Workshop manual on "Techniques and Methodologies in fishery biology of finfishes and shellfishes"

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MARINE FISH CATCH ESTIMATION

Commercial fishing along the Indian coast is a dynamic and complex process with several types of crafts, gears exploiting more than 500 species of fishes and shell fishes. Further, changing fishing patterns, practice of innovative fishing methods, improvisation of existing fishing methods, etc. further add to the already complex nature of fishing. Estimation of catch landed along the coast is thus a mammoth task.

Systematic, regular and unbiased sampling is an integral vital aspect of fishery biology work. Biological process like growth, maturation, feeding patterns, etc. follows regular patterns. Long term studies are generally carried on subsamples collected from the landing centres to get information on the different aspects of the life cycle of the fish. These results are then extrapolated t get a clear picture of the fish population in the commercially fished area. To obtain, a subsample one has to initially estimate the total catch available. Such sampling can be done only by following a statistically valid sampling design.

Estimation of the total marine fish catch of the county is one of the important mandates of the Central Marine Fisheries Research Institute. The institute has developed and adopted a reliable sampling methodology based to estimate resource-wise/region-wiselandings is based on **stratified multi-stage random sampling technique**. In this, the stratification is over space and time. Over space, each maritime state is divided into suitable, non-overlapping zones on the basis of fishing intensity and geographical considerations. The number of centres may vary from zone to zone. These zones have been further stratified into substrata, on the basis of intensity of fishing.There are some major fisheries harbours/centres which are classified as *single centre zones* for which there is an exclusive and extensive coverage. The stratification over time is a calendar month. One zone and a calendar month is a space-time stratum and primary stage sampling units are landing centre days.

Example: In Karnataka, 14 zones have been identified. Of these seven of them namely- Mangalore, Malpe, Gangolli, Bhatkal, Kesarkodi, Tadri and Karwar fishing harbours are single centre zones. The remaining seven zones have multiple centres ranging from 10-12 landing centres. Kn-I zone include the following 10 centres – Talapady, Someshwara, Ullala, Panambur, Baikampady, Hosabettu, Suratkal, Mukka, Lachil and Sasihitlu. The centres included under a zone are reviewed regularly and changes made if required based on the latest fishing status of the centre.

If in a zone, there are 20 landing centres, there will be 20 x 30 = 600 landing centre days in that zone for that month (of 30 days). For observation purpose, a month is divided into 3 groups, each of 10 days. From the first five days of a month, a day is selected at random, and the next 5 consecutive days are automatically selected. From this three clusters of two consecutive days are formed. For example, for a given zone, in a given month, from the five days if the date (day) selected at random is 4, then these clusters are formed, namely, (4, 5); (6,7) and (8, 9) in the first ten day group. In the remaining ten day groups, the clusters are systematically selected with an interval of 10 days. For example, in the above case, the cluster of observation days in the remaining groups are (14, 15), (16, 17), (18, 19) (24, 25), (26, 27) and (28, 29). Normally, in a month there will be 9 clusters of two days each. From among the total number of landing centers in the given zone, 9 centres are selected with replacement and allotted to the 9 cluster days as described earlier. Thus in a month 9 landing centre days are observed. The observation is made from 1200 hrs to 1800 hrs on the first day and from 0600 hrs to 1200 hrs on the second day, in a centre. For the intervening period of these two days, the data are collected by enquiry from 1800 hrs of the first day of observation to 0600 hrs of the 2nd day of observation of a landing centre-day, which is termed as 'night

landing '. The `night landing' obtained by enquiry on the second day covering the period of 1800 hrs of the first day to 0600 hrs of the next day are added to the day landings so as to arrive at the landings for one (landing centre day) day (24 hours). It may not be practicable to record the catches of all boats landed during an observation period, if the number of boats/craft landings is large. A sampling of the boats/craft becomes essential. When the total number of boats landed is 15 or less, the landings from all the boats are enumerated for catch and other particulars. When the total number of boats exceeds 15, the following procedure is followed to sample the number of boats (Alagaraja, 1984):

Number of units landed	Fraction sampled
Less than or equal to 15	100 %
Between 16 and 19	First 10 and the balance 50 %
Between 20 and 29	1 in 2
Between 30 and 39	1 in 3
Between 40 and 49	1 in 4
Between 50 and 59	1 in 5

The basic information collected from the samples units are type of craft, craft material, fish hold capacity when present, gear used, fishing duration, area of operation, direction of wind, depth of operation, no. of hauls per day, species composition, estimated wet weight of the different species, etc. Catch from the boat is generally removed in baskets or crates. The weight of fish per basket/crate is known and form this total weight of the particular fish landed by the unit is estimated.

Estimation of marine fish landings:

The unit sampled is based on the type of craft, gear used, fishing days per trip and status of mechanization. So if a trawler is being monitored; it sampled unit can be a traditional non-mechanized hand trawl or a motorized canoe operating the small trawl net or a single day mechanized trawler or a multiday mechanized trawler or a multiday deep water trawl, etc. The catch observed in the sampled unit is added to get the total catch made by the sampled units at the observed centre. The catch made by all the units (sampled type) during the observation is estimated. By adding the catch made during the two six hour periods of observation and the catch made during the twelve hour duration (night landings), the total quantity for a centre day is estimated. Catch made during the sampling days are added to get an estimation of catch made during all the sampling days for the centre. This data is then used to estimate the monthly catch for a particular type of unit from a sampled centre. The monthly estimates are added to get the annual estimates. The procedure for estimating the catch for different centres, zones and states to arrive at the National catch estimates has been discussed in detail by Srinath *et al*. 2005 (CMFRI Spl. Pub. 86).

Effort is generally given as actual number of units or as actual fishing hours. The use of hours is relevant especially when fishing operation is carried on for more than one fishing day and also when the fishing operation is active. In the case of trawlers, the actual time taken for trawling per haul is taken into account. Appropriate weightage is given while estimating the catch made by single day and multiday trawl based on the actual time used per haul and number of hauls made during 24 hours.

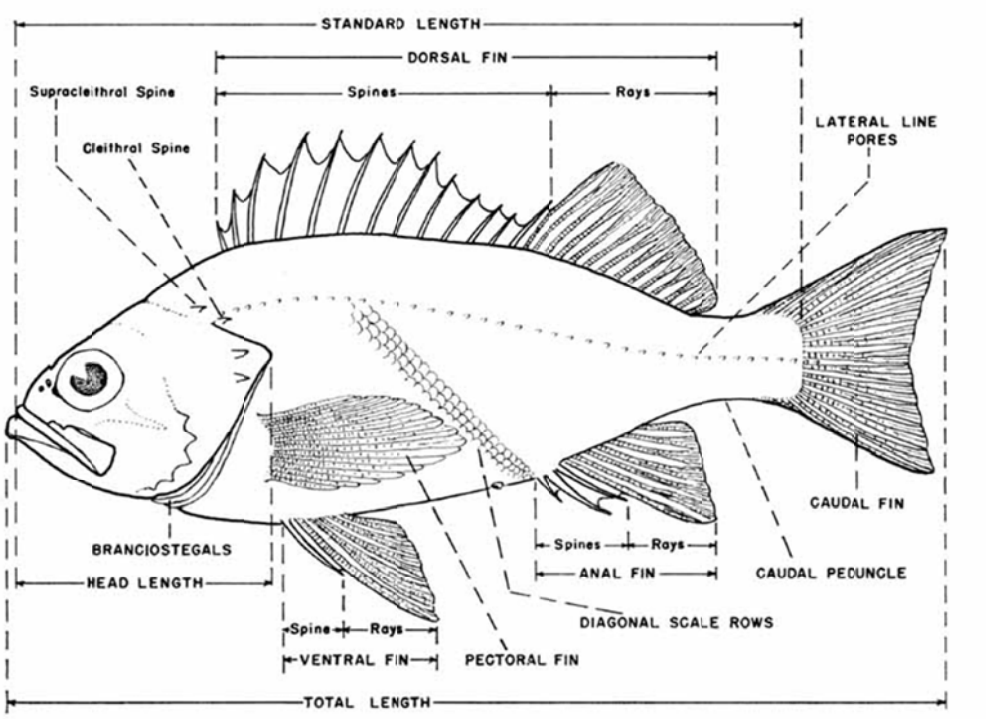
Development process in the fishing industry has been very rapid and with the advent of multi-day/night fishing, use of combination gears and introduction of high speed engines for fishing sampling and catch

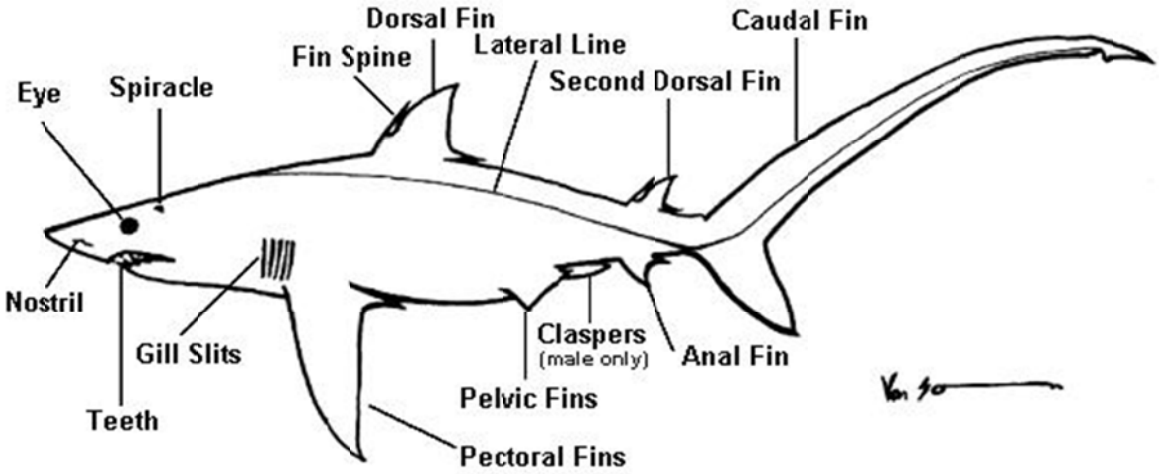
estimation has becoming even more complex. However the stratified multi-stage sampling technique used by CMFRI is the best to estimate species -wise/ gearwise catch for different centres, states and for the country over space and time. The FAO has recognized this method as a model sampling design which can be followed by all developing nations. The design was further evaluated by an independent panel of scientists (Kutty et al, 1973) and the standard error of the estimates was found to be within reasonable limits.

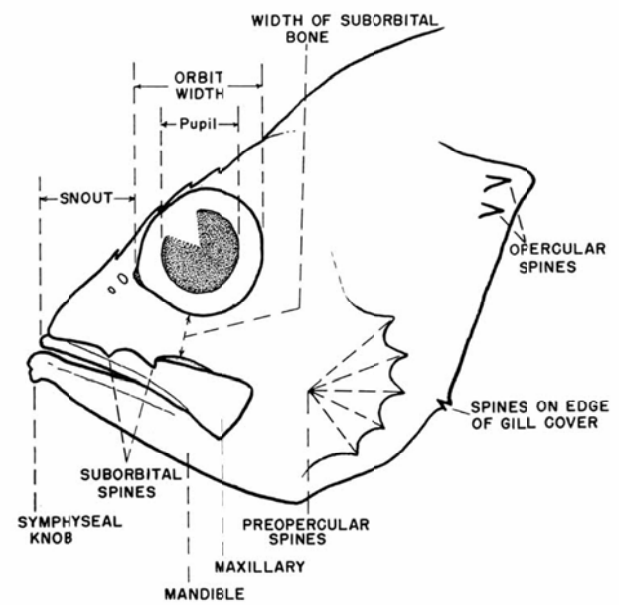
MORPHOMETRIC MESUREMENTS USED FOR FISHERY BIOLOGICAL STUDIES

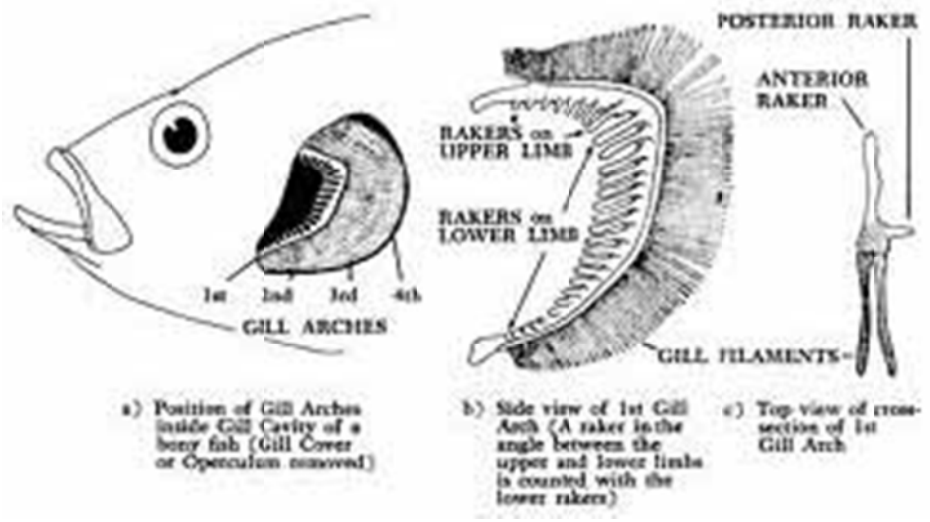
Metric and meristic characters are important to identify fish species and their habitat peculiarities as well as ecological criteria. Variety of morphological, physiological, behavioral and biochemical characteristics are used to identify and classify fishes. Though morphometric measurements are used directly they are usually presented as a proportion of standard or total length. Shape and structure of marine organisms vary greatly among fishes crustaceans and molluscs therefore the morphometric measurements used for taxonomic studies is different for the three groups.

