GEOLOGICAL SURVEY OF CANADA

ROBERT BELL, M.D., Sc.D. (Cantab.), LL.D., F.R.S., I.S.O.

CONTRIBUTIONS

TO

CANADIAN PALÆONTOLOGY

VOLUME III (Quarto).

PART III.—ON DRYPTOSAURUS INCRASSATUS (COPE), FROM THE EDMONTON SERIES OF THE NORTH WEST TERRITORY.

BY

LAWRENCE M. LAMBE, F.G.S., F.R.S.C.

Vertebrate Palæontologist.

OTTAWA

GOVERNMENT PRINTING BUREAU

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The present monograph constitutes the third part of volume III (quarto) of Contributions to Canadian Palæontology and is descriptive of the skull and certain other parts of the skeleton of the large carnivorous dinosaur *Dryptosaurus incrassatus* (Cope). The fossil remains now described by Mr. Lambe were collected by officers of this department from the Edmonton series of the Cretaceous system of the North-west Territory of Canada. A preliminary description of the skull, by Professor Edward D. Cope, based on the same material, was published, in 1892, without illustrations.

Part I of this volume, on Vertebrate Species from the Oligocene or Lower Miocene beds of the Cypress Hills, by Professor Cope, appeared in 1891.

Part II, on Vertebrata of the Mid-Cretaceous (Belly River series) by Professor Henry F. Osborn and Mr. Lawrence M. Lambe, was published in 1902.

The present part, continuing the series of descriptive and illustrated quarto memoirs on fossil Vertebrata of the North-west Territory, consists of twenty-six pages of letter-press with text figures and eight photogravure plates.

ROBERT BELL.

GEOLOGICAL SURVEY DEPARTMENT,
OTTAWA, June 22, 1904.

GEOLOGICAL SURVEY OF CANADA

ON DRYPTOSAURUS INCRASSATUS (COPE), FROM THE EDMONTON SERIES OF THE NORTH-WEST TERRITORY.

By Lawrence M. Lambe.

Since 1824 when *Megalosaurus* was first described by Buckland * our knowledge of the osteology of the carnivorous dinosaurs has been increasing slowly yet with encouraging surety. For this knowledge, so laboriously gained, we are indebted to many enthusiastic workers on both sides of the Atlantic, amongst whom, have been, and are at the present time, some of the most noted and eminent men whose names are inseparably linked with the progress of vertebrate palæontology.

A splendid advance was made when Marsh in 1884 published his description of *Ceratosaurus nasicornis* ** from the Upper Jurassic of Colorado. Much that had previously been either little known or imperfectly understood, regarding the structure of the skull, was then made clear. The finding of moderately well preserved skulls of carnivorous dinosaurs has been of such rare occurrence or the parts discovered have generally been so fragmentary, that the reconstruction of the entire skull of so large and interesting a form as *Ceratosaurus* was of the greatest importance even without considering the almost complete knowledge gained of the remainder of the skeleton of that species.

Nearly related to *Ceratosaurus* is the Upper Cretaceous *Dryptosaurus* *** the type of which Cope's *Lælaps aquilunguis* † from the Greensand of New Jersey, was first described in 1866. Another species of *Dryptosaurus* is the western form *D. incrassatus*, †† from the uppermost beds of the Cretaceous system (Edmonton series), described by Cope at a later date. Another form from a lower horizon than *Dryptosaurus*, and probably generically distinct, is the imperfectly known *Deinodon* ††† of Leidy from the Judith River beds of Montana and the Belly River series of the Canadian North-west Territory (Red Deer river, District of Alberta).

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* Notice on the Megalosaurus or great Fossil Lizard of Stonesfield, by the Rev. William Buckland, F.R.S., F.L.S. Transactions of the Geological Society, London, second series, vol. 1, p. 390, pls. XL–XLIV.

** Principal characters of American Jurassic Dinosaurs, part VIII, The Order Theropoda. American Journal of Science and Arts, third series, vol. XXVII, p. 329.

***American journal of Science and Arts, third series, Vol. XIV, p. 88, 1877. In a foot-note Marsh here proposes the name *Dryptosaurus* to replace *Lælaps*, Cope, preoccupied.

† Proceedings of the Academy of Natural Sciences of Philadelphia, Vol. XVIII, p. 276, 1866.

†† On the Skull of the Dinosaurian *Lælaps incrassatus*, Cope. Proceedings of the American Philosophical Society, Vol. XXX, p. 240, 1892.

††† Proceedings of the Academy of Natural Sciences of Philadelphia, Vol. VIII, p. 72, 1856.

Cope, in October 1876, proposed the name *Lælaps incrassatus*,* for teeth collected in supposed Fort Union beds in Montana (later referred to the Judith River formation), and in December of the same year he assigned a nearly complete dentary bone with teeth from the same district to his species. In 1892 the same author published a description (see foot-note p. 5), of two skulls from the Edmonton series of Alberta, identifying them with *L. incrassatus*. It is likely that the teeth, and the dentary bone, from Montana should properly be referred to the large carnivorous dinosaur *Deinodon horridus*, Leidy, of the Judith River beds of Montana and of the Belly River series of Alberta, in which case the skulls from the Edmonton series would become the types of *Dryptosaurus incrassatus*. In part II of this volume it has been pointed out that *Deinodon horridus* is in all probability generically distinct from *Dryptosaurus incrassatus* of the Edmonton series.

The description of the two skulls of *D. incrassatus* by Professor Cope was read before the American Philosophical Society in May 1892 and it was this gifted author's intention to supplement what he had already written by publishing an illustrated memoir giving the results of a further study of the remains. His purpose had not been carried into effect, however, when unfortunately his death occurred in 1897.

Remains of *D. incrassatus* from the Edmonton series of Alberta form the basis of the present memoir. They consist of the skulls, above mentioned, with some other parts of the skeleton, which have been in the possession of the Geological Survey of Canada and on exhibition in its museum for some years. The skulls are of special interest and are the only two of this species known, so far as the writer is aware. They were obtained in different years, from the same horizon, at localities a few miles apart. The first was found, during the summer of 1884, by Mr. J. B. Tyrrell, on, and about two miles from the mouth of, Knee Hills creek, a tributary of Red Deer river, whilst engaged in a geological exploration in the Districts of Alberta, Assiniboia and Saskachewan. The second representing a slightly smaller individual, was discovered by Mr. T. C. Weston in 1889 on the east bank of Red Deer river, at a point about twenty-one miles above the mouth of Knee Hills creek, whilst making a collection of fossils in the Red Deer river country. With the remains of the second skull and probably belonging to the same individual, Mr. Weston found the distal end of a right tibia with the astragalus, a metatarsal bone, three ungual phalanges of the manus, a neural spine and a large portion of a left ilium with the neural arches and spines of sacral vertebræ. Both of the skulls are crushed and distorted and both are incomplete. Some portions are in an excellent state of preservation, especially the rami of the mandible of the smaller specimen, which in part compensates for the injury the specimens received whilst being removed from the rock in which they lay.

The Edmonton series, defined by Tyrrell in his report on the geology of northern Alberta,** as the lower of his two sub-divisions of the Laramie rocks of that region and as constituting the uppermost beds of the Cretaceous system as there exposed, consists of brackish-water deposits, 700 feet in thickness, overlying the marine Fox Hill and Pierre group conformably. The upper sub-divison, the Paskapoo series, comprising beds of fresh-water origin and reaching a thickness of 5,700 feet, was considered to be of Tertiary age. The Edmonton series is represented by " soft whitish sandstones and white or gray,

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* Proceedings of the Academy of Natural Sciences of Philadelphia, Vol. XXVIII, pp. 248 and 340.

** Geological and Natural History Survey of Canada, new series, vol. II, 1887 (Annual Report, 1886), part E, Report on a part of Northern Alberta and portions of adjacent Districts of Assiniboia and Saskatchewan.

often arenaceous, clays, with bands and nodules of clay ironstone and numerous seams of lignite ". It corresponds to the lowest portion of Dr. Dawson's St. Mary River beds * of the region more to the south and to the Wapiti River group ** of the country to the north. According to Tyrrell the Edmonton series is essentially the coal-bearing horizon of this district and underlies a large extent of country. To the west it thins out and disappears beneath the overlying Paskapoo series and is apparently absent in the foot-hills. No dinosaurian bones have been found above the Edmonton series ; a fact, that, taken together with the lithological characters of the rocks, the manner of deposition of the same and the palæontological evidence generally, led to the separation of this series from the higher Laramie rocks and to the belief that the Paskapoo series marked the beginning of Tertiary times. On the evidence of fossil plants alone, Penhallow † comes to the conclusion, and supports Tyrrell in his contention, that the Paskapoo formation is of Eocene age.

The reader is referred to the publications of the Geological Survey for an exposition of the geology of the western plains, and principally to the reports of Dr. Dawson, Mr. McConnell and Mr. Tyrrell, in which the position of the Edmonton series, and its supposed equivalents, in the geological scale, is discussed in some detail.

General description of specimens.

Of the skulls from the Red Deer river district, the one found in 1884 on Knee Hills creek is somewhat larger than the other. In this specimen (plates IV and V) the arches are missing with the entire upper part of the cranium from the parietal region forward. The brain case is preserved, with the bones of the palate behind, as well as the posterior lower portion of the maxillæ and the anterior half of the jugals. The two rami of the mandible are almost entire. The specimen is crushed downward, and what remains of the upper part of the skull is distorted to the left, with the two rami of the mandible lying turned over, beneath. The two halves of the jaw have been displaced, posteriorly, so as to partially expose the bones of the back portion of the palate in the space between them. This displacement of the jaw has brought to view the inner surface of the right ramus, which lies, posteriorly, almost in the same plane as the exposed outer surface of the left ramus. From this specimen we gain information regarding the form and construction of the brain case and the anterior part of the lower or infratemporal arcade, the composition of the palate and the shape of the several elements of the mandible with their relations to each other.

The second and smaller skull supplies to some extent the deficiencies of the cranium of the larger skull. In this specimen (plates I, II and III) the lateral parts of the facial region are preserved, from the orbits forward, with most of the jugal on the left side. The nasals are apparently missing and, with the exception of a small piece of bone on the left side, the premaxillæ are not represented. The two halves of the lower jaw are turned sideways and pressed against the palate, so as to hide from view the inner surface of the left ramus and the outer side of the right one. The left ramus is preserved

* Geological and Natural History Survey of Canada, Report of Progress, 1882-83-84, Report on the region in the vicinity of the Bow and Belly rivers, North-west Territory, p. 112c, 1884.

** Ibid, Report of Progress for 1879-80, Report on an exploration from Port Simpson on the Pacific coast, to Edmonton on the Saskatchewan, p. 124 B, 1881.

† Proceedings and Transactions of the Royal Society of Canada, second series, vol. VIII, section IV, Notes on Cretaceous and Tertiary plants of Canada, p. 67, 1902.

for about three-fourths of its entire length and the right ramus is broken off at about its mid-length. The palate has been crushed upward against the upper part of the cranium and lies between it and the lower jaw ; part of it is exposed to view in the large preorbital vacuity of the left side.

