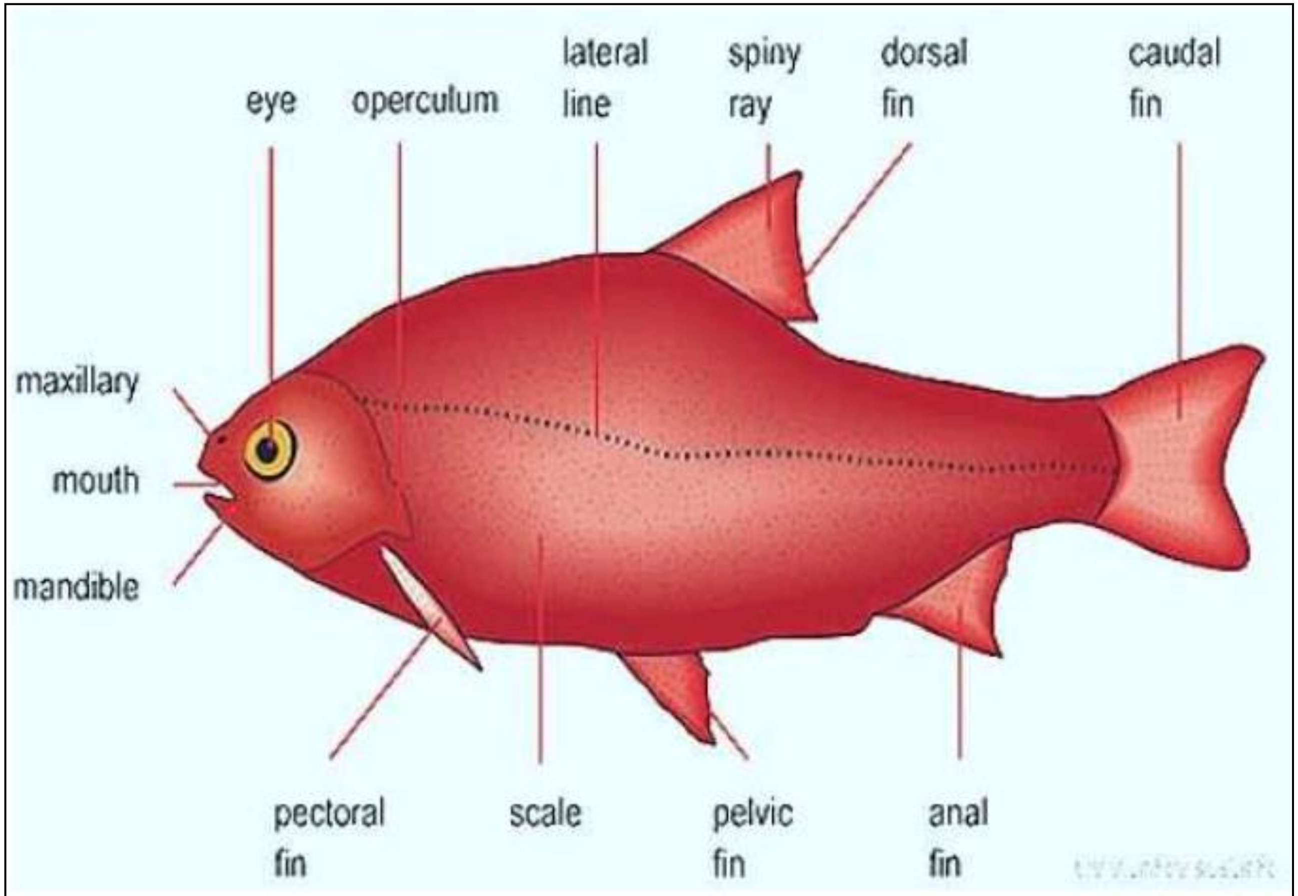

Fig 1.1 General characteristics of fish

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General characteristics of fishes:

i. Fishes differ from each other in shape, size, habits and habitats.
ii. Fishes can live in all the rivers, seas, oceans, lakes, reservoirs, canals, tanks, ponds etc, either freshwater or marine.
iii. Fishes have streamlined body differentiated into head, trunk and tail and use fins for locomotion.
iv. Body covered by scales, denticles or bony plates (in Placodermi), Placoid scales in Chondrichthyes and ganoid, cycloid or ctenoid in Osteichthyes.
v. Cartilaginous or bony endoskeleton is cartilaginous or bony. Presence of well-developed skull.
vi. Gills used for respiration. Have 5-7 pairs of Gill-slits, naked or covered by an operculum.
vii. Poikilothermic.
viii. Heart is venous and two chambered, i.e., one auricle and one ventricle.
ix. Ureotelic excretions and Kidneys mesonephros.
x. 10 pairs of Cranial nerves.
xi. Paired nostrils.
xii. Well-developed lateral line system.
xiii. Sexes are separate.
xiv. Fertilization is internal or external.

