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CONTRIBUTIONS TO THE CRANIAL OSTEOLOGY OF THE FISHES.

No. I.

Tandanus tandanus Mitchell.

BY

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INTRODUCTION.

(Figures 1-5.)

Though presenting a general similitude throughout the class, the skull of the bony fishes is subject to a variety of modifications. These modifications affect not only the form but also the number, and therefore the relations one to another of the component bones.

These modifications have been subjected to analysis from time to time incidentally to the description of several isolated forms. Except however in text books, where perforce the reviews are brief, no general attempt has been made to harmonise the various modifications.

The Director, Dr. C. Anderson, has kindly placed at my disposal a very fine series of heads of Elasmobranchs and Teleostei. From the American Museum of Natural History I have received heads of *Amia, Acipenser, Lepidosteus,* and other Teleostei. My thanks are also due to Dr. T. L. Bancroft of Eidsvold, Queensland, for *Ceratodus* heads.

With all this mass of material to work upon, it is hoped to present a comprehensive review of the piscine cranium. A series of descriptions accompanied by drawings will be offered first. In these descriptions comparative notes will be made as brief as possible. The descriptive series will be followed by a review of the whole, and it is towards this last that each of the others is contributory.

In 1922 I published "A New Interpretation of the Bones in the Palate and Upper Jaw of the Fishes[1]." Throughout this series the nomenclature there introduced will be used. In order to obviate

[1] Kesteven—Journ. Anat., lvi, 1922, pp. 307-324.

reference to that paper the new nomenclature is tabulated opposite the old below.

Old Nomenclature.	New.
Parasphenoid	Conjoint- or Mesopterygoid
Hyomandibular	Hyomandibular
Symplectic	Symplectic
Quadrate	Quadrate
Metapterygoid	Os transversum
Pterygoid or Ectopterygoid	Quadratojugal
Mesopterygoid or Entopterygoid	Palatine
Palatine	Maxilla
Maxilla	Maxillary labial
Premaxilla	Premaxillary labial
Vomer	Premaxilla
Parethmoid or Ectethmoid	Prefrontal

The terms conjoint- or mesopterygoid and os transversum were proposed in this new sense in an earlier paper[2]. Synpterygoid is a happier term and will be used in these papers. Maxillary labial and premaxillary labial are terms proposed here, which will be used in future contributions.

Skull of *Tandanus tandanus* Mitchell.

The skull has the dorso-ventral compression of the Siluroids, and, whilst conforming generally to type, it presents marked departures from the normal in the arrangement of the anterior facial components.

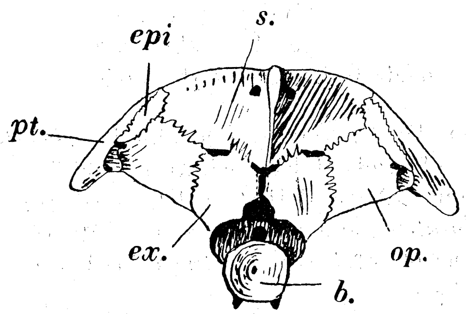

Fig. 1.—*Tandanus tandanus,* posterior aspect.

The neurocranium is roughly triangular in outline as viewed from behind (Fig. 1), two sides of the triangle being ventro-lateral and the third dorsal. The dorsum of the cranium is arched, and, being continued out and down by the pterotic processes, describes approximately one-third of a circle. The ventral plane of the skull approaches that of the roof not rapidly but evenly towards the snout. Near the anterior end of the skull, there is an abrupt down-turning of the dorsal and a less abrupt down turn of the ventral surface, so that the two surfaces meet at a point below the ventral plane.

[2] Kesteven—Journ. Anat., liii, 1919, pp. 223-238.

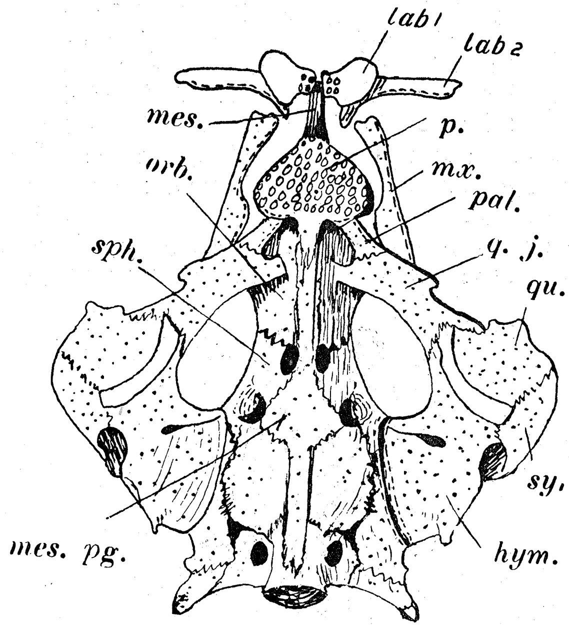

Fig. 2.—*Tandanus tandanus,* ventral aspect.