The most obvious features in the skull of *Dryptosaurus incrassatus* are, its depressed form above, the presence of two preorbital openings (agreeing in this respect with *Creosaurus*) and the large proportionate size of the mandible compared with that of the cranium. With some allowance for crushing, a restoration of the skull, fig. A. p. 25, gives its length as nearly twice as great as its height. Its probable maximum width is equal to about three-fourths the height of the skull but considerably greater than the height of the cranium. In side view the general outline is roughly elliptical but decidedly pointed in front. When seen from above, and again allowing for distortion, the general outline is a long oval, truncated posteriorly, with flat sides and narrower in front than behind.

In comparing the skull of this species with that of *Ceratosaurus nasicornis*, Marsh, the proportions of length to height in both are about the same but the jaw in the former species is much heavier and the facial part not so elevated. When viewed from above the width and the amount of elongation, in both species, is somewhat similar.

In the form of the muzzle *D. incrassatus* apparently approaches more nearly the Upper Jurassic species *Creosaurus atrox*, Marsh lately described *by Professor Osborn from two specimens from Bone Cabin quarry, near Medicine Bow, Wyoming.

THE SMALLER SKULL.

Considering first the upper portions of the skull of the smaller specimen (plates I, II and III). The maxilla is a large, robust bone of considerable height in front. It narrows rapidly backward below, terminating posteriorly in a sharp point. Anteriorly its border curves evenly upward and backward. On the left side the premaxillo-maxillary suture, PMS, (plate I), is seen for a short distance upward from the alveolar border. A small piece only of the premaxilla, PM, is here preserved, and in it is the inner side of the base of a moderate sized tooth. Beyond this no indication of the premaxillæ is observed and they are presumably for the most part missing. The nasals are also thought to be absent, or if not, at least preserved in so fragmentary a state or so crushed as to be unrecognizable.

The jugal succeeds the maxilla behind uniting with and slightly overlapping it in a long, very oblique suture. It throws upward from its superior border, near its anterior end, a procees that meets a prolongation downward of the prefrontal bone. This divisional bar, in which the lachrymal is probably included, separates the orbit from a large preorbital vacuity. The latter opening is of large size, is subtriangular in shape and approaches close to the superior border of the skull. Its upper anterior margin is formed by the upper posterior extension of the maxilla. Below it is bounded, in almost equal part, by the maxilla in front and the jugal behind. In advance of the preorbital fossa is a relatively small opening, APV, the anterior preorbital or maxillary vacuity, somewhat broadly oval in outline, separated from the larger opening behind by a nar-

*Bulletin of the American Museum of Natural History, vol. XIX, article XXXI, pp. 697-701, 1903, "The Skull of Creosaurus."

row bar of bone. The surface of the bone, along the lower margin of the preorbital vacuity and surrounding the smaller opening, is smooth and depressed, forming a marginal tract at a lower level than the general surface of the bone. This depressed area is also continued along the anterior upper border of the preorbital vacuity for a short distance.

The large opening, here regarded as the preorbital vacuity, was described in the preliminary report by Cope as the orbit. The present writer is, however, of the opinion that the orbit is to be found in the opening farther back in the skull and that *Dryptosaurus* had, in common with the ancestral type *Creosaurus*, at least two preorbital openings.

Dryptosourus incrassatus has, hitherto, been considered rather exceptional in the possession of, and in differing from *Ceratosaurus* in having, so large an orbit placed so far forward in the skull. With the present interpretation, the orbit is in about the same position as is that of the latter species and also that of *Creosaurus*. *Ceratosaurus nasicornis* is described as not having an aperture in advance of the preorbital vacuity. In an examination of the skull of this species in the National Museum at Washington, D.C., the writer did not observe a second, smaller opening in advance of the preorbital fossa nor was an indication of such a structure likely to escape the notice of so accurate an observer as Professor Marsh, although, in his published figure, a decided depression is shewn near the upper edge of the maxilla immediately under the nasal horn core.

The number of teeth in the maxilla was apparently twelve; of these the bases of the first four, the sixth and the twelfth are preserved; the fifth and the eleventh are entire. Between the sixth and the eighth (of which about half the crown is preserved) is sufficient space for one tooth, the seventh, and another space between the eighth and the eleventh, indicates evidently where the ninth and tenth were lodged.

The tooth, already mentioned, of which the inner side only of the base is seen, in the outer lateral portion remaining of the left premaxilla, is in the position of the third incisor if each premaxillary bone held three teeth.

Above the preorbital fossa is a two-branched bone interpreted as the prefrontal, PF. It consists of a prominent knob, flattened above, from which proceeds a horizontal, forwardly directed limb lying above the preorbital vacuity and a vertical part that passes downward to meet the process of the jugal below. This bone, posteriorly, overhangs, and forms part of the upper anterior border of, the orbit; its vertical limb with the upward extension of the jugal separates the orbit from the preorbital opening. The horizontal and more robust portion of the bone projects over the preorbital fossa, forming its posterior upper border, and tapers rapidly forward to a sharp point. It is impossible to tell from this specimen to what extent the nasals are developed as no portion of them can be recognized, indeed, it is extremely doubtful if they are at all represented in the fossil. Judging, however, from the curve of the upper anterior margin of the maxillæ and the narrowness of the space between the preorbital openings (no doubt greatly reduced by distortion) they are thought to have been long and slender, extending almost as far forward as the maxillæ and extending back to a point midway between the posterior prominences of the prefrontals. With this length allotted to the nasals the premaxillæ would have been short.

The exterior surface of the maxilla is rough and a few foramina, occurring at intervals (as shewn in plate II), not far distant from the alveolar border, are conspicuous.

The jugal extends forward for some distance in advance of the posterior termination of the maxilla, meeting the latter in a long, oblique suture, and slightly overlapping it; it narrows rapidly to a point in front. Back of the orbit it throws up a process, POB, to form the lower half of the postorbital bar. It is of considerable depth below the orbit but is not preserved to its posterior termination. In plates I and II, the emargination of the bone at *a* indicates the curve of the lower front margin of the infratemporal fossa.

Within the preorbital vacuity on the left side are preserved certain bones (plates I and II, *b*, *c* and *d*) which are spoken of, in Cope's preliminary description, as the orbito-sphenoid, the postoptic and the epipterygoid respectively. The present writer believes that the bone *b* is the left element of the paired vomers (the prevomer of Broom*). Posterior to the vomer is what is thought to be the palatine (*c* and *d*) as seen from above, fractured so as to be easily mistaken for two separate bones. The space between the palatine and the vomer evidently represents the internal nares (I N, plates I and II) and the concavity behind the palatine (corresponding with that seen in the larger skull) a suborbital vacuity (S O V, plates I, II and III) of considerable size bounded posteriorly by the transpalatine (ectopterygoid). Further reference will be made later to this portion of the palate in the description of the larger skull.

Passing to the mandible ** it is only to be regretted that it is not entire. About three-fourths of the left ramus and half of the right ramus are preserved in a very excellent state of fossilization. Fortunately the right ramus has shifted its position so as to exhibit the elements composing the inner surface, except in the symphyseal region where the two rami lie against each other; behind they have opened like the blades of scissors. The outer surface of the left ramus is almost as perfect as could be desired, from behind the highest point of the upper curve of the surangular, forward. The left ramus exhibits the greater part of the dentary, D, and a large portion of the surangular, SA, the dentary passing beneath the surangular. The surangular is broadly arched above, as seen in side view, its curve continuing forward into the reversed curve of the alveolar border of the dentary. This latter bone is narrow anteriorly, its lower margin being for some distance back from the symphyseal region, parallel to the alveolar border. In front its lower border curves obliquely forward and upward. The symphysis is hidden from view in this specimen. The greatest depth of the dentary is reached where it meets the surangular above, the suture between these two bones curving evenly downward and backward so as to reduce the depth of the dentary rapidly as it passes beneath the surangular.

The outer surface of the dentary is rough and exhibits a number of foramina and vascular grooves, the latter of which are numerous and particularly conspicuous anteriorly (plate III). Farther back near the surangular the surface of the bone becomes quite smooth. Some of the foramina follow the upward curve of the dentary in front; the remainder are in a rather regular line below the alveolar border. This foraminal line, of the same length as the dental series, is slightly over an inch below the alveolar border at its mid-length; it approaches closer to the border in front and behind. The foramina in

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* Proceedings of the Linnean Society of New South Wales, 1903, vol. XXVII. "On the Mammalian and Reptilian Vomerine bones," p. 545, by R. Broom.

** The lower jaw of *Dryptosaurus incrassatus* (Cope), by Lawrence M. Lambe. The Ottawa Naturalist, vol. XVII, 1903, pp. 133-139, plates I, II and III.

this line are connected laterally by a nearly continuous groove from which a number of short, deep grooves are given off at right angles and extend upward toward the alveolar border.

There are fifteen teeth in the left ramus, agreeing thus in number with the supposed number of maxillary and premaxillary teeth combined. Fourteen full-sized teeth are preserved whilst in advance of the anterior one a small tooth, *e*, partially protudes at a lower level. This tooth is apparently an additional one in the series and not a successional tooth, making the total number in the complete dental series, fifteen. It is truncated posteriorly so as to be similar in this respect to some of the teeth described by Leidy, under the name *Deinodon horridus* as being peculiar in form, * and to a tooth referred to by the writer in his description of *Ornithomimus altus* † as being from the anterior portion of the jaw.

On the inner side of the right ramus the front part of the splenial, SP, is seen preceded by a narrow presplenial, PSP, which extends forward between the dentary below and the alveolar plate of the dentary, DP, above, to the symphysis.

The splenial as shewn in this specimen, is a deep lamellar bone, immediately above the dentary and occupying nearly the whole depth of the ramus, from its upper border behind the dental series downward, cutting off the alveolar dentary plate posteriorly and greatly diminishing the depth of the dentary behind. It is obtusely wedge-shaped in front passing below the presplenial and terminating in a sharp point a short distance in advance of the posterior end of that bone. It is perforated near its anterior end and close to its lower margin by a large oval foramen. At a short distance behind this foramen, in the line of the vertical fracture, a well marked emargination (*f*, plate III) of the bone occurs, that is shewn, however, to a greater extent and more decidedly in the specimen figured in plate V. The outline of this emargination bears a strong resemblance to the anterior end of a second foraminal opening, which, if it did exist, may have been partly enclosed by the angular as in *Crocodilus*. A transverse section of the lower part of the splenial is seen at *i*, plate III, in the left half of the jaw.

The dentary occupies about one-half of the lower depth of the inner surface of the jaw anteriorly, narrowing backward gradually below the splenial until it disappears from the inner side altogether.

Above the presplenial the inner alveolar plate of the dentary, of somewhat greater depth than the presplenial, forms the inner wall of the dental chamber and completes the inner anterior surface of the ramus. It meets the splenial posteriorly and narrows rapidly upward, but its relation to the dentary and the splenial, behind the dental series, has not been ascertained. Its upper border is at a lower level than the outer alveolar border of the dentary. The full depth of the dentary plate is seen at *g* where the inner surface of a tooth rising above its border, is just hidden, in a direct side view of the mandible such as is shewn in figure 3, by the lower edge of the dentary of the left ramus.

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* Transactions of the American Philosophical Society. Extinct Vertebrata from the Judith River and Great Lignite formations of Nebraska, by Joseph Leidy, 1860, p. 144, plate 9, figs. 37-40.

