Ctenacanthus amblyxiphias, sp. nov. Fig. 3.

Spine elongate, but little curved, moderately compressed; the posterior face with a flat median plane bounded by a shallow groove on each side. The ridges are wider than their interspaces, and they gradually become smaller posteriorly, so as to be half the diameter of the anterior ribs. The anterior border consists of a single rib of twice the diameter of the largest lateral ribs. Its front surface is smooth; the sides are marked with shallow grooves directed downward, and the border is serrate with subacute tubercles, which point backward. The tubercles of the ribs are closely placed and vary from round to transverse in shape, and have a finely grooved surface. The line of the posterior hooks is flush with the sides of the spine. They are small, decurved, and subacute.

The apex of the spine is wanting, so I can not give its length with certainty. It was probably about 10½ inches. Measurements: Length of fragment, 190 millimeters; length of base presented (at front), 42 millimeters; diameters at middle, anteroposterior, 28 millimeters; transverse, 17 millimeters; transverse diameter of spine 140 millimeters, from base of fore surface 11 millimeters.

The Permian formation of Texas; W. F. Cummins.

III.—On the Cranial Structure of Macropetalichthys.

The typical specimen of the *Macropetalichthys rapheidolabis* Owen remains one of the best for the elucidation of the type of fishes which it represents, although it is very imperfect. It has the advantage of having lost most of the surface of the cranial ossification, so that its true structure is the more easily determined. The cavities of the cranium are occupied by the Corniferous limestone, which formation is its proper horizon, and one of the orbits contains a characteristic brachiopodous mollusc. The extremity of the muzzle is broken away obliquely, and the (?) maxillary region of the right side is lost. The matrix has been split from the inferior surface so as to show much of the structure of the latter.

The orbits are much in advance of the line dividing the superior headshield transversely into equal halves. There are no distinct indications of the existence of hyomandibular supports of a lower jaw. There are unsymmetrical transverse sections of hollow rods, which form areæ immediately behind the position of the orbit on the inferior fractured surface of the specimen. The fractured surfaces are suboval, and have different directions of their long axes, owing probably to different directions of pressure. This they would be liable to from the extreme tenuity of their walls. It is probable that this genus had a lower jaw. As to the upper jaw, this was probably present also, but whether it belongs to the palatopterygoid arch or to the maxillary can not be

stated. Its presence is indicated by the longitudinal transversely concave inferior surface of the element called jugal below. This articular surface might have supported some form of tooth, but as no such have been found associated with the rather abundant remains of Macropetalichthys, it is more probable that a distinct element was attached to this surface.

As is well known, the superior surface of the head-shield is divided into symmetrical tracts by well-marked lines. These areas have been regarded as the osseous cranial elements, and have been named by Newberry in correspondence with those of higher vertebrata.* The lines referred to, however, are not sutures, but tubes which belong to the lateral line system; and they traverse the centers of the true bony elements instead of bounding them. They join at the centers of some of the elements, and in such cases mark the points of origin of the osseous radii, whose direction they follow. The direction of these tubes is as follows in the present species, and approximately in all the other members of the genus: In the first place there is a frontal lyra, whose branches are parallel for a distance in front of the orbits (as far as the specimen is preserved), and which begin to converge at a point a little in front of the anterior border of the orbit. They join on the middle line about half an orbit's diameter behind the line connecting the posterior borders of the same. From this point they diverge at an angle a little greater than 90 degrees to a point immediately behind the superior border of the orbit, and nearly two orbits' diameter posterior to the latter. From this point two lines diverge, one toward the externo-posterior angle of the skull, the other downwards and forwards at an angle a little over 90 degrees from the other branch. The lines are all perfectly straight except those of the lyra, which are bent just in front of the anterior border of the orbits. That these lines represent tubes is readily seen where they are broken across. That of the lyra has a subtriangular section. Below it, in front of the orbit, is a smaller one of round section which the fracture of one side enables me to trace as far as opposite the anterior border of the orbit.