The two ventro-lateral sides (Fig. 2) are inclined to one another at a right angle in the older specimens, and at a more obtuse angle in the younger. The width of the neurocranium is reduced fairly regularly from behind forward. The large *foramen prooticum* imparts an appearance of abrupt lateral constriction just forward of the anterior limit of the hyomandibular articulation. At the anterior limit of the infraorbital vacuity, the orbitosphenoid bone contributes a laterally expanded section to the central structure. The attachment of the fore end of the suborbital arch to the ventro-lateral edges of this bone, and the heart-shaped expanse of the premaxilla immediately in front of it, give to the anterior end of the skull, as viewed from below, an appearance of massiveness which is not really present.

Viewed from above (Fig. 3) the brain box has a nearly square outline behind the orbits. The centre of the orbit (antero-posterior measurement) marks the centre of symmetrical bays which excavate the sides of the neurocranial outline. In front of the orbit the central mass of the skull maintains a roughly oblong outline for a space, and is then suddenly constricted. Beyond the point of constriction the central axis is continued by the bizarre mesethmoid only. It will be evident later that a lateral constriction of the skull in front of the orbit is hidden from above by the massive prefrontals.

The saucer-shaped articular facet and the tips of two ventral struts thereto is all that is visible of the *Basioccipital* posteriorly. The foramen magnum, immediately above the basioccipital, is shaped like a broad gothic arch. A "step" to this "door way" is formed by a narrow area of the dorsal surface of the basioccipital. The *Exoccipital* bones entirely surround the foramen. The basioccipital "door step" is situated outside the plane of the exoccipital door frame. Just before meeting in the mid line the exoccipitals leave the dorsal surface of the basioccipital. The short bony canal thus formed between the dorsum of the basioccipital and the exoccipitals transmits the anterior vertebral artery and vein to and from the cranial cavity.

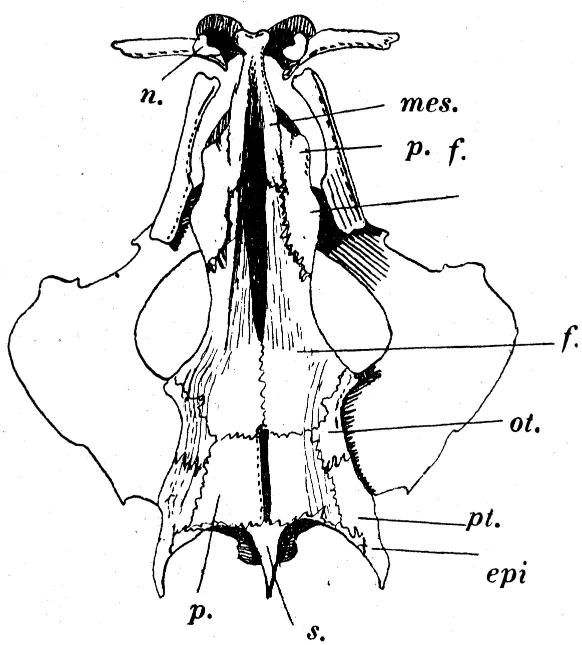

Fig. 3.—*Tandanus tandanus,* dorsal aspect.

Where each exoccipital is reflected off the floor to form the lateral boundary of the foramen it is so reflected as to form a broad shallow gutter, whose floor slopes downward, outwards, and back. The upper limit of this gutter is a spur of bone, which with its fellow of the opposite side determines the centre way of the gothic arch. This "centre way" alone is the foramen magnum (*sensu stricto*). In the fresh state strong membranous bands close the two lateral gutters, converting them into canals separate from the centre way in which the cord lies.

Above and beside the foramen the exoccipital of each side presents a broad expanse of bone on the posterior aspect of the skull. Meeting in the midline above, the two bones form the sides and floor of a groove whose dorsal roof is formed by the base of the supraoccipital crest. To this groove the dorsal spine of the first vertebra is fitted by cartilaginous packing.

The *Supraoccipital* bone contributes the middle two-fourths of the dorsal margin of the skull as viewed from behind. The occipital crest is a flange which arises from the full depth of the bone in the median sagittal plane. As viewed from the side the crest is roughly triangular in outline. The dorsal side of the triangle continues the dorsal line of the skull backward. For the most part suture between exoccipitals and supraoccipital is effected by cartilage, but there is a short true bony suture bridging the gap present in the dried skull between these bones. Above and lateral to the exoccipital the supraoccipital suturates with the opisthotic and epiotic. Along the dorsal margin the sutures are with the parietal medially and pterotic laterally. On either side of the crest the bone is perforated by the foramen of exit of the accessory lateralis ramus of the facial nerve. This foramen is overhung by a relatively heavy flange of the dorsal margin of the bone.

