THE

AMERICAN JOURNAL OF SCIENCE.

[THIRD SERIES.]

ART. XXVI.—*Professor Marsh's Monograph of the Dinocerata.**

THE previous numbers of this Journal have contained all, or nearly all, of the original papers on the *Dinocerata* by the author of the present memoir, and it is especially fitting, on the completion of his investigations, that at least an abstract of the main points of the volume should also be placed here on record. The extracts which follow have been selected with a view to give to the reader a brief sketch of the discovery, and general characteristics, of this remarkable group of mammals, and their relations to other members of the same class, living and extinct.

The general plan of the present volume, essentially the same as that of the author's previous memoir on the *Odontornithes*, is especially worthy of notice, and might well serve as a model for all monographs on similar subjects. In the Introduction, the history of the discovery of the *Dinocerata*, and their distribution in time and space, are first presented. A description of the various parts of the skeleton in the typical genera of the order next follows, richly illustrated, with restorations of two forms, and the biologist has then before him a vivid picture of characteristic members of the group. In the Appendix, is a Synopsis of all the known genera and species, with many details for the systematic zoölogist.

* *Dinocerata*, a Monograph of an Extinct Order of Gigantic Mammals; by Othniel Charles Marsh. 56 plates and 200 woodcuts. i–xviii and 237 pp., 4to. Washington, 1884. United States Geological Survey, vol. x. Advance copy issued with the permission of the Director.

The volume ends with a Bibliography of all the important literature on the *Dinocerata*, and thus the librarian, also, has at hand material ready for a catalogue. In most volumes on palæontology, as well as on other branches of natural science, these four divisions are mixed together, so that each different class of readers must seek out what it needs with much labor.

The author's general plan of publication was given in the introduction to his previous memoir, and this is supplemented in the preface of the present volume, from which we quote the following:

"The present memoir is the second of a series of Monographs designed to make known to science the Extinct Vertebrate Life of North America. In the first volume, on the Odontornithes, or Birds with Teeth, the author gave the result of his investigations of that remarkable group, which he discovered in the Cretaceous deposits on the Eastern slope of the Rocky Mountains.

"This second Monograph contains the full record of a peculiar order of Mammals, which the author also brought to light in the early Tertiary strata of the great central plateau of the continent.

"In preparing the present volume, it has been the aim of the author to do full justice to the ample material at his command, and, where possible, to make the illustrations tell the main story to anatomists. The text of such a memoir may soon lose its interest, and belong to the past, but good figures are of permanent value in all departments of Natural Science. What is now especially needed in Palæontology is, not long descriptions of fragmentary fossils, but accurate illustrations of characteristic type specimens. In the fifty-six lithographic plates, and nearly two hundred original woodcuts, in the present volume, it is believed that this requirement is fairly met; since all the more important specimens of the *Dinocerata* now known are represented, and at least one figure is given of every species."

In the Introduction, the author gives an account of the discovery of the *Dinocerata*, with the localities and geological horizon in which they are found, beginning as follows:

"Among the many extinct animals discovered in the Tertiary deposits of the Rocky Mountain region, none, perhaps, are more remarkable than the huge mammals of the order *Dinocerata*. Their remains have hitherto been found in a single Eocene lake-basin in Wyoming, and none are known from any other part of this country, or from the Old World. These gigantic beasts, which nearly equaled the elephant in size, roamed in great numbers about the borders of the ancient tropical lake in which many of them were entombed.

"This lake-basin, now drained by the Green River, the main tributary of the Colorado, slowly filled up with sediment, but remained a lake so long that the deposits formed in it, during Eocene time, reached a vertical thickness of more than a mile. The Wasatch Mountains on the West, and the Uinta chain on the South, were the main sources of this sediment, and still protect it, but the Wind River range to the North, and other mountain elevations, also sent down a vast amount of material into this great fresh-water lake, then more than one hundred miles in extent.

"At the present time, this ancient lake-basin, now six to eight thousand feet above the sea, shows evidence of a vast erosion, and probably more than one-half of the deposits once left in it have been washed away, mainly through the Colorado River. What remains forms one of the most picturesque regions in the whole West, veritable *mauvaises terres*, or bad lands, where slow denudation has carved out cliffs, peaks, and columns of the most fantastic shapes, and varied colors. This same action has brought to light the remains of many extinct animals, and the bones of the *Dinocerata*, from their great size, naturally first attract the attention of the explorer.

"The first remains of the *Dinocerata* discovered were found by the author, in September, 1870, while investigating this Eocene lake-basin, which had never before been explored. Various remains of this group were also collected by other members of the expedition, and among the specimens thus secured was the type of *Tinoceras anceps*, described by the author in the following year, and now more fully in the present volume. In the same geological horizon with these remains, a rich and varied vertebrate fauna, hitherto unknown, was found.

"Among the animals here represented were ancestral forms of the modern horse and tapir, and also of the pig. Many others were found related to the recent Lemurs; also various Carnivors, Insectivors, Rodents, and small Marsupials; and of still more importance, remains were here brought to light of another new order of mammals, the Tillodonts, quite unlike any now living. Crocodiles, tortoises, lizards, serpents, and fishes also swarmed in and about the waters of this ancient lake, while around its borders grew palms, and other tropical vegetation.

"The remarkable Eocene basin North of the Uinta Mountains, where alone the *Dinocerata* had been found, offered so inviting a field for exploration, that in the spring of the following year, 1871, the author began its systematic investigation. An expedition was again organized, with an escort of United States soldiers, and the work continued during the

entire season. Among the very large collections thus secured, were numerous specimens of the *Dinocerata*, which furnished important characters of the group.

"In the succeeding spring, 1872, the explorations in this region were continued, and soon resulted in the discovery of the type specimen, including the skull, and a large portion of the skeleton, of *Dinoceras mirabile*, and on this new genus the author based the order *Dinocerata*.

"Other important specimens, obtained at this time, and described by the author, were the types of *Dinoceras lucare*, *Tinoceras grande*, *Tinoceras lacustre*, and others of scarcely less interest.

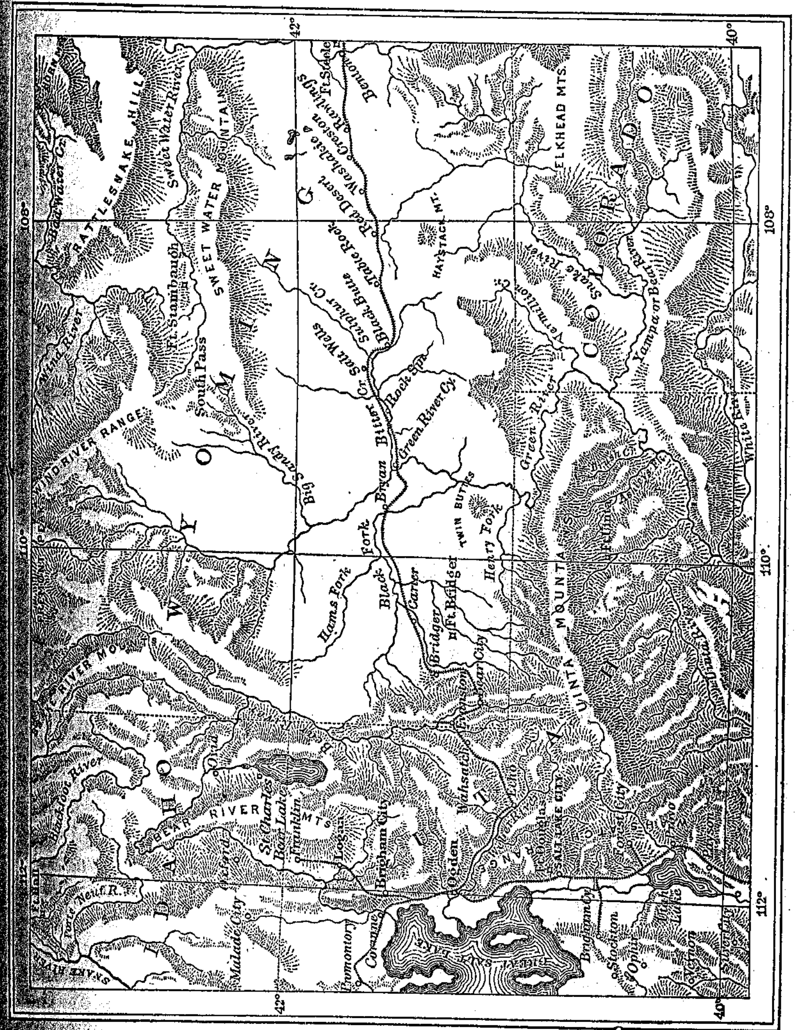
"In the following season, 1873, the author organized another large expedition, with government escort, and made a very careful examination of the regions in this same basin that remained unexplored. One of the specimens of special importance thus secured was the type of *Dinoceras laticeps*, with the skull and lower jaw nearly complete. Many other individuals of the *Dinocerata* were also discovered, and the abundant material then collected was sufficient to clear up most of the doubtful points in this group.

"The research was continued systematically during the next season, also, 1874, and again in 1875, with good results. Since then, various small parties, at different times, have been equipped and sent out by the author to collect in this basin; and, finally, during the entire season of 1882, the work was vigorously prosecuted under the direction of the author, and, from July of that year, under the auspices of the United States Geological Survey.

"The specimens thus brought together by all these various expeditions and parties are now in the museum of Yale College, and represent more than two hundred individuals of the *Dinocerata* alone. * * * * The present volume is based on this material, amply sufficient, it is believed, to illustrate all the more important parts of the structure of this remarkable group.

"The remaining material of the *Dinocerata*, now known, consists of a few specimens collected by Dr. Leidy in 1872, including the type of the genus *Uintatherium;* various remains secured in the same year by Prof. Cope, to which he applied the names *Loxolophodon* and *Eobasileus*, with a later acquisition called *Bathyopsis;* and a number of specimens more recently obtained by parties from Princeton College. Although these remains show few, if any, characters of the *Dinocerata* not better represented in the larger collection of the Yale Museum, full references to the more important specimens, in most cases with illustrations, are given in the present memoir.

