

THE ANATOMY OF THE TASMANIAN PARROT FISH Pseudolabrus

tetricus (RICHARDSON) IN DETAIL

By

Paul Ching-ning Wu B. Sc.

submitted for the degree of
Master of Science

University of Tasmania
Hobart

1979

CONTENTS

1.	ABSTRACT	1
2.	INTRODUCTION	3
3.	PART I SKELETAL SYSTEM (with Discussion)	7
4.	PART II MUSCULAR SYSTEM (with Discussion)	92
5.	PART III DIGESTIVE SYSTEM (with Discussion)	133
6.	SUMMARY	147
7.	ACKNOWLEDGEMENTS	155
8.	REFERENCES	156

ABSTRACT

The parrot fishes of the family Labridae are brilliantly-coloured, perch-like, elongate-oval, moderately compressed fishes of small to large size.

Essentially they live in tropical regions but some occur in cooler Tasmanian waters. These herbivorous or carnivorous fishes hide themselves in coral reefs and among sea weeds. They have been called tuskfish because the mouth is equipped with the protruding tusk-like canines anteriorly in the jaw. Cheeks and operculum are scaled but the serrated preoperculum flange is naked. The single dorsal fin has 1st part with 11-13 spines and 2nd part of soft rays. Anal fin has 3 spines. Pectoral fins are moderately large and ventral fins thoracic. Caudal fin is round or truncate.

?
Two nostrils are on each side and the 4th gill arch is with a single gill lamella. Its scales are large cycloid and mostly brightly coloured and sometimes form the low basal sheaths of the dorsal and anal fins and the covering of the base of the caudal fin.

The musculature on the head and trunk have no large difference among the 3 species of the genus Pseudolabrus. The muscle of most species is soft and not particularly tasty.

The structure of the digestive tract of these 3 species ^{is} are very similar and can be divided into 6 parts: mouth cavity, pharynx, esophagus, stomach, intestinal bulb and intestine, which are lined with a soft mucous membrane.

Because its colour markings, body proportions, development of fins, distribution of scales and sex dimorphism change with age, many of the species are difficult to be identified on external features and internal structure. Those fishes of this family are not perfectly classified yet.

INTRODUCTION

There are 3 species of parrot fishes, *P. tetricus* (RICHARDSON), *P. fucicola* (RICHARDSON) and *P. mile* (BLOCH & SCHNEIDER) of Genus *Pseudolabrus* in Tasmania. It is very hard to find the differences from the morphological study on the specific characters based upon the anatomy of the skeletal system, muscular system and the digestive system.

Sometimes, the differences between the adult and juvenile of the same species are much larger than those among the different species. Interbreeding between two species may take place and then the hybrids have the intermediate characters of two species. This fact increase the complications and confusions of the comparative anatomy.

Therefore, this research concentrates emphasis on the detailed anatomy instead of comparative anatomy as in papers by Allis (1897) researched on the complex structure and connection between the cranial and first spinal nerves and cranial muscles in *Auia calva*, which showed the most primary type of the teleost. Chapman (1941, 1942, 1948) made a series of detailed reports on the osteology of the osmerid fishes, Argentinidae and round herring *Etrumeus micropus*, Curry (1939) described the histology of the digestive tube of carp (*Cyprinus carpio*), It showed that the intestine had a very thickened anterior region. Intestinal fold had a complex reticulate pattern with columnar epithelium and goblet cells present. Liver is a storage organ for oil and glycogen. Daves (1929) studied the histology of the alimentary tract of the plaice (*Pleuronectes platessa*). He found that the eosinophils.

in the mucosa of the esophagus changed from connective tissue cells and lymphocytes and neutrophils are existed. The lamina propria is composed of a stratum granulosum, stratum compactum, blood vessels and loose areolar tissue. The stratum compactum, circular and longitudinal muscle layers and serosa are presented. Gosline (1955, 1961) had reported some osteological features of gobioid fishes Kraemeria and Microdesmus and modern lower teleostean fishes and made their classification based on skeletal system. Greene (1914) examined the skeletal musculature of the king salmon in detail anatomy. Gregory (1959) had a great work on the systematic comparative study on fish skulls of different orders and the evolution of natural mechanisms. Hollister (1936, 1937) researched on the caudal skeleton of Bermuda shallow water fishes Order Isospondyli, Elopidae, Megalopidae, Albulidae, Clupeidae, Dussumieridae, Engraulidae, Iniomi, Synodontidae etc. and emphasized its importance on taxonomy. McVay and Kaan (1940) stated the morphology of the digestive tract of the Carassius auratus was studied from histological section. The stomach is between the siphonal and caecal type and has well-developed glands compared to other teleosts. Pear-shaped cells with enzyme-producing are present in the epithelium and glands of the ileum and pyloric caeca. Mujib (1967) studied the cranial skeletons of four gadid fishes, Gadus morhua (Subfamily Gadinae), Urophycis chuss (Lotinae), Lota lota (lotinae) and Merluccius bilinearis (Merluccinae) are described in detail. The Merluccinae probably give rise, on one hand, to the Subfamily Lotinae, on the other, to the Subfamily Gadinae, both of those subfamilies became further specialized. All three subfamilies differ from each other in their cranial osteology, as well as in other characters. Nursall (1956) reported on the lateral musculature and swimming of the fish. Histological studies have concluded that in addition to a superficial strip of muscle small diameter red fibres occur throughout the trout myotome. Parker (1886) made some

important studies in New-Zealand ichthyology on the skeleton of Regalecus argenteus. Regan (1907, 1910, 1911, 1912) had a series of reports on the anatomy of the teleostean fishes of the Order Allostriognathi, Zeomorphi, Iniomi, Salmopercae, Opisthomi etc. which had more descriptions than the former researchers. Ridewood (1904) researched on the comparative cranial osteology of the fishes of Families Mormyridae, Notopteridae and Hyodontidae. Rosen and Mendelson (1960) examined the sensory canal of the head in poeciliid fishes (Cyprinodontiformes) with reference to dentitional types and relation to lateral sensory system. Sarbahi (1951) studied the digestive tracts and digestive enzymes of gold-fish, Carassius auratus and the large mouth black bass, Micropterus salmoides. The histology of the digestive tract of these fishes were examined that their esophagus both showed longitudinal folding, stratified epithelium, columnar epithelium and goblet cells. Many enzyme activities were known in the pharynx, midgut and caeca. These activities indicated both secretory and absorptive abilities. Starks (1899, 1904, 1905, 1916, 1926, 1930) had the most abundant research works on the osteological characters of the fishes of the suborder Percosces, berycoid fishes and Caularchus macandricus (GIRARD); and the sesamoid articular, bones of the ethmoid region of the fish skull, and the primary shoulder girdle of the bony fishes etc. Suehiro (1942) worked on the digestive system and feeding habits of fish, which had more careful comparative statement than former research. Vickers (1962) studied the intestinal epithelium of gold-fish Carassius auratus, he found striated muscle fibers formed the thick muscular coat and columnar epithelium and gastric gland cells were present, the latter being absent from the pyloric region. Weinreb and Bilstad (1955) stated the alimentary tract of the rainbow trout, Salmo gairdneri inideus is a carnivorous type have a short esophagus, pouch-like stomach and a short intestine. Stratified epithelium with columnar cells and many goblet cells are

present in the esophagus. Columnar epithelial cells are only in the stomach. Both cells are in the intestine.

The samples of fish for this study were collected from Storm Bay and Bruny Island of Southern Tasmania, Northern Tasmania (through Queen Victoria Museum, Launceston) and Eastern Tasmania (through Sea Fisheries Laboratory).

For the work on histological study, the fresh special tissues of the fish P. tetricus are fixed in Bouin's solution for 1 week at first. Then these were washed in water for 2 hrs, dehydrated in 80-100% Alcohol for 6 hrs. Sections were cut at 3-5u thickness and stained in Hematoxylin and Eosin solution. Dehydration, clearing and mount in balsam complete the staining procedures. The microscopic photopictures were taken for the histological research.

Pseudolabrus tetricus (RICHARDSON).

- 1840 Labrus tetricus Richardson, Proc. Zool. Soc. Lond., Aug. 1840, p. 25. Port Arthur, Tasmania.
- 1872 Labrichthys tetrica var. fuscipinnis Klunzinger, Arch. Naturg. (Wiegmann)xxxviii, 1, 1872, p.37. Port Phillip, Victoria.
- 1872 Labrichthys tetrica var. tigripinnis Klunzinger, Arch. Naturg. (Wiegmann)xxxviii, 1, 1872, p. 37. Southern Australia.
- 1872 Labrichthys richardsoni Castelnau, Proc. Zool. Acclim. Soc. Vict. i, July 15, 1872, p. 150. Melbourne Market. Type in Paris Museum. Not Pseudolabrus richardsoni Steindachner, 1867.
- 1872 Labrichthys vestita Castelnau, Proc. Zool. Acclim. Sol. Vict. i, July 15, 1872, p. 151. Melbourne Market. Type in Paris Museum.
- 1879 Labrichthys tetrica var. ocellata Klunzinger, Sitzb. Akad. Wiss. Wien, lxxx, 1, 1879, p. 401. Murray R., S. Australia.
- 1887 Labrichthys cyanogenys Ramsay and Ogilby, Proc. Linn. Soc. N.S. Wales (2) ii, 2, Aug. 31, 1887, p. 242. Broken Bay, N.S. Wales. Type (I. 1245) in Austr. Mus.
- 1888 Labrichthys ceruleus Saville-Kent, Pap. Proc. Roy. Soc. Tasm. 1887 (1888), pp. xxx and 47. Ex Ogilby MS. Tasmania. Tasmania, Victoria, South Australia, New South Wales.

PART I

SKELETAL SYSTEM

Pseudolabrus tetricus belongs to the family Labridae and has a very well ossified skeleton.

Group 1. skull

(Fig. 6 to 11)

The complete skeleton of the head of P. tetricus is wedge-shaped presenting a triangular shape from the side view. The contour of the head ~~is~~, it has a blunt point of the wedge anteriorly and a wide posterior part. The length of the skull is almost equal to the width.

It is characterized by a prominent supraoccipital crest, a strong toothed premaxillary and dentary, a large lacrymal, a rugged frontal and a set of well developed opercular bones.

Two prominent ridges extend from the middle portion of the frontal to the epiotic and pterotic individually.

There are three grooves, the dilatator, temporal and supratemporal groove on the skull. From the posterior lateral corner of the frontal there is a shallow groove, the dilatator groove which runs postero-laterally over the dorsal part of the sphenotic and pterotic and terminates at the middle portion of the pterotic.

The temporal groove is median to the dilatator groove. Its anterior portion traverses a part of the frontal, parietal and pterotic, and posterior portion is very deep and open out at the hind end of the skull.

The paired supratemporal groove is situated medially on the top of the skull. It is shallower than ^{the} other two grooves. The two supratemporal

grooves are separated by the median supertemporal crest in which the trunk muscles extend.

Ethmoidal Region

(Fig. 6 to 10)

The olfactory region is the anterior most part of the skull and on a lower level than the frontal. The vomer is a dermal bone and the mesethmoid is a cartilage bone in origin but replaced by dermal bone latterly.

The vomer has a lateral process on each side, a depression into which the anterior arm of the palatine is situated dorsally to this process. The antero-ventral part (head) of the vomer is stout broad and bulbous and the posterior part is a shaft which has a very deep keel ventrally. The posterior end of this shaft insert into a median V-shaped depression on the antero-ventral portion of the parasphenoid

which extends anteriorly on both sides of the shaft to the head of the vomer.

The vomer connects dorsal-medially with the mesethmoid by which its posterior part is overlapped and is mutually united with the anterior edge of the prefrontal on each side laterally.

There are no tooth on the vomer, showing an advanced character of the higher Teleost.

A smooth concave articular surface on either side of the anterior portion of the head of the vomer gives an articulation to the posterior surface of the inner arm of the maxillary through a pad of thin cartilages.

The mesethmoid which is convex antero-dorsally connects with the medio-dorsal border of the vomer. There is a median ridge from the dorsal portion of the vomer, ending on the mesethmoid.

The mesethmoid protrudes a process dorso-medially between two frontals. The portion of the mesethmoid posterior to the above process is tucked in beneath the frontals.

The lateral portion of the mesethmoid is one part of the wall of the olfactory fossa.

The rostral cartilage is elongated with a deep median ventral groove attaching to the median ridge of the vomer and mesethmoid. The ascending processes of the premaxillaries connect with the dorsal surface of this cartilage which serves to bind these two processes together.

There is a cavity between the vomer, mesethmoid and prefrontals.
Parker(1873) stated it as the mes-ethmoidal fat cavity in Salmo.

Orbital Region

(Fig. 6 to 10)

The orbit is a large fossa which occupies almost half the length of the skull. It is bounded dorsally by the frontal, anteriorly by the lateral process of the prefrontal.

The prefrontal is on the latero-dorsal portion of the vomer. It has a large broad wing laterally. The anterior arm of the palatine is fixed in a concavity between the lateral wing of the prefrontal and the lateral ridge of the vomer .

The ventral surface of the base of its lateral wing bears a flat facet which glides forward and upward over the similar facet at the postero-dorsal portion of the anterior arm of the palatine. The articulation between these two facets is ill defined.

The anterior surface of the prefrontal is one part of the posterior wall of the olfactory fossa. There is a deep anterior depression which bears the foramen for the olfactory nerve. The mesethmoid separates the paired prefrontals on each side.

The lateral wing of the prefrontal also forms one part of the anterior border of the orbital fossa. Actually it is the septum between the orbital fossa and the olfactory fossa.

The paired frontals form a large part of the roof of the cranium and the dorsal border of the orbital fossa. In the orbital region the lateral part of each frontal is arched upwards to accommodate the eye ball. The frontal shows a convexity here. Its lateral margin is serrated. The anterior portion of the frontal has a sharp process which is inserted between the prefrontal and mesethmoid.

The supraorbital and the epiphyseal branch of the lateral sensory canal system are contained in the frontal and they divide into many sub-branches. Each of these sub-branches has a funnel-like opening on the surface of this bone.

Below the frontal, the orbital fossa which is formed by the antero-dorsal portion of the frontal and the posterior portion of the mesethmoid, is concave dorsally.

The high frontal crests of each side converge to medial-line

posteriorly and form the posterior border of the deep frontal fossa. The posterior most part of the frontal contribute partly to the formation of the posterior part of the skull which is dome-shaped.

The anterior most part of the frontal lies over the posterior part of the prefrontal and also projects slightly forward to form a small roof to the posterior part of the nasal cavity (olfactory fossa).

The anterior end of the prefrontal unites with a dorsal, beak-like process from the vomer. Both the mesethmoid and prefrontal are not tunneled by any lateral sensory canal.

On some fishes, such as Brycon meeki, the two frontals do not unite together. Weitzman(1955) stated that each frontal contacts the other only through the ossified epiphyseal bar (=infrafrontal bar of Gregory and Conrad. 1938, P.333. fig.12) being separated, as are the parietals, by the large dorso-median cranial fontanel. Each half of the epiphyseal bar continues in a lateral direction, its widening base lying against the median side of the ventral sheet of the frontal and the pterospheneid below.

The frontals of the P. tetricus unite together along the middle line of the skull. The epiphyseal bar of the frontal contacts its opposite partner and forms an ossified spine at the middle point and just anterior to the supraoccipital crest.

The frontal articulates with the supraoccipital parietal, pterotic, and sphenotic by the suture connection.

The two epiphyseal branches of the lateral sensory canal system which come from opposite sides, traverse the posterior portion of the

frontal crest and unite into one at the middle line of the skull, and then the single epiphyseal branch associates with the united two supratemporal branches posteriorly. There is no bone covering the lateral sensory canal system on this section.

There are two ridges on the posterior portion of the frontal. One ridge comes from the parietal medially and another is the pterotic ridge, through which passes the pterotic branch of the latero-sensory canal system .

The frontal is concave ventrally. The ventral surface of the frontal has a very high longitudinal ridge which is used as a septum separating the brain case and the dorsal portion of the orbital fossa. There is one of these paired septae on each side. Additionally some small tranverse septae are found on the ventral surface of the frontal.

The sphenotic of the P. tetricus actually consists of two parts, the dermal sphenotic(or postfrontal) is a small dermal bone. This bone sometimes can be considered as the 7th infraorbital bone. The lateral process of the sphenotic is on this part. The infraorbital branch of the laterosensory canal system connects with the supraorbital branch through the foramen on the tip of this process.

The posterior part, autosphenotic, is a cartilage bone which forms the larger part of the sphenotic, the fusion between these two bones is rather complete, but traces still can be found.

The anterior margin of the sphenotic conjoins with the frontal and the medio-posterior portion is overlapped by the pterotic.

A process is on the antero-lateral portion of the sphenotic. This

process which connects with the lateral margin of the frontal anteriorly, forms the dorsal boundary of the orbital fossa.

The 6th infraorbital attaches to this process ventrally.

The sphenotic conjoins with the prootic ventrally. There is a large socket, the 1st hyomandibular fossa, between these two bones. This socket articulates with the anterior head of the hyomandibular.

The ventral surface of the sphenotic is concave toward the ventral direction. A transversal bony septum protrudes from this surface.

There is no orbitosphenoid. Kingsley(1925) stated that orbitosphenoids are absent from tropibasic skulls, the Berycoids, Regalecus, Lampris and Velifer excepted. In platybasic crania they arise as paired bones which often fuse in the middle line, the orbital foramen lying between them and the ectethmoids.

The pterosphenoid is bounded posteriorly by the prootic and posterolaterally by the sphenotic. the antero-dorsal portion of the pterosphenoid is overlain by the frontal laterally.

The basisphenoid attaches to the postero-ventral portion of the paired pterosphenoids.

The antero-dorsal portion of the pterosphenoid is overlain by the frontal laterally. The longitudinal ventral ridge of the frontal extends posteriorly and connects with the ventral margin of the pterosphenoid. It contributes as the border of the opening from the orbital fossa into the braincase and as the anterior wall of the cranium.

Kingsley(1925) described that the pterosphenoids are reduced in

tropibasic skulls, and in some cases e.g. Cyprinus they afford attachment to a part of the hyomandibular.

The ventral margin of the pterospheneid has a serrated process. This serrated process is the vestige of the connective process of the paired pterospheneid. Liem(1963) stated that in Belontia the pterospheneids of the right and left sides are united by wing-like processes which run transversely across the orbit, forming the orbital roof.

The basisphenoid is a Y-shaped bone. Its two dorsal-lateral arms conjoin individually with the pterospheneid and the prootic of each side forming the floor of the anterior portion of the brain-case.

The ventral portion of the basisphenoid protrudes vertically and forms a leaf-shaped bone lamella, the interorbital septum, which has a serrated margin. According to the young specimens, it is not attached to the parasphenoid, but in the adult it is more ossified and combined with the parasphenoid ventrally. It contributes as a median septum in the postero-ventral portion of the orbital fossa.

The rhinosphenoid is a double layered bony lamella, which extends vertically on the posterior surface of the ethmoid. A cartilage, the orbital septum, inserts its anterior portion into the slit of the two bony lamellae. These three parts unite together and form the median septum of the orbital fossa.

Weitzman(1962) stated that this bone projects forward to between the median edges of the lateral ethmoids. In a very young specimen 32mm in standard length, the rhinosphenoid consisted of two thin discs set side by side sandwiching a disc of cartilage. In large specimens the bone has

a crescent shape and the two lamellar halves of this bone are fused along their dorsal edges.

Otic Region

(Fig. 6 to 11)

The auditory capsule in Teleostei is commonly formed by the ossification of several cartilage bones. The sphenotic covers the anterior semicircular canal and the prootic surround the facial foramen for the jugular vein.

The pterotic overlies the horizontal canal and the epiotic to which the posttemporal connects through the ligament forms the posterior border of the auditory capsule.

The pterotic (supratemporal) is on the posterolateral corner of the skull. It is a curved bone and V-shaped in cross section. The dorsal surface of the median half of this bone forms one part of the floor of the posttemporal fossa and the lateral half protruding dorsally

contributes to the most part of the pterotic ridge.

Goodrich(1930) described that the supratemporal(pterotic) invades the posterior region of the auditory capsule as the prefrontal(sphenotic) does in front.

The pterotic has an anterior process which is overlain on the median-posterior portion of the sphenotic. There are three other processes on the pterotic. The first is lateral process which has a opening on the tip for the mandibular branch of the laterosensory canal system. The second is the postero-dorsal process. The opening on its tip is the exit for the supratemporal branch of the laterosensory canal system. The third is the posterior process which has a very sharp posterior end and projects postero-laterally.

The pterotic is bordered antero-medially by the frontal and the parietal, medially by the epiotic, postero-medially by the exoccipital and ventrally by the prootic.

There is a foramen(temporal foramen) between the pterotic and the sphenotic.

Weitzman(1955) stated "A large foramen is present between the sphenotic and pterotic. This foramen may be seen in the lateral view of the cranium, although in the 82mm specimen figured it is partially covered by a shelf of the bone of the pterotic that extends outward and downward leaving an elongate fossa or groove beneath it."

There also has a large crescent foramen which exists even in the adult specimens on the bottom of the posttemporal fossa among the pterotic, parietal and epiotic. A cartilage covers (on) this foramen.

The third foramen is on the floor of the subtemporal fossa, among the pterotic, prootic and exoccipital. In the older specimen this foramen is not conspicuous.

A^b ovoid socket in which the posterior head of the hyomandibular is fixed, is on the latero-ventral portion of the pterotic.

The parietal is one part of the roof of the skull, which contacts anteriorly with the frontal, medially with the supraoccipital and posteriorly with the epiotic. The anterior portion of its lateral border contacts with the pterotic, but on its posterior portion this connection is separated by the large crescent foramen on the bottom of the posttemporal.

The parietal ridge comes along the middle line of this bone and extends forward to the posterior portion of the frontal and backward to the epiotic.

In some ^{of} other fishes, the parietal consists of two elements. One is the extrascapular element and another is the proper parietal element.

Weitzman(1962) stated "In a specimen of Hydrocynus lineatus, the parietal region of the left side consists of two elements, one of which might appear to correspond to an extrascapular element and one to the parietal. These two elements are separate and quite distinct. The right parietal in this fish is a structure similar to that in Brycon meeki and other characids examined in that it is a single bone."

Lekander(1949) stated the parietal of some cyprinids to be of the extrascapular and parietal elements.

Westoll(1944) considered that the degeneration of the posterior part of the supraorbital canal (=parietal canal) is found in numerous other groups of fishes and is frequently associated with the loss of separated parietal elements.

Weitzman(1955) believed in certain Teleostei(e.g. Macrodon(=Hoplias), Hydrocyon(=Hydrocynus) and Carassius the parietals seem to have been replaced by the anterior extension of the extrascapulars.

In P. tetricus the extrascapular I and II are on the parietal, meanwhile these bones do not fuse together. The supratemporal branch of the laterosensory canal system passes through the tubular extrascapular I and II but has no connection with the parietal.

Harrington(1955) described the tubular medial extrascapular as following "Its medial two-thirds is fused to the lateral two-thirds of the parietal, its lateral third is free and extends along the posterior edge of the supratemporal(pterotic) bone above the dorso-anterior surface of the epiotic."

Goodrich(1930) discussed the development of the frontals and parietals, his opinion was that in most Teleosts the frontals and parietals sink deeply below the soft tissues and prolongations of the anterior myomeres. Ordinary scales may then secondarily extend over the greater part of the head in higher Acanthoptergii. In these also the parietals usually become separated by the supraoccipital.

Epiotic

(Fig. 7 to 11)

The epiotic is an anvil-shaped bone. Its upper portion protrudes dorso-posteriorly. The lower portion of the bone conjoins medially with the supraoccipital laterally with the pterotic and ventrally with the

exoccipital. The parietal overlaps its antero-lateral portion and extends the parietal ridge to the epiotic.

There is a fossa on the dorsal surface of the upper portion of this bone. The dorsal process of the posttemporal is fixed in this fossa.

The epiotic forms the postero-medial border of the posttemporal fossa.

Marathe(1958) stated "The epiotic and pterotic bones are internally excavated for the passage of the posterior vertical and horizontal semicircular canals respectively."

Supraoccipital

(Fig. 7, 9, 10 & 11)

The supraoccipital which occupies almost half length of the skull forms the postero-medial roof of the cranium.

Weitzman(1962) described the dorsal surface of the supraoccipital as containing a groove, the supraoccipital sulcus, that passes back from the posterior edge of the dorsal cranial fontanelle to near the posterior edge of the supraoccipital spine.

Harrington(1955) stated its concave anterior border conforms to the postero-medial margin of the posterior chondrocranial fontanelle.

The ossification of the skull of the P. tetricus is quite complete, so there is no cranial fontanelle nor a supraoccipital sulcus.

The supraoccipital can be described as two parts, the antero-dorsal part and the postero-vertical part. The former which tapers into an anterior process, is a narrow and triangular bone.

The latter which also is a triangular bone extends between two exoccipitals but does not reach the foramen magnum. These two parts fuse together at a right angle.

The high crest extends from the antero-dorsal part to the posterior vertical part.

Harrington(1955) stated "The occipital spine may possibly represent the demomesupraoccipital. It is composed of two thin plates overlying and fused to the postero-lateral surfaces of the supraoccipital. The plates converge in the sagittal plane to form the spine, Which projects beyond the hind edge of the supraoccipital."

Goodrich(1930) concluded that the history of the supraoccipital is still obscure, there is no good evidence that it has been derived from the median dermal occipital of lower fish(Grossopterygii, Chondrostei).

It develops as an endochondral bone and may possibly correspond to the neural spines further back. Recently, however, Watson has described a supraoccipital in an Osteolepid, a Coelacanth and a Palaeoniscoid, it may after all be a primitive bone, perhaps homologous with that of Tetrapods.

Prootic

(Fig. 8 & 11)

The anterior margin of the prootic forms the lateral border of the myodome which extends forward from the posterior portion of the parasphenoid and the medial side of the prootic to the orbital region. The prootic conjions antero-dorsally with the sphenotic, postero-dorsally with the pterotic, posteriorly with the exoccipital, antero-ventrally with the basioccipital.

Lien(1963) described the myodome in Anabantoidei as following" The myodome expands dorso-laterally, reaching the ventral surface of the trigemino-facial chamber, posteriorly the myodome narrows rapidly and ends in the anterior quarter of the prootic.

A large round socket which articulates with the anterior head of the hyomandibular exists between the prootic and the sphenoid.

The lateral detailed aspect of the prootic can be described as following "There are two large recesses on the dorsal portion of the prootic. The openings of these two recesses are separated by a bony bridge, but their inner parts connect each other under this bony bridge. Three foramen exist on the bottom of these two recesses.

The large dorsal foramen is the facial foramen, the antero-ventral one is the trigeminal foramen and the postero-ventral one is the auditory foramen.

There are 4 small foramina on the dorsal portion of the prootic along the horizontal bony lamella except the auditory, facial and trigeminal foramen.

A prominent ridge starts from the ventral border of the posterior recesses running postero-ventrally and extends to the basioccipital. The posterior portion of the prootic is concave laterally, which forms the anterior portion of the subtemporal fossa.

A horizontal bony lamella extends longitudinally from antero-dorsal to posterior portion of the prootic. A prootic bridge is formed by the junction of the horizontal lamellay processes of two prootic bones on the midline of the skull. This prootic bridge is the floor of the cranial

cavity in front of the parachordal plate and behind the infundibulum. The ventral myodome exists in the cavity between the basis cranii and the parasphenoid in Teleostei.

As Harrington(1955) stated that the more extensive, dorsal lamellae meet in the midline to form the prootic bridge over the posterior eye-muscle canal(myodome), which is also the floor of the braincavity. These dorsal lamellae diverge anteriorly, leaving a gap between the hypophyseal foramen through which the stalk of the hypophysis passes.

Exoccipital (Fig. 9 & 11)

The exoccipital conjoins dorsally with the supraoccipital, dorso-laterally with the epiotic, laterally with the pterotic, anteriorly with the prootic and ventrally with the basioccipital. The glosso-pharyngeal nerve(IX) pierces the exoccipital and becomes two branches in the bone, so it has two exits on the postero-ventral portion of the exoccipital. In the same condition, the vagus nerve has two small and one large exit on the posterior portion of the exoccipital. The posterior portion of the exoccipital forms the border of the foramen magnum. The dorsal portion of the exoccipital has a lamella which extends medially and meets its counter part in the midline to form the dorsal roof of the foramen magnum.

There are two ridges on the posterior portion of the exoccipital,

one runs from the base of the occipital condyle and extends dorsally, to the dorsal portion of the exoccipital, another extends ventrally closing but not fusing to the basioccipital.

The exoccipital has two occipital condyles on the posteriormost portion. Each articulates with the anterior sockets of the 1st precaudal vertebra. This articulation is almost immovable.

Goodrich(1930) believed that the exoccipitals more or less completely enclose the foramen magnum above and laterally as well as let through the hypoglossal nerve and define the hinder limit of the vagal foramen.

In the higher Teleostei they may have a facet for the first vertebra. On the middle portion of the inner surface of the exoccipital a bony lamella extends ventrally and parallel to the exoccipital and attaches to the basioccipital. The cavity between this lamella and the exoccipital is the saccular cavity.

Weitzman(1962)insisted that internally and externally the exoccipital forms the dorsal portion of the bony lagenar, and from the ventral surface of each of these lamella, another sheet of bone extends downward to meet a similar structure extending upward from the basioccipital. Together these two lamellae of bone form the upper median wall of the posterior portion of the saccular cavity.

The anterior vertical semicircular canal does not pass through any otic bone but is held in place by a small cartilaginous septum connected generally with the pterotic and sphenotic or pterotic and supraoccipital.

Marathe(1958)stated that this bone (exoccipital) exhibits a large, rounded foramen, through which the diverticulum of the air-bladder

enters the auditory capsule.

The P. tetricus does not have this foramen on the exoccipital.

Basicranial Region (Fig. 8)

Basioccipital (Fig. 8 & 11)

The basioccipital conjoins anteriorly with the parasphenoid, dorsally with the exoccipital.

The basioccipital is externally excluded from contact with the prootic by the exoccipital but the anteriormost border of the basioccipital contacts the prootic internally.

The antero-dorsal portion of the basioccipital is a large square process(four sided bar, tenon-like)which is H-shaped in cross-section and fixed in a square furrow on the posteriormost portion of the parasphenoid.

The upper part of the H-shaped process forms the lower floor of the lagenar chamber and the posterior portion of the saccular cavity. The lower part of it is a channel for the dorsal aorta which comes from the branchial region through a foramen between the basioccipital and the parasphenoid to the body cavity. Below the bony lamellae of the prootic, between the basioccipital and above the parasphenoid, there is a long cavity for the posterior myodome for the orbital region.

The posterior portion of the basioccipital is a conical bone. The point of this bone is toward the anterior direction. A deep furrow which forms the dorsal half of a foramen for the dorsal aorta, is on the ventral surface of it. Just beside this furrow there has a small joint surface on each side for the posterior spines of the parasphenoid.

Marathe(1958) described the basioccipital as a small cylindrical bone, enclosing the sacculus and lagena of the membranous labyrinth.

Parasphenoid

The parasphenoid is an elongated bone which extends almost the same length of the skull, the anterior portion connects with the postero-dorsal portion of the prevomer. The posterior part conjoins with the prootic, basioccipital and exoccipital, and contributes as the floor of the skull. The middle portion is the ventral border of the orbital fossa. The parasphenoid forms the posterior myodomal chamber along with the prootics.

The posterior myodome of the orbital region and the dorsal aorta is

in this chamber above the posterior portion of the parasphenoid.

The anterior portion of the parasphenoid is a spine which is a inversed V-shaped in cross-section, There has a groove which ends posteriorly to a cavity on ventral surface of this bone. The posterior end of the shaft of the vomer inserts into this groove and cavity.

Harrington(1955)stated"At its anterior end, it overlaps and is closely applied to the upper surface of the hind end of the prevomer, and is overlain dorsally by the posterior end of the cartilaginous planum ethmoidale, which separates it from the ventromesial borders of the lateral ethmoids and form the hind end of the ventral edge of the ethmoid."

Goodrich(1930) described that Acipenser and the Teleostei are distinguished by the possession of a median prevomer. Since, however it shows signs of paired origin in Salmo and is stated by Walther to arise from paired rudiments in Esox, this bone probably represents the two prevomers fused.

There has a strong carina(Keel) which is for the attachment of the muscles of the branchial region on the ventral surface of the parasphenoid. It starts from the middle portion of this bone under the posterior border of the orbital fossa and extends posteriorly between two pharyngeal condyles.

Between the middle and posterior portion of the parasphenoid, there has a large foramen for the carotic artery.

Goodrich(1930)stated"Primitively the parasphenoid closely adheres to the basis cranii, though allowing the internal carotids to reach the

fenestra hypophysis by the parabasal canals, but in Teleostei where the ventral chamber of the myodome becomes much developed, it may become widely separated from the floor of the brain cavity."

The posterior portion of the parasphenoid differentiated into two pharyngeal condyles which articulate with the socket on the posterodorsal portion of the upper pharyngeal teeth mills on each side.

On the lateral surface of the posterior portion of the parasphenoid there is a high ridge on each side, which comes from the prootic and connects to the pharyngeal condyle. This ridge forms a reinforcement for the pharyngeal condyle.

The posteriormost portion of the parasphenoid is a trough-shaped bone which has two spines protruded posteriorly. The anterior portion of the basioccipital, a square process, is fixed in this trough. The notch between these two spines forms the ventral half of the dorsal aorta foramen.

Lien(1963)described the pharyngeal processes on the basioccipital and the parasphenoid as following: Posteriorly the parasphenoid is differentiated into a stout pharyngeal process at an angle of about eighty degree with the horizontal axis. The pharyngeal process bears eight stout conical teeth and ventrally it is produced into a short and stout bilobed pharyngeal process. The anterior border of the pharyngeal process does not articulate with the posterior border of the pharyngeal process of the parasphenoid.

P. tetricus has the parasphenoid process only, but the parasphenoid process differentiates into two very strong pharyngeal condyles for the suspension of the upper pharyngeal teeth mill.

Group 2. Visceral Skeleton

The visceral skeleton is derived from seven visceral arches which originate from the splanchnic mesoblast in embryonic stage. In Teleosts the first or mandibular arch becomes two cartilage, the palatopterygo-quadrate and the mandibular or Meckel's cartilage. The palato-ptyerygo-quadrate cartilage of each side connects to the prefrontal process. Its quadrate part support the Meckel's cartilage and pterygo-palatine part with some dermal bones forms the wall of palate. The premaxillary, maxillary, dentary, articular, and angular etc. are secondary dermal bones which replace or fuse with the cartilage bone laterally.

The second or the hyomandibular arch becomes the hyomandibular and hyoid arch. The former serves as a suspension for the two jaws and the hyoid arch to the skull. The remaining five visceral arches are branchial arches. Each branchial arch is divided into paired pharyngo-, Epi-, Cerato-,Hypo- and single basibranchial from dorsal to medio-ventral part.

Upper Jaw (Fig. 16 to 19)

One pair of the premaxillary and one pair of the maxillary form the upper jaw which is attached to the otic region of the skull by the intervention of the hyomandibula and symplectic. In front it connects with ethmoid region through the palatine. The premaxillary is L-shaped and curved medially slightly. It has a ascending process which is

almost equal to the length of the body of the premaxillary extends postero-dorsally from antero-medial end of the premaxillary.

The two process are so long that they can attach upward to the mesethmoid region through the rostral cartilage. The process of each premaxillary conjoins with its counter-part of the opposite side and bound to it by connective tissue on the middle line of the head. A convoluted jointed is then formed.

The maxillary and premaxillary are strongly bound together by fibrous ligaments and the premaxillary is similarly bound to its fellow of opposite side. The four bones thus form a compact single piece with a little bit of movement between one another. Liem(1963) stated " The ascending processes from both sides are closely conjoined and fit into a notch formed by the ethmoid and the prefrontal-lateral ethmoid complex. The ascending process is as long as the body of the premaxillary in *Belontia*, one-half the length of the body in *Betta*. *Trichopsis* and *Macropodus opercularis* twice the length of the body in *Sphaerichthys*, and more than twice the length of the body in *Trichogaster* and *Colisa*". Harrington(1955) described" It expands dorsoventrally to form a prominent ascending process. The ascending process of the two premaxillaries are connected by the sigmoid ligament to the "rostral" bone and thence to the anterior end of the ethmoid".

Bridge(1877)stated "Each premaxillar consists of an expanded and thickened marginal portion in which the long and curved teeth fringing the anterior margin of the gape are situated, and of an ascending portion which passes backwards beneath the nasals in contact with the subnasal cartilage and inter-nasal septum as far as the anterior edges of the frontals". The ventral surface of the premaxillary bears 2 to 3 row conic teeth and forms the upper border of the gape. The number of

the teeth is indefinite because the replacement is happened. The teeth on the outer row are larger and stouter than those on the inner rows.

The medial-most teeth of the outer row is largest tooth on the premaxillary. The lateralmost tooth of the same row is the second large one. All the teeth are conic, only one cusp, called monocuspid. Sometimes thecodont lost tooth and becomes empty. In this condition the most outside tooth of inner row will grow gradually outward for replacing the tooth of outer row at last. So we perhaps may call the teeth of inner row, replacement tooth. There is a notch between the paired medial most teeth, in which the paired largest teeth of the dentary lie when the mouth is closed.

The premaxilla is partly overlapped by the maxilla but the only articulation is the inner surface of the base of the posterior end of the premaxillary bend antero-ventrally and an arm on which the second large tooth of the premaxilla is beared is formed on this portion. This arm is situated on the corner of the mouth and attaches loosely the dentary of the lower jaw.

Just as in some advanced Teleosts, the maxillary which is a quite thick bone and convex on its outer surface does not contribute to the border of the gape and has no teeth. From the dorsal view it is Y-shaped, the medial end has two arm, the outer arm projects forward, which has a sharp anterior tip. The inner surface of this tip attaches to the premaxillary. The another arm, inner arm, is shorter and stronger with a rather smooth knob on its tip. This knob articulate with the postero-ventral surface of the ascending process of the premaxillary, the articulation is ill defined.

The premaxillary rest on the fork between these two arms, and then it

forms as sheath. When the fish opens mouth the ascending process of premaxillary can be movable a little bit in this sheath. On the postero-dorsal surface of the inner arm there rises up a facet with articulation with the ventral surface of the lateral process of the vomer. The median side of the inner arm attaches to the antero-lateral surface of the vomer by connective tissue.

Palato-Quadrate Arch

(Fig. 34 to 43)

The palatine, ecto-palatine, meso-palatine and meta-palatine forms the palato-quadrate arch which serves as the accessory apparatus of two jaws and the roof of the oral cavity. The palatine is a inversed L-shaped bone. It has a strong arm which is long and projected forward and attached to the anterior part of a depression on the outer arm of maxillary through the notch between the lateral process of the prefrontal and the lateral process of the vomer.

The three bones, the quadrate, palatine and metapterygoid of the palato-quadrate arch are ossified from the cartilage, the palato-ptyergo- quadrate bar. Two dermal bones, the ectoptyergoid and meso-ptyergoid add on it latterly. These bones do not form the gape of the mouth.

Its ventral edge is smooth, but on the right angle of the inversed L-shaped palatine there is a small articulatory process dorsally. The anterior surface of the process articulates with a depression on the postero-ventral surface of the lateral prefrontal process. This articulation which suggests a connection between the palatine arch and the skull through a ligament is slightly movable. This articulation is not the same as Harrington(1955) described the palatine of N. bifrenatus as following " The anterior half of the bone is more complicated having laterally a longitudinal ridge terminating anteriorly in a maxillary process and medially a ventral and a dorsal wing which receive between them the cartilage covered lateral surface of the preethmoid bone. This is the type of articulation termed discussed by Swinnerton(1902) who also noted in other cyprinids that the mobility of the suspensory apparatus is ensured by the autopalatine-endopterygoid articulation."

The endopterygoid of the P. tetricus is not attached to the prefrontal. From the study of Dharmarajan(1936) Otolitus ruber " The process is directed downwards and outwards, and dorsally at its base is a deep V-shaped concavity into which the ventral ball-like knob of the lateral ethmoid fits. Anterior to this depression is a dorsal ill-defined facet which glides under a similar one found dorsally on the lateral ethmoid at the base of the lateral ethmoidal process.

There is an ill-defined facet on the ventral surface of the arm. This facet glides on the dorsal surface of the round lateral process of the vomer. The posterior edge of the palatine is a longitudinal depression which lies over the anterior border of the ectopterygoid.

Liem(1963) stated that the palatine consists of two components, the slender and curved ethmoid process directed antero-dorsally, articulates with the prefrontal-lateral ethmoid complex, and the body articulates

ventrally with the quadrate and posteriorly with the ectopterygoid. The body of the palatine is somewhat variable in shape mostly it is elliptical, but in Trichopsis it is triangular and in Betta irregular."

There are not any teeth on the palatine. The arrangement is different from Chapman(1944) described " The palatine is a short rod of bone abutting against the vomer anteriorly and against the palatine band of cartilage posteriorly. The anterior end is cupped, and the cup lined with cartilage. The posterior end is flattened and broadened but is not greatly thickened or in any other way differentiated for attachment to the prefrontal as is customary in the Isospondylous fishes. A broad band of cartilage extends down from the palatine along the mesopterygoid, send a spur down along half of the anterior face of the quadrate, continues around the dorsal side of the quadrate and then dorsally between the symplectic and the metapterygoid. It sends a broad branch dorso-medially between the mesopterygoid and metapterygoid. The latter, the quadrate and the palatine are contined with the cartilage and undoubtedly derived from centers of ossification in it.

Bridge(1877) stated about Amia calva " The palato-pterygoid apparatus is constructed on the normal Teleostean type as regards the number and mutual relations of its component bones. It consists of a thin axial core of cartilage which posteriorly become continuous with a projecting spur of the quadrate, and anteriorly, in the prefrontal region, swells out into a thickened mass of cartilage and bone overlying the exosteal portion of the palatine. Its connections with this axial core, palatine, pterygoid and mesopterygoid elements are developed. He also described the palatine " It is composed of two distinct elements, an exosteal lamella which forms the inferior part and lateral margin of the bone, and an endosteal portion by which the anterior part of the arcade is connected with the prefrontal and apparently formed by the ossification of a mass of cartilage similar

to that which in the Salmon performs a like function. The exosteal element is prolonged forwards in front of the prefrontal bone so as to be ultimately connected with the premaxilla, vomer and septo-maxillary. The palatine of P. tetricus has not any conspicuous difference between the exosteal and endosteal."

Marathe(1959) studied T. trichepterus and stated that the palatine is generally formed of two bony elements the autopalatine and dermopalatine. The former is a cartilage bone and the latter a dermal one. In Trichopodus the palatine is in the form of a bent rod-shaped bone with a broadened posterior part, joining the anterior end of the ecto- and endo-pterygoids. The dermopalatine is absent in this fish.

Only the autopalatine is found in P. tetricus.

The ectopterygoid is a slender compressed bone. It tapers at both ends with a dorsal sharp process which wedges between the palatine and the mesopterygoid. There are two bony lamella folded on the postero-ventral edge. The quadrate and mesopterygoid are fitted in the groove between these two folds.

The posterior border of the ventral process overlaps on the antero-dorsal portion of the quadrate . Its anterior border is free.

The metapterygoid which affords the wall for the orbit is a large thin bone. Its anterior edge overlaps on the ectopterygoid. The posterior edge of metapterygoid joins and partly overlies the antero-ventral portion of the hyomandibular and its postero-ventral border connects with the symplectic through a cartilage line. So the palato-quadrate arch and hyoid arch connect each other. This also serves as the suspensory mechanisms of two jaws to the skull indirectly.

In P. tetricus there is not any conspicuous cartilage-tipped process, even a small one on the dorsal portion of the metapterygoid as in Amia calva. The metapterygoid is far from the skull. A thin bony splint protrudes from the anterior ventral portion of the metapterygoid attached to the inner surface of the quadrate. It is the hyostylic type of the lower jaw suspension in P. tetricus. The metapterygoid does not connect or attach to the cranium. In Amia calva, the conspicuous cartilage tipped process of the metapterygoid almost reaches the level of the cranial end of the hyomandibular. This is the vestige of the amphistylic type. The metapterygoid of P. tetricus is far below this level.

Goodrich(1930) stated " It is the processus ascendens typically developed from the pterygoid region of the palato-quadrato bar near the origin of the basal process as a dorsal cartilage passing vertically upwards between the profundus nerve and the maxillary branch of the trigeminal, and laterally to the vena capitis lateralis. Its upper end fuses with the orbital wall of the cranium in Dipnoi. It is found neither in Chondrichthys nor in modern Teleostomi except possibly as a vestige. Whether it occurred in early primitive Teleostomes is not yet certain but Watson describes traces of it in an Osteolepid."

The palatine, mesopterygoid and ectopterygoid form the anterior border of the optic cup. The dorso-posterior and ventro-anterior part of the metapterygoid are thicker than its middle part. Harrington(1955) stated " Each bone (each metapterygoid) shows traces of its cartilaginous origin in the retention of some calcification within its two thick, bony struts. One strut extends in the dorso-posterior angle of the bone, forming the chief point of articulation with the hyomandibular, the other extends to the cartilage separating hyomandibular and symplectic, opposite the interhyal." The mesopterygoid is a very thin, dermal bone. It is spade-shaped and tapered dorsally. The medio-dorsal margin of it is free. The

rest margins of this bone are overlapped by the ectopterygoid antero-ventrally, quadrate ventrally and metapterygoid posteriorly. The mesopterygoid, metapterygoid are both without any tooth. The quadrate is a triangular bone. Its anterior and ventral borders are thicker than the central portion. The posterior portion of the ventral margin rests on the preopercle. There are two grooves on the median side of the ventral portion. The upper one embeds half of the length of the symplectic in it. The lower one is in the protruded shovel-shaped process beyond the body of the quadrate. The antero-dorsal border of the preopercle is fixed in this process and the lower groove. There is a broad smooth ridge along the ventral border of the quadrate. It corresponds with the lower groove on the inner surface. Namely it tucks into a groove along the ventral border and on the inner surface. The postero-ventral border of the ectopterygoid contact with the quadrate. The postero-dorsal portion of the quadrate lies over the antero-ventral portion of the mesopterygoid and connects with the metapterygoid through a plate of thin cartilage.