The *Opisthotic* bone, approximately square in outline, fits in between exoccipital, supraoccipital, epiotic and pterotic bones, and contributes to the lower margin of the skull.

The nearly oblong *Epiotic* lies near the dorsal margin, separated therefrom by the pterotic and having the supraoccipital and exoccipital bones to its inner side.

Of the *Pterotic* bone the process alone is seen from behind.

There is a square socket formed at the outer angle of the exoccipital by small flanges of that bone on three sides and the distal end of the epiotic above. This socket is adapted to receive the proximal end of the *Posttemporal.*

The *Basioccipital* bone is of a shape very common among the fishes; it may be compared to a vertebra which has been extended and tapered anteriorly. Inferiorly it is covered to some extent by the synpterygoid, so that rather less than half its antero-posterior length is visible from below; in the mid line, though, on either side of the synpterygoid the bone is visible for its full length. The anterior limit corresponds with the short articulation with the prootic, at the postero-medial angle of that bone.

The synpterygoid extends along nearly the full length of the base of the skull; its forward limit corresponds with the hinder boundary of the tooth-bearing area of the premaxilla in the mid line. The bone is uncovered below except anteriorly, where the median palatine spur-like lamina of the premaxilla lies below it. In the younger specimens the bone is as depicted in Fig. 2, whilst in older specimens it tapers from the widest point backwards to the posterior limit.

Immediately above the basioccipital the exoccipital is placed behind the prootic and below the pterotic and opisthotic. The exoccipital and opisthotic thus have posterior and lateral faces. The foramen of exit for nerves ix and x is very obvious in the centre of the lateral face of the exoccippital.

The *Pterotic* bone is perforated ventral to the root of the spur and just below the posterior end of the hyomandibular sulcus for the transit of blood vessels to and from the bone and perhaps also the contents of the otic capsule.

The *Prootic* is the largest contributor to the side wall of the cranium. Its anterior boundary is deeply notched for the transit of nerves v and vii, and by this notch the suture with the alisphenoid is interrupted.

The *Alisphenoid* suturates with the prootic both above and below the prootic foramen, with the synpterygoid in front of the lower contact, and with the sphenotic in front of the upper contact with the prootic. Immediately above the prootic foramen the alisphenoid contributes three sides to a socket for the anterior end of the hyomandibular bone. In front of the base of this hollow boss the bone is traversed by a canal, which transmits a branch from the trigemino-facial nerve complex. In front of the short contact with the synpterygoid the alisphenoid contributes posterior and superior boundaries to the sphenoptic foramen; the superior boundary is arched and almost reaches the synpterygoid again in front of the foramen. The orbito-sphenoid fills the small interval between the two.

The *Sphenotic* contributes both to the side wall and to the roof of the cranial cavity, situated above the alisphenoid and prootic; it is in contact behind with the pterotic both laterally and on the roof. In front it suturates with the frontal, again both on the roof and laterally. Between frontal and pterotic there is a short suture with the parietal.

The *Epiotic* is a small chip of bone wedged in between pterotic in front and opisthotic below and behind it, and having a short suture with the supraoccipital, as shown in Fig. 1.

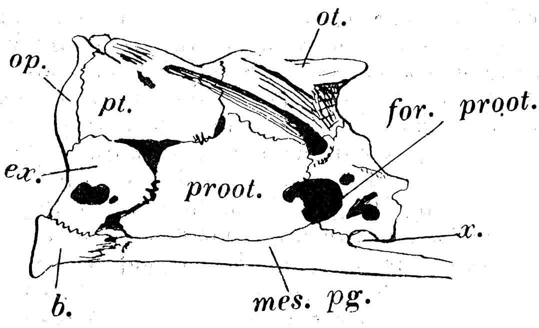

Fig. 4.—*Tandanus tandanus,* side view of cranium.

The bones in the side wall of the cranium are depicted in Fig. 4.

In front of the alisphenoids, between them and the synpterygoid below, the prefrontals in front, and the frontals above, there is a massive spongy bone, bilaterally symmetrical, but possibly developed from two centres. Since it occupies the situation of the two bones which in other fishes (for example, *Amia* and *Salmo*) have been termed orbitosphenoids, and is probably homologous with them, that name is applied here.

