CHAPTER III

THE OSTEOLOGY OF THE GIRDLES AND THE PAIRED FINS

The capacity of an organism for locomotor manoeuvring as we have seen earlier, is inter-dependent upon several factors including the form of the body, its framework in general and that of its fins in particular. The relative disposition of the fins and the nature and disposition of the fin muscles play an equally important role. With the divergent locomotory habits, the fins as specific organs are called upon to perform a variety of functions. It is but natural therefore to expect structural adaptations in the skeletal elements of the pectoral and the pelvic girdles of different fishes, to suit the operational efficiency expected of the paired fins. The skeletal elements of the girdles form the base for the attachment of the fin muscles and a critical understanding of skeletal system of the girdles is therefore considered essential.

A number of workers in the past have studied the skeletons of the girdles in different groups of fishes. As regards the structure of the paired fins and the girdles in the fishes selected for the present investigation, a mention may be made of Bay (1914), who studied the skeleton of *Ophioccephalus striatus*. An account of the pectoral girdle in *Nematognathi, Cyprinidae, Ophioccephalidae, Anabantidae* and *Gobiidae* is available from the work of Starks (1930). Sarbahi
(1932) and Nawar (1954) have given a brief account of the girdles in *Labeo rohita* and *Clarias lazera* respectively. Raj Tilak (1963) has studied the pectoral girdle in certain Nematognathi.

The accounts provided by the above listed workers are mostly from a taxonomic and/or phylogenetic points of view. The skeleton of the girdles and the fins have been hardly studied with a view to explain the varied adaptive modifications for the diverse locomotory habits of the fishes. An attempt has therefore been made here to study the girdles bearing in mind the various roles played by the paired fins in different fishes. The present chapter deals with the study of the skeletal elements of the pectoral and pelvic girdles of fishes selected for the present work.

Before describing the bony elements in the selected fishes, it has been considered desirable to give a general account of the pectoral and pelvic girdles in teleosts to facilitate better understanding. The following is the general account of the skeletal elements supporting the paired fins.

A. THE PECTORAL GIRDLE

The pectoral girdle in the fishes is situated close behind the neurocranium. It can be divided into two equal halves, each of which is composed of both the investing and the dermal bones. The components present as the investing bones are the coracoid, scapula and the mesocoracoid whereas the dermal bones
present are the cleithrum, supracleithrum, post-cleithrum and the post-temporal. One or more of these bones may be absent in one fish or the other.

The two halves of the pectoral girdle are in contact with each other along the mid-ventral axis of the body so as to form the pectoral symphysis. Generally, only the cleithrum takes part in the formation of the symphysis but in a few cases, the coracoid also shares in the formation of the symphysis. The symphysis is either a sutural union or only a ligamentous contact of the relevant components of the two opposite sides. Certain additional structures like denticles, grooves and plates etc. strengthen the symphysis.

Starting with the dorsal articulation of the pectoral girdle with the neurocranium and proceeding ventrally, the first bone of the girdle is the post-temporal which affords the principal articulation of the pectoral girdle with the skull. Anteriorly, the bone is generally provided with two processes, a long and sharp dorsal and a short blunt ventral one, by means of which the bone articulates with the supracleithrum. Where the supracleithrum is absent, the post-temporal is attached on the cleithrum directly.

The supracleithrum is a small bone having a spathe-like appearance. The bone is situated imbetween the post-temporal and the cleithrum. At the anterior end, the supracleithrum is partially overlapped by the post-temporal whereas its posterior end is attached to the dorso-posterior region of the cleithrum.
The cleithrum being the largest bone, forms the major part of the girdle. It is a well defined 'L' shaped, or bow shaped or is extremely irregular in structure. The bone constitutes the antero-medial, the lateral and the dorsal portions of the girdle. Besides, it also forms the posterior boundary of the branchial chamber. The antero-medial arm of the cleithrum is well developed and is thrown into ventral, dorsal and the medial laminae which exhibit variations in form and structure. In certain forms the surface of the antero-medial arm bears one or more than one ridges. The antero-medial arm takes part in the formation of the pectoral symphysis and the related surface is provided with grooves, ridges and plate like structures.

The lateral portion of the cleithrum forms an angle between the dorsal and the antero-medial arms. It forms a cup for the ball and socket joint with the pectoral spine, wherever the spine is present.

The dorsal arm of the cleithrum is an upward prolongation of the lateral portion and is a club shaped or a flat plate-like structure. In those forms where the supracleithrum is absent, the distal end of the dorsal arm is provided with two small processes which afford the articulation with the post-temporal. Where the supracleithrum is present, this arm of cleithrum is either flattened or bears a long groove to facilitate the articulation. At the junction of the lateral and the dorsal parts of the cleithrum, a posteriorly directed small process
viz. the humero-cubital process is present. In some fishes an anteriorly directed small crescentic process is also present at this junction and it supports the posterior edge of the operculum.

The post-cleithrum is a fine rib-like bone situated on the dorsal side of the girdle and is attached on the dorsal cleithral arm. This attachment is either ligamentous or the two bones may fuse with each other. The post-cleithrum is directed posteriorly downwards and is embedded in the lateral trunk musculature. In some forms the bone is composed of two elements both of which are connected with each other by means of ligaments.

