COURSE CODE: FIS301

COURSE TITLE: Fish Biology

NUMBER OF UNITS: 3 Units

COURSE DURATION: Three hours per week

COURSE DETAILS:

Course Coordinator: Dr. I.T. Omoniyi
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Other Lecturers: Dr. F.I. Adeosun and Dr. A.A. Akinyemi

COURSE CONTENT:

The gross external and internal anatomy of a typical bony and a typical cartilaginous fish. The different types of anatomical systems and basic functions of each systems of organs of fish. Embryology and life history of a fish with special reference to commercially important fish, e. g. Tilapia, catfish and Mullets.

COURSE REQUIREMENTS:

This is a compulsory course for all students in Department of Aquaculture & Fisheries Management. In view of this, students are expected to participate in all the course activities and have minimum of 75% attendance to be eligible to write the final examination.

READING LIST:

The Fresh Water Fishes and Fisheries of Nigeria by D.H.J Sydenham Fish and Fisheries of Northern Nigeria

Ikenweiwe, **N.B**, D. Odulate, B. Adigun (2011) *Ichthyology and Limnology: Tools In Fisheries Management Fisheries Management.* United Kingdom. Lap Lambert Academic Publishing. ISBN: 978-3-8433-9364-5. Available online at http://dnb.b-nb.de 127 pages

http://www.fishbase.org/summary/species

LECTURE NOTES

GROSS EXTERNAL ANATOMY
By way of introduction, basic diagnostic features of fish need to be identified.
1. Fishes are cold blooded/poikilothermic animals i.e. their body temperature varying passively in accordance with the ambient temperature (surrounding water temperature).

Although, fishes as a group can tolerate wide range of temperature from just below O0C to 450C, individual species generally have a preferred or optimum as well as a more restricted temperature range. For example, salmonids inhabit water with temperature range from 0-200C. Any change within the optimum range can significant influence the biology as related to the anatomy.

2. The adoption of aquatic habit has other implications for the structure and physiology of fish. For instance, it makes the streamlining and shaping of the body an important pre-requisite
for success in aquatic life. The shapes range from ovoid to torpedo-like or fusiform shape. This is
due to the higher density of water than air.

3. Respiration assumes a greater important through the gills when compared to terrestrial
animals because water contains 1/20th of 02 available in air. This proportion of 02 is still further
reduced by an increase in temperature and/or ionic concentration. Fishes are exposed to much greater ionic and osmoregulatory challenges than land animals because their bodies are permanently immersed in water (a medium) which is not only the universal solvent but also the
fluid in which gases must diffuse during respiration exchange. Microbial infection and multiplication are more likely to occur from the water medium.

Therefore, there is the need to consider the structural implication of fish to an aquatic existence.

The gross external anatomy allows an individual especially the fisheries scientist to identify most
species with a fair degree of accuracy. When doubt exists, other anatomical details may have to
be examined. The body shape of fish is totally adapted to a free-swimming life in water and it is
adapted to give maximum efficiency to its propulsion through the water.

Make a drawing each of body and cartilaginous fish. e.g tilapia as bony and *Scoliodon* (shark) as
cartilaginous fish. Label each fully during class lecture.

There are basically two shapes of fish-round and flat fishes. Flat fish such as Skate, Rays, Plaice
and Soles are adapted to life on the bottom of the water body. Round fish in general have evolved an efficient hydrodynamic shape to allow them to move through the water body with the
minimum expenditure of energy. Body shapes of fishes can also be described based on the crosssections
of the body. These shapes include:

i Fusiform shape- Cross section fish is round e.g in tuna, mackerel. Draw.

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ii Compressiform shape-Shows lateral compression e.g Tilapias, *Ilisha* etc. (Draw)

iii Anguilliform shape-compressed body form but are laterally long e.g *Gymnarchus.*(Draw)

iv Filliform shape- Round cross-section but with long body e.g eel, *Calamiochthys calabaricus.*(Draw)

v Teaniform shape- cross-section shows oval outlook e.g *Clarias, Heterobranchus.*(Draw)

vi Sagittiform- eound but with upper part flat e.g *Hepsetus odoe* (the African pike). (Draw)

vii Depressiform shape-cross section is dorso-ventrally compressed. e.g Soles,Skates and Rays.
(Draw)

viii Globiform shape- Round cross-section and looks like a ball when viewed from the side. e.g
globefish, sunfish (Draw)

