CHAPTER I

INTRODUCTION

The oldest known vertebrate seems to be Astraspis, an Ostracoderm whose fossil fragments of the head shield and detached scales have been collected from the Ordovician fresh water deposits (Moore 1949, Gregory 1951, Colbert 1955 etc.). The earliest Ostracoderm fossils are no doubt from the Ordovician but only a few fossils have been collected during this period. The succeeding Silurian period however is well known for the rich deposits of these jawless vertebrates (Dodson 1952). These vertebrates lived in fresh waters which were probably shallow and stagnated (Carter 1960) and they are generally conceived, "... as being essentially self-propelled foodtraps, with an expanded mouth-gill apparatus and with various mouth openings adapted for scooping in different kinds of food; also with varying body forms implying different ways of approach and pursuit in waters of varying movements" (Gregory 1951).

The Ostracoderms were succeeded by Placoderms - the primitive gnathostome vertebrates - during the late Silurian. These fresh water animals (Romer 1953), by virtue of jaws which they possessed, were bestowed with immense advantages over their jawless progenators. By slowly evolving as streamlined predators, they developed potentialities towards leading an active life. The best known Placoderms are Acanthodians, found in fresh water deposits extending from the upper Silurian to
the Permian period but chiefly in the Devonian (Young 1950). The Devonian Acanthodians were small fishes, completely predatory and having fusiform body (Gregory 1951, Young 1950). The more primitive Acanthodians possessed five pairs of lateral fins and the later members had as many as seven. These lateral fins served as stabilizers possibly having an effect different from that of the postulated continuous finfold of later forms.

It may be mentioned here that the paired flap-like appendages are observed behind the gills in Cephalaspid Ostracoderms like the Hemicyclapsis (Stensio 1927). In a way these appendages could be compared with the paired fins. But they are not regarded as, in any way, homologous with the paired fins of modern fishes (Newman 1939). In any event, the presence of the pelvic fins is not traced in these Ostracoderms.

From the above mentioned statements, it is seen that during the course of evolution certain Ostracoderms and some of the Placoderm successors changed their mode of feeding and instead of merely serving as self-propelled foodtraps, they took to predatory feeding. This meant an active life and as hunters, they had to move quickly in water to catch the prey and instead of spending their life as bottom living creatures, they slowly took to an active life in open waters. For this new mode of life they required the development of certain adaptive structures to help them in free and efficient mode of locomotion, conferring a better control on movements of the body in the fluid environment while darting after their prey.
To satisfy these anatomical demands probably, there arose the necessity of stabilizers resulting in the origin of fins. There is a consensus of opinion that the median fins were first to appear during the course of evolution. The presence of these primitive median fins must have been of great advantage to the fishes which took to active movements in water, as these fins possibly served as stabilizing keels and prevented the body from rolling sideways. In due course of time the fishes developed lateral appendages whose utility can be easily surmised, as organs helping in following the prey as it moved sideways and also serving as brakes in retarding the speed or manoeuvring sudden stops.

The origin and the evolution of the paired fins have been subjects of great controversy for last several years. It has invited the attention of many a research worker both in the past and present, and perhaps a correct explanation is yet to come. So far different workers have put forth different points of view to explain the origin and the evolution of paired fins. As early as 1898, Gegenbaur postulated what is to-day known as the 'Archipterygium theory'. According to this theory, the pectoral fins were derived as a result of the change in the function of the cartilaginous branchial rays, which in sharks, form long fringes around the outer margins of the gill arches. Gradually the middle rays became longer while those above and below were drawn outwards because of their growth on the basal portion of the fringe. This resulted in the formation of leaf-like appendages having a central axis formed
by the middle ray. The muscular action operating this appendage ultimately culminated in the fragmentation or the budding of the central axis and gave rise to a structure similar to the archipterygium of the lung fishes. Earlier, Dohrn (1876) had proposed that both the pectoral and the pelvic fins arose from the gill arches.

However Gegenbaur's Archipterygium theory is mainly based on hypothetical explanations that even some of his contemporaries rejected his views as simply fanciful. The Archipterygium theory is based on the assumption that the paired fins had derived from the branchial arches which in turn, extended along the lateral sides of the body much in the same way as the parapodia of the Annelids. It may be mentioned here that both Gegenbaur and Dohrn conceived Annelids as the ancestors of the vertebrates. As such, the very foundation of the Gegenbaur and Dohrn theory was illusory and is maintained these days mostly because of its historic interest.