Finfishes:









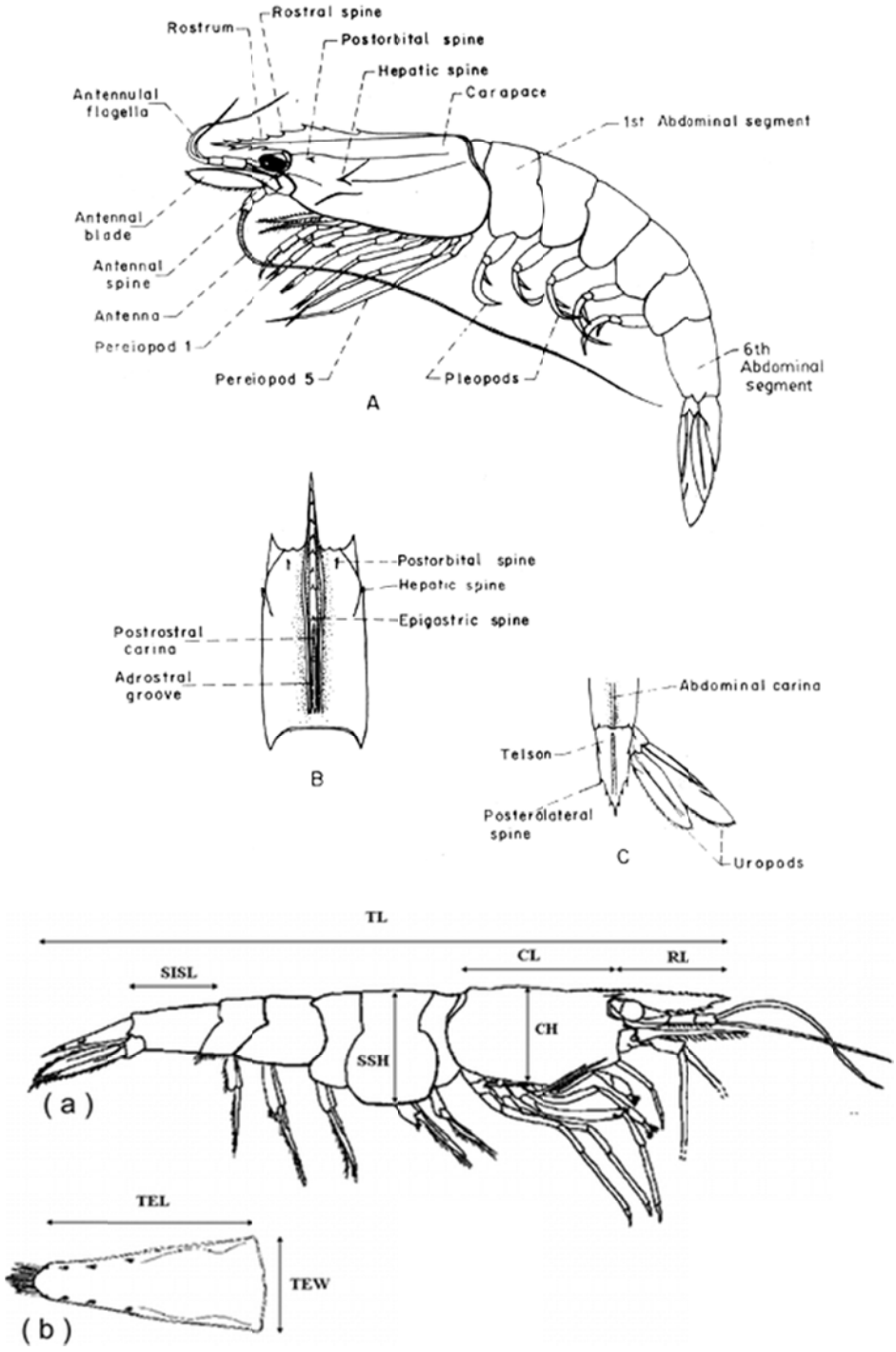
a) Position of Gill Arches inside Gill Cavity of a bony fish (Gill Cover or Operculum removed)

b) Side view of 1st Gill Arch (A raker in the angle between the upper and lower limbs is counted with the lower rakers)

c) Top view of cross-section of 1st Gill Arch

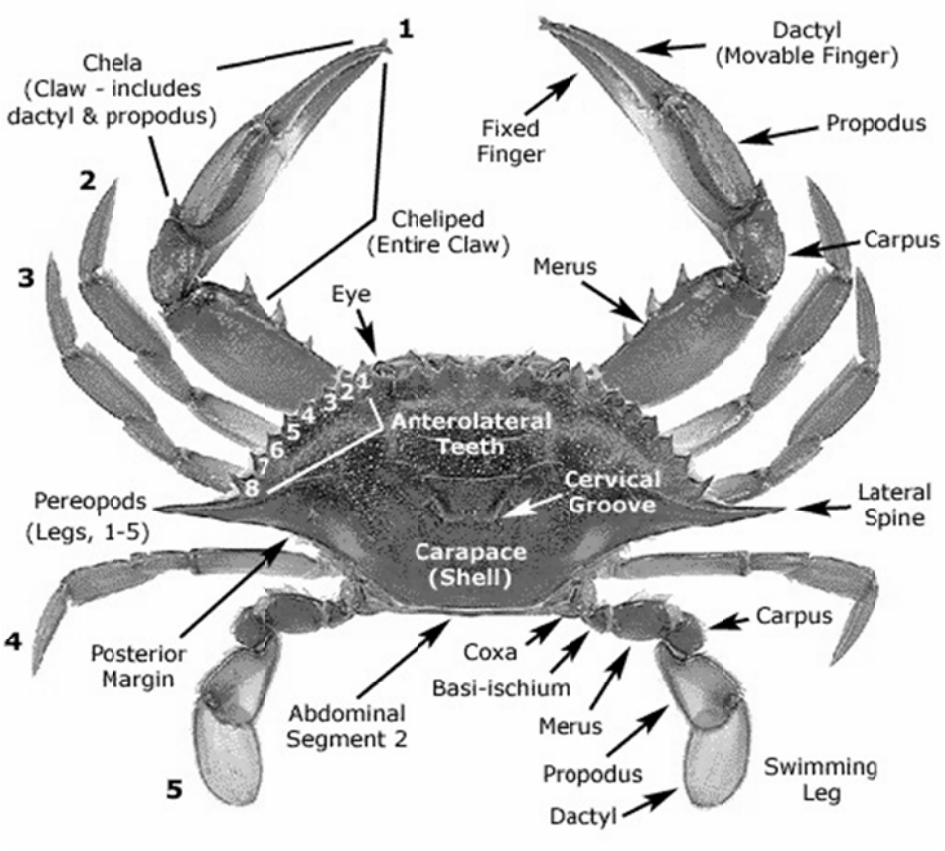
Crustaceans

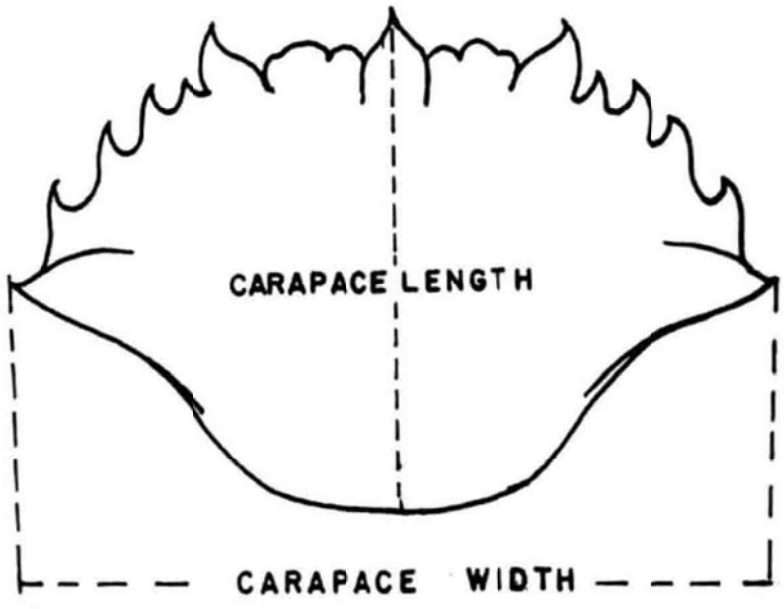
Shrimp



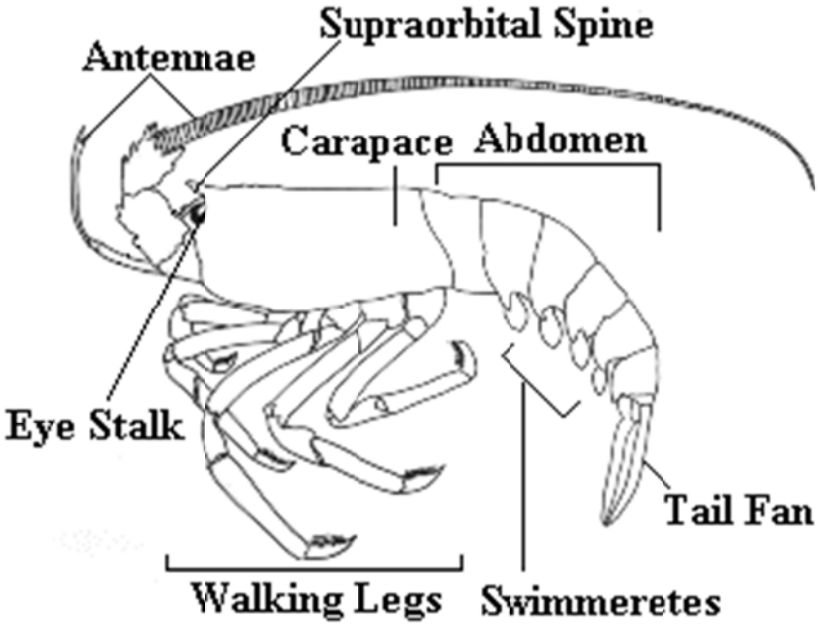
Morphometric measurements.: , Lateral view of the specimen; b, dorsal view of telson. TL: total length, CL: carapace length, CH: carapace height, RL: rostral length, SSH: second pleon segment height, SISL: sixth pleon segment length, TEL: telson length and TEW: telson width.

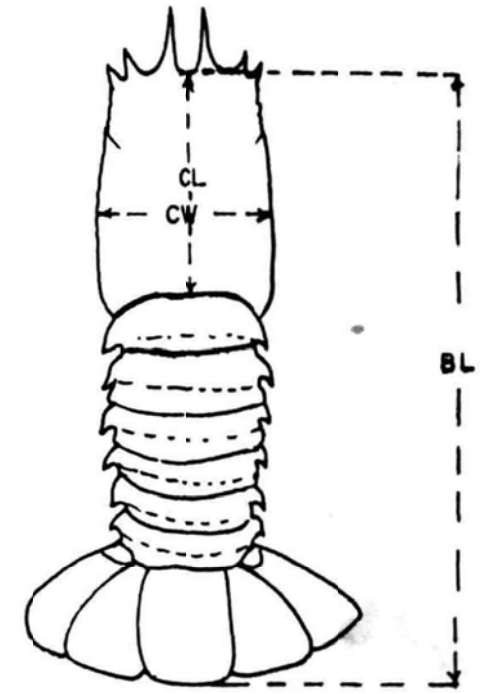
Crab


1
Chela
(Claw - includes
dactyl & propodus)
Dactyl
(Movable Finger)
Fixed
Finger
Propodus
2
Cheliped
(Entire Claw)
Carpus
3
Merus
Eye
Anterolateral
Teeth
Cervical
Groove
Lateral
Spine
Pereopods
(Legs, 1-5)
Carapace
(Shell)
Carpus
4
Posterior
Margin
Coxa
Basi-ischium
Abdominal
Segment 2
Merus
Propodus
Swimming
Leg
5
Dactyl


