OSTEOLOGY OF *WALLAGO ATTU* BLOCH AND SCHNEIDER

PART I. OSTEOLOGY OF THE HEAD

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ABSTRACT

A study of the skull of *Wallago attu* shows that the neurocranium is platybasic. Both the anterior and posterior myodomes are absent. The trigenino-facial chamber is reduced to a foramen and the pars ganglionaris is represented only by a spacious depression on the antero-dorsal aspect of the prootic. The rostral, parietals and basisphenoid are apparently absent. The supraoccipital does not contribute to the foramen magnum.

There is no temporal fossa but the post-temporal arcade is represented by the posterior supraoccipital ridge. The relationship of the opthalmicus profundus to the lateral ethmoids and the vestiges of the orbitonasal and spiracular canals are reported here for the first time in the Siluroidei.

The posterior firm interdigitation of the lateral ethmoids with the sphenotics seems to be a primitive feature. There is a firm articulation between the prevomer and the lateral ethmoids. The orbitosphenoid is not tubular. The reduction in the size and number of the pterygoids and the nature of the articulation of the ectopterygoids to the surrounding bones seems to be a measure of evolution in the Siluroidei.

In the visceral skeleton, the maxillaries support the maxillary barbels. The palatines are reduced. The pre-maxillaries stop far short of the angle of the mouth. The symplectics and basihyal are absent. A comparative study seems to indicate that the bones carrying the dorsal patches of pharyngeal teeth are the fourth pharyngobranchials.

INTRODUCTION

The osteology of catfishes was first studied by Bliss (1870–71). He studied the anterior vertebrae of *Doras niger* and noted that the tendency for fusion is similar to that found in Sturgeons and Plagiostomes. The complete osteology of *Amiurus* was worked out for the first time by McMurrich (1884). He came to the conclusion that the Siluroids are a highly specialised group due to the absence of the eye muscle canal and the absence of cartilage. Wright (1885) studied the skull of Hypophthalmus and was the first to name the complex centrum. He also stated that the suboperculum is absent. Regan (1911) studied the osteology of the Siluroidei from a taxonomic point and Kindred (1919) was first to make a developmental study of the bones of the head and fix their true homology. He noted a relationship with the Ganoids shown by a primitive relation of certain parts. Frost (1925) and Adams (1940) made a similar study of the otoliths. Bhimachar (1933) and Gregory (1933) made a comparative study of the skull, the former author restricting his studies to certain Indian species. De Beer (1937) made a critical study of the homology of the bones of the skull and Eaton (1948) tried to correlate the form and function of the head in *Ictalurus*. Nawar (1954) gave a reasonably complete account of the osteology of *Clarias lazera*.

It is therefore clear that not much work has been done on the osteology of the head of Siluroidei. The complete osteology of only two species has been studied belonging to the families Amiuridae and Clariidae. As regards the family Siluridae to which *W. attu* belongs, very little has been done excepting a page description of the skull of *W. attu* by Bhimachar (1933) and a shorter account of the osteology by Regan (1911). The complete osteology of the head of even a single species of this important family has not been worked out in spite of the many points of interest.

The author has therefore attempted to study in detail the osteology of the head of *W. attu*. The osteology of the remaining parts will be published as a series under the following heads :

Part II—Osteology of the vertebral column and associated ribs, weberian ossicles and median fins.

III—Osteology of the pectoral and pelvic girdles and paired fins.

IV—The lateral line ossicles.

Material and Methods

Over a hundred specimens of *W. attu* were examined ranging in length from 3 inches to over 3 feet. The collections were mostly made in person from the fishing centres of Changanacherry and Trivandrum. A few specimens over 2 feet were collected during the South-west monsoon flood from the Vembanad lake.

As a rule skeletons over 6 inches were prepared by the maceration process. Care was taken to locate the positions of the surface lying dermal bones and other bones which are loosely attached. They were subsequently replaced in situ on the dry skeleton by means of adhesive cement or by passing wires through the lateral line canal system wherever present.

A great advantage of this method of preparation was that the freshly prepared skeleton was still flexible and the degree of relative movement possessed by the different parts of the skeletal system could be studied.

The skeleton of specimens less than 6 inches was prepared by the alizarin technique and was used for the study of the position of surface lying dermal bones. Disarticulated skeletons were also studied.

Osteology of the Head

The head skeleton or the skull *W. attu* is a well ossified compact structure. The chondrocranium is ossified excepting small portions in the cranium. The main cartilaginous part is the posterior ethmoid region which remains unossified as the internasal septum. There are also cartilaginous surfaces on the lateral ethmoids* for the palatines. The prootics have an inner lining of cartilage and are separated from the exoccipitals by cartilage. Cartilage forms the floor and side walls of the foramen magnum and the epiotics have cartilage between the exoccipitals and pterotics. Most of the bones are well ossified, hard and are strongly connected with one another. The sutural connections formed by the interlocking of splint like processes are so intimate that they are in many cases invisible in the prepared skull. Many of the dorsal bones have shallow impressions on their dorsal surface.

Viewed from above, the skull is wedge shaped (T. Fig. I), with the point of the wedge directed anteriorly. The greatest width is in the auditory region and the length is about $1\frac{1}{2}$ times the maximum width. The side view (T. Fig. II) presents a triangular outline. The greatest height is in the region of the pre-opercular and this is about two times the length of the skull. The orbits are not well defined and the post-orbital process of the sphenotic is rudimentary. Posteriorly (T. Fig. III) there are seen the five processes characteristic of the teleostean skull—the two pterotic, the two epiotic and the supraoccipital spine.

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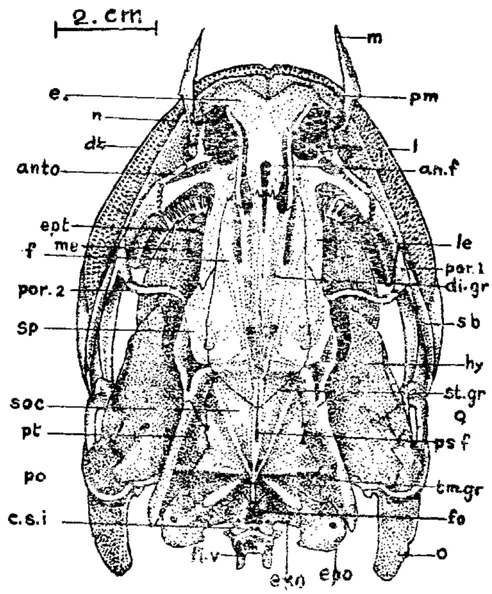
* The terminology of bones included in this paper is according to De Beer (1937) unless otherwise stated.

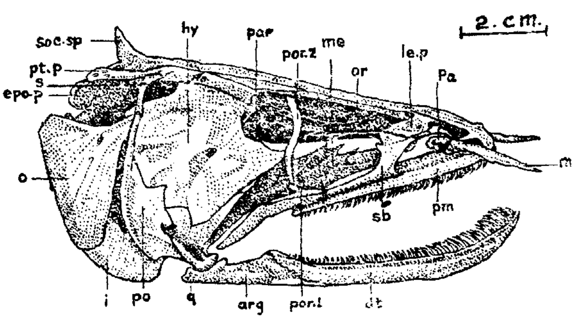
The skeleton of the head is composed of the following parts:

1. The neurocranium consisting of the cranium enclosing and protecting the brain and the sense capsules which protect the olfactory, optic and auditory organs.
2. The visceral arches and associated bones which form the jaws and the hyobranchial skeleton to support the gills.



TEXT-FIG. I.

Dorsal aspect of the skull (Hyoid cornua and Branchial arches removed)



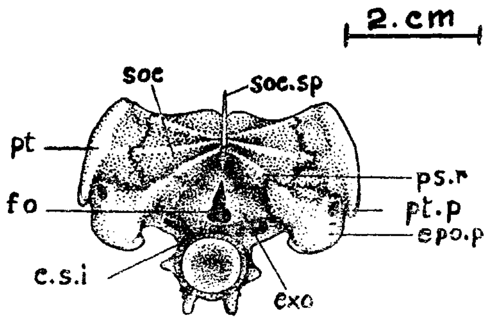
TEXT-FIG. II.

Lateral aspect of the skull (Hyoid cornua and Branchial arches removed)

1. The neurocranium

The neurocranium is platybasic (Kindred, 1919) as the cavum cranii extends widely up to the ethmoid region (T. Fig. IV). The mid-dorsal line of the cranium (T. Fig. IV) is not straight and the anterior 2/3 forms an angle of about 30° with the mid-ventral line. The mid-ventral line of the cranium (T. Fig. IV) is perfectly straight and the posterior region forms the deepest part.

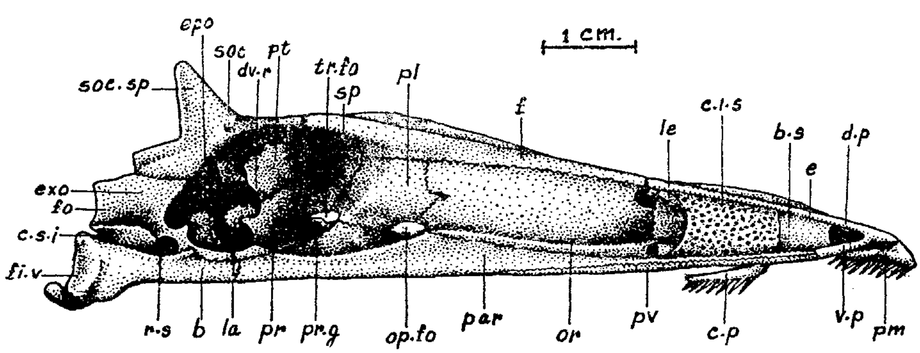
There are two narrow fontanelles in the roof of the cranium along the mid-dorsal line. The anterior fontanelle (T. Fig. I, an. f.) is between the ethmoid and the anterior region of the frontals. The posterior fontanelle (T. Fig. I, ps. f.) is between the posterior region of the frontals and the supra occipital.



Text-fig. III.

Posterior aspect of the skull (Hyoid cornua and Branchial arches removed)

The dorsal surface of the cranium is flat, sloping forwards and slightly backwards. The anterior end—the ethmoid region—is broadly obtuse. The width then sharply decreases in the preorbital region to provide space for the orbit and then again gradually increases beyond the orbit till the posterior extremity of the neurocranium. Hence the lateral edges beyond the orbits are slightly divergent.



Text-fig. IV.

Median aspect of the bisected skull (Hyoid cornua and Branchial arches removed)

From the midlateral region of each frontal a shallow groove arises—the dilator groove (T. Fig. I, di. gr.)—which runs outward towards the sphenotic and lateral ethmoid and terminates. There are two other grooves—the temporal groove

(T. Fig. I, tm. gr.) and the supratemporal groove (T. Fig. I, st. gr.) which are deeper. The more lateral of the two—the temporal groove—is the deeper and consists of three portions—an anterior portion in the anterolateral supraoccipital and antero-mesial pterotic regions, a middle portion in the postero-lateral supraoccipital, postero-mesial pterotic and anterior epiotic, and a posterior portion in the posterior supraoccipital, anteromesial epiotic and anterodorsal exoccipital regions. The supratemporal groove is anterior and inner to the temporal groove. It is shallower and originates from the mesial posterior region of the frontal. Anteriorly from the sphenotic it slants diagonally inwards and proceeds to the base of the supra-occipital spine, by which it is separated from its fellow of the opposite side.