A few years before Gegenbaur postulated his Archipterygium theory on the origin of the paired fins, Thacher (1876) and Balfour (1881) had already offered an explanation on the origin and the evolution of the paired fins. Their theory is generally known as 'Fin-fold theory' and is widely accepted by most of the workers in the field. According to this theory the formation of the median fins resulted in the development of the stabilizing keels. The median fin itself arose as a fold of skin. In due course of time the median fin
became strengthened by the addition of slender supporting fin rays. This median finfold made an advance from near the head, round the tail and thence to the anus. In this way after the fin fold had taken a strong foot-hold due to the selective forces, a further advance was made by the continuation of this fold forwards towards the head. Since the vent lay in its path, the original fold split into two portions, each of which ran forwards and a little upwards along the ventro-lateral aspects of the fish body, extending right up to the gill opening. Shortly afterwards the middle portion of these folds degenerated. The parts left at the either end became larger in size and with the passage of time they took definite shape resulting in the formation of the pectoral and pelvic fins. It may be interesting to note that this view gains support not only by identical structures of the paired and median fins but also in the embryological development of the present day cartilaginous fishes and workers like Woodwards (1892) and Dean (1909) were among the first to support this explanation on the origin of paired fins. The embryos of sharks and skates exhibit the presence of a transitory ridge of thickened epiblast between the pectoral and the pelvic fins, which is like the original ridge from which the fins arise.

The Fin-fold theory however has not met with universal approval. The main objection seems to be more against Cladoselachian type of paired fins being mentioned in support of the Fin-fold theory. According to Gregory (1936) and White (1936, 1937) the Placoderms such as Acanthodians and
Macropetalichthyids had already developed a concentrated fin skeleton and as such they argue that these Placoderms were first to arise. The fact that these Placodermi members had structures comparable with the lateral fins, which has already been mentioned earlier.

But whatever the views of the paleontologists regarding the origin and the evolution of the fin skeleton, it may be stated that the development of finfold in Cladoselachi is primitive and probably in all fishes it remains unaltered. Thus as Young (1950) has stated, "We cannot say yet for certain what has been the course of evolution of the paired fins, but the fin-fold theory has much plausibility, inspite of the difficulties raised by the paleontologists."

A study of the morphology of the paired fins and their functions has been made by several workers in the past. A good deal of work has been done to understand the osteology of these fins. A number of workers have also investigated the disposition of the muscles operating these fins. The role of the fins in various forms however has not drawn the attention it deserves.

One of the earliest accounts available on the fin osteology and the associated musculature of fishes is from the publication of Owen (1866) on the "Anatomy of the vertebrates". This was followed by the publication of Parker (1868) "On the shoulder girdle and sternum of vertebrates." Several papers have been published during the present century
which deal with the osteology of both the girdles and the paired fins. A number of workers have studied the osteology of the pectoral girdle only. Swinnerton (1905) was one such earlier worker. Later Starks in 1930 investigated the skeleton of the pectoral girdle of a number of species distributed over several families. His work is of great importance to taxonomists. Of equal importance is the work of Howell (1933) who studied the osteology of cod fish. Recently Raj Tilak (1963) has investigated the pectoral girdles of nemategnathins forms in order to find out the phylogenetic relations.

Majority of the workers in the field have studied the skeletal system of both the pectoral and the pelvic girdles. Notable among them are Day (1919) who has worked on the osteology of Ophiocephalus striatus, and Dayashanker (1933) on Labeo rohita. Awati & Bal (1933) have described the skeletal components of the girdles of globe fish (Tetradon oblongus). A mention may be made of the detailed works of Lele & Kulkarni who studied the skeleton of Periophthalmus barbarus and Karandikar & Thakur on Sciaenoides brunneus. Among the recent workers in the field are Nawar (1954), Willimovesky & Weitzmann (1955), James (1961) and Saxena (1962) who have worked on the skeletons of a cat fish (Clarias lazera), a carp (Cyprinus carpio), four ribbon fishes from the family Trichiuridae, and a common carp (Catla catla) respectively.

