INTRODUCTION TO TAXONOMY

Dr Rekha J Nair
Principal Scientist, ICAR -CMFRI, Kochi

What Is Taxonomy?

Taxonomy is a study of organisms for their identification, description, naming and classification. This field classifies organisms into categories and groups based on their characteristics. It is therefore a methodology that helps in organising plants and animals in hierarchies of higher ranking and subordinate groups. The term is derived from the Greek *taxis* ("arrangement") and *nomos* ("law"). The taxonomic classification given by Carl Linnaeus in 1750 is globally accepted.

Historical Background

- People who live close to nature often have an excellent working knowledge of local fauna and flora. Biologists aim to view all living organisms with equal thoroughness, leading to the development of formal classifications.
- The **Linnaean system** of binomial nomenclature, created by Swedish naturalist Carolus Linnaeus, is internationally accepted for naming and classifying organisms.
- Ernest Haeckel studied about the unicellular eukaryotic organisms and classified them as a separate kingdom and named it Protista, and then the classification was made based on three kingdom classification.
- R.H. Whittaker gave the five kingdom classification (**Monera, Protista, Fungi, Plantae, and Animalia**) where all the organisms are classified based on their physiological structure, habitat, anatomical structure.

However, **Carolus Linnaeus is often regarded as the "Father of Taxonomy**." He is the one who devised a method for naming and organizing species. This method is being followed today. The starting date of binominal nomenclature is fixed as 1st January, 1758, the publication of 10th edition of *Systemae naturae* by Carl Linnaeus.His contributions to taxonomy were many.

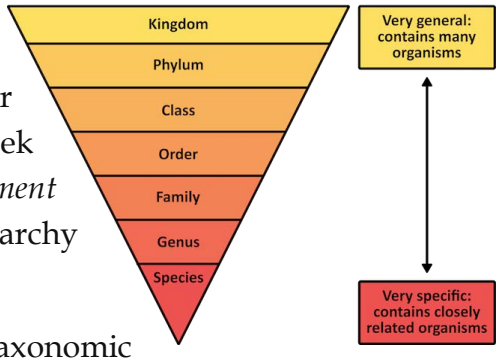
There are several stages of taxonomy such as

Alpha taxonomy: In this stage species are identified and characterized on the basis of gross morphological features.

Beta taxonomy: In this stage species are arranged from lower to higher categories, i.e., hierarchic system of classification.

Gamma taxonomy: In this stage intraspecific differences and evolutionary history are studied.

Taxonomic hierarchy is a system for classifying living species into successive levels of biological classification, called taxonomic categories or ranks. The word "taxonomy" comes from the Greek words "*taxis*" and "*nomos*", which mean "*arrangement division*" and "method". The taxonomic hierarchy categories are:



or

- Class: The most general rank in the taxonomic hierarchy until phyla were introduced
- Order: A more specific rank than class
- Family: Includes various genera that share a few similarities
- Genus: A group of similar species
- Species: The lowest level of taxonomic hierarchy

Systematics: In biology, systematics is the study and classification of living things; in other words, grouping organisms based on a set of rules (or system). The word systematics is derived from the Latinized Greek word 'systema' applied to the system of classification developed by Carolus Linnaeus in the 4th edition of his historical book Systema Naturae in 1735.
Systematics can be divided into two closely related and overlapping levels of classification: taxonomic (known as the Linnaean System) and phylogenetic.

The typological species concept

For practical reasons, the typological species concept is still used to this day: a species is a set of individuals that are identical to each other and to the "type" specimen, i.e., the specimen used to describe and characterize the species in morphological terms. This type is deposited in a museum where it serves as a reference or a sort of standard for comparisons or future revisions

Type definitions

(EXTRACT OF THE INTERNATIONAL CODE OF ZOOLOGICAL NOMENCLATURE FOURTH EDITION -as adopted by the XX General Assembly of the International Union of Biological Sciences, December 1999)

type, n. A term used alone, or forming part of a compound term, to denote a particular kind of specimen or taxon. allotype, n. A term, not regulated by the Code, for a designated specimen of opposite sex to the holotype [Recommendation 72A].

cotype, n. A term not recognized by the Code, formerly used for either syntype or paratype, but that should not now be used in zoological nomenclature [Recommendation 73E].

genotype, n. A term not recognized by the Code, formerly used for type species, but that should not now be used in zoological nomenclature [Recommendation 67A].

hapantotype, n. One or more preparations consisting of directly related individuals representing distinct stages in the life cycle, which together form the name-bearing type in an extant species of protistan [Arts 72.5.4, 73.3]. A hapantotype, while a series of individuals, is a holotype that must not be restricted by lectotype selection; however, if a hapantotype is found to contain individuals of more than one species, components may be excluded until it contains individuals of only one species [Art. 73.3.2]. holotype, n. The single specimen (except in the case of a hapantotype, q.v.) designated or otherwise fixed as the name-bearing type of a nominal species or subspecies when the nominal taxon is established.

lectotype, n. A syntype designated as the single name-bearing type specimen subsequent to the establishment of a nominal species or subspecies [Art. 74].

neotype, n. The single specimen designated as the name-bearing type of a nominal species or subspecies when there is a need to define the nominal taxon objectively and no name-bearing type is believed to be extant. If stability and universality are threatened, because an existing name-bearing type is either taxonomically inadequate or not in accord with the prevailing usage of a name, the Commission may use its plenary power to set aside that type and designate a neotype. paralectotype, n. Each specimen of a former syntype series remaining after the designation of a lectotype [Art. 72.1.3, Recommendation 74F].

paratype, n. Each specimen of a type series other than the holotype [Recommendation 73D].

syntype, n. Each specimen of a type series (q.v.) from which neither a holotype nor a lectotype has been designated [Arts. 72.1.2, 73.2, 74]. The syntypes collectively constitute the name-bearing type.

topotype, n. (topotypic, a.). A term, not regulated by the Code, for a specimen originating from the type locality of the species or subspecies to which it is thought to belong, whether or not the specimen is part of the type series.

Sister species Sister species are biological species that have achieved reproductive isolation but are still difficult to discern based on morphology alone. These species probably result most frequently from recent speciation

Science of naming

Taxonomy is far from simple. A complicated, book devoted to all the rules that must be followed when giving an organism a name called the **International Code of Zoological Nomenclature** is to be followed. It is revised periodically and the latest edition, the Fourth, was published in 1999.

