# Dayanand Science College, Latur

## Department of Zoology and Fishery Science

## Class: B.Sc. I Year

## Subject: Type Study- *Wallago attu* Freshwater Shark (II)

**Dr. Suraj Satish Kolhe**

**Assistant Professor**

**Department of Zoology & Fishery Science**

# Type Study - *Wallago attu* Freshwater Shark

## Syllabus

**UNIT I**

1) Introduction and classification
2) External characters
3) Skin – structure and functions.
4) Endoskeleton
   i. Axial skeleton – typical trunk vertebra, caudal vertebra, ribs
   ii. Appendicular skeleton – pectoral girdle and fin, pelvic girdle and fin.
5) Air bladder – structure and functions.
6) Weberian ossicles – structure and functions.

**UNIT II**

1) Coelom and alimentary canal.
2) Associated glands of digestive system.
   i. Liver
   ii. Pancreas
   iii. Gall bladder
3) Physiology of digestion
4) Respiratory system
   i. Structure of gills
   ii. Physiology of respiration

**UNIT III**

1) Blood circulatory system
   i. Structure & working of heart
   ii. Arterial system
   iii. Venous system
   iv. Composition of blood
2) Nervous system
   i. Structure of brain
   ii. Cranial nerves
   iii. Spinal nerves

**UNIT IV**

1) Excretory system
2) Male reproductive system
3) Female reproductive system
4) Spawning habits and structure of eggs.
5) Photoreceptor organs (eye)
6) Internal ear (membranos labyrinth) – Structure and functions.
7) Olfactory organs – Structure and functions.

## UNIT I

### 1) Introduction and classification

Fishes are gill bearing cold-blooded aquatic animals. The body temperature varies according to the environment. This helps fishes to keep their metabolic activity and food intake very low especially when they live in ice or frozen in north or in hot springs of volcanic region. Fish meat contains protein, carbohydrates, minerals, water and fat which are most essential components of human food. Fishes are found in all three aquatic environments the freshwater, brackishwater and the marine ecosystem. But they are more diverse and numerous in marine ecosystem, distributed from warm tropic to ice cold arctic region, from surface to deepest region. The group, fish exhibits a great variation in their shape and size. Some are torpedo shaped, fusiform, round, flat, angular, and laterally compressed. There are four classes of fishes, Elasmobrachii, Teleostomi, Holocephali and Dipnoi. Majority of the fishes belong to two common classes namely Elasmobranchii the cartilaginous fishes and Teleostomi the bony fishes.

Fishes inhabiting all the three aquatic ecosystems (The freshwater, brackishwater and seawater) do not exhibit any distinguishing characters externally. However, there are some differences in their salt regulatory mechanisms and hence variation is observed in the structure of kidney and some other related internal organs.

The external parts of the fish include the operculum, which is a hard, moveable flap that covers and protects the gills. The operculum also mediates water flow over the gills as part of the respiratory process. The lateral line is made up of a series of canals that helps sense movement in the water. There are also several fish fins including the pectoral fins, pelvic fins, dorsal fin, anal fin, caudal fin, and adipose fin. These fins have various purposes related to fish movement and stability, and the purpose of the adipose fin is not completely understood.

**Phylum: Chordata :**
- Notochord present
- Bilateral symmetry
- Perforated pharynx
- A hollow tubular nerve chord
- Heart ventral to gut
- Tail is present

Acraniata (Protocraniata)
- No cranium (brainbox)

Craniata (Vertebrata)
- Cranium present
- Notochord is replaced by vertebral coloumn
- Few gill slits found in larvae and adult fishes
- Dorsal tubular nerve chord

Craniata

Agnatha
- Without jaw
- Single nostril (external)

Gnathostomata
- With jaw and teeth
- Two external nostril

Class

Ostracodermii
- Armoured fishes

e.g. *Cephalaspis* (extinct)

Cyclostomata (Hag fish)
- Circular suctorial mouth
- 5-16 pairs of gill slits
- Skeleton cartilaginous

e.g. *Petromyzon, Myxine* (Lamprey)

**Gnathostomata**

**Super classess**

**Tetrapoda**
- Two pairs of pentadactyle limbs

e.g. Amphibian, Reptiles, Aves, Mammals

**Pisces**
- Primarily aquatic
- Paired fins for locomotion
- Gills for respiration, upto 7 pairs
- With or without scales

**Classes**

1**. Elasmobranchii**
- Cartilaginous endoskeleton
- 5-7 pairs of gill arches opening seperately
- Without operculum
- Placoid scales
- Cloaca
- Claspers
- Tail heterocercal
- Exclusively marine

2. **Holocephali**
- 4 pairs of gill slits
- Without operculum
- No cloaca

e.g. *Chimaera*

3. **Dipnoi**
- Lungfishes
- Single gill slit
- Air bladder/lungs

4. **Teleostomi**
- Bony endoskeleton
- 4 pairs of gill arches covered by operculum
- Cycloid and ctenoid scales
- Tail mostly homocercal
- Freshwater estuarine as well as marine species

**Teleostomi**

**sub classes,**

1. Crossopterygii, 2.Dipneusti, 3. Brachiopterygii, 4. Actinopterygii (modern bony fishes)

## 2) External characters

Fish has streamlined for fusiform body. Having a shape like this makes it easier to glide through the water. The body is compressed at the sides and tapers more at the tail than at the head. Generally fish body is divided into three parts namely (a) Head (b) Trunk and (c) Tail.

