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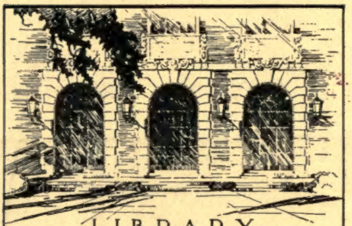

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PUBLICATION 73.

GEOLOGICAL SERIES. VOL. II, NO. 1.

NORTH AMERICAN PLESIOSAURS.

PART I.

BY

SAMUEL W. WILLISTON, M.D., PH.D.,
Associate Curator, Division of Palæontology;
Professor of Palæontology, University of Chicago.

OLIVER C. FARRINGTON, PH.D.,
Curator of Geology.

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CONTENTS.

	Page
Introduction,	3
Bibliography and catalogue of North American Plesiosaurs,	7
Dolichorhynchops osborni Williston. Description of skeleton, with restoration,	13
Cimoliasaurus snowii Williston. Description of skull and neck,	52
Brachauchenius lucasii Williston. Description of skull, vertebræ and ribs,	57
Polycotylus latipinnis Cope. Description of paddle,	67
Polycotylus ischiadicus Williston. Description of pelvis,	72
Plesiosaurus gouldii Williston. Description of dorsal vertebra,	72
Propodial bones of young Plesiosaurs from the Cretaceous of Kansas,	73
A peculiar food-habit of the Plesiosaurs,	75
Plates I to XXIX,	79

INTRODUCTION.

There are few orders of reptiles, so long and so widely known as are the plesiosaurs, of which our knowledge is more unsatisfactory. It has been within the past decade only that a tolerably complete knowledge of any form has been obtained, thanks largely to the researches of Seeley, Dames and Andrews. Especially is our ignorance of the American forms yet great. Very few figures or adequate descriptions have been published of our numerous and diverse types. Not only are the specific characters of the descriptions almost wholly undecipherable, but the generic characters even can be satisfactorily made out in but few. Thirty-two species and fifteen genera have been described from the United States, and in not a single one of them has there been even a considerable part of the skeleton made known. The skull is known in but three species, and in only one has there been any description of it. With the exception of a sketch of the incomplete girdles of *Elasmosaurus platyurus*, and of a few limb bones by Leidy, with an outline figure of a *Megalneusaurus* paddle by Knight, nothing of the extremities has been published. And yet, specimens of plesiosaurs are not at all rare in American deposits and collections.

Although most of the genera and species of the United States have been founded on such scant material, and even more scanty descriptions, that their identification is almost impossible, except by actual comparison of the type specimens, it is not at all improbable that nearly all the names which have been proposed will eventually be found valid. The group has a wide geological range, from the Jurassic to the uppermost Cretaceous, nearly every epoch being represented by one or more species.

The writer has for some time given such attention as his duties permitted to the study of the American plesiosaurs, in the hopes eventually of clearing up much of the confusion now existing concerning these animals, and the present paper was intended to be published as a portion of this monographic study. As, however, the publication of so extensive a paper must be deferred for some time, he has thought best to publish that portion now prepared in advance of a more final review of the subject. The present paper contains detailed descriptions of *Dolichorhynchops osborni* Williston and *Brachauchenius lucasi* Williston; a revised description of *Cimoliasaurus snowii* Williston, together with certain descriptions of and remarks upon such other forms from the Kansas Cretaceous as bear more or less directly upon the principal species here discussed. As will be seen from the list given below, no less than nine distinct species of plesiosaurs have been described from the Kansas Cretaceous, all of which, except one or two, are autoptically more or less known to the writer, together with nearly as many more hitherto undescribed. The true generic determination of the most of these species is impossible at present. So little is known of the real generic characters, not only of the American but also of the European plesiosaurs, that, unless specimens are very complete, it is impossible to correctly assign them. Furthermore, there is in many respects such wide diversity between the different forms now known that almost every species seems rightfully to belong in a different genus. On the other hand, in our present ignorance of their value, generic differences can rarely be recognized unless one has a considerable portion of the skeleton. Generic determination is, therefore, for the most part, at the present time simply guess-work. In the present paper I have, for convenience sake, given names to some of these new forms, but the generic names are always provisional, and the specific names also in some cases. *Cimoliasaurus snowii* I do not believe is congeneric with the type species of the genus; it belongs as well in several other genera proposed by American writers. I do not see, however, much use in giving new generic names to every form until some *raison d'être* can be discovered for them. I have departed from this conviction in proposing two new generic names for species herewith described, largely because the specimens upon which the names are based are more than usually complete, and because there seems to be positive characters to sustain the names.

The full description and illustration of *Dolichorhynchops osborni* will, I trust, aid in the solution of many of these generic problems; they will at least furnish a means of comparison for other forms known already or to be discovered in the future.

A second part of this work is to follow soon, I trust. It will contain the descriptions and illustrations of two or three other skulls, different in structure from those herewith described and from each other, together with other important material.

I am glad to express my thanks to Prof. Dr. E. Fraas for kind suggestions, and for the communication of photographs; and to Prof. H. F. Osborn for kind favors.

Seeley* has proposed to divide the plesiosaurs into two chief groups, the Dicranopleura, including those forms with double-headed ribs in the cervical region, both long-necked (Dolichodeira) and short-necked (Brachydeira); and of which singularly no certain representatives have been discovered in America; and the Cercidopleura, those with single-headed ribs, also including both long-necked and short-necked types. Cope in 1887† proposed the two sub-families: *Polycotylinæ* for those with broad epipodial bones; and the *Plesiosaurinæ* for those with elongated epipodial bones, of which there are no certain representatives in America. But objections may be urged against both of these classifications. Certain forms very closely allied to *Pliosaurus*, a dicranopleuran, have single-headed ribs throughout. *Polycotylus* is a short-necked type, with single-headed cervical ribs, and it seems almost certain that certain long-necked forms that should be widely separated have also broad epipodial bones.

Nevertheless, I feel pretty confident that the final classification of the Plesiosauria will include three or four distinct families and twenty or thirty well-defined genera. There is scarcely a group of extinct reptiles, unless it be the Dinosauria, which offers more divergent characters than do the plesiosaurs. The skull may be long and slender or short and broad; the teeth irregular in size and large, or small and nearly uniform; the prefrontals and postorbitals separated or suturally united; the parietals with a high thin crest, or without such a crest; the palatines widely separated or broadly contiguous; the supraoccipitals paired or single(?). The neck may include as few as thirteen vertebræ or as many as seventy-two, the vertebræ all very short or the posterior ones elongated; the ribs single or double-headed; the arches anchylosed to the centra or suturally free throughout life. The dorsal vertebræ may be no longer than the anterior cervicals or much elongated; all the vertebræ may have conspicuous vascular foramina below or be without them; the diapophyses may be much elongated and situated low down, or shorter and situated high up; the vertebral spines elongated or short. In the pectoral girdle there may be a long epicoracoidal process; the clavicles and episternum either present or absent. The epipodial bones are two

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* Proc. Royal Soc. Lond. 1892, 151.

† American Naturalist, 1887, 564.

in number and elongated, or three or four and broad. The ilium may differ in its mode of attachment and the form of both pubis and ischium may differ much.

Certainly among all these characters, and probably not a few others, there will be no dearth of material for classification. Unfortunately there are yet many forms in which we do not know what relations these different characters bear to each other, and until we do, any classification must be provisional. I believe that most herpetological taxonomists will agree with me that the differences between *Dolichorhynchops* and *Brachauchenius* are more than generic in value, and I doubt not that differences of equal value will be discovered in yet other species when we shall know more about them than we do at present.

The origin of the Plesiosauria I will discuss in a later paper. For the present, I may say that I believe that their nearest affinities among all reptiles, recent or extinct, are with the Dicynodonts.

CATALOGUE AND BIBLIOGRAPHY OF THE NORTH AMERICAN PLESIOSAURIA.

PLESIOSAURUS.

Conybeare, Trans. Geol. Soc. Lond. v, 560, 1821.

BREVIFEMUR Cope, Cret. Vertebr. 256, 1875.—Greensand No. 5, New Jersey.

Cimoliasaurus magnus (Leidy) Cope, Ext. Batrach. 1869, 43. ff. 13–15.

*GULO Cope, Proc. Acad. Nat. Sci. Phil. 1872, 228; Cret. Vert. 1875, 256.—Fort Pierre Cretaceous, Kansas (*errore*, Niobrara).

*MUDGEI Cragin, Fifth Pub. Colorado Col. Sci. Soc. 69. ff. 1–3.—Comanche Cretaceous, Kansas.

*GOULDII Williston, Kansas Univ. Quart. vi, 57, 1897.—Comanche Cretaceous, Kansas.

SHIRLEYENSIS Knight, Amer. Journ. Sci. 1900, p. 115.—Jurassic, Wyoming.

All of the foregoing species were based upon fragmentary material, and it is improbable that any belong in the genus *Plesiosaurus*.

CIMOLIASAURUS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1851, 325 (1852).

MAGNUS Leidy, l. c.; ibid. 1854, 72, pl. ii, ff. 4–6; Cretac. Rept. 1865, 25, pl. v, ff. 13–19, pl. vi; Cope, Ext. Batrachia, etc. 1869, 42; Lydekker, Cat. Fos. Rept. Brit. Mus. ii, 211.—Cretaceous No. 5, New Jersey.

PLANIOR Leidy, Proc. Acad. Nat. Sci. Phil. 1870, 22.—Cretaceous, New Jersey (see also *Discosaurus*).

*SNOWII Williston, Science, xvi, 262; Trans. Kansas Acad. Sci. xii, 174, 1890; Cope, Proc. Amer. Phil. Soc. xxxiii, 109.—Niobrara Cretaceous, Kansas.

LARAMIENSIS Knight, Amer. Jour. Sci. x, 117, 119.—Jurassic, Wyoming.

This genus was based upon vertebral centra alone, from the cervical, dorsal and caudal regions; the author, however, referred them all erroneously to the dorsal and lumbar regions. The type is well figured in Leidy's work on Cretaceous Reptiles, plates v and vi. The vertebræ have infracentral vascular foramina. The ribs are single-headed. The largest centrum measures 110 millimeters in the greatest diameter. This genus has served as a sort of waste basket for the reception of fragments and poorly known forms. *C. snowii* is known from a skull and long neck. It can scarcely belong in *Cimoliasaurus*.

DISCOSAURUS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1851, 326 (1852).

PLANIOR Leidy, Proc. Acad. Nat. Sci. Phil. 1870, 20, 22; Cope, Cretac. Vert. 1875, 255 (*Cimoliasaurus*).—Cretaceous, Mississippi.

Discosaurus vetustus Leidy, Cretac. Reptilia, 23, pl. 5, ff. 10–12.

VETUSTUS Leidy, Cretac. Reptilia, 22, pl. iv, ff. 13–18, pl. v, ff. 1–9; Proc. Acad. Nat. Sci. Phil. 1851, 326; Cope, Ext. Batrachia etc. 256; Amer. Journ. Sci. 1870, 141; Cretac. Vert. 1875, 255 (*Cimoliasaurus*).—Cretaceous, Alabama.

This genus was based upon the mutilated bodies of two caudal vertebræ from the Cretaceous of Alabama. Leidy associated with these other mutilated vertebræ from the Cretaceous of Mississippi, New Jersey and Alabama. Cope suppressed the name, as of a genus insufficiently differentiated from *Cimoliasaurus*. This is quite true, as it is also true of several of Cope's own genera of the plesiosaurs. It is not at all improbable, however, that there are different species, and perhaps different genera represented by the specimens Leidy described and figured.

BRIMOSAURUS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1854, 73.

GRANDIS Leidy, Proc. Acad. Nat. Sci. Phil. 1854, 73, pl. i, ff. 1–3; ibid. 1870, 10; ibid. 1871, 22 (*Discosaurus*); Cope, Ext. Batrachia, etc. 1869, 43, 54 (*Cimoliasaurus*); Proc. Bost. Soc. Nat. Hist. 1869, 266 (*id.*); Amer. Journ. Sci. 1870, 269 (*id.*), Rep. Geol. Surv. Terr. 1871, 400 (*id.*); Cretac. Vert. 1875, 255 (*id.*)—Cretaceous, Arkansas.

This genus and species were founded upon more or less imperfect dorsal vertebræ from the Cretaceous, probably Benton, of Clark County, Arkansas. Cope suppressed the generic name as of a genus not sufficiently differentiated from *Cimoliasaurus*. I believe, however, that both genus and species are valid; and that the former will include some of the species from Kansas. Lambe has identified the species from the Belly River Cretaceous of Canada, but it seems to me that the identity must be more or less problematical.

ELASMOSAURUS.

Cope, Proc. Acad. Nat. Sci. Phil. 1868, 68.

*PLATYURUS Cope, l. c.; Notes on Geology, Leconte, 1868, 68; Proc. Bost. Soc. Nat. Hist. 1869, 266; Amer. Nat. iii, 87; Ext. Batrachia, etc. 1869, 47, ff. 7–12, pl. ii, ff. 1–9, pl. iii; Amer. Jour. Sci. 1870, 140, 268; Amer. Nat. v, 47; Rep. U. S. Geol. Surv. Terr. 1871, 393, 1872, 320, 336; Cretac. Vert. 1875, 44, 79, 256; Bull. U. S. Geol. Surv. Terr. iii, 1877, 578; Amer. Nat. xxii, 724; Leidy, Amer. Jour. Sci. xlix, 1870, 392; Proc. Acad. Nat. Sci. Phil. 1870, 9, 18; Lydekker, Cat. Foss. Rept. Brit. Museum, ii, 181 (*Cimoliasaurus*).—Fort Pierre Cretaceous, Kansas.

INTERMEDIUS Cope, Proc. Amer. Phil. Soc. 1894, 112.—Fort Pierre Cretaceous, South Dakota.

ORIENTALIS Cope, Proc. Acad. Nat. Sci. Phil. 1868, 313; Proc. Bost. Soc. Nat. Hist 1869, 266; Geological Surv. New Jersey, Cook, Append. (1868), 1869, 733; Amer. Nat. 1869, 87; Ext. Batrachia, etc. 1869, 44, 55, pl. ii, f. 10; Amer. Jour. Sci. 1870, 368; Cretac. Vert. 1875, 255; Bull. U. S. Geol. Surv. Terr. iii, 1877, 567, 578; Am. Nat. xi, 1877, 311; Leidy, Proc. Acad. Nat. Sci. Phil. 1870, 22 (*Discosaurus*).—Greensand No. 4, New Jersey.

SERPENTINUS Cope, Bull. U. S. Geol. Surv. Terr. iii, 578, 1877; Amer. Nat. xi, 1877, 311.—Niobrara Cretaceous, Nebraska.

The genus *Elasmosaurus* was founded upon a nearly complete series of vertebræ obtained near the vicinity of Fort Wallace, Kansas, wrongly ascribed to the Niobrara epoch. The neck was very long. The incomplete girdles are also known. No additional material has been ascribed to the type species since the original description by Cope.

POLYCOTYLUS.

Cope, Proc. Amer. Phil. Soc. xi, 117, 1869.

*LATIPINNIS Cope, l. c.; Ext. Batrachia, etc. 36, pl. 1, ff. 1–12; An. Rep. U. S. Geol. Surv. 1871, 388; ibid. 1872, 320, 335; Bull. U. S. Geol. Surv. Terr. 27, 1874; Cretac. Vertebrata, 45, 72, 255, 1, vii, ff. 7, 7a; Leidy, Ext. Vert. Fauna, 279.—Niobrara Cretaceous of Kansas.

*ISCHIADICUS Williston, posteà, Niobrara Cretaceous, Kansas.

This genus was based upon a portion of a propodial bone and imperfect cervical and dorsal vertebræ. The ribs of the neck are single-headed.

PIRATOSAURUS.

Leidy, Cretaceous Rept. N. Amer. p. 29, 1865.

PLICATUS Leidy, l. c. pl. xix, fig. 8.—Cretaceous, Minnesota.

Based upon a single tooth. Believed by the author to be Crocodilian. The horizon is probably Niobrara, judging from the accompanying fossils. If so, it would seem very probable that the tooth belongs to a plesiosaur, though rather sharply conical in shape.

NOTHOSAUROPS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1870, 74.

OCCIDUUS Leidy, l. c.; Rep. Geol. Surv. Terr. 1873, i, 345, pl. xv, ff. 11–23; Cope, Bull. U. S. Geol. Surv. Terr. i, 28, 1874 (*Plesiosaurus*); Cretac. Vert. 1875, 256 (*id.*).—Laramie [?] Cretaceous, Dakota.

TAPHROSAURUS.

Cope, Proc. Amer. Phil. Soc. xi, 274, 1870.

LOCKWOODI Cope, Ext. Batrachia, etc. 1869, 40 (*Plesiosaurus*); Proc. Amer. Phil. Soc. xi, 274.—Cretaceous No. 1, New Jersey.

OLIGOSIMUS.

Leidy, Proc. Acad. Nat. Sci. Phil. 1872, 39 (1873).

GRANDÆVUS Leidy, l. c. 40; Extinct Vert. Fauna, 286, 345, pl. xvi, ff. 18, 19.—

This genus and species were proposed for a detached caudal vertebra of small size, without definite horizon, from Green River, Wyoming. The processes are attached. The description will apply to caudal vertebræ of various genera.

URONAUTES.

Cope, Proc. Acad. Nat. Sci. Phil. 1876, 345.

cetiformis Cope, l. c. 346.—Fort Pierre (?) Cretaceous, Montana.

species Cope. Amer. Nat. 1887, 566.—Fox Hills Cretaceous, New Mexico.

This genus was based upon cervical, dorsal and caudal vertebræ. The cervicals are short, with the processes partly attached, and the ribs single-headed.

Professor Cope referred the type species to the Fox Hills Cretaceous with doubt. I suspect, rather, that the horizon is Fort Pierre.

OROPHOSAURUS.

Cope, Amer. Naturalist, 1887, 564.

pauciporus Cope, l. c.—Fox Hills Cretaceous of New Mexico.

Based upon parts of three cervical vertebræ. The neural arches are coössified, the ribs free. Centra short; ribs single-headed.

PIPTOMERUS.

Cope, Amer. Nat. 1867, 564.

megaloporus Cope, l. c. 564.—Fox Hills Cretaceous, New Mexico.

microporus Cope, l. c.—Fox Hills Cretaceous, New Mexico.

hexagonus Cope. l. c.—Fox Hills Cretaceous, New Mexico.

This genus and species are based upon cervical and dorsal vertebræ only. The cervicals are short, the processes free and the ribs single-headed.

TRINACROMERUM.

Cragin, Amer. Geologist, Dec. 1888.

*bentonianum Cragin, l. c.; ibid, 1891, 171.—Benton Cretaceous, Kansas.

A large part of the skeleton was known to the describer, including the skull, vertebræ, part of the girdles and limbs.

PANTOSAURUS.

Marsh, Report Geological Congress, 1891, 159; Amer. Journ. Sci. xli, 1895, 406; *Parasaurus* Marsh, Amer. Journ. Sci. xliii, 338, 1891 (preoccupied).

STRIATUS Marsh, Amer. Journ. Sci. xliii, 338, 1891 (*Parasaurus*); ibid, i, 406, 1895, ff.—Baptanodon Beds, Wyoming.

Based upon a posterior cervical centrum. "Vertebræ strongly grooved. Neck long and slender, the vertebræ preserved resemble most in form and size those of *Plesiosaurus plicatus* Phillips."

EMBAPHIAS.

Cope, Proc. Amer. Phil. Soc. 1894, 111.

CIRCULOSUS Cope, l. c.—Pierre Cretaceous, South Dakota.

This genus and species were founded on three vertebræ, cervical and dorsal. The cervicals are short, with persistent sutures. Ribs double-headed(?).

MEGALNEUSAURUS.

Knight, Amer. Journ. Sci. v, 1898, 375.

REX Knight, Science, 1895, 449 (*Cimoliasaurus*); Amer. Journ. Sci. v, 1898, 379, ff. 1–3.—Jurassic, Wyoming.

A large portion of the skeleton of the type species is known; the parts so far described are the vertebræ and limbs.

DOLICHORHYNCHOPS.

Williston, Kansas Univ. Sci. Bulletin, No. 9, p. 141, Sept. 1902.

*OSBORNI Williston, l. c.—Niobrara Cretaceous, Kansas.

BRACHAUCHENIUS.

Williston, posteà.

*LUCASI Williston, posteà.—Benton Cretaceous, Kansas.

DOLICHORHYNCHOPS OSBORNI.

The specimen of *Dolichorhynchops osborni* herewith described and illustrated was discovered by Mr. George Sternberg in the chalk of Logan County, Kansas, in the summer of 1900, and skilfully collected by his father, Mr. Chas. H. Sternberg, the veteran collector of fossil vertebrates. The specimen was purchased of Mr. Sternberg in the following spring for the University of Kansas, where it has been mounted and where it now is. When received at the museum the skeleton was almost wholly contained in a large slab of soft yellow chalk, with all its bones disassociated and more or less entangled together. The left ischium, lying by the side of the maxilla, was protruding from the surface, and a part of it was lost. The bones of the tail and some of the smaller podial bones were removed a little distance from the rest of the skeleton, and were collected separately by Mr. Sternberg. The head was lying partly upon its left side and some of the bones of the right side had been macerated away; the maxilla indeed had disappeared.

The task of removing and mounting the bones has required the labor of Mr. H. T. Martin the larger part of a year, and is, as finally mounted, an example of great labor and skill on his part. For the position of the bones in the recreated skeleton and their general arrangement I am of course responsible. There is some little doubt as to the exact position of the pectoral girdle, as respects the ribs and vertebræ. The position as shown in the restoration is that which seemed, upon the whole, most nearly the truth, judging from the figured skeletons of *Plesiosaurus*. There is also some doubt about the proper length of the tail. The relations of the preserved centra seemed to indicate a loss of a few vertebræ in this region, and for that reason four plaster models have been intercalated. There are nineteen vertebræ preserved in the neck; there may have been one more, or possibly two, but for reasons discussed further on this is doubtful. In the dorsal region there are thirty vertebræ, three of which may be called pectoral. Twenty-five are preserved in the tail. The skull, after its complete removal from the matrix, was found to be so very fragile that it was not thought expedient to mount it. It was also somewhat distorted, as will be seen from the illustrations. A model, therefore, was made under my careful supervision, and mounted in its stead. The skeleton as mounted is just ten feet in length. The neck in life must have been thick and heavy at the base, tapering rapidly from the trunk to the head. The trunk was broad, as is evident from the position of the ribs, with the under side not flat, as might be supposed, but strongly convex from side to side. The abdominal region proper, between the girdles, must have been short, and could not have been very distensible. The short tail was thick at its base, as is conclusively shown by the attachment of the ilia and the elongated ischia. Furthermore, the fore legs, at least, must have been enclosed for a considerable distance at their attachment by the skin and muscles of the pectoral region; they could not have been pedunculated to the extent that they are usually represented to be in the restorations. The species was named in honor of Prof. H. F. Osborn of Columbia University.

The distinguishing characters, both family and generic, may be summed up as follows:

DOLICHORHYNCHOPS.—*Head elongate, the facial region much attenuated; teeth nearly uniform in size, small; prefrontal and postfrontal bones not joined; parietals extending into a high crest; supraoccipital bones separated; internal nares small, included between the vomer and palatine only; palatines broadly separated throughout; a large vacuity between the pterygoids anteriorly; quadrate process of pterygoids short. Neck but little longer than the head, composed of nineteen or twenty vertebræ; all presacral vertebræ of nearly equal length, moderately concave, and with vascular foramina below; spines short, uniform in length; diapophyses of the dorsal vertebræ situated high up. Coracoids with long epicoracoid process; clavicles and scapulæ free; episternum with an emargination in front and behind, the latter forming part of a large interclavicular foramen. Three epipodial bones, all broader than long. Ischium elongated. Length ten feet.*

SKULL.—The skull of *Dolichorhynchops osborni* is of a remarkably elongate and slender form, attenuated in front of the orbits, and with a thin, high, parietal crest. The region between the eyes is very narrow, the superior temporal vacuities large, and the teeth numerous and slender. The head is more nearly of the typical aquatic fish-eating type than is perhaps known in any other plesiosaur, and the neck is as short as or shorter than in any other plesiosaur hitherto described. The skull, as received, was lying partly upon its left side, with a part of the right side separated and injured, some of the bones having been macerated away. The specimen was completely removed from the matrix, including even that which was between the bones, and the elements of the brain case were separated out. In consequence, the fragility of the skull was such that it was not deemed prudent to mount it with the remainder of the skeleton. A model of it was therefore made, based upon my drawings and studies, and which, I think, represents the skull very nearly as it must have been during life. Its width in all parts may not have been accurately determined, but the discrepancies from the reality can not be great.

The *premaxillaries* are separated from each other distinctly by suture, the long facial processes apparently lying in contact with each other without close union. The suture separating them from the maxilla begins just back of the sixth tooth; it curves upward and backward for a short distance, and then runs parallel with the upper border as far back as the narial opening, whence the margin runs more obliquely to the tip of the processes above the middle of the orbit. Each premaxilla bears six teeth, which are among the largest of the jaws, and are all of nearly uniform size, the first one curved forward. The facial process is slender, flattened on its opposing, sutural surface, and with its external, convex surface distinctly striated longitudinally. The dentigerous portion is convex, pitted toward the anterior part, and about twenty- five millimeters in height, opposite the last tooth. The relations of the bone on the palatal surface can not be determined.