As stated, the full name of a species is given as two words: its genus (always capitalized) followed by the specific epithet (never capitalized)

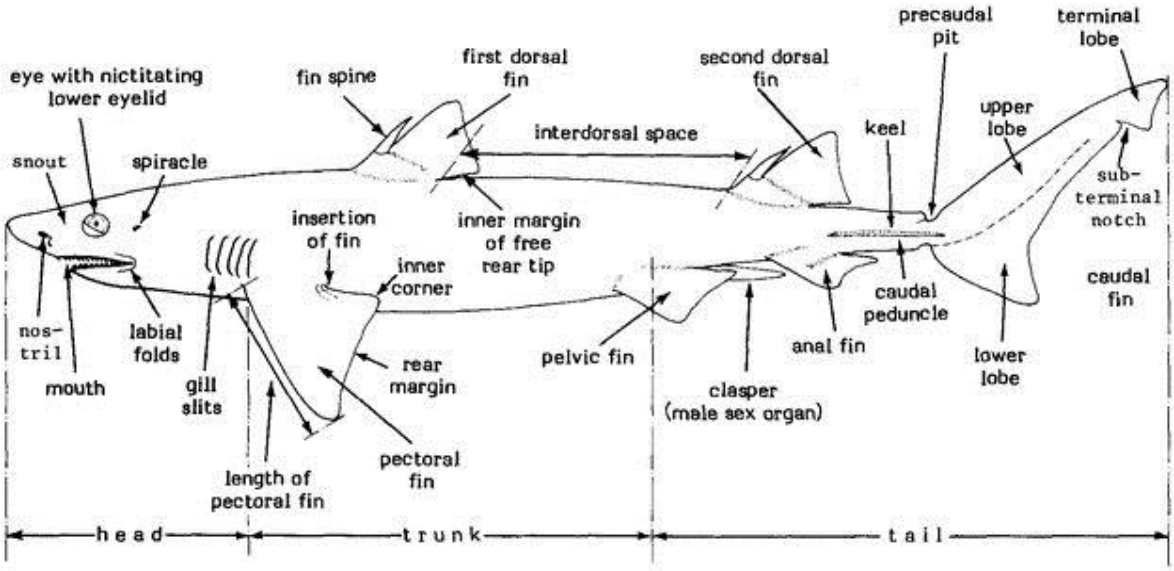
Formation_of_names – (www.iczn.org)

How to proceed in taxonomy

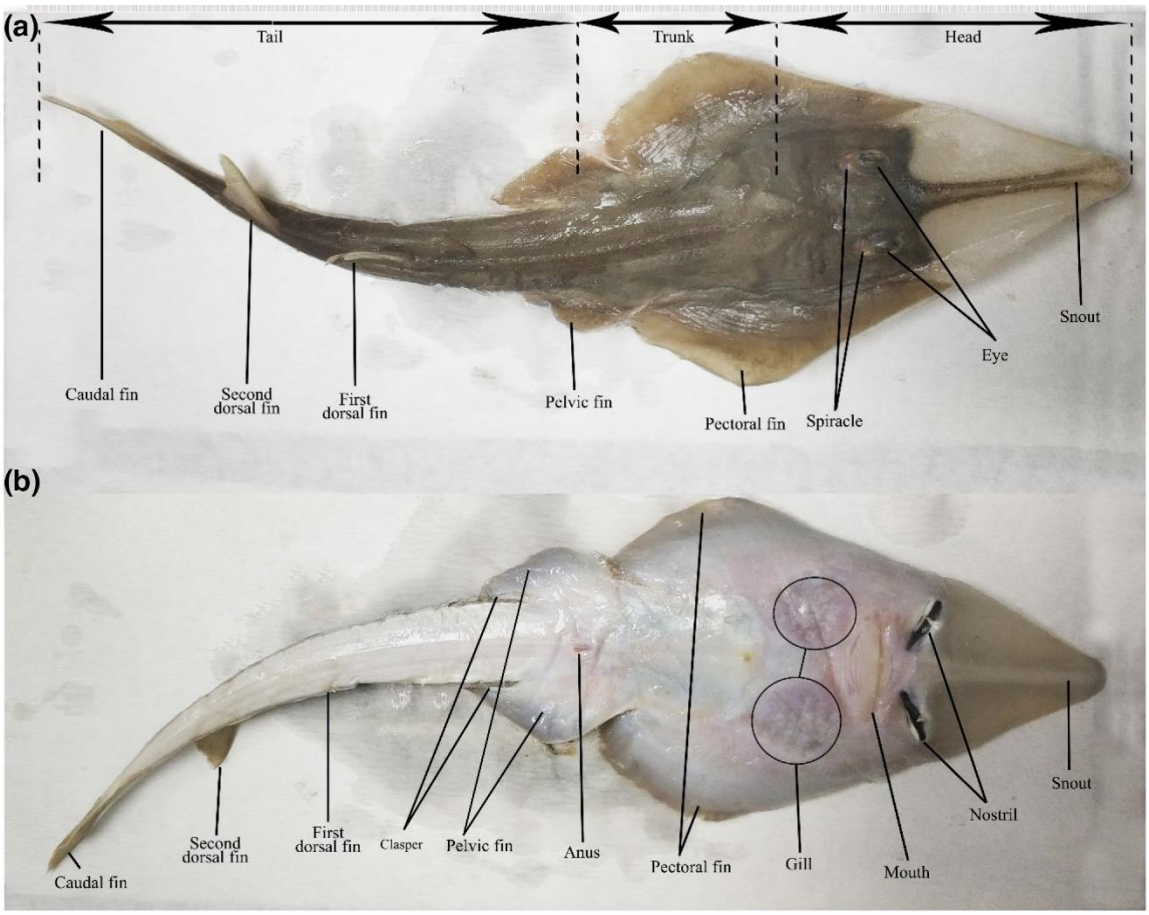
Steps:

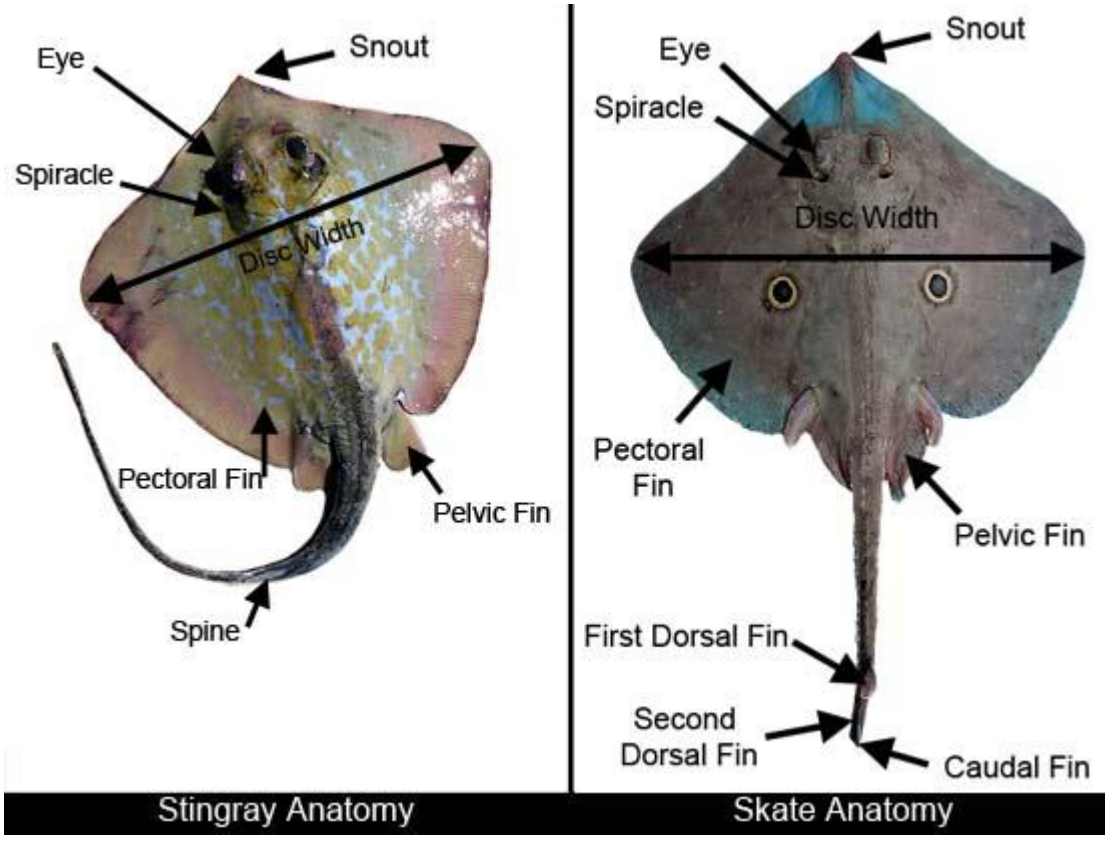
1. Collection from wild/harbours

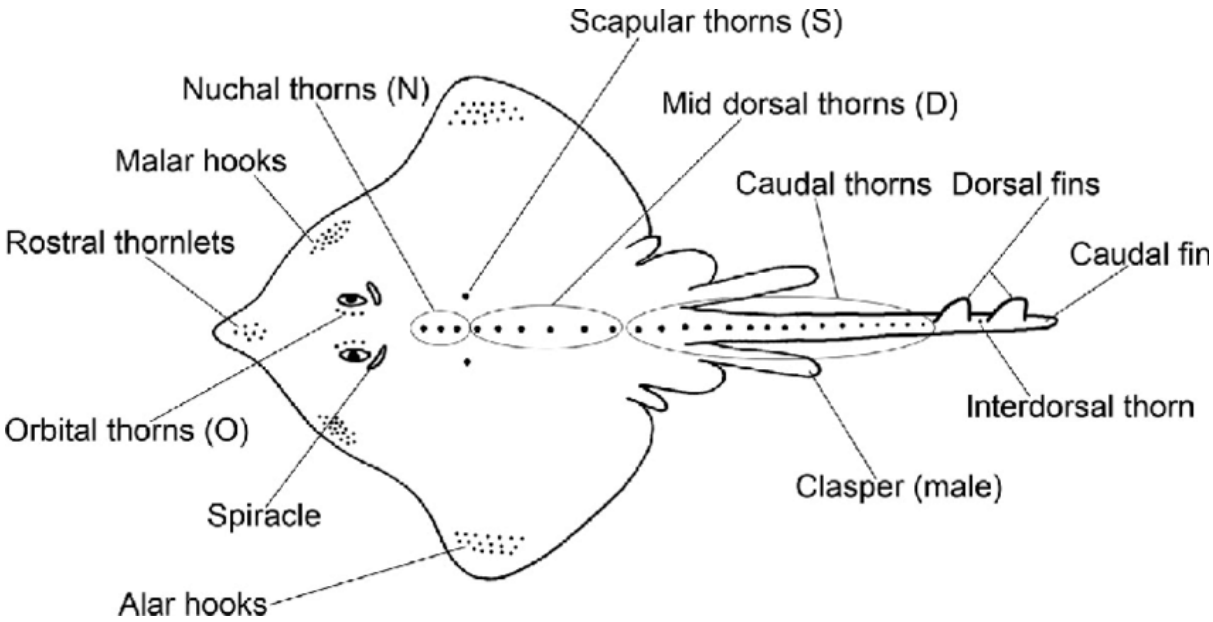
2. The fish is to be first cleaned well, with all debris and slime removed. It is then to be spread out on a thermocol with all fins expanded to get full coverage. A photograph is to be taken in fresh condition to note the colour in fresh
3. All external characters is to be noted down
4. The morpho and meristic features of the fish is to be measured (Figs)

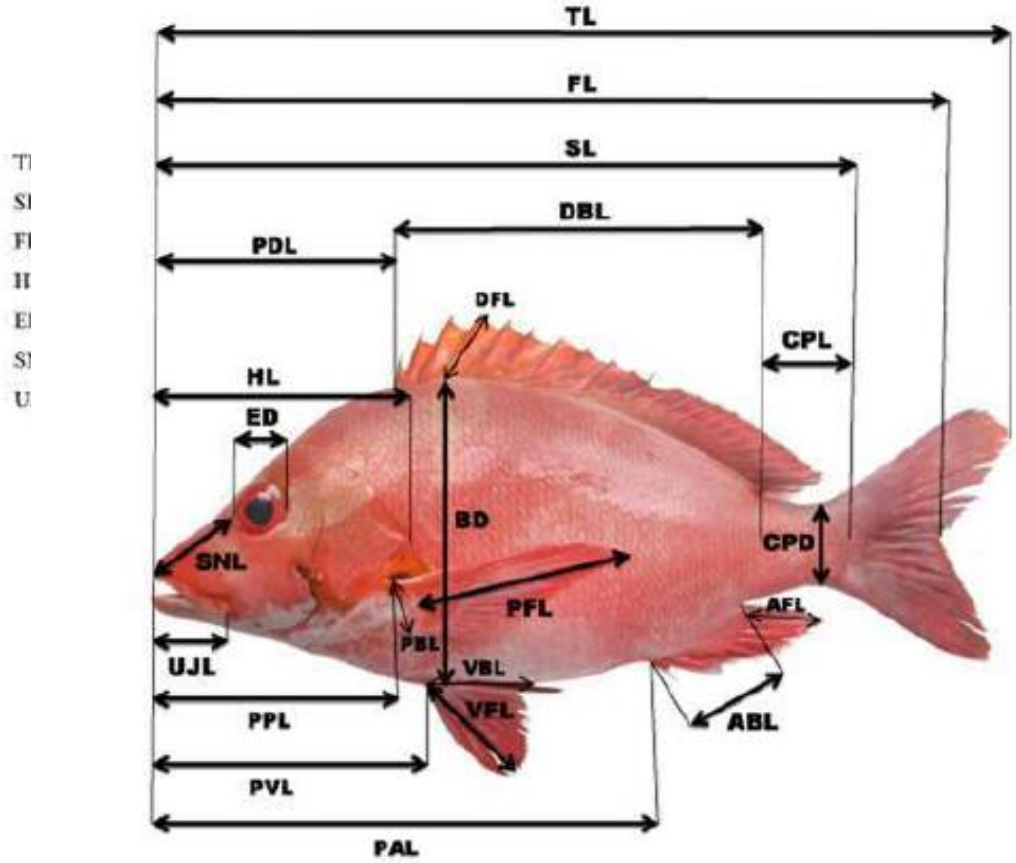


(Source: FAO)