The Skin: The external surface of the body of fish is the skin which is composed of two layers –
an outer epidermis and the inner dermis. It is from the underlying dermal layer that the
characteristic scale covering of fish is produced. The epidermis is a thin, fragile layer which is
constantly sloughed off and renewed. It contains mucous cells which secrete the sliming outer
covering of fish. The slime on the epidermis is called mucus which makes the fish slippery to
handle. The mucus protects the epidermal layer against abrasion and by lubrication makes the
fish more streamlined and also difficult to hold. It also renders the skin less permeable and
prevents entry of pollutant materials and microorganisms which would otherwise infect the
fish.
This is why fish are handled with care to avoid damage or injury to the skin or its protective
coating. The lipoprotein properties of the slime also trap or bind heavy metals and bacteria
which
are then lost as the mucus is washed off the surface of the fish. Draw the TS of Skin. The scale
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which are composed of bone and connective tissue growth in size in accord with other tissue in
the body. Each scale overlaps the one behind producing a relatively impermeable but living
cover. Growth rings or annuli are seen on the scale. Variations in thickness of these rings are
produced by seasonal changes in diets or temperature or by spawning. The annuli can be used to
determine age of fish. Note that these rings are more difficult to interpret with tropical fishes
than the temperate fishes. The reason being that growth in tropical fishes is usually more rapid
than it is in temperate water. Also, growth rings are not clearly seen in cultured fish because they
are maintained under relatively stable conditions and feed at constant rates.
Types of scales: (i) Placoid scales – sometimes called dermal denticles. It has an ectodermal cusp
made up of an enamel-like substance. Commonly found in shark (Elasmobranchii/cartilaginous
fish).
(ii) Cosmoid scale – is another type of scale in this category. It resembles placoid but thinner
and with harder water layer. It is made up of material known as virtrodentine. Found in the living
and extinct lobefin fishes.
(iii) Ganoid is another type of scale in this category. It differs in having inorganic salt
substance called ganoine. It has a diamond-shape flat, smooth enamel-like surface. Sometimes
called rhombic scale because of its shape. Found in *Polypterus*, *Calamoichthys calabaricus.*
The other two types of scales commonly called bony ridge scales are found in many living fish
species especially the Osteichthyes. These are:
(a) Cycloid scale which is characterized by its exposed surface being smoothly rounded.
That is, its thin smooth disc-like surface edge has a more or less circular outline. Fishes having
this type of scales are therefore smooth to touch e.g. tilapias, *Heterotis, niloticus* (Draw)
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(b) Ctenoid scale has its posterior surface or margin toothed i.e. comb-like.
Therefore, fish is rough to touch e.g. *Ctenopoma kingsleyae*. It should be noted that there are
fishes without scales. These are called Scaleless or 'naked' fishes. These fishes are usually
covered with thick slime/mucus which make them more slippery to touch or handle e.g.
Malapterurus electricus, Clarius sp.

Mouth positioning can be used to describe fish. Make diagrams of such which include:
(i) Terminal mouth e.g. in tilapias
(ii) Sub-terminal mouth e.g. in *Clarias*
(iii) Inferior mouth e.g. in Shark
(iv) Superior mouth e.g. in *Hemichromis*
(v) Retracted mouth e.g. in African barrel fish (*Hyperoglyphe*)
(vi) Protrusible/Protracted mouth e.g. Star gazer (*Uranoscopus*)
The mouth of fish is equipped with teeth are used in connection with feeding. Teeth are one of
the structural adaptations to feeding habit. Based on location in the mouth, teeth could be described as:
(i) Premaxillary – teeth located on the front margin of the upper jaw.
(ii) Maxillary – teeth located on the sides of the upper jaw on separate bones
(iii) Mandibular teeth – these are located on the margin of the lower jaw
(iv) Vomerine – these are located on the front part of the roof of the buccal cavity.
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(v) Pharyngeal teeth – these are located on the throat.
Based on the types cusps, there are 3 types:
Unicuspid teeth – Have one cusp each
Bicuspid teeth – Each tooth has two cusps
Tricuspid teeth – Each tooth has three cusps
Tricuspid teeth – Each tooth has three cusps.
Based on the form, there are
(i) Villiform teeth – these are numerous, short, fine and pointed teeth e.g. found in *Channa*, stargazer.
(ii) Incisor-like teeth – these are with sharp edges used for cutting. Highly characteristic of the carnivorous e.g. *Gymnarchus*
(iii) Canine-like teeth – these are relatively big pointed teeth used for piercing and holding prey. Found in piscivorous fish e.g. Barracuda, *Hepsetus odoe, Hydocynus*, Shark etc.
(iv) Molar-like teeth – these are flattened broad teeth used for cutting and crushing e.g. in benthic fishes feeding on shellfish and detritus e.g. Rays, Skates.
Note that in some fishes, teeth may remain vestigial e.g. the planktophagous feeding fishes – *Ilisha africana* and in Carps which are omnivorous.