The *maxillæ* are long and narrow on the facial surface, and very narrow on the palatal surface, at least posteriorly. They bear twenty teeth on each side, the first ten or eleven of which are of nearly equal size, and scarcely smaller than those of the premaxillæ. The posterior ten teeth are crowded, occupying a space less than one-half that of the preceding ten, and they are smaller. The greatest width of the maxilla on the facial surface —about twenty-five millimeters—is at about seventy millimeters in front of the orbit, whence the bone narrows to a width of ten millimeters below the anterior border of the orbit. Below the orbit, the bone extends as a narrow bar, becoming slightly narrower posteriorly, before the beginning of the jugal suture. Beyond this, it flattens posteriorly to near its extremity, which is about midway of the temporal bar, and one hundred millimeters beyond the last tooth.

There are twenty-five or twenty-six teeth in each jaw. They are inserted by a long fang, the pulp cavity of which occupies more than one-third of the diameter, extending a short distance into the crown. In the largest teeth, the crown is about twenty millimeters in length, with a diameter at the base of six millimeters. The crown is relatively slender, strongly convex anteriorly, sharply conical, and with slender, delicate, longitudinal striæ, except on the outer, anterior part, where the surface is nearly smooth. The posterior teeth are much smaller, as already stated, and are much more closely placed, their length varying from six to twelve millimeters.

The united *parietals* form a high, thin, vertical plate of bone, convex in outline, about fifty millimeters in height in the middle, and only three or four in thickness at the margin, and extending nearly as far forward as the pineal foramen. Posteriorly, the sides extend downward and outward into a broad flattened process for union with the upper ramus of the squamosal. The suture, which is clearly apparent, runs downward and outward to the free margin of the parietal on each side, beginning in front of the posterior thickened bar of the squamosal. Anteriorly this free margin of the parietal is continued outward, like the eaves of a roof, to the posterior part of the orbit, where it is somewhat roughened; it turns upward here rather abruptly. About twenty millimeters above this angle, separated by a concave space, is the massive projection for the epipterygoid. This bone has been broken away from its attachment on each side, and separated for a short distance, leaving a jagged fracture, without indications of suture. The upper margin of this thickened epipterygoid protuberance is continued by sutural union with the postfrontal. A little in front of the parietal foramen, the bone narrows to a width of four or five millimeters, blended with and continued into the frontal, which continues forward to the premaxillary, under which it disappears. The sutural union for the postfrontal is well marked on the right side, beginning a little back of the pineal foramen and running downward, outward and backward to the upper margin of the epipterygoid protuberance. Internally the parietals form a broad roof, to which is attached, rather far forward, by distinct, oval, obliquely placed, V-shaped articular surfaces, the paired supraoccipitals, which do not reach quite to the lower free margin of the parietals on each side.

Anteriorly, as already stated, the frontal (?) continues, without the slightest indication of a suture with the parietals, forward for forty millimeters or so more, as a narrow, flattened surface above, distinctly divided by a median suture, to the upper end of the facial processes of the premaxillæ, which articulate on the outer side of the slender projection, overlapping the upper surface. How much further the bones continue I can not say, but evidently as far forward as the anterior end of the orbits. On the right side, the "postprefrontonasal" has been macerated away, so that its relations are clearly marked. Below these bones are broader, continuous on each side with the free margin of the roof, as already described. The rostrum formed by the "frontals" is stout and rounded, and is continued at least as far forward as the anterior end of the orbit, clearly separated above and below by the median suture. The anterior ends are lost in front in the broken fragments of bone, between and beyond the anterior end of the orbits. Lying between the orbits, and separated from each other by a narrow interval, are the narrow bones which may represent the conjoined postfrontals and prefrontals and nasals. On the right side, as stated above, the bone had been macerated away, and while some of its processes had been broken off and lost, the sutures for union with the parietal, frontal and prefrontal are beautifully preserved, showing the relation to these bones in a way that precludes doubt. The bone shows no trace of division whatever into its supposed elements. It articulates with the "frontal," parietal, epipterygoid, "postorbital," "supraorbital," premaxilla and maxilla. Posteriorly the bone extends downward, outward and backward to the upper margin of the epipterygoid protuberance; externally and posteriorly it sends off a projection for union with the post-orbital; anteriorly the bone fits into a groove on the outer side of the facial processes of the premaxillaries for a distance of thirty or forty millimeters, and has a stout process on the outer side for union with the supraorbital, or whatever the element may be here. On the under side there is a broad, flattened, vertical plate, continuous from the posterior, inferior angle, and widened in the middle so as to reach the greater part of the way to the upper surface of the palatal bone, forming the inner wall of the orbit in large part. The plate given off for union with the "supraorbital" is separated by a sharp, deep notch from a similar process for union with the "postorbital." The "supraorbital" bone has been crushed back over this process, so that the distinguishing suture can be perceived in one place only, anteriorly. In front of the orbit, the bone sends out a thin, triangular plate, which curves downward to meet the maxillæ, separated from its mate by the premaxillæ. Doubtless this part represents the nasal, and perhaps also the lachrymal, but there are no indications of distinguishing sutures, and I do not believe that the nasal exists as a separate element in the adult plesiosaur — I can not find that it has ever been described in any plesiosaur. It joins the maxillæ broadly and the "supraorbital" behind; in the angle between the three bones is located the small external nares. Below the supraciliar plate, near the anterior part of the orbit, on the side of the prefrontal, there is a well-defined fossa, leading forward into the ethmoidal region, into which opens a small foramen from the upper surface between the prefrontal and supraorbital.

The *supraorbital* forms, as already stated, a horizontal plate extending out over the orbit in front. Its union with the prefrontal posteriorly is obscured by fracture, but indications of a suture are seen anteriorly. Between this bone and the postorbital there is a deep notch, angulated externally. The suture between the prefrontal and supraorbital is clearly seen anteriorly, running from the small foramen already mentioned forward and outward to terminate near the maxilla, at the posterior end of the nares. The connection of the bone with the maxilla can not be made out, as there has been an infolding here; its connecting suture with the ascending process of the maxilla is, however, well defined, running obliquely forward. The descending plate of the supraorbital has, in its orbital margin near the upper part, a small foramen, piercing the bone obliquely. The horizontal portion terminates anteriorly by sinking to the surface of the descending portion. The whole bone reminds one of the prefrontal of *Clidastes.*

The *postorbital* bone is a narrow, elongate and thin bone, united above with the postfrontal, and to a slight extent with the parietal, near the top of the epipterygoid; below to the jugal. On the right side, this bone, like the postprefrontal and jugal, has been macerated away, and, although somewhat distorted, presents no evidence of being composed of more than one element.

In the above description of these frontal elements, I have followed the usual determinations, but I am not satisfied with them. The "supraorbital," though occupying the position usual for this bone above the orbit, has relations anteriorly that are altogether unusual; the nasal and the lachrymal do not appear to exist as independent elements. It would seem more likely that this supposed "supraorbital" is really the lachrymal, if the postfrontal and prefrontal are fused into one element. Again, such a combination of the postfrontal and prefrontal and their peculiar articulations is remarkable. The very narrow frontal, while showing a distinct suture in the middle, presents no evidence of any connection with the parietal — it seems more to be a very narrow rostrum projecting in front of the parietal and separating the bones, which otherwise would answer very well for frontals. In this latter case, the so-called "supraorbital" would really be the prefrontal, and the postorbital the postfrontal or postfronto-orbital. This may seem a violent supposition, but it does not seem at all improbable to me. Nor is the union of the parietal with the premaxilla any more extraordinary than is the union of the supraoccipital with the frontal in many Cetacea.

Sclerotic plates are present in the left orbit of this specimen in a nearly undisturbed condition. There are fourteen in the ring with beveled and imbricated contiguous margins, in texture, size and position very much like the corresponding bones of the mosasaurs. The pupillary opening measures about thirty millimeters in diameter, and the entire diameter of the ring is about seventy millimeters. The occurrence of sclerotic plates in the plesiosaurs has long been known. I described them in *Cimoliasaurus snowii* in 1890, and Owen many years earlier (Fossil Reptilia of the Liassic Formation, p. 10) said: "In both orbits some of the thin sclerotic plates of the eyeball are preserved; this is the first specimen in which I have had evidence of their structure."

The *jugal* is a small element intercalated between maxilla, postorbital and squamoso-prosquamosal. The suture separating it from the maxilla runs nearly parallel with the lower border of the bone. In its posterior third this suture is very distinct; it seems to be continued forward to attain the margin of the orbit at its lower posterior part. Above, the bone is distinguished from the postorbital by a nearly parallel suture; behind by a nearly transverse suture from the squamosal. On the right side, the jugal had been separated from the other bones by maceration; its relations, therefore, are positively indicated. The bone terminates about twenty millimeters before the posterior end of the maxilla. On the inner side, just back of the rounded orbital margin, the bone articulates by a flattened surface, about the size of one's finger-nail, with the ectopterygoid. The bone is pierced on its outer surface by three or four small zygomatic foramina.

The broad, triradiate element, variously considered as being composed of, or the homologue of, the squamosal and mastoid by Owen*, the squamosal and supratemporal by Andrews†, the squamosal and prosquamosal by Owen and Baur, the supratemporal and supramastoid by Cope‡, the squamosal, supratemporal and quadratojugal by Woodward§, differs materially in its structure from that described or figured in other plesiosaurian skulls, in that the element, or elements, whatever they are, articulate proximally with the maxilla, as well as the postfrontal and jugal. Posteriorly, the suture separating the bone

* Trans. Geol. Soc. Lond. (2), v, pt. iii, pl. xlv, 1840.

† Quart. Journ. Geol. Soc. Lond. lvii, 249, 1896.

‡ Proc. Amer. Phil. Soc. xxxiii, 110. 1894. Cope, in his essay on the posterior cranial arches in the Reptilia (Trans. Amer. Phil. Soc. 1892), reaches the conclusion that the lower temporal bar of the Crocodilia, *Sphenodon*, etc., corresponds with the zygomatic arch of the mammalia, and therefore suppresses the term "squamosal." The squamosal—so-called—in the Reptilia he calls the supramastoid, absent in the lacertilia and other forms.

§ Vert. Paleont., f. 116 A, 1898.

from the quadrate is situated as in *Cimoliasaurus snowii*, at the external angle of the quadrate, which it borders to its upper extremity. At the lower extremity there is a very distinct squamate suture, running upward and forward and becoming lost about twenty millimeters from its origin. This suture is clearly apparent on the two sides, and is also seen in the skull of *Cimoliasaurus snowii*, as it was figured by myself (l. c.) and Cope*. Just what the course of the suture is anteriorly I cannot say, but I believe that it is indicated by a line passing forward to the maxilla, and excluding that bone from union with the squamosal. Whatever be its relations anteriorly, I doubt not that the quadratojugal exists as a distinct ossification in the plesiosaurs. In a separated quadrate of another species of plesiosaur (*T. anonymum* Will.), from the Benton of Kansas, the sutural surfaces for union with the quadratojugal and squamosal are clearly distinguished. The quadratojugal does not enter into the formation of the condylar surface of the quadrate, as has been suspected, and as it does in *Sphenodon;* this is certain. On the outer side of this quadrate, just above the articular surface, there are two sutural surfaces—one on the posterior and outer border, for the attachment of the squamosal, the other on the anterior border for the attachment of the quadratojugal, which, in this case, as also in *Dolichorhynchops osborni*, must have been overlapped in part by the squamosal. In *Cimoliasaurus snowii*, the suture between the squamosal and the quadratojugal is very clearly indicated from the exterior, the squamosal not descending as low as in the other species. The suture shown as separating the quadratojugal from the squamosal anteriorly is conjectural, but I believe, as already stated, that it will be found to extend as far forward as the maxilla.

The suture separating the squamosal from the postorbital is short and vertical, joining the border near the anterior extremity of the bone, as seen from the outer side. The suture joining the jugal is a squamous one, extending on the inner side nearly to the margin of the orbit, but leaving a small space for the union of the ectopterygoid with the jugal. The suture with the maxilla is long and oblique, concealed in about half its extent by the jugal. I believe, however, that the squamosal is really separated from the maxilla by the intervention of the quadratojugal, as already described, and for which there seems to be some evidence in the specimen. On the right side the maxilla had been removed by maceration, leaving the sutural surface for the temporal element very clear in its whole extent.

Posteriorly, the sutural line of the squamosal passes downward

* Proc. Amer. Phil. Soc. 1894.

by a somewhat zigzag line to reach the inner border of the quadrate a little above the border of the pterygoid process. On the inner side, the sutural line passes nearly directly across, and then upward to the inner border.

The connection with the parietal is definite. The suture indicated by Cope in his figure of *Cimoliasaurus snowii* (l. c.) does not exist in the specimen figured, nor is there any such in the skull of *Dolichorhynchops osborni* here described. In order to definitely determine this fact I removed the portion supposed by Cope to be the supramastoid from the skull of the *Cimoliasaurus* specimen and carefully cleaned it, thereby proving beyond peradventure that the supposed suture is in reality a fracture. The squamosal, or as it should be called, the squamoso-prosquamosal, in that form, as will be described hereinafter, reaches to the top of the skull, notwithstanding Baur's opinion to the contrary. The two squamosals touch each other, or nearly do so, as in the skull of *Cryptoclidus* described by Andrews.

The temporal bar in the plesiosaurs, it is thus seen, is composed of the jugal, quadratojugal, squamosal and prosquamosal (supratemporal). This last element is not distinct in either of the skulls here described, nor is it usually apparent in the adult skull, but Owen* describes and figures it as distinct; Andrews also says† that "In several Plesiosaurian skulls in the British Museum the suture between these elements is distinct."

The *quadrate* is a short and broad bone, united by a pit-like sutural surface on the inner side with the posterior prolongation of the pterygoid, on the outer side with the squamosal and quadratojugal, as already described. Posteriorly the sutural surface for the squamosal begins a little above the pterygoid articulation, runs downward and outward for a short distance, then upward and outward to another point, whence it goes downward to appear on the outer surface a little below the angle of the bone, which it follows nearly to the lower articulation. The articulation for the paroccipital is immediately above and before the pit for the articulation of the pterygoid. A separated quadrate of another species (*T. anonymum*), already described in part, with its sutures distinct and the bone undistorted, shows an elongated articular surface, broadest upon the inner end, narrowed and turned upward at the outer extremity nearly to the lower end of the squamosal articulation. A non-articular groove on the inner side of the middle behind divides the articular surface; it does not appear to be present in either of the other species. The

*Trans. Geol. Soc. (2), v, Pl. xiv (1840).

†Quart. Journ. Geol. Soc. lii, 250, 1896.

pterygoid articular surface reaches to within about twenty-five millimeters of the articular extremity. The inner border of the pit is produced forward for articulation, apparently, with the paroccipital. The two narrow, concave, articular surfaces for the squamosal and quadratojugal are separated by a narrow, non-articular ridge. They both extend very nearly to the cotylar surface of the bone.

The *pterygoids* articulate posteriorly by a deep, pit-like suture with the inner side of the distal extremity of the quadrate; the latter does not send out a process to meet the bone. The bar connecting the quadrate with the body of the bone is oval in cross-section, with a rounded inferior border. It is about thirty millimeters in length and is placed obliquely; it does not extend much posteriorly to the coronal plane of the occipital condyle. In front of this quadrate process there is an elongate, flattened or concave plate, with nearly parallel sides, separated from the parasphenoid by a slender, elongated vacuity.* At the posterior extremity of this plate there is a narrow bridge connection with the basisphenoid. The connecting suture is not determinable, so that one cannot say whether the two pterygoids meet here in the middle, as in *Peloneustes* and *Pliosaurus*, or are separated, as in *Plesiosaurus*. In front of the interpterygoid vacuity the pterygoids unite with the parasphenoid broadly; here also the connecting suture cannot be determined. Opposite this connection exteriorly, the bone sends out a stout process for union with the ectopterygoid or transverse bone. Back of both of these, and on the inner side, near the margin of the vacuities above, there is the attachment of a stout *epipterygoid* pillar, passing upward, and apparently a little inward to unite with the lower anterior part of the parietals, as already described: both extremities are tumid, and the connecting sutures cannot be determined. The rod is broken on both sides in the specimen near the parietal end, and, as preserved, is curved forward. It is oval in cross-section, with the greater diameter of about ten millimeters; the entire length is thirty millimeters. Anteriorly, the pterygoid sends a flattened process to meet the posterior extremity of the vomers; it is flattened and pointed. This process is gently expanded at each extremity, especially the proximal; it has a smooth, thin edge on each side, except at the distal end, where it meets its mate, suturally, in the middle. Between the two processes there is an elongate, oval vacuity, which is not filled by the ossified para-

* Andrews calls this opening the posterior palatine vacuity or foramen; but this term is more properly restricted to the opening between the palatine, pterygoids and maxillæ, corresponding to the posterior palatine foramina of mammals, and is thus used in the Chelonia—the sub- or infraorbital vacuity of Andrews and other authors.

sphenoid in this specimen. There is, however, a slight projection in the middle of the opening behind, which may represent a more extensive ossification, but it seems very probable that there was a real vacuity here, unlike the condition in *Peloneustes* and *Plesiosaurus*. The union with the vomer is oblique, from without inward and forward.

The *palatine* and ectopterygoid on one side, though retaining

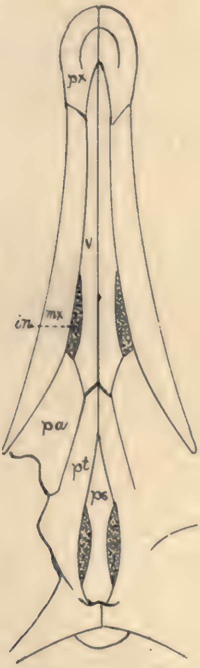

FIG. 1.

Palate of *Peloneustes*.

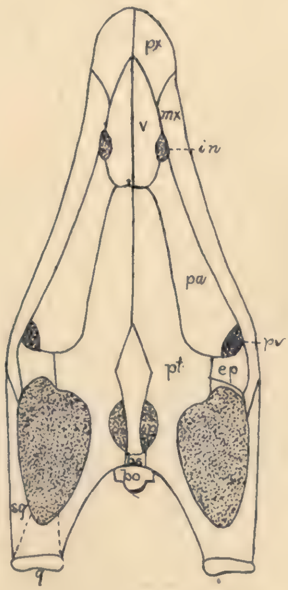

FIG. 2.

Palate of *Plesiosaurus*.

Px., premaxilla; *mx.*, maxilla; *v.*, vomer; *in.*, internal nares; *pa.*, palatine; *pt.*, pterygoid; *pv.*, posterior palatine vacuity; *ep.*, ectopterygoid; *bs.*, basisphenoid; *bo.*, basioccipital; *q.*, quadrate; *sq.*, squamosal. After Andrews.

their original positions approximately, were free in the specimen; they are complete and show their sutural relations very well. On the other side, they are both in position. The palatine is a long, narrow, thin bone, concave from side to side above, and correspondingly convex below. The inner, slightly sinuous margin is thin, and overlaps the outer margin of the palatine process of the pterygoid. Near its anterior extremity there is a small emargination for the nares*, where

*See description of the palate in *Brachauchenius* beyond.

the bone comes in contact with the proximal end of the vomer; for a little distance in front of this emargination, and distad to the pointed extremity of the bone, the border is slightly thickened for union with the vomer. Posteriorly, the rounded extremity of the bone is slightly thickened, and with sutural roughening for union with the ectopterygoid process of the pterygoid. The outer border is slightly concave throughout nearly its whole extent; it is also thin for nearly its whole extent. Anterior to the small narial emargination, the bone forms a long, slender point. On the proximal end, the thin border is underlapped by the thin anterior prolongation of the ectopterygoid for a distance of about fifty millimeters; the remainder of the extent comes in contact with the maxilla, but presents no distinct sutural surface, unless it be near the anterior extremity. There is no posterior palatine foramen.

The *ectopterygoid* or *transverse* bone is of a slender, triangular shape. Its slender anterior end extends forward on the outer margin of the palatine. The posterior inner angle has a well marked sutural surface underlapping the pterygoid process. The outer extremity is thickened, curving somewhat downward to unite with the jugal, and, by a thin border, with the maxilla.

The *vomer* is a very long, narrow bone, uniting with the palatine process of the pterygoids posteriorly by a squamous suture, and, for a short distance on the outer side posteriorly, with the slender pointed extremity of the palatine, the small narial opening intervening. They lie closely side by side, apparently without sutural union. They are concave above, and convex below from side to side, and are rather stout. The anterior ends are so concealed that they can not be described or figured.

BRAIN-CASE.—The lateral walls of the brain-case in the reptilian skull are composed of six distinct elements, according to the views of some comparative anatomists. Two of these may be fused with contiguous elements in the adult skull, or one or more of them may be entirely absent. Those elements supposed to contain the otic capsule were called by Huxley, in his lectures on the structure of the vertebrate skull (Elements of Comparative Anatomy, 1864), the epiotic, proötic and opisthotic. The other three are the supraoccipital, exoccipital and alisphenoid. The epiotic, Huxley homologized with the so-called epiotic of fishes and batrachians, and, although indistinguishably united with the supraoccipital in all adult reptilian skulls*, he believed to be a distinct ossificatory element. This has

* Parker describes the epiotic as a distinct element in *Tropidonotus natrix*. Phil. Trans., 1878, p. 405.

been denied by Baur*. No indications of such an ossification have been found in adult reptiles, living or extinct, even in those in which the opisthotic remains as a permanently free ossification. The opisthotic was previously called paroccipital by Owen in 1838, and the name must take precedence. Cope†, however, suspected that the opisthotic or paroccipital is really composed of two elements, the outer of which is the true paroccipital, while the inner, that entering into the formation of the otic canals, may be properly called the opisthotic. Baur denies this, insisting that there is but a single element, persistent in the Testudinata, Ichthyopterygia, the young of *Sphenodon*, and other Rhynchocephalia, as well as in some of the Cotylosauria; firmly and indistinguishably fused with the exoccipital in all other reptiles, so far as is known: free, according to Cope, also, as the so-called squamosal of Baur, the paroccipital of Cope, the supratemporal of Woodward‡, in the lacertilia.

If there be but one element here, and, so far, the evidence is inconclusive that there are two, then it must be called the paroccipital, a name first given to it by Owen. Andrews describes the element as distinct in the young of *Cryptoclidus*§, but there are no indications of it in the present specimen.

The proötic of Huxley, the alisphenoid of Owen (Comparative

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*Zool. Anzeiger, No. 296, 1889; Journ. Morphology, 1889, p. 467.

† "The opisthotic in reptiles is generally early fused with the exoccipital, but in the Ichthyopterygia and Testudinata it is distinct, and takes the place of the petrosal as a support for the quadrate in conjunction with the exoccipital. In the Pythonomorpha a bone which occupies the position of the terminal part of the opisthotic (or paroccipital, which is the older name) issues from between the exoccipital and petrosal, and supports the quadrate. Whether this is homologous with part or all of the paroccipital is an open question. For the present I call it the paroccipital and it is probably a distinct element from the opisthotic." Cope, Syllabus, 2d ed., 1898. A fuller description of the relations of this bone the reader may find in my paper on the Mosasaurs (Univ. Kansas Geol. Surv., vol. iv, p. 121). After much reflection I believe that Cope is right in rejecting the term squamosal for this element, whatever it is. Parker describes and figures the opisthotic as a large element in the snake (l. c.), occupying its usual and normal position. At the same time it is exceedingly difficult to believe that the remarkable relations of the bone in the mosasaurs can be those of the squamosal, occupying almost the normal position of the real opisthotic. That the bone called the prosquamosal in the lizards is not the squamosal would also seem probable, though not impossible. I prefer to call the elements, until it be proven that there are two opisthotics in the lizard, the paroccipital and prosquamosal with Cope. It is of interest to note, however, that Cope, in his last edition of the Syllabus (published posthumously), retains the name of squamosal for the element he previously called the supratemporal (*i. e.*, the prosquamosal). Further on he defines the plesiosaurs as follows: "No supramastoid; paroccipital not distinct; a quadrato jugal arch; scapula triradiate; no clavicle; ribs one-headed." Cope's supramastoid is the bone he thought erroneously to exist in the skull of *Cimoliasaurus snowii*, that is the real squamosal if present, and Andrews assures us that it is sometimes present in the young animal. I do not understand what is meant by "no clavicle," unless it be that he accepted Hulke's determination of these elements as the omosternum, a subject which will be discussed further on. He forgets also that some plesiosaurs do have rudimentary double-headed ribs in the cervical region.

Notwithstanding all that has been written, the homologies of the temporal bars in the reptilia are yet uncertain, more so than any other parts of the reptilian skull.

‡ Vertebrate Paleontology, 1898.

§ Geological Magazine, 1895, p. 242.

Anatomy), is the petrosal of earlier authors, about which there is now no discussion. It always articulates behind with the exoccipital and paroccipital, above with the supraoccipital, below with the basisphenoid, and to a greater or less extent with the parietal (in certain lizards, etc.), the alisphenoids, when present, and epipterygoids. The epipterygoid, the columella of earlier authors, unites the pterygoids with the parietals or frontals. It has been supposed to be identical with the alisphenoids by Baur and others, but Baur* later retracted this opinion, with reason, as may be seen by an inspection of the cranial walls of *Sphenodon*.

The alisphenoids (orbitosphenoids of Owen) articulate with the basisphenoid below, when present, and with the petrosals behind. In the crocodilia and *Sphenodon* they also articulate with the epipterygoids. They seem to be absent in the plesiosaurs.

