

**INTERRELATIONSHIPS AMONG THE SPECIES OF THE GENUS
PUNTIUS (TELEOSTEI: CYPRINIDAE) AS INDICATED BY THE
OSTEOLOGY**

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Abstract

The osteology of twelve species of *Puntius* based on a study of 3-43 specimens from each species is described. Study material ranging in size from 30 mm to 90 mm in standard length included cleared and stained specimens and preserved specimens in formaline.

The skull of the Genus *Puntius* is characterized by the presence of preethmoids, lateralethmoids, orbitosphenoids, interorbital septum completely separating the two orbits, pharyngeal process which is an elongation of basioccipitals, exoccipitals dividing the foramen magnum into three parts, triserial pharyngeal teeth on fifth ceratobranchials, and absence of basisphenoid. The total number of vertebrae of *Puntius* varies from 27 to 41. The first four vertebrae are reduced and fused to form the Weberian apparatus which is a characteristic feature of all Cypriniformes. All the vertebrae except the first four are typified by the presence of Y-shaped epineurals and epihaemals. The caudal skeleton is of primitive perciform type with five or six hypurals, one parhypural, two uroneurals, two epurals, and fifteen or more branched rays.

The main species specific characteristics of the Genus *Puntius* are the numbers of vertebrae, gill rakers, pectoral fin rays, and shapes of some skull bones.

Key Words: taxonomy, Cyprinidae, Weberian apparatus, osteology, branchiocranium, neurocranium, axial skeleton, median fins, appendicular skeleton, caudal skeleton.

1. Introduction

The Cyprinidae contributes mostly to the richness of fish species in freshwaters of Sri Lanka. Out of 64 reported freshwater fish species 40 are cyprinids of which 16 are endemic, 16 are indigenous and 8 are exotic to Sri Lanka (Pethiyagoda 1991). Out of these 40 cyprinids 16 are *Puntius* of which 8 are endemic to Sri Lanka. Some of these Sri Lankan cyprinids have been listed as endangered species (Evans, 1981, Senanayake and Moyle, 1982). The species of *Puntius* are small and possess attractive colour patterns and hence are important as ornamental species. Some species (*P. sarana*, *P. filamentosus*, *P. pleurotaenia* and *P. dorsalis*) provide a cheap source of protein for villagers.

There is much controversy on the name of this genus. The early workers described these species as *Puntius* spp. (Deraniyagala, 1952; Munro, 1955; Mendis and Fernando, 1962) while recent workers who are interested in conservation and ecological studies prefer to refer them as *Barbus* spp. The essential character of the genus *Barbus* is the presence of barbels. However, because of the flood of discoveries of new species, many of which deviated from the prototype, it became increasingly difficult to define the genus and a new system of classification was needed. In 1822 Buchanan instigated the new genus *Puntius* with *Puntius puntio* as a prototype (Ramshort, 1981). The characteristic feature of the new genus *Puntius* was the absence of barbels. It became apparent later, however that within the new genus *Puntius* there were some species with barbels. Therefore, a great deal of uncertainty remains and *Barbus* and *Puntius* are both used as names for the genus. In this study we used the name *Puntius*.

All previous Sri Lankan workers who studied the family Cyprinidae were primarily concerned with describing of new species (Deraniyagala, 1952 : Munro, 1955; Mendis and Fernando, 1962; Pethiyagoda, 1990). Almost all the authors studied only colour patterns and meristics and ignored the internal anatomy and osteology which are very important in understanding the taxonomy and phylogeny of fishes. As the phylogenetic studies are the basis of Zoological Classification, attention was given to the osteology of Sri Lankan cyprinids with a view to resolve the identity and phylogeny of *Puntius*.

The importance of osteology in the taxonomy of fishes is evident by the work carried out on other fishes by Norden (1961), Goslin (1965), Collette and Chao (1975), Tyler et.al (1989), Frame et.al. (1978), Weitzman (1962) and Topp and Cole (1968). However, literature on comparative osteological studies of Cyprinidae is rare. Osteological studies on some Cyprinids have been carried out by Wilimovesky and Weitzmann (1955), Harrington (1955), and Yousuf et.al (1988). In this paper, a detailed review of the osteology of *Puntius* species is provided as baseline information.

2. Materials and Methods

The species of *Puntius* were collected from freshwater bodies of South-western Ichthyological Province of Sri Lanka (Fig 1) and identified according to Deraniyagala (1952), Munro (1955) and Mendis and Fernando (1962). Six adult specimens from each species were digested in 2% KOH and stained in Alizarian Red s and kept in 50% glicerol. The specimens were examined and studied using a stereomicroscope under reflected light. Some of the prepared specimens were disarticulated by boiling in 4% KOH in order to study the individual bones and their articulations. The length of skulls was measured from tip of the ethmoid to the end of basioccipital. Counts of vertebra, predorsals, pterygiophores, rays and spines of fins, epineurals and epihaemals and neural and haemal zygapophysis of vertebrae were done using digested specimens under the stereomicroscope.

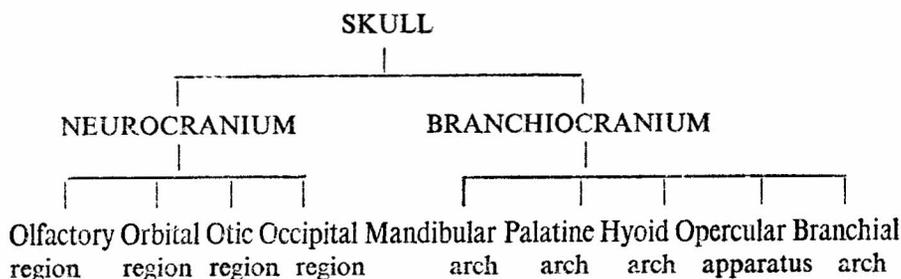
The terminology of bones adopted here is mostly based on the works of Harrington (1955), Wilimovesky and Weitzmann (1955) and Topp and Cole (1968).

3. Results

The osteological description of *Puntius* species studied is divided into four sections; the skull, the axial skeleton, the median fins and the appendicular skeletons.

3.1 Skull

The overall shape of skulls of the twelve species of *Puntius* studied were more or less same. However, they were different in size. Table I shows the standard length and the length of the neurocranium of the species studied. The skull was described as follows.



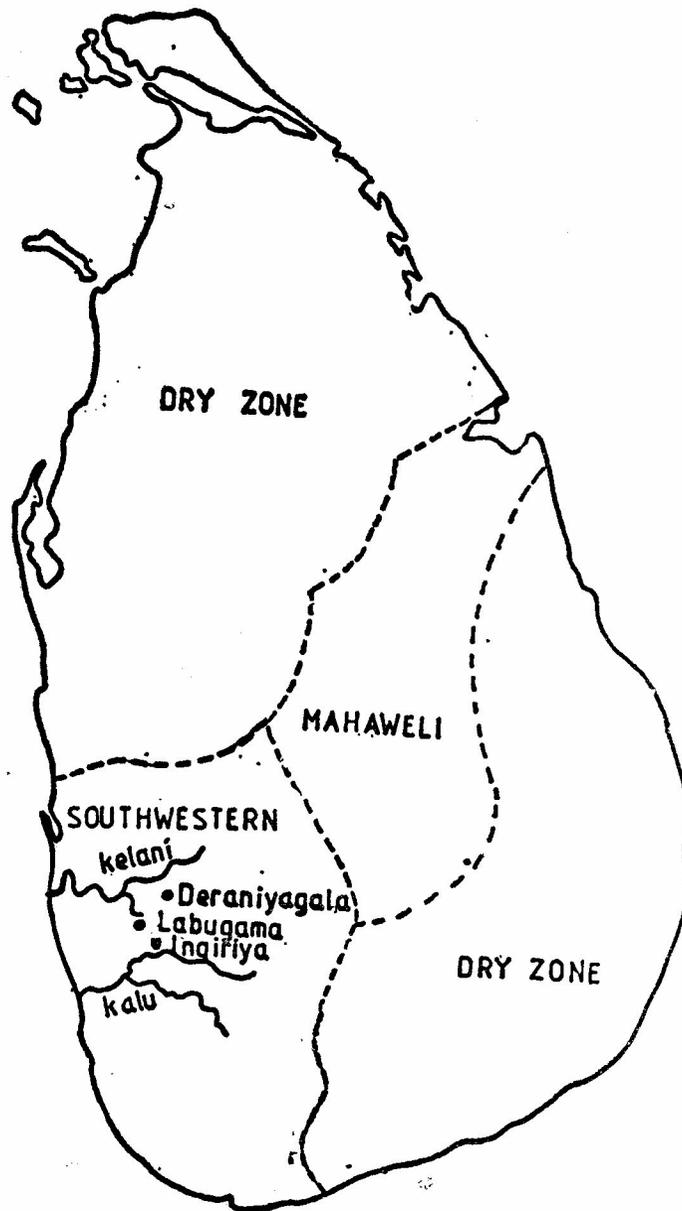


Fig 1. Locations of Southwestern Ichthyological province where species of *Puntius* were collected.

Table 1. The standard length (S L) and the length of neurocranium of different species of *Puntius*.

Species	SL (mm)	Length of neurocranium (mm)
<i>P. amphibius</i>	48	13
<i>P. bimaculatus</i>	37	10
<i>P. chola</i>	40	10
<i>P. cumingi</i>	30	8.5
<i>P. dorsalis</i>	65	16
<i>P. filamentosus</i>	50	13.5
<i>P. nigrofasciatus</i>	28	8
<i>P. pleurotaenia</i>	58	15
<i>P. sarana</i>	86	16.5
<i>P. ticto</i>	27	6.5
<i>P. titteya</i>	28	5.5
<i>P. vittatus</i>	25	7

Table II gives the number of bones and their names found by regions. The relative positions of bones of neurocranium and banchiocranium is shown in Fig. 2.

3.2 Neurocranium (Figs. 2, 3, 4, 5, 6,)

The neurocranium of *Puntius* is elongated and narrow. Dorsally, the pineal foramen in the mid region, the laterosensory canals at the lateral edges, the semicircular ridge on paritals and the supraoccipital crest and the two crests on epiotics are the characteristic features of all the species studied (Fig.3). Ventrally, the two large otic foramens of either sides of dagger shaped parasphenoid are prominent (Fig.4). The two orbits were completely separated by the interorbital septum (Fig 5). The foramen magnum is divided into three parts by the exoccipitals (Fig 6.) The four major regions of the neurocranium identified are, the olfactory, the orbital., the otic and the occipital.

Table 11. The list of bones by region

NEUROCRANIUM	BRANCHIOCRANIUM
Olfactory region	Mandibular arch
1 ethmoid	2 premaxilla
1 prevomer	2 maxilla
2 lateral ethmoid	2 dentary
2 nasals	2 angular
1 rostral or kinethmoid	2 retroarticular
2 preethmoids	
Orbital region	Palatine arch
2 frontals	2 palatine
3 pterosphenoids	2 ectopterygoid
2 orbitosphenoids	2 endopterygoid
2 lachrymals	2 metapterygoid
2 (5) suborbitals	
2 supraorbitals	Hyoid arch
2 pairs of sclerotic bones	2 hyomandibular
2 dermosphenotics	2 symplectic
	2 quadrate
Otic region	2 hyoid complex
2 parietals	Opercular apparatus
2 epiotics	2 opercles
2 prootics	2 subopercles
2 pterotics	2 preopercles
2 sphenotics	2 interopercles
2 opisthotics	
2 otoliths	Branchial arch
Occipital region	3 basibranchials
1 supraoccipital	6 hypobranchials
2 exoccipitals	10 ceratobranchials
1 basioccipital	8 epibranchials
1 parasphenoid	4 pharyngobranchials
	gill rakers

3.2.1. Olfactory Region

This is the anteriormost region of the skull, and is composed of three median bones (ethmoid, prevomer, rostral) and four paired bones (lateral ethmoids, prefrontals, nasals, preethmoids).

Ethmoid (Figs. 2, 3, 5, 7)

The ethmoid is a vertically oriented median bone articulating with the anterior edges of frontals and prevomer. The dorsal side of this bone is pentagonal and its middle part is concaved while two sides are convexed. On either side of ethmoid are the two olfactory foramina. Each olfactory foramen is thus bordered anteriorly by the posterior edge of ethmoid and dorsally and posteriorly by the lateral ethmoids.

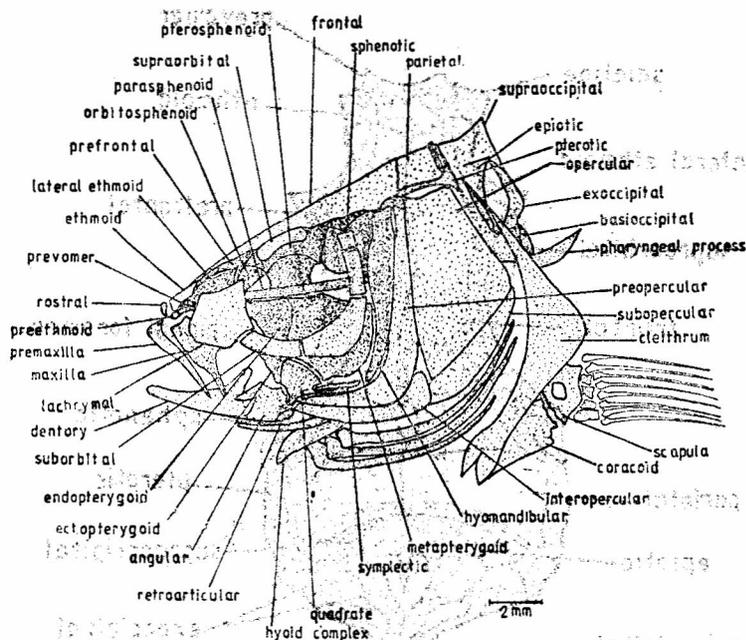


Fig. 2. The relative positions of bones in the neurocranium and branchiocranium of *Puntius*

Lateral ethmoid (Figs. 3, 4, 7)

The lateral ethmoid is an angular bone with a broad base (Fig 4). Ventrally it articulates with the lateral side of prevomer while anterodorsally it articulates with the ethmoid. Latero-posteriorly it is inseparably fused to the downward arching prefrontals. The posterior end of palatine normally rests against this downward arching lateral ethmoid—prefrontal complex.

Prefrontals (Figs. 2, 3, 4, 5, 7)

Prefrontals are thin curved paired angular bones where one angle curves vertically downward. The posterior part of this bone is overlain by the anterior end of two frontals. The downward arching prefrontals form the anterior boundaries of orbits.

Rostral (=kinethmoid, Figs. 2, 7)

Rostral bone is a "question mark shaped" tiny bone which is easily displaceable in handling of digested specimens. It fits into the gap formed by the two premaxillaries and the anterior groove of the ethmoid (Fig. 7). Rostral helps to lever the premaxillaries and the maxillaries in the protrusion of mouth.

