THE DIFFERENT TYPES OF ANATOMICAL SYSTEMS AND BASIC FUNCTIONS OF EACH SYSTEM OF ORGANS OF FISH

Fish anatomy Internal anatomy of a bony fish: finned aquatic vertebrates animal with skin covered with scales. It lives in water and is usually oviparous.

Brain: seat of the mental faculties of a fish.

Esophagus: part of the digestive tract connecting the mouth to the stomach.

Dorsal aorta: vessel in the back that carries blood from the heart to the organs.

Stomach: part of the digestive tract between the esophagus and the intestine.

Air bladder: pocket in which urine collects.

Spinal cord: part of the nervous system that connects the brain to all other parts of a fish.

Kidney: blood-purifying organ.

Urinary orifice: opening for eliminating urine.

Genital Orifice: opening related to the genital organs.

Anus: end of the digestive tract.

Gonad: hormone-secreting sexual gland of a fish.

Intestine: last part of the digestive tract.

Pyloric ceacum: cul-de-sac related to the intestine.

Gall bladder: small sac containing the bile.

Liver: bile-producing digestive gland.

Heart: blood-pumping organ.

Gills: respiratory organ of a fish.

Tooth: hard organ of a fish used to shred food.

Eye: sight organ of a fish.

Olfactory bulb: bulging part of the smell organ of smell of a fish.

The digestive system

Fish Digestive System

The digestive system, in a functional sense, starts at the mouth, with the teeth used to capture prey or collect
plant foods.

Mouth shape and tooth structure vary greatly in fishes, depending on the kind of food normally eaten. Most fishes are predacious, feeding on small invertebrates or other fishes and have simple conical teeth on the jaws, on at least some of the bones of the roof of the mouth, and on special gill arch structures just in front of the esophagus. The latter are throat teeth. Most predacious fishes swallow their prey whole, and the teeth are used for grasping and holding prey, for orienting prey to be swallowed (head first) and for working the prey toward the esophagus. There are a variety of tooth types in fishes.

Some, such as sharks and the piranhas, have cutting teeth for biting chunks out of their victims. A shark's tooth, although superficially like that of a piranha, appears in many respects to be a modified scale, while that of the piranha is like that of other bony fishes, consisting of dentine and enamel. Parrot fishes have beaklike mouths with short incisor-like teeth for breaking off coral and have heavy pavement-like throat teeth for crushing the
coral. Some catfishes have small brush-like teeth, arranged in rows on the jaws, for scraping plant and animal growth from rocks. Many fishes (e.g., the Cyprinidae or minnows) have no jaw teeth at all but have very strong throat teeth.

Some fishes gather planktonic food by straining it from their gill cavities with numerous elongate stiff rods (gill rakers), anchored by one end to the gill bars. The food collected on these rods is

passed to the throat where it is swallowed. Most fishes have only short gill rakers that help keep food particles from escaping out the mouth cavity into the gill chamber.

Once reaching the throat, food enters a short, often greatly distensible esophagus, a simple tube with a muscular wall leading into a stomach. The stomach varies greatly in fishes, depending upon the diet. In most predacious fishes it is a simple straight or curved tube or pouch with a muscular wall and a glandular lining. Food is largely digested here and leaves the stomach in liquid form.

Between the stomach and the intestine, ducts enter the digestive tube from the liver and pancreas. The liver is a large, clearly defined organ. The pancreas may be imbedded in it, diffused through it, or broken into small parts spread along some of the intestine. The junction between the stomach and the intestine is marked by a muscular valve. Pyloric ceaca (blind sacs) occur in some fishes at this junction and have a digestive or an absorptive function, or both.

The intestine itself is quite variable in length depending upon the diet. It is short in predacious forms, sometimes

no longer than the body cavity, but long in herbivorous forms, being coiled and several times longer than the

entire length of the fish in some species of South American catfishes. The intestine is primarily an organ for

absorbing nutrients into the bloodstream. The larger its internal surface, the greater its absorptive efficiency, and

a spiral valve is one method of increasing its absorption surface.

Sharks, rays, chimaeras, lungfishes, surviving chondrosteans, holosteans, and even a few of the more primitive

teleosts have a spiral valve or at least traces of it in the intestine. Most modern teleosts have increased the area

of the intestinal walls by having numerous folds and villi (fingerlike projections) somewhat like those in man.

