CHAPTER THREE
Primitive Jawed Mouth Vertebrates (Fishes)

Jawed mouth vertebrates (Gnathostomes)

All jawed vertebrates, whether extinct or living, are collectively called gnathostomes ("jawed mouth"). All gnathostomes share in presence of jaws and paired pectoral and pelvic appendages in the form of fins or limbs. Living gnathostomes are a diverse group that includes sharks and their relatives, ray-finned fishes, lobe-finned fishes, amphibians, reptiles, birds and mammals. The last three groups are amniotes, while amphibians, fishes and agnathans are anamniotes. The last four groups are collectively called tetrapods due to having two pairs of limbs, while appendages of fishes are fins so called finned vertebrates. Fishes are grouped into **three classes**: Placodermi, Chondrichthyes and Osteichthyes. Individuals of first class are extinct and of other two classes are living.

Class 1: Placodermi

Important features

The placoderms combined the heavy external bony armor of the ostracoderms with powerful jaws of efficient fishes.

1. Bony armor: placoderms were highly diversified, despite the differences among them, all were characterized by the presence of a bony skeleton. The name Plactodermi means armored fish or plate-skinned (Gr., Plakos= plate, derma= skin). A heavy bony shield or plate (armor) covered the head and gills or anterior part of trunk, and another covered part of the trunk. The remainder of the body was either naked or had small bony scales.

2. Jaws: all placoderms, like other gnathostomes, possessed jaws. A fundamentally important evolutionary advance was achieved in vertebrates was the development of the jaws. As illustrated in **Fig.(1),** jaws seem to have evolved from the frontmost of a series of arches used to reinforce the tissue between gill slits, holding slits open. Jaws are supposed to have originated from the first pair of gill arch (mandibular arch). The second arch (hyoid arch) supports the jaws.

3. Paireds fins: most placoderms possessed paired fins for swimming faster.

Examples of Plactodermi: ***Dunkieosteus, Dinichthyes, Pterichthyodes,*** **and** ***Coccosteus sp.***, see **Fig.2.**

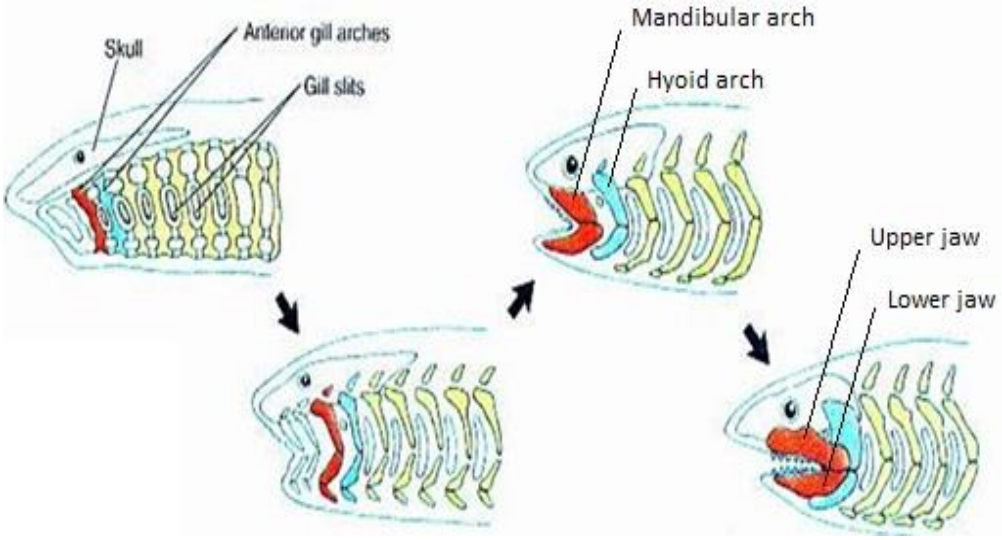


FIGURE 1: Evolution of the jaws from gill arches.