The coracoid is a small bone situated almost at a right angle to the antero-medial arm of the cleithrum. In certain forms the coracoid shares in the formation of the pectoral symphysis. In such forms the corresponding surface of the coracoid is supplied with denticles. Anteriorly, the coracoid bears ridges along its dorsal and ventral surfaces and is provided with anterior and posterior coracoid-processes. The coracoid joins with the cleithrum by means of the anterior process, leaving a conspicuously large interosseous space inbetween. The union between the coracoid and the cleithrum may be sutural, ligamentous or by fusion, obscuring any distinction between them. Wherever the scapula and mesocoracoid are present, they are attached laterally to the coracoid. Posteriorly, the coracoid is slightly thickened to provide an articulatory surface for the radials.
The mesocoracoid is bar shaped, 'Y' shaped or a strip-like small bone, situated on the dorso-posterior aspect of the pectoral girdle. The bone extends across the coracoid and the cleithrum, forming an arch inbetween. This arch leaves a wide gap for the passage of the fin muscles.

The scapula is a thin translucent bone, surrounded by the cleithrum, coracoid and the radials. The bone invariably bears a scapular foramen in the middle, through which the brachial vessels and nerves pass on to the ventral side of the girdle. The posterior portion of the scapula is thickened to form an articulatory surface for the radials and thus forms the glenoid articulation along with the coracoid.

B. THE PECTORAL FIN

In close contact with the posterior half of the pectoral girdle, the proximal radials and the distal fin rays form the pectoral fin of the fishes. The radials are generally dumb-bell shaped structures, four in number and are attached to the coracoid and the scapula. The number and the shape of the radials may vary to provide flexibility to the fin.

The pectoral fin is composed of fin rays. The fin rays vary in their structure and number in different fishes. Each fin ray is composed of two elements; a dorsal and a ventral lepidotrichia. The anterior end of each lepidotrichium is modified into a well developed knob which attaches with the radial for the support of the fin. The knobs also provide
surface for the insertion of the fin muscles. Distally, each lepidotrichium is segmented and is profusely branched, exhibiting different patterns of branching. In a number of fishes the first ray is modified into a well developed spine which is strong and thick with a sharp distal end. Its proximal end is modified into a prominent head. This head bears three conspicuous articular facets which fit into the corresponding grooves present in the socket formed by the cleithrum and the coracoid. Thus the entire structure forms a peculiar locking mechanism.

G. THE PELVIC GIRDLE

The pelvic girdle and the pelvic fins exhibit a great deal of variations in their disposition which according to Norman (1958) is of some importance in classification. The pelvic girdle in the bony fishes may be abdominal, thoracic or jugular in position. Compared with the pectoral girdle, the pelvic girdle is much simple in its form and structure. It consists of two equal halves which join with each other along the mid-ventral axis of the body so as to form the ischial symphysis. The symphysis may be cartilaginous or ligamentous or at times the two halves of the girdle may fuse completely.

Each of the pelvic half is composed of a single bone known as basipterygium or the pelvic bone. The basipterygium is generally a flat triangular bone but the shape and the structure vary in different forms. The basipterygium may be provided with certain processes towards the anterior as well as posterior ends. These processes may further bear lamina-like
or ridge-like structures on their dorsal, ventral and medial aspects.

B. THE PELVIC FIN

Each pelvic fin is composed of a number of fin rays which resemble those of the pectoral fin in their structure and form. The rays are however smaller in size. They are articulated with the basipterygium generally by means of radials or cartilaginous pads. In a few forms the rays are directly attached to the girdle by means of ligaments. In certain fishes the first ray is modified into a well developed spine or a long thread-like filament. In some forms an extra curved piece of small bone called the supernumerary bone is present, attached with the proximal end of the first fin ray.

THE SKELETAL ELEMENTS OF THE GIRDLES AND THE PAIRED FINS OF THE FISHES STUDIED

A. THE PECTORAL GIRDLE AND THE FIN

NEMATOGNATHI

The skeletal elements of the pectoral girdle in Nematognathi are the cleithrum, coracoid and the mesocoracoid. The supracleithrum, post-cleithrum and the scapula are absent. The post-temporal may form either a part of the pectoral girdle or may be completely fused with the skull.
WALLAGO ATTU (Plate I)

A definite symphysis as such is not formed but the tip of the antero-medial arm of the cleithrum merely touches the corresponding surface of its counterpart. This joint is supported by ligaments.

The post-temporal is a forked bone having a dorsal and a ventral process. The dorsal process is broad and blunt and articulates with the epiotic whereas the ventral one is long and thin, articulating with the pterotic bone. The post-temporal is provided with a well developed groove which serves to house the dorsal arm of the cleithrum forming a movable joint.

The cleithrum is a well defined 'L' shaped bone. Its antero-medial arm is long and possesses prominent ventral and medial laminae. The dorsal lamina is poorly developed. The humero-cubital process is reduced. The dorsal arm of the cleithrum is approximately two thirds in length of the antero-medial arm and is bifid distally having a large anterior and a small posterior process.