CARAPACE LENGTH
CARAPACE WIDTH

Lobster

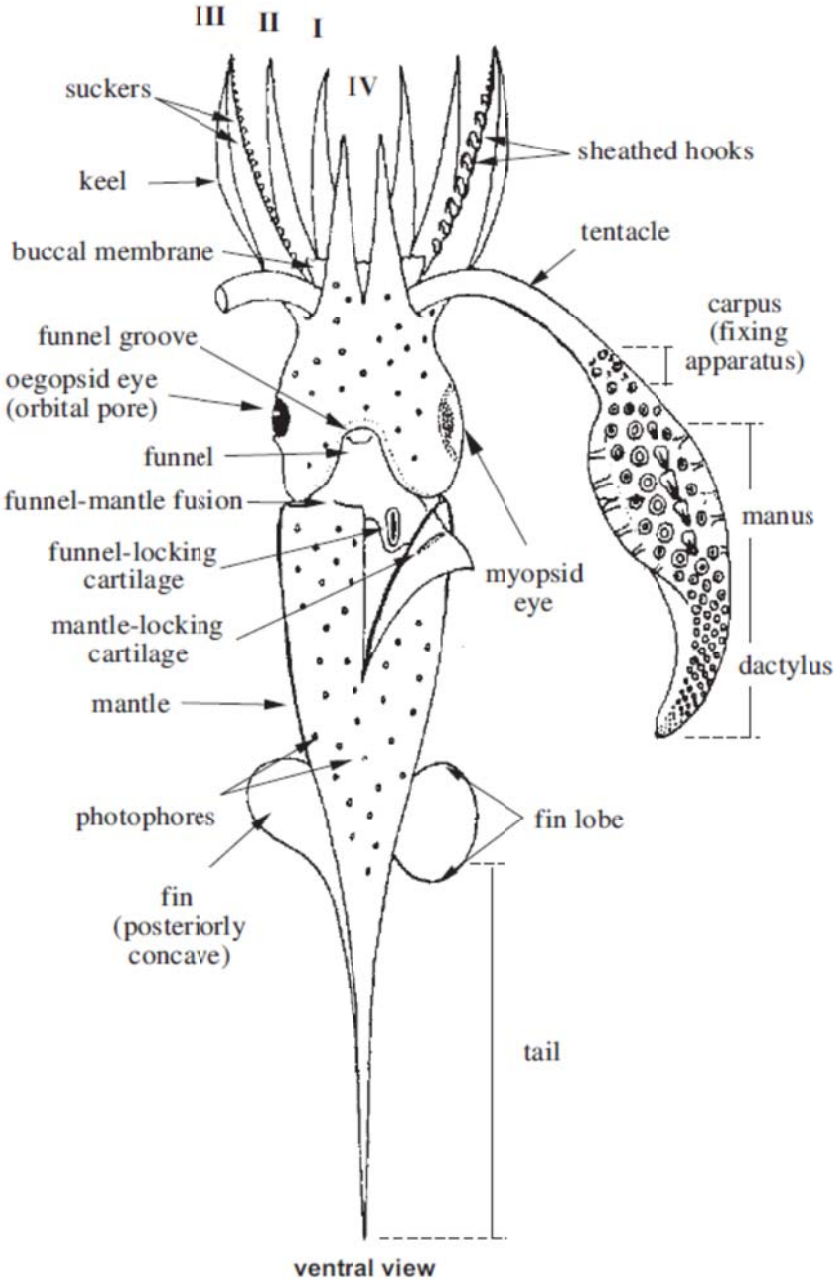




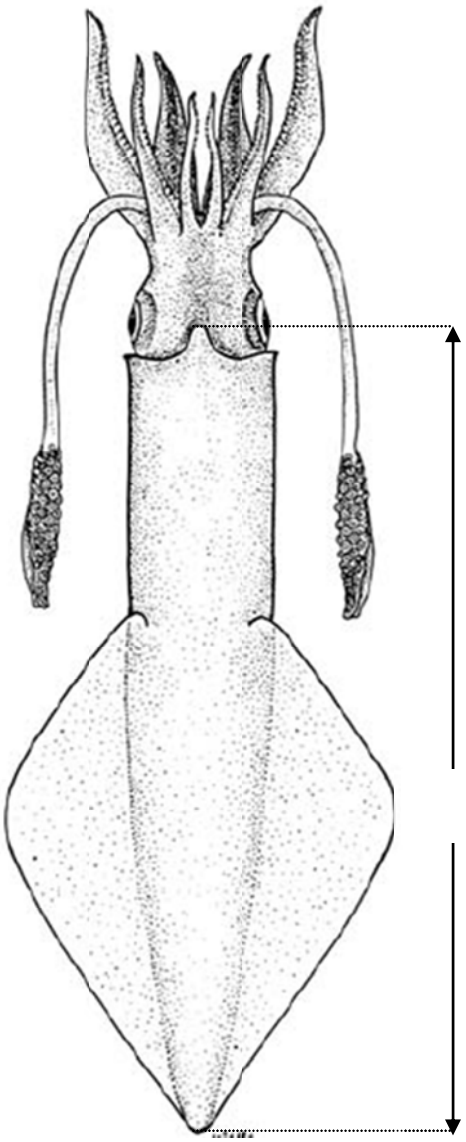
CL – CARAPACE LENGTH
CW – CARAPACE WIDTH
BL – BODY LENGTH

Cephalopods

Squid



Basic squid features



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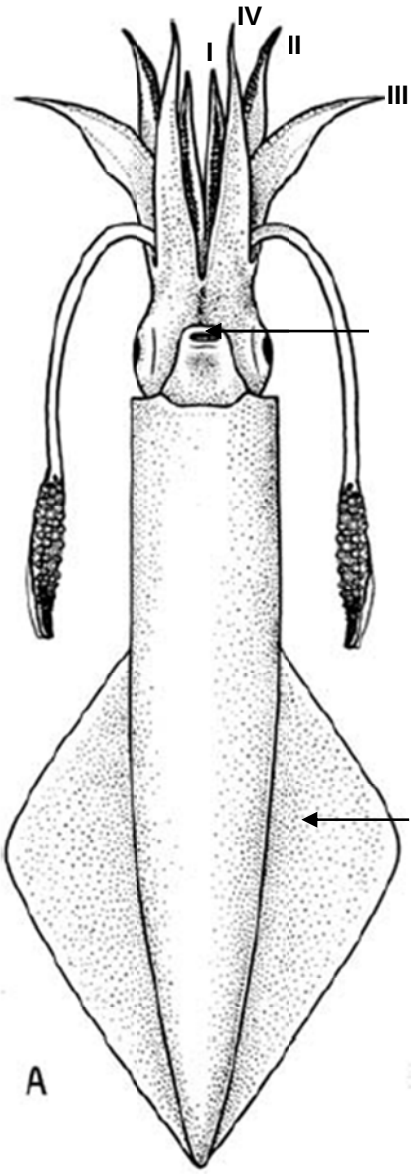
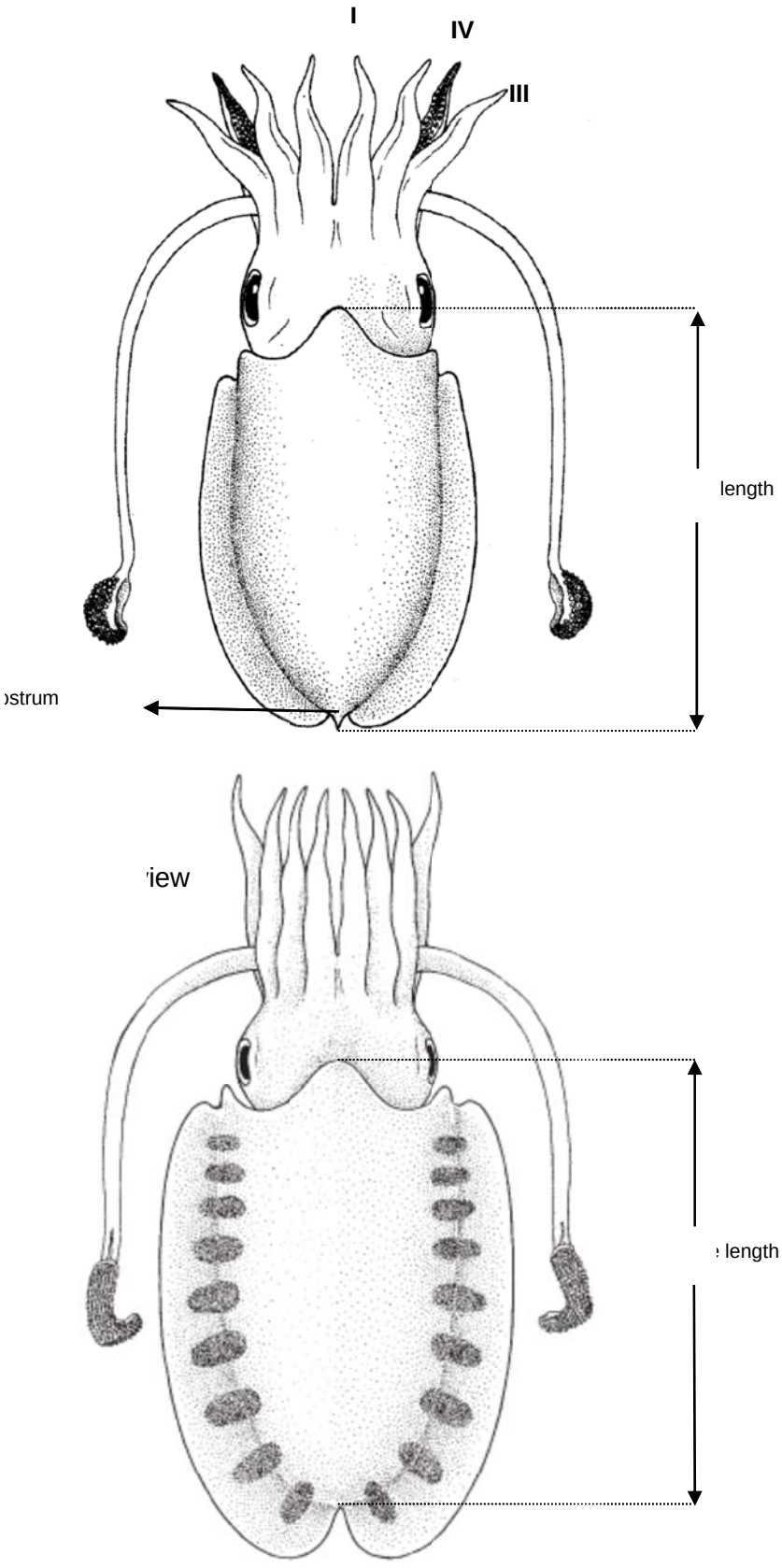
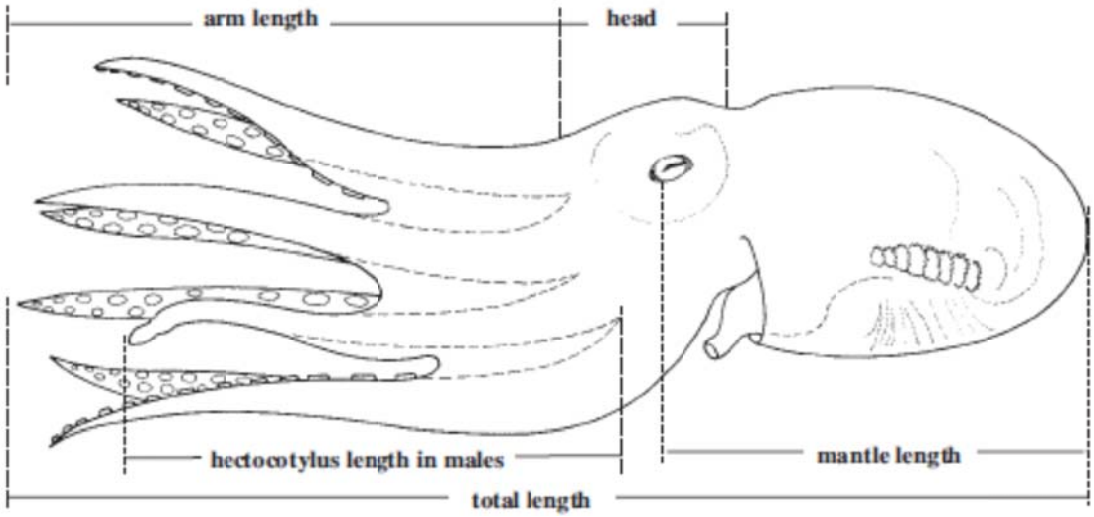
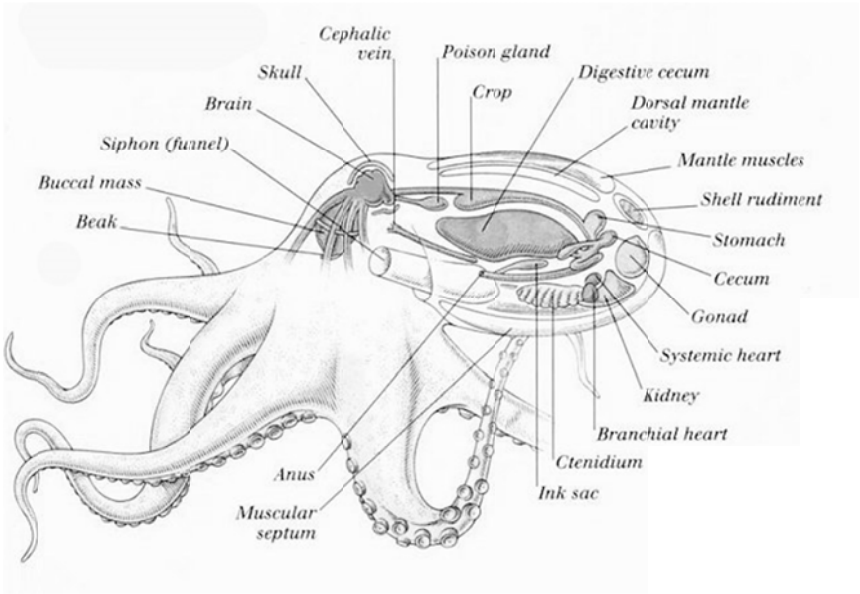