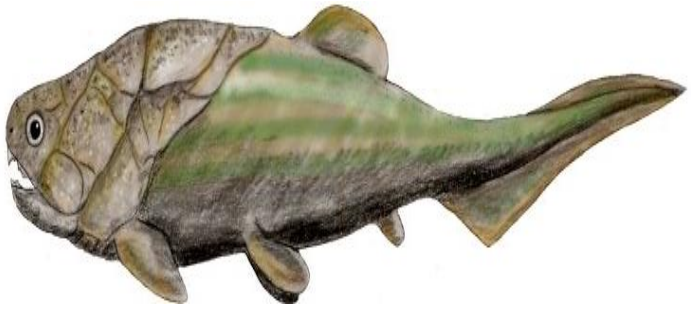
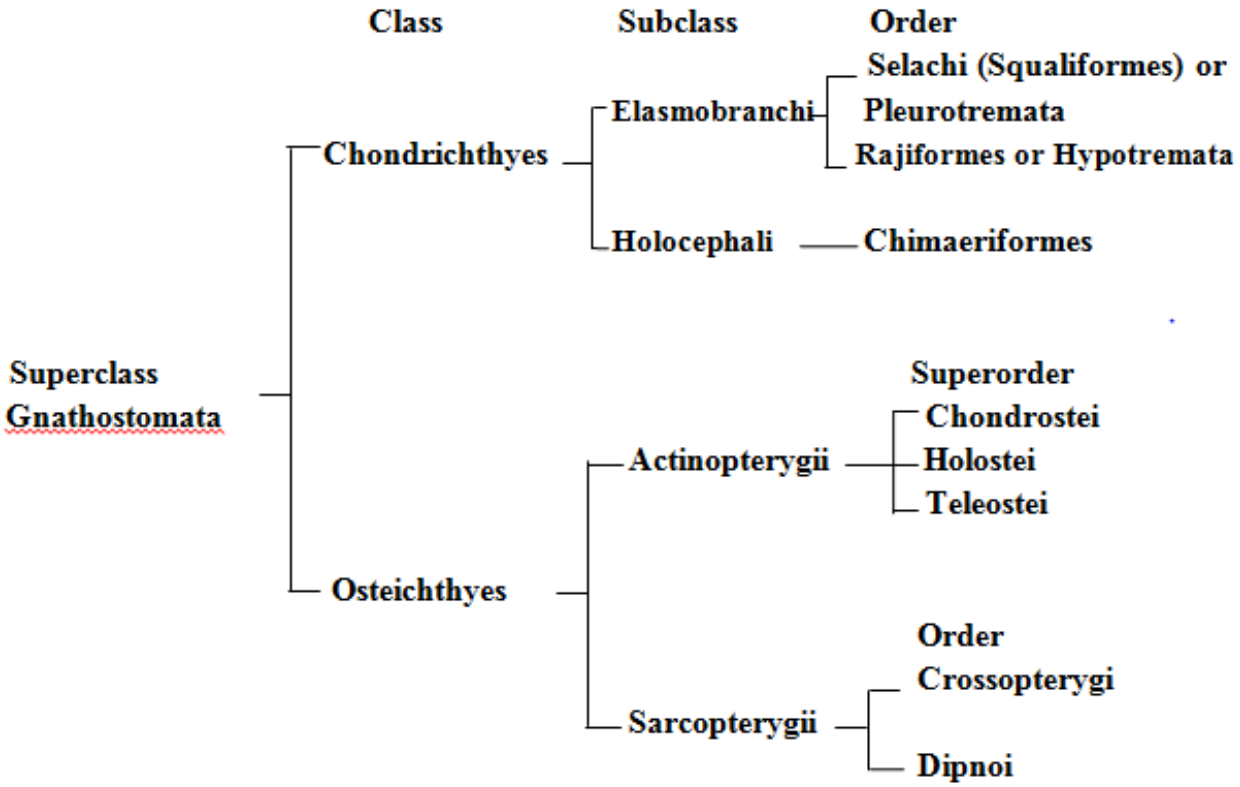


FIGURE 2: Some extinct species of Placodermi.

Living Fishes (Pisces)

Living fishes with jaws, in Latin they named pisces, while in Greek ichthyes. Ichthology science deals with study of fishes. Living or extant fishes fall mostly into two well-marked classes: the cartilagenous fishes (Class Chondrichthyes) and the bony fishes (Class Osteichthyes). Bony fishes include the familiar ray-finned fishes and the lung fishes.

The preferable scheme for classification of living fishes as follows:



Class 2. Chondrichthyes (Cartilaginous fishes) (Gr.,chondros = cartilage, ichthyes = fish)

General characteristics for all cartilaginous fishes

1. Large, about 2m long, body fusiform and dorsoventrally depressed.
2. Most of the members are marine animals and are predators.
3. Epidermis is covered by close set of placoid scales.
4. Endoskeleton is entirely cartilaginous, notochord persistent but reduced, vertebrae complete and separate.
5. Mouth is subterminal in position, each two ventral nostril leads to olfactory sacs that do not connect to the mouth cavity.
6. Jaws are armored with rows of sharp teeth.
7. Generally, true operculum (gill cover) is absent in these fishes; instead, gill slits are present. A spiracle is present which is remnant of the first gill slit.
8. Paired pectoral and pelvic fins are present in addition to the median fins. Fins are supported by cartilaginous fin rays, called **ceratotrichia**.
9. Caudal fin is mostly of heterocercal type, i.e., two lobes of the fins are unequal, diphycercal in chimaeras.
10. Swim bladder is absent.

