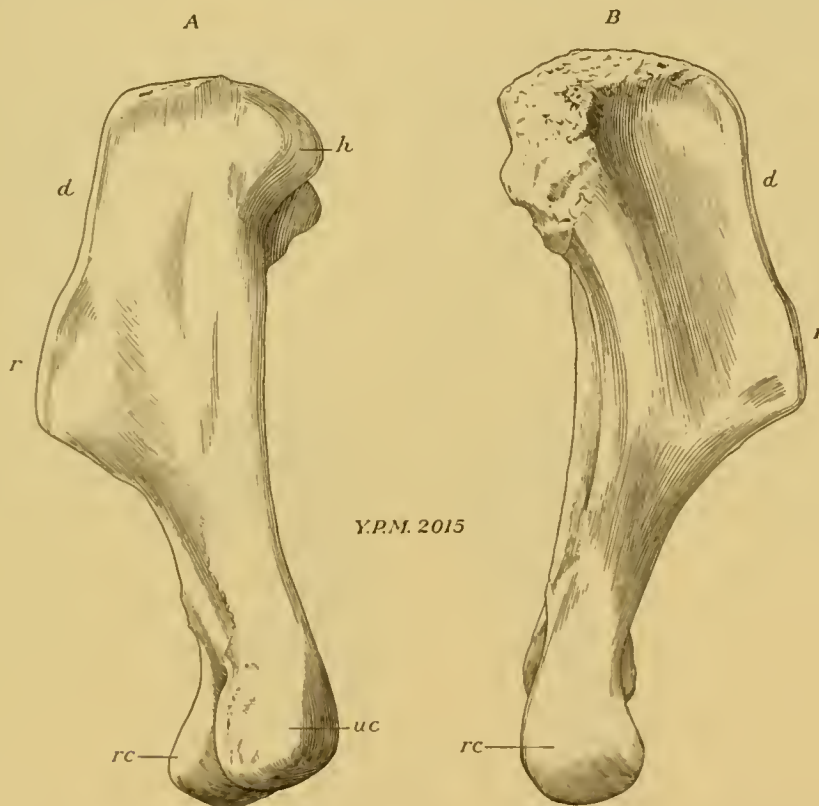


FIG. 21.—Left humerus of *Monoclonius* (*Centrosaurus*) *flexus*. A, external view; B, internal view; 1/6 natural size. d, deltoid ridge; h, head; r, radial crest; rc, radial condyle; uc, ulnar condyle.

HUMERUS

(Fig. 21)

Both humeri in the Yale specimen are comparatively well preserved, with little restoration, though the right one is somewhat distorted by crushing. The left humerus agrees essentially with

²⁵ Brown, B., 1917, p. 292.

Hatcher's description of that of *Monoclonius crassus*.²⁶ The humerus is a heavy bone with a very prominent deltoid ridge which is continued into the radial crest and extends more than halfway toward the distal end. In *Triceratops* the radial crest bears a separate rugosity quite distinct apparently from the deltoid ridge, whereas in *Monoclonius* including *Centrosaurus* the two combine more or less into the deltoid ridge. The head is a comparatively small, almost hemispherical eminence which lies within the median half of the proximal end and looks backward at right angles to the shaft of the bone, so that the humerus during life must have been nearly horizontal in position. In this respect it agrees with that of *Chasmosaurus*, but differs from that of *Triceratops* in which the head seems to merge into the summit of the bone, implying that the normal angulation of the shoulder was greater than a right angle.

Another crest comparable to the deltoid ridge lies on the extensor side of the head of the humerus but continues little more than half as far as does the former. Distally, the trochlear end of the humerus is well developed, the radial condyle being the more prominent. Here again there is indication that extreme flexion of the elbow joint was habitual.

There is little if any distinction between the humerus under discussion and that of *M. crassus* except that the latter seems more robust. It differs markedly from *Triceratops* in its greater slenderness and especially in the conformation of the proximal end.

DIMENSIONS OF HUMERUS

	<i>C. flexus</i> No. 2015 Y.P.M. left	<i>M. crassus</i> No. 3998 A.M.N.H.	<i>C. nasicornus</i> No. 5351 A.M.N.H.	<i>Triceratops</i> ²⁷ No. 4842 U.S.N.M.
Length	585 mm.	560 mm.	600 mm.	776 mm.
Width across radial crest	180	205	—	312.4
Least width of shaft	99	85	—	—
Width across trochlear end	195	—	—	364
Length of deltoid ridge and radial crest	275	—	—	412

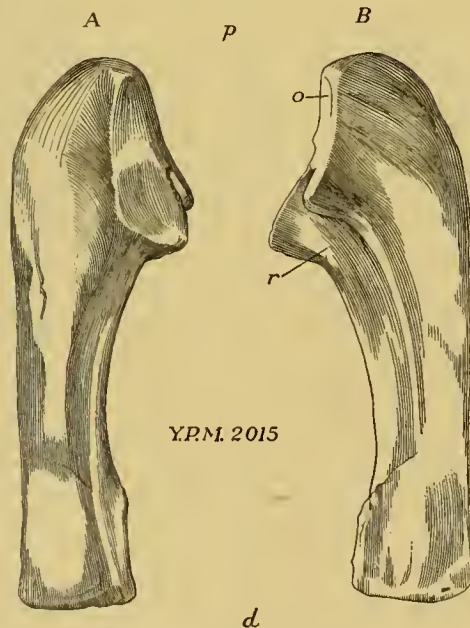


FIG. 22.—Left ulna of *Monoclonius* (*Centrosaurus*) *flexus*. A, posterior view; B, anterior view; 1/6 natural size. p, proximal extremity; d, distal extremity; o, olecranon; r, surface for proximal end of radius.

²⁶ Hatcher, Marsh, Lull, 1907, pp. 79-80.

²⁷ Estimated from figure.

ULNA

(Fig. 22)

The general character of the ulna is not unlike that of *Triceratops* except that it is much less robust, and the olecranon process, as preserved, is much less pronounced, occupying little more than one-third the total length of the bone, whereas in *Triceratops*, measured in the same way, it is about one-half. The ulna of *Centrosaurus* has a somewhat curved shaft, flattened distally. As preserved, there is a longitudinal hollow on the inner face and a corresponding low ridge on the outer face which disappears in the distal third of the bone. Proximally, this ridge culminates in a high crest which, together with the anterior margin of the bone, bounds a deep depression to receive the proximal end of the radius. The olecranon seems to be defective as it does not begin to show the massiveness of that of *Triceratops*, either relatively or actually.

DIMENSIONS OF ULNA

	— <i>C. flexus</i> Y.P.M.—		<i>C. nasicornus</i>
	left	right	
Length over all	437 mm.	457 mm.	450 mm.
Greatest width			
Proximal end	156	—	—
Distal end	96.5	—	—

RADIUS

(Fig. 23)

Both radii are fairly well preserved, especially the left. The radius is a slender, slightly curved bone dilating proximally to form the humeral facet, the superior aspect of which is concave to receive the radial condyle of the humerus. Distally, the radius is somewhat flattened. At mid-shaft, on the other hand, it is trihedral in section. Several roughened areas occur for muscle attachment.



FIG. 23.—Left radius of *Monoclonius* (*Centrosaurus*) *flexus*. A, posterior view; B, anterior view, 1/6 natural size. p, proximal extremity; d, distal extremity.

DIMENSIONS OF RADIUS

Length over all	345 mm.
Greatest proximal width	83
Greatest distal width	99

MANUS

(Figs. 24, 25)

The left manus is almost entire, including the two carpalia, only five phalanges being missing and these have been restored. The right manus, on the contrary, contains but two actual bones. The bones of the manus differ very little from those described by Brown for *C. nasicornus*.

Distally, the metacarpals are rugose, implying, as Brown has said, considerable cartilage there as well as in the wrist, where but two small osseous elements were apparently present. These evi-

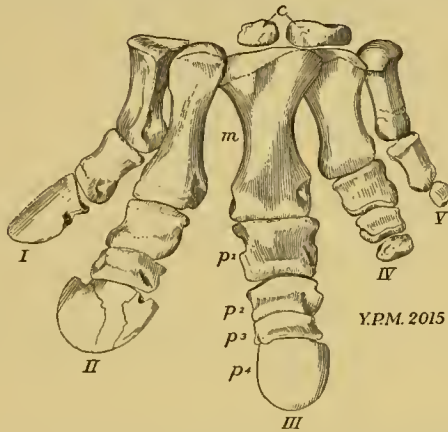


FIG. 24.—Anterior view of left fore foot of *Monoclonius (Centrosaurus) flexus*, 1/6 natural size. *c*, carpalia; *m*, metacarpal; *p*¹-*p*⁴, phalanges; I-V, digits.

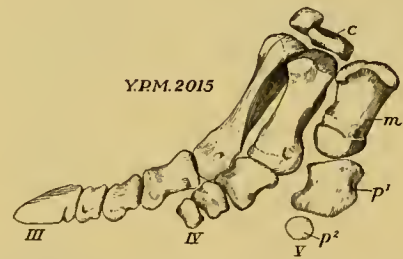


FIG. 25.—Lateral view of left fore foot of *Monoclonius (Centrosaurus) flexus*, 1/6 natural size. *c*, carpalia; *m*, metacarpal; *p*¹, first phalanx; *p*², second phalanx; digits III, IV, V.

dently pertained to the distal row of carpalia. Of these the larger has more or less smooth opposite surfaces, otherwise it is deeply pitted and irregular. The lesser carpal has about one-half the bulk of the latter—a highly irregular nodule of bone. In Brown's restoration of the manus²⁸ the larger carpal lies over the proximal end of metacarpal IV, the smaller over III. In the specimen of *Anchiceratops* in the Ottawa museum, which was found with all the skeletal bones articulated *in situ*, the carpalia correspond both in number and position to those of *Centrosaurus*, which corroborates Brown's description of what and where they were. The larger probably represents carpal IV, the smaller carpal III.

As the measurements show, the manus of the two specimens, *C. nasicornus* and *C. flexus* (Yale), average about the same size.

The phalangeal formula was 2, 3, 4, 3, 2. Flattened ungual phalanges were borne on digits I-III, those of IV and V being reduced to nodules only, but digit IV must have aided in bearing the creature's weight and perhaps also digit V to a lesser extent. The entire foot was enclosed in a weight-absorbing cushion although, unlike that of an elephant, the three hoofed digits protruded in front as our restoration (Pl. II), based in part on footprints, shows.

²⁸ Brown, B., 1917, Pl. XII.

MEASUREMENTS OF MANUS

	<i>C. nasicornus</i>	<i>C. flexus</i> Y.P.M.
Length of metacarpal I	83 mm.	88 mm.
Length of metacarpal II	127	127.7
Length of metacarpal III	130	131
Length of metacarpal IV	99	101
Length of metacarpal V	80	76
Length of phalanx I, digit 1	56	54
Length of phalanx I, digit 2	64	66.4 ²⁹
Length of phalanx II, digit 1	46	35
Length of phalanx II, digit 2	30	31.5 ²⁹
Length of phalanx II, digit 3	55	56
Length of phalanx III, digit 1	38	40.5
Length of phalanx III, digit 2	27	29
Length of phalanx III, digit 3	20	absent
Length of phalanx III, digit 4	41	56.5
Length of phalanx IV, digit 1	34	30
Length of phalanx IV, digit 2	21	20
Length of phalanx IV, digit 3	18	16
Length of phalanx V, digit 1	43	43 ²⁹
Length of phalanx V, digit 2	13	13 ²⁹

ILIUM

(Figs. 17, 18)

The ilia of *Centrosaurus* have much the same general form as in *Triceratops* in that they are elongated fore and aft and the blade is horizontal in position. In *Centrosaurus* that portion of the blade forward of the pubic peduncle is relatively longer and more slender. Brown considers this a generic character; it does differentiate *Centrosaurus* from *Triceratops*, but not from *Chasmosaurus*, with which he was apparently unfamiliar. Thus, in *C. nasicornus*, as mounted, the forward end of the ilium nearly covers the last presacral, as it does also in the Yale specimen and in the *C. cutleri* type. In *C. nasicornus* the ilium reaches the antipenultimate rib; in *Chasmosaurus*, it covers the penultimate, but falls short of the rib in front, whereas in *Anchiceratops*, it just overlaps the last rib, but does not cover it. Doubtless the curvature of the ribs, as preserved, controls this to some extent, but the evolutionary tendency seems to be a relative shortening of this portion of the ilium; otherwise, the resemblance in all Ceratopsidae is very marked. The entire ilium has a greater downward curve in the *C. nasicornus* type, especially in this anterior portion, than in any other known species.

PUBIS

Both pubes (Fig. 26) are well preserved in their entirety, including the postpubes. They are relatively more slender than in *Triceratops*, especially in the distal half of the more elongate postpubis. The prepubis has a straight shaft which dilates toward the anterior end in a gentle curve in contrast to the more abrupt widening in *Triceratops* and in *C. nasicornus*. The anterior margin is somewhat curved, rugose, and apparently does not articulate with a rugosity on the penultimate rib as it does in *Chasmosaurus*. The prepubes flare strongly outward so that the postpubes have a decided curve proximally and are not in line with the prepubic shaft. The greatest vertical diameter of the postpubis is at mid-length, whence it tapers in both directions, especially distally.

DIMENSIONS OF PUBIS

	<i>C. flexus</i> Y.P.M.	<i>C. nasicornus</i>	<i>C. cutleri</i>
Length, excluding postpubis	434 mm.	450 mm.	500 mm.
Length, including postpubis (measured on the chord)	617	—	—

²⁹ Artificial.

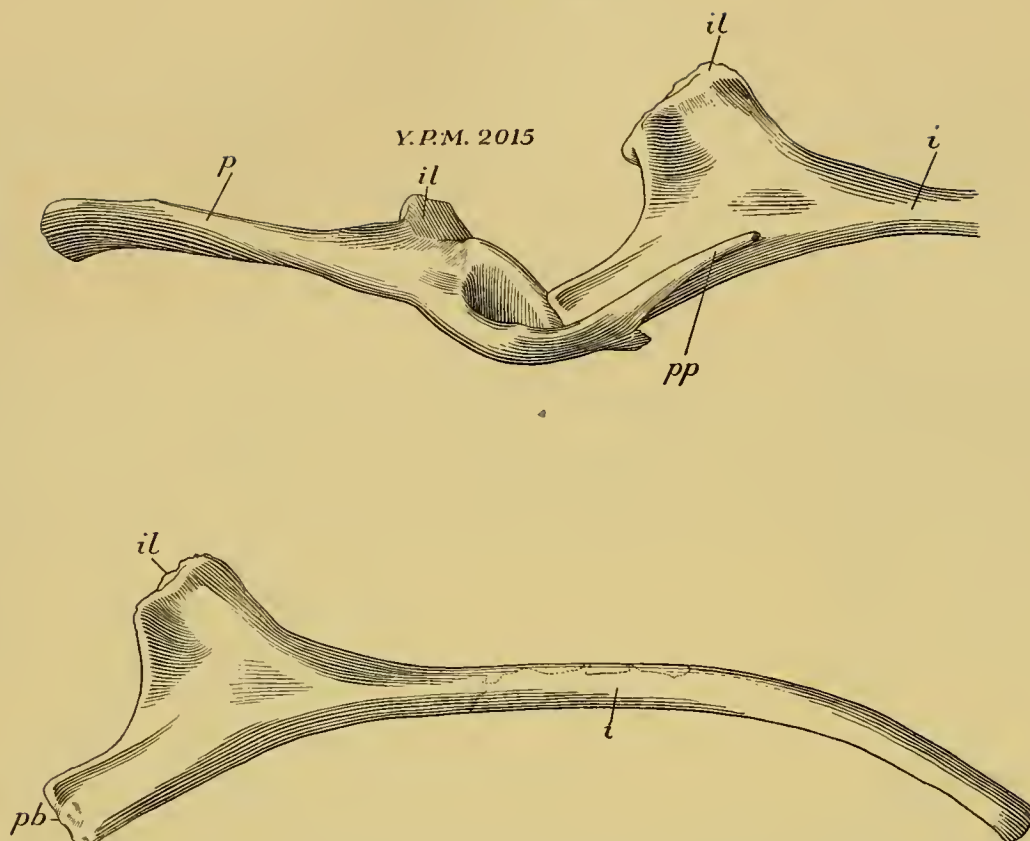


FIG. 26.—Right pubis and ischium of *Monoclonius* (*Centrosaurus*) *flexus*, viewed from the inner surface, 1/6 natural size. *i*, ischium; *il*, facet for articulation with ilium; *p*, pubis; *pb*, facet for articulation with pubis; *pp*, postpubis.

ISCHIUM

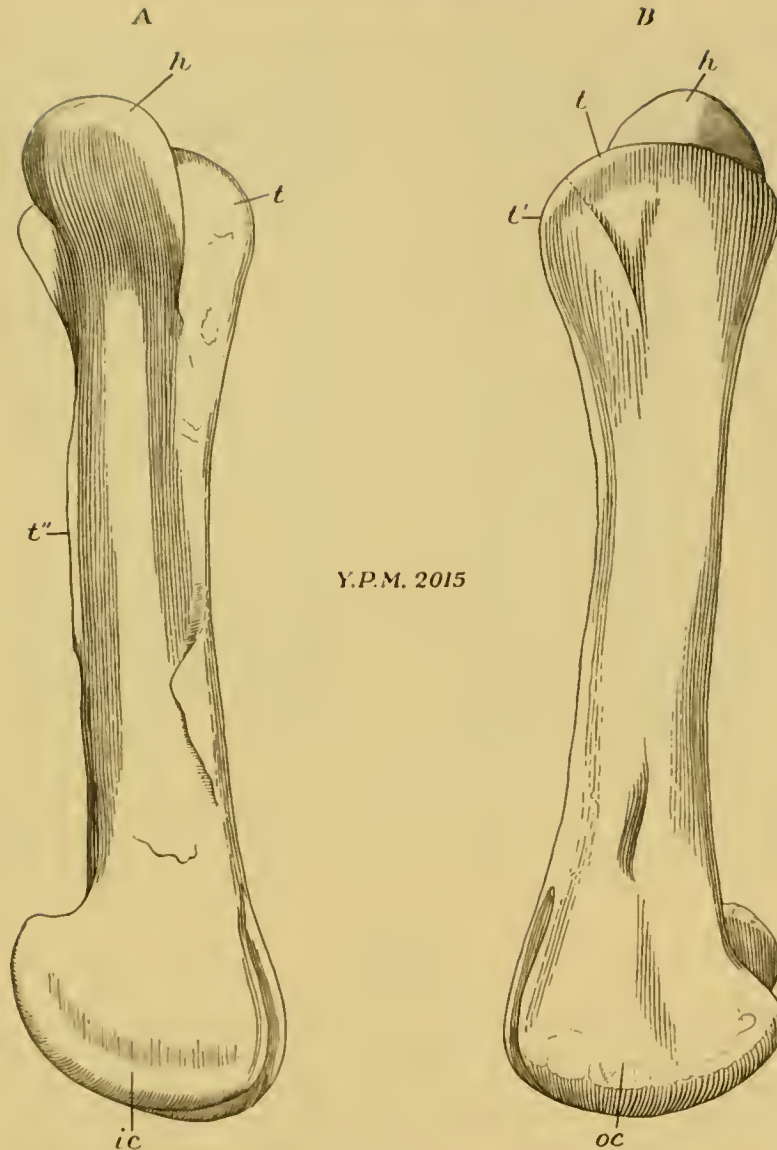
(Fig. 26)

The proximal halves of both ischia are present in the Yale specimen, with clean-cut breaks. As preserved, they seem to agree more nearly with *C. cutleri* and *Monoclonius crassus* in being straighter than in *C. nasicornus*. In the latter, the shaft, viewed from the side, has an almost uniform curve, increasing somewhat distally, whereas in *C. cutleri* the bone is straighter until the extreme end is reached, when the curve is very marked and the end dilated, recalling the hammerhead-like termination seen in the crested trachodons of the Belly River.³⁰ *Chasmosaurus* (Pl. XIV, B), as mounted in Ottawa, also possesses this type of ischia, while *C. nasicornus* is more like *Triceratops* in this respect. Proximally, there is little distinction between the ischia belonging to the several *Centrosaurus* species. The surface for articulation with the pubis is smaller and lighter than the iliac facet, which is continued into a rugose area on the outer aspect of the bone. There is a corresponding rugosity on the outer aspect of the pubis.

DIMENSIONS OF ISCHIUM

	<i>C. flexus</i> Y.P.M.	<i>C. cutleri</i>	<i>C. nasicornus</i>
Width across proximal end	250.0 mm.	— mm.	— mm.
Least diameter of shaft	35.0	—	—
Greatest diameter of shaft	57.5	—	—
Iliac peduncle to end (measured on curve), estimated	770.0	800.0	740.0

³⁰ This feature Nopsca (1929 B) considered indicative of the male sex, those which did not possess it being females. Unfortunately for his argument, however, all known specimens of the Lance genus *Trachodon* would be females!



Y.P.M. 2015

FIG. 27.—Left femur of *Monoclonius* (*Centrosaurus*) *flexus*. A, internal view; B, external view, 1/6 natural size. h, head; ic, inner condyle; oc, outer condyle; t, great trochanter; t' lesser trochanter; t'', 4th trochanter.

FEMUR

(Fig. 27)

The left femur in the Yale specimen is entire, but quite badly crushed from side to side, especially at the distal end. The head is also eroded, so that its dimensions do not equal those of the right. The latter has the great trochanter and the distal end restored. Hatcher figures but does not describe the femur of *M. crassus*, for he found none among the bones corresponding to Cope's original description, as they are too long and, according to Hatcher, out of proportion to the tibia.³¹

The femur of the Yale specimen resembles the figure of *M. crassus* except that it appears to be relatively more slender. This may be due in part to the fact that the two bones are crushed differ-

³¹ Judging from Hatcher's figures (1907, Fig. 86), however, the proportions are about the same as in *C. nasicornus* i.e., femur:tibia::7.4:6.

ently, the first from side to side, the second from front to rear. In *Centrosaurus cutleri*, Brown³² describes the femur as "flattened but the general form is well preserved, displaying a long, straight shaft with a large head that rises slightly above the level of the great trochanter. The lesser trochanter is separated from the great trochanter by a narrow cleft and terminates slightly below its summit. The fourth trochanter is a faint elevated ridge about six inches long that terminates a little below the middle of the shaft. The distal end of the femur curves inward from the line of the shaft and the inner condyle appears to be larger than the outer condyle, a condition which if true is the reverse of *Triceratops*. The crushed femora in the type specimen of *C. nasicornus* fail to settle this point." In the Yale femora the agreement with *C. cutleri* is essential except that the shaft is not flattened and the fourth trochanter seems to be lower down than in *C. cutleri*. The length of each is about the same as is the ratio of femoral to tibial length. In the femur under discussion, that is, the left, the inner condyle is eroded and crushed in such a way that the outer one is much the larger, agreeing with *Triceratops* but the reverse of Brown's description of *C. cutleri*, whereas in the right femur the restorers have made the inner condyle the larger, agreeing with *C. cutleri*. Which of these is correct is not apparent.

DIMENSIONS OF FEMUR

	<i>C. flexus</i> Y.P.M.	<i>C. nasicornus</i>	<i>C. cutleri</i>	<i>M. crassus</i>
Outside length from top of great trochanter to bottom of external condyle	789 mm.	740 mm.	800 mm.	713 mm.
Girth, mid-shaft	320	—	—	—
Width, mid-shaft	85	—	—	—
Fore and aft diameter of shaft	97.5	—	—	—
Width of proximal end	180	—	—	—
Width, fore and aft (at great trochanter)	167	—	—	—
Width, fore and aft (at external condyle)	189	—	—	—

TIBIA

(Fig. 28)

The tibia differs from that of *Triceratops* in being more slender throughout, and having relatively less expansion at the ends. In both genera the distal end of the tibia is widened transversely, there being no antero-posterior increase in the dimensions of the bone. Apparently lacking in *Triceratops*, the calcaneum seems to be present in *Centrosaurus*, *Chasmosaurus*, and *Anchiceratops* although not always distinguishable from the astragalus. Between them, these two bones cover the entire distal end of the tibia in these earlier genera. In *Triceratops*, on the other hand, the calcaneum has either been replaced by, or absorbed into, a heavy, downwardly directed process of the tibia comparable to that of the inner side but, unlike the former, descending somewhat below the level of the astragalus, with which it is in close contact on the latter's external side. This, Hatcher says,³³ "may be regarded as having performed the same functions as did the external malleolus or distal end of the fibula in the mammalia."

The proportionate lengths of tibia and femur vary with the species. In *Triceratops prorsus* (mounted specimen in U. S. Nat. Mus.) the femur is half again as long as the tibia. In *Centrosaurus nasicornus* and *Monoclonius crassus* the tibia is relatively longer, while in *C. cutleri* and the Yale specimen of *C. flexus* the proportions are similar to those of *Triceratops*. Brown believes this relative size to be of at least specific value in this family; Nopsca,³⁴ however, would consider such variation as is here indicated to be sexual. In any case, these proportions form an additional point of similarity between the Yale specimen and the partial skeleton forming the type of *C. cutleri*.

³² Brown, B., 1917, p. 304.

³³ Hatcher, Marsh, Lull, 1907, p. 62.

³⁴ Nopsca, F., 1929, B.

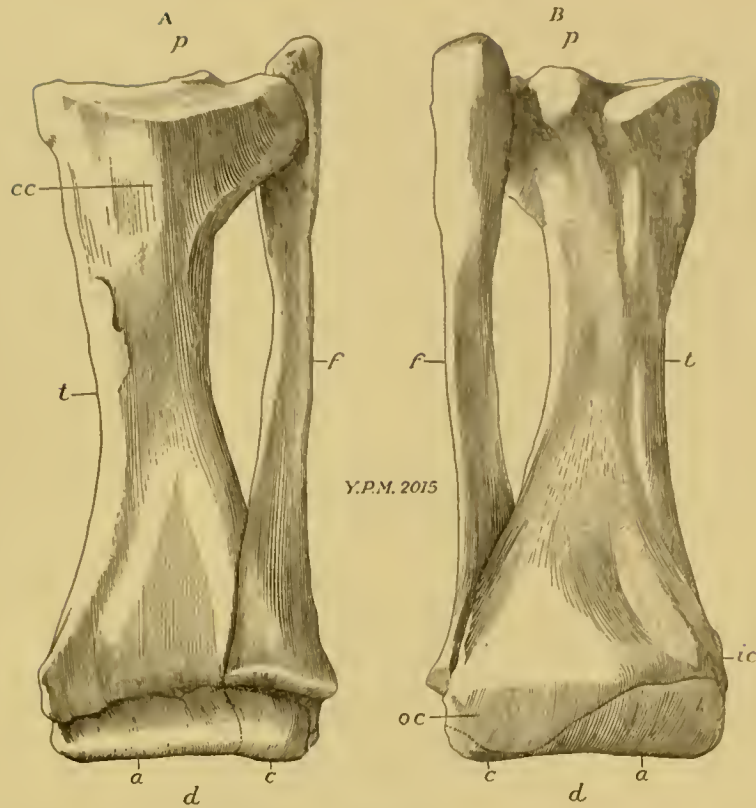


FIG. 28.—Left tibia and fibula of *Monoclonius* (*Centrosaurus*) *flexus*. A, anterior view; B, posterior view; 1/6 natural size. *p*, proximal extremity; *d*, distal extremity; *a*, astragalus; *c*, calcaneum; *cc*, cnemial crest; *f*, fibula; *ic*, inner condyle; *oc*, outer condyle; *t*, tibia.

FIBULA

(Fig. 28)

The fibula is a long, slender bone with a more or less cylindrical shaft and flattened, dilated extremities which lie in planes at right angles to each other. The over-all length is somewhat less than that of the tibia, although the proximal end rises above the articular face of the latter. Proximally, the fibula lies against the outer rear surface of the tibia; distally, against the outer front surface. The distal end articulates with the calcaneum. The shaft of the bone, aside from a certain torsion, is curved toward either end in the reverse direction, proximally toward the rear, and distally toward the front.

DIMENSIONS OF TIBIA AND FIBULA

	<i>C. flexus</i> Y.P.M.	<i>C. cutleri</i>	<i>C. nasicornus</i>	<i>M. crassus</i>
Total length of tibia including astragalus ..	552 mm.	500 mm.	600 mm.	538 mm. ³⁵
Length of fibula	527	460	560	505
Width of tibia				
Proximal end	222	—	—	230 ³⁵
Mid-shaft	93	—	—	—
Distal end	220	—	—	184 ³⁵
Width of fibula				
Proximal end	54	—	—	—
Mid-shaft	34	—	—	—
Distal end	82	—	—	—

³⁵ Estimated from Cope's figure.

PES

Of the tarsalia in the Ceratopsia, but four elements have been discovered, two in the proximal row, the astragalus and calcaneum, and two³⁶ in the distal row of which the larger represents tarsal IV. Hatcher knew only the astragalus among the tarsalia, although he assumed that others were present. His description of the astragalus of *Triceratops* was brief; he says, "It was closely applied and early became coössified with the tibia, covering over the internal two-thirds of the distal extremity of that bone." In *Centrosaurus*, on the other hand, the astragalus covered about three-fourths of the end of the tibia. The astragalus is thick, with a convex distal surface and a concave proximal one. The posterior border is thin and rises higher on the surface of the tibia than does the thicker anterior margin. There is no ascending process, as in certain other groups of dinosaurs.

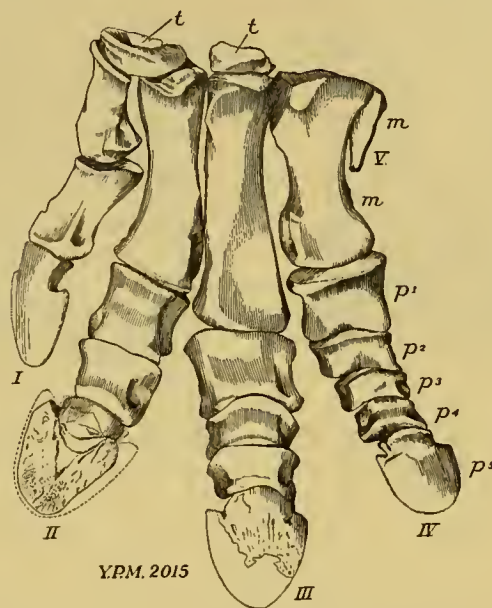


FIG. 29.—Anterior view of left hind foot of *Monoclonius (Centrosaurus) flexus*, 1/6 natural size. *m*, metatarsal; *p*¹-*p*⁵, phalanges; digits I-V; *t*, tarsals.

The calcaneum is a much smaller bone which in the Yale specimen is so closely fused with the astragalus that its presence as a separate element would hardly be detected. It has somewhat the form of the astragalus but does not rise so high on the posterior surface of the tibia. Between them, these two bones cover the entire distal end of the tibia and form a very perfect surface for articulation with the remainder of the tarsus which, however, must have been largely cartilaginous, as the small distal tarsals do not begin to complete this segment of the limb. Of the distal tarsalia the larger, according to Brown, articulated with the fourth metatarsal. The position of the other is doubtful; possibly it lay above metatarsal III.

The left foot (Fig. 29) is practically entire in the Yale specimen, only the fifth metatarsal and the first and fourth ungual phalanges being artificial. Four functional digits are present, all of which are provided with ungual phalanges, as against three in the manus. The fifth digit is vestigial and is represented by the proximal part of the metatarsal only. Thus, the phalangeal formula is 2, 3, 4, 5, 0, which is normal for a predentate dinosaur.

Metatarsal I is short, heavy, and rather irregular, the proximal end somewhat triangular, but with one of the angles rounded. The articular surface is slightly concave. There is a rugose area

³⁶ See, however, p. 69, *Chasmosaurus*.

on the flattened external face of the bone. The distal end is expanded, with the outer aspect concave in the vertical plane. The articular face is quadrangular and turned to look somewhat outward as though the digit divaricated away from the axis of the foot. The first digit could not have borne much if any weight. Metatarsal II is a little longer than IV. The proximal end is elongated antero-posteriorly, the lateral sides flattened and parallel, and the posterior somewhat rounded, with a slightly rugose area opposing that of metatarsal I. The proximal facet is slightly concave as in I. The distal end is dilated, with the distal facet convex antero-posteriorly. The shaft is fairly straight, but tapering fore and aft.

Metatarsal III, evidently the axial one, is the longest. The proximal end is flattened on the inner side, rounded more or less externally except where it makes contact with metatarsal IV. The shaft is slightly curved, with the concave side outermost. The shaft is thickest antero-posteriorly at the proximal end and widens somewhat transversely distally but not as much as in *C. nasicornus*. The bone is somewhat rugose on the proximal half of the inner face.

Metatarsal IV is broadly expanded proximally, and has a flattened shaft, with a distinct keel on the outer face of the distal half. The rear of the shaft is concave, the front only slightly so. There is a triangular, flattened area on the interior aspect for contact with the third metatarsal, which is half as long again.

Metatarsal V is vestigial and about two-thirds the length of metatarsal I. The proximal end is comparatively large and ovate and the shaft laterally compressed, the antero-posterior diameter being three or four times as great as the transverse. The distal end is small and rounded, without trace of articular facet. This bone bore no phalanges and served no other function than to increase the lateral diameter of the metatarsus and thus to aid indirectly in supporting the creature's weight.

The phalanges exhibit nothing unusual. The proximal one of digit I is nearly twice as long as wide, but all of the others are wider than long, except the unguals, which are depressed, spade-like bones. The general pose of both manus and pes is digitigrade. The circumference of the restored foot, with the sole pad, is about 1360 mm., that of the hand is 1090 mm., which makes the plantar area of the pes roughly nearly twice that of the manus and presumably gives an approximation of the relative weight borne by each.

DIMENSIONS OF PES

	<i>C. nasicornus</i>	<i>C. cutleri</i>	<i>C. flexus</i> Y.P.M.
Length of metatarsal I.....	123 mm.	103 mm.	103 mm.
Length of metatarsal II.....	180	200	186
Length of metatarsal III.....	215	230	209
Length of metatarsal IV.....	160	184	160
Length of metatarsal V.....	77	69	73 ³⁷
Length of phalanx I-1.....	101	92	94
Length of phalanx I-2.....	97	—	90.5 ³⁷
Length of phalanx II-1.....	69	64	61
Length of phalanx II-2.....	46	—	50
Length of phalanx II-3.....	93	77	90 partly restored
Length of phalanx III-1.....	60	40	59
Length of phalanx III-2.....	37	—	34.5
Length of phalanx III-3.....	35	—	38.5
Length of phalanx III-4.....	80	—	87 partly restored
Length of phalanx IV-1.....	54	—	59
Length of phalanx IV-2.....	35	—	43
Length of phalanx IV-3.....	32	—	32.5
Length of phalanx IV-4.....	23	77 ³⁸	25
Length of phalanx IV-5.....	69	—	67 ³⁷

³⁷ Artificial.

³⁸ Is it not more probable that this is III-4? It would seem so from the photograph.

MOUNTED SPECIMENS

Two specimens of *Centrosaurus* have been mounted in their entirety, both of which were collected by Barnum Brown. Of these the first is the type of *Centrosaurus nasicornus* at the American Museum, and the second is the specimen which forms the basis of the morphological section of this memoir, *Centrosaurus flexus*, at Yale.

C. nasicornus is a slab mount exposing the right side of the skeleton in the posture in which it was found. *C. flexus*, on the other hand, is a "plastic mount," that is, the skeleton is fully articulated and may be viewed from the left side, while the right has been clothed with a synthetically constructed restoration of the animal in the flesh.

The American Museum mount (Pl. IX, A) is admirably executed, but the pose is that of death rather than of life, as though the creature were lying on its side with the neck flexed dorsad much more than when living. The pelvic elements are also somewhat displaced, as the ischia are much too near the tail to allow for the posterior outlets of the body. The feet, of course, are not in their normal position. As Brown says,³⁹ it "differs in several important features from the Marsh reconstruction of *Triceratops* and from the composite *Triceratops* skeleton mounted in the National Museum.

"The body is shorter and deeper in the posterior dorsal region, while the feet are more digitigrade with toes turning out, the axis of the manus through digit II and the axis of the pes between digits II and III.

"A *Triceratops* skeleton in the American Museum [Pl. XIV, A] determines the general construction to have been essentially the same in the two genera and the skeletal structure in *Monoclonius* may be considered as typical of the family Ceratopsia."

The Yale specimen, as mounted (Pl. II), differs from that at the American Museum in several particulars which may be in part matters of interpretation and in part due to specific and individual variation. As has been shown, not only are the usual three anterior cervicals fused into a solid mass, but as a result of some pathologic condition the centra of the fifth and sixth vertebrae are also coössified. The latter seem to indicate that the centra cannot have been spaced apart to the extent shown in the New York mount, which precludes the possibility of the strong dorsad flexion of the neck during life. This flexion is often seen in recent as well as in prehistoric animals as a result of postmortem contraction of the ligaments and muscles of the neck. Hence the neck of the Yale specimen is nearly straight, with the centra spaced much more nearly together. The curious backward offsetting of the neural arch in the vertebrae of the back in this specimen has resulted in a certain obliquity of the vertebral centra of this region which may or may not be correct. The sacrum has been given a more nearly horizontal pose and the tail as a result does not droop at its base, which, together with the position of the ischia, gives ample clearance as compared with the American Museum specimen. The anterior long rib (cervical VIII) has a curious reversed curve. This has evidently been placed at the posterior end of the series in the specimen at New York. The character of the proximal end of this rib, however, determines its position, in addition to which the actual posterior one is in position, fused with the ilium, both in the Yale specimen and in the *Centrosaurus cutleri* type. The penultimate rib in both of the latter specimens is highly peculiar as it has a remarkable backward curve extending through nearly half a circle. This is not shown in the type of *C. nasicornus* or in any of the other six ceratopsian skeletons which have been mounted. It was evidently a specific character.

In placing the feet, reference was made to what may well have been ceratopsian footprints discovered by C. M. Sternberg⁴⁰ on Peace River, British Columbia, in strata correlated with the lower Blairmore of middle Lower Cretaceous age. These footprints, which are those of a quadruped, as opposed to the associated tridactyl bipedal tracks, and which Sternberg calls *Tetrapodosaurus borealis*, agree in character, in length of stride, and in width of trackway with our conception of such

³⁹ Brown, B., 1917, p. 300.