The *Orbitosphenoid,* then, is a median bone, quite clearly developed in cartilage. Viewed from above it is roughly oblong, the hinder end being however narrower than the fore end. The ventral margin, as viewed from the side, is straight. The central portion of the ventral surface is furrowed to receive the upper surface of the synpterygoid. From the edge of this furrow each side of the ventral surface slopes upward. Viewed again from the side, it has a straight ventral margin which is the edge of the furrow, and above this the sloping ventral face is foreshortened. It has been already noted that the fore end of the bone is the broader; in consonance with that, the fore end of the ventral surface reaches a higher level than the hinder end. Above the ridge developed along the lateral margin of the ventral surface is a rough vacuolated sulcus, overhung by the outer edge of the area of articulation with the frontal and prefrontal bones. Viewed from above the bone may be described as composed of two massive right and left halves, joined together by a ventral lamina, and having between them a deep furrow or ditch. The massive halves are thickest through from side to side a little forward of the centre of their length. From this point each half tapers both forward and backward. In front the tapering is but slight, and there is a bluff truncated fore end to each half. Behind the broadest point the solid side walls of the ditch taper to nothing. The ditch is therefore broad and open behind, and narrow but still wider in front than it is near the mid point of its length. Since the lateral masses are deepest dorso-ventrally at the point where they are thickest, here also the ditch is deepest. In front of this point the full height of the walls is maintained for a very short distance, and then there is an abrupt truncation, with a very slight inclination forwards as well as down. Behind the highest point the wall is lowered gradually for an interval, is then almost vertically truncated for half its height, continues at that height a little way, and then is brought to floor level by a second step. At the narrowest point the ditch is V-shaped in vertical section. Behind and in front of this point the *floor* of the space is V-shaped. Behind the narrowest point it is as though the two arms of the V had been separated further and shortened. In front of the narrowest point the contours are somewhat different, the side walls diverging as do those at the back, but there is a bulge inward, which begins at the floor at the narrow point, becomes more marked as it passes forward, and rises to just above the middle of the height at the forward end.

Posteriorly the space between the walls merges with the cranial cavity; anteriorly the divergent walls permit the olfactory peduncles, which lie upon the floor of the cavity, to pass right and left towards their respective capsules. The broad dorsal edge of the massive side pieces are in contact by suture with the sphenoidal ridge of the frontal and with the prefrontal. A very obvious pit divides the frontal area behind from the prefrontal area in front. With the bones in situ it is found that the sphenoidal ridge of the frontal is notched on the outside to permit the transmission of a vessel towards this pit, and that, on the inside, a bigger foramen interrupts the suture just behind the pit; doubtless nutrient vessels alone pass this way. Suture between the orbitosphenoid and prefrontal is largely effected per medium of cartilage; there is however a small true sutural contact at the fore end of the lamina delimiting the lateral border of the sloping ventral surface, and also just in front of the frontal area of suture.

The *Frontal* bone presents little of interest; of a common shape it suturates with its fellow of the opposite side, and with parietal, sphenotic, alisophenoid, orbitosphenoid, and prefrontal. It roofs the orbit and contributes to the roof and side wall of the cranial cavity; this latter per medium of a low sphenoidal lamina, which articulates with alisphenoid and orbitosphenoid. At a point a little in front of the situation of the sphenoptic foramen, the underside of each frontal presents a broad ridge of low elevation. This may be regarded as the forward limit of the true cranial cavity. It corresponds to an abrupt narrowing of the cavity, clearly indicating its forward limit; this is found in many fish skulls. Forward of this ridge the central portions of the frontals and the sphenoidal laminae contribute to the roof and side walls of a cavity whose remaining bony walls are supplied by the orbitosphenoid. Just a little way in front of the low ridge above described, the frontal bones diverge from the mid line leaving a fontanelle which in the fresh state is filled by tough fibrous tissue and covered by the skin. The anterior portion of the roof of the orbit is much thickened; the thickening ceases abruptly and gives place to a rough surface for articulation with the prefrontal. Forward of this the bone tapers and becomes thinner, overlying the prefrontal. Cavities between the two bones, present in the dry state, are in the fresh filled by hyaline cartilage.

The *Prefrontal* bone supplies a solid triangular boss to the front of the bony margin of the orbit. Its position beneath the narrowing fore end of the frontal has already been described. Its outer margin is arcuate, and it terminates in front and laterally in a second prominence, not so marked as the orbital, to which the maxilla is attached by a short stout pedicle of fibro-cartilage. There is rather more of the dorsum of the bone exposed than is covered by the frontal. In front of the area covered by this last bone there is a small area covered by the corresponding dorsal arm of the mesethmoid. In front of and below this and to the inner side of the roughened area which gives attachment to the maxilla, is an area which gives attachment to hyaline cartilage which fills the gap here present between this bone, the mesethnoid, and the dental plate of the premaxilla. To the outer side of this area, in front of that which gives attachment to the maxilla, there is a very short true suture with the outer corner of the dental plate of the premaxilla.

The front of each prefrontal is hollowed out; the cavities they contribute to will be discussed later, together with certain canals and cavities in the bones.

The *Mesethmoid* is composed of a body and three prongs. Two of the prongs are dorsal and subdermal in position. Each suturates with a small area on the antero-medial and dorsal corner of the corresponding prefrontal, covering this area and extending back to interdigitate with the fore end of the frontal of the same side. The body of the mesethmoid, approximately cylindrical, tapers anteriorly and terminates in a laterally expanded and down turned triangular spatulate plate. The third prong, median in position, extends back from the ventral aspect of the body to interdigitate with the fore end of the synpterygoid.