11. Presence of a variety of sensory systems, including mechanosensory lateral line.
12. Sex separate fishes, males having claspers for reproduction. **Clasper** is the modified organ from pelvic fins act as intermittent organ for copulation (**Fig. 3).**

14. Gonads paired, reproductive ducts open into **cloaca** but chimaeras have **anus**.

15. Internal fertilization is the feature of these fishes and the development is direct.

A B

FIGURE 3: Shows the claspers, a morphological difference between the cartilaginous fishes; (A) male, and (B) female. Dimorphism

Subclass A. Elasmobranchii: Sharks, Skates, and Rays

Elasmobranchii (Gr., Elasma = plate, branchii = gills. i.e. plate like gilled fishes). Elasmobranchs are either oviparous or mostly ovoviviparous. Gestation periods are of two years, the longest period of any known vertebrates.

Examples: sharks, skates, rays.

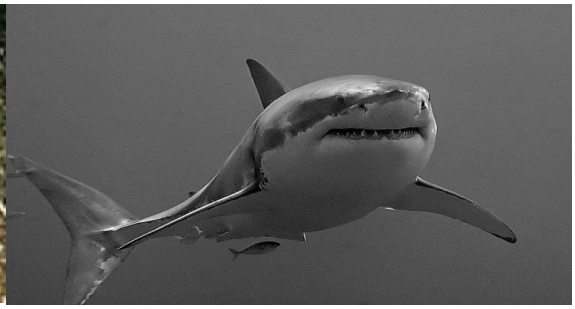
Order 1. Selachi (Squaliformes) or Pleurotremata (Gr., selakhe = a shark, pluero = side, trema = opening).

Special characteristics

1. Body typically spindle shaped and moderately dorsoventrally pressed.
2. Gill slits 5 to 7, laterally located, so-named Pleurotermata. Spiracles are small.
3. Pectoral fin moderate, constricted at base.
4. Caudal fin is heterocercal.

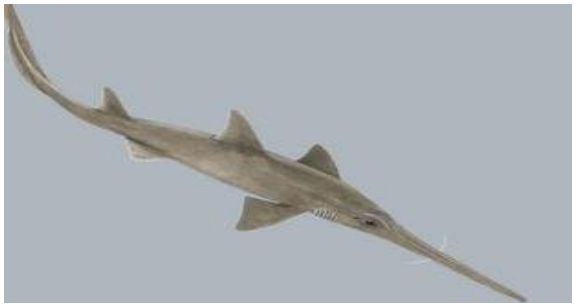
Examples: True shark, about 250 living species, **whale sharks, Basking shark, White shark, *Z*ebra shark, Frilled shark, Hammer headed shark, Dogfishes, spiny dogfish shark, Sawshark (Fig.4).**

Spiny dogfish *Squalus sp.*



White shark *Carcharodon sp.*

Hammer headed shark *Sphyma sp.*



Sawshark Peristiophorus

FIGURE 4: Some species of Squaliformes.

Order 2. Rajiformes or Hypotremata (Gr.,hypo=below,trema= opening) The term hypotremata refers that the gill openings of the members of this order are located lateroventrally, but like all other cartilaginous fishes in ventral location of mouth. Nostrils (external nares) are located behind the eyes, they appear in dorsal view **(Fig.5).**

Special characteristics

1. Body highly depressed, flattened dorsoventrally.
2. Gill slits 5 pairs located ventrally so-named Hypotremata.
3. Enlarged pectoral fins, fused to the side of head and body, are used in swimming like wings. In giant mantas or devil fishes (***Manta, Mobula)*** many have pectoral fin spread of 6 meters and weight nearly half ton.
4. Spiracles large and highly functional.
5. Tail has changed to a whip-like organ for defense.
6. They spend much time in the bottom and are mollusk-eating fishes.