"The localities in which the *Dinocerata* have been found are on both sides of the Green River, and mainly south of the Union Pacific Railroad, in Wyoming. Of two hundred individuals in the Yale Museum, about equal numbers were found east and west of this river, the distance between the extreme localities in this direction being more than one hundred miles. The map below covers this region.



MAP SHOWING REGION OF DINOCERAS BEDS.

"The *Dinocerata* have hitherto been found in a well marked geological horizon of the middle Eocene.

"The *Dinocerata* form a well marked order in the great group of *Ungulata*. In some of their characters, they resemble the Artiodactyls (*Paraxonia*); in others they are like the Perissodactyls (*Mesaxonia*); and in others still, they agree with the Proboscidians. The points of similarity, however, are in most cases general characters, which point back to an earlier, primitive ungulate, rather than indicate a near affinity with existing forms of these groups.

"The *Dinocerata*, so far as now definitely known, may be placed in three genera, *Dinoceras*, Marsh, *Tinoceras*, Marsh and *Uintatherium*, Leidy. The type specimen of *Uintatherium* was discovered near the base of the series of strata containing the remains of the *Dinocerata*. *Dinoceras*, so far as known, occurs only at a higher horizon, while *Tinoceras* has been found at the highest level of all. The characters of these three genera correspond in general with their geological position. *Uintatherium* appears to be the most primitive type, and *Tinoceras* the most specialized, *Dinoceras* being an intermediate form.

"The number of species of the known *Dinocerata* is a difficult matter to determine, especially as the limitations between species are now generally regarded as uncertain. About thirty forms, more or less distinct, are recognized in the Synopsis at the end of the volume.

The Skull.

"The skull of *Dinoceras mirabile* is long and narrow, the facial portion being greatly produced. The basal line, extending from the end of the premaxillaries along the palate to the lower margin of the foramen magnum, is nearly straight. The top of the skull supports three, separate, transverse pairs of osseous elevations, or horn-cores, which form its most conspicuous feature, and suggested the name of the genus. The smallest of these protuberances are situated near the extremity of the nasals; two others, much larger, arise from the maxillaries, in front of the orbits; while the largest are mainly on the parietals, and are supported by an enormous crest, which extends from near the orbits entirely around the lateral and posterior margins of the true cranium. These general characters are well shown in figure 2, which represents the skull of the type specimen.

"There are no upper incisors, but the canines in the male are enormously developed, forming sharp, trenchant, decurved tusks, which were each protected by a dependent process on the lower jaw. The premolar and molar teeth are very small.

"The orbit is large, and confluent with the temporal fossa. The latter is of great extent posteriorly, but the zygomatic arches are only moderately expanded. There is no post-orbital process.

"The nasal bones are greatly elongated, being nearly half the length of the entire skull. They project forward over the anterior nares, and overhang the premaxillaries. They are thick and massive bones, especially in front, and are united together by a nearly straight suture.

"The anterior extremity of the nasal bones, in both *Dinoceras* and *Tinoceras*, is formed of an osseous projection, pointing forward and downward, and situated in front of and below the nasal protuberances. Several specimens in the Yale Museum show that this projection is formed of two separate ossifications, each in front of its respective nasal bone.

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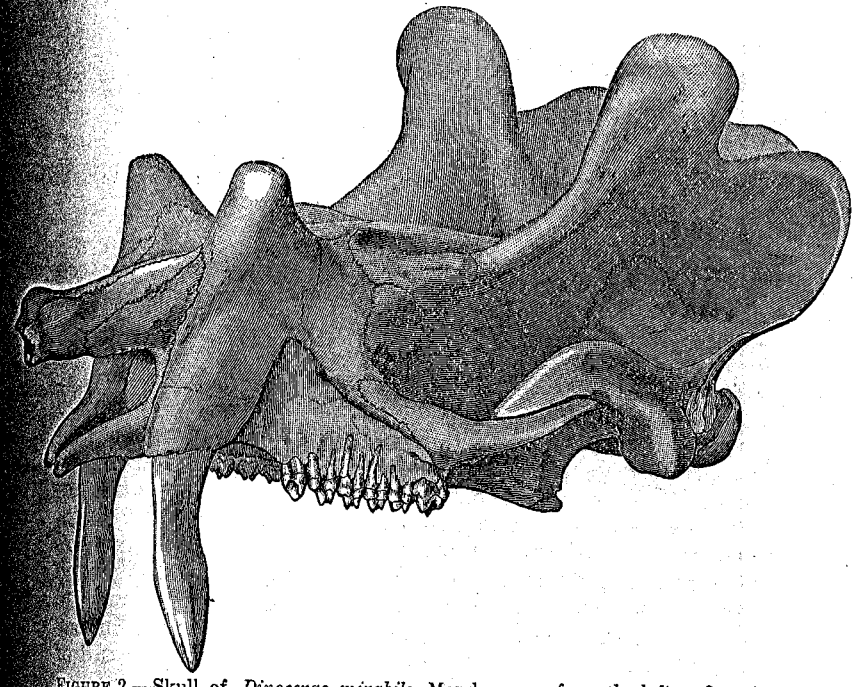

Figure 2.—Skull of *Dinoceras mirabile*, Marsh; seen from the left. One-sixth natural size.

"These bones are a peculiar feature in the skull of *Dinocerata*, and may be called the pre-nasal bones. In very young animals, they are unossified; in adult animals, they are distinct, as in the specimen figured; but in very old animals they become coössified with the nasals, and with each other.

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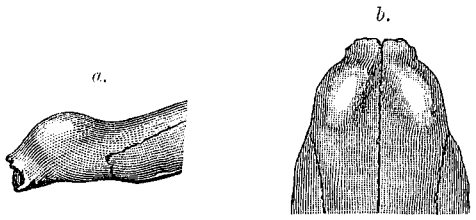

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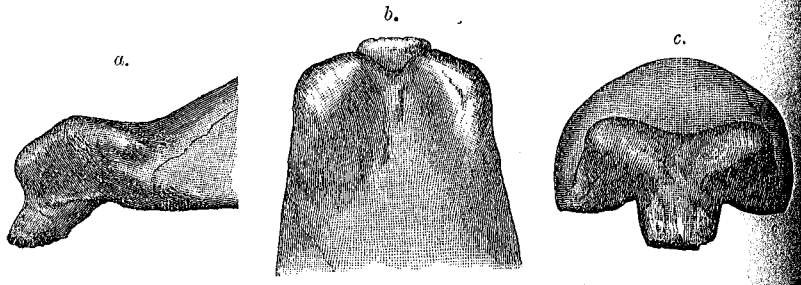

FIGURE 3.—Nasals of *Dinoceras mirabile*, Marsh; type specimen.
FIGURE 4.—Nasals of *Tinoceras annectens*, Marsh. Both figures are one-fifth natural size. *a*, side view; *b*, top view; *c*, front view.

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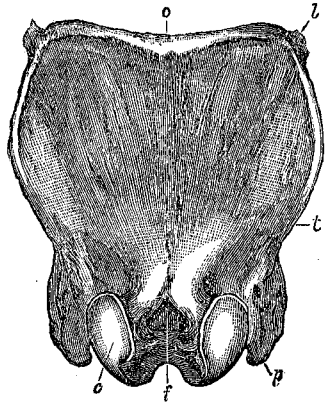

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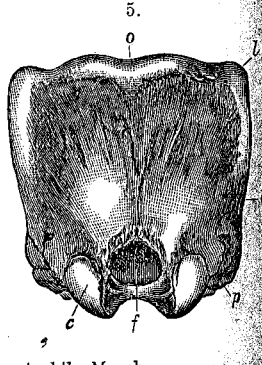

FIGURE 5.—Posterior surface of skull of *Dinoceras mirabile*, Marsh.
FIGURE 6.—Posterior surface of skull of *Tinoceras ingens*, Marsh. Both figures are one-eighth natural size. *c*, occipital condyle; *f*, foramen magnum; *l*, lateral crest; *o*, occipital crest; *p*, post-tympanic process; *t*, crest behind temporal fossa.

"The frontal bones in *Dinoceras mirabile* are shorter than the nasals. In all of the known skulls of the *Dinocerata*, the median suture uniting the two frontals is entirely obliterated. The suture joining them with the nasals in front, and with the maxillaries on the side, is distinct in the type of *Dinoceras*.

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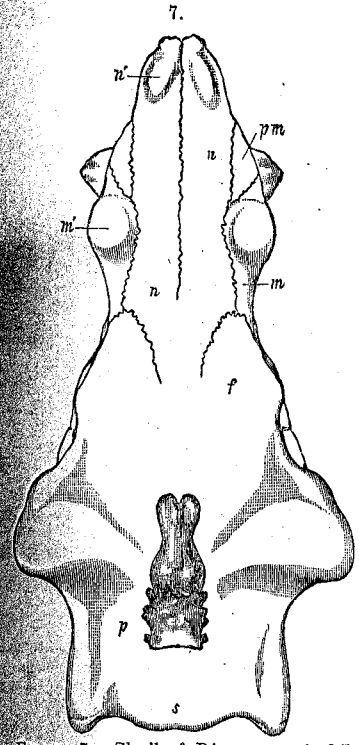

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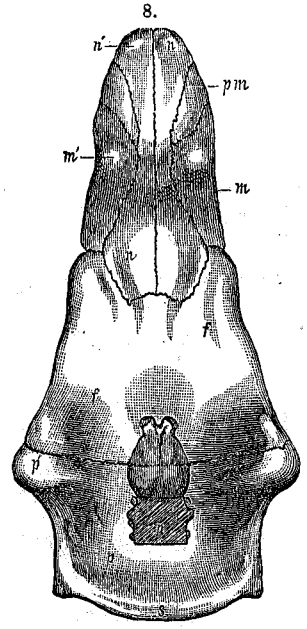

FIGURE 7.—Skull of *Dinoceras mirabile*, Marsh; with brain-cast in natural position; seen from above.
FIGURE 8.—The same view of a young specimen of *Dinoceras distans*, Marsh. Both figures are one-eighth natural size. *f*, frontal bone; *m*, maxillary bone; *m'*, maxillary protuberance; *n*, nasal bone; *n'*, nasal protuberance; *p*, parietal bone; *p'*, parietal protuberance; *pm*, premaxillary bone; *s*, supra-occipital crest.