The head region consists of different parts like mouth, eyes, nostrils and gill cover (operculum). Mouth is made up of upper jaw (made up of maxillar bones) and lower jaw (made up of mandibular bones). In some fishes operculum is divided into pre-opercle, sub-opercle and opercle.

Trunk region consists of different types of fins. A fin is a membrane supported by rays or spines that function in swimming or orientation in the water. Trunk region has one or more dorsal fins located along the center of the back. If two dorsal fins present, first one is made up of only spines or spines and rays whereas the second dorsal is made up of usually rays. Other fins in the trunk region include pectoral and pelvic fins.

Tail region constitutes anal and caudal fins. Caudal fin lies at the end of the tail and is the primary organ for generating thrust to move through the water. Caudal fin in body fishes is generally homocercal. One or more anal fins are situated on the ventral midline near the caudal fin.

Fish needs scales to protect their bodies. The bodies of most fish are covered with overlapping rows of scales. In a number of species, the scales have developed into bony plates. In some species, such as the eel, the scales are minute. In others, such as the catfish, they are almost absent. Fishes are sometimes classified according to the shape and characteristics of their scales. Bonyfishes will generally have either cycloid scales or ctenoid scales. Bone formation in bony fishes is through calcification as well as ossification processes. The lateral line, which runs along the middle of the body, is a set of sense organs having connection to the brain.

### Shape:

A lot of variation are found in body shape of the fishes viz. elongated (ribbon fishes, eels), cylindrical (Lizard fish, snake headed fishes), laterally compressed (pomfrets), dorsoventrally flattened (sole fishes) and oblong/ deep (Catla catla, Atropus atropos.) Body of the fish is normally divided into head, trunk and tail.

### Head:

Head is anterior most part of the body which bears mouth opening, jaws, barbles, eyes, buccal cavity, pharynx, gills, operculum etc. Size and shape of the head also varies in different species.

### Mouth:

It is the anterior most opening of the fish body through which food and water are taken in by the fish. The shape and size of the mouth and type of dentition varies according to their food and feeding habits, for example predators have long canine teeth and herbivores like carps have pharyngeal teeth

**Eyes:**

Eyes are the visual organs present in the head, usually lateral in position, but in flat fishes (*Cynoglossus arel* and *Psettodus erumei*) it is dorsal. Size of the eyes varies in different species. Sometimes color variation is also seen among species.

**Barbels:**

These are the elongated thread like tactile structures provided with sensory buds. The size and number of these barbels vary according to the species; usually one to four pairs are present in catfishes, rudimentary in carps. The barbels are usually used for locating the food material by the fish.

**Operculum:**

It is a flap like structure, which covers the gill arches leaving a vertical slit like opening for passing out the water taken in through the mouth. In the case of cartilaginous fishes, gill arches (5-7 pairs) open out through separate gill slits; operculum is absent in these fishes.

**Fins:**

Fishes have specialized organs for propulsion, stabilization, maneuvering and protection called fins. The paired fins are pectoral, pelvic and the unpaired fins are dorsal, anal and caudal. These fins have soft rays or hard, or may be composition of soft rays as well as spines. Adipose fins are present in some fishes (Cat fishes). In some species the dorsal and anal fins are very long and confluent with the caudal fin (*H. fossilis, C. batrachus* and sole fishes).

**Spines:**

Varying number and strength of spines are present along with the fins, especially before the base of different fins. Sometimes entire fins are spineous. Spines of some catfishes are poisonous too (*H. fossilis*).

**Trunk:**

Trunk includes the body parts present between the ends of operculum to the base of caudal fin.

**Scales:**

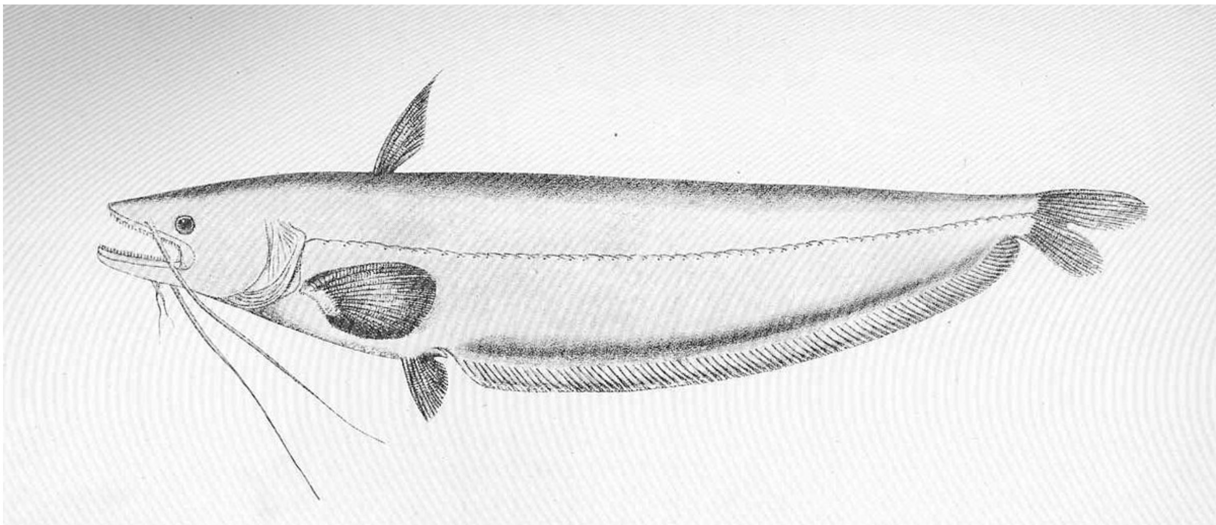
Body of most the fishes is covered by plate like structures called the scales. However, some cave dwelling fishes, catfishes, eels lacks scales. Scales are dermal in origin made up of calcareous deposition and meant for protection of the animal from external injuries. Cycloid and Ctenoid type are the characteristic of bony fishes, Placoid scales are found in cartilaginous fishes. Fast swimming pelagic fishes like mackerel posses very rudimentary scales, in some fishes like horse mackerel, *Megalaspis cordyla* and cIupeids, it is modified into scutes.