The bones of the brain capsule in our specimen of *Dolichorhynchops* had been separated by maceration before fossilization, and were more or less displaced and entangled with one another. Moreover, in each temporal vacuity there had lodged deeply a thoracic vertebra, wedged in and causing more or less distortion of the temporal arches. The atlas and axis, also, were crowded into the occipital region. The vertebræ had to be sacrificed in order not to endanger the other bones. Mr. Martin, with great care and patience, removed the disassociated bones of the capsule in more or less completeness. They were all soft and mealy, almost of the consistency of brown sugar when wetted, but by carefully infiltrating them with a solution of gum arabic, the bones were hardened bit by bit and then removed from the matrix. This exposed the surface of the basioccipital and basisphenoid in their entirety, in an undisturbed and uninjured condition. A gelatine mould of this surface was then made, from which a plaster cast was taken, showing the sutural surfaces for the exoccipitals and petrosals. While none of the bones were obtained quite complete, yet the mates, for the most part, mutually indicate the complete characters of each, thus enabling a nearly complete restoration of the capsule to be made. And the results have been well worth all the trouble, as the bones present certain features of much interest.

The brain cavity is broadly open in front, as in the lizards† and *Sphenodon*, with a broad base on the basisphenoid, a deep depression

*Zool. Anzeiger, No. 298, 1889.

† In the Pythonomorpha I have recently discovered that the brain-case is bounded in front in part by a well developed orbitosphenoid, uniting the frontal with the basisphenoid. The same bone is present in the lizards and snakes. See Bulletin Kans. Univ., 1, No. 9, p. 14.

for the pituitary, a narrow roof under the parietal, an open vacuity posteriorly in the supraoccipitals, and with a relatively large otic capsule. The *exoccipitals* unite obliquely with the basioccipital, taking no part in the formation of the condyle. The paroccipital processes are small and slender, and there is no indication of a distinct ossification. They are dilated slightly at the extremity, where they abut against the upper part of the quadrate. They are directed downward and outward, the distal extremity reaching a level below the top of the occipital condyle. The occipital foramen is transversely oval, if the upper end is assumed to be near the top of the exoccipitals, which show a slight angularity at the place of their union with the separated supraoccipitals. At the upper posterior extremity of each exoccipital there is a small, deeply excavated, angular cavity, excavated almost wholly from the exoccipital, its upper border only touching the posterior angle of the supraoccipital. Its excavated surface is smooth and sharply angular, looking upward and inward. This surface probably corresponds to the smooth tendinous surface seen on the outer angle of the supraoccipital, extending slightly on the corresponding angle of the exoccipital, in the crocodile. At the posterior part, the exoccipitals approach each other rather closely, leaving about four millimeters of basioccipital space in the circumference of the foramen magnum. Anteriorly, however, the two bones diverge rather widely, terminating a little posterior to the suture separating the basioccipital from the basisphenoid. On the inner side, back of the middle of the bone, and a third of the distance above the sutural margin, is the large oval foramen for the vagus, opening exteriorly below the middle of the moderately expanded paroccipital process. The smaller foramen for the hypoglossal is situated midway between this and the posterior margin, and nearer to the sutural surface; it opens near the vagal orifice. The sutural surface for the supraoccipital is flat and broadly triangular, pierced near its middle by a small foramen leading into the posterior semicircular canal in the supraoccipital, the floor of which is seen on this surface, leading

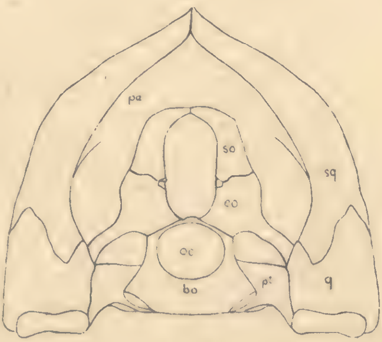


FIG. 3.

Dolichorhynchops osborni. Occipital view of skull. x ⅓. *Pa.*, parietal; *sq.*, squamosal; *q.*, quadrate; *so.*, supraoccipital; *eo.*, exoccipital; *pt.*, pterygoid; *oc.*, occipital condyle; *bo.*, basioccipital.

as a narrow groove to the inner posterior margin of the surface. Posteriorly the slit for the eighth nerve seems to be a little above and back of the vagal opening, in the interstice between the exoccipital and petrosal. The large cavity of this bone looks backward to communicate broadly with a similar cavity in the petrosal on the inner side. On the outer side there is a small foramen, nearly or quite separated from the inner opening, also communicating with a small foramen in the opposed sutural surface of the petrosal. Externally the exoparoccipital shows a narrow fossa below the process, into which open the vagal and hypoglossal foramina. Above, the gently convex surface continues into the similar surface on the sides of the supraoccipitals. The posterior borders of the exoccipital and supraoccipital meet in an obtuse angle, which is excavated, as already described for ligamentous attachment.

The *supraoccipitals* are not only parial, but they are widely separated from each other, approaching each other only at the upper extremity posteriorly. They enclose between their smooth, narrow edges posteriorly a large vacuity, continuing the foramen magnum quite to the parietal roof. This relation of these bones I can not find paralleled in any reptiles. Though paired in the Stegocephalia, as also in *Pariotichus*, they meet in a median suture. Whether this peculiar structure obtains in all other plesiosaurs I can not say, inasmuch as the only references to the supraoccipitals which I find in the literature is a brief one by Andrews* concerning the bone in the young of *Cryptoclidus*, in which nothing is said of a similar structure, and a notice by Owen†, who describes the supraoccipital in *Plesiosaurus dolichodeirus* as a single, arched bone.

The inferior articular surface for union with the exoccipital is flat and triangular in shape, looking downward or slightly backward. It is pierced near its middle by the foramen for the superior semicircular canal. The sutural surface for union with the petrosal meets the exoccipital at an angle of about one hundred degrees, and is flattened or gently concave, and shorter than the other sutural surface. The external surface is moderately convex, and a little roughened. The posterior border is thin and smooth, deeply concave and sinuous, the upper extremity curved inward. The inner surface is quite smooth, gently convex from before backward, nearly straight to its upper third, where it bends strongly inward. The posterior border is short, thick, convex from side to side, and concave on its upper part before joining the sutural surface. The sutural surface above, for union with

*Geol. Mag. 1895, p. 242.

†Fossil Rept. Liassic Formation, p. 8.

the parietal, is elongate oval in shape, slightly convex in both directions, and turned obliquely inward posteriorly, so that the two bones when in place form a V. The surface looks forward and upward, and joins a projecting sutural surface of like shape on the parietal bone.

MANDIBLE.—From the exterior of the mandible four elements are visible, arranged much as in the crocodile or *Sphenodon*. The dentary extends far back along the upper border, quite to the top of the coronary eminence. Thence its suture runs obliquely to a little beyond the posterior end of the symphysis on the lower border. The element back of this on the upper border is doubtless the surangular, separated from the angular below by a suture placed very much as it is in the crocodile, beginning at the extreme posterior end of the mandible. The bone extends anteriorly as an elongated point between the dentary above and the angular below. The suture separating the element from the articular cannot be made out. The two, united, agree quite with the element described by Guenther in *Sphenodon*, and as seen in a specimen fifty-eight millimeters in length before me. I distinguish in this mandible, as did Guenther in his, only four elements —the dentary, which reaches far back; the coronoid, a flat triangular bone occupying its usual place; the articular, inclusive of the surangular; and the angular. Baur* describes five elements in a *Sphenodon* skull fifty-six millimeters in length. The articular he restricts to a small nodule or disk of bone, similar to that of the turtles, forming the articular surface; the surangular, the bone before the cotylus, which he indicates as separated by a suture; the angular he considers to be the inner prolongation of the bone which reaches to the coronoid. The slender bone usually called the angular he believes to be the splenial; while the bone usually called the splenial (presplenial, Baur) in the crocodile and lizard he believes to be wanting in the *Sphenodon*, as it usually is in the turtles. The small ossification which he finds in the cotylus of the young *Sphenodon*, similar to the element in a like place in the *Testudinata*, he assumes to be present in all reptilian mandibles, but is obliterated in the adult skull by the anchylosis of the suture. I certainly do not find such a bone in the *Sphenodon* mandible before me, nor could Guenther distinguish such an element. He believes then, that the element usually considered the articular, is in reality composed of two bones—a chondrogenous articular part and a dermogenous anterior prolongation. This is probably true, but I do not see the necessity of changing the names of the other anterior elements and of calling this

* American Naturalist, 1891.

anterior prolongation the angular, as does Baur. From the fact that the bone on the inner side of the dentary, covering Meckel's groove, is the only one which can with propriety be called "splenial" (a "bandage" or "patch"), or opercular (a cover), it will be better to retain the former name for the element, as usually applied, and to give a new name to the part separated from the articular, wherever it exists as an independent bone; it may be called the *prearticular*.

FIG. 4.

Right mandible of *Clidastes tortor* Cope. *D.*, dentary; *sp.*, splenial; *pra.*, prearticular; *ang.*, angular; *cor.*, coronary; *art.*, articular; *sur.*, surangular.

I assume that the element containing the cotylus must be the *articular*, and that the one in front of it, back of the coronoid and dentary, must be the surangular, though, as already stated, I can find no positive evidence of a separating suture in the present specimen, as is also the case in the adult *Sphenodon* mandible. Doubtless in some more fortunately preserved specimen, or in one of a younger animal, the separating suture will be traced. I will add that the suture indicated by Cope* in his figure of the skull of *Cimoliasaurus snowii*, as separating the articular from the surangular, does not exist in the specimen; the place is indicated by a mere groove only.

The *angular* is very long, and is extensively visible from both within and without. On the outer side it is seen reaching to a little beyond the proximal end of the symphysis, where the pointed extremity is visibly intercalated between the dentary and a small portion of the splenial. On the inner side, the suture follows inward below the cotylus to the anterior inner angle of the articulation, near which it passes upward to meet the prearticular. The bone passes beneath this latter element but its connection with the surangular cannot be made out. Along the inferior border of Meckel's groove and the splenial, the suture goes forward to near the proximal end of the symphysis.

On the inner side of the mandible, there is an extraordinary arrangement of the bones. After much deliberation, I interpret them

* Proc. Amer. Phil. Soc. 1894.

as the splenial (presplenial of Baur), the prearticular (angular of Baur), and the coronoid. The identity of the *splenial* is assured. It has been dislodged upward slightly, disclosing the narrow Meckelian groove, which terminates in an orifice at the proximal end of the splenial. The bone ends posteriorly below the coronoid eminence. Anteriorly it broadens so as to cover all but the upper inner part of this surface, uniting with its mate to form the symphysis. From

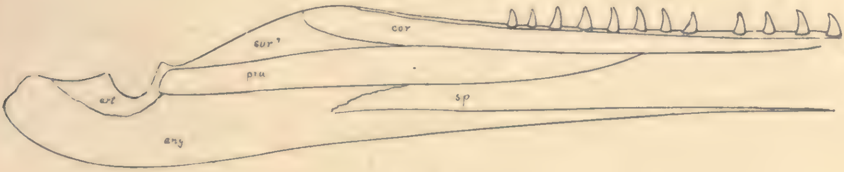


FIG. 5.

Left mandible to symphysis of *Dolichorhynchops osborni*. *art.*, articular; *pra.*, prearticular; *sur.*, surangular; *cor.*, coronary; *sp.*, splenial. Compare also Pl. II.

below, the thickened bone forms the inner part of the symphysis for a short distance forward, at least. How far it extends can not be determined, as it gradually becomes thinner and disappears from view. (See Pl. II.)

The bone which I determine as the *coronoid* is most peculiar, remarkably unlike that in any other animal which I know. It is a long, slender, flattened, trihedral bone, extending far forward, and like the splenial, meeting its mate in the median symphysis. It extends as far back as the end of the dentary, along its inner side, to the most elevated part of the surangular, where it is thin and spatulate. It follows the inner margin of the dental border of the dentary, apparently at least as far as the middle of the symphysis. At the beginning of the symphysis with its mate, the bone is somewhat triangular in cross-section, with its thin margin below touching the splenial; the mesial surface is in contact with that of its mate, while the upper surface is narrow. On one side the bone, while still retaining its proper relation with that of the opposite side, has been partially dislocated from the mandible, so that there can be no question of its morphological relations to the contiguous elements.*

Between the splenial and the coronoid, on the inner side, is seen a narrow, thin bone, corresponding quite to the dermogenous portion of the articular in the turtles and Rhynchocephalians, that is,

* This peculiar relation of the coronoid is well illustrated in fig. 13, p. 476, vol. xxxvii, of the Quarterly Journal of the Geological Society, in Prof. Sollas' article on "A New Species of Plesiosaurus from the Lower Lias of Charmouth."

the angular of Baur. It lies above the splenial, disappearing beneath the coronoid anteriorly. Posteriorly it is joined by a suture with the articular, approaching but not quite entering into the cotylar surface, or if so, only to a slight extent. This end has been dislodged slightly from its normal position and is slightly twisted upward. It is scarcely possible that this is due to fracture, since the surface has all the indications of a suture, and a fracture could hardly have occurred here without injury to the bone underneath. The end is slightly thickened and fits into a pit on the anterior upper part of the articular rim; just below the suture, separating it from the articular, there is a longitudinal ridge-like roughening, and a narrow, deep pit. This element I call the *prearticular*.

For the sake of comparison, I have figured in Pl. V the mandible of *Sphenodon*, *Crocodilus*, *Chelydra*, *Varanus*, with the interpretation of the elements as here accepted.

The bones of the skull, as of the entire skeleton, seem to have had a sort of postmortem plasticity. Apparently during life the sutures everywhere were free, and the parts all readily separable, and wherever the bones have been disturbed or distorted the sutures have pulled apart and widened. Where there has not been such disturbance, however, the sutures are often obliterated, the elements fusing together. This would seem to indicate youth, but plasticity in the Cretaceous skeletons was largely due to the composition of the bones, which may have been more or less persistent throughout life. Those in which the inorganic proportions were large have suffered less from postmortem disturbances than those in which the organic material was considerable. Bird bones were never plastic, and very rarely are the bones crushed, the cavities being filled with crystalline material often. Of the pterodactyls, however, the bones are invariably found crushed, though presenting little evidence of plasticity. Among the mosasaurs, the more firmly ossified bones of *Clidastes* are less often changed in shape, while the Tylosaurs, on the other hand, were more or less subjected to a plastic distortion. The structure of the plesiosaur bones in all that I have seen is unusually soft.

VERTEBRÆ.—*Atlas* and *axis*. (Pl. XXII.) The *atlas* has the usual number of elements, the intercentrum and the two side pieces, or neurapophyses. It will be convenient, however, to describe in this connection the parts of the whole axial and atlantal complex, that is, in addition to the odontoid, the axial intercentrum and the axial centrum and arch. The arrangement of all these parts is very like that in the lizards, crocodiles and various other reptiles, save that the structure is somewhat more primitive or generalized. The atlantal intercentrum is the largest element of the complex, save the axial centrum. It has five articular surfaces for union with as many bones: four of these surfaces are sutural, and, doubtless in old animals or in other species, the sutures may be obliterated. The inferior or ventral surface has an obtuse ridge along the middle, on either side of which the surface is flattened or a trifle convex. This surface is free, and its anterior and posterior margins are parallel. The anterior or cephalic surface is concave for articulation with the hemispherical occipital condyle, its rim forming more than one-third of the entire circumference of the cup. The posterior surface is flat, elongated triangular in shape, with a V-shaped emargination, for articulation with the axial intercentrum. Dorsally the bone articulates by a broad sutural surface with the odontoid, except on the cephalic part of each lateral margin, which unites by a small, semi-oval surface with the neurapophysis.

The axial intercentrum is not unlike the atlantal in shape, when seen from the ventral side, though smaller. Its ventral surface continues the obtuse ridge of that intercentrum, but it is here quite prominent, the nearly square free surface on either side being distinctly concave. The posterior surface for sutural union with the body of the axis is flat or gently concave; its free margin is broadly V-shaped, with the inferior angle rounded: the dorsal margin is gently concave in the middle to the truncated, very broad arms of the V. The cephalic sutural surface is flat, for union with the atlantal intercentrum, and like that of this bone, its surface is broadly triangular in shape. On either side the bone articulates, through the greater part of its extent, by an oblique, concave surface with the axial rib, forming part of the pit for the reception of that bone. Its upper lateral part unites by a small surface with the odontoid, forming with it and with the axis the complete margin of the rib-pit. Dorsally the bone articulates on its caudal half with the axis; on its cephalic half with the odontoid.

The odontoid, or atlantal centrum, unites posteriorly by a broad, flattened, sutural surface with the body of the axis. On the cephalic side there is a concave surface in the middle, occupying about one-half of the diameter for articulation with the condyle, the deep cup being completed ventrally by the atlantal intercentrum and on the sides by the neurapophyses. Dorsally the neurapophyses leave a small notch of the rim incomplete, which is partly filled out by the odontoid, making the diameter of the cupped surface of this bone greater dorso-ventrally than from side to side. The sides of the bone have a free, irregularly trapezoidal surface, the longer, cephalic border articulating with the atlantal neurapophysis, the caudal, oblique border with the axial intercentrum, the ventrocaudal angle with the axial intercentrum, and the ventral part of the caudal border with the axial rib, its dorsal angle touching the axial neurapophysis. The ventral side of the body unites suturally with the intercentra. On the dorsal surface there is a narrow, free space, which helps form the floor of the neural canal.

The *lateral pieces* or *neurapophyses* are composed of a large body for sutural union with the other elements, and a small, laminar, dorsal projection, which is free. The body is irregularly five-sided, the external free surface convex dorso-ventrally. The cephalic surface is smooth and concave, forming the lateral rim of the condylar cavity. Ventrally a small articular surface is for union with the condylar rim of the atlantal intercentrum; the border nearly parallel with the upper. Caudad, there is a small articular surface for union with the arch of the axis; the long border between these two joins the lateral surface of the odontoid; the dorsal surface sends a flat projection backward to touch, or nearly touch the small, vestigial prezygapophysis of the axis: this lamina is continued into a small, flat process, the vestige of the neural lamina. These neurapophyses are peculiar in articulating at their base for a short distance with the neurapophyses of the axis, doubtlessly corresponding to the articular surfaces between the body of the axis and the lateral masses of the atlas in the mammalian vertebræ. It is very plainly evident, therefore, that the name zygapophysis, when applied to this articulation in the mammalian axis and atlas is incorrect—the real zygapophyses are completely lost.

The atlas, as a whole, is of a primitive and generalized character, in that the neurapophyses are, for the most part, borne by their own centrum, and the atlantal arch only in small part by the atlantal intercentrum.

The *axis* has its anterior surface flattened for sutural union with the odontoid. On the cephalic ventral part is received the axial intercentrum, the lines of the union reaching midway of the body on the ventral side. The pit for the reception of the rib is very large and deep, and is formed in part by the odontoid and intercentrum. The pedicles of the arch are stouter and broader than in the following vertebræ, articulating in front with the lateral pieces of the atlas, and, to a slight extent, with the odontoid. The prezygapophyses are represented by a small tubercle, approximated to the flattened posterior process of the lateral atlantal pieces. Back of this there is a thickened, rugose, horizontal ridge, reaching to the intervertebral notch. The posterior zygapophyses are situated rather high, and do not differ materially from the same processes in the following vertebræ. The spine is incomplete posteriorly, but seems to have been short, stout and much inclined.

The structure of the plesiosaurian atlas and axis has been described by Owen,* Huxley† and Barratt.‡ In the specimen of a *Plesiosaurus* described by Barratt the different elements were separated and were for the most part complete. The neurapophyses differ markedly in their expansion inward to form a roof for the neural canal, though they do not touch each other. The atlantal intercentrum also differs in its posterior projection into "two long processes," which are, however, broken away, leaving only their bases. The axial rib seems to articulate with the axis and axial intercentrum only. In *Plesiosaurus etheridgii*, the atlas and axis of which are described by Huxley, the bases of the atlantal neurapophyses are much larger and meet above the odontoid. In *Plesiosaurus pachyomus*, as described by Owen, "the anchylosed bases of the neurapophyses form the upper border of the cup," and the atlantal intercentrum "develops a thick but short rough tuberosity from its under part," and the rib projects from the centrum of the axis only. The processes were all broken away.

It is seen that the structure in *Dolichorhynchops* is more specialized than in these species of *Plesiosaurus*.

The atlantal and axial intercentra, variously considered by different authors as "subvertebral wedge-bones," hypapophyses or hypocentra, are correctly homologized by Baur,§ Albrecht‖ and Osborn.¶ It is a little interesting to note, however, that Owen (l. c.) long ago gave a correct hint of their homology: "According to the latter view, what has usually been regarded as the centrum or body of the atlas in Saurians, Chelonians and the higher Vertebrata, would be the hæmapophyses of that vertebra; and the odontoid process the true centrum." He concludes, however, that these elements are "detached cortical parts of the real centrum;" though later he correctly compares them with the hypocentra of the labyrinthodonts.

Perhaps the most primitive and unchanged condition of these ele-

* Ann. Mag. Nat. Hist. xx, 217, 1850.

† Geological Journal, 1858.

‡ Ann. Mag. Nat. Hist. Nov. 1858.

§ American Naturalist, 1887, Sept., p. 839.

‖ Bull. Mus. Roy. d'hist. Nat. de Belg. ii, 185.

¶ Mem. Amer. Mus. Nat. Hist. i, p. 157.

ments in the reptilia is found in *Ichthyosaurus*, in which, as shown in the figures given of the axis and atlas by Owen, the intercentra of the first three vertebræ occupy nearly their normal and unaltered relations to the vertebræ. It is difficult to understand, however, how such a primitive condition of these parts could have been inherited from a terrestrial ancestor. In the plesiosaurs the specialization has been carried further, still the structure is yet more primitive than is known in any modern reptiles and in most of the extinct. We certainly can look for ancestral forms of these vertebræ among the Stegocephalia or Anomodonts only; in all other reptilia they have acquired too great specialization to easily revert to the generalized structure.

In the modern crocodiles the specialization has been carried so far that the axial rib has become supported by the atlantal centrum only, while the atlantal rib has been pushed forward on the atlantal intercentrum.

It is of interest to observe that in *Shastosaurus* of the earlier Ichthyopterygia, according to Merriam, there were probably five intercentra present in the anterior cervical region, while in *Ichthyosaurus* there are but three, and in the more specialized forms, *Baptanodon*,* they have entirely disappeared.

Beyond the axis there are seventeen distinctly *cervical vertebræ* preserved, together with one or two transitional ones, which must be classed with the dorsals, however. I believe that these were all that the animal possessed, though it is possible there may have been one or two more. The arches and ribs of all, save of the third, were detached and scattered about among the other bones, so that much difficulty was encountered in properly associating the parts. Because of a gradual increase in size of the ribs and arches, as well as the centra, it would seem that the final collocation made is correct, and because all these processes agree in number it would seem still more probable that no vertebræ are missing. (See Pls. VI–IX.)

The centra increase in height and width gradually throughout the series. The third has a transverse diameter of thirty-five millimeters, a height of thirty and length of twenty-eight. The sixteenth centrum has its corresponding diameters as follows: forty-five, thirty-eight and twenty-six. The three following are somewhat distorted, but seem likewise to increase slightly in height and width. It will be observed that the length is nearly or quite the same in all, the differences being exhibited in the width and height only. The articular surfaces of the centra are gently and evenly concave, with a slight rounded eminence

*W. C. Knight, *in litt.*

in the middle of the concavity, sometimes apparently obsolete. The margins are rounded, the cartilaginous borders limited exteriorly by a slender, smooth line. On the ventral surface, near the middle antero-posteriorly, there are two vascular foramina, at the bottom of a slight depression, and separated from each other by a rounded ridge. Posteriorly the distance between these foramina becomes greater. The pit for the articulation of the cervical rib occupies nearly the whole length of the centrum, between the cartilaginous margins, and reaches also nearly to the plane of the neural surface. The ribs increase in length and width from the axis to the beginning of the thorax. They are single headed, flattened, with the free extremity moderately dilated and thinned, except those of the axis, which are more styliform, and are directed more obliquely backward. On the following vertebræ they are directed outward and backward, with the distal extremity rounded, except in those of the anterior vertebræ, where the anterior part distally is slightly angulated, as though suggesting a rudimentary anterior projection. The spines slope gently backward. They increase but little in length, that of the third vertebra measuring forty-eight millimeters in length while that of the last is but fifty-five above the zygapophyses. They increase in stoutness, however, much more than in length, the anterior ones being slender, the posterior broad and thick with a somewhat expanded cartilaginous extremity. The zygapophyses are broadly separated throughout, with an obliquity of about thirty degrees from the dorsoventral plane. They are broadly oval in outline, of large size and nearly flat. They project strongly from the body of the vertebra, leaving a space of about ten millimeters in extent between the centra, when in close articulation, for the intervening cartilage. The diameter of the spinal canal throughout the series is about fifteen millimeters. Upon the floor of the canal there are two venous foramina, near the middle.

Thirty *dorsal* vertebræ were found in the matrix. The arches were invariably separated from the centra, and, because of the general resemblance of the latter it is impossible to say whether all have been correctly associated. The centra were in large part crushed or compressed, and in some cases were so soft that it was found impossible to remove them entire. Two of the arches were wedged into the temporal fossæ of the skull in such a way that it was found necessary to largely destroy them in cleaning the skull. In general, the spines of the dorsal region were so soft and frail, intermingled as they were, that they could not be removed. A large part of them, hence, have been modeled in the restored skeleton. Because, however, of not a few arches that were recovered complete, or nearly so, from different parts of the series, the restoration of the intervening parts of the series has presented few difficulties.

