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STRUCTURE AND RELATIONSHIPS OF AMERICAN LABYRINTHODONTIDÆ

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BY
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The term "Labyrinthodontidæ" is used in this paper with the same signification as Zittel uses it in his *Handbuch der Palaeontologie.* A discussion of the genus *Eryops* is included here because it was studied by the writer for comparison with the Labyrinthodontidæ, and some interesting facts were brought out by this study.

The first remains of Labyrinthodontidæ known from America were discovered by Ebenezer Emmons in the Trias of North Carolina, and were mentioned by him in *The Geological Report of the Midland Counties of North Carolina* in 1856. The same year Leidy described these remains and proposed the generic name *Dictyocephalus* for them.[1] In 1866 Cope described some skull bones from the Trias of Chester County, Pennsylvania, and referred them to the European genus *Mastodonsaurus.*[2] Two years later[3] he founded the genus *Eupelor* on these skull bones and some teeth from the same locality, but the following year referred the teeth to thecodont reptiles.[4] In 1868 he described a skull from the Trias of Chatham County, North Carolina, giving to the genus which it represented the name *Pariostegus.*[5] In the *Report of the United States Geographical Survey West of the 100th Meridian* for 1875 he described some fossils from the Trias of northwestern New Mexico, among which were three sculptured plates that he referred to *Typothorax*, a genus of Parasuchians; but they are without doubt fragments of a labyrinthodont skull. In 1892 the same writer mentions the occurrence of a form allied to *Eupelor* from the Docum Beds of northwestern Texas.[6]

[1] *Proceedings of the Academy of Natural Sciences of Philadelphia*, Vol. VIII, pp. 255, 256.

[2] *Ibid.*, 1866, p. 250. [3] *Ibid.*, 1868, p. 221.

[4] *Transactions of the American Philosophical Society*, Vol. XIV, p. 25.

[5] *Proceedings of the Academy of Natural Sciences of Philadelphia*, 1868, p. 211.

[6] Geological Survey of Texas, *Fourth Annual Report*, pp. 12, 17.

In 1899 Dr. Lester F. Ward collected, among other things, a fragment of a Labyrinthodont cranial plate from the Trias of northeastern Arizona, near Tanners Crossing on the Little Colorado River. The following year Mr. Barnum Brown obtained from the same locality an interclavicle of a large Labyrinthodont which Mr. Lucas described as *Metoposaurus fraasi*.[1]

In 1902 Mr. Newton H. Brown found various Labyrinthodont bones in the Triassic deposits near Lander, Wyoming. He sent some fragments of these to Mr. Lucas, of the National Museum, and others to Professor Knight, of the University of Wyoming. After the death of Professor Knight, the fragments sent to him were forwarded to Professor Merriam, who recently sent them to the University of Chicago. Among them was the back part of a mandible belonging to one of the skulls described in this paper. Mr. Brown very generously gave the benefit of his intimate acquaintance with the Triassic deposits of the Lander region to a University of Chicago party that collected there in 1904, and it has given the writer much pleasure to name the type species of *Anaschisma* in his honor.

In the fall of 1904 Mr. Reed, of the University of Wyoming, sent to the University of Chicago, for examination, some vertebræ and fragments of cranial bones of Labyrinthodonts obtained from the Trias about forty miles south of Laramie, Wyoming. Dr. Williston, in company with Mr. Reed, had visited this locality a few months previously, and ascertained that their horizon is not far from the top of the Red Beds, and provisionally refers it to the Hallopus Beds of Marsh.

SPECIMENS OF LABYRINTHODONTIDÆ FROM THE LANDER REGION

The material collected by the University of Chicago party of 1904 includes vertebræ, fragments of skulls, breast-plates, ribs, and limb bones. All of the vertebræ have the arches broken away. There are more than forty in the collection, but no two are known to belong to the same animal. The skull bones are fragmentary, and the fragments are usually small, though one specimen includes the frontals, prefontals, and nasals. Fragments of breast-plates are

[1] *Proceedings of the U. S. National Museum*, Vol. XXVII, No. 1353, p. 194.

numerous, and are usually of larger size than those of the skull, while two nearly complete clavicles and one interclavicle were obtained. The fragments of ribs and limb bones are small, and are referred to Labyrinthodonts with some doubt.

The best material known is two skulls collected by Mr. Brown from the same locality as that mentioned above. The skulls were found closely associated, one slightly overlapping the other. They represent two species here described as *Anaschisma browni* and *Anaschisma brachygnatha.* For convenience in the general descriptions, the skull of the former species is designated as A, and that of the latter as B.

In A most of the left maxillary, the lower part of the left quadratojugal, the left condyle, part of the posterior end of the parasphenoid, part of the outer end of the right exoccipital, a small portion of the posterior margins of the epiotics and prosquamosals, and the right opisthotic are missing. In B most of the right maxillary, part of the right premaxillary, part of the lachrymals, the condyles, and the upward projections of the exoccipitals are not present. About 8^{cm} of the anterior end of the left mandible of A is broken away. The right mandible of B lacks a part of the anterior and part of the posterior end of the dentary, and also most of the surangular.

The skulls were incased in a hard matrix of arenaceous shale, and had been broken in many pieces. This matrix has been removed in the laboratory with considerable labor, and both skulls now present the outer surface of all of the bones.

The inner surface of most of the bones was examined by the writer, but has necessarily been concealed in the restoration of the skulls. Nearly all of the sutures were distinctly traced either on the inside or on the outside of the bones. The skulls are but little distorted.

Anaschisma, *gen. nov.*

Skull large, subtriangular. Bones of the roof all deeply sculptured. Frontals excluded from orbits by the junction of the pre- and postfrontals; all of the bones behind the orbits, excepting the supraoccipitals and epiotics, elongated; lachrymal forming part of the posterior border of the nares. Opisthotics short, not coalesced with the exoccipitals. Parasphenoid with a long, narrow, cultriform process

anteriorly; exoccipitals meeting in the median line in the floor of the skull. Parietal foramen small, subcircular; no auditory notches; orbits very large, subcircular, situated in anterior half of skull, and widely separated from each other; premaxillary vacuities large, double, penetrating the roof of the skull at the anterior end of the nares; nares terminal, large, ovate. Base of skull with large quadrate foramina; foramen magnum large, with no inward projections of the exoccipitals. Palatine foramina expanded anteriorly. Teeth with labyrinthine structure much like that of *Mastodonsaurus;* a large tooth on each ramus of the mandible near the symphysis. Mandible broad and thin, breadth and thickness as 4 to 1; a strong postcotylar process present.

Skull.—The skull of *Anaschisma* resembles that of *Metoposaurus* and *Capitosaurus* in shape. It is subtriangular, with the margins gently convex anteriorly, gently concave in the middle, and again gently convex posteriorly. The roof is almost flat in front of the parietal foramen, but from this foramen the surface ascends rapidly to the posterior margin. The margins of the orbits and nares are not elevated. The lateral arching is considerable posteriorly, including the quadratojugals, jugals, prosquamosals, and postorbitals. The underpart of the skull is in one plane, save in the region of the quadrates, the inner ends of which descend about 2^{cm} below the level of the rest.

The shape of the bones in the roof of the skull is well shown in Figs. 6 and 9. They resemble those of *Metoposaurus diagnosticus*, but present some notable differences. The premaxillæ are more elongate and narrower; the supraoccipitals are shorter; and the epiotics are proportionally narrower and shorter. The suture between the lachrymal and jugal has not been definitely determined, but the lachrymal reaches forward to the posterior border of the nares.[1] There is no prominent projection inward of the lachrymal between the orbits and nares. The quadratojugal articulates with the outer

[1] In the January number of the *Sitzungs-Berichte der Gesellschaft naturforschender Freunde*, Jaekel attempts to show that the prefrontal of the Reptilia is homologous with the lachrymal of the Mammalia, and he gives to the so-called lachrymal of the Reptilia the name "postnasal." The evidence that he presents does not, however, seem strong enough to warrant his conclusions.

upper corner of the quadrate, and takes no part in the articular surface as it does in *Mastodonsaurus*.

The orbits are in the anterior half of the skull and far apart, but they differ from those of *Metoposaurus* in being subcircular instead of oval. In a skull of *Metoposaurus diagnosticus* 405^{mm} long the orbits are 53^{mm} long by 32^{mm} broad.[1] In a skull of *Anaschisma* 415^{mm} long the orbits are 55^{mm} long by 49^{mm} broad. The external nares are ovate, with the apex near the tip of the snout, and they are larger and closer together than in *Metoposaurus*. In the skull of *Metoposaurus diagnosticus* mentioned above the nares are 35^{mm} long, 27^{mm} broad, and 48^{mm} apart; while in the skull of *Anaschisma* they are 49^{mm} long, 36^{mm} broad, and 35^{mm} apart. At the anterior end of the nares there are openings through the premaxillæ for the reception of the mandibular teeth. The parietal foramen is small, subcircular, and located about one-fourth the length of the parietals from the posterior end. No auditory slits are present, but the epiotics and prosquamosals have a slightly concave posterior margin in the region where the slits occur in other genera.

The bones of the roof are sculptured much as in *Metoposaurus*, but with much more of the space pitted, and without such long radiating ridges and furrows as in that genus. The pits are not so large, and the ridges between them are rounded instead of angular. None of the space in the lyra is furrowed.

The mucous canals of the lyra begin in a broad depression slightly inside of the posterior inner border of the orbits, and pass forward about 1½^{cm} inside the orbits, approaching a little nearer at their anterior inner corner. From the posterior inner angle of the prefontals the canals pass forward and outward in a straight line to about the middle of the outer margin of these bones, and thence forward in a straight line to the posterior outer corner of the nares. From here they pass inward and forward, following the margin of the nares. Near the tip of the snout the canals turn outward slightly, become shallower and broader, and end at the margin of the premaxillæ. They are nowhere very deep, and they maintain a width of a little more than 1^{cm} throughout their length.

The canals on the posterior part begin far back on the squamosals,

[1] *Paleontographica*, Vol. XXXVI, p. 142.

pass straight forward to in front of the middle of the postorbitals, thence outward and forward on the jugals, thence backward on the jugals and quadratojugals to near the base of the skull, where they turn upward slightly on the prosquamosal, and end at its posterior

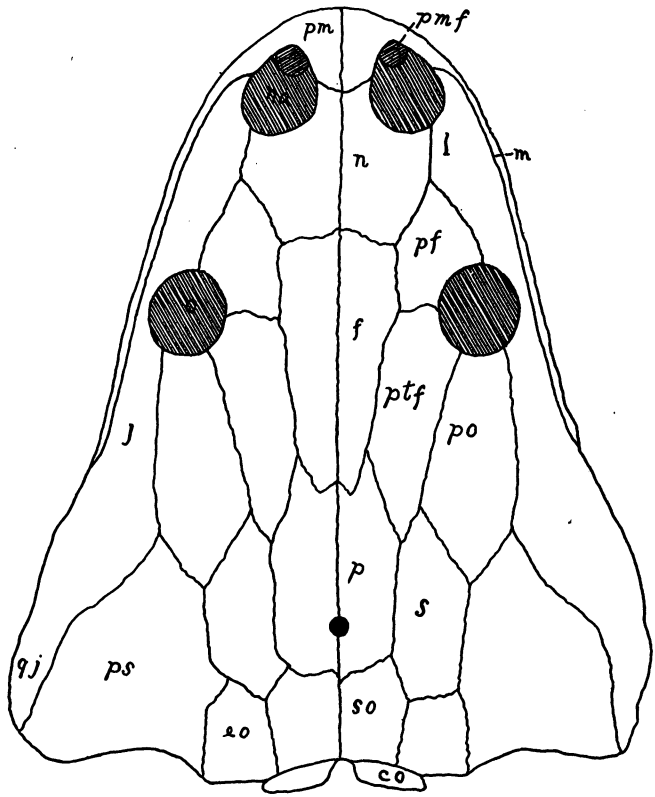


FIG. 1.—*Anaschisma browni;* view of top of skull, one-fifth natural size.
co, condyle; eo, epiotic; f, frontal; j, jugal; l, lachrymal; m, maxillary; n, nasal; na, nares; o, orbit; p, parietal; pf, prefrontal; pm, premaxillary; pmf, premaxillary foramen; po, postorbital; ps, prosquamosal; ptf, post-frontal; qj, quadratojugal; s, squamosal; so, supraoccipital.

margin. The part running forward on the squamosals and post-orbitals is shallow and narrow, while the remainder is deeper and twice as broad.