Examples: Skates, rays, and sawfishes, about 300 species. **Common skates, Sting ray, electric ray, eagle ray, Guitar fish, sawfish (Fig.6).**

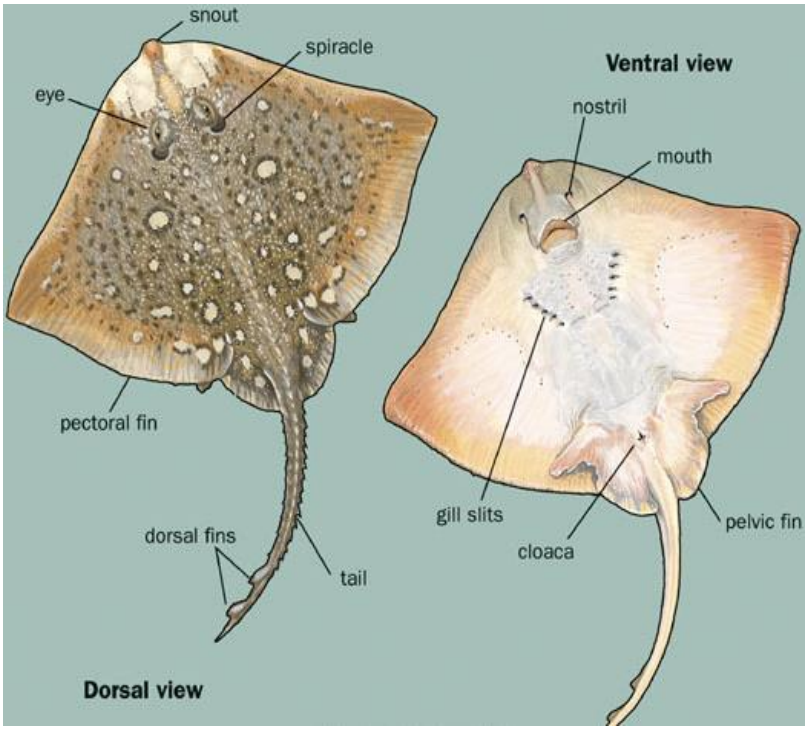


FIGURE 5: Dorsal and ventral view of rajiform fish, *Raja sp.*

Common skate *Raja sp.* (Ventral view) **Electric ray *Torpedo sp.***

Eagle ray *Myliobti sp.* **Sawfish *Pristis sp.***

FIGURE 6: Some Rajiformes species.

Electric rays have electric organs (muscles) capable of generating a high voltage that immobilizes the prey. Sawfishes, not to be confused with sawfish shark , the latter (sawshark) have the rajiiform shape.

Subclass B. Holocephali

Order Chimaeriformes

The subclass Holocephali contains just this order. The Members of this small subclass distinguished by such suggestive names as chimaeras, also spelled chimeras, also called **ghost sharks**. A chimaera is a strange fish has a big head with large eyes and a snout in front of its eyes. It has a network of lines over its surface. The lines often look like seams. They give the impression especially in Ancient Greek mythology that its body consisted of parts of different animals joined together.

Some chimaeras are known as ratfish because their body tapers into a long, rat-like tail and their teeth look somewhat like rat incisors. Others are called rabbitfish because their face reminded early naturalists of a rabbit's face. The name "elephant fish" arose because in some species the tip of the snout has a curled projection that looks like a miniature elephant's trunk. Rhinochimaeras have a long projection from their snout. Their closest living relatives are sharks.

Chimaeras are cartilaginous fish

Like other members of the class Chondrichthyes, chimaeras have several characteristics lead to linking them to members of this class and similar to sharks.

1. Body is somewhat compressed and the skin is naked in adults and if placoid scales present they occur only in a few patches.
2. Their color can range from black to brownish gray.
3. Endoskeletons are constructed of cartilage.
4. Fins supported by ceratotrichia.
5. For defense, most chimaeras have a venomous spine in front of the dorsal fin.
6. They employ claspers for internal fertilization of females.
7. They lay eggs in spindle-shaped, leathery egg cases.
8. They use electroreception to find their prey.

Unique characteristics of chimaeras

They differ from sharks through possessing their unique following charcteristics:

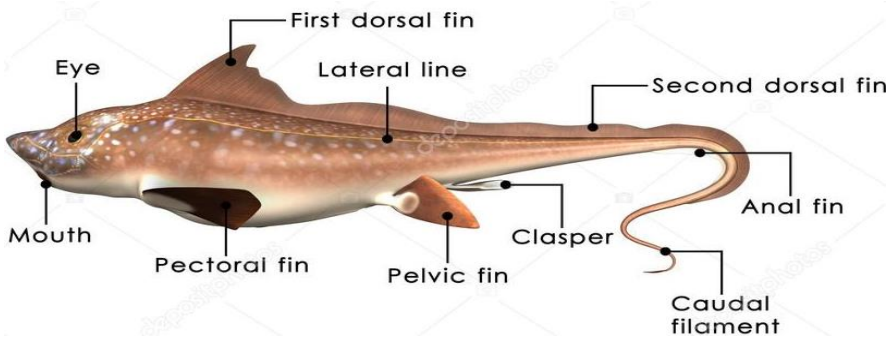
1. Holostylic upper jaw, i.e., upper jaw is completely fused to the cranium, the most unusual feature in fishes. This feature indicates the name (holos = whole, cephalos = head).
2. Spiracle absent.