HABIT AND HABITAT

In fisheries Food and feeding pattern or habit is very important factor that helps to choose the fish type for cultivation.

It helps to avoid fight among them for getting food in different water levels.

According to their feeding habits fishes are

- Carnivorous
- Herbivorous
- Omnivorous

While a large portion of them are adaptable in their feeding habits and use the promptly available diet. Only a few fish groups are strictly herbivorous or carnivorous and the available food helps to decide if it will be eaten by the fish.

Fishes show diversity in behavior and variety of foods adapted to feed on zooplankton, snails, and coral, many classes of animal and some plants.Fishes can eat plants, macro algae (seaweed), plankton (microscopic animals and plants), invertebrates (mosquito larvae, dragonflies, and shrimp) and even other fish. These also needs particular habitat conditions for better survival.

Fish habitat means a place used by any fish at any stage at any time of the year.

Fishes have difference in shape, size, eating quality, fighting ability, reproduction and growth but they all have a common characteristic, i.e. they all depend on habitat and the type of habitat may sometimes depend on their stage of life. The water in which fish live has to be the right type whether it is freshwater, estuarine or saltwater.

Fish habitat is more than just the water it includes:

- The materials that provide the underlying structure: e.g. rocks, coral, gravel, sand and mud
- Types of vegetation present: e.g. overhanging vegetation, reeds, water plants, algae, dead wood (snags), seaweeds, sea grasses, mangroves and saltmarsh
- Shape and nature of the habitat: e.g. pools and riffles, billabongs and reefs
- Connections to other water bodies and ecosystems. Like streams, beaches, estuaries

Based on temperature tolerance fishes can be of two types

i. **Eurythermal:** wide temperature tolerance.

ii. **Stenothermal:** narrow range of temperature tolerance.

Based on salinity tolerance fishes are

i. **Euryhaline :** Fishes that can tolerate a wide range of salinity

ii. **Stenohaline :** that can tolerate a narrow range of salinity.

Some fishes can survive in pure freshwater (0.01 ppt total dissolved solids) and in very salty lakes (100 ppt).

Thus based on salinity fishes are divided into

a) **Brackishwater Fish**: fishes that tolerate a wide range of salinity (0.5 – 30.0 ppt).
Mostly found in backwaters, estuaries and coastal waters.
Example: Mullet, Milkfish, Seabass,Pearlspot, Mudskipper, etc.

b) **Marine Fish**: Fish that live most of their life in seawater, like Seas and Oceans,having salinity above 30 ppt.
Example: Sardines, Mackerel, Ribbonfish, Anchovies, Grouper, Cobia, Tuna, etc.

TYPES OF FINS

The primary locomotory organs of fish are their fins, which come in two varieties: middle or unpaired fins and paired fins. Three fins make up the median fins: a dorsal on the back, an anal behind the ventral side, and a caudal at the end of the tail. The pectorals and pelvics, which correspond to the fore and hind limbs of terrestrial animals, are represented by the paired fins. Skeletal rods known as the radials and dermal fin rays support both the median and paired fins. The fin rays of teleosts are bony structures with branches and joints called lepidotrichia. A fin is a little part or limb that is joined to a bigger body or structure.

Fins are characteristic anatomical features composed of bony spines or rays protruding from the body of a fish. They are enclosed with skin and joined together either in a webbed fashion, as seen in most bony fish, or similar to a flipper, as seen in sharks. Apart from the tail or caudal fin, fish fins have no direct connection with the spine and are supported only by muscles. Their principal function is to help the fish swim.

Fins located in different places on the fish serve different purposes such as moving forward, turning, keeping an upright position or stopping. Most fish use fins when swimming, flying fish use pectoral fins for gliding, and frogfish use them for crawling. Fins can also be used for other purposes; male sharks and mosquito fish use a modified fin to deliver sperm, thresher sharks use their caudal fin to stun prey, reef stonefish have spines in their dorsal fins that inject venom, anglerfish use the first spine of their dorsal fin like a fishing rod to lure prey, and triggerfish avoid predators by squeezing into coral crevices and using spines in their fins to lock themselves in place.