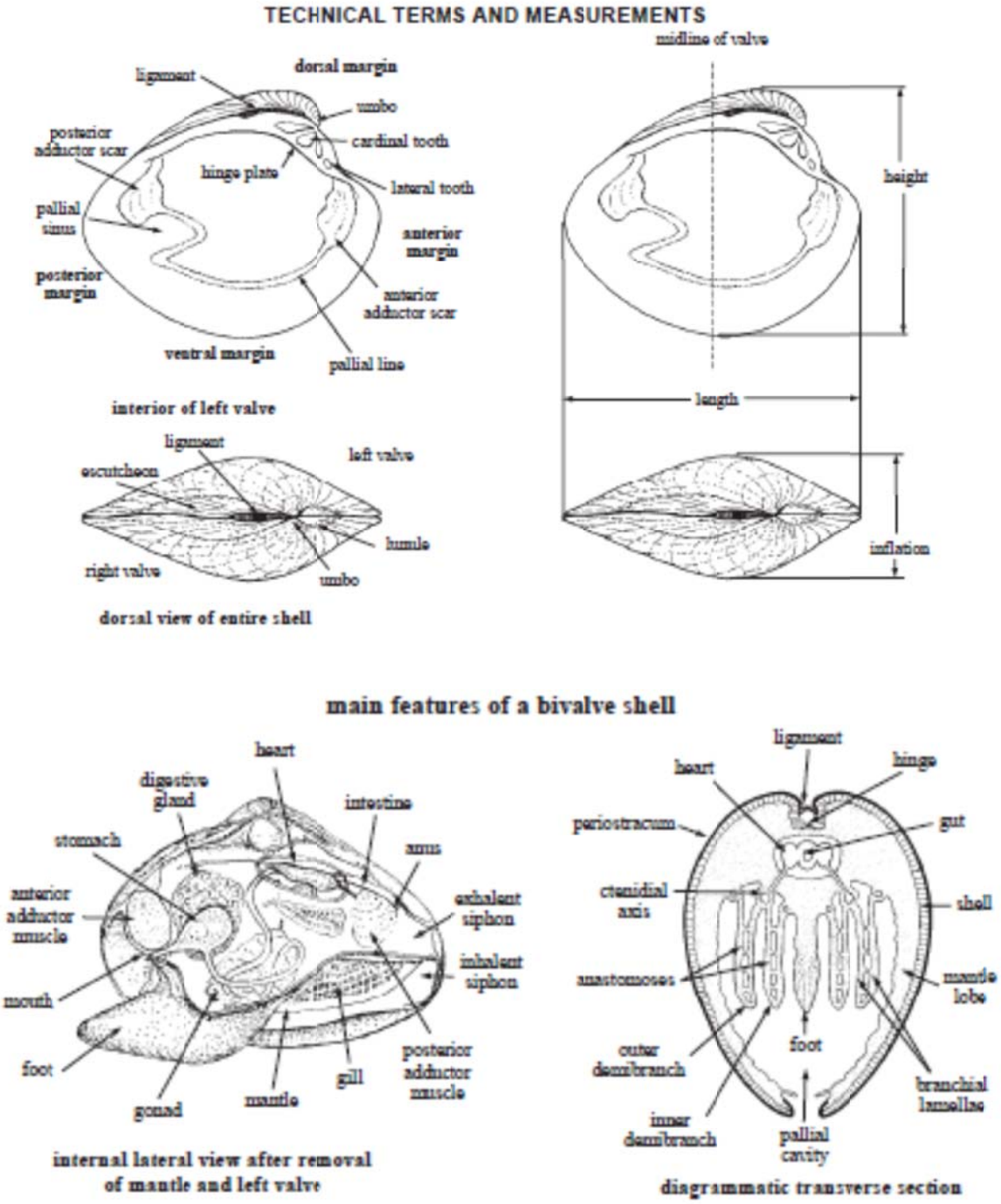

I
IV
III
length
ostrum
view
length

Octopus

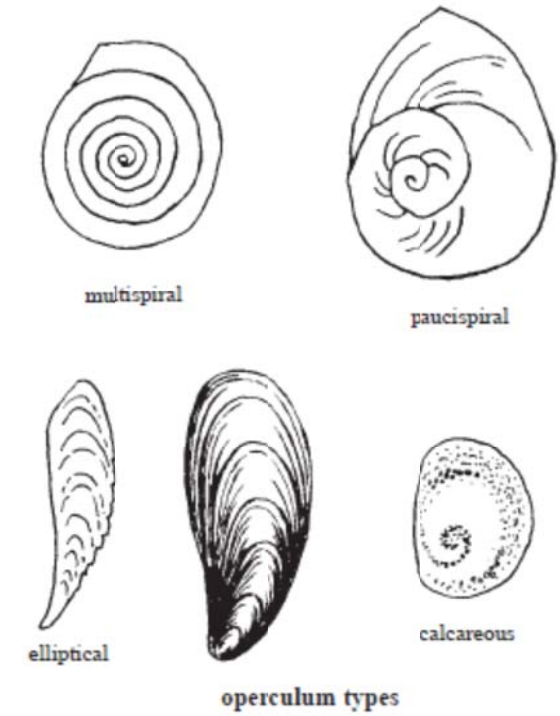

arm length
head
hectocotylus length in males
mantle length
total length


Cephalic vein
Poison gland
Digestive cecum
Skull
Crop
Brain
Dorsal mantle cavity
Siphon (funnel)
Mantle muscles
Buccal mass
Shell rudiment
Beak
Stomach
Cecum
Gonad
Systemic heart
Kidney
Branchial heart
Ctenidium
Anus
Ink sac
Muscular septum

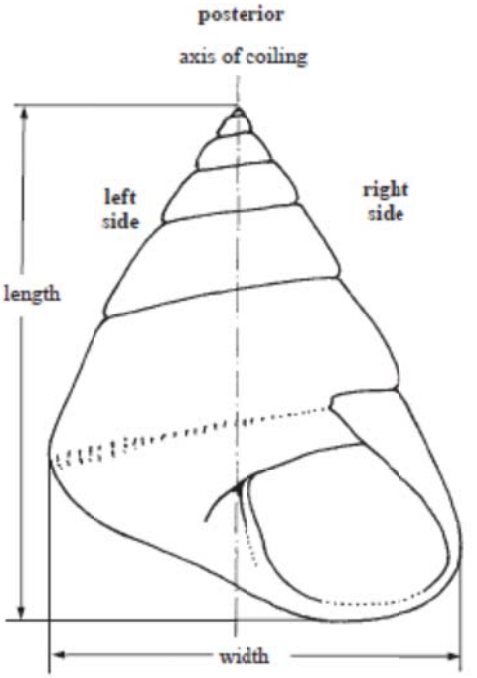
Bivalves


TECHNICAL TERMS AND MEASUREMENTS
ligament
dorsal margin
umbo
cardinal tooth
posterior adductor scar
hinge plate
lateral tooth
pallial sinus
anterior margin
posterior margin
anterior adductor scar
ventral margin
pallial line
interior of left valve
ligament
left valve
escutcheon
humle
right valve
umbo
dorsal view of entire shell
midline of valve
height
length
inflation
main features of a bivalve shell
heart
digestive gland
intestine
stomach
anus
anterior adductor muscle
exhalent siphon
inhalent siphon
mouth
foot
gonad
mantle
gill
posterior adductor muscle
internal lateral view after removal of mantle and left valve
ligament
heart
hinge
periostracum
gut
ctenidial axis
shell
anastomoses
mantle lobe
foot
outer demibranch
branchial lamellae
inner demibranch
pallial cavity
diagrammatic transverse section
general anatomy of bivalves

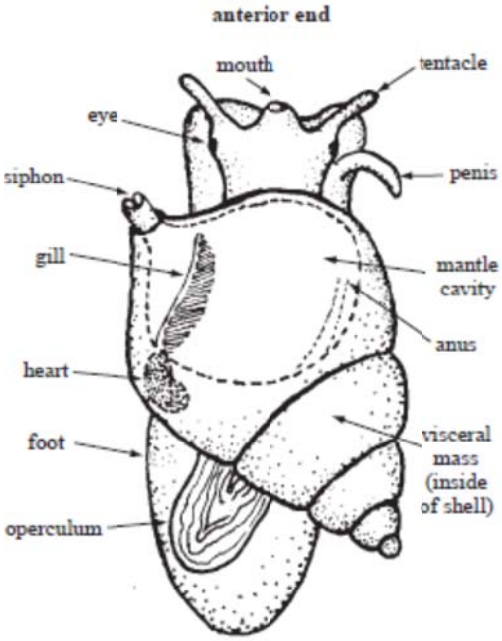
Gastropods



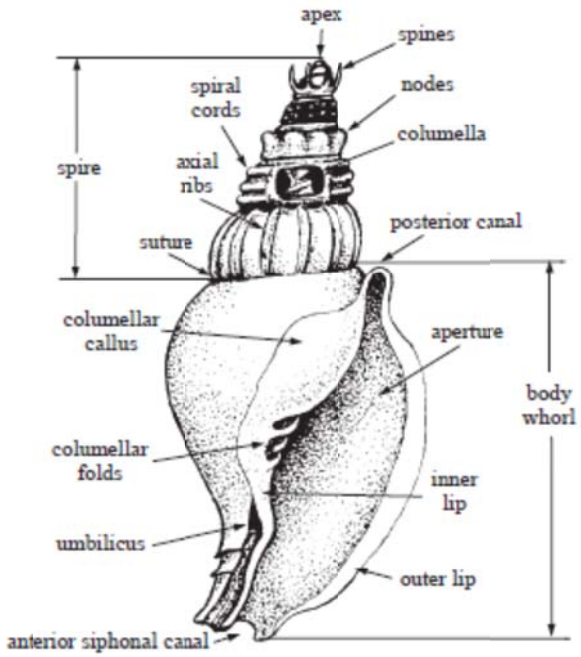
operculum types



orientation and measurements of a shell



dorsal view of animal



ventral view of a composite shell

LENGTH-WEIGHT RELATIONSHIP

Every animal in its life grows both in length and weight, the relationship between these two has both theoretical and practical importance. It has been mathematically proved that there is a fairly constant relationship between total length and weight of the individuals of the species. It helps to establish a direct mathematical relationship between the two variables, namely length and weight, so that if one is known the other could be easily computed. Length-weight relationship is also needed for studies on maturity and yield estimates by analytical models

The total length is measured to the nearest (0.1) centimeter (TL/FL for fish, TL for shrimp, CW for crab and DML for cephalopods). The individual weight is recorded to an accuracy of 0.01 g. The linear equation (log W = log a +b log L) can be fitted for males, females and sex pooled separately with the log transformed values of length and weight. Regression analysis performed to determine the constants a and b and relationship between length and weight. The correlation coefficient (r) should be determined to know the strength and pattern of association between the two variables.

Analysis of covariance (Snedecor and Cochran, 1967) technique is suggested to test for any significant difference in the relationship in the above parameters between the sexes at 1% level. The Student's t test is dome to find out whether the b values for males, females and sex pooled are significantly different from 3 using the formula.

$$t = \frac{b - \beta}{S_b}$$ where β is equal to 3.

GUT CONTENT ANALYSIS

Information on food and feeding habits of fishes is essential for better understanding of their growth, breeding and migration and also for improving the harvest from the commercially important fisheries resources. Food is the most important factor regulating or influencing the abundance, growth and migration. Information on food and feeding will add to the existing knowledge needed for better management of fish stocks. Study of seasonal variation in diet and dietary comparison between different sub-groups of the species like year-class will help to understand whether there is competition for food. Study on the diet of marine organisms also gives a clear indication of prey-predator relationship and feeding migration if any. Diets of fishes represents an integration of many important ecological components that include behavior, condition, habitat use, energy intake and intra/interspecific interactions.

Stomach contents can be collected either from the live or fresh died fish. Regardless of the method, investigators should ensure that the removal technique effectively samples all items in the gut. Other wise data will be skewed toward items that are more easily displaced from the stomach. Alternatively, live fish can be sacrificed and stomach contents removed for analysis. If fish are to be sacrificed, they should be preserved immediately either by freezing or by fixing in formalin. Stomach contents will continue to digest, rendering rapid preservation of the fish or removed contents necessary to prevent loss of resolution. As in most fish groups feeding behavior of juveniles and adults vary distinctly attention should be taken to encounter more samples which will include all size groups of the particular fish. The specimens either from live or preserved should be measured to its total length to the nearest 1mm and weight to the nearest 0.1 g. Cut open the fish and record the sex and maturity stage of the fish. Remove the stomach and preserve them in 5% neutralized formalin for further analysis. For the analysis, a longitudinal cut must be made across the stomach and the contents are transferred into a Petri dish. The contents then keep for five minutes to remove excess formalin and then examine under binocular microscope. Identify the gut content up to the genus and if possible up to species level depending up on the state of digestion. Various taxa digest at different rates. As such, all recently consumed taxa may be present in the foregut but only resistant items remain in the hindgut. To avoid bias when both easily digested prey and resistant prey are present, only the immediate foregut (e.g., stomach) should be sampled.

Fish diets can be measured in a variety of ways. Methods of gut contents analysis are broadly divisible into two, *viz.*, qualitative and quantitative. The qualitative analysis consists of a complete identification of the organisms in the gut contents. Only with extensive experience and with the aid of good references it is possible to identify them from digested, broken and finely comminuted materials. Quantitative methods of analysis are three types, *viz.*, numerical, gravimetric and volumetric.