There is a condyle on the antero-ventral corner of the quadrate. This condyle articulates with the posterior socket of the articular to form a movable articulation for the lower jaw. On the ventral side of the antero-ventral condyle there also has a small but very deep socket. The hook on the ventral part of the posterior socket of the articular is fixed in this socket. So the strong connection between the articular and quadrate is a very extraordinary double articulation. A very prominent cartilage line exists on the posterior border of the quadrate.

Lower Jaw

(Fig. 20 to 21)

The bones of the lower jaw, such as the dentary, articular and angular etc. derive from a double origin. The Meckel's cartilage exists on the inner surface of the articular. A small endochondral element of the dentary perhaps represent the rudimentary Mento-Meckelian.

The dentary is the foremost bone of the lower jaw. It has two large backward extending arms which meet at an angle of about 45 degree. The articular is fitted in the deep V-shaped indentation between these two arms. There is a shallow longitudinal depression on each arm. The depression on the ventral arm of the dentary is for the insertion of the intermandibularis muscle. The laterosensory canal system which comes from the articular traverse the ventral arm of the dentary longitudinally. Two rows of teeth are born on its dorsal surface except the posteriormost portion. The number of teeth is variable, all being conic and monocuspid. The teeth of the outer row are larger than those of the inner row. The medial pair is the largest on the lower jaw and the teeth of the inner row can be replacement teeth as mentioned above for the premaxillary.

Goodrich(1930) described " The dentary is also of compound origin, being formed of a true dermal dentary and a small anterior element probably representing the Mento-Meckelian. The anterior portion of the dentary bends mesially and conjoins with its counter part on the midline of the lower jaw by a symphysis." Haines(1937) stated that the articular of teleosts is another bone called retroarticular. Lekander(1949) made observation on the cyprinid "Phoxinus" and he agreed to this theory. Goodrich(1930) agreed to it too. He used "angular" instead of "articular" and "retroarticular" instead of "angular".

(Fig. 44 to 45)

The articular is irregular in shape and concave on its medial surface.

It has a slender process on its dorsal portion. The anterior border of this process abuts against the posterior end of the dorsal arm of the dentary. The anterior portion of the articular is a large triangular process which inserts anteriorly into the V-shaped indentation of the dentary. This process is convex on the lateral surface and concave on the medial surface for the attachment of the sesamoid articular and Meckel's cartilage. On the posterior end of the articular, there is a stout socket. The ventral part of this socket rises dorsally a hook. The socket and hook both articulate with the corresponding condyle and socket on the anterior end of the quadrate. The laterosensory canal system pierces this bone from the base of the posterior socket to the ventral portion of the anterior process and connects with the dentary anteriorly .

On the medial surface of the articular lies the ectosteal which contributes to the large part of the articular is a flat bone, outside of endosteal, sesamoid articular and Meckel's cartilage. Although endosteal is one part of the articular, there is not any prominent separation. The endosteal forms the articular socket in posterior end and projects forward in a process. This process abruptly ossifies to become the endosteal process.

The angular(=Retroarticular) is a small bone. The dorsal portion of this bone is fixed in a depression on the inner surface of the postero-ventral corner of the articular. Its ventral border is free. There is a small depression on the postero-ventral edge of the bone. A tough ligament attaches to its end on this depression and another end on the inner surface of the interoperculum. No laterosensory canal system passes through the angular. The angular is a mixed ossified bone which has a core of endochondral bone and is overlain by dermal bone.

The sesamoid articular is a small bone attached on the inner surface of

articular. The adductor mandibular muscles is adhensive on it.

Cuvier(1827) called it the "operculaire". Owen (1846) used another name "splenial" instead of the operculaire, but unfortunately he made some mistakes. It appears that Owen's "splenial" is a bone that usually bears the names in the Ganoids and is clearly a dental cement bone. No homology exists between this bone and the sesamoid articular (Cuvier's operculaire).

Erdl(1847)called it "Coronoidea mandibulae". Cope(1878) used the term "Coronoid", and "sesamoid articular" was used by Ridewood(1909) and Starks(1916).

But another name "Coronockelian" is adopted by de Beer(1937), Lekander (1949), Harrington(1955) and Weitzman(1962).

The sesamoid articular of P. tetricus is a small triangular bone which is just situated on the junction between the endosteal process and Meckel's cartilage. Starks(1916) described Dentex vulgaris as following " The sesamoid articular is very much as in Lobotes et. al. (moderate in size or small) but is on top of the endosteal process and Meckel's cartilage, and very little, if at all, hidden behind them. In Archosargus and Pagrus it is much more over the endosteal process than over Meckel's cartilage. In Diplodus this condition is reversed. In the other it is about equally over both. It is much more over the endosteal process than over the Meckel's cartilage as in Archosargus and Pagrus.

According to Starks(1916) paper in which he stated"Typically as in the perch-like fishes, it is rather small and more or less covered by Meckel's cartilage. Sometimes, as in Albula, it is as large as the endosteal process, or as in some of the Synentognathous fishes, it is so large that it projects

above its surrounding elements. So that it is visible from the outer surface. Sometimes it is loosely attached to the mandible and is easily pulled away with its tendon. Sometimes it is attached to the mandible by a dentate suture and is disarticulated with difficulty. Usually it is more or less broadly attached to the ectosteal plate of the articular, but sometimes only narrowly attached, and occasionally scarcely, or not at all in contact. Sometimes it lies saddle-like over the top of Meckel's cartilage, remote from any bone. It is variable in its connection with the endosteal process, but as the attachment may depend upon the extent of the ossification of Meckel's cartilage to form the process. This is without significance."

Starks(1916) also stated" It is significant, that in every case the sesamoid articular is in close relationship with Meckel's cartilage (or with the endosteal process which is ontologically the same). Even in case where it has developed upwards towards the coronoid region it still retains its connection with the primitive cartilage.

Goodrich(1930) stated the coronoids have disappeared and even the "angular" may vanish. The so-called articular is made up of an endochondral articular fused to an outer dermal element usually called "derm-articular". The latter corresponds in position to the large angular of Amia and is probably its homologue, in that case the " angular", which develops from an endochondral and dermal element, has been wrongly named. The Meckel's cartilage is a long slender rod-like cartilage which conjoins with the endosteal process of the articular and almost to the anterior end of this bone.

Hyomandibular Arch (Fig. 46 to 48)

The hyomandibular arch consists of two half-loops united together by a medial basihyal.

The dorsal portion of each half-loop ossifies into epihyal, ceratohyal and hypohyal etc. The hyoid cornu is included in the hyo-branchial skeleton. Because it is so close connected with the branchial arches.

The hyomandibula is a long flat bone. The posterior portion of the hyomandibula is thicker than its anterior portion. It has a very broad thin wing on the anterior portion and a deep groove on the posterior margin formed by the posterior edge of the hyomandibular and a bony lamella which is parallel to it. The wing forms the posterior wall of orbital fossa and the groove is for fixing the anterior border of the preopercle in it.

The hyomandibular has a long broad and thick process projecting ventrally. At the tip of this process is a cartilage, connecting with the dorsal end of the symplectic. There are two openings, one is on the inner surface of the process for the anterior facet and another on the ventral end of the posterior groove. A canal connects these two openings in this bone. Both the canal and the openings are for the passage of the ramus hyomandibularis facial nerve. The posterior edge of the metapterygoid overlies its thin border on the anterior portion of the hyomandibular. Actually the end of the process is lodged in a depression on the midway of the anterior border of the preoperculum. Then the median surface of the preoperculum connects with the ventral process of the hyomandibular.

Goodrich stated" The hyomandibula of Teleostomes articulates dorsally with the lateral surface of the auditory capsule, the broad facet for its reception being usually share by the postfrontal (sphenetic) and

supratemporal(pterotic)" and " The articular head of the hyomandibula in many of the higher Teleostei (Acanthopterygii) becomes subdivided into two, the anterior abutting against the postfrontal and the posterior against the supratemporal. The posterior edge of the hyomandibula acquires a knob for articulation with the opercular".

Edgeworth (1926) has shown that the hyomandibula of Teleostomes is in early stages a cartilaginous rod situated entirely in front of the hyomandibular nerve (except in Polypterus) and that later it may surround the nerve by backward growth, maintains that this hyomandibula is homologous throughout the fishes.

Goodrich(1916) stated about the position on which the hyomandibular attaches to the skull said " That the articular head dorsal to vein and nerve in Teleostomes is an otic process is doubtful, but it is not impossible that an articulation, originally ventral in Selachians may have moved up to a new position by passing over the bridge, forming the outer wall of the jugular canal into which the vein and nerve have sunk in Teleostomes" and also stated, "But in the Teleostomi its articulation with the auditory capsule shifts possibly over the jugular canal, to a more dorsal position above the vein and nerve."

Gregory (1933) adopted the view that the hyomandibula of the teleostomes is truly homologous with that of the Selachii but that it has shifted dorsally, passing over a groove and bridge containing the vena capitis lateralis and part of the facial nerve. The hyomandibula is the posterior suspensory mechanism for the opercular apparatus, two jaws, hyoid cornu and branchial arches. This kind of suspensorium which exists in all Teleosteans and many Selachii is called hyostylic.

There are two ball-like facets on the dorsal surface of the hyomandibula. The anterior facet which is on the top of a process directing

antero-dorsally articulates with the 1st hyomandibular socket of the cranium, a large round socket between the sphenotic and prootic. The posterior facet directing dorsally articulates with the 2nd hyomandibular socket of the cranium which is an ovoid socket on the pterotic. All these are capped with cartilage.

Gregory (1933) stated " When, as in some Teleostomi, the hyomandibular has two articular heads, this is due to the gradual development of the primary single articular head into two heads, and is not due to the fusion of any extra cartilage. The dorsal border of the hyomandibular attaches tightly to the cranium between these two facets.

On the postero-dorsal portion of the hyomandibular there has a condyle which is fixed in a socket on the antero-dorsal corner of the opercle.

The symplectic is a slender bone lies between the metapterygoid, quadrate and hyomandibular. Its anterior portion is embeded in the upper groove of the ventral portion of the quadrate. The dorsal part of it lies between the posterior edge of the metapterygoid and the dorsal border of the pre-operculum.

The dorsal end of the symplectic conjoins the hyomandibular through a cartilage. On the interspace of this cartilage is a depression into which the dorsal head of the interhyal fits. Gregory(1933) acknowledged that the symplectic of teleostomes appears to represent only the lower part of the hyomandibular, which in Polypterus is not yet separated off from the main part of the element.

Opercular Apparatus

(Fig. 22 to 29)

The opercular apparatus includes preopercle, opercle, subopercle and interopercle. The preopercle is a sickle-shaped bone with a concave anterior edge and a convex posterior edge. Both the dorsal and the ventral ends of the bone are pointed. It is thicker, bearing no conspicuous growth lines and is different from other opercular bones.

The dorsal part of its anterior border is partly fitted in the groove on the posterior border of the hyomandibular. Its middle-dorsal border connects with the hyomandibular and the symplectic. The postero-dorsal border of the preopercle lies on the anterior border of the opercle and the ventral border parallel to the dorsal border of the interopercle.

The serrated posterior margin of the preopercle has an external flange. The preopercle encloses the laterosensory canal system. The main canal runs along the longitudinal axis through all the length of the bone and subdivides into many ray-like branches in the serration of the posterior margin. Each of the branches has a funnel-like opening which connects with the sensory receptors on the skin.

The dorsal portion of the interopercle is overlaid by the preopercle. It has a skin-like fold between these two bones. Regan(1929) acknowledged that the interopercular apparatus to be the separated lower end of the subopercular. In the oldest Actinoptेरans, it is represented by the first branchiostegal. The interopercle is shaped like the shell of the clam. Its dorsal edge is more or less straight and thick, but its ventral edge is convex and thin. It has many growth lines along its ventral border. A depression on the postero-dorsal portion of the interopercle joins it to the posterior end of the epihyal. The anterior end of the interopercle is connected to the articular by a ligament.

The opercle is a smooth and irregularly triangular bone. The antero-dorsal portion is the apex of this bone which is thicker and has a socket on the medial surface. This socket articulates with the postero-dorsal condyle of the hyomandibular. It has two strong ridges starting from the base of the socket on the medial surface of the opercular. The large one runs to the middle portion of this bone and the small one runs ventrally to the large one at an angle of 20 degree. A small fossa which is dorso-posterior to the socket for the hyomandibular serves as the insertion of the *M. levator operculii*.

On its lateral surface the anterior border on which the preopercle attaches becomes very thick. The ventral border of the opercular is overlapped on the dorsal portion of the sub-opercular.

Nasal Region

(Fig. 49 to 50)

The nasal is an elongated flat bone and hollow inside. The laterosensory system traverses this bone longitudinally. Its mesial edge lies parallel to the inner ascending process of the premaxilla.

One pair of the nasals is separated ^{from} the other. On each side of the most anterior portion of the cranium there is an olfactory fossa formed by the ascending processes of the premaxillary, palatine, prefrontal, ethmoid and a little part of the frontal. The nasal covers on this fossa is the olfactory cavity. ?

There are two external openings between the nasal and preorbital through which the water may flow inward and out ward to the olfactory cavity.

Infraorbital and Antorbital

(Fig. 51 to 54)

These six dermal bones contribute to the formation of the orbital ring. Because the dorsal supra-orbital is absent the ring is completed by the frontal and sphenotic partly. The inner edge of these bones are more smooth than the the serrated outer edge.

The lachrymal is a large rhomboid bone covered on the maxillary, a part of the palatine, premaxillary and prefrontal. It forms the antero-ventral border of the orbit. Its inwardly directed dorsal process has socket. The free end of the lateral process of the prefrontal articulates with this socket by tiny ligament, and then the lachrymal attaches to the skull. The upper portion of the lachrymal is thick and the lower portion is thin just as the case with all the orbital ring bones. There are two indentations on the lachrymal. The anterior one is for the two nostrils and the posterior one fitting the second infraorbital.

The lachrymal associates with the laterosensory system. The main canal passes through the dorsal portion of this bone and branches many small tubes inside of it. Each tube has a opening on the terminal and connect with the sensory receptor which is on the skin.

The 2nd, 3rd, 4th, infraorbital are irregularly shaped bone much small than the lachrymal, the laterosensory system passes through their dorsal border.

The 5th, 6th infraorbital are flat tube-shaped bones, the canal of the laterosensory system also traverses them.

The 6th infraorbital contacts with the sphenotic process, therefore the laterosensory system on the infraorbital bones connect with that on the cranium.

All the infraorbital bones connect together and form the ventral border of the orbital fossa.

Branchial Arches (Fig. 12 to 15)

The first pharyngobranchial is a very small vestigial cartilage, attached to the anterior end of the first epibranchial. The second pharyngobranchial is a thin bone which is concave on the ventral surface and attached on the anterior border of the upper pharyngeal teeth mill. Its lateral end connects at about the middle of its length to the second epibranchial. Both of these two bones neither become the suspensory mechanism which suspends the branchial arches from the skull, nor have any supporting function. Srinivasachar (1955) described Ophicephalus striatus that the first and second pharyngeal branchial bear teeth of uniform size on the ventral surface.

Marathe (1959) also stated that the second pharyngeal-branchial bears dentigerous patches. These are different from the P.tetricus. The 3rd and 4th pharyngobranchial unite together and form a large upper pharyngeal teeth mill. On the ventral surface of this mill the teeth situated on the lateral portion are monocuspid with a sharp top, but

those on the central portion having a blunt top after a long period of grinding are larger than the former. The upper pharyngeal teeth mill can grow larger as the body grows.

The upper pharyngeal teeth mill is a triangular solid bone. There is a large socket on the medial portion of the dorsal surface. This socket articulates with the condyle on the postero-ventral surface of the parasphenoid. The two upper pharyngeal teeth mill of the opposite side close together, but do not fuse to each other. The dorsal half of the masticatory apparatus is formed.

It also serves as the suspensory mechanism of the branchial arches to the cranium. In many other fishes, such as B. meeki, the 1st, 2nd and 3rd pharyngobranchial become suspensory pharyngeal. See Weitzmans (1955) statement " Each of the first three branchial arches has a suspensory pharyngeal or modified pharyngobranch. These short bones form the bony part of the suspensory mechanism of the branchial arches." But in Labrids the two upper pharyngeal teeth mills which are used for grinding the hard food have a very strong conjunction to the skull. Therefore, it is not necessary to develop another suspensory mechanism, and the 1st and 2nd pharyngobranchial have no use for the suspension at all.

Goodrich(1930) stated " The usual four paired lateral and median ventral elements are typically present in the Teleostome branchial arch, and generally ossified, But are subject to considerable modification and reduction, especially in the posterior arches. The 5th arch, usually of one piece, frequently become conspicuously toothed forming "The OS pharyngeus inferior". While the pharyngobranchials of the last three arches similarly form a toothed " OS pharyngeus superior" these often become powerful masticating plates armed with

large teeth". Sometimes the pharyngobranchials have more modification than other branchials.

Srinivasachar(1955) stated " But in the first branchial arch the pharyngobranch of each side is fused with the epibranch of its side."and "In the third and fourth branchial arches the pharyngobranchs of both arches of either side have fused and bear a single dentigerous plate though a suture divides it apparently into two."

The 1st, 2nd, and 3rd epibranchials all have a suprapharyngeal process on its mesial end. The 1st and 2nd epibranchials are bifurcated thin trianguloid bones. Its lateral ends articulate with the posterior end of the ceratobranchial of its own arch. The first epibranchial is slightly curved. The concavity is on the postero-medial surface. There is a wide and shallow depression on its dorsal surface. A flattened triangular process protrudes medially and connects with the small cartilage, the first pharyngeal branchial. The posterior process connects with the upper pharyngeal teeth mill through a tendon. Its lateral end unites with the first ceratobranchial through a cartilage.

The second epibranchial takes after the first, but smaller in size. Its antero-medial portion connects with the second pharyngeal branchial, and its medial and posterior processes attach on the upper pharyngeal teeth mill.

The third epibranchial is a rhomboid bone. Its medial surface articulates with the lateral surface of the upper pharyngeal teeth mill through a strong articulation. The posterior process is very sharp and has a free end. There is a round depression on the middle portion of it.

The 4th epibranchial is a strong wing-shaped bone. Its medio-ventral

end conjoins with the postero-lateral portion of the upper pharyngeal teeth mill through a large articulation. Many muscles connect with the upper pharyngeal teeth mill and the 4th epibranchial, and operate the grinding function.

The first 3 ceratobranchials are elongated thin bones which are concave dorsally slightly. Each forms a central broad groove on the ventral surface. The medial portion of the first 3 ceratobranchials are uncomplete ossificated. Both two ends of the ceratobranchial are connected by a piece of cartilage. Its anterior end conjoins with the posterior end of the hypobranchials and its posterior end articulates with the epibranch of the same arch.

The 4th ceratobranchial which bents dorsally upwards is a slender stick-like bone. Its central groove is more narrow and its medial portion is more complete ossificated than the former three.

The anterior end of the 4th ceratobranchial connects with the cartilage slip as the 4th hypobranchial.

The paired 5th ceratobranchials fuse together and become a large inversed T-shaped solid bone. This is the lower pharyngeal teeth mill. The anterior process of the lower pharyngeal teeth mill extends about half length of its horizontal bar. The anterior half part of this process protrudes beneath the 3rd basibranchial, and the posterior half is dentulous. The ends of the horizontal bar of the lower pharyngeal teeth mill attache to the cleithrum of the pectoral girdle on each side. The lower pharyngeal teeth mill connects with many muscles on the lower jaw for the purpose of the grinding function. There are 4 to 6 row of the teeth which are polyphyodont and monocuspid. It has not definite arrangement. These on the medial portion are large and more blunt than

those on the border. The number of the teeth is indefinite.

The dorsal surface of lower pharyngeal teeth mill attaching against the ventral surface of the paired upper pharyngeal teeth mills forms a very well masticatory apparatus for P. tetricus. The first 2 pairs of hypobranchials are short bones. The antero-dorsal portion of 1st hypobranchial is produced into a process which articulates with the 2nd basibranchial. It also has a ventral triangular process directed medially and protruded below the 2nd basibranchial. The anterior end of this process almost touch the postero-ventral corner of the 1st basibranchial. There is an angle of 70 degree between the 1st hypobranchial and the midline of the head. Its dorsal surface is smooth but its ventral surface is concaved longitudinally for ledgeing the branchial blood vessel. The 2nd hypobranchial has two anterior processes the dorsal one articulates with the lateral depression of the 3rd basibranchial and the ventral one is free. The longitudinal groove of the 2nd hypobranchial is deeper than the first, it articulates with the 2nd ceratobranchial through a cartilage.

The 3rd hypobranchial is a large triangular bone situated on the ventral surface of the branchial arches and extends vertically. Its dorsal corner conjoins the cartilage between the 3rd ceratobranchial and 3rd basibranchial, its ventral corner projects postero-ventrally, and its medial corner almost connects with its counter part of the other side. The truncus arteriosus passes between two 3rd hypobranchials. It is concave on medial surface. On its posterior portion there is a depression for the insertion of the muscle of the lower pharyngeal teeth mill.

A small piece of cartilage among the 3rd, the 4th basibranchial and the 3rd hypobranchial. Allis(1903) considered it as the 4th hypobranchial.

The 5th hypobranchials lie in the mid-ventral line of the branchial arches. They are connected by synchondrosis. The first is a four-faced bar situated between the hypohyals and extends antero-ventrally joined to the basihyal. Its ventral surface articulates with the urohyal.

The second has a small depression on the middle portion of each side. The 1st hypobranchial fixes its anterior process in this depression. Its dorsal surface is flat but the ventral surface is rugged.

The 3rd basibranchial is a rhomboid bone and longer than the other two basibranchial. The 2nd hypobranchial and the 3rd hypobranchial articulate with its proximal end on each side of this bone individually. The anterior end of the 3rd basibranchial is broader but its posterior end is a narrow process which connects with a cartilage. Otherwise the upper portion of the 2nd hypobranchial conjoins to the postero-lateral corner of the 2nd basibranchial.

Goodrich(1930) acknowledged" The copulae (basihyobranchial) are well developed and usually along the base of all the arches. Amia has three separate median elements apparently representing the five basibranchials, while Teleosts have in addition a basihyal. A median urohyal, attached in front below the hypohyals and passing back between the sterohyoid muscles, is peculiar to the Teleostei. It is generally considered to be an ossification of the median ligament. Similar but paired bones occur in Polypterus, possibly enlarged branchial ray."

Both the 2nd basibranchial and the 3rd basibranchial have some uncomplete ossified foramina on the ventral surface. The bony 4th basibranchial is not exist but the cartilage which connects the 3rd and 4th ceratobranchial, probably is the vestige of the 4th basibranchial. Allis(1903) stated there is a unossified 4th basibranch in Scomber.

Hyo-branchial Arches (Fig. 12 to 15)

There have five well ossified branchial arches, the first four support the pharyngeal cavity and form the frame-work for the gill. The last arch lesser, the epibranchial and the pharyngeal branchial. Its rest parts fuse together and form the lower pharyngeal teeth mill. Each branchial arch consists of two half parts, conjoined by the basibranchial on the midline and each half part has four pieces of bones, the pharyngeal branchial, epibranchial, ceratobranchial and hypobranchial.

Some fishes have a suprapharyngo-branchial bone, Dhamarajan (1936) stated " The first arch contains all the pieces and in addition, a small dorsal cartilaginous piece the supro-pharyngo branchial. Allis(1903) also stated " The first suprapharyngobranchial is a short cylindrical rod of cartilage, that runs downward, forward and mesially from the anterior end of the posterior-mesial process of the first epibranchial to the small facet on the hind end of the anterior cartilaginous portion of the dorsal edge of the second infrapharyngobranchial." and " supra-pharyngeal elements were found on the other arches."

There is no suprapharyngobranchial in P. tetricus.

Hyoid Cornu (Fig. 12 to 15)

The five elements that constitute each half of the hyoid cornu. are the epihyal, ceratohyal, paired hypohyal and interhyal. Each half of

the hyoid cornu is connected posteriorly to the inner face of the ventral end of the hyomandibular and anteriorly the two halves are conjoined by the median basihyal.

The interhyal or stylohyal is a small cylindrical bone. The dorsal head of interhyal is connected to the hyomandibula through a cartilage just at the region where the symplectic is also attached with the ventral end of the hyomandibular. So the hyoid cornu suspends on the hyomandibular arch. Its ventral end is a knob articulated with the epihyal and its lateral surface is connected to the inner surface of the pre-operculum by a ligament.

Srinivasachar (1953) stated the development of the Chondrocranium of Ophicephalus that the dorsal half of the hyoid arch is the hyosymplectic cartilage and the ventral half is the segmented hyoid cornu in the chondrocranium stage. The former is ossified into the hyomandibula and symplectic, and the latter differentiates the basihyal, hypohyal, ceratohyal and interhyal.

The epihyal is a thick trianguloid bone. Its apex is directed dorsolaterally toward the interhyal. It is a depression into which fits the proximal end of the interhyal on the dorsal side of apex. Its base is broadly articulated with the posterior end of the ceratohyal through a large piece of cartilage. There is a knob on its latero-dorsal portion. It conjoins with the socket which is on postero-dorsal portion of the interopercle. Allis(1903) considered the epihyal and the ceratohyal as one bone with two ossifications, a proximal and a distal.

The elongated ceratohyal is a very thick and broad bone. Its posterior border connects to the epihyal through a cartilage, but there is a ossified ridge extended longitudinally along dorsal border on the outer

surface of these two bones. This gives a reinforcement for the connection. Its dorsal and ventral edges are concave. On its ventral edge there have some notches for the accomodation of anterior three branchiostegal rays. In other words the epihyal and ceratohyal are connected by the cartilage ventrally and a sutural contact dorsally.

The anterior end of the ceratohyal terminates on two heads, the dorsal head articulates with the upper hypohyal, the ventral head with the lower hypohyal.

The upper hypohyal is a triangular bone which attaches to the anterior dorsal border of the ceratohyal.

It has a process which projects medially conjoined to the posterior part of the basihyal and the 1st basibranchial of the branchial arch. The upper hypohyal articulates ventrally with the lower hypohyal through cartilage.

The anterior end of the lower hypohyal is very thick, but the posterior end is thin and scale-like bone. It articulates with the ceratohyal and the upper hypohyal on the dorsal border. Its medial border conjoins with the counter part on the midline of the head. A splint of bone connects the lower hypohyal and the ceratohyal reinforced the cartilage articulation between each other.

The basihyal is a thick bone. It is flat on the dorsal surface and has a keel on the ventral surface. This bone lies on the midline of the head and over the junction of the two lower hypohyals. It extends anteriorly to support the tongue and posteriorly connected with the 1st basibranchial. Actually the basihyal does not close laterally to the upper hypohyal, but there two bones are attached each other through the

connective tissue.

Below the median junction of two lower hypohyals is the urohyal. The urohyal comes along the midline of the body and expands vertically. The antero-ventral margin of the urohyal becomes a very thick border. There are two articulations on the antero-dorsal portion, the anterior one articulates with the paired lower hypohyal from each side, the postero-dorsal one articulates with the ventral surface of the 1st basibranchial. A obvious ridge which starts from the anterior articulation postero-ventrally to the posterior margin runs across the middle portion of the urohyal. The urohyal (or parahyoid, basibranchiostegal) has not any cartilaginous predecessor in the development of the chondrocranium. This bone which perhaps is derived from a membrane bone, should be included in the hyoid arch or not, is very dubious. "It is peculiar to the Teleostei and is generally considered to be an ossification of the median ligament." stated by Goodrich (1930). A ligament which connects the urohyal and the cleithra has its insertion on the postero-ventral end of the urohyal. There also has a ligament on each side of the anterior end of the urohyal. This ligament attached on the outer lower corner of the lower hypohyal.

The 6 lateral compressed branchiostegals which are covered by the inter-operculum are flat, sickle-like bone. It tapers to the posterior end and have an ill formed wing along its anterior border and a flat enlarged base. The posterior one is longer but bends lesser dorsally than the anterior one. The 1st to 4th attach themselves proximally by their base to the lower lateral surface of the ceratohyal their distal end are all free. The 5th and 6th branchiostegals are on the junction of the epihyal and ceratohyal. Gregory (1930) stated that the interopercular and branchiostegals of high fish are probably represented by so-called "lateralgulars" of crossopterygians.

Laterosensory Canal System

(Fig. 55)

The laterosensory canal system divides into many branches. (Fig. 96)

1. Supraorbital branch
2. Infraorbital branch
3. Mandibular branch
4. Supratemporal branch
5. Nasal branch
6. Epiphyseal branch
7. Pterotic branch

Goodrich(1930) described the origin of the laterosensory canal system, "Lastly, in the teleostei the thin covering of ganoin, still present in the extinct Leptolepidae, soon disappears altogether, and the dermal bones tend to sink more below the soft tissues. This lead in higher forms to the subdivision of these which harbour lateral-line canals into deep plates and independent, more superficial, narrow grooved " canal bone " The latter remain near the surface forming more or less complete chains of ossicles protecting the canals.

The pterotic branch which connects with the supratemporal, mandibular and supraorbital branch of the laterosensory system, starts from the opening on the top of the dorso-posterior process of the pterotic and proceeds forward along the pterotic ridge to the frontal. Weitzman(1962) stated " The laterosensory canal system pierces the pterotic in two places in the region of the extrascapular. One of these, the posteriormost, connects with the extrascapular canal, the other connects with the preopercular mandibular canal."

The supratemporal branch begins at the point between the opening of the dorso-posterior process of the pterotic and supratemporal I. It divides several branches in this bone, one of these branch passes into the posttemporal and the major branch passes into supratemporal II. two major

branches of the opposite sides unit together and then connect with the epiphyseal branch anteriorly.

The mandibular branch is the longest branch of the laterosensory canal system. It traverses the preoperculum longitudinally and divides many subbranches, postero-ventrally, in this bone. Each sub-branch terminates a funnel-like opening on the posterior and ventral margin of the preoperculum. The major branch passes through the quadrate and articular, and ends in the dentary. It connects with the pterotic branch through the opening on the tip of the lateral process of the pterotic.

The infraorbital branch surrounds the lower portion of the orbital region. It divides into many branches in the 1st suborbital(lachrymal) and penetrates the dorsal margin of other suborbital bones. Both two ends of the infraorbital branch are connected with the supraorbital branch. Its anterior end connects with the supraorbital branch at the anterior portion of the frontal and the posterior end at the lateral process of the sphenotic.

The single epiphyseal branch is right on the top of the skull. It associates with two supraorbitals from the opposite side, and connects posteriorly with the united supratemporal branches.

The nasal branch which connects with the anterior end of the supratemporal branch, traves the nasal longitudinally.

The pterotic branch passes forward into the frontal and connects with the supraorbital branch which divides into one major branch and many subbranches in this bone. The major supraorbital branch extends anteriorly along the lateral margin of the frontal and meets the nasal branch and the anterior end of the infraorbital branch individually, and connects

with the posterior end of the infraorbital branch posteriorly, through the sphenotic.

Goodrich(1930) stated " The supraorbital line is supplied by the superior ophthalmic branch of the facial nerve, the infraorbital by its buccal branch, the hyomandibular and mandibular by the truncus hyomandibularis of the facial, the jugal and oral by branches of the lateral nerve, the transverse, occipital by the ramus supratemporalis of the vagus ———— This region is generally included in the "infra-orbital " but since between the anterior part supplied by the otic branch of the facial and the beginning of the main canal (on trunk) there is generally intercalated a short region innervated by the supra-temporal branch of the glossopharyngeal, it would seem better to name these two horizontal regions the postorbital and temporal respectively".

The paired frontals enclose the supra-orbital and commissural sensory canals. The commissural canal is open dorsally at the junction of two frontals.

Group 3. The Pectoral Fin (Fig. 56 to 57)

The various types of paired finskeleton found in the teleosts may be derived from the archipterygium. It seems that the axis becomes shortened and finally disappear, and the radials are reduced in number, especially the postaxial radials are lost extremely.

Wiedersheim(1907) thought that the originally segmental separate and parallel radials of the paired longitudinal fin-folds become more or less concentrated and fused at their base, giving rise to uniserial type of skeleton.

In this type the concentration was greater at the anterior than at the posterior end of the fin. The longitudinal axis withdraws into the body wall and bears a single row of radials along its outer edge. The basal elements of the radials fused, especially anteriorly, to form the large bones of the girdle.

The pectoral girdle of the teleosts is consisted of dermal bones forming the posterior boundary of the branchial chambers, and on to which attach the opercular bones. This dermal secondary girdle comprises some paired bones, such as the cleithra overlying the articular portion and the post-temporal (suprascapular) on dorsal portion.

The dermal girdle in all teleosts is connected to the posterior portion of the skull by means of the post-temporal, which is bifurcated. Each end attaches to the opisthotic or the pterotic and the epiotic. The general tendency in teleosts is that the endoskeletal part of girdles, Scapulo-coracoids become reduced and the dermal bones, cleithra to serve more and more for the support of the fin and the attachment of the muscles.

The primitive clavicles have been lost in most Actinopterygii, where their position has been taken by forward extensions of the cleithra which meet ventrally. Gegenbaur (1895) called the large bone, the clavicle of the teleost which is a more dorsal element, a new name, cleithrum.

The pectoral girdle is situated just behind the opercular apparatus. It comprises two symmetrical parts which connect together at the ventral end of the two cleithra by a ligament.

The cleithrum is a very large dermal bone. Its medial border is closed to the hyoid cornu. It forms the posterior border of the gill opening, and comprises a broad, flat horizontal plate submounted by a vertical plate. The cleithrum conjoins its counter part on the middle line of the body through a suture joint which is a strong connection. The two ends of the horizontal bar of the lower pharyngeal teeth will attach the middle portion of the horizontal plate of the cleithrum on each side. The cleithrum also serves as the posterior part of the floor of the hyobranchial apparatus. There have many strong muscles attach all over the surface of the cleithrum.

The horizontal plate of the cleithrum has a broad lateral wing extending postero-ventrally which covers part of the scapular and the postcleithrum I and its large dorso-posterior process which conjoins with the supra-cleithrum laterally.

The scapula is a ring-shaped cartilage bone. There has a large foramen on the middle portion for the passing of the dorso-medial muscles of the fin.

The dorsal portion of the scapula over-lies on the medial surface of the vertical plate of the cleithrum and conjoins with it. Its ventral

border connects with the cleithrum through a prominent cartilaginous line which separates the bone from the adjacent border of other bones.

The first 3 radials articulate with the posterior border of the scapula.

The coracoid, a L-shaped flat thin bone, is derived from cartilage. The dorsal portion of its short arm overlies on the medial surface of the vertical plate of the cleithrum and its posterior margin articulates with the scapula and the 4th radial of the pectoral fin.

The long arm of the coracoid tapers to its end and extends antero-ventrally forming the precoracoid process. It conjoins with the ventral end of the cleithrum dorsally through a cartilage.

A very large oval coracoid foramen is surrounded by the coracoid posteriorly and the cleithrum anteriorly. It also develops a post-coracoid process on the posteriormost end of the coracoid.

The supracleithrum is a long bone and has a vane on the postero-dorsal border. Its ventral end overlies laterally on the dorsal process of the cleithrum and the dorsal end forms a socket articulates with the ventral condyle of the posttemporal.

The posttemporal has two arms on the anterior portion. The long arm is fixed in a groove on the dorsal surface of the epiotic and the end of the short arm is fixed in a small depression at the posterior end of the temporal fossa.

Lien(1963) described " The posttemporal consists of a somewhat rectangular body and two very distinct forks. The dorsal fork is attached by means of a ligament to the articular facet of the epiotic, just

lateral to the epiotic process. The ventral fork rests on the dorsal surface of the intercalary. The body of the posttemporal overlaps the dorsal tip of the supracleithrum."

Its posterior portion is a scale-like thin bone. There has a condyle on the ventral portion of the posttemporal which articulates with the dorsal socket of the supracleithrum. The laterosensory canal system extends from the extrascapular I and branches on the posterior portion on this bone. There also has a depression on the base of the long arm, in which the posterior branch of the extrascapular I is lain.

The extrascapulars are the dermal bones in origin. Goodrich(1930) stated that in *Polypterus*, the supratemporal(extrascapular) appeared to have fused with the parietal. In higher teleosts the frontals and parietals sink deeply in the soft tissue and for the attachment of the anterior myomeres of the trunk, so the parietal and the extrascapulars are separated again.

Allis(1904) acknowledged that each of the parietals of the characids *Alestes nurse* and *Hydrocynus brevis* composed of two components, a fused mesial extrascapular unit and the parietal itself.

The extrascapular I is a branched tubular bone. It has four branches on the antero-dorsal portion. One branch on the ventral portion and one branch on the postero-dorsal portion. The laterosensory canal system, which comes from the lateral process of the pterotic, passes through the opening on the tip of the ventral process into this bone. The openings on the tip of the postero-dorsal and the most antero-dorsal branches are also for the laterosensory canal system connecting to the posttemporal and the extrascapular II, individually.

The extrascapular II is a long simple tubular bone which conjoins with

the dorsal end of the extrascapular I. The laterosensory canal system comes from the extrascapular I and traverses this bone. It connects with its counter part of the opposite side on the top of the skull.

The postcleithrum I is a broad thin bone. Its anterior border becomes thicker. The dorsal end of the postcleithrum I attaches to the medial surface of the lateral wing of the cleithrum. Its ventral margin is round and overlaps its antero-ventral portion on the postcleithrum II.

(Fig. 30 to 31)

The postcleithrum II which lies in the muscle is lance-head-shaped bone. It tapes to ventral end and attaches to the postcleithrum I on its postero-dorsal portion. Some of the teleosts have 3 postcleithra.

(Fig. 32 to 33)

Weitzman(1962) stated B. neeki "there are three postcleithra. The upper posterior edge of the cleithrum has two flat postcleithra pressed against its median surface. The upper, or first, of these lies at the posterior junction of the cleithrum and supracleithrum. Below this a flat second postcleithrum lies along the posterior median surface of the cleithrum. Applied to the anterior lower median surface of the second postcleithrum is a 3rd spinelike postcleithrum.

In the teleosts the axis of the paired fin does not exist. Therefore the radials articulate with the girdle directly. The number of the radials is usually not over five. In P. tetricus here are 4 radials which are hour-glass shaped. The ventral-most radial is the largest one while the other three each small than the one below in orders. The 1st three radials on the dorsal portion connect with the scapular and the ventral-most one lies between the scapular and the coracoid. The 13 fin rays are supported by these 4 radials. Each fin ray are segmented and branched and consists of two lepidotrichia. Its proximal ends which diverge and clasp the narrow cartilage, each has a articular process

directed downwards. This makes a strong connect between rays and radials and among the rays.

An additional spine-like fin ray which has a swollen projecting head, attaches to the dorsal margin of the first fin ray. It articulates with a knob-like joint on the scapula directly. The distal ends of the radials on which a narrow cartilage line exists for attachment of the fin-rays, is more flat and broad than its proximal ends.

Group 4. Pelvic girdle (Fig. 58 to 59)

The paired pelvic girdles which ossify from the cartilaginous origin lie horizontally on the body wall. Two pelvic bones (or basipterygia) are paired straight, slender bones, which are elongated and tapered into a spine anteriorly. A trough extends on the dorsal surface longitudinally through all the length of this bone. The base of the pelvic bones unite together along mid-ventral line and form a bilaterally symmetrical pelvic girdle. These thickened posterior bases contribute as attachment of the pelvic fin rays. Ventrally, there is a longitudinal ridge which corresponds to the dorsal groove and being the attachment of muscles. A small process directs backwards from the base of this bone on each side of the mid-ventral line.

The united anterior spine of the two pelvic bones lies dorsally on the sutural joint of the two cleithrum. A strong ligament which is between the united anterior spine and this joint contributes as a firm connection for pelvic girdle to the pectoral girdle.

The radials of the pelvic fin is fused with the pelvic bone. So one spinous and the 5 dermal fin rays of each side articulate with the pelvic bone directly. The outermost is on the spinous fin ray and the rest are the branched and segmented dermal fin ray. Each is formed by two lepidotrichia and each has a inwardly directed process and clasps on the Pelvic bone just as the pectoral fin ray.

Group 5. Vertebrae (Fig. 60)

Precaudal vertebrae (1st to 9th) (Fig. 61 to 64)

The Teleostei usually have well-developed amphicoelous bony centra strongly constricting the notochord and its sheaths.

Goodrich stated " Special intervertebral articulation are formed by anterior processes from the neural or haemal arches which rest on corresponding processes in front, and these may be supplemented or replaced by dorsal and ventral processes from the centra themselves, analogous to the pre- and post- zygapophyses of Tetrapods, Basidorsal and basiventral cartilages rest on the notochordal sheath in the young, but interbasals do not usually appear at all, though traces of inter-ventrals occasionally have been found." and "According to Schauinsland the vertebra is really formed by the coalescence of an anterior half (developed in relation to the basalia) and a posterior half (developed in relation to the interbasalia) derived from the Sclerotome of the segment behind. He claims that in *Fistularia* where the nerves issue through the neural arches these two halves develop similar arches , both dorsal and ventral" and "ossification may extend from the centrum over the basalia, the neural and haemal arches being then continuous with the centrum as in most of the higher Teleostei and the tail region of, even the lower forms" and " The latter in the form of an inter-segmental biconcave bony cylinder develops chiefly in the skeletogenous layer surrounding the notochordal sheaths, this in accordance with the general tendency throughout the endoskeleton of these fishes, for the cartilage to be reduced even in development and for the bone to be formed and more directly precociously from skeletogenous tissue" and " In the Teleostei, it is the basidorsal which together with the basiventral is the important element. The interdorsal extending primarily between the ventral and dorsal root of a spinal nerve are liable to be

interrupted and hindered in development, hence the main element of the neural arch is always the basidorsal."

The vertebrae column of P. tetricus consists of twenty five vertebrae. The 1st through 9th vertebrae are the piscine amphicoelous type without a haemal spine being called the precaudal vertebrae. A spherical space is enclosed between two vertebrae and filled with notochordal tissue. There also is a notochordal strand penetrates the center of each centrum.

The strengthening ridges are existed on the lateral depressions of the centrum. The prezygapophyses and the postzygapophyses are the articulate surface. The paired postzygapophyses of a vertebra connect with the prezygapophyses of the next vertebra. The zygapophyses of the first two vertebrae are not well developed.

The parazygapophyses exist in all nine precaudal vertebrae.

The anterior and posterior concavity on the centrum are connected by a narrow notochordal canal which is filled with notochord tissue, even in the adult. The mediodorsal depression and the medio-ventral depression are existed, and the lateral ventral depression is not so obvious as the lateral dorsal depression. Two neural arches protrude dorsally, fuse into a neural spine and enclose the neural canal through which the spinal cord passes. on the base of each neural arch, there is paired foramina for the exits of the two roots of the spinal nerve.

The 1st vertebra divides into two parts, its ventral part is the central disc (centrum) which is flat and connects anteriorly with the round disc of the posterior portion of the basioccipital. On the antero-dorsal portion of this centrum, there are two large sockets, Each articulates with the occipital condyle of the exoccipital. on the medio-

dorsal portion of this centrum there also are two deep sockets. The paired ventral processes of the movable neural arch are fixed in these sockets. A small depression presents on the lateral surface for the lodging of the first rib. The medio-dorsal depression is narrow and deep and the medio-ventral depression is absent.

The 1st and 2nd vertebra each has a hook-like process of the haemal postzygapophysis on the postero-ventral portion of the centrum, to strengthen its articulation with the next vertebra. The cylindrical centrum of the 2nd vertebra has a pair of the parapophysis for the attachment of the pleural ribs to its postero-lateral surface. From anterior part to posterior part of the body, the centra become longer gradually.

The dorsal part of the 1st vertebra is the neural arch which is inverted Y-shaped bone. There are two pairs of the processes on the ventral surface. It articulates with the centrum by its two ventral process. The rib of the 1st vertebra connects with its parapophysis. The neural spine of the 1st vertebra is a broad bone which is compressed laterally and concaved anteriorly. It is shorter and blunter than other neural spine and points upwards.

From the 2nd, the neural spines are thinner longer and slender than the 1st one and pointed upward, there is a groove on the anterior surface of each till the last one. The 2nd neural spine curves slightly forwards.

The parapophysis of the 1st and 2nd vertebra are small but they are very long from the 3rd to the 9th vertebrae. All are situated at the antero-ventral portion of the centra and bear movable ribs.

The 3rd through 7th vertebrae are much alike, each has two prominent

neural prezygapophysis, two neural postzygapophysis, a neural arch and a neural spine. The parapophysis which becomes larger and broader gradually in the orders and have a groove on the postero-lateral surface, conjoins immovably with the centrum. A pleural rib is fixed in the postero-lateral groove of each parapophysis through ligaments.

The neural spines of these vertebrae are inclined slightly posteriorwards. The first three neural spine are increase in length gradually but the fourth is shorter than the third. From 4th, it gradually increase in length again till the 14th vertebra.

The 8th and 9th vertebrae are almost similar to the 7th, but each has a slender bony bridge or transverse bony bar between the bases of the two parapophysis. This bridge is the origin of the haemal arch, sometimes the bony bridge of the 8th vertebra is cartilage and not ossified completely. It also has one pair of the prezygapophysis.