The midventral line of the cranium is keeled and in the posterior region, due to the depth of the keel, two large triangular lateral surfaces are formed, one on each side, for the attachment of muscles. There are two shallow wide fossae—one on each side in front of the auditory chamber bounded by the pleurosphenoids, sphenotics, and posterior regions of the frontals and orbitosphenoid.

The posterior surface of the neurocranium is only a gradual slope from the supraoccipital backwards. It forms an obtuse angle with the dorsal surface of the skull.

The neurocranium is divided into the following regions:

The ethmoidal region.

The orbito-temporal region.

The otic or auditory region.

The occipital region which articulates behind with the vertebral column.

The Ethmoidal Region

This is the anteriormost region of the neurocranium situated in front of and at a lower level than the frontals. It consists of those bones developed in relation to the snout and nostrils and comprises of the following: the ethmoid, the lateral ethmoids, the nasals, and the prevomer (Plate XII, Figs. 1–4).

The *ethmoid* is a large irregular median bone with anterior lateral processes —ethmoid cornua—(Plate XII, Fig. 1, e.c.). Posteriorly it is bifurcated into two horizontal processes (Plate XII, Fig. 1, h.p.) that go to meet the frontals and are tucked beneath them. These processes can be traced as faint flat ridges up to the anterior end of the bone. The body of the bone is hollow and posteriorly it is divided into two lateral chambers by a thin bony septum (T. Fig. IV, b.s.). These two chambers unite with one another anteriorly and together form the anterior portion of the ethmoidal cavity. Thus, this region of the ethmoid may be said to be split into a dorsal and a ventral plate (T. Fig. IV, d.p. and v.p.) which form an angle of about 30° with one another at the anterior end. The bone is broad anteriorly and the ethmoid cornua project laterally as stout horns, forming part of the anterior wall and floor of the nasal capsule (T. Fig. I, e.). The dorsal surface of the bone is smooth, ventrally there is a small backward projection for articulation with the parasphenoid. Both the dorsal and ventral articular surfaces are highly split up into splint-like processes for articulattion with the adjoining bones.

The ethmoid articulates with the premaxillaries anteriorly, with the para-sphenoid, and prevomer ventrally, with the frontals postero-dorsally and the nasals and lateral ethmoids laterally.

The *Lateral Ethmoids.* These are paired bones situated one on either side of the ethmoid. Each is a stout bone and has a central body from which arises a stout lateral process called the lateral ethmoid process (Plate XII, Fig. 2, le.p.) or the antorbital process. There is another less stout but longer process situated posterior to the former and called the postero-lateral ethmoid process (Plate XII,

Fig. 2, ps.l.p.). These two lateral processes of the lateral ethmoid make an angle of about 40° between them and form the anterior and mesial boundaries of the orbit. Posterio-mesially between the ethmoid, frontals and lateral ethmoid, there is an unossified region for the passage of the ophthalmicus superficialis. In the centre of the dorsal surface of the body of the lateral ethmoid there is a foramen for the exit of the ophthalmicus profundus (Plate XII, Fig. 2, fo.o.p.) which enters the bone through another ventromesial foramen. At about the centre of the ventral surface of the body of the bone is a small foramen through which a vein draining the ventral surface of the snout enters the orbitonasal canal and leaves the same through another foramen situated just outer to the foramen for the entry of the ophthalmicus profundus. At the antorbital angle of the lateral ethmoid are two foramina, one above the other. The dorsal foramen is for the entry of the artery supplying the olfactory capsule and the ventral foramen for two of the branches of the ophthalmicus profoundus. The main body of the bone is scooped out mesially to form an inner dorsal and ventral plate thus forming the roof, floor and outer wall of the passage for the olfactory nerve which enters the nasal capsule through the olfactory foramen. Anterior to the origin of the lateral ethmoid process, there is a conspicuous antero-dorsal concavity—the posterior wall and floor of the olfactory capsule (Plate XII, Fig. 2, o.c.). At the posterior extremity of the nasal capsule is a large foramen—the foramen orbito-nasale—which leads into the orbitonasal canal. This leads into a spacious chamber in the body of the bone and also serves as passage for a vein draining the anterior region of the snout, an artery supplying the nasal capsule and anterior region of the snout and also for two twigs of the ophthalmicus profundus. The lateral ethmoid process bears a small stout anterior process (Plate XII, Fig. 2, an.p.) near its tip for articulation with the antorbital and suborbital. Outer to the concavity forming the posterior region of the olfactory capsule is a partially ossified stout anterior articular surface for articulation with the lachrymal and palatine (Plate XII, Fig. 2, ar.l. and pa.).

Dorsally the lateral ethmoids articulate with the ethmoid. The nasals lie over them. Ventrally there is articulation with the prevomer and orbitosphenoid. Posteriorly there is a firm interdigitation with the frontals and sphenoids by means of the postero-lateral ethmoid processes. Laterally there is a double flexible union with the suborbitals and a loose articulation with the antorbitals by means of the lateral ethmoid processes. Anteriorly there is a loose articulation with the lachrymals and a ligamentous union with the palatines.

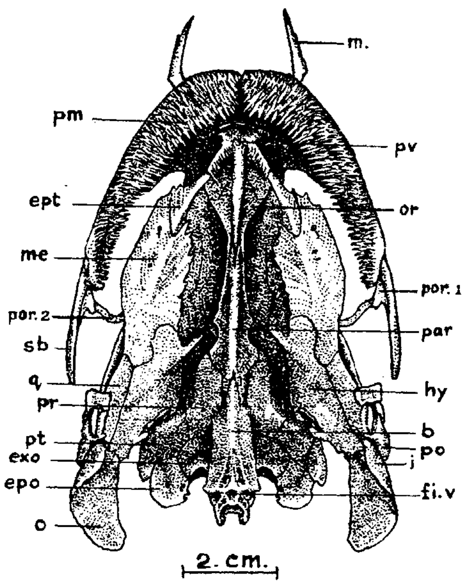
The two lateral ethmoids do not meet each other along the mid-dorsal line and the posterior roof of the ethmoid is incomplete. Thus an anterior fontanelle is formed, situated between the two posterior processes of the ethmoid and the frontals. This region forms the posterior portion of the ethmoidal cavity and there is a cartilaginous internasal septum (T. Fig. IV, c.i.s.) in continuation with the anterior bony septum which here divides the posterior ethmoidal cavity into right and left portions and forms the boundaries for the olfactory passages.

Both the ethmoid and lateral ethmoids are not traversed by any portion of the lateral line sensory canal.

The *Nasals*. These are two narrow long tubular bones lying one on either side of the ethmoid and over the lateral ethmoids, anterior to the frontals. They are not directly connected to the cranium but lie embedded in the connective tissue. The whole bone is traversed by the supraorbital portion of the sensory canal (Plate XII, Fig. 3 sor.c.). There is a small flat lateral process (Plate XII, Fig. 3, l.p.) near the anterior tip where the anterior end of the supraorbitalc anal bifurcates (Collinge, 1895).

The *prevomer* is a ventro-median 'T' shaped bone situated below the ethmoid. At the junction of the head with the body of the bone, there are two elongated conical processes (Plate XII, Fig. 4 c.p.) directed backwards and outwards and set with numerous minute conical teeth—the vomerine teeth—placed in shallow sockets. On the dorsal surface of the head of the bone there are two shallow lateral depressions one on each side. These form part of the floor of the nasal capsule. The body of the bone extends backwards below the orbito-sphenoid to meet the parasphenoid with which it is united by means of a prominent interdigitation. The middorsal surface of the prevomer forms part of the floor of the ethmoidal cavity.

The prevomer is united antero-dorsally with the ethmoid, antero-laterally with the lateral ethmoids and postero-dorsally with the parasphenoid (Plate XII, Fig. 4, ar. par. and T. Fig. V, pv.). Posteriorly the body of the prevomer lies in a groove below the parasphenoid.



TEXT-FIG. V.

Ventral aspect of the skull (Hyoid cornua and Branchial arches removed)

The anterior tip of the ectopterygoid is united by a strong ligament to a small vertically flat protuberance placed dorsal to the origin of the process carrying the vomerine teeth.

There is no rostral bone or cartilage. The space between the two anterior lateral horn like projections of the ethmoid is filled with connective tissue.

The Orbito-temporal Region

The orbito-temporal region is sub-divided into :

a. The orbital region.
b. The temporal region.

a. The Orbital Region

The orbital region consists of the bones that go to form the orbital ring. The orbits are large in size and lie in the anterior half of the neurocranium in the dorsolateral aspect and occupy about 1/3 of its length. Since the neurocranium is platybasic, the orbits are separated mesially by a narrow portion of the cranium. Each orbit is bounded anteriorly and dorsally by the lateral ethmoid, mesially by the prevomer, orbitosphenoid frontal and parasphenoid and postero-dorsally by the autosphenotic. Part of the ventrolateral and posterior boundaries are formed by the orbital bones, the lachrymals, the antorbitals, the suborbitals and the two post-orbitals (T. Fig. I, II and Plate XII, Figs. 5–9) formed in relation to the infraorbital branch of the sensory canal.

The *lachrymals*. Each is a small triangular bone lying in front of the antorbital and just over the anterior edge of the lateral ethmoid with which it is loosely articulated. The anterior angle of the bone is drawn out into a long spine like process (Plate XII, Fig. 5, sp.p.) which meets the ethmoid cornu thereby forming the outer lateral wall of the nasal capsule. Its posterior surface forms a small part of the anterior boundary of the orbit. The infraorbital branch of the sensory canal traverses the base of the bone emerging out at the inner posterior corner.

The *antorbitals*. These are small tubular bones found posterior to the lachrymals and anterior to the lateral ethmoid processes. They are united in front with the lachrymals (Plate XII, Fig. 6, ar.l.) and behind with the suborbitals and lateral ethmoids.

The *suborbitals*. These are long sturdy 'S' shaped bones found movably articulated with the lateral ethmoid process and lying posterior to the antorbital. They are about ½ the length of the neurocranium and are traversed by the infraorbital branch of the sensory canal (Plate XII, Fig. 7 ior. c.) in its thicker anterior half. They are broader at the two ends and lie parallel to the long axis of the neurocranium extending from the lateral ethmoid process to the posteroventral angle of the neurocranium. The middle region lies firmly apposed to the posterior region of the premaxilaries. Each suborbital is articulated dorsally to the lateral ethmoid (Plate XII, Fig. 7, ar.le.) and to the antorbital and below to the premaxillary.

The first postorbitals. Each is a small flat roughly triangular bone found above the dorsal midregion of the suborbital to which it is loosely articulated by its base. It lies embedded in the connective tissue and is also loosely articulated to the second postorbital above. The infraorbital branch of the sensory canal is continued into it along its dorsal border from the second postorbital (Plate XII, Fig. 8, ior.c.).

The *second postorbitals*. These are slightly curved slender tubular bones situated between the sphenotics and the first postorbitals. They form the posterodorsal boundary of the orbit and is traversed by the sensory canal throughout their length. Each lies just beneath the surface of the skin and is loosely attached to the lateral edge of the sphenotic above and to the first postorbital below. The infraorbital branch of the sensory canal is continued into it from the sphenotic (Plate XII, Fig. 9, ior.c.).

b. The Temporal Region

The temporal region is subdivided into :

b_1. The frontal region.
b_2. The sphenoidal region.

b_1. The Frontal Region

The frontal region lies posterior to the ethmoid region between it and the sphenoidal region. It is formed by the frontals and the orbito-sphenoid (Plate XII, Figs. 10 and 11).