† Part II of this volume, p. 53, plate XIV.

Measurements of smaller skull.

	MM.
Maximum length of specimen (length of left ramus preserved)	610
Maximum thickness of specimen; from posterior end of prefrontal to outer surface of left ramus	210
Maximum breadth of specimen posteriorly	412
Breadth of specimen at eighth maxillary tooth	290
Extreme length of left maxilla	457
Length of left preorbital vacuity	190
Width of same	127
Length of left anterior preorbital vacuity	63
Width of same	48
Distance from lower margin of anterior preorbital vacuity to alveolar border of maxilla	111
Length of dental series of maxilla	330
Length of dentary, above, to its junction with the surangular	380
Depth of dentary at its junction above with the surangular	160
Depth of dentary below the tenth tooth	96
Length of dental series of dentary	325
Depth of inner alveolar plate of dentary at *g*, below the ? tenth tooth, plate III.	23
Depth of presplenial below *g*	17
Depth of dentary below *g* (+depth of anterior end of splenial = 4 mm.)	48
Distance from alveolar border of dentary plate at *g* to lower border of ramus	88
Difference in level of inner and outer alveolar borders of ramus at tenth tooth	8
Length of crown of fifth maxillary tooth	49
Breadth of same at base	22
Thickness of same at base	14
Length of crown of sixth tooth of lower jaw	38
Breadth of same at base	18
Length of crown of seventh tooth of lower jaw	55
Breadth of crown of same at base	21
Length of crown of eighth tooth of lower jaw	46
Breadth of crown of same at base	21
Length of splenial foramen	52
Height of same	30
Distance between splenial foramina	47

THE LARGER SKULL.

Owing to the pressure that has been exerted on this specimen (plates IV and V) obliquely downward from the right, the cranium is distorted to the left and the mandible has turned over sideways beneath the cranium so that the left side of the left ramus and the inner side of the right ramus face downward. The two halves of the mandible have been forced apart, anteriorly but little, posteriorly to a considerable extent so as to expose the bones of the palate behind. The brain case is preserved, also the posterior ends of the maxillæ with the anterior part of each jugal and, as just mentioned, some of the bones of the palate; with these exceptions almost all of the other parts of the cranium have disappeared.

The roof of the brain case appears to have been horizontal in lateral aspect above and to have been met posteriorly from below by the plane of the occiput at slightly more than a right angle, the latter being not quite vertical but inclined slightly backward.

It was angulate in the median line above, at least anteriorly, as is evinced by the parietals (P, plate IV and fig. 15, plate VII) of which the front ends remain. The upper surface of the roof has been damaged to a large extent, but on either side of its longitudinal axis the inner surfaces of the supratemporal vacuities, *h*, plate IV, partially remain shewing that these openings were small and situated close together at about the mid-length of the parietals. The remains of the inward sloping surfaces of the supratemporal fossæ shew that the parietals here met above to form a very narrow angular ridge in continuation backward of the median angulation preserved in the anterior part of the parietals.

In the occipital region, plate VII, fig. 15, the exoccipitals and the basi-occipital are represented but the supra-occipital is missing. The occipital condyle is considerably broader than high, somewhat angulated below transversely, shallowly excavated above longitudinally in continuation of the floor of the foramen magnum, and presents a well rounded articular surface pointing horizontally to the rear. Both the foramen magnum and the occipital condyle are small.

The sutures between the bones of the occiput have not been detected, so that the limits of the different elements are still obscure. A prominent flange of bone, directed backward and outward, forms the lateral boundary of the occiput on either side as seen from behind. On the inner side of this flange, between it and the basi-occipital, occurs a deep fossa which is the outer termination of a pair of foraminal openings. Beneath the occipital condyle the basi-occipital presents a vertical plane surface, standing out prominently between the fossæ. Its breadth is less than that of the condyle and less than that of its own downward extension; unfortunately it is broken below. The exoccipitals, of which the lateral flange forms a part, bound the foramen magnum laterally and above. On either side of the occipital condyle are two foramina, one, of moderate size, at a higher level and farther out from the condyle than the other which is quite small. The larger opening was probably for the transmission of the *nervus vagus* or *pneumogastric nerve*, *X*, fig. 15, plate VII, the smaller one, judging from its position immediately behind the vagus, is thought to be the foramen for the *accessory nerve*, *XI*, which made its first appearance in the reptiles. Below these foramina and occupying the inner end of the deeply excavated fossa are two openings, of equal size, side by side, separated from each other by a thin partition of bone. One of these may represent the *hypoglossal* foramen, *XII*, on account of its ventral and posterior position, the *twelfth* or *hypoglossal nerve* arising from the lower aspect of the medulla behind. The other opening of the pair, may be the *carotid* foramen which in the crocodile is somewhat similarly placed. Anterior to the lateral flange of the exoccipital are two other large foramina, one above and considerably in advance of the other (see plate IV) A deep groove in the bone leads forward to the hinder opening which forms its front termination. The upper and front opening is regarded as the *foramen ovale* through which the *trigeminal nerve*, (*V*, plate IV) passed out of the skull, the other one probably provided for the exit of the *facial* and *auditory nerves*, *VII* and *VIII*, which are to be looked for a short distance behind the trigeminal. Cope in his reference (in the preliminary description) to the same two foramina expresses the opinion that " one or both of these is the *trigeminal* ".

The supra-occipital is not distinguishable and has probably been entirely removed, or if present in part, is crushed beyond recognition.

Passing to the lower surface of the brain case or cranium proper, it is seen to be strongly keeled posteriorly, the keel apparently representing the anterior portion of the basisphenoid element of the basicranial axis. Anteriorly the keel decreases in depth and terminates immediately behind a transversely elongated opening (PN, fig. 22, plate VIII) regarded as a pituitary foramen. In advance of the keel and projecting forward for some distance from beneath the pituitary foramen are the remains of a median, unpaired bone, presumably the vomer (parasphenoid). This bone (PS, plate IV), allowing for the distortion of the specimen, would be in its proper position in the interpterygoid vacuity. Posteriorly it seems to reach the basisphenoid keel at its greatest depth behind. On either side of the pituitary foramen, close to and slightly behind it, is a deep reniform depression from which a small foramen leads upward, *III*, fig. 22, plate VIII. The *third* or *oculomotor nerve* given off from the ventral region of the mid-brain in close proximity to and behind the *pituitary body* is certainly suggestive of the nature of the foramina in question

In this specimen the maxillæ are both broken off at about the mid-length of the preorbital vacuity, that is, near the sharp front termination of the jugal; in advance of the line of fracture which continues across through the palate nothing whatever is left of the muzzle. On either side about one-third of the jugal remains overlapping the maxilla from behind, the suture between the two bones being well preserved in each case (*k*, plates IV and V). On the right side a large piece of the jugal has been displaced and forced inward into the orbital opening. The lachrymal bone, or possibly that portion of the jugal immediately beneath the lachrymal, is shewn in the upper part of the displaced fragment (L, plate IV) and indicates the position of the orbit, O, behind.

The conico-cylindrical bone, EPT, shewn in plate IV, is regarded as the epipterygoid (columella cranii). It is curved but more so in its upper half than below. Its lower end is hidden but is apparently connected with the pterygoid. It passes upward with a diminishing diameter to the neighbourhood of the parietal, its slender upper termination pointing outward and slightly backward. A similarly curved bone, preserved in the smaller skull and exposed in the fractured posterior end of the specimen (not visible in the figures of plates I, II and III) is thought also to be the epipterygoid but its position relative to other bones of the skull cannot be ascertained except that it at present lies near the orbit.

As regards the mandible it affords information of considerable interest. The structure of the anterior half of the inner surface, as exhibited in the smaller skull, here finds corroboration. Also the relations to each other of the different bones entering into the composition of the posterior half are made clear, except on the inner side in the vicinity of where the splenial would be expected to meet the angular and these two the coronoid. The extent to which the angular is developed on the inner side is not known, the splenial has not been seen posteriorly, and the coronoid is hidden in the left ramus, and if preserved, even in part, in the right ramus it has not been recognized.

The greater part of each half of the jaw is preserved. The left ramus lies against the lower left half of the cranium so as to conceal its inner surface in the vicinity of the anterior half of the surangular, and the corresponding part of the right ramus is hidden by some of the bones of the palate. In both rami, unfortunately, a considerable part of the lower border is missing below the front part of the surangular.

The mandible of *D. incrassatus* is deeper in proportion to its length than that of *Ceratosaurus nasicornis*, otherwise the general contour in both species is somewhat similar.

The different bones of the mandible seen, wholly or in part, in this larger skull are :—the dentary, the surangular, the angular, the articular, the splenial and the presplenial.

The dentary, already known from the smaller skull to be a large and robust bone, is here found to extend backward to beneath the articular cotylus. After attaining its greatest depth at about its mid-length, where it meets the surangular above, it passes backward below that element and overlapping it posteriorly as a thin plate, terminates in an acute point (plate V). As already seen, the dentary, on the inner surface, occupies about one-half of the lower depth of the jaw anteriorly. Its depth diminishes gradually backward but the exact point where it disappears from the inner surface has not been ascertained. It is thus seen that the dentary of *Dryptosaurus* in the amount of its backward extension equals that of the dentary of *Sphenodon* and far surpasses that of *Ceratosaurus*.

The upper border of the surangular extends in a low sweeping curve forward from the articular cotylus above the level of which its highest point is but little elevated. This bone almost completes the remainder of the outer surface of the mandible, the posterior end of the angular being visible inferiorly to a limited extent with a still smaller surface of the articular shewing behind. It is strengthened exteriorly near its upper border, by a prominent rounded ridge extending for some distance forward from the articular cotylus into the composition of which it enters. A small boss of bone rises from the superior border within the back end of the ridge and in front of the outer end of the articular cotylus. The surangular embraces the articular anteriorly, and passing beneath it, extends as far back as the posterior limit of that element. It is pierced by a foraminal opening at about one-fourth of its length in advance of its back termination and at about its mid-depth; its inner surface in this region is deeply concave, fig. 21, plate VIII. Below the foramen the bone becomes gradually thinner, where it is overlapped by the dentary, and is continued forward with a thickness, inferiorly, of only a few millimetres, although posteriorly and along its upper border it is a strong and thick bone.

The articular is small and compact, roughly triangular in shape, and is scarcely seen except when viewed from above. It forms about two-thirds of the cotylus and is overlapped on its inner side by the angular, which extends nearly as far back as either the surangular or the articular. Its breadth exceeds its antero-posterior diameter.

The articular cotylus is transverse, deeply bifossate and evidently points to a strictly upward and downward motion of the jaw, as the distal end of the quadrate fits closely into it. The movement of the jaw is, therefore, restricted, and differs from that of *Sphenodon*, in which the articulating surface is nearly four times as great antero-posteriorly as the condyle of the quadrate and admitted of a backward motion of the mandible.