Mainly two types of fins in fishes: Median or unpaired fins and Paired fins.

Median or unpaired fins: All fishes' median fins grow as a result of differentiation within an ongoing embryonic fin fold. A tissue fold that runs continuously along the back from the tip of the tail to the cloaca forms initially dorsally along the body during development. This condition is exhibited in lampreys and denotes a primordial state of the median fin. A succession of cartilaginous rods is then used to strengthen this fold. The formation of distinct dorsal, caudal, and anal fins in higher fishes results from the concentration of radials in specific regions and the degeneration of the fold in the spaces in between the fins. According to the ontogeny of the median fins in telesots, concentration is a critical developmental phase since these fins are essentially segmental structures in terms of their neurological, muscular, and skeletal components. The middle fins of sturgeons represent a primordial kind among modern bony fishes. A fleshy lobe with fin muscles enclosing the basal and radials is given on the dorsal and anal at their bases. The fleshy lobe at the base of the fin has vanished in all upper bony fish species, and the radials have been reduced to bone or cartilage nodules.

The dorsal, anal and caudal fins are unpaired and situated along the midline of the body. Cadual fin are: (i) Protocercal ii) Heterocercal iii) Homocercal

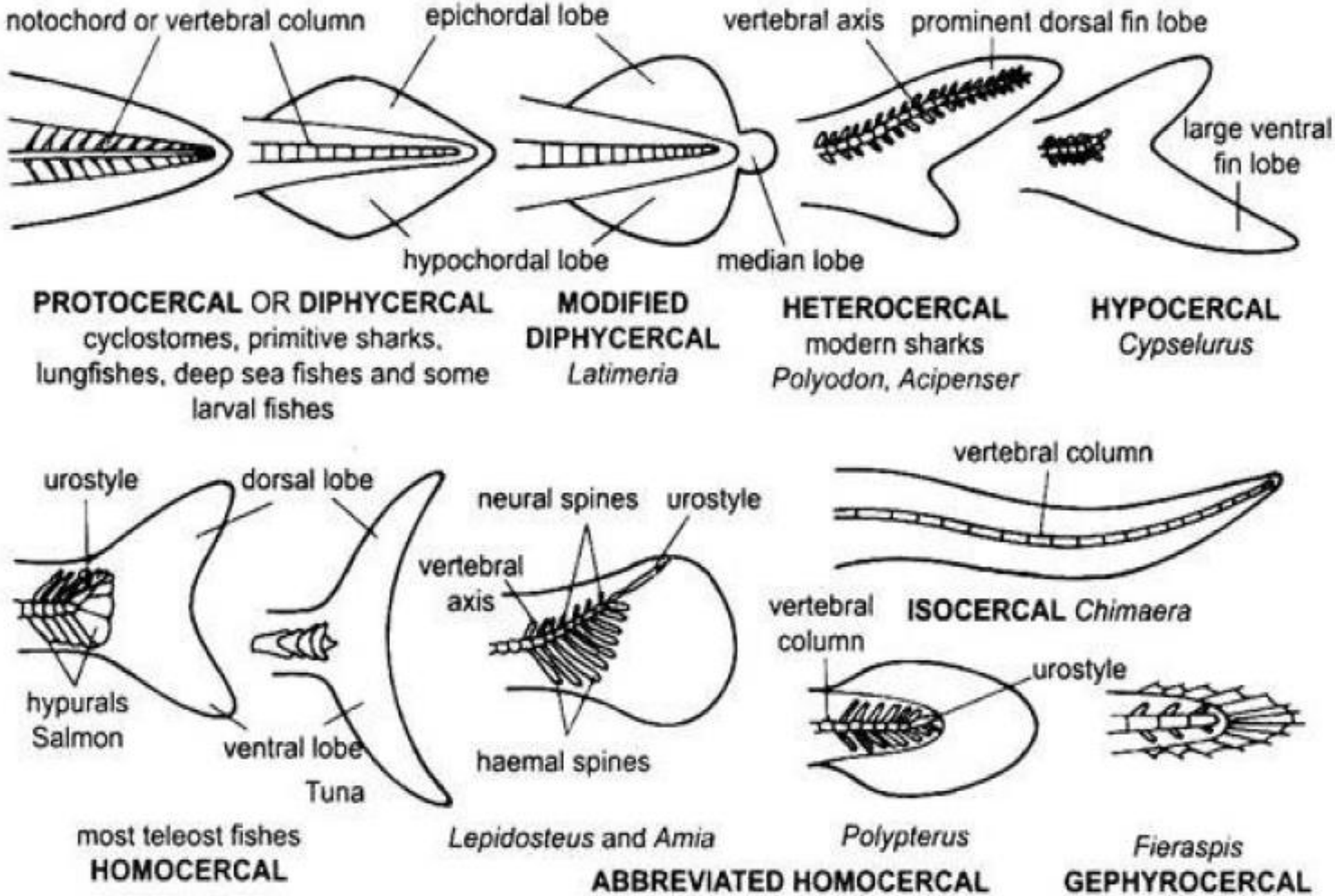


Fig. 3.3 Different types of caudal fins or tail in fishes

Paired fins: Paired fins were an early development in fish evolution that did not exist in the ancestors of vertebrates. Diverse kinds of fishes have a wide range of variation in the endoskeleton that supports the paired fins. The "archipterygium" is the term for the original, prehistoric state, which resembled Ceratodus' fins. It was given an anterior preaxial and a posterior post-axial set of radials attached to it, and it has a middle jointed axis that articulates with the girdle. The size of the radials reduced as they approached the tip and were positioned on either side of the median axis. A biserial arrangement of the radials is what this is. Only *Ceratodus* has this sort of "biserial archipterygium," which was present in uniserial kind of skeleton present in teleosts is thought to have originated from the archipterygii through shortening of the median axis and reduction in the post axial radials that eventually disappeared completely.

This particular variety of "biserial archipterygium" is only seen in Ceratodus, and it existed in the Devonian Crossopterygii. It caused the fin to have an acutely lobate shape. The 'pleuroarchic' or uniserial kind of skeleton present in teleosts may have developed from the archipterygii by shortening the median axis and reducing the post axial radials, which eventually disappeared entirely.

The pectoral and pelvic fins are paired.

MODIFICATIONS AND FUNCTIONS OF FINS

Many fishes have specific adapted types of caudal fins such as:

1. Isocercal or leptocercal