3. They lack shark's many sharp and replaceable teeth, having instead just three pairs of large permanent grinding tooth plates used in crushing mollusks.
4. They have soft fleshy gill covers or opercula, cover a common opening for 4 gills.
5. Pectoral fin broad and leaf-shaped. These fishes move by using sweeping movements of these large pectoral fins.
6. They have separate anal and urogenital openings like some bony fishes.
7. In addition to pelvic claspers, males possess other unknown function claspers on the head.
8. They have long slender and whip-like tails.

The above external features indicate that holocephalan fishes occupy a position between elasmobranchs and bony fishes. It resembles elasmobranch in some characters and bony fishes in others, so they are of special interest to the comparative anatomist.

Today, there only 25 species are extant.

Examples: Ratfish *Chimaera*, *Callorhynchus* and *Harriotta* (Fig.7).



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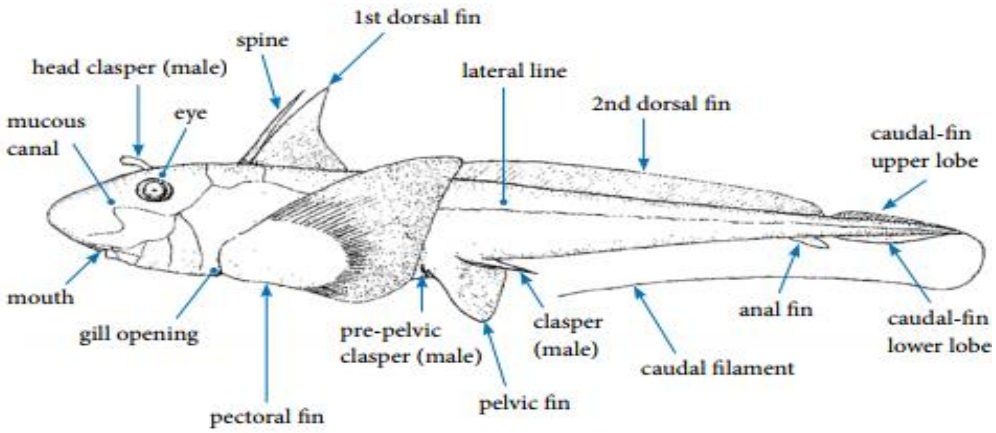


B

FIGURE 7: (A) *Chimaera sp.*, Ratfish and (B) Ratfish general form.

Class 3. Osteichthyes (bony fishes) (Gr., Osteon = bone, ichthys = a fish).

The class Osteichthyes is truly the most successful group of aquatic vertebrates**.** **Osteichthyans** includes the dominant fishes of seas today. No other group surpasses them in evolutionary diversity and number. Osteicthyes contain 96% of living fishes and all living tetrapods. Bony fishes and tetrapods are united by the presence of endochondral bone (bone that replaces cartilage developmentally), lungs or swim bladder derived from the gut, and several cranial and dental characters.

General characteristics

1. All are aquatic, either marine or fresh water.
2. Body covered by dermal scales cycloid, ctenoid or ganoid.
3. The endoskeleton is partly or largely constructed of bone.
4. Mouth usually terminal. Jaws are with teeth.
5. Paired and unpaired fins are present. Fin rays are spiny and supported by long dermal rays called **lepidotrichia.**
6. 4 pairs of gills on bony gill arches remain in pouch and covered with true bony **operculum**.
7. Gills are of the filamentous type.
8. Spiracle is absent except in some primitive forms (***Acipenser*** and ***Polypterus***).
9. Caudal fin usually homocercal, i.e., the two lobes of the fin are equal.
10. A **swim bladder** often present with or without duct connected to pharynx. Lung-like in some (dipnoi), benthic feeder and deep sea fishes lack it.
11. Claspers are absent in males.
12. Notochord replaced by distinct vertebrae.
13. Cloaca lacking, anus present.
14. Well-developed lateral line system.