The slender bone meeting the surangular below the articular, and embracing the latter element on its inner surface, is regarded as the angular, of which mention has been already made. It passes forward on the inner surface of the ramus in contact externally with the inferior edge of the posterior extension of the dentary but is broken in both rami at a point slightly behind the mid-length of the surangular, unless, as is strongly suspected, its more anterior extension is seen more in advance at *l* plate V, where the border of a lamellar piece of bone ascends, corresponding with that part of the angular that would form the lower, and together with the coronoid the anterior border of the large vacuity in the inner surface of the ramus. The break in both halves of the jaw at this point is unfortunate, as it is here that the junction of the angular with the splenial would have been looked for. It is probable that anteriorly the angular increases very much in depth, reaching the coronoid above and the splenial in front.

In this specimen the front part of the splenial is displaced and its relation to the dentary and the presplenial is not so well shewn as in the smaller skull. The emargination of the bone behind suggesting the presence of a second splenial foramen is, however, very marked (*f*, plate V). Its narrow, pointed anterior termination, properly fitting below the back end of the presplenial, is seen passing up between the rami (S P, plate IV).

The presplenial and the inner alveolar plate of the dentary are seen in both rami but the hinder end of the former is hidden. In front, where the rami have separated slightly, the outline of the presplenial is obscure so that it is doubtful to what extent it passed forward although apparently it reached the symphyseal surface at least. The alveolar plate is slightly deeper than the presplenial and together they about equal in depth the inner development of the dentary below. As seen in the smaller skull the splenial passes behind the alveolar plate so as to materially reduce its depth near the termination of the dental series. In the larger specimen the alveolar plate, although its exact outline is not seen in front, is nevertheless considerably reduced in size anteriorly where it would be expected to join the dentary from without. The symphyseal surface is narrow and extends, with the direction of the anterior border of the mandible, obliquely upward and forward. The union of the rami as in all dinosaurs was ligamental. As has been already mentioned the inner alveolar border was at a slightly lower level than the outer border but the amount of difference in level is more exactly determinable in the smaller skull than in this specimen.

The outer surface of the mandible is rather smooth throughout and in this respect shews a marked difference to the jaw of the smaller skull in which the anterior part of the rami are decidedly rugose. The front portion of the surangular is striated as shewn in plate V. In the dentary a number of foramina are present, near its anterior lower border, of a size and in disposition, as indicated in the figure. Across this bone, at about its mid-length, a somewhat obscure row of shallow depressions extends upward and backward in an oblique curve as shewn in plate V above the anterior end of the break in the left ramus. This feature is suggested in the dentary of the smaller specimen but is too indistinct to be spoken of with certainty.

In *Megalosaurus* * the bony partitions separating the alveoli from each other are described as springing from the inner alveolar wall and projecting outward to the inner surface of the outer wall. The reverse of this seems to be the case in *Dryptosaurus*, in which the principal alveolar grooves are apparently formed on the inner surface of the outer dentary wall with little or no development of grooves in the alveolar plate. In this particular the alveoli of *Dryptosaurus* are slightly suggestive in general plan of structure of those of the dental chamber of the mandible of the Cretaceous species of *Trachodon* ** in which the teeth move upward in well defined grooves in the inner surface of the outer

* Trans. Geol. Soc., London, second series, vol. 1, p. 395, pls. XL and XLI, 1824 (full reference on p. 5) and "On the skull of Megalosaurus," by Professor Owen, Quarterly Journal Geological Society, London, vol. XXXIX, p. 339, pl. XI, 1883.

** Part II of this volume, p. 69.

wall of the dental chamber, whilst the surface of the inner wall of the chamber is comparatively even and smooth. The partitions between the alveoli in *Dryptosaurus* seem to form part of, and to be continuations or extensions of, the inner surface of the outer dentary wall, inward toward the dentary plate with which they are apparently not very strongly connected.

The teeth of this species (without reference to such as may be considered to be incisors) are carinated on their anterior and posterior edges, the carinations being minutely serrated, with about ten to twelve denticulations in a space of 5 mm. They are lenticular in section above (plate VI, figs. 9—14) but in passing downward a flattening of the anterior and posterior borders takes place and becomes more pronounced near the base of the crown, a slight flattening of the sides of the teeth also becoming more decided in the lower portion of the crown. The anterior carina passes gradually to the inner side of the crown whilst the posterior one is well over toward the outer side for the greater part of its length. The posterior keel extends downward for the whole length of the crown but the anterior one stops at about one-fourth the height of the crown from its base.

In the left ramus of the larger skull the crowns of all the teeth except the twelfth, *m*, plate V, are broken off close to the alveolar border leaving sections of their bases exposed at this level, so that the exact position of the teeth, in this half of the jaw, is definitely determined. In the right ramus, plate IV, however, seven of the teeth are preserved intact whilst the bases of the first four and of the eleventh remain in position.

In all the teeth of the mandible except the anterior one of either ramus, the antero-posterior diameter of the base of the crown is greater than the transverse diameter. In the front or first tooth the section of the base shews that the transverse diameter was equal to or if anything greater than the antero-posterior one.

No successional teeth have been observed, in the two skulls of *Dryptosaurus* from the Edmonton series, except one in the left maxilla of the larger specimen, *n*, plate V, and another in the right maxilla of the smaller one, not sufficiently conspicuous to be shewn in the figure, plate 1.

The lower end of the left quadrate, fig. 19, plate VII, is transversely elongate and fits closely into the two oblique depressions of the articular cotylus. Above its articular surface the quadrate contracts into a narrow neck, retaining a transverse diameter greater than the antero-posterior one. Its forward surface is slightly concave and when the bone is in position the neck is directed obliquely upward and forward. In the right ramus the inner surface of the quadrate, Q, plate V, is seen, but much crushed and probably distorted so as to give little accurate information as to its true shape, although it evidently was expanded above to some extent and reached the pterygoid.

In the palatal region the following elements are represented or more or less clearly seen, from below:—the basisphenoid, the basipterygoid processes of the basisphenoid (basipterygoids), the pterygoids, the right transpalatine (ectopterygoid) and the back half of the right palatine.

The pterygoids, PT, are moderately large bones, narrow anteriorly where they appear to meet in the middle line of the head. They are evenly rounded in front where their margins underlie the palatines. At a short distance behind their front ends they turn outward, become broader, and then pass obliquely backward toward the quadrates which they apparently reach. At about their mid-length they clasp the downwardly directed basipterygoids by means of a process that reaches back on the inner side of the basipterygoids, the main part of the bone by its abrupt curve outward passing on the outer side.

The basipterygoids, BT, are widely separated from each other; they are robust and point downward.

The basisphenoid, BS, is very much distorted but its posterior surface is seen to have two deeply depressed oval areas, one on either side of the axial line of the head, separated from the surface of the bone in front by a well defined transverse ridge.

The palatines, PL, appear to be in contact posteriorly where they are almost of the same breadth as the pterygoids anteriorly. This bone is of considerable size and broadens rapidly outward a short distance in advance of its back termination. In front it is apparently separated from its fellow by a space; it is here quite thin but farther back it appears to be robust and thick.

The transpalatine, TPL, is a strong, curved bone lying against the outer edge of the pterygoid, connecting apparently in front with the palatine and laterally with the maxilla. At the side, presumably near its connection with the maxilla, it becomes thin and lamellar. A hook-shaped process is directed downward from the anterior border of the hinder part of its curve. This bone agrees in general shape with the transpalatine of *Ceratosaurus nasicornis* as described by Marsh.

The supposed internal nares (IN, plate IV) is shewn in this specimen on the inner side of the anterior end of the palatine between it and fragments of bone that are thought to represent the posterior ends of the paired vomers (prevomers), VO, plate IV. That this is the true interpretation of this opening and of the elements between which it lies is probable, taking into consideration as well the corroboration found in the position of the internal nares in the smaller skull. The opening behind the palatine and in advance of the transpalatine (SOV, plates IV and V), referred to as the suborbital vacuity on page 10, is seen also in the smaller specimen (plates I and II). To what extent the palatines meet in the median line, if they meet at all, is extremely doubtful. The position of the supposed prevomerine fragments in the larger skull and the more perfectly preserved bone (*b*) in the smaller one leads to the belief that if the palatines did effect a junction it was of a limited extent. The prevomers were probably well developed and posteriorly may have extended backward between the internal narial openings almost to the pterygoids.

The composition of the palate in this species may be summarized as follows:—pterygoids of fair size, embracing the basipterygoids, extending back to effect a junction with the quadrates, and leaving an interpterygoid vacuity in which the vomer (parasphenoid) lies. Transpalatines narrow and much curved, connecting the pterygoids with the maxillæ and apparently reaching the palatines in front. Palatines broadly transverse uniting with the pterygoids and maxillæ, possibly meeting to a limited extent in the median line, enclosing, with the transpalatines and the ? maxillæ, a large surborbital vacuity on either side. Prevomers apparently of large size, doubtfully meeting the pterygoids behind separating the internal nares, and probably uniting with the maxillæ and premaxillæ in front.

Measurements of larger skull,

	MM.
Extreme length of specimen (length of left ramus, 38 inches)	970
Distance between maxillæ slightly in advance of their posterior terminations	332
Length of suture preserved between maxilla and jugal on left side	185
Length of same suture preserved on right side	160
Maximum breadth of occipital condyle	69
Height of same at mid-breadth	46
Width of foramen magnum	32
Height of same	36
Breadth of basi-occipital	50
Thickness of lateral flange of exoccipital	21
Distance from articular face of occipital condyle to anterior end of parietal ridge.	250
Distance between inner surfaces of supratemporal vacuities (approx.)	107
Width of pituitary foramen from front to back at mid-length	11
Length of same	22
Greatest depth of left ramus (approx.)	227
Length of dentary	905
Maximum depth of dentary at its mid-length (approx.)	185
Thickness of left ramus at mid-height anteriorly, below sixth tooth	52
Length of superior border of surangular	490
Thickness of surangular through the ridge near its upper border	33
Thickness of surangular above the ridge	23
Thickness of surangular below the ridge	14
Height of surangular foramen	38
Width of same	33
Width of posterior end of angular	50
Width of same at *o*, fig., 21 plate VIII	30
Thickness of same at same point	23
Transverse diameter of articular cotylus	112
Thickness of ramus from upper surface of cotylus, at its mid-length, to lower surface of dentary	42
Combined thickness of dentary and surangular at *p*, fig. 20, plate VIII	10
Length of crown of fifth tooth of right ramus	54
Breadth of base of crown of same	28
Thickness of base of crown of same	18
Length of crown of twelfth tooth of right ramus	46
Depth of inner alveolar plate of dentary below sixth tooth	31
Depth of presplenial below same tooth	29
Length of splenial foramen	68
Height of same	37
Distance between splenial foramina	55
Breadth of pterygoid at its anterior end (approx.)	45
Breadth of same in advance of basipterygoid	85
Breadth of exposed portion of palatine a short distance in advance of its posterior end	57
Breadth of transpalatine near the front end of pterygoid	40
Length of hooked process of pterygoid (imperfect at lower end)	75

Tibia and Astragalus.

The distal end of the right tibia, embraced below by the astragalus, is shewn in plate VI, figs. 6, 7 and 8. This specimen was found with the smaller skull and shews that the two bones were not co-ossified, at least below.