⁴⁰ Sternberg, C. M., 1932, p. 74, Pl. V, Fig. 8.

an animal as *Centrosaurus*. They were made by a digitigrade form and exhibit the correct number of digits. The rear pad-like part of the foot, however, did not make a full impression, which is understandable, as the toes would dig into the sand somewhat more deeply at the end of the step when the heel of the foot was lifted from the ground. At the same time the fore foot, which may have toed in at first, would be brought into line with the hind foot. The animal is therefore posed with an easy stride, with the elbows flexed and bowed outward, and the humerus nearly horizontal. The hind limb, on the other hand, was nearly straight, with a slight flexing of the knee at the beginning of the stride, before the weight was fully borne. All four feet are on the ground although the several feet probably struck the ground at slightly different intervals. The normal stride must have been slow, the body swaying in front to bring the weight toward the hand that bore it when the other one was lifted. One imagines the foot movement to have been somewhat shuffling, as with a modern elephant, the feet never rising far above the ground. In charging, the movement must have been more rapid, but only for a short distance.

The head was probably carried low, with the muzzle near the ground. This was determined in part by the articulation of the cervicals, which do not indicate a great deal of intervertebral play, and in part by the direction of the pedunculate occipital condyle, the axis of which must have been carried normally in line with that of the three coalesced anterior cervicals. This is also in harmony with the findings of Tait and Brown based upon the position of the horizontal semicircular canal in *Anchiceratops*.⁴¹ A further discussion of this problem will be found under the section on the Brain and Special Sense Organs, p. 73. The jaws in our specimen have been set somewhat agape.

On the right side the flesh (Pl. II, B) of the animal has been restored. The original modeling was done synthetically, the muscles, especially those of the limbs, being built on from within outward although, as the completed restoration is in the form of a shell, only such as determine the outer contour of the muscular system are preserved. In accordance with my former practice, not only is the entire right side of the head, body, and tail covered by flesh but that of both right and left limbs as well, in so far as the latter may be seen from the right aspect. Thus, when viewed squarely from the right, one gets a complete silhouette of flesh, no bone being visible, while from the left the entire skeleton may be seen, including the inside of the right limbs and the outside of the left.⁴²

In restoring the musculature, reference was made to the very careful studies on "The Pelvic Musculature of Ornithischian Dinosaurs" by Alfred S. Romer,⁴³ as well as to papers on the myology of the chameleon and the iguana by St. George Mivart,⁴⁴ together with some dissection of a young alligator.

The processes at the rear of the crest in this genus were a problem. Brown, in his published drawing,⁴⁵ encloses them in the general integument of the crest, which would require a very considerable thickness of subcutaneous tissue, muscular or otherwise, and which is out of harmony with the bloodvessel impressions on the surface of the crest, since the latter imply a close-fitting, resistant investiture. We have therefore deemed it wise to show these as processes sheathed like the horns, without trying to solve the question of their possible utility. Of course, the horny covering must have overlain the parietal fenestrae, the presence of which is indicated by a slightly depressed area.

In restoring the mouth, we compared the beak and bones of a loggerhead turtle with the rostral and predentary of *Centrosaurus*. With the remainder of the mouth we have varied somewhat from my previous ceratopsian restorations, in which the gape was limited to the prehensile part only, the masticating portion being covered by integument to retain the food in the mouth. But the integument of the face was horny and resistant, and would be either creased and folded over opposite the tooth row when the mouth was closed or, as in the Crocodilia, the gape would apparently extend to the articulation of the jaws. The crocodiles show, when the mouth is open, certain muscular soft

⁴¹ Tait, J., and Brown, B., 1928.

⁴² Note. The photograph of the right or flesh side of the animal has been reversed in the plate, for ease of comparison.

⁴³ Romer, A. S., 1927.

⁴⁴ Mivart, St. G., 1867, 1870.

⁴⁵ Brown, B., 1917, Pl. XIV.

parts at the rear on either side, extending a short distance in front of the limit of the gape. From this we conceived the idea that the same thing would be true of the Ceratopsia, but that the muscular area would extend forward to the anterior limit of the tooth row and so serve, not as cheek pouches, which Hatcher thought might have existed, but merely to retain the chopped food that would otherwise be lost out of the mouth. Incidentally, these are the masseter muscles which also serve in mastication and for which there is abundant indication on the bones of the jaws themselves.⁴⁶

INTEGUMENT

In restoring the external surface, recourse was had to a cast of the skin impression of *Chasmosaurus* received from the National Museum of Canada at Ottawa, and more particularly to the skin which is preserved with the type of *Centrosaurus cutleri* (Pl. III, B) in the American Museum. From the latter dies were cut which could be applied to the soft outer layer of plasteline, leaving a positive imprint comparable to that of the hide itself. The integumentary impression, as preserved in the *C. cutleri* over the flank and over the lower end of the femur, consisted of "small polygonal tubercles and large round tubercles, all low and of the same height. The small tubercles are five or six-sided, close set together and do not grade in size up to the larger, round ones as they do in *Ceratops* [*Chasmosaurus*]. . . . The large tubercles are defined by a circumscribing groove and are uniformly round; they were disposed in rows over a part, probably the ventral surface of the body."⁴⁷ The disposition of these larger tubercles elsewhere is a matter of conjecture and we have shown them in more or less regular rows over the entire animal with the exception of the face. The wrinkling of the inelastic skin has been suggested by various modern reptiles.

CHASMOSAURUS

While a number of skulls of this interesting genus are known in several museums, three skeletons also have been mounted, two in Ottawa, and one in Toronto. The last has not as yet been described or figured, and while it is a praiseworthy attempt, many of the bones themselves, especially the posterior presacral vertebrae, are so badly distorted by crushing that they could not be articulated with one another. The Ottawa specimens (described by Sternberg),⁴⁸ on the other hand, are much more normal and give a very accurate idea of the general morphology of the skeleton, especially as each one supplies supplementary information which the other lacks. The two animals are approximately the same size, though varying slightly in proportions, as the measurements show.

The two skeletons (Pl. XIV, B) stand side by side, one being No. 2245 G.S.C., collected in 1913, and the other No. 2280 G.S.C., collected in 1914. The former is of especial interest in that it constitutes the paratype of *Chasmosaurus belli* as described by Lambe⁴⁹ in 1914, the partial skull being figured at that time.

SKULL

The skull of *Chasmosaurus* departs very widely from that of both *Centrosaurus* and *Triceratops*, and resembles that of *Torosaurus* in the character of the crest. The entire skull is longer and wider but less deep than that of a *Centrosaurus*, although the over-all length of the two animals is nearly the same, e.g., *C. flexus* (Y.P.M.) 17 feet 8 inches, *Chasmosaurus* (No. 2280 G.S.C.) 16 feet 3 inches. The muzzle in front of the nasal horn is notably longer and shallower, and the same is true of the low, flat, crest. The latter is broadly quadrangular, with very long squamosals, longer than in any genus other than *Pentaceratops* and *Torosaurus*. The fenestrae are correspondingly large. The epoccipitals are normal, and there are no enlarged spine-like processes as in the contemporaneous

⁴⁶ Lull, R. S., 1908, p. 389.

⁴⁷ Brown, B., 1917, p. 305.

⁴⁸ Sternberg, C. M., 1927.

⁴⁹ Lambe, L. M., 1914, B, Pls. XIX-XX.

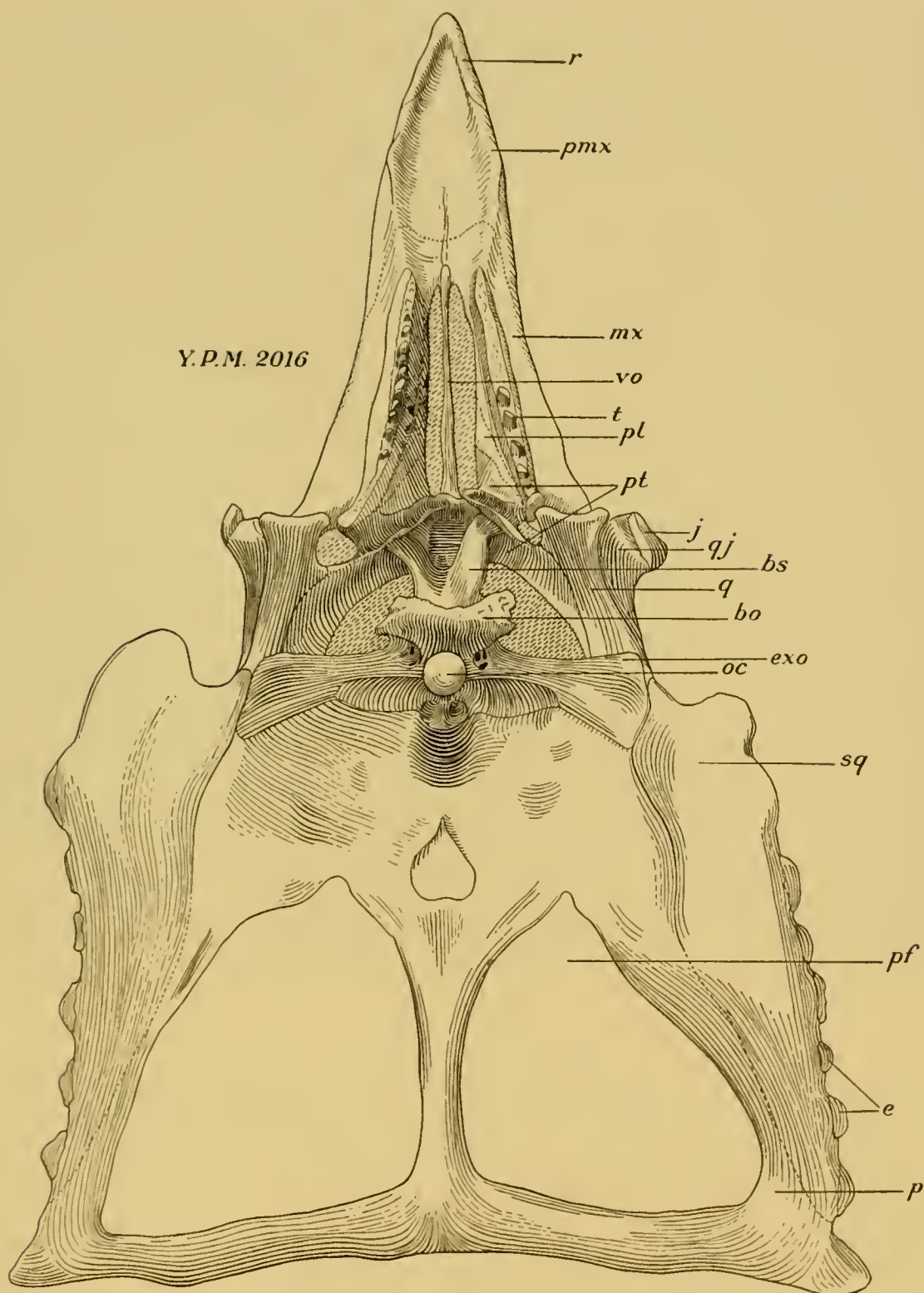


FIG. 30.—Skull of *Chasmosaurus belli*, palatal view, $\frac{1}{8}$ natural size. *bo*, basioccipital; *bs*, basisphenoid; *e*, epoccipitals; *exo*, exoccipital; *j*, jugal; *mx*, maxillary; *oc*, occipital condyle; *p*, parietal; *pf*, parietal fenestra; *pl*, palatine; *pmx*, premaxillary; *pt*, pterygoid; *q*, quadrate; *qj*, quadratojugal; *r*, rostral; *sq*, squamosal; *t*, tooth; *vo*, vomer.

Centrosaurus or *Styracosaurus*. *Chasmosaurus* differs further from both of these genera in having a low nasal horn which may be curved backward. The supraorbital horns, on the other hand, may be more prominent, although extremely variable, ranging from practically nothing (see Pl. VI) to a remarkable pair of *Ceratops*-like horns in a specimen in the American Museum (*Chasmosaurus kaiseni* Brown, No. 5401 A.M.N.H., see Pl. V, A and Fig. 38). These last arise close together, flare outward, and curve strongly forward and upward. In this specimen, the nasal horn apparently consists of three elements, one of which may represent the espinasal, whereas in a companion skull (No. 5402 A.M.N.H.) the nasal horn is more prominent, and without sutures, while the supraorbitals are small, and trihedral in section, with a rounded outer face. All of these horns have deep vascular impressions. The skulls, except for certain minor variations, are quite similar and are certainly generically, but not specifically, identical. At the American Museum, the skull, No. 5401, with small nasal and large supraorbital horns, has been considered a male, the other, with larger nasal and smaller supraorbitals, a female. This so-called male skull has supraorbitals not unlike the type of *Ceratops montanus* from the Judith River beds, which consists of supraorbital horns only, with no other diagnostic parts of the skull preserved. It is the only *Chasmosaurus* skull known in which there is the least correspondence between the two genera, which in itself is not sufficient evidence for their synonymy. This will be further emphasized in the discussion on genera and species (see p. 94).

Reverting to the crest once more (Fig. 30), the large fenestrae lie entirely within the central element (parietal), which is reduced to a rather slender bar of bone between them and a yet more slender portion between fenestra and squamosal on either side. A peculiar feature is an overlapping suture in this lateral bar, about mid-length of the fenestra. This apparently is not a suture between two separate cranial elements, but seems to represent the place of contact of two progressive processes of the same bone, one of which developed backward laterally to enclose the opening, the other forward from the transverse posterior bar to meet, but not fuse with, the first.⁵⁰ A large epoccipital accentuates each postero-lateral angle of the crest and lies just behind the posterior limit of the squamosal. The form of the posterior bar of the parietal varies. Sometimes, as in the Yale and American Museum specimens, it is more or less straight across, again it may be curved so as to form a distinct emargination at the midline as in the Ottawa skull, No. 2280 (see p. 93). The squamosals are long, extending nearly to the posterior corner of the crest, being three or four times longer than wide. The inner border is thickened and rounded and the outer slightly crenulated, bearing seven to nine epoccipital bones. Between the outer and inner margins the after part of the squamosal is depressed, and differs from most of the dorsal surface of the skull in possessing no vascular grooves, another point of similarity with the crest of *Torosaurus*. There are, however, vascular impressions on the surface of the parietal element in *Chasmosaurus* which, together with the possession of epoccipitals, distinguish it from *Torosaurus*, in which the entire crest, except the anterior end, is smooth. The epijugals are prominent.

VERTEBRAL COLUMN

The vertebral column is comparable to that of *Centrosaurus* except for the sudden increase in the height of the neural arches and spines posterior to the crest, i.e., beyond the tenth presacral vertebra. Both have twenty-one presacral vertebrae; the sacrum has the usual ten vertebrae, in four of which (the second to fifth) the parapophyses or sacral ribs coalesce distally to form the acetabular bar as in *Centrosaurus*; behind these are four other fused centra whose transverse processes do not meet the ilium. The anterior fused sacral also has free diapophyses. The spinous process of sacral I is isolated, those of II to VI are fused into a continuous plate, while those of VII to X are isolated again. The sacral ribs all seem to spring from the point of union of adjacent centra, whereas in *Centrosaurus* the last arises from the middle of its centrum.

⁵⁰ In the skull of *Chasmosaurus* No. 2016 Y.P.M., these processes do not meet, hence a portion of the outer margin of the fenestra is formed by the squamosal (see *Torosaurus gladius*, p. 132). This appeared in the course of further preparation of the skull, subsequent to the drawing of the figure.

The caudals seem to have a lighter neural arch than in that of *Monoclonius* figured by Hatcher.⁵¹ The spinous processes are fairly tall, with a gentle decrease, as in *Centrosaurus*.

The shafts of the posterior cervical ribs are quite straight, more so than in *Centrosaurus*, in which the first long rib, borne on presacral VIII, has a curious reversed curve. In *Chasmosaurus*, the first ribs are very peculiar at the proximal end, in that the tubercular process is in line with the straight shaft and is elevated high above the capitular, which in turn arises some distance below, and projects at right angles to the axis of the rib. The result is that in attempting to articulate the rib, the tuberculum could not possibly meet the diapophysis of the vertebra unless the shaft were thrown outward at an utterly impossible angle. The posterior ribs are slender and well arched and the capitular process does not form the right angle with the shaft as in the anterior ribs but is more as in *Centrosaurus*. When articulated with the diapophyses of the vertebrae, the posterior ribs are thrown outward in such a way as to give a flat back and broad abdominal cavity. Thus, the mounted skeletons have a narrow chest and broad abdominal region. But the ribs are almost always subject to postmortem deformation and the diapophyses in the fossil may be bent upward or downward, thus materially altering the shape of the body from that which it possessed in life. The Yale *Centrosaurus*, as mounted, presents a very different appearance, as it is somewhat slab-sided and not at all broad in the abdominal region. One cannot, however, trust too implicitly the curvature of the ribs in their present condition. The last presacral ribs in *Chasmosaurus* differ from those of *Centrosaurus*. The posterior one curves outward and downward, passing beneath, but apparently not fusing with, the ilium. The penultimate rib is much longer and heavier than the last, and curves forward and outward to clear the anterior end of the ilium, according to description, although passing beneath it in No. 2280 G.S.C. Thence it curves backward and slightly inward. At mid-length, this rib thickens and bears a flattened rugosity on its hinder margin for attachment with the anterior end of the pubis. These posterior ribs all lack the decided backward sweep seen in *Centrosaurus cutleri* and the Yale specimen of *C. flexus*.

The only other distinction of note lies in the tarsus where there are three distal tarsalia, but this may be due to preserval rather than a real distinction from *Centrosaurus* in which but two are known.

One peculiarity seen both in the Toronto specimen and in one of the Ottawa animals lies in the proximal end of the humerus, which has not only the large deltoid crest, but a corresponding one on the opposite side of the bone. With the head of the humerus in articulation, this posterior crest impinges against the ribs in such a way that the upper arm could not be swayed backward without either a fracture of the ribs or a displacement of the shoulder. There seems to be something mechanically wrong about either the skeletons or the way they are mounted. This difficulty did not appear in posing the Yale specimen of *Centrosaurus*, in which the posterior crest is smaller and of a different shape. It is quite evident that the coracoids are placed much too far apart in both Ottawa specimens, a point which Mr. Sternberg concedes.

INTEGUMENT

A portion of the integument⁵² was preserved with the skeleton, No. 2245 G.S.C. The section, measuring about 1½ x 3 feet, lay over the pelvic arch and right flank, and extended from a point nor far from the median line. There is no evidence of bony plates in the skin. The surface was covered with "large round plates . . . arranged in irregular, longitudinal rows and . . . spaced from two to four inches apart. They vary considerably in size and are not always distinctly differentiated from the larger polygonal tubercles either in size or shape. The large plates, one of which is two and one-fourth inches in diameter, were low, flat, circular, and are defined by a circumscribing groove. The edges of many of the larger polygonal tubercles as well as the large round plates have a crinkled appearance due to short grooves placed at right angles to, and ending at the edge of the plates. Closely surrounding these large plates are smaller polygonal tubercles giving the appearance

⁵¹ Hatcher, Marsh, Lull, 1907, Fig. 81.

⁵² Lambe, L. M., 1914, A, Pl. XIV.

of a rosette. The intervening spaces were filled with polygonal, tubercle-like, non-imbricating scales of varied but smaller size. In general the large round plates decrease in size from the dorsal surface of the body downward over the femur and ischium though the general arrangement seems to be the same.⁵³

A very interesting flesh restoration of *Chasmosaurus* by L. S. Russell is shown on Plate XVII.

MEASUREMENTS OF *Chasmosaurus*
(From Sternberg 1927, converted into mm.)

	No. 2245 (Geol. Surv., Canada)	No. 2280
Total length of skeleton	4927	4952
Greatest length of skull	1676	1651
Length, occipital condyle to back of crest	864	838
Greatest breadth of crest	1067	991
Greatest length of fenestrae	457	521
Greatest breadth of fenestrae (at center)	286	337
Anterior end of rostrum to center of skull between orbits	635	622
Depth of skull taken just back of nasal horn core, including dentary	381	356
Length of mandible including prementary	—	660
Length of brow horn from upper rim of orbit	—	127
Length of vertebral column measured along tops of spines	4114	4089
Length of presacral vertebrae measured along center of centra	1524	1563
Length of sacrum	724	—
Length of tail measured along centra	1651	—
Height of skeleton at pelvis	1498	1447
Height of skeleton at first dorsal [eighth cervical?]	1193	1219
Length of ilium	965	965
Length of ischium	699	—
Length of femur	749	—
Length of tibia	533	—
Length of fibula	483	—
Length of scapula	679	737
Greatest length of coracoid	—	330
Length of sternum	311	305
Length of humerus	508	546
Length of ulna	432	—
Length of radius	318	—

⁵³ Sternberg, C. M., 1925.

BRAIN AND SPECIAL SENSE ORGANS

The ceratopsian brain is known in at least five excellent instances, four of which are from the skulls of *Triceratops* and one from *Anchiceratops*. Descriptions and figures have been published as follows:

Triceratops flabellatus, No. 1821 Y.P.M., Ceratopsia Monograph, Fig. 31, p. 37, Fig. 33, p. 38

Triceratops serratus, No. 2416 U.S.N.M., Ceratopsia Monograph, Fig. 32, p. 37, Fig. 34, p. 39

Triceratops sp., No. 5740 U.S.N.M., Gilmore 1919 B, Fig. 1; this Memoir, Fig. 31

Triceratops sulcatus, No. 4286 U.S.N.M., brain not figured

Anchiceratops ornatus, No. 5259 A.M.N.H., Brown 1914, Pls. XXXIV, XXXV; this Memoir, Pl. XI

Hatcher says that the brain, compared with the size of the skull, is smaller in the Ceratopsia than in any other known group of vertebrates. This is due in part to the great expansion of the skull beyond the limits of the actual cranium, especially the crest and facial region. In proportion to the cranium alone, the brain size compares favorably with that of other dinosaurs, and in actual size considerably exceeds that of a stegosaur of equivalent body bulk. In *Stegosaurus*, there are marked dilatations of the neural canal in the spinal column; a huge one in the sacrum, at least twenty times the size of the cranial cavity, and a lesser one in the brachial region of the thorax. In *Triceratops*, these dilatations, while present, are by no means so marked, for the tail, which was innervated largely from the sacral nerve mass, is a much smaller organ relatively and had not the offensive and defensive functions in the Ceratopsia which are usually attributed to that of *Stegosaurus*.

From comparisons with studies by Dendy¹ on the mid-section of the skull and brain of *Sphenodon*, Osborn² concludes that "The intracranial cavity in *Tyrannosaurus* corresponds with the outer surface and foldings of the *dura mater* and is thus merely a cast of the outer envelope of the brain, which gives us little idea either of the form or size of the brain itself. The reasonable inference is that the intracranial cast of *Tyrannosaurus* greatly exceeds and possibly doubles in cubic capacity the actual brain which was formerly contained within it.

"In *Sphenodon* the cubic capacity of the *dura mater* envelope appears to be double that of the brain itself. Thus the cast of *Tyrannosaurus* . . . gives us a means of measuring the size of the *dura mater* envelope. It displaces 530 cubic centimeters of water. If the brain proper bore the same proportion to the *dura mater* envelope as that of *Sphenodon*, the bulk of the brain of *Tyrannosaurus* may be estimated at 250 cubic centimeters. The brain proper was extremely small in comparison with the enormous size of the body."

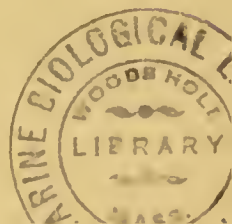
I find that the brain cast of *Triceratops serratus* displaces 300 cubic centimeters of water, which, according to Osborn's conclusions, would give an estimated volume for the actual brain of not more than 150 cubic centimeters. This, I imagine, would give much the same ratio of brain to body bulk as in *Tyrannosaurus*. *Triceratops* and *Tyrannosaurus* were actual competitors in the same environment, so that their nervous and hence psychic requirements would be much the same, but far less than those of a large ungulate and its competitive carnivore, today.

The endocranial casts of both *Tyrannosaurus* and *Triceratops*, but more especially of *Anchiceratops* (Pl. XI), show certain protrusions on the superior and lateral aspects which do not represent cranial nerves but membranous extensions of the *dura mater* into corresponding depressions in the endocranial wall. There is no evidence that the actual brain bore such appendages; they seem to represent spaces for the passage of bloodvessels for cerebral nourishment.

In the ceratopsian brain, the olfactory lobe is large, and the olfactory nerve emerges in the young *T. flabellatus* skull from a single median foramen which, in the types of *T. horridus* and *prorsus*, is divided into two by a median bony partition. But the skulls of *horridus* and *prorsus* are

¹ Dendy, A., 1911.

² Osborn, H. F., 1912, p. 21.



both fully ossified specimens, while that of *flabellatus* is very young, so that the partition may still have been cartilaginous. One assumes that the olfactory nerves themselves were always paired and that the sense of smell was amply developed. The cerebrum, on the other hand, was small in proportion to the bulk of the brain as a whole, which gives evidence of an extremely low grade of intelligence, compared with mammalian standards. The cerebellum is relatively large and is followed by a distinct constriction of the mass, as viewed from above, the cranial cavity expanding again for the reception of the enlarged medulla oblongata. In the region of the constriction lay the otic mass, including the semicircular canals, which are beautifully preserved in the *Anchiceratops* specimen

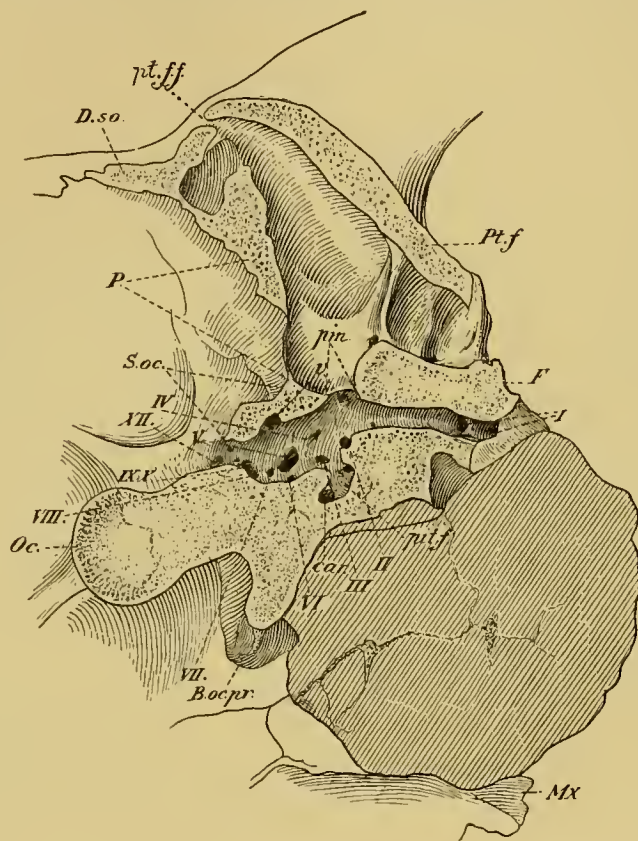


FIG. 31.—Left side of longitudinal section of skull, showing brain cavity of *Triceratops*, from No. 5740 U.S.N.M., about $\frac{1}{8}$ natural size. *B.oc.pr.*, basioccipital process; *car.*, foramen for left carotid artery; *D.so.*, anterior end of dermo-supraoccipital [parietal]; *F.*, posterior portion of frontal; *Mx.*, maxillary; *Oc.*, occipital condyle; *P.*, parietal [supraoccipital]; *pin.*, pineal foramen[?]; *pit.f.*, pituitary fossa; *Pt.f.*, postfrontal; *pt.f.f.*, postfrontal fontanelle; *S.oc.*, supraoccipital [exoccipital]; *e.*, foramina for exit of supposed veins; *I, II, III, IV, V, VI, VII, VIII, IX, X, XII*, foramina for exit of cephalic nerves of corresponding numbers. (Figure and legend after Gilmore.)

(Pl. XI). The foramina for the emission of the cerebral nerves are large and clearly defined, but in the interpretation of some of them Brown, Hatcher, and Gilmore differed, nor am I able to come to any more definite conclusions. Brown's interpretations for *Anchiceratops*, as indicated in the legend of Pl. XI, are the latest and most acceptable.

One innovation in the brain cast of a *Trachodon*, as well as in that of the *Anchiceratops* described by Brown, is the demonstration of the semi-circular canals, the seat of the organ of equilibration. "These canals," according to Brown,³ "have the normal reptilian position and open freely from one to the other with distinct ampullae at the origin, but the horizontal is much shorter and smaller than either the anterior or posterior divisions." The cochlea if present was not preserved. Something

³ Brown, B., 1914, A, pp. 546-547.

in the form of a cochlea must have been present for the perception of sound, but it would not have had the degree of development seen in the birds and mammals. Reverting to the semi-circular canals once more, it is interesting to note that the plane of the horizontal one with reference to the longitudinal axis of the skull has been considered as evidence for the static carriage of the head with muzzle pointed somewhat downward near the ground, a position which we had previously determined as correct upon evidence afforded by the occipital condyle and the fused anterior cervicals, the long axes of which should be in line. The comparatively large extent of the circular or angular sweep of the vertical canals, as opposed to those of the horizontal ones, has been taken as an index of the extent of accelerated movement habitually carried out by the animal in the plane and in the directed sense of the canal itself. The conclusion is, therefore, "that *Anchiceratops* vigorously swung its head about a vertical axis to a far less extent than about horizontal axes."⁴ But *Anchiceratops*, with well developed vascular impressions on the underside of the crest, must have had the latter largely free of the neck musculature and the head was, therefore, capable of freer rotational movement than *Centrosaurus*, for instance, which we necessarily restored with the crest, except for the periphery, in contact with the underlying muscles (Pl. II, B). In *Centrosaurus*, freedom of rotational movement seems to have been very limited.

Another interesting detail of the nervous system which has been alluded to previously is the lack of bony protection for the spinal cord from its exit from the foramen magnum to its entrance into the enclosed neural canal of the axis, a distance, according to Tait and Brown, of at least 11 inches in a large *Triceratops*. Moreover, the plane of the occiput slopes away from that of the beginning of the neural arch, the one sloping from below upward and backward, the other, upward and forward, so that the upper surface of the spinal cord was free of bone restriction to a greater extent than the lower. All this is taken by Tait and Brown as further evidence for marked rotational movement of the skull on its longitudinal axis, necessitated by the laterally compressed form of the prehensile beak and its use in severing vertically growing stalks of vegetation such as tall ferns, cycads, Equisetae, and other elevated and luxuriantly crowned plants which formed the creature's food. But the Ceratopsia lived during a time of modernized flora and it is not necessary to imagine their dietary restriction to plants of so primitive a character. Frankly, I do not believe that the head was ever rotated to such an extent that "like a hen viewing a hawk, they looked upwards with the upper eye"⁵ and thus were enabled to grasp with their recurved beak the bases of vertically growing stems and bring the foliage down from above.

Hatcher,⁶ in speaking of the sense organs of the Ceratopsia, says that the large comparative size of the olfactory lobe and the foramina for the exit of the olfactory nerves, as well as that of the orbits, and the ample dimensions of the optic foramina, imply that both the sense of smell and that of sight were well developed. He thought, however, that from the structure of the skull in the auditory region and the small size of the foramen through which the auditory nerve may have had its exit the sense of hearing was extremely dull. And, as he says, perhaps this deficiency in hearing may have hastened to some extent at least the extinction of the group. In the *Anchiceratops* brain case, while the cochlea could not be explored, there is, nevertheless, little evidence of deficiency of the auditory apparatus, nor am I inclined to accept Hatcher's conclusion in the matter, especially his final suggestion that this difficulty may have hastened extinction. *Triceratops* and *Torosaurus* lived to the very close of the Mesozoic, when the wholesale reptilian extinctions occurred. It is not necessary to find any specific cause of racial death which would apply to Ceratopsia alone, for that death was indiscriminate among reptiles and not restricted solely to the ceratopsians.

Even though the sense of hearing was somewhat dull as compared with that of modern grazing mammals, I imagine the noise of approaching danger was proportionately loud; for there were no stealthy beasts of prey of sufficient prowess to menace a *Triceratops* in his prime.

⁴ Tait, J., and Brown, B., 1928, pp. 21, 22.

⁵ Op. cit., p. 23.

⁶ Hatcher, Marsh, Lull, 1907, pp. 38-39.

SYSTEMATIC DESCRIPTION OF GENERA AND SPECIES

The classification of the Ceratopsia, as modified from Williston,¹ may be stated as follows:

- Class—Reptilia
 - Sub-class—Diapsida
 - Super-order—Archosauria
 - Order—Ornithischia
 - Sub-order—Ceratopsia
 - Family 1—Protoceratopsidae
 - Genera—*Protoceratops*, *Leptoceratops*
 - Family 2—Ceratopsidae
 - Genera—*Anchiceratops*, *Arrhinoceratops*, *Brachyceratops*, *Chasmosaurus*, *Ceratops*, *Eoceratops*, *Monoclonius* (*Centrosaurus*), *Pentaceratops*, *Styracosaurus*, *Triceratops*, *Torosaurus*.

Family PROTOCERATOPSIDAE Granger and Gregory³

The family characters are as follows:² primitive, small ceratopsians, with a hornless skull; without secondary skull roof above the frontals; no epoccipital bones; well developed crest with sagittal ridge and persistent parietal fenestrae; premaxillaries with teeth; cheek teeth arranged in a vertical series of not more than two developed at one time, roots simple not bifid; fore limb slender, manus much smaller and shorter than pes, the latter elongate with compressed unguals; ilium with blade but slightly inclined outward to the sagittal plane, not reflected or produced laterally above the femur; prepubic process relatively small, not expanded vertically; femur with large fourth trochanter, femur shorter than tibia; midcaudal vertebrae with very long spines.

Genus PROTOCERATOPS Granger and Gregory³

Protoceratops andrewsi Granger and Gregory³

Pls. I, IV; Text Figs. 32-34, 36

Holotype: No. 6251, A.M.N.H., a skull, lacking the occiput. Much other material has subsequently been found, consisting of several skeletons and no fewer than seventy-three skulls, ranging in age from the newly hatched young to the senescent.

Horizon: Cretaceous; Shamo series, Dja-doch-ta formation.

Locality: On the Kwei-wa-ting trail, east of Artsa Bogdo, Gobi Desert, Mongolia (Lat. 44°N., Long. 104°E.)

Collector: Walter Granger and party, Sept. 2, 1922.

The original description is as follows: "The skull (A.M.N.H. No. 6251) is hornless and far smaller than that of any known ceratopsian or ankylosaur, being only about 160 mm. in length from the anterior end of the premaxilla to the posterior border of the jugal. As seen from above, it is broadly triangular, with a pointed apex and wide lateral crests, the latter composed chiefly of the backward-and-downwardly expanded jugals. The greatest width of the skull across the posterior borders of the jugals is about 190 mm., while the depth of the jugal below the middle of the orbit

¹ Williston, S. W., 1925.

² Revised from Gregory and Mook, 1925, p. 4.

³ Granger, W., and Gregory, W. K., 1923, pp. 1-9.

is 43 mm. The orbits are very large (50 mm. in anteroposterior length), not surmounted by supra-orbital bones or horns. The postorbital-squamosal bar is narrow. Parts of the anterior and lateral borders of the supratemporal fenestra as preserved indicate that the fenestra was large and that the occipital roof was very delicate and not produced as far backward as in later Ceratopsia. The squamosal broadly overlapped the enlarged jugal and was produced posterosuperiorly but was not greatly enlarged. The pineal foramen is small or absent. The single preorbital fossae are far larger than in other predentates. The premaxillae were very large and probably supported a large rostral bone, which is broken off; the premaxillae and nasals approach the ceratopsian type and the same is true of the pterygoids, the internal nares, and the quadrates. The quadratojugal lies on the posterior surface of the quadrate.

"The mandible has on each side a straight row of about nine relatively large and long-crowned teeth, worn on their buccal sides and set far inward toward the midline. The remains of the lower

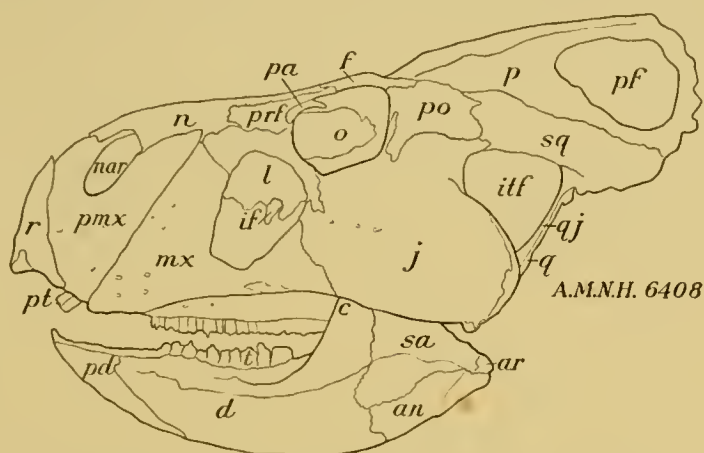


Fig. 32.—Left lateral view of skull of *Protoceratops andrewsi*, $\frac{1}{4}$ natural size. *an*, angular; *ar*, articular; *c*, coronoid; *d*, dentary; *f*, frontal; *if*, preorbital fossa; *itf*, infratemporal fossa; *j*, jugal; *l*, lacrymal; *mx*, maxillary; *n*, nasal; *nar*, narial opening; *o*, orbit; *p*, parietal; *pa*, palpebral; *pd*, predentary; *pf*, parietal fenestra; *pmx*, premaxillary; *po*, post-frontal (postorbital); *prf*, prefrontal; *pt*, premaxillary teeth; *q*, quadrate; *qj*, quadratojugal; *r*, rostral; *sa*, surangular; *sq*, squamosal; *t*, teeth.

molar crowns suggest the three-pointed lower molars of ceratopsians, rather than the spatulate, many-cusped teeth of ankylosaurs and of European Acanthopholidae. The anteroposterior measurement of the four teeth . . . is 28 mm. The last tooth preserved has its tip about 13 mm. above the alveolus. The first four teeth are represented by their alveoli. The diastema from the first alveolus to the predentary bone was about 14 mm. in length. The strong coronoid process rises from the dentary at a gentle slope. The predentary bone is well developed and has a pair of long inferior processes, one on either side of the midline.

" . . . The true Ceratopsia, [Ceratopsidae] hitherto unknown below the Upper Cretaceous of America, are all far larger than *Protoceratops*; all of them have horns; the crest is much expanded above and behind the occiput; there are epoccipital and supraorbital bones; and the orbit is small, placed high up and bounded by a wide postorbital bar. The preorbital fossa is reduced to a small slit.