The *frontals* are a pair of flat thin bones found between the ethmoid in front and the supraoccipital behind. They form the largest part of the dorsal surface of the neurocranium and occupy more than 1/3 of its length. The dorsal surface is sculptured to form the supra-temporal and dilator grooves (Plate XII, Fig. 10, di. gr., st. gr.). From the outer lateral angle of each there arises a canal which passes diagonally inwards to the median posterior region at a point about 1/3 the length of the bone from the posterior end. This is the supraorbital sensory canal (Plate XII, Fig. 10, sor.c.) which is continued into the nasal in front. At this point the sensory canal emerges from the bone and lies exposed in a groove giving rise to two branches at two different points which unite again before entering the sphenotic. Further behind, the sensory canal unites with its fellow of the opposite side and continues up to the posterior end of the frontals as a deep groove formed by the two frontals between them.

The two frontals do not unite along the anterior middorsal line for about more than ½ their length, thus forming the posterior 2/3 of the anterior fontanelle. In this region the frontals dip down vertically and mesially forming the side walls of the fontanelle. Posterior to this, the two frontals unite for a short space and then again diverage slightly forming the anterior half of the posterior fontanelle.

The frontals unite anteriomesially with the ethmoid, antero-laterally with the lateral ethmoids, and posterolaterally with the sphenotics. The posterior edge of the nasals lie over the anterior edge of the frontals outer to the ethmoidal suture. Posteriorly they unite with the supra-occipitals and posteroventrally with the pleurosphenoids. The frontal is a well ossified somewhat translucent bone.

The *orbitosphenoid* (Plate XII, Fig. 11). It lies below the frontals and forms the floor and side walls of the cranium in this region. The two lateral walls directed upwards do not unite with each other but unite with the downwardly directed mesial posterior portions of the frontals, thereby contributing to the side walls of the anterior fontanelle. The side walls are thinner, almost leaf like, when compared to the ventral portion of the bone. The ventral portion of the bone is broadened out and there is a groove on the ventral surface for receiving the elongated rod-like portion of the parasphenoid. The orbitosphenoid articulates anteriorly with the lateral ethmoids (Plate XII, Fig. 11, ar.le.) by means of two patches of interdigitation, dorsally with the frontals, ventrally with the parasphenoid and posteriorly with the pleuro-sphenoids (Plate XII, Fig. 11, ar. pl.).

b_2. The Sphenoidal Region

The sphenoidal region (T. Fig. I and IV) includes the parietals, pleuro-sphenoids and the parasphenoid. In *W. attu*, the parietals are absent (Goodrich, 1930). Their place in the formation of the roof of the skull seems to be taken up by the anterior region of the supraoccipital.

The *pleurosphenoids*. They are irregular curved bones situated between the sphenotics above the parasphenoid below and contribute to the formation of the posterior boundary of the optic and anterior boundary of the trigemino-facial foramen. Each forms the anterior lateral wall of the cranium in this region. The inner surface is concave and smooth while the outer surface is ridged forming the ridge found between the ventrolateral angle of the sphenotic and the optic foramen. The pleurosphenoids unite anteriorly with the frontals and orbitosphenoid, ventrally with the parasphenoid, ventrolaterally with the prootics and dorsolaterally with the sphenotics (Plate XII, Fig. 12, ar. f., ar. par., ar. pr., ar. sp., ar. or.).

The *parasphenoid* is a median, ventral, elongated, dagger shaped bone. The anterior elongated part of the parasphenoid which lies between the prevomer and orbitosphenoid reaches up to the ethmoid. Posterior to the orbitosphenoid the bone extends laterally upwards to form the characteristic wings of the teleostean parasphenoid.

The parasphenoid articulates anteriorly with the ventral plate of the ethmoid by means of splint like processes, dorsally with the orbitosphenoid and prootics, ventrally with the prevomer and posteriorly with the basioccipital (Plate XII, Fig. 13, ar.e., ar.or., ar.pr.; ar.b.). The posterior end of the prevomer overlaps the anterior end of the parasphenoid for about ½ the length of the latter and there is an anteroventral recess on the parasphenoid for the reception of the body of the prevomer.

The *myodome.* Both the anterior and posterior mydodomes are absent in *W. attu.* There is not even a myodomic space, (Bhimachar, 1933).

The *trigeminofacial chamber.* In *W. attu* the trigeminofacial chamber is not well developed. There is no well defined pars ganglionaris and at best it is represented only by a spacious depression or ledge on the antero-dorsal aspect of the prootic. The anterior and posterior openings are large and about equal to the length of the chamber or ledge in this case. They have almost coalesced and this makes the dorsal and lateral walls of the chamber separating it from the cranial cavity very negligible.

The trigeminofacial chamber may in this case be better called the trigemino-facial foramen (T. Fig. IV, tr. fo.) as it is only an elongated oval foramen with a broad concave ventral ledge which corresponds to the pars ganglionaris (T. Fig. IV and Plate XII, Fig. 14, pr. g.) in other forms.

The Otic or Auditory Region

The otic region (Plate XII, Firs. 14—18) is situated between the sphenoidal and occipital regions. It is formed of the following four chondral bones—the prootics, the pterotics, the sphenotics and the epiotics.

The *prootics.* These are large flat irregularly angular bones forming the anterolateral wall and the major part of the floor of the auditory capsule. The bone is concave and the concavity is divided, by a dorsoventral ridge (Plate XII, Fig. 14, dv.r.) which slopes backwards, into two portions. The anterior part forms the ventral ledge of the trigeminofacial foramen or the pars ganglionaris. The posterior part lodges the utriculus with the lapillus (Plate XII, Fig. 14, dep.la. and Fig. 18, la.) inside it, in a thin transparent shallow depression and also the horizontal semicircular canal. The dorso-ventral ridge itself has in its dorso-posterolateral region a tubular canal for lodging the anterior semi-circular canal.

The prootic unites with its fellow of the opposite side along the median ventral line over the parasphenoid, thus forming the ventral floor of the cranium in that region. It unites anteroventrally with the parasphenoid, posteroventrally with the basioccipital, anteriorly with the pleurosphenoid, posteriorly with the exoccipital, anterodorsally with the sphenotic and posterodorsally with the pterotic.

The *sphenotic.* These are irregular bones situated dorso-laterally just anterior to the prootic and between the pleurosphenoid and the frontals. The sphenotics are the anteriormost of the auditory bones forming the lateral edge of the roof of the cranium in this region. Each has a thick irregular spongy body and a flat horizontal anterior process. The dorsal surface is flat and smooth in contrast to the ridged irregular ventral surface. The lateral line sensory canal splits up into the supraorbital and infraorbital branches (Plate XII, Fig. 15, sor.c., ior.c.) in the sphenotic and thus there is a three rayed sensory groove in the posterior dorsolateral surface of the bone inner to the sphenotic ridge (Plate XII, Fig. 15, sp.r.). The outer ventrolateral surface of the bone has a groove for articulation with the hyomandibular. The antero-lateral angle of the bone is produced into a concave facet for accommodation of the spine like articular process of the hyomandibular. The ventral surface has a conical convexity in the inner posterolateral corner of the bone. This forms the portion of the cranium above the trigeminofacial foramen. The posterior tip of the bone is thick and spongy and bears a faint shallow depression which is the antero-lateral wall of the canal enclosing the anterior vertical canal.

On the anterior or orbital face of the body of the sphenotics there is a well defined concavity or pit towards the mesial region, inner to the articular facet for the hyomandibular. From the bottom of this concavity there is often a foramen (or sometimes a series of foramina) leading to a canal in the body of the bone. This canal is spacious and is directed posteriorly upwards and outwards opening behind by means of another posterior dorsolateral foramen placed dorsal to the groove for articulation with the hyomandibular. This is apparently the vestige of the spiracular canal.

The sphenotic articulates anteriorly with the lateral ethmoid, antero-mesially with the frontal, posteromesially with the supraoccipital, posteriorly with the pterotic, ventrally with the pleuro-sphenoid and prootic; ventrolaterally with the hyomandibular (Plate XII, Fig. 15, ar.le., ar.f., ar.soc., ar.pt.).

The *pterotics* are also irregular bones found in the posterior dorsolateral region of the neurocranium. The upper surface is smooth and shows shallow depressions corresponding to the anterior and median portions of the temporal groove. The lateral dorsal edge is formed into a ridge (Plate XII, Fig. 16, pt.r.) on a line with that of the sphenotic. This ridge corresponds to the bifid pterotic process found in other fishes, Dharmarajen (1936). The posterior end of the pterotic ridge is at a lower level than the preceeding portion. The pterotics form the posterior lateral portion of the auditory capsule and are traversed by the horizontal semicircular canal which perforates internally the lateral wall of the bone. Posteriorly the bone is traversed by the inner and outer branches of the lateral line sensory canal which unites in the pterotic ridge at about the middle of its length. It is then continued forward into the sphenotic as a single canal giving off the preopercular mandibular branch.

The pterotics adjoin the sphenotics anteriorly, the epiotic and exoccipitals posteriorly (Plate XII, Fig. 16, ar.sp., ar.soc., ar.epo.).

The *epiotics*. These are roughly semicircular bones forming the posterior corner of the auditory capsule. From its posterior end there arises a flat downwardly directed epiotic process (Plate XII, Fig. 17, epo.p.) the base of which is traversed by the inner branch of the sensory canal before passing on to the pterotics. Anteromesially the bone shows a small recess for the posterior vertical semicircular canal.

The epiotic unites laterally with the pterotic, anteriorly with the supraoccipital and mesially with the exoccipital (Plate XII, Fig. 17, ar. pt., ar. exo.). A small articular facet is present at the junction of the epiotic with the posterior end of the pterotic ridge. This facet is for the movable articulation with the epiotic limb (superior limb) of the post temporal (described along with the pectoral girdle in Part III of this series.).

The Occipital Region

This is the hindmost region of the neurocranium connected in front with the otic and frontal regions and behind with the first vertebra. It forms the posterior roof, wall and floor of the cranium and is pierced by the foramen magnum at about the centre of its posterior surface. This region consists of the following bones: a dorsomedian supraoccipital, a ventromedian basioccipital and lateral exoccipitals (Plate XII, Figs. 19–21).

The *supraoccipital*. This is the largest of all the occipital bones. It is flat, forming the roof of the cranium behind the frontals and bears a broad median posterior vertical occipital process, the *supraoccipital spine* which is about ½ the total length of the bone. The dorsal surface of the bone is smooth but grooved forming the posterior portions of the temporal and supratemporal grooves. The supraoccipital does not form the dorsal boundary of the foramen magnum as that region is cartilaginous due to insufficient ossification between it and the exoccipitals. There is a dorsomedian ridge and the anterior 1/3 of the bone is cleft in the median line giving rise to the posterior portion of the posterior fontanella (Plate XII, Fig. 19, ps.f.). The bone also shows three pairs of lateral ridges which arise from the base of the supraoccipital spine. These are the anterior, lateral and posterior supraoccipital ridges (Plate XII, Fig. 19, an.r., l.r., ps. r.) of which the last is the most prominent. The anterior ridge proceeds forwards and outwards and meets the angular ridge over the posterior region of the frontal and sphenotic as in *Silundia*, Bhimachar (1933). The lateral ridge goes outwards towards the central basal portion of the pterotic ridge and the posterior ridge goes backwards and outwards to meet with a similar ridge on the epiotic. The posterior supraoccipital ridge is traversed by the posterior vertical semi-circular canal.