The coracoid is a triradiate bone having anterior, posterior, dorsal and the ventral processes. The anterior process is the largest and is suturedly united with the medial lamina of the antero-medial cleithral arm for most of its length and then forms a wide interosseous space inbetween. Besides, the coracoid reunites with the cleithrum by its dorsal and ventral processes leaving a wide muscle canal. The dorsal process is flat and triangular in shape and is pierced by a
Plate I

Dorsal view of the pectoral girdles of
1. Wallago attu
3. Ompok macrophthalmus

Ventral view of the pectoral girdles of
2. Wallago attu
4. Ompok macrophthalmus

ADCL - Anterior process of the dorsal cleithral arm; APC - anterior process of the coracoid; DCL - Dorsal cleithral arm; DLCL - Dorsal lamina of the cleithrum; DPC - Dorsal process of the coracoid; DPTM - Dorsal process of the post-temporal; HCP - Humero-cubital process; MA - Mesocoracoid; MLCL - Medial lamina of the cleithrum; PDCL - Posterior process of the dorsal cleithral arm; PPC - Posterior process of the coracoid; PTM - Post-temporal; RAD - Radials; $R_1$ and $R_2$ - Ridges; SP - Spine; VLCL - Ventral lamina of the cleithrum; VPC - Ventral process of the coracoid; VPTM - Ventral process of the post-temporal.
nerve foramen whereas the ventral process is small and strip
like. The posterior process is poorly developed.

The mesocoracoid is a bar-like bone extending between
the dorsal arm of the cleithrum and the coracoid. It leaves a
wide muscle canal.

The pectoral fin in Wallago is composed of 15 to 16
rays which are supported by radials. There are in all 5 radials
of which the first two do not support the rays but the remaining
three radials support 4, 3 and 7 rays respectively. The first
ray of the fin is the longest and thickest but is not modified
into a spine. Excepting the first, all rays of the fin divide
twice or thrice, forming six to eight branches at the fin margin.

**Ompok Macrophthalmus** (Plate I)

The bony elements of the pectoral girdle are translucent
in Ompok and are quite similar to those of Wallago except the
anterior process of the coracoid, the radials and the fin. The
anterior process of coracoid is broad and triangular in shape
and possesses two long ridges. There are 7 radials which support
the fin. The fin is composed of 14 rays. While the first ray is
directly attached to the cleithrum and the coracoid the remaining
rays are supported by 6 radials. The first ray is modified into
a spine which is provided with a serrated inner lateral margin.
The last serration bears a small soft ray. The spine has a well
developed head which fits into the socket formed by the cleithrum
and the coracoid. The remaining fin rays are branched, each
forming six to eight branches. The pattern of branching is
dictomous. However, out of the first two branches, only the outer one is further divided in this fashion.

**MYSTUS BLEEKERI (Plate II)**

The pectoral symphysis is broad, immovable and is formed by the cleithrum and the coracoid. The coracoid takes greater part in the formation of the symphysis than the cleithrum and the union of the corresponding parts is sutural.

The post-temporal forms a part of the skull in Mystus. The cleithrum is irregular in shape and its antero-medial arm which is dorso-ventrally flattened bears a dorsal and a ventral ridges. The dorsal ridge is very prominent and becomes continuous with the vertical ridge of the coracoid whereas the ventral ridge is long but not as prominent as the dorsal one. The humero-cubital process is remarkably very well developed in Mystus. The dorsal arm of the cleithrum is short but its anterior and the posterior processes are very well pronounced.

Unlike that of Wallago and Ompok, the coracoid here is not a triradiate bone but is an irregular structure, not differentiated into any of its processes. The coracoid fuses completely with the corresponding part of the cleithrum leaving a small foramen-like space inbetween. On the dorsal side the bone bears a very high vertical ridge which becomes continuous with the dorsal cleithral ridge, leaving a wide muscle canal.

The mesocoracoid is a delicate bone extending between the coracoid and the dorsal cleithral ridge.

The fin is composed of 10 rays which are attached on
Plate II

Dorsal view of the pectoral girdles of
1. Mystus bleekeri
3. Clarias magur
5. Heteropneustes fossilis

Ventral view of the pectoral girdles of
2. Mystus bleekeri
4. Clarias magur
6. Heteropneustes fossilis

ADCL - Anterior process of the dorsal cleithral arm; CL - Cleithrum; COR - Coracoid; DCL - Dorsal cleithral arm;
DRCL - Dorsal ridge of the cleithrum; HCP - Humero-cubital process of the cleithrum; MA - Mesocoracoid; PDCL - Posterior process of the dorsal cleithral arm; PFC - Posterior process of the coracoid; RAD - Radials; Sp - Spine; VRC - Vertical ridge of the coracoid; VRCL - Ventral ridge of the cleithrum.
4 radials, each of which carries 3, 2, 2 and 2 rays respectively. The first ray is modified into a thick spine with its inner lateral margin well serrated. At the last serration a small soft ray is attached. The remaining rays are divided monocotomously where at each division only one branch undergoes further division forming six to eight ultimate branches.

**CLARIAS MAGUR (Plate II)**

As in Mystus, the pectoral symphysis in Clarias is broad and strong and is formed by the cleithrum and the coracoid. The cleithrum forms approximately two third portion of the symphysis and is supplied with a shallow groove whereas the coracoid is provided with denticle-like structures.

In Clarias, the post-temporal forms a part of the skull. The cleithrum is irregular in shape. Its antero-medial part is a dorso-ventrally flattened plate-like structure having a rough ventral and a smooth dorsal surfaces. On the dorsal side, the dorsal ridge is very high and becomes continuous with the vertical ridge of the coracoid. The humero-cubital process is small. The dorsal arm of the cleithrum is a small bifid rod with an anterior and a posterior processes.

The coracoid is dorso-ventrally flattened plate which fuses with the cleithrum leaving a very small interosseous space inbetween. The coracoid is supplied with denticles which are 7 or 8 in number. Each denticle is deeply concave anteriorly and convex posteriorly, thus it firmly fits into the corresponding part of its counterpart forming a strong interlock. The vertical
ridge is high. The posterior process of the coracoid is disc-like in structure.