All the 3rd through 9th vertebrae have the pleural ribs and epipleural intermuscular bones. The ribs is so long that it sometimes exceeds the next two vertebrae.

Caudal Vertebrae and Caudal Fin (Fig. 65 to 68)

P. tetricus has 16 caudal vertebrae, the 10th through 25 are caudal vertebrae. There has no much difference among the vertebrae of the caudal region than among those of the precaudal region. The neural and haemal spines, both become shorter gradually from the anterior to posterior vertebrae. In the anterior portion the haemal spine is longer than the neural spine of the same vertebra but they become the equal length and direct more backward on the posterior portion. The dorso-lateral depression is more deep and large than the ventro-lateral depression. The medio-dorsal depression exists under the neural arch and the medio-ventral depression under the haemal arch. The bases of the neural arch extend the whole length of the centrum, but those of the haemal arch are only restricted to the anterior third of it. There is a groove anteriorly and a ridge posteriorly on each of the neural and haemal spine. This groove and ridge serve for the attachment of the ligaments which connect the adjacent spine. The prezygapophysis and the postzygapophysis of the neural part is well developed through all the vertebrae, meanwhile, the prezygapophysis of the haemal part is not existed except the last 4 vertebrae, but the postzygapophysis is very prominent and connect directly with the base of the haemal arches of the next centrum. Paired two foramina for the exits of two roots of the spinal nerves are on the base of the neural arch.

The 10th vertebra which contributes of the supporting for the posterior wall of the bodycavity, has a very different shape to the rest of the caudal vertebrae.

The large broad parapophysis of the 10th vertebrae unites with the counter part of the other side along the middle line of the body. It forms the haemal arch and the haemal spine. The haemal arch has a expanded wing on each side.

The haemal spine has a longitudinal slit and a groove, which show the rudiment of the incomplete fusion of the two parapophysis.

McMurrich (1884) described Amiurus catus as following: "The first tail vertebra has the haemal arches firmly united below, but somewhat broadened so as to separate, as it were, the trunk and tail regions. The remaining haemal arches are exactly similar in appearance to the neural arches of their vertebrae, possessing long spinous processes certain of which assist in supporting the interspinalia of the anal fin. There is then in A. catus a gradual passage from the transverse processes of the trunk region to the haemal arches of the tail, and thus a strong argument in opposition to the view that the haemal arches of the tail represent the transverse processes plus the ribs of the trunk".

The centrum of these vertebrae are the piscine amphicoelous type and has two depression on the lateral side 1 or 2 strong longitudinal ridges extend in these depression.

The centrum and the arches are ossified throughly, but the notochord remains in the centre cavity of the centrum.

The haemal spines of the 11th through 23rd vertebrae are longer than the neural spines. Both are not completely vertical to the vertebral column. The more on the posterior portion, the vertebra is, the more posteriorly, the spines direct.

The 11th through 23th vertebrae, each have a neural arch dorsally, a neural spine, two neural prezygapophysis and two neural postzygapophysis, and ventrally a haemal arch and a haemal spine.

on the anterior portion of the body, the haemal arch of the vertebra

is on the anterior border of the centrum. So the haemal prezygapophysis is not existed, but the haemal postzygapophysis is projected obviously. The haemal arch which is posterior to the 21st vertebra moves to the posterior part of the centrum. Therefore, the haemal prezygapophysis are more conspicuous than the haemal postzygapophysis.

The neural and haemal spine of the 23th vertebra each connects with a piece of cartilage and contributes as the support of the caudal fin.

The caudal fin of P. tetricus is typically is homocercal. The last two caudal vertebrae (24-25) support the fin.

The 24th vertebra has a normal centrum, one pair neural prezygapophysis and postzygapophysis but no haemal zygapophysis (pre- and post-).

Goodrich(1930) stated (clupea) " The neural arch of the penultimate centrum may become modified into a pair of bones embracing the urostylar region. A few dorsal radial may remain free bearing dermal rays in this region , but tend to disappear in the more specialized tails. One of these radials may fuse with a dorsal arch to form a true "epural".

The first epural is formed by the fusing of the radials and the neural arch of the 24th vertebra. It is a slender and flat bone. The antero-ventral portion of this bone attaches to the neural spine of the 23rd vertebra directly, but there is a large space between the dorsal portion of the 1st epural and the neural spine of the 23rd vertebra. A cartilage exists in this space and connects these two bones. The 1st epural and this cartilage contribute as a supporting for the dorsal-most 4 pro-current rays. On the antero-dorsal surface of the neural spine of the 23rd vertebra there also has a small piece of cartilage which is probably the extension of the former cartilage.

The 2nd epural is also a slender bone which attaches to the 1st epural anteriorly, the 3rd epural postero-dorsally and the 4th hypural postero-ventrally. It supports one procurent caudal fin ray.

The 3rd epural is a small bony plate which conjoins with the antero-dorsal portion of the 4th hypural and supports the most inner procurent ray of the dorsal half of the caudal fin.

Goodrich(1930) stated " In the most advanced or homocercal type occurring only in the Teleostei, the notochord is much shortened and withdrawn, though in some primitive forms (clupea) it may still project surrounded by cartilage a little beyond the vertebral elements. The returned region of the notochord is enclosed in a urostyle, a process of the last vertebral centrum which may represent the fused centra of this posterior region. This urostyle at first independent (clupea) become in more specialized forms fused with the last hypural and reduced to a mere vestige".

Just as some of the percoid fishes, the urostyle is not clear in the caudal fin. There is only a vestige of the urostyle attached on the dorsal surface of the conic centrum of the 25th vertebra and almost invisible. There is a tiny canal which seems to be a continuation of the preceding vertebra, extending in the urostyle.

The centrum of the last vertebra fuses with the urostyle and the 4th hypural. The borders among these bones are not obvious.

There are four hypurals connected with the last 3 vertebrae. Goodrich (1930) described the development of the hypural as following "More numerous and free along the urostyle in primitive forms (clupeiformes) they tend to become reduced in number, increased in size, and the

hindmost fused with the last centrum. Finally, in the most specialized tails the hypurals are two in number, fused to the last centrum, and symmetrically disposed above and below the longitudinal axis".

The 1st hypural is a long bone, the dorsal part of this bone becomes a broad bony plate. There is a condyle on the postero-dorsal portion, this condyle articulates with the socket on the ventral surface of the centrum of the 24th vertebra. The haemal canal penetrates the 1st hypural longitudinally just below this condyle.

The ventral part of the 1st hypural which is a rod-like bone connects with two inner-most procurent rays of the ventral half of the caudal fin.

The dorsal part of the anterior border of the 1st hypural attaches to the neural spine of the 23rd vertebra. A cartilage inserts into the space between the ventral part of the 1st hypural and the haemal spine of the 23rd vertebra, this cartilage bears 6 outer-most procurent rays of the ventral half of the caudal fin.

Goodrich(1930) discussed about to the origin of the hypural "As in the Selachians so in the Holostei, they are typically formed by the fusion of the radial with the spine of a haemal arch. Their structure in Amia spp. for instance, with a distal or terminal cartilage resembling that of the radial, strongly suggests this origin. In Teleosts, also separate terminal cartilages may appear, but in the higher form they no longer occur, and possibly the hypural are there formed entirely from the haemal spine".

The 2nd hypural which is fixed tightly between the 1st and 3rd hypural is much alike of the 1st hypural. It bears the 13rd and 14th principal

rays. The haemal canal pass through the dorsal end of this hypural.

The 3rd and 4th hypural which are symmetrical on shap, support the most principal rays of the caudal fin.

The 3rd hypural is a trianguloid bony plate which has an enlargement on the anterior end and gradually broadens out towards its distal end. the dorsal surface of this enlargement is an articulation which conjoins with the ventral surface of the conic centrum of the last vertebra.

A paired processes which are the vestige of the haemal arch project below this enlargement. It connects anteriorly with the haemal canal. There is a thin bony keel on the anterior border of the 3rd hypural. The 3rd hypural bears the 8th to 12th principal rays.

The 4th hypural which fuses with the centrum of the 25th vertebra completely. The anterior part of the 4th hypural is thicker than other part of this bone. On each side, a bony ridge extends from the centrum of the 25th vertebra to the antero-ventral portion of it for the reinforcement of the fusing of this two bones.

Another bony ridge which is the vestige of the urostyle exists on the antero-dorsal margin of this bone.

The 4th hypural is the largest hypural in these 4 hypurals. It contributes as the support for the 1st to 7th principal ray of the caudal fin.

Dharmarajan(1936) described that the hypurals of Otolithus ruber, he stated that the 2nd and 3rd hypurals are compound hypural. Lines separating its three parts are clearly visible but at the proximal end they unite

with the last vertebra.

The 3rd and 4th hypural of P. tetricus probably come from the same origin, but the fusing is very complete and the hint is imperceptible.

Intermuscular Bones

There are nine pairs of pleural ribs conjoined with the distal end of the parapophysis. One pair on each vertebra, lying between the muscle and the peritoneum. The first two pairs are short and thin, but the rest are long and strong. Each has a well-ossified head which is fixed in the groove on the postero-dorsal surface of the parazygapophysis by ligament. Each rib is concaved medially and directed postero-ventrally.

There are no epineural ribs in P. tetricus. Goodrich(1930) stated "Separated supraneurals are well developed in the lower Amiidei (Eugnathidae, Pachycormidae) and lower Teleostei (Leptolepidae), but tend to disappear in the higher forms".

The 9 epipleurals which are more slender than the pleural ribs project backward and downward in the myocommata of the hypaxial muscles.

There are no epipleurals on the parazygapophysis of the 1st and 2nd vertebrae.

The 1st to 7th epipleurals lie on the postero-lateral groove of the parazygapophysis of the 3rd to 9th vertebrae, and just over the dorsal head of the pleural ribs.

The 8th epipleural , which attaches on the ventral process of the expanded wing of the haemal arch, conjoins with the 10th vertebrae.

The 9th epipleural projects from the haemal arch of the 11th vertebra.

All the 9 epipleurals are unforked. They become shorter and slender in the orders from the anterior to the posterior portion of the body.

Group 6. Median fin

Dorsal fin

(Fig. 69)

The number of the pterygiophore of P. tetricus corresponds to the number of the neural spines of the vertebrae which support the pterygiophore except for the last two pterygiophore. These pterygiophores are connected together by the longitudinal ligament and they also have paired transverse ligaments to attach it in position.

Each of the dorsal fins is composed of two parts: (1). A series of pterygiophores endoskeletal in origin and lying parallel to one another and (2). The dermal fin ray, dermal in origin and supporting the fin.

The relation between the median fin-supports or radials to the vertebrae column is obscure. It is indefinite, whether they only have a secondary connection or derived from it primarily. Goodrich(1930) "Thacher considered that the radials are special structures developed to support the median fin, comparable to the radial of the paired fin therefore forming part of the appendicular skeleton and only coming into secondary connection with the axial skeleton. On the contrary, Gegenbaur(1870) and Cope regarded the medianfin radials as derivatives of the axial skeleton which may become secondary separated off and specialised. Gegenbaur, indeed, considered them to be merely extensions of the neural and haemal spines. According to Cope the several pieces of each ray were simultaneously developed in lines of maximum strain, extended originally from neural arch to fin-base, and become differentiated into proximal neural spine, middle "axonost" and distal "baseost" the axonost afterwards being separated from the spine, become the "interspinal" of Cuvier, which together with the baseost support the fin-base.

In the median fins there may be two radials to each body-segment. Such as in Chondrostei and many Teleostei, whether the double number

is due to secondary duplication of the original radial or derived from a radial in each half of a segment is very dubious.

Originally, the pterygiophore is formed by the fusing of three radials. The proximal piece of the radial is a long sharp bone with a vertical ridge on its lateral surface, pointed ventrally. The medial piece of radial is a small cartilage.

Eaton(1945) describing Tilapia macrocephala stated "The pterygiophores in young specimens are in three pieces. In the adult they are fused and in addition a hook-like process from the distal radial of one pterygiophore has grown back and fused with a corresponding hook from the middle radial of the next thus forming a loop which passes through a foramen in the base of the corresponding spiny ray of the fin, by this the ray is allowed to bend within definite limits, in an anterior or posterior direction, but can not be disarticulated without fracture."

The proximal radial, medial radial and distal radial of P. tetricus fused into a pterygiophore very completely.

The dorsal fin is formed not only by the endoskeletal radials but also by the dermal fin-rays disposed on both sides of the fins. Goodrich (1930) stated " There are two chief kind of these dermotrichia, ——— and the bony lepidotrichia of teleostomes, usually branching and jointed. Delicate horny ray (actinotrichia) develop in the embryonic fins of all Teleostomes and are doubtless homologous with the ceratotrichia. They persist at the growing margin of the fin, but they are functionally replaced in later stages by the more superficial lepidotrichia formed from modified scales." In P. tetricus the most part of the dorsal fin consists of the paired lepidotrichia, and the radials of the fin

become more restricted to its base. The base of two lepidotrichia diverge and clasp the proximal end of the pterygiophore. He also stated "The teleostomi also have thier radials usually subdivided into three pieces (Thacher, Bridge, Schmalhausen.) but while the proximal piece becomes the main support (interspinal, axonost.) the middle piece is shortened, and the distal element further reduced in size. In the higher forms the bases of the paired lepdotrichia which come to correspond to them in number are firmly fixed to these rounded distal pieces."

The 1st pterygiophore is supported by the neural spine of the 2nd vertebra. It is a plate-shaped bone which has a ridge on each side from the medio-distal portion to the tip of the proximal process serving for the attachment of the muscle controlling the movement of the fin-ray. The proximal end of the pterygiophore is connected by ligaments to the neural spines. On the distal portion of the pterygiophore there is a foramen in which the proximal ring of the spinous dorsal fin ray is fixed. A large median keel projects forward from the 1st pterygiophore. A T-shaped supraneural which bears no fin ray is antecedent to the first pterygiophore. It attached on the anterior surface of the neural spine of the 2nd vertebra. (Fig. 71)

The 2nd to 8th pterygiophores of the dorsal fin are a thin bone. Each has a projecting ridge on the anterior border and a ridge on each side both extending distal-proximally to the tip of the proximal process.

There also is a foramen on the medio-distal portion in which the proximal ring of the spine is fixed. On the distal portion of the pterygiophore, it develops one paired hook-like process anteriorly and another pair posteriorly, this gives the spinous dorsal fin ray a

block for the limited angle of movement. The posterior processes only attach to the anterior processes of the next pterygiophore but do not articulate with it .

The 9th pterygiophore which associates with the last spinous ray and the 1st soft ray, is a very special one. It is similar to the 8th pterygiophore bears the 9th spinous ray but it has also a large process on the postero-distal portion of this pterygiophore which articulates with the 1st soft dorsal fin ray through a cartilage. From the first to the ninth pterygiophore it increases in length and from the tenth to the last pterygiophore it decreases in length posteriorly .

Eaton(1945) stated "dermal rays thus defined, are formed of two essentially different parts, occurring either alone or variously combined in different groups of fishes, These are: (a). Ceratotrichia, embryonically and primitively paired rod either horny, fibrous or bony, which may or may not take on any relationship with scale rows ——— and (b). Actinotrichia, in Actinopteri, the ceratotrichial portion of rays forms in early Paleoniscids, a basis for attachment of the scale-rows superficial to it, but in the higher fishes of the class it is entirely superseded by the scale-rows, except for the "actinotrichia" which are surviving ceratotrichia in the margins of the fins and in the adipose fin." He also stated " The lepidotrichia of Actinopteri are modified scale rows in combination with (primitively) or replacing (subsequently) the ancestral ceratotrichia. "

Each spinous dorsal fin ray is composed of one paired lepidotrichia. These two lepidotrichia fuse completely at the upper dorsal portion of the spine. But on the ventral portion each has a enlargement of hook-like process fused with the counter part of the other side through a foramen which is on the distal portion of the pterygiophores. So there

is a completed chain-shaped connection between the spinous spine and the pterygiophore .

The 10th to 19th pterygiophores are a wedge-shaped thin bone which is bent concavely in the posterior direction. A ridge runs along the anterior margin of each side of this bone. The distal process protrudes postero-dorsally and articulates with the soft dorsal fin ray through a cartilage.

There is a Y-shaped dorsal fin stay, an end piece behind the 19th pterygiophore. There also are right and left special fin-muscles on both sides of the median fin. Its fibers run parallel to the radials and vertical to the myomeres of the body.

Anal fin (Fig. 70)

The anal fin of the P. tetricus is consists of eleven pterygiophores and one anal fin stay. The pterygiophores decrease in length from its anterior backwards. Each connects with the succeeding one posteriorly and the haemal spines of the vertebrae dorsally by the longitudinal ligament. The paired transverse ligaments also exist, which are fused by the distal, medial and proximal radial. The pterygiophores of the anal fin which are fused by the distal, medial and proximal radials are similar to those of the dorsal fin. It curves concavely backwards and its proximal radial is directed upwards.

The first pterygiophore which lies anteriorly to and connects with the anterior surface of the haemal spine of the tenth vertebra is a spine-like bone and has a prominent ridge on each side. The proximal end of this bone is enlarged. There are two foramina on the distal border of this enlargement for the proximal ring of the 1st and 2nd spinous fin rays. These form chain-shaped connections as usually one pterygiophore bears one spine or fin ray. However it can extraordinarily bears two or three. The explanation is that it might be the result of the fusion of two or three pterygiophores.

The 2nd pterygiophore is much like the 1st one. The 3rd spinous fin ray conjoins with the ventral enlargement of the 2nd pterygiophore through a cartilage (synchondrosis) not a chain-shaped connection. There is a ventral ring on the proximal end of the spinous ray.

The 3rd to 10th pterygiophores are slender spine-like bones. Each also has an enlargement on the distal end. The articulation between this enlargement and the proximal end of the soft fin ray is synchondrosic.

The 11th pterygiophore is similar to the 10th pterygiophore. The ventral enlargement articulates not only with the soft fin ray but also with the anal fin stay.

All the spinous and soft fin rays of the anal fin are paired halves or of lepidotrichial type as in the dorsal fin.

A Y-shaped anal fin stay is posterior to the 11th pterygiophore. Its anterior process conjoins with the proximal enlargement of this pterygiophore.

From the 3rd to 9th pterygiophores, each is supported by a haemal spine of the vertebra from the 11th to 17th. The 10th and 11th pterygiophores are supported by that of the 18th vertebra.

Discussion

The skeletal system of P. tetricus is composed of completely ossified bones. There are some cartilages in the development but no cartilage in the adult animal. ^{bones} ?

The jaws are of a strong-biting type with a terminal horizontal mouth and forward and downward loping snout. For this reason the premaxillary and dentary are protruded forward and carry many strong teeth.

The dermal bones, which develop much better than the cartilage bones cover the external part of the skull being the major part of the skull.

The primary jaws or oromandibular arches of teleosts are serially homologous with the branchial arches. Allis (1915, 1923, 1925) has suggested that the trabeculae of the embryonic chondrocranium represent premandibular arches and the polar cartilages which connect the trabeculae with the parachordals represent the dorsal elements of the mandibular arches, of which the palatoquadrates represent the epimandibular while the Meckel's cartilages represent ceratomandibulars.

Allis (1918) stated that the hyomandibula of teleosts consists of two parts, the anterior derived from the anterior branchial-ray bar of the hyal arch; and the posterior derived from the dorsal extra-branchial of the hyal arch. But Edgeworth (1926) insisted that it is a single structure and in spite of the fact that in teleostomes the head of hyomandibular lies above the vena capitis lateralis, while in sharks it lies below it. From the relation to the auditory capsule the hyomandibula in sharks or teleosts is fully homologous.

The symplectic of P. tetricus represents the lower part of the hyomandibula which in polypterus is not separated off from the main part of the element.

There are two different forms of branchial arch. The E-shaped arch of the Selachii in which the pharyngobranchials project postero-mesially and the V-shaped arch of the Teleostomi in which the pharyngobranchials project antero-mesially. Allis's considered that the prolongation of the process on the anterior sides of the pharyngobranchials become segmented off and articulated with the epibranchials in the same way that the entire branchial arch originally become segmented.

P. tetricus feeds on crustaceans, coral and shells. The species has developed a special grinding mechanism on the branchial arches. The pharyngobranchials of the 4th and 5th arches of each side unite together and are modified into two upper pharyngeal tooth mills on which the conical teeth are attached. The ceratobranchials of the 5th arch of each side unite together and form a single T-shaped lower pharyngeal tooth mill. In comparison to the Cyprinidae, the pharyngeal teeth of the latter are more varied ranging from sharp in the carnivores such as the creek chub (Semotilus) to molariform in the common carp (Cyprinus carpio) and have almost disappeared in some species.

Similar to the origin of the opercular of most actinopterygii, the oromandibular arch grows backward over the cheek and under the circumorbital bones likewise the hyoid arch grows backward and its dermal fold gives rise to the opercular, subopercular, branchiostegals and interopercular.

Regan (1929) has suggested that the interopercular appears to be the separated lower end of the subopercular and may be represented by the first branchiostegal. The interopercular is tied by ligament to the angular projection of the mandible. Below the interopercular there is a sharp crease separating the opercular from the branchiostegals and permitting the former to move with the jaws, the latter with the branchial arches.

The preopercular is associated with the supratemporal and with the pterotic and the posttemporal in carrying a branch of the laterosensory canal system. These elements along with the circumorbital bones. The dermosphenotics and some others have relatively constant relations with the lateral-line system of the head. The modification of the jaws and gill apparatus is correlated with the feeding, respiration, body-form and locomotion.

In P. tetricus the premaxillae protrude excluding the maxillae from the oral border, the maxillae serving as levers for the depression of the alveolar bar of premaxilla; mandible without coronoid elements; branchiostegals attached to the epi- and cerato- hyal; orbitosphenoid absent, basisphenoid much reduced; supraoccipital forming a large median keel and connecting with the frontal; occipital condyles, tripartite. Those facts show the characters of typical percomorph fishes.

The pelvic girdle of P. tetricus moves forward to connect with the pectoral girdle and reduces of the number of the intermuscular bones. This is the tendency of the evolution from the lower class to high class teleosts.

There are two sorts of jaws. The outer upper jaws are bony dentigerous facial tracts, the premaxillae and maxillae which in the oldest ganoids form part of the bony facial mask. The inner or primary upper jaw has a cartilaginous core which in the shark is represented by the palatopterygo-quadrates gives rise in the teleosts to paired quadrate, metapterygoid, mesopterygoid, pterygoid and palatine bones.

The mandible consists of an outer dermal shell the dentary bone and of an inner core homologous with the Meckelian bar of the shark and represented by the endosteal portion of the articular bone.

The metapterygoid connects the upper part of the palato-pterygo-quadrato arch with the hyomandibular and helps to strengthen the whole arch and to give insertion to part of the adductor muscles.

PART II
MUSCULAR SYSTEM

Group 1. Muscles of mandible

(Fig. 72 to 74)

1. Adductor mandibulae

The adductor mandibulae is a broad thick muscle which is divided into four parts, an upper portion A1, two lower portion A2, A3 and a deeper portion A4.

A1 arises mostly from the upper portion of the outer surface of the preoperculum, a part of the fibers at the internal side of the muscle arises from the outer surface of the hyomandibular.

The fibers of the muscle run forward, crossing externally and covering the lower half of the levator arcus palatini.

Those fibers of the muscle that arise from the hyomandibular form a small and somewhat separate bundle on the inner surface of the muscle.

The outer surface of the muscle is marked by some faint tendinous lines. There is a broad longitudinal tendinous band on the distal half of the muscle. An anterior tendon arising from the tendinous band of the muscle separates into two part, one of these parts runs forward and upward along the inner surface of the lachrymal and is inserted between the lachrymal and the maxillary. The other, a small part, runs downward and forward and joins a tendon of A2 A3. The muscle along its postero-ventral edge is partly continuous with A2 A3.

The tendons of the former part is long and stout which passes antero-dorsally along the inner surface of the premaxilla. Its distal end is connected with the posterior surface of the ascending process of the premaxillary. The latter part is stout and broad which runs downward and

attaches to the postero-dorsal border of the articular.

A2A3 lies ventral to A1. It is single at its origin but double at its insertion and is apparently formed by the almost fusing together of these two parts. It arises from the anterior edge of the preoperculum and the outer surface of the hyomandibular. On its outer surface there are two strong tendinous lines which mark the outer edges of two aponeurotic formations. A tendon is formed by the converging of the fiber and inserted into the inner surface of the articular and the dentary.

The A4 originates from the antero-dorsal surface of the hyomandibular and also from the dorsal edge and adjoining surface of the metapterygoid that projects backward mesial to the hyomandibular. Its upper-portion is covered by the levator arcus palatini and its lower portion is covered by the adductor mandibulae A1 and A2A3. The fifth or trigeminal nerve is parallel to the antero-dorsal border of this muscle. Both portions form the posterior boundary of the orbit. From the line of origin the fibers run almost directly forward. There are two strong tendons on its anterior end one of these two tendons attaches to the inner surface of the ventral arm of the dentary and another one attaches to internal groove of the articular.

The levator arcus palatini arises from the antero-lateral process of the sphenotic, the posterior part of the frontal and anterior part of the pterotic ridge, the fibers of the muscle run downward and backward it has a thick origin and a thin insertion. The surface of insertion includes the dorsal end and the anterior margin of the hyomandibular, the dorsal end of the metapterygoid, the upper edge of the metapterygoid that projects backward internal to the hyomandibular. The ventral portion of this muscle is crossed nearly at right angles by adductor mandibulae.

The tendon of this muscle is broad and flat and passes downward and backward into the muscle and give connection to the fibers of the muscle on both sides of the origin and insertion. On the anterior margin of this muscle, this tendon becomes a flat and tough border for the reinforcement of the attachment of the muscle.

The function of this muscle is to raise and pull the hyomandibular arch forward.

2. Intermandibularis

Intermandibularis, a well-developed muscle, stretches between two dentaries and lies between two anterior tendon of the geniohyoideus and covered by it. It has two tendons, each is fixed in a groove on the postero-dorsal part of the dentary.

In some fishes this muscle is not well developed. Allis (1903) described that of Scomber scomber as follows " The intermandibularis is a small , much degenerated muscle lying between the rami of the mandibles and extending backward a short distance from the symphysis. " But the intermandibularis of P. tetricus is rather big and well-developed muscle. The reason is it cooperates with the strong lower jaw for the mastication.

This is an opponent muscle of the levator arcus palatini and connects each half of the lower jaw when the latter muscle is on action.

Group 2. Muscles of operculum

(Fig. 72 to 74)

1. Levator operculi

This muscle is situated on the inner surface of the operculum. It passes from the posterior edge of the hyomandibular and preoperculum and attaches to the ventral surface of the pterotic ridge of the skull. Its fibers go downwards and slightly backwards and contact with the upper portion of the operculum. There is a fossa on the antero-dorsal corner of the operculum, on which the tendon of this muscle attaches.

The function of this muscle is to pull the operculum upwards and forwards coordinating with the dilator. Its origin is immediately continuous with the dilator operculi.

2. Dilatator operculi

This muscle occupies the entire dilatator groove and origins from frontal, sphenotic and pterotic.

The fibers of the muscle pass downward and backward obliquely to form a tendon which inserts in the antero-dorsal corner where the operculum articulates with the hyomandibular. This tendon connects with opercular process directly. However, a few of its fibers start from the surface of the postero-dorsal part of the hyomandibular. The function of this muscle is to raise and open the operculum outwards.

McMurrioh (1884) stated " In Esox this muscle is weak and does not extend forwards beyond the posterior extremity of the articulation of the hyomandibular with the pterotic. In Perca it reaches the sphenotic, but in none does it extend as far as in Amiurus. "

3. Adductor operculi

It is a small muscle arising from the ventral surface of the pterotic. Its fibers spread outward and backward and are inserted along the ridge that runs backward attaching to the upper portion and the dorsal surface of the oblique ridge on the inner surface of the operculum. It extends backward almost halfway across the operculum.

This muscle is opponent of the levator and dilatator operculi, it pulls the operculum to the side of the head.

Group 3. Muscles of the hyoid arch

(Fig. 75 to 78)

1. Inferior geniohyoideus

The two inferior geniohyoidei are completely fused together to form a single muscle. It lies between the two superior geniohyoidei and runs directly forward in the middle line of the head.

The fibers of the muscles separate at the anterior end and form two round and tapering muscle bundles. Each attaches, by a strong tendon, to the inner surface of the dentary of its own side near symphysis.

The tendons of the inferior Ghi lie ventral to the intermandibularis but the tendons of the superior geniohyoidei lie dorsal to it.

McMurrich (1844) compared it with that of the other fishes he described " In Cyprinus the origin is similar and in Barbus the muscles of either side do not interdigitate as they appear to do in other fishes. In Esox and Cyprinus a median enlargement of the muscle occurs. "

It has different functions. If the hyoid arch is attached to the hyo-clavicularis. Its function is to depress the mandible otherwise. If the mandible is fixed by the strong adductor mandibular, its function is to raise the hyoid arch and to aid the levator and dilatator operculi.

2. Superior geniohyoideus

Each of the paired superior geniohyoideus has two heads. One of these two head is muscular and the other is entirely tendinous.

The muscular head which arises from the external surface of the ceratohyal is larger of the two. The tendinous head is firmly attached to the epihyal.

These two bundle of muscles pass forward along the external surface of the ceratohyal and unite together to become one muscle. As it passes anteriorly a tendon is formed and then the tendons of the corresponding muscle of the opposite side are united by a median aponeurosis. These tendons, one on each side, attach to the inner surface of the dentary close to the symphysis.

The united muscles of opposite sides of the head form one part of the floor of the mouth cavity that lies in front of and under the tongue. The tongue lies between the dorsal surface of the united muscles.

3. Hyopectoralis

It arises from the most anterior part of the cleithrum and runs forward attaching to the lateral surface of the urohyal below its upper plate. The muscle is separated from the abductor superficialis and abductor profundus of the pectoral fin by the horizontal plate or lateral wing of the cleithrum and from its fellow by the median crest of the urohyal.

Its function is to draw the anterior part of the hyoid arches downward and enlarge the oral cavity.

4. Hyohyoideus

This is a broad sheet of muscle fibers which gradually become thick from the posterior to the anterior portion. It can be divided into two parts. The posterior part, a very thin muscle originates in the inner surface of the ventral border of the operculum and interoperculum extending to the dorsal margin of the most dorsal branchiostegal ray. The muscle continue as fibers that lie between the most dorsal and the next ventral ray and so on to the most ventral ray. These muscle fibers extend from the preceeding succeeding ray along the inner surface of gill cover. Its fibers insert into the aponeurisis separated from the opposite part. There is no significant tendon on this muscle.

The anterior portion of this muscle comes from the dorsal and lateral surface of the ceratohyal and the epihyal, which passes medially connecting with its fellow through the aponeurosis. The posterior part of this muscle is continuous with the hypopectoral and attaches to the base of the branchiostegal ray. The hyohyoideus are in different forms.

McMurrich (1844) stated that in Esox it passes as a continous sheet over the branchiostegal rays not passing from one to the other as in Amiurus and the Cyprinoids. Vetter(1878) terms that portion of the muscle which runs between the branchiostegal ray the "hyohyoideus superior" grouping

those portions coming from the most anterior ray and from the ceratohyal together as the "hyohyoideus inferior" an arrangement which in Esox is quite proper, but does not hold with Amiurus.

The function of the anterior portion is to draw the hyoid apparatus dorsally. Meanwhile the function of the posterior portion is to close the gill opening. But the complete closing of the gill opening must be performed by both portions and the muscle on the hyoid apparatus.

Group 4. Muscles on the ventral surface of pharynx

1. Pharyngo-hyoideus

(Fig. 75 to 80)

The pharyngo-hyoideus lies to the side of the median line on each side of the under surface of the branchial arches. It arises from the dorsal border of the posterior part of the urohyal and passes upward and backward. Finally it attaches to the latero-ventral surface of the horizontal bar of the lower pharyngeal teeth mill (fifth ceratobranchial). It is tendinous both at its origin and insertion.

The function of this muscle is to pull the pharyngeal bone downward and forward and the urohyal upward and backward.

2. Pharyngo-clavicularis externus

It originates from the antero-mesial surface of the antero-lateral wing of the clavicle behind the insertion of the hyopectoralis. The fibers pass antero-dorsally and attach to the anterior part of the ventral surface of the horizontal bar of the lower pharyngeal teeth mill (fifth ceratobranchial) just internally to the pharyngo-hyoideus.

The function of this muscle is opposed to the transversus and obliqui ventrales. It draws the pharyngeal backward, downward and slightly outward.

3. The pharyngo-clavicularis interuus

This is a short, stout and column-like muscle, which arises from the intero-middle part of the lateral wing of cleithrum. It runs antero-dorsally and attaches to the latero-dorsal surface of the horizontal bar of the lower pharyngeal teeth mill (fifth ceratobranchial) through a strong tendon.

It lies internal to the pharyngo-clavicularis.

4. Obliqui ventrales (I, II, III)

There are three obliqui ventrales in P. tetricus extending from the hypobranchials I, II, III to the ceratobranchials of the same arches. They fill the concave ventral surface of the first three hypobranchials and are covered externally by tendinous tissue.

Each of them runs laterally and backward to form a tendon, which passes parallel to the antero-lateral edge of the hypobranchial and insert on the distal end of the ceratobranchial near the cartilaginous tip of it.

Some evidence suggests that they must have been transferred from their original position. McMurich (1884) stated " According to this view the fibers of the first muscle originally ran from the ceratohyal to ceratobr. I as indeed slip do in Esox and the Cyprinoids, those of the second from ceratobr. I to ceratobr. II and those of the third

from ceratobr. II to ceratobr. III. This supposition is supported by the fact that in other Teleostei there is a fourth obliquus ventralis and no slip between ceratobrs. III and IV as in *Amiurus*. "

Their function is to draw the arches ventrally towards the middle line.

4. Transversus ventralis IV

It is a large triangular muscle, which arises from the concave mesial surface of the anterior end of the fourth ceratobranchial and extends across the middle line of the head to the ceratobranchial of the opposite side. The deep portion of this muscle is separated by the anterior process of the lower pharyngeal teeth mill and a very strong tendon is attached to it.

The function of this muscle is to draw the arches of opposite side closed together and slightly downward.

The transversus ventralis IV is derivated from the obliqui ventrales. In *P. tetricus* the paired ceratobranchial V fuse together and form a lower pharyngeal teeth mill. So transversus ventralis V is unnecessary and disappeared.

Group 5. Muscles on the dorsal surface of the pharyngeal

(Fig. 79)

1. Levatores branchiales

There are 7 levatores branchiales in P. tetricus 3 externi and 4 interni. There may be exposed by removing the opercular and hyomandibular apparatus.

The levatores branchiales internus of the first arch (Li I) arise from the lateral surface of the skull just below and behind the facial foramen. Most of this muscle lies on the prootic and a part attaches to the anterior part of the pterotic.

It runs postero-ventrally and mesially and is inserted by a tendinous end on the dorsal surface of the posterior process of the first epibranchial.

The levatores branchiales internus of the second arch (Li II) also arise from the lateral surface of the skull. Its fibers lies immediately internal to that of the first internus.

It runs ventro-mesially and is inserted by a tendinous end on the suprapharyngeal process of the second epibranchial near the mesial end of the process. Its tendon also attaches on the anterior part of the lower pharyngeal teeth.

The levatores branchiales internus of the third arch (Li III) arises immediately behind the former two internus muscles and it runs postero-ventrally approximately parallel to them.

It is inserted by tendon on the suprapharyngeal process of the third epibranchial and also connected with the antero-lateral part of the upper pharyngeal teeth.

The levatores branchiales externus III and the externus IV also arises from the lateral surface of the pterotic and the prootic. It is inserted by a tendon on the 2nd and 3rd arches. The surface of insertion lies at about the middle of both arches. It serves as a connection between these two arches.

The externus IV has the same condition as the former externus and inserts on the 3rd and 4th arches.

The levatores branchiales externus of the fifth arch is a very large round and stout muscle which is developed for the coordinate function with the large upper pharyngeal teeth for powerful mastication. It arises from the ventral surface of the posterior process of the pterotic and runs almost direct ventrally to connect with the horizontal bar of the lower pharyngeal teeth. The surface of the insertion is on the postero-lateral surface of the end of the bar. Both ends of the muscle are tendinous. The tendon on the insertion is very long and strong. An aponeurosis covers on the whole muscle.

The levatores branchiales internus of the fifth arch which is covered mesially to and by the externus V also is a large muscle. It has tendons on both end of the origin and insertion. The tendon of the insertion attaches to the postero-lateral surface of the horizontal bar of the lower pharyngeal teeth immediately mesial to the externus V. It origin from ventral portion of the skull.

The externus V and internus V are specially developed muscles in P. tetricus which impart a rocking motion to the upper pharyngeal teeth which are very effective in grinding the food against the lower pharyngeal teeth.

2. Transversus dorsalis A1 and A2.

These are two muscle- mass round the anterior and lateral border of the upper pharyngeal teeth participating the grinding function.

The transversus dorsalis A1 arises on each side of the head from the latero-ventral surface of the upper pharyngeal teeth. Its anterior fibers run forward and mesially and its posterior fibers directly mesially or slightly backward. The fibers of these two muscles cross the middle line of the head and are inserted on the corresponding portion of the upper pharyngeal teeth of the opposite side.

The muscle is much wider projecting strongly forward in the median line of the head than at its origins. Its rounded anterior border reaches forward to the level of the first epibranchials.

The transversus dorsalis A2, Which arises on the anterior portion of each side of the upper pharyngeal teeth is smaller and shorter than the transversus dorsalis A1. It is dorsally and parallel to transversus dorsalis A1 and has the same function as the latter.

3. Transversus dorsalis posterior

This muscle arises from the postero-dorsal surface of the upper pharyngeal teeth. Its fibers, a flat muscular bundle, run on the posterior surface of the upper pharyngeal teeth and across the middle line of the head to the corresponding surfaces on the opposite side.

The function of this muscle is similar to transversus dorsalis A1 and A2 as a part of the grinding mechanism.

McMurrich (1884) stated " These muscles probably correspond with the transversi dorsales of Perca, the anterior of which extend between epibr. II , the posterior between pharyngobr. III and IV of opposite sides. In the Cyprinoids only a single muscle is present which corresponds to the posterior muscle in Amiurus. "

4. Interarcuales obliqui dorsales

The interarcuales obliqui dorsales, a large and stout muscle-mass, arises from the meso-dorsal surface of the epibranchial III and IV. Its fibers run mesially and are inserted into the depression on the lateral surface of the upper pharyngeal teeth. It gives a strong connection for the epibranchial III and IV to the upper pharyngeal teeth.

This muscle is close to the levatores branchiales internus and externus of third arch anteriorly, to levator branchiales externus of the fourth arch laterally, to levatores internus and externus of the fifth arch posteriorly.

McMurrich (1884) stated " In the Cyprinoids there are two sets of muscles termed by Vetter (1878) obliqui dorsalis inferiores and obliqui dorsalis superiores, but in Amiurus, no such division can be made nor is it possible to indicate homologies between the forms. "

5. Adductores arcuum branchialium

These are three in number, each on the I, II and III arch. They lie in the angle between the epibranchial and ceratobranchial of it arch.

The first of the series which arises from the dorsal lateral surface of the first ceratobranchial near its posterior pointed end, and extends forward almost all the length of the first epibranchial is the longest one in the three.

The 2nd muscle of the same width as the first arises from the same position of the 2nd ceratobranchial and extends further forward on the 2nd epibranchial.

The 3rd muscle is the shortest of the three and arises from dorsal-lateral surface of the third ceratobranchial and is inserted on the third epibranchial.

6. Retractores arcuum branchialium dorsales

It is a large triangular muscle mass and , one on each side, arises from the ventro-lateral surface of the second, third and fourth vertebrae runs directly forward and ventral to the transversus dorsalis posterior.

Its origin is a large muscle sheet which attaches and covers the whole lateral and ventral surface of the second, third and fourth vertebrae. As the fibers run forward, it is inserted in a strong tendon on the posterior surface of the upper pharyngeal teeth.

This muscle specially suggests a very strong support to the upper pharyngeal teeth and participates to the grinding function of the P. tetricus.

Group 6. Muscles of the pectoral arch and fin (Fig. 76)

There are three muscles on the lateral surface of the pectoral arch, one is the abductor superficialis, a superficial muscle and other two are the abductor profundus and so called the third lateral muscle, two deeper muscles.

1. Abductor superficialis

This is the largest muscle of the pectoral fin. Its origin extends almost the full length of the posterior surface of the lateral wing of the cleithrum, Klaatsch used the name extensor superficialis in Polypterus and Thane described it as a flexor and also an adductor, depending on the definition of angular movement.

There are two parts of this muscle, the dorsal part goes posterodorsally and is separated into many tendinous bundles. These bundle attach to the base of the fin and each bundle sometimes can be separated into two tendons and connecting with a fin ray.

The ventral part of its muscle bundle usually is larger than the dorsal part, its fibers form some long tendons passing posteriolly and connecting with the ventral rays of the fin. In this condition, a large part of muscle may cause the movement of the certain single ray.

The function of this muscle moves the rays downward backward and laterally.

2. Abductor profundus

Its dorsal part is covered by the superficial abductor muscle. Its ventral part projects outside and has an exposed lateral surface.

It arises from the lateral surface of the coracoid except its dorsal part arising from the antero-ventral surface of the clavicle. Its fibers extending posteriorly on the fenestra between the coracoid and the clavicle, and the surface of the scapular, converge and become many tendons which are inserted on the lateral surface on the proximal ends of the dermal rays. The tendinous distal end of the muscle is distinctly separated into many tendons as in the abductor superficialis.

The function of this muscle is contraction but it acts as an abductor more than a depressor.

3. The third lateral muscle

The third lateral muscle which lies in front of the abductor profundus is totally covered by the abductor superficialis laterally. It is the levator muscles of the fin and arises from the bottom of the groove of the lateral wing of the cleithrum. Its fibers converge and are inserted into a tendon which connects with the proximal end of the first dorsal ray of the pectoral fin for the function of spreading the rays one from the other.

The antero-ventral connection of the muscle to the lateral surface of the cleithrum is not so strong as the tendinous formation on the

dorsal part with the proximal end of the 1st dorsal ray. The tendon is traversed by a well formed depression which lodges the distal end of the levator muscle and holding it and adds to its efficiency.

This muscle abducts the first ray and entire fin. Sometimes the rotation is brought by muscle being inserted into the upper surface of the fin ray.

4. Adductor superficialis

This triangular shaped muscle arises from the anterior boundary of the dorsal portion of the mesial surface of the cleithrum and passes postero-ventrally. Its fibers are inserted into separate tendons, each connects with the projection on the mesial surface of the proximal end of dermal rays except the first three dorsal rays of the fin.

The function of this muscle is to pull the fin mesially and ventrally against the trunk. When this muscle is abducted the rhythmical action and the superficial abductors and adductor are on relaxation, it will produce an undulatory movement of the fin.

5. Adductor profundus

There are two adductor profundus. The adductor profundus I is usually partially continuous with the adductor superficialis. The surface of origin of this muscle (Addp1) lies anterior to that of the adductor superficialis. Its fibers extend backward along the dorsal edge of the cleithrum, converge strongly into one bundle and are inserted by a tendon. This tendon attaches on the mesial surface of the first half ray through a enlarged and strong connection.

The function of this muscle is to pull the dorsal portion of the fin mesially.

The ventral part, the adductor profundus II (Addp2) is a flat rectangular muscle larger than Addp1. It almost occupies all the surface of the ventral part of the mesial surface of the pectoral girdle. Its fibers originate from the dorsal portion of the procoracoid, the anterior portion of the cleithrum and the membrane which fills the large coracoid fenestra (foramen). And then it extends postero-dorsally and insert twelve separated tendons on the pretruded base of the fin rays.

It pulls the rays and with it the entire fin toward the body and gives the necessary rotation to release the ray from its fixation.

Group 7. Muscles of the pelvic girdle and fin (Fig. 77)

The muscles of the pelvic fin are arranged in two layers on the ventral and dorsal surface of the pelvic girdle. The ventral muscles are abductors and the dorsal are adductors. These muscles are those which move the pelvic fins.

1. Abductor superficialis pelvis

It arises through a tendon from the tip of the anterior spine of the pelvic bones. The fibers run almost directly backward and are divided into separated tendons and inserted into the base of the fin rays.

The function of this muscle is to pull the fin downward and also to separate the rays.

2. Abductor profundus pelvis

This muscle, mostly covered by abductor superficialis pelvis mesially and partly exposed laterally, arises from the surface of the anterior part of the pelvic bone and is inserted into some tendons on the bases of the rays.

It is divided longitudinally into two parts by the ridge on the ventral surface. The lateral part is larger than the mesial part.

Its function is to assist the abductor superficialis pelvis but not to separate the rays.

3. Adductor superficialis pelvis

This is seen on cutting the tendons and ventral trunk muscles and bending the pelvic girdle back.

The superficial muscle arises from the tip of the anterior spine of the pelvic bones as in the case of its ventral equivalent. Its fibers pass directly backward and divide imperfectly into some tendons being inserted into the upper surface of the base of each ray.

Its function is to adduct the fin and separate the rays.

4. Adductor profundus pelvis

It, lying in the dorsal groove of the pelvic girdle, covered by a adductor superficialis pelvis and arises from the anterior part of this bone. The fibers run posteriorly and inserted into the bases of rays below the adductor superficialis pelvis.

The function of this muscle is to aid the superficial muscle and to approximate the rays.

Group 8. Muscles of the eyeball**(Fig. 81 to 82)**

There are six muscles on the eyeball. Two of them belong to the obliqui muscles and the rest are the recti muscles. The obliqui muscles originate from the anterior part of the orbit and the recti muscle from the posterior part of orbit or the cavity of eye-muscle canal situated among the basisphenoid, pterosphenoïds, prootics and parasphenoid.