"The maxillary bones form a large portion of the lateral surface of the skull. They contain all the teeth, except those of the lower jaw, and also expand into the large median pair of osseous elevations, or horn-cores.

"In one young specimen, the fronto-parietal suture is still open, and passes in a nearly straight line across the top of the

cranium just in front of the summit of the cerebral hemispheres. It also divides the posterior elevations, or horn-cores, so as to leave the anterior part of them on the frontals, and the posterior and highest portion on the parietals.

"In all of the crania of the *Dinocerata* examined, the parietal bones are firmly united to each other on the medial line, and with the supra-occipital behind. * * * * On the sides of the cranium, the parietals form the upper portion of the large temporal fossæ.

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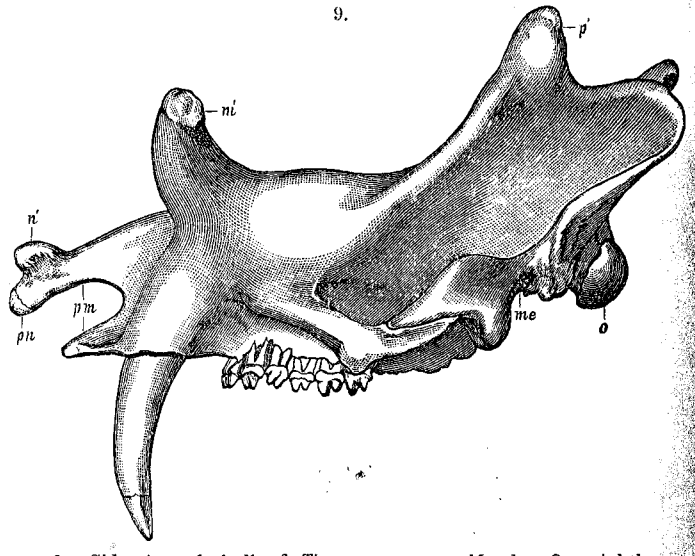

FIGURE 9.—Side view of skull of *Tinoceras pugnax*, Marsh. One-eighth natural size. *m'*, maxillary protuberance; *me*, external auditory meatus; *n'*, nasal protuberance; *o*, occipital condyle; *p'*, parietal protuberance; *pm*, premaxillary bone; *pn*, prenasal ossicle.

"The occipital region in all the known *Dinocerata* is large, elevated, and sub-quadrate in outline. It varies much in shape and size in the different genera and species, and two of the principal forms are represented in the figures below.

"The malar bone completes the anterior portion of the zygomatic arch, extending to the front of the orbit. The suture uniting the malar with the maxillary remains distinct till adult life, and may usually be traced, even in old animals. This forward extension of the malar bone is a general ungulate character, and quite different from what is seen in the Proboscidians, where the malar forms the middle portion only of the zygomatic arch.

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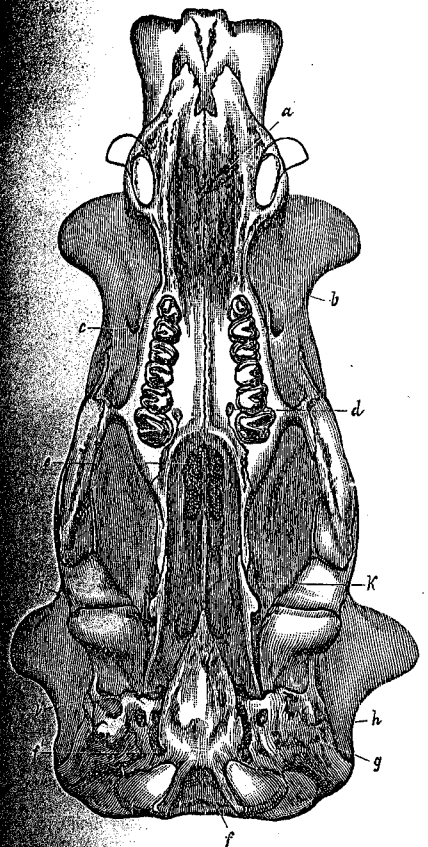

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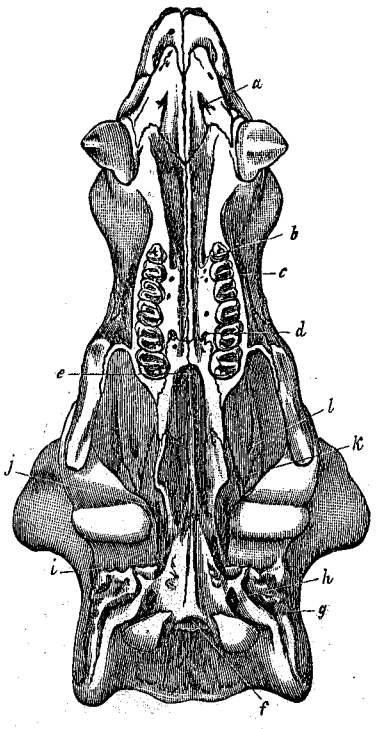

FIGURE 10.—Skull of *Tinoceras ingens*, Marsh; seen from below.
FIGURE 11.—Skull of *Dinoceras mirabile*, Marsh; seen from below. Both figures are one-eighth natural size. *a*, anterior palatine foramen; *b*, palato-maxillary foramen; *c*, antorbital foramen; *d*, posterior palatine foramen; *e*, posterior nares; *f*, foramen magnum; *f'*, occipital foramen; *g*, stylo-mastoid foramen; *h*, foramen lacerum posterius; *i*, vascular foramen in basisphenoid; *j*, posterior opening of alisphenoid canal; *k*, anterior opening of alisphenoid canal; *l*, optic foramen.

"The lachrymal is large, and forms the anterior border of the orbit. It is perforated by a large foramen. In *Dinoceras mirabile*, this is oval in outline, with the apex above. The base of the lachrymal is excavated for the posterior opening of the large antorbital foramen.

"The large canine tusk is entirely enclosed in the maxillary, and, in the genus *Dinoceras*, its root extends upward into the base of the maxillary horn-core. In all known *Dinocerata*, there is a diastema between the upper canine and the premolars.

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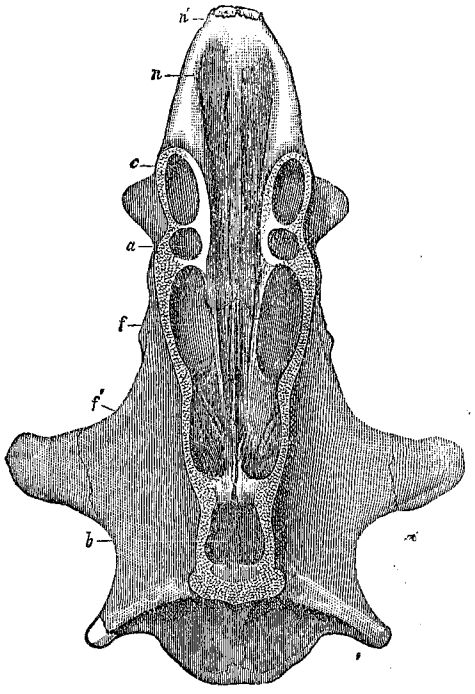

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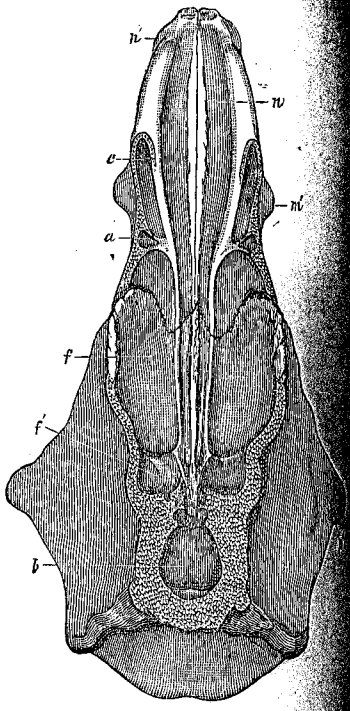

FIGURE 12.—Horizontal section of skull of *Tinoceras crassifrons*, Marsh.
FIGURE 13.—Horizontal section of skull of *Dinoceras laticeps*, Marsh; (female). Both figures are one-eighth natural size. *a*, cavity behind base of canine tooth; *b*, brain-cavity; *c*, alveole of canine tooth; *f*, anterior olfactory chamber; *f'*, posterior olfactory chamber; *m'*, maxillary protuberance; *n*, nasal bones; *n'*, nasal protuberance; *p'*, parietal protuberance.

"The premaxillary bones are edentulous, and, even in young specimens, contain no teeth. * * * The premaxillaries vary much in form in the different genera and species of *Dinocerata*. Two of the principal forms are shown in figures 10 and 11."

The palate is very narrow, and much excavated, especially in front. The bony palate extends back as far as the last upper molar, and, in some specimens, beyond. It is deeply excavated on each side in the region of the diastema, and near the posterior part of each excavation on either side is situated a large foramen, which may be called the palato-maxillary foramen.

"In the type of *Dinoceras*, the palatine fossa of the posterior nares is roofed over, so that the passage from the palate into the large nasal cavities above leads forward and upward, as shown indistinctly in figure 11. In *Tinoceras ingens* and *Tinoceras pugnax*, the roof of this fossa is excavated in front by a pair of oval apertures, and, through these, the posterior nares open directly upward, as represented in figure 10.

14.