The tibia above its rounded distal end is nearly rhomboidal in transverse section. The anterior surface is shallowly excavated to receive the astragalus and its ascending process; the posterior surface is plane. The inner and outer sides of the bone, corresponding with the ends of the rhomboid, are oblique, the posterior surface, internally, bending at an obtuse angle forward, the anterior surface, externally, being inclined obliquely backward. The lateral edges of the bone are sharp and its greatest antero-posterior thickness is near the inner side. The lower end of a concavity, evidently extending up into the shaft, is visible in the fractured upper surface of the specimen; it is filled with iron-stone and is shewn, in fig. 7, plate VI, by the dark area.

The astragalus fits closely against the tibia below and in front. Its form is that of a transversely elongated plate curving round the lower end of the tibia, constricted at its mid-length, evenly rounded toward either end, and terminating behind in a thin edge. In front a broad, lamellar process, comparable in relative size with that of *Ornithomimus*, ascends closely applied to the anterior surface of the tibia, between which and the upper part of the process there may possibly have been a certain amount of co-osssification although below the two bones remain distinct. A wide transverse groove or concavity occurs in the lower part of the ascending process accentuating its junction with the basal portion. In this groove and in the constricted middle part in front, a number of vertical, linear depressions, shallow pits and small foramina are conspicuous. At the outer end a well defined concave area marks the position of the calcaneum which is missing.

Overlooking the difference in size, there is a remarkable resemblance between the astragalus of this species and that of *Ornithomimus altus*. The inner and outer ends are more oblique to the transverse axis of the bone than in *O. altus*, also it does not overlap the tibia behind to so great an extent. In *O. altus* the astragalus does not coalesce with the tibia, and there are two facets in the upper border of the calcaneum, one behind to aid the astragalus in supporting the tibia, the other in front for the distal end of the fibula.* In *D. incrassatus* the calcaneum evidently contributed only to the support of the fibula.

Measurements of tibia and astragalus.

	MM.
Combined thickness of tibia and astragalus near outer side	102
Combined thickness of tibia and astragalus at outer side of centre (where latter is most constricted)	77
Combined thickness of tibia and astragalus near inner side	119

Tibia.

Breadth of distal end	248
Breadth at fractured upper end of specimen	130
Approximate thickness at centre of fractured upper end of specimen	55
Maximum thickness near outer side	46
Breadth below of oblique surface of inner side	106
Breadth below of oblique surface of outer side	55

* Part II of this volume p. 50, fig. 11.

Astragalus.

	MM.
Breadth of articular face ; equals that of distal end of tibia	248
Breadth of ascending process below	154
Breadth of same where fractured above (approx.)	90
Thickness of same above, near outer side	13
Thickness of same above, near inner side	3
Maximum thickness in front of tibia, at outer side	55
Maximum thickness in front of tibia, near inner side	42
Thickness below tibia at outer side	22
Thickness below tibia at inner side	39
Height of facet for calcaneum	76
Breadth of facet for calcaneum	32

Metatarsal.

The metatarsal figured in plate VII also goes with the smaller skull ; it is remarkable for its length and slenderness and is regarded as the second of the right limb. It is laterally compressed above, has a straight shaft and near its lower end is bent suddenly inward away from Mt. III. The shaft is narrowly rounded in front and flattened on the side that would come next to Mt. III indicating a close approximation of the bones of the metatarsus to one another. This lateral flat surface is rugose and meets the posterior surface, which is also rather flat, in a decided angulation that is conspicuously prominent (at *a*, fig. 18, plate VII) above the sudden inturn of the bone below. The proximal articular surface is flat and antero-posteriorly elongated with a length about twice the breadth, the distal articular surface is rounded and produced well up in front and behind, pointing to a considerable flexibility at this joint. There are well marked vascular grooves and pits in both articular surfaces. Externally the distal end is deeply excavated, posteriorly a shallow groove (*b*, fig. 18) passes upward from the articular surface ; viewed from below it is semicircular in outline, flat externally and curved on the inner side. On the inner posterior surface of the shaft, below its mid-height, a roughened vertical groove, *c*, marks the position of the distal half of Mt. I, the position of whose lower end is indicated by the raised surface at *d*. The first digit or hallux would thus be directed inward and backward in a manner similar to that of the grasping toe of *Allosaurus* first described by Osborn * in 1899.

It is probable that the shaft of Mt. I was interrupted at its mid-height. A slight roughening of the surface of Mt. II near its upper end (*e*, fig. 18) no doubt indicates the position of the proximal half of Mt. I. The greater portion of one of the tarsal bones remains and is shewn at *f*.

Measurements of metatarsal.

	MM.
Length	505
Antero-posterior diameter of upper articular face	135
Transverse diameter of same	60
Antero-posterior diameter of lower articular face	88
Transverse diameter of same	65

* Bulletin of the American Museum of Natural History, Vol. XII, article XI, pp. 161–172, 1899, "Fore and Hind Limbs of Carnivorous and Herbivorous Dinosaurs from the Jurassic of Wyoming."

As regards the total length of the skeleton of *Dryptosaurus incrassatus*, from the end of the muzzle to the last joint of the tail, it can safely be said to have been in the neighbourhood of 30 feet. In the Upper Jurassic *Ornitholestes hermanni*, *Osborn, of which the skeleton is practically complete, Mt. IV measures 4⅜ inches in length and the total length, from the muzzle to the tip of the tail along the vertebral column, is 7 feet 3½ inches. Using the length of the metatarsus as compared with the total length as a basis for calculation, by the rule of proportion, a length of 33 feet is obtained for *D. incrassatus*. In a similar manner the length of *Ornithomimus altus*** was estimated to be 22 feet. Sir Richard Owen gives the length of *Megalosaurus bucklandi* *** as 30 feet and Cope that of *D. aquilunguis*† as 17 feet 4 inches. According to Marsh *Ceratosaurus nasicornis*,†† an animal much smaller than *D. incrassatus* (the length of the head in the two species being respectively 26 and 38 inches) was about 22 feet long when alive.

In the light of our present knowledge of the large carnivorous dinosaurs, a length of 17 feet 4 inches for *D. aquilunguis* is probably much below the mark. Professor Cope's estimated length of 18 inches for the metatarsus would give about 30 feet as the total length of the animal.

Ungual Phalanges.

Of the remains found with the smaller skull three ungual phalanges need mention; they are very similar in size and shape, the largest and best preserved one being figured in plate VII.

Judging from the size of the terminal phalanges of the pes of other large carnivores, these would appear to belong to the manus. The largest clawbone of the foot of *Allosaurus fragilis*††† Marsh is nearly 6 inches long, whilst Cope figures a corresponding bone of *D. aquilunguis*‡ that has a length of almost 8 inches measured in a straight line from the tip to the upper edge of the articular surface (or over 9½ inches along the upper curve between the same points). The phalanx of *Dryptosaurus* figured in plate VII, measures about 4¼ inches in a straight line from the tip to the upper articular margin (or 4¾ inches along the upper curve). This would represent large and powerful claws to the manus much larger in proportion to the size of the animal, than those of the manus of *Allosaurus*, *Ceratosaurus* and other allied forms. As regards the possibility of their belonging to the pes, they do not appear to be in keeping with the size and evident strength of the hind limb.

The phalanx, fig. 16, plate VII, is stout, subtriangular in transverse section, sharply pointed in front and curved so that the tip points almost directly downward when the plane of the articular face is vertical. The lower surface is slightly convex in a transverse direction but concavely curved longitudinally. The upper surface is laterally compressed so as to be angularly rounded along the median line. The greatest depth, behind the mid-length, is about equal to the maximum breadth. On the lower side posteriorly there

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* Bulletin of the American Museum of Natural History, Vol. XIX, article XII, pp. 459-464, 1903.

** Part II of this volume, pp. 18 and 53, 1902.

*** Palæontographical Society, Monograph on the fossil reptilia of the Wealden and Purbeck formations, pt. III, p. 25, 1857.

† Transactions of the American Philosophical Society, Philadelphia, Vol. XIV, pt. I, Synopsis of the extinct Batrachia and Reptilia of North America, pp. 108 and 113, 1870.

†† American Journal of Science and Arts, Vol. XLIV, p. 347, plate VII, 1892. Restorations of Claosaurus and Ceratosaurus.

††† American Journal of Science and Arts, Vol. XXVII, 1884. Principal characters of American Jurassic Dinosaurs, plate XII.

‡ Transactions of the American Philosophical Society, Philadelphia, Vol. XIV, pt. I, pl. X, fig. 2, 1870.

is a roughened transverse tuberosity, *a*, of rather small size, for the attachment of the flexor tendon. This tuberosity is separated from the lower border of the articular surface by a well defined groove *c*, that passes upward on each side of the bone and curves forward, with greater distinctness, to the tip. Laterally at mid-length, beneath the groove, the bone is expanded outward into a prominent ridge, *b*, that materially increases the area of the inferior surface. The phalanx, when viewed from above, inclines to the right. The articular surface is shallowly concave and has a median groove directed from its lower border upward. For a short distance in advance of the sharp edge of the articular face the surface of the bone is longitudinally striated and subrugose, elsewhere with the exception of the tuberosity beneath, the bone is rather smooth.

Measurements of ungual phalanx of manus.

	MM.
Distance in a straight line from tip to upper edge of articular face	109
Distance from tip along upper curve to upper edge of articular face	122
Maximum breadth (behind mid-length)	42
Maximum height, from lower surface of posterior tuberosity to upper border	41
Height of articular face	40
Maximum breadth of same	35

Ilium.

With the smaller skull was also found part (about half) of the left ilium against which are crushed the neural arches and spines of three sacral vertebræ. The neural spines are well co-ossified; the central one is much greater in its antero-posterior diameter than the third, and apparently also than the first which is imperfect in front. The spines are striated above in a vertical direction on their exposed right lateral surfaces; they are broken off in a line with the upper border of the ilium. The ilium itself is broken in front, below and behind but intact above. The part represented in the specimen extends from above the acetabulum for some distance backward. It is thin and plate-like presenting a smooth surface exteriorly; it is slightly concave at the centre and developes a prominent ridge posteriorly below. Beneath the ridge the bone is conspicuously excavated, evidently above and in close proximity to the ischiac attachment. The acetabular border is not included in the specimen. In lateral aspect the upper border has a very slightly arched curve; it is rendered rugose by decided striations directed upward and slightly backward. The portion of the ilium remaining measures 303 mm. in height and 370 mm. in length. The middle neural spine measures 138 mm., from front to back, near its upper end, and the posterior one 95 mm.; the anterior one is incomplete. *Megalosaurus* had five co-ossified sacral vertebræ of which the second, third and fourth neural spines united above. *Dryptosaurus* had at least three, and possibly five vertebræ, included in the sacrum.

Some of the chief points of difference in the interpretation and enumeration of the elements and openings of the skull of *Dryptosaurus incrassatus* as set forth, in the preliminary description by Professor Cope in 1892, and in the present description, may be conveniently summarized, in tabular form, as follows:—

Preliminary description.	*Present description.*
Orbit.	Preorbital vacuity.
Preorbital foramen.	Anterior preorbital vacuity.
Frontal.	Nasal region : nasals not recognized.
Prefrontal.	Nasal region.
Postfrontoörbital.	Prefrontal. (? + lachrymal).
{ Epipterygoid. + Postoptic.	Palatine.
Orbitosphenoid.	Prevomer.
Surangular: extends to border of articular cotylus.	Surangular : enters into composition of articular cotylus.
Splenial.	Presplenial.
Opercular (of Cuvier).	Splenial.
Dentary + Angular in part.	Dentary.
Angular.	In part posterior portion of dentary.
Articular.	Articular + Angular.
Articular cotylus : not bifossate.	Articular cotylus : bifossate.