On the ventral surface of the bone in the centre, there are two pairs of foramina one behind the other. The anterior and posterior pairs are for the passage of the ramus lateralis accessorius and the auditory nerve respectively. On the dorsal surface, on either side of the median ridge at the anterior region of the base of the occipital crest, there is a pair of prominent foramina for the exit of the ramus lateralis accessorius (Plate XII, Fig. 19, fo.l.a.).

The supraoccipital articulates in front with the frontals, laterally with the sphenotics and pterotics, posteriorly with the epiotics and ventrally with the exoccipitals with which it is only apposed, cartilage still persisting between the two (Plate XII, Fig. 19, ar.f., ar.sp., ar.pt., ar.exo., ar.epo.).

The *exoccipitals* are situated laterally on either side of the foramen magnum and meet each other along the ventromedian line above the cavum sinus imparis thereby forming its roof and the ventral and lateral boundary of the foramen magnum. Each is highly irregular in shape and shows a posterior, anterior, mesial and ventral aspects. Mesially there are two smooth depressions one above the other separated by a ridge. The dorsal depression leads to the foramen magnum (Plate XII, Fig. 20, fo.). The ventral depression is the cavum sinus imparis (Plate XII, Fig. 20, c.s.i.) containing the sinus impar. It leads from a deep recess closed posteriorly—the recessus sacculus (Plate XII, Fig. 20, r.s.) which lodges the saccule and lagena containing the sagitta and asteriscus respectively (Plate XII, Fig. 18, sa., as.). The median ridge forms the floor of the foramen magnum and the roof of the cavum sinus imparis.

Anteriorly there is a large anterolateral concavity which forms the posterior boundary of the otic capsule and contains the root of the vagus nerve. Viewed posteriorly there is a broad backwardly directed lateral ridge with a large foramen at its base. This is the foramen for the vagus nerve. Slightly dorsal to this is a small foramen for the exit of the branchial branch of the glossopharyngeal nerve. Anteroventrally towards the ventral median line is another small foramen for the exit of the palatine branch of the glossopharyngeal nerve.

The exoccopitals show clearly, posteriorly, the two lateral occipital condyles for articulation with the first vertebra which in this case is fused to the basioccipital.

The exoccipitals articulate anterodorsally with the supraoccipital, posterodorsally and posteroventrally with the epiotics, anteroventrally with the prootics, ventrolaterally with the pterotics and ventromesially with the basioccipital (Plate XII, Fig. 20, ar.soc., ar.b., ar.epo.). Below the occipital condyle there is a very small ventrolaterally directed process which unites with a similar process—the lateral process—of the basioccipital to form an articular facet for the lower limb of the posttemporal.

The *basioccipital* is a midventral bone forming the posterior end of the neurocranium. It is situated beneath the exoccipitals and is broad and thick posteriorly and thin, pointed and splintered anteriorly. As mentioned before it is fused with the ventral half of the first vertebra and has at its posterior end two ventral posteriorly directed processes (Plate XII, Fig. 21, ps.p.) which fuse with similar processes of the first vertebra and form articulations with the second as well as the complex vertebra. Anterior to this on each side is a slight concavity bounded in front by a small stout lateral process. This is the articular facet for the lower limb of the posttemporal (Plate XII, Fig. 21, ar.pst.).

The anterior third of the bone is tucked between the parasphenoid and the prootics. Posterior to this the bone is thicker and on the dorsal surface there is a median ridge separating two smooth shallow lateral depressions. These are closed posteriorly and form the floor and mesial walls of the recessus sacculi. The median ridge is concave posteriorly forming a well marked groove which corresponds to the floor and side walls of the cavum sinus imparis (Plate XII, Fig. 21, fl. c.s.l.).

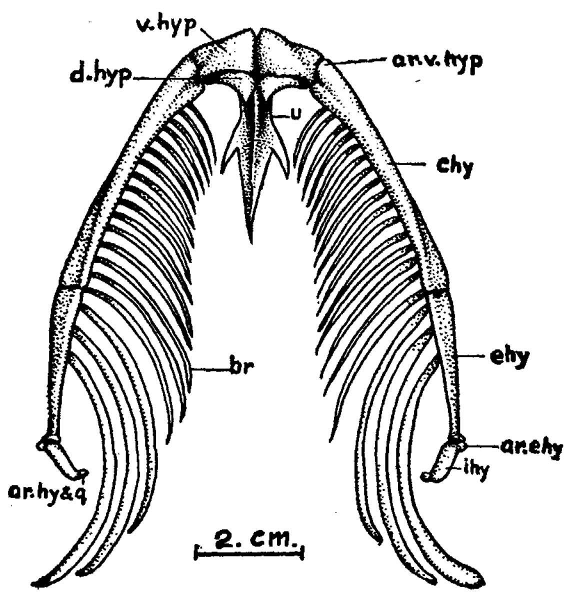
The basioccipital articulates anteriorly with the parasphenoid, antero-dorsally with the prootics, postero-dorsally with the exoccipitals and posteriorly with the posttemporals (Plate I, Fig. 21, ar. par., ar. pr., ar. exo., ar. pst.).

2. The Visceral Arches

The visceral arches lie mainly in the pharyngeal wall internal to the coelom and they encircle the buccal and pharyngeal cavities. They are described as follows:

The mandibular arch or the first visceral arch. This forms the skeleton of the palate and gives rise to the secondary jaws or the jaws of the adult (Plate XII, Figs. 22–29).

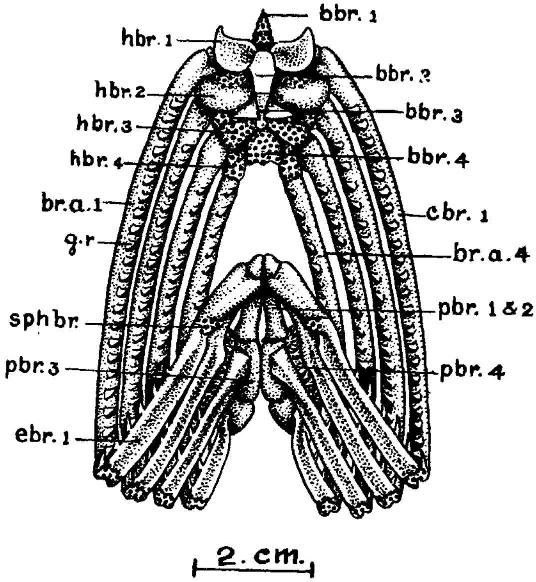
The hyoid arch or the second visceral arch. This forms the suspensorium and the hyobranchial skeleton (hyoid cornu) (Plate XII, Figs. 30–34 and T. Fig. VI).



Text-fig. VI.

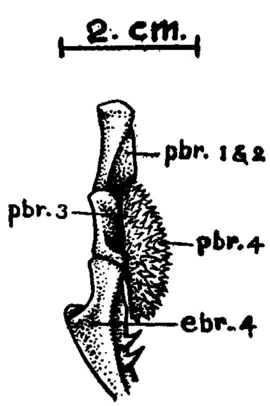
Hyoid cornua and associated bones

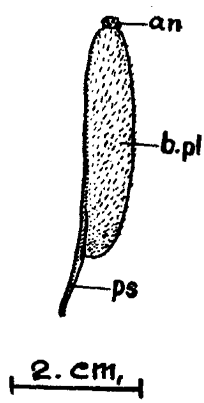
The branchial arches. The third to the sixth visceral arches from the four branchial arches which support the pharyngeal walls and the gills (T. Fig. VII and VIII).



TEXT-FIG. VII.

Branchial arches and associated bones





TEXT-FIG. VIII.

Fourth Pharyngobranchial

TEXT-FIG. IX.

Infrapharyngeal bone

The infapharyngeal bones. The seventh visceral arch is incomplete and is represented on each side by a single bone, the infrapharyngeal bone, which bears teeth for pharyngeal mastication (T. Fig. IX).

The Mandibular Arch

The primary upper jaw is formed of three chondral bones on each side—the palatine, the metapterygoid and the quadrate. A paired dermal bone— the ectopterygoid—gets attached to this arch. In the adult all the above bones form only the skeleton of the palate and part of the suspensorium. There are in addition two more paired dermal bones—the premaxillary and the maxillary—of which the former alone bear teeth and take part in the formation of the adult upper jaw. The maxillary is highly modified for the support of the maxillary barbel.

The primary lower jaw formed of paired Meckel's cartilage persists as small rods of cartilage inside the adult or secondary lower jaw. Paired dermal bones, the angulars and the dentaries form the adult lower jaw.

The *premaxillaries.* They are thick curved bones which unite with each other anteriorly in the middle line. They form the anteriormost bone in the skull and are broad anteriorly but tapering posteriorly. Each is flattened dorsoventrally and the ventral surface is set with numerous irregular rows of sharp conical teeth in sockets. The teeth are directed backwards, the larger ones towards the inside. The premaxillaries alone form the gape of the mouth. The dorsal surface has the lateral margins slightly elevated. There are two slight irregular protruberances near the anterior end on either side of the shallow concave articular surface for the ethmoid (Plate XII, Fig. 22, ar.e.).

The premaxillaries are united anteromesially with the ethmoid, and posteriorly with the suborbitals for about half their length. They have a strong ligamentous connection with the maxillaries. The palatines are apposed to them on the dorsal surface behind the maxillaries. The anterior dorsal surface of the premaxillaries between the ethmoid and the maxillaries form the floor of the nasal capsule. The skull is akinetic since the upper jaw is immovably fixed to the braincase.

The *maxillaries* are small rod like bones placed parallel to the long axis of the skull over the dorsal surface of the premaxillaries external to the ethmoid. Each has a double groove along its length on the ventral aspect and the anterior end is pointed and dorsally forms a sheath for the cartilage of the maxillary barbel. The posterior end is flattened from side to side and expands into a double convexity which fits into shallow depressions found on the anterior surface of the palatine forming an incipient gliding joint that allows lateral movement.

The maxillaries are ligamentously united to the premaxillaries ventrally and also mesially to the protruberances outer to the ethmoid. Posterolaterally they are movably articulated to the palatines (Plate XII, Fig. 23, ar.pa.).

The *palatines.* These are very small irregular bones placed above the anterior dorsal surface of the premaxillaries between the maxillaries and the lateral ethmoids. Anteriorly they form a gliding movable articulation with the maxillaries (Plate XII, Fig. 24, ar.m.) and posteromesially they have a strong ligamentous attachment to the lateral ethmoids. The posterior surface is irregularly concave for the attachment of muscles. The anterior spinous angle of the lachrymals lies apposed to them dorsally.

The *ectopterygoids.* These are small flattened bones found anterior to the metapterygoids and placed obliquely. There is a narrow rod like anterior portion and a broad flat and slightly dorsally concave posterior portion. They form the anterior roof of the palate. The ectopterygoids are ligamentously attached anteriorly to the prevomers just dorsomesial to the process carrying the vomerine teeth (Plate XII, Fig. 25, ar.pv.). Posteriorly they are loosely united to the metapterygoids (Plate XII, Fig. 25, ar.me.). The endopterygoids are absent.