"As *Protoceratops* presents the opposite of these characters, it may prove necessary to erect for it a new suborder (Protoceratopsia) but we prefer at present to regard it only as the type of a new and probably primitive family, the Protoceratopsidae, characterized by the lack of horns, the very large size of the orbits, and the narrowness of the postorbital-squamosal bar."

Protoceratops skull No. 6408 A.M.N.H. (Figs. 32, 33), figured by Gregory and Mook in 1925, and described as a small, young adult skull, possibly a female, may be taken as a plesiotype. Upon this the following observations were made: The muzzle is deep and laterally compressed, with a well developed rostral bone bearing vascular impressions. There are abundant nutritive foramina scattered over the facial bones. The premaxillaries lack the sculpturing of the typical ceratopsians and form

but a small portion of the inferior margin of the jaws. There is no septum formed of the premaxillaries and nasals partially dividing the nares, although it is present in the Ceratopsidae. As usual, however, the premaxillaries enter into the profile of the muzzle between the limits of the rostral and the nasals. An unusual feature among Ceratopsia, found elsewhere only in *Leptoceratops*, is the possession of a pair of cylindrical teeth in close mutual contact on either side of the muzzle just behind the rostral border. The nares are elongated ellipses with their long axes directed upward and backward at an angle of about 45° from the perpendicular.

The maxillaries, together with the jugals, are the largest bones of the face. They are roughly triangular in form, being bounded in front by the premaxillaries, above by the lacrymals, and for a very brief space by a downwardly projecting process of the nasals. Posteriorly, the maxillaries are bounded by the jugals and pterygoids. Inferiorly, there is an unusually long, edentulous margin before the tooth row is reached. The number of dental alveoli is 13 to 15, and, because there are but two horizontal rows of successional teeth, there is no such deep alveolar groove as that seen in the later ceratopsians. The preorbital fossa forms a not very deep depression on the side of the face, and includes within its area about equal moieties of the maxillary and lacrymal bones. The actual foramen (lacrymal foramen of authors) is much smaller and lies within the lacrymo-maxillary suture. This fossa is reduced to a narrow slit in the later ceratopsians. Mr. Granger thinks it may have lodged a facial gland, possibly hedonic, like those found within either ramus of the lower jaws in the Crocodilia. This is, however, a matter of pure conjecture, and the gland would of necessity become practically vestigial in later forms. What then would be its utility? The foramen is apparently the vestige of the preorbital opening, large in saurischian dinosaurs, but always reduced in the Ornithischia.

The nasal bones meet in a median suture throughout, without the customary fusion seen in most later genera. Anterior to the nares there is a slender process which meets an ascending process of the premaxillary. There is the suggestion of a prominence about mid-length of the nasals, with a concentration of the grain of the bone toward it, seemingly foreshadowing the coming of a nasal horn. There is a median longitudinal depression on the nose, reaching back beyond the limits of the frontals in specimen No. 6408, but less pronounced in No. 6429. The nasals are bounded by the premaxillaries in front and below, with an area of contact with the maxillaries, of varying width, followed by that with the lacrymal and prefrontal bones. At their hinder end, they articulate with the frontal bones.

The complex of bones surrounding the orbit has been subject to varied interpretation. It is generally assumed that the true frontals, as discrete bones, do not appear on the surface of the skull in the later ceratopsians in which the secondary roofing has been developed. One would expect to find them, however, in *Protoceratops*, and probably in *Leptoceratops*, in which the secondary roofing is incomplete. I should interpret the pair of bones lying between the orbits on the dorsal surface of this skull as frontals, flanked in front and behind the orbit by the prefrontals and postfrontals respectively, the "freely articulating palpebral bones" of Gregory and Mook representing the supra-orbitals. The prefrontal lies above the lacrymal, the suture between them being clearly visible in the skull under discussion. They form the anterosuperior border of the orbit except where excluded therefrom by the palpebral bones. Above and anteriorly, the prefrontals are bounded by the nasals, and posteriorly by the frontals which form the superior orbital border. Nowhere is the rim of the orbit thickened as in later ceratopsians, for this is a defensive modification concomitant with the development of horns. The postfrontal bones bound the orbit on the rear and articulate in turn with the frontals above, the squamosals behind, and the jugals below. Near the junction with the postfrontals, the frontals become somewhat roughened, and over the suture, especially on the right side of the skull, there appears once more a decided prominence suggestive of the brow horn yet to come. There is no trace of the pineal foramen nor of the pseudo-pineal fontanelle which is seen only in forms with the secondary roofing and may disappear even in them, as in the type of *Triceratops prorsus*. The absence of the true pineal foramen casts doubt upon Gilmore's interpretation of an aperture in the roof of the actual brain case of *Triceratops*⁴ below the secondary roofing. (See p. 72, Fig. 31.)

⁴ Gilmore, C. W., 1919, B, p. 107, Fig. 1.

The lacrymal is an irregular-shaped bone forming the anterior limit of the orbit and containing the upper half of the preorbital fossa. The lacrymal is bounded by the nasal and prefrontal above, the jugal behind and below, and the maxillary below and in front. The preorbital (lacrymal) foramen lies in the mid-length of its inferior border.

The jugal is one of the largest bones of the skull. It is roughly quadrangular, with the longest axis nearly horizontal. It is bounded in front by the maxillary and lacrymal, above by the postorbital, and has a long process above the infratemporal fossa which meets the squamosal. Within, the jugal bears upon the quadratojugal and quadrate. In skull No. 6429 A.M.N.H., a horizontal ridge divides the posterior part of the jugal into an upper and lower portion. The rear lower part of the jugal flares outward very strongly in some skulls of *Protoceratops* (see Pl. I), suggesting

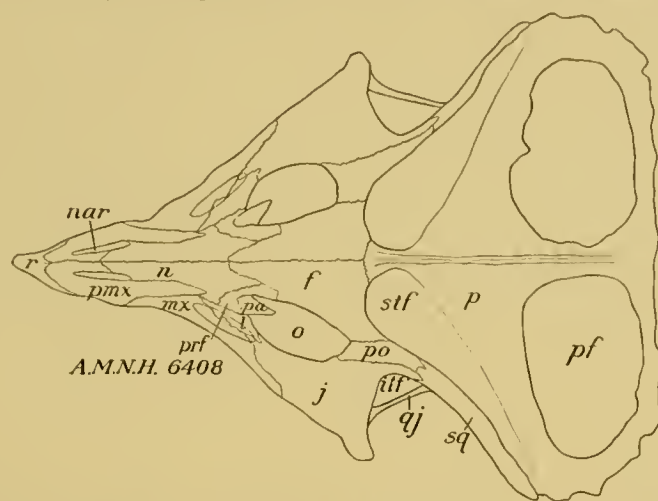


Fig. 33.—Dorsal view of skull of *Protoceratops andrewsi*, $\frac{1}{4}$ natural size. f, frontal; itf, infratemporal fossa; j, jugal; l, lacrymal; mx, maxillary; n, nasal; nar, narial opening; o, orbit; p, parietal; pa, palpebral; pf, parietal fenestra; pmx, premaxillary; po, postfrontal; prf, prefrontal; qj, quadratojugal; r, rostral; sq, squamosal; stf, supratermporal fossa.

somewhat the jugal horns of *Pentaceratops*. There is no trace, however, of an epijugal bone, although the surface of the jugal is in places somewhat rugose and pitted.

The postfrontal (postorbital) is bounded by the prefrontal and the supratermporal fossa above, the rear of the orbit and the squamosal laterally, and the jugal below.

The crest is composed of the usual three elements of which the unpaired median one is generally considered as the fused parietals. The skull of *Protoceratops*, with its primitive simplicity, affords the best of evidence for this interpretation. In this, Gregory and Mook agree. The lateral elements are of course the squamosals; concerning these, opinion is undivided. The latter bones lie in their usual position bounding the parietals on their outer anterior margins. Anteriorly, the squamosal articulates with the postfrontal and the extended process of the jugal, while its lower margin meets the quadratojugal and quadrate, which combine to form the infratemporal arcade and, together with the jugal and squamosal, enclose the very large infratemporal fossa. The squamosals bear slight vascular impressions on the outer surface. The parietal bones are broadly expanded, completely surround the large, slightly irregular fenestrae, and form the periphery of the crest beyond the limits of the squamosals. They are peculiar in having the midline raised into a pronounced sagittal crest. Anteriorly, their surface, together with that of part of each squamosal, dips below the general level of the surface of the crest, especially in the wake of the supratermporal fossae. Such depressed areas are always present in varying degree among Ceratopsia, especially in *Chasmosaurus*, but never to the relative extent seen in *Protoceratops*. They seem to be the areas of origin of the temporal muscles which, passing downward and slightly forward beneath the postfrontal and jugal bones, were finally inserted into the coronoid process of the jaw and served to actuate that powerful member. Here the pull is more directly upward than in later Ceratopsia and as a consequence the coronoid process of the jaw has a different shape from that of *Triceratops* or *Monoclonius* (*Centrosaurus*), for instance.

The rear of the skull exhibits the usual ceratopsian complex—a spherical condyle, heavy basioccipital region, and two forwardly directed processes which abut against the pterygoids. The pterygoids are typically ceratopsian, but have an immensely greater vertical extent than in the Ceratopsidae. The exoccipitals are widespread but are narrow vertically and do not dilate so much toward their outer end as in the latter. The pterygoid groove is not in evidence as it is in *Triceratops serratus*. The suture between the parietals and occipital complex is clear, crossing the vertical ridge above the foramen magnum at its mid-height, as in *Monoclonius* (*Centrosaurus*). As usual, one cannot determine the limits between the supra- and exoccipitals.

The lower jaw is extremely hollow and must have possessed a large splenial which is not now in evidence. There is a row of 12 to 13 large nutritive foramina on the inside of the dentary, one at the base of each vertical tooth row, and a corresponding series of 13 to 15 on the inner side of the maxillary. The angular and surangular are large. The coronoid seems to lack the forwardly turned hook-like summit characteristic of later ceratopsians, but is grooved slightly in the direction of the temporal muscle pull. (See above, p. 37.)

The outer surface of both mandible and maxilla bears ridges limiting the masseter muscle. Between the latter and the teeth were hollows which formed deep but probably not distensible cheek pouches, as Hatcher suggested for *Triceratops*. These are merely for the retention of food which, falling outside of the teeth, would otherwise be lost. They were in no sense for storage. Below the masseter ridge the mandible has a flattened outer surface more suggestive of *Monoclonius* (*Centrosaurus*) than of *Triceratops*. The prementary is sharply pointed, with a keel-like profile. The shape of the various sutures of skull and jaws varies in the two specimens, No. 6408 and No. 6429 A.M.N.H.

As but one species of *Protoceratops* is known, it is impossible as yet to determine what are the specific as opposed to the generic characters.

The generic relationship is nearest to *Leptoceratops* among the American forms. The distinctions from *Brachyceratops* are much more marked. (See contrast of *Leptoceratops* and *Brachyceratops*, p. 79.)

Genus LEPTOCERATOPS Brown

Leptoceratops gracilis Brown⁵

Text Figs. 35, 37

Holotype: No. 5205 A.M.N.H.; parts of skull and jaws, including nasals, maxillaries, portions of the orbital border, back part of crest, dentary, prementary, and splenial; a series of articulated caudal vertebrae; a complete fore limb and parts of hind limbs.

Horizon: Edmonton Cretaceous, about 400 feet above the Pierre.

Locality: Three miles above Tolman, on the east bank of the Red Deer River, Alberta.

Collector: American Museum of Natural History expedition of 1910.

The generic and specific characters are as follows: "Skeleton small. Skull short and deep, without nasal horn. Crest with a high thin sagittal ridge, posterior border of crest smooth; squamosal extending to extreme posterior border of crest. Teeth single-rooted. Dentary massive, short and deep, with less than fifteen rows of teeth; splenial large extending to symphysis. Prementary long and narrow. Manus with digits I, II and III terminating in hoofs; carpals ossified, ulnare and radiale large. Femur straight, with fourth trochanter comparatively large. Tail long and deep, with high slender spines and long chevrons."

Another fine specimen of *Leptoceratops* has come to light, collected by Brown, Kaisen, and Johnson in 1916, from near the bottom of the St. Mary formation, 3 miles west of Buffalo Lake, Montana. This specimen, which bears the number 5464 A.M.N.H., is a nearly entire skeleton, except for most of the skull and the fore limbs. The left hind limb is represented by a femur, tibia

⁵ Brown, B., 1914, C.

and fibula, the right by the femur only. The caudals are intermittently present. Except for the hind feet, of which only a few phalanges are preserved, and parts of the skull, this specimen has been restored completely from the type specimen, and is to be mounted. Hence, it affords an admirable basis for comparison with *Protoceratops*, its nearest ally. With *Brachyceratops*, on the other hand, there is little basis for comparison; nevertheless, as such comparison has been made, it is well to discuss here the points of contrast.

The skull of *Leptoceratops* has little in common with *Brachyceratops*. The latter has a large nasal horn composed of a right and a left element divided by suture, the entire structure, with the exception of a small terminal ossicle, being a continuation of the nasal bones. In *Leptoceratops*, there is no trace of a nasal horn, the nasals, wide at their posterior end, terminating in a point, with no elevation of profile or other indication of even an incipient nasal horn. The supraorbital horns, which are present, though small, in *Brachyceratops*, are also presumably absent in *Leptoceratops*, although of this there is no direct proof. Other skull details, available for comparison, lie in the crest, mandible, and teeth. In *Leptoceratops*, the posterior median part of the crest (parietal) only is preserved. It differs from that of *Brachyceratops* in the form of the hinder margin, which in the former is straight, in the latter with a shallow reëntrant angle. *Leptoceratops* has a rather high, thin sagittal ridge extending nearly to the posterior edge; *Brachyceratops* has none, although the midline is somewhat elevated, with the undulating profile which is characteristic of several ceratopsian genera, notably *Monoclonius* (*crassus*), and *Triceratops*. Judging from the position of the squamoso-parietal suture, the squamosals in *Leptoceratops* must have extended to the rear of the crest; in *Brachyceratops*, the same evidence indicates that they were short, and terminated at about the middle of the lateral margins. Finally, there is no evidence whatever of the presence of parietal fenestrae in the preserved portion of the *Leptoceratops* crest. They were present, but apparently small, in *Brachyceratops*. This, however, may be only a difference of degree and not of kind, for all other Edmonton Ceratopsia possess these openings, and *Leptoceratops* may have. The mandible and prementary differ markedly, those of *Leptoceratops* being short and deep, with an unusually large prementary in proportion to the dentary. In *Brachyceratops*, the mandible is slender and the prementary relatively small, more as in normal ceratopsians. Alveoli in the premaxillary of *Leptoceratops* betray the presence of premaxillary teeth which certainly do not occur in *Brachyceratops*. Apparently, *Leptoceratops* has single-rooted teeth, those of *Brachyceratops* being probably of the regular ceratopsian bifanged sort, although this cannot be verified.

Among skeletal contrasts there are marked differences in the ilia, pubes, ungual phalanges, and in the spines of the caudal vertebrae, all of which are typically ceratopsian in *Brachyceratops* and differ widely from those of *Leptoceratops*, in which these elements are highly diagnostic, as the comparison with *Protoceratops* will show. On the whole, I see no indication whatever of relationship between *Brachyceratops* and *Leptoceratops*, the latter being something very much apart from the remainder of the American Ceratopsia.

Mr. Brown has already stressed a number of points of comparison between *Leptoceratops* and *Protoceratops*, and the newly acquired skeleton, instead of showing distinctions, serves only to emphasize further likenesses which indicate real relationship between the genera even though they were remotely removed from one another in space. Several instances of such discontinuous distribution are known, however, notably the extant *Tapirus*, the surviving members of which, living as they do in Brazil and the Malay peninsula, are yet more remote.

So far as the skulls of *Leptoceratops* and *Protoceratops* can be compared, the similarities include hornlessness, the presence of premaxillary teeth, the single-rooted character of the other teeth, and a general agreement of size on the part of some of the larger *Protoceratops* skulls. The lower jaws agree somewhat in shortness and depth, but the form of the coronoid differs, as does the proportionate size of the prementary bone, which is much the larger in *Leptoceratops*.

The parietals are alike in the possession of the sagittal crest, and in the comparatively straight posterior border, but there the resemblance ceases, for the squamosal sutures are much farther apart in *Protoceratops*, where they form a wide angle of about 90° with each other, while in *Leptoceratops* they are more nearly parallel, thus implying a short squamosal on the part of the former, and a long

one on the part of the latter. The form of the squamosals has high diagnostic value in other ceratopsians. But perhaps the most striking contrast lies in the very large parietal fenestrae in *Protoceratops*, so large that there is merely a narrow band of bone between them and the rear of

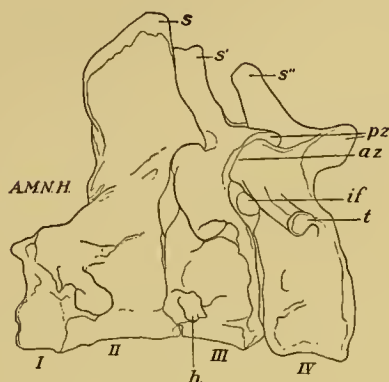


Fig. 34.—Lateral view of anterior cervicals of *Protoceratops andrewsi*, No. 6417 A.M.N.H., $\frac{1}{2}$ natural size. az, anterior zygapophysis of fourth cervical; h, capitular facet; if, intervertebral foramen; pz, posterior zygapophysis of fourth cervical; s, neural spine of axis; s', neural spine of third cervical; s'', neural spine of fourth cervical; t, tubercular facet.



Fig. 35.—Lateral view of anterior cervicals of *Leptoceratops*, $\frac{1}{2}$ natural size. h, capitular facet; if, intervertebral foramen; pz, posterior zygapophysis of fourth cervical; r, rib; s, neural spine of axis; s', neural spine of third cervical; s'', neural spine of fourth cervical.

the crest. The rather large portion of the *Leptoceratops* parietal preserved shows no trace of fenestrae at all, so that if fenestrae shall ultimately be found in *Leptoceratops*, they will be much smaller and farther forward, for the area where they occur in *Protoceratops* is here solid bone. This one element is so distinctive that, however closely allied these forms may prove to be on other counts, their dis-

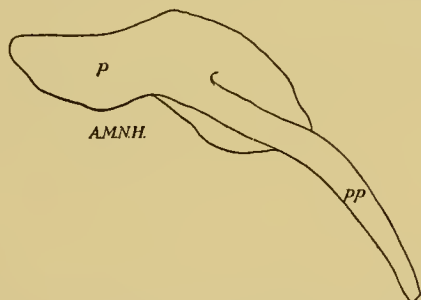


Fig. 36.—Right pubis of *Protoceratops andrewsi*, No. 6417 A.M.N.H., internal view, $\frac{1}{2}$ natural size. p, pubis; pp, postpubis.

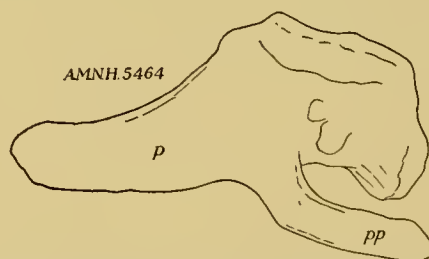


Fig. 37.—Right pubis of *Leptoceratops*, internal view, $\frac{1}{2}$ natural size. p, pubis; pp, postpubis.

tinction is surely generic. The general form of the skulls was probably quite different, as the much longer nasals in *Leptoceratops* give further evidence.

Of the anterior cervicals, all are thoroughly coössified in *Leptoceratops* (Fig. 35), while in the unmounted skeleton of *Protoceratops* (Fig. 34), No. 6417 A.M.N.H., the atlas and axis are fully fused, the axis and third cervical are coössified at the base of the centrum, but the zygapophyses are distinct. The spine of the axis is erect in both genera and not bent backward as in all other ceratopsians. The caudal vertebrae are similar in the two genera, but otherwise unique among horned

dinosaurs in the possession of extremely long spines, especially in that area of the tail which lies behind the greatly elongated ischia, as though each possessed a flattened, crested tail almost that of a modern basilisk. See, however, Knight's restoration of *Protoceratops* in the frontispiece.

The ilia are alike, and differ from those of other ceratopsians in that they lack the reflected upper border which, in the latter, overhangs the acetabulum, making the blade of the ilium nearly horizontal instead of vertical. The ischia, long and straight, and the very peculiar pubes (Figs. 36, 37), with relatively short prepubes, are also in agreement with each other to the exclusion of other forms. Comparable also are the femora, with a large fourth trochanter, and a well-defined third trochanter. In each, the unguals are slender and compressed, more like those of *Camptosaurus* than of a more typical ceratopsian.

These many details of agreement point to a very close relationship on the part of the two genera and a wide divergence from all other known members of the superfamily Ceratopsioidea. I see no indication of ancestry on the part of *Protoceratops*; certainly *Leptoceratops* of the Edmonton, which is later in time than all of the Belly River, Judith River, and Two Medicine genera, and contemporaneous with *Anchiceratops* and *Arrhinoceratops*, is debarred by time from actual ancestry of any of them, and its characters are not such as would permit it to be even a structural ancestor of any of the Lance forms.

Protoceratops and *Leptoceratops*, each with its single known species, belong to the same family Protoceratopsidae proposed by Granger and Gregory,⁶ but defined by Gregory and Mook.⁷ The family characters lie in those details which both genera show in contrast to the Ceratopsidae, and include hornlessness, premaxillary teeth, single-rooted maxillary and mandibular teeth, and the peculiarities of ilia, pubes, and caudals which I have stressed.

Family CERATOPSIDAE Marsh

The characters of the family may be stated as follows: large; highly specialized; skull bearing horns; with secondary roofing above the frontals; crest generally with epoccipital bones; without premaxillary teeth; cheek teeth with bifid roots; fore limb shorter than hind; blade of ilium horizontal; prepubic process comparatively large and expanded vertically at the anterior end; fourth trochanter of femur nearly obsolete, femur longer than tibia; unguals of manus and pes depressed and hoof-like; midcaudal vertebral spines not elongated.

Genus MONOCLONIUS Cope (Judith River phase)

The type species of the genus *Monoclonius* is *M. crassus*, described by Cope in 1876, from the Judith River beds of Montana. Three other species were described later in 1889. They were *M. fissus*, *M. recurvicornis*, and *M. sphenocerus*. Because of the fragmentary character of the type material, the doubt of actual association of the various elements in single individuals or even species, and the fact that homologous parts of the different types are rarely preserved, it is extremely difficult to define the genus in detail, and next to impossible to compare all the species. The same is true of the species of *Ceratops*, as described by Marsh, which come from the same general horizon and locality.

The several species from the Belly River formation which have been described by Brown as *Monoclonius* belong to the genus originally described by Lambe as *Centrosaurus*, with the species *apertus* as the type. If the generic identity of *Centrosaurus* and *Monoclonius* is finally determined without question, the latter takes precedence. On the basis of present evidence, I am inclined to consider *Centrosaurus* a local, Belly River phase of *Monoclonius*, possibly of sub-generic rank.

In the morphological chapter of this memoir the skeleton of *Monoclonius* (*Centrosaurus*) *flexus*

⁶ Granger, W., and Gregory, W. K., 1923, p. 4.

⁷ Gregory, W. K., and Mook, C. C., 1925, p. 4.

at Yale was used for a basis of description, and comparison was made in so far as possible with the type of *Monoclonius crassus* Cope, as described in considerable detail by Hatcher in the Ceratopsia monograph. So far as the skeleton was concerned, no differences other than of specific rank were discernible; without the skull, however, generic identity is difficult of establishment. The chief distinctive characters of *Monoclonius*, as determined by Hatcher,⁸ "are its small size, the diminutive supraorbital horn cores pointing directly upward; the short, broad, and widely fenestrated parietals; the short squamosals, as indicated by the squamosal border on the parietals in the type."

The type of *M. crassus* does not include a nasal horn core, so that the character of this element cannot be included in the generic description, as based upon that type. The horn of *M. sphenocerus* is present, but is unassociated with a crest and therefore might as readily have pertained to a *Styracosaurus*, to which it has actually been referred (see beyond, p. 90). Hence, one cannot prove from the original material whether this type of horn was characteristic of *Monoclonius* or not.

The crest of *M. crassus* differs from that of *Centrosaurus apertus* in the presence of five prominences, forming a median row as in *Triceratops*, and in the lack of any indication of the four posterior horn-like processes which are highly diagnostic of every Belly River specimen pertaining to Lambe's genus, except that one or the other of the forwardly-directed pair may be missing, as in Brown's *M. (C.) flexus* type, but never both so far as I can ascertain. On the other hand, their presence has never been demonstrated on any Judith River specimen.

The long nasal horn and short brow horns; the short, deep muzzle; the saddle-shaped crest, with its short squamosals and widely fenestrated parietals, the latter with a smooth median bar; and the two pairs of processes arising from the rear, an anterior sulcated pair (one of which may be undeveloped) projecting forward to overhang the fenestrae, and the posterior curved, hook-like pair, constitute the diagnostic characters of the sub-genus *Centrosaurus*.

The nasal horn presents little difficulty, as it is not demonstrably absent from Cope's type, but the processes of the crest are, to my mind, a serious obstacle to the acceptance of generic identity, as they are demonstrably absent in the type of the genus. Geographically, the two genera come from areas at least 250 miles apart; stratigraphically, the Belly River and Judith River formations are stated to be equivalent (see chapter on distribution, p. 6). Be that as it may, the predentate dinosaurs from the two areas present a very different aspect, and this refers to the unarmored trachodonts as well as to the ceratopsians; for the Belly River forms are often grotesque, such as the helmeted dinosaurs culminating in the remarkable *Parasaurolophus* with the extreme backward extension of the skull, and *Monoclonius (Centrosaurus)* and *Styracosaurus* with equally remarkable spinescence. That this condition may be due to racial abnormality having its seat in the pituitary gland, which, as is well known, does react to certain peculiar conditions of the physical or chemical environment, may have been true. Nevertheless, the specializations to which such conditions give rise may be considered as having taxonomic value, whether generic or specific. It cannot be that, as Nopsca and others have argued, these distinctions are sexual, for that would mean permanent segregation of the sexes either geographically or in time, a manifest absurdity from the standpoint of racial continuity.

***Monoclonius crassus* Cope⁹**

Holotype: No. 3998 A.M.N.H.; incomplete median element of crest. The sacrum and other skeletal elements, described in detail in the Ceratopsia Monograph, bear the same catalogue number as the holotype (No. 3998), although sometimes with a query. There are also a number of isolated vertebrae, with no record available as to their associations although in size and general character they agree with the remainder of the skeleton.

No. 3997: prefrontal and postfrontal with brow horn, questionably referred to *M. crassus*.

Horizon: Judith River formation.

Locality: Nearly opposite the mouth of Dog Creek on the north side of the Missouri River, Montana, in the same locality as *M. recurvicornis*.

Collector: E. D. Cope, 1876.

⁸ Hatcher, Marsh, Lull, 1907, p. 70.

⁹ Cope, E. D., 1876, pp. 255-256.

Monoclonius recurvicornis Cope¹⁰

Holotype: No. 3999 A.M.N.H.; upper portion of facial region bearing both supraorbital and nasal horns, together with a fragment of the left jugal, and part of the margin of the right squamosal with two epoccipitals.

Horizon: Judith River formation.

Locality: The same as *M. crassus*.

Collector: E. D. Cope and party, 1876.

Except for the supraorbital horn of *M. crassus*, which does not belong to the holotype, there are no parts of the skulls of *M. crassus* and *M. recurvicornis* preserved which are homologous and therefore, comparable. Hence, specific distinction is not demonstrable.

There is a skull of *Monoclonius* (*Centrosaurus*) in Ottawa (No. 348 G.S.C.) in which the nasal horn is quite similar to that of Cope's type in the degree of its forward curvature. The left brow horn is relatively nearly as large as in *recurvicornis*, but the right is much smaller, nor have either of them the same form as in *recurvicornis*. There the resemblance ceases, as the Ottawa specimen shows no trace of a small horn-like prominence borne on the prefrontal on either side about midway between the nasal and brow horns. Beyond this, comparison cannot be made.

Monoclonius sphenocerus Cope¹¹

Holotype: No. 3989 A.M.N.H.; nasal horn, nasal and left premaxillary.

Horizon: Judith River formation.

Locality: On Missouri River, near Cow Island.

Collector: C. H. Sternberg, 1876.

Here, again, no comparison can be made with homologous elements in *M. crassus*. This is not true, however, of *M. recurvicornis* and *M. sphenocerus*, for in each instance the nasal horn is present. The two horns are very different in character, that of the species under discussion being straight, erect, laterally compressed, and of great fore and aft diameter at the base, with a rapid diminution of this dimension toward the tip. In *recurvicornis*, on the other hand, the basal section is more broadly elliptical and the horn curves sharply forward. Clearly, therefore, *M. recurvicornis* and *M. sphenocerus* are specifically distinct, but, unfortunately, neither species can be differentiated from *M. crassus*, the type of the genus, which, in case of proved identity, would take precedence over either *recurvicornis* or *sphenocerus*, but which one cannot say. So here the matter rests until more adequate material is secured from the Judith River formation.

The comparison between the *M. sphenocerus* horn and that of *Styracosaurus albertensis* will shortly be discussed and the relationship between them, which some have argued, dismissed as unproved.

(?) Monoclonius dawsoni Lambe¹²

Holotype: No. 1173 G.S.C.; parts of two skulls.

Horizon: Belly River formation.

Locality: Red Deer River, between Berry Creek and Dead Lodge Canyon, Alberta.

Collector: L. M. Lambe, 1901.

Mr. Lambe's description is as follows: "The remains of an apparently undescribed species of this genus, consisting of the skull of one individual and the posterior crest of another, are of especial interest. The skull when found lay on its right side and although very much crushed, certain parts of it supply definite information as to its structure and size. The two orbits, the right maxilla, a quadrate, and the occipital condyle were conspicuous and apparently in place, with a large posterior

¹⁰ Cope, E. D., 1889, p. 716.

¹¹ Cope, E. D., 1889, pp. 716-717.

¹² Lambe, L. M., 1902, pp. 57-63.

crest extending to the rear. Somewhat in advance of the orbits a horn core, of large size and apparently symmetrical form, occupied a position suggestive of a nasal origin, the nasal bones and the frontals being probably represented by the fragments filling the space between the orbit and the horn core

"The large posterior crest forms the back part of the skull above; its exact shape is fortunately supplied by the admirably preserved specimen shown in outline, [This crest, No. 971 G.S.C. was later made the type of the genus and species *Centrosaurus apertus* Lambe.¹³] The surface of the bone, above the orbit and from there inward for a short distance toward the median line of the skull, is moderately smooth and shows no trace of a horn core." The remainder of the description pertains to the second crest.

It is unfortunate that the condition of the actual crest of this specimen rendered it incapable of preservation and that Mr. Lambe, instead of describing it in detail, should have turned to the other crest to complete his description of the species. So far as the nasal horn is concerned, Lambe's first reference of the species to *Monoclonius* would be valid, although it is the only known specimen of this genus in which the horn curves backward. In all the other *Monoclonius* skulls it is either erect or forwardly curved. No other detail debars the type from *Monoclonius* except possibly the crest.

The known characters of the species *M. dawsoni* are as follows:¹⁴ nasal horn large, curved backward; supraorbital horns incipient; squamosals small, smooth undulating margins to crest; epoccipitals absent; parietal fenestrae greatly reduced or absent. If the last statement is true the form cannot be *Monoclonius* or *Centrosaurus*. This species has, however, been also referred to *Brachyceratops*, a genus described by Gilmore from the Two Medicine formation, although evidence for such inclusion is very inadequate. The nasal horns are very different, for in *Brachyceratops* it was made up of two elements, one derived from each nasal bone and therefore separated in the median plane, a juvenile character known in no other ceratopsian skull except *Eoceratops canadensis*. A presumable element of agreement lies in the apparently small size of the parietal fenestrae and the general form of the squamosals, with their undulating border and lack of epoccipital bones. The shape of the orbit is somewhat similar in each form. The actual form of the crest which belonged to the type skull, at present vaguely understood, will determine the generic status, and not until another undoubted specimen is found can the real position be known. Tentatively, I would leave the form as Lambe originally named it.

Sub-genus CENTROSAURUS Lambe (Belly River phase)

This sub-genus was founded upon a parietal crest first described by Lambe¹⁵ in conjunction with the Belly River type of *Monoclonius dawsoni*. The latter consisted of an extremely fragmentary skull, No. 1173 G.S.C., discovered by Lambe in 1901, but in such condition that the crest could not be preserved, so that the one under discussion, No. 971 G.S.C., was considered part of the type, although from a somewhat different locality and level, and was used in the original description; no record was taken of the actual crest other than a rather vague, though measured, field sketch made before the parts were removed.¹⁶ From this sketch it is evident that *Monoclonius dawsoni* had a different type of crest from that of *Centrosaurus apertus* and that Lambe was justified in erecting a new genus for the inclusion of the latter. But the species of *Centrosaurus* are confused in the same way as are those of *Monoclonius*, since in each genus the genoholotype is based on a crest only, which cannot be compared with the same element in the types of the other species, because these types

¹³ Lambe, L. M., 1904, p. 81.

¹⁴ Lambe, L. M., 1915, p. 21.

¹⁵ Lambe, L. M., 1902, pp. 58-59, also Hatcher, Marsh, Lull, 1907, p. 89, Fig. 92.

¹⁶ In a letter to the present author dated May 30, 1905, and published in the Ceratopsia Monograph, page 179, Mr. Lambe places the type of *Centrosaurus apertus*, No. 971, in what he calls the Lower (primitive mammal) beds with *Eoceratops canadensis*; while *Monoclonius dawsoni*, No. 1173, is referred to the Middle beds, and *Chasmosaurus belli* to the Upper. *Centrosaurus apertus* was collected on the west side of Red Deer River, July 26, 1901, while *Monoclonius dawsoni* came from the east side, August 15 of the same year.

do not possess a crest (*Monoclonius*), or the specific distinctions seem to lie in other parts of the skull, the crests alone being specifically indistinguishable from the genoholotype, or from one another (*Centrosaurus*). Lambe's original description stressed the curved, hook-like processes at the posterior end of the saddle-shaped frill, hence *Centrosaurus*. He did not, however, recognize the forwardly projecting process as such, for it was detached and hence mistaken for a rather peculiar nasal horn. Later, it became evident that this horn fitted accurately on a fractured portion of the posterior parietal bar, and it was then cemented into place. The right one only is present, however, there being no sign that the animal ever had possessed the left one. That was later found to be of occasional occurrence (cf. *Monoclonius* (*Centrosaurus*) *flexus* type).

The sub-genus *Centrosaurus* is now known in its entirety, even to the hide (Pl. III, B), and the description of it appears in detail in the morphological portion of this memoir (pp. 30-66). We have already stressed the sub-generic characters in distinguishing *Centrosaurus* from *Monoclonius*; but the specific distinctions separating the various centrosaurs are not so clear, and seem to lie mainly in the character of the nasal horn, whether straight or forwardly curved. The named species are: *Centrosaurus apertus* Lambe, genoholotype; *C. flexus* Brown; *C. nasicornus* Brown; and *C. cutleri* Brown. Of these, *C. nasicornus* is based upon an entire skeleton with skull and jaws, all of a single individual, and is, therefore, entirely adequate. Of *C. flexus*, on the other hand, the type consists of a skull only, without the lower jaws, or other skeletal elements; while *C. cutleri* is based upon a partial skeleton with the merest fragments of skull which cannot be compared with the *flexus* or any other skull. In other words, there is no assurance that these two species are distinct, as the types contain no homologous parts for comparison. Furthermore, the Yale specimen, again a single individual, possesses a *flexus* skull while the skeleton is more suggestive of *cutleri*, as the descriptions show. I am inclined, therefore, to consider *C. cutleri* as possibly invalid, which reduces the species to three, or possibly two, since neither *flexus* nor *nasicornus* can be distinguished from *apertus* on the basis of the crest alone.

Characters, shown by the skulls, which may be contrasted and are hence of specific value, are as follows:

The nasal horn is always well developed, much more so than in *Chasmosaurus*, and is either erect as in *nasicornus*, or curved forward as in *flexus*. The only variant known to me is in skull No. 4519, at Toronto, in which it is erect but curves slightly backward toward the tip.

The brow horns are never large in the Belly River forms, except in *Chasmosaurus kaiseni* (Pl. V, A). In *Centrosaurus*, they have the same degree of development as in the other chasmosaurs, and vary from mere rugosities over the orbits, as in *nasicornus*, to pointed, trihedral horns, of which the height about equals the fore and aft diameter at the base, as in the Toronto specimen, No. 4519, mentioned above. Strangely enough, in both the *flexus* type and that at Yale, as well as in a curious skull, No. 348, at Ottawa, one horn is developed to a much greater extent than is the other and, through coincidence or otherwise, in each of the three it is the left which is the larger.

The forwardly directed processes at the rear of the crest may be straight or have varying degrees of curvature. An extreme instance is shown in the skull No. 348 referred to, in which the curvature of both the nasal horn and the processes reaches a maximum. The posterior processes of the crest also vary in their degree of curvature, as well as in their distance apart at the base. The crest is always saddle-shaped, but varies in the degree of transverse curvature, from rather flat in the *apertus* type to the extreme curve of the greater number of skulls. This may be due in part to the orientation of the specimens in their original position in the strata. The *apertus* crest was, I believe, detached and lying flat, whereas most of the specimens lie on their side when found, which, in either case, must influence the ultimate form of the fossil due to crushing. It does not seem as though this feature can be of specific significance.

Finally, the muzzle, while always short and deep as compared with that in *Chasmosaurus*, nevertheless varies, especially in profile and in the degree of rugosity of the part immediately above the rostrum. Extreme curvature and rugosity is seen in the type of *nasicornus*, and also in specimen No. 8897 U.S.N.M., which agrees with the type in other details as well.

On the basis of these details, I recognize two clearly defined species, *flexus* and *nasicornus*, either of which may be referable to the genoholotype *apertus*. But in view of the paucity of this type, it merely serves to establish the sub-genus as compared with *Monoclonius* and not the species, hence no reference of any other skull to this species can be made with any assurance at all. It is the custom in the Canadian museums to label as *apertus* all exhibition specimens of *Centrosaurus*, the correctness of which can neither be affirmed nor denied. I shall try to allocate each to one or the other of Brown's species, with the following results.

***Monoclonius (Centrosaurus) flexus* Brown¹⁷**

Pls. II, III; Text Figs. 4, 5, 7-10, 13, 14, 16-29

Holotype: No. 5239 A.M.N.H.; skull.

Horizon: Belly River formation.