The following are the dimensions of the skulls and of the openings in the roof:

	A	B
Skull—		
Total length	490mm	...
Length of roof	445	415mm
Breadth at posterior end	405	335
Breadth at posterior end of nares	190	158
Breadth at posterior end of orbits	270	235
Height at base	120	105
Orbits—		
Length	57	55
Breadth	46	49
Distance apart	122	110
Distance from posterior end of skull (median line)	240	220
Distance from anterior end of skull	180	170
Nares—		
Length	55	49
Breadth	42	36
Distance apart	32	35
Distance from anterior end of skull	40	36
Distance from orbits	86	90
Parietal foramen—		
Length	...	11
Breadth	...	9
Distance from posterior end of skull	...	57
Distance from orbits	...	155

Under side of skull.—The parasphenoid is long, slender, expanded posteriorly, and with a long, slender, cultriform process anteriorly. Its greatest length in A is 335mm, in B 310mm. The width along the shaft is about 40mm in A, 38mm in B. The prevomers articulate with it on each side along the anterior two-fifths of its length. Between the prevomers the width gradually decreases forward to about 15mm from its anterior end, where it is 8mm broad. From here to the anterior end its edges are parallel. Its greatest width, 75mm in A, 70mm in B, is at the posterior end of the palatine foramina. Posterior to this it is nearly semicircular as seen from below, but it sends out a wing-like process on either side that is overlapped by the pterygoid and exoccipital. At the posterior end on the upper side are two elongated oval pits, one on each side of the median line. They are about 10mm apart at their closest approach, and extend obliquely backward from the median line.

In general appearance the parasphenoid resembles that of *Metoposaurus*, but differs from it in the rounded posterior part and the slender cultriform process. The posterior part in *Metoposaurus diagnosticus*, as figured by Fraas,[1] resembles the posterior part in

[1] *Paleontographica*, Vol. XXXVI, Plate XIII.

Anaschisma as seen from above. The anterior part of the cultriform process resembles that of *Capitosaurus*.

The pterygoids form a considerable portion of the back part of the under side of the skull. A long anterior wing, about 32^{mm} wide posteriorly, but broadening abruptly to a width of 52^{mm}, 60^{mm} in advance of the posterior part of the palatine foramina, separates the palatine and infratemporal foramina, and articulates with the parasphenoid and exoccipitals. The posterior outer wing is narrow where it diverges from the main part of the bone, but broadens abruptly, sending up a broad triangular wing, which reaches the prosquamosal above, articulates with the quadrate at its outer end and forms a large part of the base of the skull. In the middle of the lower portion on the posterior side of this broad wing there is a deep, oval pit, with a groove running forward from it.

Passing upward from the pterygoid, just in front of the place where the posterior wing diverges, there is a slender, incompletely ossified bone that ends freely above. If the slender column continued upward, it would articulate with the parietals above. In *Gondwanosaurus*,[1] two slender bones articulate with the parietals above, and it is probable that these are the same elements that occur in *Anaschisma*, though more completely ossified in the former genus. This bone is probably the epipterygoid.

The palatines are long and slender. The posterior part reaches as far back as the hinder part of the orbit, and is wedged in between the maxillary and the transverse. A slender branch, with a minimum width of 1^{cm}, passes inward between the palatine foramen and the internal naris, and articulates with the prevomer. Between the naris and the maxilla the bone is narrow, but it broadens again in front of the naris. About 2^{cm} anterior to the naris there is a large tooth, and just in front of this the palatine articulates with the premaxilla. The palatine bears only the one tooth.

The prevomers are paired. Posteriorly they are separated by the cultriform process of the parasphenoid, but anteriorly they meet in a suture in the median line of the skull. A slender, tapering process runs backward from the posterior inner part of the bone

[1] *Paleontographica Indica*, Series IV, Vol. I, "The Bijori Labyrinthodont," p. 4,

between the parasphenoid and the palatine foramen. From the postero-outer corner a short process projects between the nares and the palatine foramina to articulate with an inward projection of the palatine. In front of the internal nares the prevomers articulate with the palatines as far as the anterior edge of the large palatine

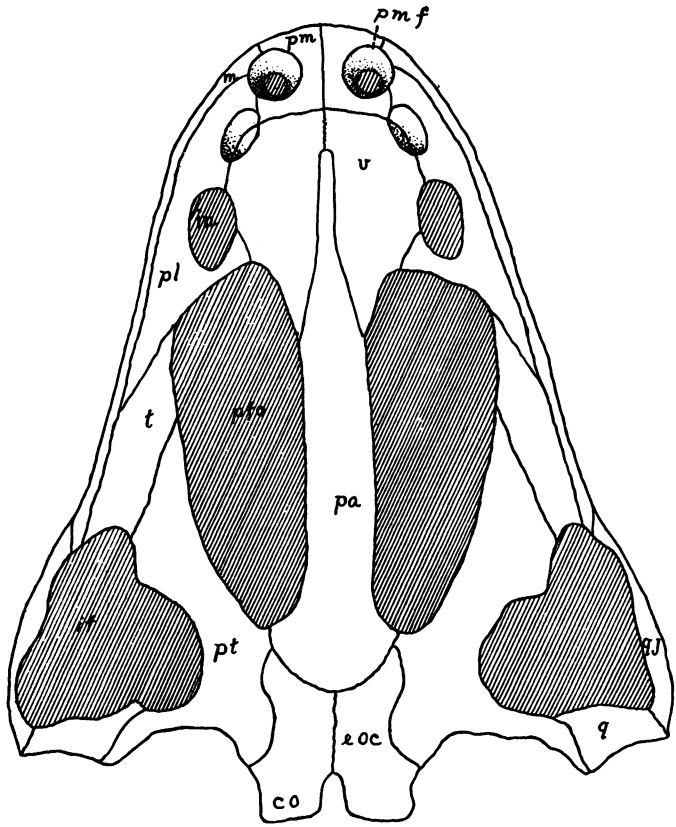


FIG. 2.—*Anaschisma browni;* palatal view of skull, one-fifth natural size.

co, condyle; eoc, exoccipital; if, infratemporal foramen; in, internal nares; m, maxillary; pa, parasphenoid; pfo, palatine foramen; pl, palatine; pm, premaxillary; pmf, premaxillary foramen; pt, pterygoid; q, quadrate; qj, quadrato-jugal; t, transverse; v, vomer.

tooth. From this point the anterior margin passes inward in a broadly rounded curve to the median line, which it meets about 5^{cm} posterior to the tip of the snout. There is a series of four or more small teeth on the anterior margin of each prevomer.

The transverse is a small bone, about 14^{cm} long by 3^{cm} broad, which articulates with the maxillary on the outside, with the pterygoid on the inside, and with the palatine in front. The suture between the transverse and the pterygoid has been definitely determined only on the right side of A, but it is indicated on the left side of the same skull and on the left side of B, where the bones are not so well preserved. The suture between it and the maxilla is distinct, but the one between it and the palatine is almost indistinguishable; only on the right side of A can it be distinguished with any degree of certainty, and even here a second line back of the one indicated in Plate II has very much the indication of a suture. On the right side of the same skull the bones are partially lost in the place where the palatine and transverse meet, but there is an indication of a suture in the same region as the one shown on the left side.

Viewed from the under side of the skull, the premaxillæ are nearly rectangular in shape. Each is pierced by a large opening for the passage of a mandibular tooth. This opening occupies more than half of the area of the bone. It is conical in shape, with the apex of the cone passing through the anterior end of the external nares. The suture between the premaxillæ and the maxillæ has not been definitely determined, but it appears to be just outside the opening for the mandibular tooth. The teeth are all broken off at the surface of the bone. Their sockets are no larger than those on the anterior part of the maxillæ. The suture between the premaxillæ and nasals is directly between the external nares.

The maxillæ are very slender. They extend from just outside the external nares to the anterior end of the infratemporal foramen. They bear a single series of small teeth that seem to increase gradually in size anteriorly. Only the roots of the teeth are preserved, and unfortunately most of them are badly obscured.

The palatine foramina are long, narrow posteriorly and expanded anteriorly. The infratemporal foramina are short and broad. The internal nares are large, oval, and situated near the anterior end of the palatine foramina. The premaxillary foramina are large and nearly circular.

The openings on the inferior side of the skull are almost perfectly shown in both specimens. The following table gives their dimensions:

	A	B
Premaxillary foramina—		
Length	24mm	22mm
Breadth	28	23
Distance apart	20	20
Distance from tip of skull	14	24
Internal nares—		
Length	50	46
Breadth	30	26
Distance apart	120	110
Distance from tip of skull	...	...
Palatine foramina—		
Length	225	200
Breadth	76	71
Distance from premaxillary foramina	100	105
Distance from internal nares	10	13
Distance from tip of skull	145	145
Distance from end of condyle	125	...
Infratemporal foramina—		
Length	130	115
Breadth	115	82
Distance apart	165	150

Base of skull.—The base of the skull is in an excellent state of preservation in A, but in B the upper part of the exoccipitals, the opisthotics, and the downward projections of the supraoccipitals are missing. The shape is well shown in Figs. 3 and 3*a*. The roof is regularly convex; the under border nearly plane, save for a downward projection at the union of the quadrate and pterygoid.

The foramen magnum is large, oval, and no projections inward from the exoccipitals tend to divide it into two parts as in *Mastodonsaurus* and *Metoposaurus*. The foramen more nearly resembles that of *Capitosaurus stantonensis* Woodward, though even in that form there is a slight projection inward from the sides, while in *Anaschisma* the sides are slightly concave outward. No fragments of cartilage or bone are present to indicate the presence of partially ossified basioccipitals or supraoccipitals, as in *Capitosaurus stantonensis* Woodward.[1] Between the exoccipitals and opisthotics below, and epiotics and supraoccipitals above, there is a small foramen, rounded above and angular below. This foramen is homologous with the posttemporal foramen of reptiles, as will be readily understood by reference to the text-figure of the base of the skull of *Eryops*, in which the relationship of the foramen is the same as in *Anaschisma*, though the opisthotic and foramen are larger.

[1] *Proceedings of the Zoölogical Society of London*, 1904, Vol. II, p. 172.

At the infra-basal angle of the skull there is an elongate oval foramen which clearly bears the same relation to its investing bones as does the quadrate foramen in the Ichthyosaurs, and nearly the same relation as in Sphenodon, the parasuchians some of the theropod dinosaurs, and *Dimetrodon*. On the outside it is bounded by the prosquamosal and quadratojugal; below and on the inside, by the quadrate. In Sphenodon, the parasuchians, theropod dinosaurs, and *Dimetrodon* the squamosal does not enter into the outer wall of the foramen. Dr. A. S. Woodward figures this foramen, and calls it the posttemporal.[1] The posttemporal in reptiles is bounded on the inside by the exoccipitals and supraoccipitals, below by the exoccipitals or opisthotics or both, on the outside by the squamosal or parietal or by both, and above by the parietal and squamosal. As the relations of this foramen in *Anaschisma* and *Capitosaurus* are entirely different from those of the posttemporal foramen in reptiles, it cannot be homologized with that foramen. On a previous page it is shown that another foramen is homologous with the posttemporal foramen of reptiles. As the relations of this opening are almost identical with those of the quadrate foramen in reptiles, it is here considered as homologous with that foramen.

Case postulates[2] that the quadrate foramen is in its inception in *Dimetrodon*, but its presence in the Labyrinthodontidæ indicates that it is a much more primitive character than he supposed.

The exoccipitals are expanded in the base of the skull, articulating with the parasphenoid in front, with the pterygoids on the outer sides, and with each other in the median line. The two condyles form strong projections from the posterior part. Passing upward and slightly forward from near the end of the condyles, there is a strong column which divides at the upper end, one branch meeting a downward projection of the supraoccipitals, the other articulating with the opisthotic. The lateral margins of the foramen magnum, formed by the inner part of the exoccipitals and the downward projections of the supraoccipitals, curve gently outward. Just above the condyle on the posterior inner side of the upward projection of

[1] *Loc. cit.*, p. 172.