The associated musculature of the paired fins of teleosts has been worked out by several workers since the later
half of the nineteenth century. The nineteenth century workers are Hartmann (1871), Furbringer (1873), M'murrich (1884) and Hammele (1898). The investigation of these workers is mainly restricted to a brief study of the fin musculature restricting their observations mainly to the general morphology, in a number of fishes. Their work was followed by that of Hamburger (1904), Berjugin (1909) and Green & Green (1914). Unfortunately most of these references are not available and one has mainly to depend upon their work as cited by other investigators. A big break through came with the monumental work of Shana (1921) who studied the pectoral musculature of a number of elasmobranch and teleostean fishes. Of equal importance is the work of Grenholm (1923) who described the muscles of both the pectoral and pelvic fins in a number of teleostean fishes of several families, giving detailed morphology of the various muscles. Romer (1924) has given a very brief account on the pectoral fin osteology and the related musculature of a few fishes and has made an attempt to correlate them with that of various tetrapods. Howell (1933) has worked on skeleton and the muscle system of the pectoral fin in cod fish and he has also tried to explain the architecture of the pectoral appendage. The works of Eggert (1929) on the pectoral fin musculature of some gobids, Sheldon (1937) on the pelvic fin musculature of nemategnathine fishes and that of Harris (1960) on Periophthalmus koelreuteri are highly valuable to those who are interested in the study of fin muscles of the teleostean fishes. Greenwood & Thomson have studied the pectoral fin muscles of the fresh
water flying fish *Pantodon butchhotzi*. A mention may also be made of some of the Indian workers at this stage. Notable among them are Dubale & Sheshgiri Rao (1961) who studied the pectoral fin muscles of some fresh water cat fishes, Agrawal (1962) who investigated the osteology and the pelvic fin musculature of a grey mullet viz. *Mugil corsula*, Dubale & Christian (1963) who worked on pelvic fin skeleton and the related muscles of four fresh water siluroids, Ganguly & Nag (1964) who worked on the pectoral musculature of *Ophichthys bero* and Dubale & Christian (1965) on the osteology and the pectoral fin muscles of *Ophiocephalus punctatus*.

That the principal function of the paired fins is locomotor manoeuvring is too well known. Pectoral fins are mainly useful in this connection whereas, as Lagler (1962) points out, the role of pelvic fins is only accessory. Possibly, mainly on this account the pectoral fins alone have drawn a greater attraction of the workers in the field and the statement made by Harris (1936) that, "It is surprising to find that very few observers have offered any opinion on the role of the pelvic fins.", holds good even to this day. Nevertheless, Young (1950) has made a mention of different functions of the pelvic fins. An amputation of the pelvic fins does not seem to produce accessive rolling (Monoyer 1866, Mayer 1868, Duges 1905 and Young 1950 etc.). Presumably this function has been taken over by the dorsal and the anal fins of fishes.

Osburn (1906) was among the first to study the functions of the pectoral fins of fishes. According to him the pectorals help in the slow backward movement of the fish and act as organs
for producing a drag or as braking mechanism. In addition to the functions mentioned by Osburn, the pectoral fins also serve as the organs of equilibrium in some forms and also help the fish in creeping movements on the ground. Perhaps the most descriptive account on the locomotion of fishes in general has been given by Breeder (1926), who has described the role of the body form, lateral muscles and the paired and unpaired fins in locomotion. He has also made an attempt to correlate all these factors. Harris (1936, 1938) and Gray (1944, 1957) have described in some details the functions of the pectoral and pelvic fins and the locomotion of the fishes in general.

Interesting and sometimes fantastic accounts are given to describe the sojourn on land of some air-breathing fishes. Daldorf (1797) thought that Anabas climbs the palm trees and sucks their juice. Quite likely as Das (1940) pointed out that this Anabas was seized by a crow or a kite and deposited high up in the forks of the branches of the trees to be devoured at leisure. It is also a common knowledge that many gobid fishes - popularly known as mudskippers - move about on the sea shore. Ophiocephalids are known to move about on land. Eels are also known to creep about on land, sometimes covering pretty long distances. In most of these forms the paired fins play an important role in their sojourn.