There are three fontanelles in the roof of the younger skulls and two in the older. The posterior sagittal fontanelle is between the parietal and hinder end of the frontal bones. The anterior sagittal is between the fore end of the frontal bones. The intra-mesethmoid fontanelle lies between the two dorsal prongs of the mesethmoid bone. In adult specimens the posterior sagittal fontanelle is closed. In some cases the two anterior fontanelles are continuous, in others suture between the extreme tips of the frontal bones separates them.

The fore end of each prefrontal is hollowed out. When the two bones are in situ these recesses are opposite and open towards one another. In the intact skull a cartilaginous septum is present between them. Dorsally this septum sends a lamina out horizontally to line a narrow area of the roof of each cavity. The septum commences behind about the centre of the length of the intra-mesethmoid fontanelle, and with its dorsal outspread flanges is continued forward to the hinder face of the body of the mesethmoid. Since the under surface of the dorsal prongs and upper surface of the ventral prong of the mesethmoid approach one another anteriorly, it follows that this septum decreases in height as it passes forward. Ventrally the septum is planted on a broad sheet of cartilage which extends from one prefrontal recess to the other, filling the interval between prefrontal and synpterygoid, clothing the upper surface of that bone and extending back to reach the fore end of the floor of the orbitosphenoid. Continued forward this sheet of cartilage covers the upper surface of the ventral arm of the mesethmoid and a small area of the premaxilla on either side. Anteriorly dorsal and ventral cartilaginous laminae become continuous with the cartilage already described as filling the gap between prefrontal, mesethmoid, and dental border of the premaxilla.

There are thus formed here two conical cavities divided from one another by a common septum. Posteriorly the roof, side wall, and a small portion of the floor are formed of bone, the bone being prefrontal. For the rest the floor is carpeted with cartilage throughout, and anteriorly where bone is wanting the side walls are of the same tissue. Posteriorly the cavities are open to the sphenoidal cavity on either side of the abruptly truncated septum. Anteriorly each capsule terminates around a foramen which interrupts the premaxillo-mesethmoid suture. The olfactory peduncle enters each capsule at the back along the floor from the sphenoidal cavity; together with accompanying blood vessels it terminates in the small olfactory bulb.

The incomplete posterior bony wall provided by the prefrontal is perforated by the anterior opening of a canal which transmits the artery to the olfactory bulb from the orbit. The orbital opening of this canal is situated above the fore end of the sulcus on the orbitosphenoid formed by the flange on the edge of the sloping ventral face. There is a larger opening to the inner side of it, leading into a canal (*canalis nervo tentaculi medialis*) whose outer end is on the dorsal surface near the anterior end of the bone; it transmits a nerve (*ramus opth. superfic. trigemini*) and blood vessels. Towards the anterior end this canal suddenly dilates into a small rounded chamber. It has not been possible to examine the contents of this chamber, but it is believed that a ganglion is here present.

Sphenoidal cavity. This name is applied to the continuation of the cranial cavity beneath the frontal bones and their sphenoidal lamina, and above the orbitosphenoid.

Clearly the forward limit of the true *cavum cerebrale* is in the situation previously indicated. As stated above this point corresponds to an abrupt narrowing of the cavity in many fish (for example *Epinephelus*). In those forms (for example *Sebastodes*) in which an inter-orbital septum is developed, the olfactory peduncles quite obviously leave the cranial cavity at this point and continue forward on either side of the septum. In the majority of birds this point is recognisable as the cribriform plate or olfactory foramen, the peduncles continuing forward on either side of the inter-orbital septum as in *Sebastodes.* In the majority of reptiles, the condition is as in *Epinephelus,* but in some of the chelonians the resemblance is rather to *Tandanus.* Among the birds it appears that in the rhea and in the toucan the upper end of the intorbital septum divides to form one or two bony canals for the olfactory peduncles.

It is apparent then that in some fishes, all (?) reptiles, and some birds there is a cavity continuous behind with the cranial cavity, in which are lodged the olfactory peduncles; it is equally apparent that this cavity cannot be regarded as portion of the true cranial cavity. It has therefore been termed the sphenoidal cavity.