FISH APPENDAGES – FINS
The fish external appendages are essentially the fins which constitute the most vital external features for identifying fish using the ray counts especially of the dorsal and anal fins. The sizes
and shapes of fins, their location on the body and positions in relation to each other are important
in classification. Each fin is made up of a number of rays which are usually bony and flexible and they may be either simple or branched. In many fishes, some of the rays especially of the dorsal fin are replaced by strong and sharp spines which are counted as a tool in systematic e.g.
Tilapias. An appendage may be median in that their rays are in line with the axis of the fish.
They are found at the back of the fish e.g. dorsal fin or at the tail region referred to as the caudal
fin and the lower edge behind the vent called the anal fin. In some fishes, there are two dorsal fins e.g. lamprey, shark, *Mugil, Pentanemus.*
However, there are some species which second smaller posterior dorsal fin is soft, fleshy tissue
that is not rayed. This is termed adipose fin e.g. in *Heterobranchus, Bagrus, Chrysichthys* etc.
The function of the adipose fin remains unclear but it is useful to fishery scientists and farmers to
mark or identify individual fish. It is incapable of regeneration once cuts.

Some mackerel groups have small series of dorsal fins which are soft rayed, referred to as finlets,

may also occur ventrally. (Illustrate all these in class).

The second categories of fins are called the paired fins. These are the pectoral and pelvic fins. Fins are generally used by fishes to achieve all forms of locomotion, stabilization, balancing, change of direction and brake in the aquatic environment.

It should be noted that the internal skeleton is noted to form the frame to which are attached the

muscles used for swimming and breathing. The fish propels itself through the water by sinusoidal movements of the body amplified by the flat tail.

There are modifications in some fishes to the general functions of some fins e.g.

Pectoral fins are modified for crawling in Australian lungfish; used as tactile organ for feeling in

Trichurus tricurus; as gliding organ in some flying fish e.g. *Exocoetus sp*; as taste organ in primitive species e.g. Hag fishes or as a protective organ because of the associated powerful spines e.g. *Synodontis, Clarias, Heterobranchus*.

Pelvic fin is also modified as tactile organ in *Protopterus;* as suckers in gobies or even as intromittent organ known as Clasper e.g. in shark and skates. It aids in reproductive activity. Anal fin is modified as intromittent organ in the family Poecillidae.

The caudal fin in most fishes is lobed i.e. it is forked given rise to upper and lower lobes attenuated to points. But in some fishes, it is rounded, pointed, truncate etc. Candal fin is used for

identification.

Illustrate in class the different types of caudal fins in fishes.

The Lateral line: Constitutes a visible feature of the extraordinary sensory system in fishes. It

consists of a series of marks or pits usually one on each scale, running along. The midline of each side of the body and also at times on the head e.g. *Heterotis.*

Some fishes have a discontinuous lateral line, the anterior part often being higher on the body and more conspicuous e.g. Tilapias. A few fishes have no lateral lines e.g. Clariids. These pits

are connected through special sensory organs to the nerves running to the brain. By means of these sense organ, fishes are able to detect movement and vibrations which are far beyond their

range of vision.

REPRODUCTIVE BIOLOGY IN FISHES

Briefly, reproduction is a process or means whereby a fish can maintain its continual existence

mainly by sexual method. This method allows for genetic variation, leads to hybrids and evolution of new species. Three types of reproduction are recognized in fishes.

(a) Bisexual reproduction – involves two individuals male and female. This method is mostly common in fishes.

(b) Hermaphroditic reproduction – occurs in very few fishes e.g. some salmonids and perches and Black bass (*Micropterus* being introduced in Nigeria). In this case, both male and female reproductive organs are present in each individual. In some fishes, there is sex reversal

i.e. at any point in time there is either testis or ovary. But it can change when it is necessary, ovary changing to testis and vice versa. The two sex organs do not occur at the same time.

(c) Parthenogenetic reproduction – in fishes, it is appropriately known as Gynogenetic reproduction where sperm penetrates the egg but will not fuse with the nucleus of the egg. It only

stimulates the egg.

Reproductive systems include ovaries in female and testis in female. The system also include reproductive ducts. In primitive fishes e.g. jawless fishes (Agnatha), there are no productive