The mesocoracoid is small but strong bone which suturally unites with the dorsal ridge of the cleithrum forming a wide muscle canal.

The fin is composed of 9 rays which are attached upon two small delicate radials. The first ray is modified into a strong spine. The head of the spine has three prominent articular facets and a round striated rim, all of which fits into the corresponding parts in the socket formed by the cleithrum and the coracoid. The middle part of the head is concave and is pivoted on a special narrow surface on the coracoid. The lateral margins of the spine are serrated. The remaining rays divide to form six to eight branches each, although the division decreases gradually towards the last rays.

HETEROPNEUSTES FOSSILIS (Plate II)

The pectoral girdle of Heteropneustes resembles that of Clarias except with a slight change in the shape of the humero-cubital process of the cleithrum, the posterior process of the coracoid and the mesocoracoid. The humero-cubital process is broad and runs almost the entire length of the dorsal cleithral arm. The posterior coracoid process is small. The mesocoracoid is a small 'Y' shaped bone as compared to the flat and strong mesocoracoid of Clarias.

The fin is composed of 8 fin rays which are attached upon two delicate radials. The first ray is a strong spine.
The pectoral girdle of cyprinids is composed of the post-temporal, supracleithrum, cleithrum, post-cleithrum, coracoid, mesocoracoid and the scapula. The fin is attached on 4 radials.

**LABEO ROHITA (Plate III & IV)**

In labeo the pectoral symphysis is formed by the cleithrum only. The relative tips of the cleithra of the two sides are bound by strong ligaments.

The post-temporal is a small triangular bone. It fits into a corresponding groove on the pterotic bone where it is partially overlapped by the supra-temporal. The articulation with the supracleithrum is not firm.

The supracleithrum is a long dagger shaped bone. The articulation with the cleithrum is facilitated by a long groove.

The cleithrum is crescentic in shape. Its antero-medial and dorsal arms are equal in length and can be differentiated by a well pronounced crescentic ridge. The ventral lamina of the cleithrum is very prominent forming a concave surface for the origin of the fin muscles. The anterior and the posterior oblique ridges are present. The anterior oblique ridge forms the pectoral symphysis. The dorsal arm of the bone is long and triangular in shape. On its inner side, along with the post-cleithrum, it forms a deep concavity which provides a broad and firm surface for the origin of the adductor muscle of the fin.

The post-cleithrum is a small, stout rib-like bone.
Plate III

Dorsal view of the pectoral girdles of

1. *Labeo rohita*
2. *Catla catla*
3. *Cyprinus carpio*

AMCL - Antero-medial arm of the cleithrum; AOCL - Anterior oblique ridge of the cleithrum; APC - Anterior process of the coracoid; COR - Coracoid; CPCL - Crescentic process of the cleithrum; DCL - Dorsal cleithral arm; MA - Mesocoracoid; PCL - Post-cleithrum; POCL - Posterior oblique ridge of the cleithrum; PPC - Posterior process of the coracoid; PTM - Post-temporal; RAD - Radials; SCAP - Scapula; SUPCL - Supracleithrum; I RAY - first ray of the fin.
The coracoid is irregular in shape and has a well-developed anterior process. This process unites with the two oblique ridges of the cleithrum leaving a long interosseous space inbetween. The posterior process is very small. Posteriorly the bone attaches with the mesocoracoid, scapula and the third radial.

The mesocoracoid is a small flat 'Y' shaped bone. Its two small anterior arms unite with the cleithrum leaving a small foramen inbetween whereas its posterior arm is a long and strip-like bone which unites with the scapula and the coracoid, leaving a wide canal through which passes the arrector muscle of the fin.

The scapula lies along the inner surface of the cleithrum. The bone is provided with two flattened outgrowths - a lateral and a mesial one. The lateral outgrowth is in close contact with the cleithrum whereas the mesial one attaches itself on the coracoid and the mesocoracoid. Posteriorly, the scapula articulates with the first two radials. The scapular foramen is large.

The fin is composed of 19 rays which are supported by 4 radials. The first radial which is stout, attaches on the scapula. The second is slightly larger and is also attached on the scapula. The third is the largest and is attached on the coracoid whereas the fourth radial is small and abuts against the lateral edge of the third radial and does not participate in the glenoid articulation. The first three radials carry 4 rays each and the last radial carries 7 rays. The first ray of
Plate IV

Ventral view of the pectoral girdles of
1. Labeo rohita
2. Catla catla
3. Cyprinus carpio

AMCL - Antero-medial arm of the cleithrum; AOCL - Anterior oblique ridge of the cleithrum; APC - Anterior process of the coracoid; CPCL - Crescentic process of the cleithrum; DCL - Dorsal cleithral arm; POCL - Posterior oblique ridge of the cleithrum; PPC - Posterior process of the coracoid; PTM - Post-temporal; RAD - Radials; SCAF - Scapular foramen; SCAP - Scapula; SUPCL - Supracleithrum; VLCL - Ventral lamina of the cleithrum; I RAY - First ray of the fin.
the fin is the longest and the thickest. Except the first, each ray of the fin forms four branches at the distal end.

**CATLA CATLA (Plate III & IV)**

The bony elements of the pectoral girdle resemble those of Labeo excepting the post-temporal which is irregular in shape. The fin is composed of 17 rays and excepting the first, each ray of the fin forms only two branches distally.