Turning our attention next to the floor of the cranial cavity, we have first to define the basisphenoid. On viewing the side wall of the cavity from within, the articulation of the alisphenoid with a short stout pedicle rising from the floor between optic and prootic foramina, immediately attracts attention in the present connection. This is the situation in which in the typical piscine skull the transverse arm of the basisphenoid articulates with the alisphenoid. This articulation of the alisphenoid below the *foramen prooticum* has previously been described from outside as with the synpterygoid, and that is justified, because no trace of discontinuity in bone structure can be found in this view between the suture and the midline where unquestionably the bone is synpterygoid. It is true also that in many fishes there is an upflung spur of the synpterygoid in this region which articulates with the alisphenoid, but in these cases, as in all that I have been able to inspect, the identity of the bones is placed beyond cavil by the presence of an eye muscle canal. In the present case as viewed from within, the suture is between an unquestionable component of the cranial floor and the alisphenoid. By carefully disarticulating a young skull the orbitosphenoid may be freed from the synpterygoid just in front of the optic foramen, but must be broken from the thin bone forming the floor behind it. Again the prootic and exoccipital may be separated from the synpterygoid and from their fellows of the opposite side, but must be broken from the thin bony floor in front. Except actually between the pedicles the floor is exceedingly thin, and there is a definite space between it and the underlying synpterygoid. The area between the pedicles and for a little way both in front and behind them is either basisphenoid or it is synpterygoid. But the synpterygoid (our old friend the parasphenoid) is a ventral covering bone and nowhere enters into the formation of the cranial floor. Clearly then the basisphenoid and synpterygoid are here intimately fused.

The sulcus beside the *foramen magnum* has already been described in the intact skull; this constitutes the most posterior nerve exit. The others are situated as follows. Foramen for nerves ix and x perforates the exoccipital, portion of the nerves issue through a small foramen situated just on the lower anterior margin of the main foramen. In the dry skull there is of course the usual hiatus in the region of the auditory capsule. The *foramen prooticum* (nerves v and vii) is bounded by the alisphenoid in front and the sphenotic behind; it also has a small subsidiary foramen close alongside of it behind and above the centre. The strut of the alisphenoid which articulates with the basisphenoid separates the sphenoptic from the prootic foramen, the former being slightly lower. There is also a small short canal perforating the top end of the alisphenoid strut. The inner end of this canal begins actually within the boundary of the prootic foramen at its upper anterior segment and issues on the outside just in front of the larger foramen, and at the base of a spur on the alisphenoid which forms the anterior buttress to the hyomandibular groove. Whilst this small canal may transmit one or more of the oculomotor nerves, I am more inclined to deem it a part of the *foramen prooticum.* None of the oculomotor nerves have been traced to their foramina of exit, but since there are no foramina present which appear likely to transmit them, I incline to the belief that they leave with the optic nerve, and accordingly have designated the common foramen sphenoptic foramen[3]. The foramen for the exit of the *ramus accessorius lateralis nervi facialis* perforates the supraoccipital on either side of the middle just posterior to parieto-supraoccipital suture, and passes just to the inner side of the cavity of the superior semicircular canal.

Before passing to the description of the palate and upper jaw I shall deal with a few points of interest in the skull and anterior cranio-visceral axis.

It will be remembered that two pairs of round areas where the floor is very thin have been described in the floor of the cranial cavity, one pair in front of the basisphenoid the other behind that bone. Beneath these thin scales of bone there is in each case a space whose floor is provided by the synpterygoid. No communication can be detected between the anterior and posterior pairs of spaces. On the other hand the posterior pair communicates freely with a roomy cavity beneath the posterior portion of both sphenotics and extending back into the substance of the basioccipital. Since these cavities beneath the cranial floor are undoubtedly what remains of the well developed eye muscle canal of other teleosts, they call for more detailed description.

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[3] Kesteven—Journ. Anat., lii, 1918, p. 466.

All the cavities are shallow from above down; the anterior pair commence just where the pedicles of the basisphenoid begin to lift above the level of the cranial floor. Here they are but small nearly circular canals; passing forward they very rapidly expand laterally, and come to underlie nearly the whole width of the cranial floor between the two sphenoptic fissures. At the transverse level of the anterior boundary of those fissures, the space enters the substance of the orbitosphenoid, and again narrowing from side to side terminates before the narrowest portion of the sphenoidal cavity is reached. A most careful examination of several disarticulated skulls has failed to reveal any definite foramen or canal connecting either of these cavities with the cranial cavity or the orbit. The roof and side walls of the space are demonstrably constituted by the basisphenoid behind and by the orbitosphenoid in front. Where the cavity extends into the orbitosphenoid, although confined to the area above the synpterygoid, that bone does not contribute to the floor, there being a very definite floor formed by the orbitosphenoid. This floor comes away with the bone when the skull is disarticulated, so that with the orbitosphenoid alone in hand one may study the shape and constitution of the anterior portion of the cavity. In the region of the basisphenoid that bone and the synpterygoid are intimately fused, and cannot be disarticulated. It is therefore not possible to assert that this or that bone forms the floor, but appearances support the belief that it is formed by the synpterygoid.