**Lateral line:**

It is present on the lateral sides of the fish body. In the case of sole fishes both the lateral lines have been shifted to the dorsal side of the body, possibly an adaptation to the environment it habitats, a bottom dweller. Lateral line may be straight or curved, covered with scales. These scales are sometimes modified in to scutes (Carangidae). The function of lateral line is possibly sensory.

**Caudal fin:**

The last part of the fish is caudal fin, the tail. The shape and size vary greatly in different species.



### 3) Skin – structure and functions

The integument or skin is an outermost covering or wrapping of the body, hence it is the most exposed part of the body to the environment. For this reason, it plays an important role of first line of defence in a number of ways. In fishes, the skin is well-adapted for protection from injuries and diseases. It also serves for respiration, excretion and osmoregulation.

In some fishes, special colouring devices and phosphorescent organs are present in the skin, which either conceal the organism or make it present or used for sexual recognition. In addition, some species have special structures like electric organs, mucous glands and poison glands.

**Structure of Skin of Fishes:**

The skin of fish is made up of two distinct layers, viz. an outermost layer, the epidermis and an inner layer dermis or corium. The epidermis originates from ectoderm and the dermis derives from mesoderm layer.

**1. The Epidermis layer of skin in fishes:**

It is composed of many layers of flattened and moist epithelial cells. The innermost layer is called stratum germinativum. This layer is made up of active columnar cells that continuously divide by mitotic division. The newly formed cells occupy the lowermost stratum and the older cells move outside and are worn off time to time and maintain growth. These migrating epithelial cells fill the superficial wounds.

**Epidermal glands:**

**The epithelium of epidermis is modified into a variety of glands, which are:**

**(i) Mucous gland:**

The epidermis is provided with a number of mucous glands, which open at the surface of the skin by minute pores. These glands are flask-shaped or tubular extending to the dermis. The mucus glands secrete slippery mucus, which contain a lipoprotein, known as mucin.

The slimy mucus reduces drag on fish while swimming in the water. Continuous secretion and sloughing of mucus wash away micro-organism and irritants, which may cause disease if accumulated. In some species (Protopterus and Lepidosiren), the mucus forms a cocoon-like structure around the body to avoid dry condition of weather, especially during aestivation. The mucus gives a characteristic fish odour.

Among some fishes, mucous is used for chemical communication. Many teleosts feed their young ones on the mucus, secreted in large quantity on the surface of the body. Some species like Macropodus and Gasterosteus use their sticky mucus for preparation of nest for laying eggs.

The mucus also helps in regulating to some extent, the osmotic exchange of water and ions between the body-fluids and the water. The number and size of mucus gland cells vary with species. Generally, fishes with no scales, have large numbers of mucus cells.

**(ii) Poison glands:**

Venom or poison glands have evolved in different families of fishes. Glandular cells of epidermis are modified into poison glands. These glands secrete poisonous substance to protect themselves from the enemy for defence.

They are also used for offence as well. The poison glands are generally present at the base of certain structures like sting, spine of dorsal fin and tooth. Poison glands open at the tip of these structures to inject poison by penetration into the prey.

The most common example is the stingray, which is provided with venomous caudal sting. Similarly, Chimaeras possess venom glands in spine of the dorsal fin. The poison glands are present in the grooves of spines of dorsal, pelvic and anal fins of the Scorpion fish (Scorpionidae). In Sturgeon fish (Acanthuridae), the poison glands are found at each side of the caudal peduncle.

**(iii) Photophores:**

In many marine species of fish, special multicellular glands are developed from stratum germinativum of epidermis. These glands are deeply seated into dermis and produce light. These light producing luminous organs are mostly found in deep-sea elasmobranches and in some teleosts inhabiting total darkness in sea.

Each gland has an apex consisting of mucus cells that helps to magnify light, produced from the basal glandular part of the gland.

**2. The Dermis layer of skin in fishes:**

The dermis lies beneath the epidermis (Fig. 3.2). This layer contains blood vessels, nerves, connective tissues and sense organs. The upper layer of dermis is made of loose connective tissues and is known as stratum spongiosum, while the lower part is occupied by thick and dense connective tissues, called the stratum compactum.

This layer generally has proteinaceous collagen fibres and mesenchymal cells. The dermis is well supplied by blood vessels, hence it also provides nourishment to the epidermis.