(a)
Tail
Trunk
Head
Caudal fin
Second dorsal fin
First dorsal fin
Pelvic fin
Pectoral fin
Spiracle
Eye
Snout
(b)
Caudal fin
Second dorsal fin
First dorsal fin
Clasper
Pelvic fin
Anus
Pectoral fin
Gill
Mouth
Nostril
Snout


Eye
Snout
Spiracle
Disc Width
Pectoral Fin
Pelvic Fin
Spine
Stingray Anatomy
Eye
Snout
Spiracle
Disc Width
Pectoral Fin
Pelvic Fin
First Dorsal Fin
Second Dorsal Fin
Caudal Fin
Skate Anatomy





5. Descriptive characters in taxonomy to be noted are

a.Mouth: The position of a fish's mouth can tell you a lot about the feeding habits, living style and type of behaviour it exhibits.

Fishes mouth types are broadly divided based on three categories

midwater feeders, surface feeders and bottom-feeders.

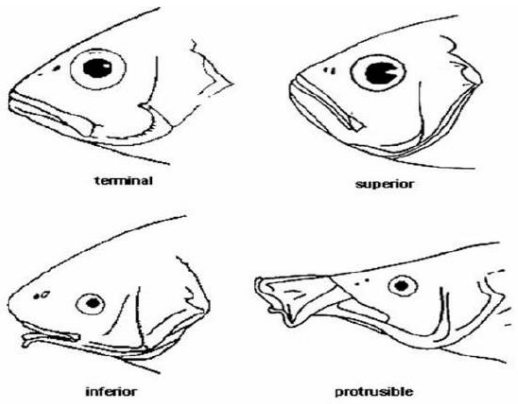
a. Mouth types:

Terminal: Fish with a terminal mouth position have a mouth in the middle, or centre of the head. These fish are mostly predators who either chase their food or feed on what is seen in front of them. The terminal mouth position is the "normal" position of mouth for most of the fishes inhabiting the middle levels of the water column of oceans or lakes.

Superior: This kind of fish has scoop-like mouth which is designed to feed on prey that swims above the fish (on the surface of the water), such as insects or plankton.

Inferior: Bottom feeding fish generally have inferior or sub-terminal mouths. Mouths located under the fishes head that are adapted for scavenging or grazing on algae, molluscs or bottom dwelling invertebrates.

Protrusible: Protrusible or protractile mouth in fish is a structural arrangement of the jaws that enables the animal to extend the mouth at will. When fully protruded, the cavity of the mouth is enlarged to form a funnel-like space facilitating the uptake of food. Fishes with feeds on small invertebrates in hidings has protrusible mouth.



Different mouth patterns (Source: Florida museum)

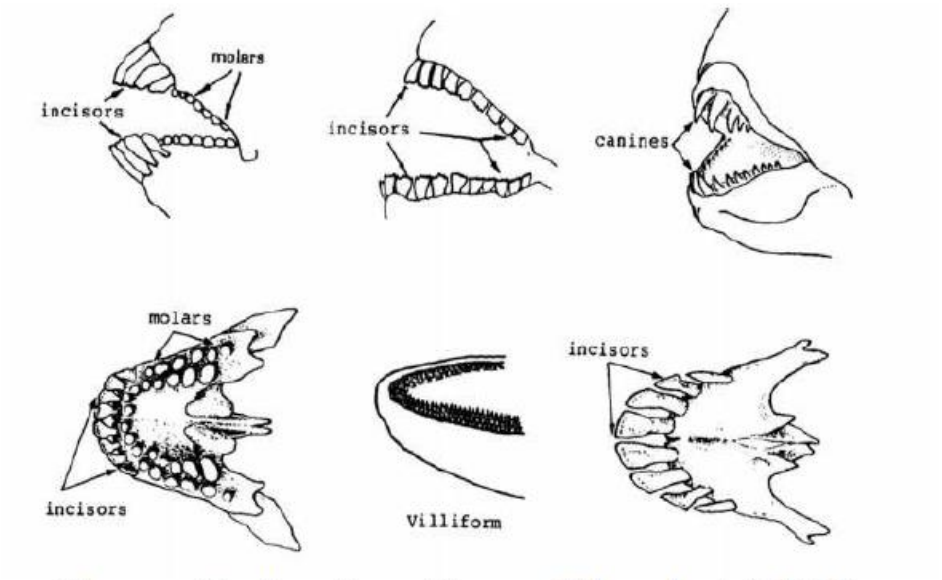
b. **Teeth:** These serve as a very important taxonomic character. Generally, five types of teeth are recognised in fish based on their cardiform, villiform, caniniform, incisiform and molariform.

Teeth types: The following teeth patterns are encountered in the fishes *Canine teeth*: They are sharp, highly pointed teeth seen in predatory fishes which are seen to attack and hold prey in their sharp teeth. The teeth are also used to tear of flesh from the prey. Sharks are best examples of fishes with canine teeth.

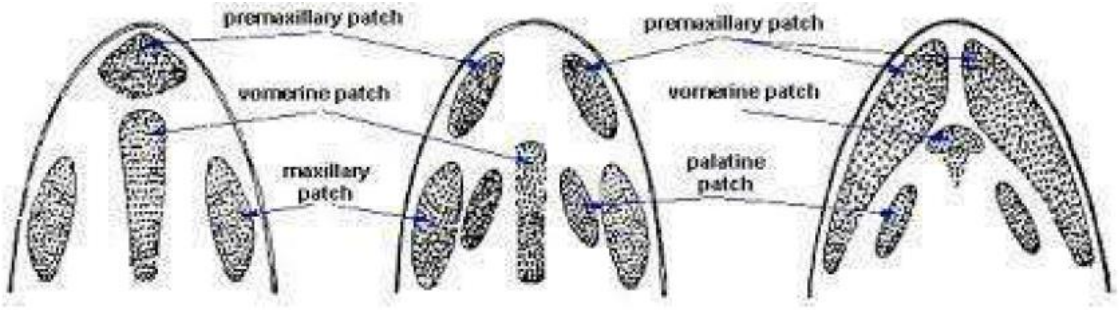
Incisor teeth: Incisors are used for cutting and they come in variety of shapes. These are flattened tooth with chisel like or saw edges.

Molar teeth: These are blunt, rounded, broad tooth adapted for crushing and grinding shellfish. They are generally found in bottom dwelling fish.