In their distribution these tubes do not nearly resemble those of Homosteus as represented by Traquair.† A closer resemblance can be traced to those of Coccosteus‡, of Dinichthys, and especially to those of Titanichthys.§ The lateral branches of the frontal lyra unite posteriorly at an angle in *Dinichthys terrellii*, are slightly separated by a transverse tube in *Titanichthys agassizii*, and are more widely separated in *Coccosteus decipiens*. In all three, divergent branches extend posteriorly, as in Macropetalichthys. In the three forms mentioned, these posterior branches send, anteriorly and exteriorly, a branch from a point close to the posterior border of the skull, on each side. This mar-

* The Paleozoic Fishes of North America, 1890, p. 43.

† Geological Magazine, 1889, p. 1, pl. I.

‡ Traquair, *loc. cit.*

§ Newberry, *l. c.*, pls. I and III.

ginal tube sends a branch laterally to the external angle of the skull in all the genera mentioned, except in Macropetalichthys, where this point can not be demonstrated in my specimen, owing to the loss of the border. Still more anteriorly on the postorbital bone it diverges again, sending a short branch inward and one forwards in Coccosteus and Titanichthys. In *Dinichthys terrellii* it does not divide, but continues, and joins the lateral tube of the lyra. In both Coccosteus and Macropetalichthys the transverse branch extends towards the middle line. In the former it unites with that of the opposite side, and forms at its middle portion, the posterior border of the lyra. In Macropetalichthys on the other hand, it joins the posterior tube at an angle well behind the extremity of the lyra as already described. Thus the last-named genus resembles Coccosteus in this one point more than it does any of the other Arthrodira. (Fig. 6.)

The cranial segments discernible are as follows. They may be readily traced on the specimen, since the sculptured surface and indeed the greater part of the bone-substances have disappeared, and the cast of the inferior surface is distinctly preserved. This surface, is however, wanting from most of the top of the muzzle, so that the relations of the ethmoid elements can not be made out. From the middle of the superior border of the orbits forwards extends an element which is prefrontal or frontal; but which one the injury to the top of the muzzle does not permit me to determine. It extends down on each side of the muzzle in front of the orbit. At the anterior border of the latter, it is pierced upwards and forwards by a deep notch-like groove which receives a corresponding wedgelike anterosuperior extremity of the element which I call provisionally the jugal or malar element. This bone extends below and behind the orbit, containing in the latter region a center of radiating ossification. The median or (?) frontoparietal element encroaches on the median element of the top of the muzzle as far forwards as opposite the middle of the orbits by a convex anterior border. Its ossification radiates from the junction of the lateral branches of the lyra, in all directions, and, while its anterior and lateral borders are easily discernible, its posterior ones are not so clear. It probably extends to a point half way between its anterior border and the posterior border of the head-shield. The posterior section of the prefrontal extends obliquely backwards and is succeeded by a wide longitudinally oval element, which from its position might be termed a postfrontal, although it includes within itself the region of the postorbital. Posterior to it is a subdiscoid element of similar size, and a little wider than long, which is in the position of the supratemporal element of the Stegocephalous skull. Its center is the point of divergence of three tubes already described, and its ossification radiates from the same point. Exterior to this element and the one in front of it, and joining the posterior face of the malar is a large area in the position of the Stegocephalous squamosal element. Ossification radiates from

the posterior lateral angles of the head-shield, and there are two lines which penetrate the matrix more deeply than the rest. I can not make out that any canal radiates from this point except the one which reaches to the center of the supratemporal. This region corresponds to that of the intercalary of the fishes, but its boundaries I can not make out.