**Functions of Skin**

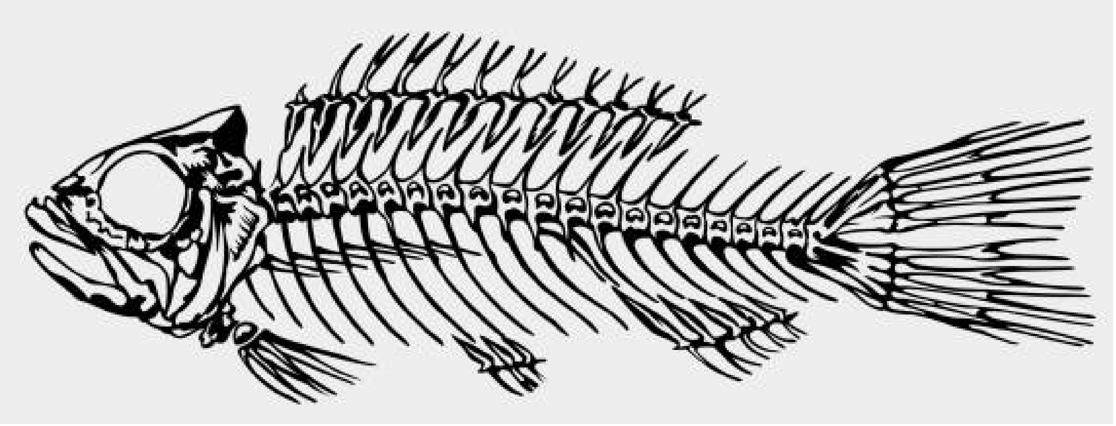
- It support and protect soft tissues against abrasion, microbes. Mucous glands secrete copious mucous which forms a thick slimy layer all over the body and protect it from parasite, fungi and bacteria.

- The mucous lubricates the body of fish so as to reduce the friction in water enabling the fish to swim with greater speed.
- The mucous helps in repair and healing of the wounds of fish.
- Some fishes like Betta, Gasterosteus and Macropodus use their mucous for preparing the nest.
- Integument receives the external stimuli like, heat, cold, chemical change in water quality etc.
- It helps the fish to regulate the exchange of water and ions between the body fluids and external medium.
- It helps in heat regulation.
- It helps in cutaneous respiration. In some fishes like Anguilla and Periopthalamus, integument acts as an accessory respiratory organ. In these fishes the dermis becomes highly vascular.
- Scales, plates, spines etc. are the derivatives of integument and protect the body of fish.
- Poison gland of scorpion fish and toad fish are the modification of mucous gland and are useful organ of offence and defence.

**4) Endoskeleton**

iv. **Axial skeleton – typical trunk vertebra, caudal vertebra, ribs**

v. **Appendicular skeleton – pectoral girdle and fin, pelvic girdle and fin.**



**5) Air bladder – structure and functions.**

Swim bladder is a gas filled sac, arising from gut as a dorsal outgrowth in most bony fishes. Because swim-bladder primarily regulates buoyancy at different depths, it is also called air bladder. It is a characteristic organ of Osteichthyes (bony fishes). Air-bladder does not occur in elasmobranchs.

However, it is found in all Osteichthyes (bony fishes) except a few bottom dwellers (*Lophius*, *Pleuronectes*, etc.). It is vestigial in *Latimeria*, the only living crossopterygian. Air-bladder shows a number of structural modifications in various groups of bony fishes.

**Gas Composition of Swim-Bladder**

The gas secreted by the swim-bladder is mostly oxygen. Nitrogen, and little quantity of carbon-dioxide are also present. Generally the gas composition varies in different species. In salmonids, the maximum amount of gas in the swim-bladder is Nitrogen. Again in many species the composition includes mostly a mixture of oxygen and carbon dioxide.

**Functions of Air-Bladder**

**The air-bladder or swim-bladder in fishes performs a number of functions, the more important of which are discussed below:**

**1. Hydrostatic Organ**

Primary function of swim bladder is to help the fish in buoyancy. By filling or expelling air, a fish can change the amount and pressure of gas within bladder. A filled and expanded bladder results ascend, and a compressed bladder results descend in water depths.

**2. Regulation of Centre of Gravity**

The swim bladder helps to maintain the proper centre of gravity by shifting the contained gas from one part of it to the other and this facilitates in exhibiting a variety of movement.

**3. Sound Production**

Fishes may produce sound within bladder or use it as resonator, such as *Cynoscian*, *Neoceratodus* and *Balistes*.Many fishes as Doras, Platystoma, Malapterurus, Trigla can produce grunting or hissing or drumming sound.

**4. Auditory Function**

In carps and cat fishes, chain of small bones-weberianossicles, connect air bladder with internal ear. Underwater sound waves received by these ossicles to the internal ear and air in hearing.

**5. Accessory Respiratory Organ**

Physostomous swim bladder in *Amia*, *Lepidosiren* are alveolar and vascular, which help in aerial respiration.

**6. Display Function**

In some fishes, sound production is confined to males only, thus sound production is a part of terrestrial or courtship display.

**6) Weberian ossicles – structure and functions.**

**Functions of the Weberian Ossicles:**

**1. As pressure register:**

They are sensitive to changes in the volume of the swim-bladder due to variations in the hydrostatic pressure. Any change in the volume of the swim-bladder causes movements of the sinus impar. This is then conveyed to the sacculus through the endolymph of the transverse canal.

**2. As barometer:**

It is presumed that fish can detect variation in the atmospheric pressure through Weberian ossicles.

**3. As auditory organ:**

The ossicles transmit the vibrations of the bladder wall to the perilymph of sinus impar. The vibration reach the saccular otoliths via endolymph.

**4. As sound locator:**

The vibrations received on the side of the bladder nearest the source are stronger than the other side.

## Unit II

### 1) Coelom and alimentary canal

The feeding habits and behavior of fishes refer to the process of the search for and ingestion of food. This also includes the manner and the stimuli for feeding.