Undigested substances are passed to the exterior through the anus in most teleost fishes. In lungfishes, sharks,

and rays it is first passed through the cloaca, a common cavity receiving the intestinal opening and the ducts

from the uro-genital system.

The respiratory system
Fish Respiratory System

Oxygen and carbon dioxide dissolve in water and most fishes exchange dissolved oxygen and carbon dioxide

in water by means of the gills. The gills lie behind and to the side of the mouth cavity and consist of fleshy

filaments supported by the gill arches and filled with blood vessels, which give gills a bright red colour. Water

taken in continuously through the mouth passes backward between the gill bars and over the gill filaments,

where the exchange of gases takes place. The gills are protected by a gill cover in teleosts and many other

fishes, but by flaps of skin in sharks, rays, and some of the older fossil fish groups. The blood capillaries in the

gill filaments are close to the gill surface to take up oxygen from the water and to give up excess carbon dioxide
to the water.

Most modern fishes have a hydrostatic (ballast) organ, called the swim bladder, that lies in the body cavity just
below the kidney and above the stomach and intestine. It originated as a diverticulum of the digestive canal. In
advanced teleosts, especially the acanthopterygians, the bladder has lost its connection with the digestive tract, a
condition called physoclistic. The connection has been retained (physostomous) by many relatively primitive
teleosts. In several unrelated lines of fishes the bladder has become specialized as a lung or, at least, as a highly
vascularized accessory breathing organ. Some fishes with such accessory organs are obligate air breathers and
will drown if denied access to the surface, even in well-oxygenated water.

Fishes with a hydrostatic form of swim bladder can control their depth by regulating the amount of gas in the
bladder. The gas, mostly oxygen, is secreted into the bladder by special glands, rendering the fish more buoyant;
it is absorbed into the bloodstream by another special organ, reducing the overall buoyancy and allowing the
fish to sink. Some deep-sea fishes may have oil in the bladder, rather than gas. Other deep-sea and some
bottom-living forms have much reduced swim bladders or have lost the organ entirely.

The swim bladder of fishes follows the same developmental pattern as the lungs of land vertebrates. There is no
doubt that the two structures have the same historical origin in primitive fishes. More or less intermediate forms
still survive among the more primitive types of fishes such as the lungfishes Lepidosiren and Protopterus.

The circulatory system

Fish Circulatory System

The circulatory, or blood vascular, system consists of the heart, the arteries, the capillaries, and the veins: it
is in the capillaries that the interchange of oxygen, carbon dioxide, nutrients, and other substances such as
hormones and waste products takes place.

The capillaries in turn lead to the veins, which return the venous blood with its waste products to the heart,
kidneys, and gills. There are two kinds of capillary beds, those in the gills and those in the rest of the body. The
heart, a folded continuous muscular tube with three or four sacklike enlargements, undergoes rhythmic
contractions, and receives venous blood in a sinus venosus. It then passes the blood to an auricle and then into a

thick, muscular pump, the ventricle. From the ventricle the blood goes to a bulbous structure at the base of a

ventral aorta just below the gills. The blood then passes to the afferent (receiving) arteries of the gill arches and

then to the gill capillaries.

There waste gases are given off to the environment and oxygen is absorbed. From there the oxygenated blood

enters efferent (exuant) arteries of the gill arches and then into the dorsal aorta. From there blood is distributed

to the tissues and organs of the body. One-way valves prevent backflow. The circulation of fishes thus differs

from that of the reptiles, birds, and mammals, in that oxygenated blood is not returned to the heart prior to

distribution to the other parts of the body.

Excretory organs

The primary excretory organ in fishes, as in other vertebrates, is the kidney. In fishes some excretion also

takes place in the digestive tract, skin, and especially the gills (where ammonia is given off). Compared with

land vertebrates, fishes have a special problem in maintaining their internal environment at a constant

concentration of water and dissolved substances, such as salts. Proper balance of the internal environment

(homeostasis) of a fish is in a great part maintained by the excretory system, especially the kidney.