Locality: About 1 mile below Steveville, on the east bank of Red Deer River, Alberta.

Collector: American Museum expedition of 1912.

Plesiotype: No. 2015 Y.P.M.

Horizon: Belly River formation.

Locality: 12 miles below Steveville, 2 miles from the mouth of Sand Creek, on the east bank.

Collector: American Museum expedition of 1914.

The chief distinguishing character of this species lies in the nasal horn which is long and curved forward.

To this species I would also refer skull No. 348 G.S.C., at Ottawa, although it departs from the definition in the extreme curvature of the nasal horn and anterior processes, and in the decided rugosity of the premaxillary profile of the muzzle. These may be due in part, however, to age. Skull No. 347, at Ottawa, agrees in the forward curvature of the nasal horn, but disagrees in the rudimentary character of the brow horns, and in the straight anterior processes. This last detail corresponds with the *apertus* type, beyond which comparison fails.

***Monoclonius (Centrosaurus) nasicornus* Brown¹⁸**

Pl. IX, A; Text Figs. 11, 12, 15

Holotype: No. 5351 A.M.N.H.; a complete skeleton.

Horizon: Belly River formation.

Locality: North fork of Sand Creek, 12 miles below Steveville, Red Deer River, Alberta, Canada.

Collector: American Museum expedition of 1914.

The skull characters of this type are as follows: Nasal horn erect, brow horns rudimentary, being represented by a heavy rugosity above the orbits (whether or not the actual horn core was detached in maceration can not be proved), crest processes moderately curved, muzzle deep, profile very convex and rugose.

To this species, besides the holotype, No. 5351 A.M.N.H., I would refer the skull No. 8897 U.S.N.M. in which the nasal horn, so far as preserved, is erect, although restored by the collector, C. H. Sternberg, as curving slightly forward. Otherwise, it conforms well with the type. Another skull, No. 4519 R.O.M., Toronto, agrees with the type in its erect nasal horn and rugose muzzle, although the latter is not so extreme as in the type. The brow horns, on the contrary, do not correspond, as they are pointed and trihedral, being about as well developed as in any *Centrosaurus*.

¹⁷ Brown, B., 1914 B, pp. 549-558.

¹⁸ Brown, B., 1917, pp. 281-301.

Monoclonius (Centrosaurus) cutleri Brown¹⁹

Holotype: No. 5427 A.M.N.H.; posterior half of the skeleton, and a section of the epidermal impression overlying the right femur.

Horizon: Belly River formation.

Locality: North fork of Sand Creek, 12 miles below Steveville, Red Deer River, Alberta, Canada.

Collector: American Museum expedition of 1913.

A few skeletal comparisons can also be made in the three specimens which are sufficiently complete, namely, the types of *asicornus* and *cutleri*, and the Yale specimen of *flexus*. These contrasts lie in the form of the ilia, ischia, sternal plates, femur-tibia ratio, curvature of the posterior ribs and, in the Yale specimen, the curious backward offsetting of the neural arch and spines of the dorsals as compared with those of *asicornus* (see Figs. 9-15).

Comparing the type specimens of *asicornus* and *cutleri*, the following differences are observed: The preserved vertebrae are a little larger in *cutleri*, but, according to Brown, of exactly the same form as in *asicornus*, no distinctions being seen in any part of the column. The sternal plates of *cutleri* are markedly longer, narrower proximally, and wider distally than in *asicornus*. The anterior blade of the ilium is much longer in *cutleri* than in *asicornus*. The ischium of *cutleri* is long and comparatively straight, with the distal end sharply decurved and expanded, in contrast to the more even curve throughout in *asicornus*. The femora are more than one and one-half times the length of the tibiae in *cutleri*, and not over one-third longer in *asicornus*, the ratios being 1.60 to 1 in the former, 1.32 to 1 in the latter. A final detail is the remarkable curvature of the last dorsal rib through an arc of more than 180° in *cutleri* and in the Yale specimen, and not at all in *asicornus*.

The skeleton belonging to the Yale specimen, which the skull characters determine to be *flexus*, is a curious compromise between *asicornus* and *cutleri*. The dorsal vertebrae differ in a marked way from those of *asicornus* in the offsetting of the neural arch and spines to the rear, as has been mentioned. In this they disagree with *cutleri*. The femur-tibia ratio in the Yale specimen, which is as 1.43 to 1, is intermediate between that of *asicornus* and *cutleri*. Unfortunately, the distal half of each ischium has been restored after *asicornus*, but the elongation of the ilia is again intermediate. And last of all, the two sternal plates, imperfect in outline, resemble in the one *cutleri*, and in the other *asicornus*. These are the distinctive features which characterize the Yale skeleton; but without the skull, one would hardly be justified in erecting a new species for its inclusion. The feeling is quite strong, however, that were the skull of *cutleri* known, it would prove to resemble one of those we have included under the species *flexus*.

Genus STYRACOSAURUS Lambe**Styracosaurus albertensis Lambe²⁰****Pl. VIII**

Holotype: No. 344 G.S.C.; skull without lower jaws.

Horizon: Belly River formation.

Locality: 1½ miles south of Denhart Ferry, Red Deer River, Alberta.

Collector: C. H. Sternberg, 1913.

Generic characters are as follows: "Skull massive, elongate, pointed in front, and greatly extended behind to form a neck-frill with long, robust, tapering outgrowths projecting obliquely backward and outward from its posterior border. Fontanelles of moderate size within the coalesced parietals. Squamosals somewhat quadrangular and entering largely into the formation of the front

¹⁹ Brown, B., 1917, pp. 301-306.

²⁰ Lambe, L. M., 1913, p. 109.

part of the frill. Postfrontal fontanelle large. Supratemporal fossae opening widely behind. Nasal horn-core large, upright, straight, rising from the back of the nasals. Supraorbital horn-core incipient."

This is the most bizarre of all the ceratopsian genera, one in which the spines and processes borne on the skull have run riot. The holotype of *S. albertensis* is preserved at Ottawa, and consists of a splendid skull without the lower jaw, although an artificial mandible has been taken from another genus and modified to fit. The skull is entire, except for the following: part of the rostral bone, a little more than the distal half of the nasal horn core, and portions of the spines bordering the parietal part of the crest. There is no reason to suppose that these restorations are other than correct, as they continue the contour of the elements to which they are attached.

The nasal horn core is heavy, with an elliptical cross-section and, as preserved, there is no trace of axial curvature either forward or backward. It is not quite erect, however, but inclines slightly forward. As with *Monoclonius* including *Centrosaurus*, the horn is slightly constricted at the base before the vascular impressions begin. The anterior margin of the horn lies just over the posterior limit of the nares as in *Chasmosaurus*, hence it lies relatively farther back than in *Monoclonius*, wherein the middle of the horn core overlies the posterior margin of the nares. The nasal extends but little behind the horn.

The supraorbital horns were incipient, and the actual ossifications were apparently lost during maceration, for a distinct but irregular facet is visible over the rear margin of each orbit. A second specimen, mentioned by Lambe, shows the same condition. The premaxillaries are broadened out below, but are deeply depressed and smooth in the narial area. The length and comparative shallowness of the muzzle recall *Chasmosaurus* rather than *Monoclonius*. The posterior limit of the premaxillary is far removed from the lacrymal. This was found to be a variable condition in *Monoclonius*. The vestigial preorbital fossa (lacrymal foramen) lies, therefore, between the nasal and maxillary only.

The jugal is deep, and not very extensive fore and aft. There is no indication of an epijugal. The squamosal is short, as in *Monoclonius*, and bears five crenulations, but no separate epoccipitals. The fused parietals form the bulk of the crest. The sutures between them and the frontals and postfrontals are clearly defined on either side of and within the postfrontal fontanelle.²¹

The orbit is broadly elliptical, the longitudinal axis lying upward and slightly backward, about 45° out of the perpendicular. The crest bears three pairs of large spike-like prominences and three pairs of small ones. There are some faint vascular impressions on the surface of the crest itself, but they are many and deep on the processes. The posterior pair of large processes is divergent and slightly curved outward; they are not, however, complete throughout their entire length, so this is conjectural. The intermediate pair is straight and also diverges outward, but they are more perfect, especially as the tip of the left one is preserved, so that there is little doubt of their correct restoration. The forward pair, which again is slightly curved outward, underlies the intermediate pair a little, at their base. Here, again, there is some restoration, but it is evidently correct. Of the small prominences, the hinder pair, which arises on the superior surface of the crest, is suggestive in position of the forwardly projecting processes on the crest of *Monoclonius* (*Centrosaurus*), while the pair on the lateral margins of the crest, just in front of the anterior large processes, is like those of *Monoclonius* (*Centrosaurus*) in character but not in position, in that they show the same grooved or fluted surface. In front of these processes on either parietal margin are two other prominences comparable to and probably homologous with epoccipitals, although again without sutural limitation. Viewed from above, the crest gives the impression of having been pulled away from the frontal area of the skull at the posterior limit of the fontanelle. There is, however, no evidence of fracture. It gives the entire skull, when viewed from the side, a flattened aspect unlike any other ceratopsian except *Torosaurus gladius* as restored (see Pl. XVI). As Lambe says,²² "In lateral aspect the skull is depressed and very long in contrast with its height. The spike-shaped processes double the length

²¹ Sternberg, C. M., 1927, A, p. 140.

²² Lambe, L. M., 1913, p. 110.

of the frill, which, without them, would compare favourably in relative size with the corresponding expansion in later forms of the Ceratopsia, such as *Triceratops*, in which the orbit is but slightly in advance of the mid-length of the skull. Behind the nasal horn the upper outline is straight, then somewhat depressed near the middle of the crest, finally rising to its highest point at the termination of the hindermost process."

The parietal fenestrae are irregularly oval in outline, with their longer diameter extending from anterior to posterior and slightly diverging outward. Anteriorly, they approach but do not reach the squamosal suture. Beneath the large nasal horn the nasals are massive, to withstand the heavy strains to which the use of the horn subjected them; a bulky transverse arch is formed by the descending processes, which meet ascending processes from the premaxillaries, while in front, the nasals form a shallow, laterally compressed arch, which descends vertically in a sweeping curve to meet the premaxillaries in advance of the narial openings, after the manner of a flying buttress. The vertical nasal septum supports this arch from beneath and is, as in *Monoclonius*, contributed to jointly by both nasals and premaxillaries. The septum is not fenestrated, agreeing again with *Monoclonius* but in contrast to *Triceratops*.²³ The infratemporal arcade is formed by the quadrate, quadratojugal, and a forward process of the squamosal. The last, together with the jugal, forms the actual limits of the infratemporal fossa itself.

No skeletal elements attributable to *Styracosaurus* are known, but presumably, in size and proportions, the body and limbs were not unlike those of its contemporaries, *Chasmosaurus* and *Monoclonius* (*Centrosaurus*).

DIMENSIONS OF THE SKULL

(After Lambe 1913, but converted into mm.)

Maximum length of specimen from midway between the points of the back processes	1861 mm.
Greatest breadth of same across the processes	1435
Length of squamosal from the posterior termination of its free edge to the back margin of the jugal	397
Breadth of same from its lowest point to the top of the squamoso-postfrontal suture	311
Length of nasal horn core as found	251
Transverse diameter of same, at break	70
Longitudinal diameter of same, at break	98
Transverse diameter of same, at base	111
Longitudinal diameter of same, at base	162
Length of nasal horn core as restored	552

MEASUREMENTS MADE FROM THE SKULL BY R. S. LULL

From tip of rostral to rear of crest between processes, measured over the curve	1390 mm.
From tip of rostral to tip of left rear process	1970
Length of posterior left process	550
Length of intermediate left process	500
Length of anterior left process	390 (Calculated)
Nasal horn on rear margin, actual bone	260
Nasal horn on rear margin, as restored	580
Depth of premaxillary	280
Rostral to supraorbital horn suture	770
Width over orbits	300
Width over squamosals, on curve	1000
Length of left parietal fenestra	265
Width of left parietal fenestra	210

²³ Even in the several *Triceratops* specimens this is so variable a feature that the perforation may be merely the result of postmortem accident, as the septum is extremely thin.

Styracosaurus ovatus Gilmore²⁴

Holotype: No. 11,869 U.S.N.M.; posterior portion of the crest and numerous detached fragments.

Horizon: Two Medicine formation.

Locality: Milk River, Blackfoot Indian Reservation, Glacier County, Montana.

Collector: G. F. Sternberg, 1928.

This species conforms to the generic characters in so far as determinable from the extremely meagre type, which consists of the posterior part of the crest bearing the four median processes together with a detached fragment bearing another.

The original description follows: "The outstanding peculiarity of the skull of *Styracosaurus albertensis* is the large horn-like processes that project outward and backward from the posterior border of the frill. Somewhat similar processes are present on the frill before me. The two processes forming the hindermost pair lack their tips but it is quite evident they were not as long as in the Canadian specimen. . . . Furthermore, these two horns are convergent as opposed to the divergent processes in *S. albertensis*. It would seem that if completely preserved the extremities of these two horns would nearly meet on the median line. Those of the next pair in advance are nearly as large as the hinder pair but point outward more than backward. That there was a third pair is shown by the presence of a small lateral section of the frill, from the side of which a small, stubby process projects outward. . . . If, as is apparent, this fragmentary part represents the third pair, these processes have their origin considerably forward of the second pair as shown by the smooth, rounded border between them. In *S. albertensis* these processes are relatively shorter, curved, and twinned with the second pair at the base.

". . . That large fontanelles were present on either side of a median bar as in *S. albertensis* is shown by the rapid thinning of the bone on the anterior borders on either side of the middle, and also of the posterior portion of the bar which is preserved. This part of the median bar is broadly rounded transversely on the upper side but flattened beneath.

"The upper and lower surfaces of the frill parts are marked by the usual vascular grooves. The horn-like processes are much flattened above and below and cross sections taken from almost any part would be broadly ovate in cross section."

Thus, the main distinctions of the present species from *S. albertensis* are: processes III are closer at the base and converging instead of diverging toward their tip, and there is a wider separation of processes I and II at the base. In *albertensis*, the processes are in contact; in *ovatus*, a rounded-edged margin of crest lies between them, flat and sometimes slightly hollowed on the under side. The presence of vascular impressions on the crest of *ovatus* in contrast to the smooth surface in *albertensis* may be a matter of individual age, the former being the older, although somewhat more recent in geologic time.

The type of *Monoclonius sphenocerus* Cope, from the Judith River of Montana, which consists of the nasal horn, nasals, and part of the left premaxillary, is quite suggestive of the corresponding part of *S. albertensis*. Of these, Lambe says,²⁵ "In Cope's species the nasal horn-core is farther forward on the nasals, is proportionately shorter, and more laterally compressed, with a much greater antero-posterior diameter at the base. The nasals in front of the horn descend rapidly instead of rising conspicuously before they curve downward, and the nasal opening is larger and placed more under the horn."

As a matter of fact, the type of *Monoclonius* (*Centrosaurus*) *nasicornus* Brown is even more like *Styracosaurus* in this particular portion than is that of *M. sphenocerus*. The nasals in front of the horn rise as in *Styracosaurus*, and agree in being highly rugose; the smaller nasal opening lies under the anterior part of the horn, and the character of the horn itself agrees except for minor differences which may be due in part to the manner in which the distal half of the *Styracosaurus* horn is

²⁴ Gilmore, C. W., 1930, pp. 36-37, Pl. 10, Figs. 1, 2.

²⁵ Lambe, L. M., 1913, p. 115.

restored. *M. (C.) nasicornus* is not *Styracosaurus*, for the crests, while possessing processes and short squamosals, are otherwise totally different, as are the general proportions of the entire skull. The two cannot be congeneric, and there is no more assurance that *Styracosaurus albertensis* and *Monoclonius sphenocerus* were. On the other hand, *Styracosaurus*, being a short squamosal form, lies nearer *Monoclonius (Centrosaurus)* in relationship than any other contemporary genus, evidently representing a highly aberrant offshoot of the same ancestral stock as that of *Monoclonius*. Certainly, no known Lance genus or species gives any evidence of relationship. The evolutionary trend in *Styracosaurus*, as shown by the available material, seems to be toward a shortening, broadening, and straightening, together with a convergence, of the posterior processes.

Genus EOCERATOPS Lambe

Eoceratops canadensis Lambe²⁶

Holotype: Right squamosal, No. 1254a G.S.C.; the right posterior lateral extension of the parietal, No. 1254b; the right postfrontal and prefrontal with the supraorbital horn core rising from the former bone, No. 1254d; the right nasal including the right half of the nasal horn core, No. 1254c; the left dentary without teeth, No. 1254e; and an anterior dorsal vertebra, No. 1254.

Horizon: Belly River formation.

Locality: On the east side of Red Deer River, Alberta, a short distance below the mouth of Berry Creek.

Collector: L. M. Lambe, 1901.

Generic characters are: "Skull small, short, compact; supraorbital horn-core moderately large, slender, overhanging the orbit, circular in cross section, tapering to a point and directed upward, and slightly inward and backward above; nasal abbreviated and deep; nasal horn-core short, contributed to by the nasals and two separate, anterior ossifications; crest or neck-frill slightly longer than half the total length of the head; squamosal broadly triangular, longer than broad, with a smooth, undulating outer border, without epoccipitals, forming the greater part of the crest laterally; fenestrae of the crest long, enclosed without by the squamosal, and behind by a slender parietal bar which passes forward beneath the inner posterior border of the squamosal; dentary robust, with about twenty-five vertical series of teeth."

The type material upon which the genus *Eoceratops* is based consists of several isolated bones, pertaining to an immature individual, which might well account for such features as the absence of epoccipitals, and the character of the nasal horn core. Lambe's outline of the skull, with the short and very deep muzzle, is highly conjectural except for the fact that a deep facial region generally goes with a short broad squamosal. It is noteworthy that in the presence of so many nearly perfect skulls of the other Belly River genera, especially of *Monoclonius (Centrosaurus)* and *Chasmosaurus*, this should be the only recognizable specimen referable to this genus. The full understanding of relationships in this instance, as in that of *Monoclonius dawsoni* and the Judith River genera, must await further discovery.

The skull, as at present understood, differs from all other Belly River genera in the nature and position of the nasal horn core. The character may be partly juvenile, but the position over the forward margin of the narial opening, instead of over the rear, separates it from *Monoclonius (Centrosaurus)*, *Chasmosaurus*, and *Styracosaurus*, and likens it to the Lance *Triceratops*.

The form of the squamosal also resembles that in *Triceratops*. It is short like that of *Monoclonius (Centrosaurus)*, but differs in being generally triangular instead of quadrangular, as in the latter genus. The long fenestra, apparently but partly enclosed by the parietal element, is suggestive of an imperfect *Chasmosaurus* crest rather than of *Monoclonius (Centrosaurus)* in which the fenestrae are widely removed from the squamosal. The absence of epoccipital bones is not invariably diagnostic, since they are lacking in several *Triceratops* skulls, notably that on the mounted skeleton at the American Museum, in which they have probably been lost through lack of coössification before fossilization.

²⁶ Lambe, L. M., 1915, pp. 1-25.

Genus CHASMOSAURUS Lambe

The type of this genus, No. 491 G.S.C., is a portion of the crest consisting of the median bar and part of the posterior transverse bar, first described by Lambe²⁷ as *Monoclonius belli*. Because of Lambe's conviction that this genus was directly ancestral to the Lance genus *Torosaurus*, the name *Protorosaurus* was given to it in 1914,²⁸ together with a detailed description based upon the plesiotype, which supplied all the necessary details except the anterior part of the skull, including the muzzle and nasal horn. The first of these I find to be important in *Chasmosaurus*, the second rather less so, although a principal diagnostic character in other genera. Later in the same year,²⁹ a further description of this species was given, with the new generic name, *Chasmosaurus*, replacing *Protorosaurus*, which was found to be preoccupied by H. v. Meyer for a genus of Permian reptiles.

The generic characters, as given by Lambe,²⁹ are as follows: "Skull large, broadly triangular in superior aspect, with a narrow, abbreviated facial portion, and a broad and greatly expanded posterior crest ending squarely behind. Coalesced parietals forming a slender framework enclosing large sub-triangular fontanelles. Squamosals very long and narrow with a scalloped free border. Epoccipitals present. Supraorbital horn-cores small, upright. Supratemporal fossae of moderate size. Postfrontal fontanelle present. Jaws robust. Teeth large, of the ceratopsian type. Body covered with non-imbricating, small plate-like, and smaller tubercle-like scales."

The holotype of this genus, incomplete as it is, shows no specific characters; but, as in *Monoclonius* and *Centrosaurus*, serves only to establish the genus. The plesiotype, on the other hand, allows for an almost complete generic description and establishes the species *belli* as well. In spite of the fact that the various skulls show considerable variation among themselves, two other species seem to be definable, although in each instance based upon a single skull.

The contrasting specific characters lie in the brow horns, whether longer or shorter than the nasal horn, the former being the more progressive condition. The muzzle, whether long or short, seems also to be distinctive. The emargination of the posterior bar of the crest may prove to be distinctive; at present, it seems to be merely an individual, or possibly a sexual variation. On the basis of these and certain minor distinctions, the following species may be defined.

Chasmosaurus belli Lambe³⁰

Pl. VI, XIV, B; Text Fig. 30

Holotype: No. 491 G.S.C.; parietal.

Horizon: Belly River. Upper (primitive mammal) beds.

Locality: On the east side of Red Deer River, below the mouth of Berry Creek, Alberta.

Collector: L. M. Lambe, 1898.

Plesiotype: No. 2245 G.S.C. (Pl. XIV, B), consisting of a large part of the skull and skeleton now mounted at Ottawa.

Horizon: Belly River formation.

Locality: On the east side of Red Deer River, a short distance below the mouth of Berry Creek.

Collector: C. H. Sternberg, 1913.

The distinctive characters of this species are as follows: Brow horns short, trihedral, and erect; orbit elliptical, with long axis nearly horizontal; posterior bar of crest not emarginate—large epoccipitals are present at the outer rear corners of the crest just behind the termination of the squamosal, but there is none borne on the parietals; squamosals bearing seven or eight epoccipitals, increasing progressively in size from front to rear. To these features, determinable from the plesiotype, may be added: Nasal horn larger than the brow horns, although short and robust; and muzzle long and slender.

²⁷ Lambe, L. M., 1902, pp. 66-67, Pl. xx, Figs. 1, 2, Text Fig. 20.²⁸ Lambe, L. M., 1914, A, pp. 131-132.²⁹ Lambe, L. M., 1914, B, pp. 149-155.³⁰ Lambe, L. M., 1902, pp. 66-67.

As further representatives of this species, I would add the companion skeleton, No. 2280 G.S.C. (Pl. XIV, B); skull No. 5402 A.M.N.H. (Pl. VI); and No. 2016 Y.P.M. The skull of No. 2280, at Ottawa, differs in having a deeply emarginate posterior bar which bears two more epoccipitals on either side of the midline. The orbit is more nearly circular, with the long axis more nearly vertical and the brow horns, especially the left, somewhat recurved. Skull No. 5402 A.M.N.H. conforms, except that the brow horns slope forward and are somewhat more anteriorly placed with relation to the orbit than in the type. The rear of the crest is not emarginate, and has four epoccipitals. The Yale specimen also agrees, except that the brow horns are rudimentary, being merely rugose areas above the orbit.

There is in the American Museum collection the partial skull of a chasmosaur, No. 5656 A.M.N.H., collected by C. H. Sternberg in 1917, from the Belly River horizon of Sand Creek, Red Deer River, Alberta. The upper surface of the cranium, including the horns, and the muzzle have been eroded away, but the crest is in a remarkable state of preservation. The specimen is that of a young individual, about 80 per cent grown, with clearly defined sutures and with apparently all of the epoccipitals preserved *in situ*.

The outstanding features of this skull are the deeply emarginate posterior bar, bearing two large, sharply pointed epoccipitals on either side of the reëtrant curve, together with a marked prominence just behind the terminus of the squamosal which does not at present bear an epoccipital, although in the position of the largest of these in an adult chasmosaur. The parietals have the usual overlapping suture on the outer border of the very large fenestrae just within the squamosal. The latter bone is very short for *Chasmosaurus*, extending for about two-thirds the length of the parietal. The squamosals are deeply concave transversely as seen from above and bear a longitudinal row of boss-like prominences. There are four distinctly sutured epoccipitals at this stage of growth on either squamosal, and the antero-external angle is acuminate. The outer end of the jugal is rounded, with no evidence of an epijugal. Vascular impressions are absent except on the posterior bar of the parietals and on the epoccipitals. This crest resembles most nearly that of No. 2280 in the Ottawa group (Pl. XIV, B), the main distinctions, other than size, being the presence of the row of bosses on the squamosal, its somewhat less relative length (although it is still short in No. 2280 as compared with the *Chasmosaurus belli* plesiotype, No. 2245), four as compared with six squamosal epoccipitals, and the absence of the large epoccipital just behind the terminus of the squamosal.

In these two animals the differences may be due entirely to age, for it is conceivable that the epoccipitals might increase in number with the lengthening of the bones bearing them. Hence, the two specimens seem without question to be conspecific. The deeply emarginate crest with its four to six epoccipitals and the shorter squamosals may prove to be specific characters, distinguishing this form from No. 2245, the *Chasmosaurus belli* plesiotype, in which the crest is not emarginate and the squamosals are relatively long. On the other hand, these may be sex differences. This would accord with the idea of C. M. Sternberg³¹ who thinks that No. 2245 may have been a male and No. 2280 a female on the ground that, "it is common, among reptiles, for the female to be larger than the male," No. 2280 being somewhat the more robust. I have referred the question of the relative size of the sexes in reptiles to Raymond Ditmars whose authority no one will question. He writes as follows:³² "I have found, with the greater number of snakes, that the females are larger and heavier than the males. With some species, this is so marked that the sexes can be distinguished at a glance.

"Among the lizards, however, the reverse is generally the case. In fact, it may be fairly safe to say that with the majority of the species, the males are a bit larger and certainly more ornate."

It would seem that the analogy lies with the lizards if anywhere, so that on two counts the specimen with greater robustness and greater ornamentation at the rear of the crest (No. 2280) should be considered the male. It is unfortunate that the muzzle and nasal horn, as well as the distal end of the ischium, cannot be contrasted, for these elements, lacking in one or the other animal, were restored from the one possessing them.

³¹ Sternberg, C. M., 1927, B, p. 67.

³² Letter of October 22, 1932.

The chasmosaur skeleton in the Royal Ontario Museum, No. 5499, was also found by the expedition of 1926, on the east side of Red Deer River, two miles south of Steveville, Alberta, and 125 feet above the river level. Therefore, it was 75 feet below the *Chasmosaurus brevirostris* skull. Whether this means 75 feet of intervening strata is not clear. This skeleton is, as yet, undescribed, but varies from those in Ottawa in minor details only. The skull has been partially restored, and with a rather short muzzle somewhat suggestive of *brevirostris*, but there detailed resemblance ceases, for there are no brow horns, only the rugose area above the nearly circular orbit as in the Yale skull. The nasal horn, on the other hand, is stout, straight, and abruptly truncated. The crest is deeply emarginate, the effect of which is heightened by the very large epoccipitals at the postero-lateral corners of the crest. This skull and that on the skeleton No. 2280 at Ottawa, show the deepest emargination, but otherwise, the resemblance is not very close. The value of this character in itself is difficult to determine. In view, however, of the high specialization of the entire crest, I should imagine that minor individual variations were common—no two crests, in fact, no two skulls, are ever exactly alike.

Chasmosaurus brevirostris, n. sp.

Pl. VII, A

Holotype: No. 5436 R.O.M., Toronto; skull without lower jaws, the rear of the crest slightly restored.

Horizon: Belly River formation.

Locality: On the west side of Red Deer River, Alberta, three miles southwest of Steveville, along the railway grade, at an elevation of 200 feet above the river.

Collector: University of Toronto expedition of 1926.

This specimen conforms to *belli*, except that the muzzle is very short and deep, more as in *Monoclonius*, and the nasal horn is large and curves somewhat backward, although inclined forward at the base. The brow horns are like the nasal but smaller. The last epoccipital on the squamosal is markedly larger than in any other specimen, and the broadly elliptical orbit is almost vertical. The right epijugal is sharp and trihedral, like that of *Pentaceratops*. There were nine epoccipitals borne on the squamosal.

Chasmosaurus kaiseni Brown³³

Pl. V, A; Text Fig. 38

Holotype: No. 5401 A.M.N.H.; a splendidly preserved skull without lower jaws.

Horizon: Belly River formation.

Locality: About 12 miles below Steveville, on the Red Deer River, Alberta.

Collector: American Museum expedition of 1913.

The specific characters are as follows: Muzzle very long, terminating in a relatively small rostrum. Nasal horn of medium length, consisting apparently of three elements, one median, grooved on its posterior face, the others anterior and lateral to the first, the lateral ones being highly rugose, and the entire horn unlike that of any other known chasmosaur; brow horns very large for a Belly River ceratopsian, since those of no other skull, except *Eoceratops canadensis* and a chasmosaur to be described below, approach them in size. They rise above the anterior half of the orbit, curve outward, and sharply forward, then upward, and bear abundant vascular impressions. It is these horns alone that show any approach of *Chasmosaurus* to *Ceratops* (see p. 97). The orbit is very large, and broadly oval, with the long axis inclined upward and backward at an angle of 45°. The rear of the crest is but slightly emarginate, with the usual large epoccipitals just

³³ Brown, B., 1933, B.

behind the end of the squamosals. Anteriorly, the squamosal is broad, with a pointed epoccipital at the antero-external corner. The jugal notch is deep, with parallel sides. The jugal is long, and slopes backward and outward, with a long pointed epijugal, thus resembling that of *Pentaceratops*, as does a number of other details of this very interesting type.

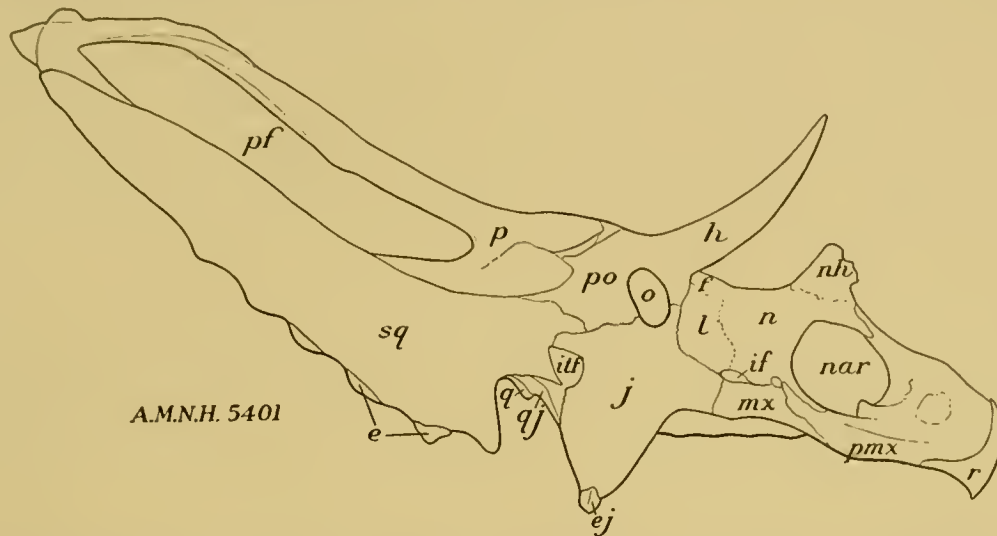


Fig. 38.—Right lateral view of skull of *Chasmosaurus kaiseni*, holotype, 1/12 natural size. *e*, epoccipitals; *ej*, epijugal; *f*, prefrontal; *h*, supraorbital horn; *if*, preorbital fossa; *itf*, infratemporal fossa; *j*, jugal; *l*, lacrymal; *mx*, maxillary; *n*, nasal; *nh*, nasal horn; *nar*, narial opening; *o*, orbit; *p*, parietal; *pf*, parietal fenestra; *pmx*, premaxillary; *po*, postfrontal; *q*, quadrate; *qj*, quadratojugal; *r*, rostral; *sq*, squamosal.

DIMENSIONS

Greatest length, from tip of rostrum to outer angle of crest	1520 mm.
Width of crest at posterior end of squamosals	820
Tip of rostrum to posterior end of nasal horn	463
Tip of rostrum to anterior edge of orbit	560
Tip of rostrum to posterior end of jugal	724
Height of orbit	102
Width of orbit	62
Brow horn, from rim of orbit to summit	370
Height of nasal horn above nares	130

Chasmosaurus cf. *C. kaiseni* Brown

Pl. VII, B

Specimen: No. 40, Univ. Alberta; anterior part of a skull to about one-third the length of the crest, and a few bones of the skeleton.

Horizon: Belly River formation.

Locality: Red Deer River, 2 miles southeast and 1 mile east of the mouth of Sand Creek, Alberta.

Collector: G. F. Sternberg, 1920.

Yet another remarkable chasmosaur skull is preserved in the museum of the University of Alberta, Edmonton, and was briefly described by Gilmore,³⁴ who referred it, with a query, to the genus *Eoceratops* Lambe. Gilmore's description stresses the following points: Fully adult; short, deep nasal region, small, upturned nasal horn; subcircular, tapering, slightly recurved brow horns; triangular squamosal having the dimensions of the type of *Eoceratops canadensis*. These are all fea-

³⁴ Gilmore, C. W., 1923, pp. 51-52.

tures found in *Eoceratops*. Contrasts with *Eoceratops* are found in the inclination of the postorbital horns and the presence of epoccipitals, which are absent in *Eoceratops*. These are not significant points, but the longitudinally-divided nasal horn core of *Eoceratops* type, as distinguished from that of the present specimen, is of importance. In comparison with *Chasmosaurus*, the epoccipitals and the parietal fenestrae agree, but Gilmore thinks the squamosal too short, even if continued beyond the broken end. Our figure shows, however, that the squamosal could be prolonged to agree with *Chasmosaurus* without lack of harmony with the preserved lines. With the rostral added, this skull shows rather marked similarity with *Chasmosaurus kaiseni*. The muzzle is somewhat shorter, the nasal horn differs, and the brow horns are not so long, but the character of the jugal and the anterior margin of the squamosal defining the jugal notch are very similar, as well as the comparatively long brow horns. Gilmore's objection, on the ground of the small size of the skull, is hardly valid, for the specimen seems to be nearly as large as the type of *kaiseni*.

DIMENSIONS
(From Gilmore)

Greatest length of skull, estimated about	1200 mm. ³⁵
Greatest width of squamosal	280
Height of brow horn above superior border of orbit	170
Antero-posterior diameter of horn at base	65
Height of skull, from border of alveolus to tip of nasal horn, about	320

My identification would place this as a variant, possibly sexual, of *Chasmosaurus kaiseni*.

Genus CERATOPS Marsh

This Judith River genus is based on so very inadequate material as to be undefinable. Four species were described by Marsh, of which one, *Ceratops paucidens*, was based upon a left premaxillary and maxillary with its contained teeth. This Hatcher determined to belong to one of the trachodonts, and hence not ceratopsian at all. Another skull described as *Ceratops horridus*, was afterward made the type of a new genus *Triceratops*, while the third, *Ceratops alticornis*, consisting of a pair of brow horns, from the Denver beds, was later removed to the genus *Triceratops*, where it evidently belongs. Thus, only one is left, *Ceratops montanus*, which is the genoholotype.

Ceratops montanus Marsh³⁶

Holotype: No. 2411 U.S.N.M.; occipital condyle, and a pair of supraorbital horn cores.

Horizon: Judith River formation.

Locality: Cow Creek, about 10 miles above the confluence of that stream with the Missouri River, Montana.

Collector: J. B. Hatcher, 1888.

In addition to this scanty material, Marsh referred the squamosal, No. 4802 U.S.N.M., to this species, while another, No. 2415 U.S.N.M., was also figured in the Ceratopsia Monograph and referred to *C. montanus*.³⁷ These are both short squamosals and might with equal, if not greater, propriety, be referred to *Monoclonius*, for they are of the character of those borne by *M. crassus*, as the short sutural surface in the type shows. They give no aid whatever in defining the genus *Ceratops*, because of their lack of actual association with the type. The only known character, therefore, lies in the brow horns themselves, which, in the absence of other skull features, are insufficient to define the genus.

³⁵ I would estimate this at nearer 1500 mm.

³⁶ Marsh, O. C., 1888, pp. 477-478.

³⁷ Hatcher, Marsh, Lull, 1907, Pl. III, Figs. 1, 2.

The brow horns which constitute the type are large and, as reoriented by Hatcher, curve sharply outward from their base, when viewed from in front. From the oblique rear, they are straight, but taper rather abruptly. The only possible comparisons with contemporary forms are with *Monoclonius recurvicornis* Cope, *Eoceratops canadensis* Lambe, and *Chasmosaurus kaiseni* Brown, of which the first only is Judith River, the others being Belly River forms. In the first of these, the brow horns are much shorter, truncated, and erect, without axial curvature, hence differing decidedly from the widely curved horns of *Ceratops montanus*. The comparison with *Eoceratops canadensis* is nearer; in fact, Hatcher says the horns "are strikingly similar."³⁸ They are nearly the same length in each species, that of *Eoceratops* being a little the shorter, but much more slender and backwardly curved. These distinctions may be specific only. Comparison with *Chasmosaurus kaiseni* (see Fig. 38) also shows about the same degree of likeness and difference, the latter having to do with the greater relative slenderness and curvature, for here the horns slope outward and forward at their base, and curve upward toward their summit in a single curve. Fortunately, *Chasmosaurus kaiseni* is founded upon a perfect skull, and its reference to *Chasmosaurus* is unquestioned on the basis of the crest, but it and one other (No. 40, Univ. of Alberta (see p. 95)) are the only instances, in any of the nine *Chasmosaurus* skulls known to me, in which long brow horns occur, all of the others, in which they are preserved, having rudimentary horns. One cannot, therefore, accept the synonymy of *Ceratops* and *Chasmosaurus* on such slender evidence as this, especially as the latter is a well defined genus, and from a different region, although perhaps of nearly equivalent age. *Ceratops montanus* comes from the summit of the Judith River series and may represent a more advanced evolutionary stage of the same phylum as *Chasmosaurus*, but until more perfect diagnostic material, including the entire crest, is collected from this horizon and locality, the status of *Ceratops* cannot be solved. The relationship between *Monoclonius* and *Centrosaurus* is more nearly proved, but the inferred assumption that if these genera are nearly related, *Ceratops* and *Chasmosaurus* must also be, is based upon no evidence whatever. No fragment of a long squamosal, such as that of *Chasmosaurus*, has come to light in the Judith River collections.