This arrangement of cranial elements may be compared with those of Coccosteus and Homosteus. It differs from the former in the presence of a malar bone bounding the orbit below, and in the presence of the "squamosal" behind it. In Homosteus, elements which occupy the position of the two mentioned are present (Traquair, *l. c.*), but they are called by Traquair postorbital and marginal, names which he applies to my possible postorbital and supratemporal. I think the elements described by Traquair are homologous with the malar and squamosal of Macropetalichthys, so that the "postorbital" (my postfrontal) and "marginal" (my supratemporal) must be sought for elsewhere in Homosteus. Traquair's "central" appears, from its position, to include my postfrontal, while the supratemporal may be embraced in the anterior part of Traquair's "external occipital." This question can, however, only be settled by the discovery of intermediate types. In any case, a general affinity to the Arthrodira is indicated by the segmental structure of the skull, as well as by the character of the tubes of the lateral line system.

The inferior surface of the skull presents the following characters. This is important, as I do not know of any description of this region in an Arthrodire, excepting in the cases of the Dinichthys and Titanichthys described by Newberry. (Fig. 6.)

In the first place the posterior part of the head-shield, the "median occipital" region of Traquair, is produced very far posteriorly, as in Homosteus. This region does not seem to have protected the brain, but rather the anterior part of the vertebral axis, and seems to have been a nuchal plate. In the specimen I am now describing, the posterior extremity of this element is broken away for a short distance on both sides of the middle line, revealing a cast of its interior. This is bilobate, by reason of a vertical constriction at the middle line. That this is not a cast of the cranial cavity is proven not only by its form, but by the fact that there is no cast representing a *medulla oblongata* or a *foramen magnum*. The chamber was absolutely closed posteriorly. The lateroposterior angle of this cavity is exposed by the loss of the external wall. It is obtusely angular. Turning now to the inferior aspect of the skull, we observed, at the middle line of the inferior-posterior border, a wide, upward excavation, looking backwards and downwards. It rapidly contracts into a groove with an angular superior middle line. Whether this groove is part of a tube can not be ascertained, owing to the loss of the bony tissue on each side and below, but it may be only the apical angle of a roof-shaped space, whose lateral slopes are produced on each side, sloping well downwards and out-

wards. These sloping faces of the matrix represent a pair of osseous plates, which descended on each side from the sheath of the myelon and chorda dorsalis, for the latter occupied this position in the groove already described. Such a structure would indicate the presence of a number of fixed vertebral elements, such as exists in the chimæras, the rays, and the sturgeons. The two-thirds of the inferior face of the skull which lies in front of this groove is covered by a single thin plate, which may be the parasphenoid. Its posterior border reaches to the anterior extremity of the roof-shaped descending plates already described, and, joining them by a rounded angle, turns downwards and outwards, the descending portion sloping forwards into the horizontal portion. Where it joins the descending plates of the axis there are three grooves on each side, which are separated by two ribs. At the point of junction of the parasphenoid with the lateral alæ of the axis, is situated what I suppose to be the foramen magnum. It is the direct continuation of the groove already described, and, being floored by the parasphenoid, has a triangular section. There is no trace here of a fossa for the chorda dorsalis, nor of an occipital condyle, nor is it probable that either existed at this point. The parasphenoid is thin, and there are no indications of teeth to be observed on it.

For the opportunity of studying this specimen I am greatly indebted to Prof. J. W. Spencer, of the University of Missouri, and to the late president of that institution, Prof. S. S. Laws, who lent it to me out of their museum.

I here describe the characters presented by another specimen of Macropetalichthys which belongs to the geological museum of the State of Ohio, and which was kindly lent me by the director of the survey, Prof. Edward Orton. This specimen is broken transversely across the median part of the area which includes the median occipital plate, showing that the posterior part of that area is a distinct element separated from it by suture. I call it therefore the median nuchal plate, and the two angular elements on each side of the posterior region, which are also shown to be distinct, I call the lateral nuchal elements. One of these is wanting in the specimen, showing that its junction with the median element is by a smooth squamosal suture. The anterior face of the nuchal mass has a vertical groove on the middle line which fits a corresponding keel of the cranium proper. The triangular foramen magnum issues at the inferior extremity of this keel; at the lateral extremity of this occipitonuchal suture under the free lateral margin of the skull is a fossa, one-half of which is in the cranium and one-half in the nuchal element. This looks like an articular glenoid cavity, possibly for the condyle of a mandible. It is bounded posteriorly by a transverse crest, posterior to which is the extensive longitudinal fossa beneath the free border of the nuchal plate. There is a small fossa on the middle line 20 millimeters in front of the occipitonuchal suture, in the parasphenoid bone. The anterior part of the skull is better preserved than in