ducts, but have gonads only. He gonads are internal, longitudinal and originate as paired in most
fishes. In few fishes, the two may become partly fished or fused totally together. In some, one
may become degenerate, one functions (Illustrate all these during lecture hours). Gonads are
enclosed and suspended in mesenteries called mesorchia and attached to the air bladder. In very
rare or abnormal cases, some fishes may have two pairs of gonads. The size, weight and colour
of gonads vary depending on the stage of sexual maturity. The weight of gonad is usually
expressed as percentage of the body weight of fish. This is known as Gonado-somatic index
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(GSI). The GSI in male fish is about 12% or less while in female it is between 30-40%. In terms
of colours, the virgin or immature gonads are almost colourless and translucent. But the
developing and mature testis, it is usually creamy white and flocculent while the developing and
maturing ovaries, colour ranges from yellow through golden yellow to green. The ovaries are
usually granular in texture, testis and smooth. The size of granular in texture, testes are smooth.
The size of granules depends on the stage of gonads. In outline, the ovary is usually longer than
the testis and when they ripen, the ovaries occupy most of the body cavity leaving vary little
space for other viscerals. In some fishes especially the catfish Clarias, Synodontis the testis looks
wavy or folded in outline. Illustrate the TS of testis.
The structure of sperms varies from species to species. Illustrate with examples of eel, trouts,
perch, guppy. Most eggs in fishes are spherical, some are oval in outline e.g. Cichlid, may look
like tear-drops e.g. in guppy. Some eggs may have appendages used for anchorage e.g. Shark
(Draw). The maximum size of eggs varies from species to species. This is attributed to parental
care exhibited by the fish. Fishes which show some care for their egg and young one tend to have
large sized eggs and young have tiny or small eggs. Fish with large sized eggs produce fewer
numbers of eggs while those produce small sized eggs spawn large number of eggs. The
smallness of the eggs is associated with the fecundity or number of eggs produced by the fish.
The small sized tends to have higher density of yolk and hatch faster than big sized eggs. The
sperm cells are produced in large number in a juicy fluid secreted by the sperm duct. The sperm
cells (Spermatozoa) and the sperm duct secretion make up the white fluid called MILT. A drop
of milt may contain thousands of sperm cells

Fecundity
Simply, fecundity is the number of eggs produced by a fish. This term has been variously defined
by authors e.g. (i) defined as the number of eggs produced by fish at each spawning (number of
eggs/spawn) (ii) Number of eggs produced in a season (number of eggs/season) (iii) Number of
eggs produced in a year (number of eggs/life time). The first three definitions for fishes which
spawn in a year are essentially the same. But, in case of fishes e.g. Tilapias, which spawn
between 4 and 14 times in a year, these definitions are not useful. The 4th definition above is
more difficult because it is not easy to know the life span of a fish. Therefore, the more

convenient definition of fecundity is taken as the number of eggs in the ripe ovary of a fish. As

fishery biologist, look for ripe ovary and count number of eggs. This is called total or individual

or absolute fecundity of a fish. Relative fecundity is taken as number of eggs in the ripe ovary of

a fish per unit weight or length of a fish. Relative fecundity is a more reliable expression of fecundity of a fish for comparative purpose.

Importance of Fecundity (i) used as part of systematic in racial studies (ii) useful in studies of

population dynamics and productivity (iii) Preserves species and relative stability both in space

and time.

In order to assess fecundity, the stage of gonad development need to be determined e.g. Using Kesteven (1960) key.

Stage I – Gonad appears as a strand lying within the visceral.

Usually, it is impossible to determine sex except by microscopical examination.

Stage II – Enlargement of gonads. Stages I and II are immature.

Stage III – Further increase in size of gonads. The ovary takes on a pale greenish colour whereas

testis assumes a cream colour e.g. in Sarotherodon. The stage is maturing.

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Stage IV – Gonads tend to move in the mid-line thus increase in size. No further numbers of eggs can be added. Counting of eggs can start at this stage.

Stage V – Ripe stage. With small taping, few eggs are released.

Stage VI – With taping, the eggs are running. The stage is referred to as running stage of spawning.

Stage VII – Gonads empty

Stage VIII – Recovery stage

Stages IV and V can be used in estimation of fecundity.

How to determine the fecundity of a fish

   Measure length and weight of the fish, preferably when still fresh.

   Take out the ovaries, weigh and then take a sub-sample of 1g or 5g or 10g. Count the

eggs. A lens or a binocular microscope can be used in the counting. It may be necessary to take

sub-samples from different parts of the ovary and calculate the average number of eggs per unit

weight or length of fish.

Multiply the number of eggs in sub-samples by the weight of the ovary to get the total number of

eggs in the ovary. This method is known as Gravimetric method. For example –

W – Weight of two ovaries

w – Weight of subsample of ovary

n – Number of eggs in sub-sample

N = n x W (N = total number of eggs i.e. fecundity)

W

The second method is volumetric which utilizes volume of eggs instead of weight of the eggs.

Direct enumeration is another method. This is a direct count, very accurate and useful when the

ovary is small and number of eggs is very low. During counting, eggs may damage, it is

therefore necessary to harden the eggs before counting. Different technique for hardening eggs,

the most convenient method is by using the Gilson's fluid. Put ovaries in the fluid and shake

intermittently for 1-2 weeks after which the count could be made. Before preserving the ovary,

remove the ovarian walls for the fluid to penetrate into the eggs. Other method is by boiling the

ovary, many eggs are gummed together hence break at counting. 70% alcohol or 10% formalin

may be used but still stick together and break during counting.

Factors affecting fecundity will be discussed during lecture hours. Endeavour to attend.

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