1. Rectus superior

The rectus superior starts from the anterior part of the horizontal membrane which separates the eye muscle cavity. It lies mesially to the obliquus superior and is inserted into a tendon attaching to the eyeball.

2. Rectus inferior

The rectus inferior originates from the membranous interorbital septum and dorsal surface of the basisphenoid.

The insertion of this close to obliquus inferior.

3. Rectus internus

The rectus internus originates from the mesial part of the ventral surface of the horizontal membrane of the eye muscle canal. Its fibers pass forward ventral to the rectus inferior.

There is a rudimentary muscle along the dorsal edge and parallel to the rectus internus. Both of these two muscles are inserted in loose connective tissue that covers the eyeball.

4. Rectus externus

It arises from the posterior end of the eye muscle canal and runs forward on the dorsal surface of the horizontal membrane. Its insertion becomes reduced to a tendinous point which attaches to the surface of the cornea and the outer surface of the sclerotic of the eye ball.

5. Obliquus superior

The obliquus superior arises from the lateral surface of the membranous interorbital septum of the orbit.

The insertion of the obliquus superior is very close to that of the rectus superior. The former lies just dorsal to the latter and superficial to it.

These two muscles all become broad tendons at their insertion. Each pair is covered by a thin and transparent but strong membrane which is a derivation of the edge of the cornea, and inserts on the outer surface of the two muscles.

6. Obliquus inferior

The obliquus inferior is similarly inserted close to the insertion of the rectus inferior and lies immediately ventral and superficial to it. It is also covered by a membrane which arises on the eyeball as the same condition of the obliquus superior and the rectus superior.

The origin of the obliquus inferior is also on the lateral surface of the membranous interorbital septum, and situated immediately ventro-posterior to it. Sometime the origins of these two muscle overlap each other slightly.

Group 9. Muscles of the dorsal fin and anal fin (Fig. 84)

There are three kinds of muscles on each ray. These muscles are concealed by the lateral trunk muscles which require to be pulled aside to expose them.

1. Erector

The erector lies anterior to the depressor. It arises from the anterior surface of the vertical ridge of the pterygiophores and is inserted in a tendon attaching to a process on the anterior surface of the base of the ray. The erector is larger in size than the depressor in P. tetricus.

The function of the erector is to draw the fin ray forward and upward.

2. Depressor

The depressor arises from the postero-lateral surface of the pterygiophores and is inserted in a tendon dorsally on the posterior process of the base of the ray.

The function of the depressor is to pull the fin ray downward and backward.

3. Lateral

They consist of some small muscles, one on each side of the pterygiophores. It arises from the fascia covering the outer surface of the lateral trunk muscle and is inserted into the lateral surface of the bases of the rays ventral to the insertion of the erectors and depressors.

Its function is to make a sinuous motion of the fin by suitable contraction of the muscles of one side and a corresponding relaxation of the opposing muscle occurring at the same time.

Group 10. Muscles of the caudal fin

(Fig. 83)

1. Superficial muscles

The superficial muscles of the caudal fin are the extension of the lateral muscles of the trunk. The upper and lower portion of the myomeres of the trunk are prolonged into two large fasciae inserted into the surface of the base of rays, when the myomeres of the body contract, the fasciae act on the rays and draw them either to one side or the other.

The half rays of the dorsal portion of the caudal fin and those of the ventral portion are only inserted by the superficial muscles and not by any deep muscle except the 7th and 8th of the dorsal portion and the same of the ventral portion.

2. Intrinsic muscles

The intrinsic muscles exist between the rays of the caudal fin posteriorly to the insertion of the fasciae of the superficial muscles, each arises from the abaxial surface of a ray and is inserted into the axial surface of the outer ray to it.

The fibers of the central muscles, which lie above and below on the axial line of the fin, arise from the fascia between them.

The function of these muscles is to approximate the rays being aided by the dorsal and ventral portion of the deep muscles and opposing those of the superficial muscles.

3. Flexor caudalis dorsalis

The flexor caudalis dorsalis and the flexor caudalis ventralis are two triangular muscles symmetrical to the middle line of the body. The flexor caudalis dorsalis lies almost in the axial plane of the tail.

It originates from the dorsal surface and the neural spines of the last three vertebrae. The fascias of this muscle are attached to the median septum last vertebra and adductor caudalis ventralis.

The muscle passes posteriorly in a line, parallel with the general axis of the body, running under the adductor caudalis ventralis and is separated into 8 tendons inserting into the dorsal 6 caudal rays.

The function of this muscle is to cause a strong flexion of the dorsal part of the caudal fin toward the side on which the contractions act.

4. Flexor caudalis ventralis

The flexor caudalis ventralis, also a triangular muscle, arises from the ventral surface of the centra and the bases of the haemal spines of the last three vertebrae of the caudal peduncle.

The fibers run slightly ventrally and caudally to insert into 8 tendons into the bases of each fin ray and the 7th and 8th half rays of the ventral part of the caudal fin.

The contraction of this muscle may cause the sharp flexion of the whole ventral half of the caudal fin towards that side on which the contraction happens.

5. Adductor caudalis ventralis

It is also a triangular broad muscle, lying on the middle line of the caudal vertebral axis. Its fibers are arising from the posterolateral surface of the last vertebra and the axial margin and surface of the third and fourth hypural, running backward and then upward and ending into four tendons which attaches to the 8th dorsal half-ray and the 1st to third rays.

The contractions of the adductor cause a sharp flexion and adduction of the dorsal caudal lobe.

It pulls the rays downward as the intrinsic muscles do and is the opponent of the dorsal superficial muscle.

Group 11. Muscles of the trunk

(Fig. 77)

The trunk muscles are derived from the embryonic myomeres, the lateral trunk muscles (myotomes) are separated by myosepta. The muscle mass does not extend at right angles to the sagittal plane of the body. It is in W shape.

(Fig. 95)

There are two septae separating the trunk muscles. One is the median dorsal skeletogenous septum, another is the horizontal skeletogenous septum.

The two large lateral muscle masses of each side are separated by the horizontal skeletogenous septum. The epaxial lies above the horizontal skeletogenous septum and the hypaxial is below this septum.

Epaxialis

The epaxialis forms the dorsal component of the body musculature, lying above the lateral septum. Anteriorly, it attaches to the posterior and posterodorsal surface of the skull. Fibers also attach to the dorsal parts of pectoral girdle. The myocommata take a V shaped course passing from the dorsal midline posteroventrally and then anteroventrally to the lateral septum. The myocommata tend to take an increasingly vertical path as they near the midlateral line. The angle between the two main directions of the myocommata tend to become increasingly acute in the region of the caudal peduncle.

Hypaxialis

The hypaxialis consists of that part of the body musculature lying ventral to the mid-lateral horizontal septum. The myocommata in these caudal fin rays often run in three directions between the lateral septum and the ventral midline, posteroventrally, anteroventrally and then posteroventrally again. The hypaxialis attaches to the vertebral centra, neural arches and spines in the region between the pectoral girdle and caudal fin. The posterior part of the muscle inserts aponeurotically on the lateral bases of the dorsal branched fin rays. Its insertion may also include the unbranched and procurent fin rays.

Discussion

In the P. tetricus some of the dorsal muscles of the gill-arches are spring from the side of the braincase and the ventral ones form a complex system extending forward from the anterior border of the cleithrum and extending transversely across the floor of the throat between the hyoid arches. The branchial muscles of different fishes are doubtless modified in many special ways in accordance with the various movements of the branchial arches.

The jaw muscles, which are regarded by Vetter (1874, 1878) as serially homologous with the middle deep flexors of the branchial arches, extend fan-wise from the curved border of the preopercular to the mandible, one division (A₁) being connected with a tendon that is inserted on the medial surface of the maxilla. These muscles have been described in detail especially by Vetter (1874, 1878) and by Allis (1903, 1909). Their tendinous parts meet in a complex central tendon with several branches to the maxilla and mandible. The fan-like origin of A₁, A₂ from the preopercular and from the area in front of it insures efficient action as the mandible moves upward and as one part of the adductor after another comes into the phase of maximum extension.

It seems that the adductor mandibulae became subdivided early in the history of the neopterygians and certainly by the Palaeoniscoid stage. These subdivisions (A₁ occupying the Meckelian fossa and A₂ connecting the lateral face of the pterygoid arch to either the coronoid process of the angular or the posterodorsal region of A₁) are present in Ania and many teleosts.

With the complete freeing of the maxilla from the cheek and a more mobile premaxilla, the maxilla-mandibular ligament become well consolidated passing from the posterolateral region of the angular to the posterodorsal

part of the maxilla. The more dorsal fibers of A2 attach on the lower end of this ligament, a process resulting in the separation of a dorsal muscle (A1) serving the maxilla posterodorsally, the origin of this new section tend to expand medially on the hyomandibular resulting in two heads of the muscles separated by the insertion of the levator arcus palatini onto the dorsal face of the hyomandibular.

Two superficial and sequential muscles lie between the rear of the orbit and the posterodorsal tip of the opercle, the levator arcus palatini and the dilatator operculi. In most fishes, a further muscle, the levator operculi, develops behind the dilatator operculi. Immediately beneath the levator arcus palatini and the hyomandibular articulation lies the adductor operculi, a muscle frequently expands anteriorly to fill the fissura infraorbitalis. Most fishes possess a posterior section of this muscle, the adductor operculi which migrate posterodorsally and then curve anterodorsally to form the levator operculi. These two muscles are continuous in Elops spp. In certain forms an adductor hyomandibulae may also be present.

The levator arcus palatini may be very well developed as in the stomiatoids or almost absent as in the Tetraodontidae and Diodontidae. It is sometimes subdivided into two separate parts as in the Harpodon, Ammodytes, Ictalurus. The lower subdivision recognized by Greenwood (1968) in clupeoids probably represents the adductor hyomandibulae.

The intermandibularis is present in most teleosts. But in the tetraodontiforms and some other fishes, the fusion of the halves of the lower jaw in the midline makes the muscle lose function and become absent. Girgis (1952) reported it was absent in the cyprinid Labeo. Embryologically, the muscle is separated into two portions. The anterior of these remains as the intermandibularis, the latter forms one part of the protractor hyoidei.

The hyohyoideus of P. tetricus is normal in size and may serve many branchiostegal rays. In balistids the section to the first ray has expanded to form a broad, flat sheet, while in the Tetraodontidae and Diodontidae, the first muscle becomes enormously enlarged to operate the plate-like first branchiostegal ray as a respiratory and inflatory pump.

In more generalized neoteleosts, the pharyngo-hyoideus connects hypobranchial 3 to ceratobranchial 5, the anterior site of attachment moving forward to the urohyal in more advanced forms. Edgeworth (1935) and Millard (1966) considered the muscle to be derived from the anterior part of rectus ventralis V. Nelson (1967) stated that the rectus communis developed from the splitting off of the ventral fibers of rectus ventralis IV. Dietz (1912) recorded the muscle between ceratobranchial 4 and hypobranchial 1. Nelson (1967) showed that it connected the ceratobranchial 4 and hypobranchial 2 and 3 in eels, or attaches anteriorly to the ventral hypohyal (Edgeworth 1935). It is absent in cyprinids where there are four to five recti ventralis and connects ceratobranchial 5 to hypobranchial 1 in the cobitids (Takahasi 1925) or it may connect ceratobranchial 5 to hypohyal, receiving fibers from ceratobranchial 1 to 4, as in Siluriforms (Juge 1898, McMurrich 1884).

The pharyngoclavicularis of teleosts represent a single division of the fifth branchial arch muscle plate (Edgeworth, 1935) and becomes subdivided into an externus and an internus portion in most groups of fishes except Anguilliformes. Nelson (1967) has argued that the subdivision of this muscle represents the primitive condition for the teleosts and that the two muscles so formed, together with the sphincter oesophagi derived from the obliquus ventralis V of the preteleostean.

Edgeworth (1935) suggested that the transversi ventrales represented the plesiomorph condition for the Teleostei and that the obliqui ventrales

developed from them. But Kesteven (1943) stated the embryonic branchial muscle plates did not meet in the ventral midline therefore there was no embryological transversi ventrales and Nelson (1967) considered that no "Generalized" teleost was known to have an obliquus ventralis and transversus ventralis on the same arch and because the former muscles always occurred when both hypo- and ceratobranchial elements were present. This seems to indicate that transversus ventralis IV are developed with the loss of hypobranchial 4, which form one of the attachment sites of the obliquus ventralis IV in holosteans. However both Kesteven and Nelson insisted that the obliqui ventrales represented the ancestral teleostean condition.

There are three levatores externi in P. tetricus. The muscles of the first two arches are absent. In specialized Acanthopterygians that of the first and third arch may be absent. (Diets 1914, Field 1966). In the Sternoptychid argyropelecus, the muscles originate as a single tendon just medial to the hyomandibular fossa, and then diverges to insert on epibranchials 1-4. In Tetraodontids and Diodontids, the fibres of Le 5 may reach the branchial chamber and cleithrum.

The levator internus IV of the P. tetricus is absent and the Le 5 and Li 5 are enormously developed. In Cyprinus the more lateral fibres of the Li 2 and Li 3 attach to epibranchial 3 and 4.

The interarcuales obliqui dorsales of the P. tetricus interconnect the epibranchial III and IV, and the upper pharyngeal teeth (pharyngobranchials III, IV, V). In Tetraodontinae, the anterior fibers arise from epibranchial 3 but the posterior one come from epibranchial 4. In the Canthigasterinae all the fibers arise from epibranchial IV. In some genera of the Sternoptychidae (Maurolicus, Argyripnus) obliquus dorsalis IV is the only muscle of this complex present but here a few of the lateral fibers course

forward to attach to the postero-medial face of epibranchial 2 or epibranchials 2 and 3.

The number of adductores arcuum branchialium may vary from five as in Tetraodontidae (Quignard 1962) to none as in Ostraciinae and Nandidae (Liem 1970). There are three in the P. tetricus.

In the investigations on the embryology of Belone, Favaro (1902) stated that the retractor arcuum branchialium dorsalis developed from the trunk myomeres. Holstvoogd (1965) had the same opinion and stated that two retractor muscles of cyprinids develop from the sphincter oesophagi, a view expressed by Edgeworth (1935) for the teleosts generally. Dietz (1914) and Holstvoogd (1965) expressed the opinion that these muscles which insert on ceratobranchial 5, were not homologous with the retractors of the neoteleosts.

In both cyprinids and neoteleosts, these muscles arise from some part of the muscle plate of the fifth branchial arch. It may be assumed that the muscles between the basioccipital and ceratobranchial 5 of cyprinids are embryologically derived from the same origin as the retractor dorsalis of neoteleosts, but there is no sufficient evidence as to whether they are morphologically and phylogenetically homologous or not.

In certain generalized forms as in Elops the abductor superficialis does not separate from the deeper fibers, which, in more advanced fishes, form the abductor profundus, even the variation in fiber direction leading to this separation is apparent. In Osteoglossum, the abductor profundus to the last ray is continuous with the abductor superficialis section to that ray. The adductor superficialis crosses over itself, the more dorsomedial fibers serve the more ventral fin rays, while the more ventrolateral fibers serve the more dorsal rays.

Takahasi (1917) suggested that the three muscles of the dorsal and anal fins (the erector, depressor and inclinator muscles) developed from the the anlagen which formed the supracarinales and infracarinales muscles in the areas where the fins did not develop.

The carinal muscles are paired, cord-like bundles of muscle fibers lying along the dorsal and ventral midlines, interconnecting the supportive elements of both median and paired fins. A supracarinalis medialis develops between the two dorsal fin. In the case of muscles of the paired fins, however, the anlage of the carinal muscles in these regions do not appear to be related to the muscles of the fins. In Elops saurus the first two fin rays are not served by erector muscles the first of which attaches to the third ray. The erector and depressor muscles serving the last two rays fuse together, each ray receiving a single compound muscle which inserts broadly over its lateral base.

In Branchionichthys, the inclinator to the second spine consist of three subdivisions but only two major divisions are apparent in Histrio, the more posterior one inserting ventral to the more anterior division. Inclinator may be entirely absent in Pimelodus (Alexander 1965) and has a single inclinator to first ray which arises from the medial edge of the posterolateral process of the basal pterygiophore supporting the dorsal spine.

Development of a slender peduncle and a narrow caudal fin usually results in considerable reduction in size and frequent loss of these intrinsic caudal fin muscles, their services presumably no longer being required with the loss of sophisticated movements of individual fin rays. But the attachment of tendinous sheets from the body muscles onto the bases of the fin rays is emphasized. The adductor dorsalis exists in certain perciform families and absent in others. Nursall (1963) reports it in a

lutjanid. Nag (1967) in a Kuhlid and an Apogonid, and Grenholm (1923) found it in Acanthuids and most tetraodontiforms. It probably develops from the dorsal migration on the interradiales serving the dorsalmost of the ventral fin rays. In certain tetraodontiformes, the muscle may insert on more than one ray except the first ventral ray in Ostraciins.

In certain Atherinids and Clupeids, the lateralis superficialis (the dark or red muscle) is encased in a silvery pigment (Denton and Nicol 1965), while it becomes enormously developed in many mesopelagic fishes (Marshall 1971). The development of the muscle is related to the need for sustained effort as has been shown by Baretts (1961), Marshall (1971) and others. It is not existed in the P. tetricus.

PART III

DIGESTIVE SYSTEM

The mouth cavity of P. tetricus is not very large. There are many large canine-like teeth on the premaxillary and dentary bones. The pharyngeal teeth are molar-like and well developed. Longitudinal ridges of mucous membrane pass along the posterior roof of the buccal cavity. A well developed mucous secreting layer covers the posterior part of the buccal cavity. The peritoneal cavity is rather small, the peritoneum is silvery. The pharynx is wide and the esophagus short and wide. On its wall, the thick mucous membrane consists of about 10 longitudinal folds. The stomach is absent, the digestive tract consists merely of the intestinal bulb and the intestine. The intestine is short and rounded in a small circle. The mucous membrane of the intestinal bulb consists of papillary processes which are arranged in 12 to 13 longitudinal serpentine rows. A valve exists between the intestinal bulb and the intestine. The mucous membrane of the intestine is almost flat. It has no pyloric caecum.

The liver has 2 lobes, the left lobe is large and the right small and rather thick, covering the anterior part of the intestinal bulb ventrally. The gall bladder is ovate and the cystic duct rather long. The mesentry is developed about the rounded part of ^{the} intestine.

The Buccal Cavity

(Fig. 85 to 86)

The mouth and esophagus are lined with a stratified squamous epithelium in which are goblet cells and taste buds. The wall of the buccal cavity is made of two layers, the mucosa and submucosa. The mucosa which is thrown into folds is formed of stratified epithelium and sits on the basement membrane. It is supported by stratum compactum. The submucosa is formed of areolar connective tissue.

There are many longitudinal folds extending along the buccal cavity. The stratified epithelium differs in thickness from 5 to 12 layers. The basal one or two layers of cells are low columnar cells with large nuclei. The inner surface of the buccal valves is not significant and the epithelium covering the outer and inner surface of the valves has the same thickness.

There are many mucus-secreting cells which are of a saccular type. Most of the adjoining epithelial cells lose their shape due to the compression of a large number of mucus-secreting cells. The striated muscle occurs peripherally to the connective tissue. No muscle is present in the tongue. Taste buds are situated on the roof and the floor of the buccal cavity usually one taste bud appears on the top of a fold but sometimes two buds are seen. Each taste-bud is formed of two types of cells:

1. The elongated cells bearing an ovoid nucleus at their broad inner ends with their narrow ends exposed on the mucous surface.
 2. The slender supporting cells are between the elongated cells.
- Blood vessels and nerves are also found.

The lymphocytes and granular cells can invade into the stratified epithelium.

The pharynx

The pharynx is lined with stratified epithelium which is of 5 to 10 layers, but the lateral mucosa of the pharyngeal cavity is one cell thick and is entirely constructed of mucous secreting cell. The basal layer is formed of low columnar cells with elongated nuclei, and the upper part is lined with polyhedral cells. The mucous folds are prominent on the midline of the roof and floor of the anterior part of the pharyngeal regions.

The stratified epithelium contains taste buds and many mucous secreting cells which are saccular on the papillae. The taste buds extend from the inside of the lips to the pharyngeal teeth. A thick submucous layer contains the nerve fibers and forms the base of the taste buds. In the anterior part of the pharynx taste buds are few and are located along the sides of the crypts. Gradually they increase both in size and number encroaching upon the epithelial cell-layers and forming a continuous series of crowded patches. The taste buds in the pharynx are still long but decrease in size. The basement membrane is very significant. The stratum compactum is very thick. The tunica propria is areolae connective tissue and carries nerves and blood vessels.

The submucosa is made up of fibrous connective tissue containing nerves, adipose cells and blood vessels. Its thickness is coordinated with the depth of the mucous folds. It is no different from the areolar connective tissue of the tunica propria and submucosa in this region. From the middle region of the pharynx the adipose cells disappear but there are many scattered muscle fibers which are of the striated type and run in various directions. The muscularis which is made of a thick layer of striated circular muscle fiber, connective tissue with nerves and blood vessels, is external to the areolar connective tissue.

The epithelium and submucosa of the tongue are much more compact than that of the pharyngeal cavity.

Esophagus

(Fig. 87)

The esophagus connects with the pharynx and opens posteriorly into the intestine through a muscular valve. The longitudinal folds of the pharynx extend to the esophageal-intestinal valve as well. The wall of the esophagus contains five layers. These are the mucosa, submucosa, muscularis, subserosa and serosa. It has a somewhat incomplete inner longitudinal and thicker outer circular layer of striated muscle.

The stratified epithelium without cilia is made up of 7 layers of cell. The mucus-secreting cells which can occupy a large part of the surface and thickness of the epithelium are saccular type on the superficial layers of the epithelium. Their oval nuclei are pressed against the bottom of the cell by the large vacuole. The esophageal folds are branched and passed toward the posterior part of esophagus. Finally, the stratified epithelium is replaced by a simple epithelium, the

columnar cells. The saccular mucus-secreting cells exist in the anterior esophagus and then disappear entirely from the middle and posterior esophagus except the esophageal-intestinal valve. The taste buds have a further modification. They become very small in size and consist of a small number of cells and disappear on the columnar epithelium entirely. The cells of the basal layer, which are small with rather large nuclei, keep a definite thickness throughout the esophagus. The basement membrane is well developed.

The tunica propria is made up of connective tissue carrying blood and lymphatic vessels. The striated muscle fibers exist from the pharynx to the esophageal-intestinal valve. The nerve supply becomes much poorer than in the pharynx because there are no taste buds. The granular cell is in the submucous connective tissue in the posterior part of esophagus and pyloric valve.

The muscularis is a single layer of circular or striated muscle and decreases on thickness toward the esophageal-intestinal valve forming a sphincter on the base of the valve. The fibers are arranged in small bundles and connect together by an areolar connective tissue.

The subserosa is thick and made up of collagenous and elastic fibrous connective tissue. In this layer large blood vessels are present. It extends posteriorly into the mid-gut. The serosa is made up a single layer of pavement epithelium and sometimes contains the peripheral muscle fibers.

The pyloric valve shows stratified epithelium and simple epithelium at its anterior and posterior surface. The muscular valve is made up of striated muscle fibers mainly, but longitudinal unstriated muscle fibers are scattered in the submucosa of the intestinal side. As it passes

posteriorly, these muscle fibers form a layer and extend to the mid-gut.

The anterior part of the esophagus is attached to a layer of the skeletal muscles. The dorsal side of the middle part of the esophagus is connected to the kidney and skeletal muscles through a membrane and the ventral side is covered by peritoneum.

Intestinal Bulb

(Fig. 88)

In the intestinal bulb of P. tetricus the lining epithelium is arranged in folds. The intestinal papillae are simple and finger-like. Some small papillae are conical in shape and exist. The wall of the intestinal bulb is built up of the mucosa, submucosa, musculosa, subserosa and serosa from inside to outside. The musculosa which sometimes has secondary and tertiary folds, is more complex in the intestinal bulb than in the esophagus. The lining epithelial cells of the intestinal bulb and intestine are mainly columnar.

The columnar cells of the intestinal epithelium are very high. Their nuclei are oval and small in size and at the middle or the basal third of the columnar epithelium and then move to upper portion on the posterior

part. At the free surface of the cell is a striated border. It is difficult to determine with the light microscope whether the brush and long fibers are microvilli or cilia. The granular layer is lightly basophilic. Many unstained vacuoles are present in the subborder and supranuclear zone and occasionally present in the infranuclear zone. The depth of the supranuclear zone becomes less posteriorly. The nuclei of the developing columnar cells, the mucous cells, the goblet cells and others may be found in the infranuclear zone. The mucous secreting cells of the intestine, which has a thin neck, a rodlike root and the ovoid nucleus sitting at the bottom of the cell, are different morphologically from those of the pre-esophagus. The goblet cell and granular cells are as those in the esophagus and are irregularly scattered in the intestinal epithelium.

The tunica propria passes into the submucosa. The submucosa is a layer of fibrous connective tissue between the epithelium and muscularis. The collagenous fibers of the submucosa are more dense posteriorly. The stratum compactum is a layer of dense connective tissue under the mucosa. The submucosa contains blood vessels. The young fibrocytes with basophilic cytoplasm, the mature fibroblasts with elongate or oval nuclei, the granulocytes with basophilic cytoplasm and the amoebocytes with a round nucleus, are present in the submucosa.

The muscularis of the intestinal bulb is made up of unstriated fibers. In the well-developed anterior part of the intestinal bulb the musculosa has three layers, an inner thin longitudinal, a middle circular and an outer longitudinal. The inner layer sends many muscle fibers into the submucosa to the pyloric valve. The outer two layers extend throughout the length of the intestinal bulb but the circular muscle layer becomes thin posteriorly. The connective tissue separating these two layers is very thick. Both are well supplied with small blood vessels. A nerve plexus

may be found between the muscle layer.

The subserosa limited to a few fibrous strands, consists of connective tissue which is connected with the esophagus and becomes then posteriorly scattered between the epithelium and the longitudinal muscle.

There is no distinct lamina propria which consists of vascular areolar connective tissue.

The serosa consists of a single layer of peritoneal cells of cuboidal or even flattened shape.

Intestine

(Fig. 89 to 93)

Between the posterior part of intestinal bulb and the anterior part of the intestine, an ileo-rectal valve projects into the intestinal cavity. It is formed by a folding of the circular muscle layer and is not a sphincter valve. A layer of connective tissue containing granular cells separates the two layers of the fold. There are blood vessels, nerve plexus and longitudinal muscle fibers in the base of the valve. The muscle of this valve is continuous with the circular fibers of the

intestinal bulb and intestine. In the region of the valve, the subserosa becomes much thickened.

The internal lining epithelium of the intestine is arranged in folds. The depressions between the folds often simulate glands of the tubular type by physical arrangement only. The structures are in no sense true intestinal glands.

The mucosal papillae are larger than those of the intestinal bulb. Two types of cells are usually found in the intestinal mucosa; the columnar cells which have many vacuoles in the supernuclear zone, and mucous or goblet cells. The former which are long and slender with large coarsely granular nuclei, are greater in number than the latter.

Posteriorly, the mucous cells decrease in number and then increase around the anus.

The goblet cells which have a swollen portion, a narrow tail portion and the nucleus are on the top of the papillae and are more numerous at the intestinal bulb. There are other cells, the wandering cells, presumably leucocytes. The appearance of their nuclei are quite distinct from the epithelial nuclei being smaller, more nearly spherical, staining a more deeply chromatin structure. They are always at the bases of the epithelial cells near the tunica propria.

The tunica propria extends from the basal membrane of the epithelium and extends to the submucosa. It is composed of rich areolar tissue of white fibers and small or large oval nuclei, and is somewhat less in thickness than the epithelial layer. The blood supply of the tunica propria is abundant.

There are no granular cells in the submucosa which is thinner in between the bases of the papillae than in the intestinal-bulb.

The muscularis of the unstriated fibers is thicker than the intestinal bulb and is made up of an inner circular and outer longitudinal muscle layer. The former is the thicker of the two muscle layers and is well supplied with small blood vessels and the latter is about half the thickness of the circularis and rather more densely constructed than the former. It can not easily be differentiated near the ileo-rectal valve. The circular muscle layer develops into a sphincterlike structure. The longitudinal muscle layer and nerve plexus are scattered into the connective tissue of the anus.

The subserosa connective tissue is much thicker than the intestinal bulb. The connective tissue layer is of the ordinary loose type and consists mainly of collagenous fiber with a few elastic fibers. It is scattered between the epithelium and the longitudinal muscle and is well supplied with blood vessels.

The serosa is composed of a single layer of cuboidal or even cylindrical cells, the usual flattened serosa cell as found in higher forms. Its thickness may be in part at least altered during digestive processes.

Liver

(Fig. 94)

In P. tetricus, the liver, a large tubular gland is divided into two lobes and covers the esophagus, intestinal bulb and spleen. The left lobe is the large one, triangular in shape and the right lobe is small and located lateral-dorsally. The hepatic lobule, the small unit of the structure of the liver consist of two parts, the epithelial parenchyma and a system of blood channels. The parenchyma is made of hepatic cells in irregular, branching cell cords, the hepatic cords. In three dimensions, the cells of the hepatic cords are arranged in broad plates or laminae and the plates are arranged in a radiating manner around the central blood vessel of the lobule.

The spaces suspended in the hepatic labyrinth of these plates are the hepatic sinusoids. In mammals, each lobule is completely invested by connective tissue but in fish this structure is less completed. The blood comes from two afferent vessels, the hepatic artery and portal vein to individual interlobular branches then to hepatic sinusoids. The capillaries all converges to central veins and thence to the hepatic veins, the efferent vessels of the liver.

The hepatic cells which make up the hepatic plates have a central nucleus with a distinct nuclear membrane. Multinucleate cells are usually seen.

Bile, a product of the hepatic cells is carried out by the minute channels, the bile canaliculi, between the hepatic cells to the system of bile ducts into the duodenum.

Schreiber and Angleletti(1940) found a rhythmic increase and decrease in size of the liver of the carp independently of growth changes in the organ. Rhythmic frequencies are related to the age of the fish.

Discussion

In various fishes different degrees of reduction in the stomach and of absence of gastric characteristics occur. In some fish, as the carp, the stomach is lacking entirely, the striated skeletal muscle of the esophagus extends far posteriorly and even into the walls of the intestine.

In P. tetricus, a macroscopically identified stomach is absent and no multicellular gastric glands were detected in any part of the alimentary tract. The lack of a stomach means that there is no lateral expansion of the alimentary tract between the end of the esophagus and the junction of the bile duct and the intestine. The mucosa of this part has neither gastric epithelium nor gastric glands.

The absence of a stomach of teleostes is a phylogenetic character of certain families more than an adaption of feeding habit in a particular species and has been recorded in many families as Atherinidae, Blennidae, Cobitidae, Cyprinidae, Gobiidae, Mugilidae, Poeciliidae, Scoridae and Syngnathidae etc. These families each have their own special feeding habits.

The wall of the buccal cavity consists of mucosa and submucosa only. It is similar to studies by Dawes (1930), Al-Hussaini (1945) and Kholy (1953) and others, the muscularis sometimes can be seen in the buccal lining too. The stratum compactum is limited to the buccal and pharyngeal cavities.

The mucus-secreting cells of the buccal cavity and pharynx are saccular or pyriform and not goblet-shaped. The pharynx has many more mucus-secreting cells than the buccal cavity neither part appears to be of particular enzymatic importance. There were no specialised glands in either except mucus secreting cells.

Blake (1930) considered the condition in sea bass indicates the formation of goblet cells by modification of the simple epithelial type.

In the esophagus the stratified epithelium is in the anterior part and the simple epithelium is in the posterior-most part. The mucous-secreting cells exist along the whole length of the esophagus.

A pyloric valve, the sphincter, is made up of striated muscle fibers between the esophagus and intestine. No stomach can be found.

The carnivorous P. tetricus feed on crayfish and shellfish etc. So there is no need to have a stomach for the storage of the food. The structure of the digestive system is a typical carnivorous.

A subserosa has not been recorded in the esophagus of teleosts. The musculature of the pyloric valve is composed of fasciculi made up of striated muscle fibers which extend into the valve.

The intestinal bulb is divided with regard to its musculature into two parts. In the first part the musculosa is formed of three layers, an outer longitudinal, a middle circular and an inner longitudinal, but the second part has not the inner longitudinal. So the first part can be regarded as duodenum and the second part as ileum.

The ileo-rectal valve is made up of unstriated muscle fibers circularly arranged and in continuation with those of the intestinal bulb and intestine.

The rectum differs from the ileum by the possession of a thicker muscularis, higher mucosal papillae and a great number of goblet cells.

Special granular cells are observed in the different parts of the alimentary canal. They are related to internal secretion and lipase production.

In mammals, the division of the parenchyma of the liver into lobules is very obvious. Each has a central vein, and the branches of the bile duct, hepatic artery and portal vein in the connective tissue at the angles of these lobules. The sinusoids of each lobule converge from the periphery to the central vein of that lobe. In fishes less prominent division has been seen in the lobule.

SUMMARY

The skeletal system of p. tetricus is described including axial skeleton and appendicular skeleton. This bony-fish skull is composed of two significant parts, the neurocranium and the branchiocranium. The neurocranium has two major parts: (I) a series of inner (endosteal) elements that provide a floor to the brain case and protect the olfactory, optic and otic capsules. (II) a series of outer (ectosteal) dermal bones that roof the brain case. The branchiocranium has three regions: (I) jaws or mandibular. (II) hyal (the jaw-supporting hyoid arch and the bones of gill-covering opercular series). (III) branchial (the gill arches).

The bones of the neurocranium may also be grouped by location into four regions: olfactory, orbital, otic and basicranial. There are cartilage bone and dermal bones exist in each of these regions. Cartilage bone, also termed replacement bone, is always deeper in location than dermal bone. It is laid down as cartilage at first and then replaced by bone later. Dermal bones are on the surface in position usually and derives from the dermis. Bones of both two types are generally bilaterally paired but only a few of median bones are unpaired.

The vertebral column of P. tetricus is composed of a series of segments, the vertebrae which are modified gradually according to body region. The first and second, the atlas and axis, are altered for connection with cranium. Some vertebrae have lateral processes which bear ribs. Ribs of this fish are of two types, dorsal and ventral. The ventral ribs develop in the myosepta of the myomeres at the peritoneum. The dorsal ribs form the " intermuscular bones ". The

body of the vertebra is the centrum, neural arch, hemal arch and some processes. The caudal fin is supported by penultimate, vertebrate, hypurals, epurals and urostyle.

The internal bones which support the dorsal and anal fin are pterygiophores. The pterygiophore includes two parts, the proximal part which originates from an interneural dorsally or an interhemal ventrally and the distal pterygiophore which articulates with fin ray. The dorsal fins are connected with neural spines through cartilages.

The elements of the pectoral girdle of P. tetricus are the cartilage bones including paired coracoids, scapulae and four pairs of radials and dermal bones including paired posttemporals, supra-oleithra, oleithra and postoleithra. The pectoral girdle articulates with the neurocranium dorsally.

In P. tetricus the pelvic radials disappear and the fin rays articulate directly with the basipterygia. During the evolution, the pelvic girdle moves forward and sometimes inserted to connect with the pectoral girdle.

The musculature on the head of P. tetricus is connected with the jaws and with the gill arches. Both the superficial and deep muscles have no large difference in the genus Pseudolabrus. The muscles on the head may have more than one origin and insertion. So their function and nomination are very complex.

The segments of the trunk muscle extend from the skin deeply to the body axis and are limited a midline by the median skeletal septum. They are W shap in cross section on anterior and posterior part of the body in which many myotomes are to overlap as wedges. The red muscle (*lateralis superficialis*) is not prominent in P. tetricus on the posterior part of the body. The deep trunk muscles of non-significance are the *supracrinales*.

The skeletal muscles of the median fins are paired protractor, retractor and lateral inclinators to each fin ray from each side. The caudal fin has more complex lateral muscles masses which are flexors, adductor and interfilaments.

The skeletal muscles of the paired fins arise from embryonic axial myomeres to supply the paired fins. The bundles of appendicular muscle are visible at the bases of the fins, which are abductors and adductors generally. These muscles serve to hold or move the girdle.

P. tetricus is a predacious fish. Its digestive tract can be divided into 6 parts: mouth cavity, pharynx, esophagus, stomach, intestinal bulb and intestine, which are lined with a soft mucous membrane.

The esophagus is so distensible that the fish can get large food piece to pass through it. The mouth cavity, pharynx and esophagus have no function on digestion but are for the accomodation of the food.

The thickened and muscularized stomach is elongated in shape for adaptation, which is an important portion of the digestive tube with acid secretion and special epithelial lining. Gastric glands exist in the stomach. These glands secrete hydrochloric acid and pepsinogen to split large protein molecules.

Because the meaty food can be digested more quickly than vegetable food, the intestine is not long for the carnivorous parrot fish. The wall of intestine supplies with glands for digestion and protecting the gut lining which absorbs the digested products in solution.

The liver arises as a part of the developing intestine in the embryonic stage, which consists of lobules of tubular glands and blood vessel. Bile is secreted into the bile canals and contains the fat emulsifying bile salts and biliverdin and bilirubin.

Characteristics of Pseudolabrus tetricus (RICHARDSON), P. fucicola (RICHARDSON) and P. miles (BLOCH & SCHNEIDER);

Pseudolabrus tetricus (RICHARDSON). Blue-Throated Parrot Fish.

(Plate 1 to 2)

D. ix, 11. P. 13. A. iii, 10. V. i, 5. C. 14. L. lat. 26-27.

Body elongate and slightly compressed, much deeper in the adult than in the young. Mouth of medium size, the gape reaching below the front border of the eye. A single row of teeth in the jaws, the anterior pair enlarged and curved inside to form canines. Eye small, its diameter about $1/7$ of the head length in adults.

The rays of dorsal fin are somewhat longer than the spines. The dorsal membrane produces a short filament beyond the tips of the spines. Anal fin similar and opposite to the soft dorsal fin. Pectoral fin not round. Caudal fin straight. Large scales on the body and operculum. Preoperculum with 3 rows of small scales behind the eye.

Colour of body largely variable with age. In the young, there is a dark brown band from the spinous dorsal to behind the pectoral and many brown bands radiating from the eye. Pectoral and ventral fins yellow, the former with a black bar on base. In the adult, there are two broad dark stripes across the body, and the chin and throat are dark blue. Pectoral and ventral fins are light yellow, the former with a black band on base. Soft dorsal and anal fins black, the caudal fin dark anteriorly, bright yellow posteriorly.

Pseudolabrus fucicola (RICHARDSON). Blue Parrot Fish.

(Plate 3)

D.ix,11. P.13. A.iii,10-11. V.i,5. C.14. L.lat.26-27.

Body deep and robust, slightly compressed. Caudal peduncle thick. Mouth of medium size. A single row of teeth in the jaws, with a pair of anterior curved canine teeth. Eye somewhat small, its diameter $1/6$ of the head length.

The spines of the single dorsal fin shorter than the rays. Dorsal membrane beyond the tip of the spine. Anal fin beginning below the last dorsal spine. Pectoral and caudal fins rounded. Operculum with large scales. 5 rows of scales on the preoperculum behind eye.

Body and fins deep black-purplish in colour without conspicuous markings. Smaller than P. tetricus.

Pseudolabrus miles (BLOCH & SCHNEIDER). Rosy Parrot Fish.

(Plate 5)

D.ix,11. P.13. A.iii,10-11. V.i,5. C.14. L.lat.26-27.

Body elongate, becoming deeper with age. Mouth rather small. A single series of teeth in the jaws, the large anterior pair curved to form the canines. Eye larger compared with adult of P. tetricus.

A single dorsal fin, beginning above the posterior border of the operculum. A short filament from dorsal membrane beyond the tips of spines. Anal fin beginning below the second dorsal ray. Upper pectoral rays about twice the length of the lower rays. Caudal fin with a lunate appearance. Scales of operculum larger. Preoperculum with smaller scales of 5 rows behind the eye.

Colour of body pink and reddish. The centre of each scale with a yellowish spot. Membrane of dorsal and anal fins with yellow and orange spots. Caudal fin grey. Smaller than P. tetricus and P. fucicola.

Intermediate characteristics of the hybrid of P. tetricus &
P. fucicola.

(Plate 4)

- (1). Body and some fins (except pectoral fins) deep black-purplish in colour, as in P. fucicola.
- (2). Pectoral fins reddish and yellow, with a black band on base, as in P. tetricus.
- (3). 5 rows of scales on preoperculum, behind eye, as in P. fucicola.
- (4). Body not robust, but elongate and somewhat compressed, as in P. tetricus.

ACKNOWLEDGEMENTS

I am deeply grateful to:

My supervisor, Dr. E. R. Guiler for his instruction of the research work and correction of the manuscript; Professor B. Johnson and Dr. S. Lake for their encouragement and help; Mr. Tas Sward for his help to catch the fishes in the field; All the other staff in the Department of Zoology, the University of Tasmania, for their help in many ways.

Mr. D. C. Wolfe for his help on collection of fishes from the research vessel of Sea Fisheries Division, Tasmanian Department of Agriculture; Mr. E. O. G. Scott for his experienced advice.

REFERENCES

- Alexander, R. M., (1965). Structure and function in the catfish. J. Zool. 148, 88-152.
- Alexander, R. M., (1967). The functions and mechanisms of the protrusible upper jaws of some acanthopterygian fish. J. Zool. 151, 43-64.
- Al-Hussaini, A. H., (1946). The anatomy and histology of the alimentary tract of the bottom-feeder, Mulloides auriflamma. J. Morphol. 78, 121-153.
- Al-Hussaini, A. H., (1949). On the functional morphology of the alimentary tract of some fishes in relation to differences in their feeding habits: anatomy and histology. Quart. J. Micro. Sci. 90, 109-139.
- Allis, E. P., (1897). The cranial muscles and cranial and first spinal nerves in Amia calva. J. Morphol. 12, 487-808.
- Allis, E. P., (1903). Skull and cranial muscles etc., in scomber. J. Morph. 18.
- Allis, E. P., (1904). The lateral sensory canals and related bones in fishes. Internat. Monatsschr. fur Anat. und Physiol. Bd. 21, 401-503.
- Allis, E. P., (1909). The cranial anatomy of the mail-cheeked fishes. Zoologica (Stuttgart) Bd. 22, Heft 57-219.

- Allis, E. P., (1925). On the morphology of certain bones of the cheek and snout of Amia calva. J. Morph. 14, 425-466.
- Babkin, B. P. and D. J. Bowie, (1928). The digestive system and its function in Fundulus heteroclitus. Biol. Bull. 54, 254-277.
- Bailey, R. J., (1936). The osteology and relationships of the phallostethid fishes. J. Morph. 59, 36.
- Barets, A., (1961). Contribution a l'etude des systemes moteurs 'lent' et 'rapide' du muscle lateral des teleosteens- Archives d'anatomie microscopique 50-1, 91-187.
- Barrington, E. J. W., (1937). The structure and development of the tail in the plaice (Pleuronectes platessa) and the cod (Gadus morhua). Quart. J. Micros. Sci. 79, 447-469.
- De Beer, G. R., (1937). The development of the vertebrate skull. Oxford Univ. Press.
- Berg, L. S., (1955). Classification of the fishes both recent and fossil. Trav. l'Inst. Zool. l'Acad. Sci. l'URSS. 5-2, 20.
- Berry, F. H., (1964). Aspects of the development of the upper jaw bones in teleosts. Copeia, 375-384.
- Blake, I. H., (1930). Studies on the comparative histology of the digestive tube of certain fishes. I. A predaceous fish, the sea-bass (Centropristes striatus). J. Morph. 50, 39-70.
- Bridge, T. W., (1877). The cranial osteology of Amia calva. J.

Anat. and Physiol. 11, 605-622.

Burnstock, G., (1959). The morphology of the gut of the brown trout (Salmo trutta). Quart. J. Micro. Sci. 100, 183-198.

Burnstock, G., (1959). The innervation of the gut of the brown trout (Salmo trutta). Quart. J. Micro. Sci. 100, 199-220.

Chapman, W. M., (1941). The osteology and relationships of the osmerid fishes. J. Morph. 89-2.

Chapman, W. M., (1942). The osteology and relationships of the Argentinidae. J. Washington, Acad. Sci. 32-4.

Chapman, W. M., (1944). The osteology of the deep-bodied anchovy, Anchoa compressa. J. Morph. 74, 311-329.

Chapman, W. M., (1948). The osteology and relationships of the round herring Etrumeus micropus TEMMINCK & SCHLEGEL. Proc. California Acad. Sci., Fourth Ser. 26-2.

Choat, J. H., (1964). Parrot fish. Aust. Nat. Hist. 15-8, 265-268.

Choat, J. H., (1965). Sexual dimorphism in the labrid fish Pseudolabrus celidotus (BLOCH & SCHNEIDER). Pacif. Sci. 19-4, 451-457.

Chu, Y. T., (1935). Comparative studies on the scales and on the pharyngeals and their teeth in chinese cyprinids with particular reference to taxonomy and evolution. Biol. Bull. St. John's Univ. 2.