the skull of the *M. rapheidolabis* first described. The borders of the muzzle are bounded on each side by a shallow longitudinal fossa, which looks outward and downward. Each is bounded on the inner inferior side by a longitudinal crest which looks downwards and extends backwards and outwards. The palate between these ridges is concave from side to side. The median portion is filled with matrix so that the surface and its relations with the parasphenoid can not be seen. The lateral ridges are continued to below the orbit. In front of the supposed glenoid fossa is another longitudinally oval fossa below the edge of the skull. The chordal groove and the laminar plates descending on each side of it are as in the specimen first described.

The lateral nuchal element is separated from the median, so as to show that the latter has an approximately semicircular outline when seen from above. Viewed from behind, the nuchal element displays an obtuse median vertical keel with a shallow fossa on each side, bounded by an angle on each side at the superior margin, but fading out below. The vertical diameter is considerably greater relatively than in the *M. rapheidolabis*. I suspect that the specimen belongs to the *M. sullivantii* Newb.

Returning to the *M. rapheidolabis* I observe that the anterior borders of the descending axial alæ are about opposite to the lateral center of radiation of the lateral line tubes, or the center of the so-called supratemporal bone. Below the anterior border of the orbit, on each side of the middle line, about 7 centimetres apart, is a pair of medium-sized round foramina. Exterior to these, a little anteriorly, at double the space between the two median foramina, is another pair of foramina of oval section, which look outward, forward, and downward. The bony wall of the neural canal, already described, is quite thick.

There is no trace of pineal foramen such as is described by Newberry in Dinichthyidæ. The sclerotica was protected, but whether by a thin extension of the prefrontal and postfrontal bones or by a special ossification is not determinable. The impression only remains. A considerable fossa is inclosed between the descending axial plates and the lateral borders of the posterior part of the head-shield, which opens downward and outward. The sculpture of the surface of the skull is preserved in one or two places. It consists of round, flattened, rugose tubercles of a diameter of about 2 millimeters placed close together.

Affinities of Macropetalichthys and of the Arthrodira.—It has been shown by Agassiz that Coccosteus has a mandibular arch, and by Newberry that this region is present in the Dinichthyidæ. Traquair has also shown that in the former genus it is connected with the cranium by a suspensorium. Free elements beneath the anterior part of the head-shield have been demonstrated to exist in Homosteus by Traquair, which probably include a mandibular arch. The general resemblance of Macropetalichthys to the Arthrodira renders it almost certain that it possesses a lower jaw, and that it is a member of that order. I have

included this order in the Crossopterygia with doubt * on the supposition that they possess a maxillary arch and suspensorium. The former is however not described so as to distinguish it from a palatopterygoid arch by authors, and no evidence of the existence of such an arch can be derived from American forms. Advance sheets of volume II of the Catalogue of Fossil Fishes in the British Museum, by A. Smith Woodward, show that this able authority places the Placodermata in the Dipnoi, thus indicating that they possess neither maxillary arch nor suspensorium.