15 Sexes separate, fertilization usually external, mostly oviparous.

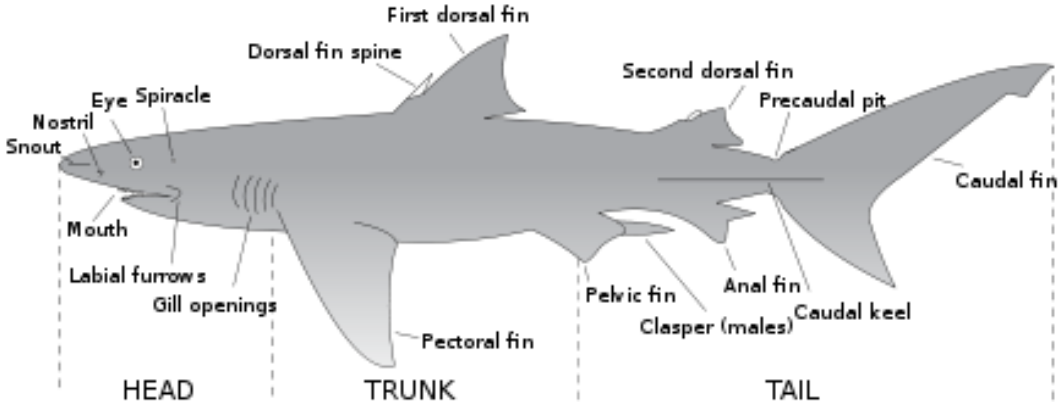
16. Development direct, rarely with metamorphosis.

There are as well over 30,000 – 40,000 living species. The class Osteichthyes includes all the bony fishes that we are familiar with them. Class Osteichthyes is divided into two subclasses based on the structure of the paired appendages (fins). **Actinopterygii** (ray-finned fishes) and **Sacropterygii** (lobe-finned fishes).

General comparison between Chondrichthyes and Osteichthyes is shown in **Table (1)**, and **Fig. (8)**.

Table 1. Comparison between cartilaginous and bony fishes

Chondrichthyes (cartilaginous fishes)	Osteichthyes (bony fishes)
1. Mostly marine.	1. Both marine and freshwater.
2. Usually dorso-ventrally flattened.	2. Bilaterally flattened.
3. Mouth and nostrils are ventral, mouth large and with crescent shape	3. Mouth terminal and variable in shape and size. Nostrils above to mouth.
4. Mostly first gill slits reduced to spiracles which just behind the eyes.	4. Spiracles are lacking.
5. Five pairs of naked gill slits, no true operculum.	5. Four pairs of gills lie in pouch covered by Bony flap which is true bony operculum.
6. Exoskeleton comprises separate dermal Placoid scales.	6. Exoskeleton comprises various types of Overlapping dermal scales: cosmoid, ganoid, cycloid or ctenoid.
7. Endoskeleton is wholly cartilaginous.	7. Endoskeleton is mostly bony.
8. Pelvic fins far more from pectoral fins.	8. Pelvic fins usually near to pectoral fins.
9. In males two claspers each inside to pelvic Fin for transferring sperm into female genital tract.	9. Claspers are absent.
10. Cloaca is a common opening for three ducts: alimentary, urinary and genital. cloaca lies between two pelvic fins.	10. Anus and urinogenital apertures open separately, no cloaca.
11. Fertilization internal.	11. Fertilization external in water.
12. Eggs few, large with much yolk.	12. Eggs numerous, small with less yolk.
13. Internal development in ovoviviparous type, and if external (oviparous) occurs in egg case.	13. Development usually external without egg case.
14. Swim bladder absent.	14. Swim bladder present for buoyancy.



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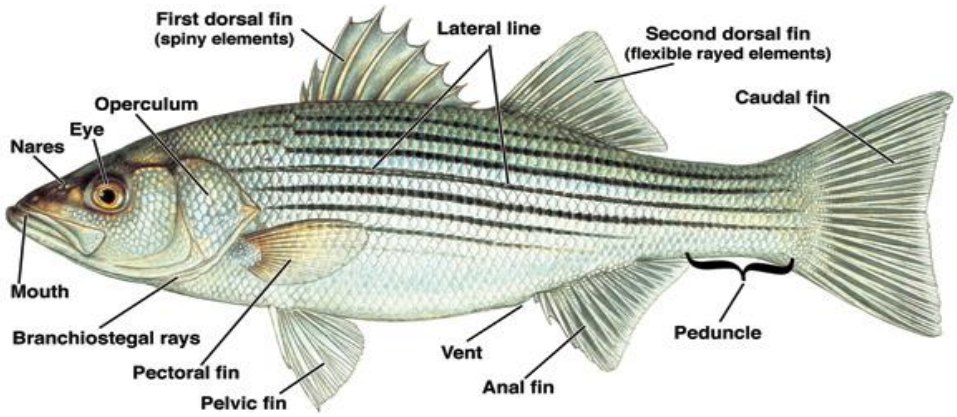

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FIGURE 8: Morphological differences between (A) cartilaginous fish and (B) bony fish.