Genus BRACHYCERATOPS Gilmore

Brachyceratops montanensis Gilmore³⁹

Pl. IX, B

Holotype: No. 7951 U.S.N.M., considerable portion of a disarticulated skull with which is provisionally associated a fragmentary part of the crest and a right dentary and predentary.

Paratypes: No. 7952, U.S.N.M., rostral and portions of the premaxillaries; No. 7953, U.S.N.M., sacrum, pelvis, articulated caudal series of 50 vertebrae, with which are provisionally associated dorsal vertebrae and ribs; No. 7957, U.S.N.M., tibia, fibula, and partly articulated hind foot from the left side, consisting of an astragalus, calcaneum, and 2 tarsals of the distal row, 4 metatarsals and a portion of a fifth, and 11 phalanges.

Horizon: Two Medicine formation.

Locality: N.E. $\frac{1}{4}$ sec. 16, Township 37N., Range 8 W., Milk River, Blackfeet Indian Reservation, Glacier County, Montana.

Collector: C. W. Gilmore, 1913.

The original description of generic and specific characters, as emended by Gilmore,⁴⁰ is as follows: "Typically of small size. [Note. The small size of the animal, Gilmore says, may be due to some extent to the immaturity of the individuals. I should say to a large extent, for the impression one gets from the open sutures and general proportions is that of a creature not half grown. A very *Monoclonius*-like squamosal in the collection, which is nearly if not quite as large

³⁸ Hatcher, Marsh, Lull, 1907, p. 102.

³⁹ Gilmore, C. W., 1914, pp. 1-10.

⁴⁰ Gilmore, C. W., 1917, p. 7.

as that of an adult *Monoclonius*, may possibly have pertained to a full-grown *Brachyceratops*.] Skull with facial portion much abbreviated and deep vertically. Supraorbital horn cores small and firmly united with postorbitals. Nasal horn core outgrowth from nasals, large, slightly recurved, laterally compressed, and divided longitudinally by median suture. Frill with comparatively sharp median crest, fenestrae apparently of small size, and entirely within the median element. Border of frill scalloped but without separate marginal ossifications. Dentition as compared with *Triceratops* greatly reduced. Five digits in the pes, the fifth being vestigial. Ilium with greatly expanded anterior blade that curves strongly outward."

The narial opening, Gilmore states, is situated "well forward and under the nasal horn." This position is midway between that of the Belly River Ceratopsia and those of the Lance, for primitively the horn arises over the posterior border of the nares; in the Edmonton forms, *Arrhinoceratops* and *Anchiceratops*, and in the contemporary *Pentaceratops*, it is over the opening itself, whereas in *Triceratops* it overlies the anterior margin. This is a progressive evolutionary change which is true of all phyla.

Viewed laterally, in profile, the skull shows a great abbreviation of the facial portion, when compared with the Lance genera. It is to this shortening that the generic name refers. This reduction of the face is also true of *Chasmosaurus* to an even greater degree, but there the similarity between *Brachyceratops* and *Chasmosaurus* ends. The distance between the nasal horn and the supraorbital horns is exceedingly short, due to the shortened nasal bones, the great fore and aft development of the nasal horn, and to the forward position over the orbits of the small supraorbital horns.

"An entirely new phase of nasal horn development and one which appears to be unique among dinosaurs appears in the longitudinal separation of the horn core into two halves by the nasal suture. The nasal horn itself appears to be an outgrowth from the nasal bones instead of having originated from a separate center of ossification, as in the more specialized *Triceratops*"⁴¹ [notably the types of *T. serratus* and *flabellatus*, in each of which the sutures are well indicated and the horn ossification is lost]. The *Eoceratops canadensis* type from the Belly River also shows a suture separating not only the nasal bones, but the horn as well. There is here, however, an epinasal⁴² forming the anterior portion of the horn, which is lacking in *Brachyceratops*, according to Gilmore, although his figure indicates a small, separate ossicle on the summit of the left half of the horn, with a facet indicating the former presence of one on the right. Whether these are homologues of the epinasal of *Eoceratops*, or the separate horn ossification as in *Triceratops*, or both, I am not sure. The latter would seem probable.

The nasal horn is directed somewhat forward, but the curve of the posterior margin gives it a slightly recurved appearance. The upper half bears vascular grooves.

The maxillaries are triangular in outline, with alveolar grooves for 20 vertical rows of teeth, as compared with ± 30 in *Triceratops*, 27 for *Pentaceratops*, and 35 for *Monoclonius* (*Centrosaurus*) *flexus*. The small number of alveoli may again be due to the juvenile character of the specimen for, as the jaws elongate with growth, the teeth with their alveolar grooves would either have to increase in size, which is rather doubtful, or the number of rows would increase.

The dorsal aspect of the cranium is of interest. There is no trace of frontal bones, according to Gilmore, as the pre- and post-frontals are in contact. In most reptiles the frontal is interposed between them, although the condition shown in *Brachyceratops* is found in all the *Ceratopsia* except *Protoceratops* and possibly *Leptoceratops*.

The postorbital, which gives rise to the small supraorbital horn core, forms nearly one-half the border of the orbit. It is separated from the postfrontal by a longitudinal suture which is elsewhere unknown, even in *Protoceratops*.⁴³ Posteriorly, it overhangs the supratemporal fossa, while ante-

⁴¹ Gilmore, C. W., 1917, p. 8.

⁴² Lambe, L. M., 1915, p. 6, Pl. V, Fig. 1.

⁴³ In all other *Ceratopsia*, the absence of this suture makes it impossible to distinguish the postorbital from the postfrontal elements, hence the two terms are considered synonymous.

riorly, it shows a short suture for the small supraorbital bone which is missing. The horn is situated on the extreme anterior end of the postorbital and not on the supraorbital at all. Gilmore⁴⁴ doubts the propriety of designating these horns as supraorbital, but as generally understood, the name refers to their position above the eyes rather than to the element which bore them. The horn core is low, with a summit obtusely rounded longitudinally but sharply pointed transversely. The external surface is plane, the internal one strongly convex, and the antero-posterior diameter greatly exceeds the transverse. The height of the horn above the orbit is 31 mm.

The crest is represented by the median elements from two individuals (No. 7950 and No. 7951 U.S.N.M.). For this median element Gilmore⁴⁵ accepts the designation dermosupraoccipital or interparietal, after Von Huene. It is united by suture with the anterior portion of the skull at the postfrontal fontanelle, articulated with the postfrontals above and questionably with the parietals (our supraoccipital) beneath. The median part is sharply ridged except at the posterior extremity, where it flattens into a thinner portion with an emarginate median border. Between the fenestrae the median bar has a thickened triangular cross-section. The bone surrounding the frill fenestrae is very thin, but it thickens toward the lateral free edges and posteriorly. The exact shape and extent of the frill fenestrae cannot be determined from the available specimens; in fact, judging from Gilmore's figure, there is only a small portion of the antero-internal margin of the right one which can be determined at all. He is probably right in saying that they were comparatively small. In this, as in the short squamosal, *Brachyceratops* agrees more with *Monoclonius* than with *Chasmosaurus*. There were no epoccipital bones on the margins of the frill, but a series of prominences on either side of the median emargination give the periphery a scalloped effect comparable to that produced by the epoccipitals of *Triceratops*. Epoccipitals may have been present, however, and may yet be demonstrated by the discovery of a more mature skull.

As Gilmore⁴⁶ rightly says, "The modifications found in the ceratopsian skull are greater perhaps than in any other known group of reptiles, living or extinct. . . . The inclosed and compact nature of the skull was of the greatest value as a means of protection, and it contrasts strongly with the open structure of most other dinosaurian skulls. These modifications have led to a rearrangement of the elements of the cranium, that until interpreted is as confusing as it is unusual. . . .

"It now appears that the prefrontals and postfrontals, which in the normal reptilian cranium are lateral to the parietals and frontals, have in the ceratopsian skull pushed upward and inward above those bones, completely covering their dorsal aspect,"⁴⁷ although they are not in contact with them because of the intervening frontal sinus.

DIMENSIONS OF SKULL (After Gilmore)

Greatest length, about	565 mm.
Greatest breadth, estimated	400
Length of crest along median line	315
Height of nasal horn core above nares	125
Breadth between center of orbits	130
Postorbital horn cores at base	
Anteroposterior diameter	34
Transverse diameter	27
Horizontal diameter of orbit	57
Nasal horn core at base	
Anteroposterior diameter	90
Transverse diameter	41

⁴⁴ Gilmore, C. W., 1917, p. 11.

⁴⁵ Loc. cit., p. 11.

⁴⁶ Loc. cit., pp. 17-18.

⁴⁷ Our usage excepts the parietal which forms the median element of the crest.

There is nothing distinctive about the vertebrae of *Brachyceratops*. The sacrum is of interest, however, as it is the most immature ceratopsian sacrum on record. "The sacrum in the paratype, No. 7953, is represented by all the centra, portions of the neural processes of the posterior vertebrae, and numerous detached sacral ribs. . . . The centra are all suturally united and in an adult individual would doubtless be firmly coössified, as in other ceratopsians. The paratype has nine articulated centra, of which the anterior six are regarded as true sacrals and the posterior two as true caudals. The remaining intermediate vertebra between tail and sacrum constitutes a modified caudal that functions to a certain extent as a sacral and can therefore be designated a sacrocaudal.

"The sacrum of the paratype, including the sacrodorsal and the sacrocaudal, had eight centra with sutured articular ends whereas *Monoclonius* and *Triceratops* had ten such vertebrae.⁴⁸ [This is, however, a juvenile condition and not necessarily a generic distinction, for it is probable that at least two more vertebrae would later be added to the sacral series, bringing the number up to the standard ten.]

". . . The first sacral may be recognized at once by the great transverse breadth of the centrum, its flattened ventral surface, and the inferior position of the posterior articular facets for the second sacral rib The second sacral centrum is also distinguished from all others by the much greater breadth of the anterior as compared with the posterior extremity. The centra of the remaining sacrals are of about equal dimensions, higher than wide, constricted medially, with slightly flattened inferior surfaces.

"A second specimen (No. 8072, U.S.N.M.), however, shows centra that are broader than high and that have a shallow longitudinal depression on their inferior surfaces. The differences are in all probability due to crushing. The first three vertebrae of the sacral region . . . are decidedly heavier than any that succeed them. The sacral ribs are borne jointly by all the centra. . . . The second and strongest sacral rib of the series articulates jointly with the first and second dorsals [sacrals] low down on the sides of the centra, the inferior surface of the rib being on a level with the ventral surface of the sacrals. . . . The succeeding ribs articulate with facets that are but little below the level of the floor of the neural canal.

". . . The few spinous processes are exceedingly short thin plates of bone with little transverse thickening of their superior extremities. That these were united into a bony plate is indicated by a detached sacral process belonging to another individual (No. 8072, U.S.N.M.), which shows sutural edges fore and aft that continue to the top of the spine. The same condition prevails on the spine of the fifth sacral, . . . so it would appear that this plate may have been continuous from the first to the fifth, much as it is in *Triceratops*. [The sacrum of *Triceratops* figured by Marsh, and now part of the mounted animal in the United States National Museum, is peculiar in that the first spinous process is free, the second to fifth fused into a plate, and the remaining ones free; that of sacral VI slants aft so as to make a wide-angled notch between it and number five. Compare *Monoclonius* (*Centrosaurus*), Fig. 17.] The relative shortness of the spines in *Brachyceratops* would at once distinguish its sacrum from that of the former genus. [It is conceivable, however, that as a mechanical adjustment to increasing weight the spinous processes would lengthen with age.]

"As in *Triceratops* the spinal cord appears to have been only slightly enlarged in the anterior sacral region. The diapophyses are comparatively weak and are given off on a horizontal plane from the neural arches, with thin ends directed forward. . . . Their inferior borders extend obliquely downward and inward and present a narrow sutural edge for articulation with the upper and inner borders of the sacral ribs. . . . Nearly all of the transverse processes are missing, but their point of origin, as shown by the broken surfaces, is indicated"

A complete series of caudal vertebrae, 50 in number, was discovered for the first time in *Brachyceratops*. Since then a complete series of 45 has been found in *Protoceratops* and of 38 in *Anchiceratops*. Thus the number is greater than in any other ceratopsian genus, as evidenced either by actual count or by estimate. "The greater number were found articulated, and such displacement as existed was so slight that there can be no question that they represent a consecutive series. . . ."

⁴⁸ Gilmore, C. W., 1917, pp. 21-23.

"The centrum of the first or sacrocaudal . . . is longer than wide and has an articular facet on its superoantero lateral angle for the articulation of the last sacral rib. The neural arch, although poorly preserved, indicates that the spine was distinct from the spines forward of it. . . . The anterior and posterior zygapophyses are also differentiated, not coalesced, as in all preceding sacral vertebrae. The diapophyses on the first and second caudals are given off from the sides of the arch well below the zygapophyses but above the neurocentral suture, but that on the fourth caudal is below that suture." Thence backward to caudal 25 the diapophyses are borne on the centra of their respective vertebrae, although bearing somewhat on the pedicels of the arch until the 20th is reached.

There is nothing particularly distinctive about either the pectoral arch or fore limb, except perhaps the slenderness of the preserved elements. The coracoid and humerus are unknown as yet, which is also true of the carpus. A few phalanges of the manus are preserved.

The ilium is peculiar as compared with that of *Monoclonius* and *Triceratops*. It is not only much smaller, but the transverse expansion of its anterior plate, the greater inclination outward of the crenulated outer margin, and the differentiation of the thickened deflected border above the ischiac peduncle are all distinctive from described forms, including *Pentaceratops*. The pubic peduncle is rather slender, but the ischiac peduncle is relatively very heavy.

The dimensions of the left ilium of the paratype, No. 7953, U.S.N.M. are as follows:

Length over all	362 mm.
Width of anterior blade	65
Transverse width at center	39
Depth of posterior blade	37
Depth at center of acetabulum	51

The pubis is not unusual. The ischium is a long, slender, slightly curved bone with an expanded proximal end which bears a heavy articulation for the proportionately massive pubic peduncle. The bone compares in curvature with that of *Monoclonius* (*Centrosaurus*), and contrasts sharply with that of *Pentaceratops* and *Triceratops*.

The ratio of tibia to femur in *Brachyceratops* is as 1:1.28; while in *Triceratops* it is 1:1.59, and in *Monoclonius* (*Centrosaurus*) 1:1.43. That is, in the first, the femur is about one-quarter longer than the tibia, in the others it is one-half longer. May this not be another juvenile character?

DIMENSIONS

	Femur (No. 7953)	Tibia (No. 7957)
Greatest length	337 mm.	268 mm.
Greatest width		
Proximal end	100	99 anteroposteriorly, estimated
Distal end	83	30 " "
Least width of shaft	45	—

There are two distal tarsals in addition to the astragalus and calcaneum. The former are "irregularly rounded discoidal elements with upper surfaces concave and lower convex. . . . The largest articulates with the proximal end of metatarsal II, the smallest with metatarsal III, . . . to which it was found securely attached by matrix. The third tarsal was wholly in apposition to metatarsal IV."⁴⁹

The metatarsals were four functional and one vestigial, as in *Monoclonius* (*Centrosaurus*), and the general appearance of the entire foot is comparable.

The complete skeletal restoration of *Brachyceratops* (Pl. IX, B), erected in the United States National Museum in 1922, was the first attempt to mount one of the earlier Ceratopsia, and it is a highly commendable result, viewed in the light of later finds. The skeleton is composite, with such elements as were not present in the collection modeled preferably from Judith River forms. The

⁴⁹ Loc. cit., p. 33.

total length of the animal from the end of the nose to the tip of the tail is about 6 feet 9 inches, and its height at the hips, about 2 feet 4 inches. The number of presacral vertebrae was made to correspond with that of *Triceratops brevicornus* type, at that time the only complete presacral series known. As interpreted by Gilmore, this number was 22, as he seemingly followed Lull in interpreting the number of coalesced (anterior) cervicals as four, instead of the generally accepted three. The number should be 21, cervicals 7-9, and dorsals 14-12, according as one interprets numbers 8 and 9. The number of sacrals is given as 6, and caudals as 50, making 78 in all, according to Gilmore, or 77 with the corrected number of cervicals. This is exactly the same total as in *Monoclonius* (*Centrosaurus*), the latter having 4 more sacrals and 4 fewer caudals, which again may be merely a matter of greater maturity.

Brachyceratops once more has but a single species *montanensis*, so that the specific characters, as distinguished from the generic, are not definable, especially in light of the juvenile state of the only known material.

The relationship of *Brachyceratops* with other genera is obscure. The form of the squamosal—of highly diagnostic value in the Ceratopsia—places it nearest to *Monoclonius*, but Gilmore makes the following points of contrast. He says that *Brachyceratops* has no epoccipital bones around the margin of the crest. However, this is negative evidence and should be evaluated as such, for at the ontogenetic stage represented by the type material they would not be coössified, and hence would be readily lost; and they may have been very much smaller than in a mature animal. He says also that there are no hook-like processes on the posterior border of the parietals, but the anterior pair of these is variable in occurrence and even the rear ones—invariably present in all known *Centrosaurus* species—are missing in the generic type, *Monoclonius crassus*. The fenestrae of the crest are decidedly smaller than in *Monoclonius*, but this again may be expected in a somewhat later phylogenetic stage. The real distinction lies in the longitudinally divided nasal horn which is apparently unique except for *Eoceratops canadensis* Lambe from the Belly River formation. Here, however, there is what has been called an epinasal on the anterior face of the nasal horn which finds no parallel in *Brachyceratops*, unless the small terminal ossicle which Gilmore figures as capping the left of the paired bones is its homologue. The brow horns in the two genera are totally different. The species *Monoclonius dawsoni* Lambe has been referred to *Brachyceratops* by Lambe⁵⁰ but on insufficient evidence, for the nasal horn is a large backwardly curved element without trace of division into right and left halves except at its base and for a short distance upward into the horn core. The other characters stressed by Lambe are the incipient supraorbital horn cores, small squamosal, smooth undulating border to the crest without epoccipitals, and greatly reduced openings in the parietals, if they were present at all. The type of *dawsoni* was so ill preserved that it was not all collected, and one has to depend upon Lambe's field sketch and personal description for the character of the crest. It is, in other words, impossible to verify the specific description from the present condition of the type, and its inclusion in the genus *Brachyceratops* is therefore unprovable.

Genus *Anchiceratops* Brown

The most distinctive generic characters of *Anchiceratops* (Pl. X) lie in the crest, which is rectangular in form, with rather small fenestrae as compared with the area of the crest. Around the rear margin are very large epoccipitals, six borne on the parietal, and on the squamosals a large posterior pair with others of the usual form and size. The squamosals are long, but do not come so near the end of the crest as is usual in *Chasmosaurus*. The latter also differs from *Anchiceratops* in the much larger parietal fenestrae. In addition to the epoccipitals, there is a smaller pair of prominences arising from the midline at the rear of the parietals and diverging outward. Brown describes these as knob-like, but they are somewhat flattened and curved so as to be convex upward. The degree of development of the horns is what one finds in all genera of this and succeeding geological levels, namely, large, curved brow horns and a much smaller nasal horn.

⁵⁰ Lambe, L. M., 1915, pp. 6-7.

Anchiceratops agrees most nearly with *Pentaceratops* (Pl. V, B) in the character of ornamentation at the rear of the crest, but differs from it in the relatively smaller parietal fenestrae, and in the smaller and differently shaped nasal horn. With its contemporary, *Arrhinoceratops* (Pl. XII), in the Edmonton formation, there is even less agreement. The wide, flat crests are similar in their relatively small parietal fenestrae, and in the extent of vascular grooving on the under side; but there are no great prominences, epoccipital or otherwise, at the rear of the *Arrhinoceratops* crest, which is extremely thin. The brow horns are somewhat alike, but the nasal horn in *Arrhinoceratops* is supposed by Parks to be lacking. If so, there was certainly a functional organ formed by the nasal bones that took its place, which in form was not unlike that of *Anchiceratops longirostris*. The muzzle of the latter is much longer and slenderer than in *Arrhinoceratops*.

Two species of *Anchiceratops* have been described, *A. ornatus* Brown, and *A. longirostris* Sternberg. Unfortunately, the material upon which the first is based lacks the anterior part of the skull, as there is very little preserved in front of the orbits, so that the long rostrum which gives its name to Sternberg's species may have been equally characteristic of the other. The specific contrasts, therefore, must be found in the remainder of the skull. One of the chief distinctions between *longirostris* and *ornatus* is the curvature of the brow horns, which can be in part the result of pressure deformation, for those of *longirostris* curve upward, decidedly forward, and then slightly outward, while the *ornatus* horns curve outward and then forward. The horns of the former are also smaller and wider apart at their base, which may be sex or individual variation. The distinctions of crest lie in the parietal fenestrae, which are proportionately much longer in *longirostris*, and the whole crest is thinner, with relatively smaller prominences.

The two type specimens were collected in approximately the same place and horizon, while a third partial skull in the Royal Ontario Museum resembles *longirostris* more than *ornatus* in the extreme forward curvature of the horns and in the somewhat thinner crest, and in the absence of the large epoccipital at the rear end of the squamosal. But the absence of epoccipitals is never to be taken seriously as diagnostic because they are so readily lost from a skull after death, especially if the individual is young.

The two species may be held tentatively, pending more perfect material of *A. ornatus*, which is the type of the genus, and must stand in any event. The variations of ceratopsian skulls due to age, sex, or the individual are such that no two ever seem to agree.

Anchiceratops ornatus Brown⁵¹

Holotype: No. 5251 A.M.N.H.; an incomplete skull, anterior end, and top of supraorbital horns missing.

Paratype: No. 5259 A.M.N.H.; brain case and supraorbital horns nearly complete.

Horizon: Edmonton formation.

Locality: 7 miles below Tolman Ferry, Red Deer River, Alberta, Canada.

Collector: American Museum expedition of 1912.

The generic and specific characters are stated to be as follows: "Skull large. Supraorbital horns rising close together, massive at base and divergent, curving outward, then forward. Crest large, thick and flat with small lateral fontanelles; border ornamented by large epoccipital bones; a pair of short knob-like processes on superior posterior end of crest. Squamosal intermediate in length between *Monoclonius* and *Triceratops*.

"... The bone that forms the brain-case as well as that of the crest is unusually thick, with such surfaces as were not deeply embedded in muscle, furrowed by wide vascular grooves.

"The crest ... is broad, flat and quadrilateral in outline and on the upper surface is composed of three elements ... ; paired lateral bones [squamosals] suturally distinct and a median element, which is interpreted as the fused postfrontals ('parietals').

"... The squamosal is elongate and terminates just in front of the third epoccipital bone counting from the rear, opposite the posterior border of the fontanelle. ... In front its extent cannot be

⁵¹ Brown, B., 1914, A, pp. 539-548.

determined above the free border but posteriorly it is well defined. The extreme anterior border is concave and the angle formed by the two borders is produced into a sharp process followed by the epoccipital bones.

"The epoccipital bones are one of the most striking features of the skull. They are extensive, covering the margin of the crest completely, all firmly coössified to the underlying bone but with sutural union distinct. On the squamosal there are six, the anterior five about equal in size, the sixth very much larger. . . . Following these on each side are three epoccipitals equally of enormous size. They are attached to the border of the postfrontals ('parietals') and directed backward and outward. The surface is slightly roughened and they taper from the thick elongate base to the rounded point and thin borders.

"Immediately above the base of the last epoccipital is a pair of massive, short, curved processes suturally united to each other and in the type specimen not distinct from the postfrontals below. In the skull of the young specimen, No. 5273, however, one of these processes was taken off and found to be united by suture to the supporting bone. They are large and curve outward ending in short blunt points. They differ slightly in form and position from the hook-like processes of *Monoclonius* [*Centrosaurus*] but, as in that genus, probably served as attachment for muscles and were not sheathed in horn" [see, however, p. 35].

Brown compares *Anchiceratops* with *Styracosaurus albertensis*, from the Belly River of Alberta, which he says "resembles *Anchiceratops* in some respects and may have been its ancestor. In both the crest is comparatively flat with [ep?] occipital bones unusually developed but in this later form the squamosals are progressively lengthened, the lateral fontanelles are reduced and the ex [ep?] occipitals are shortened. The development of the supraorbital horns is also distinctive."

The fragmentary crest of *Styracosaurus ovatus* Gilmore, from the Two Medicine formation of Montana, with its further shortened epoccipital spines, is still more like the posterior part of the crest of *Anchiceratops*.

When one sees the entire skull of *Anchiceratops*, as in the type specimen of *A. longirostris* Sternberg, the resemblance to *Styracosaurus* is less marked, especially in the forward region of the skull. For the face and muzzle of *Anchiceratops* are elongated more as in *Chasmosaurus*, and the nasal horn is low, projects forward, and has a sharp dorsal edge, very different from the long, nearly erect horn of *Styracosaurus*.

Anchiceratops longirostris Sternberg⁵²

Pl. X

Holotype: No. 8535 G.S.C.; nearly complete skull, without lower jaws.

Horizon: Edmonton formation.

Locality: 12 miles northwest of Morrin, Red Deer River, Alberta, from approximately the same locality as *A. ornatus*.

Collector: C. M. Sternberg, 1924.

Sternberg's description adds the following points, some of which, like the very long and slender nose, may be specific rather than generic characters. For instance, though the same type of muzzle ordinarily prevails in *Chasmosaurus*, yet there is at least one skull of the genus (No. 5436 Ct. R.O.M. Pl. VII, A), preserved at Toronto, in which the muzzle is shorter and deeper than usual. And so it may have been with *Anchiceratops* where, in the only known specimen in which the anterior part of the skull is preserved, the latter is long and slender, yet it may have varied, specifically, to a shorter, deeper, muzzle correlated with a shorter, wider, crest.

"Viewed from the side, . . . [Pl. X, A] the skull [of *A. longirostris*] is very long and flat, the orbit is well in advance of the midline; the anterior naris is long and situated nearer to the orbit than to the end of the beak. . . . The rostral bone resembles that of *Chasmosaurus* and as in that genus the beak is made up largely of the premaxillae. . . .

⁵² Sternberg, C. M., 1929.

"The *nasal horn core* . . . is triangular in cross-section with the apex of the triangle above, and it points forward and upward. Vascular grooves are not so well developed as on the brow horns, but there is no doubt it carried a fair-sized horny sheath.

" . . . The *orbit* is moderately large and circular in outline. . . .

"The *brow horn cores* . . . are moderately large and circular in cross-section, except at the base where they are sub-triangular. They rise from the supero-posterior border of the orbits and continue upward, forward, and slightly outward, thus differing from *A. ornatus* in which they curve outward, then forward. They taper gradually to the tip, but are farther apart at the base and much smaller than those of *A. ornatus*. The horn cores bear well-defined, longitudinal, vascular grooves. . . .

"The [post] *frontal fontanelle* is closed superiorly, due to the union of the [post] frontals, thus completing the secondary roof on the superior surface. This [post] frontal fontanelle opens posteriorly, however, and, apparently, is larger than in *A. ornatus*. . . .

"The *supratemporal fossae* do not appear to differ materially from those of *A. ornatus*. They open posteriorly, as in that species and in the genera *Torosaurus* and *Triceratops*.

"The *crest* is large, rectangular, and quite flat. . . . The fontanelles are proportionately much longer than in *A. ornatus* and, as in that species, are wholly within the parietals. The crest is relatively thin, especially in advance of the fontanelles. The maximum thickness of the crest, through the posterior portions . . . is 30 mm., but the average thickness is not more than half this.

"The *squamosals* are long and narrow. . . . The epoccipitals are so thoroughly fused with the squamosals that they appear as serrated edges rather than separate ossifications. The same is true of the large epoccipitals on the posterior edge of the parietals. The squamosals are marked by vascular grooves both above and below.

"The *parietals* resemble those of *A. ornatus*, but are thinner, and the epoccipitals are much thinner and smaller. As in *A. ornatus*, there is a pair of short, thick, hook-like processes, thoroughly fused to the median posterior extremity of the superior surface of the parietals. On the superior surface of the parietal, in advance of the fontanelle, there is an area in which the surface is lower than the rest of the bone and quite smooth. This is a backward extension of the floor of the supratemporal fossa and the bone is very thin. Except for these areas in advance of the fontanelles the parietals are covered with vascular markings."

DIMENSIONS OF TYPE

(From Sternberg)

Length, tip of rostral to extremity of crest	1660 mm.
Greatest breadth of skull (anterior portion of crest), as restored	730
Breadth of posterior portion of crest, including epoccipitals	660
Height of nasal horn core	72
Length from tip of rostral to anterior border of orbit	600
Length, anterior border of orbit to extremity of crest	1060
Greatest depth of muzzle in front of nasal horn core	220
Distance between antero-external edges of orbital rims	260
Length of brow horn from superior border of orbit	310
Circumference of brow horn near base	255
Greatest diameter of orbit	110
Greatest diameter (fore and aft) of parietal fontanelles	280
Transverse diameter of parietal fontanelles	150
Occipital condyle to extremity of crest	860

The beautiful skeleton of *Anchiceratops longirostris* mounted at Ottawa (No. 8538, G.S.C.) (Pl. X, C) was found on the Red Deer River in the Edmonton formation, and except that it lacks a skull, is complete to the tip of the tail. There were, however, a few diagnostic fragments of the posterior portion of the crest which determined the genus and probably the species. A plaster skull has been modeled from the type of *A. longirostris* which in all probability is essentially correct.

When found, the animal lay fully articulated on its right side, but as this was the better preserved, its position was reversed in mounting so that now the right aspect of the completed mount is exposed.

In size, it is somewhat smaller, curiously enough, than are either of its Belly River predecessors, *Chasmosaurus* or *Monoclonius* (*Centrosaurus*), but exceeds both in relative robustness, especially of the ribs. The lesser over-all length is due in part to the short tail.

This skeleton is as yet undescribed but a few notes taken by the author may be of interest.

The vertebral formula, except for the short tail, corresponds with that of the Belly River genera. The eighth presacral bears the first long rib; the latter, and also the rib articulating with the ninth vertebra, has a capitulum which bears upon the centrum of the vertebra as do the typical cervical ribs. The sacrum, as restored, has low spines, equal in height, and separated from one another by a slender line of matrix. Curiously enough, there are thirteen such spines. Whether or not there are thirteen centra in the sacrum instead of the normal ten, one cannot at present tell. The dorsal spines are also low although that of presacral XVIII is higher than the preceding one. Not only are the caudals fewer than usual, numbering 38 as against 46 for *Monoclonius* (*Centrosaurus*), and 45 for *Chasmosaurus*, but the distal vertebrae are small, which accounts, in part, for the lesser over-all length.

The first chevron is light and is borne on caudal IV. The last six or seven vertebrae are without chevrons. The pubis articulates with the penultimate rib, and the last rib underlies the anterior part of the ilium. These are points of agreement with *Chasmosaurus*. All of the dorsal ribs seem heavy, due in part to the way the middle and after ones are swayed together as the specimen lies, so that they are in contact from rib number 12 to number 21. The posterior rib has a decided curve backward, as it now lies. The ischia are curved as in *Triceratops*, and meet in a short symphysis. The scapula is heavy, the distal end widening out, and the median longitudinal ridge not approaching so near the anterior border distally as it does in the Belly River genera. It shows an evolutionary trend toward the condition seen in *Triceratops*. The humerus is heavy, with a very pronounced deltoid ridge. The position of the head of the humerus is such that the angulation of the fore limb in life was similar to that of the earlier forms. There is no crest on the rear of the proximal end of the humerus, as in *Chasmosaurus*, which makes one wonder whether the latter can be correct (see p. 69). There is no mechanical difficulty in swaying the humerus backward as seems to be true of the mounted *Chasmosaurus* skeletons. The ulna has a very robust olecranon which heightens the feeling of mechanical power in comparison with *Chasmosaurus*.

The pes, as preserved, shows no trace of the vestigial fifth digit seen in the Belly River forms. This has apparently been lost from the specimen, as it is present in the mounted *Triceratops* in the American Museum.⁵³

Genus **ARRHINOCERATOPS** Parks

Arrhinoceratops brachyops Parks⁵⁴

Pl. XII

Holotype: No. 5135 Ct. R.O.M.; nearly complete skull without lower jaw.

Horizon: Edmonton formation.

Locality: 3 miles above Bleriot Ferry, on the Red Deer River, Alberta.

Collector: University of Toronto Expedition of 1923.

The generic and specific characters are described as follows: "Supraorbital horn cores large, directed outwards and forward; nasal horn core absent; facial region short; crest relatively large, subquadrate, flat; squamosals long; parietals with oval fontanelles of moderate size; anterior process of jugal unusually long."

⁵³ Osborn, H. F., 1933, p. 12.

⁵⁴ Parks, W. A., 1925.

Doctor Parks goes on to say: "The nasal horn core is apparently absent, but the nasal bone is sharp above and somewhat rugose, suggesting that it may have carried a horny sheath. The nasal bone rises very abruptly, posterior to the suture with the rostral, suggesting the condition that maintains in *Triceratops prorsus*, but there is no trace of a horn core nor of an epinasal; neither does the surface of the bone indicate that a structure of this kind has been lost." There is, if anything, more of an indication of a nasal horn than in the type of *Triceratops obtusus* at the United States National Museum. And the position of the horn-like area lies over the anterior margin of the narial opening as in the Lance genus, not above the posterior margin as in all Belly River forms.

The face is characteristically short, resembling *Chasmosaurus*, and the crest is also typical, being subquadrate in outline and very flat toward the rear. Herein it again resembles both *Chasmosaurus* and the Lance *Torosaurus*, as it also does in the extremely elongate squamosals which, however, are relatively broader anteriorly than in either genus. The parietal fenestrae are smaller than in *Chasmosaurus*, and are narrower, though relatively longer, than in *Torosaurus*. The jugals are extremely long fore and aft, especially in their anterior process which overlaps the maxillary to a remarkable extent. This, as Parks says, makes the distance between the maxillary and the orbit strikingly great. The infratemporal arcade is long and straight, which gives the infratemporal fossa a subtriangular shape, with a sharp apex and rounded base.

The supraorbital horn cores are stout, tapering sharply, circular in cross-section at their base instead of being laterally compressed as in *Torosaurus*. There are the usual vascular impressions and, in addition, each bears a shallow longitudinal sulcation extending for about 250 mm. from the tip downward, in line with the edge of the orbital rim. The horn cores are rather close together at their base and flare strongly outward and then curve forward in a manner similar to those of the paratype of *Anchiceratops ornatus* described by Brown.

The crest, composed of the usual elements, squamosals and parietals, is subquadrangular, with somewhat curved lateral and straight posterior margins. It is deeply marked by vascular impressions not only on its dorsal side, but over as great a part of the ventral aspect as in any other ceratopsian skull. The parietal fenestrae are elongated, and oval in shape. Another opening, doubtless of a pathologic nature, pierces the left squamosal.

The orbits are elliptical, with the long diameter directed upward and backward. They almost entirely underlie the anterior half of the horn core, being both in form and position very similar to the type of *Triceratops obtusus*, and differing from *Diceratops* in which the front margin of the horn would, if continued downward, about bisect the orbit.

Parks stresses the absence of sutures in the occipital condyle, the presence of which would indicate that the exoccipitals form part of it. "Nevertheless," he says, "it would be hazardous to conclude that the condyle is composed of the basioccipital alone." I know of but two instances among the horned dinosaurs in which any trace of these sutures is present, indicating the tripartite character of this element. One is that of a detached condyle belonging to the type skull of *Torosaurus gladius* (No. 1831 Y.P.M.) figured by Hatcher in the *Ceratopsia Monograph* (Fig. 7), in which the sutures are clearly visible on the articular surface; the other is the plesiotype of *Triceratops elatus* (No. 4805 U.S.N.M.) in which the sutures show at the fractured base but not on the surface. The assumption is, however, that every ceratopsian condyle includes portions of both exoccipitals and the basioccipital.

Quoting from Parks again, "The anterior tips of the nasals embrace the posterior end of the rostral," which, if true, is a very unusual occurrence, for generally, if not always, the premaxillaries are interposed between the rostral and nasal bones. As usual, the nasals form a part of the bony nasal septum though the greater portion is of premaxillary origin. That portion of the nasals which functioned as a horn core is trihedral in shape. It arises abruptly in front, forming a triangular face, while the two plane, sloping, lateral sides meet above in a sharp somewhat convex ridge extending backward halfway to the orbits. The bone is quite rugose on the anterior face and slightly so on the left side at the anterior end. There must have been a close-fitting horny investment, but hardly a progressively growing horn as in the supraorbitals, for the deep, vascular impressions present in the latter are absent in the nasal region.

The epjugals are quite conspicuous, almost horn-like processes, very suggestive of those of *Pentaceratops*. The crests in the two genera are also somewhat alike, with elongate fenestrae. The nasal horns, however, are very dissimilar. That of *Anchiceratops*, on the other hand, resembles the nasal of *Arrhinoceratops* much more closely, even to the sharp upper edge. The crests in these two genera are also somewhat similar except at the rear, for that of *Arrhinoceratops* lacks the epoccipitals and the two knob-like prominences on the rear of the parietals. In proportions, *Arrhinoceratops* has a relatively short, deep muzzle while that of *Anchiceratops longirostris* is elongate, as the name implies.

MEASUREMENTS OF SKULL OF *Arrhinoceratops*
(After Parks)

Length, from tip of rostral to extremity of crest	1520 mm.
Width, across tips of epjugals	700
Width, across posterior margin of crest	830
Width, across anterior end of crest	834
Maximum width of crest	1080
Tip of rostral to occipital condyle	718
Occipital condyle to rear of crest	810

There is but one species, as but two specimens only are as yet referable to this genus, one of which is unprepared, hence specific characters as distinguished from those of the genus cannot be determined. The relationship of *Arrhinoceratops* to other genera is not evident. It belongs to the group characterized by long squamosals, and on this basis alone would lie nearer the *Chasmosaurus-Torosaurus* phylum than the *Monoclonius-Triceratops* line in which the squamosal is either short or of medium length (see p. 27 and Fig. 3). This is in accordance with Doctor Parks' opinion.

Genus **PENTACERATOPS** Osborn

Pentaceratops sternbergii Osborn⁵⁵

Pl. V, B; Text Fig. 39

Holotype: No. 6325 A.M.N.H.; skull without lower jaw (skeleton discarded).

Horizon: Fruitland formation.

Locality: Nine miles northeast of Tsaya, New Mexico.

Collector: C. H. Sternberg, 1922.