(For further reading, detailed methods of gut content analysis "Methods of stomach content analysis of fishes" given by Dr.P.U. Zacharia & Dr. K.P. Abdurahiman in *CMFRI eprints*)

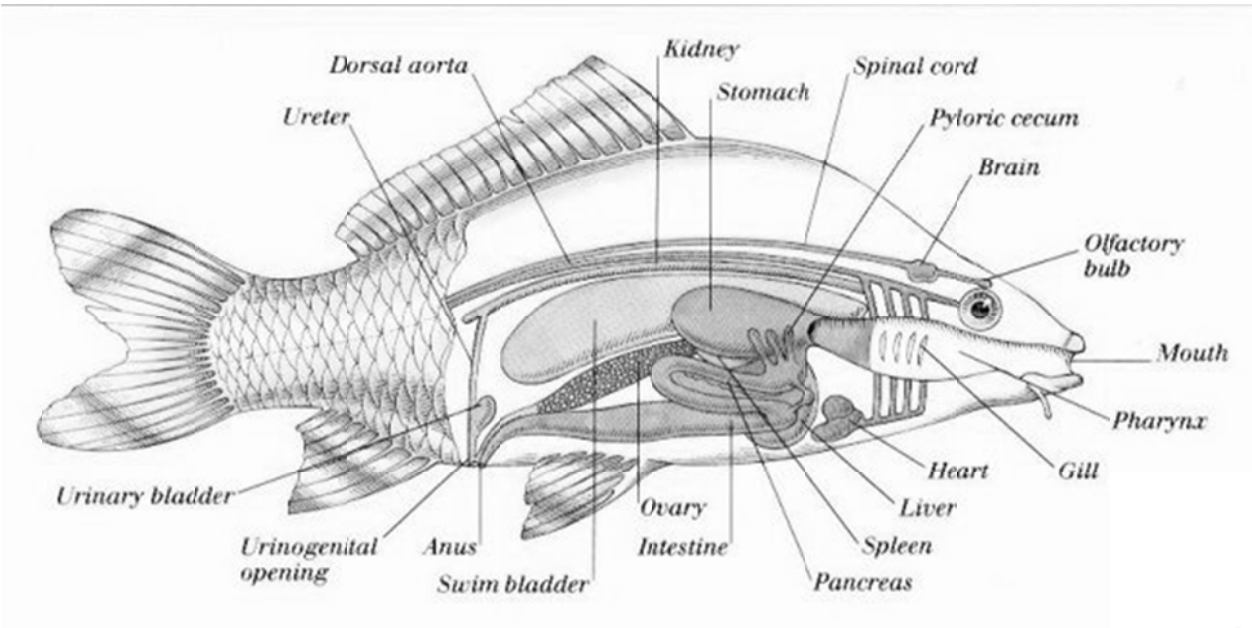
FISH

The fullness of fish stomachs were classified as 'gorged', 'full', '¾ full', '½ full', '¼ full', trace and 'empty'. The stomachs of fishes were removed, weighed and preserved in 7% buffered formalin for further analysis.

The index of preponderance method (Natarajan and Jhingran, 1961) suitable for carnivorus fishes was adopted in this study. The index of preponderance was worked out by the following formula:

$$I = \frac{V_i O_i}{\sum V_i O_i} \times 100$$

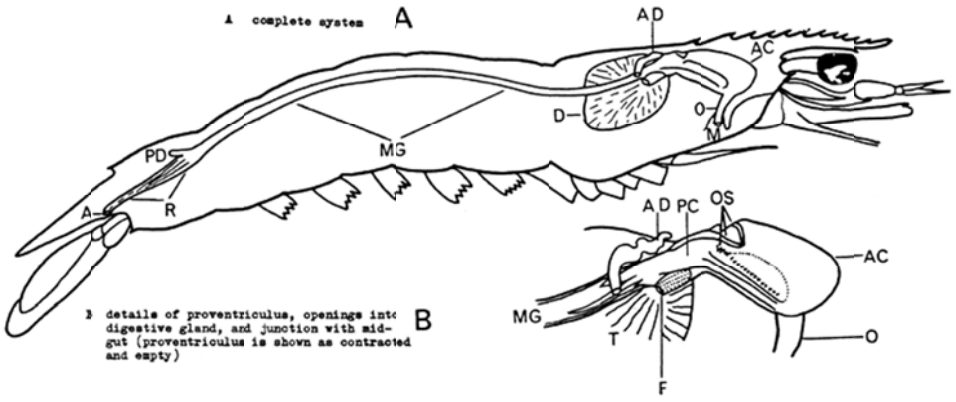
where V_i and O_i represent the percentage of volume and percentage of occurrence indices of each food item respectively and I the index.



Digestive system in fish

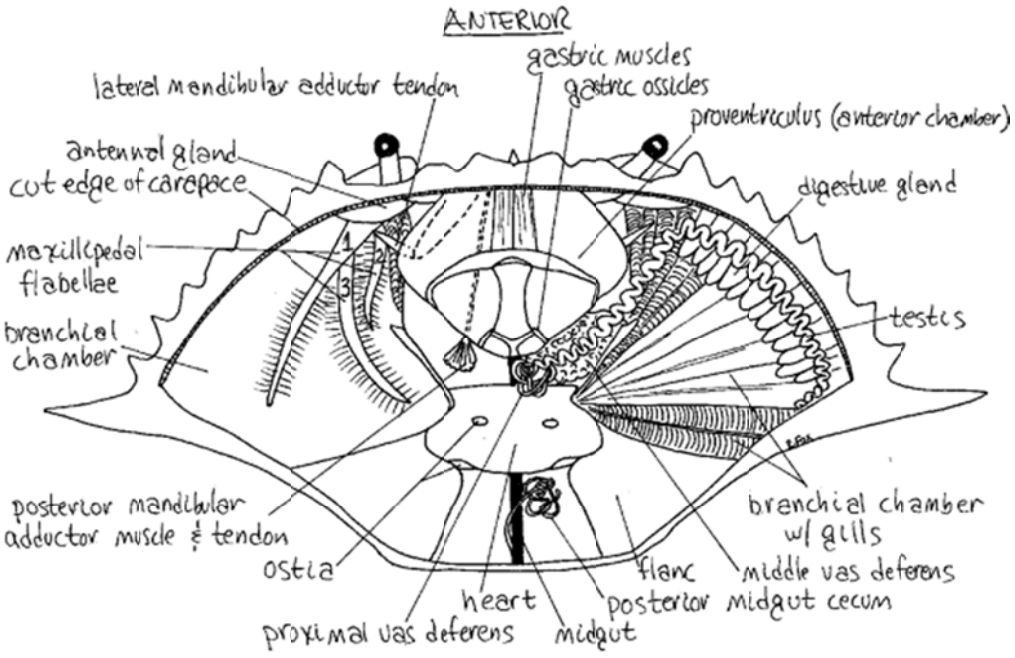
CRUSTACEANS

Due to the nibbling action of mandibles on the food and mastication of food inside the stomach by the action of gastric mill, identification of the food organisms is based mainly on broken shell remains, spines, cetae etc. The stomach contents can be grouped as follows: decapod crustaceans (mostly shrimps), fishes, molluscs, polychaetes, crustaceans other than decapods, foraminiferans, sand, detritus and unidentifiable digested matter (decomposed plant and animal matter and their remains mixed with mud) Since the quantity of food in the stomach of shrimps are very little, the 'points method' is generally used for food content study. The intensity of feeding is determined by the degree of distension of the stomach due to the quantity of food inside the anterior and posterior chambers of the proventricCOulus. The condition of feeding is expressed as full, ¾ full, ½ full, ¼ full, trace and empty and each one is assigned, 100, 75, 50, 25, 10 and 0 points respectively



Digestive system in shrimps

A, anus; AC, anterior chamber of proventriculus ("stomach"); AD, anterior diverticulum of mid-gut (this is a paired structure); D, digestive gland; F, opening (paired) from "filter press" of posterior diverticulum into digestive gland; M, mouth, MG, mid-gut; O , oesophagus, OS, ossicles of gastric mil; PC, posterior chamber of proventriculus; PD, posterior diverticulum of mid-gut; R, rectum; T, tubules of digestive gland.



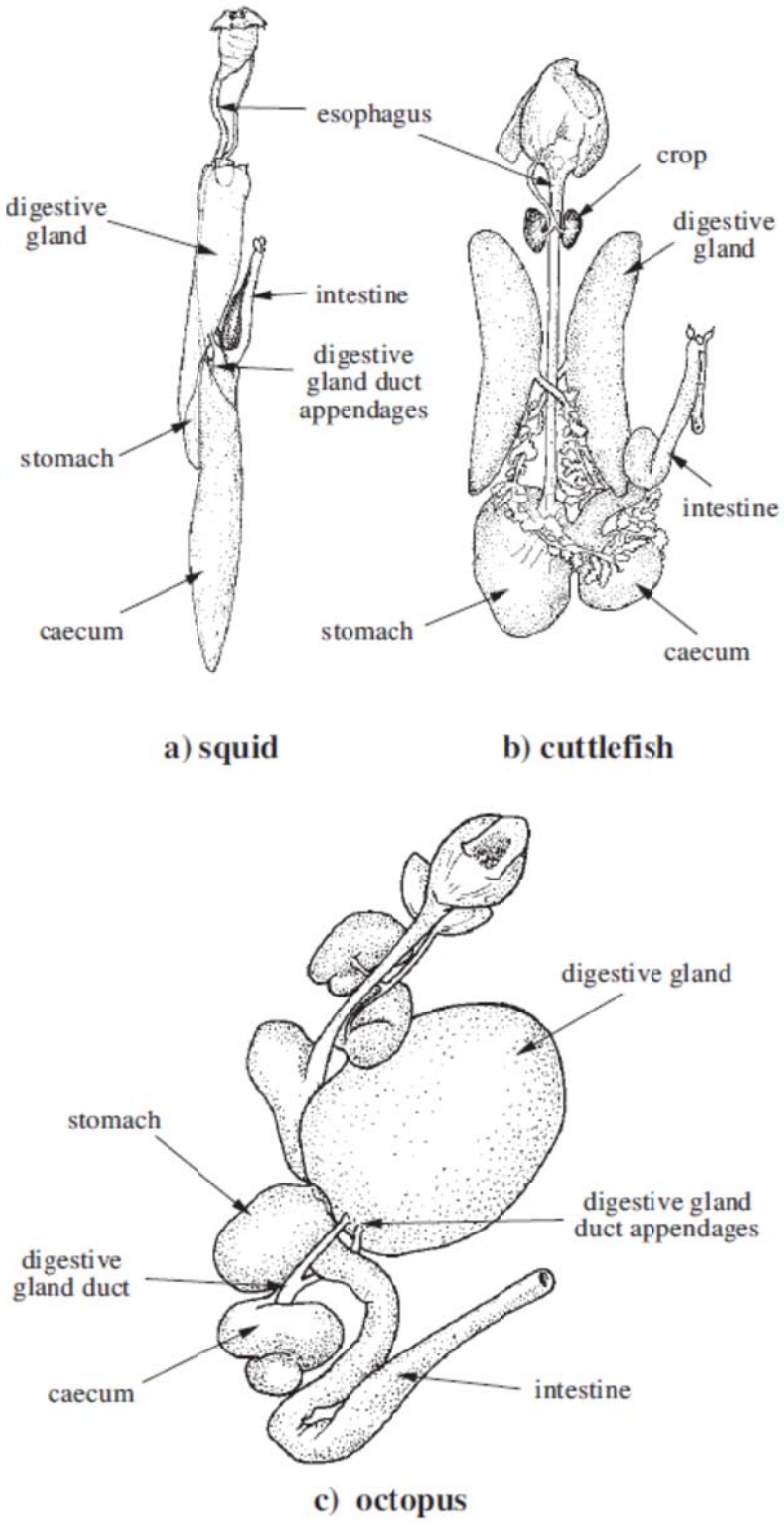
Anatomy of crab showing positions of stomach (proventriculus) and gonads

CEPHALOPODS

All cephalopods are active carnivores feeding on live prey during their entire life cycle. They are generally considered as night-time feeders, but some species feed during the day. The range of prey organisms in the gut content of cephalopods are wide and include representatives of crustaceans, molluscs and fish. They are opportunistic feeders, switching easily from one prey to another, though distinct preferences seem to exist for some species. For example, the main prey for the coastal octopus species are generally crustaceans and shelled molluscs.

The captured prey is brought to the mouth by the arms where it is killed or paralysed. The dorsal beak, or the 'upper' beak is inserted within the 'lower' (ventral) beak to tear tissue of the prey with a scissors-like cutting action. The gut has spontaneous peristaltic activity. The chopped food passes from the buccal cavity through the oesophagus to the stomach, where most of the digestion takes place. The digestive tract except for glandular area, is chitin lined from the buccal mass to the stomach. The cuticular ridges in the stomach aid in grinding food. The food is broken down with enzymes in the stomach from the digestive gland. The stomach may be greatly expandable in size and serve as a storage area until food can be fully processed.

The degree of fullness of the stomach is visually assigned and recorded as 'completely full', 'half full', 'one-fourth full', 'trace remains' and 'empty'. For gut content analysis, the individual stomach is cut opened, examined under dissecting microscope, prey items identified and separated for weighing. In cephalopods the advanced degree of digestion of stomach contents generally impeded the exact and complete separation of prey for weighing. Undigested cephalopod tissue remains, indicative of cannibalism need to be considered apart from natural prey. Crustaceans are identified by their exoskeleton. The number of fish or cephalopods consumed may be estimated based on fish otoliths or of upper or lower cephalopod beaks. Frequency of occurrence and numeric and gravimetric (volumetric) methods are used to quantify the diet. Frequency of occurrence (%FO) is calculated as the percentage of cephalopod that fed on a certain prey, %number (%*N*) is the number of individuals of a certain prey relative to the total number of individual prey, and %weight (%*W*) is defined as the weight of a certain prey relative to the total weight of all prey, expressed as a percentage.