2. Internally symmetrical Caudal Fin
3. Pseudocercal Caudal Fin
4. Hypocercal Caudal Fin
5. Gephyrocercal Caudal Fin

1. Leptocercal or Isocercal

Some fish have a tapering caudal fin, and the balanced kind is referred to as isocercal or leptocercal. The spine of isocercal fins has a long, straight rod-like shape. The isocercal caudal fin is present in rat tails (Macruidae), Blennies (Blennidae), Eels (Anguilliformes), featherbacks (Notopteridae), and gymnarchids (Gymnarchidae), among other species.

2. Internally Symmetrical Caudal Fin

Where a few fin components are fused together, the caudal fin is compact in this case. They are found in cods (Order: Gadiformes).

3. Pseudo-caudal Caudal Fin

The pseudocaudal caudal fins are seen in the Dipnoi. In this instance, the dorsal and ventral elements grow ventrally before developing into fins.

4. Hypocercal Caudal Fin

The dorsal lobe of the caudal fin of the Hypocercal type is considerably larger than the ventral lobe, which is considerably more compact. It is also known as inverted heterocercal caudal fin. There are hypocercal type cadual fins in several early Agnathans. Where the lobe grows from the vertebra's upper surface in this instance, the vertebral axis abruptly bends downward.

5. Gephyrocercal Caudal Fin

A highly particular variety of caudal fin is the gephyrocercal caudal fin, commonly referred to as the bridge caudal fin. They frequently resemble isocercal fins, however the fins are simply remnants. Where the spinal column's hypurals are missing in this instance, the caudal lobe is diminished. The pearlfishes (Carpus), Flerasfer, and Orthagoriscus have these kinds of fins.

FUNCTIONS OF FINS

For various purposes fish use their fins. Some important functions of fins are described below:

Fish use their fins for a number of things. Some important functions of fins are described below:

1. Usually, a fish's pectoral fins aid in turning.
2. Some bony fish, including Cirrhitichthys, use their pectoral fins to assist them rest on the bottom or in reef environments.
3. Flying fish (Exocoetidae family) glide over the water by using their large pectoral fins.
4. Some bottom-dwelling fish, including threadfins (Polynemidae), have taste buds and touch receptors on their pectoral fins that assist them locate food.
5. Fish with pelvic fins float more steadily in the water.
6. Some fish, including clingfish (family Gobiesocidae), use their pelvic fins as sucking appendages to hold on to immobile things on the ocean floor.
7. The majority of bony fishes use their dorsal fin to shift their orientation quickly.
8. Dorsal fins function as a 'keel' to keep fish anchored in the water.
9. Some angelfishes in the phylum Lophiiformes use their dorsal fin as a lure to draw in prey.
10. Some fish (Echeneidae) use their modified dorsal fin as a sucking disc.
11. Gymnarchus niloticus, the African knife fish, uses its dorsal fin to create undulations in order to swim forward or backward.
12. The majority of bony fish use their caudal fins to propel themselves.