The spines decrease very slightly in height, in breadth and in thickness. Anteriorly they are directed somewhat backward, but soon become quite vertical in position. In the posterior cervical and anterior dorsal region the spines present a much larger, oval and truncate extremity for ligament or cartilage; this surface measures from twelve to fifteen millimeters in width in some of the posterior cervicals. In the posterior dorsals the extremity is narrow—three or four millimeters in width. The first diapophysis* is small, for the attachment of a small, short rib, and is situated low down on the pedicle,† close to the sutural surface. The next is much stouter and longer, for the attachment of a long and strong rib. The next two or three ascend progressively on the pedicle, until in the fifth the upper margin of the root is above the plane of the anterior zygapophyses. They retain this position throughout the series, the last two or three, only, descending toward the centrum. The diapophyses have acquired their greatest length by the sixth or seventh, and are directed upward and outward. In the articulated skeleton there is a deep costo-spinal groove on either side. The zygapophyses are largest and stoutest in the posterior cervical region, decreasing gradually in size, and becoming obsolete at the base of the tail. Throughout the dorsal region they are but slightly cupped, and are directed dorsad and ventrad, at only a slight angle from the median plane. There are no indications whatever in any region of a zygosphene. The centra throughout this region were more or less crushed in the specimen, but seem to be very uniform in character. Their size is but very little different from that of the posterior cervicals, their length no greater; the venous foramina on the ventral side become gradually more remote from each other.

Some of the *dorsal ribs* were so badly decomposed that they could not be recovered from the matrix; others were so intermingled with other bones that they could not be removed entire. The larger part, however, have been recovered and restored nearly to their living condition. The anterior long ribs are flattened, with an expanded head, only moderately curved and with the distal extremity only a little attenuated, the cartilaginous continuation evidently of some

*Baur (Anatom. Anzeiger ix. No. 4, 1893, p. 120) would restrict this term to the process bearing the head of the rib in the Stapedifera.

†Seeley has proposed to call these vertebræ in which the rib is ascending from the centrum, pectorals.

length. The posterior ribs are short, less flattened, with a less expanded head and with a pointed distal extremity. From the position of the diapophyses anteriorly, it is quite evident that the ribs were directed much more outwardly than downwardly. In the restored skeleton, the transition from the long to the short ribs has been made gradual, and two or three on each side have been modeled here. (See Pl. XI.)

About fifteen *ventral ribs* were preserved: others have undoubtedly been lost. Only one is symmetrical; it is about thirty centimeters in length and is thickest near its middle, tapering to a point on each side, and has a moderate curvature. The others preserved measure from twelve to sixteen centimeters, and have a thickness near their middle of about ten millimeters. They are gently curved, irregularly prismoidal in section, and taper to a point at each extremity. Because of their number and the scattered positions in which they were found, it has not been possible to arrange them in the mounted skeleton with any degree of precision. In the known European specimens they form a double series of three, with a larger symmetrical median one. Abdominal ribs are known only in the crocodilia, rhyncocephalia pterosaurs, ichthyosaurs, dinosaurs and plesiosaurs.

The *caudal* vertebræ were found at some little distance from the remainder of the skeleton, and for the most part had been collected separately by Mr. Sternberg. The processes, as elsewhere in the column, had been separated, and were, many of them, found variously intermixed with the other bones. Both the centra and the processes, however, were in excellent condition, as were those of the neck, in marked contrast to the dorsal vertebræ. The last twelve taper so uniformly that it is quite certain they all belonged together, and that no intervening ones were missing. This series has a diameter of forty millimeters at the beginning and only twelve at the extremity, with lengths respectively of twenty-five and twelve millimeters. The greatest decrease in size occurs in the last five or six of the series. These distal five or six have the shortening much more pronounced on the dorsal than on the ventral side, indicating a well-marked upward curvature of the extremity of the tail. Because of the rapid change in the characters of these vertebræ there has been no difficulty of associating the processes with their respective vertebræ. The spines in the early ones of the series slope at a moderate angle backward, the obliquity being greatest in the twelfth from the end. In the last six, the spines are much shorter and stand nearly vertically, or even with an anterior slope. The diameter of the last centrum preserved indicates the presence of two, or perhaps three smaller ones forming the extreme tip of the tail; these must have been mere nodules of bone, without processes. (See Pl. X.)

Several other vertebræ are assigned to the caudal series, chiefly on the evidence of the venous foramina on the ventral side of the centra, though they have no facets for the chevrons. Between these and the continuous series, four vertebræ have been intercalated; the number may be too great; possibly not enough. That some were missing is quite certain, since the change in the direction of the spine is too abrupt in the ones preserved. Because the tail as restored seems to be of about the length of some other known forms, I am inclined to believe that the number of the caudal vertebræ, all told, did not exceed twenty-five. All those preserved, except the anterior ones, show a nearly circular and somewhat cupped surface on each side for the attachment of the hæmapophyses. The separate branches are directed downward, outward and backward. They are somewhat flattened and expanded distally, except the distal ones, which are more rod-like. The diapophyses or ribs of the connected series spring from near the middle of the centra dorso-ventrally, and are directed outward horizontally, the most posterior ones also slightly forward. They have a somewhat expanded extremity, with a cartilaginous margin. At the beginning of the series they arise near the middle of the centra antero-posteriorly, but gradually approach the anterior margin. They terminate as free ribs on the seventh before the end, that is on the ninth or tenth before the extreme tip of the the tail. The sixth has a small exogenous tubercle to represent the process. None of the caudal vertebræ, save at the immediate base, have functional zygapophyses, and the tail was evidently capable of considerable lateral and vertical movements. There are no indications whatever of a terminal fin, unless the upward curvature of the tip of the tail suggests such an appendage. Its use, however, could not have been great, since the evident shortness of the tail, and its interference with the hind limbs would have deprived it of much service as a propelling organ.

PECTORAL GIRDLE.—The *scapula* is of the usual triradiate shape. The coracoid or glenoid ramus is short and rather stout, somewhat expanded at the extremity, with the two articular facets meeting in an obtuse angle, the larger, oval one for the glenoid articulation; the smaller, triangular one for union with the coracoid. The dorsal ramus is narrowest, is rather stout, thickened on the posterior and thinned on the anterior border; it terminates in a flattened surface for attachment of a suprascapular cartilage. The ventral or clavicular (proscapular) extremity is broad and thin and deeply concave on its visceral surface. Its inner border is rounded for the most part and thin, except

FIG. 6.

Part of right scapula of *Plesiosaurus mudgei* Cragin, external (left) and internal (right) views.

on the anterior part, where it is moderately thickened, as though for cartilage. The posterior and inner border is quite thin throughout and evenly concave, forming the outer anterior border of the scapulo-coracoidal foramen. The anterior border is sinuous and thinned, having a knife-like edge throughout its whole extent. The exterior border, between the glenoid and suprascapular extremities, is deeply concave, with the margin thickened and convex. The ventral surface of the bones forms two nearly flat planes, meeting in a straight, prominent ridge, which extends from the ventral side of the anterior border of the glenoid surface to the anterior angle of the ventral ramus. The two surfaces meet in a very obtuse angle. The visceral surface is, for the most part, concave. On the ventral ramus this concavity is marked, receiving the clavicle on its anterior part. There is a sutural roughening continued along the anterior border

FIG. 7.

Ventral extremity of scapula of *Plesiosaurus gulo* Cope (type specimen), one-half natural size.

to the base of the dorsal ramus, throughout the whole extent of the concave portion of the border. The bone differs from the scapula of *Murænosaurus** in the less expanded ventral ramus, which is separated from its mate by the clavicle and episternum. From the *Cryptoclidus*† scapula it differs in having a more slender and elongate dorsal ramus, and in the non-expansion of the ventral ramus. From a scapula of *Pl. mudgei* Crag. from the Lower Cretaceous in the University of Kansas Museum, it differs in its much less slender coracoidal and dorsal rami. The bone is also much more slender than in *Peloneustes*. (See Pl. XII.)

The *coracoid* is a very large and broad plate, with a slender, blade-like epicoracoid projection. Its glenoid portion is massive, with a smaller humeral articular surface, and a larger scapular facet, meeting each other in a very obtuse angle. The external border is thickened and concave, produced into a considerable projection at the posterior angle. Just before its termination there are several tooth-like projections of small size, evidently for muscular attachment. The posterior margin is thin, with rounded angles and a slight concavity between them. Opposite the glenoid articulation the bone is massive, meeting its fellow in a thickened bar with an oblique sutural surface. Immediately posterior to this interglenoid thickening, the bone on the mesial side is very thin, and in the anterior part of this thinned portion, near the middle line, there are two large, well-defined, round foramina that have never before been described in the coracoid, though perhaps indicated in the description of *Trinacromerum*. The clavicular or epicoracoid process in front is long and thin, with nearly parallel sides, the anterior end slightly expanded and its margin with a cartilaginous border. The sutural surface for the clavicle extends back on the upper surface to nearly midway of the process. The coraco-scapular foramen is elongate in shape and is bounded entirely by the two bones, save for a short distance at the front inner part where the clavicle completes the margin. The coracoid has the posterior outer angle more produced than in either *Cryptoclidus*, *Peloneustes* or *Murænosaurus*, and the clavicular process is longer and better developed than has been described in any form, except perhaps in *Trinacromerum*.

The *clavicle* is a thin, concave, irregularly triangular or triradiate bone, and is well developed. It lies upon the ventral plate of the scapula and the epicoracoid process of the coracoid, and above the squamous margin of the episternum, a remarkable position for a

*Andrews, Ann. Mag. Nat. His. xv, 431.

†Andrews, Ann. Mag. Nat. Hist. xv, 355.

membrane bone to attain on the visceral side of all three cartilage bones. The anterior border is gently thickened, somewhat sinuous in outline, and is free for a part of its extent. The other borders are

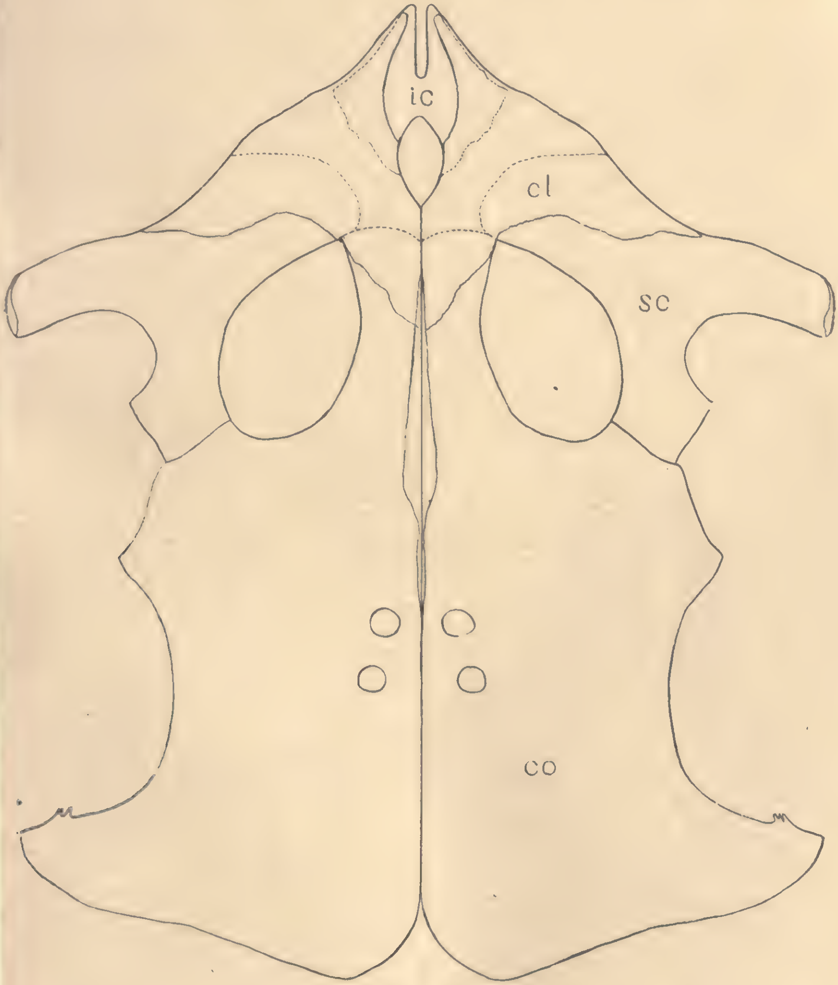


FIG. 8.

Diagram of pectoral girdle of *Dolichorhynchops osborni*, from above; the outlines of concealed parts are indicated by dotted lines. *Ic.*, episternum (interclavicle); *cl.*, clavicle; *sc.*, scapula; *co.*, coracoid.

thin, for the most part squamous, and nowhere free, save for a short distance at the anterior end of the coraco-scapular foramen, and the posterior part of the interclavicular foramen. The two bones meet in a median symphysis for a short distance back of this interclavicular foramen. The under or convex surface appears only for a small space between the ends of the scapulæ, epicoracoid processes and the episternum. Its outer extremity extends into a slender process, broken away in the specimen figured, which reaches along the front margin of the ventral ramus of the scapula to the base of the dorsal ramus. (See Pl. XIII.)

The *clavicle* seems to be the most variable bone in the skeleton; I know of no form in which it is better developed. In *Cryptoclidus* it is a small, triangular bone, meeting its mate in the middle line, according to Andrews, the episternum being absent. In *Plesiosaurus mudgei* Cragin (see Pl. XXVII), the clavicle appears to have been smaller and more triangular than in the present species. It is generally assumed that this bone is the real clavicle by Seeley, Andrews, Fürbringer and others, and one may, with Andrews, explain its position in relation to the ventral ramus of the scapula by the peculiar method of ossification of that bone. But, can its visceral relations to the coracoid and episternum be explained as easily? It is true that many authors call the median, unpaired piece the interclavicle, a membrane bone, and, if this origin is accepted, its position in relation to the clavicle is not remarkable. But I am inclined, with Gegenbaur and Fürbringer, to believe that this central piece is really the episternum, a cartilage bone. Andrews described the clavicle in some forms as showing a sutural tendency with the scapula, and in some forms, as *Elasmosaurus*, it seems to become entirely fused with that bone, or if not, has disappeared entirely.

FIG. 9.
Episternum of *Trinacromerum anonymum* Will. one-half natural size.

The *episternum* (interclavicle) is a small, symmetrical bone deeply emarginate in front and behind. The thin squamous margin on each side underlaps the clavicle. These squamous borders seem to have been covered with cartilage below, leaving a free, convex, ventral surface, elongate oval in shape, including the emarginations, limited by a distinct ridge or angle. The striation of this thinned margin points to a covering of cartilage. The anterior emargination of the bone is narrow and deep, while the posterior one is broader and even deeper. It differs markedly from the corresponding bone of *Pl. mudgei* (see Pl. XXVII), in its less broad and deep emarginations. An episternum which I provisionally refer to the species *Tr. anonymum*, herewith figured, resembles that of *D. osborni* more closely. In all three, perhaps belonging to distinct genera, it will be seen that

Fig. 10.

1. Episternum and clavicles of *Muraenosaurus*; 2, 3, the same of *Plesiosaurus*, from above and below. After Seeley.

the emargination behind represents a distinct foramen in the completed girdle—the interclavicular foramen, of which the only mention hitherto that I can find is by Seeley (Proc. Roy. Soc. Lond. li, p. 140), whose figures I reproduce here.

In Pl. XV is shown the articulated pectoral girdle from below, and in Pl. XIV, the same is shown in front view. As a whole, the girdle forms a rather deep trough, with the dorsal rami of the scapula directed upward and somewhat outward. Its exact position in relation to the ribs is difficult to state, but I do not think that the position given in the restoration can be far wrong. The slight

FIG. 11.

Scapulo-clavicular girdle of *Plesiosaurus mudgei* from above; the missing parts restored in dotted lines. *Ic.*, episternum; *cl.*, clavicle; *sc.*, scapula; *co.*, epicoracoid process.

degree of curvature of the ribs in the pectoral region must have left a rather angular margin to the thorax on either side, filled in, in part at least, by the cartilaginous continuation of the thoracic ribs, which the preserved ends plainly show were present. The upper surface of the girdle was not hollowed much, if any, longitudinally, so that the base of the neck must have been in life quite deep.

An examination of the under surface of the girdle, as shown in Pl. XV, furnishes, I think, convincing proof that the space between the scapulæ, epicoracoid process and the elliptical lines on the ventral surface of the episternum was filled in in life by cartilage, joining the coracoid and scapula and covering the squamous portion of the episternum, but leaving the interclavicular foramen free. Ossification of this cartilage evidently occurs in some forms, uniting the whole into a single ventral plate, which is said to have a sutural connection with the epicoracoid processes, forming what Seeley calls the Elasmosaurian type of girdle. Seeley suggests that this cartilage may represent the precoracoid: "In all Plesiosaurs, on the other hand, the precoracoid, if developed, remains cartilaginous; but I infer that a cartilage always extended from the anterior margin of the coracoid to the anterior extremity of the scapula, and, by ossification of such cartilage, the Plesiosaurian shoulder girdle would become Elasmosaurian."*

This precoracoid nature of the cartilage is contested by Koken: "The view that the bone considered to be the scapula in the Plesiosaurs also includes the precoracoid is supported neither by comparison nor observation. In no reptile has there been shown to be a union of the scapula with the precoracoid more intimate than its union with the coracoid, and its fusion with the scapula without union with the coracoid would be remarkable. I agree quite with Baur, who considers the forked bone of the turtles to be the scapula only, its two branches being homologous with those of the plesiosaurian scapula. Seeley believes that the precoracoid was cartilaginous, connecting the front end of the coracoid with the anterior end of the scapula, and that this became ossified in the Elasmosaurians in such a way that it was separated from the coracoid by suture, but was fused with the scapula. That is, it is the precoracoids and not the scapulæ which meet in the middle line. It seems to me that this would be the method of extension and ossification of the scapulæ. Why, then, should we call in the aid of a cartilaginous precoracoid as an unknown quantity, which later becomes indistinguishably fused with the scapula?"†

The precoracoid arises from a distinct ossificatory center, when ossified. Is it reasonable to suppose, then, if this is a distinct element, that any such mode of extension of the scapula as Andrews has shown to be the case in *Cryptoclidus oxoniensis*‡ would occur if there was really a union of scapula and precoracoid? He shows clearly that the scapula increases in length peripherally, and not by the addition of an ossified cartilage. If it arose from a distinct center, as it must, one would certainly expect to find it in a separated condition in the young animal, but this was not the case in the ones that Andrews examined. Furthermore, in what possible way could a carti-

*Proc. Roy. Soc. Lond. li, p. 138, 1892.

†Koken, Zeitschr. Deutschen Geol. Gesellsch. 1893, xlv, 346.

‡Ann. Mag. Nat. Hist. 1895.

lage bone like the precoracoid get entirely on the outside and seal in a membrane or dermal bone? I would sooner believe that the so-called clavicles are really precoracoids, and for this belief their position on the visceral side of all three cartilage bones, the scapula, episternum and coracoid, would lend some support. In no case, however, can I believe it probable that this cartilage represents the precoracoid.

The same argument will apply in its entirety to the assumption that the ventral ramus of the scapula is in reality the precoracoid. In no specimen has it ever been found as a distinct ossification. It grows peripherally, enclosing the clavicles on their outer side. The elongated clavicles unite by suture with the scapula in the Nothosauria without the intervention of any precoracoid process. By the reduction of the clavicles and the extension of the acromial process in these animals we would get the Plesiosaurian girdle. Is it necessary to insert a distinct ossificatory element in this development?

It may be added that Koken believes the precoracoid to be fused with the coracoid.

I cannot, therefore, believe that the precoracoid is represented by any ossification in the plesiosaurian clavicular girdle. Nor do I believe there is any genetic relationship between the ventral ramus of the Plesiosaurs and that of the Chelonian scapula. If there is, is it not strange that in the one case the branch should lie ventrad to the clavicle and in the other dorsad? I am well aware that in thus concurring in the views held by Seeley, Andrews, Koken, Baur and others, there are pertinent arguments on the other side given by Hulke, and especially Fürbringer.*

PELVIC GIRDLE.—The *pubis* varies but little from the usual form. It is a broad, flattened plate of bone, thinned throughout, except at the symphysial and acetabular articulations. It is, in general, quadrilateral in shape, with the anterior inner angle broadly rounded, and the acetabular angle truncated. The posterior and outer borders are both markedly concave, and of about equal length. The anterior border is more nearly straight and irregular. The inner border is thickened on the posterior third or half, gradually becoming thinner anteriorly. The obliquely truncated sutural surface is much roughened. The two bones, when united, must have made an angle with each other of about one hundred and twenty-five degrees. I do not think that there was much cartilage between the two, or that it extended back to the ischial symphysis, though it may. Anteriorly

Jena. Zeitschr. 1900, p. 332.

the cartilage continued to the rounded outer anterior angle, where the bone is a little more thickened. The acetabular surface is much the larger of the articulating facets. It meets the smaller and roughened facet for the ischium in a very obtuse angle. The bone is more thickened on the outer and posterior parts, that is, near the non-cartilaginous border, than elsewhere. (See Pl. XVI.)

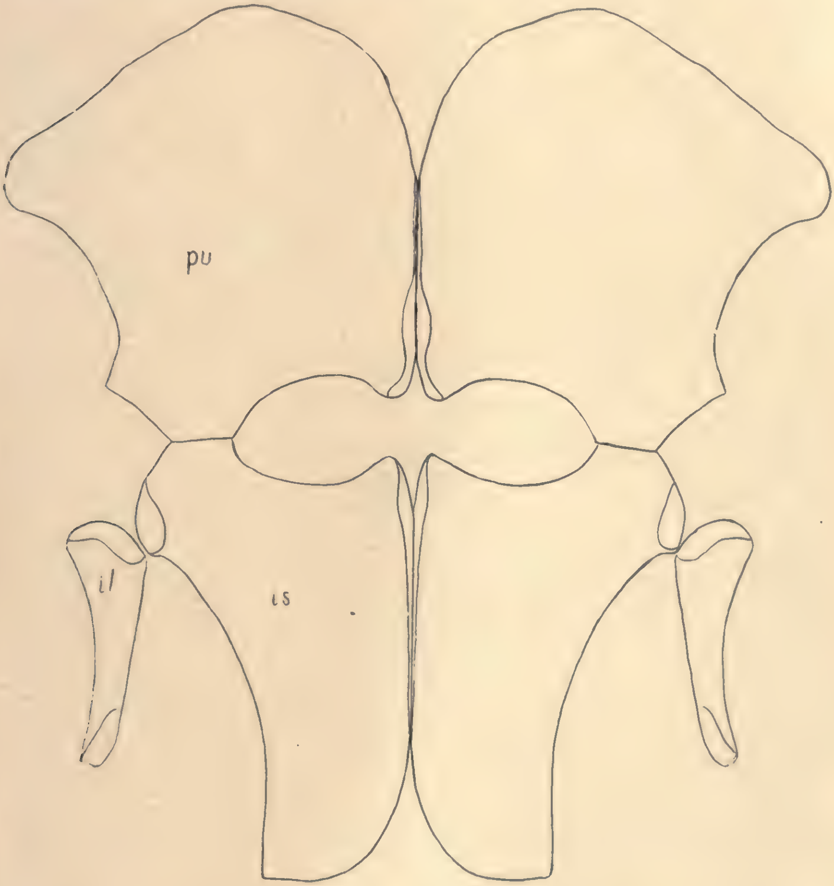


FIG. 12.

Diagram of pelvic girdle of *Dolichorhynchops osborni*, visceral surface. *Pu.*, pubis; *is*. ischium; *il.*, ilium.

The *ischium* is more elongate and proportionally larger than is usual among plesiosaurs, though of the usual hatchet shape. It has three non-sutural articular surfaces—the larger middle one, looking directly outward in the articulated ischium; a smaller posterior one, looking upward; and a small one looking forward and a little downward for the pubis. The anterior border is concave, and the portion adjacent to this border is the thickest of the bone. The symphysial border is thickened on the anterior third, gradually thinning posteriorly. This border is obliquely truncated, as in the pubis, anteriorly; posteriorly the cartilaginous border, moderately thin, is continued around the inner angle to the outer one, where it meets the free outer border abruptly. The outer border is gently concave in its whole extent, and only a little thicker than the inner portion of the bone. It ends in a right angle. (Pl. XVII.)

The *ilium* is a small, rod-like bone, moderately expanded at its ischial extremity. Of the two articulating extremities, that for the ischium is much larger than the one for the acetabulum. In the middle of the bone, a cross-section is roundly oval. The upper extremity has a small, flattened, parallelogrammatic surface, which, in the articulated pelvis, looks inward, slightly backward, and perhaps a little downward. The bone when articulated was directed backward at an angle of about thirty degrees, and inward perhaps a little more. There is very little evidence of articulation with the sacral ribs. The union must have been weak and slight.

The pelvis, as a whole, was troughlike, as was the pectoral girdle. The two bones meet at a considerable angle, and it is also certain that there was a large angle between the ischium and pubis, so that, with the ischial symphysis nearly horizontal, the pubes were directed at a considerable angle downward. This position, indeed, is necessary, since otherwise there would have been a strongly upward turn of the abdominal contour immediately behind the coracoids, and the ischia and pubes will articulate in this position only in this specimen.