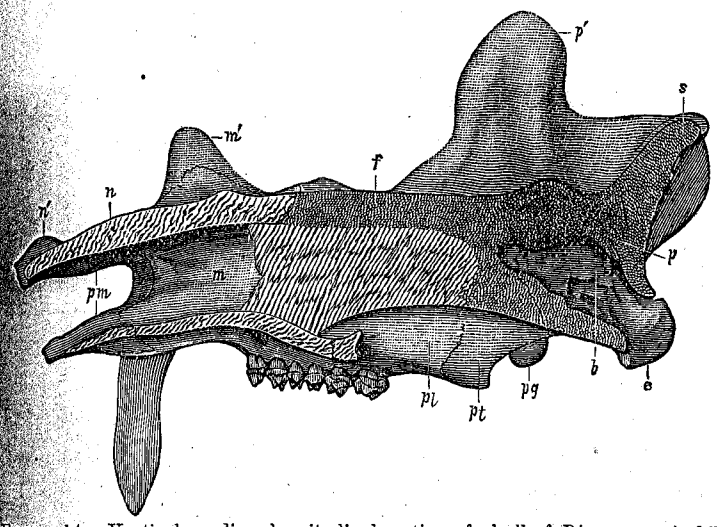

FIGURE 14.—Vertical median longitudinal section of skull of *Dinoceras mirabile*, Marsh. One-eighth natural size. *b*, brain-cavity; *f*, frontal bone; *m*, maxillary bone; *m'*, maxillary protuberance; *n*, nasal bone; *n'*, nasal protuberance; *o*, occipital condyle; *p*, parietal bone; *p'*, parietal protuberance; *pg*, post-glenoid process; *pl*, palatine bone; *pm*, premaxillary bone; *pt*, pterygoid bone; *s*, supra-occipital crest.

THE LOWER JAW.

"The lower jaw in *Dinoceras* is as remarkable as the skull. Its most peculiar feature in the male is a massive decurved process on each ramus, extending downward and outward. These long, pendent processes were apparently to protect the upper canine tusks, which would otherwise be very liable to be broken. * * * * In the female, this process is much reduced in size, but is quite sufficient to protect the diminutive tusk which overlaps it.

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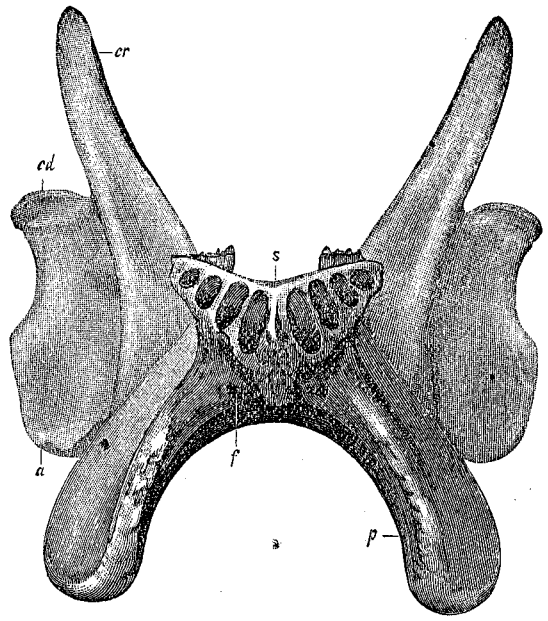

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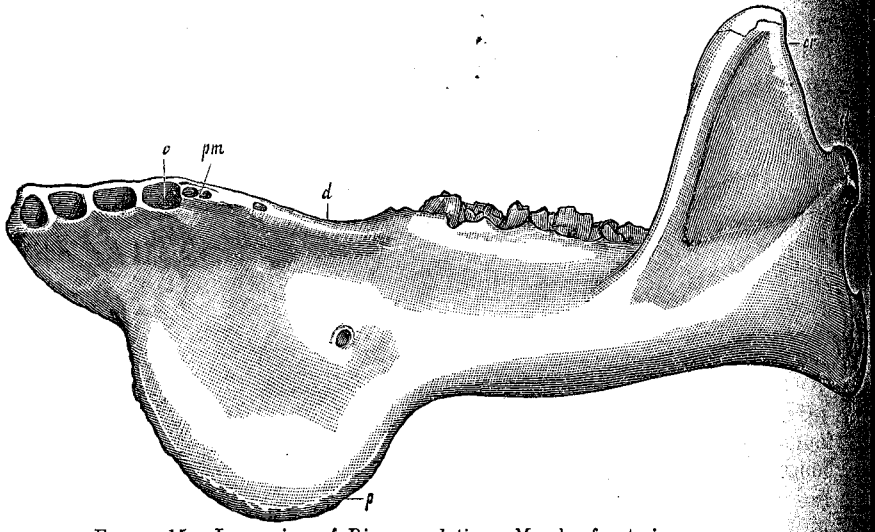

FIGURE 15.—Lower jaw of *Dinoceras laticeps*, Marsh; front view.
FIGURE 16.—Lower jaw of *Uintatherium segne*, Marsh; seen from the left. Both figures are one-fourth natural size. *a*, angle; *c*, canine; *cr*, coronoid process; *cd*, condyle; *d*, diastema; *f*, anterior foramen; *p*, process for protection of tusk; *pm*, premolar.

"Another remarkable feature in the lower jaw of the *Dinocerata* is the posterior direction of the condyles, hitherto unknown in Ungulates.

"In the genus *Dinoceras*, there are three incisor teeth, and a small incisiform canine on each side, forming a continuous series at the front extremity of the lower jaw. These are all of moderate size, and inclined well forward, as in the ruminant mammals. Behind this series, and immediately over the dependent process, is a long diastema. Further back, there are three premolars, and three molars, forming together a close series. This is the dentition, essentially, in the lower jaw of both *Dinoceras* and *Tinoceras*.

"In the genus *Tinoceras*, the same general characters of the lower jaws are seen. In the male, the pendent process is large and elongate, but less massive than in the genus *Dinoceras*, and its lower outline less regularly rounded. This corresponds with the position of the large upper canine tusk, which it protects.

"In the female of *Tinoceras*, the pendent process is much reduced, its size in all cases corresponding to the size of the canine tusk above.

"That the same relation in size between the tusk and process below it, holds equally in both the genera *Dinoceras* and *Tinoceras*, is conclusively shown by various specimens in the Yale Museum.

The Teeth.

"The teeth of the *Dinocerata* constitute one of their most interesting features.

"In the genus *Dinoceras*, the dentition is represented by the following formula:

$$\text{Incisors } \frac{0}{3},\ \text{canines } \frac{1}{1},\ \text{premolars } \frac{3}{3},\ \text{molars } \frac{3}{3} = 34.$$

"So far as now known, the same formula applies equally well to the genus *Tinoceras*.

"In *Uintatherium*, the dentition is apparently as follows:

$$\text{Incisors } \frac{0}{3},\ \text{canines } \frac{1}{1},\ \text{premolars } \frac{3}{4},\ \text{molars } \frac{3}{3} = 36.$$

"In none of the *Dinocerata* have any upper incisors been found, even in the youngest specimens. The premaxillary bones appear to be entirely edentulous.

17.

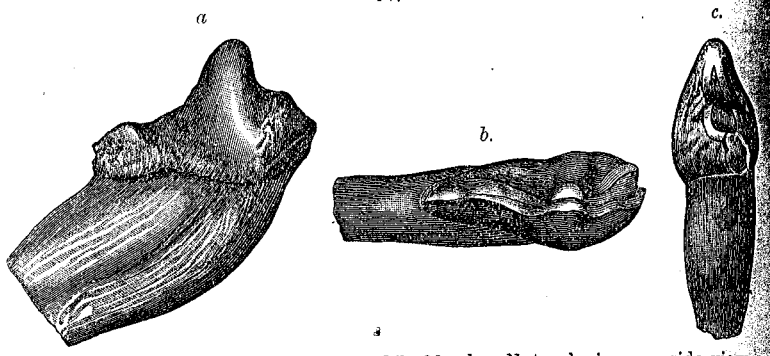

FIGURE 17.—Incisor of *Dinoceras mirabile*, Marsh. Natural size. *a*, side view; *b*, top view; *c*, antero-posterior view.

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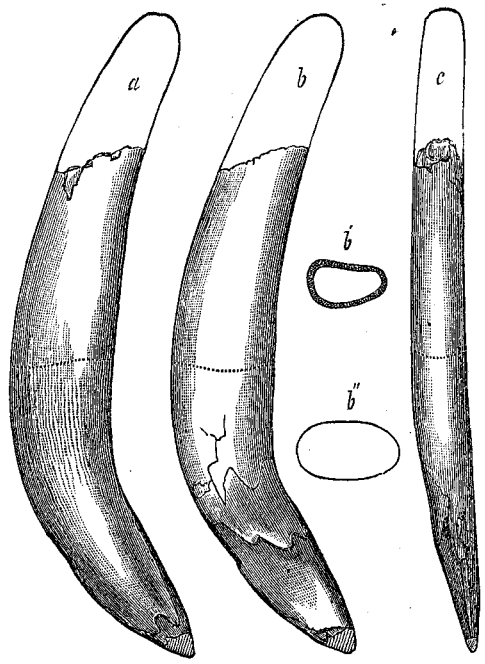

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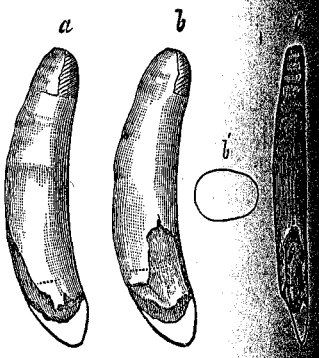

FIGURE 18.—Upper canine of *Dinoceras laticeps*, Marsh; (male).
FIGURE 19.—Upper canine of *Dinoceras laticeps* (female). Both figures are one-fourth natural size. *a*, lateral view, showing outer surface; *b*, inner surface; *b' b''*, sections; *c*, front view.

"In the lower jaw of all the known *Dinocerata*, there are three well developed incisors on each side. They are inserted, each by a single root, and are procumbent, all directed well forward.

"The superior canines of *Dinoceras* are long, decurved, trenchant tusks. The crown is covered with enamel, and the root extends upward into the base of the maxillary protuberance, or horn-core. When the animal is young, these tusks grow from a persistent pulp, but, in old age, the cavity becomes nearly closed. In the male, these tusks are large and powerful, and extend downward nearly or quite to the extremity of the pendent process of the lower jaw.