LOCOMOTION IN FISHES

Fishes are perfectly adapted for locomotion in the water. The body is spindle shaped, thicker in front than behind and is perfectly streamlined for movement through water. The body covered with a layer of mucus which reduces drag on it. Usually, the shape of the body is fusiform but variations occur when the fish becomes adapted to specific mode of life.

Fish swim by exert force beside the surrounding water. There are exceptions, except this is normally achieved by the fish contracting muscles on each side of its body in order to produce waves of flexion that journey the length of the body from nose to tail, usually getting larger as they go along. The vector forces exerted on the water by such movement cancel out laterally, but produce a net force backwards which in turn push the fish forward during the water. The majority of fishes produce force using lateral movements of their body and caudal fin, except many other species move mostly using their median and paired fins. The concluding group swims gradually, but can turn fast, as is required when living in coral reefs for example. But they cannot swim as fast as fish with their bodies and caudal fins. Some species have laterally compressed body as in the Clupeidae, others possess dorso-ventrally depressed body as the skates, rays and many cat fishes, whereas some are elongated and eel-like. Many fishes have a streamlined body and swim freely in open water. Fish locomotion is closely connected with habitat and ecological niche.

Fishes swim by the following methods:

(a) By alternate contraction and relaxation of the muscles of the body called the myomeres. Thus, during swimming the fish oscillates from side to side showing lateral undulations.

(b) By various movements of the fins.

(c) By rapid expulsion of water as jet the gill aperture

LOCOMOTION BY BODY MOVEMENTS

Fishes swim in water by body movements brought about by alternate expansion and contraction of the myomeres and by movements of the fins.

Locomotion, only by means of fin movements, takes place when slow progress is desired, but for rapid swimming, body movement is most important. During such active swimming, the paired fins serve balancing the body so that the fish remains in position and does not float with belly upwards. The dorsal and anal fins from dorsal and ventral keel which can be lowered or raised according to needs and give stability to the body.

In elongated type of fishes such as eel the locomotion is of anguilform type. The movement is initated by the contraction of first few myomere on one side, so that the anterior part of the body is thrown into a curve, which passes backward in a series of waves by alternate contraction and relaxation of the muscle segments on each side of the body. The movement is of meandering nature and the fish looks like a crawling snake. In this case the forward thrust is obtained entirely by the pressure of the fish body against the water and the caudal fin has little function in anguilliform type of movement. Hence the caudal fin is very much reduced or absent in eel-like fishes. Instead the hider part of the body is laterally compressed and the blade-like structure thus formed, serves to provide a large amount of thrust to the fish. Fishes that have long, laterally compressed body as the Ribbon-fishes (*Trichiurus)* also swim very actively by undulating movements of their body.

LOCOMOTION BY FINS AND TAIL

Fins are extend appendages present on the body of fishes and are the chief locomotory organs. There are two types of fins, unpaired or median and paired fins. The median fins include a dorsal on the mid axis of the body, an anal on the mid ventral side behind the vent and caudal at the end of the tail. Pectorals and pelvics are the paired fins corresponding to the fore and hind limbs of the terrestrial tetrapod vertebrates. Fins are supported by skeletal rods called the radials and dermal fin rays. In teleosts the fin rays are branched and jointed bony structures and are known as the lepidotrichia. The fins without fin rays called dipose fins (e.g. Mystus)

The tail and the caudal fin are the chief organs of locomotion in fishes. During swimming, the tail is lashed from side to side by alternate contraction and relaxation of the muscles on the opposite sides of the vertebral column. During such movements the tail is first bent to one side. This is called the non-effective or backstoke. By a stroke in the reverse direction, the tail is extended and straightened. This is the forward or effective stroke. By a rapid succession of these strokes to right and left sides alternately, the fish forces its way through the water.

When a fish wants to move forwards, the first action is the contraction of first few myomeres of the anterior end of the body on one side only, so that the head is bent sharply to one side. This is followed by alternate contraction and relaxation of the successive myomeres , first on one side on one side of the body and then of other, from head towards the tail and the curve of the body passes backwards. The fish thus shows undulating movements and its body during swimming is thrown into a 'S' shaped curve.