Fishes can be classified according to their food and diet, which refer to the materials they habitually eat as:

Herbivores: those that feed exclusively on plant materials

Carnivores: those that feed exclusively on animal matter

Omnivores: those that derive their nutrients from both plants and animals

Planktivores: those that feed on plankton, the microscopic plant and animal life in water including bacteria

Detritivores: those that feed on decaying matter

The digestive system of fish includes the mouth, esophagus, stomach, pylorus, intestine, liver, and pancreas. An illustration of the digestive tract of four commonly cultured fishes that differ in their food preferences is shown in Figure. The digestive tract is tubular in structure. The whole digestive tract is often referred to as the gut and in fish, the gut usually has four divisions: these are the headgut, foregut, midgut, and hindgut. The headgut, which is the most anterior part includes the mouth (oral or buccal cavity) and gills (branchial or pharyngeal cavity). The foregut begins at the posterior edge o f the gills and includes the esophagus and stomach. The midgut consists o f the intestines and pyloric caeca, if present. The midgut is the longest portion of the gut and may be coiled into complicated loops. The hindgut includes the enlarged portion o f the intestines and the rectum or anus. Each portion of the gut has a very variable structure for adaptation. The liver and pancreas are organs involved in digestion but are found outside the tubular structure.

### 1. Headgut

Mouth and various ingestion mechanisms The first phase of digestion is the ingestion of food into the mouth. The mouth has a variety of adaptations for capturing, handling, and sorting of food before entry into the stomach. Figure 3.2A shows the different shapes o f mouth in response to their food adaptations. Fish have teeth that vary in type, number, and arrangement. They serve to catch and hold the prey. The arrangement and structure of the teeth are related to the kind of food that the fish normally eat. There is a strong correlation among kind o f teeth, feeding habits, and food eaten. Generally, the more active feeders have strong jaw s with sharp teeth to bite and shred the food. Some major kinds of jaw-teeth are the following: cardiform, villiform, canine, incisor and molariform (Figure 3.2B). Those feeding on mollusks and crustaceans have short heavy teeth, strong enough to crush the m ollusk shell. Zooplankton feeders and most planktivores have practically no teeth. The shredding of food is most often done in the throat or pharynx. Here, another set of specialized teeth may be found. Again, the structure, size and shape of the pharyngeal teeth are also variable. Plankton feeders have fine rows of pharyngeal teeth, while mollusk eaters have large but flat crowned teeth, which is better adapted to crushing their food.

2. **Foregut**

**Esophagus**

Most fish have short, wide esophagus that serves as a transitional area between the striated muscles o f the mouth and the smooth muscles of the gut. Mucus producing cells are present in the esophagus. In general, the esophagus serves only as a passage way, however, enzyme activity has been detected in the esophagus of some fishes indicating a more active role o f the esophagus in the digestion process in these species. Other fishes with long, slim body shapes like the seawater-adapted eels have a long esophagus. Osmoregulation may take place in the esophagus if mucus is present. The mucus is much thicker anteriorly than posteriorly and is electrically charged. Some reports have suggested that both passive and active transport of ions into the blood may also take place in the esophagus without addition of water such as the dilution of ingested seawater in freshwater eels.

**Stomach**

The stomachs o f fishes vary greatly in their anatomical structure due to adaptations to specific foods. There are four general configurations or shapes o f fish stomachs. These include:

a. a straight stomach with an enlarged portion

b. a U- or J-shaped stomach

c. a stomach shaped like a Y on its side where the stem faces the caudal portion

d. stomachless fish, such as in carps and other cyprinids

The stomach has a configuration or shape which is convenient for containing food in the shape in which it is ingested. Food is temporarily stored in the stomach while the rest is gradually being processed through the other portion of the digestive tract. The size or capacity of the stomach in relation to the body weight varies between species and is usually related to the interval between feedings and to the size of food particles. Generally, fish that eat relatively small, soft particles have small stomach whereas fish that eat large food particles, e.g. whole fish, or eat at infrequent intervals have larger stomach. The cecum of the Y-shaped stomach is adapted to stretch posteriorly to accommodate large food particles or prey. In contrast, the absence of a stomach has been suggested to benefit fish adapted to freshwater (low chloride concentration) where stomach acids impose added osmoregulatory pressure. This is to avoid acidify in g large am ou n ts o f a lk a lin e food, as in omnivorous fish that eat plant sources, corals, shells, and others. In milkfish, the stomach can be divided into cardiac and pyloric portion. The cardiac portion is often more enlarged while the pyloric stomach is highly muscular (Figure 3.3). The pyloric stomach intensely grind the food particles resulting in chyme (a paste like mass).

3. **Midgut**

The digestion process actively continues into the intestines after preliminary digestion in the stomach. All fishes have intestines. The length of the intestines varies from as low as 1/5 to as high as 20 times the body length. In some fish, the intestines may be short and straight while it can be long, folded, and looped in others. In general, herbivores have longer intestines than carnivores. Although there are some cases of overlaps, some general statements can be made on gut length in relation to feeding habits of fish (Table 3.2). Within the same fish species, the relative gut length can change as feeding habit of the fish changes. Gut length is directly more related to the amount of indigestible material in the food rather than whether the food source is of plant or animal origin. Fish that ingest large amounts of detritus have gut lengths similar to those of herbivores. Some fishes possess pyloric caeca. There are conflicting reports on the functions of the pyloric caeca in fish. Histologically, the pyloric caeca resembles the intestines. Most studies indicate that it serves as an extension of the intestines thus increasing the effective surface area for digestion and absorption. Other studies show that it acts as an accessory food reservoir, for temporary storage, possibly a devise for saving space. It is clear, however, that rainbow trout caeca takes up amino acids and sugars across the apical membrane o f the epithelial cells. Electron microscopy has shown that both intestinal and caecal cells are involved in lipid absorption, with caecal cells being more active.