Generic characters are stated to be: "One nasal horn, two prominent anteroverted postorbital horns, two lateral jugal osseous horns; with elongate narrow fontanelle in the dermosupraoccipital crest. Borders of the crest moderately sculptured. Generally intermediate in character between the *Eoceratops* and *Anchiceratops* types of skull, in size and proportion approaching the *Triceratops* type, in the large fontanelle resembling *Torosaurus*."

Osborn says further: "Comparing this skull with other specimens of ceratopsians, we observe the following resemblances and differences.

"(1) The fontanelles are elongate, instead of circular as in *Monoclonius* and *Torosaurus* (Hatcher-Lull Monograph, 1907, Pl. II).

"(2) The postorbital horns rise directly above the center of the orbit and curve gently forward, a different position and inclination from that observed in the types described by Hatcher and Lull (*op. cit.*, Pl. V).

"(3) The skull of *Pentaceratops*, when compared in profile with that of *Diceratops* and *Triceratops* (*op. cit.*, Pl. XLIV), shows that the lateral horns are borne upon the jugals. They project much more widely than the prominences on the jugals of *Triceratops brevicornus* [*op. cit.*, Pl. XLII]. The skull of *Pentaceratops sternbergii* . . . is relatively more elongate than that of *Tricera-*

⁵⁵ Osborn, H. F., 1923.

tops brevicornus; the fontanelles are much more elongate than in *Triceratops prorsus* (cf. Pl. XXXV); both the rostrum and the frill are more elongate than in that species. In its elongate proportions *Pentaceratops sternbergii* resembles *Triceratops serratus* more closely (cf. Pl. XXVII) although it differs widely from this species in the three generic characters above noted, namely, the fontanelles, the jugal horns, and the postorbital horns.

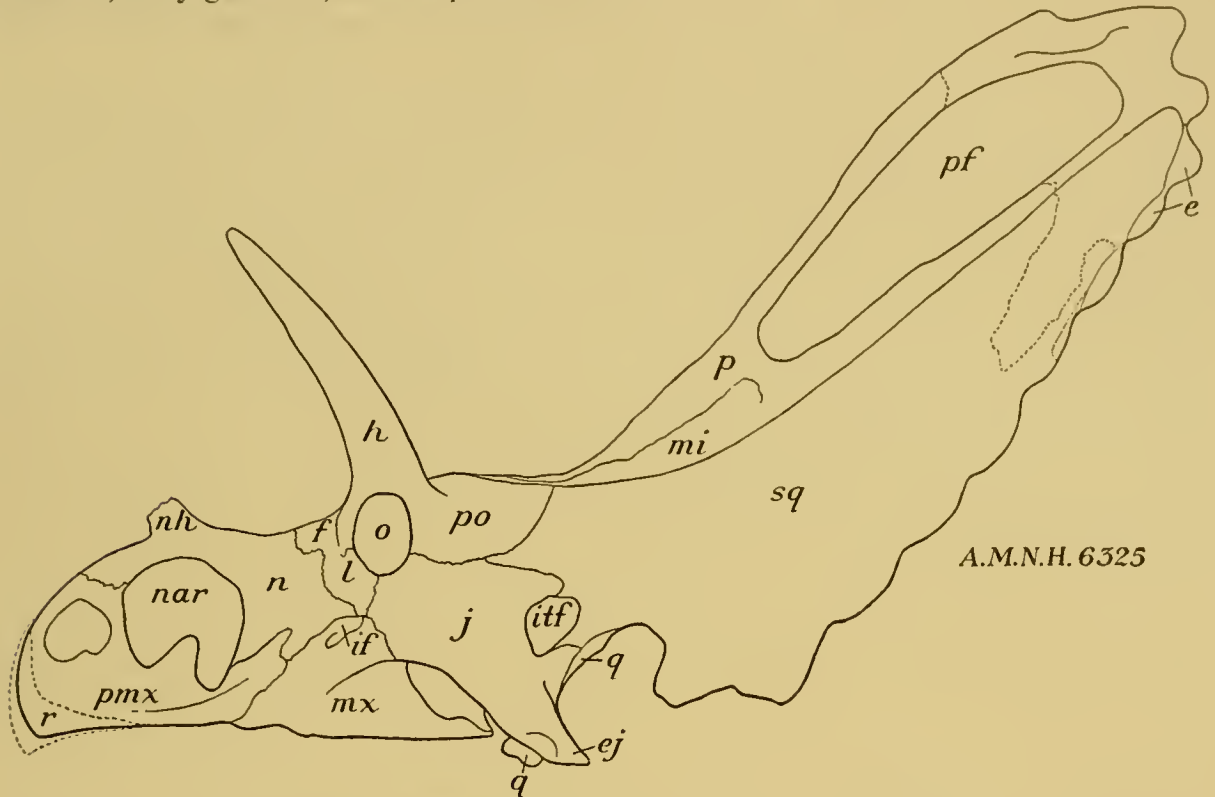


Fig. 39.—Left lateral view of skull of *Pentaceratops sternbergii*, holotype, 1/14 natural size. *e*, epoccipitals; *ej*, epi-jugal; *f*, prefrontal; *h*, supraorbital horn; *if*, preorbital fossa; *itf*, infratemporal fossa; *j*, jugal; *l*, lacrymal; *mi*, muscle impression; *mx*, maxillary; *n*, nasal; *nar*, nasal opening; *nh*, nasal horn; *o*, orbit; *p*, parietal; *pf*, parietal fenestra; *pmx*, premaxillary; *po*, postfrontal; *q*, quadrate; *r*, rostral; *sq*, squamosal.

“Considering the division of the Ceratopsia into two phyla (*op. cit.*, p. 161), *Pentaceratops* seems to represent rather the *Torosaurus* phylum than the *Triceratops* phylum. It may be an offshoot intermediate in geologic time between the Ceratopsia of the Judith River and Belly River formations and the *Torosaurus* of the Lance of Converse County, Wyoming.

“Comparing this animal with the ceratopsians described since the appearance of the Hatcher-Lull Monograph of 1907 we make the following observations:

“Belly River Formation

Styracosaurus Lambe, 1913, type *S. albertensis*

Protorosaurus (*Chasmosaurus*) Lambe, 1914, type *Monoclonius belli* Lambe

“Edmonton Formation

Anchiceratops Brown, 1914, type *A. ornatus*

Leptoceratops Brown, 1914, type *L. gracilis*

“Two Medicine Formation

Brachyceratops Gilmore, 1914, type *B. montanensis*

“Belly River Formation

Eoceratops Lambe, 1915, type *E. canadensis*

"After comparison with the above ceratopsians of Belly River, Two Medicine, Edmonton and Lance age, this new genus and species appears to be distinct from all previously described genera. It differs widely from *Anchiceratops* of the Edmonton with its ornate crest, yet it would appear to belong to a geologic stage equivalent to the Edmonton. It differs widely in its elongate proportions from *Brachyceratops*. It is naturally profoundly different from the older Belly River and Two Medicine genera described by Lambe, Gilmore, and Brown, although it might be geologically successive to the *Eoceratops canadensis* of Lambe in the Belly River stage."

The "lateral jugal osseous horns" are not new structures as they are present in nearly all Ceratopsia, and were named epijugals by Marsh. Here, they have reached a remarkable degree of elongation which distinguishes them from those of most genera. They are, however, very marked in some specimens of *Protoceratops*, notably No. 6433, No. 6439, and No. 6467 A.M.N.H., as well as in the type of *Anchiceratops ornatus*, No. 5251 A.M.N.H., and to a less extent in *Chasmosaurus kaiseni*, No. 5401 A.M.N.H., and in *Arrhinoceratops brachyops* type, No. 5135 Ct. R.O.M. This character is, therefore, one of degree and not of kind. This is true also of the nasal and supra-orbital horns.

Osborn's statement that the fontanelles are much more elongate than in *Triceratops prorsus* is clearly a slip if he means the parietal fenestrae, for there are none in *Triceratops prorsus* or in any other *Triceratops* species, a fact of which he is well aware.

Pentaceratops seems to resemble *Chasmosaurus* on the one hand, and *Torosaurus* on the other. With the former, it agrees in the rather short face and longer muzzle, in the long squamosals and large fenestrae, and in the position of the nasal horn. It disagrees in the possession of long supra-orbital horns which in *Chasmosaurus* are very short, with two known exceptions that of *Chasmosaurus kaiseni* type skull No. 5401 A.M.N.H., and the specimen No. 40 Univ. of Alberta. With *Torosaurus*, the differences are all the results of a probable evolutionary trend. The elongate crest and the short face are alike. The muzzle of *Torosaurus* was also probably somewhat elongated, but as both of the known skulls are defective in this regard, an actual comparison cannot be made. The fenestrae of *Torosaurus* are relatively smaller although still persistent, and the epoccipitals have disappeared, while the epijugals are reduced. There is also a reduction of the nasal horn, which in common with that of the contemporary *Triceratops* has shifted forward to lie over the anterior, instead of the posterior, rim of the narial opening. The base of each supraorbital horn in *Torosaurus* extends further back in relation to the orbit, a tendency which is also seen in the *Pentaceratops* specimen No. 1624 A.M.N.H.

The only point of agreement with *Eoceratops* that I can find is the position of the supraorbital horn immediately over the orbit. The shape of the horn is, however, very different. The squamosal of *Eoceratops* is rather short, a feature which would seem to debar it from a *Pentaceratops* ancestry; also the position of the nasal horn in the two genera does not agree. *Eoceratops* certainly cannot displace *Chasmosaurus*, its contemporary, as a probable ancestor of *Pentaceratops*.

With *Anchiceratops* also there is little agreement. The position of the supraorbital horn with reference to the orbit is different, for in *Anchiceratops* the orbit lies under the anterior margin of the horn. The squamosals, while long, are shorter than in *Pentaceratops*, and the fenestrae are much smaller. But there is evidence of agreement in the peculiar prominences that characterize the posterior dorsal surface of the *Anchiceratops* crest, seen also in *Pentaceratops* No. 1625 A.M.N.H. The epijugals do show a rather striking similarity but one could hardly call those of *Anchiceratops* jugal horns.

Altogether, at least seven specimens of *Pentaceratops* are known, five of which were collected by Charles H. Sternberg. Three of them, the type of *P. sternbergii*, No. 6325, and another skull, No. 1624, with the crest of a third, No. 1625, are in the American Museum, while the others, a skeleton without the skull (except the lower jaw), and another skull, are in Upsala, Sweden, and constitute the types of *Pentaceratops fenestratus* Wiman. Some material including a fine squamosal is in the National Museum.

Pentaceratops fenestratus Wiman⁵⁶

Text Fig. 40

Cotype: (A) an almost complete skull, without lower jaw.

Cotype: (B) Skeleton and lower jaw, without skull.

Horizon: Kirtland shales.

Locality: 1 mile south of Kimbetoh Wash, on the south branch of Meyers Creek, San Juan County, New Mexico.

Collector: C. H. Sternberg, 1921.

Specimens A and B have no individual bones in common, hence it is only an assumption, but highly probable, that the specimens are related. The skull of specimen A is the only element that can be compared with Osborn's type of *Pentaceratops sternbergii*, with which it agrees in all generic characters. The specific distinctions mentioned by Wiman, on the other hand, are not convincing, although the difference in geologic levels leads one to suppose that the two forms are distinct. Wiman's specific characters are: a fenestra present in the squamosal, and shorter and more numerous epoccipitals. The so-called fenestra is demonstrable through the left squamosal only and seems to be pathologic as it is in so many ceratopsian skulls, more often, as here, on the left side. It may be either a puncture caused by a horn thrust or a bone lesion from the flesh side. (See *Torosaurus latus*, p. 131, Text Fig. 42.) The crest in each of the three known skulls of *Pentaceratops* is defective posteriorly but the restoration of this region in Osborn's type is based upon the separate crest No. 1625 A.M.N.H. and is presumably correct. It does not seem, therefore, as though the number of epoccipitals—except along the squamosal—can be accurately compared. In general proportions, the two skulls are alike. The position of the broad-based horn core, with reference to the orbit in *fenestratus*, differs from that of *sternbergii*; in fact, it does not correspond to Osborn's generic definition as it is more *Triceratops*-like. The only other contrasting detail lies in the epijugal "horns" which are apparently longer in both American Museum specimens and point outward and backward, while in *fenestratus*, which is badly crushed and sheared, they project outward and slightly forward. The nasal horn seems to be longer and more slender in *fenestratus*. Its position relative to the anterior nares is the same.

Wiman remarks that the orbits are about the same size as the wide lower openings (infratemporal fossae) and the squamosal fenestrae. On the left side of the skull the infratemporal fossa seems abnormally large as compared with that on the right. The crushing of the skull may account for this. The fossa was apparently about two-thirds the size of the orbit, which is not exceptional. The parietal fenestrae are large and subtriangular, with the shorter side directed toward the rear; hence, while relatively smaller, they are comparable to those of *Chasmosaurus*, but are larger and differ in shape from the elliptical fenestrae of *Torosaurus* (as restored by Marsh).

The preorbital opening ("lacrymal foramen") seems to be lacking. This is not always demonstrable in ceratopsian skulls as it is a vestigial structure. It is present, however, in *sternbergii* and might be seen in *fenestratus* were the skull in a better state of preservation.

The nasal horn is oval in cross-section; Wiman says this is due to the crushing of the skull and that under ordinary circumstances it would be round. But I imagine that it would be oval in any case, for that is the rule. The tip has disappeared, but the horn must have been moderately high. It projects upward and forward but curves slightly posteriorly. A posteriorly curved nasal horn and forwardly curved supraorbitals is an anomaly and seems out of reason mechanically. The only other comparable instance known to me is that of a *Triceratops* skull, collected by Doctor Loomis in the Hell Creek beds of Montana, and now in the Amherst College Museum. It is possible that in both of these skulls the curve of the nasal horn is abnormal, but whether or not it is due to post-mortem deformation I cannot determine.

The horn over the left eye is round in cross-section, while that over the right is laterally compressed. In either case they are thicker than those of the type of *P. sternbergii*. This, as Wiman says, could be an age differentiation of the individual, or it might be a sexual character. The orbit

⁵⁶ Wiman, C., 1930.

in *fenestratus* is further forward in relation to the horn base than in *sternbergii* but not as far forward as in *Triceratops* and *Torosaurus*. This again may be a mechanical evolutionary trend due in part to a fore and aft thickening of the base of the horn, the Kirtland *fenestratus* being later in time than *sternbergii* from the Fruitland beds. Vascular impressions cover almost the entire cranial roof as they do the horns, indicative of the advanced age of the individual. It seems evident, therefore, that the skull of *fenestratus* does represent a species distinct from the earlier *sternbergii*, although the specific character which gives it its name, *fenestratus*, may be considered pathologic and therefore not of taxonomic value. However, the general appearance of the skull, the form of the nasal horn, the relative position of the orbit and supraorbital horns, the development and direction of the epijugal horns, and possibly the apparently greater number of epoccipitals, together with the inclusion in a later formation, are collectively sufficient to confirm the specific distinction which Wiman claims.

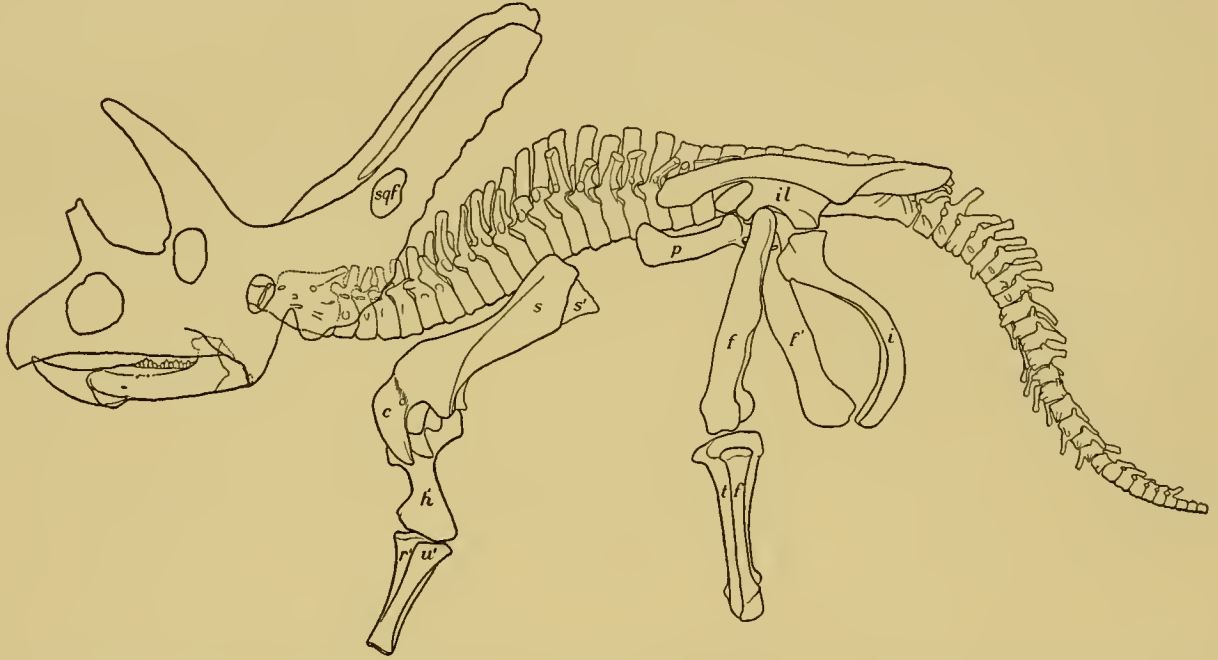


Fig. 40.—Lateral view of skull and skeleton of *Pentaceratops fenestratus*, in Upsala, Sweden (modified from Wiman), 1/28 natural size. *c*, left coracoid; *f*, left femur; *f'*, right femur; *f* (below) left fibula; *h'*, right humerus; *i*, ischium; *il*, ilium; *p*, pubis; *r'*, right ulna; *s*, left scapula; *s'*, right scapula; *sqf*, squamosal fenestra (pathologic); *t*, left tibia; *u'*, right radius.

Specimen B, the skeleton, has no bones in common with specimen A, the skull, hence the relationship between the two is assumed, although highly probable. The two animals seem to be of approximately the same size, the direct point of comparison being the lower jaw and tooth row of specimen B and the upper jaw of A. Wiman's restoration of the skull in outline as applied to the skeleton gives a most remarkable result, showing the crest extending backward over the entire presacral series of vertebrae, except for the last two or three. In his drawing, however, the crest is flattened down so that its long axis is more nearly in line with that of the cranium than in either of the American Museum specimens of *Pentaceratops*, and, I am sure, in *fenestratus* itself. In our own revision of Wiman's reconstruction (Fig. 40), this flattening of the crest is modified and the head posed somewhat differently, which gives an altered, but not less remarkable, appearance to the animal. One doubts whether the crest could be made to lie flat on the back as in Wiman's figure. In all of these long-crested and doubtless related forms, *Chasmosaurus*, *Pentaceratops*, and *Torosaurus*, the crest did extend well over the back; in *Chasmosaurus* it reached to presacral XIII, two-thirds of the back; in *Pentaceratops* to presacral XVIII. In *Torosaurus*, the vertebral column is unknown, but if it was equivalent to that of a *Triceratops* of equal body size, such as *Triceratops brevicornus* the crest would reach to beyond the 16th vertebra, more as in *Pentaceratops*.

The skeleton lay in a somewhat argillaceous sandstone with numerous carbonaceous plant

remains, and was well preserved. In no place, according to Wiman, did it need any reconstruction. Wiman's interpretation of the vertebral formula gives 20 presacrals—9 cervicals and 11 dorsals. There are also 11 sacrals and 28 caudals, the tail being incomplete. The standard ceratopsian formula gives 21 presacrals. But the apparent discrepancy here lies in the fact that the 21st presacral is so thoroughly coössified by its centrum and spine that it appears to be an integral part of the sacrum, and has been so interpreted by Wiman. He believes that the tail was probably shorter than in *Monoclonius* (*Centrosaurus*), for the last of the preserved vertebrae are so small that only a few can be lacking. This is another point of agreement with *Anchiceratops* in which the number of caudals is 38 as compared with 46 for *Monoclonius* (*Centrosaurus*). The entire skeleton is robust, compared with the Belly River forms, but not more so, relatively, than in *Anchiceratops*. The highest point in the vertebral column lies over presacral XIV, whereas on vertebra X the diapophysis rises higher than in any preceding vertebra, although this is foreshadowed to a much less extent in IX. The tenth is the first one on which the capitular rib facet rises from the centrum to the neural arch and is therefore the first thoracic according to Williston, Brown, and Wiman.

The sacrum, as now constituted in this old animal, contains 11 vertebrae, as the centrum of the last presacral is fully fused with that of the succeeding vertebra. The first parapophysis arises from the second and third actual sacrals, but does not sweep aft to the extent seen either in *Monoclonius* (*Centrosaurus*) or *Triceratops*. Apparently, five parapophyses fuse to form the acetabular bar which abuts against the ilium, rather than four as in *Monoclonius* (*Centrosaurus*) and *Triceratops*. Otherwise, the sacrum is not unusual. The ilia are quite similar to those of *Monoclonius* (*Centrosaurus*), as seen from below, except that posteriorly they extend further aft. The ilium is quite *Triceratops*-like except that the pubic peduncle is relatively smaller in *Pentaceratops*. The pubis is comparable to that of *Monoclonius* (*Centrosaurus*) except for its greater robustness, but the ischium differs markedly in its degree of curvature, which is greater than that of any other known ceratopsian, even *Triceratops*. The shoulder girdle is also very robust but otherwise quite typical. As posed by Wiman, the distal end of the scapula reaches to within three vertebrae of the anterior end of the pubis (pseudopectineal process), making a very closely coupled animal.

There is nothing distinctive about the fore limbs. The femora, on the other hand, are peculiar. Wiman says they are somewhat deformed in that they are compressed from anterior to posterior. This may be so, although a certain fore and aft compression is not unusual with the Ceratopsia. The remarkable feature, however, is their curvature when viewed from either front or rear. This is much more marked than in any ceratopsian I have seen, and must have bowed the thighs outward in an extraordinary manner. The distal face of the combined tibia and astragalus is also peculiar in that it is not perpendicular to the long axis of the bone but looks inward as well as downward, departing from the horizontal by about 20°. The fourth trochanter of the femur is more prominent than usual. Whether this bow-legged condition was generic or an individual departure from the normal cannot be determined from this one specimen. It is certainly unique among all of the ceratopsian skeletons which are known to us. The proportionate lengths of the several limb bones are comparable to those of *Chasmosaurus* and *Monoclonius* (*Centrosaurus*) *nasicornus*. Foot bones are present, but Wiman has not attempted to identify them as they were confused in the quarry.

DIMENSIONS OF SKULL A

(After Wiman)

Length, from rostrum to highest point of crest	2160 mm.
Height of left supraorbital horn	600
Circumference of same at upper edge of orbit	500
Height of right supraorbital horn	580
Circumference of same at upper edge of orbit	520
Height of nasal horn	220
Circumference of same at base	250
Length of epijugal horn core	100
Circumference of same at base, left	290
Circumference of same at base, right	230

DIMENSIONS OF SKELETON B

Length of left dentary	530 mm.
Length of entire vertebral column, as preserved	4100
Total length of the nine cervicals	820
Length of thoracic region	880
Length of sacrum	840
Total length of caudals, as preserved	1560
Length of first three coalesced cervicals	300
Greatest breadth of sacrum	610
Length of left half of shoulder girdle, measured over the curve	1000
Length of left coracoid	250
Length of scapula	730
Length of right humerus	646
Greatest proximal breadth of same	277
Length of radius	434
Length of ulna	577
Length of ilium	1120
Length of ischium, measured on curve	1000
Length of left femur	880
Length of left tibia, inclusive of astragalus	655
Length of left fibula, inclusive of calcaneum	600
Breadth of calcaneum	80

Genus *TRICERATOPS* Marsh⁵⁷

As a result of the labors of Mr. Hatcher and his aides, no fewer than thirty-two ceratopsian skulls, more or less complete, were found in the Lance formation of Niobrara County, Wyoming. These include the type of nearly every *Triceratops* and both of the *Torosaurus* species. Circumstances were such that the skulls of the upper levels were the best preserved, so that with the exception of *Triceratops horridus* and *Triceratops obtusus*, which are the lowest in the series, most of the types come from the upper portion and are all quite near one another stratigraphically. Based upon all the available data, the skulls have been arranged in their stratigraphic sequence as follows:⁵⁸

Level High	Museum	Catalogue number	Type	Genus and species
1	Y.P.M.	1830	Holotype	<i>Torosaurus latus</i>
2	Y.P.M.	1838		<i>Triceratops</i> sp. indet.
3	Y.P.M.	1831	Holotype	<i>Torosaurus gladius</i>
4	Y.P.M.	1828		<i>Triceratops horridus</i> (ingens)
5	Y.P.M.	1837		<i>Triceratops</i> sp. indet.
6	Y.P.M.	1829		<i>Triceratops elatus</i> ?
7	U.S.N.M.	5740		<i>Triceratops</i> sp. indet.
8	Y.P.M.	1832	Plesiotype	<i>Triceratops brevicornus</i> ?
9	Y.P.M.	1834	Holotype	<i>Triceratops brevicornus</i>
10	Y.P.M.	1821	Holotype	<i>Triceratops flabellatus</i>
11	U.S.N.M.	2412	Holotype	<i>Triceratops</i> (<i>Diceratops</i>) <i>hatcheri</i>
12	U.S.N.M.	1201	Holotype	<i>Triceratops elatus</i>
13	Y.P.M.	1833		<i>Triceratops</i> sp. indet.
14	Y.P.M.	1836		<i>Triceratops</i> sp. indet.
15	U.S.N.M.	2100	Plesiotype	<i>Triceratops elatus</i>
16	U.S.N.M.	4276	Holotype	<i>Triceratops sulcatus</i>
17	U.S.N.M.	4928	Holotype	<i>Triceratops calicornis</i>
18	Y.P.M.	1823	Holotype	<i>Triceratops serratus</i>

⁵⁷ Marsh, O. C., 1889, B, p. 173.

⁵⁸ Lull, R. S., 1915, p. 343.

<i>Level</i>		<i>Catalogue</i>			
<i>High</i>	<i>Museum</i>	<i>number</i>	<i>Type</i>	<i>Genus and species</i>	
19	Y.P.M.	1822	Holotype	<i>Triceratops prorsus</i>	
20	U.S.N.M.	7239		<i>Triceratops</i> sp. indet.	
21	U.S.N.M.	1208		<i>Triceratops sulcatus</i>	
22	U.S.N.M.	6679		<i>Triceratops</i> sp. indet.	
23	U.S.N.M.	5741		<i>Triceratops elatus</i>	
24	U.S.N.M.	1205		<i>Triceratops prorsus</i> ?	
25	U.S.N.M.	4708		<i>Triceratops elatus</i>	
26	U.S.N.M.	4286		<i>Triceratops sulcatus</i>	
27	U.S.N.M.	2124		<i>Triceratops</i> sp. indet.	
28	U.S.N.M.	5738		<i>Triceratops</i> sp. indet.	
29 }	U.S.N.M.	2416		<i>Triceratops serratus</i>	
30 }					
31	Y.P.M.	1820	Holotype	<i>Triceratops horridus</i>	
32	U.S.N.M.	4720	Holotype	<i>Triceratops obtusus</i>	
<i>Low</i>					

Thirteen species of *Triceratops* have been described, all but four being based upon adequate material, in every instance a more or less complete skull, together with a varying number of skeletal parts. The skeletal material does not at present offer any characters, other than that of size (see *T. maximus*), which may be used for specific determination, and it is to be doubted whether entire skeletons in each instance would show material variation other than size, with some differences of proportions, and possibly the relative height of the spinous processes of the dorsal vertebrae, correlated with the development of the crest of the skull and its degree of freedom from the underlying flesh, as shown by the extent of the vascular impressions on its under side.

We have determined certain common factors in all of the type skulls which are in any degree complete, but find difficulty in deciding as to their relative specific value, for a grouping of specimens according to the character of the nasal horn may give a different idea of relationship from that derived from the character of the brow horns, and so on. Nevertheless, it has been possible to recognize certain assemblages of species, but the reduction of the total number has not been satisfactory, even though the practice of giving a distinct specific name to every approximately complete skull, which was actually done, seems, *a priori* unreasonable.

Of the new material which has come to light since the *Ceratopsia Monograph* was published in 1907, all, with the possible exception of the skull of the mounted skeleton in the American Museum, and the huge vertebrae described by Brown,⁵⁹ may be correlated with forms already described. There are a few skulls of the older Marsh Collection at the Yale Peabody Museum, which, because of lack of complete preparation or other inaccessibility, have not been studied in full detail, but the inference is that all would be found referable to already known species.

The species, in order of their publication, but grouped also according to adequacy of the type material, are as follows:

Adequate

Triceratops horridus Marsh, 1889
Triceratops flabellatus Marsh, 1889
Triceratops prorsus Marsh, 1890
Triceratops serratus Marsh, 1890
Triceratops elatus Marsh, 1891
Triceratops calicornis Marsh, 1898
Triceratops obtusus Marsh, 1898
Triceratops brevicornus Hatcher, 1905
Triceratops (Diceratops) hatcheri Lull, 1905

Inadequate

Triceratops alticornis Marsh, 1887
Triceratops galvus Marsh, 1889
Triceratops sulcatus Marsh, 1890
Triceratops maximus Brown, 1933

⁵⁹ *T. maximus*, Brown, B, 1933, A.

The common factors which may be used are: *Size*, always considering the indicated individual age of the specimen. Thus, the *Triceratops prorsus* type skull is that of an old animal, as the sutures are almost entirely obliterated, and yet it is the smallest known *Triceratops* skull, with an over-all length of but 5 feet 1 inch. On the other hand, the *Triceratops serratus* type skull, while quite young, is 5 feet 11 inches, and the *Triceratops calicornis*, not fully adult, 6 feet 10¾ inches. This closure of the sutures does not necessarily coincide with sexual maturity, but with completion of growth.

Skull proportions is another factor; thus, the muzzle may be either long or short, and the crest either broad, in proportion to its length, or relatively narrow.

The form of the *rostrum* has also been taken into account, as has that of the *jugal*, and *jugal notch*, also the presence or absence of the *pseudopineal fontanelle*, the form and degree of inclination of the *orbit*, and the form of the *infratemporal fossa*. But the most characteristic elements in all ceratopsians are the *horns* and the *crest*; and of these, the *nasal horn* seems to have the greatest value as a specific criterion, for its form and size, if present, or even its absence, are all weighed. The *brow horns* are perhaps less diagnostic, for a grouping of specimens according to brow-horn resemblances does not coincide with a grouping based upon the nasal horns, and, moreover, the former seem to show more individual variation, especially in curvature, than does the nasal; but in no two skulls are either of these elements exactly alike.

The *vascular impressions*, on the outer surface of the crest and facial bones, are an age criterion rather than a specific one, for in older animals the horny integument became either heavier or more closely fitting, possibly both. The extent of these markings on the inferior aspect of the crest seems, however, to have been more important, for in some cases they are absent, again they are limited to a well defined peripheral zone, or they may be more widely diffused.

On the basis of these data, the following conclusions as to specific distinction or synonymy are reached:

Triceratops horridus Marsh⁶⁰

Holotype: No. 1820 Y.P.M.;⁶¹ greater portion of a skull, with parts of the lower jaws.

Horizon: Lance formation. This specimen is number 31 out of 32, and therefore about the base of the sequence (see p. 115).

Locality: Niobrara County, Wyoming.

Collectors: J. B. Hatcher, C. A. Guernsey, and E. B. Wilson, 1889.

The main characteristics of this species, which is the genoholotype, are: The skull is that of an aged, and hence full-grown individual, having an estimated over-all length of 6 feet, 8 inches. This is a large specimen, but not the largest of the species. Of the crest only the proximal part is preserved, and but a small portion of the orbit; otherwise, most of the essential details can be made out. The muzzle is fairly long, and the rostral very heavy, with deep vascular impressions. The cutting edge is not so sharp as in some species and is downwardly curved toward the tip. The nasal horn is broad at the base, short and blunt, with the dorsal contour in line with that of the nasals, which is a prevailing feature of *Triceratops*, except in the *elatus-calicornis* phylum. The anterior profile of the nasal horn slopes slightly toward the rear. The brow horns are exceedingly stout and rugose, were probably fairly long, and slope forward, as in *prorsus*. Their base is extremely heavy and is elliptical in cross-section. The orbit is not sufficiently outlined for characterization in the type, but it seems to have been elliptical, with the long axis inclined at an angle of 15° or more from the perpendicular. The descending limb of the jugal is robust, with the longitudinal axis nearly vertical, but sloping slightly backward, and with a bluntly rounded median keel which nearly bisects the bone. There is no trace of the epijugal as a separate element. The jugal notch is fairly deep, but the outline of the infratemporal opening is not preserved. The crest proportions are not obtainable, but the preserved base is heavy, with deep vascular grooves on the

⁶⁰ Marsh, O. C., 1889, A, pp. 334-335 (*Ceratops horridus*); 1889, B, p. 173 (*Triceratops horridus*).

⁶¹ Hatcher, Marsh, Lull, 1907, Pl. XXVI.

outer aspect. Those on the under side cannot now be seen. As preserved, the dorsal outline is an even curve with no prominences on the midline, as in *serratus*. These may have been present, however, farther back, but judging from referred specimens, I imagine not.

To this species, I would refer the huge skull No. 1828 Y.P.M., as far as can be ascertained in its present condition. This skull carries the manuscript name of "*ingens*," in Professor Marsh's handwriting, but, while that name has been published by Lull, it was without description and was therefore, disallowed by Hay. It is the largest of all *Triceratops* skulls, measuring over 8 feet in length, an aged individual, with deep vascular impressions on the outer surface. But it is next to the uppermost of the Niobrara County series, showing the conservativeness of this species.

To *horridus* I would also refer a skull (Pl. XIII, B) in the South Dakota School of Mines, No. P 271, collected in the Short Pine Hills, Harding County, South Dakota (see map, Fig. 2, No. 11). This skull, which has an over-all measurement of 5 feet 6½ inches, and is that of a not fully adult individual, judging from the condition of the sutures, agrees with the type in most respects, especially in the character of the horns, but not in the form of the jugal, which however is partly restored and may not be of great significance.

Another large skull, No. 12,003 (Pl. XIII, A), in the Field Museum of Natural History, from the Lance formation of Chalk Buttes, Montana (see map, Fig. 2, No. 10), is also probably referable to this species. It is 6 feet 9 inches in length.

A large skull in the American Museum, No. 5028, was collected by Brown in 1908 from the Hell Creek beds of Dawson County, Montana. This is the skull of an aged animal, and measures 6 feet 10¾ inches in over-all length, hence a little greater than the estimated length of the type, though the actual measurements of the facial region are materially larger than in the type. The main distinctions of this specimen, as compared with the type, lie in the larger nasal horn, which is more like that of *prorsus* in having the tip extend forward to a point nearly over the anterior edge of the rostral, and in the shorter and more erect brow horns. The descending limb of the jugal differs also from that of the type in its narrower proportions. The skull differs from the type of *prorsus* mainly in its much greater size and somewhat shorter horns, and in the apparent lack of the defined peripheral zone of vascular impressions on the under side of the crest. From *brevicornus*, this skull differs in greater size, longer nasal horn, and also in the lack of vascular zone. The animal quite evidently belongs to the *horridus-prorsus-brevicornus* phylum, its closest affinity being with *horridus*. It is unique in the disproportionately large facial region, as compared with the relatively abbreviated crest, which simply emphasizes once more the infinite variation of the ceratopsians.

Triceratops horridus, although conservative, seems to have been a widespread species both in space and in time. I would group *horridus* near *prorsus* and *brevicornus*, as opposed to the *elatus-calicornis* phylum, although not necessarily in the same ancestral line.

Triceratops prorsus Marsh⁶²

Holotype:⁶³ No. 1822 Y.P.M.; nearly perfect skull with lower jaw, and six anterior cervicals.

Horizon: Lance formation, No. 19 in the Niobrara County sequence.

Locality: Niobrara County, Wyoming.

Collector: J. B. Hatcher, 1889.

The type skull is that of an aged individual, but one of small size; in fact, its over-all length of but 5 feet 1 inch, makes it the smallest *Triceratops* species and specimen known.

The nasal profile is nearly straight to a point about over the middle of the narial opening, whence it curves gently upward and is continuous with that of the nasal horn. The profile of the crest begins at a point below that of the nasals, so that the two are not in line when viewed laterally. Posteriorly, the crest rises to a point about level with the tip of the nasal horn. The orbit is nearly

⁶² Marsh, O. C., 1890, p. 82.

⁶³ Hatcher, Marsh, Lull, 1907, Pls. XXXII-XXXVI.



circular, as opposed to the usual elliptical shape, but the slightly longer axis slopes, as usual, at an angle of about 45° from the perpendicular. The descending limb of the jugal is narrow and tapering, without a median keel, and the axis is inclined slightly backward. The jugal notch is fairly deep and wide, the infratemporal opening being of average size and somewhat triangular, with curved margins. The rostral is large, although less massive than in *horridus*, with a sharp cutting edge and downwardly curved inferior margin. The muzzle is rather short, although the face is long. The most distinctive feature of *prorsus* is the nasal horn, which is long and directed forward so that its tip extends over the forward margin of the rostral, the anterior profile being inclined forward at an angle of 35° from the perpendicular. This nasal horn is unique, and occurs in no other skull, although approaching that of *brevicornus* and the American Museum skull (No. 5028) mentioned above.

The brow horns are slender, directed upward, outward, and forward for half their length, and then curved gently inward and upward toward their tip. This reversed curve is characteristic of *calicornis* and *elatus*, although they both differ from *prorsus* in the possession of a rugose prominence on the rear of the horn's base. The horns of *prorsus* are more slender than are those of either *horridus* or *brevicornus*, and much longer than the latter.

The crest is deeply arched, and helmet-shaped, with an undulating dorsal line which is concave upward, the rear third being missing. A characteristic feature which links *prorsus* and *brevicornus* is the limitation of the vascular impressions on the inferior surface of the crest to a very clearly defined marginal zone averaging 15-17 cm. in width. There are deep vascular impressions also on the dorsal aspect of the crest, the nasals, and horns.

The preorbital fossa lies entirely within the maxillary; the ascending process of the premaxillary, although long and slender, does not quite reach it. The pseudopineal fontanelle is utterly lacking, in possible agreement with the *flabellatus* type skull as figured by Marsh,⁶⁴ but with no other. This is, apparently, not a matter of age, for the *flabellatus* specimen is extremely young, and no matter what the age of other skulls, young or old, it is always present. The mandible is rather slender, with a high coronoid process, expanded fore and aft at the summit. The number of vertical rows of teeth is, in the maxillary, about 30, in the mandible, about 33.