The *metapterygoids* are large irregular flat bones placed almost vertically and parallel to the long axis of the skull. Anteriorly the metapterygoids are loosely articulated to the ectopterygoids, posteriorly they are firmly united with the quadrates and the hyomandibulars (Plate XII, Fig. 26, ar. ept., ar. hy., ar. q.).

The *quadrates* are more or less irregularly triangular bones found anterior to the preoperculars and below the hyomandibulars. The lower angle is thick and has an articular facet which is concave in the transverse direction and convex in the longitudinal. This articular facet is lined with cartilage and gives articulation to a corresponding surface at the posterior dorsal surface of the articulars. From the posterior lateral margin of the articular facet, there is a small splintered posterior process (Plate XII, Fig. 27, ps.p. and ar. po.) for articulation with the preoperculars. Anteriorly, the bone is divided into an inner and an outer limb; the former articulates with the metapterygoid and the latter with the antero-ventral portion of the dorsally directed free limb of the hyomandibular (Plate XII, Fig. 27, ar. me. and ar.hy).

The quadrates articulate ventrally with the angulars (Plate XII, Fig. 27, ar.ang.) posteriorly with the preoperculars, dorsally with the hyomandibulars and anteriorly with the metapterygoids. As the quadrates are immovably articulated to the neighbouring bones, the skull is monimostylic.

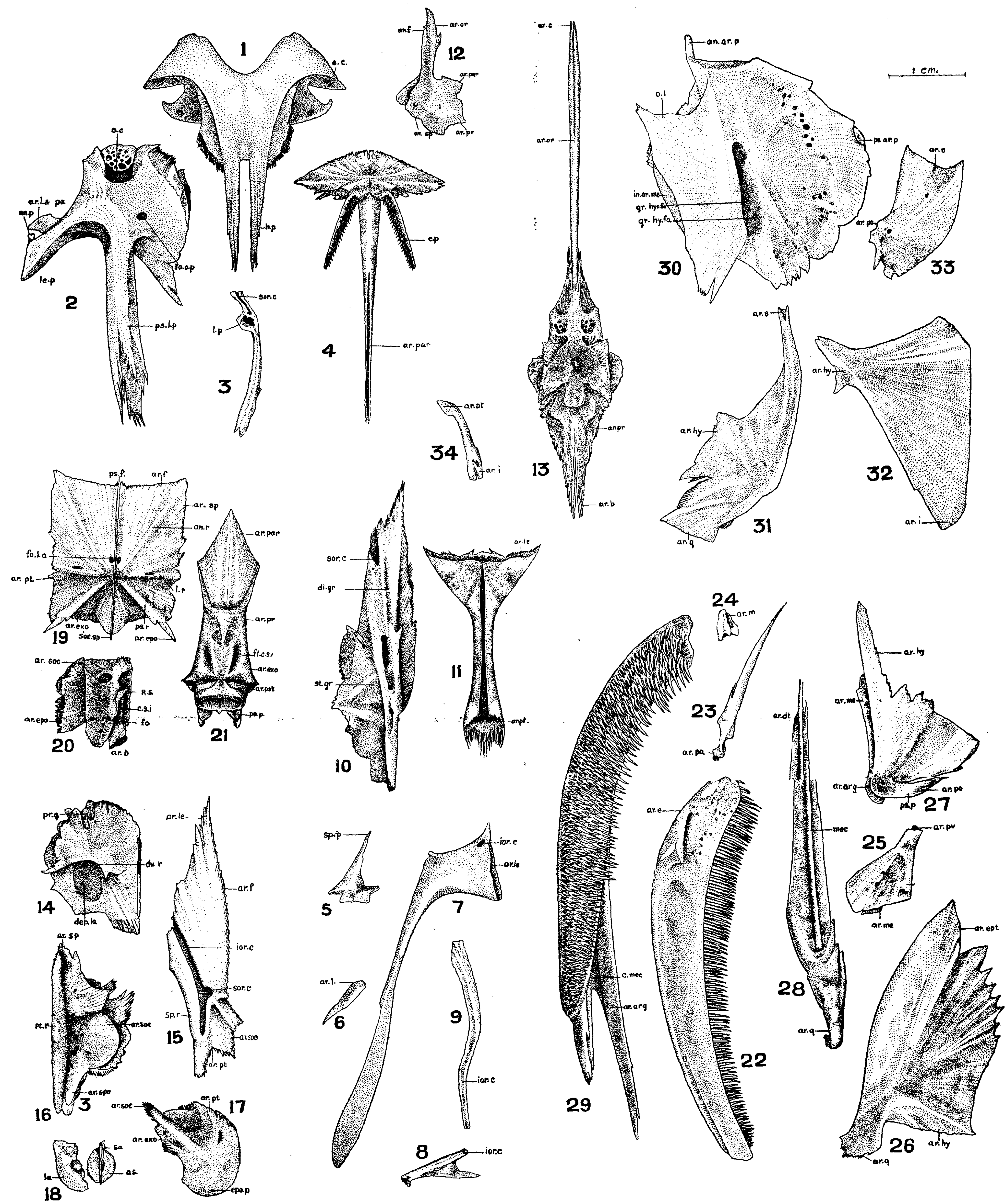
The *Angulars*. These are elongated bones, anteriorly thin, pointed splintered and hollowed out and this portion of each bone is overlapped by the dentary. Posteriorly, the bones are thick and solid. The remnant of the Meckel's cartilage is seen as a thin rod lying in the hollowed out portion (Plate XII, Fig. 28, mec.). It is attached to the solid posterior mesial portion of the angular and is continued forward into the tubular canal present in the dentaries.

The angulars articulate anteriorly with the dentaries, posterodorsally with the quadrates (Plate XII, Fig. 28, ar.dt.,ar.q.). The posterior end of the angular is ligamentously attached to the posterior ventral inner region of the preoperculars. The posterior lower surface of the angulars is traversed by the mandibular branch of the lateral line sensory canal.

The *dentaries*. These are curved elongated bones of uniform width forming about 2/3 the length of the lower jaw and carrying numerous sharp conical teeth in sockets. There is a posterior deep 'v' shaped indentation on the inner aspect of the bones for the reception of the angulars. The v-shaped indentation is continued forwards as a tubular canal (Plate XII, Fig. 29, c.mec.) in which extends the anterior end of the meckel's cartilages. The dentaries articulate with each other along the middle line, the articulation is lined with cartilage. Posteriorly, there is an articulation with the angulars (Plate XII, Fig. 29, ar. ang.).

On the outer dorsal edge, all along the length of each bone is a shallow groove in which runs the external branch of the mandibularis of the fifth cranial nerve. The anterior half of the mesial ventral edge shows anteriorly a longitudinal depression for the attachment of muscles. The mandibular branch of the sensory canal runs as a closed canal throughout the length of the bone on the inner ventral surface, outer to the above mentioned depression and there are nine sensory canal foramania distributed along its course.

The working of the adult jaws. The adult upper jaw is formed only by the premaxillaries and they are strongly united together at the anterior median line without the intervention of a rostral. This union between them is further strengthened by their firm attachment to the median ethmoid, which acts as an incipient copula. They are also indirectly attached to the ethmoidal region at two other places by means of the maxillaries and the palatines to the anterior region of the lateral ethmoids and by means of the suborbitals to the lateral ethmoid processes. Posteriorly, they have no connection either with the quadrate or with the lower jaw, since their posterior ends stop short a little anterior to the angle of the



Explanation of Figures

Fig. 1. Ethmoid. 2. Lateral ethmoid. 3. Nasal. 4. Prevomer. 5. Lachrymal. 6. Antorbital. 7. Suborbital. 8. First postorbital. 9. Second postorbital. 10. Frontal. 11. Orbitosphenoid. 12. Pleurosphenoid. 13. Parasphenoid. 14. Prootic. 15. Sphenotic. 16. Pterotic. 17. Epiotic. 18. Auditory ossicles. 19. Supraoccipital. 20. Exoccipital. 21. Basioccipital. 22. Premaxillary. 23. Maxillary. 24. Palatine. 25. Ectopterygoid. 26. Metapterygoid. 27. Quadrate. 28. Angular. 29. Dentary. 30. Hyomandibular. 31. Preopercular. 32. Opercular. 33. Interopercular. 34. Subtemporal.

mouth. However, the suborbitals to which the maxillaries are firmly attached extend beyond the angle of the mouth as far as the quardrates, thereby strengthening this region without minimising the elasticity of the mouth (T.Fig.II).

The adult lower jaw is articulated to the ventral angle of the quadrate, by a strong incipient ball and socket joint which allows up and down movement. The posterior end of the lower jaw is firmly attached by a strong tendon to the ventral end of the interhyal and the posterior lateral surface of the epihyal. The mandibular adductor muscles are inserted on the inner surface of the posterior region of the lower jaw, anterior to the quadrate articulation. The posterior ends of the premaxillaries are connected to the posterior region of the lower jaw by strong elastic dermal tissue, just anterior to the insertion of the above muscles.

Since the upper jaw is immovably fixed to the cranium, the mouth is opened or closed solely by the movement of the lower jaw. Due to the elasticity of the dermal connection between the upper and lower jaws at the angle of the mouth, the animal is enabled to open its mouth very wide in order to gulp in large pieces of food.

The Hyoid Arch

Each half of the hyoid arch consists of two segments : 1. The dorsal hyomandibula and 2. the ventral hyoid cornu. The hyomandibula consists of a single bone, the hyomandibular as the symplectic is absent. The hyoid cornu is composed of the following bones in a descending series : the interhyal, the epihyal, the ceratohyal and the two hypohyals. The basihyals are absent. Four dermal bones usually get associated with the hyomandibulars. These are the preoperculars, the operculars, the inter-opercular and the subtemporal. The suboperculars are absent (Bhimachar, 1933). Other dermal ossifications are the branchiostegals and the ventromedian urohyal which are attached to the hyoid cornu (Plate XII, Figs 30–34, and T. Fig. VI).

The *hyomandibulars*. These are large irregular thin flat bones situated vartically between the auditory capsule above and the quadrates below. Anteriorly each bone has two limbs, an inner mesial limb articulating with the metapterygoid and an outer dorsally directed free limb (Plate XII, Fig. 30, in.ar.me. and o.l.). Dorsally, there is a thickened flat articular surface for articulation with the sphenotic and the pterotic and anterodorsally there is a small thick spinous process—the anterior articular process (Plate XII, Fig. 30, an.ar.p.)—which fits into an articular facet formed by the anteroventrolateral edge of the sphenotic with the pleurosphenoid. At about the middle of the posterior edge, there is a third, thick ball like articular process—the posterior articular process (Plate XII, Fig. 30, pr.ar.p.)—for articulation with the opercular. Both the inner and outer surfaces of the bone are smooth. The outer posterodorsal surface bears two muscle impressions of the mandibular adductor muscles. Below this is a shallow groove for the passage of the hyoideus facialis nerve (Plate XII, Fig. 30, gr.hy.fa.). Anterodorsally there is another deeper groove (Plate XII, Fig. 30, gr.hyo.fa.) leading by means of an orifice into a small tubular canal in the dorsal region of the bone, the other opening of which is situated on the inner dorsal surface of the bone. This canal is for the passage of the main ramus hyomandibularis facialis nerve. On the anterior inner ventral surface of the body of the bone is a small tubular canal for the passage of a vein draining the lower jaw.