4. **Hindgut**

The hindgut is an extension o f the midgut. Digestion has been shown to continue in the hindgut although with a gradually diminishing digestive or absorptive function, an increased secretion of mucus and a pH near neutral. Histological sections show a sudden change from columnar secretory and absorptive to a squamous epithelium that produces mucus.

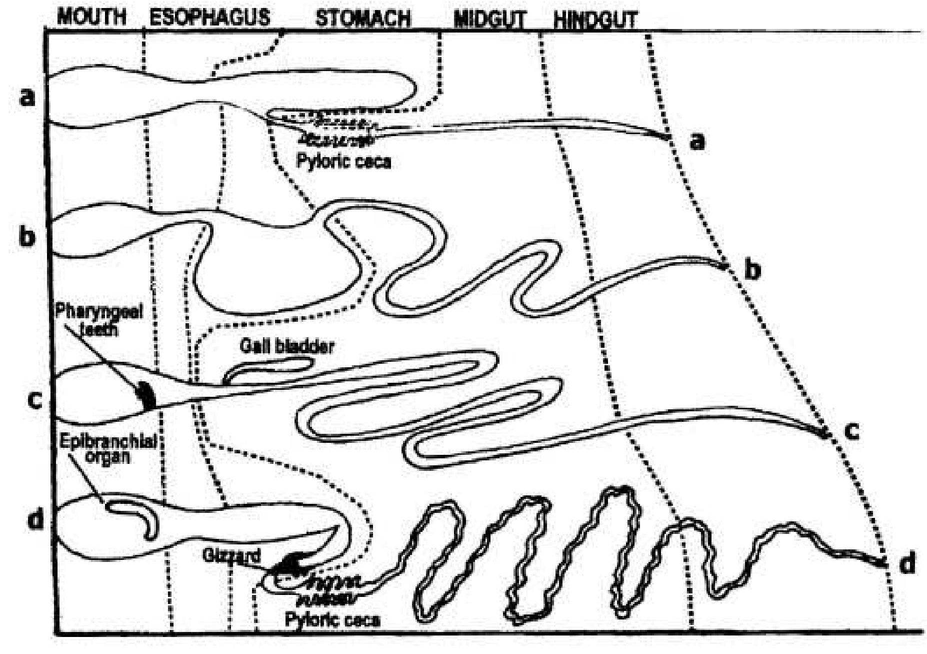



**Figure 3.1**
Diagrammatic representation of the digestive systems of four fishes, arranged in order of increasing gut length. a) Rainbow trout (carnivore); b) Catfish (omnivore, eating more of animal source); c) Carp (omnivore, eating more of plant source); d) Milkfish (omnivore, microphagus planktivore).
*Source:* Smith 1989

2) **Associated glands of digestive system.**

a. **Liver**

The liver is an important metabolic organ. It aids in digestion by secreting bile, a greenish fluid with strong emulsifying properties. The bile is stored in the gall bladder and is composed of a mixture of bile salts, taurocholate, glycocholate. Bile acids are derived from metabolism of cholesterol, and degradation products o f hemoglobin, bilirubin and biliverdin. Bile serves to emulsify lipids in the gut and may contain other waste products. The bile duct opens into the anterior intestines or into the pyloric caeca if present. Fish can reabsorb bile in the hindgut even though most lipid uptake occurs in the anterior intestine. The liver is also a storage organ for lipids and glycogen or stored starch. In some fishes, large amounts of lipid is stored in the liver to help maintain buoyancy. In other fishes, glycogen is the major stored nutrient.

b. **Pancreas**

The pancreas is involved in many important functions in digestion. Pancreati morphology is variable in many bony fishes. In most fishes, unlike in land animals, there is no discrete pancreas. The pancreas is diffused, scattered, and embedded in the mesenteries, in the liver, and clustered around the bile duct, or in combinations of sites. In a diffused pancreas, several small ducts open into the intestine and the pyloric caeca. In other cases where the pancreas is found inside the liver, the pancreas delivers its secretions directly into the gallbladder. The pancreas produces insulin and digestive secretions, principally proteases and bicarbonates. Insulin stimulates uptake of amino acids from the intestine and may stimulate growth. In the northern pike, insulin decreases blood amino acids with uptake into skeletal muscles, while in cod, insulin decreases blood glucose.

a. **Gall bladder**

c. **Physiology of digestion**

**Respiratory system**

a. **Structure of gills**
b. **Physiology of respiration**

To survive, fish must also take in oxygen and expel carbon dioxide. Instead of lungs, fish use capillaries. Capillaries are tiny, branching organs on the side of their heads that contain a significant number of smaller blood vessels. All bony fish have a bony plate called an operculum, shaped like a comb but shaped like an operculum. Water runs over the gills, and oxygen passes through the capillaries to the blood by opening its mouth.

Respiration in fish or in any entity living in the water differs from that of human beings. Organisms such as fish, living in water, need oxygen to breathe for cells to sustain. Fish possess specialized structures to carry out the respiratory function, helping them inhale oxygen dissolved in water.