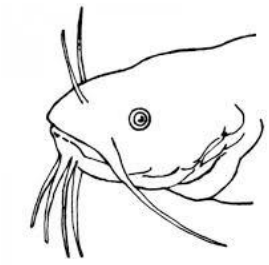
Villiform teeth: Villiform teeth are elongated teeth they are very long, slender and crowded having the appearance of velvet or fine bristles of a brush. They are more common on deep see fishes used for stabbing and direction.



Common Teeth patterns (Source: Edwards et al. 2001)



c. **Barbels**: Barbels are slender, whisker like tactile organs near the mouth. They are found in fish like catfish, carps etc, they house the taste buds used by fish to find food.



d. **Body shapes**: Body shape is a dominating factor in taxonomy; deciding on how the fish lives and its domain.

Commonly the fish body is Torpedo – shaped. In a perfectly "stream lined" body form (if head pointed trunk broadened and gradually tapering towards the tail).

Fusiform: Fusiform, or streamlined fish like the barracuda or jack are capable of swimming very fast. They

usually live in open water.

Globiform – (Puffers of family Tetraodontidae)

Serpentine (Snake like Angulliform – eels of family Anguillidae)

Thread like (spiny eel-Symbanchiformes)

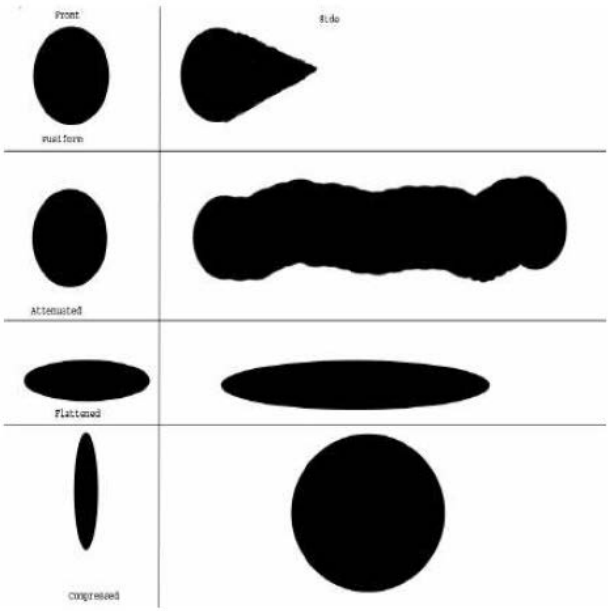
Compressed- Strongly flattened from side (butterfly fishes, Chaetodontidae and flounders – Pleuronectidae)

Flattened but greatly elongated (Trachipteriform – ribbon fishes, Trachipteridae)

Depressed: Depressed fish (flattened from top to bottom), like stingrays, live on the bottom

In a cross section, these look like

Body Shapes



Gill Rakers:
The morphology of gill rakers is so diverse that they are often used as a taxonomic tool to identify and classify fish species. For example, plankton feeders have very tightly-packed, comb-like, gill rakers to efficiently filter their food from the water column. Omnivores or piscivores, on the other hand, have shorter, more widely-spaced gill rakers, better for larger prey items.

Colour patterns: Reef fishes in particular have wide and varied colour patterns on their body which makes them highly suitable for life in reef habitats. Red is a common colour in reef fish. However, most fish that have this coloration live in dark or deep water, or are nocturnal (active at night). In deep waters and in coralline areas, red light is filtered out quickly so red is a good camouflage. At night red-coloured objects appear grey. The squirrelfish has this kind of coloration.

Camouflage: Here, the fish takes on the appearance of the environment. This makes the fish invisible to other fish as well as other predators. This is achieved by
Disruptive: This is in the form of stripes, spots and helps the fish avoid being eaten by confusion. This is a form of camouflage. The patterns and lines break up the outline of the fish or help it to blend into the background. The brightly patterned fish of coral reefs blend in with the corals despite their brilliant colours. Eg. Moorish idol exhibits disruptive coloration.
Counter Shading: This is primarily seen in marine fish where the top half of the fish is darker in colour than the bottom half.
Poster Colouration: This is the most characteristic colouration pattern usually found in reef fish. The fish is characterized by different bright colors. This helps reduce predation on reefs and could be also used as a form of communication.
Warning Colouration: Many fish use bright colours to "advertise" the presence of poisonous spines or some other defensive mechanism. Eg. the Nave surgeonfish has

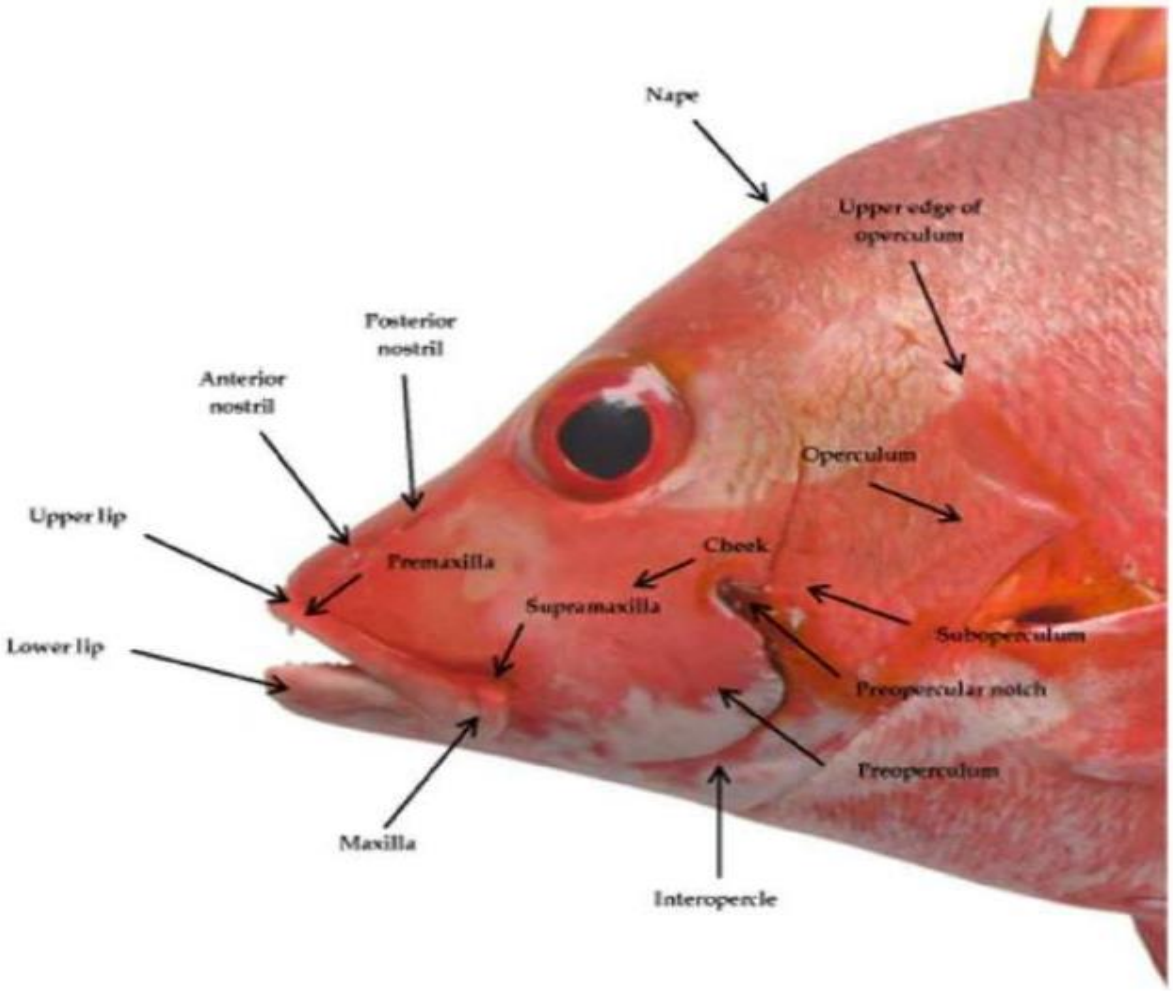
two bright orange spots near the base of the tail that advertise the presence of razor sharp spines.