Subclass A. Actinopterygii (Gr., actis = ray, Pteryx = fin): **Ray-finned Fishes**

Special characteristics in comparison with other bony fishes

1. Olfactory sacs are not connected to mouth cavity, so internal nares are lacking.
2. Swim bladder often present mostly with closed duct connecting to esophagus, functioning in buoyancy (hydrostatic organ).
3. Paired fin without fleshy lobe.
4. Most common fishes are included in this group popularly called ray-finned fishes, almost 27000 species are estimated.

There is a difference of opinion regarding the classification of Actinopterygii. The subclass is usually divided into three groups or superorders, according to the degree of ossification in their cartilaginous endoskeleton, namely **Chondrostei, Holostei** and **Teleostei.**

Superorder I. Chondrostei (Gr., chondros = cartilage, osteon = bone)
This superorder includes primitive ray-finned fishes, so it is an ancient superorder with only few living species today. Their fishes were also known as the "fring-finned ganoids" because of the fring-like appearance of the eight or more dorsal fin elements, and the presence of ganoid scales.
Examples: Bichir, Sturgeon, Paddlefish (Fig.9).

Bichir *Polypterus sp.*

Sturgeon *Acipenser sp.*

Paddlefish *Polydon sp.*

FIGURE 9: Three primitive chondrostean fishes.

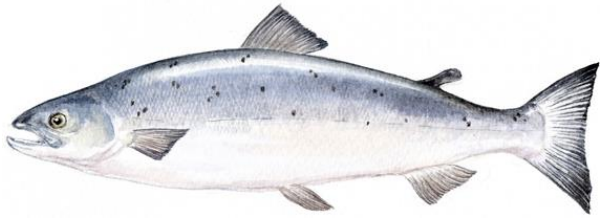
Superorder II. Holostei (Gr., holos = entire, osteon = bone)
Only two genera of living fishes belong to the superorder Holostei. Both are freshwater forms and represent a transition between Chondrostei and Teleostei. Chondrosteans and holosteans as well as numerous extinct forms have, in the past, been referred to as "ganoid" fishes.
Examples: Bowfin, Garpike (Fig.10).

Bowfin *Amia sp.*

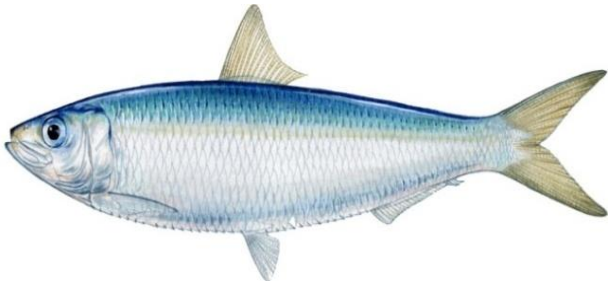
Garpike *Lepidosteus sp.*

FIGURE 10: Two holostean living fishes.

Superorder III. Teleostei (Gr., teleos = complete, Osteon = bone)
All the remaining ray-finned fishes are included in the superorder Teleostei. Teleosts are the most recently evolved ray-finned fishes and hence are referred to as "modern fishes". Ninety-five percent (%95) of all living fishes in the world come under this category. About 20,000 species have been identified. Selected species in **Fig.(11) .**

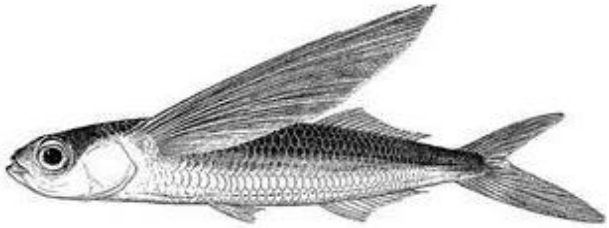


Salmon *Salmo sp.*

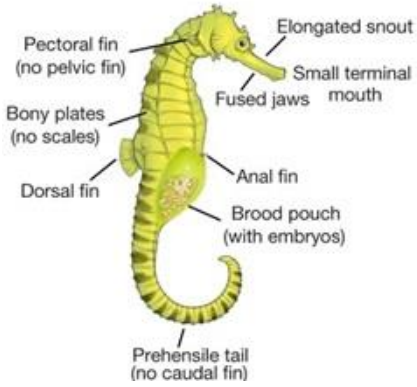


Sardine *Sardinops sp.*

Eel fish *Anguilla sp.*



Flying fish *Exocoetus sp.*



Sea horse *Hippocampus sp.*

Porcupine fish *Diodon sp*

Frog fish *Antenarius sp.*

FIGURE 11: Selected teleost fishes.