The above discrepancy in the determination of the bones of the skull is no doubt due to the fact, that the preorbital vacuity was regarded as the orbit, leading to the naming of a number of the elements in accordance with that idea. Also the removal, lately, of the matrix in certain parts, notably from the articular cotylus and from the inner side of the left ramus in the larger skull, has facilitated the further study of the specimens.

In the preliminary description this species is characterized as differing from *Ceratosaurus nasicornis* "in the much larger and more anteriorly placed orbits, and in the much smaller preorbital foramen."

According to the present writer's conclusions the skull of this species differs in a marked degree in certain directions from both that of *Ceratosaurus* and *Creosaurus*. Too little is known of the skull of *Megalosaurus* to allow of a general comparison. In comparing *Ceratosaurus* with *Dryptosaurus* the differences are not to be looked for in the position of the orbit which is placed similarly in both genera, but rather in the size, form and disposition of the various bones and the openings they enclose. Particularly is the variance apparent in the construction of the lower jaw. As regards the prominent nasal horn core of *Ceratosaurus*, a comparison here fails, as the specimens of *Dryptosaurus* are deficient in the nasal region. The apparent absence of an anterior preorbital vacuity in *Ceratosaurus* may be noticed as well as the relative shortness of the dentary bone. In *Dryptosaurus* the position of the foramen, piercing the surangular in its hinder part is peculiar; this opening is apparently represented, in the jaw of *Ceratosaurus*, by the larger and more anteriorly placed foramen in a position similar to that of the *external mandibular foramen* of the crocodile. There are reasonable grounds for supposing that there were twelve teeth in the maxilla of *Dryptosaurus* as compared with fifteen in *Ceratosaurus* also the lower jaw is larger, in comparison with the rest of the skull, in the former species than in the latter.

In *Creosaurus* there are three preorbital vacuities, two placed as in *Dryptosaurus* and an additional one of small size between the premaxilla and the maxilla. The skull is higher, in proportion to the length, than in *D. incrassatus* but in the attempted restoration of the skull (fig. A p. 25) of the Cretaceous species it is possible that sufficient allowance has not been made for the crushing from above to which the specimens have been subjected. So far as a comparison can be carried out the general disposition of the different elements are remarkably similar but when examined in detail the proportions of the bones and their enclosed fossæ are different throughout resulting in the Cretaceous type in a more depressed form of skull.

FIG. A.—Restoration of the skull of *Dryptosaurus incrassatus*; left lateral aspect; two fifteenths, or slightly more than one-eight, the natural size. The dotted lines indicate the restored parts.

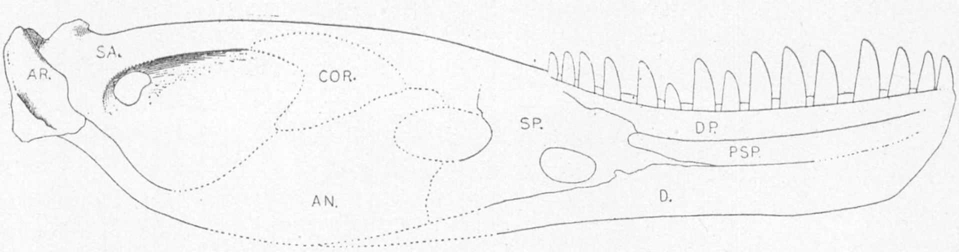

FIG. B.—Inner view of the left ramus with the coronoid and the anterior end of the angular restored.

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PLATE I.

PLATE I.

Dryptosaurus incrassatus (Cope).

Fig. 1. Skull of smaller specimen, superior view; one-third natural size. Page 8.

APV, anterior preorbital vacuity; IN, internal nares; J, jugal; L, lachrymal; M, maxilla; O, orbit; PF, prefrontal; PM, premaxilla; PMS, premaxillo-maxillary suture; POB, postorbital bar; PV, preorbital vacuity; SOV, surborbital vacuity; *a*, posterior border of postorbital bar; *b*, prevomer; *c* + *d*, palatine.

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X⅓

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HELIOTYPE CO.

PLATE II.

PLATE II.

Dryptosaurus incrassatus (Cope).

Fig. 2. Skull of smaller specimen, lateral view, seen from the left; one-third natural size. Page 8.

APV, anterior preorbital vacuity; IN, internal nares; J, jugal; L, lachrymal; M, maxilla; O, orbit; PF, prefrontal; POB, postorbital bar; PV, preorbital vacuity; SOV, suborbital vacuity; *a*, posterior border of postorbital bar; *b*, prevomer; *c* + *d*, palatine.

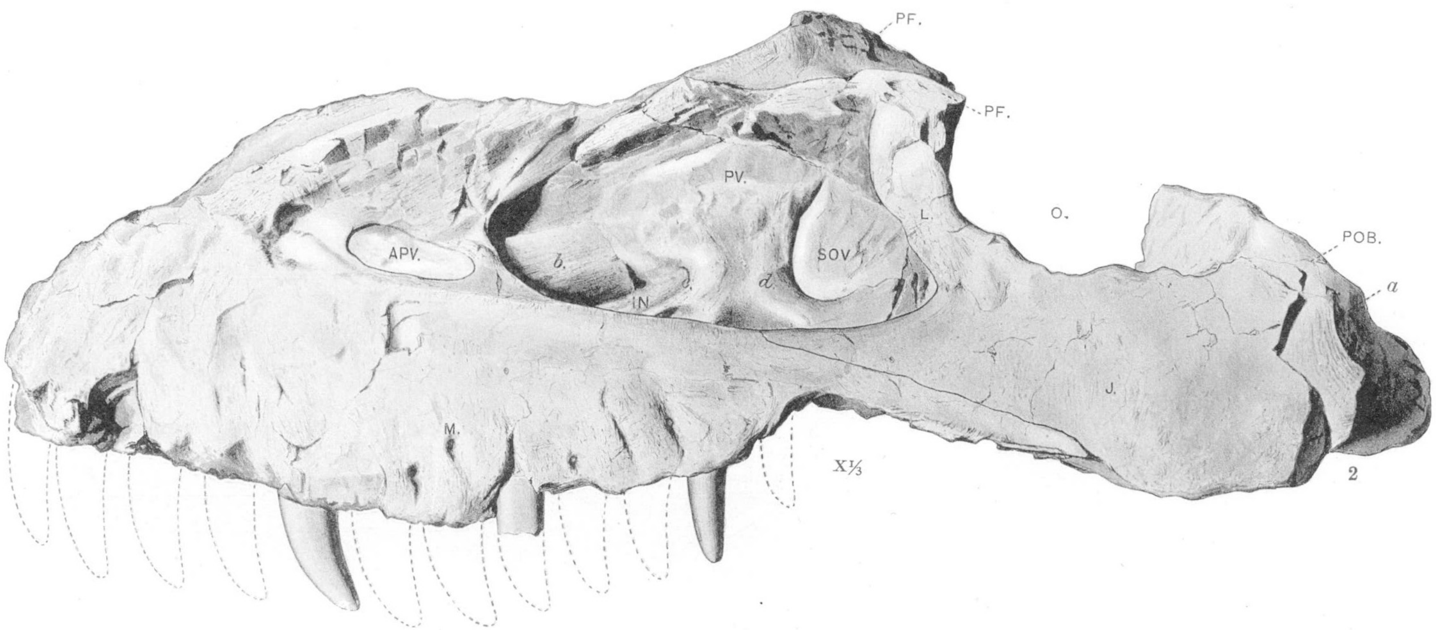

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PLATE III.

PLATE III.

Dryptosaurus incrassatus (Cope).

Fig. 3. Skull of smaller specimen; left lateral aspect of mandible lying beneath the cranium, shewing the outer side of the left ramus and the inner side of the right ramus; one-third natural size. Page 8.

D, dentary; DP, inner alveolar plate of dentary; J, jugal; M, maxilla; PSP, presplenial; SA, surangular; SP, splenial; *e*, anterior tooth of dentary; *f*, anterior margin of ? second splenial foramen; *g*, position of tooth in right ramus.

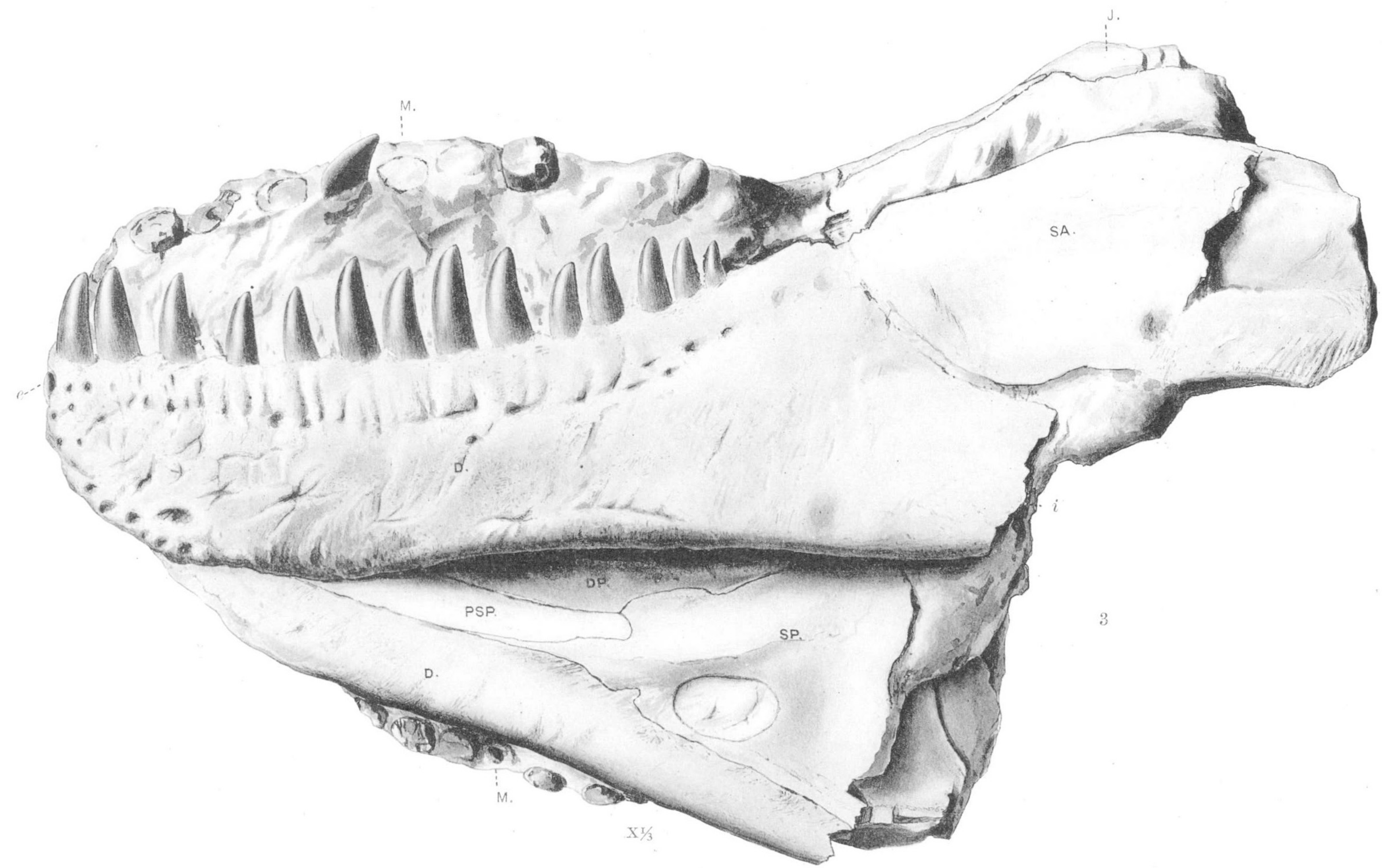

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PLATE IV.