The kidney, gills, and skin play an important role in maintaining a fish's internal environment and checking the

effects of osmosis. Marine fishes live in an environment in which the water around them has a greater

concentration of salts than they can have inside their body and still maintain life. Freshwater fishes, on the other

hand, live in water with a much lower concentration of salts than they require inside their bodies. Osmosis tends to promote the loss of water from the body of a marine fish and absorption of water by that of a

freshwater fish. Mucus in the skin tends to slow the process but is not a sufficient barrier to prevent the

movement of fluids through the permeable skin. When solutions on two sides of a permeable membrane have

different concentrations of dissolved substances, water will pass through the membrane into the more

concentrated solution, while the dissolved chemicals move into the area of lower concentration (diffusion).

The kidney of freshwater fishes is often larger in relation to body weight than that of marine fishes. In both

groups the kidney excretes wastes from the body, but that of freshwater fishes also excretes large amounts of

water, counteracting the water absorbed through the skin. Freshwater fishes tend to lose salt to the environment
and must replace it. They get some salt from their food, but the gills and skin inside the mouth actively absorb
salt from water passed through the mouth. This absorption is performed by special cells capable (like those of
the kidney) of moving salts against the diffusion gradient. Freshwater fishes drink very little water and take in
little water in their food.

Marine fishes must conserve water, therefore their kidneys excrete little water. To maintain their water balance
marine fishes drink large quantities of seawater, retaining most of the water and excreting the salt. By
reabsorption of needed water in the kidney tubules, they discharge a more concentrated urine than do freshwater
fishes. Most nitrogenous waste in marine fishes appears to be secreted by the gills as ammonia. Some marine
fishes, at least, can excrete salt by clusters of special cells in the gills and intestine.

There are several teleosts-for example, the salmon-that travel between fresh water and seawater and must adjust
to the reversal of osmotic gradients. They adjust their physiological processes by spending time (often
surprisingly little time) in the intermediate brackish environment.

Marine lampreys, hagfishes, sharks, and rays have osmotic concentrations in their blood about equal to that of
seawater so do not have to drink water nor perform much physiological work to maintain their osmotic balance.

In sharks and rays the osmotic concentration is kept high by retention of urea in the blood. Freshwater sharks
have a lowered concentration of urea in the blood.

pressure, a**nd certain aspects of skin colour.**

Locomotion in Fish

Fish swim, everybody knows that. They are in fact much better at swimming than we are, but then so are all the mammals that live their lives in the water. Fish make swimming look easy, and for them it is, millions of years of evolution have created many fascinating adaptations, many of which we do not yet understand. What we do know is that fish, and aquatic mammals are incredibly efficient at swimming. The energy required to propel a Whale Shark through the water at 10 km an hour is far less than the energy required to propel a submarine of similar size at the same speed.

While we do not understand all there is to know about how fish swim so effectively we do know that its flexible body plan helps it to greatly reduce the turbulence it creates, and that a swimming fish experiences far less drag, about 10th only, of the drag generated by a rigid model of a fish being being propelled at the same speed. Part of the efficiency also comes from the slime that a fish produces, while this is annoying when you are trying to hold a fish it reduces the friction a fish experiences by at least 65%.

Water is of course far more dense than air, (about 800 times more) and therefore it resists the

movement of any body through it much more strongly than air. However water is also noncompressible which means it is far easy to generate thrust by pushing against it. Further more, the density of water is very close to the density of a living body, which means that fish have to expend little or no energy in resisting gravity. You may have noticed, when you are tired, how heavy your head becomes, this is because gravity is pulling your head down, and your muscles have to work all day just to hold it up. A fish, or mammal, living in water doesn't have this problem.

All this means that water is actually the easiest medium to move through and that swimming is the most efficient form of locomotion known. The energetic costs of travelling 1 km (per kilogram of body weight) are 5.43 kcal for a walking Ground Squirrel, 1.45 kcal for a flying Gull and only 0.39 kcal for a swimming Salmon, which makes swimming about 7 times as efficient as walking for creatures well adapted to their respective mediums and methods.