**CYPRINUS CARPIO (Plate III & IV)**

The skeletal elements of the pectoral girdle in Cyprinus differ from those of Labeo in their size and shape only. As in Catla, the post-temporal is irregular in shape. The dorsal arm of the cleithrum is about three times bigger than the antero-medial arm. The concavity formed by the ventral lamina of the antero-medial cleithral arm is wide and shallow, providing a broad surface for the origin of the abductor series of the muscles. The crescentic ridge which is observed in Labeo and Catla is absent here. The anterior process of the coracoid is strip-like whereas the posterior process, though small, is broad as compared to that in Labeo and Catla.

The fin is composed of 17 rays. The division of each ray is similar to that in Catla.

**NOTOPTERIDAE**

The girdle is composed of the post-temporal, the supracleithrum, cleithrum, coracoid, mesocoracoid and the scapula. The post-cleithrum is absent. The fin is supported by 4 radials.
The pectoral symphysis is formed by the cleithrum and the coracoid. The symphysis is broad and immovable as the relative components are tied by very strong ligamentous tissue.

The post-temporal is a small tubular bone which serves as a passage for the lateral line canal.

The supracleithrum is a long spathe shaped bone which fits posteriorly into a long groove on the cleithrum.

The cleithrum is a long bone with its dorsal and ventral laminae well developed. These laminae provide a wide area for the attachment of the fin and girdle muscles. The dorsal arm of the cleithrum is also well pronounced having flat lamina-like structure which supports the arrector muscle of the fin.

The coracoid has highly modified anterior and posterior processes. The anterior process is broad and plate-like in appearance and forms a deep angular groove with the dorsal cleithral lamina. The posterior process is a thin bone which forms a ring-like structure. The intersosseous space between the coracoid and the cleithrum is comparatively small.

The mesocoracoid is a stout rod which forms a wide muscle canal while articulating with the cleithrum and the coracoid.

The scapula is a small oval bone surrounded by the cleithrum, coracoid and the radials. The bone provides a condyle for the first fin ray forming a highly movable joint.
Plate V

Dorsal view of the pectoral girdles of
1. *Notopterus kapirat*
4. *Ophiocephalus punctatus*

Ventral view of the pectoral girdles of
2. *Notopterus kapirat*
3. *Ophiocephalus punctatus*

AMCL - Antero-medial arm of the cleithrum; APC - Anterior process of the coracoid; CL - Cleithrum; COR - Coracoid; DCL - Dorsal cleithral arm; DLCL - Dorsal lamina of the cleithrum; DPTM - Dorsal process of the post-temporal; MA - Mesocoracoid; PCL, PCL₁, PCL₂ - Post-cleithrum; PPC - Posterior process of the coracoid; PTM - Post-temporal; RAD - Radials; SCAP - Scapula; SUPCL - Supracleithrum; VLCL - Ventral lamina of the cleithrum; VPTM - Ventral process of the post-temporal.
The fin is composed of 17 rays which are attached on the 4 radials. The first radial is small and nodular, the second and third are slightly larger and dumb-bell shaped whereas the fourth one is the largest having a flat papery nature. Excepting the first, each ray of the fin forms two to eight branches distally.

**OPHIOCEPHALIDAE**

Excepting the mesocoracoid, all the essential bony elements of the pectoral girdle are present in Ophiocephalidae. The fin is attached on 4 radials.

**OPHIOCEPHALUS PUNCTATUS** (Plate V)

Only the cleithrum forms the pectoral symphysis for which, its anterior tip is modified into a small disc.

The post-temporal is a thin flat bone with forked anterior end. The dorsal process articulates with the epiotic and the ventral process articulates with the pterotic bone. Posteriorly, the bone is scale-like and covers its articulation with the supracleithrum.

The supracleithrum is a spathe-like bone. Anteriorly it is hidden beneath the post-temporal whereas posteriorly it covers the dorsal part of the cleithrum.

The cleithrum forms a 'L' shaped structure along with the supracleithrum. The bone has a long rod shaped antero-medial arm and a disc shaped dorsal arm. The ventral lamina of the antero-medial arm is well developed and is vertical in position.
providing a firm area for the origin of fin muscles. The dorsal arm is a flat disc on which the adductor muscles of the fin are attached.

The post-cleithrum is a flat papery bone composed of two elements, the anterior one of which is semi-circular in outline whereas the posterior one is a leaf-like slender bone.

The coracoid is a flat bone. Its anterior process is narrow and has a long ventral ridge. The interosseous space is ob-ovate and quite large. The posterior process is small.

The scapula is a quadrangular bone surrounded by the cleithrum, coracoid and the radials. The bone fuses with the cleithrum but it is suturedly united with the coracoid.

The pectoral fin is composed of 17 rays which are supported by 4 radials. Each radial is a short subquadrangular bone. The first radial is the smallest and the last one the largest. The first two radials are attached on the scapula, the third radial is partly attached to the scapula and partly to the coracoid. The fourth radial is attached to the coracoid only. The 8th, 9th and 10th rays are the largest and are profusely divided at the distal end. The lateral rays on the sides are gradually shortened and are sparsely divided.