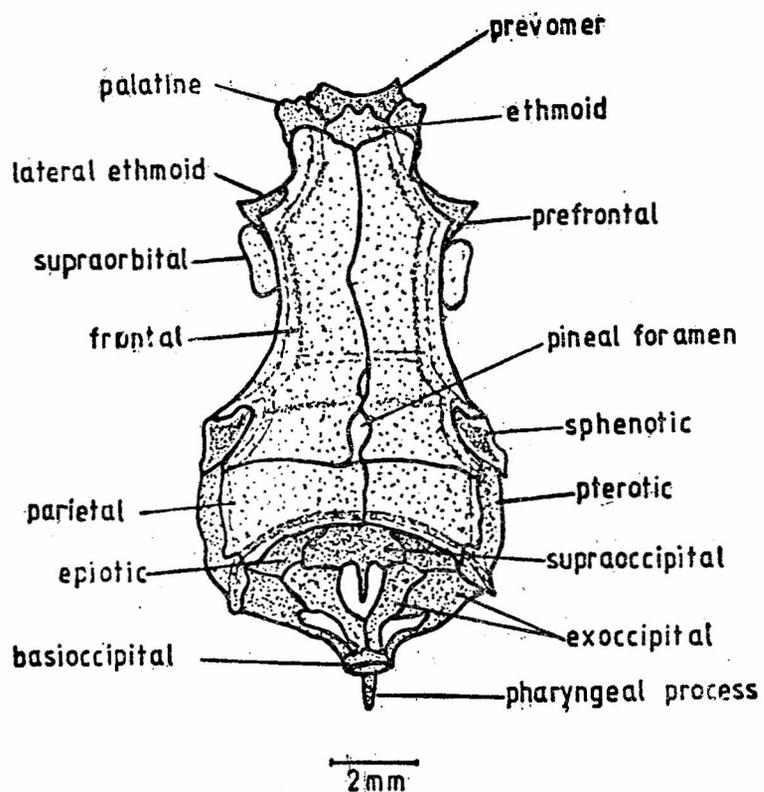


Fig. 3. The dorsal view of the neurocranium of *Puntius*.

Prevomer (Figs. 2, 3, 4, 5, 7)

Prevomer is the most anteroventrally located bone of the cranium. It is a horizontal bone with a bifurcated head and a short pointed shaft. The pointed posterior end of the shaft fits into the v — shaped anterior end of parasphenoid to form the supporting axis of the skull. The anterior end of prevomer bifurcates into two lobes which extend beyond the forward limits of dorsally articulated ethmoid. The bifurcated ends of prevomer articulates with the button shaped preethmoids.

Preethmoid (Fig. 2, 4, 5, 7)

Preethmoids are tiny knob like bones firmly fused to the anterior lateral ends of prevomer-ethmoid joints. Their position is seen from the ventral view (Fig 4). The preethmoids are exclusively supported by the prevomer. Preethmoids serve for the attachment of the palatine.

Nasals (Fig. 16)

Nasals are dorsally located small plate like bones attached to the anterior most ends of frontals. Unlike other bones of the skull they were not firmly articulated. Nasals are completely traversed by the nasal section of the supra-orbital latero - sensory canal (Fig. 16).

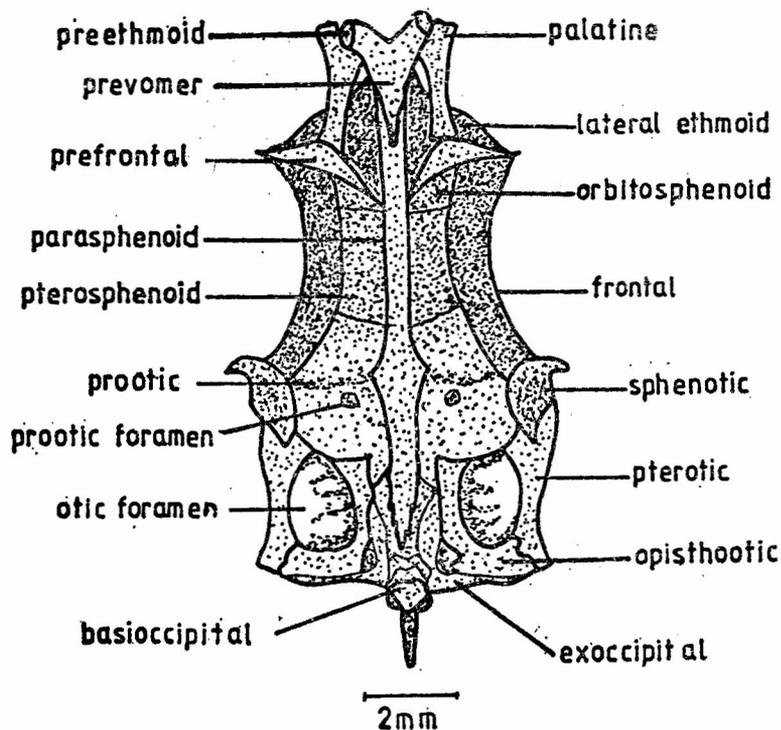


Fig. 4. The ventral view of the neurocranium of *Puntius*.

3.2.2. Orbital Region

The orbital region is prominent by the presence of eyes. Each orbit is surrounded anteriorly by prefrontals, anterodorsally by orbitosphenoids, dorsally by frontals and pterosphenoids, posterodorsally by sphenotics, posteriorly by prootics and ventrally by the parasphenoid. Anterodorsally and posteroventrally the two semicircular sclerotic bones surround the eye ball. Externally the rim of the orbit is overlain by a series of oscicles called circumorbital bones.

Dorsally the entire orbital region is covered by the thin, elongate, paired frontals. Each frontal is about two third of the entire length of the neurocranium. The narrow anterior end of frontals overlain the posterior end of

Frontal (Figs. 2, 3, 4, 5)

ethmoid while the anterior outer lateral part articulates with the prefrontals. Behind the prefrontals the supraorbitals fuse with the outer lateral wall of the frontals. The posterior edge of frontals articulate with parietals and sphenotics. Along the middorsal line, the left frontal articulates with the right frontal. However at the posterior end the two frontals are separated to form the elongated pineal foramen. The posterior margin of this foramen is formed by the left parietal. Ventrolaterally the frontals articulate with orbitosphenoids, pterosphenoids, and prootics (Fig 4). The supraorbital sensory canals traverse along the outer margin of each frontal. In front of pineal foramen, the two supraorbital canals are interconnected by a cross canal.

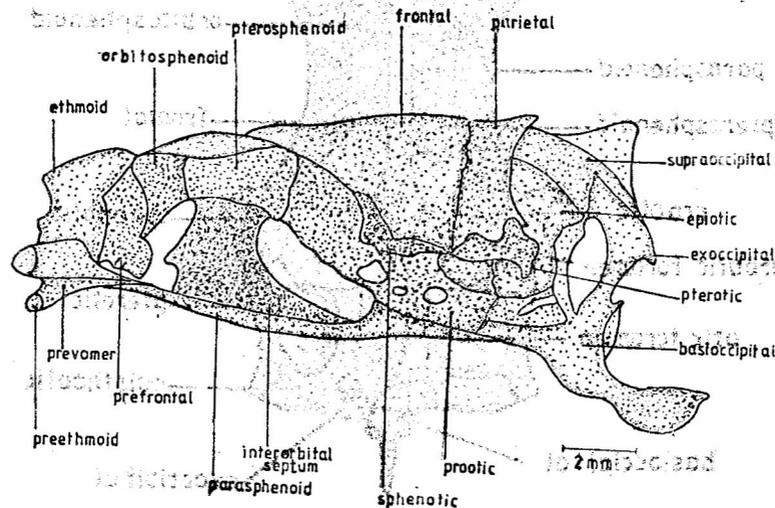


Fig 5. The lateral view of the neurocranium of *Puntius*.

Orbitosphenoid (Figs. 4, 5)

Orbitosphenoids are platelike bones lying ventral to the anterior part of frontals. The outer lateral walls of two orbitosphenoids articulate with the ventral side of frontals. The orbitosphenoid articulates anteriorly with lateral ethmoids and posteriorly with pterosphenoids. The orbitosphenoids form the floor and the side walls of the anteriormost part of the cranial cavity.

Pterosphenoid (Figs. 2, 4, 5)

Pterosphenoids are ventrally located irregularly hexagonal plates with a horizontal part and a vertical part. The vertical parts of two pterosphenoids fuse together and articulate with the interorbital septum. The horizontal part fuse anteriorly with orbitosphenoids and posteriorly with prootics to form the floor of the cranial cavity.

Circumorbital bones (Fig. 2)

There are 6 circumorbital bones (5 infraorbitals and 1 supraorbital) surrounding the orbit in all the species of *Puntius* studied. Dorsal to the maxillaries and obscuring the palatine is the broad **lachrymal**, the anteriormost bone of the circumorbital series. The second bone of the series is the anteroventrally located narrow **jugal** which joined to the lachrymal posteroventrally. The jugal is followed by the ventrally located **suborbital** bone. The **suborbital** is followed by the posteroventrally located **postorbital** which is broader than the jugal. The postorbital meets the **dermosphenotic** dorsally to complete the circumorbital ring. The dermosphenotic is posterolateral to the frontals.

This chain of five circumorbital bones include a perforated tube which passes the infraorbital laterosensory nerves. This infraorbital canal joins the supraorbital canal of frontals through the dermosphenotics.

The supraorbital of the circumorbital series is also a dermal ossicle which firmly articulates with the anterolateral border of the frontals. It resembled an eyelid and form the dorsal border of orbit.

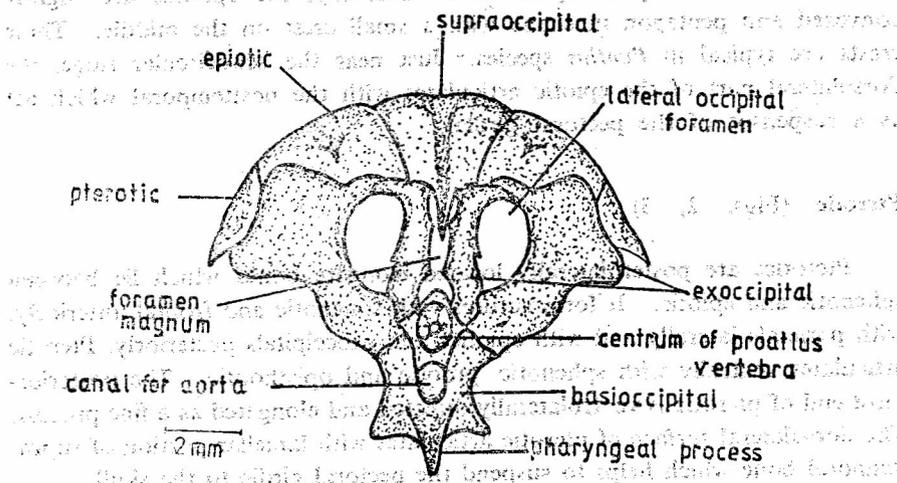


Fig. 6. The rear view of the neurocranium of *Puntius*.

Sclerotic bones

The sclerotic bones are watch glass shaped small bones capping the eye ball. The two sclerotic bones of each side covers eyeball anteriorly and posteriorly.

3.2.3 Otic Region.

The otic region consists of parietals, epiotics, pterotics, prootics, sphenotics and opisthootics. Inside the otic capsules there are some bony elements called otoliths.

Parietals (Figs. 2, 3, 5)

Rectangular parietals form the dorsal wall of the otic region. Parietals articulate anteriorly with frontals, posteriorly with supraoccipital and epiotics and laterally with pterotics. The two parietals articulate with each other at the middorsal line. The anterior wall of left parietal form the posterior margin of pineal foramen. The hind margins of parietals form a semicircular ridge at the hind end of the skull which includes a part of latero-sensory canal system called supratemporal canal. This is a characteristic feature of all *Puntius* species studied. The parietals are smooth and slightly convex dorsally.

Epiotics (Figs. 2, 3, 6)

The two epiotics lie on either side of supraoccipital bone and form the hindmost lateral wall of the skull. The epiotics articulate anteriorly with parietals, posteriorly with exoccipitals, outerlaterally with pterotics and inner laterally with the supraoccipital bone. Dorsally, the epiotics are slightly convex and pentagon in shape with a small crest on the middle. These crests are typical in *Puntius* species. Just near the semicircular ridge, the dorsolateral part of the epiotic articulates with the posttemporal which act as a suspensor of the pectoral girdle.

Pterotic (Figs. 2, 3)

Pterotics are posterolaterally located elongate bones which lie between sphenotic and epiotic. It form sutures with sphenotic and frontal anteriorly, with parietals laterally and with epiotics and exoccipitals posteriorly. Pterotic articulates ventrally with sphenotic, prootic and opisthotic. The posterior-most end of pterotic is ventrolaterally directed and elongated as a fine process. The dorsolateral surface of pterotic articulates with lamellar portion of supratemporal bone which helps to suspend the pectoral girdle to the skull.

Prootic (Figs. 4, 5)

Ventrolaterally located prootics are large, balloon like, irregular shaped bones which articulate with all the vertebral bones in the hind part of the skull. It forms sutures with pterosphenoid anteriorly, with parasphenoid ventrolaterally, with frontal and sphenotics dorsolaterally and with pterotic, opisthotic and basioccipital posteriorly. There is a foramen in the mid region of the prootic where fifth and seventh nerves comes out. The posterior region of the prootic house the otolith.

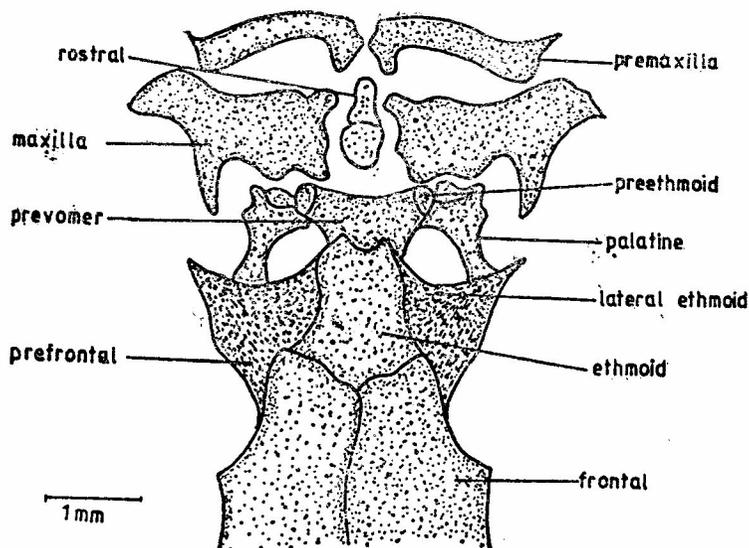


Fig. 7. The dorsal view of olfactory region of the neurocranium of *Puntius*

Sphenotic (Figs. 2, 3, 4)

Sphenotic is a small irregular bone located at the lateral margin of the cranium. It articulates dorsally with frontals, posteriorly with pterosphenoid and ventrally with prootics. Sphenotic is drawn out anterolaterally as a prominent process, against which the upper mesial surface of the fifth suborbital rests. An elongated concavity is enclosed between sphenotics, prootic and pterotic bones for the condyle of hyomandibular.