FRONT LIMBS.—The paddle-bones of the specimen were all completely intermingled and displaced, so that none could be referred to its proper limb from the position they were in.

Apparently nearly all were preserved, though some of them were distorted and crushed. The labor of assorting and correctly locating these parts was very great, especially the phalanges; indeed, of the latter there is little assurance that the final collocation in many cases is correct. Aside from the femora and humeri, the only distinction that could be made between the bones of the front and hind limbs was in the size, always slightly smaller in the hind than in the fore limb. By thus assorting into pairs and assigning the smaller pair to the hind limb it was certain that the bones of the epipodial and mesopodial regions were correctly placed. The labor was much lightened by the aid of a nearly complete paddle of another species, described further on. This paddle was less compressed and distorted, and I have therefore reserved it for a more full description of the parts and discussion of the functions.

The humerus of *Dolichorhynchops* has the head only moderately convex, with its margins rather sharply limited, its greater convexity, as usual, on the radial side; its general surface looks mesad and ventrad at an angle of about forty-five degrees. Its cartilaginous surface is continuous with that of the tuberosity, which has a large, flat surface, directed dorsad and mesad at an angle of about forty-five degrees. The grooves separating the surface from the head are broad and shallow, that of the ulnar side the broader. The anterior border of the bone is concave on the proximal part, gently convex at the middle and shallowly concave on the distal part. The posterior border is nearly straight on the shaft, deeply concave distally. The distal anterior angle is rounded in both specimens. On the distal border two facets are apparent, for the radius and ulna; the rest of this border presents no clear indications of articulations. The pectoral rugosity is strongly roughened, and produced into a broad, low tubercle; the roughening, moreover, is continued obliquely nearly to the other rugosities on the sides. It is situated nearer the head than in *Polycotylus*. The ulnar rugosity forms a deep pit above the middle of the bone, while the radial rugosity is opposite it and much nearer the head of the bone than in *Polycotylus*.

Three bones were certainly located in the fore-arm, and a fourth one seems to be represented by a pair of small nodules. The free, emarginate border between the radius and ulna is less apparent than it is in *Polycotylus*. The relations of all the smaller bones seem to be quite as they are in *Polycotylus*, and the reader is referred to the figures of the two paddles for comparison, in connection with the description of that of *Polycotylus*.

HIND LIMBS.—The femur shows the usual plesiosaurian differences from the humerus, in its greater slenderness, slightly greater length, more slender shaft and less dilated distal extremity. The anterior border, as seen in the figure, is nearly uniformly concave, terminating in a more pronounced angle than in the humerus. The posterior border is, also, concave throughout to the greatest expansion, which occurs more proximally than in the humerus, and in a rather better marked angle. The rugosities of the under side and margins are as in the humerus, though scarcely as well marked. Whether the bones of the leg and ankle have been correctly located, rather than in the fore limb, is impossible to say—the only differences that could be detected are the rather lighter weight or greater slenderness of those located here. Their relations to each other are precisely those of the fore limb. It seems probable that the fourth bone on the posterior side of the first row, articulating with the femur, was wanting in life, or at least was very small—none were preserved. The fore and hind limbs, as restored, are of the same length. All four paddles were restored as completely as those shown in the figures.

CIMOLIASAURUS SNOWII.

SKULL.—The skull of this species was briefly described by me in the Transactions of the Kansas Academy of Science for 1890, to which some additional observations were made by Cope in the Proceedings of the American Philosophical Society for 1894, p. 109. I give here a more complete comparative description, in the light of the information furnished by other known forms, especially *Dolichorhynchops*.

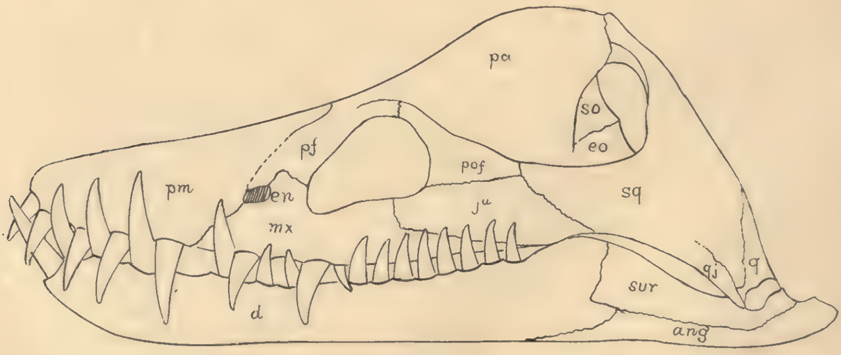


FIG. 13.

Skull of *Cimoliasaurus snowii* Will. *Pm.* premaxilla; *en.*, external naris; *mx.*, maxilla; *pf.*, prefrontal; *pof.*, postfronto orbital; *j.*, jugal; *sq.*, squamosal; *pa.*, parietal; *so.*, supraoccipital; *eo.*, exoccipital; *q.*, quadrate; *qj.* quadratojugal; *d*, dentary; *sur.*, surangular; *ang.*, angular.

The *parietals* form a steep, roof-like covering, ascending into a thin, sharp, sagittal crest, extending through nearly their whole length, from the attachment of the squamosals posteriorly as far forward as the posterior part of the orbit. This crest, throughout most of its extent, forms a thin, vertical plate, with nearly parallel sides for about two inches, its thickness on the margin varying from two to four millimeters. Posteriorly they expand into a thickened, triangular process on each side, projected downward and backward over the supraoccipitals for union with the squamosals. Extending the whole length of the crest is a well-marked suture. Near the anterior extremity of the crest is the parietal foramen, which has been closed by compression.

The postorbital appears as a narrow bar directed outward and downward. Its union with the supraorbital above and the squamosal below is shown in the figure. The bone is triangular in shape, as seen externally, the suture for the jugal extending back horizontally. and is then turned upward at right angles to meet the free margin of the arch.

The suture separating the *jugal* from the squamosal begins at the angle of the postorbital suture and runs obliquely downward and backward to meet the lower border of the arch about fifty millimeters back of the teeth. The suture is a jagged one, but its existence as described and figured is beyond doubt. Professor Cope figured it much further back on the arch, but his supposed suture is very plainly a fracture. The bone unites below with the maxilla by a long, nearly horizontal suture, that begins in an angle a little back of the middle of the orbit and joins the alveolar margin near the last tooth. The anterior part of the suture is nearly at right angles to the remainder, joining the orbital margin back of the middle of the orbit.

The *squamosal*, or squamoso-prosquamosal, is a large, triradiate bone joining the jugal and the postorbital anteriorly, the parietal above, the quadrate and quadratojugal below. Cope has figured the upper branch as a distinct bone under the name of supramastoid. This was an error, as has already been stated. At the anterior inferior part of the quadrate there is a distinct suture, as has been figured, corresponding to the suture described as existing here in the specimen of *Dolichorhynchops*. In the figures given of *C. snowii*, it was supposed that the quadratojugal was a small element. It now seems probable that its relations to the squamosal are like those of *Dolichorhynchops;* at least there is an indication that the real suture is continued upward and forward for some distance. The union of the squamosal and quadrate is very much as it is in *Dolichorhynchops*.

The *quadrate* does not seem to differ from that described in *Dolichorhynchops*.

The *premaxillary* is very large and massive. Its dentigerous portion is broad and thick, with numerous pit-like depressions. It contains six very large and powerful teeth on each side, the maxillary suture beginning just back of the sixth tooth. The distinguishing suture turns upward and backward to meet the anterior end of the external nares in front of the orbit. Above this, for a short distance, the bone is so crushed that the suture is not determinable with certainty, but the upper end is evident, nearly above the middle of the orbit. The suture separating the two premaxillæ is distinct throughout.

The *maxilla* has on each side sockets for twelve or thirteen teeth, all, except a few of the anterior ones, much smaller than those of the premaxilla, and smaller than those of the mandible in this region. From the nares, which are chiefly excavated from this bone, the suture turns upward and backward for about twelve millimeters, separating the nasals; it then turns downward and backward to join the anterior orbital margin, uniting with the prefrontal. The lower anterior margin of the orbit is thus formed by the maxillary plate, which shows a shallow groove. The maxillary plate on the left is smooth and undistorted, the nasal and prefrontal having been separated at their sutures. There is no indication whatever of a separation into two elements, nor is there any free lachrymal. Posteriorly the maxilla forms a rather broad plate below the orbits, having a convex thinned margin continuous with that of the jugal. Back of the middle on this margin, the suture for the jugal turns directly downward for about twelve millimeters, and then backward in a straight line to terminate just beyond the last tooth.

That element which, in *Dolichorhynchops*, is described as the *supraorbital*, is a much more massive bone in *Cimoliasaurus*. It unites with the postorbital by a strong suture, behind the middle of the orbit above, and is not separated by a deep notch as in that species. The bone arches forward and downward to beyond the middle of the anterior part of the orbit, as in *Dolichorhynchops*, standing out prominently over the orbit and terminates in a strong suture by which it is united to the ascending plate of the maxilla, as has been described. Its union with the prefrontal or frontal cannot be determined in the crushed state of the specimen. Such relations of a supraorbital bone with the postorbital, maxilla, nasal, etc., are almost inconceivable, but are altogether right for a prefrontal. If this be a prefrontal, then the same element in *Dolichorhynchops* must also be the prefrontal, and the so-called postprefrontonasal is in reality the frontal, while the anterior prolongation from the parietal is in reality a process from that bone, separating the frontals, a most remarkable arrangement for any vertebrate skull. I am forced to believe, however, that such is really the explanation of these bones.

The *supraoccipitals* are visible from the side behind and are not covered over by the wing-like expansions of the parietals, as in *Dolichorhynchops*. They are paired and separated throughout, as in that genus. Below they unite with the exoccipital, and include a part of the semicircular canals. Above and in front they join the parietals at their posterior margin and not under the roof. The exoccipitals are also visible. The paroccipital process is slender, its posterior margin thin, joining the supraoccipital in an angle without the small excavation which is seen in *Dolichorhynchops* at this place.

Lying within the orbit are thirteen thin, bony *sclerotic* plates, the largest about twenty millimeters in diameter, with somewhat crenulated margins. The larger number are lying in position, imbricated with each other.

There are sockets in the mandibles for nineteen or twenty teeth on each side. Those in the upper jaws seem to be the same in number, though the small posterior ones are so covered by the inferior teeth that the number cannot be positively determined. The largest teeth implanted in the upper jaw are those of the premaxilla; back of these there is but a single large tooth, situated just in front of the orbit. The largest teeth of the mandible are the ones corresponding to those of the premaxilla; the posterior ones, however, are much larger than the corresponding ones of the upper jaw. The anterior teeth, especially, are elongate, conical and lightly recurved. All are sharply pointed, with the crown, within a half or three-fourths of an inch of the socket, finely striated. The largest is that of the premaxilla just in front of the maxillary suture, which measures fifty-three millimeters in length by thirteen in width at the base of the crown. The first tooth in the mandible is fully as long, though a little more slender.

The *pterygoids* are so crowded in between the mandibles and maxillæ that only a portion of them is visible. The posterior part joins the quadrate by a stout plate, as in *Dolichorhynchops*. By the sides of the sphenoids the plates are broad and massive, with a thinned outer crenulated margin. The *ectopterygoid* unites with the jugal and maxilla. Evidently there are elongated interpterygoid vacuities, as in *Dolichorhynchops*.

The mandible, from the tip of the symphysis to the hind extremity, measures ·480 millimeters, of which the teeth occupy 320. Its least width, near the middle, is 40 millimeters; its greatest width, just back of the teeth at the coronary eminence, is 75 millimeters. The length of the symphysis is 65 millimeters. The two sides are firmly coössified, traces of the suture being visible in the posterior part only. The sutures separating the angular, surangular and dentary are shown in the figure.

CERVICAL VERTEBRÆ.—There were twenty-eight cervical vertebræ in a continuous series preserved, the last five or six, owing to exposure, in a less perfect condition; the others complete or nearly so. Traces of the sutures uniting the neural arches with the centra can be observed in the third and fourth vertebræ only. The atlas and axis are so wedged in the compressed occipital region that the former bone can not be distinguished, and the latter is visible in part only. The third vertebræ, herewith figured, differs from the following ones in the greater obliquity of the spine, in the more oblique anterior face of the centrum, in the presence of a conspicuous carina below in front, and in the simple, pointed shape of the single-headed rib. The fourth vertebræ has the neural process less oblique and broader, the carina in the middle of the concavity of the under surface not visible from the side; the rib is broad and of nearly equal width throughout. In the sixth vertebræ and beyond the neural process is broader and nearly vertical; the ribs are broad, with more marked anterior and posterior prolongations distally. The spines increase in width throughout the series, but are only a little longer posteriorly. The posterior centrum is more than three times the length of the anterior ones and the diameter posteriorly is more than twice that anteriorly. The ribs of the posterior vertebræ are but little longer, though much wider, than those of the anterior vertebræ. The following measurements will exhibit these differences in size more exactly:

NUMBER OF VERTEBRA.	3	4	6	9	14	20	27
Length of centrum	23	30	48	53	63	78	90
Height of centrum	25	27	42	44	50	60	68
Height of spine above floor of neural canal	55	46	47	47	50	62	. . .
Width of spine	. . .	24	36	40	42	65	. . .
Length of rib	. . .	40	. . .	40	48	. . .	. . .
Width of rib	. . .	24	. . .	49	56	65	. .

BRACHAUCHENIUS LUCASI, gen. et sp. nov.

The specimen upon which this genus and species are based is one of much interest, not only because of its excellent preservation and preparation, but also because of the new features which it presents. It consists of the skull, neck, and larger part of the dorsal column, all lying together in their natural relationships, and all with the ventral surface exposed, in the prepared specimen. The specimen was collected some years ago near Delphos, in Ottawa County, Kansas. Its horizon is the Benton Cretaceous. It is now preserved in a wall-case in the National Museum. I desire to express my hearty thanks to the authorities of the National Museum for permission to study and describe the specimen, and especially to Mr. F. A. Lucas for much kind assistance. It gives me great pleasure to honor, in the specific name, one who has done much valuable work in American paleontology. (Pls. XXIV, XXV.)

Skull.—The palatal surface of the skull lies exposed, with the mandibles in position. There has been but little distortion or displacement, the mandibles being slightly depressed and pushed to the left. The limestone matrix has been carefully removed from most parts, leaving the bones entirely clean. The sutures are entirely clear, and there are but few adventitious fractures to obscure the relations of the parts. It is certain that additional excavation will reveal further characters of importance, but not many, unless the specimen be entirely removed from the matrix. The specimen as now mounted in the wall slab makes a very interesting and instructive display, but I believe that some day it will be advisable to remove it entirely from its limestone bed and mount it after the manner of a recent skeleton. It was fortunate, however, that this was not done before a careful examination had been made of the natural relations of the bones, as it would have been difficult to believe that the neck comprised but thirteen vertebræ, had not the matrix conclusively demonstrated the fact. It is the shortest-necked plesiosaur known, differing in this respect not greatly from the short-necked aquatic saurians of other orders.

The *pterygoids* extend far back to unite with the lower end of the quadrates, apparently quite as usual in the plesiosaurs, though the precise place of junction is obscured by the mandibles; the process is slender. The two bones meet in a median suture on the under side of the sphenoid, their posterior border forming a wide and deep concavity. The outer margin of the bones converge from the quadrates as far forward as the posterior end of the interpterygoid vacuities, where they curve outward into the posterior border of the ectopterygoid processes. The under surface is shallowly concave on either side back of the vacuities, but in the middle there is a rather strong, obtuse ridge. A little back of the vacuities, on either side, with their origins separated, a narrow and strong ridge arises to curve outward and become lost on the under border of the somewhat descending ectopterygoid process. In front of the vacuities the two bones again meet in a long median suture. The palatal surface here occupies a somewhat higher plane than that of the posterior part, and is flat throughout. The bones of the two sides gradually narrow in width to terminate by an obtuse extremity near the middle of the palate. Between the ectopterygoid processes and between the curved ridges already described there is a narrow, deep vacuity, with two oval, elongated, well-defined foramina or vacuities at the bottom, the "palatonares" of Owen, the "posterior palatine vacuities" of Andrews, the "interpterygoid vacuities" of authors. A discussion of their character will find a place further on. The lateral walls of this fossa posteriorly are nearly vertical, but the anterior end of the fossa is but little or not at all excavated above the plane of the palate here. From the anterior end of the median posterior interpterygoid suture two sutures diverge, leaving a large angular sloping surface exposed which forms the posterior roof of the fossa; the bone exposed between the V-shaped sutures is the basisphenoid, and has attached to it by suture the so-called parasphenoid bone in front. Just how the diverging sutures terminate I cannot definitely say. They seem to follow the lower angle of the lateral wall of the fossa as far forward as the middle of the vacuities and thence return to join the parasphenoid suture at the posterior part of the vacuities. If this determination is correct, these projections would correspond to the basipterygoid processes of the lizards. The ectopterygoid processes of the pterygoids, the continuation of the curved ridges, have a rounded, prominent under border, with a terminal, large, vertical or oblique, abutting, mandibular surface. This ridge and its abutting surface are very much as they are in *Pliosaurus*, and the whole structure here also reminds one of the crocodiles.

The transverse, transpalatine or *ectopterygoid* bone is a rather small, flattened polygonal bone, whose under surface is continuous with that of the palatine and pterygoid in front. It joins the pterygoid on the inner side and behind, the posterior suture descending on the side of the projecting process of the pterygoid. To what extent the bone enters into the abutting surface for the mandible I could not determine. Anteriorly the bone joins the palatine by a clearly marked suture. Its outer border posteriorly is rounded and seems to be free, forming a part of the border of the posterior palatine vacuity, but this can not be determined without further excavation of the matrix. The outer attachment of the bone (doubtless to the jugal and maxilla) cannot be determined.

The *palatines* are long flat bones which meet for a considerable distance in a median suture in front of the pterygoids, a feature hitherto unknown among the plesiosaurs. In front this median suture divaricates to admit the pointed extremities of the vomers. A little distance from the interpalatine suture, near its middle, there are, on either side, two or three small, round foramina. The outer border of the palatines continues the border of the ectopterygoids throughout and is continuous, apparently with the lateral border of the vomers. How far this apparent border in the specimen represents the real border of the bone cannot be determined without additional excavation of the matrix, here filling in a narrow space between the apparent margin and the mandible. It is possible that there may be no free border, though I think it probable that there is a smaller or larger posterior palatine vacuity on each side posteriorly. It is probable that the sides of the bones turn upwards to meet the maxillæ in the way they are figured by Sollas in *Plesiosaurus*.*

The posterior pointed extremities of the *vomers* are seen in the middle in front, enclosed between the V-shaped suture of the palatines. The suture seems to be visible to the border of the palatine and includes no part of a narial opening. The nares hence must be situated far forward between the vomers and the maxillæ. Unfortunately this part of the skull has been injured somewhat before removal, and the complete structure here cannot be determined.

The so-called "*parasphenoid*" is different from that element in other plesiosaurs. It is a single bone separating the interpterygoid vacuities. As seen from below, it is spindle-shaped, narrow in the middle, moderately expanded at either extremity. Posteriorly it is joined by a clearly marked suture with the basisphenoid. Anteriorly it joins the two pterygoids in the entrant angles, but does not extend much, if any, beyond the angle. The vacuities separated by this bone are long and oval, situated at the bottom of the fossa already described, between the pterygoids and in front of the basi-

*Quart. Journ. Geol. Soc. 1881, p. 475, f. 12.

sphenoid. It would seem that there could be no further question as to the character of these vacuities—simply fortuitous openings—separated by a remarkably persistent, well-ossified parasphenoid, invariably found in all plesiosaurs, but never in their nearest allies, the turtles and nothosaurs. In most of the plesiosaurs in which the palate is known, the openings are situated more nearly upon the plane of the palate, and, though somewhat variable in shape, are always of moderate or considerable size. In this species, however, they are at the bottom of a well-marked, rather deep fossa, with well defined lateral walls and a sloping posterior roof.

These foramina in the plesiosaur skull were first thought to be the nares by Owen, who, however, confounded the anterior part of the pterygoids with the palatines. Huxley, who was also not clear about the palatines, suggested that the real internal nares were smaller openings situated more anteriorly. Sollas (l. c.) discussed the matter more at length and reached the conclusion that the real internal nares were situated far in front, between the premaxilla and vomer, with the palatines probably entering into the posterior border. Andrews has accepted this location of the nares, and has figured and described the openings in three genera of the plesiosaurs, always bounded by vomer, palatine and maxilla. In *Dolichorhynchops osborni*, however, as seen from the figure and descriptions, these openings can only be situated between the vomers and palatines and at some distance from the maxillæ. In my description I accepted these orifices as the true nares, though greatly astonished at their minute size, and although they correspond with similar foramina between the vomers, in the mosasaurs.

If we are to seek for the nares in their present specimen elsewhere than in the openings I have described it must be far forward, perhaps in precisely the position assigned to them by Sollas. In all the known forms, with this interpretation, they would be in front of the external nostrils, in the present species far in front. What possible combination of circumstances would have caused the recession of the external nostrils to a place so close to the orbits without affecting the position of the internal openings? I certainly suspect that in this species at least the openings between the pterygoids are the real internal nares. As to the character of the separating element I am forced to the conclusion that Andrews has reached, that it is the parasphenoid. If the element in front called the vomers are really those bones, and there could seem to be no doubt that they are, there is nothing else left, save possibly the turbinated bones. The slender bone in precisely similar position in the ichthyosaurs is usually called the presphenoid. Such perfect and persistent ossification of the parasphenoid, scarcely found elsewhere among the reptilia, unless it be the snakes, is in any case remarkable. Why should it be persistent in separating such persistent foramina, unless the openings were of functional importance? One would expect that the pterygoids would have united along the whole median line, as in the Nothosauria, or that they should have closed up in front of the basisphenoid, as in the Chelonia. Sollas objects to this posterior position of the nostrils, because there is no ossified canal for the air passages, as in the crocodiles; but his specimen, as ours, would call for a canal running in the opposite direction, from the posteriorly situated external nares anteriorly to the internal openings, and, in the present species, this canal would have been eight or more inches in length. And why may not the canal have been cartilaginous in either case?

Mandible.—The mandibles are nearly in place on the under side of the skull. They are a little compressed from above downward. The symphysis is short, the two jaws meeting in a considerable angle. The portion in front of the posterior end of the symphysis has been somewhat injured in the specimen, so that the precise shape and length can not be ascertained. The angular extends posteriorly into a relatively short process; the expansion below the cotylar cavity is rounded. In front of the cavity, the angular extends forward to within six inches of the symphysial angle, terminating in a slender, sharp end. From a little in front of the middle of the ramus it is excluded from the inner surface. In front of the cotylar cavity the greater width of the outer surface is composed of the surangular. Between these two bones, the dentary sends a long, slender process backward to within six inches of the cotylar cavity.

Length of skull to end of mandible	1.1 m.
Length of skull to condyle	.9 m.
Width of skull between outer margins of quadrate	.28 m.

Vertebræ.—The atlanto-axial complex is thoroughly united, without indications of sutural division. The axial rib appears to be united with the axis only, though it may come in contact with the axial intercentrum. The atlas is convex from side to side, without indication of a median carina. The other cervical centra, as seen from below, are nearly flat, with a slight convexity in the middle, and a slight concavity on either side before the sutural surface for the rib. This flatness is a natural character and not due to compression. The median convexity increases gradually throughout the cervical series.

The increase in length of the cervical vertebræ is slight, as will be seen from the table of measurements. The articular margin of the vertebræ, throughout both the cervical and dorsal series, is sharp, not rounded for a continuation of the cartilaginous surface, as is so often the case among plesiosaurs. The ends, as seen in the third vertebra, are distinctly though not deeply concave. The ventral vascular foramina, so characteristic of plesiosaur vertebræ, appear to be wanting throughout the whole series, nor is there the slightest indication of a median ridge and lateral grooves. The lower margin of the rib articulation approaches the ventral plane in the early cervicals, but ascends somewhat on the sides of the vertebra in the last cervical.

Twenty-two dorsal vertebræ are preserved in natural sequence. Because of the decrease in the length of the transverse process in the late dorsals, it does not seem probable that more than eight or ten presacral vertebræ could be missing, making altogether about thirty, the usual number of dorsal vertebræ. The length of the centra increases more rapidly, though gradually, in the early dorsals, and then remains constant throughout the remainder of the series. The centra are deeply concave below and on the sides, expanding outwardly on the sides above to meet the sutural surface for the arch. The surface of the centra is nearly smooth, with but slight indications of crenulations before the articular margins.