[2] *Transactions of the American Philosophical Society*, 1905, Vol. XXI, Part I, p. 10.

the exoccipitals a small round foramen for the exit of the vagus and glossopharyngeal nerves appears. Quenstedt figures[1] this foramen in *Mastodonsaurus*, and Fraas figures[2] it in *Cyclotosaurus*, but in both these forms it is on the outer side of the bone.

The opisthotics are separate elements in *Anaschisma*, as in *Cyclotosaurus* and *Capitosaurus*. They are very short and slender. They

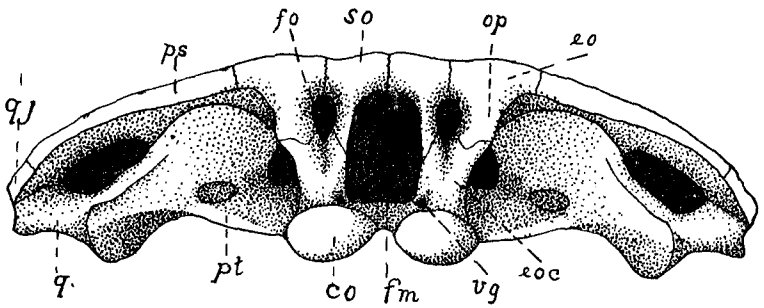


FIG. 3.—*Anaschisma browni;* hinder view of occiput, one-fourth natural size. co, condyle; eo, epiotic; eoc, exoccipital; fm, foramen magnum; fo, posttemporal foramen; op, opisthotic; ps, prosquamosal; pt, pterygoid; q, quadrate; qj, quadratojugal; so, supraoccipital; vg oramen for the vagus and glossopharyngeal nerves.

FIG. 3a.—*Anaschisma browni;* photograph of hinder view of occiput.

pass diagonally upward and outward from the exoccipitals to articulate with the epiotic at the outer end. The suture between them and the epiotic is not distinct.

Mandibles.—The left ramus of the mandible of A and the right ramus of B were procured with the skulls. A small part of the anterior end of A is missing, but B is almost complete, and the sutures

[1] *Die Mastodonsaurier im grünen Küpersandsteine Württemberg's sind Batrachier* (1850), Table II, Fig. 4.

[2] *Paleontographica*, Vol. XXXVI, Plate XI, Fig. 1, p. 132.

between the bones are readily made out. Because B is the more complete, the measurements given in the following description are taken from it.

The total length along the curve of the mandible is 495^{mm}. The greatest breadth, 94^{mm}, is a little in front of the cotylus, but a breadth of 90^{mm} or more is maintained for half the length of the ramus. Thirteen millimeters from the symphysis, the most anterior part where the full width is preserved, it is 65^{mm} broad. It is probable that at the symphysis the width was not greater than 50^{mm}. The greatest thickness is about 50^{mm}, just in front of the cotylus, where the upper part thickens abruptly. Just anterior to this the thickness decreases to 22^{mm}, and remains about the same to the symphysis. The post-cotyloid process is well developed.

The articular forms the greater part of the concave cotylus, and appears as a narrow ridge in the upper part of the postcotyloid process. It broadens abruptly as it enters the cotylus, and is of nearly uniform width to the anterior part, where it forms part of the posterior boundary of the supra-meckelian foramen. The greater portion of the inner side of the posterior part of the mandible is formed by the prearticular.[1] It projects from the end of the postcotyloid process to near the anterior end of the supra-meckelian foramen. Its upper edge forms most of the inner boundary of this foramen, and projects above the articular on the inner side. Its lower anterior part forms the boundary of the upper posterior corner of the mandibular foramen. Below it articulates with the angular for most of its length.

The angular extends the full length of the jaw on the outside, but articulates with an element anterior to it about 10^{cm} from the symphysis on the inside. On the inside it is narrow at the posterior end, broadens gradually to the mandibular foramen, where it narrows abruptly to form the part of the jaw between this foramen and the lower margin. In front of the foramen it broadens again abruptly. On the outside of the jaw the angular occupies about half the width anterior to the cotylus, but narrows rapidly behind it. It is coarsely pitted posteriorly, and ornamented with long radiating ridges and furrows anteriorly.

[1] Williston, *Field Columbian Museum Publication* 73, Geological Series, Vol. II, No. 1, p. 32; Kingsley, *American Naturalist*, Vol. XXIX, p. 61 (Dermarticulare).

The surangular is large. It articulates with the angular below in a line that runs diagonally from the postero-inferior angle of the jaw to a point just below the anterior end of the coronoid. Above it articulates with the dentary and articular, and forms part of the outer boundary of the supra-meckelian foramen. It is coarsely pitted posteriorly with coarse ridges running upward and forward from the pitting.

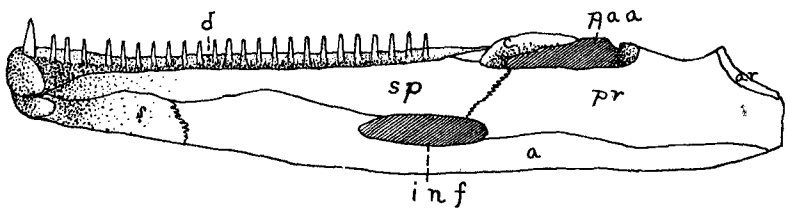


FIG. 4.—*Anaschisma brachygnatha;* right ramus of mandible, one-fifth natural size.

a, angular; c, coronoid; d, dentary; inf, internal mandibular foramen; paa, supra-meckelian foramen; sp, splenial; ?, probably a separate element; pr, prearticular.

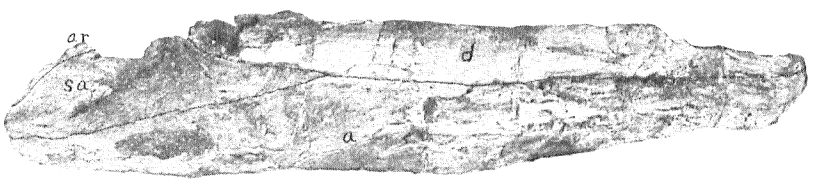


FIG. 4*a*.—*Anaschisma browni;* outer view of right ramus of mandible, one-third natural size.

a, angular; ar, articular; d, dentary; sa, surangular.

The dentary forms the upper half of the jaw in front of the middle of the supra-meckelian foramen. It is not sculptured. The teeth are set on the top of the inner side, and on the outer side there is a high, thin parapet which forms the outer margin of the jaw, and in which the outer sides of the teeth are imbedded for the height of 1^{cm} or more.

The coronoid is a small element at the anterior end of the supra-meckelian foramen. The main part of it forms the front margin of this foramen. The anterior part is slender and triangular, and is wedged in between the splenial and dentary.

The splenial extends from the prearticular to near the symphysis,

but takes no part in the symphysis. It occupies the upper half of the inside of the mandible, and is very thin.

Below the splenial, and in front of the angular, an element that seems to be separate from the dentary is present. The suture between it and the dentary is not distinct, but at the symphysis the dentary seems to be separate from it. This seems to be a separate element in *Eryops* also, but the evidence is not conclusive in either case.

On the upper border of the mandible, just in front of the cotylus, there is an opening for Meckel's cartilage. For convenience in description, this is called the supra-meckelian foramen. Perhaps a name has been given to it previously, but, if so, the writer has failed to find it. It is subtriangular in shape, 85^{mm} long by about 40^{mm} in greatest width. On the inner side the articular projects farther forward than on the outer, making the posterior margin of the foramen diagonal to the long axis of the jaw. The apex of the foramen lies between the splenial and coronoid, while the inner and outer sides are formed by the prearticular and surangular.

The jaw is hollow throughout, the bones forming a mere shell, usually only a few millimeters in thickness. The cavity extends from the symphysis to the tip of the postcotyloid process with its greatest size in the region of the prearticular foramen.

The vertebræ.—As before stated, there are about forty vertebræ referred to *Anaschisma* in the collection, but none of them has the arch preserved. Among them are two imperfect atlases of an oval shape, about 70^{mm} broad by 50^{mm} high. Anteriorly they have two slightly concave faces for articulation with the condyles; posteriorly they are concave. A supposed axis is oval, and about the same size as the atlas. It is opisthocoelous. On each side at about the middle of the vertebræ there is a large, shallow facette for the articulation of a rib. The thoracic vertebræ are nearly circular in shape, varying from 40 to 65^{mm} in diameter. One of these shows that the ribs were borne on exogenous processes arising from both the arch and body. The caudals are smaller, proportionally longer, with the vertical diameter greater than the transverse. All of the vertebral articular surfaces are for the articulation of single-headed ribs.

Among the vertebræ present there are three others besides the axis that are opisthocoelous. Whether they belong to a different

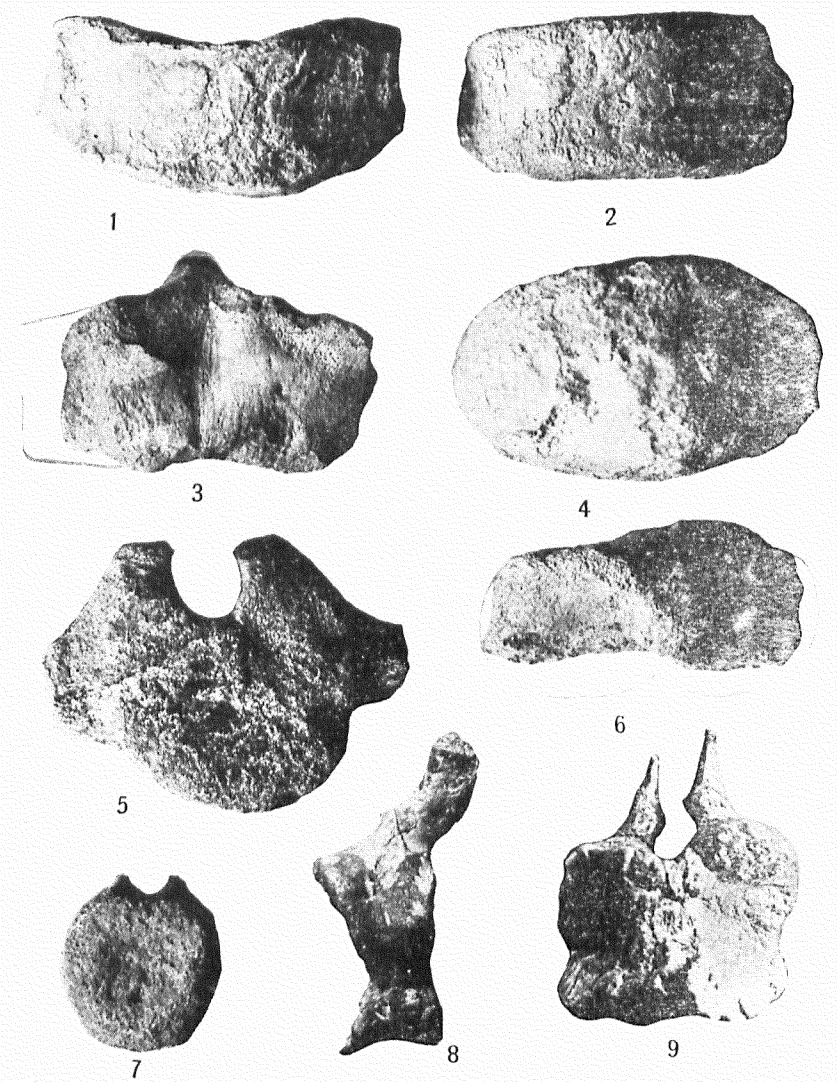


FIG. 5.—Vertebræ of *Anaschisma* and *Eryops*, two-thirds natural size.