Opisthootic (Fig 4)

Opisthootic is a ventrally located L-shaped bone bordering the inner lateral and posterior walls of large auditory foramen. It forms sutures with prootics anteriorly, with exoccipital inner laterally and posteriorly and with pterotic outer laterally.

Otoliths (Fig 8)

The paired otoliths of *Puntius* are a pear shaped, hard, white bodies found within the ventrolateral buldge of prootics. The outer surface of otoliths are convexed and granular while the inner surface is flattened and smooth. The anterior edge of otolith is deeply notched and the outer margin is dentate (Fig 8). There is a flask shaped sulcus on the inner surface. The narrow inner canal of sulcus terminates at the anterior end. Sometimes there are dark bands around the inner sulcus. In *P. pleurotaenia*, *P. chola*, *P. vittatus* and *P. bimaculatus* the mouth of flask shaped inner sulcus is divided into two.

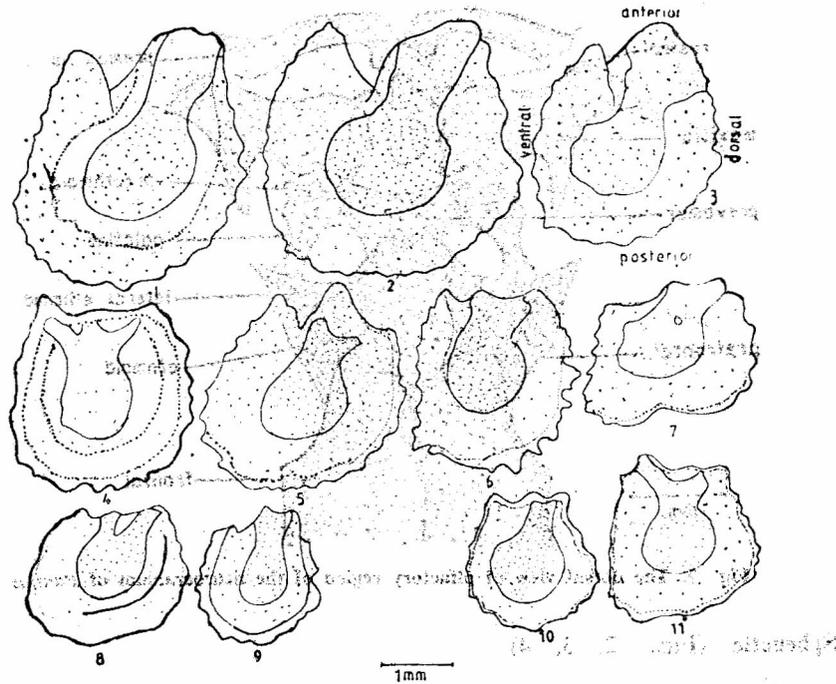


Fig. 8. The inner view of left otolith of *Puntius* species

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|-----------------------------|---------------------------|------------------------|
| 1. <i>P. nlamentosus</i> | 2. <i>P. sarana</i> | 3. <i>P. dorsalis</i> |
| 4. <i>P. pleurotaenia</i> | 5. <i>P. chola</i> | 6. <i>P. amphibius</i> |
| 7. <i>P. nigrofasciatus</i> | 8. <i>P. vittatus</i> | 9. <i>P. titteya</i> |
| 10. <i>P. cumthigi</i> | 11. <i>P. bimaculatus</i> | |

3.2.4. Occipital Region

This region forms the posteriormost portion of the neurocranium and is composed of basioccipital, exoccipitals, supraoccipital and parasphenoid. The exoccipital is a paired bone while the others are unpaired.

Basioccipital (Figs. 2, 3, 4, 5, 6)

This is a large median bone which forms the posteriormost ventral part of the neurocranium. It articulates with parasphenoid and prootics anteriorly and with exoccipitals dorsolaterally. The posteroventral ridge of the basioccipital extends into a posteroventrally directed process called pharyngeal process. It is laterally compressed and posteriorly formed into a vertical plate. Posterodorsally, the basioccipital is produced into an occipital condyle which is similar to a vertebral centrum and it is called centrum of proatlas vertebra. At the broad base of the pharyngeal process of the basioccipital, just below the proatlas vertebral centrum, a large canal is formed for the aorta.

Exoccipitals (Figs. 2, 3, 4, 5, 6)

Most of the rear side of the neurocranium is formed by the large, paired exoccipitals. It forms sutures with pterotic, epiotic and supraoccipital dorsally, and with basioccipital and opisthotic ventrally (Fig. 6). Dorsally, the exoccipitals form two wings. The broader wing articulates with the pterotic and epiotic while the narrow wing articulates with the supraoccipital. The two wings of exoccipitals articulate each other at the dorsal side forming a large gap between the two. This gap is called the lateral occipital foramen. The foramen magnum of the skull is divided into three parts by the above structure of the exoccipitals. There are two large lateral occipital foramina and the narrow slit like foramen magnum in between them (Fig 6). This is a characteristic feature of all *Puntius* species studied.

Supraoccipital (Figs. 2, 3, 5, 6)

The hexagonal supraoccipital with a triangular crest on the dorsal side is a median bone. It suturally articulates with the two parietals dorsally, with the two epiotics laterally and with the lateral wings of two exoccipitals ventrally. The ventral margin of the supraoccipital crest elongated between the two lateral wings of exoccipitals. The slightly convex supraoccipital forms the middle portion of the rear wall of the neurocranium.

Parasphenoid (Figs. 4, 5)

The dagger shaped parasphenoid is the longest bone in the skull which extends midventrally from basioccipital region to ethmoid region. It act as a keel of the cranium. Parasphenoid forms sutures with prevomer at the olfactory region, with interorbital septum at the orbital region, with prootics at the otic region and with basioccipital at the occipital region. At the ethmoid region and orbital region the parasphenoid constitute a thick narrow strut of bone. As it approaches otic region, it widens abruptly to its maximum width and become gradually narrow posteriorly. Finally it tapers into a point and articulates with the ventral surface of the basioccipital.

3.3 Branchiocranium

The branchiocranium of *Puntius* is divided into five sections : mandibular arch, palatine arch, hyoid arch, opercular apparatus and branchial arch.

3.3.1 Mandibular Arch

The mandibular arch consists of upper jaw and lower jaw. The upper jaw is formed by premaxilla and maxilla while the lower jaw is formed by dentary, angular and retroarticular. In *Puntius* species teeth is absent on both jaws.

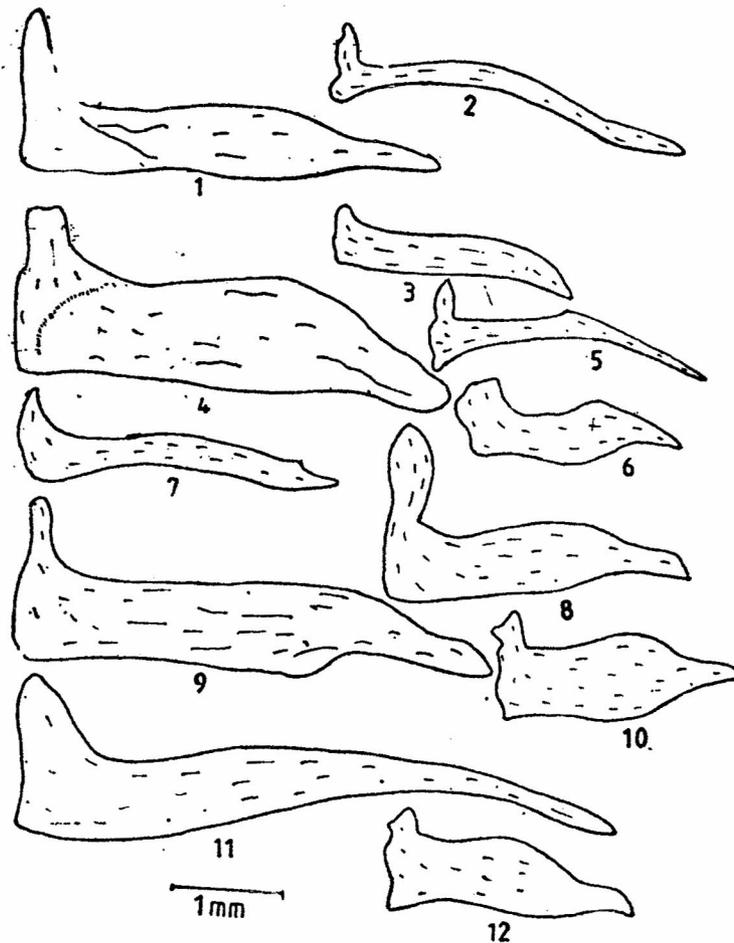


Fig 9. The outer view of the left premaxillae of *Puntius* species

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|---------------------------|--------------------------|-----------------------------|
| 1. <i>P. pleurotaenia</i> | 2. <i>P. bimaculatus</i> | 3. <i>P. vittatus</i> |
| 4. <i>P. dorsalis</i> | 5. <i>P. titteya</i> | 6. <i>P. nigrofasclatus</i> |
| 7. <i>P. chola</i> | 8. <i>P. amphibius</i> | 9. <i>P. filamentosus</i> |
| 10. <i>P. cumingi</i> | 11. <i>P. sarana</i> | 12. <i>P. ticto</i> |

Premaxilla (Figs. 2, 9)

Premaxilla is a laterally curved bone with a prominent broadened ascending limb at the anterior end. Posteriorly it tapers and slightly recurved. The ascending limbs of two premaxillae are connected by ligaments to the rostral bone and thence to the anterior end of ethmoid. The premaxillae which are connected to the maxillae by an extensible skin are protrusible. It is a characteristic feature of all *Puntius* species. The anterior end of premaxillae of *Puntius* species varied in shape (Fig. 9).

Maxilla (Figs. 2, 10)

The maxilla has a large knob like articular head at its anterior end and a laterally compressed curved shank. The maxillary head is set off from the shank by a deep notch. This knob like condyle work like an anchor and a pivot. Its proximal concavity fit over the preethmoid. The entire maxilla is covered by the large lachrymal bone in normal posture. The shape of the shank and the depth of the notch of the maxilla varies from species to species (Fig. 10).

Dentary (Fig. 2)

Dentary is a large bone which curves anteriorly to meet its fellow of the opposite side to form a symphysis. A flattened, broad vertically ascending limb is formed at the middle region of the horizontal bone. This part of bone is loosely attached to the maxillary. The ventrolateral edge of the dentary enclosed a tubule which is the mandibular canal of the laterosensory canal system. Dorsal to this tubule at the posterior part of the dentary, a deep furrow is formed. It encloses the anterior part of the angular bone.

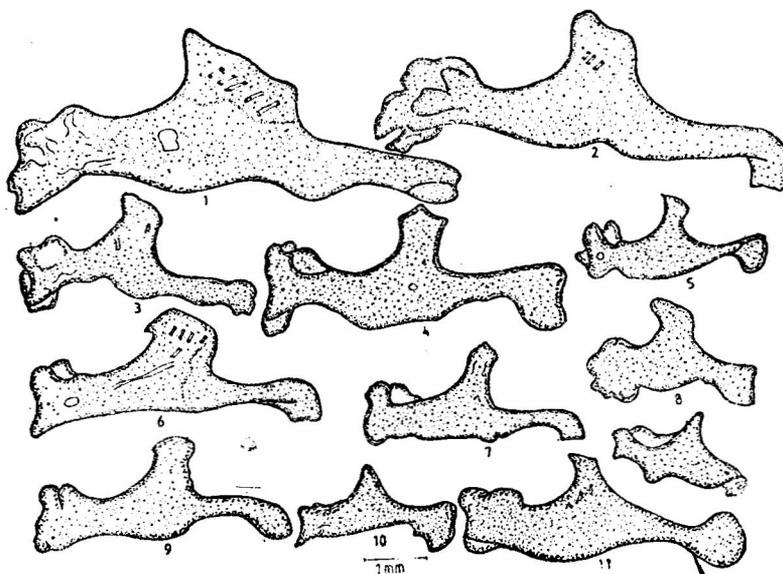


Fig. 10. The outer view of left maxillae of *Puntius* species.

- | | | |
|--------------------------|-----------------------------|---------------------------|
| 1. <i>P. sarana</i> | 2. <i>P. filamentosus</i> | 3. <i>P. chola</i> |
| 4. <i>P. dorsals</i> | 5. <i>P. cumingi</i> | 6. <i>P. pleurotaenia</i> |
| 7. <i>P. bimaculatus</i> | 8. <i>P. nigrofasciatus</i> | 9. <i>P. amphibiis</i> |
| 10. <i>P. titteya</i> | 11. <i>P. ticto</i> | 12. <i>P. vittatus</i> |

Angular (Fig. 2)

Angular is a large triangular flattened bone with a peg like anterior end and a broad posterior end. The peg like anterior end enclosed in the deep furrow of the dentary. At the posterior end of the dorsal side a semicircular fossa is formed to articulate with the quadrate. There is a canal runs across the lateral wall of the angular which encloses the mandibular nerves of the laterosensory nervous system. The ventroposterior edge of the angular articulates with the retroarticular. The elevation of the anterior dorsal margin of the angular bone slightly vary from species to species.

Retroarticular (Fig. 2)

Retroarticular is a triangular small bone articulates with the ventroposterior edge of the angular. It is the posterior segment of Meckel's cartilage.

3.3.2. Palatine Arch

Palatine arch consist of four bones and they form the roof of the mouth. These bones are palatine, endopterygoid, ectopterygoid and metapterygoid (Fig. 2).