There is much in the structure of the skull of Macropetalichthys to confirm this opinion. The nuchal portion of the structure with its lateral nuchal elements is represented by the cartilaginous mass which extends posterior to the median occipital bone in Ceratodus, in which this region has very much the form of the nuchal shield in Macropetalichthys, although it is relatively shorter. The chordal groove with its descending laminæ resembles much the produced occipital bone of Lepidosirem. The parasphenoid in both Lepidosirem and Ceratodus are produced posteriorly abnormally, and it is only necessary to imagine this part to be reduced to its normal length to have the conditions found in Macropetalichthys. The broad parasphenoid and vomer remind one of that of Ctenodus. As I have shown that Macropetalichthys is allied to Dinichthys, we can add in favor of the supposition of affinity to the Dipnoi the peculiar dentition of that genus. The ectetramerous † structure of the dorsal fin shown by Von Koenen and Traquair to exist in Coccosteus, and shown to be probably present in Dinichthys by Newberry, are in favor of the Dipnoan theory. Elements supposed to be the axial elements of pectoral fins are described by Dr. Newberry. These are simple and without lateral articulations, and are thus of the unibasal type which is general in Dipnoi as well as in some Crossopterygia and all Rhipidopterygia. They somewhat resemble those which I shall describe in this paper as characteristic of Megalichthys. It is on account of this part of the structure that the Arthrodira can not be arranged near to the sturgeons, where Macropetalichthys has been placed by Newberry and others, to say nothing of the cranial structure, which has no resemblance to that of those fishes.

I first referred Macropetalichthys to the Placodermata (Arthrodira) in a review of Professor Newberry's work on the Paleozoic Fishes of North America in the American Naturalist for September, 1890; and this view has been adopted by Mr. A. Smith Woodward as above mentioned.

Species of Macropetalichthys.—It is evident that the two crania which I have described in the preceding pages belong to two different species. The larger is the *M. rapheidolabis* of Owen, and the smaller the *M. sullivantii* Newberry. In the latter the nuchal element and its included

* Synopsis of the Families of the Vertebrata, American Naturalist, October, 1889.

† Cope, American Naturalist, 1890, p. 416.

chamber have a greater depth in proportion to the width and length of the skull than in the former. They may be characterized as follows:

Posterior nuchal depth $\frac{1}{5}$th width and $\frac{1}{6}$th length of skull above; *M. rapheidolabis;* fig. 4.

Posterior nuchal depth entering width behind $2\frac{1}{2}$ times and length $4\frac{3}{4}$ times; *M. sullivantii;* fig. 5.

The skull of the *M. sullivantii* is rather narrower than that of the *M. rapheidolabis.*

The half width at the foromam magnum enters the length to the anterior border of the lateral marginal fossa $3\frac{1}{2}$ times, while it enters but 3 times in the *M. rapheidolabis.*

IV—On the pectoral limb of the genus Holonema Newberry.

Described from fragmentary or single plates by Claypole and Newberry, the *Holonema rugosa* Claypole remained a vertebrate of uncertain affinities. At the meeting of the American Association for the Advancement of Science held at Indianapolis, August, 1890, Prof. H. S. Williams exhibited photographs of the posterior part of the carapace of a newly discovered specimen, which includes the greater part of the two median dorsal plates and the posterior laterals. The rounded posterior outline of the carapace is similar to that seen in Bothriolepis, and neither this nor any of the specimens described up to that time demonstrate the distinctness of this form from that genus.

In the collection of Mr. R. D. Lacoe, of Pittston, Pennsylvania, which that gentleman kindly placed at my disposal, there are specimens of this genus from Mansfield, Tioga County, Pennsylvania. The largest of these is a lateral plate of the plastron, partly represented by a very distinct mold of the matrix. It measures 190 millimetres in length and 105 millimetres in width. Besides this, there is a nearly complete pectoral spine, which is of much interest, as this part of the skeleton has not been previously known. (Fig. 7.)

This spine belongs to a smaller individual than any of those of the *Holonema rugosa* yet described, but until the range of dimensions of that species is known it will not be safe to regard it as representing another species. The range of size of the *Bothriolepis canadensis* is very considerable. The spine differs from that of both Bothriolepis and Pterichthys in being without complete segmentation. It is continuous throughout to the apex. This, then, will constitute the generic distinction so far known between Holonema and Bothoiolepis. The tissue of the spine is disposed in tesseræ, as in the other genera allied. A single series of three elongate narrow hexagons extends down the center of the external face, and the lower space is divided by sutures, which extend from the lateral angles of the hexagons to the border of the spine. The apex of the spine from the last hexagon, and for a length nearly equal to it, is not tessellated.