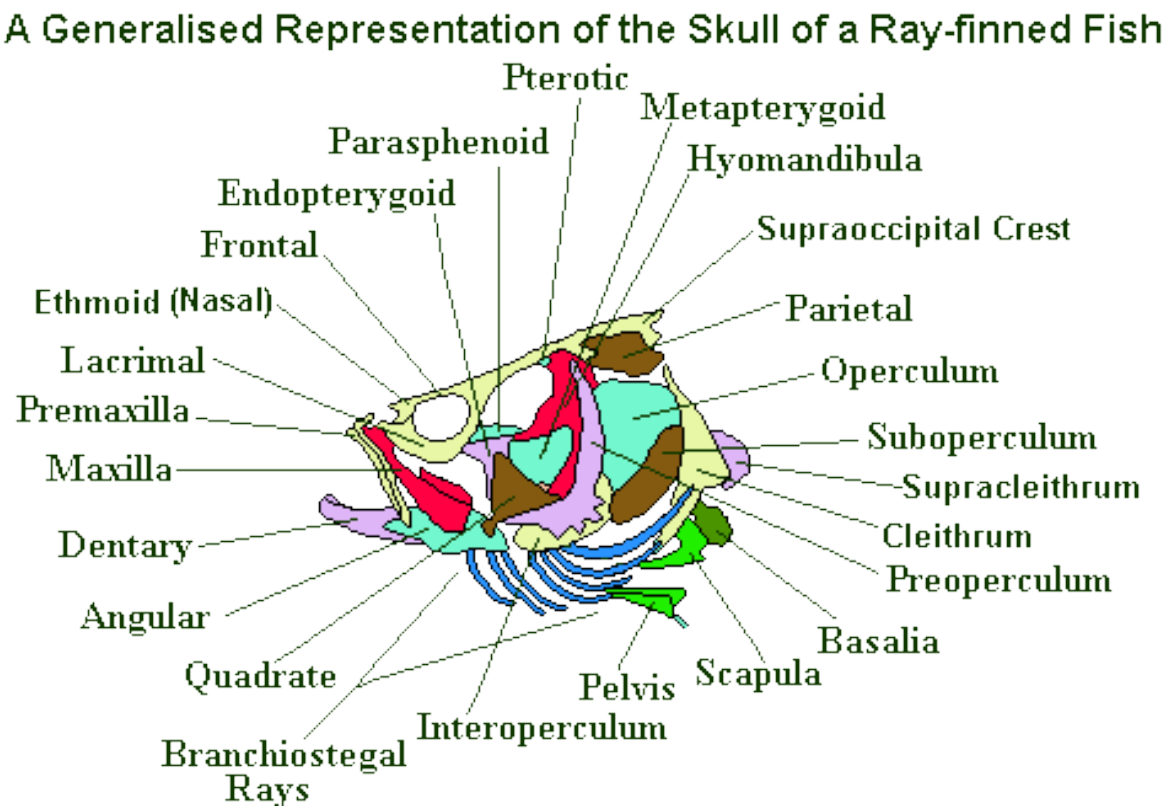
Mimicry

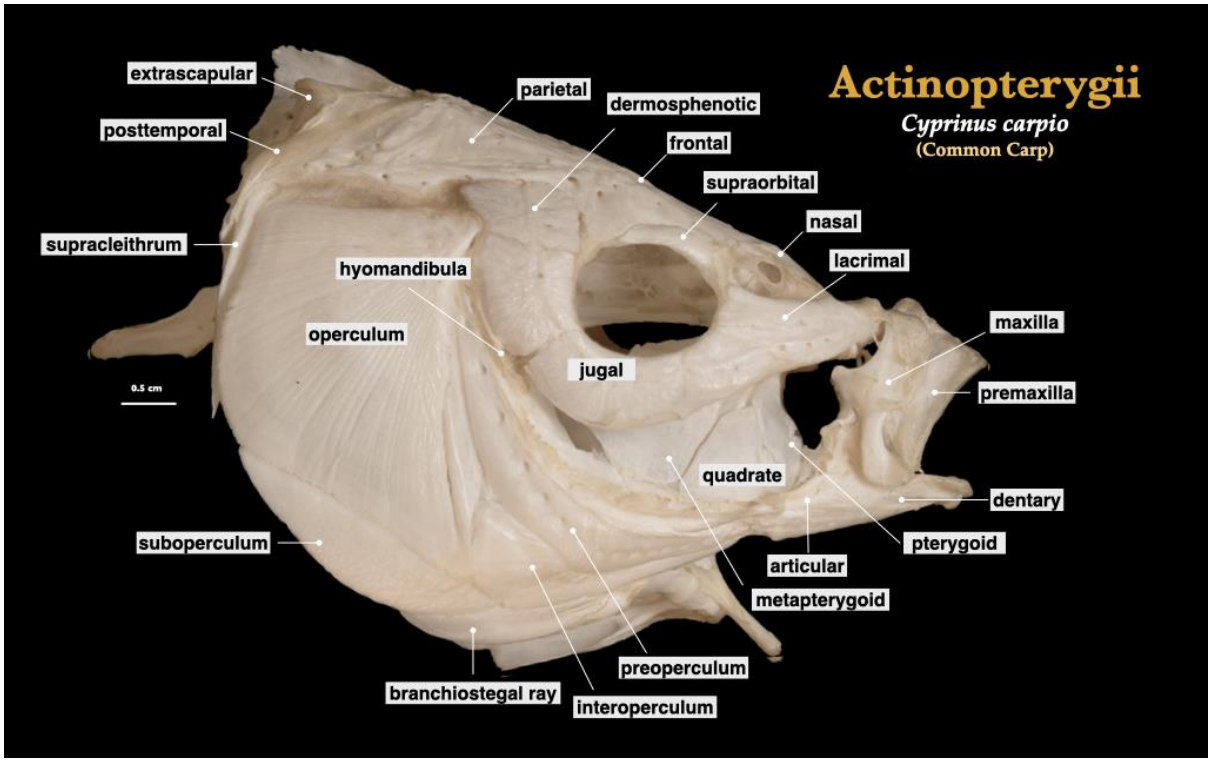
Here, nontoxic individuals mimic toxic individuals; non-aggressive fish look like aggressive species; predators can mimic prey species (ex. Sabertooth Blenny).