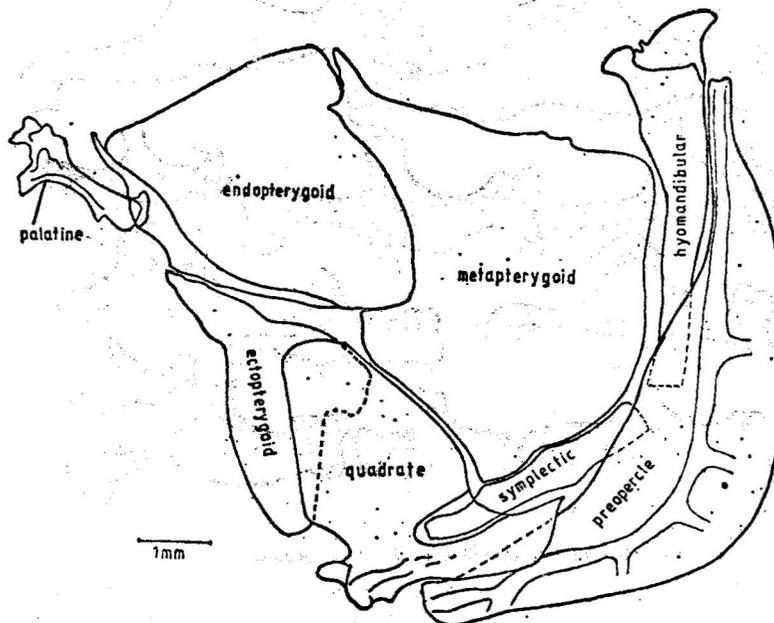


Fig. 11. The relationship of bones of palatine arch and hyoid arch of *Puntius*

Palatine (Fig. 2)

Palatine is a rod-like bone with an enlarged anterior head. There are longitudinal ridges on the anterior head and it is loosely articulates with the lateral side of prethmoid. The posterior end of palatine rests against the anterior edge of lateral ethmoid and movably articulates with the anterior facet of the endopterygoid.

Endopterygoid (Figs. 2, 11)

Endopterygoid is a fairly large flattened bone with a thickened ventral edge. The anteriormost end of the thickened ventral edge forms a facet which loosely articulates with the posterior end of the palatine. The dorso-anterior edge of endopterygoid grows over this articular facet and helps to prevent the slipping out of palatine. The endopterygoid forms a suture with metapterygoid posteriorly and with ectopterygoid ventrally. The endopterygoid forms the mesial wall of the lower half of the orbit together with metapterygoid, ectopterygoid and quadrate.

Ectopterygoid (Figs. 2, 11)

Ectopterygoid is a thin flattened, irregular bone. Its dorsal margin articulate with the posterior half of the thickened ventral boarder of the endopterygoid. The posterior half of ectopterygoid is overlain by the anterior part of the quadrate. The palatine arch is connected to the hyoid arch through this quadrate-ectopterygoid articulation.

Metapterygoid (Figs. 2, 11, 12)

Metapterygoid is the largest among the bones of palatine arch. Its anterior margin is curved to form a suture with the posterior margin of the endopterygoid. Anteroventral margin articulates with the dorsal side of quadrate while the posteroventral edge borders on the dorsal edge of the symplectic. The posterodorsal margin lies along with the hyomandibular and articulates with it. In most of the *Puntius* species the length and height of metapterygoid is more or less equal. However in *P. sarana* and *P. vittatus* the length of the bone is greater than the height. In *P. chola* and *P. nigrofasciatus* the height of bone is greater than the length (Fig. 12).

3.3.3. Hyoid Arch

Hyoid arch consist of three paired bones and a hyoid complex. The three paired bones are hyomandibular, symplectic and quadrate (Figs. 2, 11) Hyoid complex consist of two median bones: the basihyal, and the urohyal and two halves each containing lower hypohyal, upper hypohyal, ceratohyal, epihyal, interhyal and three branchiostegal rays (Fig. 13). The main function of the hyoid arch is the suspension of jaws and opercular apparatus to the neurocranium.

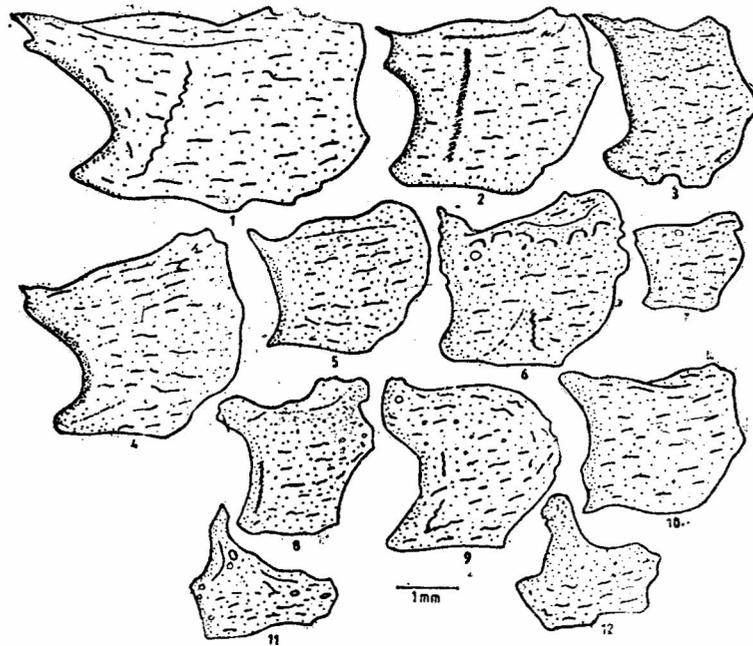


Fig. 12. The left metapterygoid of *Puntius* species.

- | | | |
|-----------------------|-----------------------------|--------------------------|
| 1. <i>P. sarana</i> | 2. <i>P. filamentosus</i> | 3. <i>P. chola</i> |
| 4. <i>P. dorsalis</i> | 5. <i>P. pleurotaenia</i> | 6. <i>P. bimaculatus</i> |
| 7. <i>P. titteya</i> | 8. <i>P. nigrofasciatus</i> | 9. <i>P. amphibius</i> |
| 10. <i>P. cumingi</i> | 11. <i>P. vittatus</i> | 12. <i>P. ticto</i> |

Hyomandibular (Figs. 2, 11)

Hyomandibular is a stout strut of bone with thin flanges extending on either sides. At the dorsal end, the main strut subdivided into three branches of which two form the dorsal head like portion to articulate with the facet of neurocranium. The third branch forms a rounded condyle which articulates with the articular facet of opercular bone. The long anterior margin of the hyomandibular articulates with the posterior margin of metapterygoid and the anteroventral edge with the symplectic. The lower posterior margin of hyomandibular is overlain by the preopercle.

Symplectic (Figs. 2, 11)

Symplectic is a slender rod shaped tiny bone whose anterior end neatly fits into a deep recess of the postventral edge of the quadrate. About two third of the symplectic bone projects beyond the posterior margin of the quadrate. The dorsal side of the bone articulates with the metapterygoid. The posterior end of symplectic articulates with the hyomandibular. This portion of symplectic and hyomandibular overlain by the anterior margin of preopercle. The shape of symplectic slightly varies among *Puntius* species.

Quadrate (Figs. 2, 11)

Quadrate is a fan shaped flattened bone with a vertical anterior margin and a curved dorsal margin. The posteroventral end of quadrate projects into a long thick handle—like strut while the anteroventral end bears a condyle, loosely articulates with the notch of the angular. Dorsal to the handle like portion of the quadrate a deep recess is formed and it accommodates one third of the symplectic bone. The anterodorsal margin of quadrate overlap and articulates with the ectopterygoid while its posterodorsal margin forms a suture with metapterygoid. The preopercle overlies the posterior end of handle like portion of quadrate. The shape of quadrate of the *Puntius* species is more or less same.

Hyoid complex (Fig. 13)

The bones of hyoid complex which is ventral and ventrolateral to the branchial arches, externally covers the bones of branchial arches. The left and right halves of the hyoid complex join midventrally by the hypohyals.

Basihyal is a four sided rod shaped bone. It extends posteriorly up to the first basibranchial of branchial arches and lies just above the junction of the two hypohyals. It is attach to hypohyals by ligaments.

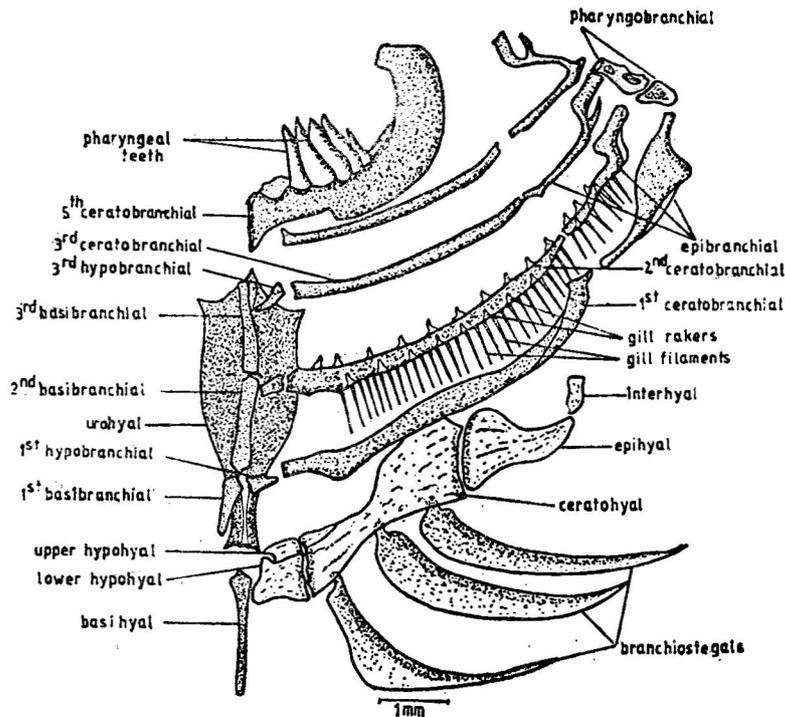


Fig 13. The relationship of hyoid complex and branchial arches of *Puntius* (right half only)

Urohyal lies posterior to the basihyal (Fig. 13). It is a broad, flat, horizontal, spatula shaped bone strengthened by a middle longitudinal ridge. The handle like anterior end of the urohyal terminate in two lateral heads separated by a notch or a deep cleft. The posterior margin of urohyal is wavy. The depth of waves vary from species to species (Fig. 14). In species like *P. sarana*, *P. filamentosus* *P. pleurotaenia*, the urohyal is thin and long while in species like *P. cumingi*, *P. nigrofasciatus* and *P. vittatus* it is short and broad. Therefore the shape of urohyal can be used in the identification of species of *Puntius* (Fig. 14).

The cone shaped **hypohyal** consist of two parts: the small subcylindrical upper hypohyal and the cone shaped large lower hypohyal. The upper hypohyal is neatly fits into the concavity formed on the dorsal side of the lower hypohyal. The hypohyal articulates with the anterior end of ceratohyal. The median surface of the hypohyal join in the midline that of its fellow of the opposite side.

Ceratohyal is a long and flattened bone with laterally broadened ends and constricted at the middle. The posterior end articulates with the epihyal. The anterior end terminates with two heads. The dorsal head articulates with upper hypohyal while the ventral head articulates with the lower hypohyal.

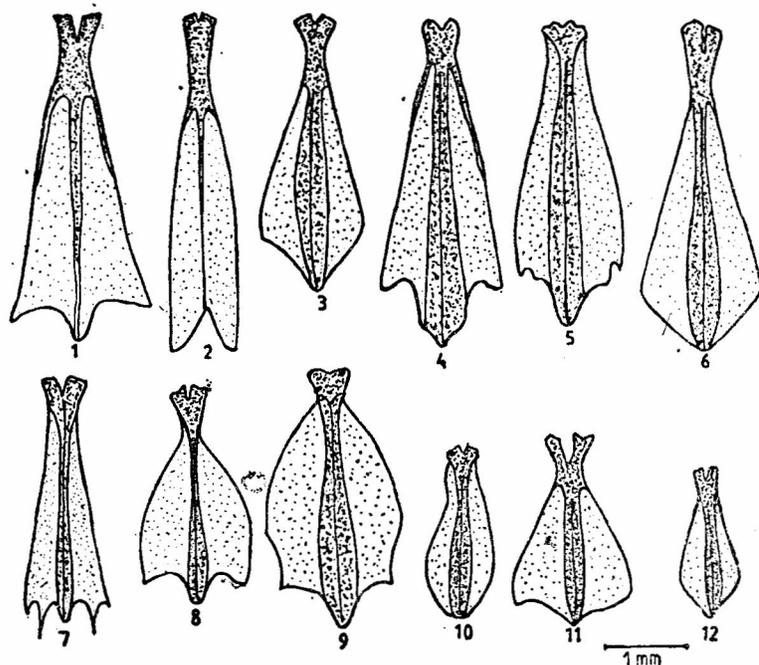


Fig. 14. The dorsal view of urchyal of *Puntius* species

- | | | |
|---------------------------|---------------------------|-----------------------------|
| 1. <i>P. sarana</i> | 2. <i>P. filamentosus</i> | 3. <i>P. chola</i> |
| 4. <i>P. dorsalis</i> | 5. <i>P. amphibius</i> | 6. <i>P. bimaculatus</i> |
| 7. <i>P. pleurotaenia</i> | 8. <i>P. cumingi</i> | 9. <i>P. nigrofasciatus</i> |
| 10. <i>P. titteya</i> | 11. <i>P. vittatus</i> | |

Epihyal is a short trianguloid bone with its apex directed dorsolaterally towards the interhyal (Fig. 13). The broad base articulates with the ceratohyal.

The small rod shaped **interhyal** is connected to the epihyal at one end (Fig. 13). The other end fits into the space between symplectic bone and the symplectic end of hyomandibular.

Branchiostegal rays are curved thin leaf like structures with a knob like anterior end and a pointed posterior end. The knob like anterior ends fits into the lateral groove of the ceratohyal. The three branchiostegals are evenly spreaded along the length of ceratohyal. The posterior ends of branchiostegals are free. There is no variation of number or shape of branchiostegals among the species of *Puntius* studied.

3.3.4 OPERCULAR APPARATUS

The opercular apparatus contained broad, flattened, four dermal bones namely opercle, subopercle, preopercle and interopercle. They overlap each other to form a gill cover to the underlying gill arches.

Opercle (Fig. 2)

Opercle is a broad rectangular, shell like thin bone except the thick strut along the anterior margin of the inner surface. This thick strut contained a tubule inside for nerves. On the anterior edge of the thick strut a socket is formed for the opercular knob of the hyomandibular. Just below the socket the thick strut with a canal ramified and form a number of branches. The opercle is overlain by the preopercle anteriorly and it overlies the subopercle ventrally and interopercle anteriorly.

Preopercle (Fig. 2)

The lunate preopercle encloses the preopercular-mandibular laterosensory canal along the curved inner margin. When the anterior end of preopercle touches the posterior margin of angular, the laterosensory canal of angular coincide with that of preopercle. Preopercle overlies the lower posterolateral surface of hyomandibular, the symplectic, the upper lateral surface of interopercle, the post lateral surface of hyomandibular, the hind end of quadrate and the anterior edge of opercle.