PLATE IV.

Dryptosaurus incrassatus (Cope)

Fig. 4. Skull of larger specimen, shewing superior view of cranium, obliquely from the right, and right lateral aspect of right ramus. Top of cranium inperfect and muzzle missing. Four-fifteenths, or slightly more than one-fourth, natural size. Page 12.

AN, angular ; AR, articular ; D, dentary ; DP, inner alveolar plate of dentary ; EO, exoccipital ; EPT, epipterygoid ; IN, internal nares ; J, jugal ; L, lachrymal ; M, maxilla ; O, orbit ; OC, occipital condyle ; P, parietal ; PL, palatine ; PS, vomer (parasphenoid) ; PSP, presplenial ; PV, preorbital vacuity ; Q, quadrate ; SA, surangular ; SOV, suborbital vacuity ; SP, splenial ; VO, prevomer ; V, VII, VIII, exits of cranial nerves ; *h*, parietal surface of right supratemporal vacuity ; *k*, suture between maxilla and jugal ; *m*, twelfth tooth ; * position of pituitary foramen.

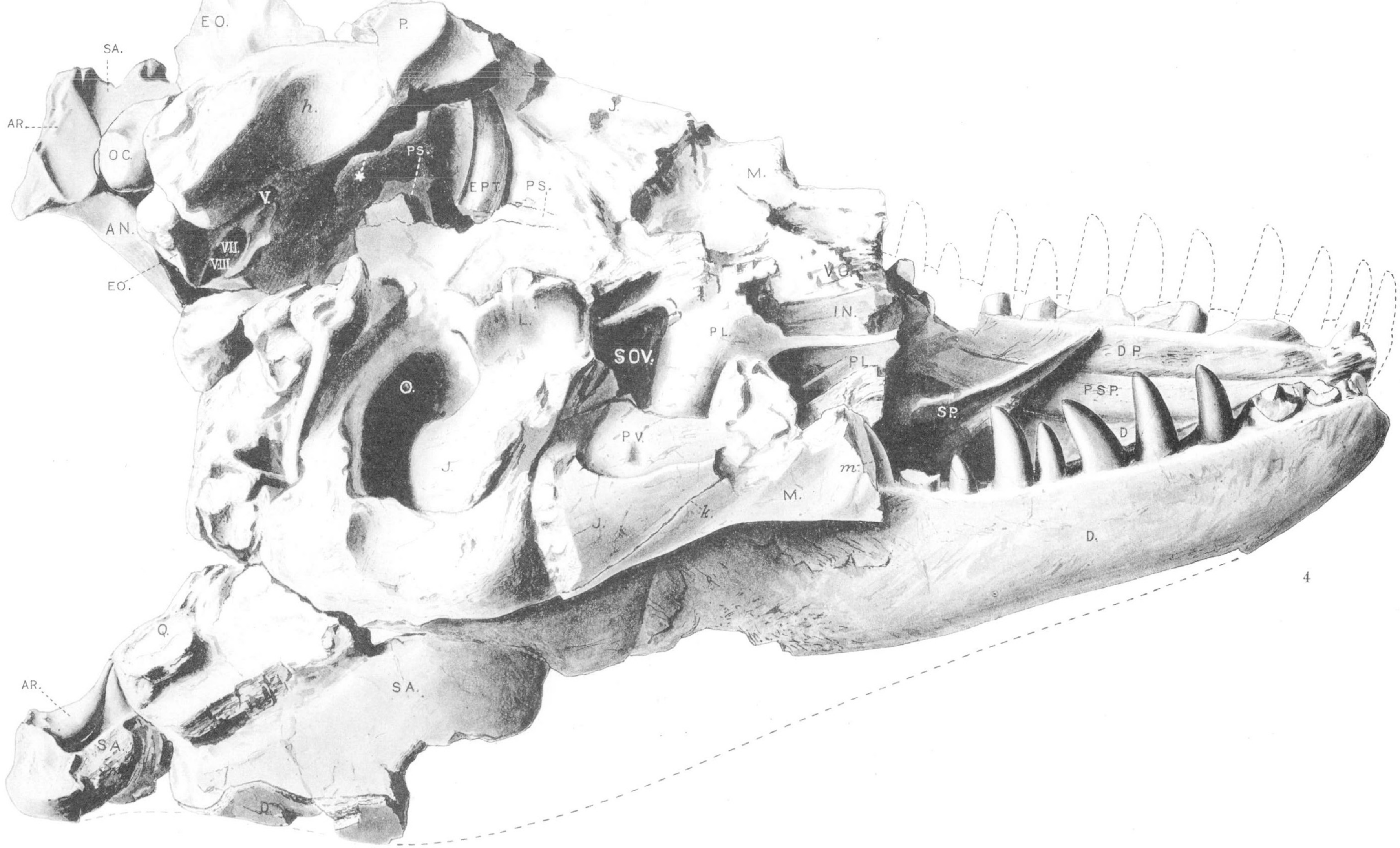

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PLATE V.

PLATE V.

Dryptosaurus incrassatus (Cope).

Fig. 5. Skull of larger specimen ; mandible, seen from the left, lying beneath the cranium, shewing the exterior surface of the left ramus and the interior surface of the right ramus. Four-fifteenths, or slightly more than one-fourth, natural size. Page 12.

AN, angular ; AR, articular ; BT, basipterygoid ; D, dentary ; DP, inner alveolar plate of dentary ; EO, exoccipital ; J, jugal ; M, maxilla ; PL, palatine ; PSP, presplenial ; PT, pterygoid ; Q, quadrate ; SA, surangular ; SOV, suborbital vacuity ; SP, splenial ; TPL, transpalatine ; *f*, anterior margin of ? second splenial foramen ; *k*, suture between maxilla and jugal ; *m*, twelfth tooth ; *n*, maxillary tooth with successional tooth above ; *BS*, basisphenoid.

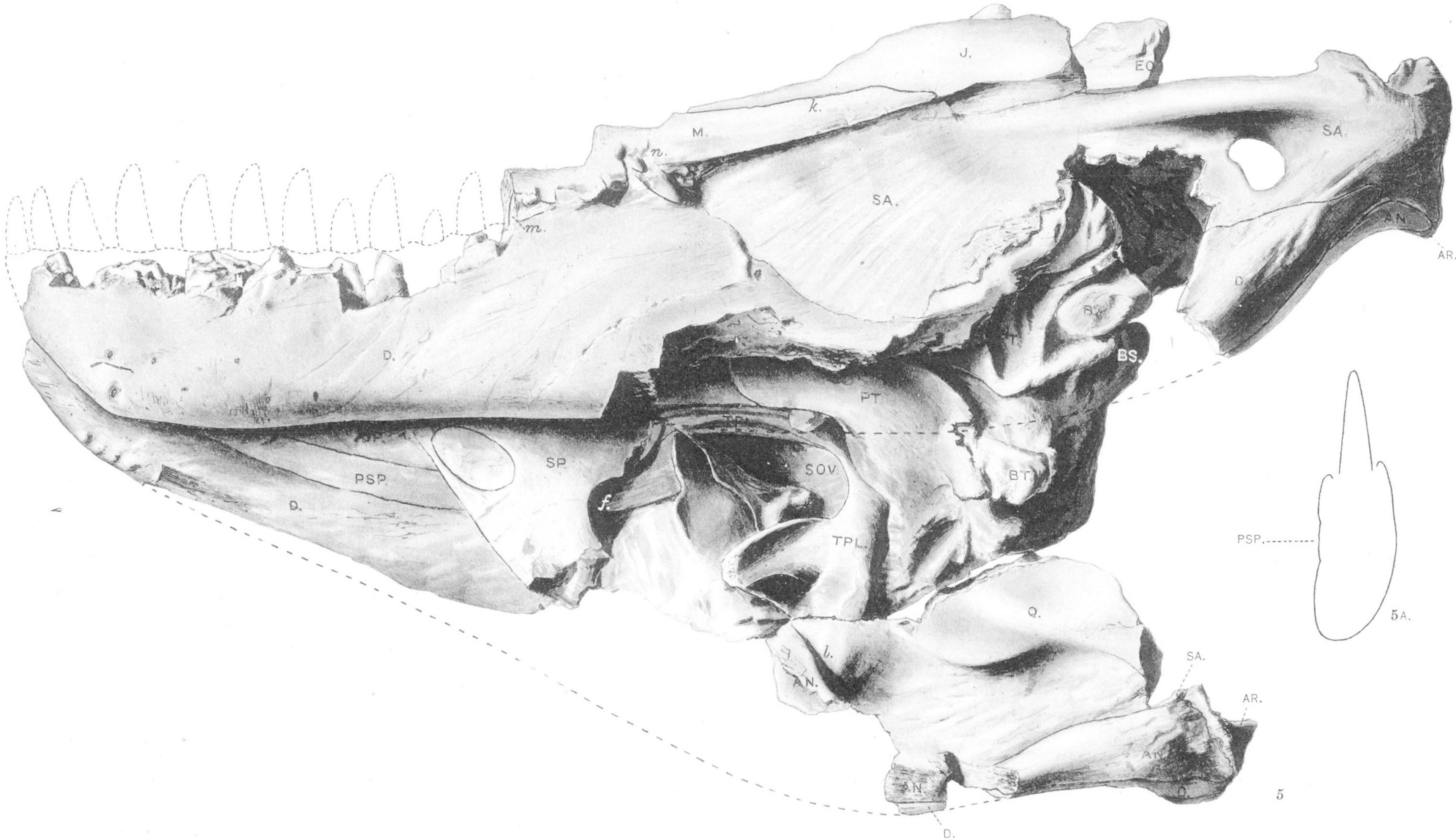

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PLATE VI.

PLATE VI.

Dryptosaurus incrassatus (Cope).

Fig. 6. The astragalus embracing the distal end of the right tibia and shewing the ascending process; anterior view. One-half natural size. Collected with the smaller skull. Page 20.

Fig. 7. Posterior view of the same; one-half natural size.

Fig. 8. Left lateral aspect of the same; one-half natural size.

Fig. 9. External lateral aspect of crown of tooth, collected with the smaller skull, natural size, with a few of the denticles enlarged four times. Pages 11 and 17.

Fig. 10. Outline of transverse section of same tooth, at about one-third the height of the crown below the apex; natural size.