1. Dorsal view of axis of *Anaschisma*.
2. Upper view of a dorsal vertebra of *Anaschisma*.
3. Upper view of atlas of *Anaschisma*,.
4. View of anterior end of axis of *Anaschisma*.
5. View of anterior end of a dorsal vertebra of *Anaschisma*.
6. View of anterior end of atlas of *Anaschisma*.
7. Caudal of *Anaschisma*.
8. Lateral view of atlas of *Eryops*.
9. View of anterior end of atlas of *Eryops*.

type of animal or to a particular region in the column of *Anaschisma* it is impossible to say. They agree in all respects with the others, save in being opisthocoelous. All of the others are slightly amphicoelous.

Pectoral girdle.—The clavicles and interclavicles collected from the Lander region were in such a poor state of preservation that nothing has been made out concerning their characters to add to what Mr. Lucas has published about *Metoposaurus fraasi.* One of the interclavicles evidently belongs to that species, but some of the others show very different types of sculpturing, and probably belong to different genera.

A cleithrum was found in position with one of the clavicles. It was complete when the writer removed it from the rock, but unfortunately part of the upper end was lost in transportation. In the figure this is restored. The bone is about 12^{cm} long, expanded at the base, and tapering to a point at the top. It projects upward and forward from the antero-outer end of the clavicle at an angle of about 45°. It is very different in shape from the cleithra that have been described from other Stegocephalians, but it can be homologized with no other element.

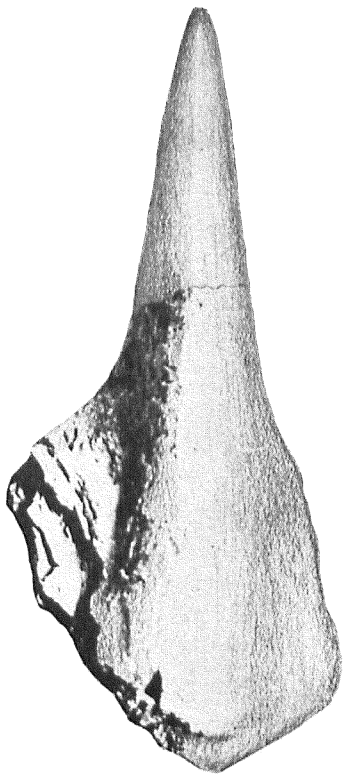


FIG. 6.—*Anaschisma;* cleithrum, natural size.

Anaschisma browni, *sp. nov.*

(Figs. 7, 8, and 10)

Skull broad posteriorly; proportion of greatest length to greatest width about 10 to 9. Bones of roof of skull coarsely sculptured, pitting predominating anteriorly, ridges and furrows posteriorly. Mucous canals of the lyra beginning in a deep depression just inside

the postero-inner corner of the orbit. The main part of the posterior mucous canals begins on the postfrontals, and passes backward in a broad curve to a point in front of the middle of the postorbitals,

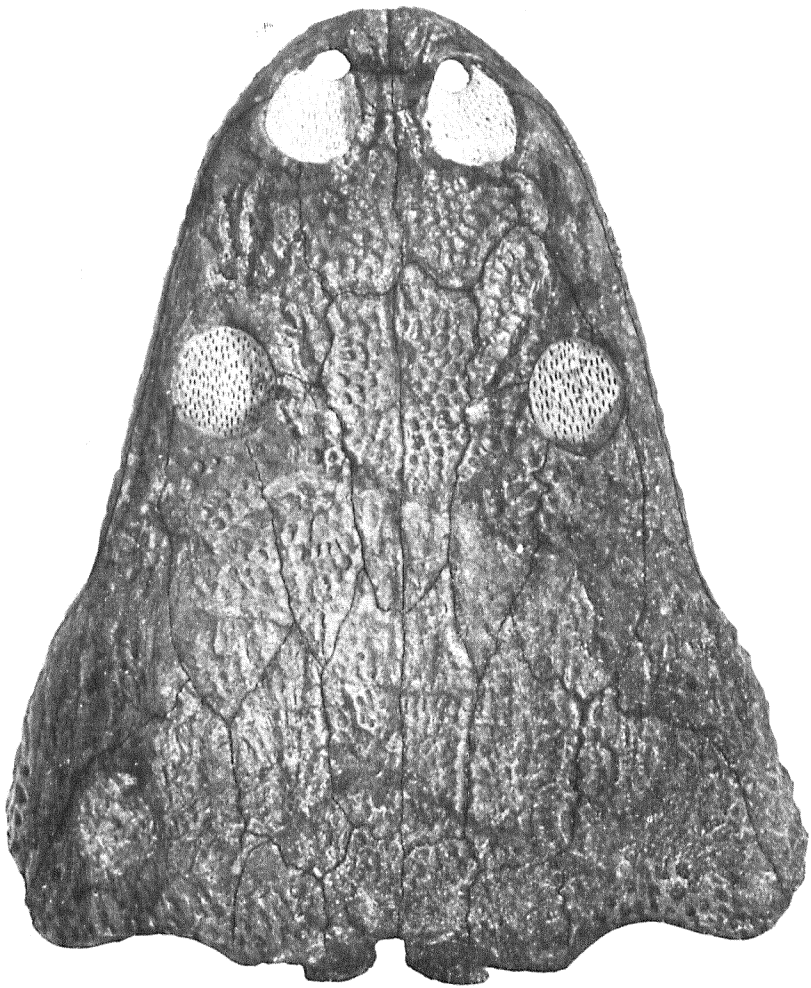


FIG. 7.—Upper view of skull of *Anaschisma browni*, one-third natural size.

where the part passing forward on the postorbitals meets it. It then turns at a sharp angle and passes outward and forward. Eyes large, subcircular, situated in anterior half of skull; nares large, approxi-

mated; infratemporal foramina very broad; internal nares close to the palatine foramina. Maxillary and premaxillary teeth small; a few small teeth on the vomers in a row parallel to those on the pre-

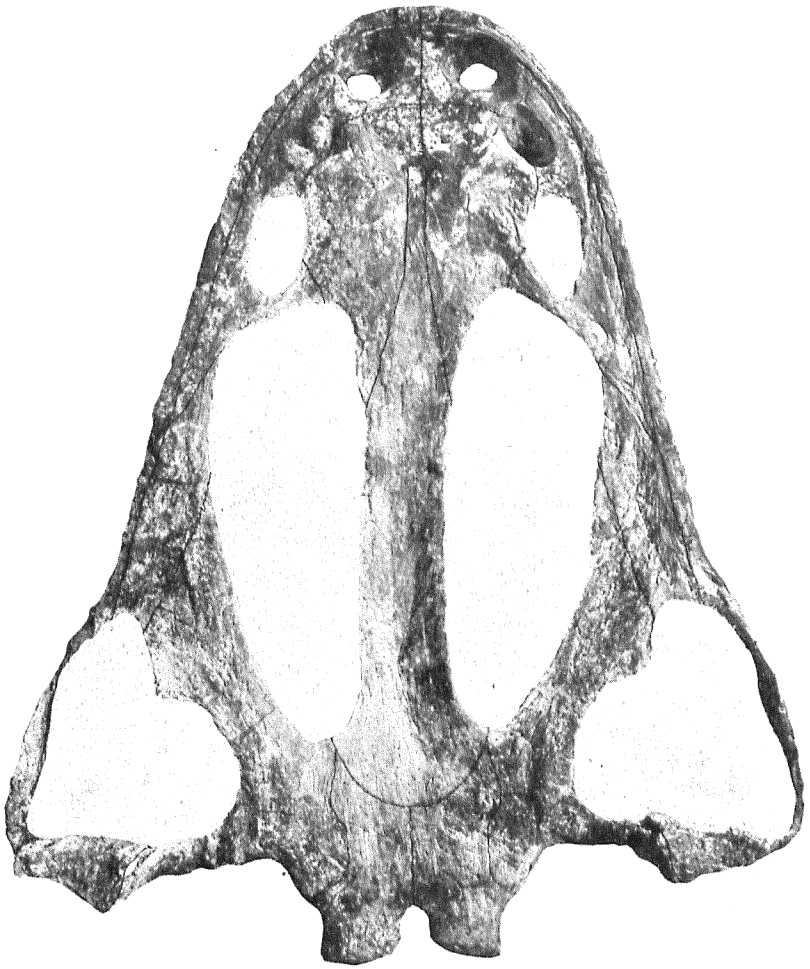


FIG. 8.—Palatal view of skull of *Anaschisma browni*, one-third natural size.

maxillæ; mandibular teeth compressed, with the long axis transverse to the long axis of the jaw; a very large tooth on each palatine a little in front of the internal nares; a few teeth on the transverse.

Anaschisma brachygnatha, *sp. nov.*

(Figs. 9 and 10)

This species differs from *Anaschisma browni* as follows: Skull much narrower posteriorly in proportion to the length; proportion

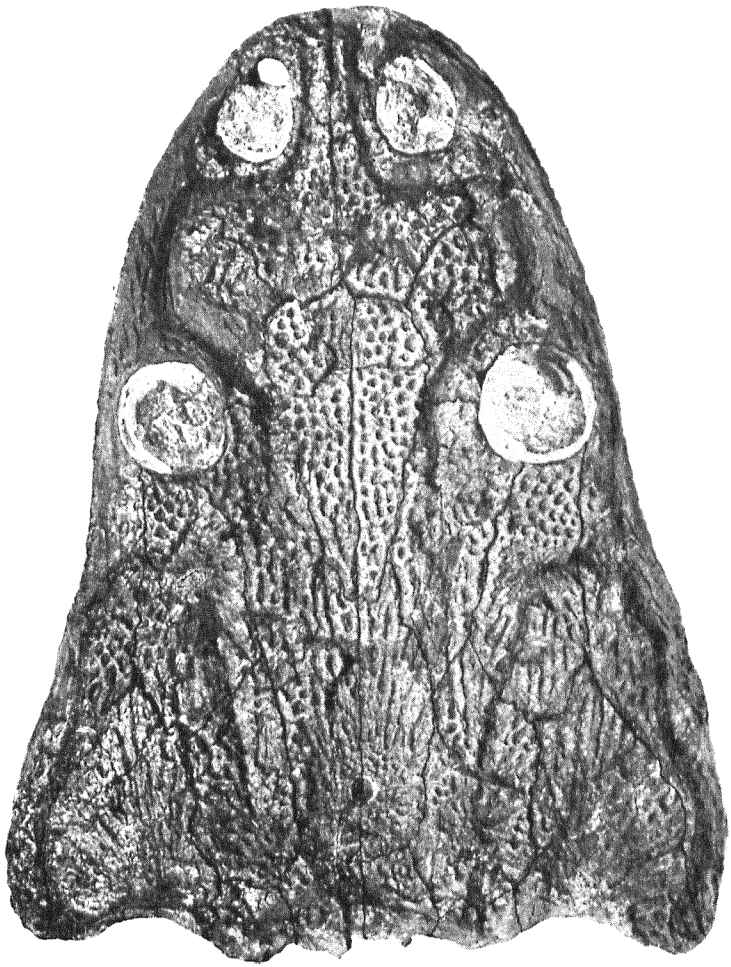
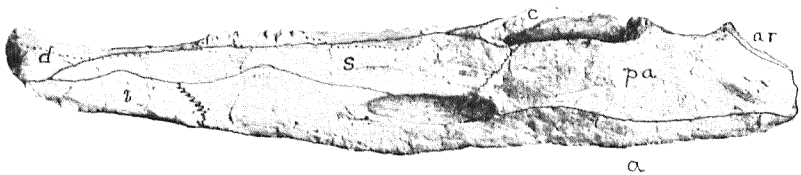


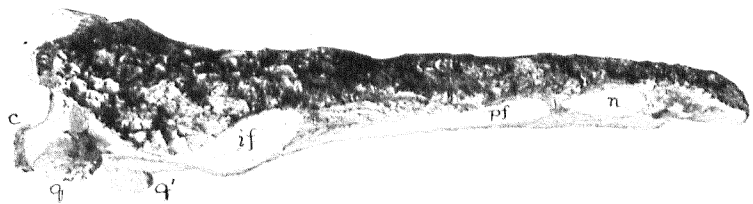
FIG. 9.—Upper view of skull of *Anaschisma brachygnatha;* one-third natural size.

of length to breadth about 5 to 4. Eyes not as far forward; nares farther apart. Bones in roof of skull with finer pitting, and broader, more rounded ridges between the pits. Mucous canals of the lyra

beginning farther back, and in a broader, shallower depression. The posterior canals beginning in a broad, shallow depression on the postorbitals, instead of on the postfrontals. Infratemporal foramina much narrower; internal nares much farther from the palatine foramina. Teeth as in *A. browni.*



1. Inner view of mandible of *Anaschisma brachygnatha;* one-fourth natural size.
a, angular; ar, articular; c, coronoid; d, dentary; ?, undetermined; pa, preartciular; s, splenial.