The hyomandibulars articulate anteriorly with the metapterygoids, dorsally with the sphenotics and pterotics, posteriorly with the operculars, preoperculars, and ventrally with the quadrates. The articulations with the auditory capsule and the operculars are movable and these together with certain parts of the articulations with the quadrates are lined with cartilage.

The *preoperculars*. These are thin cresent shaped bones placed posterior to the hyomandibulars and the quadrates. In each, the posterior edge is thick and convex. The anterior edge is thin, irregularly dentated and slightly folded on itself ventrally to give accommodation to the posterior mandibular ligement. The fold is external and so there is a channel like groove on the inner ventral surface, the posterior edge of which gives origin to a portion of the above ligament. The dorsal and ventral ends are pointed. The dorsal end lies apposed over the posterodorsal edge of the hyomandibular, while the ventral end is firmly interdigitated with the posterior process of the quadrate leaving a slit-like opening for the passage of the ramus mandibularis facialis. The bone is traversed by the preopercular branch of the lateral line sensory canal, which is divided into two ventrally below the middle region. The outer surface of the bone is ridged along the course of the inner sensory canal and indicates the limit of the origin of the mandibular adductor muscles. At about the middle line of the inner anterior surface there is a small oblique ridge bounding a shallow groove on its anterior side. The interhyal lies in this groove.

Anteriorly, the preopercular unites firmly with the hyomandibular and the quadrate; posteriorly it is loosely apposed to the opercular and the interopercular. The interhyal lies in an oblique groove in the middle of its inner surface (Plate XII, Fig. 31, ar. s., ar. hy., ar. q.).

The *operculars* are irregularly triangular bones placed posterior to the preoperculars. The apex of each bone is placed anterodorsally and is thick with a somewhat deep socket for articulation with the ball like posterior articular process of the hyomandibular (Plate XII, Fig. 32, ar. hy.). This joint allows lateral movement for opening and closing the opercles. The muscle—dilator operculi—takes origin from all over the outer surface of the opercular, and the fibres lie in the laminae of the bone. The apex of the opercular above the articulatory concavity is produced into a thick, blunt, anteriorly directed process for the insertion of the muscle levator operculi. On the dorsal inner surface of the bone, there is a low ridge running a little below and parallel to the dorsal edge. The muscle adductor operculi is inserted all long the inner surface of this ridge.

The operculars are united anterodorsally to the hyomandibulars and ventrally to the interoperculars (Plate XII, Fig. 32, ar. i.). The preoperculars are loosely apposed to it for some distance along the anterior edge.

The *interoperculars*. These are thin flat bones with a convex ventral edge and a concave dorsal edge. They are placed below the operculars between it and the preoperculars, and thereby occupy in part the position or the subopercular (of other fishes) which is absent here.

The interopercular is united to the opercular above and the preopercular in front (Plate XII, Fig. 33, ar.o., ar.po.) the union with both these bones being not very firm.

The *subtemporals*, (Bhimachar, 1933). These are small elongated tubular bones developed in connection with the dorsal region of the preopercular mandibular lateral line canal. They are situated between the middle of the lateral edge of the pterotics and the dorsal edge of the preoperculars with both of which they are loosely united (Plate XII, Fig. 34, ar.i., ar. pt.).

The *interhyals* (T. Fig. VI, ihy.) are small rod like bones found between the hyomandibulars and the epihyals and posterior to the quadrates. They lie in shallow grooves formed by the inner surfaces of the preoperculars and the quadrates, ventral to the orifice for the exit of the hyoideus facialis nerve. They are firmly united dorsally to the hyomandibulars and anteriorly to the quadrates (T. Fig. VI, ar. hy. and ar.q.). Their ventral ends have a concave articular facet for articulation with the epihyals (T. Fig. VI, ar.ehy.). This articulation allows up and down movement to the epihyals. Posteriorly they unite with the preoperculars and the posterior mandibular ligaments are partially attached to the ventral ends of these bones.

The *epihyals* (T. Fig. VI, ehy.). These are elongated flattened triangular bones occurring between the ceratohyals and the interhyals. The posterior end of each is pointed and the outer dorsal edge gives attachment to a portion of the posterior mandibular ligament. Anteriorly each epihyal is broad and adjoins the ceratohyal. Between the two bones is a distinct layer of cartilage, the middle region of which is interrupted by a strong interdigitation of splints arising from both bones. The splints are present only on the outer surface of the bones and hence the cartilagenous connection is continuous on the inner surface. The mesial and outer surfaces of the bones are smooth and a low ridge on the ventral edge gives attachment to the last four branchiostegals of which the anteriormost is found at the junction between the epihyal and the ceratohyal.

The epihyals are movably articulated to the ventral end of the interhyals. Anteriorly they are firmly articulated to the ceratohyals.

The *ceratohyals* (T. Fig. VI, chy.). The ceratohyals are elongated bones situated between the epihyals and the ventral hypohyals (T. Fig. VI, ar.v.hyp.). Each is double the length of a epihyal and narrower in the anterior middle region than at the two ends. The posterior end is broad (as broad as the adjoining end of the epihyal) and flat, while the anterior end is thick and cylindrical with a spongy concave articulatory facet for the reception of the outer end of the ventral hypohyal. The inner ventral edge of the bone has a low ridge, in continuation with that on the epihyal for the attachment of the remaining anterior branchiostegals, excepting for a small region at the very anterior end.

The *hypohyals*. There are two on each side,a dorsal and a ventral (T. Fig. VI, d. hyp., v. hyp.), situated anterodorsal and anterior to the ceratohyals respectively. The ventral hypohyal is by far the larger and longer of the two.

Each *dorsal hypohyal* is a small, thin, irregularly triangular bone found between the first hypobranchial and the ventral hypohyal. The dorsal hypohyal is separated from its fellow by the cartilagenous first basibranchial and between it and the first hypobranchial is a distinct thin layer of cartilage. A cartilagenous layer is also present between the hypohyal and the ceratohyal as a thin lining on the articulatory surface, but the two are united by slight interdigitations on the outer dorsolateral surfaces. The dorsal hypohyals adjoin the first hypobranchials behind and the ventral hypohyals in front.

The *ventral hypohyals* are solid irregular bones with a smooth rounded anterior surface and a concave posterior surface. Mesially each is united firmly with its fellow of the opposite side, a thin lining of cartilage intervening between the two. The posterior end is thicker and dips down ventrally forming an eliptic convex articular surface for uniting with the ceratohyal. Each ventral hypohyal unites dorsally with the dorsal hypohyal, posteriorly with the ceratohyal and mesially with the median urohyal and with its fellow of the opposite side.

The *urohyal* (Harrington, 1955). The urohyal is a median segittal membrane bone situated posterior to the hypohyals (T. Fig. VI, u.). It is irregular in shape, with a dorsoventrally flattened trident shaped ventral base having a laterally compressed longitudinal lamina of bone along the dorsal middle line. The teeth of the trident shaped base are directed posteriorly, the middle tooth being more than twice the length of the lateral teeth. The narrow anterior end is thick and is articulated with the two hypohyals and the cartilagenous first basibranchial. The vertical lamina of bone is broad (as broad as 1/3 the total length of the bone) and extends from the anterior end longitudinally along the dorsal middle line, stoping short a little anterior to the posterior tip of the middle tooth. The muscles from the pectoral gridle are inserted on either side of this dorso-median lamina.

The *branchiostegals*. There are 18 to 21 branchiostegals, 19 being the most common, and they are attached by their bases to the ventral edge of the epihyals and ceratohyals (T. Fig. VI, br.). Taking a case where there are 19 banchiostegals, the first 15 are usually attached to the ceratohyal, the sixteenth is attached to the junction of the ceratohyal, and the remaining three, seventeenth to nineteenth, are attached to the anterior half of the epihyal.

The size of the branchiostegals decreases from behind forwards and the first branchiostegal is only about 1/3 the size of the last branchiostegal. The branchiostegals are free distally but are interconnected by skin and muscles—adductores branchiostegalium. Each branchiostegal is comparessed laterally and consists of a dorso-ventrally enlarged slightly bifurcated base and a free curved pointed ray. The bases are attached to a low ridge along the inner ventral edge of the ceratohyals and the epihyals.

The *suspensorium* in *W. attu* is of the methyostylic type, (De Beer, 1937), where the primary upper jaw is suspended not by its own processes but by the hyomandibula articulated with the auditory region. Due to the highly modified nature of the skull, the maxillaries have lost their normal connection with the quadrates. Hence the adult upper jaw is attached to the neurocranium only in the ethmoid region. However, the quadrate still retains its articulation with the hyomandibular. The adult lower jaw is suspended only by the hyomandibular through the intervention of the quadrate, as the symplectic is absent.

The Branchial Arches

Each lateral half of a branchial arch is made up the following four bones from above downwards : the pharyngobranchial, the epibranchial, the ceratobranchial and the hypobranchial (T. Fig. VII). The two hypobranchials are united in the midventral line by a median basibranchial, which acts as a copula. The branchial arches carry gill rakers on the dorsolateral surfaces of the ceratobranchials and the ventral surfaces of the epibranchials (T. Fig. VII, g.r.). Gill filaments are present on the ventral surfaces of the ceratobranchials and the dorsal surfaces of the epibranchials.

The *pharyngobranchials* (T. Fig. VII, pbr. 1 and 2). The first and second pharyngobranchials are united to form a single elongated bone anterior to the third pharyngobranchial. It is dorsoventrally flattened, the anterior end is thick and narrow. It is placed parallel to the long axis of the skull and unites anteriorly with the united mesial end of the first and second epibranchials. a layer of cartilage separating the two. Posteriorly, it unites firmly with the third pharyngobranchial.

The third pharyngobranchials are thickened spongy bones nearly as broad as long and situated posterior to the fused first and second pharyngobranchials. On each side the third epibranchial is articulated on the anterior dorsolateral surface of the bone, while the fourth epibranchial is articulated to its posterior end. The ventrolateral surface is articulated to the fourth pharyngobranchial.

The fourth pharyngobranchials (T. Fig. VII and VIII, pbr. 4) have slipped down from their original position behind the third pharyngobranchials (to which they still retain a connection) and are placed ventrolateral to the latter bone. Each has developed as a flattened dorsoconcave, oval, toothed bony plate. The teeth are placed in sockets and are found all over the bone, excepting for a very small region mesially. The largest teeth are found posterolaterally and decrease in size anteromesially. The whole arrangement serves to work against the inferior pharyngeal bone in order to keep a firm grip on the prey while swallowing. There is an oblique anteromesial groove on the dorsal surface for firm articulation with the third pharyngobranchial. The anterior end of the fourth epibranchial is feebly articulated to it posteromesially on the dorsal surface.

The *epibranchials* (T. Fig. VII ebr.) are situated obliquely horizontally on either side of the pharynx between the pharyngobranchials and the ceratobranchials.

The posterior ends are directed outwards and backwards. They are elongated rod like bones deeply grooved dorsally for the posterior 2/3 of their length as a passage for the branchial arteries, veins and nerves. At about 1/3 the length on the anterior dorsal surface, just anterior to the grooved portion, each epibranchial has a flattened mesial process for insertion of the four muscles, levatores arcum branchialium. There is a gradual increase in the size of these processes caudad.