Ribs.—The ribs throughout are single-headed, and of the usual plesiosaurian type, though proportionally short in the thoracic region. The axial rib is flattened spatulate at the distal extremity; massive at the proximal. The lower surface is nearly flat, the upper surface deeply concave, the anterior border gently, the posterior border deeply concave. The rib of the third vertebra is more expanded distally, with the distal posterior margin somewhat more produced, and the distal border thinned. The fourth rib is more expanded distally, with a more pronounced distal expansion, and the distal border seems to be thickened for cartilage. The next four or five ribs differ only slightly from the preceding ones. The rib of the tenth vertebræ is more elongated and slender. The attachment to the centrum is sessile or nearly so, the head inserted in a shallow pit. In the eleventh vertebra there is a distinct exogenous process, standing out twenty or twenty-five millimeters from the surface of the centrum to the end of which is attached the rib. This process is equally as prominent, or more prominent on the next two centra, the twelfth and thirteenth. The rib of the twelfth vertebra is intermediate in length between that of the eleventh and of the thirteenth. On the last cervical centrum, the thirteenth, the twelfth rib is long, heavy and stout, more than half the length of the first dorsal. It is nearly as stout as any of the following, but tapers somewhat distally, though ending in a truncated, cartilaginous extremity. The distal end of the eleventh rib is lost. The first dorsal rib resembles the one preceding it, though longer. The second dorsal rib has acquired nearly the full length of the thoracic series. In the ninth rib there is a beginning of a diminution in size; the rib is less thick, a little shorter, and less expanded at its extremity. The twelfth rib is completely preserved; it is yet smaller and thinner than the eleventh, though still possessing a cartilaginous extremity. Of the following ribs, only the heads of some are preserved.

Diapophyses.—The diapophyses occupy an unusually low position on the arch of the whole dorsal series, as do also the cervical ribs. They have not been wholly freed from the matrix, and their relation to the articular process is determinable only in slight part in a few of the posterior vertebræ. The arch, like the cervical ribs, is united by a strong, persistent suture, evidently an adult character, since the sutures of the atlanto-axial complex have been entirely obliterated. The process of the first dorsal is short, compressed, and somewhat expanded at each extremity; it clearly springs from below the dorsal surface of the centrum. As already described, the last cervical rib, but little shorter than the first dorsal rib, is attached to a short process which arises, apparently wholly, from the centrum. The diapophysis of the first dorsal is less than twice the length of this process, and so much like it that its sutural connection with the centrum is the chief distinctive difference. The second dorsal diapophysis is a little stouter than, and about twice as long as the first. Its articular surface for the rib is larger, flattened, and looks downward and outward. The fourth and fifth processes have attained the maximum size of the series. They have a narrow, concave ventral border, more strongly concave posterior border, a flattened, expanded proximal end for union with the centrum and an expanded distal extremity with its flattened oblique costal surface. The height of the process distally, and its expansion beyond the plane of the articular zygapophyses, can not be determined. It is very evident, however, that the diapophyses lie below the plane of the zygapophyses, in which they differ markedly from the diapophyses of *Dolichorhynchops*, where, throughout most of the dorsal vertebræ, they are placed wholly above the plane of the zygapophyses. The succeeding diapophyses, to the sixteenth dorsal, scarcely differ in their shape and relations to the centrum. These vertebræ may, therefore, be properly called thoracic. From the seventeenth vertebra to the last one preserved, the twenty-second post-cervical, the diapophyses decrease rapidly in size, the last being scarcely more than half the length of the fourth or fifth. In these posterior processes the proximal articulation of the arch is as broad as in any of the others, but the distal end of the process is more compressed, with only a small surface for the small presacral ribs. Over the twentieth vertebra the matrix has been cleared away sufficiently to disclose a posterior zygapophysis. The free diapophysis in this vertebra is about fifty millimeters in length, thirty in height, and about twenty in width. The posterior zygapophysis arches upward and backward from the base of the free process.

MEASUREMENTS.

	Length of Centrum.	Width of Centrum.	Length of Rib.
Atlanto-axis,	90 mm.		
Third cervical,	46		
Fourth cervical,	46	82 mm.	60 mm.
Fifth cervical,	44		
Sixth cervical,	45		
Seventh cervical,	47		
Eighth cervical,	50	84	74
Ninth cervical,	50		
Tenth cervical,	50		
Eleventh cervical,	53		94
Twelfth cervical,	58		
Thirteenth cervical,	60		220
First dorsal,	64	85	260
Second dorsal,	68		370
Third dorsal,	73		400
Fourth dorsal,	74		490
Fifth dorsal,	77		445
Seventh dorsal,	77	82	370
Twelfth dorsal,	77	82	370
Twenty-second,	74	82	

LENGTH OF DIAPOPHYSES.

First,	47 mm.	Fourth,	90 mm.	Eighteenth,	75 mm.
Second,	65 "	Fifth,	95 "	Twentieth,	65 "
Third,	80 "	Thirteenth,	90 "	Twenty-second,	60 "

Among the characters which have been given in the foregoing descriptions there are some of more than usual importance, of more than generic value. It is quite evident that the form can not be placed in the same family with *Dolichorhynchops* or *Cimoliasaurus snowii*. Just what family this may be I can not say at present. It is very evident that we have to do in the plesiosaurs with several distinct families, but the material is hardly sufficient yet to clearly define them. Several names have already been proposed, based upon partial characters, but there is no unanimity in their acceptance, nor can there be until much more is known about these animals than is the case at the present time.

The essential characters of the present genus, so far as known, may be summarized as follows: Head large and broad; palatine bones broadly contiguous; a strong pterygoid ridge on either side; a deep interpterygoid fossa; neck very short; cervical ribs single-headed; cervical ribs and vertebral arches united by persistent suture; no infracentral vascular foramina.

Many of these characters, possibly the union of the palatines in the median line, are those of *Pliosaurus;* but *Pliosaurus* has the anterior cervical ribs double-headed, a character supposed to be of at least family, possibly subordinal value. Of this, however, I am very skeptical, and it is possible that a final classification may locate this genus with the Pliosauridæ.

It is very evident that the elongation of the neck is a specialized character in the plesiosaurs, since we can not conceive of any animal with so many vertebræ in the cervical region from which these animals could be derived. Considering this character alone, *Elasmosaurus* would be the most specialized of all the plesiosaurs, and *Brachauchenius* the most generalized. It is a question, however, whether such forms as the present have preserved this primitive character from their terrestrial ancestors, with only a slight increase in the number of the cervical vertebræ, or whether there has been a secondary reduction in the number from some long-necked ancestor. That the long-necked plesiosaurs are not all specialized throughout, is very evident. In the species of *Plesiosaurus*, a genus of long-necked forms, the epipodial bones are far more generalized in character than are these bones in the short-necked *Polycotylus*, where the epipodials have become not only broader than long, but have actually increased in number to four. That an increase of the number in the cervical vertebræ is a specialized character has already been affirmed by Baur, Dollo and Fürbringer in the Dolichosaurs.

It seems also evident that monocranial ribs are a specialization.

not only in these, but in other aquatic air-breathing vertebrates, such as the cetacea, some ichthyosaurs and the mosasaurs, due to environmental causes. It is true that all the Squamata show the same single-headedness of the ribs, brought about by similar conditions—the lack of the necessity of support of the abdominal organs by the ribs in animals resting prone upon the ground, or in a medium of nearly the same specific gravity as the creatures themselves.

It is a singular fact that, in many plesiosaurs, vestiges of dicranial ribs have been retained in the neck, though such have disappeared elsewhere in the vertebral column; and this character has been retained in both the long-necked and the short-necked types, such as *Plesiosaurus* and *Pliosaurus*, though utterly wanting in others, such as *Elasmosaurus* with seventy-two cervicals and the present with only thirteen. Did the long-necked forms become differentiated before the dicranial character was lost, and have they continued as a distinct phyllum until the character was wholly lost? If so, the short-necked Pliosaurs must represent a distinct branch of the order which has also undergone the same change.

The Cretaceous plesiosaurs of America, so far as known, are all cercidopleural, while many of the European Jurassic forms are dicranopleural.

This is the fourth species of plesiosaur that I know from the Fort Benton deposits of Kansas; there are none certainly referred to this epoch from other regions, though *Brimosaurus grandis* Leidy is probably of this horizon. The only one of these hitherto described is *Trinacromerum bentonianum* Cragin, a long-headed form with long mandibular symphysis and short neck, a form indeed approaching, possibly identical with *Dolichorhynchops*. Another form known of which a considerable part of the vertebral column is preserved at the museum of the University of Kansas, is of great size, the dorsal centra measuring five inches or more in diameter, with a very long neck and small anterior cervicals. The specimen is from near Beloit. It represents a distinct species that may provisionally be referred to *Cimoliasaurus* or *Brimosaurus*. A third form is much smaller, about the size of *Dolichorhynchops osborni*, with short neck. The episternum is shown in Fig. 9 and the cervical vertebræ and humerus in Pl. XXVIII. I suspect that it belongs in *Trinacromerum*, though smaller than the type species. I have called it provisionally *Trinacromerum anonymum* n. sp. From all these forms the one described may be at once satisfactorily distinguished by the entire absence of infra-central vascular foramina.

That the species described in the foregoing pages belongs in some genus named but not recognizably described from a later epoch is not probable, though possible. I have therefore given the genus the name *Brachauchenius*.

POLYCOTYLUS LATIPINNIS.

Paddle.—Some years ago an excellent specimen of a paddle of a plesiosaur belonging in all probability to *Polycotylus latipinnis* Cope, was collected by Mr. George R. Allman of Wallace, Kansas, from the upper Niobrara chalk of the Smoky Hill river, east of Fort Wallace. The bones of the paddle were, for the most part, found in their natural relations, but were separated in the collection of them. The radius and ulna of a second paddle, together with some of the smaller bones showed weathering, and doubtless had been picked up from the surface. It has required but little trouble to fit into their natural relations all the bones except most of the phalanges, which. presenting no lateral surfaces for articulation, could only be located from their other characters. A careful study of these, however, makes it probable that the positions assigned to them in the photograph are for the most part correct. Because of the considerable expansion distally of the long bone, the paddle is supposed to be the front one, but it is quite possible it may be a hind one. Pl. XXI.

The head of the *humerus* is large and broad, of a flattened ellipsoidal form. with the surface nearly evenly convex; it is slightly crushed dorso-ventrally. The tuberosity, placed at a slight distance beyond the plane of the proximal extremity, is massive. It has two, large, flattened, narrowly separated surfaces for muscular attachment, placed nearly at right angle to the longitudinal plane of the bone and separated from the head by a slight groove on either side, that of the ulnar side being the more pronounced. On the ulnar side of the tuberosity there is a slight rugosity, as though for muscular attachment. The shaft is narrowest near the upper third of the bone, where a cross-section would be nearly circular, or slightly greater in its dorso-ventral diameter. The anterior or radial border is gently convex on its upper two-thirds, gently concave below to the rectangular angle. The posterior border is more deeply concave throughout. The distal border has a deep, cupped, thickened facet at right angles to the dorso-ventral plane, for the radius; a second shorter and less thick one for the ulna joins this at a small angle; beyond this, the thinned ulnar expansion is lost in the specimen, but doubtless had two facets for the third and fourth bones of the epipodial row. On the ventral surface of the bone above, proximad to the middle, there is a large, stout rugosity for muscular attachment. The very strong muscle attached to it doubtless arose from the ventral surface of the coracoid. On the ulnar border of the bone, at its middle, there is a more pronounced, though smaller rugosity, for muscular attachment. The peculiar tooth-like projections on the outer posterior angle of the coracoid described in *Dolichorhynchops osborni* probably indicates the origin of the muscle inserted into this rugosity. It may be called the ulnar rugosity. On the radial border, a little beyond its middle, there is a smaller and less strong rugosity which may be called the radial. The origin of the muscle inserted here probably was on the lower part of the scapula. The dorsal surface of the shaft is smooth, without muscular roughening beyond the tuberosity. The distal portion of the bone is much expanded, thickest toward the radial side, and moderately thinned at the distal outer margin.

Of the four muscular rugosities, which doubtless furnished attachment for nearly all of the muscles controlling the arm, those of the tuberosity are of course the largest, though the large roughening on the ventral side may have been for the insertion of more powerful muscles, which were of course much more effective from the greater mechanical advantage under which they acted. The movement here, though strong, could not have been through a great range. The smallest of all, and placed much further away from the fulcrum is the radial. The great convexity of the head indicates considerable freedom of rotation. The glenoid surface in the articulated skeleton of *Dolichorhynchops* looks nearly directly outward. The obliquity at which the head of the humerus is placed as regards the horizontal plane, indicates that the natural resting position of the flipper was at about forty-five degrees downward, but I doubt whether the extremities of the paddles could have been raised much, if any, above a horizontal position. It is further certain that the flippers could not have been brought back against the side of the body. The posterior angle of the coracoid, projecting as it does beyond the plane of the glenoid surface, certainly prevented any great backward movement of the humerus. It seems also evident from this position of the coracoid, that the paddle was not so pedunculated as restorations usually have them, but that the humerus was largely or entirely hidden in folds of the skin, as was evidently also the case, not only in the ichthyosaurs, but also in the mosasaurs.

The largest bone beyond the humerus is the *radius*. It is irregularly four-sided in shape; the longest and convex proximal surface fits into the radial facet of the humerus; the shortest and non-articular border, that adjoining the ulna, is emarginated like its opposing border to form with it a small foramen. Doubtless these two emarginations represent the last vestige of the terrestrial type of the epipodial bones. The outer border of the radius, the second in length, is non-articular and thinned, and has an acute angle proximally. The outer distal margin is thick for articulation with the radiale of the carpus. The inner distal border, next to the shortest of the four, is for articulation with the mediale.

The *ulna* is next in size to the radius, and is irregularly six-sided. The largest, proximal border, is convex, like that of the radius, and joins the smaller facet of the humerus. The distal border has three facets of nearly equal length, and joining each other in nearly equal angles. These facets are for the mediale externally, the ulnare in the middle, and for the ulnar supernumerary, internally. On the inner side there is a longer but thinner border for articulation with the first epipodial supernumerary, while the outer border is emarginated like the opposing border of the radius.

The next bone of this row, articulating with the humerus, and of considerable size, is one of doubtful homology. I will call it the first epipodial supernumerary. If one follows Marsh in his views of these corresponding bones in *Baptanodon*, then this bone is the ulna, and the one here called the ulna is the medial carpal. But this interpretation is very doubtful. Zittel thinks this bone in the ichthyosaurs is the pisiform, while Woodward calls it the sesamoid; but I doubt these interpretations as well. Among the cetacea, the mosasaurs, ichthyosaurs and plesiosaurs there is a reduplication of bones, which have been variously explained as a splitting of the phalanges, either directly or through the intervention of the epiphyses. The latter view is hardly possible, since there are no epiphysial ossifications in most if not all these reptiles, and besides, there would not be enough epiphyses on the normal digit to furnish the great number of phalanges seen in some of the forms. The extra digits in some ichthyosaurs are also explained by the longitudinal division of the normal phalanges; but I cannot believe that this is the correct explanation. I believe that the supernumerary digits, phalanges, epipodial or mesopodial bones found in such species as this, as well as in most other American plesiosaurs, represent entirely new ossifications in cartilaginous masses, which originally formed the borders or terminations of the adjacent bones. These, in the case of the phalanges, have become separated to increase the mobility of the fingers, have increased in size and ossified, and have in turn given rise to new cartilaginous extremities, that have separated and become ossified; that is, the growth of the additional phalanges and carpals, as well as the two additional bones of the fore arm, was peripheral. The additional fingers of the ichthyosaur may be also explained in a similar way. The margin of the flipper has become hardened by fibro-cartilage, which by the movement of the fingers was broken into segments, each of which finally took on ossification. A division of the phalanges by segmentation would certainly have to take place immediately in order to preserve the integrity of the paddle as an organ of propulsion. If this explanation be correct, then these additional ossifications in the fore arm in the present form, as well as in the carpus, are *not* displaced elements, but new ones, without homologies.

To return to the description from this digression, the *first epipodial supernumerary* is irregularly five-sided in shape, for articulation with the carpal, ulna, humerus and second epipodial supernumerary, the longest, inner border, being thinned and non-articular. The *second epipodial supernumerary* is smaller than the first, and is somewhat elongate, articulating distally with the first supernumerary, proximally with the humerus, and with its longest, somewhat convex and thinned internal border non-articulate.

There are four bones in the first row of the carpus, and the same number in the second, the inner one of which partakes so strongly of the nature of a phalange that it doubtfully can be called a carpal. The first, or *radiale*, is a thick massive bone, nearly regularly parallelogrammatic in shape, and articulates with four bones. The broad proximal end articulates with the radius; the distal surface with the first distal carpal; nearly the whole length of the inner side joins the medial carpal, leaving a small space at the distal angle for union with the second distal carpal; the outer border is rounded and non-articulate. The second distal carpal is wanting in this specimen, and has been restored. It must, however, have articulated with the radiale and mediale proximally, the first distal carpal externally, the third distal carpal internally, and the second and third metacarpals. A good figure of this bone of the plesiosaur paddle will be found in Leidy, Cretaceous Reptiles, plate iv, ff. 13 and 14. The third distal carpal begins to assume something of the nature of a metacarpal, though a true carpal; it articulates proximally by two unequal facets with the ulnare and medial carpals; externally with the second distal carpal: distally with the fourth metacarpal, and internally with the fourth distal carpal by two facets, leaving an emargination between them, which, with the opposing surface, forms a foramen. The fourth bone of this row is, I believe, in reality the fifth metacarpal, which has receded proximally to articulate with the first row: with this interpretation there may have been some displacement of the carpals proximally. The bone is elongate, phalange-shaped, articulating proximally with the ulnare, externally by two facets, having an emargination between them, with the third distal carpal. Distally it articulates with a phalange, and on the outer angle with the fourth metacarpal.

The metacarpals are shorter than the first phalanges of their respective fingers. The first is nearly square, articulating with the first distal carpal, the second metacarpal and its phalange; the outer border is similar to that of the first distal carpal. The second metacarpal is a peculiar bone, easily recognizable in isolated examples: it joins the first metacarpal externally, the phalange distally, the third metacarpal internally by articular surfaces, emarginated between them, and proximally by two unequal facets, the first and second distal carpals. The third metacarpal is also closely wedged in between the second and third metacarpals, the phalange and second distal carpal. The fourth metacarpal is scarcely distinguishable from a phalange: while the fifth of the row seems to be a phalange.

Of the *phalanges* only those of the first and fifth fingers are certainly placed in the figured paddle: the others must have been, in the living animal, very nearly as they are here figured, but the absence of distinct lateral articular facets renders the assumed locations uncertain. The proximal ends of the outer four of the first row are in nearly the same straight line, but those of the inner fingers become successively less and less elongate, giving an increased obliquity of the articulations, and more and more definite interlocking of the bones. Those of the first and fifth digits are more or less thinned on the free borders, while those of the intervening fingers have the sides more or less flattened, with a greater thickness dorsoventrally than from side to side. The distal bones, however, become more and more flattened from above. They are all gently hour-glass shaped. There are at least ten phalanges in the first finger, fifteen in the second, and perhaps as many as twenty in some of the others.

POLYCOTYLUS ISCHIADICUS, N. SP.

I give this name provisionally to a species from the Niobrara Cretaceous of western Kansas, represented by a number of bones in the University of Kansas Museum, the most characteristic of which are shown in Pls. X and XXVI. There is no assurance whatever, however, that they belong in this genus; on the other hand they may belong with the type species, *P. latipinnis*, or they may belong to some unrecognized genus. The ischia, it is seen, differ very markedly from the corresponding bones of *Dolichorhynchops osborni* in the shorter length of the symphysial portion, in the greater breadth of the neck, and in the smaller extent of the cartilaginous rim posteriorly. The bones are also more massive and the face for the ilium is larger. The ilia also are materially different, in the greater expansion proximally, and in the absence of the lateral angular face distally. They have a somewhat curved neck, with a rounded head showing a cartilaginous surface. The transverse processes of the sacral vertebræ are more massive than in that species, with a considerable expansion proximally, a cylindrical shaft and a terminal, somewhat oblique face for articulation with the ilium. The somewhat compressed sacral vertebra is shown from its ventral surface.

A specimen from the Niobrara in the Kansas Museum, comprising a number of caudal vertebræ and a portion of the pelvis, I refer with much more assurance to *P. latipinnis* Cope. The vertebræ differ very materially from the present, and the probability is, therefore, that *P. ischiadicus* is not a synonym of *P. latipinnis*.

PLESIOSAURUS GOULDII.

Plesiosaurus gouldii Williston, Kansas Univ. Quart. vi, p. 57, Jan. 1897.

Among the material collected in the Lower Cretaceous shales of Clark county, Kansas, by Prof. C. N. Gould, and now preserved in the museum of the University of Kansas, are the remains of at least three different forms of Plesiosaurs, all, however, represented by rather incomplete material. Portions of one of these forms (*Plesiosaurus mudgei* (?) Cr.) are figured elsewhere in this paper; another was briefly described by me several years ago under the name of *Plesiosaurus gouldii.* The species is referred to *Plesiosaurus* because no better place is known for it: in all probability it really belongs to some other genus. The species was based upon several dorsal vertebræ in fairly good preservation, one of which, the best, is herewith figured. (Pl. XXVII.)

The specimen shows little compression, and its form is doubtless normal. The anterior face is rather deeply concave, cordate in outline, with a small neural depression above. The anterior zygapophyses are spout-like, the notch between them not extending further than the middle of the articular surfaces. The spine is rather short and small. The transverse processes are compressed, springing in part below the neural canal from the base of the arch. The body is compressed in the middle, forming an obtusely rounded surface below. About midway on the sides, below the lower root of the transverse processes, the side is pinched in, with a small vascular foramen at the bottom of the depression.

The vertebra described probably belongs near the sacrum. Its measurements are as follows:

Width of anterior end of centrum	110 mm.
Vertical diameter, same end	75
Length of centrum	79
Height of vertebra	175
Expanse of transverse processes	175
Width of neural canal	30
Expanse of anterior zygapophyses	50

PROPODIAL BONES OF YOUNG PLESIOSAURS.

It is an interesting fact that isolated propodial bones of young plesiosaurs are not at all rare in the Kansas chalk; no more so indeed than are bones of the adult animals. I have seen more than a score of such, and four or five are now preserved in the museum of the University of Kansas; there are many others in the Yale museum. Four of these bones are shown in Pl. XXIII; a fifth one, more immature than any of those, is figured in Pl. XXII, Figs. 1-4. All such bones are composed of more dense tissue than is observed in adult bones. Especially is the structure dense in the youngest specimen here figured. In this specimen the head of the bone is not at all differentiated, nor are there any muscular markings. On the posterior border, near where the ulnar rugosity should be, there are the openings of two large canals, one on either side of the margin (*b* and *c* of the figures). On what seems to be the ventral surface, near the front border of the bone and nearly opposite the other openings, there is a large one with its mouth, as in the others, directed distally. On the dorsal surface, and near the middle transversely, there is a fourth opening, much smaller than the others. All of these canals unite near the center of the bone in a rounded cavity or ampulla, as shown in Figs. 3 and 4. In Pl. XXIII, Fig. 1, a large opening is seen on the posterior border below a rugose space, and another opening is seen towards the front leading into a groove. This was apparently a canal leading into a groove on the opposite side of the bone in the uninjured specimen, with another opening corresponding to the foramen which lead into a groove shown in the photograph on the exposed surface of the bone. The bone was, however, injured before I studied it, as is indicated by the restored border in the figure. The posterior opening probably corresponds to the united *b* and *c* of the other figures. In Fig. 2 of this plate is also seen a foramen on the posterior margin of the bone (the left one of the figure). All these three bones are probably humeri. Figs. 4 and 5 of the plate do not show these canals; from their shape they are probably femora. In Fig. 1, Pl. XXII, there is seen at the lower margin a groove (e), partly converted into a canal, which probably corresponds to one or the other of the grooves of Fig. 1, Pl. XXIII. I believe this groove corresponds to the ectepicondylar groove or foramen of the chelonia, lacertilia, Belodon, Champsosaurus, and some of the nothosaurs and ichthyosaurs. I may add that a similar groove is sometimes indicated in the humerus of the mosasaurs, as shown in Pl. XLIV, Vol. IV of the University Geological Survey of Kansas. Why these canals and grooves should disappear in the adult humerus is not apparent: they are doubtless for the passage of vessels. The ampulla at the junction of the four canals in the embryonic bone is between the apices of two conical "epiphyses," the larger epiphysis occupying the chief part of the distal portion of the bone, the smaller one the proximal. The fractured specimen discloses these epiphyses with a smooth rounded surface, as shown in Pl. XXII, Fig. 3, the outer part peeling away as does the bark from a tree.

This ephiphysial-like method of ossification has been compared with a somewhat similar structure in the Chelonians as an evidence of relationship between the two orders of reptiles.

A PECULIAR FOOD HABIT OF THE PLESIOSAURS.

More than twenty years ago, Professor B. F. Mudge published, in the First Biennial Report of the Kansas State Board of Agriculture (p. 62), the following: "In the Plesiosaurs we found another interesting feature showing an aid to digestion, similar to that of many living reptiles and some birds. This consisted of well-worn siliceous pebbles, from one-fourth to one-half an inch in diameter. They were the more curious, as we never found such pebbles in the chalk or shales of the Niobrara." The specimens which led to this conclusion were collected while I was a member of Professor Mudge's party, and are now preserved in the Yale collection. Nearly ten years ago some plesiosaur bones collected near Ellsworth, Kansas, from the Benton limestone, were sent to the Kansas University museum, together with a lot of siliceous stones, with a request for information concerning both. At the first opportunity I visited the locality whence they had been discovered and collected what had been left of the specimen. The bones were in a poor state of preservation, due to the effects of frost, but by carefully digging over the shale in which they occurred we obtained about one hundred and twenty-five of the pebbles, together with several dorsal vertebræ and ribs. Some of the pebbles were still attached to the ribs by the original matrix, making it certain that their deposition was contemporaneous with that of the skeleton. The plesiosaur is one of the largest of the order, the dorsal centra measuring five or more inches in diameter. In all probability the species is identical with that mentioned in the preceding pages as coming from the vicinity of Beloit. It is impossible to determine the genus, and the species is yet undescribed. The pebbles vary in weight from less than one gramme to more than one hundred and seventy grammes. The smaller ones were worn into more or less perfect ellipsoids, but the larger ones are more irregular in shape, having suffered less abrasion. It seems probable that the most of the pebbles had been obtained by the animal from the sea beaches bordering the Black Hills, but not a few of them, consisting of red quartzite, are quite identical with the quartzite boulders so often found in the drift of eastern Kansas, which have come from the vicinity of Sioux City, Iowa.