Subclass B. Sarcopterygii (Gr., sarcos = fleshy, pterygium = fin): Lobe-Finned Fishes

Special features in comparison with actinopterygian bony fishes

1. The key derived character of lobe-fins is the presence of the rod-shaped bones surrounded by a thick layer of muscle in their pectoral and pelvic fins. This fleshy lobe at the base of the paired fins can be compared with the paired limbs of the tetrapods.

2. Most Sarcopterygians, except coelacanths, have internal nostrils or choanae, hence the previous name of subclass, **Choanichthyes**.

3. Usually with lung-like swim bladder used as a respiratory organ in some species during drought, so-called lung fishes.

4. Primitive species had heterocercal tail, but recent forms possess diphycercal tail.

The sarcopterygian today is represented by only 8 species, 6 species of lung fishes and 2 species of coelacanths. The subclass is divided into two orders, which include the typical lobe-fins, and the true lung fishes, respectively.

Order 1. Crossopterygii or Coelacanth (Gr., crossoi = fringe, pterygx = fin).
All members of this order are extinct with one exception, ***Latimeria***. The crossopterygians or coelacanths were thought to be extinct 75 million years ago until the amazing discovery of ***Latimeria***. The first living specimen was caught at a depth of about 80meters near the eastern coast of South Africa in the year 1938. The fish was steel-blue in color measuring about 1.5 meter in length. Later on, many fishes of ***Latimeria*** species were caught in different areas as those of Comoro Islands (Madagascar), North West corner of Sulawesi, a central Indonesian island. The next species was caught 10,000km away from the Comoro Island.

General features of *Latimeria* species

1. The body is covered with cycloid scales, round and overlaps.

2. In addition to its rather complex paired pectoral and pelvic fins, it has two unpaired dorsal fins and a single ventral anal fin. All except the first dorsal fin are typical lobe-fins **(Fig.12).**

3. Caudal fin diphycercal with a small median lobe, so apparently with 3 lobes.

4. Internal nares are lacking.

Latimeria sp

FIGURE 12: Living crossopterygian or a coelacanth fish. This lobed-fin fish was found living off the coasts of southern Africa and Indonesia.

Order 2: Dipnoi (Greek, di = double, pnoe = breathing)
These lobe-finned fishes are sometime referred to as true lung fishes that use swim bladders for respiration in time of drought only.

General characteristics

1. Internal nares or choanae are present.

2. Swim bladder is of the physostomous type; it is well developed, highly vascularized and used as a lung in respiration, more efficient than many amphibian's lungs.

3. Paired lobe-fin present .

4. Median fin continues to form diphycercal caudal fin.

Examples: There are three genera of dipnoans found living till date. ***Protopterus*** lives in the large lakes of tropical Africa. ***Neoceratodus*** lives in Australia. ***Lepidosiren*** lives in South America (Brazil) (**Fig.13).** All these fishes are considered a living fossil.

FIGURE 13: Three genera of dipnoans (lung fishes).

Suggested questions

1. Squaliformes or pleurotremata differ from rajiiformes or hypotremata in
A. ventral cloaca B. male claspers C. having spiracle D. compressed laterally E. no differences

2. Holocephalan (chimaeras) are cartilaginous fishes but similar to bony fishes in
A. no spiracle B. spiny (placoid) scales C. males have claspers D. no cloaca E. both A and D

3. The fishes which use a swim bladder as a lung for air breathing as you do when water is depleted belong to **order**
A. crossopterygi B. sarcopterygi C. pleurotremata D. hypotremata E. none of these

4. One of the following organ appears dorsally in skates (hypotremes):
A. gill slits B. spircles C. nostrils D. mouth E. none of these

Q2. Give the common name for the animals belong to the following taxa?

1. Mostly all fishes belong to order pleurotremata.

2. Fishes belong to order Dipnoi.

Q3. Give the Greek or Latin meaning for the following terms?

Chondrichthyes, Osteichthyes, Hypotremata, Pleurotremata , Sarcopterygii, Actinopterygii, Dipnoi.

Q4. Give three differences between chimaeras and other cartilaginous fishes?

Q5. Draw and label typical bony fish belong to subclass Actinopterygii?

Q6. Draw and label a skate from ventral view?