The absolute speed at which a fish swims is relevant both its size and its shape, and like you it can only keep going at top speed for a relatively short period of time before it gets tired. But at a more leisurely pace it can keep going all day. For your typical Trout, Herring or Sardine shaped fish the maximum speed is around 10 body lengths per second, naturally this means that larger fish swim faster. For instance a 30 cm (1 ft) Sea Trout (*Salmo trutta*) has a top speed of around 10.8 km (7.2 miles) per hour while a 20 cm specimen as a top speed of about 8.1 km (5.4 miles) per hour, while a 60 cm (2 ft) Salmon as a top speed of around 22.5 km (14 miles) per hour. Naturally fish that have evolved less dynamic shapes and attitudes in order to allow them to survive in specialist habitats, such as coral reefs, the sea floor, the deep oceans or environments with dense vegetation have lower relative top speeds. However fish can swim at many different speeds and as a general rule, excepting anguilliform swimmers, fish, when actively swimming, not just drifting with slow tail beats, develop a speed that relates to its length and the frequency of its tail beats in the following way. $V = 1/4 [L(3f-4)]$ where 'V' is the velocity in centimetres per second, 'L' is the length of the fish and 'f' is the frequency of tail beats per second. So there you have it.

A fish uses its fins to swim with, mostly it is the caudal (tail) fin that is used for propulsion while the remaining fins are for balance control and fine maneuvering. However slower moving fish, fish which simply are not in a hurry, or those working in habitats where movement is restricted are quite capable of delicate and direct movements powered only by the dorsal, pectoral and pelvic fins. The pelvic and pectoral fins are both capable of sculling, basically rowing the fish forward. The extreme proponents of pectoral fin locomotion are ofcourse the skates and rays, many of whom have given up the traditional arrow-shaped fish form for a more bird like one in which the pectoral fins are greatly enlarged and very well muscled and the fish seem to fly through the water.

The dorsal and anal fins or many fish are capable of undulating movements in which a series of oscillating waves travel along the fin. These muscularly generated waves provide a steady, if not intense forward thrust. Good examples of fish that rely on dorsal and anal fin undulations to move around are the Tube-mouths (Pipe-fishes and Sea horses) however many other fish use them as well, even larger fish such as *Esox lucius* the Pike. Most of the fish that use their fins for propulsion are also capable of using body flexure and the caudal fin as well. However some fish such as those in the order Plectognathi (Trunk-fish, Parrot-fish, Butterfly-fish, Porcupine-fish, and Trigger-fish etc) have all lost the ability to swim using body flexure and can only move using their other fins. The Sun-fishes (Molidae) are by far the largest fish to have given up body flexure and swim their lives through the vast open seas propelled entirely by the paddling of their

dorsal and anal fins.

Normal swimming involves sinuous movements of the fish's body to varying degrees. The fish flexes its muscles to produce a series of waves of contraction along each side of the body , these waves of muscular contraction alternate from one side of the fishes body to the other and the result is that the tail of the fish is moved from side to side. In long thin fish such as eels the fish's whole body undulates in series of open s-shaped curves. For most species the thrust is developed as the caudal fin and to some extent the anterior part of the body push against the water, however for species like eels, where the fins are small, but the body somewhat is flattened the whole rear section of the fish acts as a caudal fin. Scientists now divide active swimming like this into three categories depending on the amount of flexure the fish's body undergoes.

Fish that form a deep sinuous wave while they are swimming, such as eels, lampreys, lungfish and some sharks, as in the image above, are termed 'Anguilliform swimmers'. Fish that swim actively using the caudal fin, but which flex the fin in a manner that leaves the body relatively steady, such as Boxfish and Trunkfish, see image below, are termed 'Ostraciform swimmers'. In between these two extremes there are a large number of fish that flex their body to an intermediate degree, the body may make an s-shape, but it is a shallow wave, as in many sharks, or they may merely flex the anterior half of the body, as in Tuna. Such fish are referred to as 'Carangiform swimmers'. Carangiform swimmers and anguilliform swimmers only contract a portion of the muscles on either side of their body at any one moment, by controlling and varying the muscular activity on both sides of their body they create the wave like movements we see when they swim. In comparison, ostraciform swimmers contract all the muscles on one side, and then all the muscles on the other, this beats the tail, but does not through the body into a sine wave.