The first and second epibranchials are constricted and united for 2/3 their length anteriorly. The third and fourth epibranchials are constricted in the same region for about the same distance, this constriction being more pronounced in the third epibranchial. The constricted portions do not carry gill rakers and gill filaments. The epibranchials are tipped with cartilage at both ends and are a bit more than 2/3 the length of their corresponding ceratobranchials to which they are articulated posteriorly. The united end of the first and second epibranchials articulates to the anterior end of the fused first and second pharyngobranchials, the articulation being tipped with cartilage. The anterior ends of the third and fourth epibranchials are articulated to the anterior dorsolateral and posterodorsal surfaces of the third pharyn-gobranchial respectively. These articulations are tipped with cartilage.

The *ceratobranchials* (T. Fig. VII, cbr.) are elongated rod like bones situated between the epibranchials and the hypobranchials. They are the longest bones in the branchial arches and are all alike. They form the entire free ventral portion of the branchial arches. Each ceratobranchial is slightly curved upwards at both ends and at the same time slightly deflected outwards just anterior to the middle of the bone. It is deeply grooved along the ventral surface for the passage of the branchial blood vessels and nerves, the groove becoming shallower at the two ends. The ceratobranchials are also tipped with cartilage at both ends and articulate anteriorly and posteriorly with their own hypobranchials and epibranchials respectively.

The *hypobranchials*. All the four branchial arches possess hypobranchials (T. Fig. VII, hbr. 1–4), but the third and fourth are comparatively reduced and unossified. Each first hypobranchial is a flattened semicircular piece of bone, with a pointed anterior edge. It is almost as broad as long and about 1/9 the length of its own ceratobranchial. It is articulated anteriorly to the dorsal hypohyal, mesially to the second basibranchial, posteriorly to the second hypobranchial and laterally to its own ceratobranchial. All the articulations are lined with cartilage.

The second hypobranchials are also of the same shape but the anterior edge is concave. They are about the same size and the anterior edge has a lining of cartilage. Each is about 1/7 the length of its own ceratobranchial. It articulates anteriorly with the first hypobranchial, mesially with the second and the third basibranchial, posteriorly with the third hypobranchial and posterolaterally with its own ceratobranchial.

The third hypobranchials are cartilagenous excepting for a core of ossification, and their boundaries are not well defined. Each is a small roughly triangular piece of cartilage articulating by its base with the second hypobranchial and its own ceratobranchial. The narrow apex is directed mesially and gives articulation to the third and fourth basibranchial. Posteriorly it is articulated to the fourth hypobranchial.

The fourth hypobranchials are also cartilagenous and are somewhat cylindrical in shape. The boundaries are ill-defined. They are smaller and the apex is more acute and directed anteriorly. They give articulation anterolaterally to the third ceratobranchials, anteriorly to the third hypobranchials, posteriorly to the fourth basibranchial.

The *basibranchials* (T. Fig. VII, bbr. 1–4) are median bones placed along the ventral middle line between the hypobranchials and act as a copula for uniting the right and left half loops of the branchial arches. The first basibranchial is an ill-defined flat conical piece of cartilage found between the dorsal hypohyals. Posteriorly it gives articulation to the second basibranchial.

The second basibranchial is a well ossified dorsally flattened elongated semi-cylindrical piece of bone with the two ends slightly enlarged. The flat dorsal surface broadens out a little in the middle of the bone. It articulates anteriorly with the first basibranchial, anterolaterally with the first hypobranchial, postero-laterally with the second hypobranchial and posteriorly with the third basi-branchial.

The third basibranchial is an elongated bone with the posterior half narrow and the anterior half gradually broadened out to more than double the width of the posterior region. Anteriorly it articulates with the second basibranchial, antero-laterally it is slightly apposed to the second hypobranchial, posteriorly it articulates with the fourth basibranchial and posterolaterally with the third hypobranchial.

The fourth basibranchial is a broad roughly shield shaped piece of cartilage placed anterior to the infrapharyngeal bones. It articulates anteriorly with the third basibranchial and the third hypobranchials, laterally with the fourth hypo-branchials and posteriorly with the infrapharyngeal bones.

The *gill rakers*. In *W. attu*, a predacious form, feeding on live prey which it swallows, the gill rakers have become modified into sharp conical teeth like structures which thereby help to retain a strong grip on the prey and prevent its escape while being swallowed. The gill rakers are superficial structures and are not fused to the bones on which they occur. In the dried up skull, they can be easily removed and leave only a slight impression to denote their attachment. They are found here only on the epi and ceratobranchials in one or two rows, i.e. an outer and inner row. A table showing the number of gill rakers, their disposition on the bones and their variation is given below :

Names of bones	First branchial arch	Second branchial arch	Third branchial arch	Fourth branchial arch
Epibranchial	6–7 outer	7–8 outer	5–6 outer 4–6 inner	6 outer
Ceratobranchial	21–22 outer and 2 inner	20–22 outer and 7–9 inner	20 outer and 13–15 inner	22–25 outer and 2 inner

The *gill filaments* are slender laterally compressed pointed ray like structures. They are found in two dorsal rows on the epibranchials and two ventral rows on the ceratobranchials i.e. one row on either side of the groove containing the branchial blood vessels and nerves. They are cartilagenous and their bases are fused together and also with their fellows of the neighbouring row for about 1/3 their length, thus forming a continuous strong protective ventral sheath for the afore-mentioned blood vessels and nerves. Gill filaments are found on the epi-, cerato- and hypo-branchials. They decrease in size gradually anteriorly on the epibranchials and hypobranchials to about a minimum of 1/3 that of the longest gill filament of the same branchial arch.

A table showing the number of gill filaments on each of the segments of the branchial arches and their variation is given below:

Names of branchial segments	First branchial arch	Second branchial arch	Third branchial arch	Fourth branchial arch
Epibranchial	75–80	78–80	76	68
Ceratobranchial	136–140	130	120	116–118
Hypobranchial	15	23–25	26–30	34–36

The *first suprapharyngobranchials.* These are small insignificant cartilagenous pieces one on each side, arising from the dorsal region of the first epibranchials, just anterior to the flattened mesial process (T. Fig. VII, sphbr.).

The Infrapharyngeal Bones

The infrapharyngeal bones (T. Fig. IX) represent the ceratobranchial elements of the fifth branchial arch. The two infrapharyngeal bones lie adjoining each other anteriorly on either side of the ventral longitudinal middle line, posterior to the fourth basibranchial. Each bone is elongated and curved diverging outwards from its fellow posteriorly. The anterior and posterior ends (T. Fig. IX, an.,ps.) are sharply demarcated and the anterior end is short, cylindrical and partly cartilagenous. The posterior end is thin and pointed and well ossified. It is 1/3 the width of the anterior end but about double its length. In between the two ends, there is a mesial broad curved elongated toothed bony plate (T. Fig. IX, b.pl.) meeting its fellow anteromesially but diverging posteriorly. It extends for about the anterior 5/6 of the length of the bone and overlies the narrow anterior end. The teeth are conical and sharp and placed in sockets. They cover the entire surface of the bony plate and are directed postero-mesially. The infrapharyngeal bone articulates anteriorly with the fourth basibranchial and anterolaterally with the fourth hypobranchial. Its posterior end is free.

Discussion

The osteology of the head of *W. attu* presents a number of interesting modifications which can be correlated to its habits. The bones of the head are all well ossified and the articulations strong, many showing splinters and interdigitations. Such an arrangement is necessary to withstand the shock caused when it swallows or snaps at large prey or large articles of food. The dorsal surface of the skull is almost smooth and the bones arranged in a compact manner. This together with the wedge-like shape of the head enables the fish to dart after its prey. Usually in teleost fishes the angle of the mouth is bounded by the upper and lower jaws, but here, as the maxillaries are used for the support of the maxillary barbels and the premaxillaries stop far short of the angle of the mouth, the latter is formed by an elastic dermal tissue, which gives an increase to the gape of the mouth. This aspect has not been reported so far. As an adaptation to its carnivorous habits, the animal is fully equipped with several rows of backwardly directed teeth on many of the bones in the mouth. Thus the premaxillaries are very well developed and well armed so also the prevomers, the infrapharyngeals and the fourth pharyngobranchials are toothed. The branchial arches also show this adaptation with the gill rackers being modified into strong sharp teeth in two rows.

The cephalic shield, so well developed in forms like *Clarias lazera* (Nawar, 1954) with the help of the supraorbitals, the dermosphenotic and the posttemporals, is not formed in *W. attu*. This is because it is active in habits and more of a necktonic form. Hence the observations of Gregory (1933) on the cephalic shield in Siluroids is substantiated by this negative proof.

Even though *W. attu* has a comparatively large head skeleton yet the bones are very light, hence one does not find any bracing of the junction of the skull with the backbone, as noticed in *Clarias lazera* (Nawar, 1954) or *Arius sona*, *Arius sagore* and *Osteogeneosus militaris* (Bhimachar 1933).

Rudiments of the temporal fossa have been described in *Amiurus* (McMurrich, 1884) and in *Macrones* (Bridge and Haddon, 1893 and Bhimachar, 1933). In *W. attu*, there is no temporal fossa but the posttemporal arcade is represented by the posterior supraoccipital ridge which joins with a corresponding ridge on the epiotics.

The relationship of the ophthalmicus profundus to the lateral ethmoids is reported here for the first time. Eaton (1948) in *Ictalurus lacustris punctatus* describes a ligamentous connection between the lateral ethmoid and the third orbital bone. No such connection has been noted in the form under discussion. The lateral ethmoids in *W. attu* show a posterior firm interdigitation with the sphenotics by means of the posterolateral ethmoid process. This is apparently a primitive feature as it is seen in *Silundia gangetica* (Bhimachar, 1933) a primitive catfish and not seen in the more specialised forms.

A vestige of the orbitonasal canal seen in certain other teleosts, for example, in *Otolithus ruber* (Dharmarajen, 1936) has been found in this form and seems to be reported for the first time in the Siluroidei.

In *Amiurus catus*, Mc Murrich (1884) and Kindred(1919), there is no articulation between the prevomer and the lateral ethmoids. In the form studied, there is a firm articulation; this relationship is also seen in *Clarias lazera* (Nawar, 1954) and Rita buchanani (Bhimachar, 1933).

There has been some confusion with regard to the terminology of the orbital bones; Mc Murrich (1884) and Bhimachar (1933) have not clearly differentiated the orbital bones. A comparison with the orbital bones in other less specialised teleosts in relationship to the surrounding bones shows that in *W. attu*, there is only one antorbital, a single suborbital and two postorbitals on each side. The second postorbitals are identified by their relationship to the sphenotics (Dharmarajen, 1936).

The side walls of the orbitosphenoid are thick, laminated and poorly ossified in *Rita buchanani* (Bhimachar, 1933) and it is partially tubular due to the fusion of the sidewalls dorsally in *Silundia gangetica* (Bhimachar, 1933), *Amiurus catus* (Mc Murrich, 1884) and *Clarias lazera* (Nawar, 1954). In *W. attu*, the bone is not tubular and the side walls are thin but well ossified. Its floor is very thick and together with the prevomer and the parasphenoid forms a brace for the floor of of the cranium (Gregory, 1933).