TYPES OF LOCOMOTION

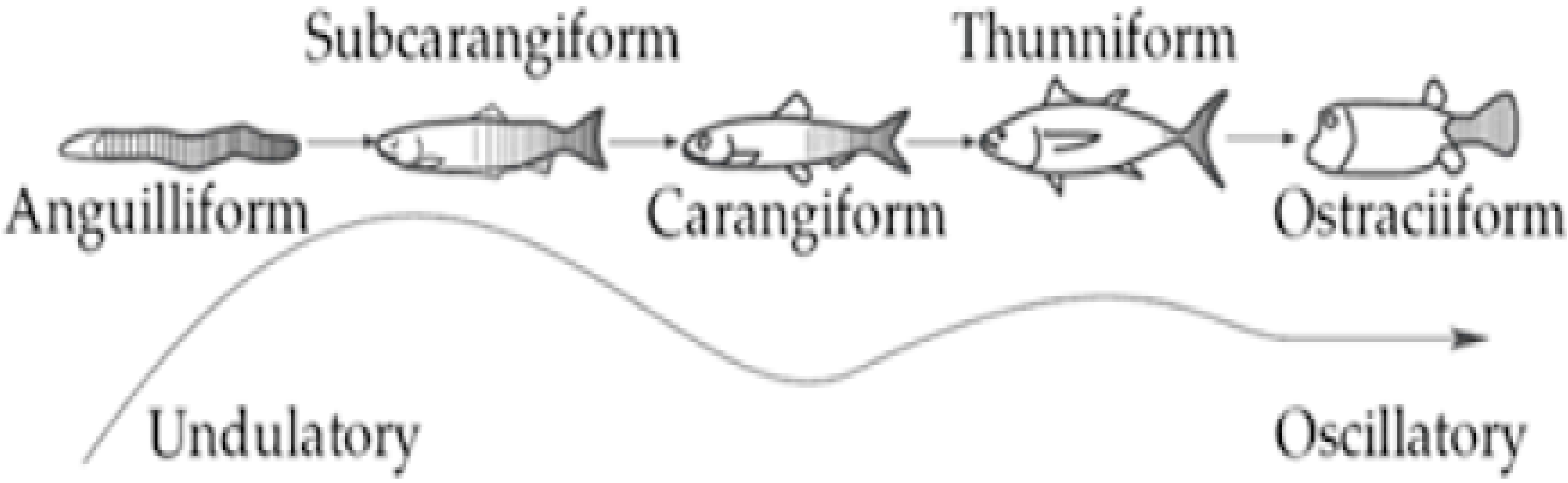


Fig. 4.2 Locomotion by body and fins

The shape of body, three types of locomotion's in fishes:

Anguilliform locomotion

In anguilliform type of locomotion, the movement is of serpentine type and the fish looks like crawling snake. The forward thrust is generated by the pressure of the fish body against the water and the tail or caudal fin has little role in it. Hence, the caudal fin is reduced in eel-like fishes. Instead, the caudal region is laterally compressed, forming a blade-like structure and provides a large thrust of the body.

Eels *(Anguilla)* and cyclostomes having serpentine body swim by lateral undulation of the entire body that is caused by metachronal rhythm in the contraction of myotomes. This type of swimming is quite efficient at low speeds but consumes a lot of energy since the whole of the body is involved in locomotion.

Carangiform locomotion

In majority of fishes lateral undulation of body is restricted to the posterior one-third of body. Tail is lashed from side to side in such a way that it always has a backwardly facing component of push and caudal fin increases the area and the force of backward push of tail.