ANABANTIDAE

Except in details of shape and size of the bony elements the pectoral girdle is quite similar to that of the ophiocephalids.
Plate VI

Ventral view of the pectoral girdles of
1. *Anabas scandens*
3. *Osphromenus gourami*

Dorsal view of the pectoral girdles of
2. *Anabas scandens*
4. *Osphromenus gourami*

AMCL - Antero-medial arm of the cleithrum; APC - Anterior process of the coracoid; COR - Coracoid; DCL - Dorsal cleithral arm; DLCL - Dorsal lamina of the cleithrum; DPTM - Dorsal process of the post-temporal; PCL, PCL₁, PCL₂ - Post-cleithrum; PPC - Posterior process of the coracoid; PTM - Post-temporal; R - Ridge on the coracoid; RAD - Radials; SCAF - Scapular foramen; SCAP - Scapula; SUPCL - Supracleithrum; VLCL - Ventral lamina of the cleithrum; VPTM - Ventral process of the post-temporal; I RAY - First ray of the fin.
ANABAS SCANDENS (Plate VI)

The bony elements of the pectoral girdle in Anabas are highly ossified as compared with those of Ophiocephalus where the bones are thin and translucent. The main features that distinguish the girdles of the two fishes are the ventral lamina of the cleithrum, the post-temporal and the post-cleithrum. While the ventral lamina of the cleithrum in Ophiocephalus is vertical and sharp edged, in Anabas, it is thick and broad and lies in a horizontal plane covering most of the parts of the girdle ventrally. The post-temporal is a small bone with long processes. It has a highly ossified knob which provides firm articulation with the supracleithrum. The post-cleithrum is a strong and compact structure as compared to the thin leaf-like elements of Ophiocephalus.

There are 4 radials which are quadrangular in shape. The fin is composed of 15 rays, out of which the middle rays are the longest. Each ray of the fin divides to form four branches.

OSPHROMENUS QOWRAMI (Plate VI)

The pectoral girdle resembles that of Anabas except in the nature of the ventral and the medial laminae of the cleithrum. The ventral lamina though well pronounced, does not overlie the other pectoral elements as in Anabas. Alongwith the dorsally placed medial lamina, it forms a deep boat shaped structure providing a broad area for the origin of the fin muscles. The ventral ridge of the anterior coracoid process is
well developed as compared with that of Anabas and forms a deep furrow on the dorsal side.

The 4 radiala are subquadrangular in shape. The fin is composed of 15 rays which are quite long, the longest being towards the middle. Excepting the first and the last, each ray of the fin forms two branches towards the fin margin.

GOBIIDAE

In Gobiidae, excepting the post-cleithrum and the mesoceraceoid, all the remaining bones of the pectoral girdle are present. The fin is attached on 4 radials.

GOBIUS STRIATUS (Plate VII)

As usual the cleithrum forms the pectoral symphysis.

The post-temporal which is a forked bone, has comparatively long dorsal and ventral processes. They are articulated with the epiotic and opisthotic bones respectively.

The supracleithrum is a small spathe shaped bone. It articulates with the post-temporal and the cleithrum.

The cleithrum has a long rod-like antero-medial arm and a short flat dorsal arm. The antero-medial arm has laterally placed ventral and dorsal laminae which extend even to the dorsal arm. The medial lamina is also present. On the dorsal side the antero-medial arm is provided with a condyle on which the pelvic girdle is articulated.

The coracoid is a small papery bone. The anterior and the posterior processes together form a common plate which
Plate VII

Ventral view of the pectoral girdles of
1. Gobius striatus
3. Mastacembelus armatus

Dorsal view of the pectoral girdles of
2. Gobius striatus
4. Mastacembelus armatus

AMCL - Antero-medial arm of the cleithrum; AP - Scapular outgrowth; APC - Anterior process of the coracoid; CON - Condyle; COR - Coracoid; DCL - Dorsal cleithral arm; DPTM - Dorsal process of the post-temporal; PPC - Posterior process of the coracoid; PTM - Post-temporal; RAD - Radials; SCAF - Scapular foramen; SCAF - Scapula; SUPCL - Supracleithrum; VLVL - Ventral lamina of the cleithrum; VPTM - Ventral process of the post-temporal; I RAY - First ray of the fin.
lies at an acute angle with the basal portion of the coracoid forming a deep furrow. The furrow provides a firm area for the origin of the coraco-radialis muscle of the fin.

The scapula is reduced and is represented by a part of the posterior extension of the cleithrum.

The fin is composed of 16 rays which are attached on 4 radials. The radials are large and sub-equal in size. They form major portion of the girdle and are attached on the coracoid and the scapulo-cleithral plate by means of cartilage. The fin rays are attached on the radials by means of a cartilaginous pad. In the fin, the middle rays are the longest and are profusely branched. The length and the branching decreases towards the lateral fin rays. The pattern of the division is monocotomous.

**MASTACEMBELIDAE**

The pectoral girdle is composed of the supracleithrum, cleithrum, coracoid and the scapula. The mesocoracoid and the post-cleithrum are absent. The post-temporal does not take any part in the formation of the girdle. The fin is supported by 4 radials.

**MASTACEMBELUS ARMATUS** (Plate VII)

The pectoral symphysis is formed by the cleithrum. The girdle does not articulate with the skull but articulates on the inter-muscular bone of the third vertebra by means of supracleithrum.
The supraeleithrum is a flat spathe shaped bone. It overlies the cleithrum on its dorsal surface.

The cleithrum is a flat bone. Only the ventral lamina of the antero-medial arm is well developed. Lying in a slanting position it forms a deep groove which serves as a firm attachment for the fin muscles. The dorsal cleithral arm is flat and has uneven ridged margin.

The coracoid is a sub-quadrangular flat bone. Its anterior and posterior processes are well developed. The bone articulates with the cleithrum, scapula and the radials by means of cartilage.