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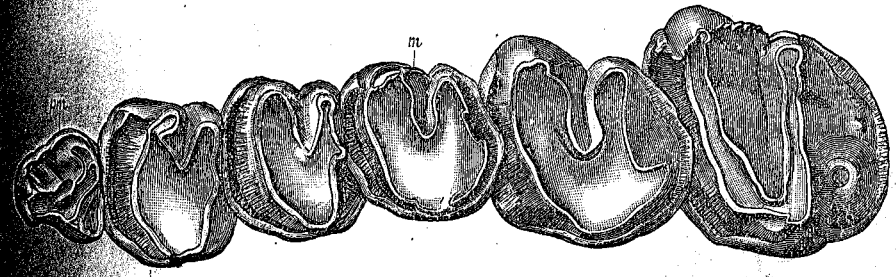

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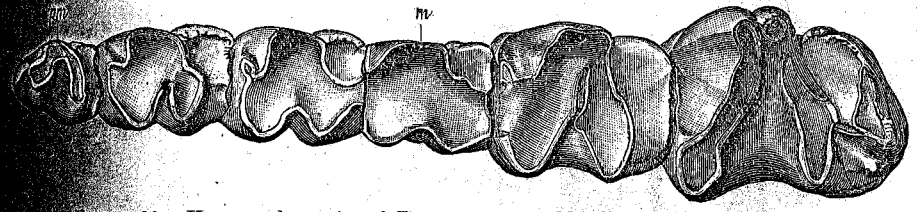

FIGURE 20.—Upper molar series of *Tinoceras stenops*, Marsh; seen from below.
FIGURE 21.—Lower molar series of same specimen; seen from above. Both figures are three-fourths natural size. *m*, molar; *pm*, premolar.

"In the female of *Dinoceras*, the upper canines are small and slender, and protrude but little below the jaw."

The crowns of the upper premolar and molar teeth in *Dinoceras*, and, in fact, in all of the known *Dinocerata*, are remarkably short, with the roots well developed, forming a true brachyodont dentition, as in all early Tertiary ungulates.

"In each ramus of the lower jaw of *Dinoceras*, there is a close series of six teeth, three of which are premolars, and three true molars. These are all inserted each by two roots This is also true of the genus *Tinoceras*.

"The molar teeth in *Dinocerata* appear to resemble more closely the corresponding teeth in the genus *Coryphodon* than those of any other animal. The general dentition, however, is quite distinct. *Coryphodon* has well developed upper incisors, and a medium sized upper canine, thus differing widely in these features from the *Dinocerata*.

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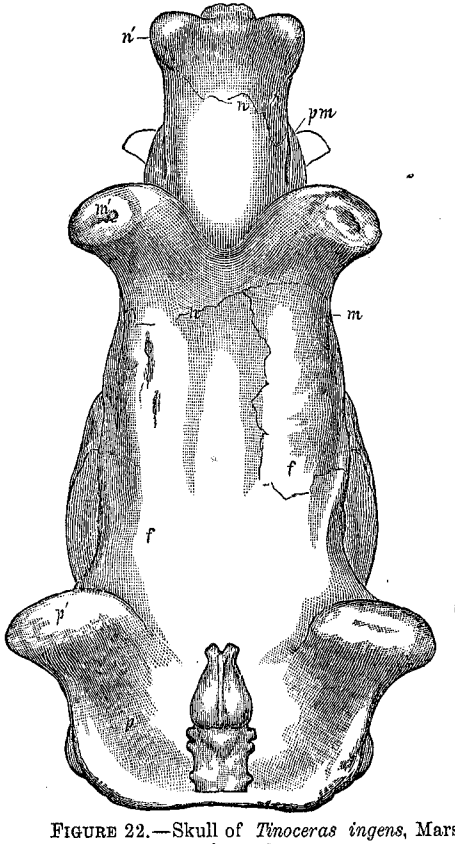

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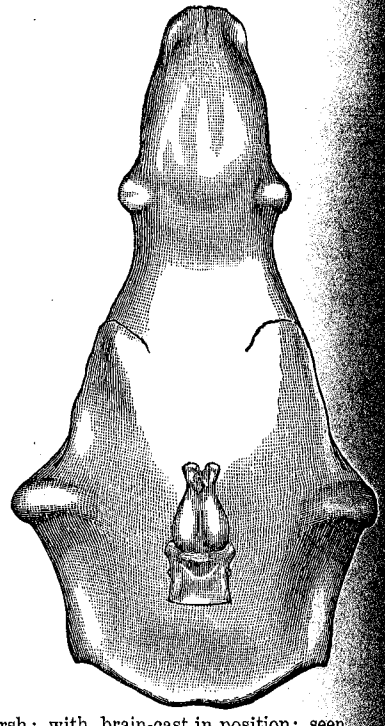

FIGURE 22.—Skull of *Tinoceras ingens*, Marsh; with brain-cast in position; seen from above.

FIGURE 23.—Skull of *Dinoceras laticeps*, female; with brain-cast in position. Both figures are one-eighth natural size. *f*, frontal bone; *m*, maxillary bone; *m'*, maxillary protuberance; *n*, nasal bone; *n'*, nasal protuberance; *p*, parietal bone; *p'*, parietal protuberance; *pm*, premaxillary bone.

THE BRAIN.

"The brain of the *Dinocerata* is one of the most peculiar features of the group. It is especially remarkable for its diminutive size. It was proportionately smaller than in any

other known mammal, recent or fossil, and even less than in some reptiles. It was, indeed, the most reptilian brain in any known mammal. In *Dinoceras mirabile*, the entire brain was actually so diminutive that it could apparently have been drawn through the neural canal of all the pre-sacral vertebræ, certainly through the cervicals and the lumbars.

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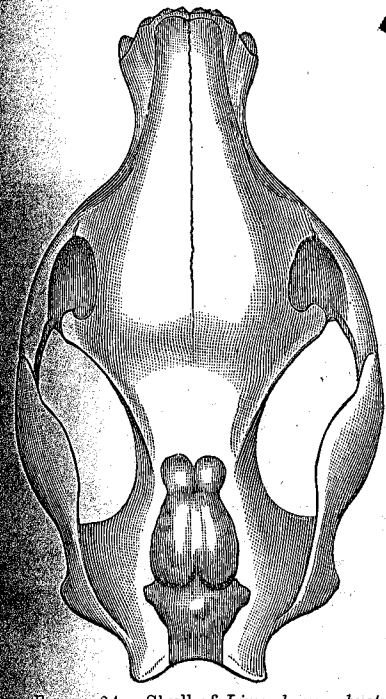

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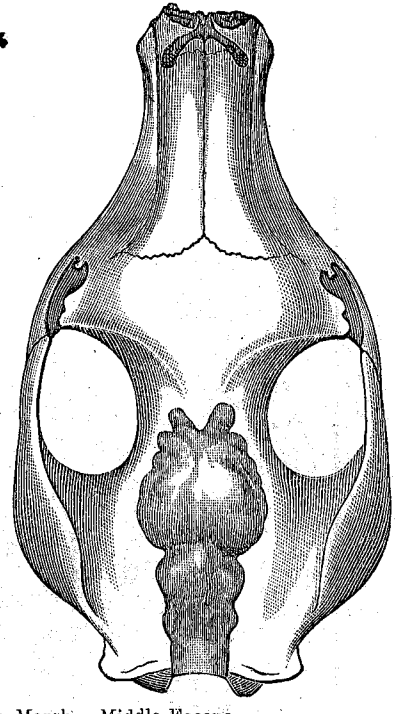

FIGURE 24.—Skull of *Limnohyus robustus*, Marsh. Middle Eocene.
FIGURE 25.—Skull of *Amynodon advenus*, Marsh. Upper Eocene.

"The size of the entire brain, as compared with that of the cranium, is shown in the accompanying cuts, figures 7, 8, and 23. The size of the brain cavity, and its position in the skull in the genus *Tinoceras*, also, is represented in figure 22.

"The most striking feature in the brain cavity itself is the relatively small size of the cerebral fossa, this being but little larger than the cerebellar portion.

"The cerebral hemispheres did not extend at all over the cerebellum or the olfactory lobes. The latter were large, and continued well forward.

"The nerves passing off from the brain were large, and can be made out with reasonable certainty. The olfactory lobes were separated in front by an osseous septum, the position of which is shown distinctly in figure 22.

"In the genus *Tinoceras*, the brain was similar in its general characters to that of *Dinoceras*, but appears to have been somewhat more highly developed. The hemispheres were more elongate, and the olfactory lobes relatively smaller.

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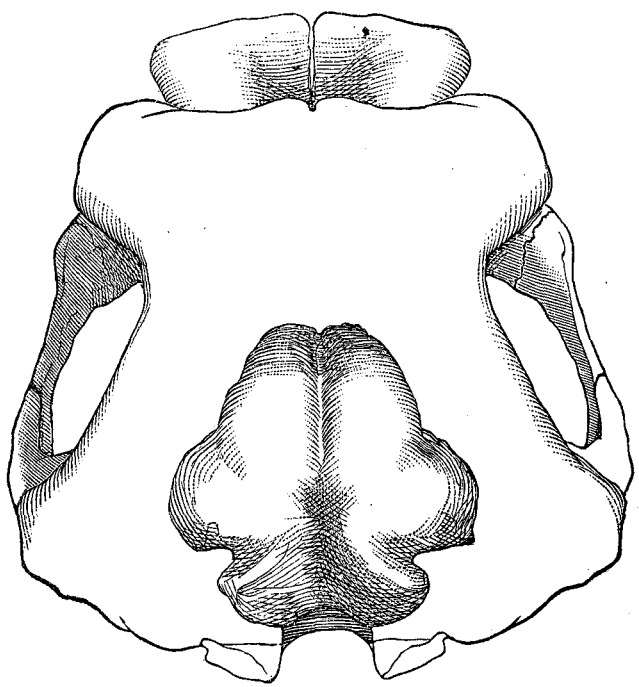

FIGURE 26.—Skull of *Mastodon Americanus*, Cuvier. Pliocene.

BRAIN GROWTH.