Interopercle (Fig. 2)

Interopercle is a elongate, trianguloid bone with a slightly curved dorsal margin. Most of laterodorsal surface of this bone overlapped by the ventral margin of preopercle. The interopercle overlaps the lateral surface of ceratohyal and the anterior end of subopercle.

Subopercle (Fig. 2)

The dorsal margin of subopercle is slightly concaved while its ventral margin is slightly convexed. It overlaps anteriorly by the interopercle and dorsally by the ventral edge of opercle.

3.3.5 Branchial Arches

There are five branchial arches in *Puntius* supporting the gill rakers, gill fillaments and pharyngeal teeth. Each arch consists of a median basibranchial, joined either sides by a hypobranchial, a ceratobranchial, an epibranchial and a pharyngobranchial arranged in the usual circumpharyngeal series. However, the following branchial elements are absent in all the species of *Puntius* studied : basibranchial 4 and 5, hypobranchial 4 and 5, epibranchial 5, pharyngobranchial 3, 4 and 5. The fifth arch represent only by s-shaped ceratobranchials. The presence of triseriate paryngeal teeth on fifth ceratobranchial is a characteristic feature of all the species of *Puntius* studied. Only ceratobranchials and epibranchials bear gill filaments and gill rakers.

Basibranchial (Figs. 13, 15)

The rod shaped, ventromesial tiny basibranchials of the first three arches are embedded in the connective tissues of the floor of the pharynx and are ventrally covered by the basihyal. Basibranchials are constricted on the midway and have a lateral groove. The first basibranchial is shorter than the other two. The three basibranchials articulate end to end. The anterior end of first basibranchial articulate with the caudal end of the basihyal.

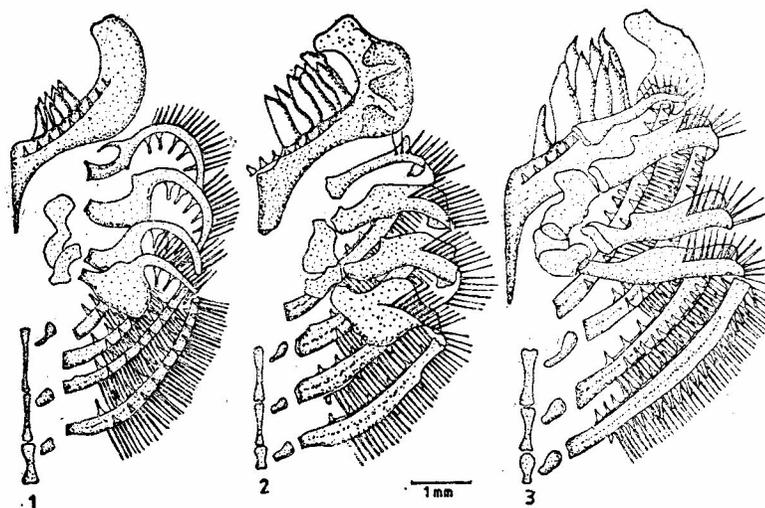


Fig. 15 Right side of the branchial arches of three species of *Puntius*

1. *P. chola*

2. *P. nigrofasciatus*

3. *P. amphibus*

Hypobranchials (Figs. 13, 15)

The three pairs of "comma-shaped" hypobranchials lie adjacent on either side of first, second and third basibranchials respectively. The third pair is longer than the other two pairs. There is no trace of fourth or fifth hypobranchials.

Ceratobranchials (Figs. 13, 15)

Out of five pairs of ceratobranchials the first four are thin, long and upwardly curved while the fifth pair is massive and faintly s-shaped. The lower ends of the first four pairs of ceratobranchials thicken to form an articular head and the opposite ends are thin. The first three ceratobranchial articulate with their respective hypobranchial below. The fourth ceratobranchial also articulate with the 3rd hypobranchial. However the fifth ceratobranchials join each other midventrally and the elongated fused inferior edges extend towards the third basibranchial. The ceratobranchials of first four arches bear both gill rakers and gill filaments. However the ceratobranchials of fifth arch do not bear gill filaments but tooth patches like short gill rakers and pharyngeal teeth. In species of *Puntius* studied, the fifth ceratobranchials bear 10 pharyngeal teeth in three rows. The pharyngeal teeth of *Puntius* are very sharp and pointed and can be used in grasping and tearing.

Epibranchials (Figs. 13, 15)

Epibranchials are thin curved bones with large thickened articular head at the upper end. The upper end of fourth epibranchial of *P. chola* is forked (Fig. 15). The upper end of epibranchials articulate with the pharyngobranchials while the lower ends articulate with the ceratobranchials.

Pharyngobranchials (Figs. 13, 15)

There are four (two on each side) dorsally located, "shoe-shaped" pharyngobranchials two in each side in species of *Puntius* studied. The front pharyngobranchial of each side is overlapped by the hind end of the preceding one. On each side the enlarged upper ends of first two epibranchials articulate with the ventral side of first pharyngobranchial while the third and fourth epibranchials articulate with the second pharyngobranchials.

Gill rakers (Figs. 13, 15)

There are two rows of gill rakers on the dorsal side of epibranchials and ceratobranchials in *Puntius*. The inner or oral row of the preceding arch intermeshes with outer row or aboral row of succeeding arch. However the fifth ceratobranchial bears only aboral row of gill rakers. In *P. nigrofasciatus* and *P. cumingi* the gill rakers of aboral row of first arch are shorter than those of other arches while in other species aboral gill rakers of first arch is longer than those of other arches.

Table III Sample size, range and mean values of first arch aboral gill rakers of *Puntius*

Species	N	Number of gill rakers																				Mean
		3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	
<i>P. amphibius</i>	3															1			1	1	20	
<i>P. bimaculatus</i>	25											3	4	4	2	10	1	1				14.76
<i>P. chola</i>	21											1		4	6	4	2	2	1	1		16.63
<i>P. cumingi</i>	20	2	6	4	7	1																4.95
<i>P. dorsalis</i>	44								1	2			14	13	7	4	2		1			15.51
<i>P. filamentosus</i>	40			1	1	8	11	11	7		1											8.0
<i>P. nigrofasciatus</i>	22	13	4	2			3															3.9
<i>P. pleurotaenia</i>	30					7	18	1	1	2			1									7.3
<i>P. sarana</i>	9		2	1	2	3	1															7.28
<i>P. ticto</i>	17			11	5	1				1				1								6.15
<i>P. titteya</i>	18	2	6	4	5	1																4.83
<i>P. vittatus</i>	27					1	3	6	3	3	4	2	2	1								10.03

The number of gill rakers on the aboral row of first arch is a species specific character and can be used in taxonomical studies (Table III). *P. amphibius* has the maximum mean number of gill rakers of first arch while *P. nigrofasciatus* had the minimum mean number of gill rakers. However, the number of gill rakers on the aboral row of first arch is always less than that of oral or aboral rows of other arches. For example *P. cumingi* and *P. nigrofasciatus* have 3 - 5 gill rakers on aboral row of first arch but there are 9 - 10 gill rakers on oral or aboral rows of other arches.

3.4 Laterosensory Canal System of Head

The arrangement of the lateral line canal system of the head is usually complicated. A number of different branches can be distinguished. Since the head of *Puntius* and most of the other fishes are usually without scales and only covered by a thin integument, the lateral line canals are normally embedded in the dermal bones of the skull. These canal tracks are very useful in the identification of dermal bones and also are important in taxonomical studies.

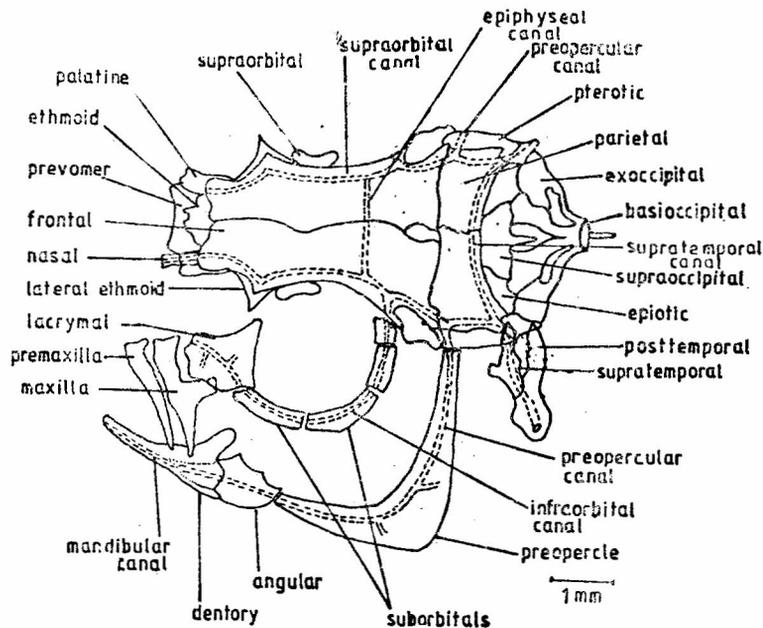


Fig. 16. Laterosensory canal system of the skull of *Puntius*

There are two longitudinal lateral lines one on each side of the dorsal side of the skull of *Puntius*. They are supraorbital canals embedded in the outer margins of the frontals and parietals (Fig. 16). Anteriorly the supraorbital canal extend upto the nasal bone while posteriorly it extend upto pterotic. At the pterotic, the supraorbital canal of each side is connected to the lateral line of the trunk of that side through the supratemporal—posttemporal bones. Two supraorbital canals are interconnected by two cross canals : the epiphyseal branch and the supra-temporal canal. The epiphyseal branch is in front of pinial foramen and the supra-temporal branch is running inside the ridges of the parietals.

The infraorbital canal of the head is embedded in the inner margins of the suborbital bones surrounding the eyes. In each side, the infraorbital canal is connected to the supraorbital canal through the dermosphenotic. The preopercular canal which is embedded in the anterior margin of the preopercle ventrally coincide with the canal of angular while dorsally connected to the supraorbital canal through the pterotic. The lateral line canal of angular is connected to that of dentory which is called mandibular canal.

3.5.1. Precadual Vertebrae

Webarian apparatus (Fig. 17)

The Webarian apparatus of *Puntius* which connects the swim bladder with the inner ear is formed by the fusion of first four precaudal vertebrae together with four pairs of Webarian ossicles (Fig. 17). These ossicles are the claustrum, the scaphium, the intercalary and the tripus forming a lateral chain on each side connecting the swimbladder with the basioccipital region of the skull. The neural spines of first three vertebrae are fuse to form a neural complex. The ventrally directed ossa suspensoria which is the anterior support of the swim bladder, originate from the ventral side of the 4th precaudal vertebra of the Webarian apparatus.

Claustrum is a quadrangular shaped bone which lies against the anterior margin of the neural complex (Fig.17). Its ventral margin touches the dorsal margin of the next ossicle scaphium and the anterior margin touches the basioccipital region of the skull.

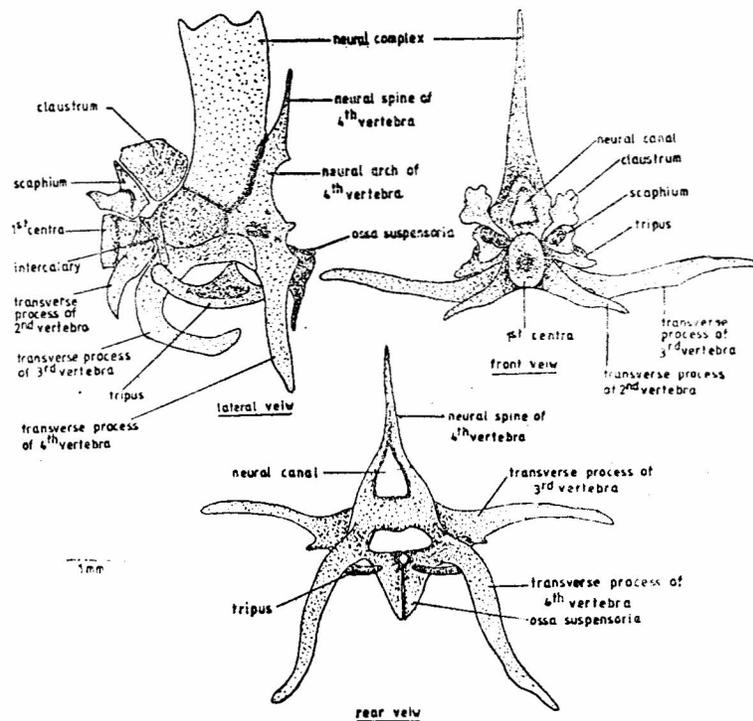


Fig 17. The Webarian apparatus of *Puntius*.

Scaphium which is a cup shaped ossicle with two pointed ends lie dorsal to the centroms of first two vertebrae and ventral to the claustrum. The ventral margin of scaphium touches the intercalary.

Intercalar is a rod shaped bone circumventing the vertebral column and touches the ventrally located tripus.

Tripus is a sword shaped elongate flattened bone with a blunt anterior end. The anterior end touches the ventral margin of intercalar. The posterior end of tripus extends ventral to the transverse process of 4th vertebra and curved around ossa suspensoria to touch the anterior end of swim bladder.

The first precaudal vertebra of the axial skeleton is a flattened, rounded biconcave disc which pierced by a tiny thread of notochord. There is no neural arch, neural canal, neural spine, transverse processes or ribs. Therefore the first vertebra of *Puntius* is represented only by the centrum. This centrum is firmly articulates with the centrum of the 2nd precaudal.

The second precaudal vertebra is represented by a centrum with two small transverse processes. It is free of neural arch, neural spine or ribs. The transverse processes which arise laterally from the disc like centrum, extend laterally and anteriorly. The centrum of 2nd vertebra firmly articulates with the centrum of 3rd precaudal vertebra.

The third vertebra constitute a centrum, neural arches, a neural canal, a neural complex and two stout transverse processes. The neural complex is a sagittal square shaped flattened plate and it is detached from the neural pedicle. The two stout transverse processes extend laterally and anteriorly and then curved posteriorly for half of its length.

The fourth vertebra which is smaller than the third, contained a centrum, neural arches, a neural canal, a reduced neural spine, two large transverse processes and a ossa suspensoria. The ventrally directed, peg like, ossa suspensoria constitute two halves, each develops from the inner lateral base of the transverse processes of the 4th vertebra. The two halves together form a trianguloid plate hanging under the ventral posterior edge of fourth centrum. At the superior edge of the median suture where two halves come together an opening or foramen is formed. The ossa suspensoria serves as a anterior support of the swim bladder.