Flying fish do not really fly. Scientists generally define flying as 'powered flight', and within this designation what flying fish do is glide, not fly. This is because all the momentum they possess whilst travelling through the air is gained while they are in the water and not from the air. In other words they don't flap their enlarged fins in the air, but only hold them out stiff.

Air travel, or gliding, has evolved in four different families of fish, all of which are marine in their habits; the Belonidae or Gar-fish, the Dactylopteridae or Flying-gurnards, the Exocoetidae, or Flying-fish and the Hemirhamphidae or Half-beaks. Of these it is the Exocoetidae, with about 50 species, which are the traditional Flying-fish. These fish have greatly enlarged pectoral fins, which they hold folded up alongside the body while they are swimming, but which they open out once their body is out of the water. They also have assymetrical dorsal fins, with the lower lobe being larger.

The fish swim rapidly, and close to the surface of the oceans they inhabit, holding their bodies with the head up and the tail down. When they wish to leave the water the tail begins to beat very rapidly, up to 50 times a second in some species. This increase in speed pushes the fish's body out of the water whereupon the pectoral fins can be unfolded. However the lower lobe of the tail or dorsal fin remains in the water a while longer and is therefore able to continue to supply propulsion even as the body escapes the resistance of the water. This final flurry of exertion drives the fish fully into the air where it glides for up to 5 or 10 seconds. As the fish's body is angled relative to the water surface the tail re-enters the water first and by flexing it rapidly a fish may enter an almost immediate second, and even 3rd, 4th and 5th take off. During such a number of repeated takeoffs a fish may rise up to one metre above the surface of the water and travel for several hundreds of metres at speeds as great as 30 km/h (20 miles/h) spending more than 40 seconds above the ocean's surface.

Two other familes of fish, both of which inhabit fresh waters, include species that were once thought to have powered flight, the Pantodontidae and the Gasteropelecidae. The Pantodontidae currently contains only one species, *Pantodon buchholizi*, the African Butterfly Fish while the Gasteropelecidae contains nine species including the Marbled Hatchet Fish, *Carnegiella strigata*. Both these species have deep bodies with a lot of muscular support for their enlarged pectoral fins, or in the case of *Pantodon*, pectoral and pelvic fins. It is now considered that both these species simply jump, if somewhat spectacularly, out of the water using their enlarged fins and extensive musculature to build up speed whilst in the water.

Finally having started with the statement that fish swim, we need to end with a mention of those fish that prefer to walk. Yes it is true, many fish are quite happy walking, because of the support that water offers their bodies they do not need strong bones for support and as long as the pectoral fins are reasonable firm, and long enough to hold the body off the substrate, then a fish can walk. Other fish have learned to leave the water and swim across the land and some have even learned to hop, or jump.

Several species of fish are known to cross short land barriers between one area of water and another using basically the same actions as they use in swimming, these include eels (*Anguilla sp.*), cuchia (*Amphipnous sp.*) and Snake-heads (Ophicephalidae) and several catfish in the genera Clarias and Saccobranchus. A rather more unusual means of terrestrial locomotion is shown by the Indian Climbing Perch (*Anabas scandens*), which uses sharp spines on the lower parts of its gill covers to hold onto the ground whilst it pushes itself forward using its tail and its pectoral fins.

However none of these fish could truly be said to be walking. There are however several species of fish which have become quite adept at fin-walking, on land, and in the water. In the water the best known, and most proficient of these are the Blennies, of which there are many species, but note should also be taken of the Lizard-fishes (Synodontidae) and the Gurnards (Trigilidae) both of which are happy to crawl across the ocean floor on their fins.

On land only a few species of fish, mostly in the genus Periopthalmus (Mud Skippers) have really taken to fin-walking. Two these are the African Mud Skipper (*Periopthalmus papilio*) and the Asiatic Snake-head (*Ophicephalus striatus*). Mud Skippers are the most adept walkers. They possess a strengthened girdle, and extra muscles to facilitate their walking, which is done using the pectoral fins with the tail supperting the end of the body. They are able to climb tree roots and survive for long periods of time out of the water. They use their unusual ability to hunt down terrestrial insects and surface dwelling crabs. Mud Skippers as well as some other fish, particularly Gobies (Gobiidae), are very good at jumping from a substrate, or hopping. In the coastal, tropical environments where they live they happily leap from one pool of water to the next at low tide. A fine example of a fish that hops by first curving up its tail and then suddenly straightening it, whilst pushing it against the ground, is the Sheep's-head Molly Miller (*Bathygobius soporator*).