"The *Dinocerata* are, by far, the largest of all known Eocene animals, and that they have, also, a very diminutive brain is a noteworthy fact, which attracted the author's attention soon after their discovery.

"The comparison of the brain in this group with that of other mammals from the same formation soon showed that the *Dinocerata* although most remarkable in this respect, were not alone in diminutive capacity of brain power. A more extended comparison led to the fact that all the early Tertiary mammals had very small brains.

"The results of this investigation were embodied by the author in a general law of brain-growth in the extinct mammals throughout Tertiary time. This law, briefly stated, was as follows:

27. 28.

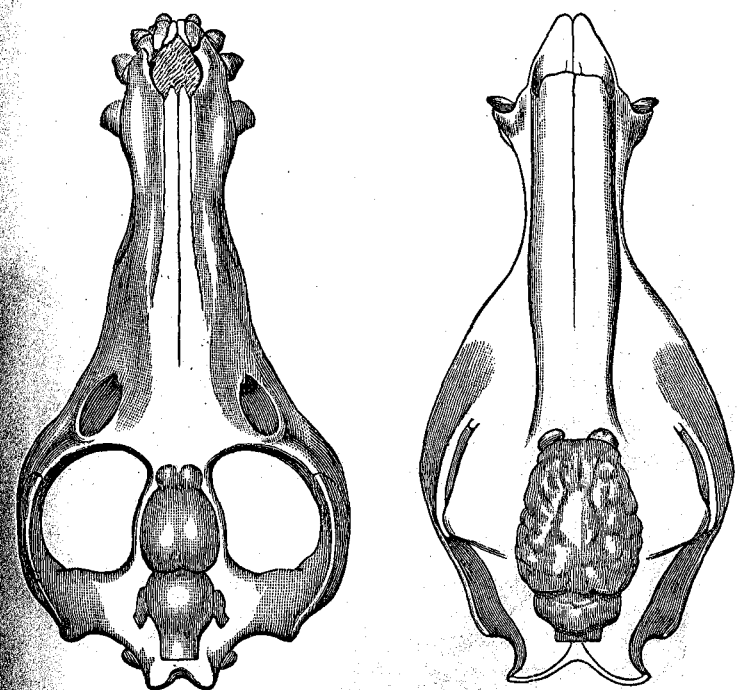

FIGURE 27.—Skull of *Elotherium crassum*, Marsh. Miocene.
FIGURE 28.—Skull of *Platygonus compressus*, LeConte. Pliocene.

1. All Tertiary mammals had small brains.
2. There was a gradual increase in the size of the brain during this period.
3. This increase was confined mainly to the cerebral hemispheres, or higher portion of the brain.
4. In some groups, the convolutions of the brain have gradually become more complex.
5. In some, the cerebellum and the olfactory lobes have even diminished in size.
6. There is some evidence that the same general law of brain growth holds good for Birds and Reptiles from the Cretaceous to the present time.*

*This Journal, vol. viii, p. 66, July, 1874; and vol. xii, p. 61, July, 1876; also Odontornithes, p. 10, 1880.

"The author has since continued this line of investigation, and has ascertained that the same general law of brain growth is true for Birds and Reptiles, from the Jurassic to the present time."

The small size of the brain in early Tertiary mammals will be indicated by an examination of the *Dinocerata* skulls, with the brain in position, shown in figures 22, 23. This is further shown by figures 24–28, which represent the skull and brain-cast of various Tertiary Mammals.

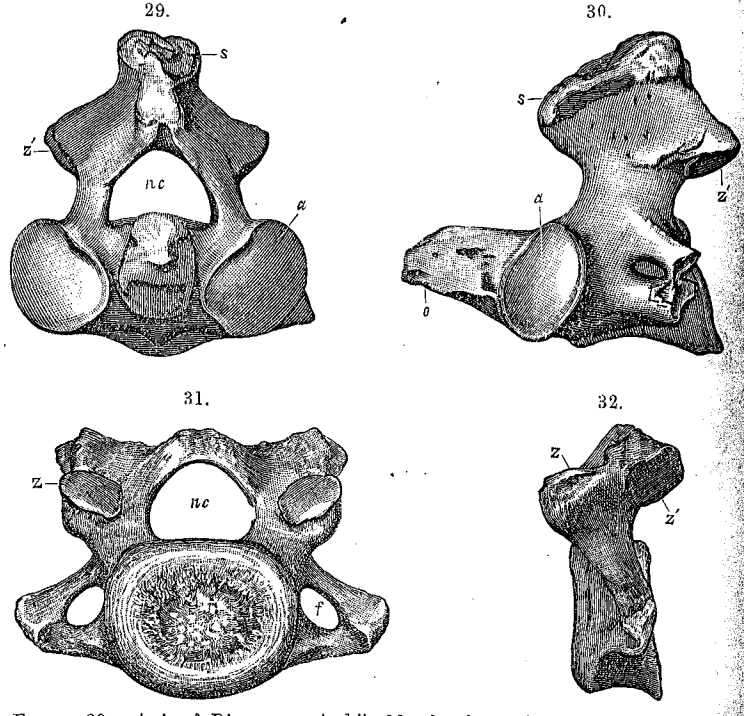

FIGURE 29.—Axis of *Dinoceras mirabile*, Marsh; front view.
FIGURE 30.—The same vertebra; side view.
FIGURE 31.—Cervical vertebra of *Tinoceras grande*. Marsh; front view.
FIGURE 32.—The same vertebra; side view. All the figures are one-fourth natural size. *a*, face for atlas; *f*, lateral foramen; *n c*, neural canal; *o*, odontoid process; *s*, neural spine; *z*, anterior zygapophysis; *z'*, posterior zygapophysis.

THE VERTEBRÆ.

"The cervical vertebræ of the *Dinocerata*, in their main characters, resemble those of the Proboscidians. The atlas and axis are somewhat similar to those of the elephant. The rest of the cervicals are proportionally longer. The entire neck was about one-third longer than in the elephant, thus rendering a proboscis unnecessary, as the head could readily reach the ground.

"All the presacral vertebræ, behind the atlas and axis, have the articular faces of the centra nearly flat, as in the typical Proboscidians.

"The trunk vertebræ in the *Dinocerata* are proportionally longer than those in the cervical region. The articular faces of the centra are likewise nearly flat, the most of them being distinctly concave.

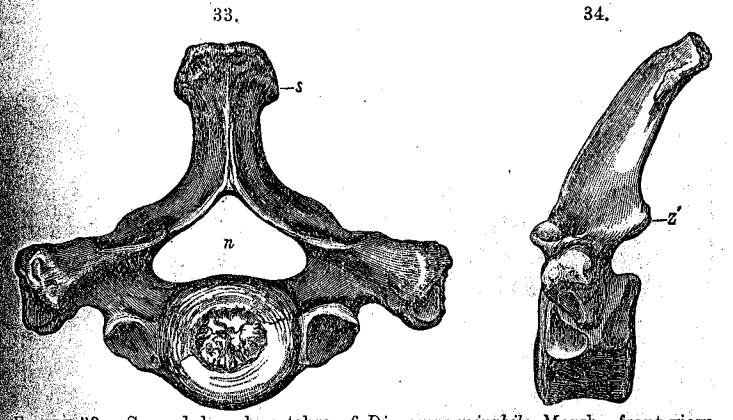

FIGURE 33.—Second dorsal vertebra of *Dinoceras mirabile*, Marsh; front view.
FIGURE 34.—The same vertebra; side view. *n*, neural canal; *s*, neural spine; *z'*, posterior zygapophysis.

THE FORE LIMBS.

"The limb bones in the *Dinocerata* are nearly or quite solid, and this is true of all the skeleton, a portion of the skull alone excepted.

"The fore limbs in the *Dinocerata* have a general resemblance to those of Proboscidians.

"The fore foot in all the *Dinocerata* is larger than the hind foot. The bones composing it are comparatively short and massive. There were five well-developed digits, as in Proboscidians, but the carpal bones were interlocked with the metacarpals, as in Perissodactyls. The general appearance of the fore foot in *Dinoceras mirabile* is well shown in figure 35. The hind foot is represented in figure 36. The feet were plantigrade, as in the elephant.

"There are eight separate carpal bones in the fore foot of all the *Dinocerata*, and a ninth, the central bone, may be separate in very young animals, and, in adults, either lost or consolidated with the scaphoid, or the trapezoid. * * * * The metacarpal bones in the *Dinocerata* are short and robust. * * * * The phalanges in the fore foot of the *Dinocerata* are very short, and comparatively small.

"Sternal bones are preserved in a number of individuals of the *Dinocerata* in the Yale Museum, but the entire series in any one individual has not been recovered. * * * * The most marked character of these bones in the *Dinocerata* is that they are flat and horizontal, as in the Artiodactyls, and not vertical, as in the Proboscidians, and the Perissodactyls."

The pelvis in the *Dinocerata* has a general resemblance to that of the elephant. The ilia were widely expanded, as in that animal. There are four sacral vertebræ.

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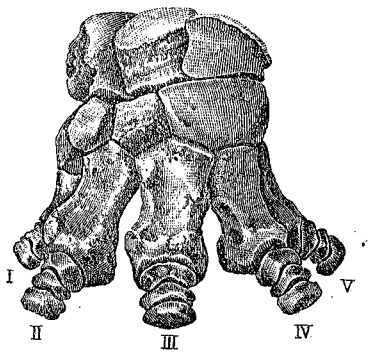

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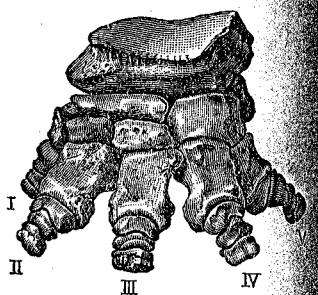

FIGURE 35.—Left fore foot of *Dinoceras mirabile*, Marsh.
FIGURE 36.—Left hind foot of the same. Both figures are one-fifth natural size.

THE HIND LIMBS.

"The hind limbs of the *Dinocerata* have a general resemblance to those of Proboscidians, but the bones composing them are comparatively shorter, and more robust. When the animal was standing at rest, the posterior limb formed a strong and nearly vertical column.