Precaudal vertebrae 5th — last (Fig. 18)

These vertebrae are typical in structure containing a centrum, neural arches, a neural spine, a neural canal, parapophyses, ribs, neural prezygapophyses (NPRZ) and neural postzygapophyses (NPOZ). Hence precaudal vertebrae are without haemal arch or haemal spine they are without haemal prezygapophyses (HPRZ) and haemal post zygapophyses (HPOZ). In species of *Puntius*, from the 5th to the 9th or 10th precaudal vertebra, the NPRZ succeeding vertebrae articulate with the posterior margin of neural arch of the preceding vertebrae. In other precaudal vertebrae the NPRZ of succeeding

vertebrae articulate with the NPOZ of the preceding vertebrae (Fig. 18). The laterally projecting parapophyses of precaudals articulate with ribs of each side. The neural spines of precaudals of species of *Puntius* interdigitate with predorsals or with proximal pterygiophores of the dorsal fin. The neural spines of precaudals form an angle of about 70° with the axis of vertebral column.

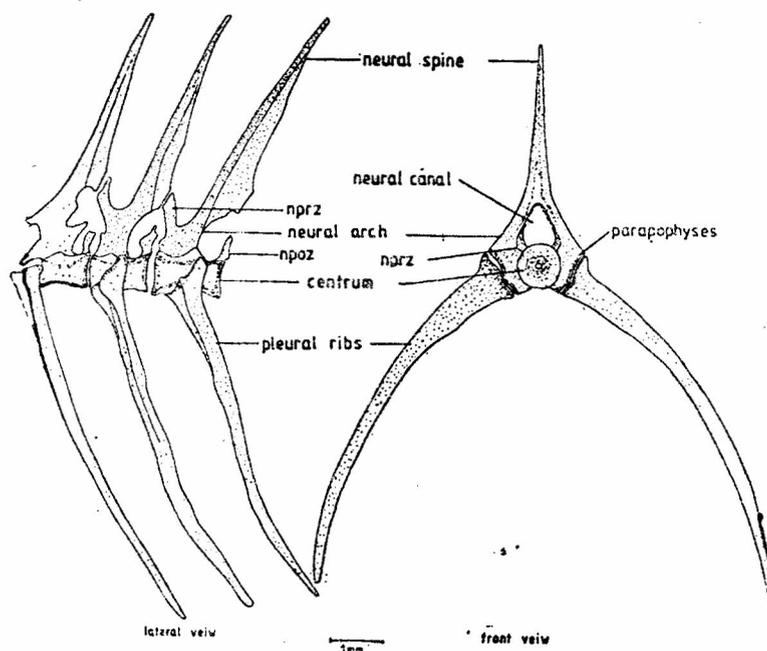


Fig. 18. Precaudal vertebrae (5th last) of *Puntius*. nprz -neural prezygapophyses, npoz -neural postzygapophyses,

Ribs (Fig. 18)

All precaudal vertebrae except the vertebrae of Weberian apparatus contained a pair of ribs loosely articulates with the parapophyses (Fig. 18). They are stout and long, curved downwardly. Sometimes the first one or two caudal vertebrae also have ribs along with the haemal arch and spine. But they are not true ribs. They are vestigial ribs (Fig.19). The stout transverse process of the 4th vertebra of the Weberian apparatus may be a fusion of ribs with the parapophyses (Wilimovsky and Weitzman 1955).

3.5.2. Caudal Vertebra (Fig. 19)

All caudal vertebrae are typified by the presence of haemal arches, haemal canal, haemal spine and absence of ribs (Fig. 19). However, there may be few vestigial ribs along with the haemal arches and spines of 1st and 2nd caudal vertebrae. The number of caudal vertebrae varies between 13 and 21 within the genus *Puntius*.

The haemal arches and spines are formed by the convergence of the paired parapophyses. In first one or two caudal vertebrae, although the haemal canal is formed by the fusion of two haemal arches they were without haemal spines. Instead they get vestige of ribs (Fig 19 a and 19 b).

All caudal vertebrae of all the species studied bear NPRZ, NPOZ and HPOZ. However all the caudal vertebrae do not bear HPRZ and the number of HPRZ bearing caudal vertebrae varies among the species studied. In the species of *P. sarana*, *P. filamentosus*, and *P. amphibius* get five to six HPRZ bearing caudal vertebrae. There are eight to nine HPRZ bearing vertebrae in *P. vittatus*, *P. pleurotaenia* and *P. cuningi* while in *P. nigrofasciatus*, *P. chola* and *P. dorsalis* there are 10 caudal vertebrae with HPRZ. In the species of *P. bimaculatus*, *P. titteya* and *P. ticto* there are 12 caudal vertebrae with HPRZ.

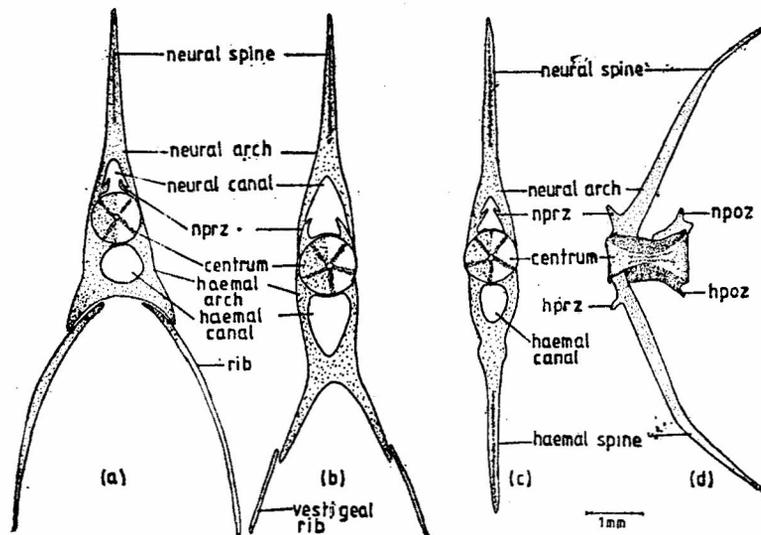


Fig 19. Caudal vertebrae of *Puntius*

- a) front view of 1st caudal vertebrae
- b) front view of 2nd caudal vertebrae
- c) front view of other caudal vertebrae with haemal spine.
- d) lateral view of caudal vertebrae.
- nprz — neural prezygapophyses
- npoz — neural postzygapophyses
- hprz — haemal prezygapophyses
- hpoz — haemal postzygapophyses

Neural and haemal spines of anterior caudal vertebrae are bent backward into an angle of 65°—70°. The haemal spines of anterior caudal vertebrae interdigitate with the pterygiophores of anal fin. The angle formed by the neural and haemal spines with the axis of the vertebral column gradually decrease

from anterior to posterior and become about 30° at the penultimate vertebra (Fig. 20a—20d). The centrum of antipenultimate, penultimate and urostyle vertebrae are shortened considerably and their specializations are so intimately associated with the support given to the caudal fin (Jinadasa and Kotalawala, 1991).

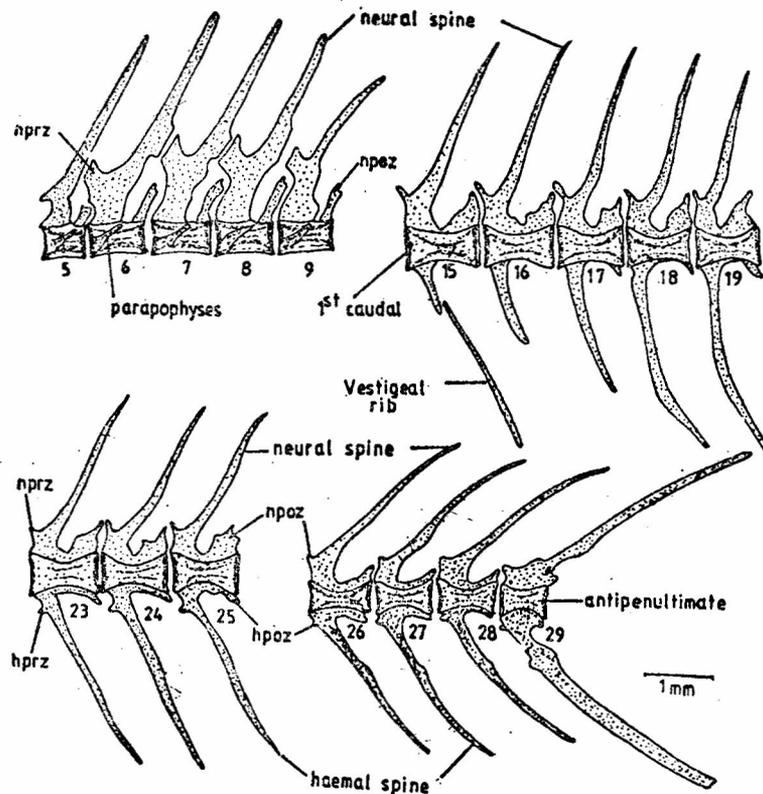


Fig. 20. Variation of the angle of neural spines and haemal spines with the axis of vertebral column of *Puntius*.

3.5.3. Epineurals And Ephaemals

There are two series of Y-shaped intermuscular splint bones loosely articulate with neural arches, neural spines, haemal arches and haemal spines (Fig. 21). The splint bones articulate with haemal arches and spines of vertebrae are called ephaemals while the splint bones articulate with neural arches and spines are called epineurals. All vertebrae except the vertebrae of Weberian apparatus and caudal skeleton contained epineurals and all caudal vertebrae except the vertebrae of caudal skeleton contained ephaemals. The epineurals project backward and upward from each neural spine while ephaemals project backward and downward from each haemal spine (Fig. 21).

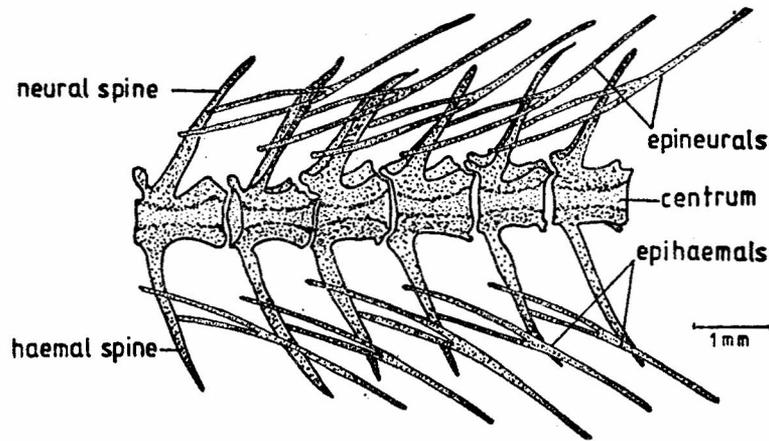


Fig. 21. The shape and orientation of epineurals and epihaemals of vertebral column of *Puntius*.

3.6. Median Fins

There are three median fins in *Puntius*. They are the dorsal and the anal fin which support in the balancing of the body and the caudal fin which is the main propulsive organ of the fish.

3.6.1. Dorsal fin (Fig. 22)

The dorsal fin constitute with tripartite pterygiophores, rays and spines. There are 9—11 proximal, intermediate and distal pterygiophors, 2 — 4 dermal spines and 7 — 9 dermal rays in the dorsal fin of *Puntius* species studied (Table V). All pterygiophores are tripartite sagittal bony elements supporting the spines and rays of dorsal fin. The proximal pterygiophores (ppt) are long and peg like, interdigitating with the neural spines of the precaudal vertebrae. The intermediate pterygiophores (ipt) are very short and rod shaped and articulate with the dorsal end of ppt. The distal pterygiophores (dpt) are small and cone shaped and articulate with the dorsal end of ipt (Fig. 22). However, all the pterygiophores of the dorsal fin of *Puntius* do not contain this tripartite structure. The first and last pterygiophore of all the species studied do not contain ipt or dpt. The three or four pterygiophores following the first pterygiophore do not contained ipt. Therefore in these pterygiophores dpt directly articulates with the ppt. The other five or six pterygiophores contained ppt, ipt and dpt. The last pterygiophore is a vestige.

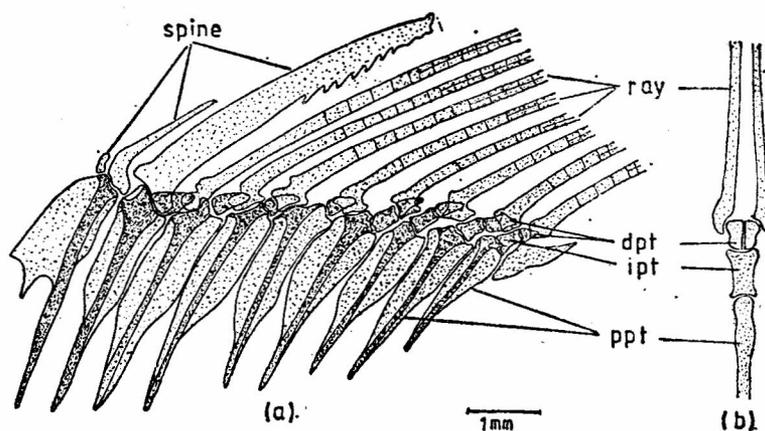


Fig. 22. The skeletal structure of the dorsal fin of *Puntius*.

- a) lateral view
- b) front view of a ray and pterygiophores.
ppt-proximal pterygiophore, dpt-distal
pterygiophore, ipt-intermediate pterygiophore.

The number and the nature of dorsal spines articulate with the pterygiophores varies among the species of *Puntius* studied (Table V). In all species, the spines of dorsal fin always directly articulate with the ppt of first two pterygiophores and not with ipt or dpt. In *Puntius* species studied the number of spines articulate with the second ppt is always one. However, the number of spines articulate with the first ppt varies among the species studied (Table V). In all species studied, the nature of spines articulate with the first ppt is smooth. However, the nature of the spine articulate with the second ppt varies among the species. In species like *P. sarana*, *P. cumingi*, *P. ticto*, *P. pleurotaenia* and *P. nigrofasciatus* the spine articulate with the 2nd ppt is serrate while in others it is smooth.

The rays of dorsal fin of *Puntius* are segmented, branched, laterally paired and articulate with the dpt of pterygiophores. The bipedal base of rays clasps the cone shaped dpt of pterygiophores (Fig. 22b). Each ray is associated with a pterygiophore but is displaced posteriorly so that it receives greater support from the pterygiophore of the succeeding ray (Fig. 22a). The number of rays of dorsal fin varies with the number of pterygiophores (Table V). The total number of rays of the dorsal fin is always less than that of ppt by two. *P. titteya* with 9 ppts contained 7 rays, *P. amphibius* with 11 ppt contained 9 rays and other species with 10 ppts contained 8 rays in the dorsal fin (Table V).