The specimens show conclusively that the pyloric orifice of the plesiosaurs must have been well provided with a sphincter, and that no solid substances passed into the intestinal canal. One need never expect to find plesiosaur coprolites containing undigested remains of bones or other solid material.

The nearest place where the animal could have found such pebbles on the sea beaches must have been several hundred miles away from Ellsworth, where the animal finally perished. We may conclude, hence, that the plesiosaurs were roving animals.

Since the discovery of this specimen two others with siliceous pebbles have been received at the Kansas University museum, one from the Niobrara of Kansas and the other from the Comanche Cretaceous of Clark County, Kansas (Pl. XXIX.) In neither of these cases were the pebbles worn into such regular figures as in the Benton specimen, and all the pebbles were dark in color, none of them quartzite.

What the use of these pebbles was I will not venture to say. They may have served as a sort of weight to regulate the specific gravity of the animals, or they may have been swallowed accidentally. If, as I believe probable, the plesiosaurs were in the habit of feeding upon invertebrate animals, seeking such in the shallow muddy bottoms, the pebbles may have been taken with their food unintentionally. I doubt this, however. I may add that all specimens do not reveal similar pebbles. In the specimen of *Dolichorhynchops osborni*, described in the preceding pages, where one would certainly expect to find them, there were none. Possibly it was only the broad-headed and more omnivorous kinds that resorted to this peculiar diet, the long-snouted types being more exclusively fish-eating in habit.

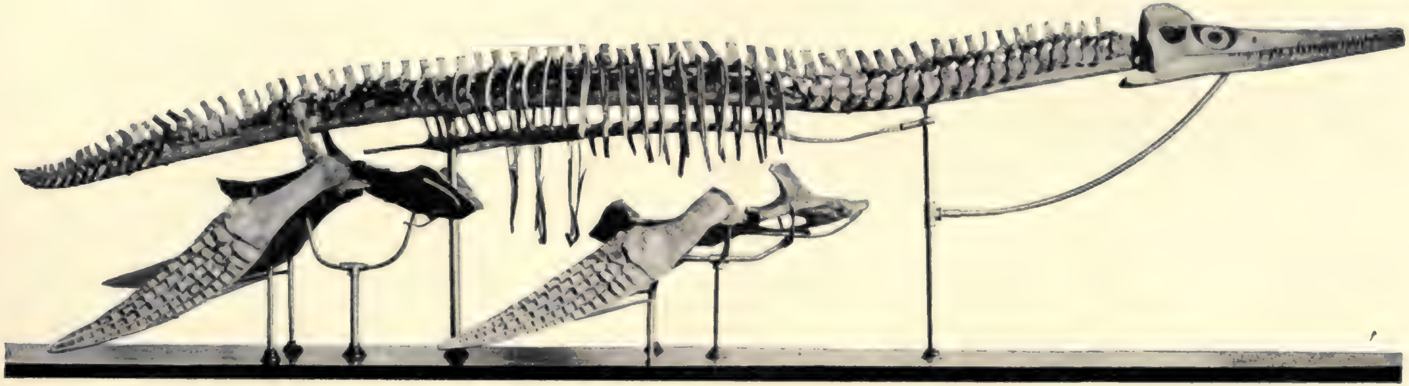
Crocodiles and seals are said to have similar habits, but I have not learned the reason therefor.

Many years ago, a similar habit was recorded of the teleosaurs by Geoffroy St. Hilaire, in the Memoires de l'Acad. des Sci., xxii, p. 48, 1833. Of the plesiosaurs, the only recorded notice, other than by myself, that I can find of such habits is the following by Seeley (Quart. Jour. Geol. Soc., xxxiii, 1877, p. 546):

"In the lower dorsal region of the animal (*Muraenosaurus gardneri*) about a peck of ovate and rounded pebbles occurred, varying in size from a diameter of a quarter of an inch to a length of nearly two inches. They are chiefly of opaque milky quartz, several are of black, metamorphosed slate, and a few of altered, fine-grained sandstone and ironstone, some of the pebbles showing a veined character, such as might be derived from the neighboring Paleozoic rocks of the north of France. Pebbles being of such rare occurrence in the Gault, it would seem natural to account for these associated ones by the hypothesis that they were swallowed by the animal with food, as is the case with several living reptiles and birds. If this view should be held admissible, it would suggest that, as the teeth were too small for anything but prehension, a structure analogous to a gizzard or the stomach of an edentate, may have used these pebbles to assist in breaking up or crushing the food on which the saurian lived."

PLATE I.

Skelèton of *Dolichorhynchops osborni*, as mounted; 1/16 natural size.



SKELETON OF DOLICHORHYNCHOPS OSBORNI.

PLATE II.

Skull of type specimen of *Dolichorhynchops osborni*, from the left (reversed). ×7/24.

SIDNEY PRENTICE, DEL.

SKULL OF DOLICHORHYNCHOPS OSBORNI.

Plate III.

Skull of *Dolichorhynchops osborni.* ×7/24.

Fig. 1, type specimen, from the right.

Fig. 2, restoration, from the left.

ang, angular; *d*, dentary; *eo*, exoccipital; *ep*, epipterygoid; *f*, frontal; *j*, jugal; *m*, maxilla; *n*, nasal; *pa*, parietal; *pet*, petrosal; *pt*, pterygoid; *pl*, palatine; *pm*, premaxilla; *pf*, prefrontal; *pof*, postorbital (postfronto-orbital?); *q*, quadrate; *qj*, quadratojugal; *sc*, sclerotic plates; *so*, supraoccipital; *sq*, squamosal; *sur*, surangular; *v*, vomer.

Fig. 1.

SIDNEY PRENTICE, DEL.

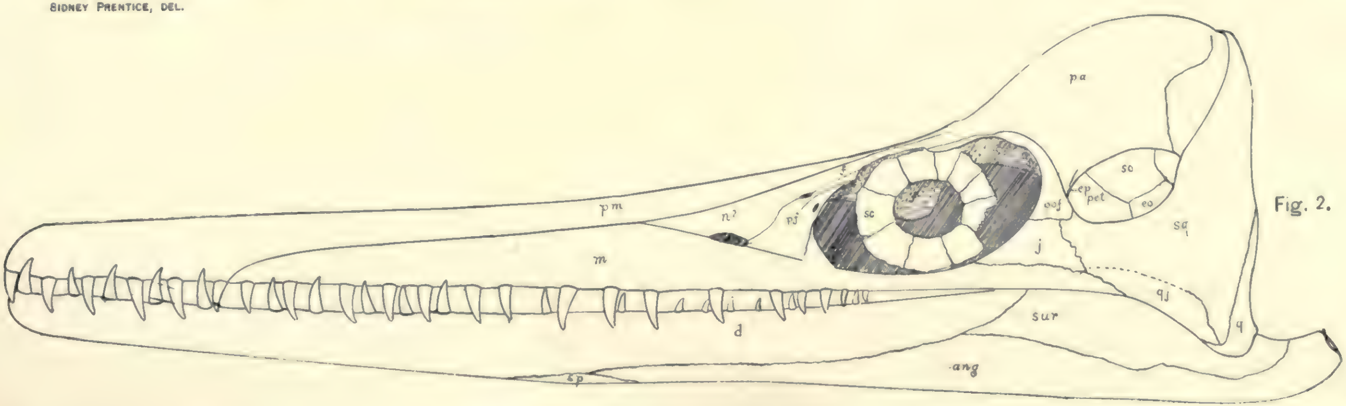


Fig. 2.

SKULL OF DOLICHORHYNCHOPS OSBORNI.

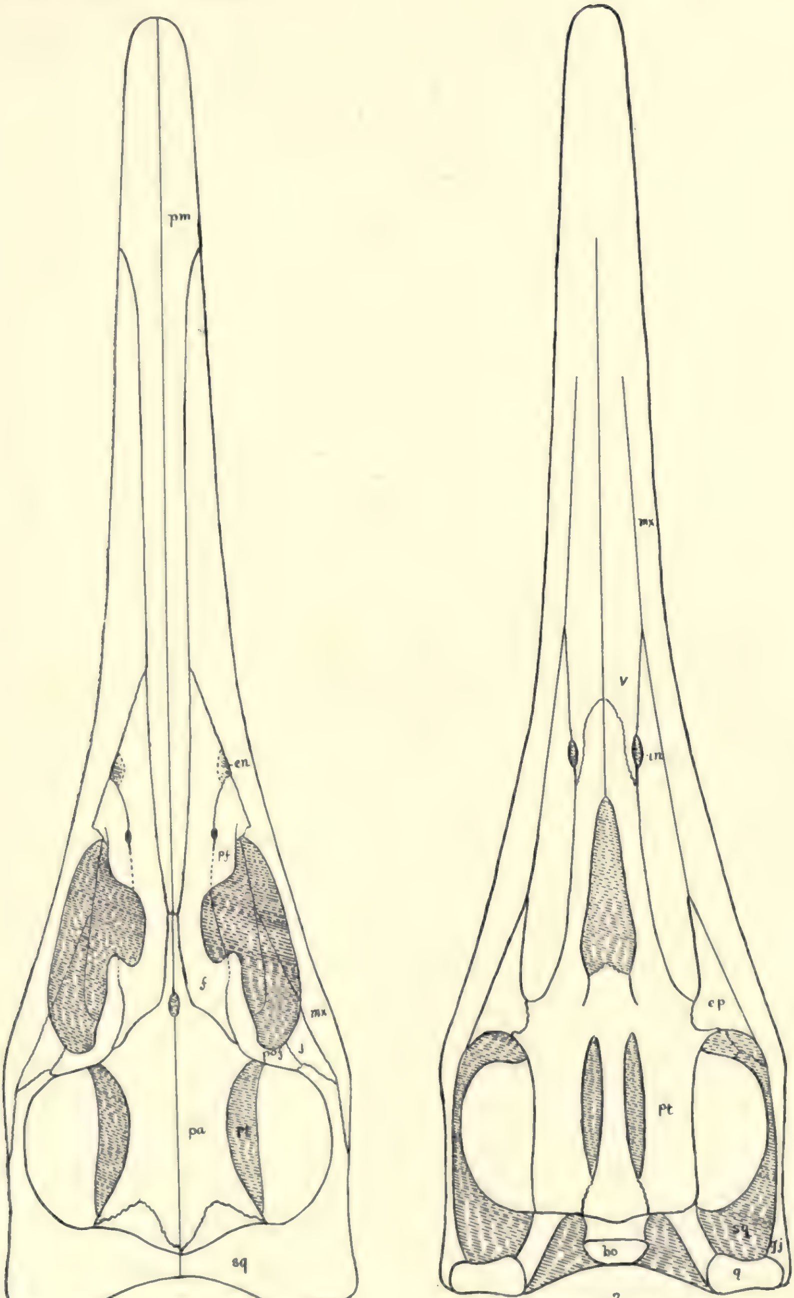
Plate IV.

Skull of *Dolichorhynchops osborni.* $\times 1/3$.

Fig. 1, from above.

Fig. 2, from below.

bo, occipital condyle; *en*, external nares; *ep*, ectopterygoid; *f*, frontal; *in*, internal nares (the letters are on the anterior end of the palatine); *j*, jugal, *mx*, maxilla; *pa*, parietal; *pf*, prefrontal; *pm*, premaxilla; *pt*, pterygoid; *pof*, postorbital; *q*, quadrate; *qj*, quadratojugal; *sq*, squamosal



SKULL OF DOLICHORHYNCHOPS OSBORNI.

Plate V.

Inner side of the left mandible of various reptiles.

Fig. 1, *Sphenodon.*

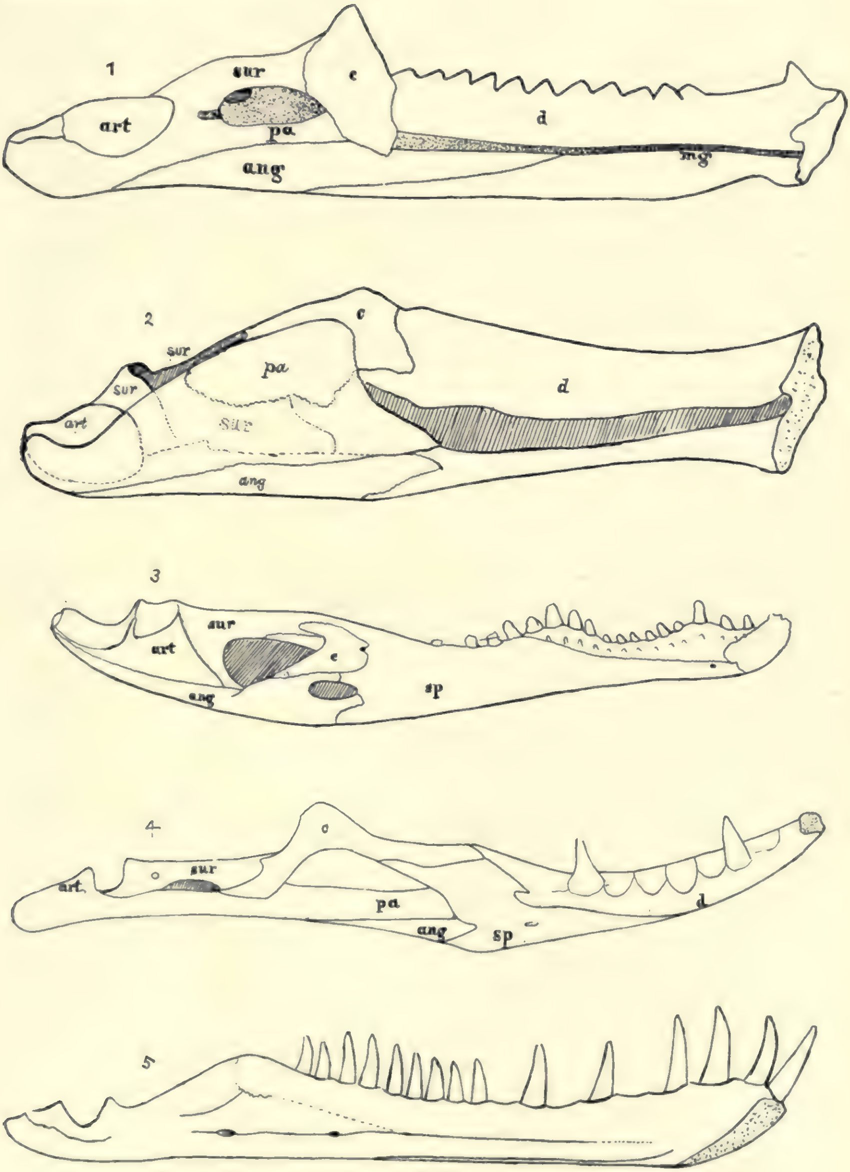
Fig. 2, *Chelydra.*

Fig. 3, *Alligator.*

Fig. 4, *Varanus.*

Fig. 5, *Cimoliasaurus snowii.*

art, articular; *sur*, surangular; *ang*, angular; *c*, coronoid; *pa*, prearticular; *sp*, splenial; *d*, dentary; *mg*, Meckel's groove.



INNER SIDE OF THE LEFT MANDIBLE OF VARIOUS REPTILES.

PLATE VI.

Fourth to eighteenth cervical vertebræ of *Dolichorhynchops osborni*, from below. ×4/15.

Cervical Vertebræ of Dolichorhynchops osborni.

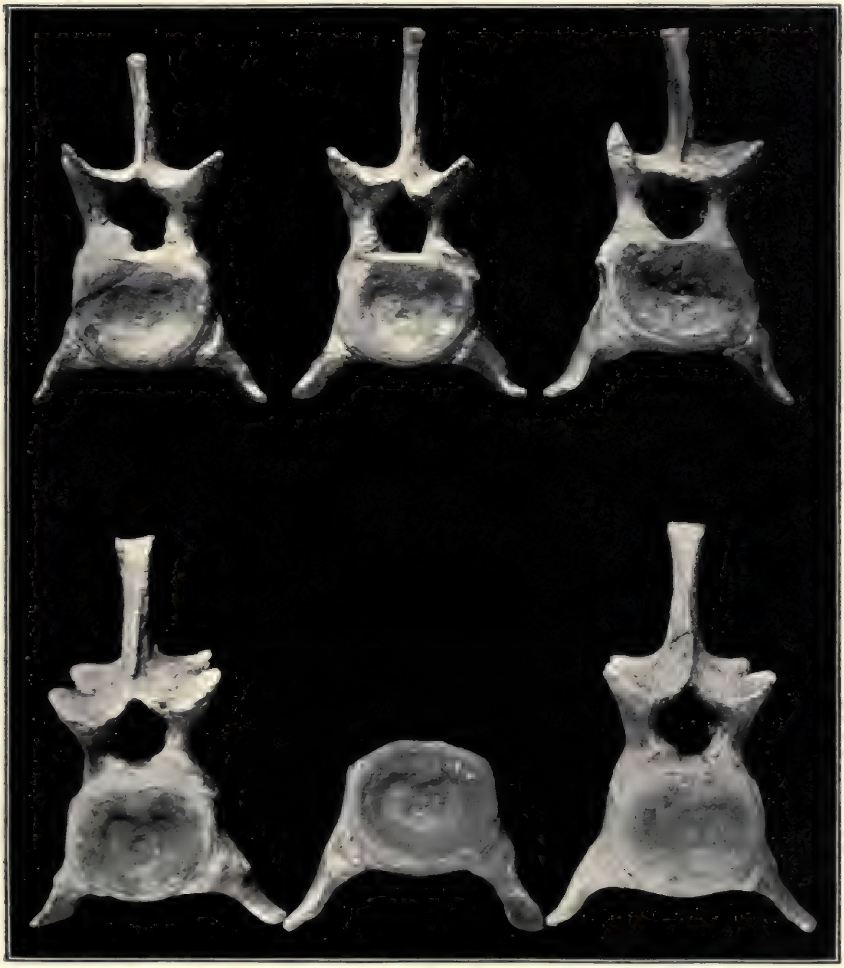
Plate VII.

Seventh to fourteenth cervical vertebræ of *Dolichorhynchops osborni*, from the side. ×4/15.

Cervical Vertebræ of Dolichorhynchops osborni.

PLATE VIII.

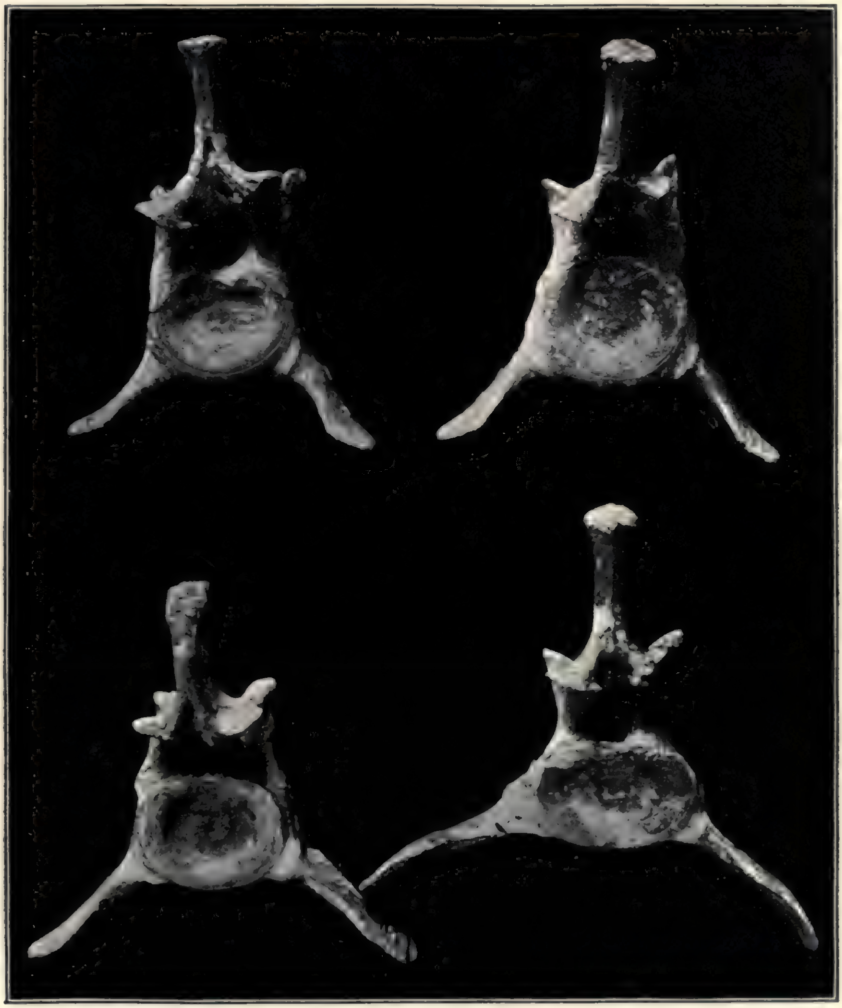
Median cervical vertebræ of *Dolichorhynchops osborni*, from the front. ×4/15.



Cervical Vertebræ of Dolichorhynchops osborni.

PLATE IX.

Posterior cervical vertebræ of *Dolichorhynchops osborni*, from behind. 4/15.



CERVICAL VERTEBRÆ OF DOLICHORHYNCHOPS OSBORNI.

PLATE X.

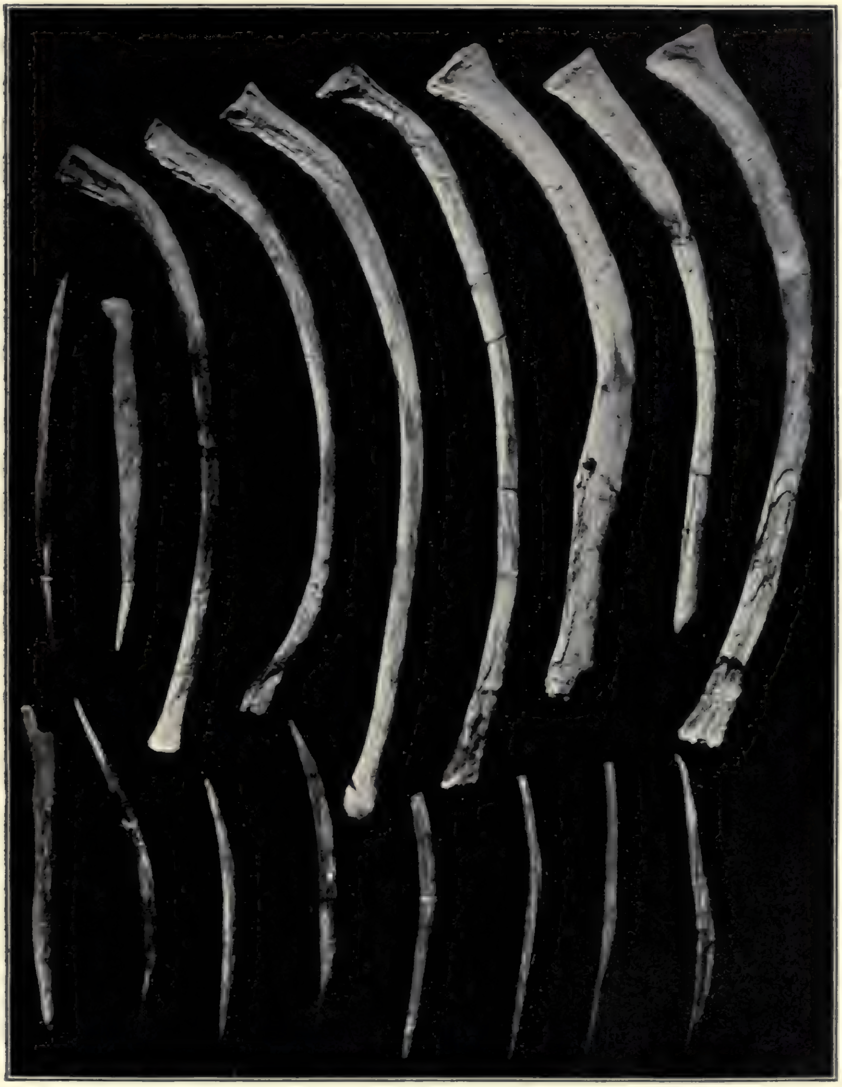
Left series, distal caudal vertebræ of *Dolichorhynchops osborni*, from above. ×11/24.

Right series, cervical vertebræ of *Polycotylus ischiadicus*, from below. ×11/24.

Left Series, Caudal Vertebræ of Dolichorhynchops osborni.
Right Series, Cervical Vertebræ of Polycotylus ischiadicus.

PLATE XI.

Thoracic and abdominal ribs of *Dolichorhynchops osborni*. $\times 1/3$.



RIBS OF DOLICHORHYNCHOPS OSBORNI.

PLATE XII.

Bones of pectoral girdle of *Dolichorhynchops osborni*. ×7/13.
Upper left figure, right scapula, from without.
Upper right figure, left scapula, from within.
Lower left figure, left clavicle, from above.
Lower right figure, episternum, from below.