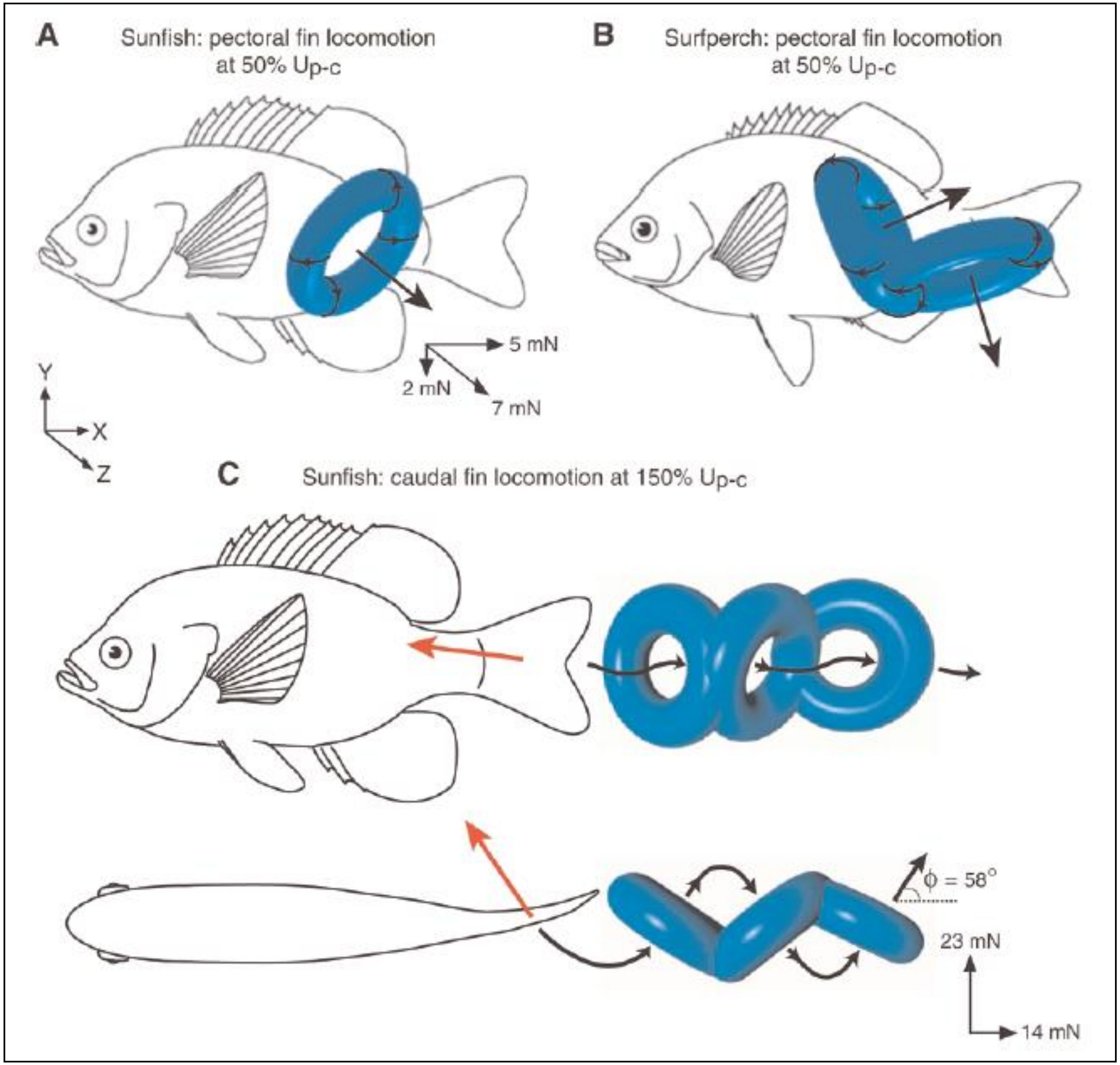
Ostraciform locomotion

This type of locomotion is found in box fishes and trunk fishes (family Ostraciidae) in which body is not flexible and hence cannot undergo lateral undulation. Therefore, only tail fin propels the body forward.

In the trunk fish (Ostracion), the head and body are enclosed in a rigid bony case, while the tail with caudal fin projects behind. Slow movement takes place by the dorsal and anal fins, while the lashing movements of the tail cause rapid swimming. This is called 'Ostraciform' locomotion.

Some species of fish seldom flex the body for swimming, and move forward by undulating movements of the median fins. Usually complete waves are seen along the fins. This is called 'balistiform' locomotion. Certain species as the catfish, parrot fish, surgeon fish do not oscillate the body or median fins. These fish use pectoral fins for locomotion and this is called 'labriform' swimming. Some species like the globe fish (Tetraodon), porcupine fish (Dindon) and the sea-horse (Hippocampus) swim with the help of dorsal and anal fins. Besides, pectoral fins are also used for slow movement. Water expelled from the gill aperture during respiration also helps in slow progression. When the fish is at rest, the pectoral fins are moving constantly to overcome the forward thrust produced by the respiratory current.