Table V. The numbers of predorsals, pterygiophores, rays, total number of spines on 1st ppt, the nature of spines on second ppt and dorsal fin formulae of species of *Puntius*, sm-Smooth, ser-serrate.

Species	N	No. of predorsal	No. of ppt.	No. of rays	Total No. of spines	No. of spines on 1st ppt	Nature of spines on 2nd ppt.	Dorsal fin formulae
<i>P. amphibius</i>	6	5	11	9	4	3	sm	0-0-0 0 0-3-1
<i>P. bimaculatus</i>	29	3	9-10	7-8	3	2	sm	0-0-0-2-1
<i>P. chola</i>	22	4	10	8	4	3	sm	0-0-0-0-3-1-
<i>P. comingi</i>	24	4	10	8	3	2	ser	0-0-0-0-2-1-
<i>P. dorsalis</i>	41	4	10	8	4	3	sm	0-0-0-0-3-1-
<i>P. filamentosus</i>	42	4	10	8	4	3	sm	0-0-0-0-3-1-
<i>P. nigrofasciatus</i>	31	4	10	8	3	2	ser	0 0-0-0-2-1
<i>P. pleurotaenia</i>	34	5	10	8	4	3	ser	0-0-0-0-0 3-
<i>P. sarana</i>	14	5	10	8	4	3	ser	0-0 0-0 0-3-1
<i>P. ticto</i>	26	4	10	8	3	2	ser	0-0-0-0 2- -
<i>P. titteya</i>	27	3	9	7	3	2	sm	0-0-0-2 1-
<i>P. vittatus</i>	30	3	10	8	2	1	sm	0-0-0-1 1

Predorsals are flattened sagittal bony elements lying in front of dorsal fin. They look like proximal pterygiophores without spines or rays and interdigitate with the neural spines of anterior precaudal vertebrae. The number of predorsals varies among the species of *Puntius* studied (Table V).

Smith and Baily's (1961) dorsal fin formulae which are based on the number of predorsals, spines on 1st ppt, and spines and rays on other ppts, varies among the species of *Puntius* studied (Table V).

3.6.2 Anal Fin

Anal fin is built on the same plan as that of dorsal fin, with spines and rays supported by tripartite pterygiophores. However, there is no preanal bones. The number of spines, rays and pterygiophores of anal fin is less than that of dorsal fin. The anal fin contained 7 ppt, 3 spines and 5 rays. The pterygiophores of anal fin interdigitate with the haemal spines of anterior caudal vertebrae.

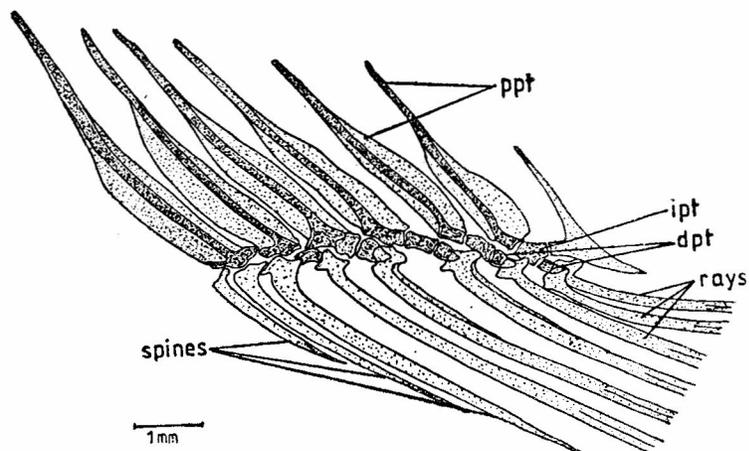


Fig. 23. The lateral view of skeletal structure of anal fin of *Puntius*. ppt-proximal pterygiophore, dpt-distal pterygiophore, ipt-intermediate pterygiophore.

The first and last pterygiophores of anal fin do not contain ipt or dpt and the last one is a vestige. Out of 3 anal spines first two directly articulate with the first ppt while the other one articulates with the 2nd ppt. The second and third pterygiophores are without ipt or dpt while the others are with ppt, ipt and dpt. The rays of anal fin articulate with the cone shaped dpts of 2nd to 6th pterygiophores. The dpts of anal fin bend over to meet the succeeding ppt and articulate with the rays. Therefore each ray is associated with a pterygiophores but is displaced posteriorly so that it receives greater support from the pterygiophores of the succeeding ray (Fig. 23). Typically all rays of anal fin are branched, segmented and bilaterally paired in all the species of *Puntius* studied. The numbers of pterygiophores, spines and rays of anal fin of species of *Puntius* studied are more or less constant.

3.6.3 Caudal Fin

The caudal fin skeleton of *Puntius* is built on a plan retaining the maximum number of independent bones. It contains two pairs of uroneurals, six unpaired hypurals, one unpaired parhypural and two unpaired epurals articulating with 15–17 branched rays and 12–19 unbranched rays. The caudal fin of *Puntius* is supported by the last three vertebrae of the axial skeleton (Jinadasa and Kotalawala, 1991).

3.7. Appendicular Skeleton

The appendicular skeleton consists of pectoral girdle, the pelvic girdle and their fins.

3.7.1 Pectoral Girdle

Pectoral girdle of *Puntius* is made up of two arches, each containing several bones and a pectoral fin. The two arches articulate each other ventromesially by a symphysis. Dorsally each arch is suspended to neurocranium by a posttemporal bone.

Each arch consists of cartilage bones and dermal bones. Scapula, coracoid and actinosts are cartilage bones while cleithrum, supracleithrum, postcleithrum, posttemporal, supratemporal, spines and rays are dermal bones (Fig. 24).

Scapula (Figs. 1, 24)

Scapula is a quadrangular flattened bone that juts from the cleithrum to support the fin. The dorsal portion of the scapula articulates with the cleithrum and the ventral portion articulates with the coracoid. A oval scapular foramen is completely surrounded by the bone. The scapula articulate with four actinosts posteriorly.

Coracoid (Figs. 1, 24)

Coracoid is a flattened, rectangular bone partially overlapped and suturally articulate with the expanded inner lamina of the cleithrum. The anterior coracoid process which arise from the ventral corner of the bone encloses a interosseous space. The postdorsal edge of the coracoid is narrowly separated from the scapula.

Actinosts (Fig. 24)

The four spool-shaped proximal actinosts articulate with the scapula and support the rays of the pectoral fin. The dorsalmost actinost is the smallest. Proceeding ventrally, the other actinosts gradually increase in size. The three distal actinosts are small and they are lying between proximal actinosts and rays.

Cleithrum (Figs. 1, 24)

Cleithrum is a large L-shaped bone forming an angle of about 110° between the two limbs (Fig. 24). The vertical limb is longer than the horizontal limb. The two L-shaped cleithra of the girdle articulate each other ventromesially by the ends of lower limbs. The blade-like vertical limb tapers to a point at its dorsal end and is bound to the medial surface of the supracleithrum along its entire length. The bend of the L-shaped cleithrum broadly expands and its medial surface articulates with the anterior one third of the scapula. The inner lamina of cleithrum overlaps and suturally articulates with the coracoid.

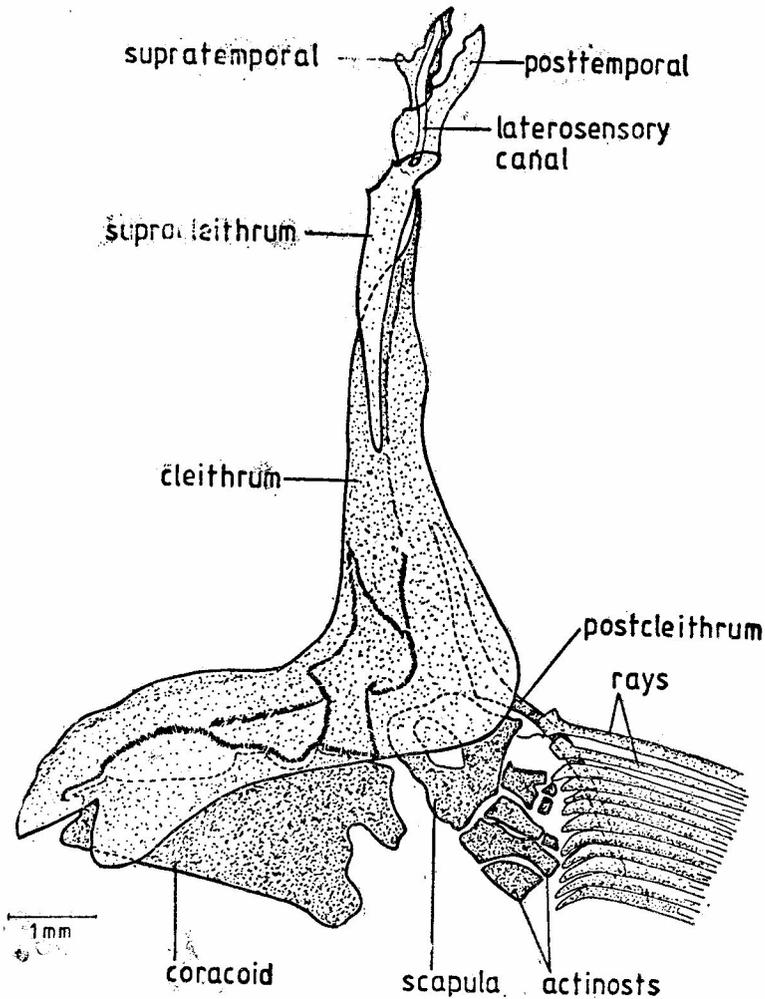


Fig. 24. Right side of the Pectoral girdle and the fin of *Puntius*.

Supracleithrum (Figs. 24. 25)

Supracleithrum is a thin, long blade—like bone with enlarged head at the dorsal end. The dorsal head articulates with the postventral surface of the post—temporal bone. The entire length of the medial surface of the supracleithrum articulates with the lateral surface of the vertical limb of the cleithrum. The shape of supracleithrum is species specific and can be used in the identification of species (Fig. 25).

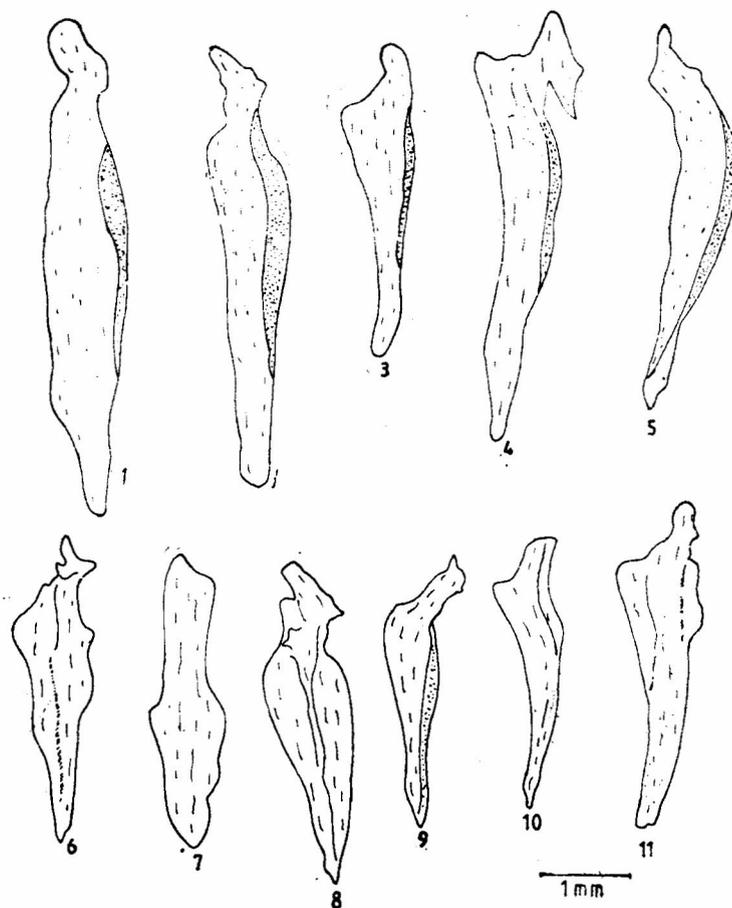


Fig. 25 Supracleithrum of species of *Purtilus*.

- | | | |
|-------------------------|-----------------------------|----------------------|
| 1. <i>P. sarana</i> | 2. <i>P. filamentosus</i> | 3. <i>P. chola</i> |
| 4. <i>P. dorsalis</i> | 5. <i>P. pleurotaenia</i> | 6. <i>P. cumingi</i> |
| 7. <i>P. vittatus</i> | 8. <i>P. nigrofasciatus</i> | 9. <i>P. titteya</i> |
| 10. <i>P. amphibius</i> | 11. <i>P. bimaculatus</i> | |

Postcleithrum (Fig. 24)

The bow-shaped thin long postcleithrum extends from posterodorsal region of the cleithrum along the abdominal wall musculature to a point of posterodorsal end of coracoid.

Posttemporal (Fig. 24)

Posttemporal is a flattened small bone articulates with the supraclithrum. It helps to suspend the pectoral girdle to the cranium. Its lancet-shaped dorsal end overlies the epiotic just beneath the semicircular ridge. It broadens out below into a wide flat plate and firmly articulates with the head of supraclithrum. On half of the way the posttemporal articulates with the forked supratemporal bone. A laterosensory canal in the posttemporal coincides with the laterosensory canal of the supratemporal.

Supratemporal (Fig. 24)

Supratemporal is a flattened, forked, dermal bone which articulate dorsally with pterotic and epiotic and ventroposteriorly with the posttemporal. Supratemporal bone is traversed by a laterosensory canal which coincide with the laterosensory canals of pterotic anteriorly and the laterosensory canal of posttemporal posteriorly.

Pectoral Fin (Fig. 24)

Pectoral fin of *Puntius* studied is characterized by the presence of one unbranched ray, 10—17 branched rays and absence of spines. The mean number and the range of pectoral rays of *Puntius* species of shown in table VI. It varies between species and very useful in taxonomical studies. The bases of pectoral rays are closely packed cradling the base of the succeeding ray and they articulate with the actinosts of the fin.

Table VI. Sample size, range and mean values of pectoral rays of *Puntius* species.