"The hind feet in the *Dinocerata* were considerably smaller than those in front. * * * * There were five digits, as in the Proboscidians, and the axis of the foot was through the third, or middle, digit.

"There are seven well developed tarsal bones in the *Dinocerata*, and their relative position in the hind foot is seen in figure 36. * * * * An eighth tarsal bone, the tibiale, appears to have been present.

"The astragalus in the *Dinocerata* considerably resembles that of the elephant, the bone being, as in that animal, very short, along the axis of the leg and foot.

"The calcaneum is short, and comparatively more robust than in the elephant. As in that animal, it is strongly tuberculated below, where, during life, it doubtless supported a thick pad, resting on the ground."

RESTORATIONS.

From Chapter XIII, on the restorations of *Dinoceras* and *Tinoceras*, the following extracts are selected:

"In the restoration of *Dinoceras mirabile* on Plate LV, the remains of the type specimen of the species, a fully adult, but not old individual, have been used for the more important parts, and the remaining portions taken from other individuals. This restoration is one-eighth natural size.

"The animal is represented as walking, and the position of the head, and the feet, has been chosen to show, to the best advantage, these portions of the skeleton as they were in life. In this restoration, only those portions are shaded which are represented by actual specimens in the Yale Museum. The parts in outline are wanting, or are so poorly preserved that only their main features can be given with accuracy.

"In the restoration of *Tinoceras ingens*, Plate LVI, the animal is represented one-sixth natural size, and standing at rest. The position here chosen shows the massive and majestic form of one of the largest individuals of this remarkable group." A reduced copy of this restoration is given in figure 37.

"In comparing *Dinoceras*, as here restored, with some of the largest ungulate mammals of the present day, a certain resemblance to the rhinoceros on the one hand, and to the elephant on the other, will naturally suggest itself. In size and proportions, *Dinoceras* was intermediate between these two existing animals, and, in various points of its structure, it resembled the one quite as much as the other. In still other features, *Dinoceras* resembled the hippopotamus.

"In its stature and movements, *Dinoceras* probably resembled the elephant as much as any other existing form. Its remarkable skull, longer neck, and more bent fore limbs, gave it, however, a very different appearance from any known Proboscidian. The high protuberances, or horn-cores, on the head, the long, trenchant, canine tusks, and the peculiar lower jaw modified for their protection, are features seen together only in this group.

"The neck was long enough to permit the head to reach the ground, and hence a proboscis was quite unnecessary. The horizontal narial opening, the long overhanging nasal bones, and the well developed turbinal bones, are likewise proof positive against the presence of such an organ. There is some evidence of a thick flexible lip, resembling, perhaps, that of the existing rhinoceros.

"The remarkably small brain, and the heavy massive limbs, indicate a dull, slow-moving animal, little fitted to withstand marked changes in its environment, and hence it did not survive the alterations of climate with which the Eocene period closed.

"Both the animals chosen for these two restorations were evidently males, as shown by the lofty protuberances, or horn-cores, on the skull, and the powerful canine tusks. In the females, these parts are but feebly developed, as shown in the specimens described in the preceding chapters. The individuals here restored were certainly thrice-armed, and well fitted to protect themselves, and their weaker associates, from any of their Eocene enemies.

"The exact form and nature of the offensive weapons which surmounted the head of the *Dinocerata* cannot, at present, be determined with certainty. That the paired osseous elevations seen on the skull in all the known species of this group did not support the kind of horns seen in the typical Ruminants is evident from their external surface, which lacks the vascular grooves so distinct on the horn-cores of those animals.

"Possibly, the *Dinocerata* may have been armed with horns similar to those seen in the American antelope (*Antilocapra*), since, in this animal, the horn-cores are even smoother than in the order here described. More probably, however, the bony protuberances on the skull were covered with bosses of thick skin, hard enough to be effective in combat. Evidence of such contests has apparently been recorded in the injuries to the horn-cores of some individuals, received during life. None of the covering of these elevations, or horn-cores, has, of course, been preserved; yet a fortunate discovery may, perhaps, reveal their nature by the form of a natural cast, as the eye-ball of the Oreodon is sometimes thus clearly indicated in the fine Miocene matrix which occasionally envelops these animals.

"The short robust feet of the *Dinocerata* were doubtless covered below with a thick pad, as in the elephant, since the whole under side of the foot clearly indicates such a protection. No portion of this covering has been preserved in any of the known specimens, and no foot-prints indicating its form, have been discovered, in the Eocene deposits in which the *Dinocerata* were entombed."

The size of *Tinoceras ingens*, as he stood in the flesh, was about twelve feet in length, or sixteen measured from the nose to the end of the tail. The height to the top of the back was about six and one-half feet, and the width across the hips about five feet. The weight, judging from that of existing mammals, was about six thousand pounds.

"*Dinoceras mirabile* was about one-fifth smaller. The neck was longer, but, in other respects, the proportions were nearly the same."

37.

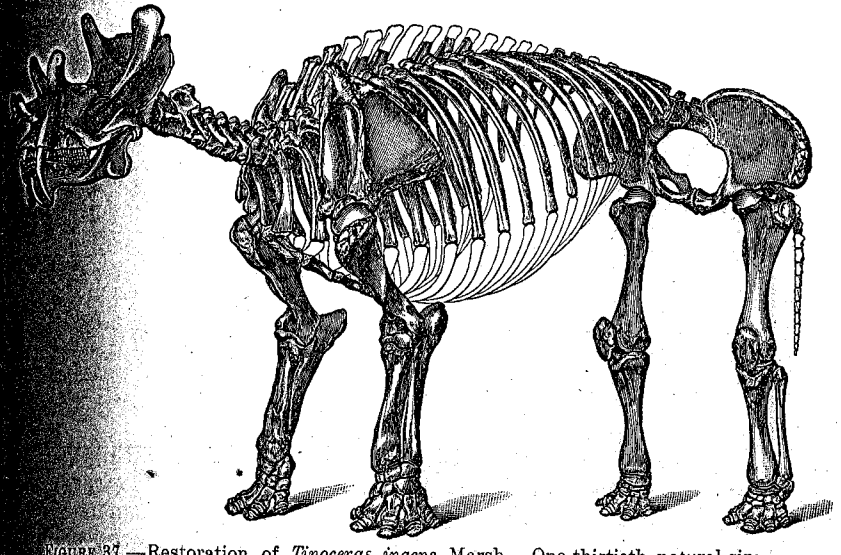

FIGURE 37.—Restoration of *Tinoceras ingens*, Marsh. One-thirtieth natural size.

The concluding chapter, XIV, contains a full discussion of the genealogy of ungulate mammals in general, and the relations of the *Dinocerata* to other groups. We quote as follows:

"Our present knowledge of the Mammalia, living and extinct, clearly indicates that they must go back at least to the Permian. The generalized mammal of that period, or of still earlier time, was probably quite small, and, in many respects, like an Insectivor. This primitive type would naturally possess all the general characters found in later forms in the various orders of mammals.

"This generalized mammal would belong to the group named *Hypotheria* by Huxley, who has laid a sure foundation for investigation in this line of research.

Genealogy of Ungulates.

"From this primitive type of mammal, a special line appar- ently led off through the Triassic and Jurassic to the Cretaceous, where it formed a well-marked group, which may be called the *Protungulata*, the probable ancestors of all succeeding ungulate mammals.

"From this generalized ungulate, the skeleton of which we now know almost as well, apparently, as if we had it before us, a direct line would appear to have continued up to the present day, and be represented by the living Hyrax. Several diverg- ent lines passed off probably from the same stem, and three of these have continued to the present time, the survivors being the *Proboscidia*, the *Artiodactyla*, and the *Perissodactyla*.

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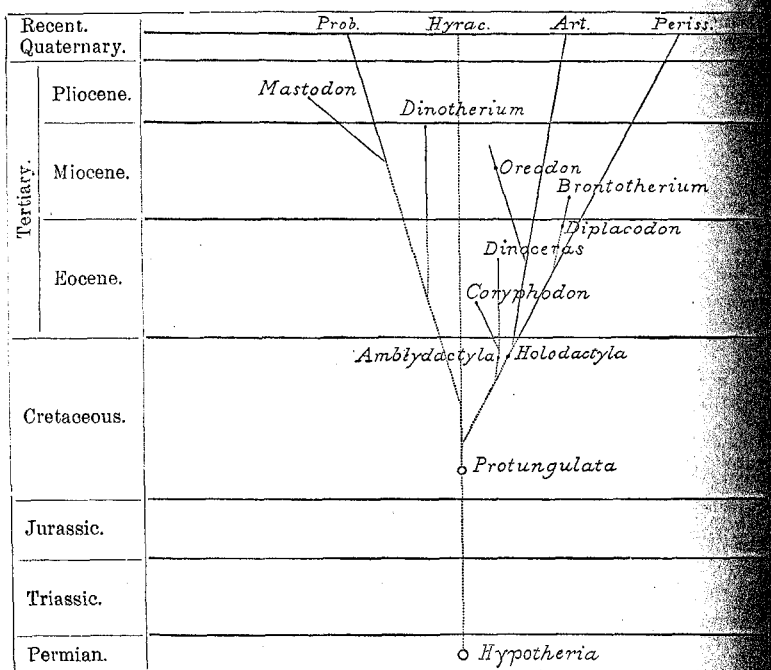

Figure 38.—Diagram to illustrate the genealogy of Ungulate Mammals.

"Another order, also, which may be termed the *Amblydac- tyla*, passed off apparently from the main ungulate stem in the Cretaceous, and became extinct in the Eocene. One branch ter- minated in *Coryphodon*, in the lower Eocene, and the other, represented by the *Dinocerata* here described, came to an end in the middle Eocene.

In figure 38, above, a diagram is given, which shows graphically these lines of descent, and the most probable genealogy of modern ungulates. The diagram, being on a plane, can only indicate the general position of these divergent lines.

"From this group came off, evidently in the late Cretaceous, first the *Coryphodontia*, having nearly all the above characters, and becoming extinct in the early Eocene.