2. Lateral view of skull of *Anaschisma browni;* two-ninths natural size.
c, condyle; if, infratemporal foramen; n, internal nares; pf, palatine foramina; q, right quadrate; q', lower end of left quadrate.

FIG. 10

DESCRIPTIONS OF ALL OTHER LABYRINTHODONTIDÆ KNOWN FROM AMERICA

Metoposaurus fraasi Lucas

Original description:[1]

The species is characterized by the coarseness of the sculpturing of the episternum, and the fact that the markings of the center of the plate consist of irregular pits which, toward the margin, are transformed into radiating grooves. These grooves are most marked on the anterior portion of the bone. The portion of clavicles present also have the ornamentation in the shape of pits rather than grooves, and in this respect and in the greater coarseness of the sculpture the present species differs from the European *Metoposaurus diagnosticus* of von Meyer. It is, furthermore, characterized by the extent of the articulation of the clavicle with the episternum, the posterior end of the clavicle being well behind a line drawn through the center of the plate. The postero-inner angle of the

[1] *Proceedings of the United States National Museum,* 1904, Vol. XXVII, p. 194.

clavicle is very much rounded, instead of being decidedly angular, as it is in *Metoposaurus diagnosticus*.

The episternum is 43^{cm} long and 30^{cm} wide.

The mandible is coarsely sculptured on the external face, and bears indications of two large teeth at the very front of the ramus, and behind these fifteen small teeth. These seem to have been largely attached to the external wall of the alveolus in a manner somewhat suggestive of the pleurodont dentition of an iguana.

Specimen from Trias five miles east of Tanners Crossing, Little Colorado River, Arizona.

This specimen is probably an *Anaschisma*, but only the finding of such interclavicles with a skull of *Anaschisma* will settle that point definitely.

Dictyocephalus Leidy

(No name) Emmons, 1856 (*Geological Report of the Midland Counties of North Carolina*, p. 347).

Dictyocephalus Leidy, 1856 ("Notice of Extinct Vertebrated Animals Discovered by Professor E. Emmons," *Proceedings of the Academy of Natural Sciences of Philadelphia*, p. 256; also *American Journal of Science*, 1857, Vol. XXIII, p. 272).

Dictyocephalus Emmons, 1857 (*American Geology*, Part VI, p. 59, Figs. 31 and 32).

Dictyocephalus Emmons, 1860 (*Manual of Geology*, 2d ed., p. 184, Fig. 182).

Dictyocephalus Cope, 1868 ("Synopsis of Extinct Batrachia of North America," *Proceedings of the Academy of Natural Sciences of Philadelphia*, p. 221).

Dictyocephalus Miall, 1875 ("On the Structure and Classification of the Labyrinthodonts," *Report of the British Association for the Advancement of Science*, p. 185).

Dictyocephalus Cope, 1875 ("Synopsis of the Vertebrata Whose Remains Have Been Preserved in the Formations of North Carolina," *Report of the Geological Survey of North Carolina*, Appendix, B p. 32).

Dictyocephalus Fritsch, 1879 (*Fauna der Gaskohle und der Kalksteine der Permformation Böhmens*, Vol. I, p. 61).

Dictyocephalus Zittel, 1890 (*Handbuch der Palaeontologie*, Vol. III, p. 408).

Dictyocephalus von Huene (*Uebersicht über der Reptilien der Trias*, p. 68).

Founded on the upper portion of a cranium discovered by Professor Emmons in the coal fields of Chatham County, North Carolina. Plates of the cranium covered with reticular ridges in a general radiant manner. Parietals comparatively short, broader in front than behind; parietal foramen near the center of the bones. Occipi-

tals quadrate, a little longer than broad. Posterior outline of the cranium with a superficial transverse concavity on each side, and not with a deep sinus as in *Trematosaurus* and *Archegosaurus*. Breadth of occipital outline 28 lines; length of parietals $8\frac{1}{2}$ lines; breadth anteriorly $3\frac{3}{4}$ lines, posteriorly 3 lines. Probable length of head, considering it to have nearly the proportions of *Trematosaurus*, 4 inches, breadth $2\frac{1}{2}$ inches.[1]

Eupelor Cope

Mastodonsaurus Cope, 1866 ("Observations on Extinct Vertebrates of the Mesozoic Red Sandstone," *Proceedings of the Academy of Natural Sciences of Philadelphia*, p. 250).

Eupelor Cope, 1868 ("Synopsis of the Extinct Batrachia of North America," *ibid.*, p. 221).

Eupelor Cope, 1869 ("The Extinct Batrachia, Reptilia, and Aves of North America," *Transactions of the American Philosophical Society*, Vol. XIV, p. 25).

Eupelor Miall, 1874 ("On the Structure and Classification of the Labyrinthodonts," *Report of the British Association for the Advancement of Science*, p. 186).

Eupelor Fritsch, 1879 (*Fauna der Gaskohle und der Kalksteine der Permformation Böhmens*, Vol. I, p. 62).

Eupelor Cope, 1886 ("Note on the Fossils of the Mesozoic Rocks in York County, Pa," *Proceedings of the American Philosophical Society*, p. 403).

Eupelor Cope, 1887 ("A Contribution to the History of the Vertebrata of the Trias of North America," *ibid.*, p. 209).

Eupelor Zittel, 1890 (*Handbuch der Palaeontologie*, Vol. III, p. 408).

Eupelor Cope, 1892 ("A Preliminary Report of the Llano Estacado," Geological Survey of Texas, *Fourth Annual Report*, pp. 12 and 17).

Eupelor von Huene, 1902 (*Uebersicht über der Reptilien der Trias*, pp. 68 82).

Postorbitals 11^{cm} long; parietals 7^{cm} wide behind and 10^{cm} between the postorbitals. On the posterior part of the interorbital region commence two smooth, shallow sulci 29^{mm} apart; between them the surface is pitted four or five to the inch. The parietal bones are longitudinally sulcate throughout. All other bones with a coarse honeycomb pattern of sculpture, the pits becoming confluent into radiating grooves near the margins. Base of mandibular teeth cylindric, with shallow grooves. An interclavicle measures 345^{mm} long by 140^{mm} broad.

[1] *Proceedings of the Academy of Natural Sciences of Philadelphia*, Vol. VIII p. 256.

The specimens that have been referred to this genus are the back part of a skull from Chester County, Pennsylvania, one ramus of a mandible, some teeth, an interclavicle, and some other fragments from York County, Pennsylvania, and some fragments from the Docum Beds of northwestern Texas. It is not at all certain that the specimens from York and Chester Counties belong to the same genus, and it seems very probable that the Texas specimens are generically distinct from those of Pennsylvania.

The data seem too meager to warrant a discussion of the relationship of this genus, but a few general conclusions may not be inappropriate. From the length of the postorbital it is evident that the part of the skull behind the orbits was shorter than in *Anaschisma*, but longer than in *Mastodonsaurus*. The breadth of the parietals posteriorly is about the same as in *Anaschisma*, but anteriorly they are much broader than in that genus. Since the mucous canals are only 3^{cm} apart between the orbits, it is probable that the orbits were approximated, though not so much so as in *Mastodonsaurus*. The interclavicle is proportionally narrower than in *Metoposaurus*. So far, then, as the characters that are known indicate, *Eupelor* is intermediate between *Mastodonsaurus* and *Anaschisma*.

In 1868 Cope referred[1] some teeth from Chester County, Pennsylvania, to this genus, but a year later he concluded[2] that they belonged to thecodont reptiles. Later he described teeth that he found *in situ*, in a mandible,[3] and suggested that those which he originally described were rightly determined. This is hardly probable, since these teeth are rarely found fossilized, except as stumps in the jaws, and his so-called thecodont reptiles teeth are not at all rare.

The known remains are all referred to one species, *Eupelor durus* Cope. No figures of the specimens have ever been published.

Pariostegus Cope

Pariostegus Cope, 1868 ("Synopsis of the Extinct Batrachia of North America," *Proceedings of the Academy of Natural Sciences of Philadelphia*, p. 221).

Pariostegus Cope, 1869 ("The Extinct Batrachia, Reptilia, and Aves of North America," *Transactions of the American Philosophical Society*, Vol. XIV, p. 10).

[1] *Loc. cit.*, p. 221. [2] *Loc. cit.*, p. 25.

[3] *Proceedings of the American Philosophical Society*, 1887, p. 209.

Pariostegus Cope, 1875 ("Synopsis of the Vertebrata Whose Remains Have Been Preserved in the Formations of North Carolina," *Report of the Geological Survey of North Carolina*, Appendix, p. 32).

Pariostegus Miall, 1875 ("On the Structure and Classification of the Labyrinthodonts," *Report of the British Association for the Advancement of Science*, 1874, p. 189).

Pariostegus Fritsch, 1879 (*Fauna der Gaskohle und der Kalksteine der Permformation Böhmens*, Vol. I, p. 64).

Pariostegus Zittel, 1890 (*Handbuch der Palaeontologie*, Vol. III, p. 488).

Pariostegus von Huene, 1902 (*Uebersicht über die Reptilien der Trias*, p. 68).

This genus is represented by a large part of the cranium of a batrachian from the Triassic coal-measures of Chatham County, North Carolina.

Contrary to what has been found the case in most genera of Stegocephalia, the maxillary appears to extend posteriorly to a free termination, as in modern Salamanders, and the supratemporal bone presents a very prominent, obtuse, arched margin. This margin extends from the margin on each side, and is inclined toward the posterior part of the cranium. There is therefore no quadratojugal piece.

The maxillary and mandibular pieces are slender, flat bones, as in *Menopoma;* the form of the posterior or articular portion of the latter cannot be ascertained from the specimen. The more or less exposed part of the median region of the latter exhibits a succession of shallow transverse notches, inclosing thirteen obtuse elevations. The former resemble rudimental lateral alveoli for minute pleurodont teeth. A few other similar minute ribs, and, perhaps, a minute curved cone without sculpture, are the only other indications of dentition.

A pair of narrow nasals, acuminate behind, penetrate between the frontals as far posteriorly as the posterior margin of the orbits. The suture between these is very distinct, and entirely straight. The preorbitals extend to above the orbit, and then appear to cease with a transverse suture. Between these and the nasals a broad triangular element enters on each side, not attaining the probable position of the nostrils. Each is divided by a longitudinal groove, which is probably a suture, and which would then divide the frontals from the parietals. The frontal would then divide the parietals entirely from the anterior

half of their length. This would give the frontals a narrow form, acuminate in front, and bounded behind by a regular, coarse, zigzag transverse suture. The cranium behind this point is rugose, and the surface not well preserved, and it can only be said that two peculiar grooves converge to a point between the posterior extremities of the frontals, like the boundaries of the supraoccipitals. When the postorbital roof bone is raised up, the meeting of the two gular dermal bones, as I interpret them, is seen. One of these is a plate directed backward and outward, bearing minute radiating lines on its upper surface. It meets a similar flat plate directed forward and outward, with similar lines radiating to the circumference.

The orbits are remarkably small, and situated probably near the middle of the longitudinal measurement of the cranium. The external nares are not defined, but symmetrical depressions in the position they usually occupy in Salamanders are distinct.

Pariostegus myops Cope

The surface of the cranial bones is little sculptured; there are small tuberculiform elevations on the parietal, and more numerous ones on the preorbitals. The postorbitals show the strongest markings of elongated pits, which radiate to their circumference, leaving a smooth, obtuse border. The nasals present a series of small warts at a little distance on each side of their common suture and transverse to it. The surface of the maxillary is marked with longitudinal grooves and shallow pits.

No suture separating maxillaries and premaxillaries can be traced with certainty, though the bones of the jaw are interrupted at the usual place of suture, opposite the nostril.