- Cope, E. D., (1878). Contribution to the ichthyology of the maranon. Proc. Amer. Phil. Soc. 11, 559-570.
- Curry, E., (1939). The histology of the digestive tube of the carp (Cyprinus carpio). J. Morph. 65, 63-78.
- Cuvier, G. L. C. F. D. & A. Valenciennes, (1827). Histoire naturelle des poissons. Vol. 22, Paris XX+92+532, 1.
- Dawes, B., (1930). The histology of the alimentary tract of the plaice (Pleuronectes platessa). Quart. J. Micro. Sci. 73, 243-274.
- Denton, E. J. and J. A. C. Nicol, (1966). A survey of reflectivity in silvery teleosts. J. Mar. Biol. Asso. Uni. King. 46, 685-722.
- Dharmarajan M., (1936). The anatomy of otolithus ruber (B & S). J. & Proc. Asiat. Soc. Bengal. N. S. 21, 1-72.
- Dietz, P. A., (1912). Vergelijkende anatomie van de kaaken kieuwboogspieren der Teleostei - Doctoral dissertation. Leiden.
- Dietz, P. A., (1914). Beitrage zur kenntnis der kiefer-und kiemenbogenmuskulatur der Teleostier I Die kiefer-und kiemenbogenmuskeln der Acanthopterygii-Mitteilungen statzione zoologica Neapel. 22-4, 99-162.
- Eaton, T. H., (1935). Evolution of the upper jaw mechanism in teleost fishes. J. Morph. 58-1.
- Eaton, T. H., (1945). Skeletal supports of the median fins of fishes. J. Morph. 76, 193-212.

Edgeworth, F. H., (1935). The cranial muscles of the vertebrates.
Cambridge Univ. Press.

Favaro, G., (1902). Cenni anatomo-embryologici intorno al
musculus retractor arcuum branchialium dorsalis nei
Teleostei-Monitore. Zoologico Italiano 13, 119-124.

Field, J. G., (1966). Contributions to the functional morpho-
logy of fishes. Pt. II. The feeding mechanism of the
angler fish. *Lophius piscatorius* Linn-Zoologica Africana
2-1, 45-67.

Gegenbaur, C., (1878). Ueber das kopfskelet von Alepocephalus
rostratus. Morph. Jahrb. Bd. 4. suppl.

Girgis, S., (1952). On the anatomy and histology of the alimen-
tary tract of an-herbivorous bottom-feeding cyprinoid fish.
Labo horie (CUVIER). J. Morph. 90, 317-362.

Goodrich, E. S., (1930). Studies on the structure and develop-
ment of vertebrates. London.

Gosline, W. A., (1955). The osteology and relationships of
certain gobioid fishes with particular reference to the
genera Kraemeria and Microdesmus. Pacific Sci. 9.

Gosline, W. A., (1961). Some osteological features of modern
lower teleostean fishes. Smithsonian Miscel. Coll. 142-3.

Greene, C. W. and C. H. Greene, (1914). The skeletal muscula-
ture of the king salmon. Bull. U.S. Bur. Fish.. 33, 21-60.

- Greenwood, P. H., (1968). The osteology and relationships of the Denticipitidae, a family of clupeomorph fishes. Bull. Brit. Museum (Nat. Hist.) Zool. 16-6, 215-273.
- Gregory, W. K., (1933). Fish skulls: A study of the evolution of natural mechanism. Trans. Amer. Philos. Soc. 23, 2.
- Grenholm, A., (1923). Studien uber die Flossenmuskulatur der Teleostier. Doctoral Dissertation Univ. Uppsala.
- Haines, R. W., (1937). The posterior end of Meckel's cartilage and related ossifications in bony fishes. Quart. J. Micr. Sci. N. S. 80, 1-38.
- Harrington, R. W., (1955). The osteocranium of the American cyprinid fish, Notropis bifrenatus, with an annotated synonymy of teleost skull bones. Copeia. 267-290.
- Hollister, G., (1936). Caudal skeleton of Bermuda shallow water fishes, I. Order Isospondyli, Elopidae, Megalopidae, Albulidae, Clupeidae, Dussumieriidae, Engraulidae. Zool. New York 21, 257-290.
- Hollister, G., (1937). Caudal skeleton of Bermuda shallow water fishes, III. Order Iniomi, Synodontidae. Zool. New York 22, 385-399.
- Holstvoogd, C., (1965). The pharyngeal bones and muscles in Teleostei, a taxonomic study. Proc. Koninklijke Nederlandse Akademie Van Wetenskap. Ser. C. 68-3, 209-218.
- Hubbs, C. L., (1919). A comparative study of the bones forming the opercular series of fishes. J. Morph. 33, 61-71.

- Hubbs, C. L., (1944). Fin structure and relationships of the phallostethid fishes. *Copeia* 2.
- Ishida, M. and M. Sato, (1960). The anatomical and histological observations of the alimentary tract of a catfish, Parasilurus asotus (L). *Sci. Rep. Hiroasaki Univ.* 7, 57-63.
- Iwai, T., (1962). Studies on the Plecoglossus altivelis problems: embriology and histophysiology of digestive and osmoregulatory organs. *Bull. Misaki Mar. Biol. Inst. Kyoto Univ.* 2.
- Johnston, R. M., (1883). General and critical observations on the fishes of Tasmania. with a classified catalogue of all the known species. Hobart.
- Jordan, D. S., (1923). Classification of fishes including families and genera as far as known. *Stanford Univ. Publ. Univ. Ser. Biol. Sci.* 3, 2.
- Juge, M., (1898). Recherches sur les nerfs cerebraux et la musculature cephalique de Silurus glanis. *Revue Suisse de Zool.* 6, 1-171.
- Kapoor, B. G., (1957). The callous pad of the pharyngeal masticatory apparatus in Indian carps. *Jap. J. Ichthyol.* 6, 26-30.
- Kapoor, B. G., (1957). The digestive tube of an omnivorous cyprinoid fish, Barbus stigma (Cuv. & Val.) *Jap. J. Ichthyol.* 6, 48-53.

Kapoor, B. G., (1957). A study on the tongue of fishes. Jap. J. Ichthyol. 6, 82-86.

Kesteven, H. L., (1943). The evolution of the skull and the cephalic muscles. Aust. Mus. Syd. Memo. VIII.

Kholy, A. A., (1953). On the functional morphology of the alimentary tract of some omnivorous teleost fish. Proc. Egypt. Acad. Sci. 6-9, 17-39.

Kingsley, J. S., (1926). Outlines of comparative anatomy of vertebrates. Blakiston Company (McGraw-Hill Book Company, New York).

Kobayashi, H., (1953). Effects of estrone upon the structure, weight and fat content of the liver in the fish, Misgurnus anguillicaudatus. Annot. Zool. Jap. 26, 213-216.

LaMonte, F. R., (1958). On the biology of the Atlantic marlins, Makaira ampla (POEY) and Makaira albida (POEY). Notes on the alimentary, excretory and reproductive organs of Atlantic Makaira. Bull. Amer. Mus. Nat. Hist. 114, 5.

Lekander, B., (1949). The sensory line system and the canal bones in the head of some ostariophysii. Acta Zool. (Stockholm) 30.

Lien, K. F., (1963). The comparative osteology and phylogeny of the Anabantoides (Teleostei, Pisces). Illinois Biol. Monogr. 149.

Marathe, V. B., (1955). The nervous system of Pseudorhombus arsinus (H & B). J. Univ. Bombay. N. S. 23B3. 60-73.

Marshall, N. B., (1971). Explorations in the life of fishes.
Harvard Univ. Press. Cambridge Mass.

Matsubara, K. & T. Iwai, (1958). Anatomy and relationships of
the Japanese fishes of the family Gempylidae. Mem. Coll.
Agri. Kyoto Univ. Fish. Ser. Spec. Number.

McAllister, D. E., (1968). The evolution of branchiostegals
and associated opercular, gular and hyoid bones and the
classification of teleostome fishes, living and fossil.
Bull. Nat. Mus. Cana. 221.

McCoy, F., (1885). Prodromus of the zoology of Victoria or
figures and descriptions of the living species of all
classes of the Victorian indigenous animals. Nat. Hist.
Vic. Melbourne.

McCulloch, A. R., (1929-30). A check-list of the fishes recorded
from Australia. Aust. Mus. Mem. V. 5. Sydney.

McMurrich, J. P., (1884). The osteology of Ameiurus catus (L)
Gill. Proc. Cana. Inst. (Toronto) n.s. 2, 270-310.

McMurrich, J. P., (1884). The myology of Ameiurus catus (L)
Gill. Proc. Cana. Inst. (Toronto) n.s. 2, 311-351.

McVay, J. A. and H. W. Kann, (1940). The digestive tract of
Carassius auratus. Biol. Bull. 78, 53-67.

Millard, N. A. H., (1966). Contributions to the functional
morphology of fishes. Pt. I. Introduction Zool. Africana
2, 37-43.

Mujib, K. A., (1967). The cranial osteology of the Gadidae. J. Fish. Res. Bd. Cana. 24-6, 1315-1375.

Munro, I. S. R., (1958). Handbook of Australian fishes. Canb. Dept. Prim. Indu.

Nag, A. C., (1967). Functional morphology of the caudal region of certain clupeiform and perciform fishes with reference to the taxonomy. J. Morph. 124-4, 423-443.

Nelson, G. J., (1954). Gill arches and the phylogeny of fishes, with notes on the classification of vertebrates. Bull. Amer. Mus. Nat. Hist. 141, 4, 475-552.

Nelson, G. J., (1967). Branchial muscles in some generalized teleostean fishes. Acta Zool. 48, 277-288.

Norden, C. R., (1961). Comparative osteology of representative salmonid fishes, with particular reference to the grayling (Thymallus arcticus) and its phylogeny. J. Fish. Res. Bd. Canada 18, 5.

Nursall, J. R., (1956). The lateral musculature and the swimming of fish. Proc. Zool. Soc. London 126-1, 127-143.

Nursall, J. R., (1963). The caudal musculature of Hoplobagrus guntheri GILL (Perciformes, Lutjanidae). Cana. J. Zool. 41, 865-880.

Owen, R., (1866). On the anatomy of vertebrates. Vol. I fishes and reptiles. Longmans Green and Co. London.

- Park, W. K., (1873). On the structure and development of the skull of the salmon. Phil. Trans. Roy. Soci. London.
- Parker, T. J., (1886). Studies in New-Zealand ichthyology I, On the skeleton of Regalecus argenteus. Trans. Zool. Soc. London 12-1.
- Phillips, J. B., (1942). Osteology of the sardine (Sardinops caerulea). J. Morph. 70-3.
- Quignard, J. P., (1962). Squellette et musculature branchiale des Labrides. Naturalia Monspeliensia (Zool.) 4, 125-147.
- Regan, C. T., (1907). On the anatomy, classification and systematic position of the teleostean fishes of the sub-order Allostriognathi. Proc. Zool. Soc. London 634-643.
- Regan, C. T., (1910). The anatomy and classification of the teleostean fishes of order Zeomorphi. Ann. Mag. Nat. Hist. 8-6.
- Regan, C. T., (1911). The anatomy and classification of the teleostean fishes of the order Iniomi. Ann. Mag. Nat. Hist. 8-7.
- Regan, C. T., (1911). The anatomy and classification of the teleostean fishes of the order Salmopercae. Ann. Mag. Nat. Hist. 8-8.
- Regan, C. T., (1912). The osteology of the teleostean fishes of the order Opisthomi. Ann. Mag. Nat. Hist. 8-9.

Regan, C. T., (1929). Fishes in Encyclopaedia Britannica. 14th ed. Vol. IX 305-328.

Ridewood, W. G., (1904). On the cranial osteology of the fishes of families Mormyridae, Notopteridae and Hyodontidae. J. Linn. Soc. London (Zool.) 29.

Ridewood, W. G., (1909). On the cranial osteology of the fishes of the family Elopidae and Albulidae, with remarks on the morphology of the skull in the lower teleostean fishes generally. Proc. Zool. Soc. London 2, 35-81.

Rogick, M. D., (1931). Studies on the comparative histology of the digestive tube of certain teleost fishes 2. A minnow (Campostoma anomalum). J. Morph. 52, 1-25.

Romer, A. E., (1959). The vertebrate story. Univ. Chicago Press. Chicago. Illinois.

Rosen, D. E. & J. R. Mendelson, (1960). The sensory canal of the head in poeciliid fishes (Cyprinodontiformes) with reference to dentitional type. Copeia 3.

Sarbahi, D. S., (1951). Studies of the digestive tracts and digestive enzymes of the goldfish, Carassius auratus and the large mouth black bass, Micropterus salmoides. Biol. Bull. 100, 244-257.

Schultz, L. P., (1969). The taxonomic status of the controversial genera and species of parrotfishes with a descriptive list (Family Scaridae). Smiths. Cont. Zool. 17 Washington.

- Scott, T. D., (1962). The marine and fresh water fishes of South Australia. Adelaide Govt. Print.
- Starks, E. C., (1899). The osteological characters of the fishes of the suborder Percosoces. Proc. U.S. Nat. Mus. 22, 1179.
- Starks, E. C., (1904). The osteology of some berycoid fishes. Proc. U.S. Nat. Mus. 27-1366.
- Starks, E. C., (1905). The osteology of Caularchus macandricus (GIRARD). Biol. Bull. Mar. Biol. Lab. Woods Hole 9, 292-303.
- Starks, E. C., (1916). The sesamoid articular, a bone in the mandible of fishes. Leland Stanford Jun. Univ. Pub. Univ. Ser.
- Starks, E. C., (1926). Bones of the ethmoid region of the fish skull. Stanford Univ. Publ. Univ. Ser. Biol. Sci. 4-3.
- Starks, E. C., (1930). The primary shoulder girdle of the bony fishes. Stanford Univ. Publ. Univ. Ser. Biol. Sci. 6-2.
- Suehiro, Y., (1942). A study on the digestive system and feeding habits of fish. Jap. J. Zool. 10-1.
- Suehiro, M., (1942). A study on the digestive system and feeding habits of fish. Jap. J. Zool. 10, 1-303.
- Swinerton, H. H., (1902). A contribution to the morphology of

the teleostean head skeleton, based upon a study of the developing skull of the three-spined stickleback (Gasterosteus aculeatus). Quart. J. Micr. Sci. n.s. 180-45, 503-597.

Takahasi, N., (1917). On the homology of the median longitudinal muscles - superacarinialis and infracarinialis - with the fin muscles of the dorsal and anal fins and their functions. Tokyo J. Coll. Agricul. 6-3, 199-213.

Takahasi, N., (1925). On the homology of the cranial muscles of the cypriniform fishes. J. Morph. 40-1, 1-103.

Tominaga, S., (1965-67). Anatomical sketches of 500 fishes. 3 Vols. (5 Books) Kadokawa shoten, Tokyo.

Vetter, B., (1878). Untersuchungen Zur Vergleichenden Anatomie der Kiemen und Kierfermuskulatur der Fische. Theil II. Jen. Zeitschr F. Naturw Bd. XII, Heft 3, Aug. I.

Vickers, T., (1962). A study of the intestinal epithelium of goldfish, Carassius auratus: Its normal structure, the dynamics of cell replacement and the changes induced by salts of cobalt and mangane. Quart. J. Micro. Sci. 103, 93-110.

Weinreb, E. L. and N. M. Bilstad, (1955). Histology of the digestive tract and adjacent structure of the rainbow trout, Salmo gairdneri irideus. Copeia 3, 194-204.

Weitzman, S. H., (1955). The osteology and relationships of the South American characid fishes of the Subfamily

- Gasteropelecinae. Stanford Ichth. Bull. 4, 212-263.
- Weitzman, S. H., (1962). The osteology of Brycon meeki, a generalized characid fish, with an osteological definition of the family. Stanford Ichth. Bull. 8-1.
- Westoll, T. S., (1944). The Haplolepidae, a new family of late carboniferous bony fishes. A study in taxonomy and evolution. Bull. Amer. Mus. Nat. Hist. 83, 1-121.
- Whitley, G. P., (1964). A check-list of the fishes recorded from the New Zealand region. Proc. Linn. Soc. N.S.W. LXXXIX.
- Wiedersheim, R., (1907). Lehrbuch der Vergleichende Anatomie der Wirbeltiere. Zweiter Auflage Jena XIV+890.
- Winterbottom, R., (1974). The familial phylogeny of the Tetraodontiformes (Acanthopterygii pisces) as evidenced by their comparative myology. Smiths. Cont. Zool. 155, 201p.
- Yamamoto, T., (1964). Some observations on the fine structure of the liver cells in the starved goldfish (Carassius auratus), with special reference to the morphology of fat mobilization during starvation to the liver. Arch. Hist. Jap. 24, 335-345.
- Yarberry, E. L., (1965). Osteology of the zoarcid fish, Melanostigma pammelas. Copeia, 442-462.

CONTENTS

1.	INTRODUCTION	1
2.	PART I SKELETAL SYSTEM	6
3.	PART II MUSCULAR SYSTEM	53
4.	PART III DIGESTIVE SYSTEM	66



PLATE 1. Pseudolabrus tetricus (RICHARDSON). Adult



PLATE 2. Pseudolabrus tetricus (RICHARDSON). Juvenile



PLATE 3. Pseudolabrus fucicola (RICHARDSON).



PLATE 4. Hybrid of *P. tetricus* & *P. fucicola*

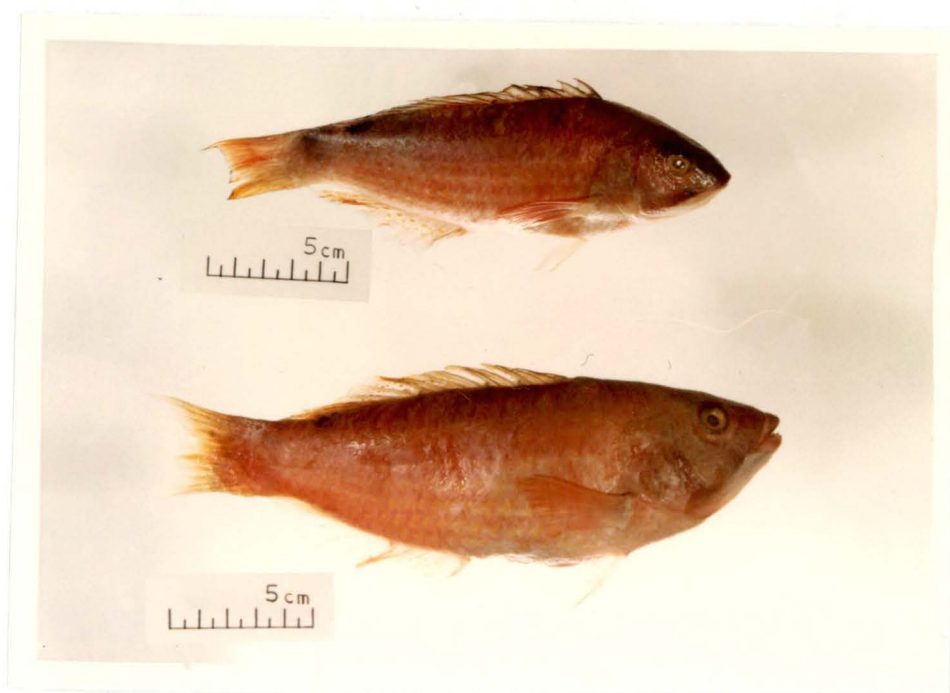


PLATE 5. Pseudolabrus mile (BLOCH & SCHNEIDER)

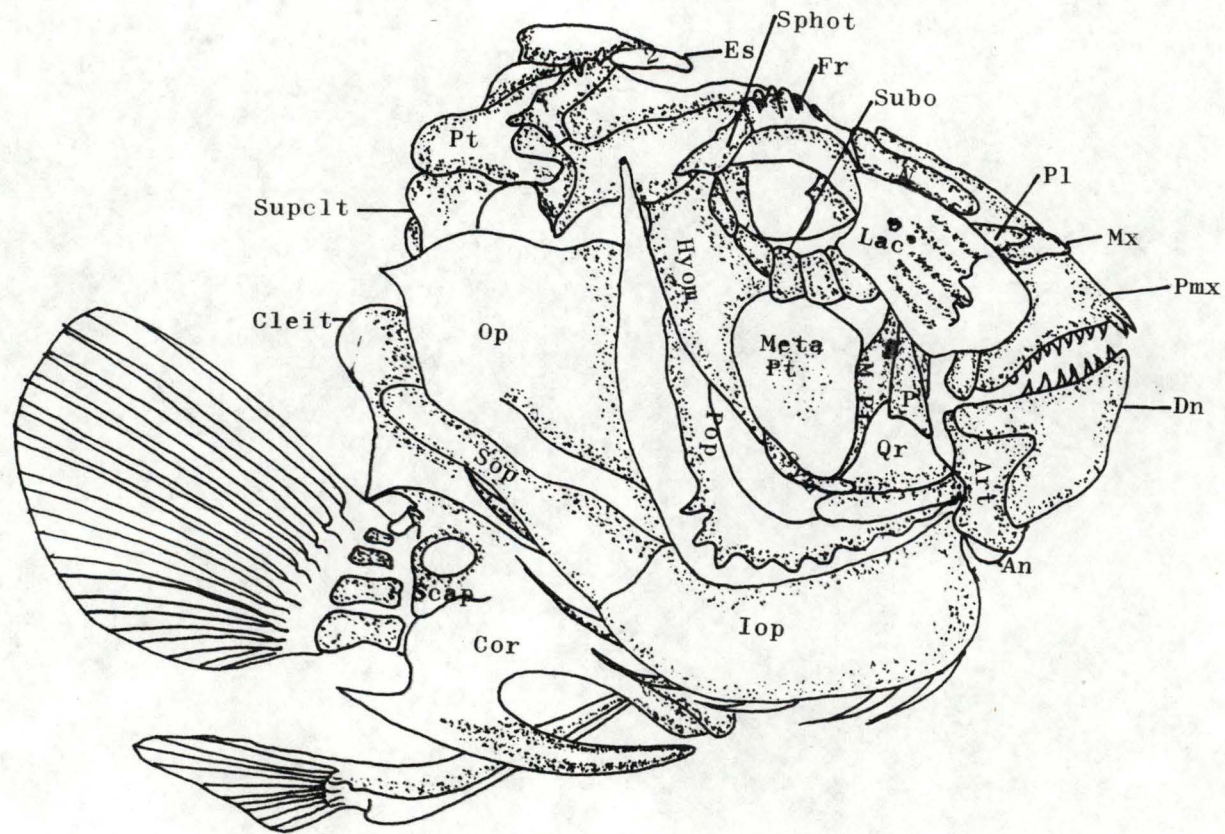


Fig 6. Bones of the head region of *P. tetricus* (R)

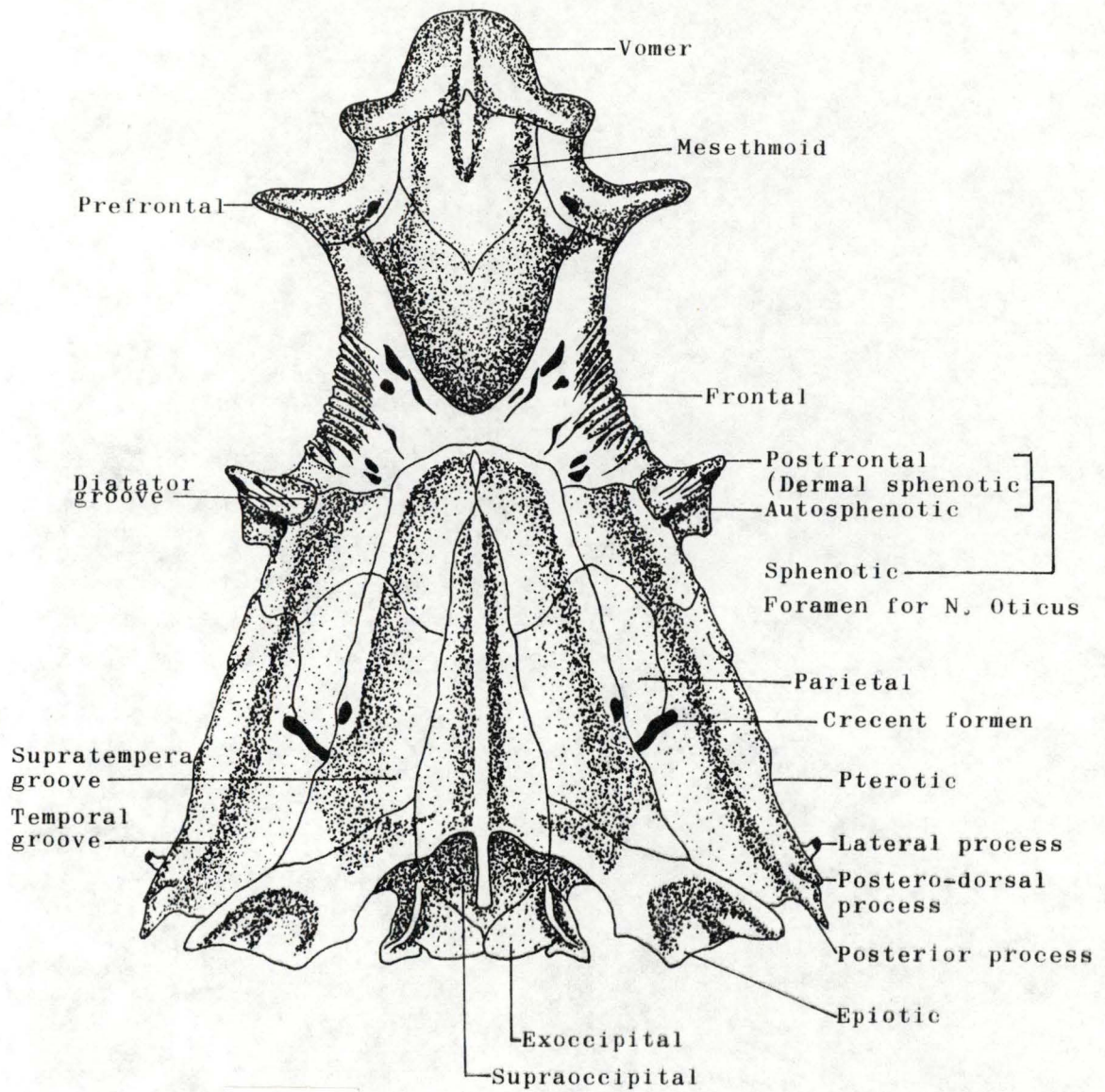


Fig. 7. Skull (Dorsal view) *

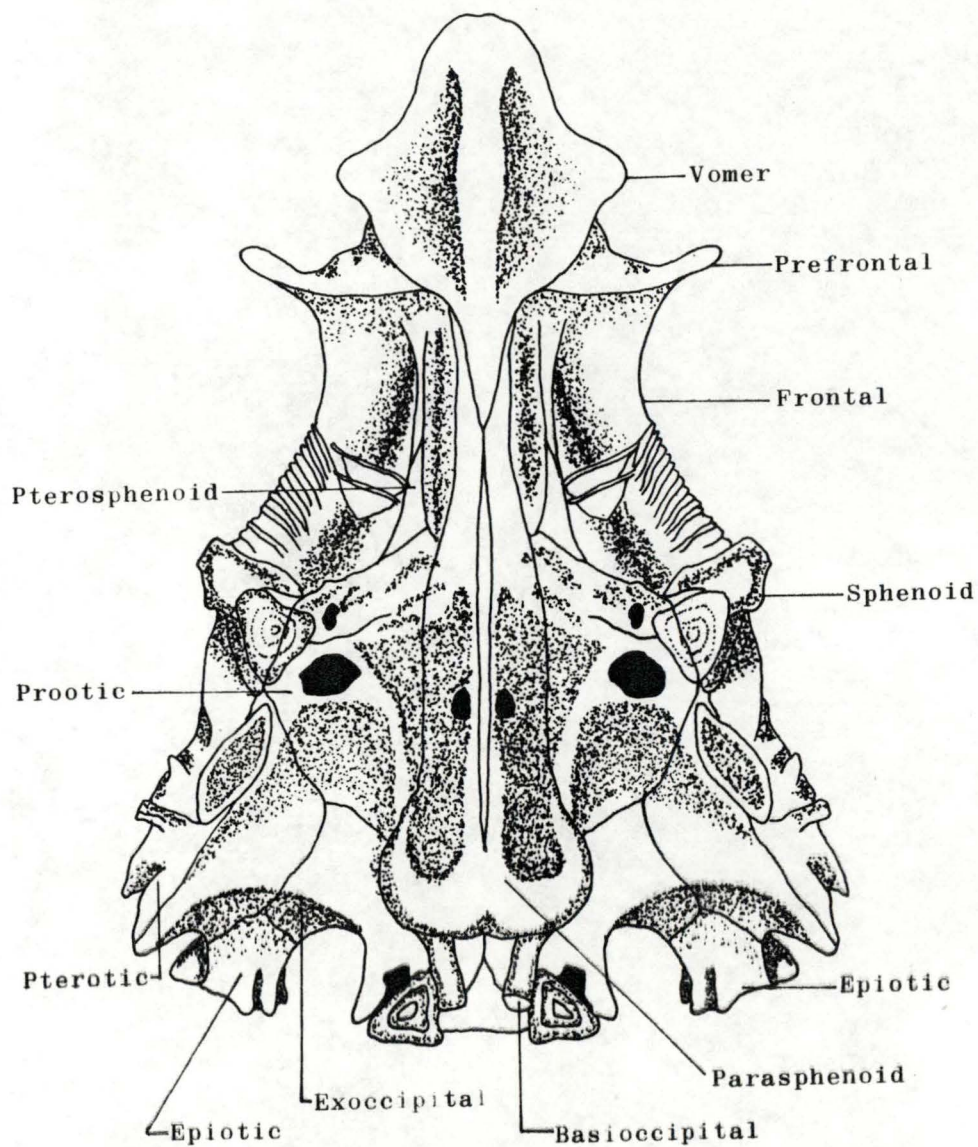


Fig. 8. Skull (Ventral view)

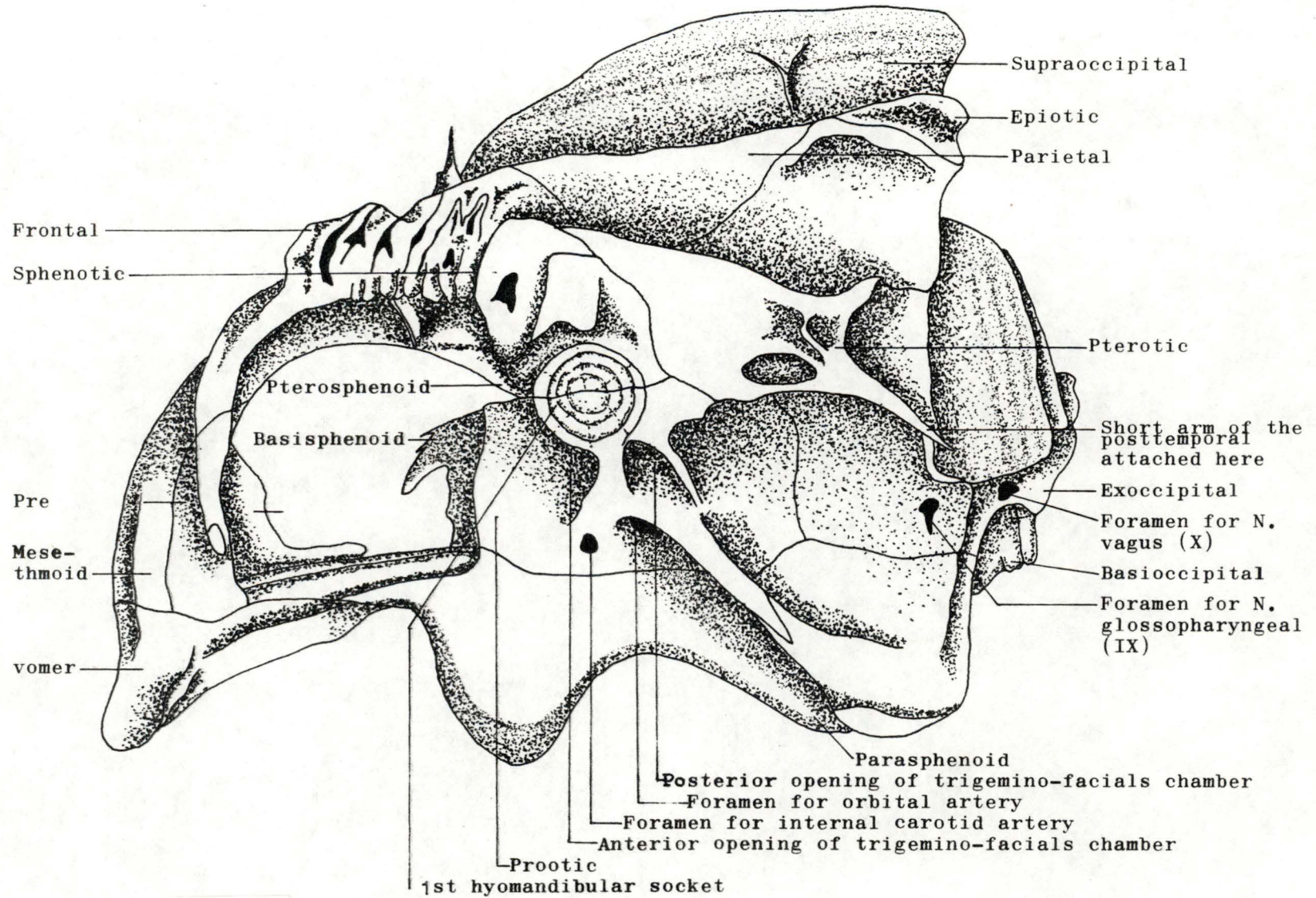


Fig. 9.

Skull (Lateral view)

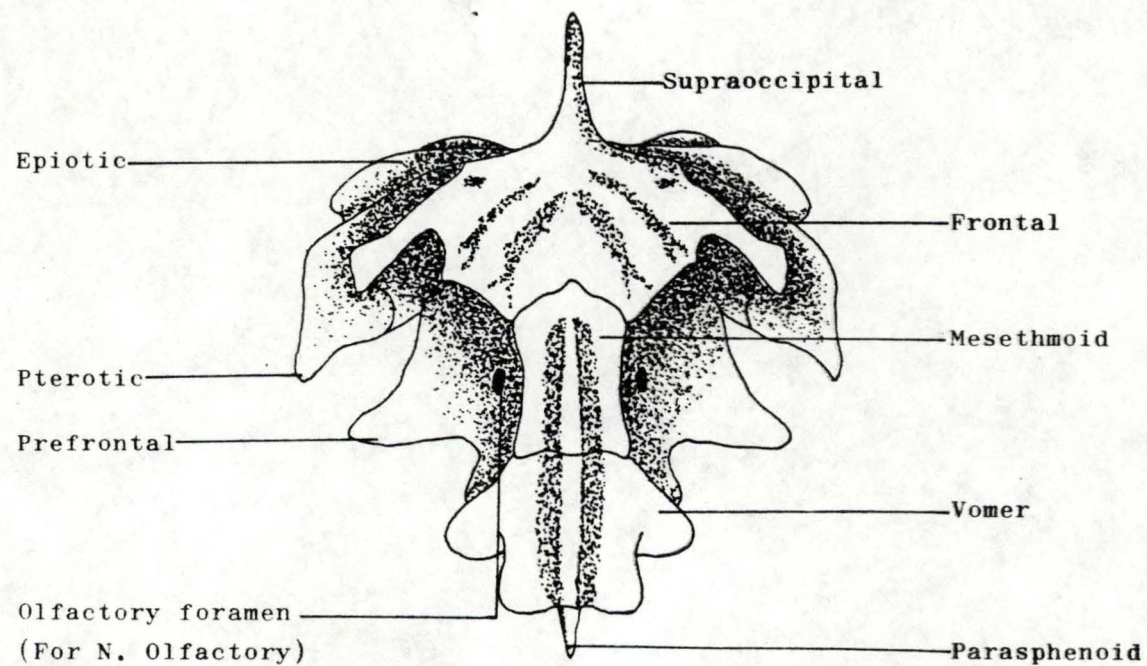


Fig. 10. Anterior view of the skull

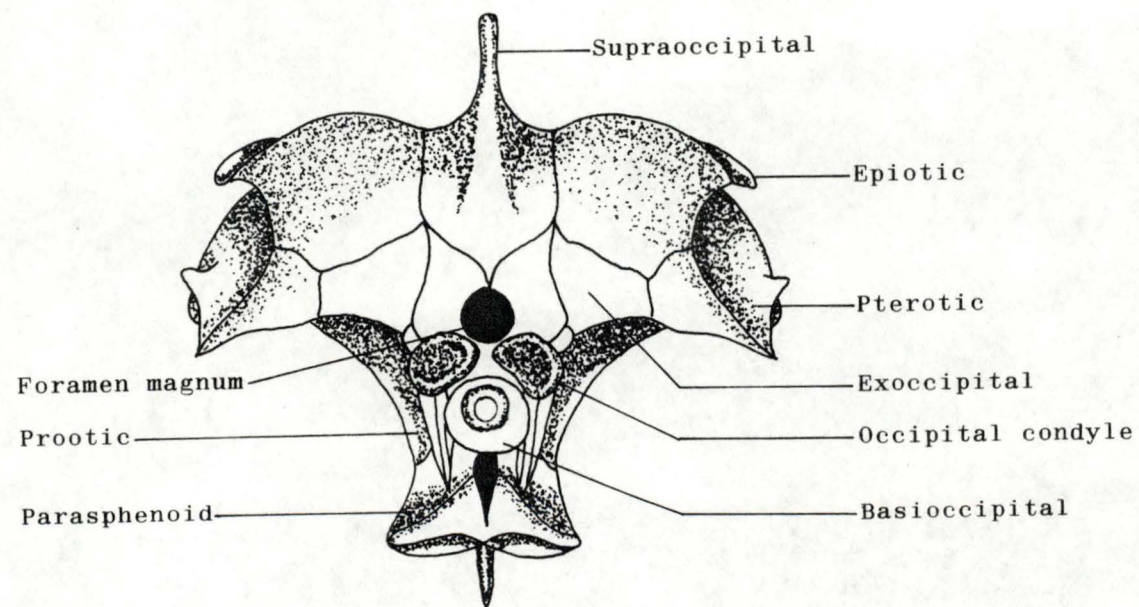


Fig. 11. Posterior view of the skull

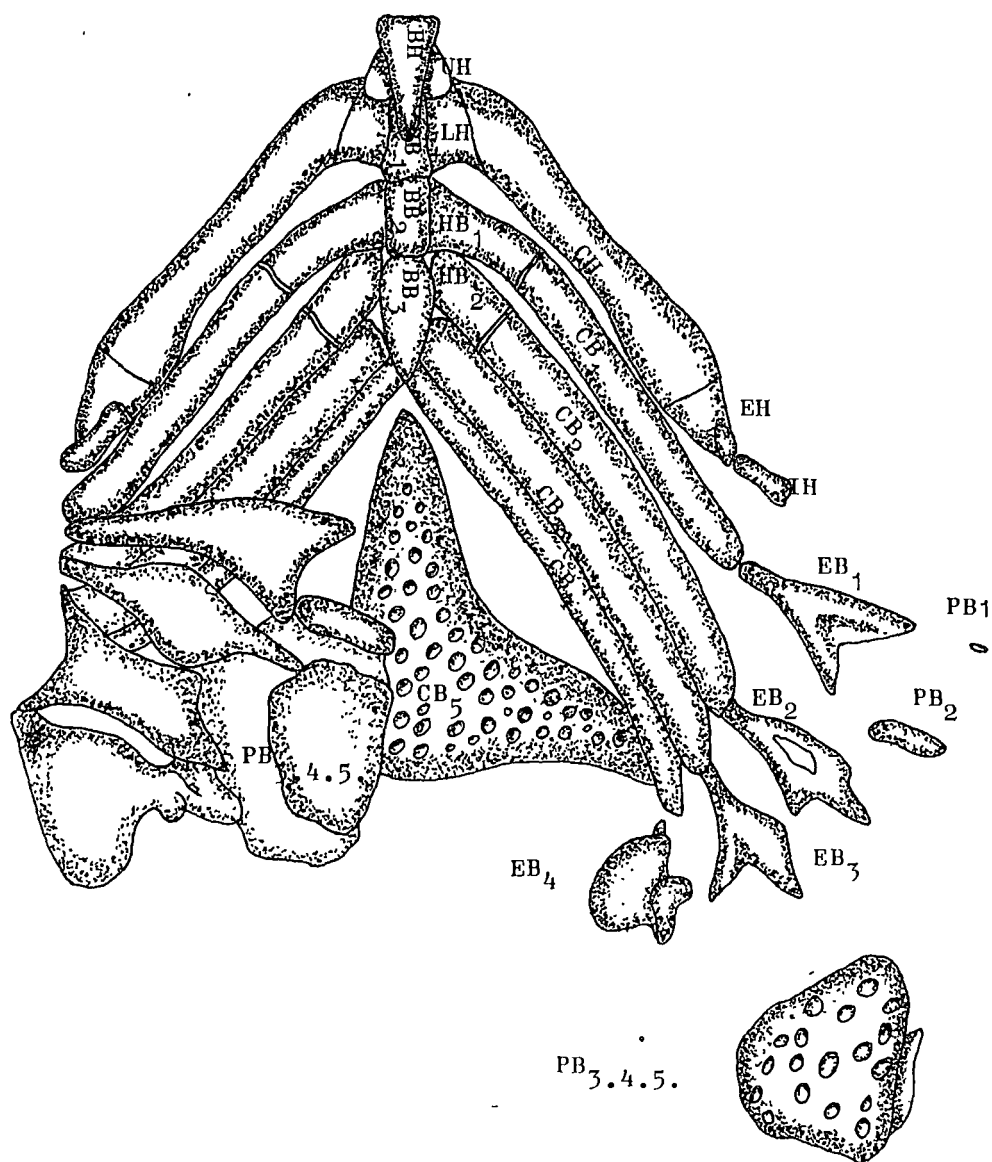


Fig. 12. Visceral arches (Dorsal view)

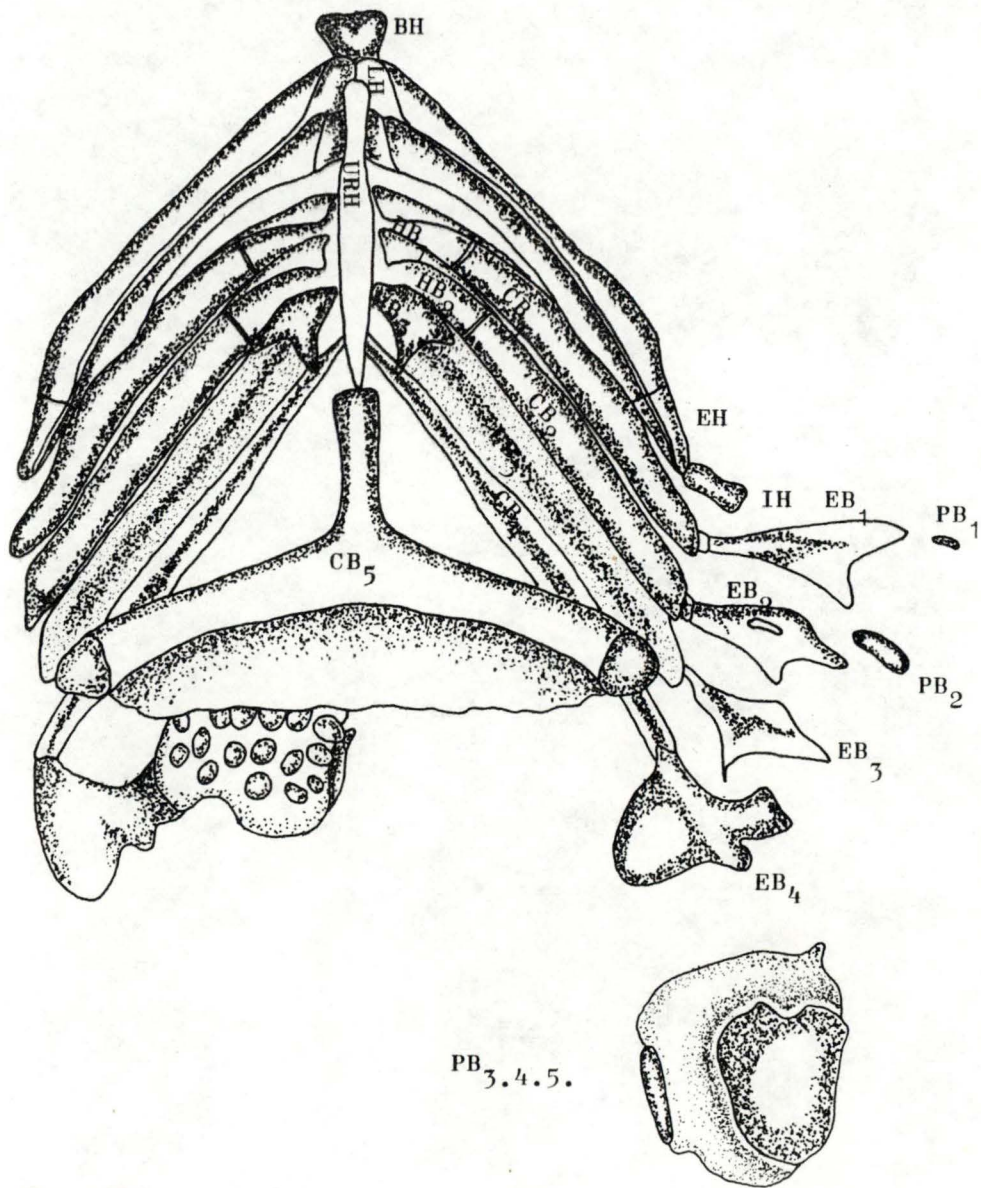


Fig. 13. Visceral arches (Ventral view)