The scapula is also a quadrangular bone articulating with the coracoid and the cleithrum by means of cartilage. Posteriorly it articulates with the radials. There is a plate-like outgrowth at the outer margin. The scapular foramen is big and oval in shape.

The fin is composed of 23 rays which are supported by 4 radials. In the fin the longest rays occupy the middle position. The knobs of the dorsal lepidetrichia are peculiar in their structure and are well developed, each having a long triangular plate-like process. These processes provide a larger surface for the insertion of the fin muscles. Excepting the first and the last, the remaining fin rays are divided twice to form three to four branches.
B. THE PELVIC GIRDLE AND THE FIN

NEMATOGNATHI

In Nematognathi the pelvic girdle is abdominal in position and is freely embedded in the flesh of the abdominal wall. The structure of the basipterygium is simple and the union of the two counterparts at the ischial symphysis is cartilaginous. The radials are absent.

WALLAGO ATTU (Plate VIII)

In Wallago each basipterygium is a flat papery bone and is provided with a foramen towards its middle. The bone is provided with three anterior processes out of which the innermost is the shortest and the middle one the longest. All the three processes converge towards the midline but only the inner and the middle ones meet their fellows of the opposite side.

The fin is composed of 10 rays. Except the first, each ray is divided so as to form four branches towards the fin margin. The supernumerary ray is present.

OMPOK (Plate VIII)

Though the pelvic girdle is smaller in size than that of Wallago, the general pattern remains the same. The fin is composed of 8 rays which except the first, form only two branches each.

MYSTUS BLEEKERI (Plate VIII)

The basipterygium is a thick and well ossified bone
having an irregular shape. There are two anterior processes and a small strip-like posterior process. Two sharp laminae arise from each of the anterior processes to provide broad area for the origin of the fin muscles. The inner process has a ventral and a medial lamina forming approximately a right angle with each other whereas the outer process has a dorsal and a ventral laminae at an angle of approximately $180^\circ$ to each other.

The fin is composed of 6 rays. Towards the fin margin, excepting the first, each ray of the fin forms 8 branches.

**Clarias Magur (Plate VIII)**

The basipterygium in Clarias is a flat bone more or less triangular in shape. There is a deep notch along its anterior surface from which arise the anterior processes. The inner process is small and gradually tapers forwards and inwards to meet its counterpart. The outer process also converges forwards but does not extend to the mid-line. The posterior process is absent.

The fin is composed of 6 rays. The rays divide to form 8 branches although the first ray remains simple.

**Heteropneustes Fossilis (Plate VIII)**

The girdle of Heteropneustes resembles that of Clarias excepting the broad papery basipterygium. Its two anterior processes are long and delicate as compared to those of Clarias. The fin is composed of 6 rays but the first ray is divided here
forming two inseparable branches. The remaining rays form 8 branches each.

**CYPRINIDAE**

In Cyprinidae, the pelvic girdle is abdominal in position. Each basipterygium is a bit complicated structure. The ischial symphysis is strong and is further strengthened by a ligamentous band. There are 4 radials.

**LABEO ROHITA (Plate IX)**

In Labeo, each basipterygium has tranversely placed basal portion and an elongate and broad anterior portion. The basal portion is well ossified, rod-like in shape and is immovably articulated with its counterpart to form the strong ischial symphysis. The posterior process is well pronounced and is a backward continuation of the basal portion. At the distal end of this process a small piece of cartilage is attached. The anterior portion of the basipterygium is forked anteriorly forming an inner and an outer processes. The ridges of these two processes extend backwards to the basal portion and form a knob-like structure at the base. These ridges form a deep groove on the dorsal surface of the girdle providing a broad area for the attachment of the fin muscles.

The fin is articulated with the basipterygium by means of 3 radials. The first two radials are composed of two pieces each whereas the third is represented by a single curved bone. The fin is composed of 9 rays. The first two radials carry two
Plate IX

Ventral view of the pelvic girdles of

1. *Labeo rohita*
2. *Catla catla*
3. *Cyprinus carpio*
4. *Notopterus kapirat*

APR - Anterior process; BBA - Basal portion of the basipterygium;
IPR - Inner process; OPR - Outer process; PPR - Posterior process;
R - Ridge; SPNB - Supernumerary bone; I RAY - First ray of the fin.
rays each while the third carries 5 rays. Excepting the first, each ray forms 8 branches. The supernumerary ray is present.

CATLA CATLA (Plate IX)

The pelvic girdle of Catla resembles that of Labeo except a slight difference in the nature of the groove on the dorsal surface. In Catla, the groove is deeper and its walls are highly concave. As compared to Labeo, the division of the fin rays is not dense and the rays form 4 ultimate branches.

CYPRINUS CARPIO (Plate IX)

The essential structure of the pelvic girdle remains the same except the ridges on the ventral surface which are highly prominent and sharp edged here. Correspondingly, the groove on the dorsal surface is deep and angular. The two walls contributing to the making of this groove form an acute angle between them. As in Labeo, the fin is composed of 9 rays and the division also follows the same pattern forming 8 ultimate branches.

NOTOPTERIDAE

In Notopteridae, the pelvic girdle is too small as compared to the pectoral elements. Each basipterygium has a simple structure. The radials are absent. The girdle is abdominal in position.
NOTOPTERUS KAPIRAT (Plate IX)

Each basipterygium is a bilaterally compressed structure which is thick and round in shape. A single long anterior process is present. The bone forms an angle with the fin and lies in a slanting position in the abdominal wall.