Eye spots are a form of mimicry. The eye spot, usually found near the tail, draws attention away from the real eye which is a target that a predator might strike. The eye spot may cause the predator to attack the wrong end and allow the fish to escape alive.

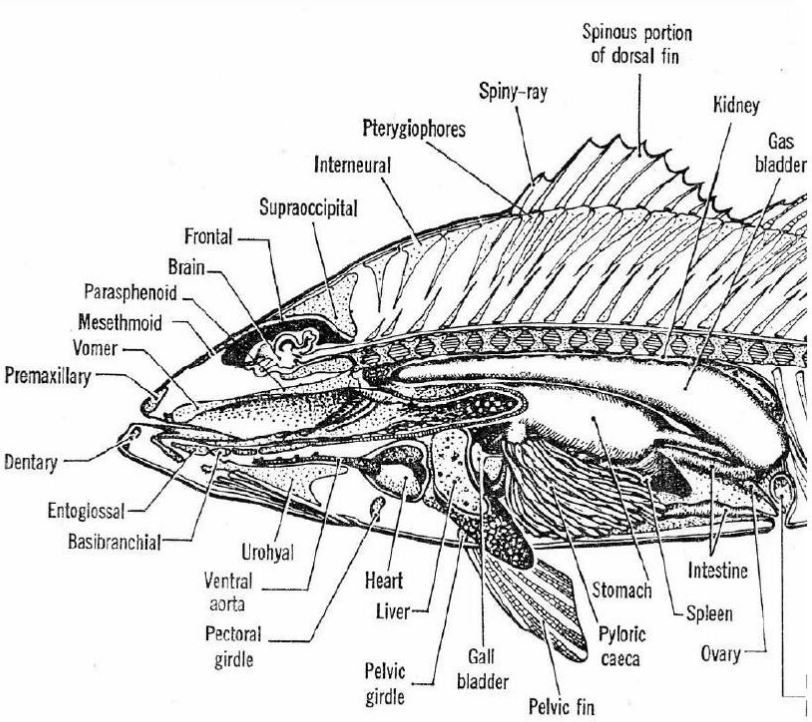
Head







(Source: Berkeley Museum)



Source: Internal anatomical features of a Largemouth Bass, *Micropterus salmoides*. The image is from Lagler, Bardach & Miller (1964) - (Source: Lagler, 1954).

Meristic Counts: Counts are generally taken on the left side of fish.

1.**Finray/Spine counts**: Both spine and ray counts are taken on all fins. Dorsal fin counts are written in Roman numerals and rays counts in Arabic numerals eg. X, 6-8., if the spinous and soft-rayed portions of the fin are continuous, the counts are separated by a comma. If the fin is divided into two parts, a plus sign (+) separates the counts, eg. D IX + 4-6. If only a single fin ray is given instead of a range, the count is taken as usual with no variations.

2. Spines are hardened, stiff, unsegmented, unpaired, unbranched fin rays. Spine counts are characteristic of the genus and does not normally vary between species of same genus.

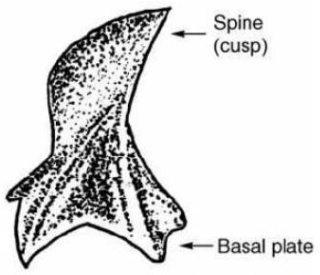
3.Rays are soft, flexible structures that may be branched or unbranched at the tips. The last ray of the dorsal and anal fins is sometimes branched at the base and is to be counted as one ray.

Body Scales

Fish scales constitute the external covering of almost all fish species. The structure and configuration of scales can be used to determine the species from which they came. Scale types also affect the behaviour of a fish--larger, heavier scales providing more protection but restricting movement, while smaller, lighter scales offering more

freedom of movement but less protection. There are four different types of fish scale, each with their own characteristics and variations.

Placoid Scales: Placoid scales are formed of a rectangular base plate that is embedded within the skin of the fish and some of spine externally. The interior of the scale is a pulp that receives blood from the fish's vascular system, while the outside is made of an enamel-like substance called vitrodentine. The shape of the spines can vary greatly depending on species. However, almost all give the fish a rough texture. Sharks and rays are examples of fish with placoid scales.

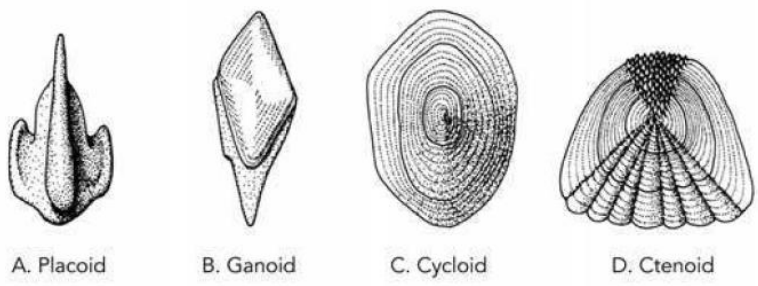


(Source: Diane Elliot, 2011)

Ganoid Scales: Ganoid scales have a bony base layer similar to that of cosmoid scales. and are modified cosmoid scales. However, they differ in that their outer layer is made of an inorganic bone salt called ganoine and that they are diamond-shaped and interconnected. Between ganoid scales are peg-and-socket joints that articulate. Ganoid scales are found on sturgeons, bowfish, paddlefishes and gars.

Cosmoid Scales: Cosmoid scales evolved from placoid scales fusing together. This is because cosmoid scales have two base plates and similar external spines composed of vitrodentine. The base plates are made from bone and new bone is added as the fish grows. Lungfishes and coelacanths have cosmoid scales.

Cycloid and Ctenoid Scales: Cycloid and ctenoid scales have different shapes but the same composition and positioning. Both are composed of collagen and calcium carbonate, rather than bone, and both are overlapping. This means that they are more flexible than the other types of scales. While the edges of cycloid scales are smooth, those of ctenoid scales have tiny teethlike protrusions called ctenii, giving them a rougher texture. The majority of bony fish have cycloid or ctenoid scales.