**Respiration in Fish**

Respiration in fish takes place with the help of gills. Most fish possess gills on either side of their head. Gills are tissues made up of feathery structures called gill filaments providing a large surface area for exchange of gases. A large surface area is crucial for gas exchange in aquatic organisms as water contains very little amount of dissolved oxygen. The filaments in fish gills are organized in rows in the gill arch. Each filament comprises lamellae, which are discs supplied with capillaries. Blood moves in and out of the gills through these small blood vessels. Though gills in fish occupy only a small section of their body, the extensive respiratory surface produced by the filaments renders the whole organism with efficient gas exchange.

Fish take in oxygen-rich water via their mouths and pump it over their gills. When water moves over the gill filaments, the blood within the capillary network takes up the dissolved oxygen. Then, the circulatory system supplies oxygen to all tissues of the body and finally to the cells while taking up carbon dioxide that is eliminated through the gills from the body. It exits the body of the fish once the water moves past the gills through the openings provided in the sides of the throat or through the operculum, a flap, usually found in bony fish, that covers and protects the fish gills.

Several fish, such as lampreys and sharks, have multiple gill openings. Rohu, a bony fish, has a single gill opening on either side.

**a.Structure of gills**

Fish gills are branching organs on the side of fish heads. They have a large number of small blood vessels called capillaries. Afterwards, the oxygen is delivered by the blood that runs through the fish's body, similar to how humans consume oxygen. Mollusks and crustaceans also use gills to pull the oxygen in the water as it runs over the gill.

## Gill Filaments

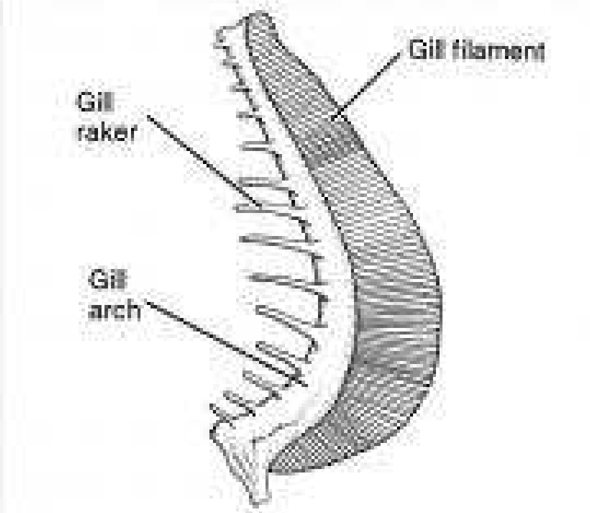
The gill filaments of fish provide oxygen to their blood by taking oxygen from the water. Each filament contains thousands of fine, flexible branches (lamellae) that are exposed to the water. Oxygen is absorbed and ultimately re-emitted into the fish's blood.