Generally in teleosts the basisphenoid is a small median Y-shaped bone placed above the parashenoid. Its presence in the Ostariophysi is the subject of much controversy. Kindred (1919) and De Beer (1937) have reported its presence in Amiurus. According to Sagemehl (1884) and Berg (1940) it is lacking in Ostariophysi. Bhimachar (1933) has reported this bone in all the catfishes he studied, including *W. attu*, and as being fused on its ventral side with the parasphenoid. Its presence or absence can be established only by embryological studies which are not included in this paper. An examination of the adult skull of *W. attu* shows no clear indication of its presence or fusion to the parasphenoid.

In the otic region there is no myodome, nor even a myodomic space. Hence it is clear that *W. attu* belongs to the group of higher catfishes where the myodome has been obliterated by secondary simplification of the region. The myodome is present in very primitive catfishes like *Silundia gangetica* (Bhimachar, 1933). A rudiment of the myodome has been described in *Amiurus catus* (Mc Murrich, 1884). The modification and almost complete obliteration of the trigeminofacial chamber in Siluroids is clearly seen in *W. attu.* This also seems to be a case of secondary simplification of the region, as the presence of a rudimentary pars ganglionaris indicates that the chamber was present in ancestral forms.

The vestige of the spiracular canal in the sphenotic described in *Amia, Allis,* 1903) and in *Otolithus,* (Dharmarajen, 1936) is often seen in *W. attu.* This is the first report of this vestige in the Siluroidei.

The supraoccipital does not contribute to the foramen magnum. This is similar to the condition seen in *Rita buchanani* (Bhimachar, 1933). The posterior foramen on the ventral surface of the supraoccipital is the larger one and it gives passage for the auditory nerve. In *Amiurus* (McMurrich, 1884) this foramen is the smaller and is for the passage for the ascending branch of the first spinal nerve. The supraoccipital articulates only with the neural spine of the complex vertebra as the first and second vertebrae (the latter is free) have no neural arches.

In *W. attu* the basioccipital is completely fused with the first vertebra; the line of fusion is clearly visible on the dried up skull. It articulates posteriorly only with the posttemporals and is excluded from the formation of the foramen magnum by the exoccipitals. Nawar (1954) in *Clarias lazera* and Bhimachar (1933) in *Rita buchanani* have described an articulation of the basioccipital with the complex centrum.

The reduction in the size and number of pterygoids appears to be a measure of evolution in the *Siluroidei*, as in *Silundia gangetica*, a primitive form (Bhimachar, 1933) all the three pterygoid bones are present. In Amiurus (Mc Murrich 1884) there is only the metapterygoid and a vestigial ectopterygoid which is a mere nodule of bone. In *Clarias lazera* (Nawar, 1954) and also in *Rita buchnani, Plotosus canius, Pangasius buchanani* and *Macrones aor* (Bhimachar, 1933) the ectopterygoids are reduced. But the degree of specialisation among these forms could be analysed by the relationship of the ectopterygoids with the prevomer and the quadrates. In the primitive form *Silundia gangetica,* it has a firm articulation with the prevomer and is toothed, the dentition being continuous with that on the prevomer. In *Rita buchanani* it looses the dentition, but retains its articulation with the prevomer. In *W. attu* it is reduced and has only a ligamentous connection with the prevomer and in *Amiurus catus* (Mc Murrich, 1884) it is vestigial. Highly specialised forms like *Arius sona* and *Arius sagore* (Bhimachar, 1933) have developed secondary, firmer articulations with the lateral ethmoids. In *Clarias lazera* (Nawar, 1954) the ectopterygoids are well developed. They do not have any relationship with the prevomer but show a firm interdigitation with the quadrate. A comparison with the condition in other teleosts seems to indicate that the relationship of the ectopterygoids with the quadrate, and the anterior distal end being free is the least specialised or the most primitive condition. Their relationship with the lateral ethmoids is the most specialised condition and that with the prevomer is the intermediate stage. Therefore, it seems safe to assume that the nature of the articulation of the ectopterygoids could also be used as a measure of specialisation in the Siluroidei.

In the hyoid arch, the symplectic is absent. Nawar (1954) has also suggested the same condition in *Clarias lazera.* Mc Murrich (1884) in *Amiurus catus* and Bhimachar (1933) in *W. attu* and certain other forms discussed by him, have reported the presence of a small rectangular sympletic cartilage persisting between the hyomandibular, quadrate and the preopercular. It is suggested that this is not a symplectic cartilage, as the same amount of cartilage of the same shape persists in the same position in teleosts where there is a well developed symplectic, for example, in *Otolithus* (Dharmarajen, 1936). In the skull of certain fishes there is persisting cartilage between several bones and it therefore seems reasonable to assume that the small amount of cartilage persisting between the hyomandibular, quadrate and preopercular is homologous to the cartilagenous interspace in Otolithus (Dharmarajen, 1936). The position of the symplectic is completely filled up by the interhyal.

In the hyoid arch there is no basihyal (Nawar, 1954) but the urohyal acts as an effective copula in this region. The branchial arches show slight fusion between parts, and some segments are cartilagenous. But all the elements are represented. This is in contrast to a form like *Clarias lazera* (Nawar, 1954) where there is reduction of all segments except the ceratobranchials.

The homology of the bone carrying the dorsal patches of pharyngeal teeth has not been clarified so far. Mc Murrich (1884) named it as the epipharyngeals in *Amiurus*, but did not give the homology. Nawar (1954) called it the dorsal pharyngeal patches of teeth and stated that the bases of the teeth fuse to give rise to a concave bone. In *W. attu*, the dorsal patches of pharyngeal teeth are placed in sockets and are in no way different from those on the premaxillaries, prevomer, or infrapharyngeals and the bones carrying these pharyngeal teeth have definite articulations both with the third pharyngobranchials and the fourth epibranchial. A comparison with the condition in a less specialised teleost like *Otolithus* (Dharmarajen, 1936) shows that in the latter, the third, fourth and to a very small extent the second pharyngobranchials carry the dorsal patches of pharyngeal teeth, and also that there is a tendency for the posterior pharyngobranchials to monopolise this function. Hence in *W. attu* as the first to third pharyngobranchials are present, and as the bones carrying the dorsal patches of pharyngeal teeth have articulations with the third pharyngobranchials and the fourth epibranchials, it appears safe to conclude that they are the fourth pharyngobranchials which have slipped down to a more ventral position in order to ensure a better grip against the infrapharyngeals.

In conclusion the osteology of *W. attu* seems to indicate that it belongs to the group of higher catfishes due to the absence of the myodome and the nature of the ectopterygoids. But the absence of the cephalic shield, the presence of a deeply situated head skeleton, the presence of all elements in the branchial arches and the lack of secondary articulations between the skull and the vertebral column, indicate that it is not a very highly specialised form. The lightness, compact arrangement of bones, and almost smooth dorsal surface, the wedge like shape of the skull together with the elasticity of the gape of the mouth and the full complement of teeth make it well suited to its active, predaceous, necktonic life.

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List of Abbreviations

an	Anterior end
ang	Angular
an.ar.p	Anterior articular process
an.f.	Anterior fontanelle
an.p.	Anterior process
an.r.	Anterior ridge
ant.o	Antorbital
ar.ang	Articular surface for the angular
ar.b	Articular surface for the basioccipital
ar.dt	Articular surface for the dentary
ar.e	Articular surface for the ethmoid
ar.ehy	Articular surface for the epihyal
ar.epo	Articular surface for the epiotic
ar.ept	Articular surface for the ectopterygoid
ar.exo	Articular surface for the exoccipital
ar.f.	Articular surface for the frontal
ar.hty	Articular surface for the hyomandibular
ar.i	Articular surface for the interopercular
ar.l	Articular surface for the lachrymal
ar.l and pa	Articular surface for the lachrymal and palatine
ar.le	Articular surface for the lateral ethmoid
ar.m	Articular surface for the maxillary
ar.me	Articular surface for the metapterygoid
ar.o	Articular surface for the opercular
ar.or	Articular surface for the orbitosphenoid
ar.pa	Articular surface for the palatine
ar.par	Articular surface for the parasphenoid
ar.pl	Articular surface for the pleurosphenoid
ar.po	Articular surface for the preopercular
ar.pr	Articular surface for the prootic
ar.pst	Articular surface for the posttemporal
ar.pt	Articular surface for the pterotic
ar.pv	Articular surface for the ligamentous attachment to the prevomer
ar.q	Articular surface for the quadrate
ar. s	Articular surface for the subtemporal
ar·soc	Articular surface for the supraoccipital
ar·sp	Articular surface for the sphenotic
ar·v.hyp	Articular surface for the ventral hypohyal
as	Asteriscus
b	Basioccipital
bbr	Basibranchial
b.pl	Bony plate
br	Branchiostegal
b.s	Bonyseptum
br.a	Branchial arch
cbr	Ceratobranchial
chy	Ceratohyal
c.i.s	Cartilagenous internasal septum
c.mec	Canal for remnant of meckel's cartilage
c.p	Conical process
c.s.i	Cavum sinus imparis
dep.la	Depression lodging the lapillus
d.hyp	Dorsal hypohyal
di.gr	Dialator groove
d.p	Dorsal plate
dt	Dentary
dv.r	Dorso ventral ridge
e	Ethmoid
e.c	Ethmoid cornu
ebr	Epibranchial
ehy	Epihyal
epo	Epiotic
epo.p	Epiotic process
ept	Ectopterygoid
exo	Exoccipital
f	Frontal
fi.v	First vertebra

fl.c.s.i	Floor of the cavum sinus imparis
fo	Foramen magnum
fo.l.a	Foramen for the exit of the lateralis accessorius
fo.o.p	Foramen for the exit of the opthalmicus profundus
g.r	Gill raker
gr.hy.fa	Groove for the passage of the hyomandibularis facialis
gr.hyo.fa	Groove for the passage of the hyodius facialis
hbr	Hypobranchial
h.p	Horizontal process
hy	Hyomandibular
i	Interopercular
ihy	Interhyal
in.ar.me	Inner mesial limb articulating with the metapterygoid
ior.c	Infraorbital sensory canal
l	Lachrymal
la	Lapillus
le	Lateral ethmoid
le.p	Lateral ethmoid process
l.p	Lateral process
l.r	Lateral ridge
m	Maxillary
mec	Meckel's cartilage
me	Metapterygoid
n	Nasal
o	Opercular
o.c	Olfactory capsule
o.l	Outer free limb
op.fo	Optic foramen
or	Orbitosphenoid
pa	Palatine
par	Parasphenoid
pbr	Pharyngobranchial
pl	Pleurosphenoid
pm	Premaxillary
po	Preopercular
por	Postorbital
pr.	Prootic
pr.g	Pars ganglionaris
ps	Posterior end
ps.ar.p	Posterior articular process
ps.f.	Posterior fontanelle
ps.l.p	Posterior lateral process
ps.p	Posterior process
ps.r	Posterior ridge
pt	Pterotic
pt.p	Pterotic process
pt.r	Pterotic ridge
pv	Prevomer
q	Quadrate
r.s	Recessus sacculus
s	Subtemporal
sa	Sagitta
sb	Suborbital
soc	Supraoccipital
soc.sp	Supraoccipital spine
sor.c	Supraorbital canal
sp.	Sphenotic
sphbr	Suprapharyngobranchial
sp.p	Spine like process
st.gr	Supratemporal groove
sp.r	Sphenotic ridge
tm.gr	Temporal groove
tr.fo	Trigeminal foramen
u	Urohyal
v.hyp	Ventral hypohyal
v.p	Ventral plate.

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