Different types of scale (Source Image from Living Ocean, CRDG, University of Hawaii at Manoa)

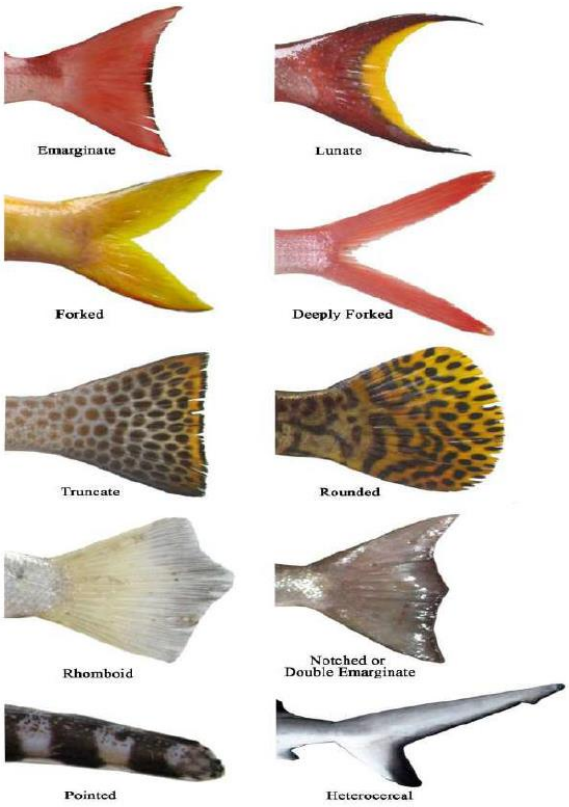
Caudal Fin types: The caudal fin is the tail fin, located at the end of the caudal peduncle and is used for propulsion.

Types of Caudal fin.

Heterocercal: the vertebrae extend into the upper lobe of the tail, making it longer. Eg., sharks.

Homocercal: the vertebrae extend for a very short distance into the upper lobe of the fin, but the fin appears superficially symmetric. Most modern fishes are homocercal tailed fishes

i. Round: ending in round shapeii.
ii.Truncate: ending in vertical edge
iii. Forked: ending in two prolonged edges
iv. Emarginate: ending in a slight inward curve
v. Lunate: ending in crescent shape
vi. Rhomboid: ending in rhomboid shape.



Measurements required for taxonomic work:

General measurements to be noted are the following; however, group wise changes/additions/deletions may be required

Morphometrics: Measurements must be accurate, point to point and measured using digital vernier callipers in a straight line

(a) *Total length (TL)*: Distance measured from tip of snout to outer free tip of caudal fin. This measurement gives the total length attained by the fish.

(b) *Standard length* (SL): Distance from tip of snout or upper jaw tip (mouth should be in closed position) to the posterior margin of the hypural bone i.e. last vertebra. This measurement is used for all taxonomic calculations since the tip of the caudal rays are often damaged during collection.

(c) *Body depth* (BD1, BD2): The maximum girth of the body along the dorso-ventral axis is taken as body depth. In bony fishes, it is measured as the distance from the base of the first dorsal fin ray downwards in a straight line (BD1). The second measurement for body depth is the distance from base of the first anal fin upwards on a perpendicular axis (BD2).

(d) *Head length (HL):* The distance from tip of snout or upper jaw to the outer most tip of the operculum.

(e) *Eye diameter (ED*): The horizontal distance at the center of the orbit is taken from the bony anterior to the posterior orbit.

(f) *Jaw length*: Measurements of upper and lower jaw are taken.

Upper jaw length (UJL) is the distance from tip of premaxillary bone to the outermost end of maxillary bone.

Lower jaw length (LJC) is the length of lower jaw from tip of lower jaw to the end of the bone.

(g) *Dorsal fin length (DFL):* This is the maximum length of the dorsal fin when stretched. Measurements are taken at both the longest spine and at the soft dorsal tip.

(h) *Anal fin length (AFL):* The maximum length of the fin when stretched; this is measured at the soft rayed part.

(i) *Pectoral fin length (P1FL):* This is the maximum length of the pelvic fin when stretched; measurements are taken at the extreme tip of the fin.

(j) *Pelvic fin length (V1FL):* This is the maximum length of the pelvic fin when stretched; measurements are taken at the extreme tip of the fin.

(k) *Caudal fin length (CFL):* Taken as the distance from base of first caudal fin ray to the outermost tip of caudal region.

(l) *Dorsal fin base length (DFBL):* The distance from base of first dorsal fin ray to the last fin ray in a straight line.

(m) *Anal fin base length (AFBL):* The distance from base of first anal fin ray to the last fin ray in a straight line.

(n) *Pectoral fin base length (PFBL):* The distance from base of first pectoral fin ray to the last fin ray in a straight line.

(o) *Pelvic fin base length (V1FB):* The distance from base of first pelvic fin ray to the last fin ray in a straight line.

(p) *Caudal fin base length (CFB):* The distance from base of first caudal fin ray to the last fin ray in a straight line.

(q) *Caudal peduncle length:* the distance from the base of the last dorsal ray to the origin of the caudal fin ray in a straight line.

(r) *Caudal peduncle base*: The vertical distance across base of the caudal fin.

(s) *Preorbital length (POL):* Distance from tip of snout to anterior tip of the diameter of orbit.

(t) *Post orbital length (PBL):* Distance from posterior tip of orbit to outer free tip of operculum.

Scales: Scales are calcified structures seen on the outer surface of the body of fish for its protection. Scales counts are variable and the range and average count is normally given in the description.

Lateral line scale count is the number of pored scales in the lateral line. The count begins with the first scale at the outer upper end of operculum and ends with at the caudal fin base.

Lateral scale count is taken as the number of scales from the lateral line to the base of the first spine of the dorsal fin excluding the lateral line scale.

Predorsal scale count is the number of scales on the middle line from the origin of the first dorsal fin to the occiput.

****

MODEL DATA ENTRY SHEET (FISH)

Parameters	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5
TL					
SL					
BDD					
BDA					
HBDD					
HBDA					
CPD					
CPW					
HD1					
HD2					
Sub Orbital D					
IO					
HL					
SNL					
POL					
ORL					
ORD					
UJL					
LJL					
SNW					
Bar L					
Bar W					
SD1					
SD2					
D1D2					
CPL					
Pre Anal Leng					
SPEL					
SPEC					
D2AnL					
D1Pelv					
D1Pec					
D1B					
D2B					
CL					
Anal Base					
Anal H					
Pelv L					

Pec L					
Pect W					
D1H					
D2H					
MERISTICS					
D1					
d2					
A					
c					
p					
v					
Lat Scales					
Ltr tr.					
wt					
Gr RU					
Gr DU					
Gr DL (corner)					
Gr RL					
Gr U (T)D					
Gr L(T)D					
Gr (D+R)					