The posterior cavities commence in front immediately behind the front pair, separated by a narrow but solid bony partition. They broaden very rapidly and then narrow slightly again, proceeding back on either side of the mid line. The septum dividing them terminates abruptly at the level of the auditory hiatus, so that the cranial floor behind this level roofs a cavity which extends uninterruptedly from side to side. As the cranial floor becomes narrower as the basioccipital is reached, so also does the underlying cavity. Its terminal portion is truly conical, lies beneath the exoccipital component of the cranial floor, and excavates the body of the basioccipital. One definite opening and one only has been detected whereby structures within this larger posterior cavity may become continuous with others without. This single opening is a fissure on the left side of the centre, and through it passes a blood vessel. But inasmuch as there is no other foramen or canal of appreciable size opening into the cavity one is forced to conclude that the blood vessel is a nutritive one entering the cavity rather than issuing from it.

In the *Palate* and upper jaw there are features of particular interest.

The *Hyomandibular* has a rather longer line of attachment than is the rule, and at the forward end the attachment is further strengthened by the development of a spur which fits very nicely into a socket on the alisphenoid just above the prootic foramen. This spur forms the lower end of a low ridge which crosses the bone directly away from the skull. As is common the bone is traversed by a branch of the mandibular nerve. The canal for this nerve commences as a groove behind the ridge just described; half way across the bone it becomes completely enclosed, and its distal opening is into an interruption of the hyomandibular-symplectic suture, so that it may be said to open upon both ventral and dorsal surfaces. There is a well developed face upon the posterior margin for articulation with the preopercle.

The *Quadrate* calls for but brief mention. Rhomboid in outline it is firmly held in place by an interdigitating suture with the symplectic, and connected to the hyomandibular by cartilage, so that in the dried skull there is a marked gap between the two.

The arcuate *Symplectic* is as firmly sutured to the upper end of the posterior margin of the hyomandibular as it is to the quadrate.

In the typical piscine subocular arch there are in front of the quadrate four bones, in *Tandanus* as in some other siluroids there are but three.

The flattened elongated bone in front of the quadrate is sutured also to the outer anterior corner of the hyomandibular, and in front it is attached by fibrous tissue to the rough side of the orbitosphenoid. To the outer side of this attachment there is a small bone sutured to that just mentioned and attached by fibrous tissue to the hinder border of the alveolar plate of the premaxilla.

Attached to the dorsal face of these two bones just where they are sutured together is the hinder swollen end of a rod of bone, which, passing forward, is attached by a fibro-cartilaginous pedicle to the outer anterior angle of the prefrontal. Continued forward this rod provides a point of attachment for the labials of its side.

Though metamorphosed somewhat, that portion of the rod of bone which projects to provide support for the labial bones, is recognisable beyond doubt as the forward projecting strut so very constantly present in the maxilla of other fishes, and there also providing support for the labial bones. The attachment to the prefrontal by fibro-cartilage is a further feature which confirms the identification of this rod of bone as the maxilla.

As an aid to the identification of the two bones between the quadrate and premaxilla, the subocular arch and suspensory bones of *Brosmius brosmius* have been drawn. The usual number of bones are here present; the *os transversum* is very much reduced, the quadratojugal expanded and plate like, the palatine reduced, and the reduced and toothless maxilla continued forward into a labial strut rather longer than is usual.

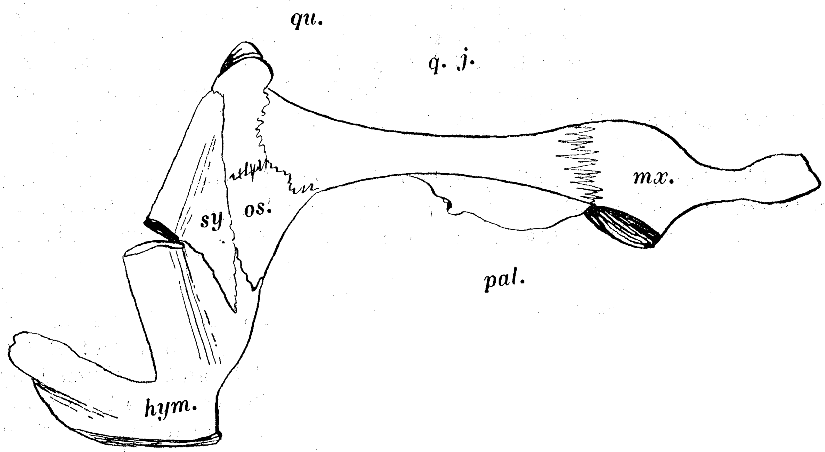

Fig. 5.—*Brosmius brosmius.* Right suspension and subocular arch viewed from below.

It will be at once apparent that in the neighbourhood of the quadrate the posterior of our two doubtful bones corresponds only to the quadrato-jugal. The *os transversum* is pretty certainly absent, and the small bone in front must be the palatine. Apparently the weakening of the palatal arch, which occurred with the loss of the support afforded by the intimate and rigid suturing of the maxilla to the other elements, has in this case been compensated by the expansion of the quadratojugal medially and its attachment to the orbitosphenoid, the palatine being thereby given a position apparently to the outer side of the quadratojugal.