Length of specimen (including mandible)	18.0 lines
Width between outer convexities postorbitals	17.0
Width between inner borders orbits	11.0
Width of same without preorbitals	8.0
Width of nasals at middle	2.5
Width of orbit	1.5
Length of frontal and nasal premaxillary	11.0
Length of supposed branchihyal	12.0[1]

[1] *Proceedings of the Academy of Natural Sciences of Philadelphia*, 1868, p. 211.

Von Huene refers *Eupelor*, *Pariostegus*, and *Dictyocephalus* to the Temnospondyli, but their relationships, so far as can be made out from the fragmentary material known, are with the Stereospondyli.

In 1897 Dr. Williston described[1] a large labyrinthodont tooth from the upper part of the coal-measures near Louisville, Kansas. This tooth is as large and complex in structure as the large fangs of *Anaschisma*. The animal to which it belonged was probably one of the true Labyrinthodontidæ. The species was provisionally referred to *Mastodonsaurus*.

SOME NEW FACTS ABOUT ERYOPS

In the collection of vertebrate fossils of Walker Museum there is a specimen of *Eryops* of great interest from the Permian of Texas. It consists of an almost complete skull, a large number of vertebræ in association, the pectoral and pelvic girdles, and some limb bones. Most of the sutures in the roof of the skull are distinct; the under part and base of the skull are in a splendid state of preservation, and the characters of the sacral and presacral vertebræ are well displayed.

The writer has studied Cope's types of *Eryops*, and the present specimen is congeneric with them. It differs widely in three important characters from *Eryops* as restored by Broili:[2] the pterygoids do not meet in the median line; the prevomers are very large; the palatine foramina are small. Cope's types show these characters definitely, and the pterygoid region of twelve other skulls studied during the present investigation show that the pterygoids do not meet in the median line.

Skull.—The skull has been distorted by pressure, the right side being flattened, while the left side is pushed to the left at the top, and the lower margin crushed inward. A small part of the quadratojugal on each side, a part of the premaxillæ from the region of the maxillary foramen, some of the jugal, prosquamosal, postfrontal, and prefrontal of the left side, and a little of the squamosal and postorbital of the right side are missing.

[1] *Kansas University Quarterly*, Vol. VI, No. 4 (1897), p. 209.

[2] *Palæontographica*, Vol. XLVI, Plate VIII, Fig. 1.

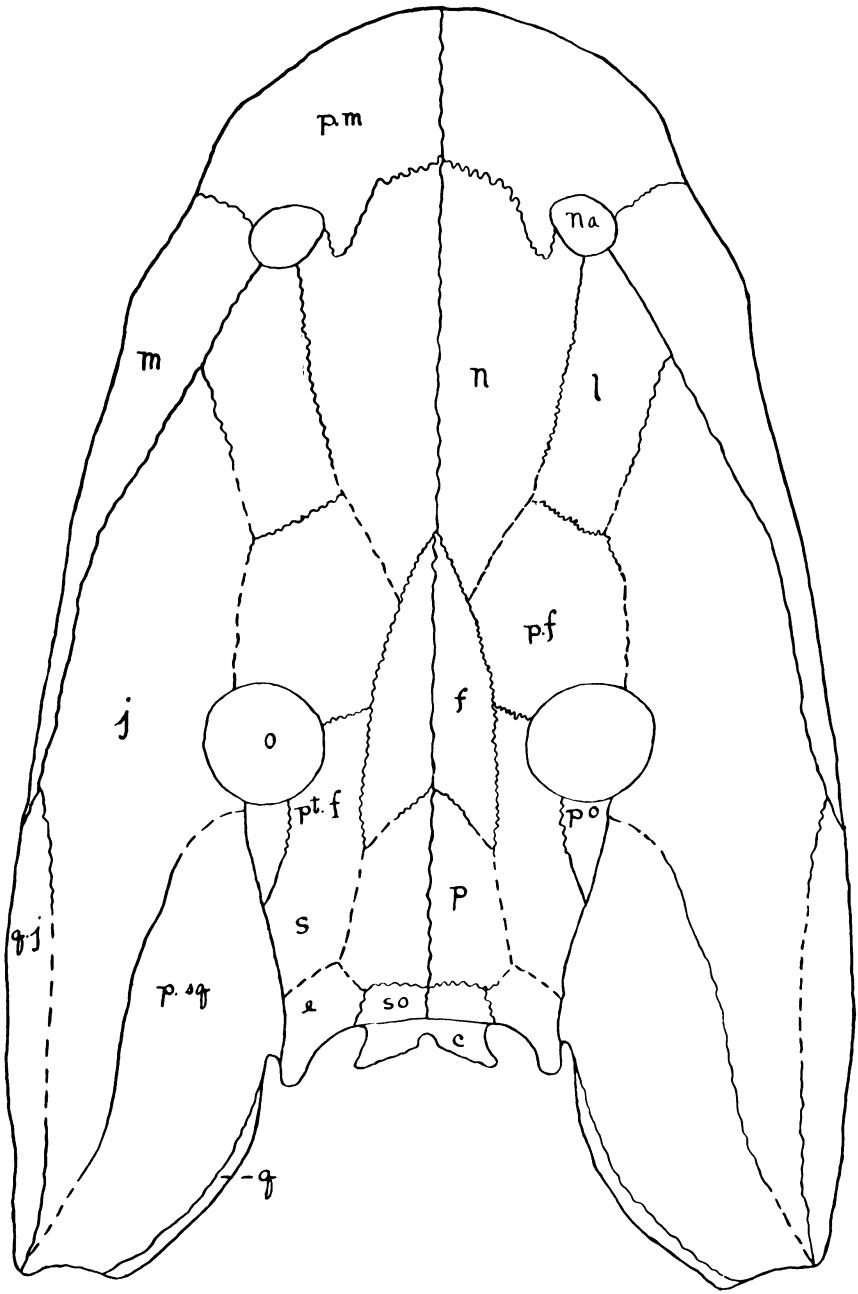


FIG. 11.—*Eryops* Cope; view of top of skull, four-thirteenths natural size.

c, condyle; e, epiotic; f, frontal; j, jugal; l, lachrymal; m, maxillary; n, nasal; na, nares; o, orbit; p, parietal; pf, prefrontal; pm, premaxillary; po, postorbital; ptf, postfrontal; qj, quadratojugal; s, squamosal; so, supraoccipital. Broken lines indicate that sutures have not been made out.

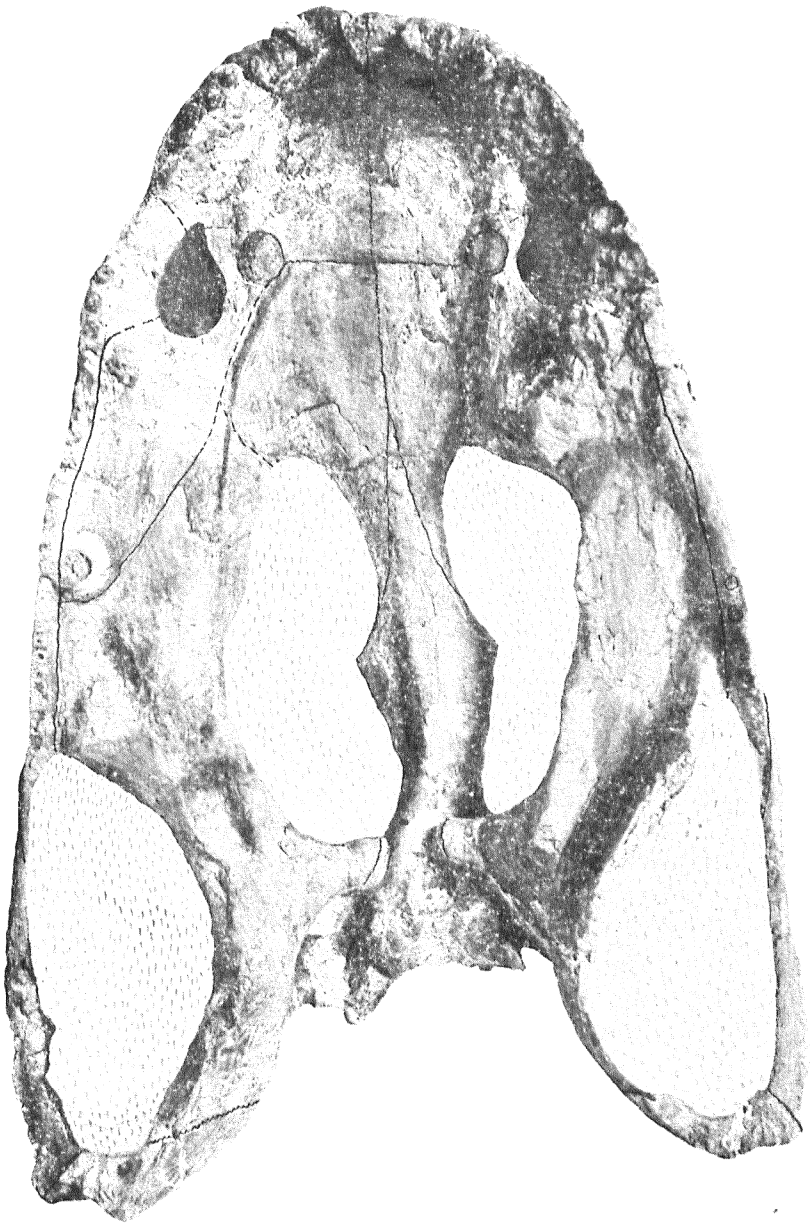


FIG. 11*a*.—Palatal view of skull.

The bones in the roof of the skull resemble those in *Actinodon* and *Mastodonsaurus*. The parietals, frontals, postfrontals, and supraoccipitals are small. The prosquamosal is elongate, reaching from just behind the orbit to the outer end of the quadrate. The quadratojugal is long and narrow. The jugals are the largest bones in the roof of the skull; they extend from a short distance behind the nares to just in front of the outer end of the quadrate. The maxillæ are long, narrow behind, expanded anteriorly. The prefrontal is pentagonal in outline. It unites with the postfrontal behind, excluding the frontal from the border of the orbits. The lachrymals are elongate, pentagonal, and reach to the nares in front. The premaxillæ are greatly expanded. The nasals are elongate and subtriangular.

The orbits are about the same size and in about the same position as in the type of *Eryops*, though they are slightly farther apart. The nares are ovate, situated at a considerable distance from the tip of the skull, and are slightly larger than in Broili's specimens, though smaller than in most other large Stegocephalians. The auditory slits are very short and narrow. No parietal foramen is present.

The anterior part of the roof is very finely sculptured with irregular elongate and subcircular pits, the ridges between the pits becoming tubercular near the median line of the skull. Toward the occiput the sculpture becomes coarser, and on the outer part of the prosquamosal the pits elongate to form radiating furrows.

From the posterior part of the epiotic a prominent ridge passes forward and outward to the back part of the orbit. A less prominent ridge passes forward from the antero-inner corner of the orbit, and gradually disappears about midway between the nares and orbits. Just in front of the antero-outer corner of the orbits there is a large, shallow depression, with a narrow furrow extending forward from it for a short distance. About 5^{cm} behind the nares there is another depression, but it is not so large as the one anterior to the orbits. Running straight forward from it on the nasals there is an indistinct narrow sulcus; passing outward from the posterior outer corner there is a broader, less well-defined, sulcus which meets the sulcus from the preorbital depression. Whether or not these canals are homologous with the slime canals of other forms it is impossible to say, but it seems probable that they are rudiments of such canals.

The dimensions of the skull and of the openings in the roof and floor are as follows:

Length along margin of jaw	580^{mm}
Length along median line from tip of snout to posterior end of quadrates	540
Length from supraoccipital to tip of snout	445
Greatest breadth	350
Breadth at posterior end of orbits	325
Breadth at posterior end of nares	233
Distance from back part of nares to fore part of orbit	185
Distance of orbit from supratemporal	120
Distance apart of nares	100
Distance apart of orbits	90
Length of nares	31
Breadth of nares	29
Length of orbits	53
Breadth of orbits	56
Length of palatine foramen	180
Breadth of palatine foramen	90
Distance from tip of skull	200
Distance from end of condyle	65
Distance from internal nares	65
Length of internal nares	45
Breadth of internal nares	27
Distance from tip of snout	110
Length of infratemporal foramen	175
Breadth of infratemporal foramen	80

Under side of skull.—The under side of the skull is not in one plane, but is arched upward very strongly along the median line posteriorly. This arching is caused by the inner wings of the pterygoids turning abruptly upward.