Fig. 11. Outline of transverse section of same tooth at a little below the mid-height of the crown; natural size.

Fig. 12. Outline of transverse section of same tooth, near the base of the crown; natural size. In the outlines of sections, shewn in figs. 10, 11 and 12, the upper side corresponds to the outer surface of the tooth and the end to the right to the anterior border of the crown.

Fig. 13. Anterior view of crown of same tooth; natural size,

Fig. 14. Posterior view of crown of same tooth; natural size.

A, astragalus; AS, ascending process of astragalus; T, tibia

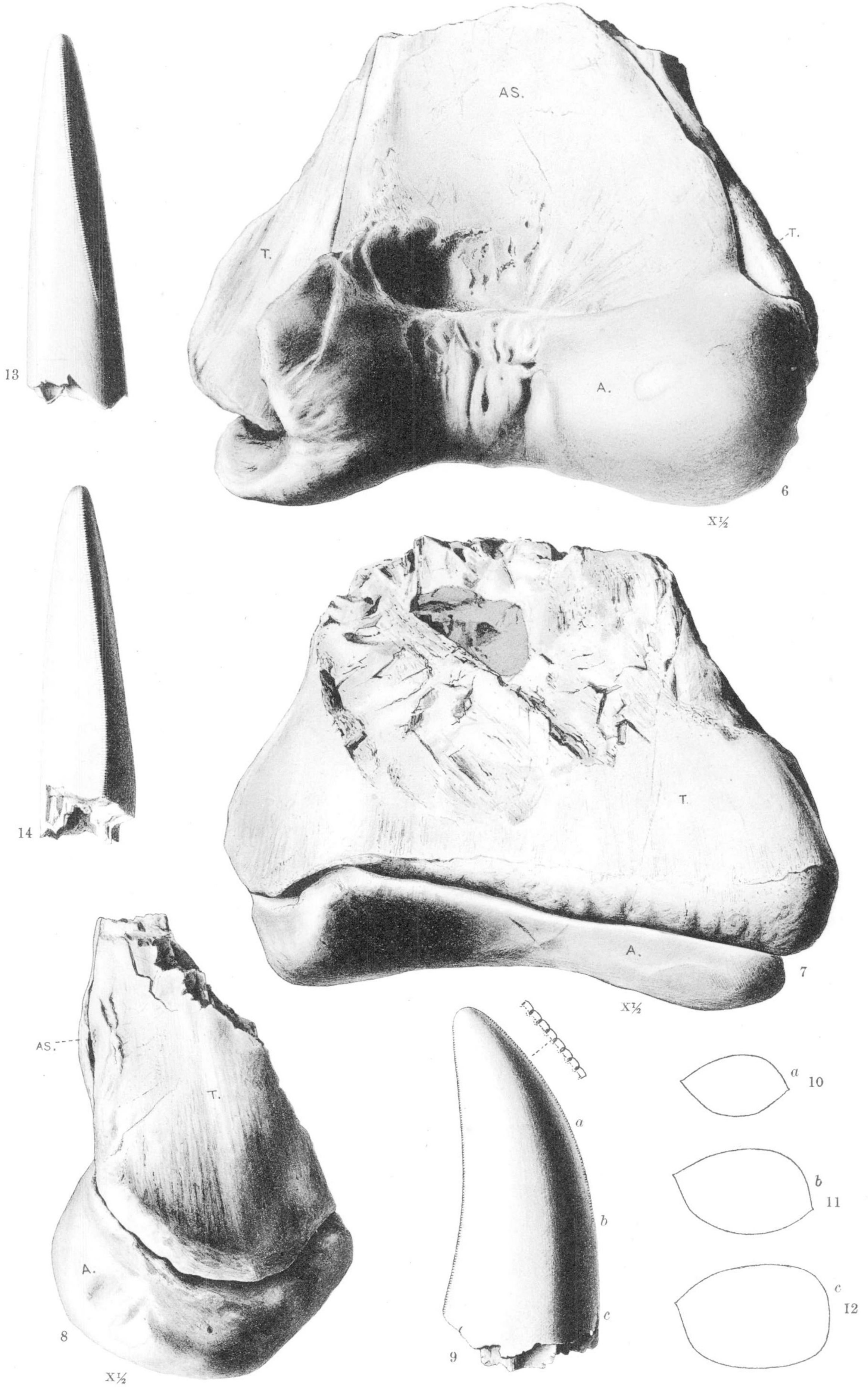

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PLATE VII.

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PLATE VII.

Dryptosaurus incrassatus (Cope).

Fig. 15. Occiput of larger skull, posterior view, shewing the occipital condyle and foramina; one-half the natural size. Page 13.

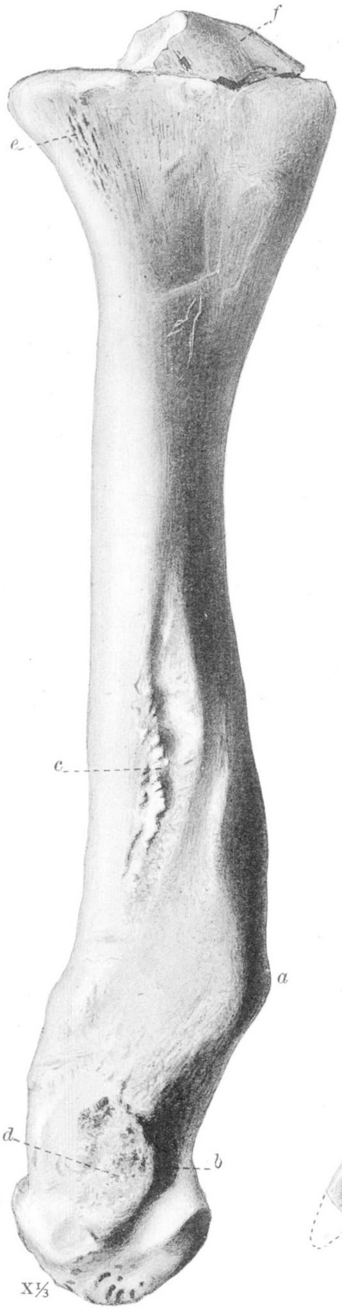
Fig. 16. Ungual phalanx of manus; found with the smaller skull. Natural size. Page 22.

Fig. 17. The same phalanx, viewed from behind, shewing the articular face; natural size.

Fig. 18. Metatarsal II of right limb; left lateral aspect obliquely from behind. One-third natural size. Found with the smaller skull. Page 21.

Fig. 19. Distal end of left quadrate of larger skull; anterior view. One-half natural size. Page 17.

BO, basi-occipital; CF, carotid foramen; EO, exoccipital; FM, foramen magnum; OC, occipital condyle; X, XI, XII, exits of cranial nerves.



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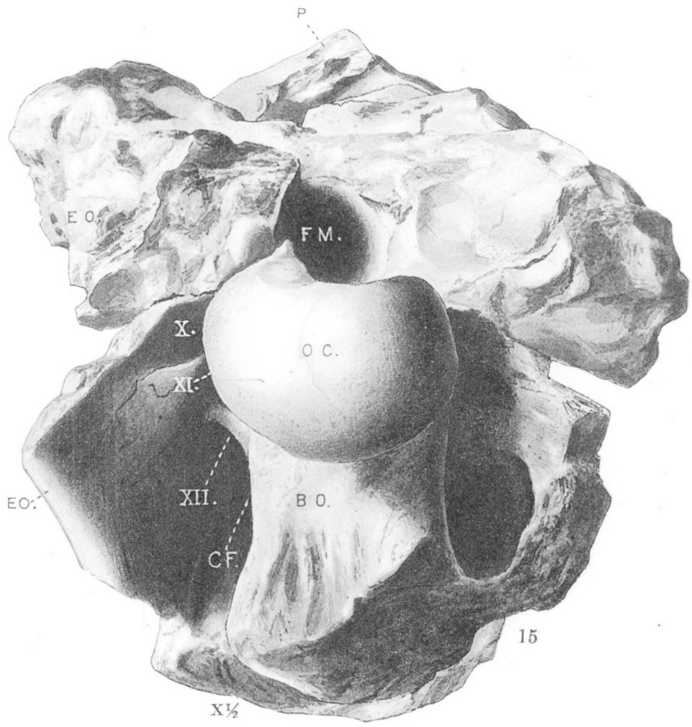

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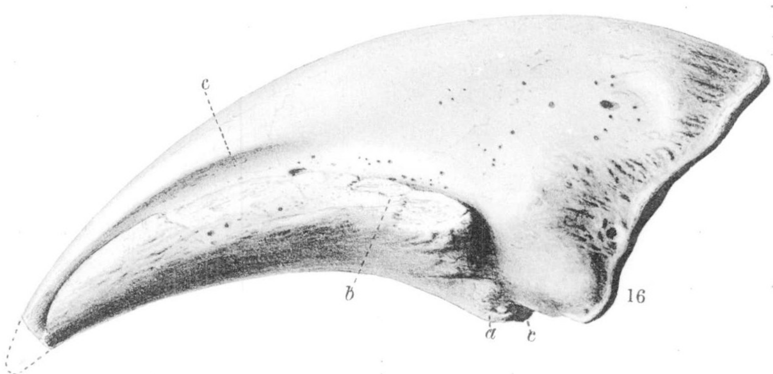

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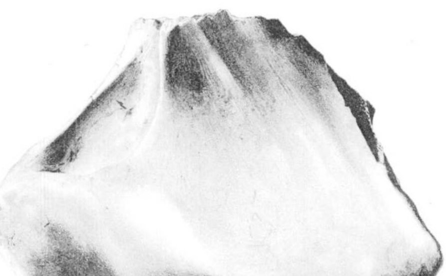
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X½

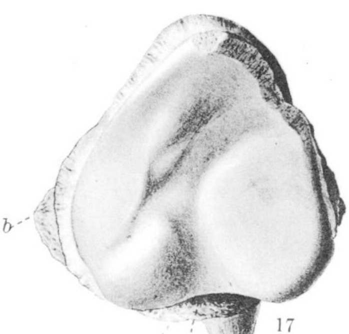

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PLATE VIII.

PLATE VIII.

Dryptosaurus incrassatus (Cope).

Fig. 20. Exterior aspect of posterior end of left ramus of larger skull; one-half natural size. Page 14.

Fig. 21. Interior view of the same; similarly reduced.

Fig. 22. Pituitary foramen, as seen in larger specimen, from below; natural size. Page 14.

PN, pituitary foramen; III, exit of oculomotor nerve; *k*, keel; *a*, anterior end.

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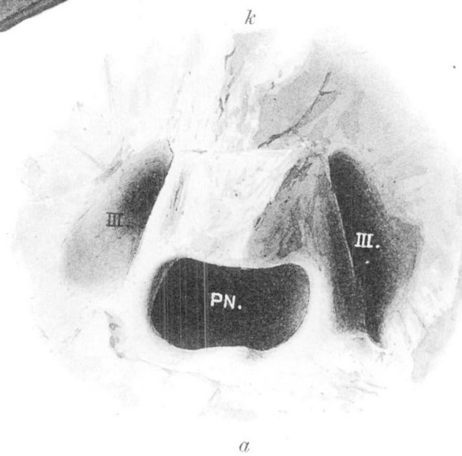

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