The fin is composed of 5 delicate rays which are not branched. The fins of the two sides are thickly bound by the connective tissue forming a combined ear-like structure.

OPHIOCEPHALIDAE

The pelvic girdle though abdominal in position lies slightly anteriorwards. The basipterygia of the two sides form a distinct bi-symmetrical triangle. Since the radials are absent, the fin is directly attached on the basipterygium.

OPHIOCEPHALUS PUNCTATUS (Plate I)

The basipterygium is made up of a highly ossified basal portion and a long translucent papery anterior portion. The anterior portion can be distinctly demarcated into a broad medial lamina towards the inner side, a narrow dorsal lamina on the lateral side and a thin linear ventral lamina. The ventral lamina forms a sharp edge on the ventral surface of the girdle. The basal portion unites with its counterpart forming a sharp crest and forms an immovable symphysis. On the dorsal surface of the basipterygium, there is a deep groove which corresponds to the wedge formed by the three laminae on the ventral surface.
Plate X

Ventral view of the pelvic girdles of
1. *Ophioccephalus punctatus*
2. *Anabas scandens*
3. *Osphromenus gourami*

Lateral view of the pelvic girdle of
4. *Osphromenus gourami*

BBA - Basal portion of the basipterygium; DL - Dorsal lamina;
FL - Filament; MBR - Medial bony rib; ML - Medial lamina;
SP - Spine; VL - Ventral lamina; VR - Ventral ridge on the
medial lamina; I RAY - First ray of the fin.
The fin is composed of 6 rays. The first ray divides into two indistinct branches whereas the remaining rays divide to form four to six branches each.

**ANABANTIDAE**

The girdle is thoracic in position, lying just below the pectoral girdle. The pattern of the bony elements in Anabantidae is similar to that in Ophiocephalidae. However certain additional structures like ridges and bony rib are also present. The radials are absent.

**ANABAS SCANDENS (Plate X)**

In Anabas, the basipterygium is made up of a thick ossified basal portion and a thin translucent anterior portion. The anterior portion has the median, the ventral and the dorsal laminae arranged in the same manner as found in Ophiocephalus. On its ventral surface the median lamina bears a small inwardly directed ventral ridge which is thin and sharp edged. The ventral lamina in Anabas is better developed than that of Ophiocephalus. The thick basal portion bears an antero-ventrally directed peg-like median rib which arises along the ischial symphysis. On the dorsal surface, the median and the dorsal laminae form a shallow groove between them.

The fin is composed of 6 rays, the first one of which is in the form of a well developed spine. The remaining rays are highly ossified like the spine but divide and subdivide at their distal ends. Each ray is slightly dorso-ventrally...
compressed forming a lateral groove. This way the rays partially overlap each other in succession. The second ray forms two branches and the remaining rays form four branches each. All the branches of the ray have a common base and the dicotomous nature of branching is absent.

**Osphromenus gourami** (Plate I)

The pelvic girdle is similar to that of Anabas except that the anterior portion of the basipterygium is very long and has prominent laminae. The ventral and the medial laminae are well developed as compared to Anabas. The dorsal one is smaller than that of Anabas. The ridge of the medial lamina is also long and prominent. The medial bony rib is long in comparison with the stumpy rib of Anabas. The basal portion of the basipterygium is small but well ossified. The ischial symphysis is immovably strong. The girdle forms an angle with the fin and lies in a slanting position in the abdominal wall.

The fin is composed of 6 rays out of which the first is modified into a strong spine and the second into a long filament. The remaining rays are small with spinous proximal region and are branched distally forming three to four branches each.

**Gobiidae**

The pelvic girdle in Gobiidae is a complex structure, thoracic in position and is directly attached to the pectoral girdle. The fins of the two sides form a cup-like structure.
GOBIUS STRIATUS (Plate II)

Each basipterygium on its outer-lateral side has a triangular structure which is dorsally concave and ventrally convex. The inner-lateral wall of this triangle bends inwards towards the dorsal surface to meet its counterpart. In this manner, it forms an arched dome dorsally and a deep bowl ventrally. The medial bony rib is present and arises from the mesial edge of the flanges of the basipterygium. The median ribs of the two sides have a common origin but they get separated distally and curve in opposite directions. At the tip, they unite with the transverse rib.

Anteriorly, the girdle has a very thick cartilaginous pad which provides a socket for the articulation on the condyle of the pectoral girdle.

The fin is composed of 6 rays which are articulated with the basipterygium by means of posterior cartilaginous pad. Excepting the first, all the fin rays are composed of a dorsal and a ventral lepidotrichia having well developed knobs. The dorsal knobs are peculiar being folded upon themselves at the free margin. The first ray has a dorsal and a ventral knob out of which the ventral one has two processes whereas the dorsal one is a folded structure. The first ray is the smallest whereas the last ray is the longest in the fin. Excepting the first ray, each ray is divided profusely forming ten to sixteen branches. The division is monocotomous. The fins of the two sides unite by means of connective tissue and form a cup-like structure.
Plate XI

Pelvic girdle of *Gobius striatus*

1. Ventral view
2. Dorsal view

BA - Basipterygium; BOW - Bowl of the basipterygium; CAR - Cartilage; DOM - Dome of the basipterygium; HBR - Transverse bony rib; MBR - Medial bony rib; SOC - Socket; I RAY - First ray of the fin.