The parasphenoid is comparatively much shorter than in Broili's specimens. One of the skulls which he describes is about 38^{cm} long, and has a parasphenoid 26^{cm} in length, while the skull described in this paper is 45^{cm} long and has a parasphenoid only 22^{cm} in length. The parasphenoid is expanded in the middle and in front of the expansion tapers gradually to a point between the prevomers. Behind the expanded part it tapers gradually to near the posterior end, where it broadens slightly, separating the pterygoids and articulating with the exoccipitals. The parasphenoid does not separate the pterygoids

or articulate with the exoccipitals in Broili's specimens. It has a broader median expansion than in this form, is narrower behind, and contracts more abruptly in front of this expansion, and has a much longer, slenderer cultriform process.

The prevomers are broad and thin. They articulate anteriorly with the premaxillæ in a straight line that runs at right angles to the main axis of the skull. On the outside they articulate with the pterygoids and palatines. They articulate with each other in the median line of the skull for the anterior half of their length, then pass backward on either side of the parasphenoid, and end just in front of the median expansion of that bone. They form the anterior inner boundary of the palatine foramina.

The palatines are long and slender, and extend from the middle of the outer margin of the skull to the anterior end of the internal nares. They are broadest immediately behind the nares, narrowest just inside their posterior end, and they form their entire inner and posterior borders. They bear three large teeth, one at the back end, one just behind the nares, and one immediately inside the anterior end of the nares.

The pterygoids have very long anterior and posterior wings, and a short, thick inner wing. The anterior wing is broad at the outer end between the maxillary and the palatine foramen, but becomes narrower anteriorly between this foramen and the palatine bones. It is narrower between the infratemporal and palatine foramina, and the part that forms the inner boundary of the former is turned upward at right angles to the main part of the bone. Just inside this upturned portion there is a deep depression that extends forward, becoming broader and shallower, until it finally disappears. The posterior wing is twisted on the main part of the bone until only the edge is seen from below. It articulates with the quadrate at the outer end and above, and projects outward nearly to the cotylus. The inner wings are present in six specimens preserved in Walker Museum, and in every specimen they are broadly separated by the parasphenoid, instead of meeting in the median line as in Broili's specimens.

The premaxillaries are greatly expanded, forming the anterior fifth of the floor of the skull.

The palatine foramina are much shorter than those shown in Broili's restoration of *Eryops*. They are separated by the parasphenoid and prevomers. The infratemporal foramina are long and narrow. The internal nares are large, rounded posteriorly and pointed anteriorly, and are widely sseparated from the palatine foramina. As the premaxillaries are somewhat imperfect anteriorily, the shape of the premaxillary foramina cannot be definitely determined. They do not penetrate the roof of the skull.

Base of skull.—The foramen magnum is remarkable because of its small size. In none of the specimens in the collection does its greatest diameter exceed 2^{cm}. As it is distorted by pressure, in all of the skulls, it is impossible to determine its exact shape, but it seems to have been oval, with its transverse diameter the greater.

The exoccipitals form the margins of the foramen, except above, where the supraoccipitals project downward between them. In the floor of the skull the exoccipitals are thick, and co-ossified with each other and with the parasphenoid. The condylar processes are short and strong, and the articular surfaces are concave. A short, strong upward projection from just in front of the condyles forms the lateral boundary of the foramen magnum and broadens to a head above, articulating firmly with the supraoccipitals. A long, slender lateral process, homologous with the opisthotic (paroccipital, Baur) of reptiles, passes outward to articulate with the epiotic (paroccipital plate, Baur) at its outer end. Between this process and the bones of the roof of the skull there is an elongate oval foramen, which is homologous with the posttemporal foramen of the Reptilia.

The posterior wing of the pterygoid, where it turns upward to articulate with the quadrate, forms a considerable part of the base of the skull. The quadrate extends from the cotylus to the auditory slit, showing as a long, narrow strip in the base of the skull. Along its entire upper edge it articulates firmly with the prosquamosal, along its lower edge with the pterygoid. The quadratojugal meets it at its lower outer corner. The surface for articulation with the mandible is somewhat saddle-shaped, and is formed entirely by the quadrate.

Mandible.—The sutures in the mandible of *Eryops* have never before been determined, but in all of the specimens in Walker Museum

most of them are distinct. In Figs. 13 and 13*a* the sutures are indicated. The suture between the prearticular and the splenial has not been definitely located.

The articular is short and thick. It is covered on the outside by the angular and surangular, and on the inside by the angular and prearticular. The articular surface is convex, the convexity passing diagonally forward from the posterior inner corner. The coronoid is very small, and is situated in front of the supra-meckelian foramen, as in *Anaschisma*. The dentary is slender, sculptured anteriorly,

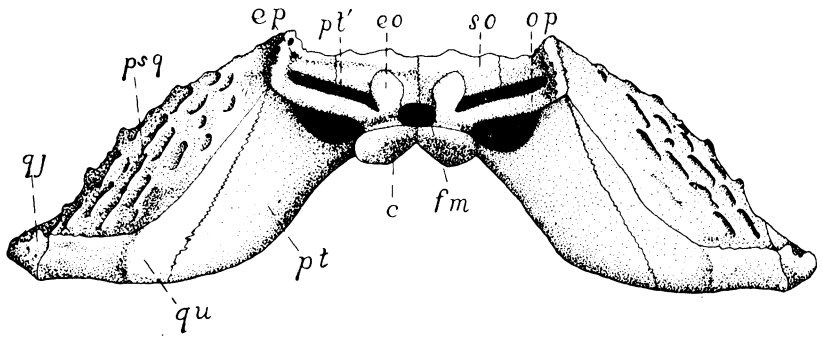


FIG. 12.—*Eryops* Cope; hinder view of occiput, one-third natural size.

c, condyle; eo, exoccipital; ep, epiotic; fm, foramen magnum; op, opisthotic; pt', posttemporal foramen; pt, pterygoid; psq, prosquamosal; qj, quadratojugal; qu, quadrate.

and smooth posteriorly. The posterior end of it projects a little way behind the coronoid. There is a high, thin parapet on the upper side of the outer part of the bone, and the outer edges of the teeth are imbedded in it. The angular forms the greater part of the outside of the mandible in front of the supra-meckelian foramen. The suture between the angular and surangular has not been definitely determined. The splenial is slender and very thin. It projects above the inner edge of the dentary anteriorly, but gradually descends posteriorly. The portion in front of the angular (Fig. 13, ?) seems to be an element separate from the dentary. The suture between it and the dentary appears to be near the lower edge of the jaw on the outer side. As previously stated, this element seems to be distinct in *Anaschisma*, but the evidence in neither case is conclusive.

The internal mandibular foramen is small, oval, situated between

the angular and prearticular directly below the anterior end of the supra-meckelian foramen. The supra-meckelian foramen is elongate and narrow.

The sculpture on the outside of the mandible consists of longitudinal ridges and furrows above, but these become coarser and have more of the pitted character below.

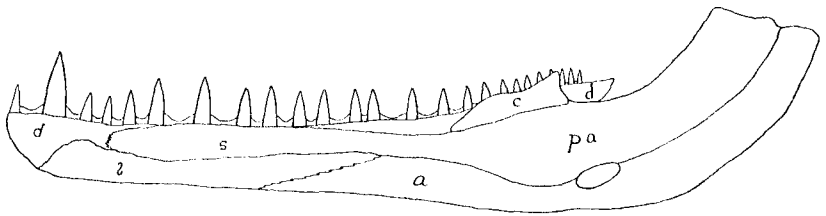


FIG. 13.—*Eryops* Cope; inner view of mandible, one-fourth natural size.
a, angular; d, dentary; c, coronoid; pa, prearticular; s, splenial; ?, probably a separate element.

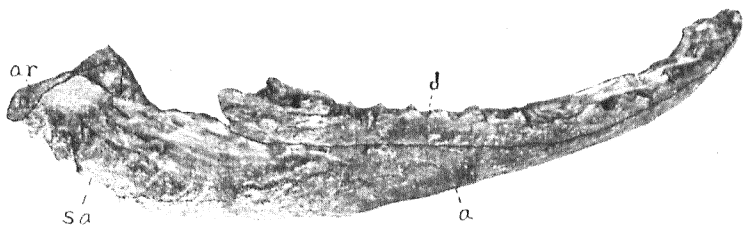


FIG. 13*a*.—*Eryops* Cope; outer view of mandible, one-third natural size.
a, angular; ar, articular; d, dentary; sa, surangular.

Vertebræ.—Belonging with the skull above described there are twenty vertebræ, five of which are caudals and the rest dorsals. A smaller specimen, probably of *Eryops megacephalus*, has twenty-four vertebræ preserved in a continuous series, beginning with the atlas. The number of presacral vertebræ can be pretty definitely determined from these two specimens, and seems to be twenty-five or twenty-six. There are two sacrals and about fifteen caudals. The number of caudals is estimated from the anterior and posterior ones figured by Cope. These specimens furnish some new and interesting facts about the vertebræ of *Eryops*.

The atlas is composed of the neurocentra and intercentrum, the neurocentra resting firmly on the intercentrum, but not co-ossified with it. The intercentrum is not divided on the middle, as Cope

supposed.[1] The arch is small and bears no rib. The axis is composed of the same elements as the atlas, with possibly small pleurocentra in addition, but its arch is larger and bears a small rib. The rib seems not to have been attached to the intercentrum. The third cervical has small pleurocentra which support the arch. Posterior to the third the pleurocentra increase in size and push the intercentra far apart below. Toward the sacrum they again decrease in size and are pushed upward, finally resting on the intercentrum of the vertebra behind. The pleurocentra of the anterior caudals are reduced in size, and they gradually decrease caudad, until those of the distal caudals are very small. In the thoracic region the pleurocentra support the arch, but, as they become more and more reduced in size, the support is shifted more and more to the intercentrum, until in the caudals the latter forms the principal support. The intercentra are enlarged in the sacral and caudal regions, and those of the sacrum are opposed below.

The specimens that furnish these new facts are the ones from which Dr. Baur drew his conclusions, published in the November number of the *American Naturalist* of 1897. But Dr. Baur saw only three or four vertebræ free from the matrix. They were from the thoracic region, and his statements concerning them are accurate. The atlas was free from the matrix only on one side, and he says of it: "Only the first intercentrum is connected with the neural arches of the first vertebra, the atlas forming the atlas ring as in all Amniota."[2] The matrix still covered the vertebræ behind the atlas when the writer began work on them, and it was not then apparent that the second vertebra, like the first, has no pleurocentra in that specimen.

In the specimen figured by Cope the axis has no pleurocentra; but he does not mention this peculiarity in his description.[3] The intercentrum of the atlas was missing, and it was natural to suppose that the pleurocentra of both atlas and axis had been lost with it. But reference to his figure shows that there is little space for pleurocentra between the third intercentrum and the diapophysis of the axis arch. After examining Cope's specimen, the writer is not fully

[1] *Proceedings of the American Philosophical Society*, 1880, Vol. XIX, pp. 52, 56.

[2] *American Naturalist*, 1897, p. 978.

[3] *Proceedings of the American Philosophical Society*, Vol. XIX, Plate III, Fig. 5.

decided that pleurocentra were not present in the axis. There is a possibility that they have been lost in the specimens examined. Cope's figure also shows that the pleurocentra of the third cervical are very small. He figures no caudals except five proximal ones, in which the pleurocentra are greatly reduced and the intercentrum bears the arch, and five at the end of the tail, in which the intercentra are large and the pleurocentra very small.