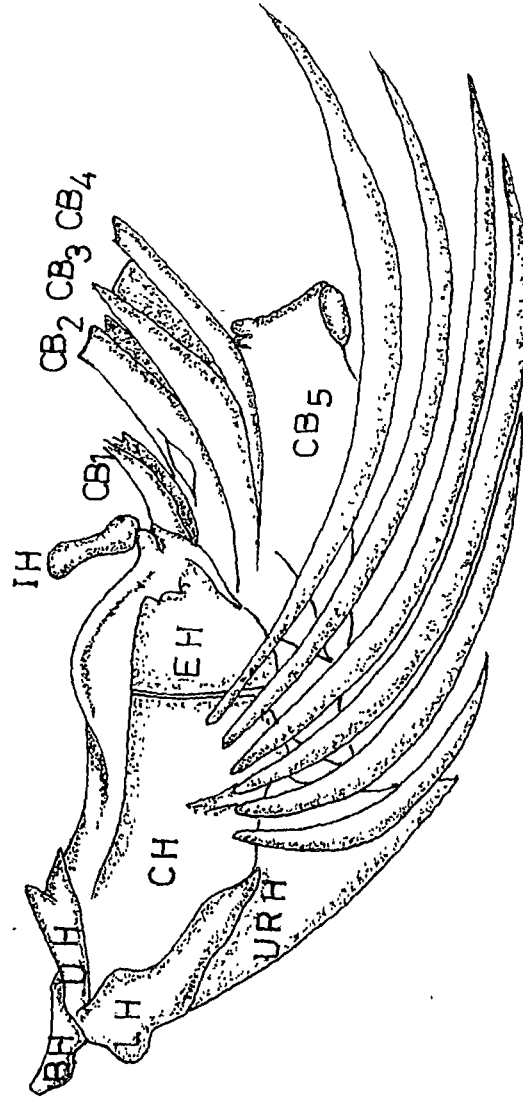


Fig. 14. Side view of visceral arches

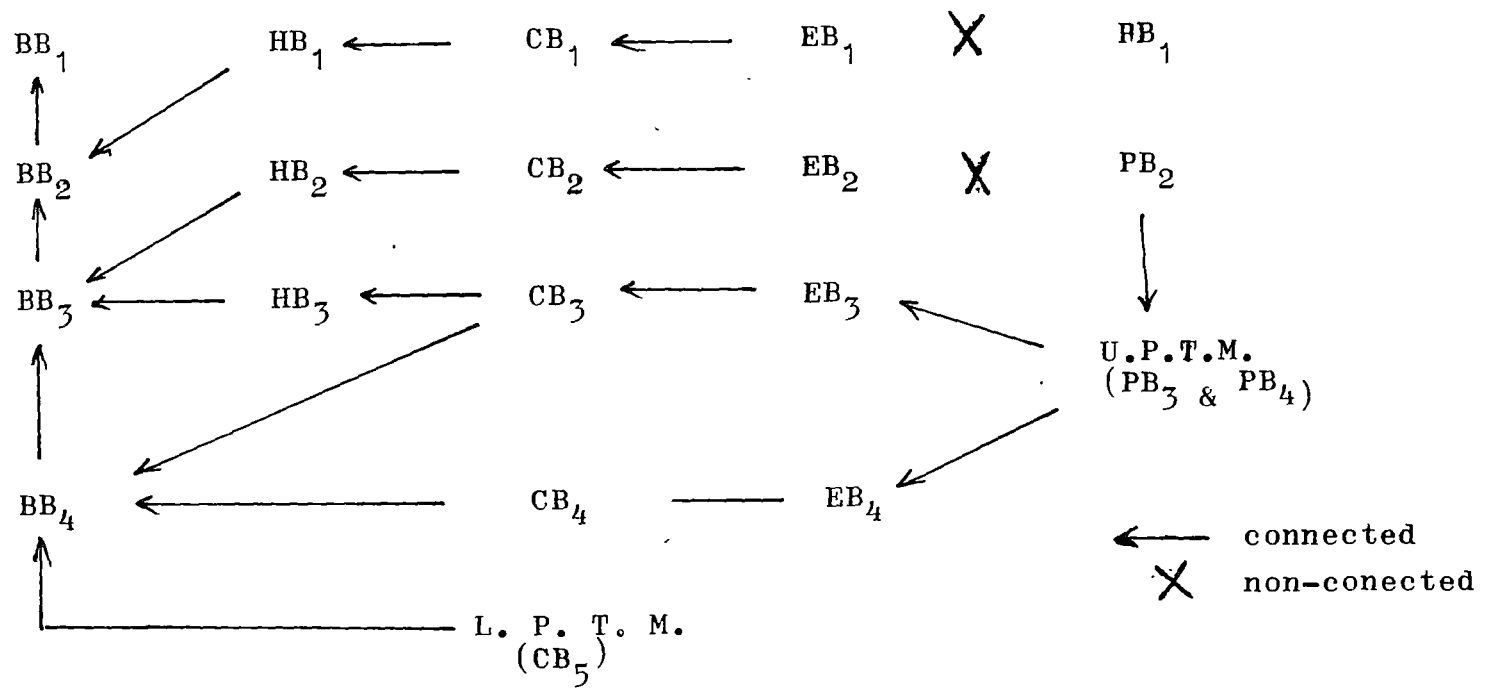


Fig. 15. The connection of the elements of the branchial arches

	Basibranchial	Hypobranchial	C
1	Square bar between HH, extended antero-ventrally to BH	Short, enlarged on both ends conjoined to next basibranchial through cartilage	Uncom and e with vent
2	Rectangular, a notch on each side fitted HB ₁	same as above	
3	Rhomboid	Extended vertically on the ventral surface of the branchial arches on the conjunction of BB ₃ and CB ₃	
4	Vestigial Cartilage	None	Com bon nar
5	There is a tendency, the BB ₄ and BB ₅ Become ruminated	None	One toget larg teat

The elements

Metobranchial	Epibranchial	Pharyngobranchial
Complete ossification, elongated thin bone with groove on surface	Thin bone bifurcated, attached to the dorsal surface of upper pharyngeal teeth mill	Vestigial bone
Same as above	Same as above	Thin bone attached to anterior surface of upper pharyngeal teeth mill
Same as above	Same as above	United with PB ₄ and formed upper pharyngeal teeth mill
Complete ossification, ventral groove	Strong, wing shaped bone articulated with upper pharyngeal teeth mill	United with PB ₃ and formed upper pharyngeal teeth mill
Each side fused, to form a lower pharyngeal mill	None	None

of the branchial arches

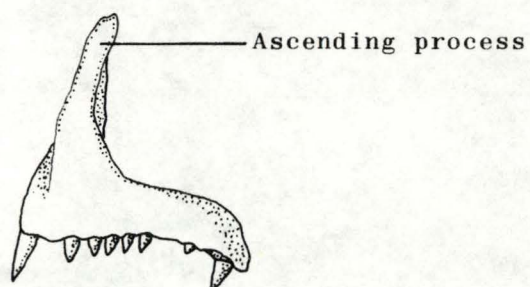


Fig. 16. Premaxillary (External surface)

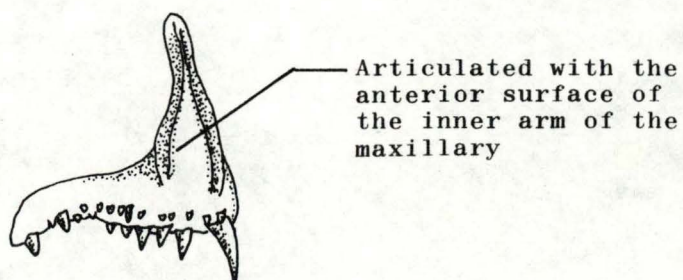


Fig. 17. Premaxillary (Internal surface)

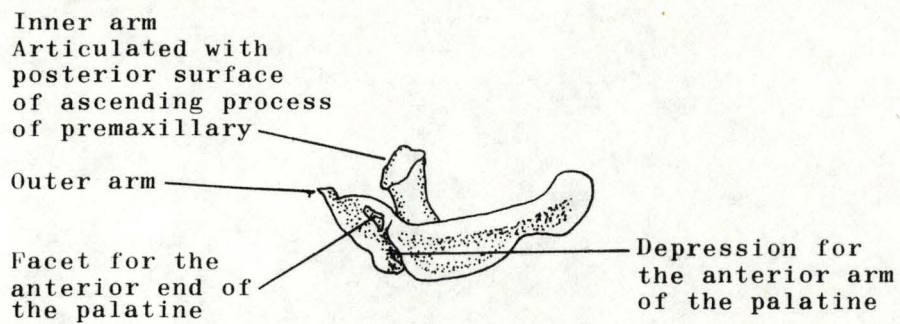


Fig. 18. Maxillary (External surface)

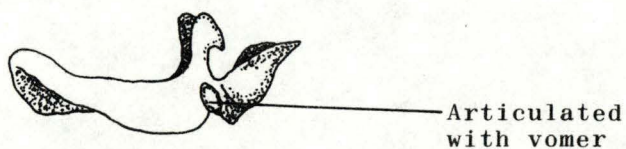
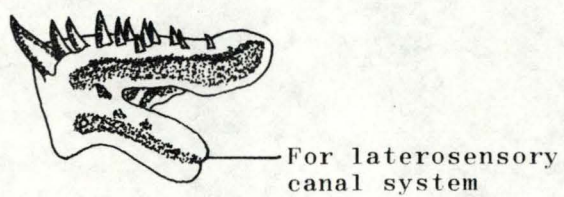
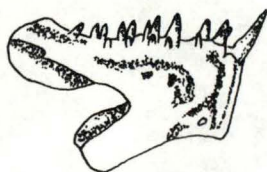


Fig. 19. Maxillary (Internal surface)



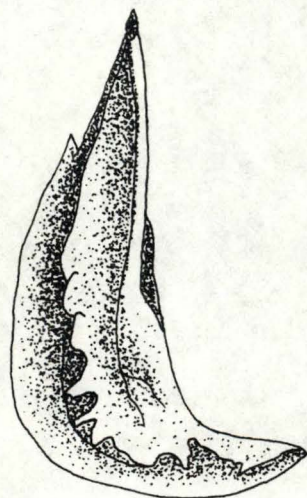
Dentary (External surface)

Fig. 20.



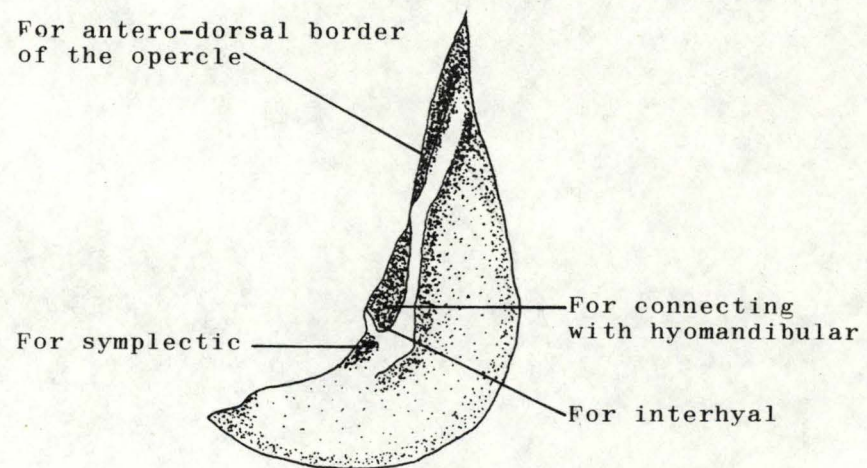
Dentary (Internal surface)

Fig. 21.



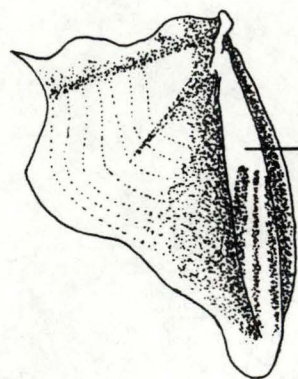
Preopercle (External surface)

Fig. 22.



Preopercle (Inner surface)

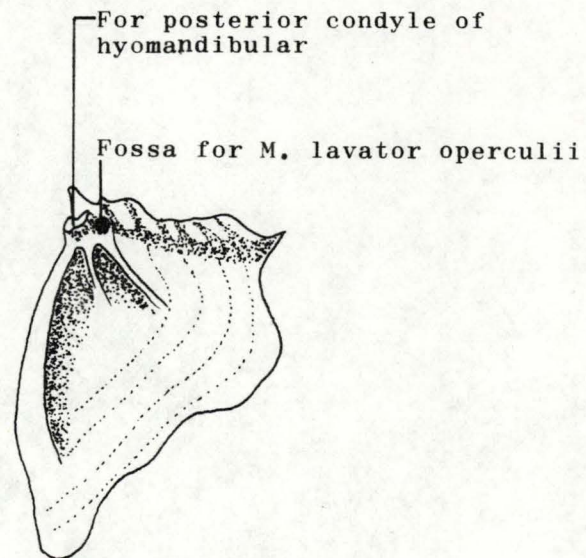
Fig. 23.



Anterior thickened
margin overlaped
by preopercle

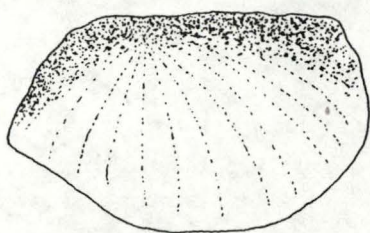
Opercle (Exernal surface)

Fig. 24.



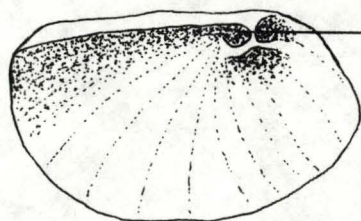
Opercle (Internal surface)

Fig. 25.



Interopercle (External surface)

Fig. 26.



Articulation conjoined
to the dorso-posterior
condyle of the hyomandibular

Interopercle (Internal surface)

Fig. 27.

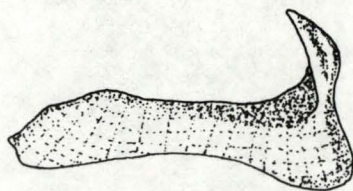


Fig. 28.

Subopercle (External surface)

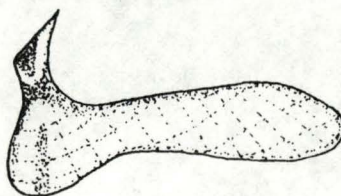


Fig. 29.

Subopercle (Internal surface)

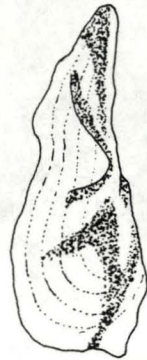


Fig. 30.

First Postcleithrum (External surface)

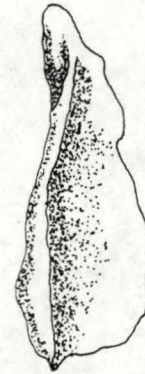


Fig. 31.

First Postcleithrum (Internal surface)



Fig. 32.

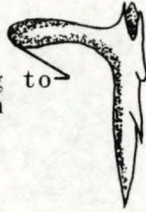
Second Postcleithrum(External surface)



Fig. 33.

Second Postcleithrum(Internal surface)

Facet articulating to
the groove between
the maxillary and
its inner arm



Palatine (External surface)

Fig. 34.



Palatine (Internal surface)

Fig. 35.



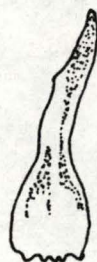
Pterygoid (External surface)

Fig. 36.



Pterygoid (Internal surface)

Fig. 37.



Mesopterygoid(External surface)

Fig. 38.



Mesopterygoid (Internal surface)

Fig. 39.



Metapterygoid (External surface)

Fig. 40.



Metapterygoid (Internal surface)

Fig. 41.



Fig. 42. Quadrate (External surface)

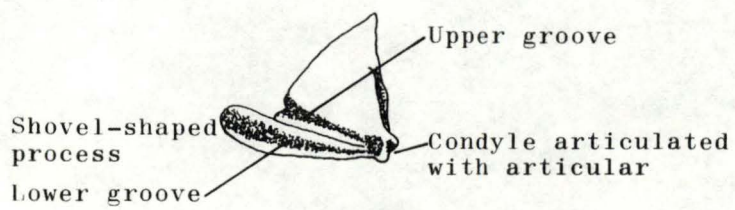


Fig. 43. Quadrate (Internal surface)

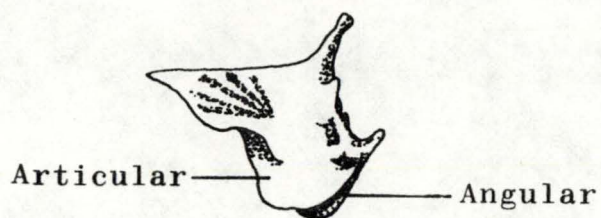


Fig. 44. External surface

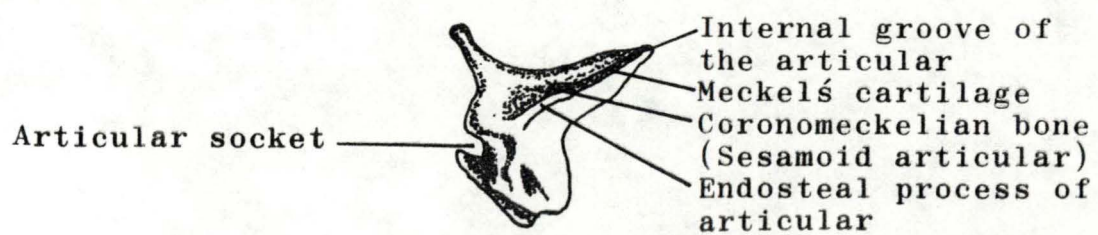


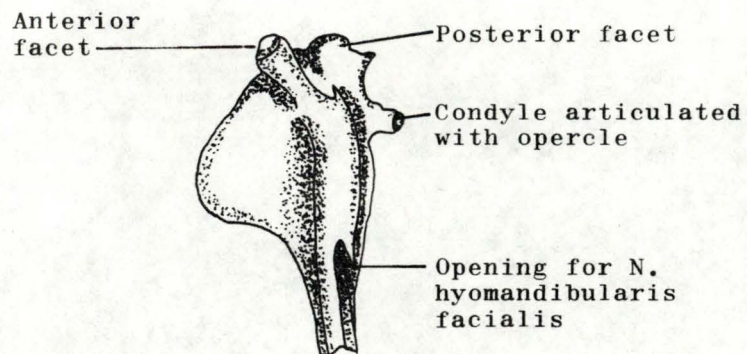
Fig. 45. Internal surface



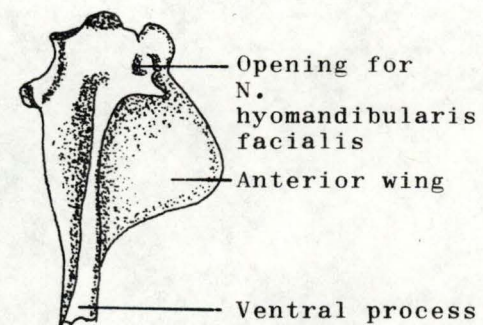
Fig. 46. Symplectic (External surface)



Fig. 47. Symplectic (Internal surface)



External surface



Internal surface

Fig. 48. Hyomandibular (Temporal)

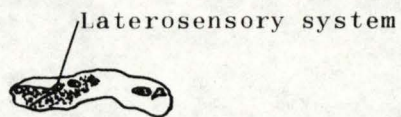


Fig. 49. Nasal (External surface)

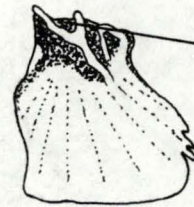


Fig. 50. Nasal (Internal surface)



Fig. 51.

Lachrymal (External surface)



Articulated with
the lateral process
of the prefrontal

Fig. 52.

Lachrymal (Internal surface)

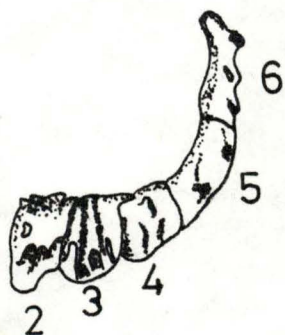


Fig. 53.

Suborbital (External surface)



Fig. 54.

Suborbital (Internal surface)

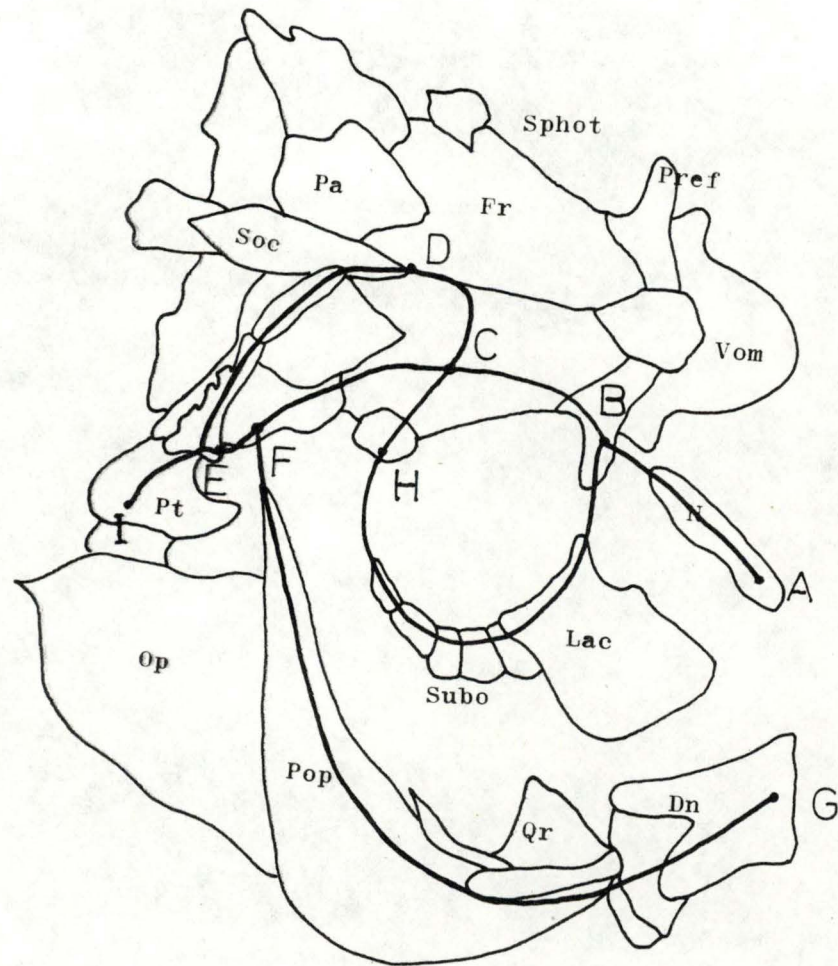


Fig. 55. Laterosensory Canal System

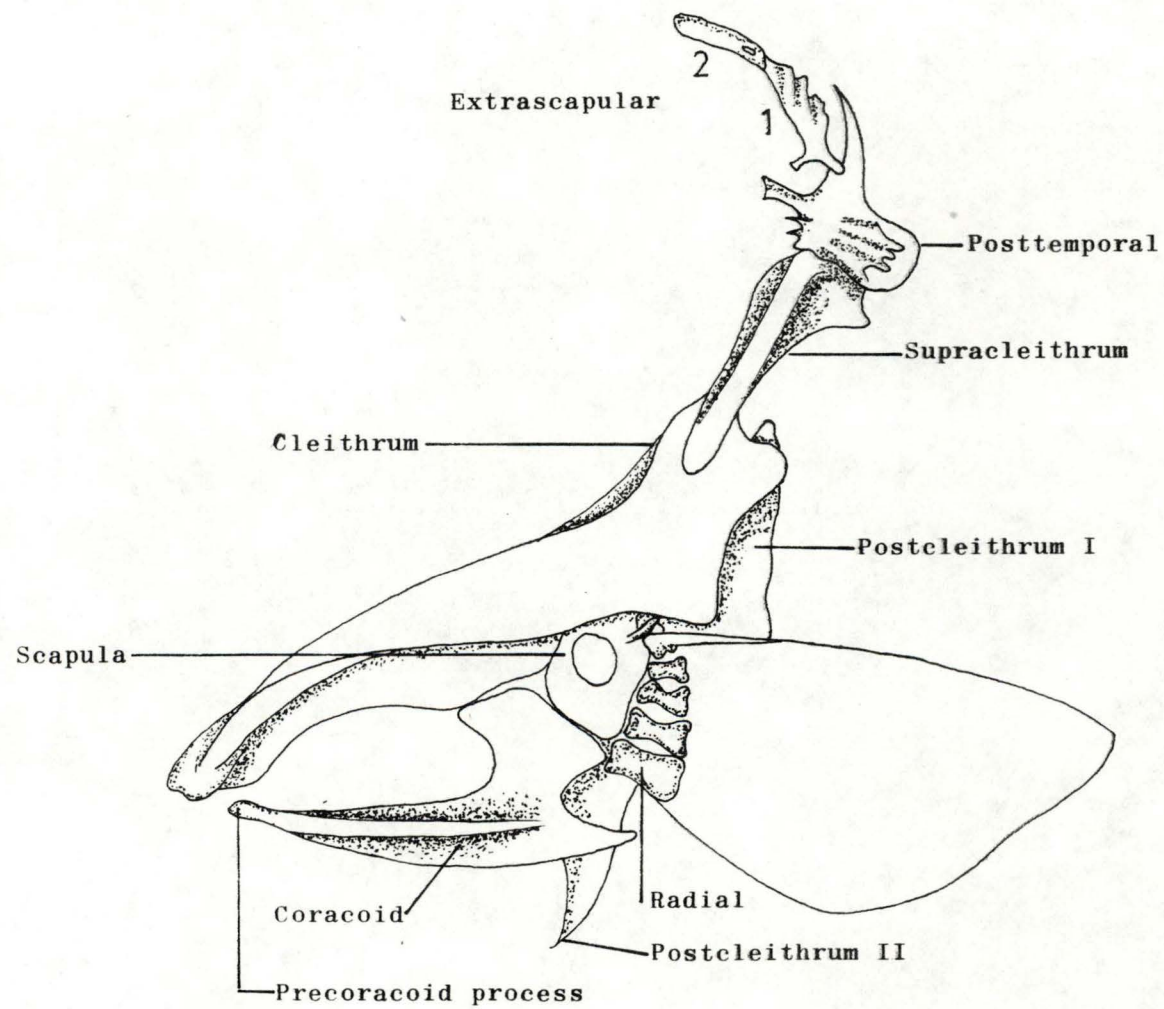


Fig. 56.

Pectoral girdle (External surface)

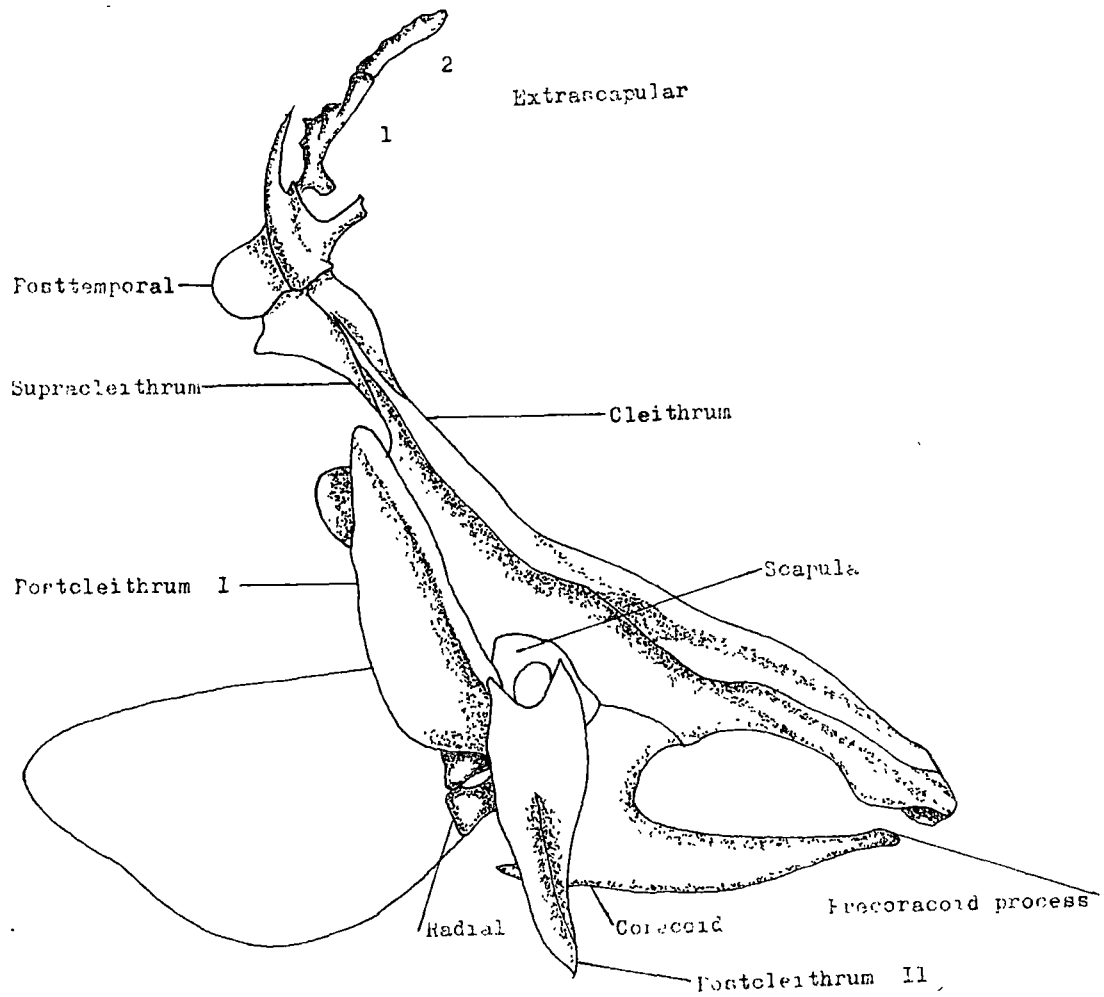


Fig 57.

Pectoral girdle (Internal surface)

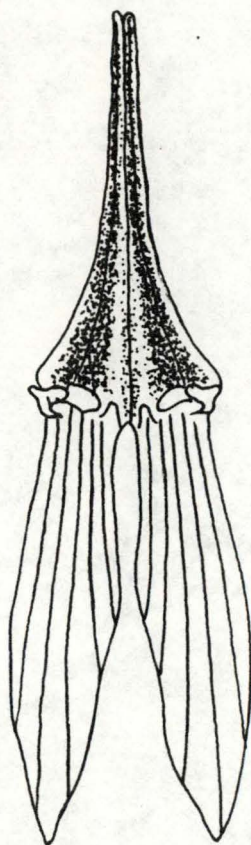


Fig. 58. Pelvic girdle (Dorsal View)

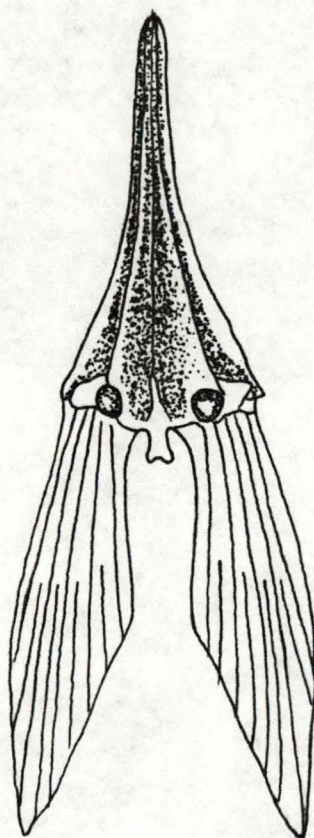


Fig. 59. Pelvic girdle (Ventral view)

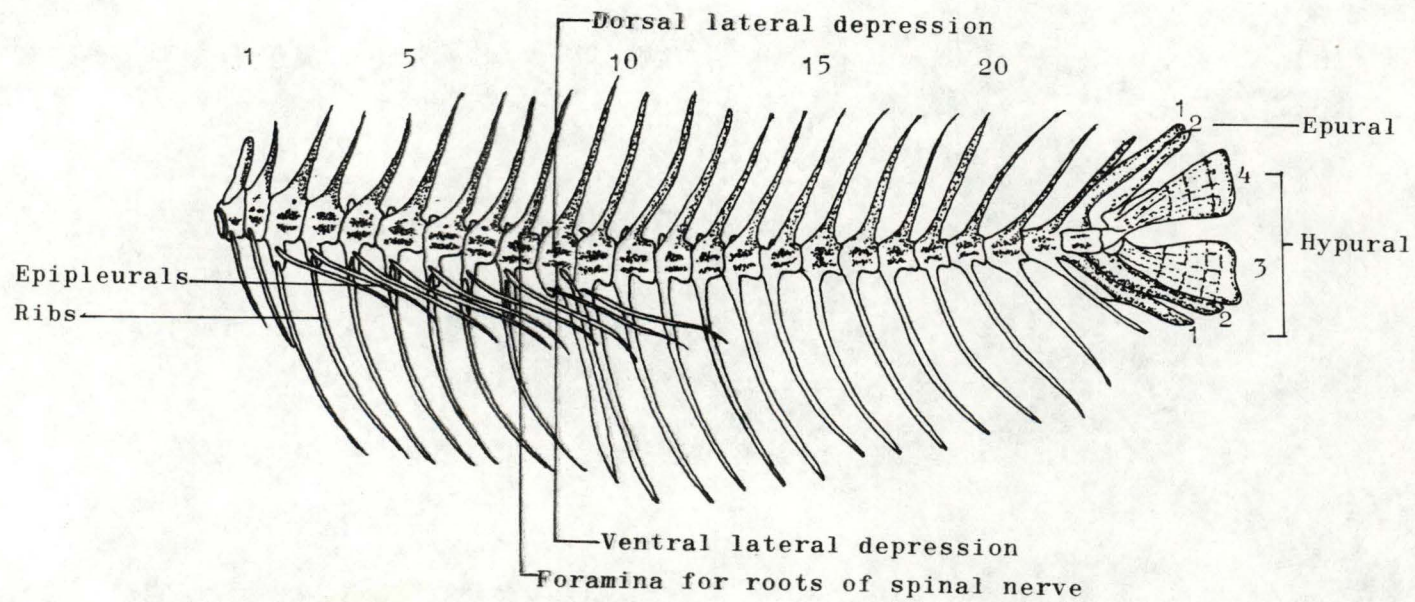
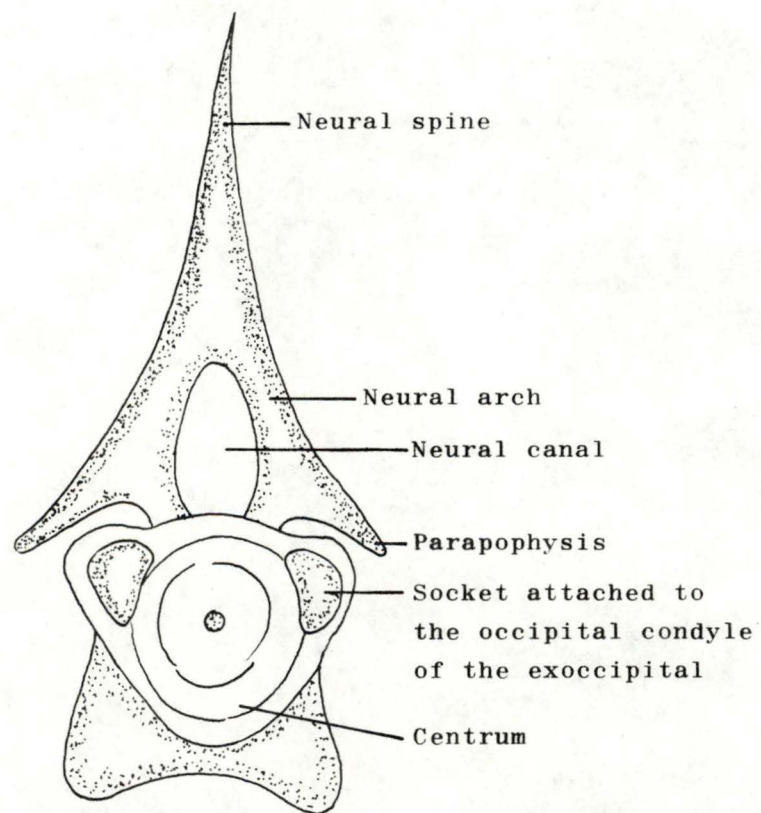
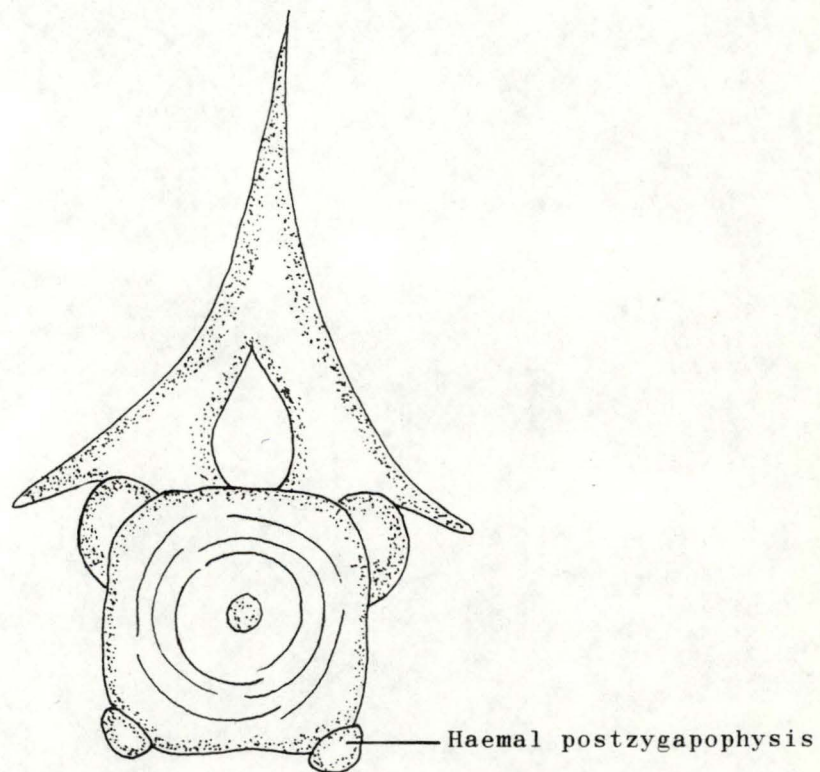