Digestive System (after Bidder, 1966)

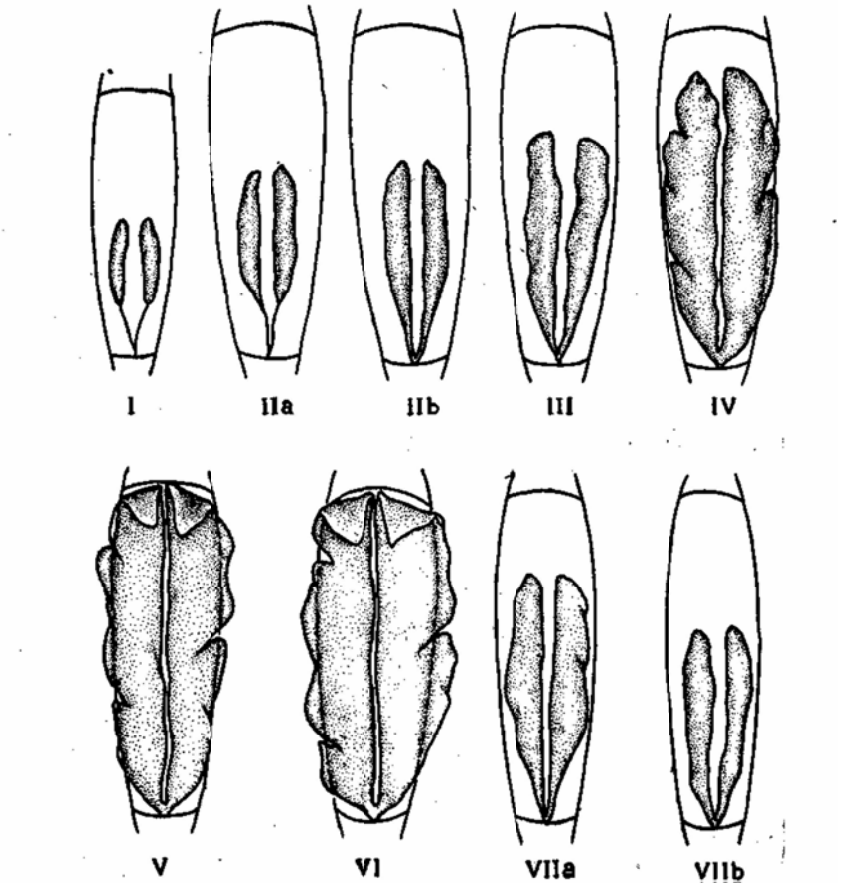
REPRODUCTIVE BIOLOGY

An understanding of the reproductive biology of any given species is an essential prerequisite for stock assessment in wild populations and sustainable exploitation.

FISHES

Development of the Ovary

The stages of ovary development can be examined by visual observation or histological survey. Fish gonad development may be divided into seven stages according to appearance, colour, size, weight, blood vessel distribution, and ova maturity. However, the classification of ovary developmental stages varies from country to country. Five stages are recognized in India, Japan, and the United States of America; several countries recognize seven stages; and, in China, six stages are defined.



Stage I ovary

By visual observation, the gonads are located at the lower part of the air bladder, closely attached to the coelomic membrane, and are lineal in shape, transparent, and flesh white in colour. It is impossible to distinguish the sexes with the naked eye.

Tissue section — Cells are tiny; diameter, 12–22 µm. The nucleus is rather large, occupying more than half of oocyte's diameter. There are few nucleoli in the centre of the nucleus.

Stage II ovary

Ribbon-shaped, flesh white, semitransparent gonads are observed. With the naked eye, it is impossible to distinguish one ova from another; however, small eggs are visible when the tissue is examined under a magnifying glass; when fixed, the eggs are petal shaped. At this stage, it is possible to distinguish visually the sexes. The gonad index (percentage of gonad weight to body weight) is 1–2 per cent.

Tissue section — Cells are multiangular or sphere-shaped; diameter 90–300 µm. A thin layer of flat follicle cells surrounds the oocyte. The nucleoli are closely attached to the nuclear membrane.

Stage III ovary

By visual observation, the capacity of the ovary has become conspicuously enlarged. Due to the appearance of melanotic pigment, the colour of the ovary changes to greenish grey. Eggs are visible with the naked eye but not easily separable. The distribution of blood vessels is clear. The gonad index is 3–6 per cent in this stage.

Tissue section — The follicular membrane surrounding the oocyte is a bilayer. The egg yolk begins to form. One or two layers of vacuoles appear on the edge of the cell. The cell is 250–500 µm in diameter. The nucleus in the centre is irregular or oval-shaped. Most of the nucleoli are distributed along the edge of the nuclear membrane; a small number is scattered in the centre of the nucleus.

The gonads of mature brooders are generally at stage III in the winter.

Stage IV ovary

The ovary is now long and saclike, occupying one-third to one-half of the coelomic cavity. Eggs are plump, greenish grey or light yellow, and can be easily separated. The ovary is fully distributed with blood vessels, and the gonad index is 12–22 per cent

T*issue section* — Egg yolk granules fill almost all the space outside the nucleus, with only a little cytoplasm spreading around the nucleus and near egg membrane; diameter 800–1580 µm. The nucleus edge is wavy, with a few nucleoli inserted in the troughs; most of the nucleoli are moving toward the centre of the nucleus.

This stage can be further divided into three substages based on oocyte diameter and nucleus location. Early stage IV: egg diameter, 800 μm; nucleus in the centre. Middle stage IV: egg diameter, 1000 μm; nucleus in the centre or slightly toward the animal pole. Late stage IV: egg diameter, 1580 μm; nucleus at the animal pole (polarization).

Experimental data and practical application have shown that mature eggs cannot be obtained by inducement of early stage IV oocytes from silver carp, bighead, grass carp, or black carp. Only in middle and late stage IV, when the nucleus is eccentric or polarized, can mature eggs be acquired; artificial induction of estrus will then succeed. These stages could last as long as 1, 2, or even 3 months, providing that the proper ecological conditions for spawning are not available and that no artificial propagation is performed.

Stage V ovary

In this stage, oocytes enter the ovarian cavity as follicular membranes break, and the eggs are flowing freely. The ovary and the belly of the fish are very soft. A slight pressure on the belly would cause the eggs to flow through the cloacal opening.

Tissue section — Yolk granules begin to fuse. The cytoplasm and the nucleus have moved to the animal pole. The nucleoli concentrate in the centre of the nucleus and the nuclear membrane dissolves. The nucleus looks transparent.

As the oocytes proceed to maturity, the follicle epithelial cells secrete a substance that dissolves and absorbs tissues between the follicular and egg membranes; thus, the eggs can easily be released from the follicles and flow freely in the ovary (ovulation). During spawning, the eggs are released from the body through the cloacal opening.

The oocytes proceed quickly from stage IV to maturity (stage V). In nature, the process may be complete 20–40 h after the rising of the river's water level. When estrus is artificially induced, maturity may be reached in 10–20 h or less. If the follicles discharged immature eggs, the rate of fertilization would be adversely affected. If the follicles did not release the mature eggs, the eggs would become overripe, and the rate of fertilization would certainly be adversely affected. Even if some of these eggs were fertilized, the embryos would not develop normally. In other words, the success of either natural spawning or artificial insemination depends upon knowing exactly the maturity stage and spawning time of the fish. If the mature eggs are not released, the oocytes would degenerate and be absorbed.

Stage VI ovary

At this stage, most of the eggs has been laid. There are still some stage IV oocytes in the ovary. The ovary is slack and noticeably smaller, and blood vessels have become enlarged with lump-shaped extravasated blood.

Tissue section — After ovulation, there are abundant follicular membranes and some undischarged mature eggs in ovary. The undischarged eggs will soon degenerate and be absorbed, forming a semi-transparent, irregular, orange-yellow structure. Many interim oocytes can still be seen.

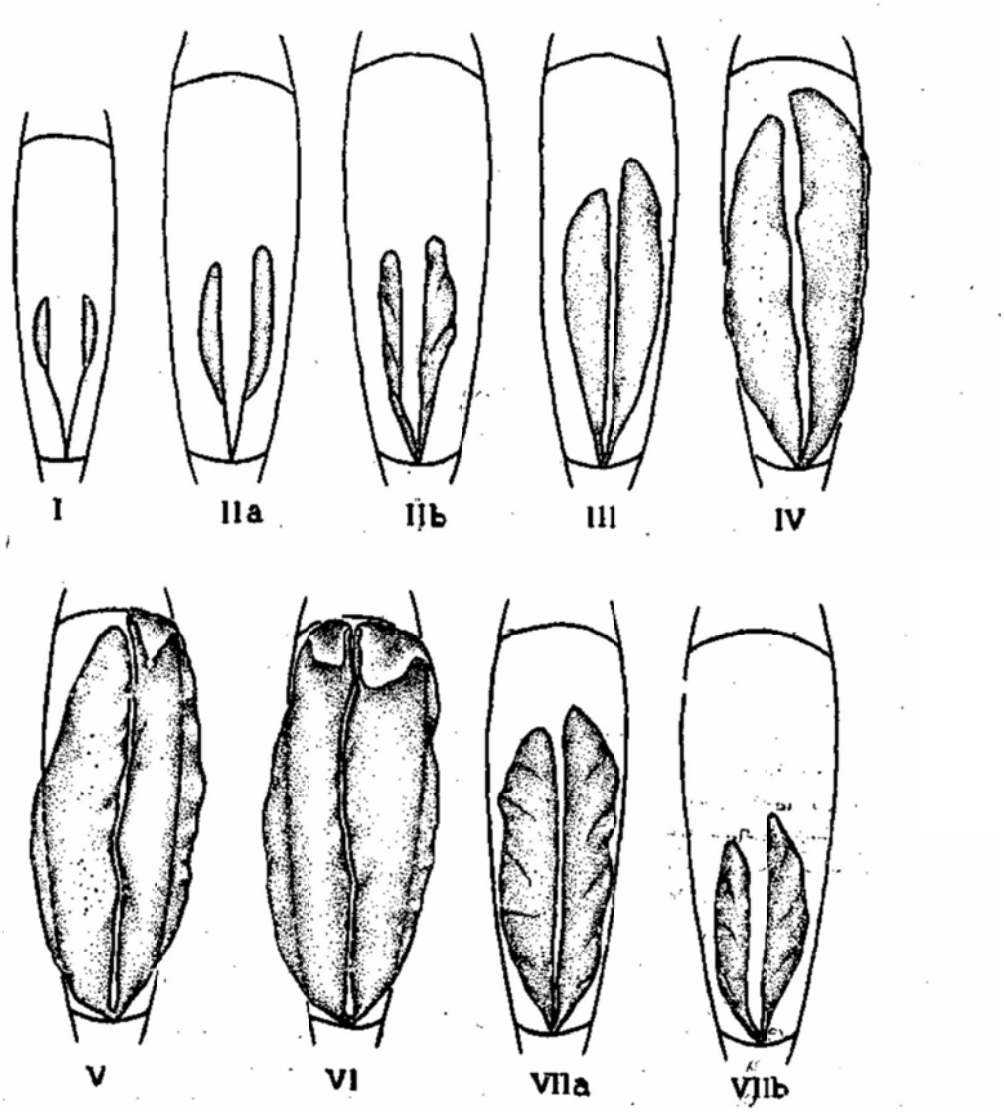
Structure of the Testes

Testis

The testes are paired and tubular. They are situated on both sides of the air bladder, attached to the coelomic wall. The mature testes are white, and, inside, there are many irregularly arranged ampullae. The spaces between ampullae are full of connective tissues. The ampullae are composed of many spores or (seminal vesicle sacs). Spore sacs are separated by a thin layer of follicular cells. Each spore sac contains synchronously developing germ cells, and germ cells in various stages of development can be seen in different spore sacs. At the centre of the ampullae, there is a hollow cavity. After the formation of sperm cells, the spore sacs dissolve and the sperms enter this cavity. The terminal end of the testis is connected to a short seminal duct with and opening to the exterior of the body.

Development of the Testis

Like the ovary, the development of the testis may be divided into seven stages.



Stage I testis

Testis are lineal in shape, transparent, and closely attached to the coelomic wall. At this stage, it is impossible to distinguish between the sexes. On the tissue slice, scattered spermatogonia, 16 µm in diameter, may be observed. The nucleus is big and round, 9 µm in diameter. Ampulli and seminal vesicles are still forming; therefore, there is no clear, fixed arrangement of sperm cells.

Stage II testis

Testis are lacelike and either translucent or opaque. Blood vessels are not clearly visible. Characteristic of this stage are the multiplication of spermatogonia and the formation of seminal vesicles, which are arrayed in bundles. At this stage, ampulli are solid and separated by connective tissue.

Stage III testis

Testis are rod-shaped, pink or yellowish, and elastic on the surface, with a clear distribution of blood vessels. On the tissue slice, a hollow cavity may appear in the middle of the solid ampullae, with one or several layers of seminal vesicles on the ampullar walls.

Stage IV testis

Testis are milky white with a clear distribution of blood vessels on the surface. It is impossible to squeeze out milt early in this stage, but becomes possible later in stage IV. On the tissue slice, some large primary spermatocytes, smaller secondary spermatocytes, and smallest spermatids can be observed; all of these cells congregate on the walls of the seminal vesicles with a small number of sperms.

Stage V testis

Testes are white and full of milt. The milt will flow out through the cloacal opening if the male's head is taken up and its belly is slightly pressed. A large number of sperms, both mature and in various stages of development, can be seen inside the ampulli on the tissue slice.

Stage VI testis

The volume of the testes has greatly decreased after milt exudation, and the testes are now yellowish white or pink. Only spermatogonia, some primary spermatocytes, and connective tissue remain in the seminal vesicles. After milt exudation, the testes revert to stage III and redevelop from there.