BONES OF PECTORAL GIRDLE OF DOLICHORHYNCHOPS OSBORNI.

Plate XIII.

Bones of pectoral girdle of *Dolichorhynchops osborni*, from above. $\times 3/14$.
Upper left figure, left clavicle.
Upper middle figure, episternum.
Upper right figure, scapula.
Lower left figure, right coracoid.
Lower right figure, humerus.

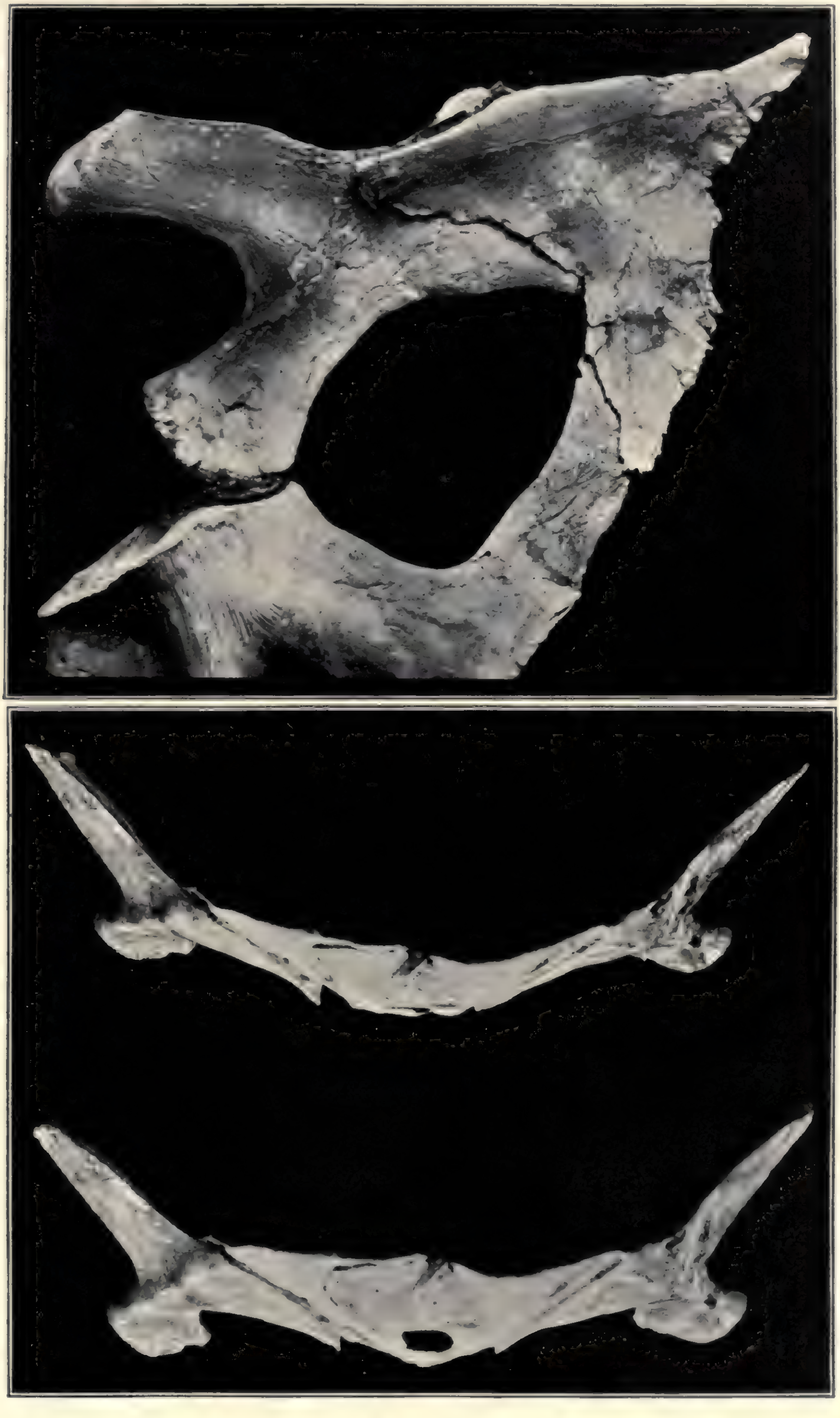
Pectoral Girdle of Dolichorhynchops osborni, from Above.

Plate XIV.

Pectoral girdle of *Dolichorhynchops osborni*.

Upper figure, left clavicle, scapula and upper extremity of coracoid, articulated, from above. $\times 1/3$.

Lower figures, scapulo-clavicular girdle of same, from in front. $\times 1/4$.



Pectoral Girdle of Dolichorhynchops osborni.

Plate XV.

Complete pectoral girdle of *Dolichorhynchops osborni*, from below, articulated. ×1/4.

PECTORAL GIRDLE OF DOLICHORHYNCHOPS OSBORNI.

PLATE XVI.

Pubes of *Dolichorhynchops osborni*, from above. $\times 3/8$.

Pubes of Dolichorhynchops osborni.

PLATE XVII.

Right ischium (left figure) and ilium of *Dolichorhynchops osborni*, visceral surface. $\times 3/8$.

ISCHIUM AND ILIUM OF DOLICHORHYNCHOPS OSBORNI.

PLATE XVIII.

Outlines of pectoral and pelvic girdles of different plesiosaurs.

Fig. 1, pectoral girdle of *Cryptoclidus oxoniensis*, after Andrews.

Fig. 2, pelvic girdle of same, after Andrews.

Fig. 3, pelvic girdle of *Cimoliasaurus sp*, from a photograph furnished by Prof. Fraas.

Fig. 4, pelvic girdle of *Cimoliasaurus trochanterius*, after Lydekker.

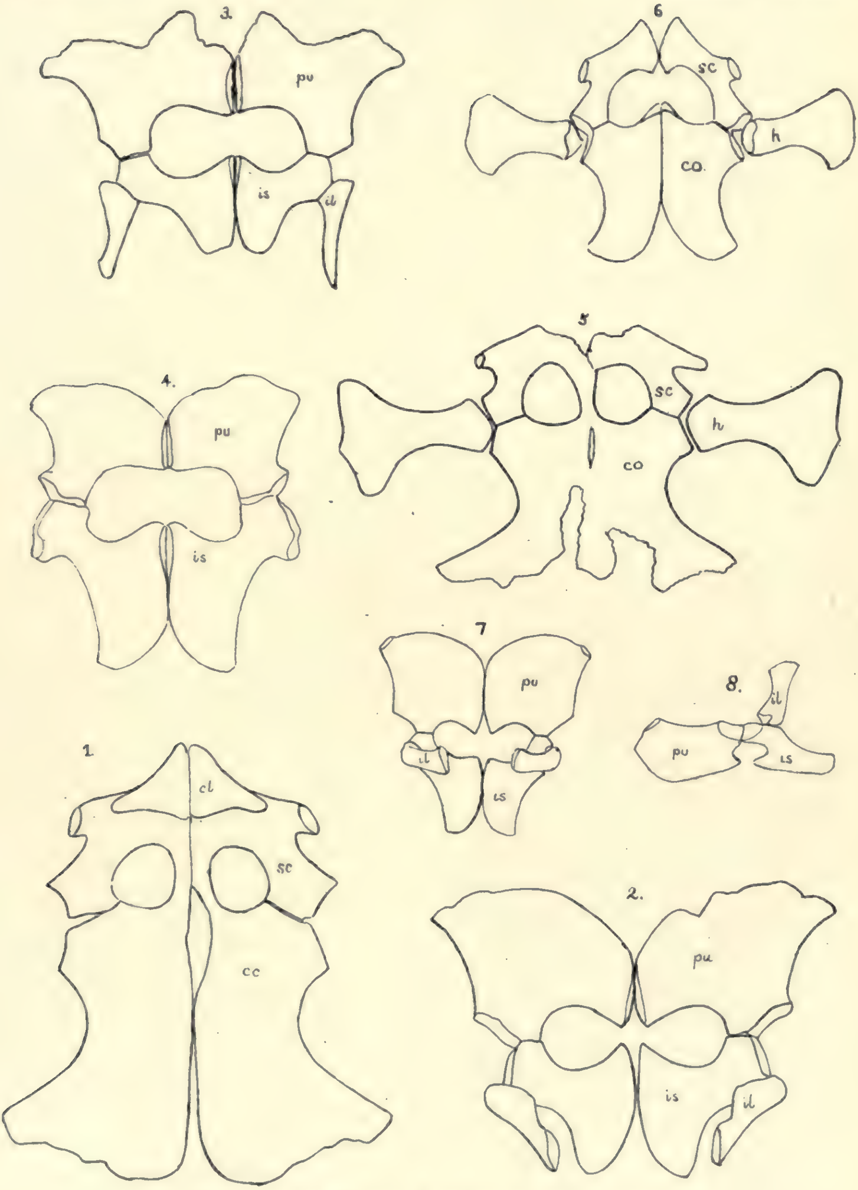
Fig. 5, pectoral girdle of *Plesiosaurus sp*, from photograph from Prof. Fraas.

Fig. 6, pectoral girdle of *Murænosaurus*, after Andrews.

Fig. 7, pelvic girdle of same, after Andrews.

Fig. 8, pelvic girdle of same, from the side, after Andrews.

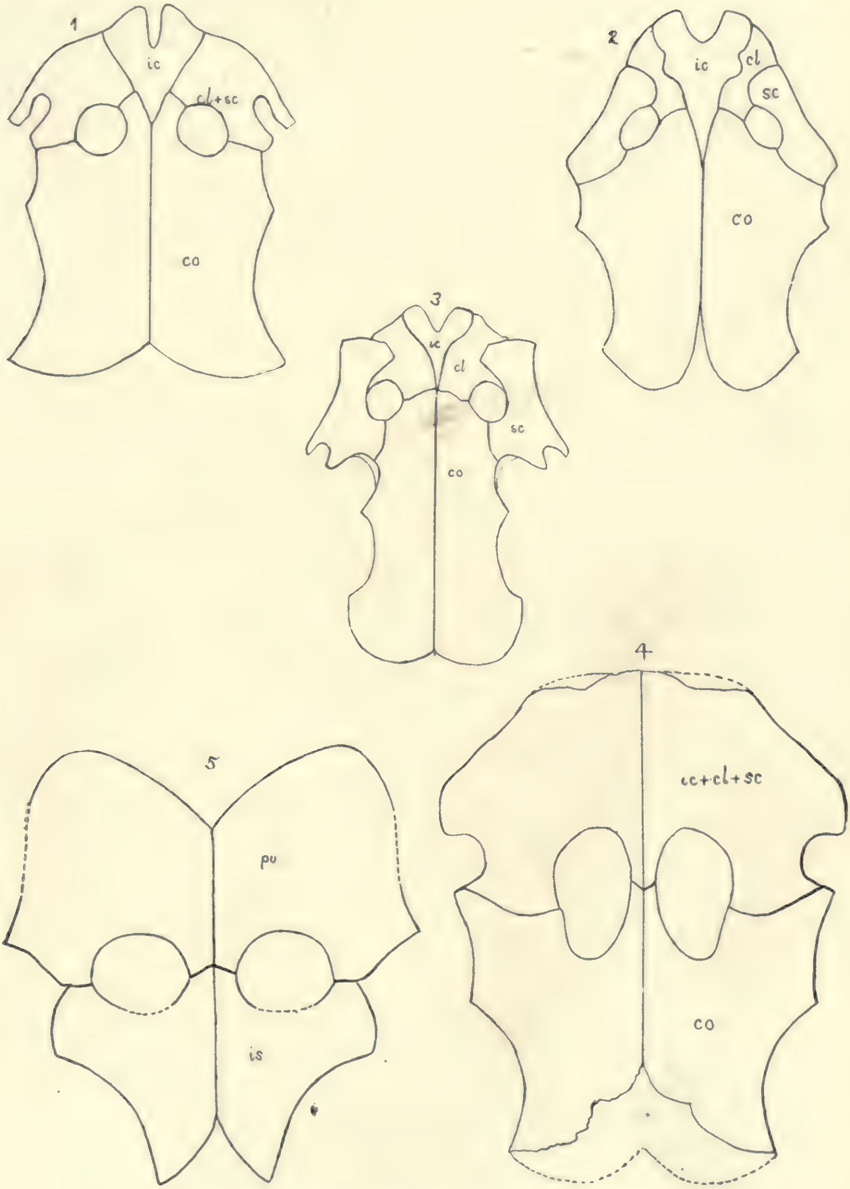
ic, episternum; *cl*, clavicle; *sc*, scapula; *co*, coracoid; *pu*, pubis; *is*, ischium.



PECTORAL AND PELVIC GIRDLES OF PLESIOSAURS.

Plate XIX.

Pectoral and pelvic girdles of plesiosaurs.
Fig. 1, pectoral girdle of *Plesiosaurus*, after Owen.
Fig. 2, pectoral girdle of *Plesiosaurus*, after Woodward.
Fig. 3, pectoral girdle of *Plesiosaurus laticeps*, after Owen.
Fig. 4, pectoral girdle of *Elasmosaurus platyurus*, after Cope.
Fig. 5, pelvic girdle of same, after Cope.
ic, episternum; *cl*, clavicle; *sc*, scapula; *co*, coracoid; *pu*, pubis; *is*, ischium.



PECTORAL AND PELVIC GIRDLES OF PLESIOSAURS.

PLATE XX.

Limbs, as mounted, of *Dolichorhynchops osborni*, dorsal surface. × 1/4.
Left figure, right pectoral paddle.
Right figure, right pelvic paddle.

LIMBS OF DOLICHORHYNCHOPS OSBORNI.

PLATE XXI.

Right pectoral paddle of *Polycotylus latipinnis* Cope, palmar surface. $\times 1/6$.

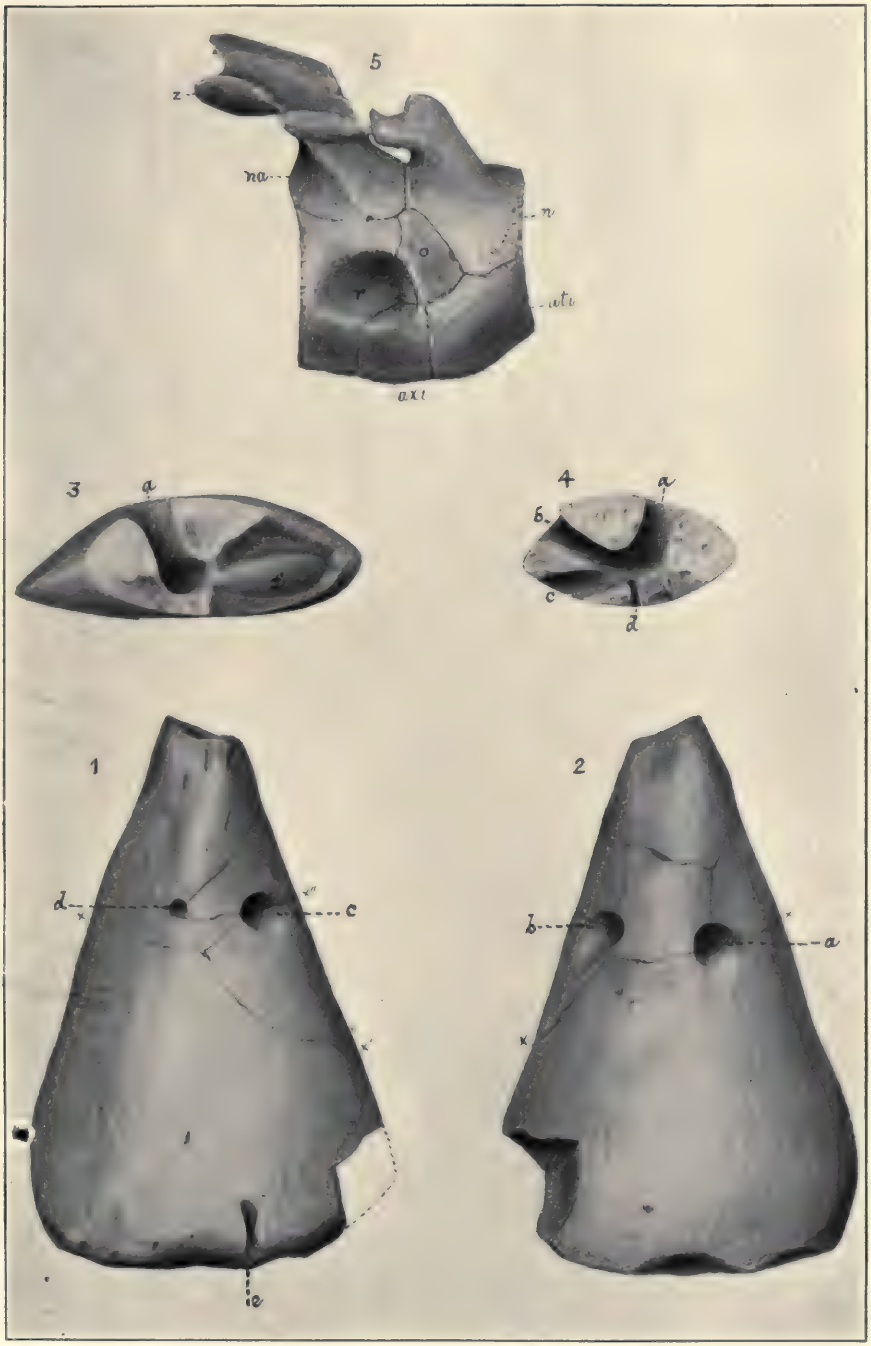
PADDLE OF POLYCOTYLUS LATIPINNIS.

Plate XXII.

Figs. 1-4, propodial bone of young plesiosaur, from Niobrara Cretaceous. ×3/4.

Fig. 5, atlanto-axis of *Dolichorhynchops osborni*, from the side. ×3/4.

ati, atlantal intercentrum; *axi*, axial intercentrum; *n*, atlantal neurapophysis; *o*, odontoid; *r*, pit for reception of axial rib; *na*, axial neurapophysis; *z*, zygapophysis.



PROPODIAL BONE OF YOUNG PLEISOSAUR. ATLANTO-AXIS OF DOLICHORHYNCHOPS OSBORNI.

PLESIOSAURS

PLATE XXIII.

Propodial bones of young plesiosaurs, from the Niobrara Cretaceous of Kansas. $\times 1/2$.

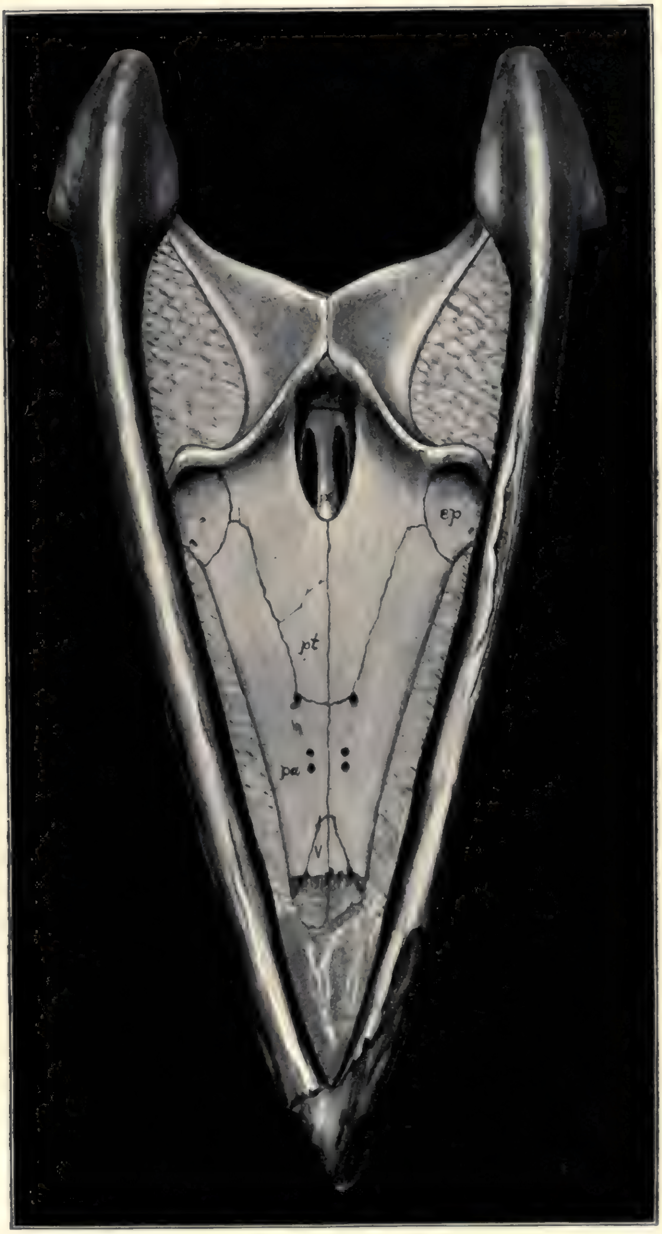
Fig. 1. Fig. 2. Fig. 3. Fig. 4.

PROPODIAL BONES OF YOUNG PLESIOSAURS.

Plate XXIV.

Palatal view of type specimen of *Brachauchenius lucasi* (redrawn from photograph and sketch). ×3/25.

pt, pterygoid; *ep*, ectopterygoid; *pa*, palatine; *ps*, parasphenoid; *v*, vomer; *bs*, basisphenoid.



PALATE OF BRACHAUCHENIUS LUCASI.

Plate XXV.

Posterior cervical and dorsal vertebræ, and ribs of *Brachauchenius lucasi*, from below. $\times 1/10$.

VERTEBRÆ AND RIBS OF BRACHAUCHENIUS LUCASI.

PLATE XXVI.

Pelvic bones of *Polycotylus ischiadicus* Willist., visceral surface. ×1/3.
is, ischium; *il*, ilium; *sp*, sacral rib; *sv*, sacral vertebra.

Pelvic Bones of Polycotylus ischiadicus.

Fig. 1.

Fig. 2. Fig. 3.

DORSAL VERTEBRA OF PLESIOSAURUS GOULDII

PLATE XXVII.

Fig. 1, episternum and portion of clavicles of *Plesiosaurus mudgei* (?) Cragin, from below. $\times 1/2$.

Fig. 2, dorsal vertebra of *Plesiosaurus gouldii* (type specimen), from the front. $\times 1/2$.

Fig. 3, the same, from the side. $\times 1/2$.

Drawn by Sidney Prentice.

Fig. 1.

EPISTERNUM AND PORTION OF CLAVICLES OF PLESIOSAURUS MUDGEI.

Fig. 2. Fig. 3.

DORSAL VERTEBRA OF PLESIOSAURUS GOULDII.

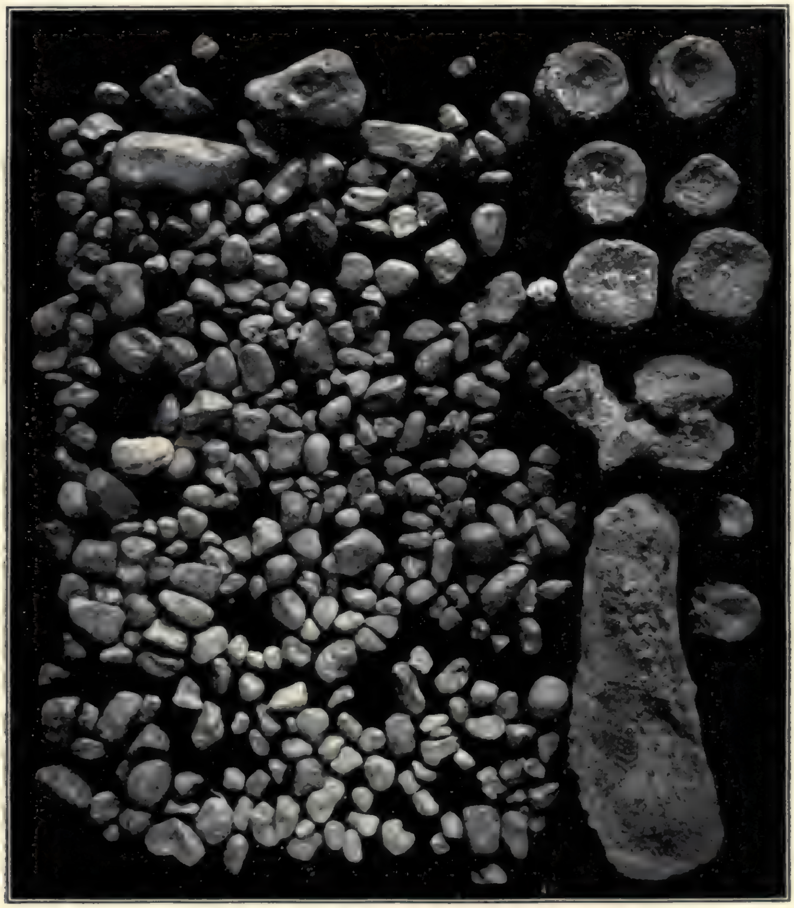
PLATE XXVIII.

Trinacromerum anonymum Willist. ×3/11.
Upper figures, parts of ilium and coracoid.
Lower figures, humerus, as restored, and cervical vertebræ.

TRINACROMERUM ANONYMUM.

PLATE XXIX.

"Stomach pebbles," vertebræ and femur of *Plesiosaurus mudgei* Cragin, reduced.



"STOMACH PEBBLES" OF PLESIOSAUR.

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