"The *Dinocerata* probably branched off about the same time, and survived to the middle Eocene, thus becoming much more specialized before their extinction.

"Accepting this general view of the origin of the Ungulates, living and extinct, their classification has been outlined in the diagram on page 200.

"The attempts hitherto made to give a detailed classification of all the Mammalia, living and extinct, have signally failed, mainly because only a small part of even the extinct forms now known were included, and almost every new discovery tended to break down the definitions so systematically recorded. The time for such an exhaustive classification has not yet arrived, and all that can be safely ventured upon in the present state of knowledge is to indicate the main groups and their affinities, and await future discoveries.

"Excluding the aberrant, aquatic, Sirenians, now regarded as of ungulate ancestry, and leaving out also *Toxodon* and other little known extinct forms, the ungulate mammals may then be arranged in natural groups, as follows:

CLASS MAMMALIA.

Sub-Class Monodelphia.

Super-Order Ungulata.

(1.) Order Hyracoidea.

(2.) Order Proboscidea.

(3.) Order Amblydactyla { Dinocerata. / Coryphodontia.

(4.) Order Clinodactyla { Mesaxonia (Perissodactyla). / Paraxonia (Artiodactyla).

"The characters found in existing mammals, and, to a great extent, in the extinct forms from the Tertiary to the present time, are clearly of two kinds; general characters, derived from ancestral forms, and special characters, acquired in adaptation to their environment. Some of the latter may be negative characters, acquired by the disuse, or loss, of parts once advantageous.

"The first series of characters are of most importance, as they indicate a genetic connection, perhaps remote, with the different groups that share them. Special characters, on the

other hand, however closely they may correspond in different groups, do not necessarily indicate affinities, but may have been acquired by adaptation to peculiar surroundings, in groups quite distinct from each other.

"These facts lie at the foundation of classification, and it is only by keeping the two series of characters separate, that the true relationship between different groups of animals can be made out, and their genealogy indicated with any probability.

* * * * * *

Modification of the Ungulate Foot.

"In the true ungulate mammals, the modifications of the foot have undoubtedly taken place very nearly in the following manner:

(1.) The primitive Ungulates (*Protungulata*) must have had plantigrade, pentadactyl, feet, with the carpals and tarsals not interlocking either with the metapodial bones, or with their own adjoining series. This would give a weak foot, adapted especially to progression in soft, swampy ground.

(2.) For locomotion on dry hard ground, a stronger foot was required, and a modification soon took place, in the interlocking of the metapodials with the second row of carpals or tarsals that supported them. Examples of nearly this stage are seen in the fore feet of *Coryphodon*, and of *Dinoceras* as shown in figure 36.

(3.) A still stronger foot was produced by the further interlocking of both the first and second row of carpals and tarsals, as well as the latter row with the metapodials below. This general type of foot belongs to the *Holodactyla*, and is seen also in some of the early Perissodactyls.

During these two stages of modification, a reduction in the number of digits also took place, evidently as a result of the same causes. The first digit, being the shortest of the series, soon left the ground, as progression on dry land with the plantigrade five-toed foot began, and was gradually lost.

The four remaining digits, having to do the work of five, were strengthened by the interlocking already mentioned, and also by coming nearer together.

(4.) In the next change that took place, two kinds of reduction began. One leading to the existing perissodactyl foot, and the other, apparently later, resulting in the artiodactyl type. In the former, the axis of the foot remained in the middle of the third digit, as in the pentadactyl foot. In the latter it shifted to the outer side of this digit, or between the third and fourth toes. An example of the former is seen in the fore foot of *Brontotherium*, while *Oreodon* shows the latter type.

The position of the axis is the distinctive feature between these two types of feet, and not the number of toes, as the names usually applied to them indicate. In this respect, the terms Artiodactyl and Perissodactyl are misleading, and hence the names *Paraxonia* and *Mesaxonia* were proposed by the author, as substitutes, to express the true axial relation.

(5.) In the further reduction of the perissodactyl foot, the fifth digit, being shorter than the remaining three, next left the ground, and gradually disappeared. Of the three remaining toes, the middle, or axial, one was the longest, and retaining its supremacy, as greater strength and speed were required, finally assumed the chief support of the foot, and the outer digits left the ground, ceased to be of use, and were lost, except as splint bones. The foot of the existing horse shows the best example of this reduction in the Perissodactyls, as it is the most specialized known in the Ungulates.

(6.) In the Artiodactyl foot, the reduction resulted in the gradual diminution of the two outer of the four remaining toes, the third and fourth doing all the work, and thus increasing in size and power. The fifth digit, for the same reasons as in the perissodactyl foot, first left the ground, and became smaller. Next, the second soon followed, and these two gradually ceased to be functional, or were lost entirely, as in some of the Artiodactyls of to-day. The foot of the goat shows this extreme reduction.

* * * * * *

Extinction of Large Mammals.

"During the Mesozoic period, all the mammals appear to have been small, and it is not probable that any of large size existed, as reptilian life then reigned supreme. With the dawn of the Tertiary, a new era began, and mammalian life first found the conditions for its full and rapid development.

"In the lower Eocene, the largest land mammal was *Coryphodon*, more than the equal, in size and power, of any of the reptiles of that time. *Dinoceras* and its allies, in the middle Eocene, were much larger, and were clearly the monarchs of the region in which they lived. In the upper Eocene, *Diplacodon*, about the size of the rhinoceros, was the largest mammal; but each of these three died out in the period in which it flourished.

"At the base of the Miocene, the huge *Brontotheridæ*, nearly as large as the elephant, suddenly appear in great numbers. They remained for a short time the dominant land animals, and then became extinct.

"The Proboscidians were the giants of the Pliocene, and hold the supremacy in size to-day, but are evidently a declining race.

"The cause of the successive disappearance of each group of these large Tertiary mammals is not difficult to find. The small brain, highly specialized characters, and huge bulk, rendered them incapable of adapting themselves to new conditions, and a change of surroundings brought extinction. The existing Proboscidians must soon disappear, for similar reasons. Smaller mammals, with larger brains, and more plastic structure, readily adapt themselves to their environment, and survive, or even send off new and vigorous lines.

"The *Dinocerata*, with their very diminutive brain, fixed characters, and massive frames, flourished as long as the conditions were especially favorable, but, with the first geological change, they perished, and left no descendants.

* * * * * * *

CLASSIFICATION.

"The *Dinocerata* now known may be placed in three genera: *Dinoceras*, *Tinoceras*, and *Uintatherium*. These may be separated by characters of the skull, vertebræ, and feet. There are also indications of several intermediate forms, which may, perhaps, be found to represent sub-genera, when additional specimens in good preservation are secured for comparison. Twenty-nine species may be distinguished, mainly by the skull alone, which, at present, offers the best distinctive characters."

Sub-order DINOCERATA, Marsh.

Family TINOCERATIDÆ, Marsh.

Uintatherium, Leidy.	*Dinoceras*, Marsh.	*Tinoceras*, Marsh.
Teeth, thirty-six.	Teeth, thirty-four.	Teeth, thirty-four.
Lower premolars, four.	Lower premolars, three.	Lower premolars, three.
Base of canine tusk, nearly vertical.	Base of canine tusk, nearly vertical.	Base of canine tusk, horizontal.
Parietal protuberance, above post-glenoid process.	Parietal protuberance, above post-glenoid process.	Parietal protuberance, behind post-glenoid process.
Cervical vertebræ, of moderate length.	Cervical vertebræ, less elongate.	Cervical vertebræ, short.
Lunar, articulating with trapezoid?	Lunar, articulating with trapezoid.	Lunar, not articulating with trapezoid.

"These three genera clearly represent three stages of development of the *Dinocerata*, and these stages correspond to the successive horizons of the middle Eocene in which the remains of these animals were entombed. *Uintatherium*, the most generalized type, is found at the lowest level; *Dinoceras* is from a somewhat higher stratum; and *Tinoceras*, the most specialized of all, occurs in the latest deposits."

In the Synopsis which follows this chapter, a systematic list of all the species of the *Dinocerata* is given in detail, and the volume closes with a Bibliography of the important literature.

L. P. B.

ART. XXVII.—*On Taconic Rocks and Stratigraphy, with a Geological map of the Taconic region* (Plate II); by JAMES D. DANA.

IN my papers of 1873 and 1877,* on the Limestone, Schists and Quartzyte of the Taconic region, I present evidence (1) from the facts illustrated by various stratigraphical sections, (2) from the continuity and common features of the conformable series of these rocks from north to south, and (3) from fossils existing (as made known by others) in some of the beds, that these rocks are (A) of one system; and (B) of Lower Silurian age; and (C) have the Taconic schists as the upper member of the series.

In my work I made no attempt to map the region, since the point in view was stratigraphical, with special reference to the "lithological canon," and its illustration did not seem to demand it. The evidence presented has been questioned on the ground (1) that the continuity of the system is not clearly established, and (2) that the relation of the quartzyte to the other rocks is not fully worked out. In order to remove as far as may be, the uncertainties on these points, I began over three years since, a new study of the region, with reference to its stratigraphy and geological structure, and the details required for the construction of a geological map. Two papers in the last volume of this Journal contain results derived from this recent investigation. In the paper here begun I present the facts gathered bearing on the constitution and stratigraphical relations of the rocks, and on their distribution and geographical relations, and illustrate the subjects by means of the prepared map as well as by diagrams.

The region is that of the Taconic rocks as first laid down by Professor Ebenezer Emmons—these rocks including according to his original enunciation of his system: (1) The Taconic schists of the Taconic range and of the subordinate ridges within the adjoining limestone area; (2) the limestone formations on the east and west sides of the Taconic Range; and (3) the quartzyte adjoining or within the limestone area.

The investigations have extended over Berkshire county in Massachusetts, Salisbury and Canaan in Connecticut, and less completely over Pownal and Bennington, Vermont, and the adjoining eastern border of the State of New York. This is not the whole of the true Taconic region, as it continues northward to central Vermont; but it comprises the portion that was the special subject of Professor Emmons's earlier investigations.

* This Journal, III, v, vi, 1873, and xiii, xiv, 1877.