SHRIMPS

For the study of reproductive biology, total length and weight of males and females are recorded. After recording length and weight, ovaries from females are dissected out carefully. The colour and size of the ovary are recorded before preserving them in 5% formalin. The maturity stages could be differentiated from fresh specimens based on the colour and thickness of ovary. However, the different maturity stages are to be confirmed later by microscopic examination. For ova-diameter studies, small portions of ovary (approximately 10 mg) taken from anterior, middle and posterior parts of the ovary are teased out on a glass slide and 300 ova from each portion are examined under microscope. As the diameter of ova collected from different regions of ovary did not indicate any variation, further studies on fecundity and ova-diameter is carried out using a portion of ovary on the right side of first abdominal segment. The diameter of ova is measured using an ocular micrometer. The ova are irregular in shape and measurement of each ovum is taken in the same parallel plane using mechanical stage of the microscope in order to avoid errors due to distortion and subjective bias. From each ovary 300 ova are measured.

The size at maturity is found out by plotting the percentage of immature males and females against the matured ones with respect to the total length of the shrimp. For the size at maturity (50%) studies in females, the specimens with early maturing ovary is rated as immature and females having late maturing, mature and spent ovaries are considered as matured ones. Shrimps with petasma with presence of spermatophores in the terminal ampoule are taken as matured males.

Preserved ovary after four or five days is washed and dried by placing it between two blotting papers. The weight of ovary is recorded and a sub-sample of ovary segment is taken out and weighed to the nearest 0.001 gm, using an electronic balance. The mature ova present in the sub-sample are counted by using a counting slide. From the number of ova in the weighed sub-sample, fecundity is calculated using the formula

$$\text{Fecundity} = \frac{\text{total weight of the ovary}}{\text{weight of the sample}} \times \text{number of ova in the sample}$$

The relationship of fecundity on total length, total weight and ovary weight is found out by fitting regression on logarithms of observed values by least square method (Snedecor and Cochran, 1968).

$$F = aX^{b}$$

where, F = Fecundity, a = constant, X = variable (total length, body weight or ovary weight) and b = correlation coefficient. The exponential relationship is transformed into a straight line logarithmic form based on the equation:

$$\log F = \log a + b \log X$$

For gonado-somatic index (GSI) estimation, females are weighed individually after wiping it dry. The gonad is dissected out carefully and weighed by using an electronic balance. The GSI is calculated by using the formula:

$$GSI = \frac{\text{Weight of the gonad}}{\text{Weight of the fish}} \times 100$$

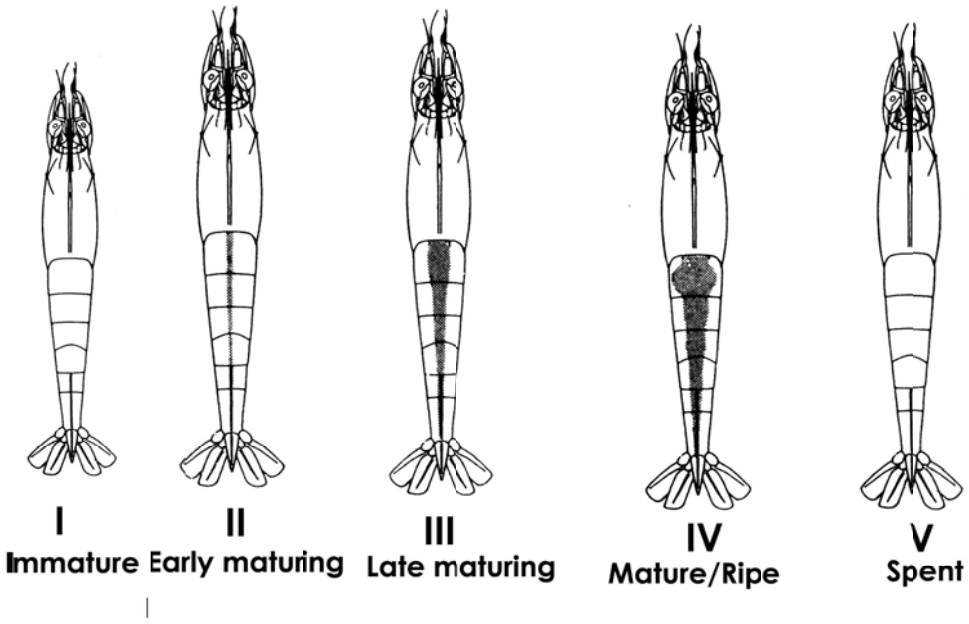
GSI values for different maturity stages are calculated. In addition, monthly variations of GSI values are also calculated to study the relationship between the spawning season and GSI value. Before making assumptions based on GSI, the index is regressed against the total length of the specimen (after log transformation) to ensure that GSI is independent of the body size.

The sex ratio is studied based on the monthly estimated numbers as to get an actual representation of males and females in the population. Homogeneity of the sex ratio (based on observed numbers) over months in two years has been tested using Chi-square test (Snedecor and Cochran, 1968).

This computed as follows:

$$\chi^2 = \frac{\sum (O - E)^2}{E}$$

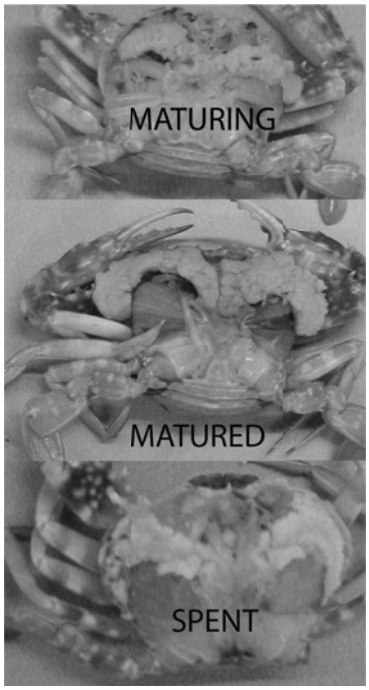
where, O = observed number of males and females in each month/length group E = expected number of males and females in each month/length group. Significant test at a probability level of p = 0.01 is carried out. Homogeneity is tested for 1:1 ratio and for common ratios as observed from the data.



CRABS

The adult male crab can be easily identified from the female the narrow abdomen is 'T' shaped instead of triangular in female. In females, gonads vary in colour, shape, consistencyand volume as the it matures. The colouring changes from white through orange to dark brown. White-coloured ovaries are cylindrical, slender and flaccid and extend to the first abdominal segment. Orange-coloured gonads are likewise cylindrical and slightly compressed dorsoventrally, but are firmer to the touch and reach the second or third abdominal segment. Dark brown ovaries are considerably larger and compressed dorsoventrally; the anterior lobes cover the entire hepatopancreas, while the posterior lobes may extend as far as the extremity of the third abdominal segment.

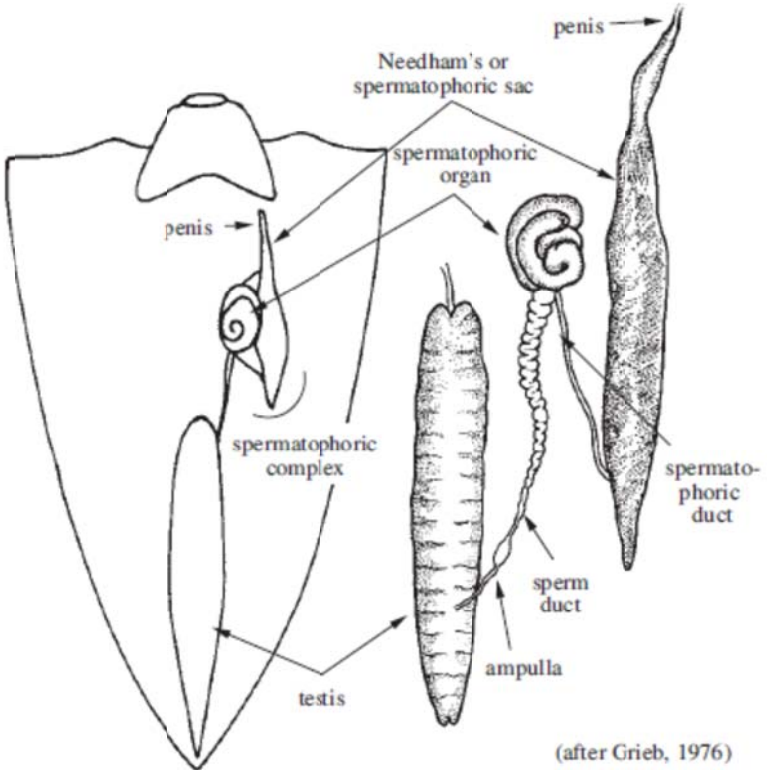
Maturity stage	**Identifying characters**
Immature	Slender and flaccid lobes
	Tubular form white in colour
Maturing	Compressed dorso-ventrally with anterior lobe almost entirely covering the hepatopancreas, orange in colour
Matured	Compressed dorso-ventrally with the anterior lobes cover the entire hepatopancres, brown in colour
Spent	Flaccid and slender white or light yellow color



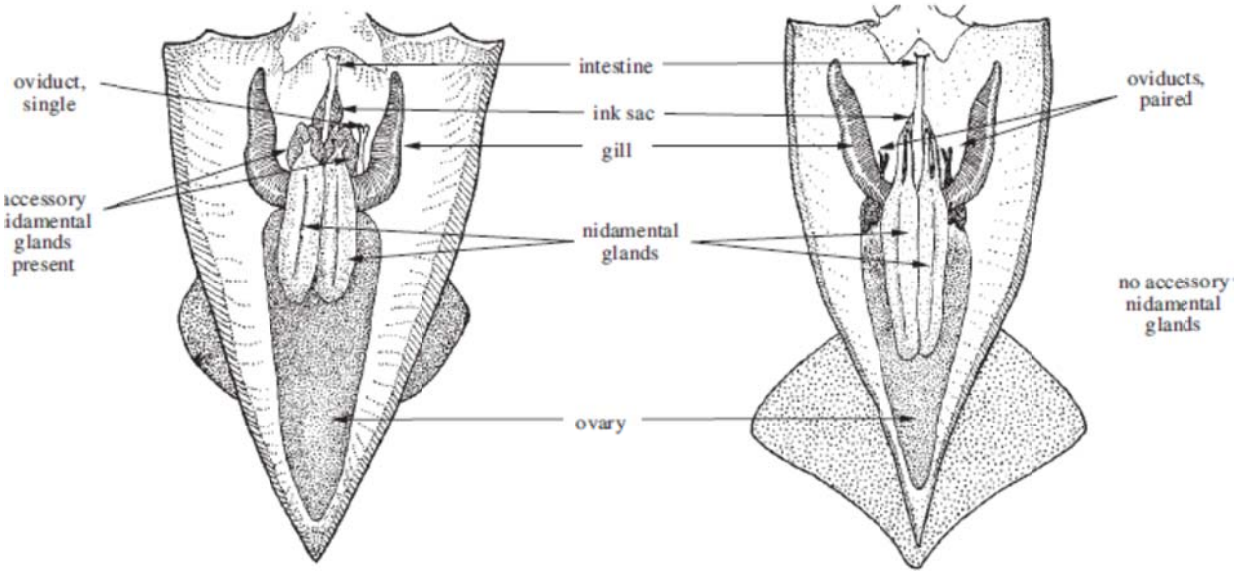
REPRODUCTIVE BIOLOGY: SQUIDS AND CUTTLEFISH

Stages	Female	Male
Immature-Stage I	Ovary small in size, appear as whitish or transluscent, does not have a granulate structure in squids. Ovary very small, occupying the posterior mantle as a whitish patch in cuttlefish. Nidamental glands appear as very fine transparent strip, small in size, accessory nidamental gland not apparent. Oviduct meander not visible.	Testis small thin and elongate in squid and small and triangular in cuttlefish. Spermatophoric (Needham's) sac small with not visible vas deferens. Spermatophores are absent.
Maturing/ Developing-Stage II	Ovary occupies nearly half of posterior body cavity. Individual ova visible. Ovary with uniform sized developing white oocytes. This stage is very brief. Nidamental glands larger and thicker, lobe-like in squids and pearl-shaped in cuttlefish; accessory nidamental gland small and creamy white in cuttlefish. Oviducts fully developed but empty in squids.	Spermatophoric (Needham's) sac with with visible vas deferens and few spermatophores. Testis larger and thicker. Hectocotylization is apparent.
Mature - Stage III	Ovary very prominent with plenty of translucent eggs in oviducts and occupies entire posterior mantle cavity. Oviduct (not paired in neretic squids) with mature ova. Nidamental glands large, whitish cream and attain maximum size in squids. In cuttlefish nidamental glands thick and white, with distant anterior pore; yellowish to orange accessory nidamental glands. The proximal oviduct in cuttlefish with smooth transparent mature eggs, the distal part of ovary with striated eggs and small eggs.	Needham's sac completely packed with plenty of well-developed spermatophores; spermatophores occur in the penis. Testis large and fully developed.
Spawning/ spent-Stage IV	Decrease in gonad volume/ degenerating eggs in oviduct/ or ova absent. Nidamental glands flaccid or diminished, noticeably smaller in volume and weight in squid. Ovary with few striated loose eggs and few medium to small eggs attached to the connective tissue core of the ovary nidamental glands flabby, accessory nidamental glands orange red in cuttlefish.	Spermatophores in gonoduct. Needham's sac flaccid with degenerating spermatophores. Testis small.