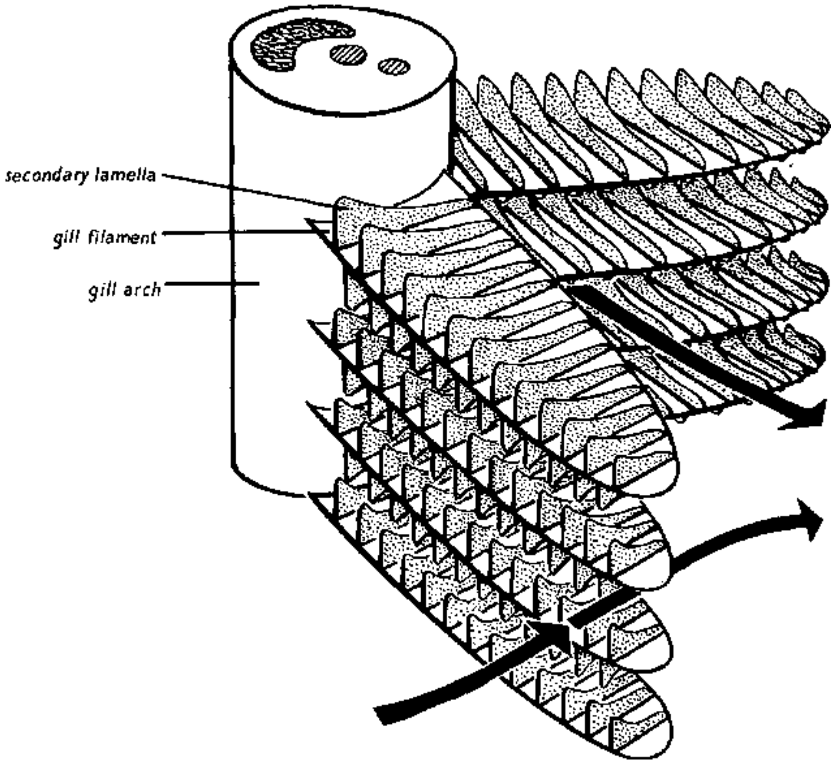
**Gill Arches**

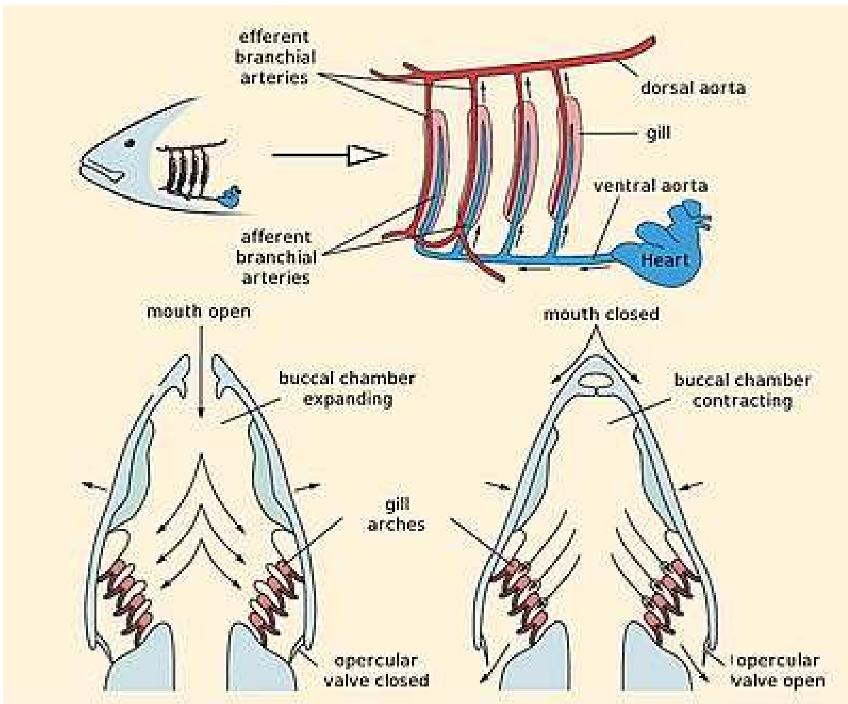
A fish's body is filled with three or more gill arches, usually shaped like a boomerang and composed of cartilaginous or bony segments connected at the back. Each gill arch comprises an upper and a lower limb. In addition to supporting the gills, the gill arches also help the blood vessels.

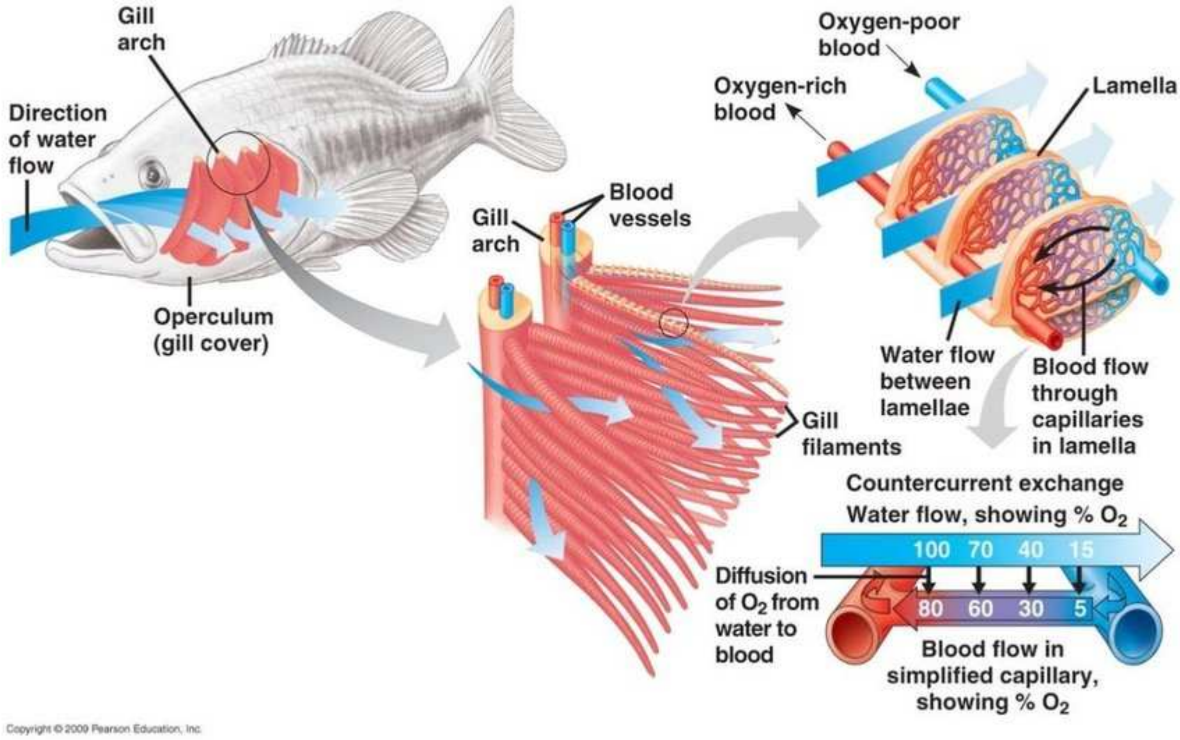
**Gill Rakers**

There are bony projections on the fish's gill arches called "gill rakers" that help them to feed. These projections are positioned forward and inward and vary in shape and number according to the fish's diet.




secondary lamella
gill filament
gill arch


efferent branchial arteries
dorsal aorta
gill
ventral aorta
afferent branchial arteries
Heart
mouth open
buccal chamber expanding
gill arches
opercular valve closed
mouth closed
buccal chamber contracting
opercular valve open


Gill
arch
Direction
of water
flow
Operculum
(gill cover)
Gill
arch
Blood
vessels
Oxygen-poor
blood
Oxygen-rich
blood
Lamella
Water flow
between
lamellae
Blood flow
through
capillaries
in lamella
Gill
filaments
Countercurrent exchange
Water flow, showing % O2
100 70 40 15
Diffusion
of O2 from
water to
blood
80 60 30 5
Blood flow in
simplified capillary,
showing % O2
Copyright © 2009 Pearson Education, Inc.