Fig. 60. Vertebral column and urostyle

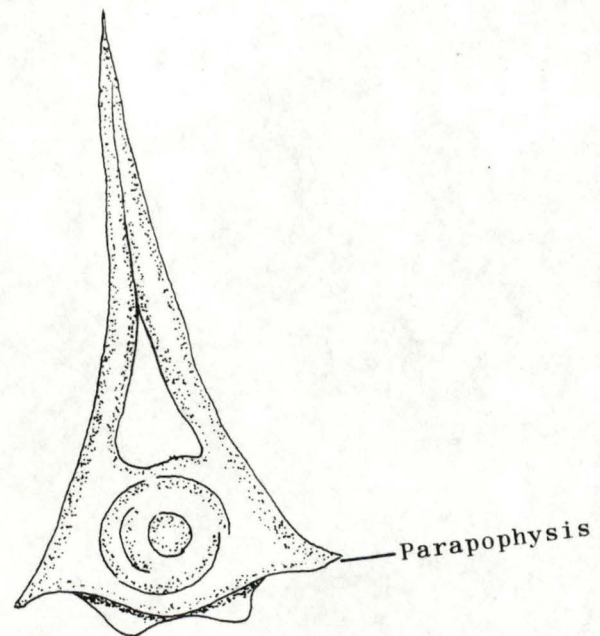


Anterior view

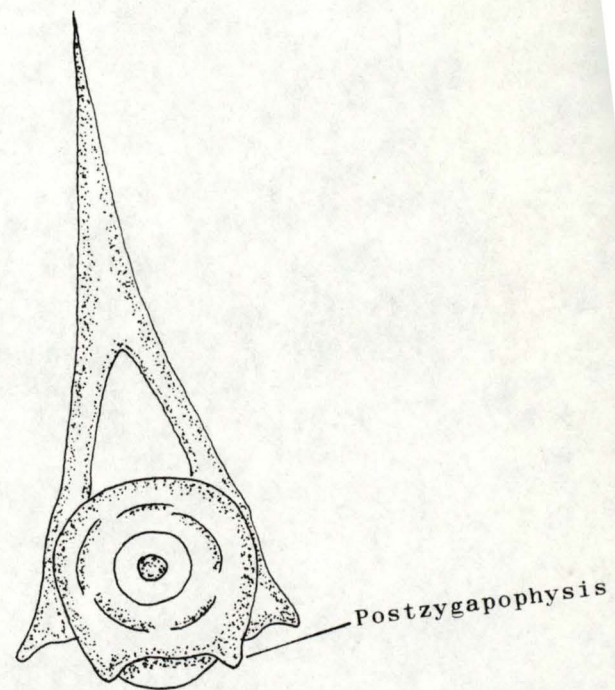


Posterior view

Fig. 61. First vertebra

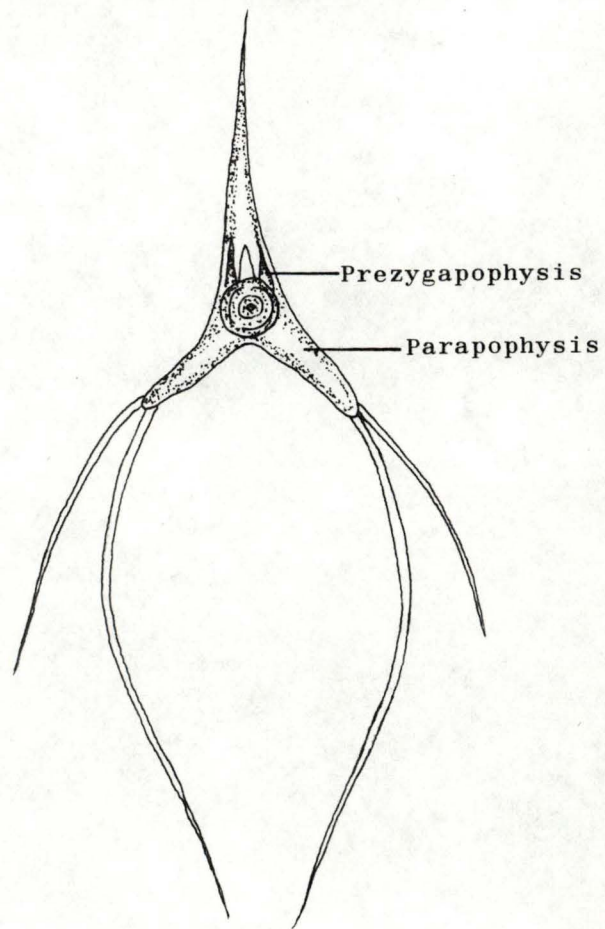


Anterior View

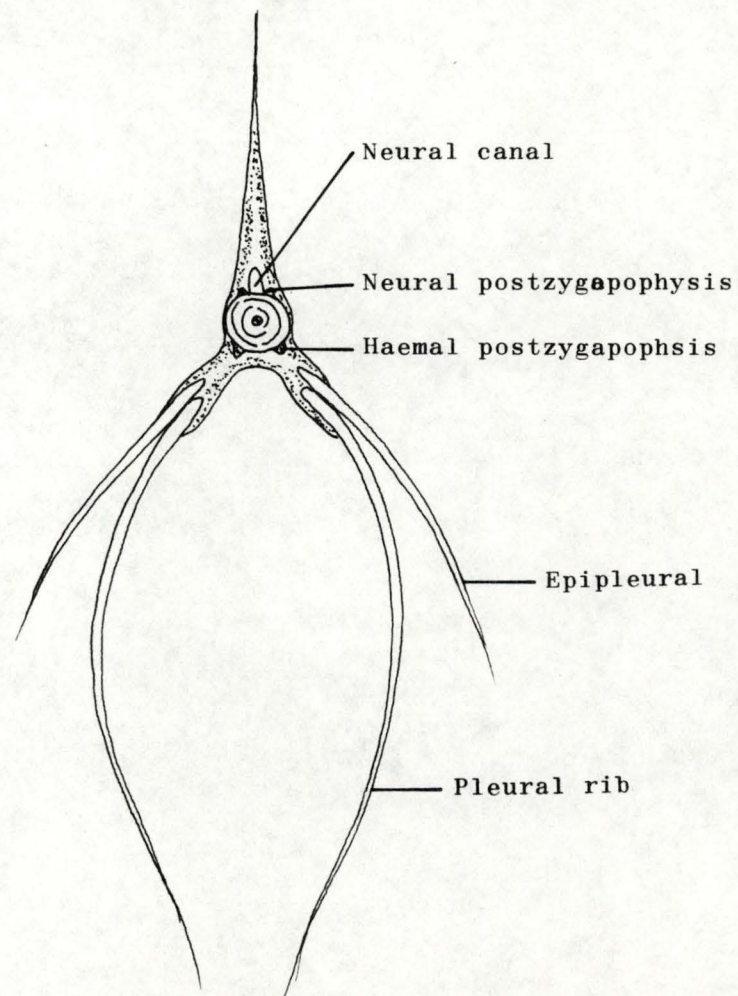


Posterior view

Fig. 62. 2nd vertebra

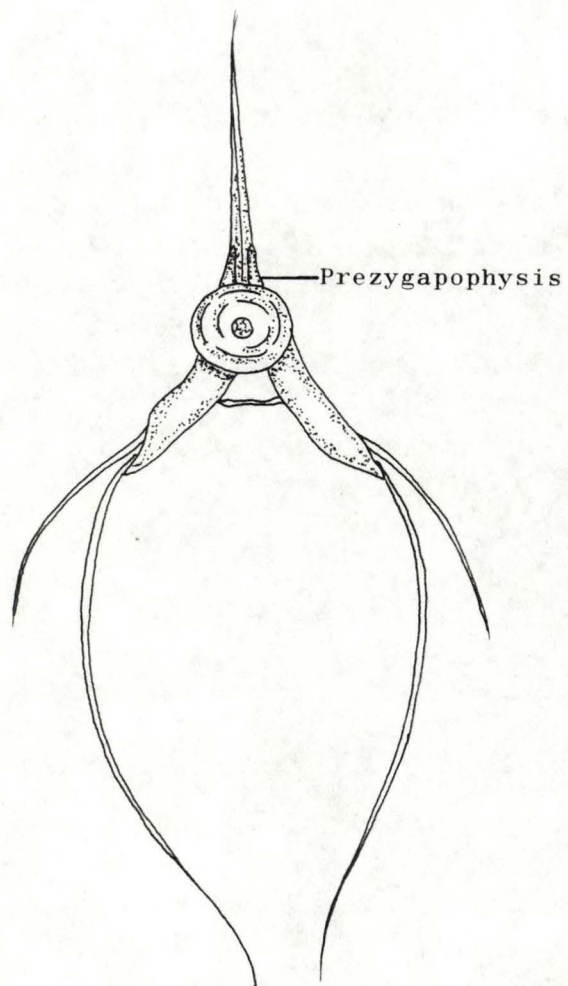


Anterior view

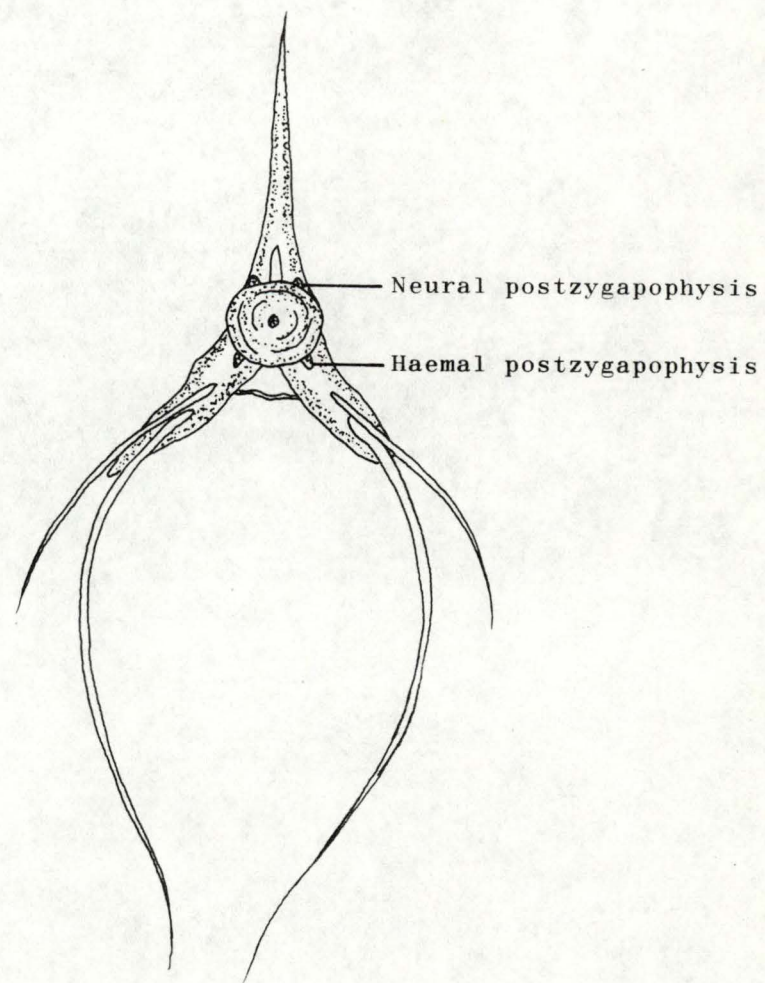


Posterior view

Fig. 63. 5th vertebra



Anterior view



Posterior view

Fig. 64. 9th vertebra

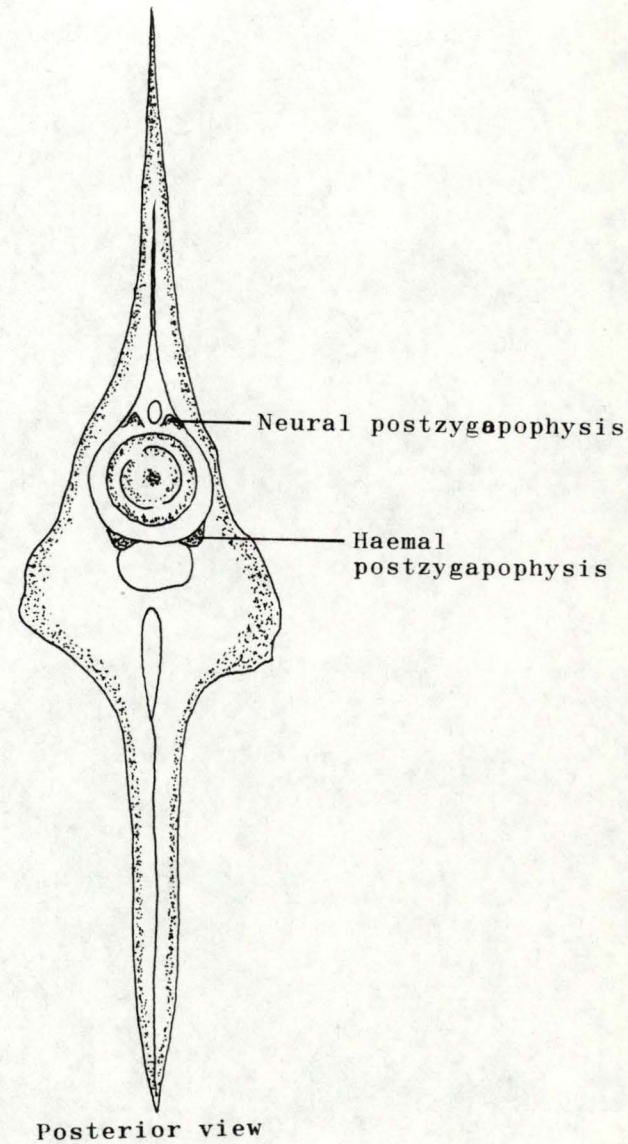
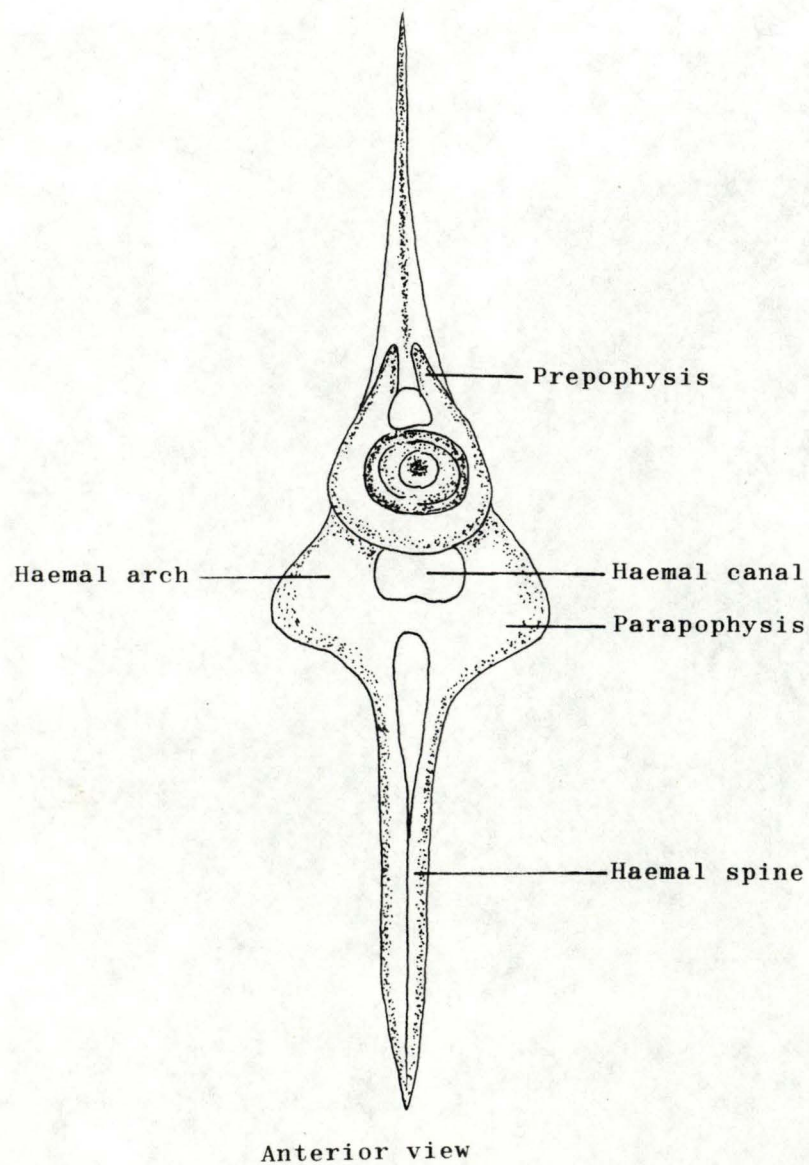
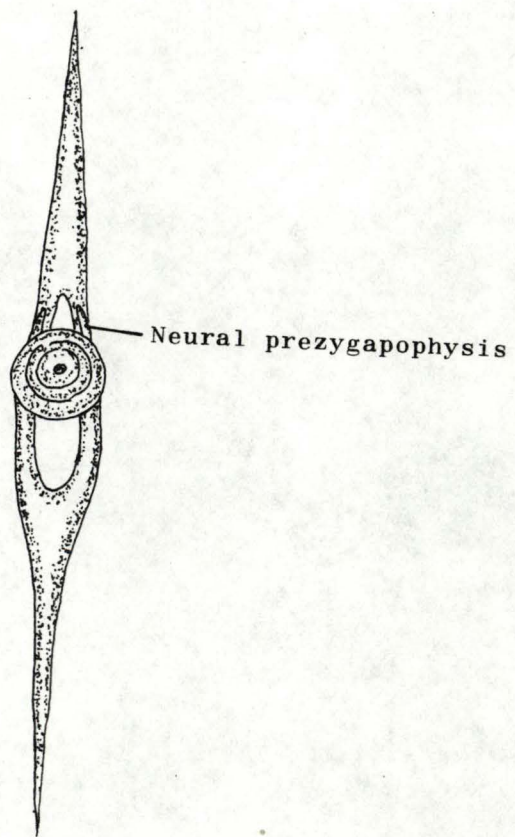
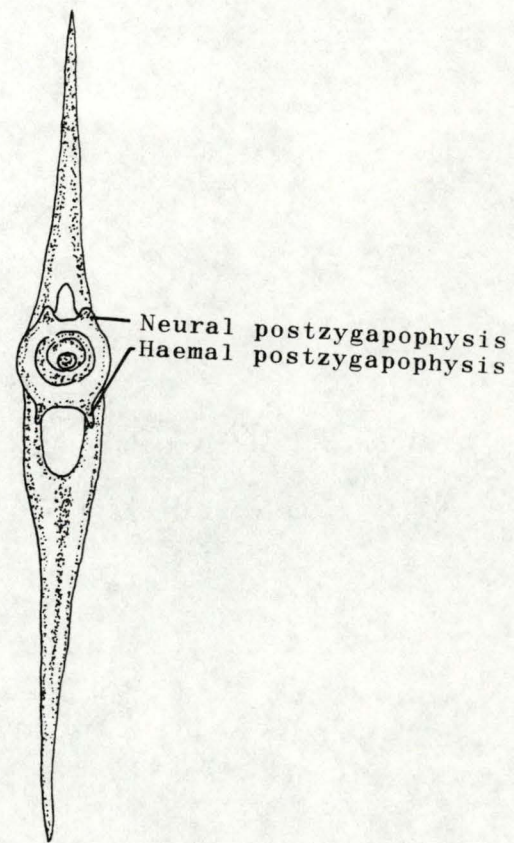


Fig. 65. 10th vertebra

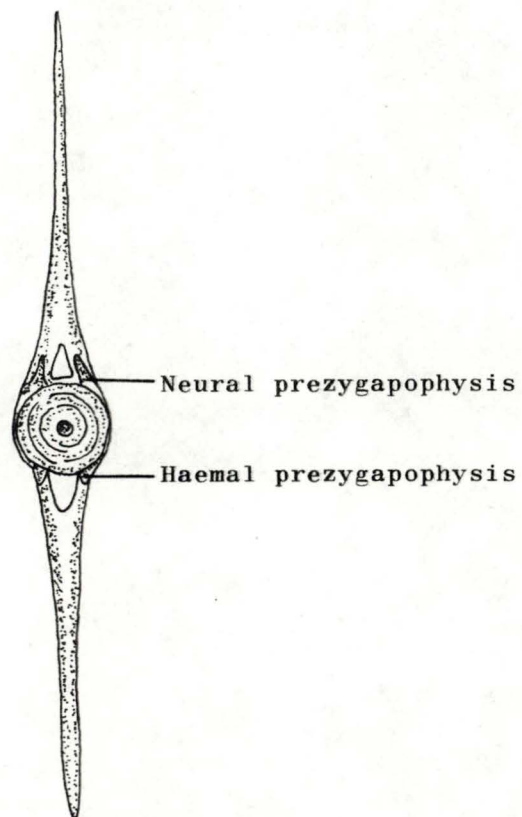


Anterior view

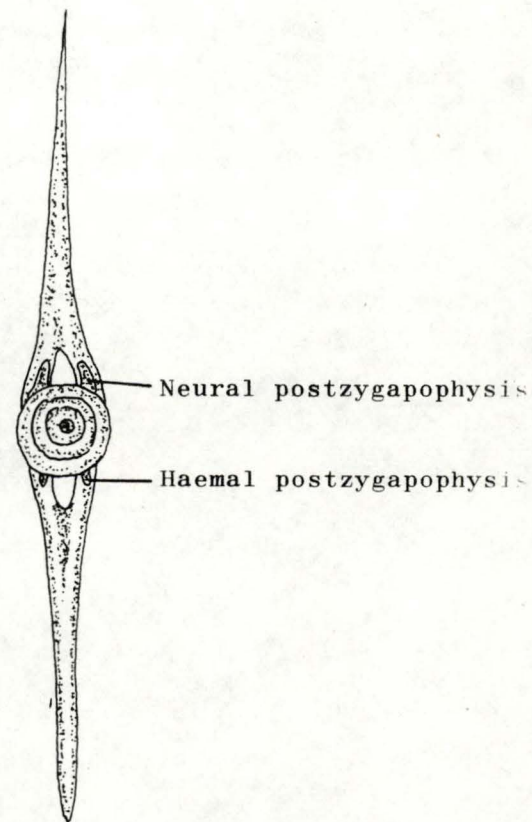


Posterior view

Fig. 66. 11th vertebra



Anterior view



posterior view

Fig. 67. 21st vertebra

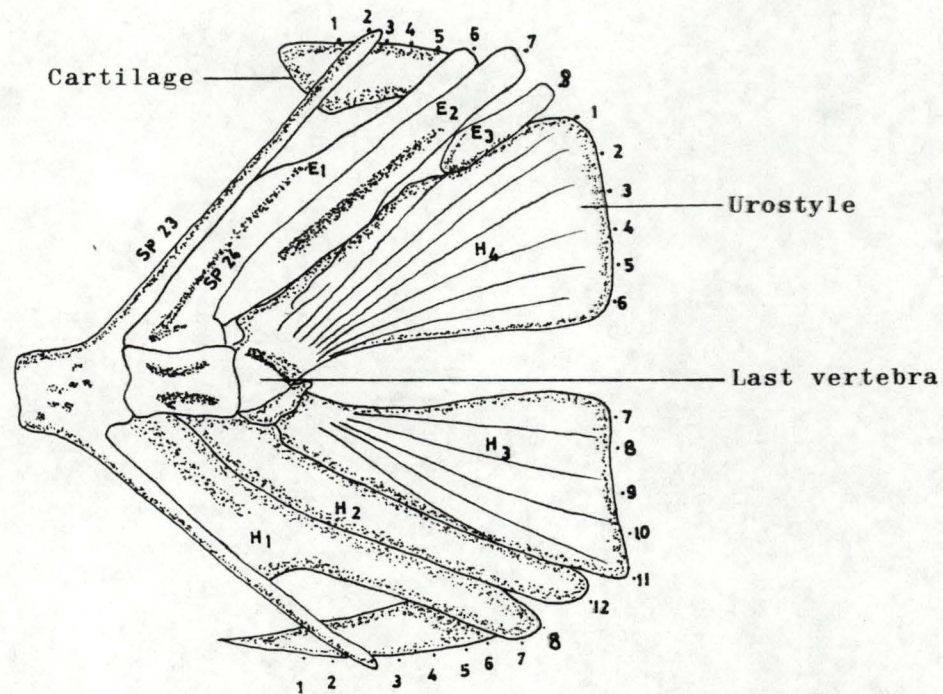


Fig. 68. Bones of the tail region

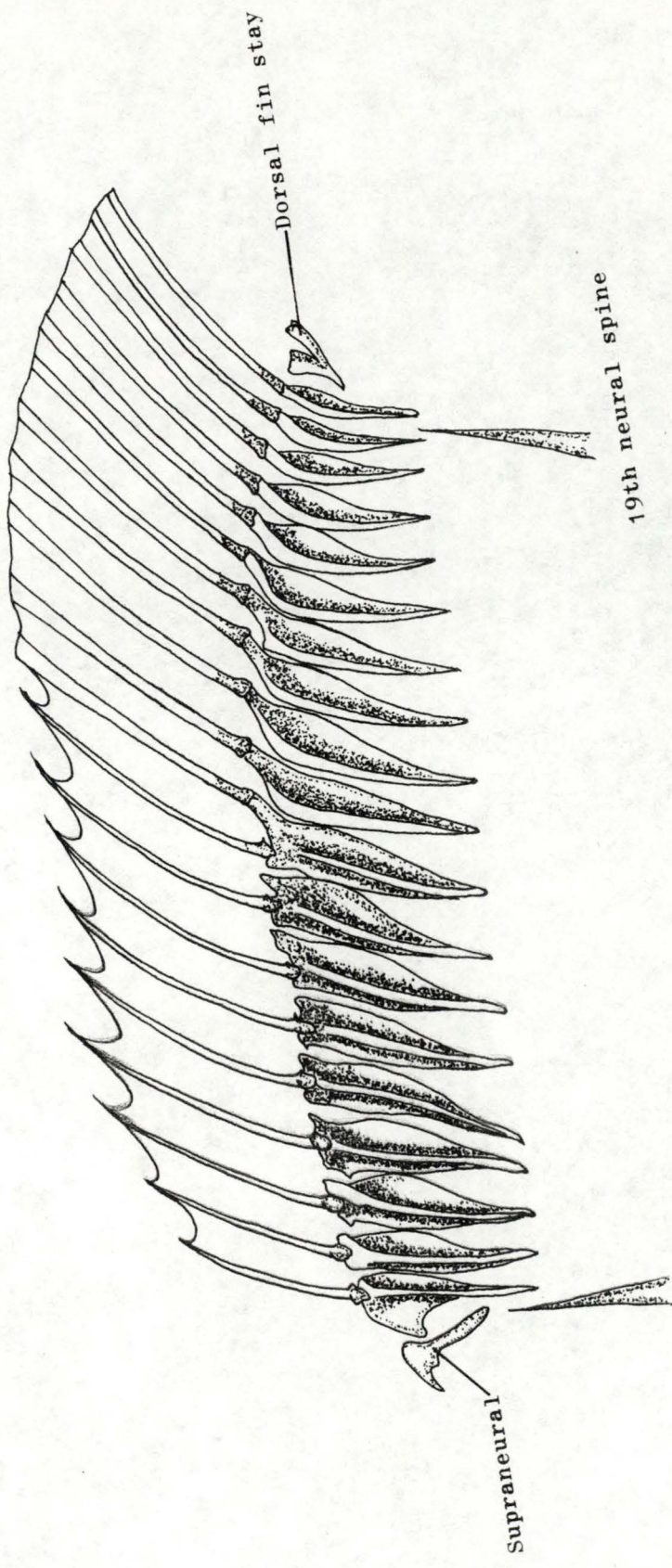


Fig. 69. Dorsal Fin

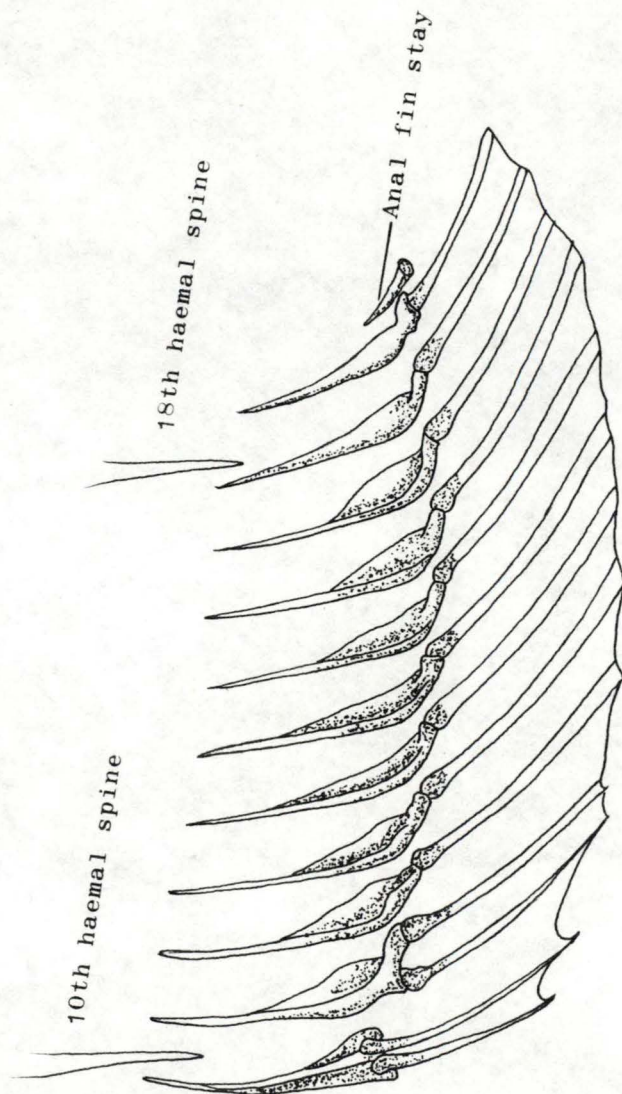


Fig. 70. Anal fin



Fig. 71. 7th dorsal spine (Anterior view)

Fig 72.

Muscles of the head.

A1-A2-A3; Adductor mandibulae

Adop: Adductor operculi

Dil. Op: Dilatator operculi

Lap: Levator arcus palatini

Lev. Op: Levator operculi

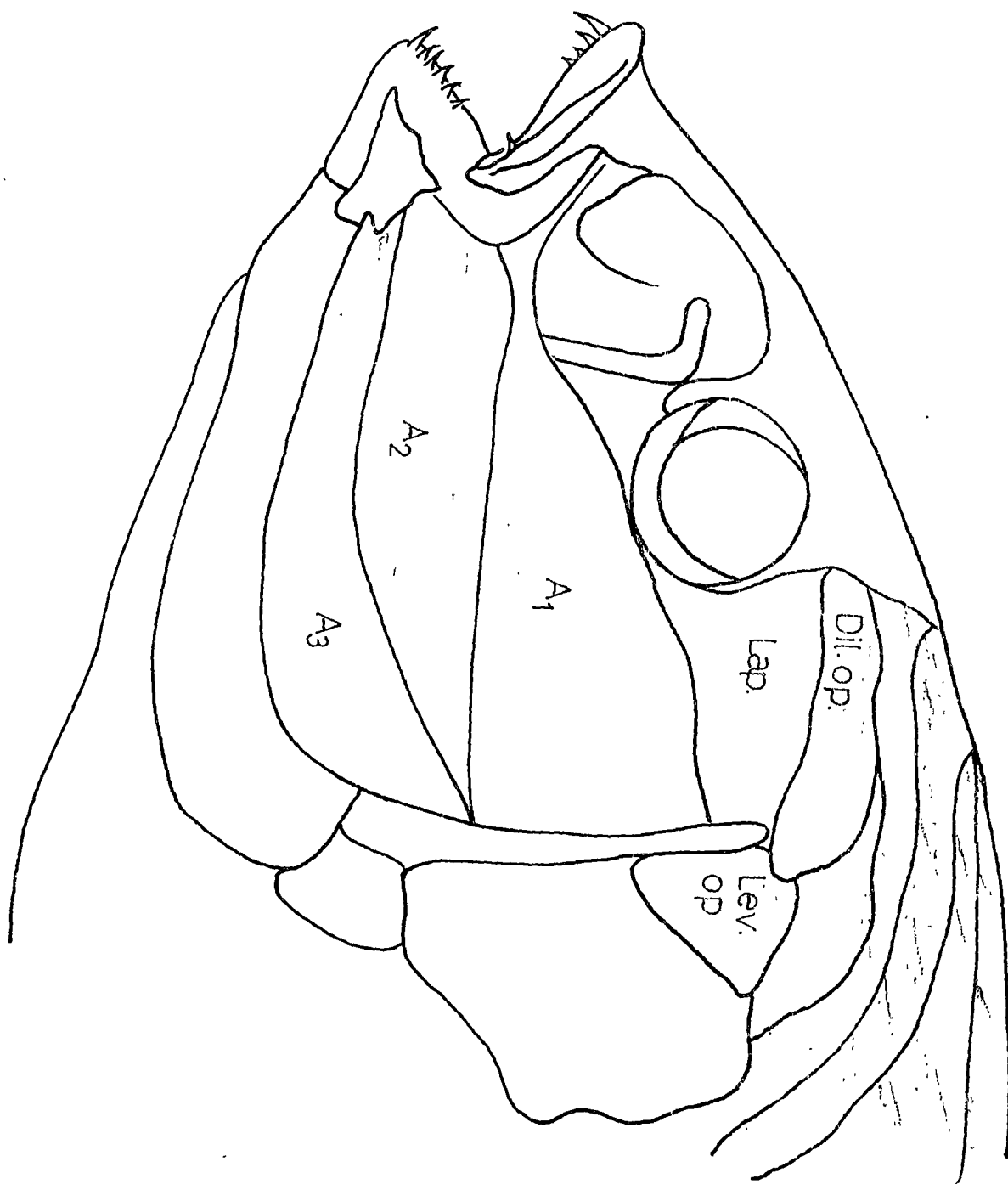


Fig. 73.

Muscles of the head.

A1-A2-A3; Adductor mandibulae

Adop: Adductor operculi

Dil. Op: Dilatator operculi

Lap: Levator arcus palatini

Lev. Op: Levator operculi

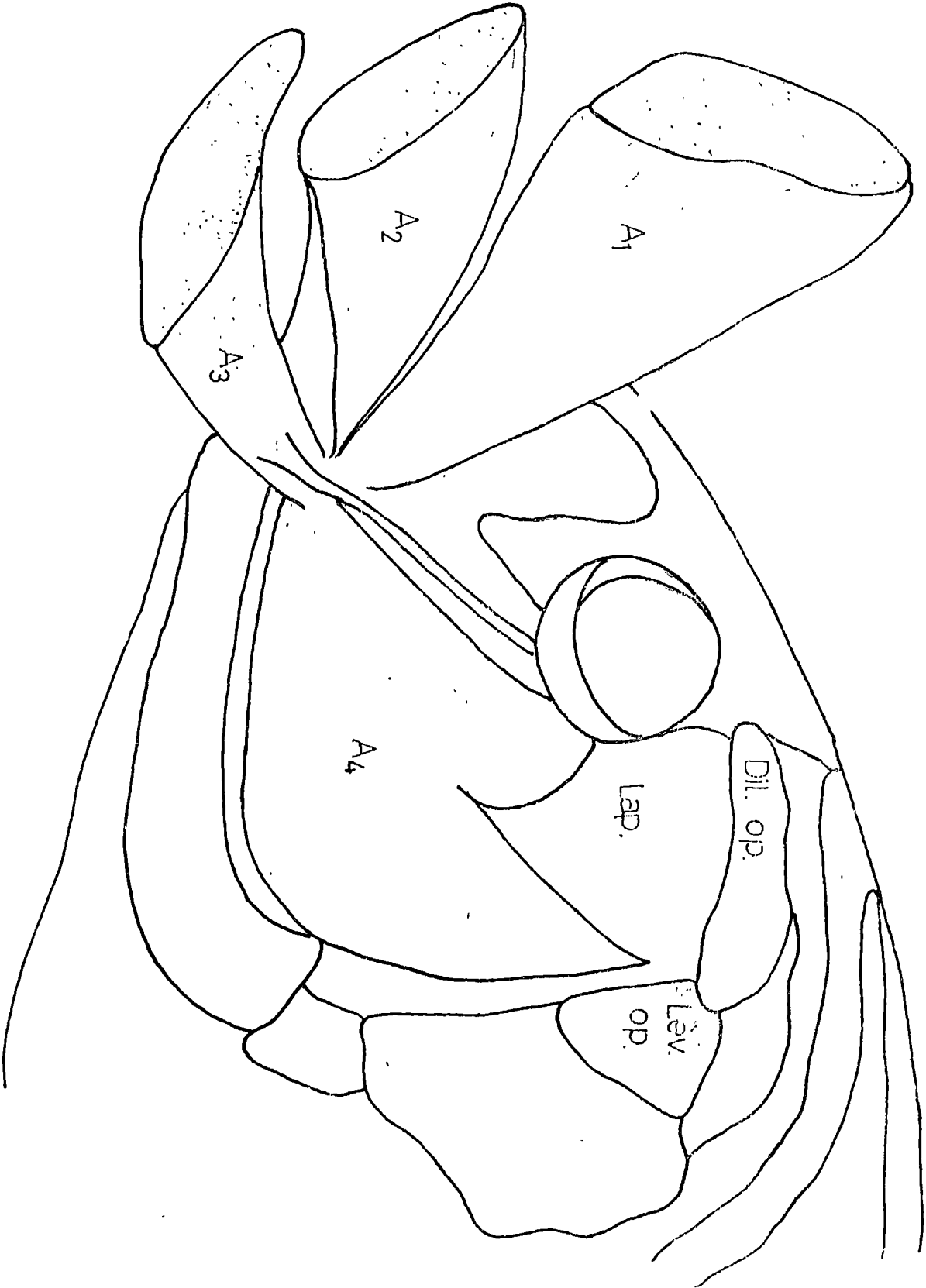


Fig 74.

Muscles of the head.

A1-A2-A3; Adductor mandibulae

Adop: Adductor operculi

Dil. Op: Dilatator operculi

Lap: Levator arcus palatini

Lev. Op: Levator operculi

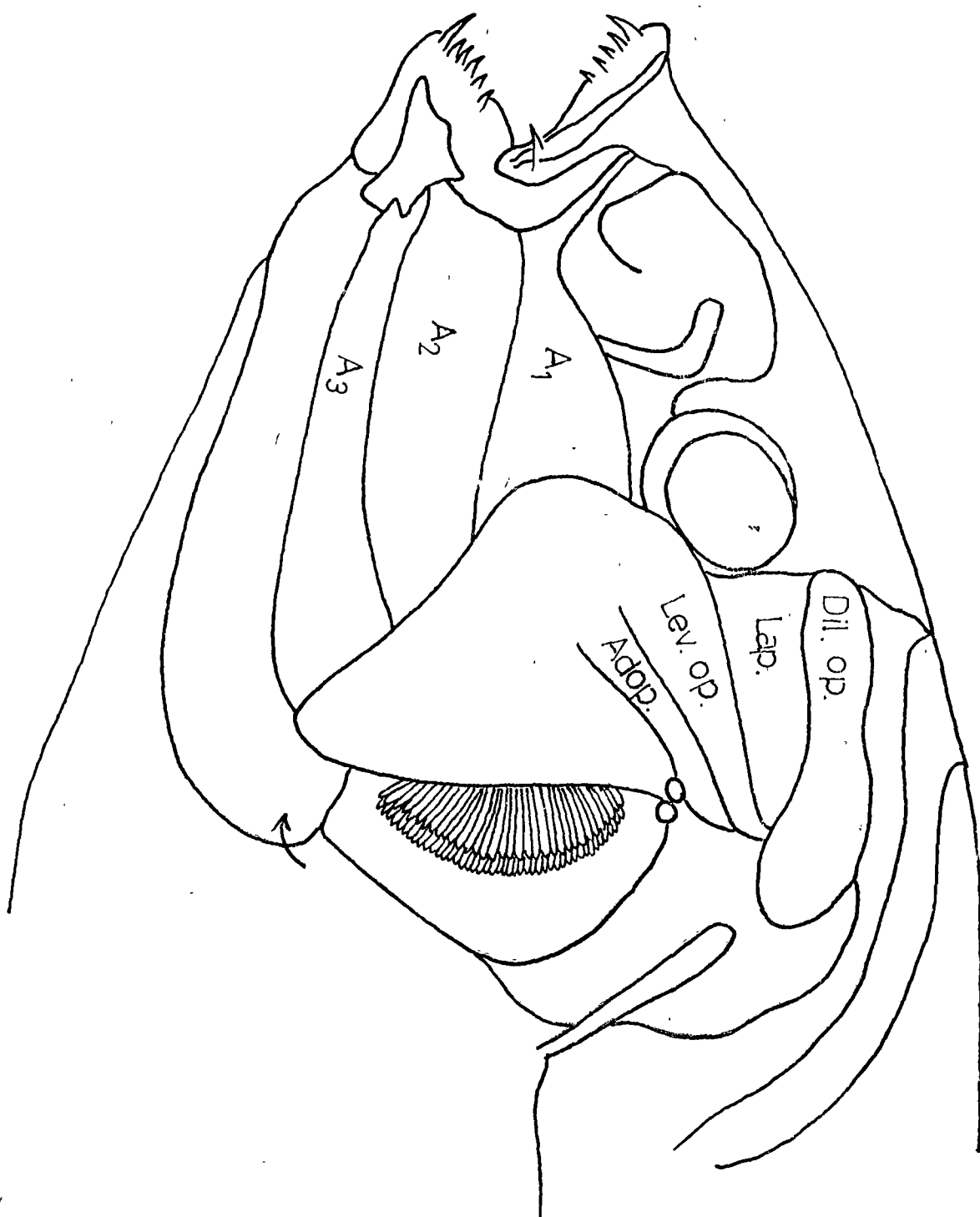


Fig 75.

Muscles of the pharynx.

Abds: Abductor superficialis
Abdp: Abductor profundus
Hy: Hyopectoralis
Pce: Pharyngo-clavicularis externus
Pci: Pharyngo-clavicularis internus
Ph: Pharyngo-hyoideus
Rabd: Retractores arcuum branchialium
dorsales

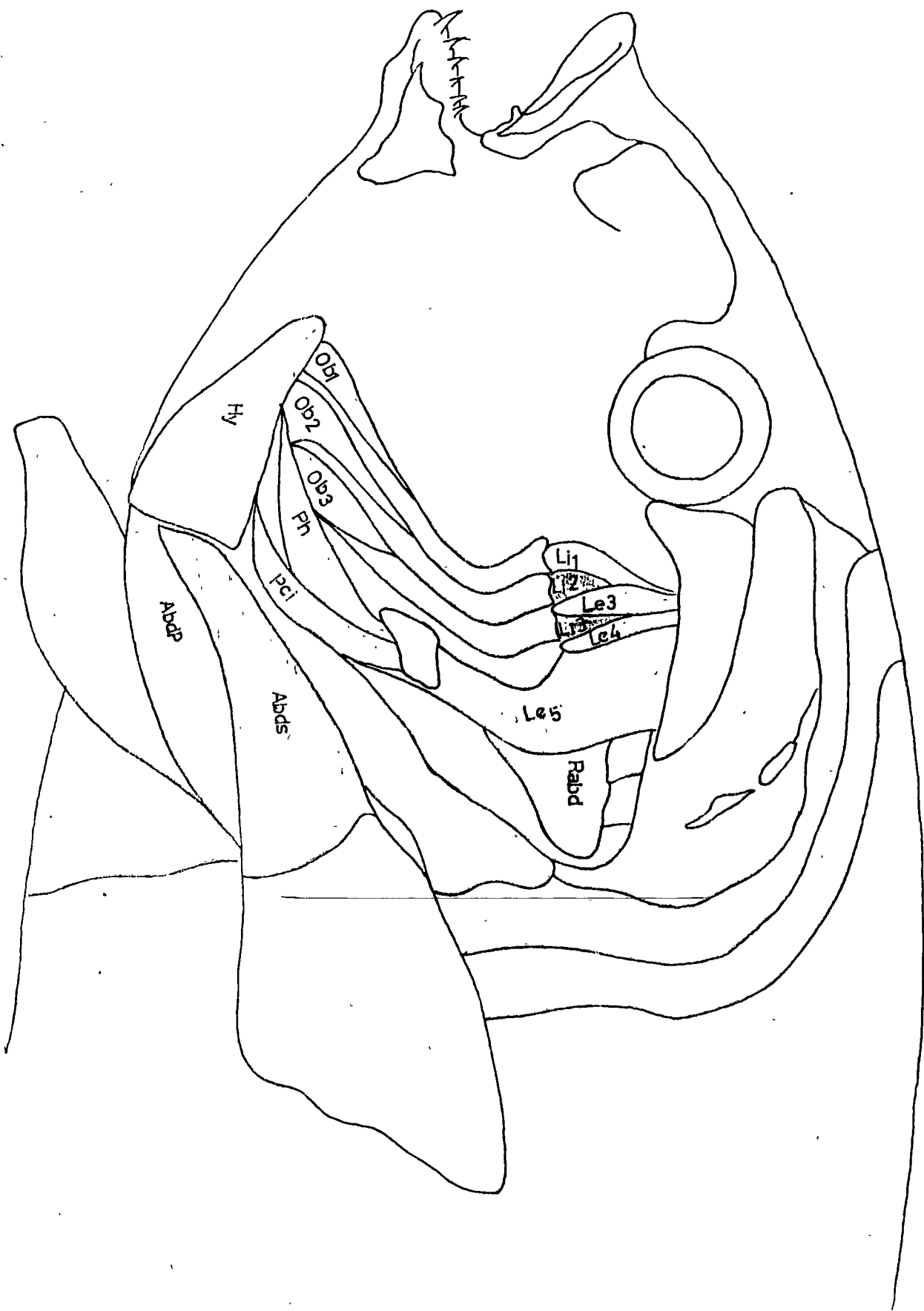


Fig 76. Muscles of the pectoral arch and fin.

Abds: Abductor superficialis
Abdp: Abductor profundus
Hy: Hyopectoralis
Pce: Pharyngo-clavicularis externus
Pci: Pharyngo-clavicularis internus
Ph: Pharyngo-hyoideus
Rabd: Retractores arcuum branchialium
dorsales

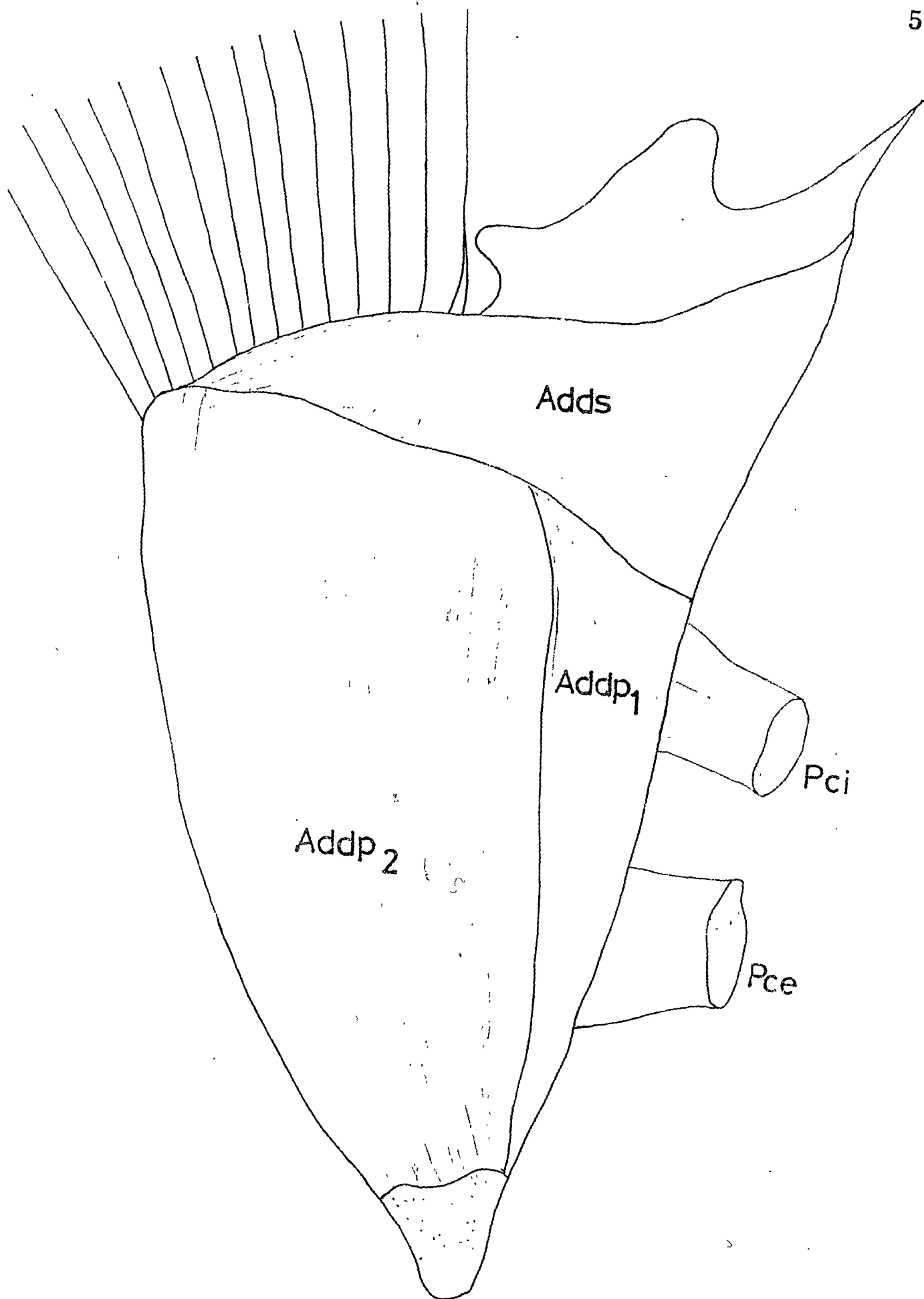


Fig 77. Muscles of the ventral portion, pelvic girdle and fin.

Abdp: Abductor profundus pectoralis
Abds: Abductor superficialis pectorlis
Abp: Abductor profundus pelvis
Abs: Abductor superficialis pelvis
Chi: Geniohyoideus inferior
Chs: Geniohyoideus superior
Hh1. Hh2: Hyohyoideus
Hyo: Hyopectoralis
Im: Intermandibularis
Vm: Myomere of the body muscles

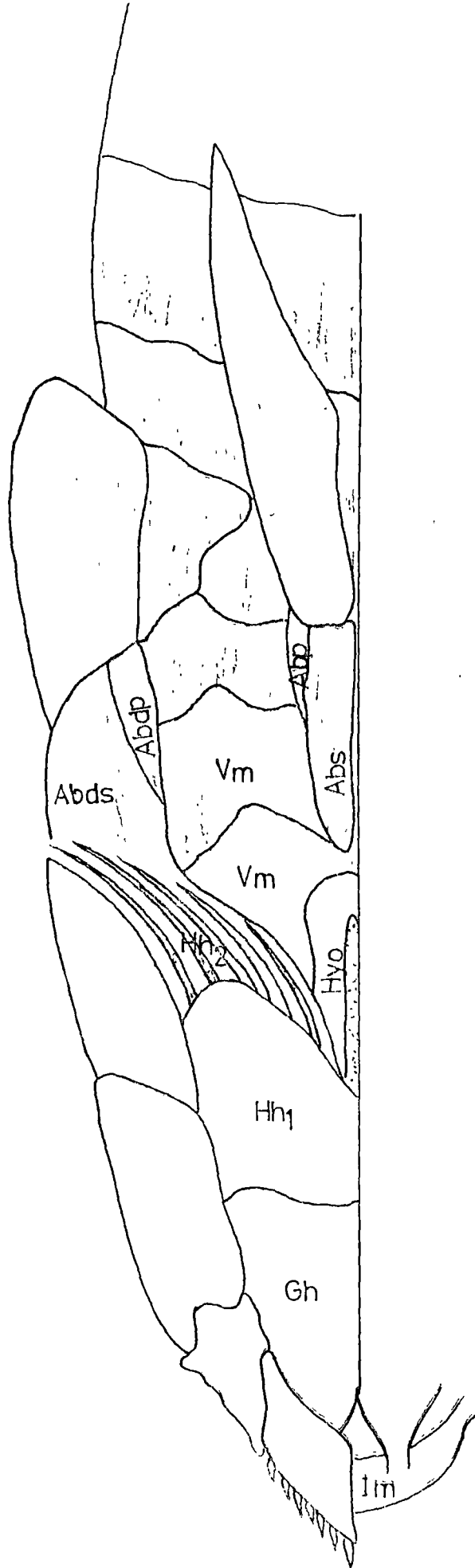


Fig 78. Muscles of the ventral portion of head.