Species	N	Number of pectoral rays								Mean	
		9	10	11	12	13	14	15	16		
<i>P. amphibius</i>	6					2	2			2	14.75
<i>P. bimaculatus</i>	22			6	13	1	2				13.2
<i>P. chola</i>	22				1	2	10	9			15.26
<i>P. cumingi</i>	22		1	18	3						12.08
<i>P. dorsalis</i>	44		1		1	5	17	18	2		15.24
<i>P. filamentosus</i>	43		1		4	5	18	15			14.95
<i>P. nigrofasciatus</i>	31		7	18	5	1					12.09
<i>P. pleurotaenia</i>	34				11	10	10	3			14.14
<i>P. sarana</i>	11						3	5	3		15.93
<i>P. ticto</i>	26			15	9	2					12.52
<i>P. titteya</i>	25	4	8	9	4						12.52
<i>P. vittatus</i>	29		8	10	11						12.16

3.7.2 Pelvic Girdle And Fin (Fig. 26)

Pelvic girdle consist of two large elongate quadrangular basipterygia that meets each other by their bases to form a sutural joint on the midventral line. Basipterygia are thin but strengthened by two longitudinal ridges on ventral side running from the base to the anterior end. The anterior end is notched and form two pointed ends which are bound by ligements to the horizontal limb of cleithra. The ischiac process is formed by the extention of basipterygia posteriorly. The posterior base of the basipterygia directly support a spine and rays of the pelvic fin without the intervention of actinosts.

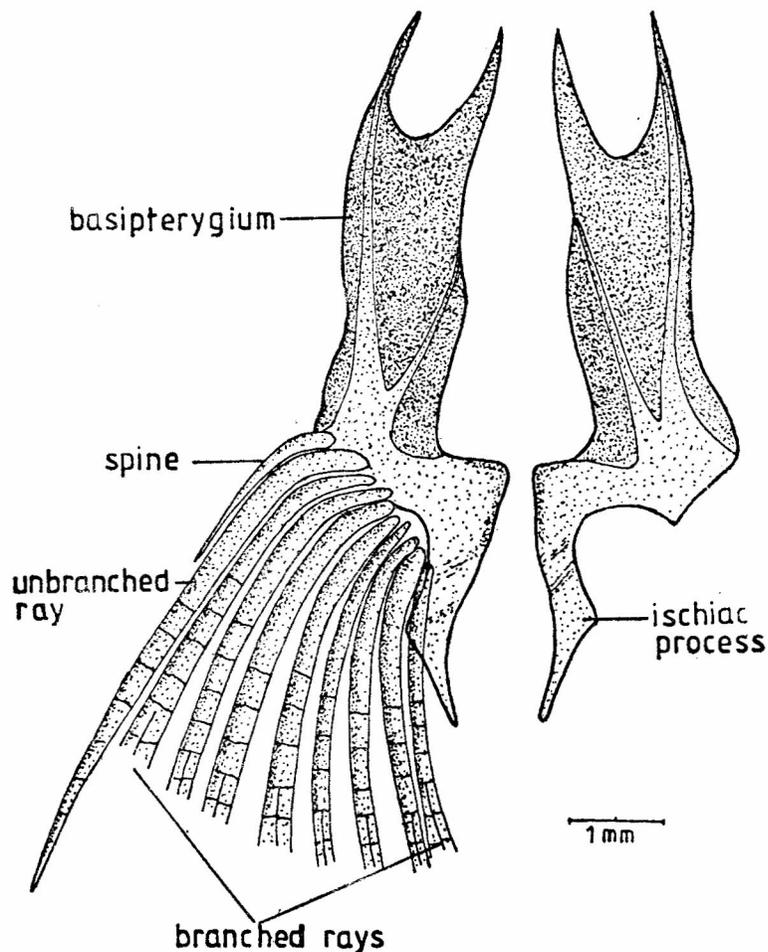


Fig. 26. Pelvic girdle and the fin of *Puntius*.

The pelvic fins of all the species of *Puntius* studied are characterized by the presence of a small spine and 9 rays except *P. titteya* which contains one spine and 8 rays. The bases of rays which are closely packed clasped the base of the basipterygia.

4. Discussion

The Cyprinidae family is very large- at least one species is found in all regions of the world except in Australia, Madagascar, New Zealand, South America, Northern Canada, Iceland and Greenland. About 1500 species of this family have been identified (Ramshort, 1981). In Sri Lanka, there are 40 species of Cyprinids belonging to three subfamilies and 10 genera (Pethiyagoda, 1990). Out of these species 16 are endemic, 8 are exotic and the remainder is shared with the ichthyofauna of the Indian Mainland (Pethiyagoda, 1990). Except the introduced species like *Cyprinus carpio*, none of the Sri Lankan species was osteologically investigated. The lack of information prevented us from attempting of giving an osteological definition for the family Cyprinidae. Out of 20 Sri Lankan species of the subfamily Cyprininae, sixteen are included in the genus *Puntius* (Pethiyagoda, 1990). Therefore based on the twelve species studied, it is possible to propose osteological characters for the genus *Puntius*.

According to Weitzman (1962), the presence of a preethmoid is an evolutionary advanced character of Cypriniforms. Presence of preethmoid is a characteristic feature of all the species of *Puntius* studied. It was noted in *Notropis bifrenatus* (Harrington, 1955), *Cyprinus carpio* (Wilimovsky and Weitzman, 1955) and *Schizothoracichthys niger* (Yousuf et al., 1988). However it was not found in *Brycon meeki* which belongs to the family Characidae of Cypriniformes (Weitzman, 1962).

The rostral bone is a specialization of Cyprinids (Weitzman, 1962). It helps to lever the premaxilla in the protrusion of mouth. As in other Cyprinids the rostral bone is present in *Puntius* also (=kinethmoid; Harrington, 1955 and Yousuf et al., 1988). But it is always absent in Characids (Weitzman, 1962).

The lateral ethmoid of *Puntius* anteriorly articulates with ethmoid and prevomer and posteriorly fused with prefrontals. It is a common feature of other Cyprinids such as *Notropis bifrenatus* (Harrington, 1955), *Cyprinus carpio* (Wilimovsky and Weitzman, 1955), *Schizothoracichthys niger* (Yousuf et al., 1988) and characids (Weitzman, 1962). As in other Cyprinids, the position of the anterior margin of the prevomer of *Puntius* is always extends forward than that of preethmoid. But in characids the anterior margin of prevomer is always behind that of ethmoid. The position of the ethmoid and the prevomer in Cyprinids is associated with the specialized mouth of these fishes and is undoubtedly more modified than the position of these bones in characids (Weitzman, 1962).

The interorbital septum completely separating the two orbits is a characteristic feature of other Cyprinids (Wilimovsky and Weitzman, 1955; Harrington, 1955; Yousuf et al. 1988) In *Puntius* also the interorbital septum completely separate the two orbits. However it is absent in Characids (Weitzman, 1962).

The orbitosphenoid which is another characteristic feature of *Puntius* and other Cyprinids, is present in characids (Weitzman, 1962). However the orbitosphenoid is absent in other fishes like Scianids (Topp and Cole, 1968), Scombrids (Collette and Chao, 1975) and Luarids and Acanthuroids (James et.al. 1990).

In Characids (Cypriniformes) there is a long cranial fontenale on the dorsal side of the skull between the two frontals and parietals (Weitzman, 1962). However in *Puntius* there is no fontenale but a small pineal foramen surrounded by frontals and parietals. The pineal foramen is found also in *Notropis bifrenatus* (Harrington, 1955) but not reported in *Schizothoraichthys niger* (Yousuf et.al., 1988). Perhaps the small pineal foramen in *Puntius* may be a evolutionarily advanced character which is found in evolutionarily advanced fishes such as Bonitos (Collette and Chao, 1975).

The basisphenoid, which is present in evolutionary advanced fishes such as Bonitos and Scianids, is absent in all the species of *Puntius* studied. The absence of basisphenoid is a characteristic feature of Cypriniformes (Harrington, 1955; Paterson, 1984).

Elongation of the ventroposterior end of basioccipital as a pharyngeal process is a characteristic feature of Cyprinids (Harrington, 1955; Wilimvesky and Weitzman, 1955; Yousuf et.al.1988) It is present also in *Puntius*. However, there is no pharyngeal process in Characids or in evolutionarily advanced fishes like Bonitos.

According to Weitzman (1962) and Ramaswami (1956), the frontal bone of all Cyprinids except *Esomus* are in contact with the pterotic and it is a primitive feature. In all the species of *Puntius* studied, the frontal is in contact with pterotic. Therefore *Puntius* is more primitive than *Esomus*. According to Weitzman (1962) and Regan (1911) the presence of a foramen between quadrate and metapterygoid is a primitive character. It is present in Characids and Chela (Cyprinidae) but not in *Puntius*.

The number of branchiostegal rays is a characteristic feature of fish. In the species of *Sarda* and their relatives there are 7 pairs of branchiostegal rays (Collette and Chao, 1968) In Characid there are 4 pairs of brachiostegal rays while in Cyprinids like *Notopris bifrenatus* there are 3 pairs of branchiostegal rays (Weitzman, 1962; and Harrington, 1955;). In *Puntius* there are 3 pairs of branchiostegal rays articulate with ceratohyals. The presence of a large number of branchiostegal rays is a primitive feature (Weitzman 1962).

As Weitzman (1962) states, Regan (1911) remarked the following charcters of cyprinidae as primitive. The terminal mouth, wide gill opening, medium dorsal fin, rounded abdomen, triserial pharyngeal teeth, complete series of

circumorbitals, separate second and third vertebrae are the all features of generalization. The species of *Puntius* studied show most of these features. All the species of *Puntius* studied are with terminal mouth and wide gill opening. Their mouth is protrusible but without any teeth on premaxilla, maxilla or palatine. But there are ten teeth in three longitudinal rows on fifth ceratobranchials.

The species of *Puntius* contained a series of 6 circumorbitals in a complete ring of which five are infraorbitals and the other one is supraorbital. As in *Notropis* (Harrington) and *Schizothoracichthys* (Yousuf et.al. 1988) the supraorbital of *Puntius* also firmly articulates with frontals.

The presence of Weberian apparatus is a characteristic feature of cypriniformes. As in other Cyprinids and Characids, the anterior four vertebrae of *Puntius* involved in the formation of Weberian apparatus. Although the four vertebrae of Weberian apparatus firmly articulated to each other, they can be separated by using a needle. In *Brycon meeki* (Cypriniform, Characidae—Weitzman 1962) the Weberian ossicle, tripus is attached to the 3rd centrum below the neural pedicle and its posterior end seem to be immovable (Weitzman 1962). However, in species of *Puntius* the tripus is easily movable. Except this character the entire Weberian apparatus of species of *Puntius* is very much similar to that of *Brycon meeki*.

According to Weitzman (1962), in *Brycon meeki* (Cypriniforms : Characidae) there are intermuscular bones attach to last few pleural ribs (epipleurals). However in species of *Puntius* there are no intermuscular bones attached to pleural ribs, but to haemal arch haemal spine, neural arch and neural spines. Weitzman (1962) named all the intermuscular bones attached to haemal arches as epipleurals but we named those intermuscular bones attached to haemal arch and haemal spines as epihaemals.

Based on caudal skeleton, all the species of *Puntius* are primitive fishes. (Jinadasa and Kotalawala 1991). They contained 6 hypurals, 1 parhypural, 2 pairs of uroneurals and two epurals and they have no procurent rays of Jonsen on the caudal fin.

In the species of *Puntius* studied, there seems to be a relationship between the number of rays and the proximal pterygiophores of the dorsal fin. The number of proximal pterygiophores is equal to the number of rays plus two. According to Weitzman (1962) in evolutionarily advanced fishes the tripartite character of pterygiophores of median fins greatly reduced and form one piece of bone. In species of *Puntius* the intermediate pterygiophores are absent only on first four or five pterygiophores of the dorsal fin. In other pterygiophore the tripartite character is easily visible. Therefore based on the structure of pterygiophores of the dorsal fin, the species of *Puntius* studied are not evolutionarily advanced.

Based on the number of predorsals and the number of spines articulated to the first pterygiophore and the others, the dorsal fin formulae can be formulated for the species of *Puntius* (Smith and Baily 1960). There are six dorsal fin formulae in the genus *Puntius*:

0-0-0-1-1—, 0-0-0-2-1—, 0-0-0-0-2-1—,
 0-0-0-0-0-2-1—, 0-0-0-0-3-1—, 0-0-0-0-0-3-1—:

According to Smith and Baily (1962) the basic and primitive plan of dorsal fin formulae are 0-0-1-1-1— and 0-0-0-2-1—. In evolution, the changes of this formulae occur due to the loss of anterior spines, reduction of predorsals and backward shifting of anterior spines (Smith and Baily 1962). Smith and Baily noted that interspecific differences of dorsal fin formulae are mainly due to the backward shift of spines of pterygiophores. Therefore, the differences of dorsal fin formulae of *Puntius* are also may be due to the backward shift of spines.

In the pectoral girdle of *Brycon meeki* (Cypriniforms: characidae) there are three post cleithra (Weitzman, 1962). In Bonitos and in Sciaenids there are 2 post cleithra (Collettle and Chao, 1975; Topp and Cole, 1968). However, as in *Cyprinus carpio*, species of *Puntius* contains only one postcleithrum. The reduction of the number of postcleithra is probably an evolutionarily advanced character.

4.1 Osteological features of *Puntius*

The paired preethmoids are articulate laterally with the articular junction of ethmoid and prevomer. The lateral ethmoid articulates laterally with prevomer, anterodorsally with ethmoid and lateroposterioly with prefrontals. The anterior margin of prevomer is little ahead of the ethmoid. Orbitosphenoïd is well developed but not directly articulate with the parasphenoid. There is a pineal foramen on the dorsal side of the skull surrounded by the frontals and parietals. The rostral bone is well developed. The two orbits are completely separated by interorbital septum. The basisphenoid is absent. No foramen between quadrate and metapterygoid. The ventroposterior margin of basioccipital is elongated backwards to form the pharyngeal process. Three pairs of branchiostegals present. Mouth is terminal and protrucible. No teeth on premaxilla, maxilla or palatine but there are 10 pharyngeal teeth in three rows on the S-shaped 5th ceratobranchials. There are five infraorbitals and one supraorbital. The supraorbital firmly articulates with the frontals. *Puntius* species are without basibranchial 4 and 5, hypobranchial 4 and 5, epibranchial 5 and pharyngobranchial 3, 4 and 5. The centrum of four vertebrae of Weberian apparatus firmly articulated to each other but can be separate. The epineurals and epihaemals present but no epipleurals. The caudal fin is of primitive type containing 6 hypurals, 1 parhypural, 2 pairs

of uroneurals and 2 epurals. In the dorsal fin, the number of pterygiophore is equal to the number of rays + 2. There are three spines and 5 rays in the anal fin and one spine and 8 or 9 rays in the pelvic fin. The number of rays of the pectoral fin vary from 10—17. The number of vertebrae vary from 27—41. There is only one postcleithra.

These osteological feature of *Puntius* studied may be common to other species of the genus and also to the other genera of the subfamily Cyprininae. This could be resolved after the study of osteology of remaining species of the genus *Puntius* and other genera belong to the subfamily Cyprininae.

5. Acknowledgement

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