As an absolute end to this section I must mention one fish that has learned to use its fins to hold onto and to climb around on the seaweed where it lives. The pectoral and pelvic fins of Sargassum-fish (*Histrio histrio*) are long and flexible and they can use them to grasp the fronds of the sargassum that creates an underwater jungle where they live. They will also move their fins in an alternating pattern to crawl along fronds. However they also swim very well.

Well I hope you have enjoyed this brief look into the world of fish locomotion. Remember that with over 29,000 species the range of possible variations is immense and there is a lot more that you could learn about fish locomotion if the subject really interests you, but for that you will

have to visit a university or college library.
The last two images of this page are of Blennies, fish which are closely related to Gobies, unfortunately I have no images of Gobies. These two images, and the one at the top of the page, are reproduced, from the book 'The Fish of Bulgaria' with the kind permission Lyubo Penev of Pensoft Publishing. They were both painted by the talented Georgi Pchelarov.

☐ Fertilization is achieved when the nucleus of the egg cell and that of the sperm unite in the cytoplasm of the egg. This fusion which completes fertilization allows the chromosomes that carry the genes (hereditary factors) to be brought together.
This enables the genes form both parent to exert their effects on the developing embryo.
☐ The embryonic period is of 2 stages.
☐ The egg stage and free-living embryo or prelarva stage.
☐ Development takes place within the membrane of the embryo during the egg stage while at prelarva stage, development continues outside the embryo.
☐ After fertilization (with study of *O. niloticus*, Omotoso, 1987), the yolk shrinks away from the membrane and this is followed by accumulation of cytoplasm at the animal pole to form a polar cap.
☐ The first division (cleavage) which occur between 3rd and 4th hour after fertilization is vertical and meroblastic and resulted into formation of two-cells of equal size.
☐ The second cleavage occurs 2 hours later and is perpendicular to the axis of the 1st division resulting in formation of four large blastomeres.
☐ Further meridional and vertical divisions of the four blastomeres *cells) produce many more blastomeres to form what is called the morula (between 7 - 9th hour after fertilization)
☐ As a result of successive cleavage which occur between 9-11th hour, the bastomeres increase in number but further decrease in size.
☐ The dome shaped mass of cells is noticeably elevated over the general outline of the yolk man to form the blastula.
☐ At about the 14th , there is flattening of the blastoderm followed by thickening and widening of a small portion of the blastodise to form the embryonic shield.
☐ About half of the yolk is encompassed by periblast and the cephalic area is discernible at about 17th hour.
☐ By the 24th hour after fertilization, the three main parts of the brain are distinctive and there is a lateral expansion of prosencephalon to form optic bud.
☐ Sometimes begin to appear.
☐ Between 30 and 40 hours after fertilization the lens is evident and the outline o heart rudiment is well defined with the brain region more prominent.
☐ When 48hours old, heart rudiment is more elongated and it shows twitches at a rate of 120-133/min. the embryo has encircled about ¾ of the yolk and possess 8-10 pairs of somites.
☐ Between 60 and 70 hours there is elongation of pericardial cavity and circulation of blood is noticeable.
☐ The heart is anterior to the brain region and the blood flows posteriorly and ventrally in the developing embryo.

☐ The brain and the head one further enlarged. The sonifes are more closely packed.

☐ Form this stage, further development entails general increase in embryo size, gradual decrease in the yolk size and differentiation of various organs.

☐ **One-day old**

☐ **Two-day old**

☐ **Three-day old**

☐ **Four-day old**

☐ **Five-day old**

☐ **Six-seven day old**

☐ This is stage of feeding on external food.

☐ The external and internal structures are not fully developed.

☐ Divided into 2 fry stage. Swim up fry and advanced fry.

☐ The third stage period is the immature (fingerlings) period. It is at time, called sub-adult stage.

☐ This stage is when the fish resembles the adult in external appearance.

☐ The gonads are under-developed; secondary sexual characters are either completely lacking or feebly developed.

☐ Diagrams and other items will be presented during the regular classes/practicals