Abdp: Abductor profundus pectoralis
Abds: Abductor superficialis pectoralis
Abp: Abductor profundus pelvis
Abs: Abductor superficialis pelvis
Ghi: Geniohyoideus inferior
Ghs: Geniohyoideus superior
Hh1. Hh2: Hyohyoideus
Hyo: Hyopectoralis
Im: Intermandibularis
Vm: Myomere of the body muscles

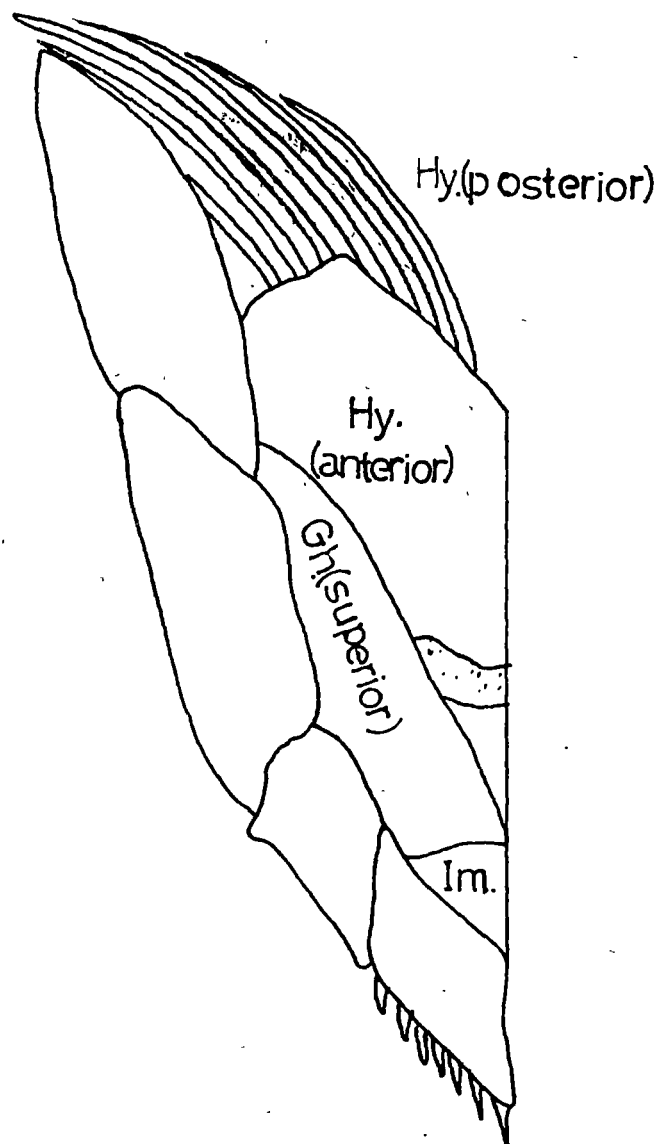
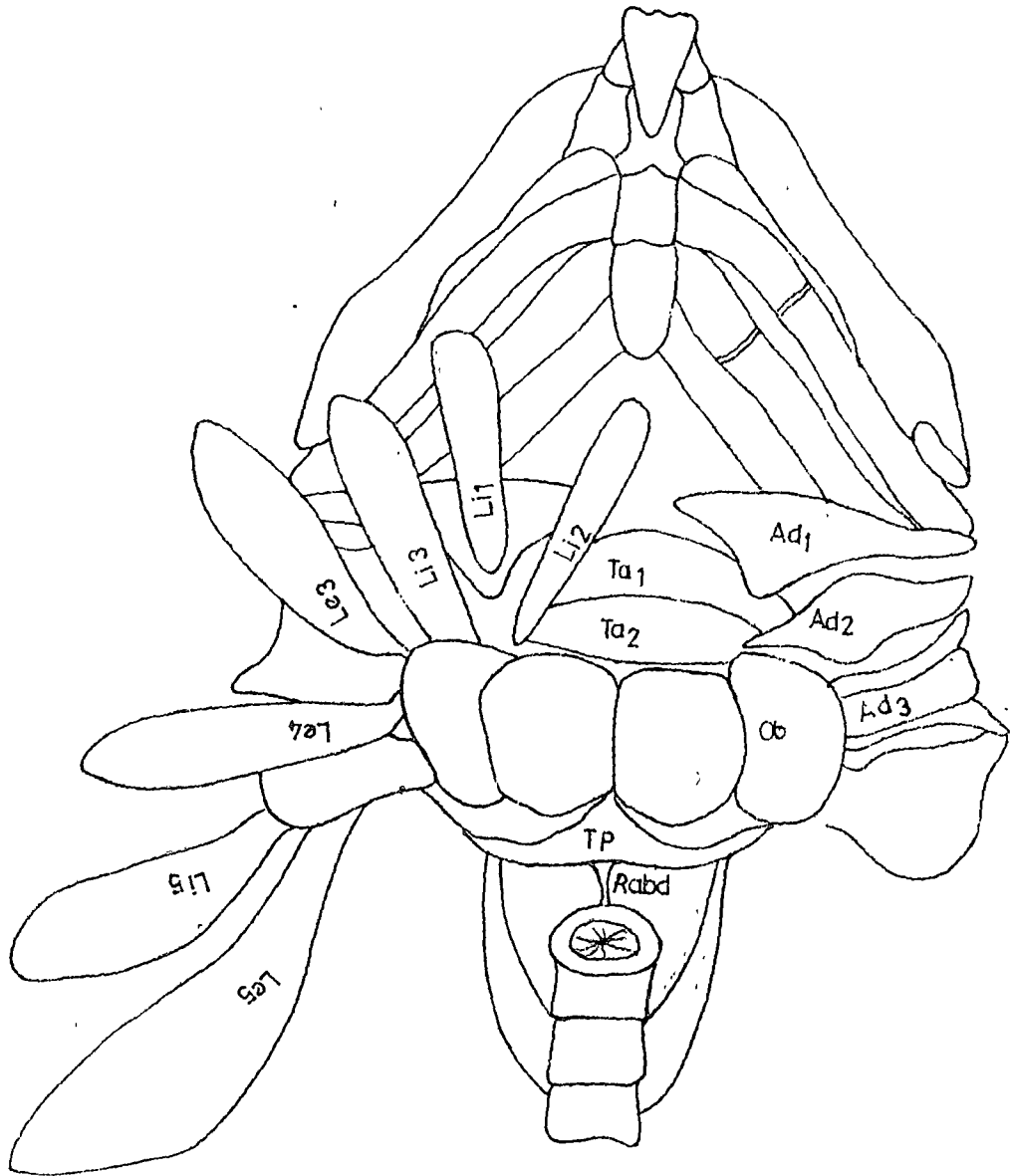


Fig 79. Muscles of the dorsal surface of pharynx.

Ad1: Adductores arcuum branchialium
Le3: Lavatores branchiales externus
of the third arch
Le4: Lavatores branchiales externus
of the 4th arch
Le5: Lavatores branchiales externus
of the 5th arch
Li1: Lavatores branchiales internus
of the first arch
Li2: Lavatores branchiales internus
of the second arch
Li3: Lavatores branchiales internus
of the third arch
Li5: Lavatores branchiales internus
of the 5th arch
Ob: Interarcuales obliqui dorsales
Rabd: Retractores arcuum branchialium
dorsales
Ta1: Transversus dorsalis A1
Ta2: Transversus dorsalis A2
Tp: Transversus dorsalis posterior



Fi 80. Muscles of the ventral surface of pharynx.

Con. eso: Constrictor esophagei

Obl: Obliqui ventrales of the
first arch

Ob2: Obliqui ventrales of the
second arch

Ob3: Obliqui ventrales of the
third arch

Fce: Pharyngo-clavicularis externus

Ph: Pharyngo-hyoideus

Pci: Pharyngo-clavicularis internus

TV4: Transversus ventralis 4

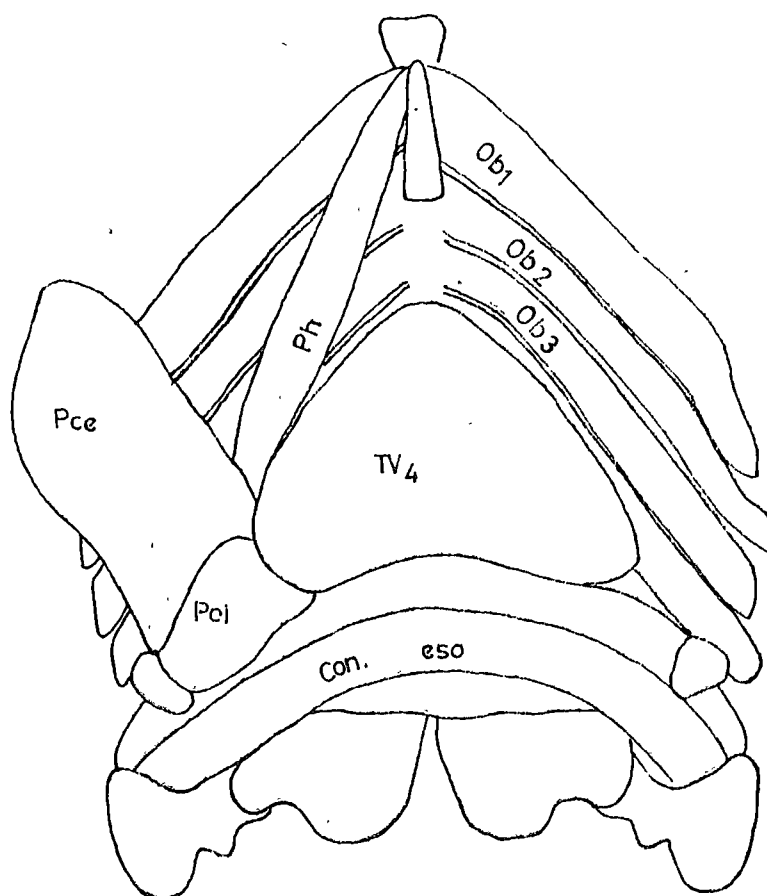


Fig 81. Muscles of the eyeball.

Oi: Obliquus inferior
Os: Obliquus superior
Rif: Rectus inferior
Rit: Rectus internus
Rex: Rectus externus
Rs: Rectus superior

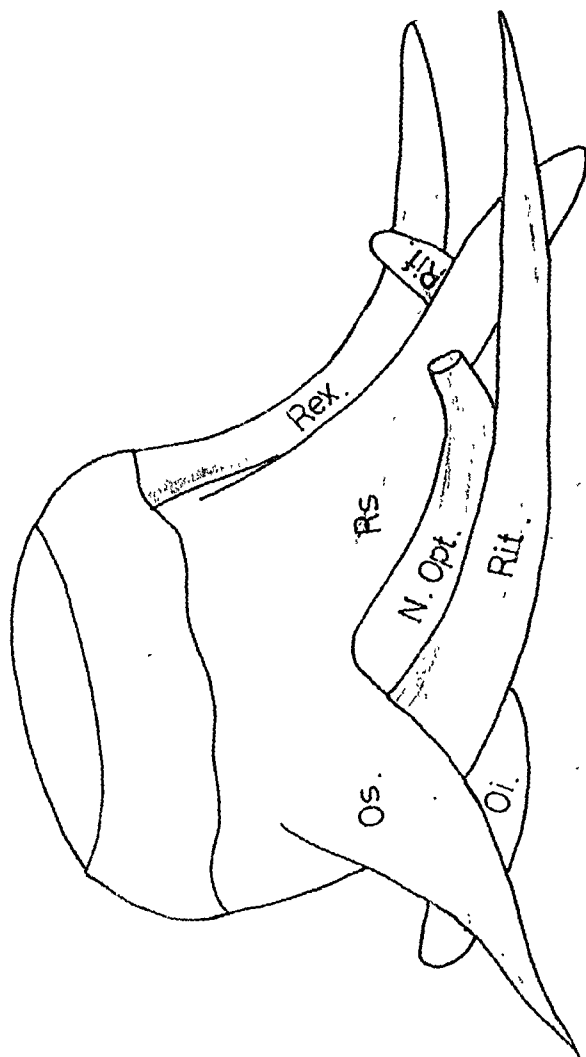


Fig 82. Muscles of the eyeball.

Oi: Obliquus inferior
Os: Obliquus superior
Rif: Rectus inferior
Rit: Rectus internus
Rex: Rectus externus
Rs: Rectus superior

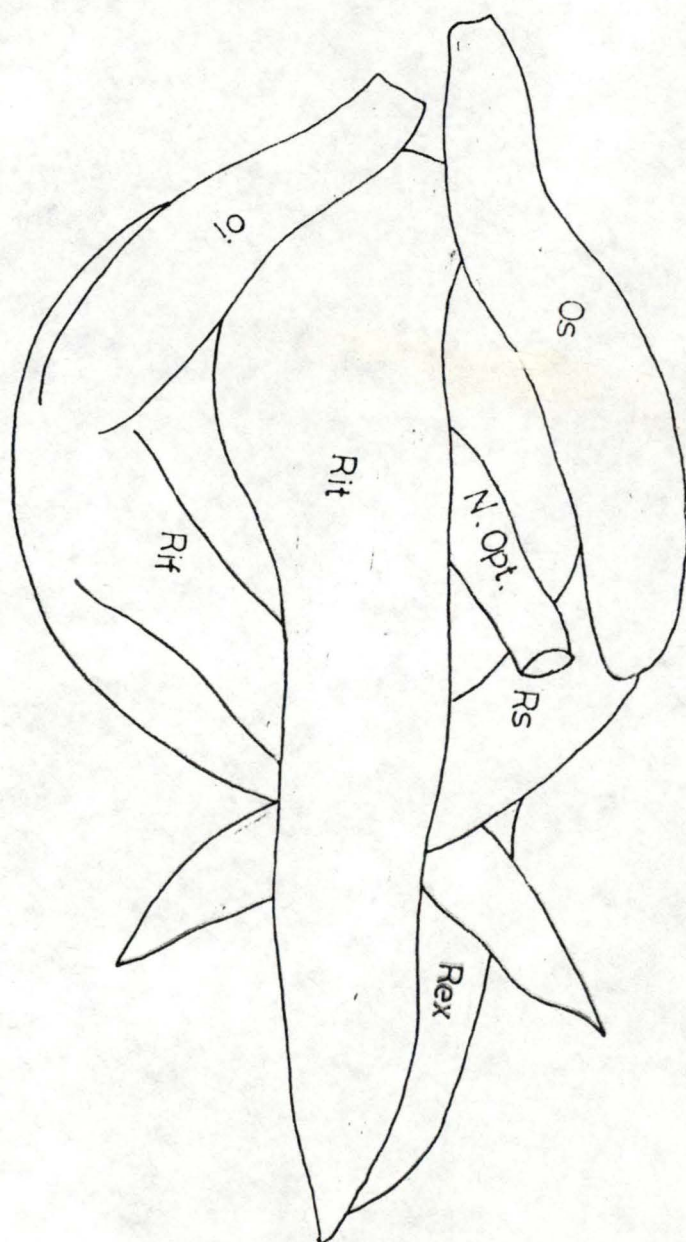
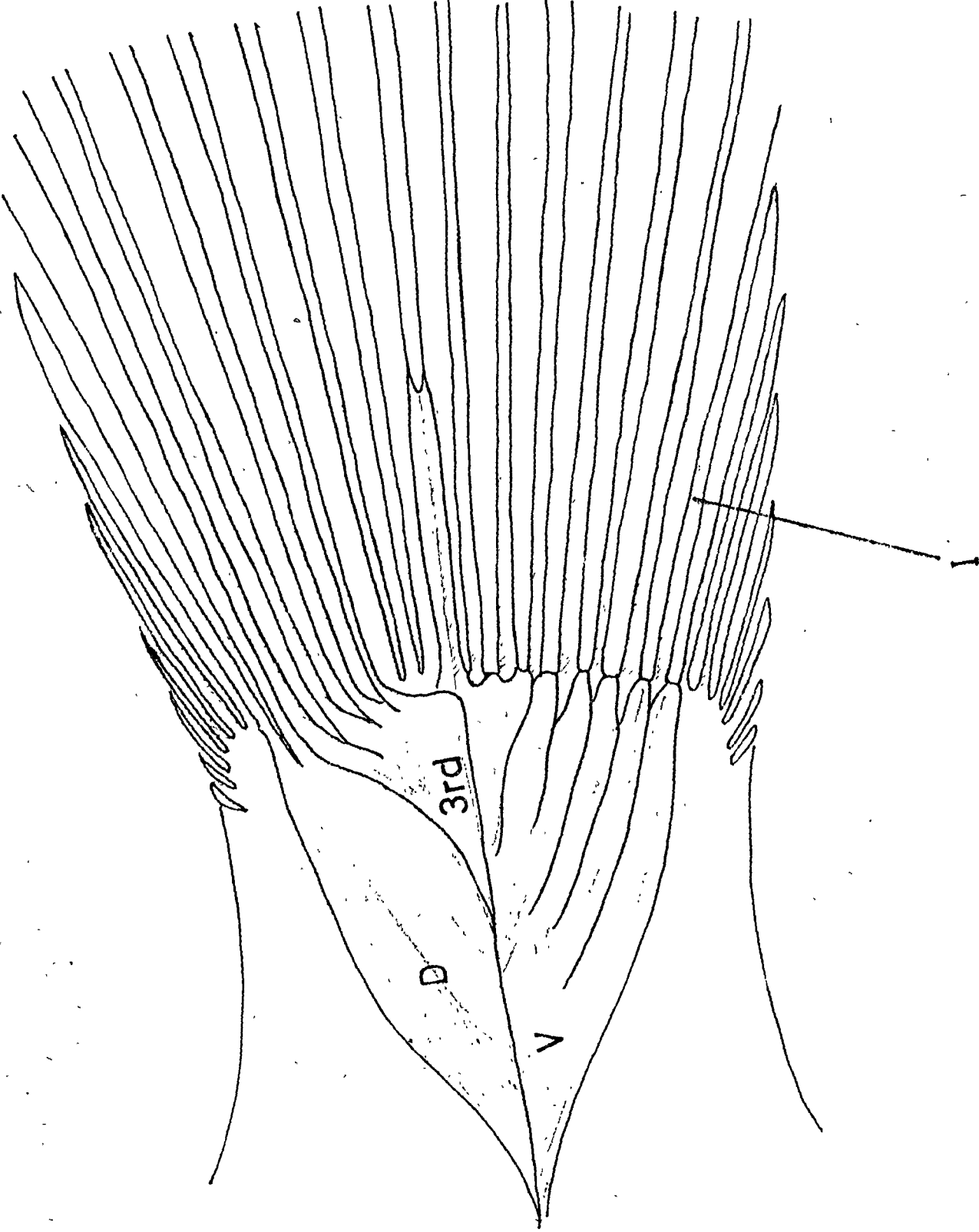


Fig 83. Muscles of the caudal fin.

D: Flexor caudalis dorsalis
V: Flexor caudalis ventralis
3rd: Adductor caudalis ventralis
I: Intrinsic muscle



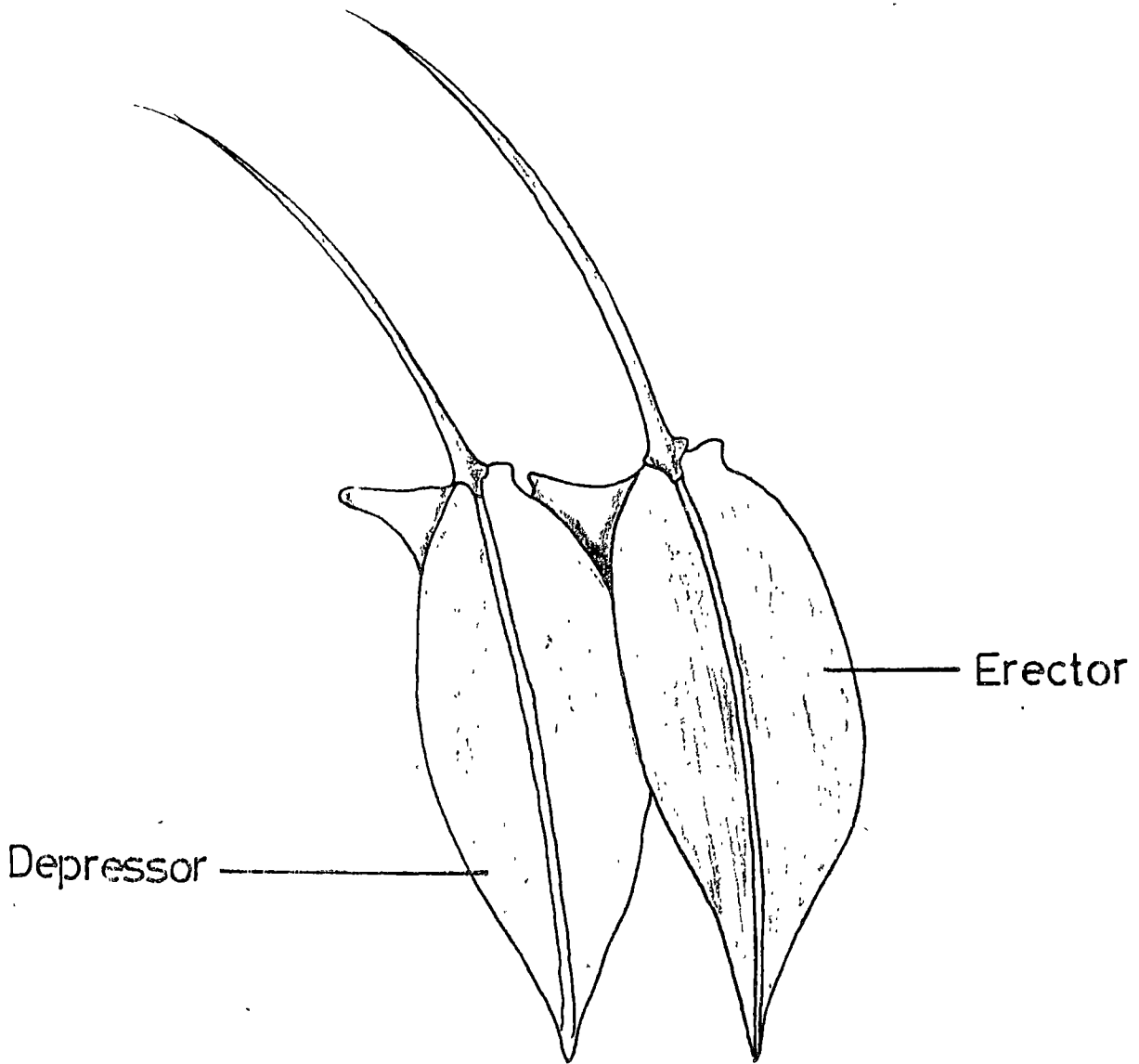


Fig. 84.

Muscle of the dorsal fin (4th & 5th dorsal fin)

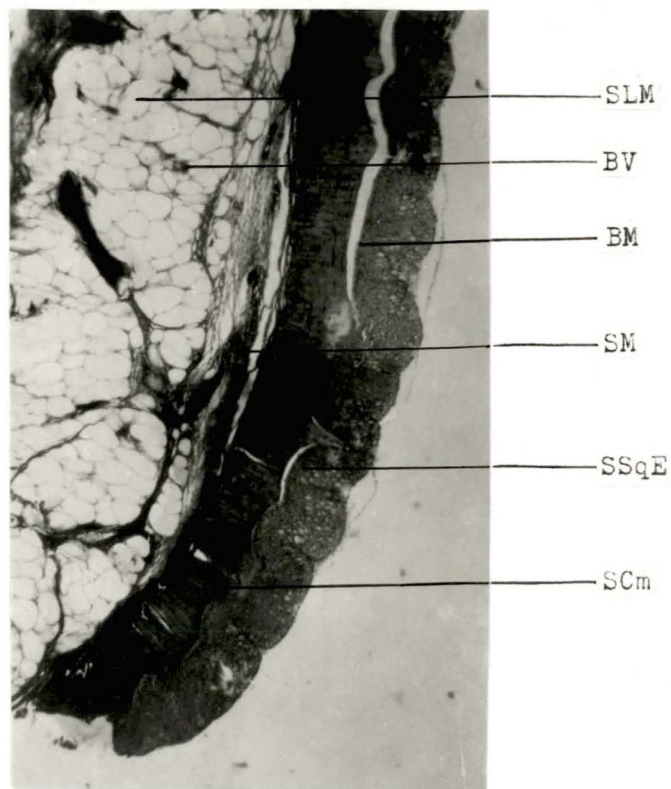


Fig 85. Section of the buccal cavity

BM: Basement membrane

BV: Blood vessel

SCm: Stratum compactum

SLM: Striated longitudinal
muscle

SM: Submucosa

SSqE: Stratified squamous epithelium

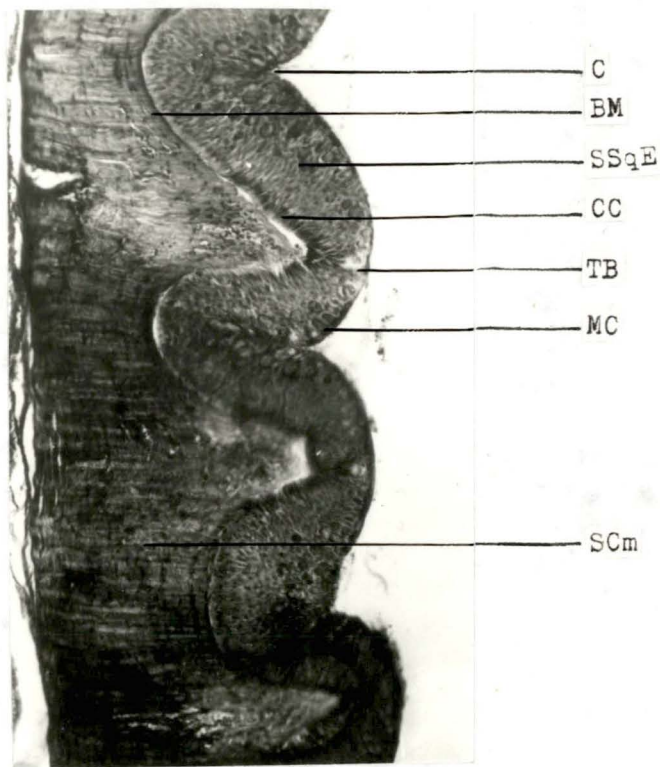


Fig 86. Section of the mucous membrane of the buccal cavity

BM: Basement membrane
C: Crypt
CC: Columnar cell
MC: Mucous-secreting cell
SCm: Stratum compactum
SSqE: Stratified squamous epithelium
TB: Taste bud

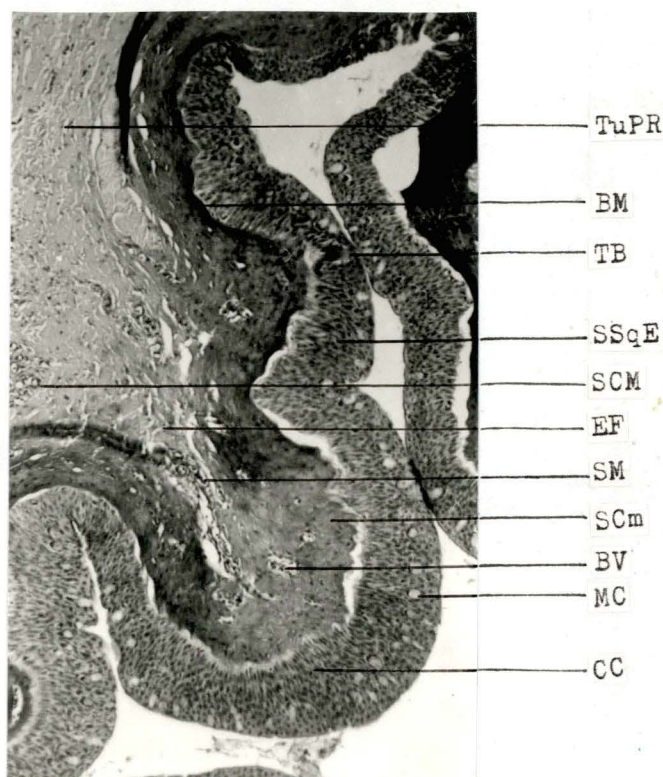


Fig 87. Section of the esophagus

BM: Basement membrane
 BV: Blood vessel
 CC: Columnar cell
 EF: Esophageal fold
 MC: Mucous-secreting cell
 SCm: Stratum compactum
 SCM: Striated circular muscle
 SM: Submucosa
 SSqE: Stratified squamous epithelium
 TB: Taste bud
 TuPR: Tunica propria

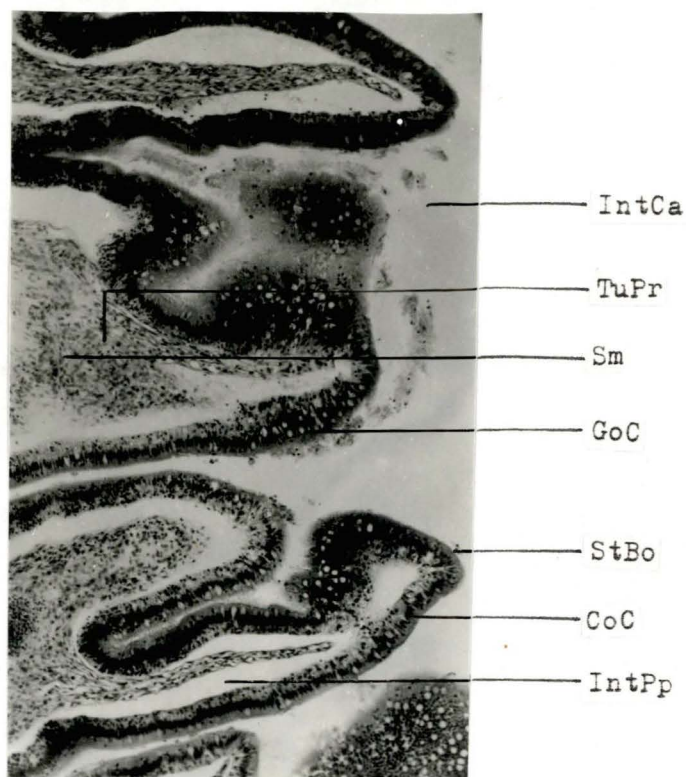


Fig 88. Section of the intestinal bulb

CoC: Columnar cell
GoC: Goblet cell
IntCa: Intestinal cavity
IntPp: Intestinal papilla
Sm: Submucosa
StBo: Striated border
TuPr: Tunica propria

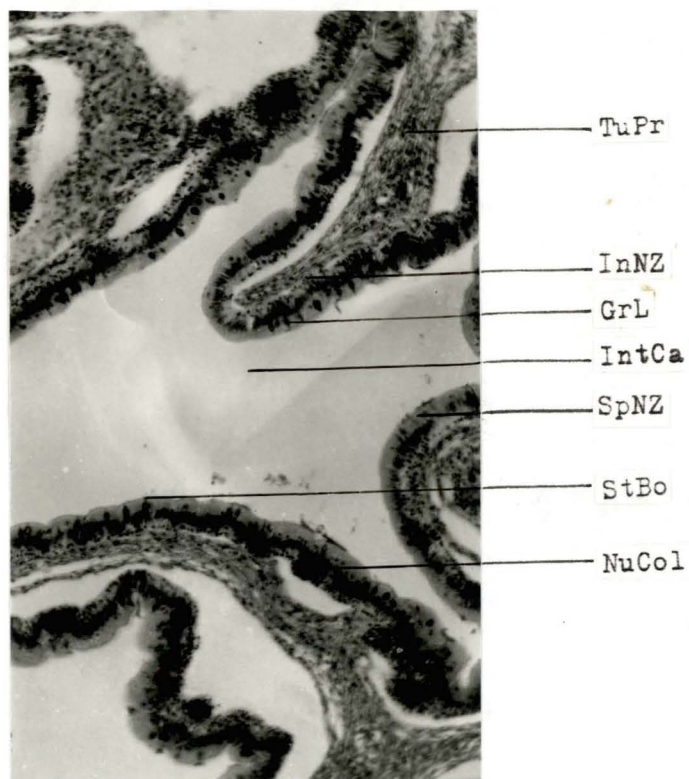


Fig 89. Section of the intestine

GrL: Granular layer
InNZ: Infranuclear zone
IntCa: Intestinal cavity
NuCol: Nucleus of columnar cell
SpNZ: Supranuclear zone
StBo: Striated border
TuPr: Tunica propria

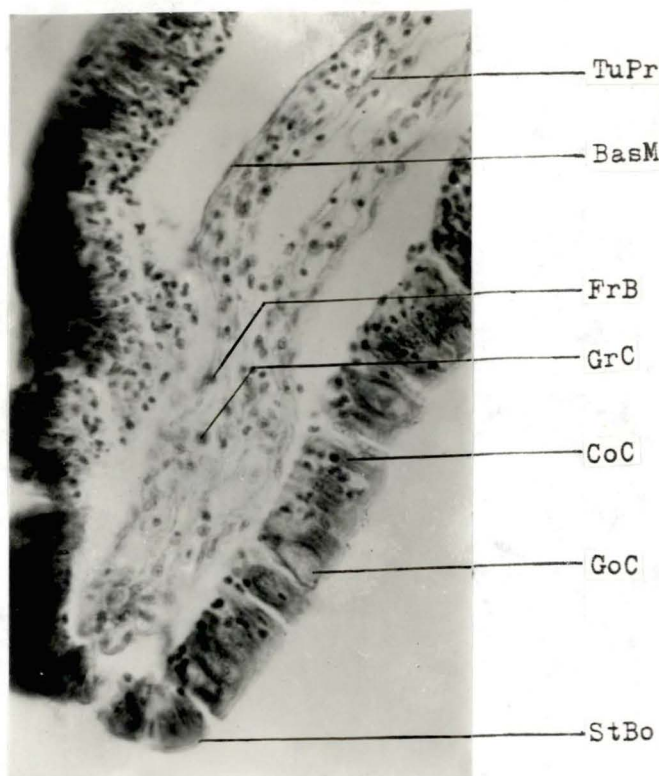


Fig 90. Section of the intestinal papilla
(High power)

BasM: Basement membrane
 CoC: Columnar Cell
 FrB: Fibroblast
 GoC: Goblet cell
 GrC: Granulocyte
 StBo: Striated border
 TuPr: Tunica propria

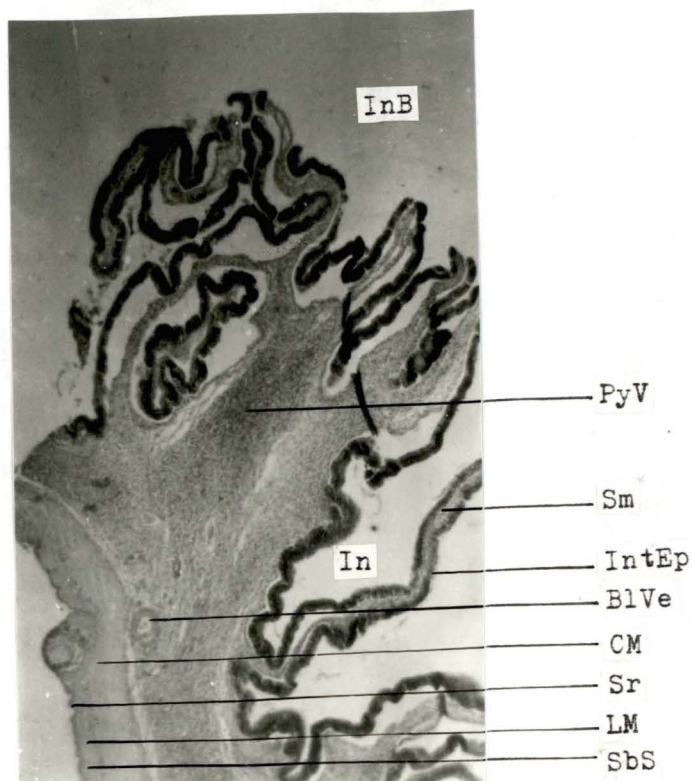


Fig 91. Section of the junction of the intestinal bulb and intestine

BlVe: Blood vessel
 CM: Circular muscle
 In: Intestine
 InB: Intestinal bulb
 IntEp: Intestinal epithelium
 LM: Longitudinal muscle
 PyV: Pyloric valve
 SbS: Subserosa
 Sm: Submucosa
 Sr: Serosa

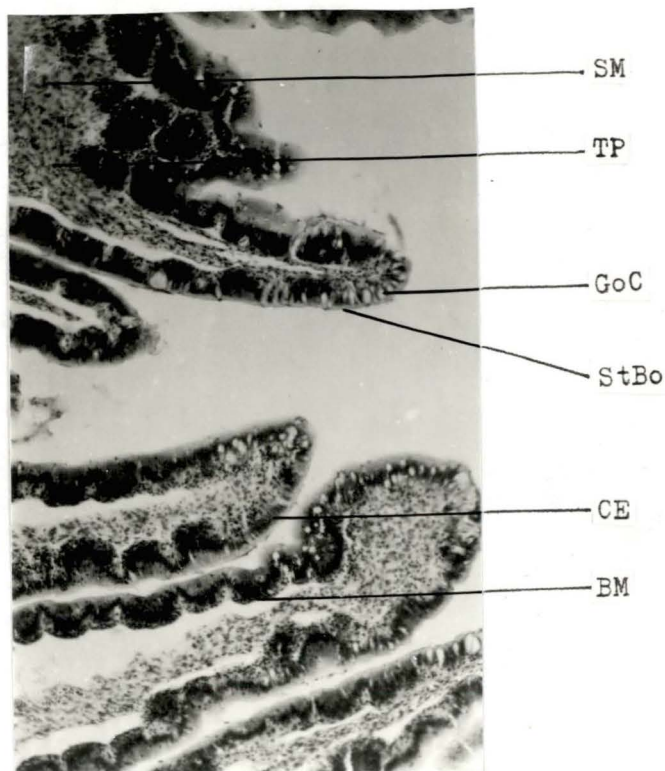


Fig 92. Section of the intestine

BM: Basement membrane
CE: Columnar epithelium
GoC: Goblet cell
SM: Submucosa
StBo: Striated border
TP: Tunica propia

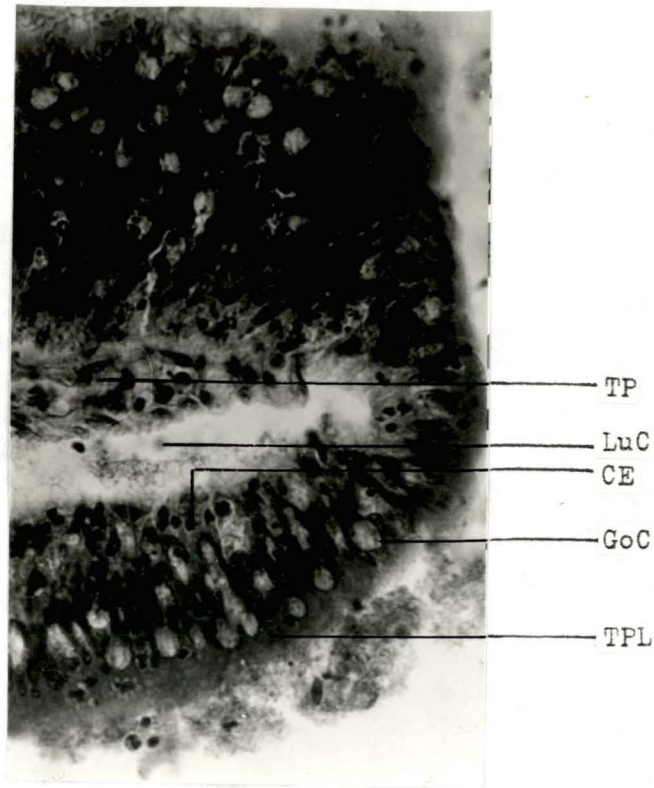


Fig 93. Section of the intestinal papillae
(High power)

CE: Columnar epithelium

GoC: Goblet cell

LuC: Leucocyte

TP: Tunica propria

TPL: Top plate

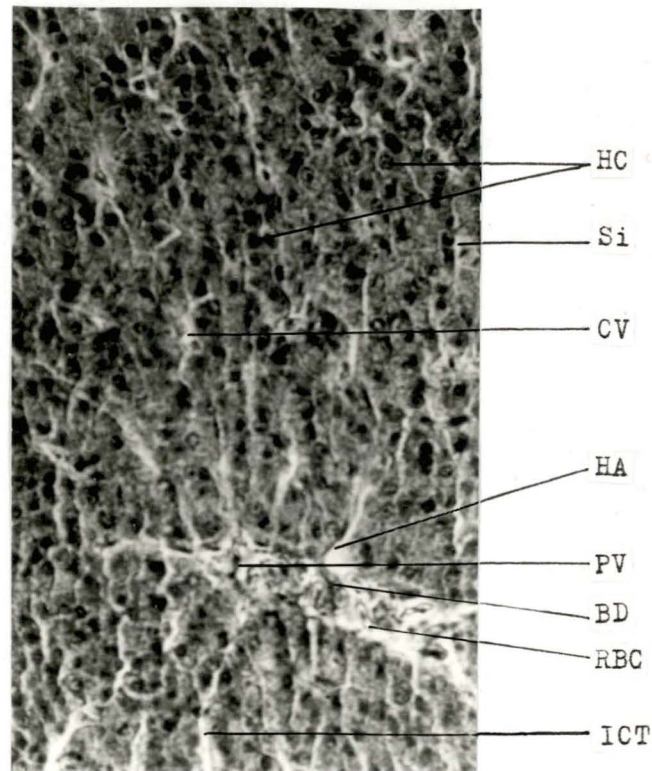


Fig 94. The structure of the lobule of the liver

BD: Bile duct
CV: Central vein
HA: Hepatic artery
HC: Hepatic cords
ICT: Interlobular connective tissue
PV: Portal vein
RBC: Red blood corpuscle
Si: Sinusoids

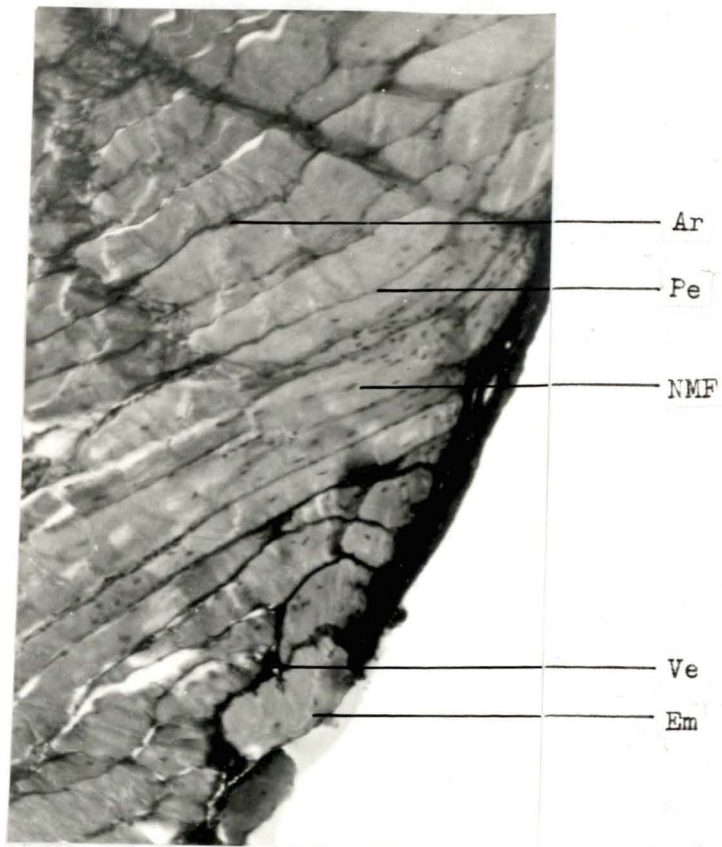


Fig 95. The structure of the skeletal muscle

Ar: Arteriole
Em: Endomysium
NMF: Nucleus of muscle fiber
Pe: Perimysium
Ve: Vein

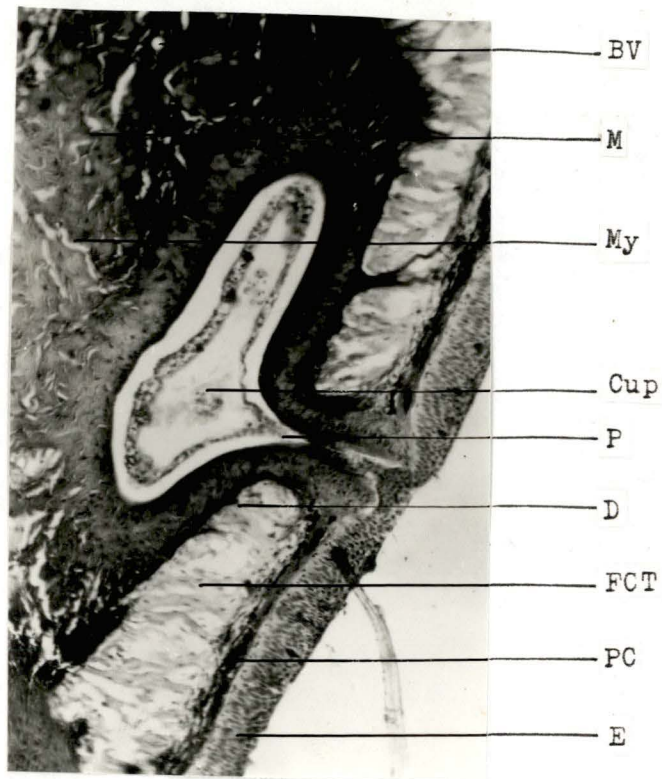


Fig 96. Section of the lateral sensory system

- BV: Blood vessel
 Cup: Cupula - one part of
 neuromast
 D; Dermis
 E: Epidermis
 FCT: Fibrous connective tissue
 M: Muscle
 My: Myoneurium
 P: Pore
 PC: Pigment cell (chromatophore)