Triceratops prorsus is nearest to *Triceratops brevicornus* in relationship, agreeing in general proportions, in the presence of the vascular zone around the periphery of the inferior aspect of the crest, and in the rather large nasal horn and its general slope which, however, is greater in *prorsus*. They disagree in the shorter and stouter brow horns of *brevicornus*, but their assignment to the same phylum can hardly be questioned.

Several skulls have been identified as pertaining to this species, notably No. 2100⁶⁵ and No. 1205 of the United States National Museum; but there seems to be little warrant for such assignment if the highly diagnostic nasal horn is taken into account, for that of the skull No. 2100 is very different in character and is of the *elatus* type, while No. 1205, a fragmentary skull, possesses none at all in its present mutilated state.

No. 2100 is the skull now borne on the mounted skeleton, but it is not the one figured in the paper restoration of the animal, published by Marsh,⁶⁶ for which he used the type skull of *prorsus*, now at Yale. The skeleton is a composite one and includes at least ten catalogue numbers and therefore as many, if not more, individual animals. Many of the separate bones were figured by Marsh or Hatcher in discussing the morphology of the *Triceratops* skeleton, but always called *Triceratops prorsus*. I have yet to find specific characters in the skeletal elements other than the skull, and see no possible assurance of the correctness of these specific identifications of the separate bones for, aside from skull and jaws, the type of *prorsus* includes only the six anterior cervical vertebrae and some of their ribs, and it is only by actual association of a specifically identifiable skull and a more or less complete skeleton in two or more instances, that skeletal contrasts of a specific nature can be determined.

⁶⁴ Hatcher, Marsh, Lull, 1907, Pl. XLV.

⁶⁵ Hatcher, Marsh, Lull, 1907, Pls. XXX-XXXI.

⁶⁶ Loc. cit., p. 190, Fig. 125.

There is a single brow horn, No. 4842 U.S.N.M., which pertains to one of the individuals making up the greater part of the mounted skeleton. It was figured in the *Ceratopsia Monograph*,⁶⁷ and was referred by Marsh to *prorsus* but, as Hatcher says, resembles more nearly the same element in *Triceratops elatus*.

Triceratops prorsus is a very popular name, and is used repeatedly in identifying material, but on the other hand, the species seems to have been rare, for but one skull, and that the type, is referable to it without question.

***Triceratops brevicornus* Hatcher⁶⁸**

Holotype:⁶⁹ No. 1834 Y.P.M.; skull and partial skeleton.

Horizon: Lance formation, No. 9 in the sequence.

Locality: Niobrara County, Wyoming.

Collector: Hatcher, Utterback, Sullins, Bostwick, 1891.

The skull, which is that of an old individual, is 5 feet 8 inches long, and hence larger than *prorsus* but smaller than the average of 6 feet 4 inches. The skull proportions resemble those of *prorsus*, except that the muzzle is relatively longer in proportion to the face. The dorsal profile of the entire skull forms a more or less continuous line, the crest rising in a gentle curve toward the rear. The rostral is proportionately very heavy, with a deeply excavated inferior surface; the cutting edge is rather sharp, but comparatively straight, although pointing downward toward the tip. The descending limb of the jugal is narrow and parallel-sided, while the rather blunt median keel divides the jugal into equal halves. The jugal slopes gently backward. The jugal notch is deep and wide, and the infratemporal opening is large and triangular, with the rounded apex behind. The orbit is an elongated ellipse, with the long axis forming an angle of about 15° with the perpendicular. The nasal horn is short and very stout, rather prominent, but smaller than in *prorsus*, and it does not extend forward over the rostrum as in the latter species. The long diameter is much greater than the transverse. The dorsal profile of the horn core is continuous with that of the nasal bones and sweeps upward in a gentle curve into that of the horn. The anterior margin is somewhat convex, and is inclined slightly forward toward the tip of the horn.

The brow horns are short, stout, and abruptly tapering, more nearly circular at the base than in any other species, except the specimen of *elatus*, No. 2100 U.S.N.M. Contrasted with the longer horns of *prorsus* and *horridus*, they curve gently forward and outward.

The crest of *brevicornus* is not very long, being proportionately shorter than in *prorsus*, and not so sharply curved transversely as in the latter species. The two crests resemble each other in having the dorsal profile undulating and slightly concave, and in the possession of the limited zone of vascular impressions on the under side; the latter is also true of No. 2100 U.S.N.M., mentioned above. The number of epoccipitals is 19 for *prorsus*, and apparently 17 for *brevicornus*. The number of maxillary teeth also corresponds at 30. The mandible is of medium proportions, the coronoid process is rather low and not much expanded at the summit, in contrast to that of *prorsus* which is high with a marked expansion. The prementary is heavy to match the jaw, and rather sharply pointed.

The preorbital fossa seems to lie entirely within the maxillary, although the ill-defined sutures make this difficult to determine with certainty.

But one other skull known to me seems referable to this species and that was collected by Mr. W. H. Utterback in the Hell Creek region of Montana, in 1904, and is now preserved in the Carnegie Museum in Pittsburgh. This skull conforms with the type except for certain minor variations as follows: Length over-all is 6 feet 3 inches as compared with 5 feet 8 inches for the type, though both are aged animals. The nasal horn is somewhat larger and heavier, which brings the center of mass further forward and makes the muzzle appear shorter, although the ratio of muzzle to

⁶⁷ Loc. cit., p. 128, Fig. 108.

⁶⁸ Hatcher, J. B., 1905, p. 413.

⁶⁹ Hatcher, Marsh, Lull, 1907, Pls. XLI-XLII.

over-all length is about the same. A similar cause may have given rise to a difference in inclination of the hinder margin of the nasal septum, which is more erect in the type. The brow horns are relatively shorter in the Carnegie Museum specimen, compared with the over-all length of the skull, and taper more uniformly, without the abrupt, somewhat truncated appearance of the type. Their curvature corresponds so far as the mass of the horn is concerned, but not in the anterior margin. The orbits are similar in shape and inclination, but those of the larger skull are relatively smaller. The jugals are alike, except that in the Carnegie skull they have a somewhat greater fore and aft diameter. The jugal notch is wider, owing to a gentler marginal curve at the anterior end of the squamosal. The infratemporal fossa is smaller and more ovoid than in the type. The crest is similar in general proportions but the dorsal profile is less undulatory, and the curve rather more abrupt at mid-length. The mandible, rostral, and prementaries agree. This skull is without doubt referable to *brevicornus*, the differences being such as are included under individual and possibly sexual, but not age variation.

Triceratops serratus Marsh⁷⁰

Holotype:⁷¹ No. 1823 Y.P.M.; nearly perfect skull with lower jaw.

Horizon: Lance formation, No. 18 in the sequence.

Locality: Niobrara County, Wyoming.

Collector: C. E. Beecher, 1889.

This type consists of a magnificently preserved skull, jaws, and hyoid, but no other skeletal material. The skull is fairly large—5 feet 11 inches—although below the average; but as the animal was immature, it might have attained average proportions had it lived. The muzzle and face are long, and the profile of the face and crest are in line with each other. The facial profile is first slightly concave, then convex, forming a reversed curve, differing therein from the simple curve, concave upward, found in every other species but *obtusus*. The orbit is a broad ellipse, with the long axis inclined as usual some 45° from the perpendicular. The descending limb of the jugal is narrow, parallel-sided for about half its length, then, after a slight dilatation, narrows to a rounded point. There is no trace of a median keel. It thus resembles the jugal of *flabellatus* more than that of any other species, the main distinction being the somewhat greater width in the latter. The axis of the jugal is nearly vertical, but inclines slightly backward. The jugal notch is deep, and the infratemporal fossa large and almost quadrangular, instead of being more nearly triangular as in most species. The angles of the fossa are rounded, with the exception of the antero-inferior one. The preorbital fossa lies between the nasal and maxillary, having a slight contact with the jugal toward the rear. The rostral is rather small, lighter and less rugose than in any other form in which this element is preserved, and the inferior border is more nearly horizontal, as the point does not project downward, as is usual. It is deeply excavated beneath, with a fairly sharp but irregular cutting edge, not so sharp nor so perfectly formed as in *prorsus*, however; this may be an age variation, the *serratus* skull being the younger. The nasal horn was a separate ossification, and was lost in maceration, but it could have been neither robust nor long. It was transversely compressed at the base, and the dorsal outline was probably continuous with that of the nasals as in the *prorsus-brevicornus-horridus* group, in contrast to that of *elatus* and *calicornis*.

The brow horns were slender and much more erect than in any species other than *flabellatus*. As less than one-half their length is preserved in each instance, one cannot be sure of the reversal of the curve either in *serratus* or *flabellatus*, although both have been restored as though it were present. There is, however, a boss-like prominence at the base of the horn, in the rear. It is one of a series of three which extend in an oblique line down to the proximal third of the squamosal. This prominence is characteristic of the brow horns of *elatus*, *calicornis*, and *obtusus*, although in these species the continuation of the prominences on to the squamosal is lacking. The base of the

⁷⁰ Marsh, O. C., 1890, pp. 81-82.

⁷¹ Hatcher, Marsh, Lull, 1907, Pls. XXVII-XXIX.

horn is somewhat elliptical, but the section becomes more nearly circular, distally. The crest proportions are, at first sight, unusual, for it seems much wider in proportion to its length, than in *prorsus* for instance. This is due, however, to the transverse curvature of the crest, which differs in each case, that of *serratus* being flattened, while the *prorsus* crest is highly convex. As a matter of fact, the relative measurements, taken over the curve of the bone, are much the same. This is true also of the undulations of the midline, although the name *serratus* was based upon the "series of bony projections on the median line of the parietal crest." The name could, with equal propriety, be applied to *prorsus* and *brevicornus*, on this detail alone. The very slight elevation of the midline of the crest toward the rear agrees with *flabellatus* and no other species. To what extent this may be due, in each specimen, to immaturity is not clear. The number of vertical rows of maxillary and mandibular teeth is about 28 in each instance, which is the average number for *Triceratops* species. The number of epoccipitals is 17.

The mandible, which is somewhat pathologic in the right ramus, is long and slender, in harmony with the facial portion of the skull. The prementary bears the same proportions, while the coronoid process is only moderately expanded fore and aft at the summit.

Triceratops flabellatus Marsh⁷²

Holotype:⁷³ No. 1821 Y.P.M.; nearly complete skull associated with several vertebrae, a few limb bones, etc.

Horizon: Lance formation, No. 10 in the sequence.

Locality: Niobrara County, Wyoming.

Collector: J. B. Hatcher, 1889.

The type is a very young, partly disarticulated skull, of which the length is 6 feet 2 inches. The depth and relative shortness, which seem to be juvenile proportions, indicate that had the animal lived, it would have attained a fairly large size, probably above the average. These general proportions would presumably have changed with age, and hence are not considered specific characters.

The dorsal profile is much straighter than usual, that of the face and crest being nearly in line. The nasal profile is a gentle curve, the degree of which remains the same throughout, instead of varying as is usual. The nasal horn is missing, as in the *serratus* type. Marsh's restoration shows, in outline, a truncated horn with an anterior margin which slopes somewhat backward. It might, however, have been restored with equal propriety, to resemble that of *brevicornus*. In other words, this essential specific feature is lacking. The brow horns rise more erectly than in any other species, except *Triceratops (Diceratops) hatcheri*, but their forward curvature above the base is somewhat greater than in the latter. The horns are laterally compressed near their base; distally, they are more nearly circular. The orbit is an elongated ellipse of slightly irregular outline, with the long axis inclined at 45° from the perpendicular, the maximum inclination for *Triceratops*. The descending limb of the jugal is quite broad, and lacks a median ridge or keel. It resembles that of *serratus* more nearly than that of any other. The jugal notch is not deep, but the infratemporal fossa is a broad oval with but one angle, the antero-inferior one. The face is deep, but of moderate length, while the muzzle is very short. The rostral and prementary are both missing. The crest, while wide for its length as measured over the curve, appears narrower, due to its curvature, than in either *serratus* or *calicornis*, wherein the crest is comparatively flat, when viewed from above. It is smooth both above and below, with no trace of vascular impressions, except immediately in the wake of the supratemporal fossa. The epoccipitals are 19 in number, which is near the average, while the number of maxillary teeth, apparently about 35, seems excessively great, especially as the number of mandibular teeth, apparently 30, is near the average and one assumes that they would approximately correspond.

⁷² Marsh, O. C., 1889, B, p. 174.

⁷³ Hatcher, Marsh, Lull, 1907, Pls. XLIV-XLV.

The mandible seems rather slender for so deep a facial region of the skull. The coronoid process is moderately expanded at the summit, and is not hook-like, as in *Monoclonius* (*Centrosaurus*).

The preorbital fossa was apparently entirely within the maxillary, although the depression was bounded also by the lacrymal and jugal on the rear side and below, respectively.

T. flabellatus is an isolated species, the affinities of which lie perhaps as near *serratus* as any other. In these two, the jugals are the most similar, and while the nasal horn has been lost in each instance, they may also have been alike. Proportions differ, for *serratus* is long and slender, viewed laterally, while *flabellatus* is deep. This, as well as the bosses on the horn base and squamosal of *serratus*, may be an age distinction. The dorsal profiles are, in general, alike, except for the prominences along the midline of the crest in *serratus*. The *flabellatus* skull is smooth throughout, lacking the vascular impressions so well marked in *serratus*, but this is a matter of age. *T. serratus* also stands alone except for this suggested affinity. Finally, they were found very near each other, although the *flabellatus* comes from a slightly higher level.

Triceratops elatus Marsh⁷⁴

Holotype:⁷⁵ No. 1201 U.S.N.M.; skull.

Horizon: Lance formation, No. 12 in the sequence.

Locality: Niobrara County, Wyoming.

Collector: J. B. Hatcher, 1890.

This specimen represents a somewhat immature animal of average size, the skull measuring 6 feet $2\frac{3}{4}$ inches in length. The dorsal profile of the skull is distinctive, the facial portion having a decided hollow curve straightening out toward the cranium proper, which is the highest point, except for the extreme rear of the crest; in this it resembles *Triceratops calicornis*, its nearest relative. The muzzle is rather slender and of moderate length, although the rostral is fairly large. The latter has deep vascular grooves and a comparatively straight inferior margin which points decidedly downward toward the tip. The narial opening is very large. The nasal horn is peculiar, although resembling that of *calicornis* more than any other species in having the dorsal margin slightly below and not continuous with that of the nasals. The horn core, while bearing vascular impressions, is truncated, the anterior and superior margins being at right angles with each other, the former overhanging the base of the muzzle and inclining slightly backward.

The brow horns are long and massive, extremely heavy at the base where they are strongly compressed laterally, becoming more circular in section toward the tip. The rear of the base bears a marked prominence, as in *calicornis*, *obtusus*, and *serratus*. The horn curves strongly forward, reversing slightly toward the extreme tip.

The orbit is a broad oval of regular outline, with the broader end uppermost, and inclines at an angle of about 15° out of the perpendicular. The jugal is unique in that it is T-shaped, having no posterior limb, as in every other ceratopsian skull, the posterior margin being continuous with a somewhat irregular suture which extends directly upward and forward to the orbit. Skull No. 2100,⁷⁶ on the mounted skeleton in Washington, is suggestive of *elatus* in this, as in certain other features, but the jugal is broader. The descending limb is long and rather narrow, with curved, nearly parallel front and rear margins. The longitudinal ridge, which is but slightly developed, lies near the rear instead of being in the center of the bone. The jugal notch is deep and wide, and the infratemporal fossa unusually large and triangular, with the apex pointing toward the orbit. Unfortunately, the jugal complex is visible only on the left, and, as the bone seems abnormal, one would like to compare it with that of the other side were it possible.

⁷⁴ Marsh, O. C., 1891, p. 265.

⁷⁵ Hatcher, Marsh, Lull, 1907, Pl. XLIII.

⁷⁶ Hatcher, Marsh, Lull, 1907, Pl. XXX.

The crest is of average size and curves strongly upward toward the rear, the dorsal profile being only slightly undulating. The epoccipitals and epijugals are lacking. They were originally present, however, the former numbering about 21. The squamosal is very wide, especially at its mid-length, but has much the same general form as in *calicornis*. The area of the crest lying about the supratemporal fossa, especially toward its rear, is deeply excavated and evidently pathologic. Otherwise, the sculpturing, especially of the vascular grooves, is not so very marked on either surface of the crest, above or below.

To the species *elatus* may also be referred the skull No. 2100 U.S.N.M., at present associated with the mounted skeleton at Washington. This fine skull is complete, except for the muzzle, which has been restored. Its dimensions are about those of the *elatus* type, the over-all length being 6 feet 3½ inches for No. 2100 U.S.N.M., and 6 feet 2¾ inches for *elatus*. The small nasal horn is like that of *elatus* with its dorsal surface depressed below the level of the nasal bones. The brow horns, on the other hand, differ in their angulation, being strongly anteroverted, with a reversed curve toward the tip, and in the form of the basal section which is nearly circular. The orbit is also nearly circular, in contrast to its elliptical form in *elatus*. The epijugal has a high ridge, and the jugal itself is broad, with a limited posterior limb, resembling somewhat the peculiar jugal of *elatus*. One marked peculiarity which resembles *prorsus* and *brevicornus*, rather than *elatus* and *calicornis*, is the limited peripheral zone of vascular impressions on the under side of the crest which, in this instance, seems correlated with an outward and upward flare of its margin. The maxillary teeth number 28 vertical rows. The affinities of this skull lie clearly with *Triceratops elatus* Marsh, the only discordant feature being the peripheral zone of vascular impressions on the under side of the crest.

Yet another skull of somewhat doubtful affinity, but nearer *elatus* perhaps than any other, is that on the mounted skeleton⁷⁷ of *Triceratops* in the American Museum of Natural History. This mount (Pl. XIV, A) is composite, the skull, No. 5116, having been collected by C. H. Sternberg in Weston County, Wyoming, while the skeleton, No. 5033, No. 5039, No. 5045, was collected by Brown and Kaisen in 1909 in the Hell Creek region in Montana. This is a large skull, 6 feet 7½ inches, of an adult but not an aged individual, as the sutures are still very clearly defined. In general proportions, it differs from *elatus* in being relatively shallow for its length, especially in the cranial region, and in the enormous crest which is smooth above and below and has an even margin, without epoccipitals in its present condition, although doubtless the usual number was originally present. The muzzle has the proportions of *elatus* rather than of *calicornis*, with a large narial opening. The nasal horn is rather larger than usual, but shows the depression of the dorsal contour slightly below that of the nasals. The brow horns are enormous, strongly anteroverted, as in No. 2100 U.S.N.M., but almost straight beyond the base, which is circular in cross section. The tips extend almost to the anterior limit of the premaxillaries. All of the horns have deep vascular impressions. The orbit is nearly circular, as in No. 2100 U.S.N.M., while the jugal is rather narrow, tapering and raking backward rather more than usual. The jugal notch is very shallow, but the infratemporal fossa is relatively larger than in the *elatus* type, almost semi-circular in form, with the upper margin nearly straight. This skull evidently belongs to the *elatus-calicornis* phylum, but of its strict specific identity with *elatus* one cannot be sure. There is infinite variation in all *Triceratops* skulls.

Triceratops calicornis Marsh⁷⁸

Holotype:⁷⁹ No. 4928 U.S.N.M.; skull and portion of skeleton.

Horizon: Lance formation, No. 17 in the sequence.

Locality: Niobrara County, Wyoming.

Collector: J. B. Hatcher, 1889.

⁷⁷ Osborn, H. F., 1933.

⁷⁸ Marsh, O. C., 1898, p. 92.

⁷⁹ Hatcher, Marsh, Lull, 1907, Pls. XXXVIII-XXXIX.

This is one of the largest *Triceratops* skulls on record, having an over-all length of 6 feet $10\frac{3}{4}$ inches, in spite of its being not fully adult. The disproportionately long muzzle increases the length over that of *elatus* which, otherwise, it resembles most closely. The dorsal profile is very comparable to that of *elatus*, as superimposed outlines would show. The imperfection of the median portion of the crest in the present specimen makes the comparison of this region of less value, however.

The orbit is an elongated ellipse, slightly broader above and, as in *elatus*, inclined at an angle of about 15° from the perpendicular. The jugal is of medium width, and tapers to a point in the distal half. It differs from that of *elatus* in having the usual rear branch above, and is, therefore, T-shaped rather than in the form of an inverted L. But that of *elatus* may be abnormal, and were that of the opposite side preserved, it might be found to resemble that of *calicornis*. There is a slight longitudinal ridge on the jugal about two-thirds of the way toward the rear of the bone. The jugal notch is of moderate depth, but is wide, with curved outline.

The infratemporal fossa is rather small for the size of the skull and differs, not only in this, but also in shape, from that of *elatus*, being oval in form, with a rather long apex pointing downward and forward. The muzzle is very long, more like that of *Chasmosaurus* than *Triceratops*. The face is also long. In this respect, *calicornis* differs from *Chasmosaurus* in which, despite the fact that the muzzle is long, the face is very short. The narial opening in *calicornis* is very large, in correspondence with the large muzzle. The rostral is also large, with a very convex profile. The downwardly curving inferior margin is rather sharp-edged.

The nasal horn is very peculiar, and here, as in *prorsus*, it was the most distinctive feature in the eyes of Professor Marsh, who gave the name *calicornis* to the species because the rear of this small nasal horn resembled a horse's hoof as seen from below. As in *elatus*, the dorsal margin of the horn core is not continuous with, but below that of the nasal bones, the horn being thus sharply marked off from the nasals. The horn is convex in front and concave behind, hence the hoof-like form. There are vascular impressions on the rounded anterior surface. Viewed laterally, the horn has a pointed apex. The horn of both the *elatus* type and of the skull No. 2100 U.S.N.M., on the mounted skeleton at Washington, are of the same general character, although the hollowed rear surface is peculiar to the present specimen.

The brow horns are large, agreeing with those of *elatus* in size, massiveness, and general curvature, and in the possession of a boss-like prominence on the rear of the base. They have a very heavy base from which they taper rapidly, curving sharply forward but without the reversed curve toward their tip.

The crest is only partially preserved, the entire left squamosal and about a third of the median element only being present. The left squamosal is about twice as long as broad, with a uniformly curved, rather than undulating, margin. Otherwise, the margin is smooth and rather thin. There were probably the usual number of epoccipitals, perhaps 19 in all, although but two are preserved. A few shallow vascular impressions are present on the upper surface of the crest. Below, they are deeper, especially in the posterior part of the squamosal, and extend further in from the margin, there being no limited zone of vascular grooves such as that of *prorsus*, *brevicornus*, and the skull No. 2100 U.S.N.M. The crest is unusually wide when viewed from above, being over twice as wide as long, according to Hatcher's figure.⁸⁰ The pseudopineal fontanelle is present, and large, but the radiating canals, if they formerly existed, are not preserved. The preorbital fossa lies between the nasal and maxillary, and is reduced to a rather wide, elongated slit.

The dentaries are of great size; otherwise, according to Gilmore,⁸¹ they show no distinctive characters. There are 38 rows of teeth in the left dentary, opposed to 28-32 in the maxillary, the exact number being difficult to determine. If this is the lower jaw actually belonging to the skull, it is difficult to account for this discrepancy, for no fore and aft or orthal movement of the mandible was possible. Microscopic striae of wear on the worn surface of the teeth prove vertical movement only.

⁸⁰ Hatcher, Marsh, Lull, 1907, Pl. XXXIX.

⁸¹ Gilmore, C. W., 1919, B, p. 101.

Undoubtedly, the relationship between *elatus* and *calicornis* is very close; the elongated muzzle of *calicornis*, the detailed form of the nasal horn, and the peculiar jugal of *elatus* seem to be about the only distinguishing features, all of which may be due to individual variation. Indeed, Hatcher expresses the opinion that the two species may prove to be synonymous. They certainly represent a group quite apart from the *prorsus-brevicornus-horridus* phylum. If they prove to be of the same species, the name *elatus* takes precedence.

Triceratops obtusus Marsh⁸²

Text Fig. 41

Holotype:⁸³ No. 4720 U.S.N.M.; a nearly complete skull and jaws, except for the parietal portion of the crest.

Horizon: Lance formation; No. 32, and therefore, the lowermost in the sequence.

Locality: Niobrara County, Wyoming.

Collector: J. B. Hatcher, 1890.

Hatcher could locate but little of this skull in the National Museum collections, either to figure or describe in the *Ceratopsia Monograph*. Later, Gilmore⁸⁴ found the remaining portions, and restored the skull, the unique yellow color of which made error of association virtually impossible.

The type is an old individual with an estimated length of at least 7 feet, hence one of the largest on record. The muzzle anterior to the nasal horn, however, is missing, and the length of this region is subject to considerable specific variation. The nasal profile is unique among *Triceratops* specimens in being convex instead of concave, although this may be due in part to crushing, especially toward the rear. The dorsal contour of the crest is conjectural, but as restored by Gilmore begins considerably below the level of the nasals, though rising above that level toward the rear. The orbit is large, a rather elongated ellipse, the axis of which is inclined at an angle of about 30° from the perpendicular.

The descending limb of the jugal is very broad for its length, and has a marked median ridge. The jugal notch is rather shallow and wide, and the infratemporal fossa very small for the size of the skull, triangular in shape, with the apex toward the rear. The nasals are very broad, especially over the posterior limit of the nares, and the two sides converge rapidly toward the anterior end. The nasal horn is reduced to a rather broad, rounded, rugose prominence, with deep vascular grooves. Laterally, the nasal profile reminds one of that of *Arrhinoceratops* of the Edmonton formation. In the latter, however, the profile is sharp-edged, while in *obtusus* it is broad.

The brow horns are very massive at their base, and have a protuberance at the rear as in *elatus* and *calicornis*. But they are relatively shorter, and lack the great forward curvature of the horns of these species. The horns of *obtusus* also resemble somewhat those of *brevicornus*, but they are relatively less stocky and taper to a longer point without showing a reversed curve.

The crest is only partly preserved, the right squamosal being entire, the left somewhat less so, but nothing is present of the parietal element. There are deep vascular grooves on the dorsal surface of the crest and on the under surface of the squamosal. They are not limited beneath to a peripheral zone. Epoccipitals must have been present although now the margin of the squamosals is smooth, without undulations. The mandible is very robust, with a low, broad coronoid, the form of which has apparently been altered by crushing, as shown in the figure. The number of mandibular tooth rows is 28, that of the maxillary series, which is partly broken away, cannot be determined. The individual teeth are very large.

The nearest ally of *Triceratops obtusus* seems to be *horridus*, the main distinction between them lying in the nasal horn, which varies considerably among the several skulls attributed to the latter species, although never to the point of obsolescence. In its loss of nasal horn and great size, *obtusus* is specialized; otherwise, it is a generalized type. It is interesting to see the reduction of the nasal

⁸² Marsh, O. C., 1898, p. 92.

⁸³ Gilmore, C. W., 1919, B, Pl. 4.

⁸⁴ Op. cit., pp. 98-101, Pl. 4.

horn so low in the Lance series, as this debars *obtusus* from the ancestral line of any other species except perhaps *T. (Diceratops) hatcheri*, which occurs two-thirds of the way up from the bottom of the sequence. That it constitutes a valid species is shown by a detached nasal horn of quite similar character in the Peabody Museum collection, No. 1825. This horn is straighter on top and with a less rounded apex when viewed laterally. It cannot be attributed to any other species than this.



Fig. 41. Left lateral view of skull of *Triceratops obtusus*, holotype, 1/12 natural size.

That *Triceratops obtusus* came from the same general ancestry as *Triceratops horridus* there can be little doubt, although it may represent a distinct line since Edmonton times. *Arrhinoceratops* is a structural ancestral possibility, although it presents difficulties, notably in the long squamosal.

The remaining species of *Triceratops* being "inadequate," I pass at once to a discussion of *Diceratops*, of which the type is ample for description, and also because of its apparent relationship with *Triceratops obtusus*.

***Triceratops (Diceratops) hatcheri* Lull⁸⁵**

Holotype:⁸⁶ No. 2412 U.S.N.M.; skull without the lower jaw.

Horizon: Lance formation, No. 11 in the sequence.

Locality: Niobrara County, Wyoming.

Collector: J. B. Hatcher, 1891.

This genus and species was described by Hatcher in his incomplete manuscript but left, unfortunately, without a name, which had to be supplied by the present author, who edited and completed the first Ceratopsia Monograph.

⁸⁵ Lull, R. S., editorial note in Hatcher, J. B., 1905, p. 413.

⁸⁶ Hatcher, Marsh, Lull, 1907, Pls. XLVII-XLVIII.

The generic characters, as given by Hatcher, are: "Nasal horn core absent. Squamosal bones pierced by large fenestrae, while smaller ones penetrate the parietals. The inferior border of the squamosal lacks a quadrate notch." Of these characters, I would dismiss the second as pathologic; for historically, the squamosal is never fenestrated as a normal character, although repeated instances of perforations through this bone occur, due either to disease or injury. (See *Torosaurus latus*, p. 131, Text Fig. 42; *Arrhinoceratops brachyops*, p. 107, Pl. XII; *Chasmosaurus brevirostris*, Pl. VII, A; and *Pentaceratops fenestratus*, p. 111, Fig. 40.) The entire region of the left squamosal, where the largest of these "fenestrae" occurs, is badly diseased on the under side; moreover, the perforation practically obliterates the area of insertion of one of the most important neck muscles which served to wield the head, so that the animal must have been partly incapacitated as a result.

The first and third characters are largely differences of degree, rather than of kind. This is especially evident if one compares *Diceratops hatcheri* and *Triceratops obtusus*. Of specific validity I have no doubt, but real generic distinction from *Triceratops* is highly questionable. There is nothing like the contrast in crests, for instance, shown in *Triceratops* and *Torosaurus*. (See beyond, p. 130.)

The skull, that of an aged individual, is about 6 feet 1 inch in over-all length, and therefore slightly below the average for *Triceratops* skulls. It is unique, for no other specimens known to me can be referred to this species.

The muzzle is long with a comparatively small rostral, although the sutural limits of the latter are not discernible. The inferior border of the rostral is curved downward toward the tip. The dorsal profile of the nasals and of the crest is almost in line, the former being concave, as usual, as contrasted with the convex profile of *obtusius*. The orbit is an elongated ellipse, with the axis inclined at an angle of about 20° from the perpendicular.

The descending limb of the jugal is of medium width, with a low ridge posterior to the mid-line. It is approximately vertical. The jugal notch is very shallow, as the outer anterior margin of the squamosal is very little below the summit of the notch. This is evidently Hatcher's third generic character, i.e., absence of quadrate notch.

The infratemporal fossa is of medium size, oval, with the apex pointing downward and forward. The nasal horn core is lacking entirely, the nasals rounding into the curve of the muzzle without a break in the even contour. The nasals terminate in a broad, rounded, rugose area more suggestive of *Triceratops obtusus* than of any other form, and, as in the latter, they are twice as broad at the rear as at the forward end.

The brow horns are comparatively short and robust, erect when viewed laterally, although flaring apart somewhat as seen from in front. There is but a slight forward curve. The horns seem to arise further back than usual with reference to the orbits, but this is more apparent than real, for the erect character of the horns heightens the illusion. The base of the horn is nearly circular in cross-section, instead of being laterally compressed as in most other species.

The crest is broad, at least twice that of its length, when viewed from above, and its dorsal profile is nearly straight, without undulations but with a slight upward turn toward the rear. Although a portion of this as well as the distal ends of the horns are artificial, the indicated curves are well carried out and are probably correct. The number of epoccipitals is 19, 5 on each squamosal, with 1 over the end of either squamoso-parietal suture, exactly as in *Triceratops*. The crest is highly vascular above and below with no limited zone on the inferior face. The perforations through the crest number four, and are asymmetrical, the left squamosal containing a large subtriangular one at about its mid-length, and a lesser, irregular one in front, near the infratemporal fossa. The right squamosal has another irregular aperture in nearly the same place as the larger one on the left, but having less than one-fifth the area of the latter. There is yet another smaller perforation through the right side of the parietal, halfway between the squamosal and the rear margin. Below, the area in front of the largest aperture is tumid, thickened, and irregular, which heightens the impression that all of these perforations are pathologic and may be cystic openings comparable to those through the squamosal of the *Torosaurus latus* type mentioned above, and

as such the result of disease, or injury, or both. Surely they can have no taxonomic significance. One wonders how many of the peculiarities of this skull, except perhaps the absence of the nasal horn, may be due to this diseased condition which, in affecting the behavior of the animal including the carriage of the head, reacted upon the entire organism.

The number of maxillary teeth is 24, less than the usual number.

Diceratops may be of sub-generic, but hardly of generic rank, for it is clearly a modified *Triceratops*, possibly the culmination of the evolutionary trend seen in *Triceratops obtusus* and out of its lineage. The species *hatcheri* I would consider valid.

"INADEQUATE" SPECIES OF TRICERATOPS

The three or four remaining species of *Triceratops*, I have called "inadequate" because of insufficiency of the type in each case, for while each form may be absolutely valid, it is impossible to define it in terms of the common factors we have been using. They will have to remain ill defined until more perfect material is found in each instance.

Of these, *Triceratops galeus*, consisting of a single nasal horn core, No. 2410 U.S.N.M., Hatcher has already discarded as based upon insufficient evidence. He says, however, that it resembles the nasal horn of *Torosaurus gladius* more than any known species of *Triceratops*, and may have pertained to that genus and species. It also resembles fairly closely that of the skull, No. 5116, on the mounted skeleton of *Triceratops* in the American Museum, which Hatcher never saw, and which has been referred tentatively to *elatus*. The evidence is too slender for determination of the species under discussion, and *galeus*, which is from the Denver beds of Colorado, must remain a nomen nudum pending further discovery.

Triceratops alticornis Marsh⁸⁷

Holotype:⁸⁸ No. 4739 U.S.N.M.; pair of brow horns with the communicating cranial bones.

Horizon: Denver beds.

Locality: On the banks of Green Mountain Creek, near Denver, Colorado (Fig. 2, loc. 17).

Collector: G. L. Cannon, Jr., 1887.

Here, the brow horns alone must determine the specific characters, which makes a clear definition impossible. The main distinction of these horns lies in their curvature, for while anteroverged at an average slope for *Triceratops*, they are otherwise straight in lateral aspect, but slope outward and then upward in a single curve, when viewed from the front. Aside from this, there is nothing to distinguish these horns from those of several other species. Here, again, the validity of this species must await further discovery.

Triceratops sulcatus Marsh⁸⁹

Holotype:⁹⁰ No. 4276 U.S.N.M.; fragmentary skull, vertebrae, etc.

Horizon: Lance formation, No. 16 in the sequence.

Locality: Niobrara County, Wyoming.

Collector: J. B. Hatcher, 1890.

There is, in addition, the plesiotype, No. 4286 U.S.N.M.,⁹¹ consisting of a pair of brow horns with the connecting cranium, which has been sectioned for the brain. This is number 26 from the top in the stratigraphic series and therefore considerably lower than the holotype.

⁸⁷ Marsh, O. C., 1887, pp. 323-324 (*Bison alticornis*).

Marsh, O. C., 1889, B, pp. 174-175 (*Ceratops alticornis*).

⁸⁸ Hatcher, Marsh, Lull, 1907, Fig. 106, p. 115.

⁸⁹ Marsh, O. C., 1890, B, p. 422.

⁹⁰ Hatcher, Marsh, Lull, 1907, p. 133-134, Figs. 112-113.

⁹¹ Ibid., Fig. 113.

Yet a third specimen in the National Museum, No. 1208, has been referred to this species. This consists of a nasal horn and a pair of brow horns, only one of which shows the sulcations which give the name to the species. Marsh's description states that "the most distinctive character of the skull is seen in the horn cores of the frontal region, which are very large and elongate. On the posterior surface of the upper half of each horn core, there is a deep groove, which has suggested the specific name."

The holotype, unfortunately, includes at present only a portion of one brow horn, which is obliquely truncated distally as though broken during the lifetime of its owner, and this does not show the distinctive sulcation on the rear, of which Marsh spoke. Possibly, as Hatcher suggests, the mate to this horn, which cannot now be located, was the one which showed the distinctive character.

The plesiotype, No. 4286, shows the sulcations on both horns very well, but they are on the antero-internal and not the posterior face of the horn.

In the third specimen, No. 1208 U.S.N.M.,⁹² the left horn has a rather shallow sulcation on the anterior side and a much deeper one on the antero-internal face, extending throughout the distal two-thirds of the horn. The sulcations on the other horn are so slight that they might be taken for vascular impressions were attention not called to them.

Sulcated horns are rare and, other than those we have mentioned, the only additional recorded instances are in the type of *Arrhinoceratops brachyops* from the Edmonton (see Pl. XII), and a slight indication of one on the antero-internal face of the left horn of *Torosaurus latus* type, and of the right horn of *Triceratops brevicornus* type. I doubt, however, the specific value of this feature alone, especially as there are no other diagnostic characters with which to correlate it. Both No. 4286 and No. 1208 possess associated nasal horns, that of No. 4286 being small and pointed, arising as a separate ossification which is now coössified with the underlying nasals. This horn does not rise above the level of the nasal profile and the anterior face slants slightly forward. In No. 1208, the dorsal outline of the nasals is slightly undulating, there being a low but distinct hump over the nares, then a depression, in front of which is a very small, rounded nasal horn with a nearly vertical anterior face, as preserved. Thus, the two nasal horns agree in being small; otherwise, they are quite unlike.

The lower jaw, associated with the holotype, is not specifically distinctive.

At present, therefore, the species *Triceratops sulcatus* cannot be defined. Although it may ultimately prove to be a distinct form, one cannot even determine its relationship with other *Triceratops* phyla except by elimination. If either of the nasal horns is distinctive, *sulcatus* cannot belong to the *prorsus-brevicornus-horridus* group; but whether its relationship lies with the *obtusus* or the *elatus* phylum, the evidence does not show.

Triceratops maximus Brown⁹³

Holotype: No. 5040 A.M.N.H., a series of eight free vertebrae and two cervical ribs.

Horizon: Lance formation, Hell Creek beds.

Locality: Rock Creek, 20 miles south of Lismas, Garfield County, Montana.

Collector: P. C. Kaisen, 1909.

Specific characters, as given by Brown, are as follows: "Axis rib reduced in size. Third cervical rib massive. Centra of free cervical vertebrae short, vertical and transverse diameters of articular faces nearly equal; sides deeply constricted; ventral surface flat. Anterior dorsal centra higher than broad."