As can be seen from the above mentioned accounts, the paired fins of different fishes are often called upon to do different functions and it is logical to expect structural
adaptive variations depending upon the particular needs of the animals concerned. The present work has therefore been undertaken primarily to find out structural variations existing if any in different forms of the paired fins of certain fresh water fishes. The following species of fishes were selected for the purpose:--

Class :- Osteichthyes
Subclass :- Actinopterygii

(A) Order :- Ostariophysi (Cypriniformes)
   (a) Suborder :- Nematognathi (Siluroidei)
       I. family .. Siluridae
          1. Wallago attu BLEEKER.
          2. Ompok macrophthalmus BLYTH.
       II. family .. Bagridae
          1. Mystus bleekeri DUMERIL.
       III. family .. Clariidae
          1. Clarias magur CUV. & VAL.
       IV. family .. Heteropneustidae
          1. Heteropneustes fossilis BLOCH.

(b) Suborder :- Cyprinoidei (Eventognathi)
       I. family .. Cyprinidae
          1. Labeo rohita HAM. & BUCH.
          2. Catla catla HAM.
          3. Cyprinus carpio LINNAEUS.

(B) Order :- Clupeiformes (Isospondyli)
   (a) Suborder :- Notoptereidei
I. family .. Notopteridae
   1. Notopterus kapirat LACEP.

(C) Order :- Ophicephaliformes
   I. family .. Ophiocephalidae
      1. Ophiocephalus punctatus BLOCH.

(D) Order :- Perciformes
   (a) Suborder :- Anabantoidei
      I. family .. Anabantidae
         1. Anabas scandens CUV. & VAL.
         2. Osphromenus goram LACEP.

   (b) Suborder :- Gobioides
      I. family .. Gobiidae
         1. Gobius striatus DAY.

(E) Order :- Opisthomi
   I. family .. Mastacembelidae
      1. Mastacembelus armatus CUV. & VAL.

The basis of the selection of the above mentioned
fishes has been as follows :-

Suborder :- Nematognathi

In Clarias, Heteropneustes and Mystus, the first ray
of the pectoral fin is modified into a well developed spine
which is used as an organ of offence and defence. Wallago and
Ompok on the other hand do not use any of their pectoral fin
rays as spine. The body form in Wallago, Ompok, Clarias and
Heteropneustes presents in general, a depressed head and a
highly compressed posterior region. In contrast, deviation from this typical nematognathine body form is met with in Mystus where the body shape is typically fusiform.

Family: Cyprinidae

The cyprinids have a typical streamline body which is generally a fusiform structure. None of the cyprinids are known to move on land and the main function of the paired fins is balancing. Cyprinids could be considered as having paired fins whose function is purely locomotor manoeuvring.

Family: Notopteridae

The members of this family have a bilaterally compressed body. The equilibrium in such forms is brought about by well developed pectoral and the anal fins. The pelvic fins are very feebly developed in these forms.

Family: Ophiocephalidae

The ophiocephalids have a torpedo shaped body which is highly adaptive for free swimming. Still their habit of walking over the land is too well known. The peculiar wriggling movements of the body are brought about with the help of the rowing actions of the pectoral fins. The pectoral fins also help the fish in burying themselves under mud during the period of drought.

Family: Anabantidae

The locomotion on land is a special feature of Anabas,
which is carried out by means of the paired fins and the gill covers. However Gourami which is closely related to Anabas, does not come on land. It is a bottom dweller and its pectoral fins are very long and are laterally placed. As the fish is bilaterally flattened, the pectorals serve as balancers and help to prevent the body from rolling. In the pelvic fins, which are also well developed, the second ray is modified into a long filament which is strong enough to serve as a support on the bottom when the fish is at rest.

Family :- Gobiidae

In Gobiidae the pectoral fins act as the mechanism for the crutching mode of locomotion whereas the pelvic fins are modified to form a sucking cup which helps in hoisting the fish on the ground before and after the skipping.

Family :- Mastacembelidae

In the spiny eel Mastacembelus, because of the distinctly elongate body form and the highly developed dorsal and anal fins, the pectoral fins do not seem to play any important role in locomotion and as such they are feebly developed as compared with other fishes. In this form the pelvic fins are absent.