Hydrodynamic Mechanisms of Aquatic Locomotion



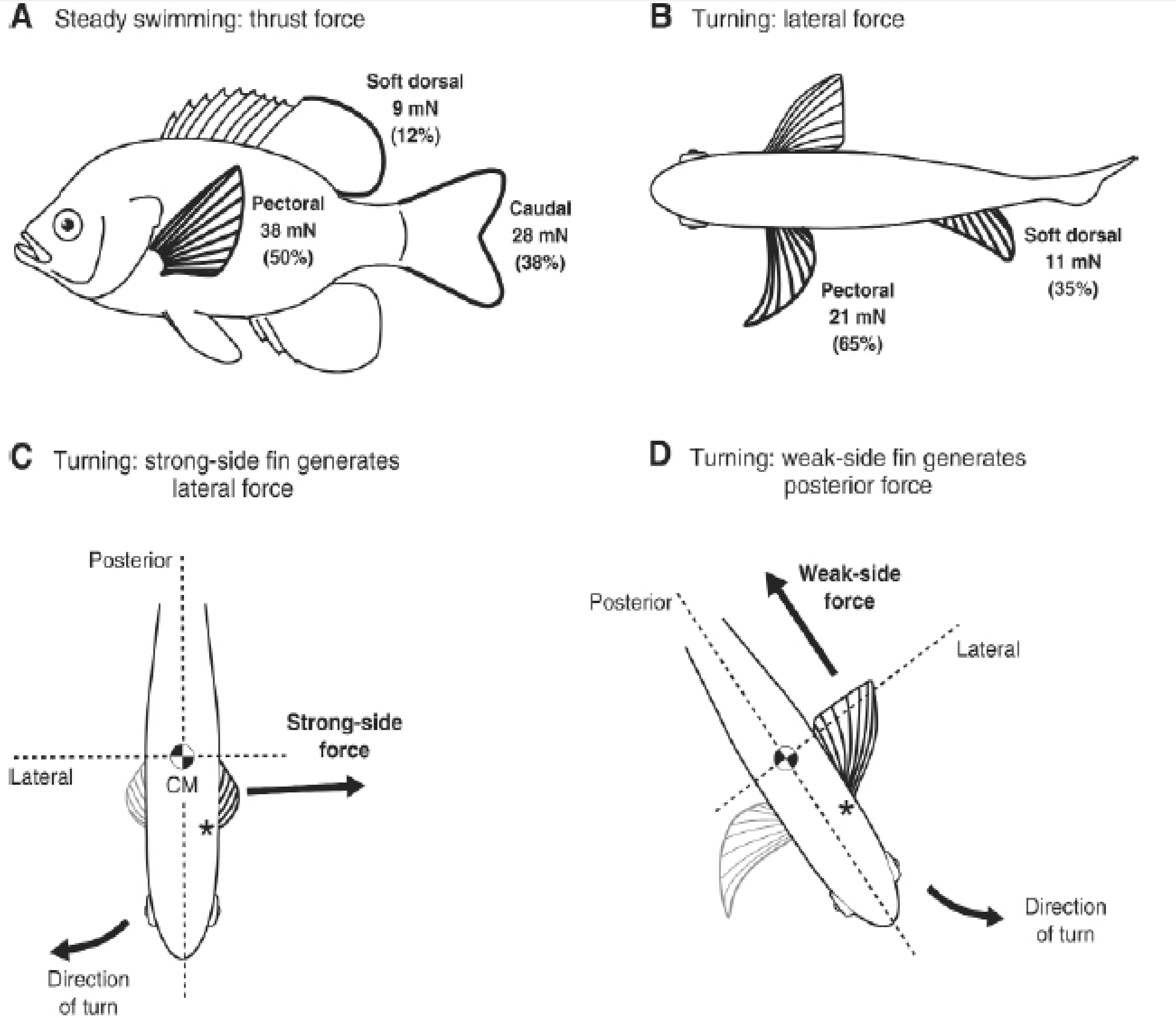


FIGURE 4. Fish fins exhibit considerable hydrodynamic versatility. *A*: at steady swimming speeds over 1.0 $L \cdot s^{-1}$, bluegill sunfish of adult size recruit multiple fins to generate thrust, which is partitioned among the dorsal, pectoral, and caudal fins. *B*: during slow turning, total lateral force is partitioned between the strong-side pectoral fin (closer to the turning stimulus) and the dorsal fin. *C* and *D*: the hydrodynamic role of the pectoral fins on each side of the body differs during turning. The strong-side fin generates lateral force to rotate the head away from the stimulus, while the weak-side fin generates posteriorly directed thrust force to cause body translation. Active fins in each panel are shown in darker outline; asterisk indicates the attachment point of the pectoral fin to the body. CM, center of mass.