Brown stresses further the deeply excavated sides and the flat, very rugose, ventral surfaces of the cervicals, the extremely large neural canal, a vertical series of three large foramina on each side of the cervical centra, spaced approximately one inch apart, and the extraordinary size of all the vertebrae.

⁹² Hatcher, Marsh, Lull, 1907, Pl. XXXVII.

⁹³ Brown, B., 1933, A.

This species cannot now be defined in terms of the criteria we have been using, for the skull is absent. A careful comparison of the description and dimensions given by Brown fails to distinguish the vertebrae from those of *Triceratops "ingens"* (No. 1828 Y.P.M.) in so far as equivalent bones are present in the two specimens, except that in certain dimensions cervical IV of *maximus* is a trifle larger, and the three equally spaced foramina on the side of the centrum are represented by one large one and others less clearly defined and not so regularly spaced. The other specific characters mentioned are common to both. In the dorsal vertebrae of *T. "ingens"* the centra have either been destroyed or are as yet hidden in the huge mass of matrix which envelops the specimen. *T. "ingens"* is a gigantic representative of the *horridus* species, but features other than size which might distinguish them are not now evident.

Triceratops maximus may prove to be but another huge specimen of the same species. The discovery of a skull sufficiently complete to show diagnostic characters, and associated with similar vertebrae, is necessary for final proof either of uniqueness or synonymy with previously described forms.

Genus *TOROSAURUS* Marsh⁹⁴

The known characters of *Torosaurus* lie in certain regions of the skull, for the skeleton, except for a few limb bone fragments, is totally unknown. While material pertaining to the genus may exist in our collections, it cannot be recognized. The skull characters have to do first with proportions, for the portion anterior to the orbits is abbreviated, and the crest extended in width and especially in length. As a consequence, the distinctive squamosal bone is extremely long and narrow, recalling that of *Chasmosaurus* of the Belly River, and *Pentaceratops* of the Fruitland, both of which may be in the line of its ancestry. Yet another generic character is the persistence of parietal fenestrae, which are characteristic of all ceratopsians below the Lance, but absent in all known Lance genera other than *Torosaurus*. In neither skull is the muzzle preserved, so that one cannot determine whether it was elongated, as in most long-crested forms, such as *Chasmosaurus* and *Pentaceratops*, or short, as in the average *Triceratops*. In the restoration of the *Torosaurus gladius* skull (Pl. XVI), the cranium and muzzle of which were modeled by the author a number of years ago, *Triceratops* was used as a guide. *Torosaurus* certainly could not have had a deep, abbreviated muzzle such as characterizes the short squamosal forms, *Monoclonius* and *Centrosaurus*.

But two specimens of *Torosaurus* are known, both of which come from the very summit of the Lance series of Niobrara County, Wyoming.

Torosaurus latus Marsh⁹⁵

Pl. XV

Holotype:⁹⁶ No. 1830 Y.P.M.; skull without lower jaw.

Horizon: Lance formation, No. 1 in the sequence.

Locality: Niobrara County, Wyoming, near the summit of the bluff on the north side of Lightning Creek, about 2 miles above its confluence with Lance Creek.

Collector: J. B. Hatcher, 1891.

This skull is that of an old individual, about 7 feet 10½ inches over all, as now restored by the author. The entire cranium, including the left maxillary, the nasal horn, and the bases of the brow horns, is preserved, together with both squamosals, and the anterior third of the fused parietals. On the left side, a portion of the antero-external outline of the fenestra seems to be present, but the form and extent of these distinctive features are highly conjectural. The dorsal profile of the nasals is in line with that of the preserved part of the parietals. There is reason to believe that beyond this the crest curved upward, balancing the upward curve of the nasals forward into the nasal horn.

⁹⁴ Marsh, O. C., 1891, p. 266.

⁹⁵ Marsh, O. C., 1891, p. 266.

⁹⁶ Hatcher, Marsh, Lull, 1907, Fig. 118.

The orbit is somewhat oval, with the broadened apex to the rear, and the long axis nearly horizontal, in contrast to the more nearly circular orbit of *gladius*. The descending limb of the jugal is not entire, but is fairly broad with apparently a low median keel. The infratemporal fossa is small, triangular, with rather straight margins. The anterior free margins of the squamosals are not preserved, so that the form and depth of the jugal notch are conjectural.

The nasal horn is small, but equal to that of the average *Triceratops*, acutely pointed, with the anterior face inclined backward, except toward the extreme summit. Its position relative to the nares is similar to that in *Triceratops*. The brow horns are large, and hollow for at least half their length; the base is oval in cross-section, with the apex pointing forward. They rise over the posterior half of the orbit which, in turn, underlies the anterior third of the horn. They arise



Fig. 42. Photograph of the visceral surface of the squamosal of *Torosaurus latus*, No. 1830, Yale Peabody Museum, showing distribution and relationship between cystic openings, erosion, and vascular channels. The similarity between the pathological conditions in the dinosaur and prehistoric man is of great importance, leading toward the same diagnosis.

rather close together, and are inclined outward and forward. There is no axial curvature in the preserved portions, for only about one-third of the left is present, and very little above the base of the right.

The crest proportions seem slightly broader for their length than in *gladius*, but this is not reliable. The mid-dorsal region is broadly rounded transversely and with extremely low undulations. The crest is smooth, both above and below, and with small marginal undulations. The pseudopineal fontanelle is unique, differing from that of *gladius*, as well as all *Triceratops* species, in being paired rather than single. The two apertures are separated by over 3 cm. of bone. From each of these, a wide, shallow groove runs backward and outward to terminate in a larger, elongated aperture which penetrates the crest.

The preorbital fossa lies between the maxillary and nasal, and is similar in form and size to that of the average *Triceratops*.

Examination of the squamosal bone (Text Fig. 42) of *Torosaurus latus* type, No. 1830 Y.P.M., reveals unquestioned evidences of disease. We submitted a photograph of the area involved, and a plaster cast of the openings, to Dr. Roy L. Moodie, who writes as follows:

"The photograph shows lesions which are identical with lesions found on the skull and skeletal elements of prehistoric Indians from the Channel Islands. There have been four cases of this disease studied from the Indian mounds. In one case there were evidences of seventy-five tumors on the skull alone. Comparisons with recent cases of the dread disease have led me to regard the condition as *Multiple Myeloma*, although there are some discrepancies in such a diagnosis.

"The association of open lesions, depressed areas, called 'erosions,' which are due to pressure atrophy from small tumors of subperiosteal origin and elongated channels, are so strikingly similar in the dinosaur bone (Fig. 42) that there would seem to be no doubt of the close relation between the condition in the dinosaur and prehistoric man.

"The etiology of the disease is uncertain, but recent work in medical laboratories would lend favor to the suggestion that such cystic tumors have to do with a disturbance in the parathyroid.

"The openings may be due to tumors arising in the medullary portion of the bone. Such pathological conditions appear first in the Triassic and are found in later reptiles and among Tertiary and Pleistocene mammals."

Torosaurus gladius Marsh⁹⁷

Pl. XVI

Holotype:⁹⁸ No. 1831 Y.P.M.; nearly complete parietal, right squamosal, nasal horn and both brow horns, an epijugal, occipital condyle, and other fragments of the skull.

Horizon: Lance formation, No. 3 from the summit of the Niobrara County sequence.

Locality: Niobrara County, Wyoming, very near that of *Torosaurus latus*, on the divide midway between Lightning and Cow creeks and about a mile from their confluence.

Collector: J. B. Hatcher, 1891.

This is a huge skull, measuring, as restored, about 8 feet 5 inches over all, and hence the largest known skull of a land animal, actually exceeded in size by only a few of the greater of the modern whales. The animal was apparently adult, but not extremely old. It was a younger individual than the *latus* type.

The dorsal profile of the skull, as restored, is flatter than that of *latus*, the line of face and crest being continuous, although the latter rises slightly toward the posterior margin. The orbit is nearly circular, in contrast to the oval one of *latus*. The descending limb of the jugal is preserved in part on the left side, is of medium width, and flat on the outer aspect. There is a fairly large, rounded, rugose epijugal. The limits of the infratemporal fossa are unknown except on its anterior side, but it seems to have been somewhat larger in proportion than that of *latus*. Its actual form cannot be determined. The nasal horn is conical, with an elliptical basal section, rugose, and with the anterior face nearly vertical.

The brow horns are slender for the size of the skull, and arise *behind* the orbits, the forward margin of the horn being immediately over the posterior limit of the orbit. This position of the horns is unique. The horns are flattened transversely at their base, and are elliptical in cross-section throughout. The right one curves toward the median line when viewed from in front, the left being straight. Laterally, the posterior margin curves more than the forward one, and in the less perfect left there is some indication of a reversal of the curve toward the tip. How much of this is postmortem cannot be determined.

The crest is immense. The median bar of the parietal, convex above, concave below, is very thin and bears four low undulations. Marsh states that in this species the parietals entirely enclose the fenestrae, while in *latus* the squamosal forms a portion of the outer limit of the aperture. But I find the evidence in the two skulls is about the same; in *gladius*, the distal part of the inner border of the squamosal shows a distinct sutural surface, about 300 mm. long, and in *latus* 270 mm., in front of which the border in each is smoothly rounded for a lesser distance when indications of sutural connection with the parietal begin again. In the presumably ancestral *Chasmosaurus* there is generally an overlapping suture in that portion of the parietal which lies between the fenestra and the squamosal (see p. 68), except in the Yale specimen No. 2016 Y.P.M. in which the contact between the two portions of the parietal is incomplete so that the squamosal resembles that of *Torosaurus* in having a smoothly rounded portion interrupting the sutural continuity for the parietal. The rear margin of the parietals is thin and undulatory, but there is no sure indication that *Torosaurus* ever possessed epoccipitals. The squamosal is extremely long, reaching the maximum length ever attained by this bone. At the forward end there are three slight undulations, but the remainder of the outer margin is smooth and rounded. There is no trace of vascular impressions on the entire crest.

The pseudopineal fontanelle is single, as in *Triceratops*, in contrast to its paired condition in *latus*, with two radiating grooves terminating in large foramina, only one of which is preserved.

⁹⁷ Marsh, O. C., 1891, pp. 266-267.

⁹⁸ Hatcher, Marsh, Lull, 1907, Fig. 119.

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PLATES

PLATE II

MONOCLONIUS (CENTROSAURUS) FLEXUS

No. 2015 Yale Peabody Museum.

A. Left lateral view showing entire skeleton.

B. Right side (photograph reversed), showing restoration by R. S. Lull and
N. E. Wright.

1/26 natural size.



PLATE III

- A. Anterior view of MONOCLONIUS (CENTROSAURUS) FLEXUS, showing restoration and skeleton of Yale Peabody Museum specimen, No. 2015.
- B. Skin impression of MONOCLONIUS (CENTROSAURUS) CUTLERI, from the flank region. American Museum specimen, No. 5427, about 1/2 natural size.

Courtesy of the American Museum of Natural History.



PLATE IV

PROTOCERATOPS ANDREWSI

- A. Ventral view of skeletal mount in original supine position, No. 6416 A.M.N.H.
 - B. Lateral view of No. 6467 A.M.N.H.
- Courtesy of the American Museum of Natural History.



PLATE V

- A. Skull of CHASMOSAURUS KAISENI, type, No. 5401 A.M.N.H., 1/8 natural size.
- B. Skull of PENTACERATOPS STERNBERGII type, No. 6325 A.M.N.H., 1/14 natural size.

Courtesy of the American Museum of Natural History.



PLATE VI
CHASMOSAURUS BELLI

No. 5402 A.M.N.H.

A. Lateral view of skull.

B. Dorsal view of skull.

1/10 natural size.

Courtesy of the American Museum of Natural History.



PLATE VII

- A. Skull of CHASMOSAURUS BREVIROSTRIS, type, No. 5436 Ct. Royal Ontario Museum of Palaeontology, about 1/12 natural size.
Courtesy of the Royal Ontario Museum of Palaeontology.
- B. Skull of CHASMOSAURUS cf. KAISENI, No. 40 University of Alberta, about 1/8 natural size.
Courtesy of the University of Alberta.

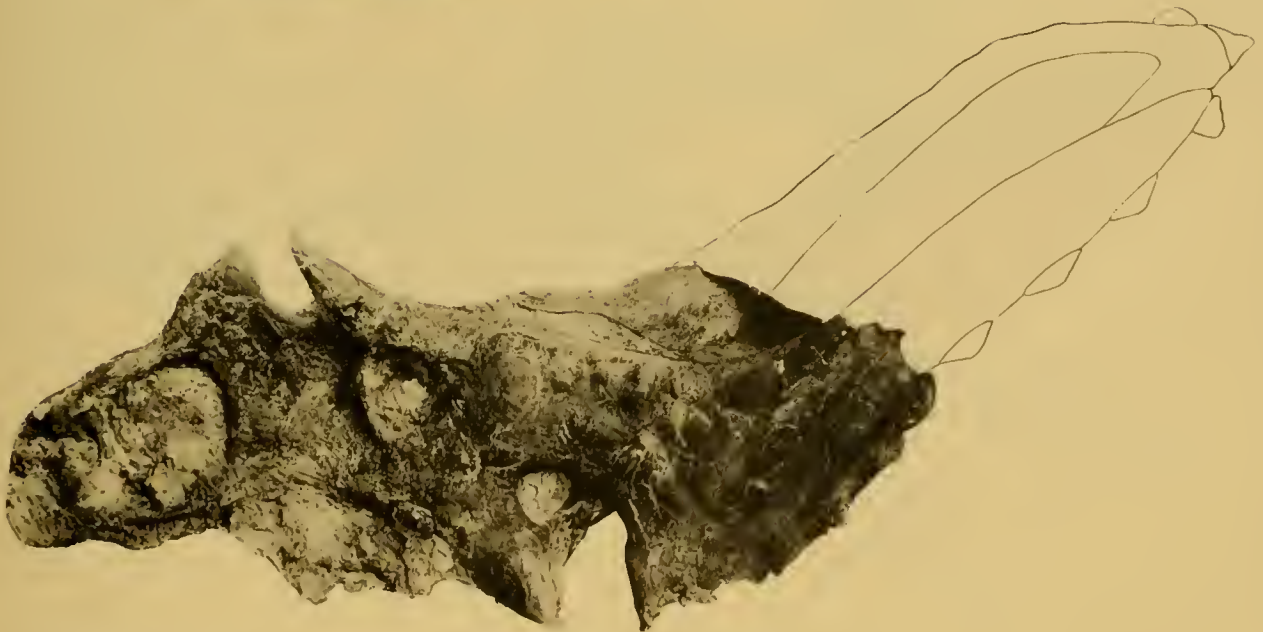


PLATE VIII
STYRACOSAURUS ALBERTENSIS

Type, No. 344 G.S.C.

A. Lateral view of skull.

B. Dorsal view of skull.

1/12 natural size.

Courtesy of the Geological Survey of Canada.

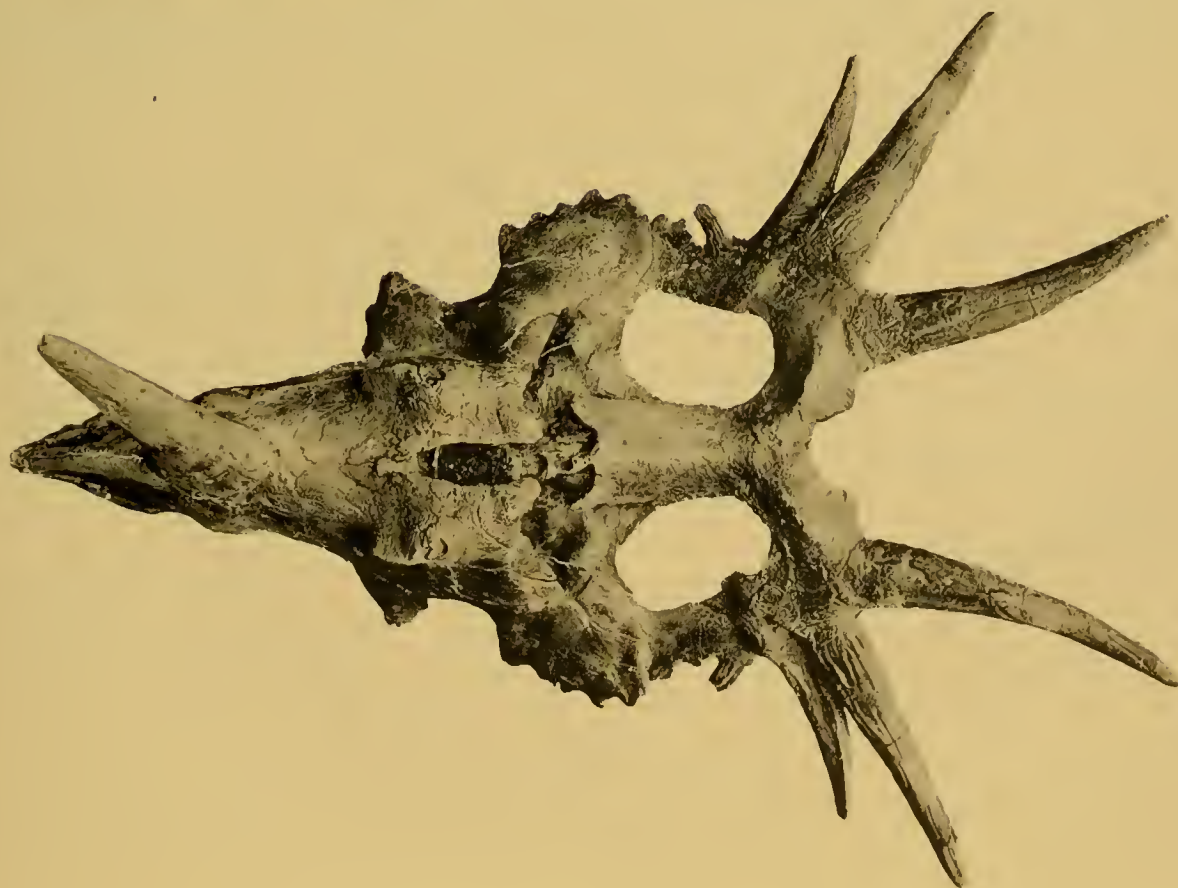
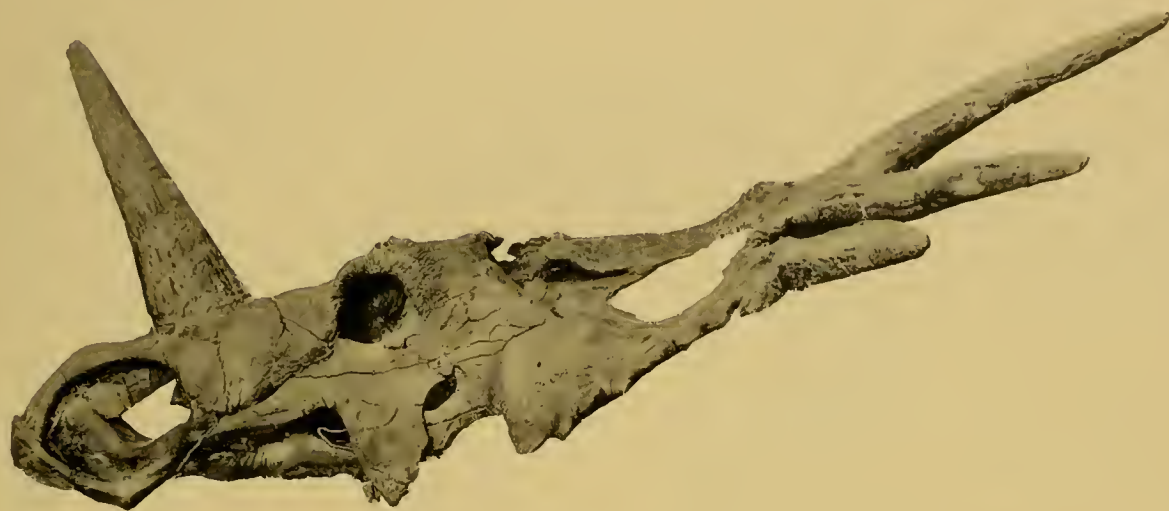


PLATE IX

- A. Skeleton of MONOCLONIUS (CENTROSAURUS) NASICORNUS,
type, No. 5351 A.M.N.H., 1/30 natural size.
Courtesy of the American Museum of Natural History.
- B. Skeleton of BRACHYCERATOPS MONTANENSIS, type, No. 7951, also
paratypes Nos. 7952-7957 U.S.N.M., 1/10 natural size.
Courtesy of the United States National Museum.

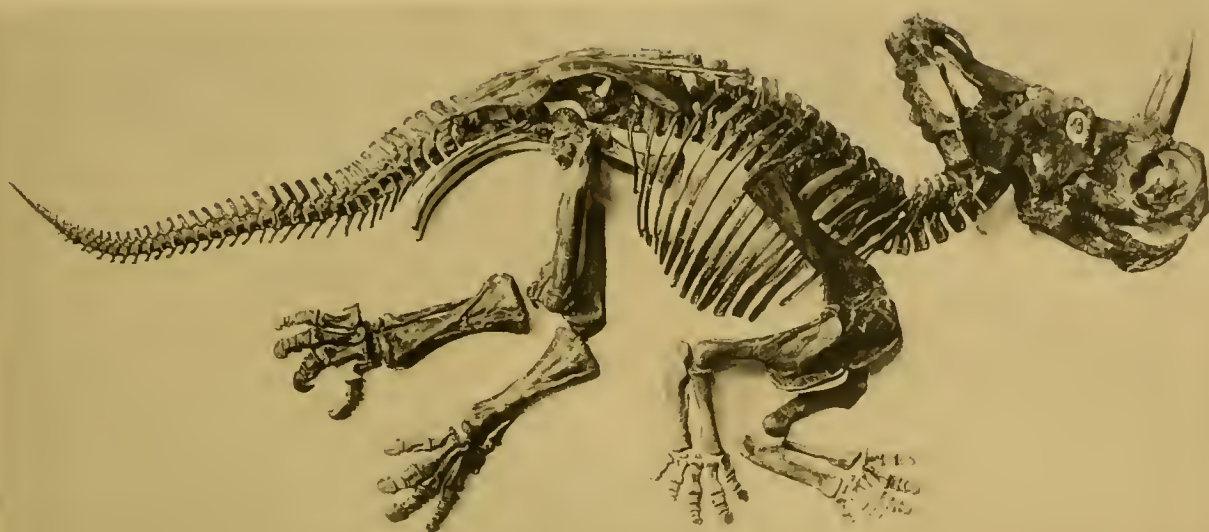


PLATE X
ANCHICERATOPS LONGIROSTRIS

- A. Lateral view of skull, No. 8535 G.S.C., 1/10 natural size.
- B. Dorsal view of skull, No. 8535 G.S.C., 1/10 natural size.
- C. Skull and skeleton as mounted in the National Museum of Canada, at Ottawa,
No. 8538 G.S.C., 1/25 natural size.
Courtesy of the Geological Survey of Canada.

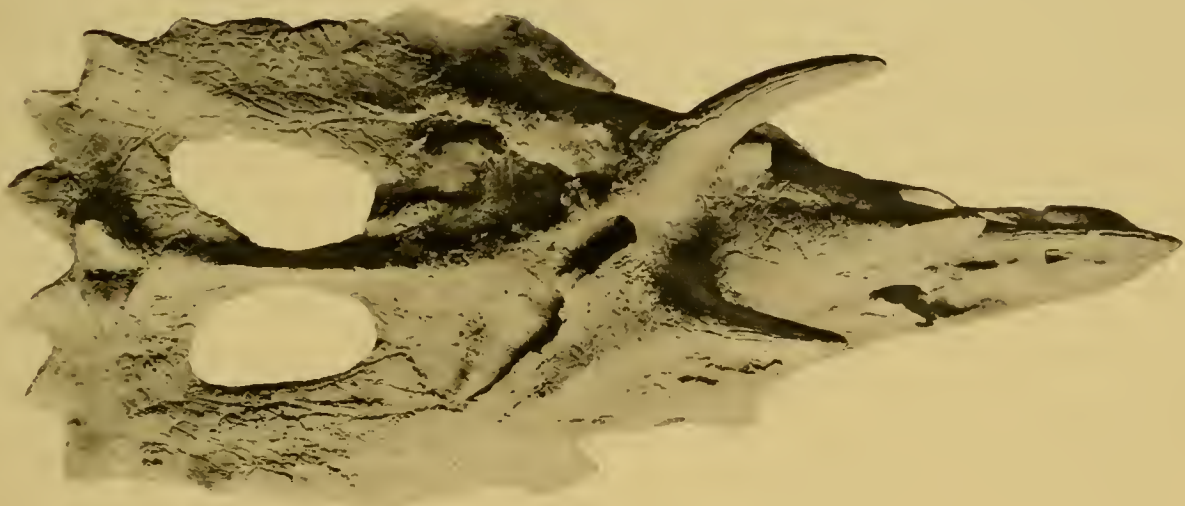
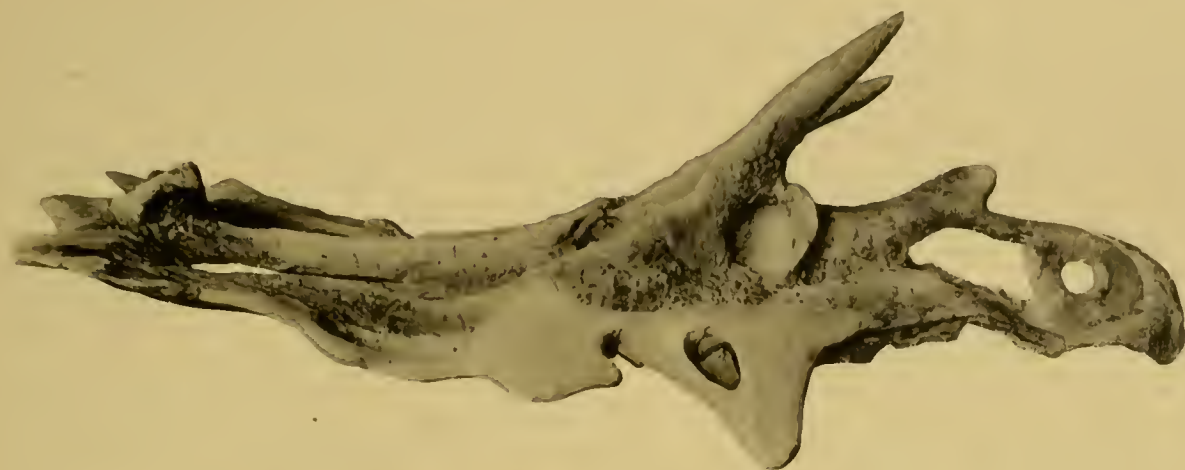


PLATE XI
ANCHICERATOPS ORNATUS

Endocranial cast of paratype, No. 5259 A.M.N.H., 3/4 natural size.

A. Dorsal view; B. Right lateral view; C. Ventral view. After Brown.

Abbreviations: a.s.c. ascending semicircular canal.
cbl. cerebellum.
cbl.p. process of cerebellum.
cer. cerebrum.
cer.p. process of cerebrum.
h.s.c. horizontal semicircular canal.
med. medulla oblongata.
op.a. ophthalmic branch of internal carotid artery.
pit. pituitary body.
p.s.c. posterior semicircular canal.

Cranial nerves

I	Olfactory.	VII	Facial.
II	Optic.	VIII	Auditory.
III	Oculomotor.	IX	Glossopharyngeal.
IV	Trochlear.	X	Vagus.
V	Trigeminus.	XI	Accessory.
VI	Abducens.	XII	Hypoglossal.

Courtesy of the American Museum of Natural History.

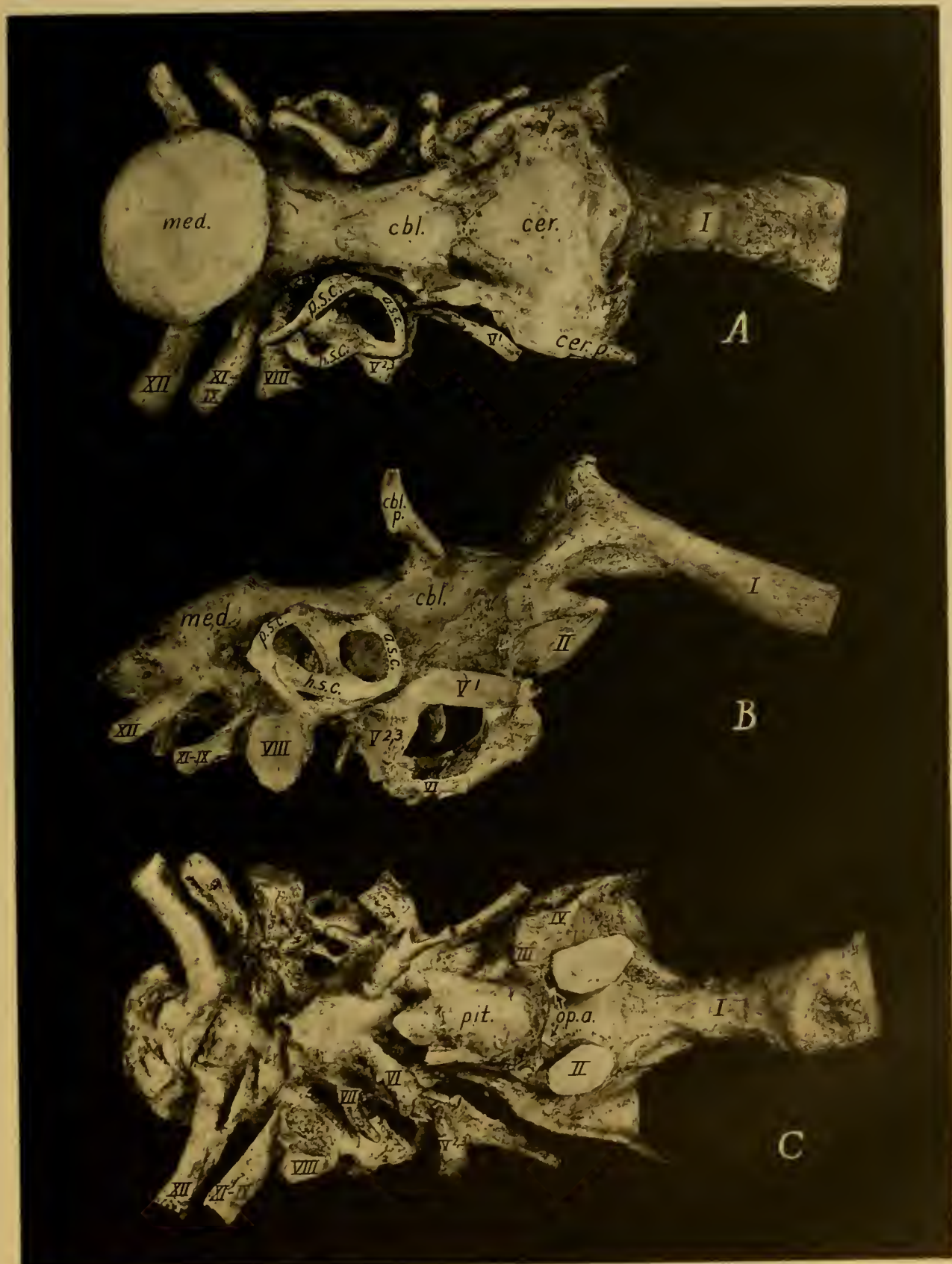


PLATE XII

ARRHINOCERATOPS BRACHYOPS

Type, No. 5135 Ct. Royal Ontario Museum of Palaeontology.

A. Oblique anterior view of skull.

B. Lateral view of skull.

1/10 natural size.

Courtesy of the Royal Ontario Museum of Palaeontology.



PLATE XIII

- A. Skull of TRICERATOPS HORRIDUS, No. 12,003 Field Museum of Natural History, 1/12 natural size.
Courtesy of the Field Museum of Natural History.
- B. Skull of TRICERATOPS HORRIDUS, No. P271 South Dakota State School of Mines, 1/12 natural size.
Courtesy of the South Dakota State School of Mines.

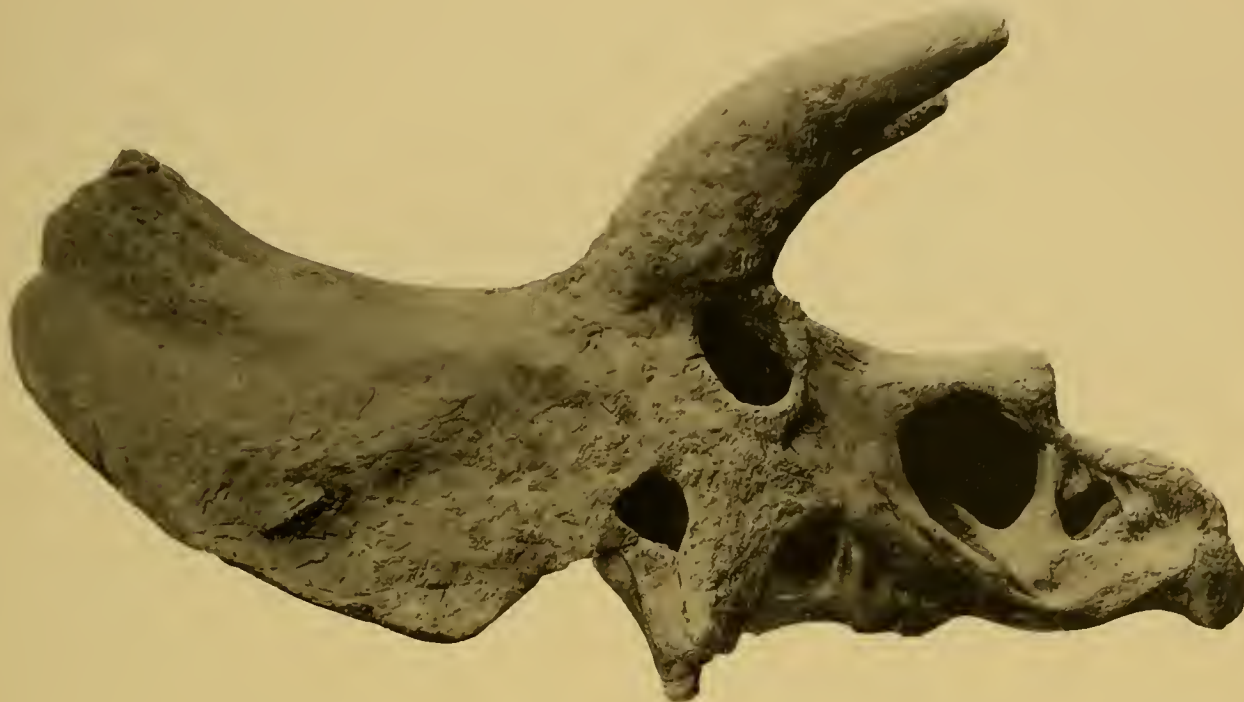


PLATE XIV

- A. Mounted skeleton of TRICERATOPS cf. ELATUS, at American Museum of Natural History, 1/38 natural size.
Courtesy of the American Museum of Natural History.
- B. Mounted skeletons of CHASMOSAURUS BELLI, at the National Museum of Canada; left, plesiotype, No. 2245; right, No. 2280.
Courtesy of the Geological Survey of Canada.



PLATE XV
TOROSAURUS LATUS

Type, No. 1830 Y.P.M., restored by R. S. Lull.

A. Lateral view of skull.

B. Anterior view of skull.

About 1/16 natural size.

Yale Peabody Museum.

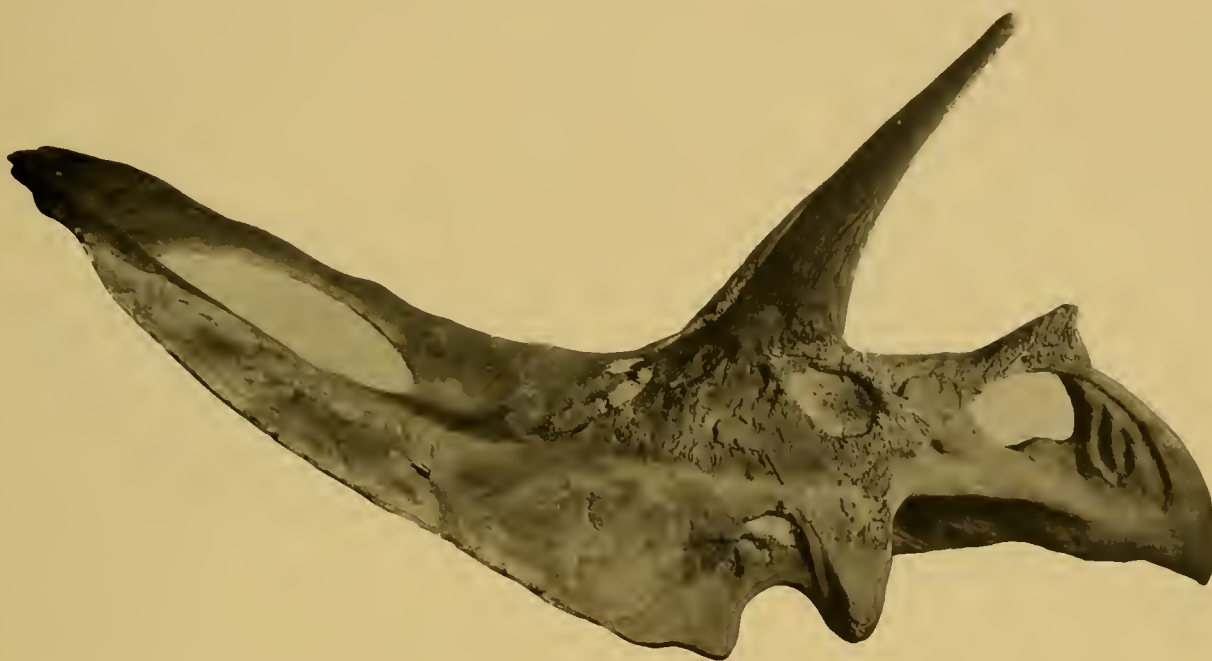


PLATE XVI
TOROSAURUS GLADIUS

Type, No. 1831 Y.P.M., restored by Hugh Gibb and R. S. Lull.

A. Lateral view of skull.

B. Oblique anterior view of skull.

About 1/16 natural size.

Yale Peabody Museum.



PLATE XVII

FLESH RESTORATION OF CHASMOSAURUS BELLI

- A. Left lateral view.
- B. Anterior view.
- C. Right lateral view.

Restored by Mr. L. S. Russell of the Geological Survey of Canada. Published with the permission of the Director, Geological Survey of Canada, Dept. of Mines, Ottawa, Canada.



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