The absence of the pleurocentra in the atlas and axis, and their reduction in the caudals, force the following conclusions: *Eryops* is not near the direct ancestry of the Amniota, because in all primitive Amniota the pleurocentra are large in the atlas and axis. On the contrary, the tendency is toward the development of true stereospondylous vertebræ, as in the Labyrinthodontidæ. The atlas and axis are composed of the same elements as in that form, and the caudals are approaching that type by the reduction of the pleurocentra. This conclusion was reached independently before the writer had read Jaekel's paper on *Archegosaurus*,[1] in which he reaches a like conclusion concerning the vertebræ of that genus, because of the great reduction of the pleurocentra in the caudals.

The problem of the homologies of the elements in the temnospondylous stegocephalian vertebræ has been much confused by misapprehension on the part of some authors, and by a lack of full information concerning the structure of this part of the skeleton of some of the forms that have been discussed most. The status of opinion to date is about as follows:

All writers are agreed that the neurapophyses are homologous with the neurapophyses of the Amniota. Gaudry[2] and Fritsch[3] believed that the intercentrum (hypocentrum) is the true centrum (pleurocentra) of the Amniota, while Cope, Baur, Albrecht, Dollo, and others maintain that it is homologous with the intercentrum of the Amniota. The evidence is overwhelmingly in favor of the latter view, and it is the one now generally accepted. But the homologies of the elements called pleurocentra and hypocentra pleuralia are

[1] *Zeitschrift der Deutschen geologischen Gesellschaft*, 1896.

[2] "Les enchainements du monde animal," *Fossiles primaires* (Paris, 1883).

[3] *Fauna der Gaskohle und der Kalksteine der Permformation Böhmens*, Vol. II (1889).

still in dispute. All are agreed that the posterior elements in the vertebræ of *Eryops* are homologous with the centrum of the Amniota, but Cope, Baur, and others believe that they are also homologous with the pleurocentra of *Archegosaurus*, *Actinodon*, and other temnospondylous stegocephalians; while Gadow holds that they are the hypocentra pleuralia of *Archegosaurus* and *Chelydosaurus*.[1]

These elements of *Eryops* are ventralia, not dorsalia, consequently not pleurocentra. They are interventralia enlarged and extending upwards. Consequently they are homologous with Fritsch's hypocentra pleuralia of *Chelydosaurus*, of the tail of *Archegosaurus* and homologous with the centra of the Amniota.

Cope, Baur, Albrecht, Dollo, and others believe that the hypocentrum pleurale is united either to the intercentrum[2] in front, or to the pleurocentrum[3] above in *Eryops;* or, as Baur puts it, "Das Hypocentrum pleurale trägt zur Vervollständigung des Wirbelkörpers bei."[4]

Jaekel has clearly shown[5] that in the caudal region of *Archegosaurus* the pleurocentra elongate and each separates into two elements, one above and one below, the lower being the hypocentrum pleurale (interventralia of Gadow). Probably no separation of this kind takes place in *Eryops*, since in the anterior caudals the pleurocentra are reduced and pushed high up by the close approach of the intercentra. A comparison of Figs. 14 and 15, and 16 and 17, shows how closely the vertebræ of *Eryops* resemble those of *Archegosaurus*. In the thoracic region there can be no doubt about the homology of the pleurocentra of the two forms. In the caudal region the evolution has progressed along different lines. In *Eryops* the hypocentra pleuralia do not separate from the pleurocentra, but both are reduced together; but the difference is not sufficient to raise a doubt about the homologies of the parts.

Dr. Hans Gadow calls *Eryops* a reptile on account of the structure of its vertebræ, but his conception of the vertebræ of this animal was wrong in several particulars. He based his conclusions on the

[1] *Philosophical Transactions of the Royal Society of London*, Vol. CLXXXVII (1896), p. 22.

[2] *Proceedings of the American Philosophical Society*, Vol. XVI, p. 245.

[3] *American Naturalist*, 1886, pp. 76, 77.

[4] *Biologisches Centralblatt*, Vol. VI, p. 333.

[5] *Zeitschrift der Deutschen geologischen Gesellschaft*, 1896.

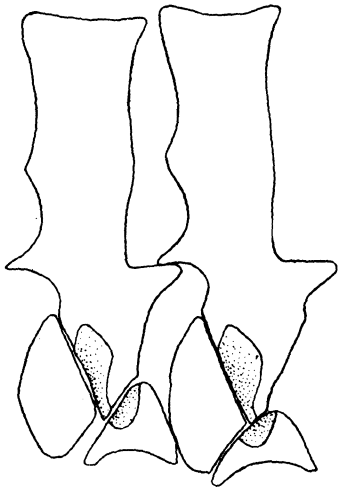


FIG. 14

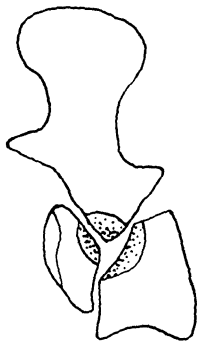


FIG. 15

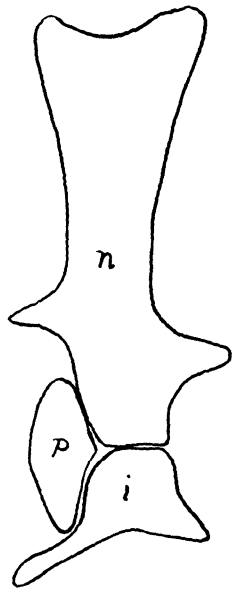


FIG. 16

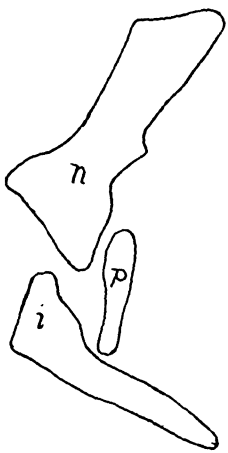


FIG. 17

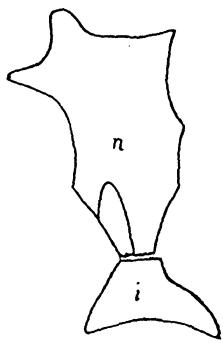


FIG. 18

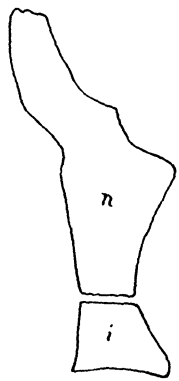


FIG. 19

FIG. 14.—*Eryops* Cope; thoracic vertebræ; one-half natural size.

FIG. 15.—*Archegosaurus* Goldfuss; thoracic vertebra (after Jaekel).

FIG. 16.—*Eryops* Cope; anterior caudal vertebra; two-thirds natural size (after Cope).

FIG. 17.—*Archegosaurus* Goldfuss; caudal vertebra (after Jaekel).

FIGS. 18, 19.—*Eryops* Cope. Fig. 18, axis with top of arch missing; Fig. 19, atlas; one-half natural size.

i, intercentrum; n, neural arch.

literature on the subject, having examined very few specimens of the vertebræ themselves. He says: "The neural arches of the tail and thorax rest exclusively upon the posterior disk (pleurocentra of Cope)."[1] As already shown in the present article, the neural arches are gradually shifted on to the intercentra in the posterior part of the thoracic region, and in the caudals the intercentra furnish the greater part of the support. Dr. Gadow's figures[2] of two vertebræ in the British Museum shows that the neural arches rest against the intercentra in the dorsal region. Cope's figures[3] of the anterior caudals show that the intercentra form most of the support for the arches. (See Fig. 16.)

Dr. Gadow says:

> In the thoracic vertebræ the diapophyses of the neural arches alone carry the single-headed ribs. In the cervicals the articular facet extends downward and forms a shallow groove on the caudal portion of the intercentrum.[4]

In all of the thoracic vertebræ the rib is borne by both the arch and the intercentrum. The intercentra of the atlas and axis are the only ones anterior to the caudals that have no facet for rib articulation. The size of the rib facet on the intercentrum increases gradually posteriorly, and on the sacral vertebræ it is more than 2^{cm} in diameter. Furthermore the ribs are not all single-headed. As Cope has pointed out,[5] the sacral ribs are distinctly double-headed, though the capitulum and tuberculum are not widely separated. Five or six of the ribs just anterior to the sacrum have the capitulum and tuberculum separate, though not as distinctly as in the sacrals; and anterior to these the ribs are really double-headed, for they articulate with both the diapophysis and intercentrum.

Dr. Gadow says of the pleurocentra:

> They are, moreover, the pieces which, in *Eryops*, are attached to the caudal end of the cervical vertebræ, figured by Cope, and there actually and rightly called hypocentra pleuralia.[6]

[1] *Loc. cit.*, *infra*, p. 21.

[2] *Philosophical Transactions of the Royal Society of London*, Vol. CLXXXVII, p. 41, Fig. 41.

[3] *Transactions of the American Philosophical Society*, Vol. XVI, Plate 1, Fig. 1.

[4] *Loc. cit.*, pp. 21. 22.

[5] *Palaeontological Bulletin*, No. 32, p. 15.

[6] *Loc. cit.*, p. 22.

Cope says that in some specimens a groove crosses the inferior side of the intercentra of the cervical region, and that the anterior part is probably the hypocentrum pleurale, but he does not figure vertebræ that have the groove. The pleurocentra are present in all of the vertebræ excepting the atlas and axis, and possibly the posterior caudals, and an examination of the specimens will convince the most skeptical that they represent the same elements throughout the column. But in some of the cervicals the other element, called by Cope hypocentrum pleurale, are present in the same vertebræ with the pleurocentra. How, then, can the hypocentrum pleurale be the pleurocentrum, when the pleurocentra are already represented in those vertebræ by other elements? The conclusion is obvious. The pleurocentra of *Eryops* are the interdorsalia of Gadow, and not the interventralia (hypocentra pleuralia), as he believes.

Recent investigations furnish almost positive proof that the homologies of the parts of *Eryops* vertebræ proposed by Cope are correct.

The neurapophyses (basidorsalia of Gadow) are homologous with the neurapophyses of other temnospondylous Stegocephalians and of the Amniota.

The intercentra (hypocentra, basiventralia of Gadow) are homologous with the intercentra of other temnospondylous Stegocephalians and of the Amniota.

The pleurocentra (interventralia of Gadow) are homologous with the pleurocentra (interdorsalia of Gadow) of other temnospondylous Stegocephalians and of the Amniota.

The hypocentra pleuralia (interventralia of Gadow) are homologous with the hypocentra pleuralia of *Archegosaurus*, *Chelydosaurus*, and *Sphenosaurus*.

In *Archegosaurus*, according to Jaekel,[1] the hypocentra pleuralia are united with the pleurocentra in the thoracic and anterior caudal regions. The fate of these elements in other temnospondylous Stegocephalians and in the Amniota is not known. They may be united with the pleurocentra, which seems the most probable; they may be united with the intercentra; they may have entirely disappeared; or all three of these conditions may be represented.

[1] *Zeitschrift der Deutschen geologischen Gesellschaft*, 1896.

Eryops Cope

Skull long, comparatively narrow; proportion of length to breadth about 9 to 7. Roof bones coarsely sculptured posteriorly, finely sculptured anteriorly. Nasals and premaxillæ very large; frontals excluded from orbits by junction of pre- and postfrontals. Pterygoids not meeting in the median line; parasphenoid dagger-shaped, tapering gradually to a point just in front of the palatine foramina; prevomers large. Orbits subcircular, situated in the posterior half of the skull; nares subovate, remote, at a considerable distance from the tip of the skull. Many minute denticles on pterygoids, palatines, prevomers, and parasphenoid. Teeth circular in cross-section, strongly ribbed near base, dentine strongly infolded. Three large teeth on each palatine. Mandible without postcotyloid process. Vertebræ rhachitomous. Ribs double headed. Pelvic bones coalesced.

ACKNOWLEDGMENTS

The investigations of the writer on *Eryops* and the Labyrinthodontidæ were carried on under the direction of Professor S. W. Williston, head of the department of vertebrate paleontology of the University of Chicago. The writer's sincerest thanks are due Professor Williston for the privilege of studying the specimens in Walker Museum, and for his valuable advice and encouragement. Thanks are also due to those in charge for permission to examine the specimens of *Eryops* preserved in the American Museum of Natural History of New York City.