The *Premaxilla* is composed of a heart-shaped or triangular dental plate and a spur-like palatine lamina projecting back from the hinder border thereof. The dental plate fits on to the lower surface of the ventral prong of the mesethmoid. The apex of the triangular plate is anterior in situation and lies upon the ventral face of the body of the mesethmoid, just behind the centre of its length. The palatine lamina lies below and in contact with the hinder moiety of the ventral prong of the mesethmoid and the fore end of the synpterygoid.

The *Premaxillary Labials* have an elongated triangular dental plate from the posterior margin of which a "nasal" lamina rises upwards and backwards when the bones are in situ. The two maxillae are attached by fibrous tissue to the edge of the down turned spatulate terminal plate of the mesethmoid. The attachment is to the inner third of the front margin of the dental plate and the dorsal surface of the bone above. The two bones are also attached to one another by fibrous tissue along the narrow side of the triangular dental plate, this attachment being of course in the mid line.

The *Maxillary Labials* are insignificant arcuate rods of bone attached at their inner end, behind to the maxilla, ventrally to the nasal lamina of the maxillary labial, and in front to the nasal bone. The distal half of the bone is free and projects out and back, continuing the line of the front margin of the premaxillary labial.

The Nasal is a small rhomboidal scale of bone, which is hung between the inner half of the maxillary labial above and behind it, and the outer half of the front margin of the premaxillary labial in front.

The arrangement of these bones in the snout is such that an incomplete bony capsule is formed on either side of the fore end of the mesethmoid. Of this capsule the floor is complete and is formed by the upper surface of the premaxillary labial. The front wall, wanting medially, is supplied by the nasal. The roof, formed by the inner half of the maxillary labial, slopes rapidly laterally, and therefore forms the outer wall. The posterior wall is supplied by the nasal lamina of the premaxillary labial. It would perhaps have been more truly descriptive had this "nasal capsule" been described as a bony trough supplied with complete walls and roof in its outer half. The portion of the capsule enclosed by soft tissue is perforated by the nasal apertures in front and by the nerves and blood vessels behind.

The foregoing description is based on a fine range of heads obtained for me by Mr. J. S. Caldwell, Inspector of Fisheries, to whom my thanks are due.

With two exceptions the descriptions of the relations of the bones to one another have been verified by actual disarticulation. None of my specimens were young enough to enable me to disarticulate synpterygoid from basisphenoid or parietals from supraoccipital. The mode of determining the extent of the fusion in the first case is already stated. My youngest specimen, a little younger than that figured, and the specimen figured, show what I am confident are sutures as indicated in the drawing. The verity of these sutures is however questioned by the fact that Koschkaroff[4] describes large dorsal laminae for the supraoccipital, and terms the bones in front thereof "fronto-parietals" in all the siluroid skulls dealt with in his memoir. Schelaputin[5] similarly describes and figures the bones in *Clarias*. Had I not these two young skulls of *Tandanus* I should in like manner have failed to find parietal bones. Maybe I am in error, but I believe that had Koschkaroff and Schelaputin had younger material they would have described them as I have done. At a later date I hope to confirm or correct my description.

[4] Koschkaroff—Bull. Soc. Imp. Nat. Moscou, xix, 1905 (1906), pp. 209-307.
[5] Schelaputin—Op. cit., pp. 85-126.

It will be observed that *Tandanus* approximates in its dorsal covering bones, *Akysis, Arius* and *Melapterurus*.

The palatine of my description is present in several of the siluroids described by Koschkaroff, notably *Akysis* (fig. 21, p. 237, *Os. d*) but is deemed by that writer to be merely an ossification in fibrous tissue, though he admits a semblance to a "pterygoid" (p. 244).

I have to admit that though I have applied the name symplectic to a bone in the previous description, I have been unable to entirely satisfy myself that the bone in question would not be more correctly termed preoperculum as is done by Koschkaroff and other writers. Whilst of the opinion expressed I leave the question *sub judice*.

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Index to abbreviations used in the drawings:—

b.	*basioccipital*
epi.	*epiotic*
ex.	*exoccipital*
f.	*frontal*
for. proot.	*foramen prooticum*
hym.	*hyomandibular*
lab. 1.	*premaxillary labial*
lab. 2.	*maxillary labial*
mes.	*mesethmoid*
mes. pg.	*synpterygoid.*
mx.	*maxilla*
n.	*nasal*
op.	*opisthotic*
orb.	*orbitosphenoid*
os.	*os transversum*
ot.	*sphenotic*
p.	*premaxilla*
pal.	*palatine*
proot.	*prootic*
pt.	*pterotic*
q.j.	*quadratojugal*
qu.	*quadrate*
s.	*supraoccipital*
sph.	*alisphenoid*
sy.	*symplectic*
x.	*sphenoptic foramen*