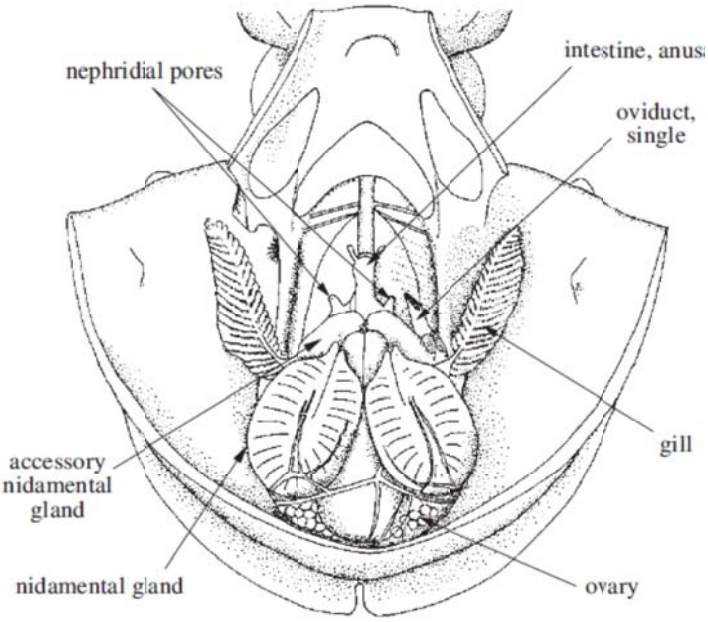
INTERNAL ORGANS



Male squid reproductive apparatus



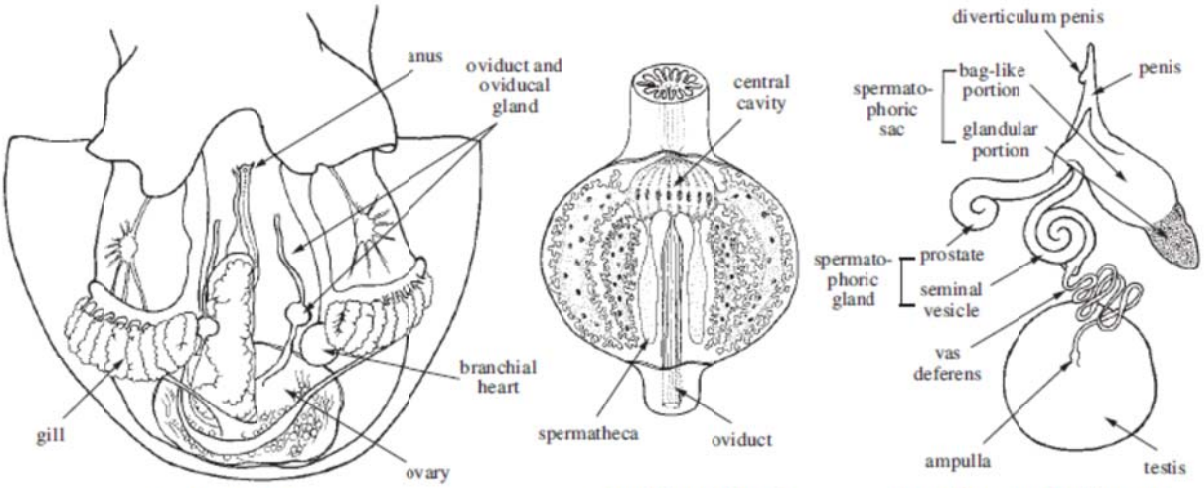
a) **Loliginidae (Female)** b) **Ommastrephidae (Female)**



c) Sepiidae (Female)

REPRODUCTIVE BIOLOGY: OCTOPUS

Stages	Female	Male
Immature	Ovary semi-transparent and lacking granular structure. Oocytes not visible to naked eyes. Oviducal glands small and translucent.	Testis small, thin and translucent. Spermatophoric complex with vas deferens not visible. Absence of spermatophores.
Developing	Ovary with granular structure clearly visible, not reaching the posterior half of mantle cavity. Oviducal gland developing.	Developing and whitish testis. Spermatophoric complex transparent with visible vas deferens. A white streak may appear. Absence of spermatophores.
Mature/ spawning	Large ovary containing high percentage of large reticulated oocytes. Well-developed oviducal glands.	Testis whitish with large and white vas deferens. Large Needham's Sac full of packed spermatophores.
Spent	Shrunken flaccid ovary, with only immature oocytes attached to the central tissue and a few loose large oocytes in the coelom	Testis flaccid. Needham's Sac empty or with few spermatophores.



d) female Octopus

e) oviducal gland (after Froesch and Marthy, 1975)

f) male reproductive tract (after Mann, 1984)

GLOSSARY OF TECHNICAL TERMS: FISH

Abdomen : Belly
Abdominal : Pertaining of the belly
Acute : Sharp - pointed
Adipose eyelids : Transparent membranes covering partly the surface of eye.
Adipose fin : Fin which is fleshy or fatty and present behind dorsal fin.
Adnate : One part adhering to the other
Anal : Pertaining to vent; abbreviation for anal fin.
Anastomosing : Inter joining
Anterio-inferior : That which is situated below anterior end of head.
Anterio-transverse : That which is situated in the middle of anterior end of head.
Antrorse : Directed forward
Anus : External opening of the intestine often referred to as the vent.
Apical : At the tip or apex
Auxiliary scales : Small scales superimposed on or along hind edges of larger ones.
Asperites : Rough bony excrescences
Axil *I* Axial *I* Axilla : Angle between pectoral fin and bod y-pertaining to pectoral axilla or pelvic axilla.
Axillary : Pertaining to the axil or upper angle of pectoral fin.
Axillary process : An accessory, enlarged scale attached to the upper or anterior base of the pectoral or pelvic fins.
Air bladder : A membraneous gas filled sac lying just beneath the back bone either open or closed.
Ankylosed : Grown firmly together
Asymmetrical : Lacking symmetry
Back : The dorsal side of a fish
Barbel : Elongate fleshy tentacular projection - usually around the mouth.
Basal : Pertaining to the base; at or near the base; used with reference to fins.
Bicuspid : Having two lobes
Bifid : Cleft into two
Bifurcate : Forked into 2 parts generally pertaining to caudal fin.
Bilaterally symmetrical : Capable of being halved in one and only one plane in such a way that the 2 halves are approximate images of each other.
Bilobate : Having 2 lobes
Bony plates : Hard plate like structures. which are modified from scales (see carapace) which encase bod y
Bony rings : Hard ring - like structures which are modified from scale which encase body.
Branched ray: : A soft ray which forks into 2 or more parts distally.
Branchial : Pertaining to the gills
Branchiostegals : Bony rays supporting the gill membrane.
Buckler : A bony shield often with a spinous projection on caudal peduncle.
Buccal : Pertaining to the mouth cavity.
Cardiform : Elongate conical teeth
Carapace : Shell like structure on the back of a fish (Ostracion) encasing the body.
Cardiform : Coarse and sharp small teeth.
Carinate : Having a keel or ridge along the midline.
Cartilaginous : Composed of cartilage.

Caudal : Pertaining to the tail; abbreviation of caudal fin.
Caudal fin (Shapes) : Pointed, truncate, emarginated, forked, lunate, wedge shaped.

Caudal peduncle	:	The narrow terminal part of body between the end of dorsal fin and the base of caudal fin.
Cephalic	:	Pertaining to the head.
Cephalic pit	:	Pore like structures present on lateral side of gill cover.
Clasper	:	Extensions of the pelvic fins in male sharks.
Clef	:	Split; divided; pertaining to fish mouth
Conical teeth	:	When blunt are called - obtuse; long and sharp called Acute - Fang like – caniniform.
Continuous	:	On contact or closely adjoining.
Crenulate	:	With the edge slightly scalloped
Ctenoid	:	With spiny (comb like) hind margin - refers to scales
Deciduous	:	Which is shed easily or rubbed off
Dendritic	:	Resembling a tree
Depth	:	Vertical height of bod
Distal	:	Distal Remote from the point of origin or insertion
Dorsal	:	Pertaining to the back. abbreviation for dorsal fin.
Dorsal origin	:	The apex of an angle which is formed by the dorsal ridge of the body and the anterior most or spine of the dorsal or first dorsal fin.
Edentulous	:	Without teeth
Emarginate	:	With definitely the margin slightly hallowed; Notched forked. Shallow notch in the tail.
Entire	:	Not serrated; pertains to undivided dorsal ray ; with a smooth margin. Refer to scales. Operculum and fin.
Epibranchial	:	A bone forming upper part of the gill arch.
Exserted	:	Fin rays much projecting beyond the fin membrane.
Eractile	:	Capable of being raised or erected
Falcate, falciform	:	Long, narrow, curved, scythe - shaped.
Filamentous	:	Thread - like, filiform.
Fimbriate	:	Fringed at the margin.
Finlet	:	Small fins in series behind the dorsal fin and ventral; Division of fin into series of smaller units.
Finrays	:	Horny supports of fins; usually called soft rays and generally though not always, flexible and bilaterally paired and segmented; may also refer to spiny rays.
Forked	:	Connected basally but separated distally. Furcate.
Fossa	:	A pit or depression
Furcate	:	Forked.
Gill arch	:	The skeleton supporting gills
Gill rakers	:	A series of bony projection along the anterior edge of the gill-arches.
Gular plate	:	A plate covering the upper part of the throat
Hipural	:	The modified terminal bone of the vertebral column. Supporting the rays of caudal fin
Heterocercal	:	Caudal fin with longer upper lobe
Hyaline	:	Transparent. devoid of pigment
Illicium	:	Modified isolated first ray of the dorsal fin in angler fish.
Imbricate	:	Having parts overlaying each other
Imperforate	:	Not pierced
Incisors	:	Flattened front cutting teeth, which is chisel shaped.
Infraorbital	:	Small bones along lower side of eye; pertaining to the area be low eye
Integument	:	A covering or coating layer
Intermaxilla	:	Anterior bone in the upper jaw and situated between the maxillaries; premaxilla.
Interopercle	:	Membrane bone between preopercle and branchiostegale.
Iris	:	The round, pigmented membrane surrou nding the pupil of the eye.
Isthmus	:	The narrow fleshy projection of the chest below the gill openings.

Jugular	:	Pertaining to the throat
Keel	:	A ridge extending longitudinally and laterally along the middle (of the side)
Labial	:	Pertaining to the lips.
Labial - fold	:	A skin flap surrounding corners of the mouth.
Lamellae	:	Thin layers of tissue.
Laminae	:	Thin layers of bone, skin or other tissue.
Lanceolate	:	Lance – shaped, gradually tapering towards the extremity: spear shaped.
Lingual	:	Pertaining to the tongue
Lobate	:	Divided into lobes or having rounded divisions.
Lunate	:	Shaped like a cresent.
Luminiscent	:	Pertaining to the production of light
Mandible	:	The bone or bones forming the lower jaw.
Mandibular pores	:	Small openings along a tube (usually hidden) on the lower side of each jaw.
Maxilla	:	The principal side bone of the upper jaw.
Maxillary	:	Pertaining to the upper jaw
Median. Mesial	:	Pertaining to the middle
Median fins	:	Combined terms of dorsal, caudal and ventral fins.
Melanophore	:	A cell containing melanin or black pigment
Mental barbel	:	On chin
Molar	:	A blunt and rounded grinding tooth.
Spiracle	:	A respiration opening behind the eye in sharks and rays.
Trilobate	:	With three lobes or divisions
Tubiform	:	Tube - like
Vestigeal	:	Pertaining to remnant; rudimentary
Villiform teeth	:	Small s lender teeth forming velvety bands
Vomer	:	A bone forming the front part of the roof of the mouth
Vomerine	:	Pertaining to the vomer bone; especially teeth bar on this bone.

GLOSSARY OF TECHNICAL TERMS: PRAWNS, CRABS AND LOBSTERS

Abdomen	:	Posterior region of body consisting of six (prawns and lobsters) or less (crabs) well defined somites, carrying equal or less number of paired appendages.
Antenna	:	Appendage of the third cephalon somite.
Antennule (Antennula)	:	Appendage of the second cephalon somite.
Anterolateral teeth	:	Teeth on anterolateral border of carapace between orbit and lateral spine in crabs and teeth on lateral margin of carapace in front of cervical incision in sand lobsters.
Appendix interna	:	Small separate branch on medial side of pleopodal endopodite tipped with hooks which interlock with opposite member in swimming
Appendix masculina	:	Accessory male organ located medially on second pair of pleopods between endopodite and appendix interna.
Branchiocardiac groove regions	:	Groove separating branchial and cardiac
Branchiostegal spine	:	Spine on anterior edge of carapace. or near it. immediately below branchiostegal groove
Branchium	:	Gill
Buccal cavity	:	Cavity on ventral surface of body in which the mouthparts are situated; it is bounded anteriorly by the epistome. laterally by the free edges of the carapace
Carapace:	:	Shield like covering of the cephalothorax
Carpus (carpopodite)	:	Third article from the distal end of a leg.
Cephalon	:	Head. It is formed by the first six somites of the body and is fused with the thoracic region of cephalothorax. The first cephalic somite carries the eyes, the second the antennulae, the third the antennae, the fourth the mandibles, the fifth the maxillule and the sixth the maxillae
Cervical groove	:	Complex groove or series of grooves running across carapace
Cephalothorax	:	Part formed by the anterior 14 somites including the first 6 somites of cephalon and the rest 8 thoracic somites.
Chela	:	Arrangement of the distal two articles of a crustacean limb by which the terminal element is opposed to the element which precedes it t so that the appendage is adapted for grasping
Chelate	:	Carrying a chela or pincer
Chelipeds	:	Pair or pairs of thoracic legs immediately behind the
Maxillipeds	:	They bear chelae or pincer, claws and are often stouter, sometimes much stouter than the succeeding walking legs
Cornea	:	The distal part of eye that carries the visual elements and is usually pigmented
Coxa (coxopodite)	:	First or proximal article of a leg or maxilliped
Dactyl (dactylus or dactylopodite)	:	Terminal or distal article of a leg or maxilliped
Efferent channels	:	Channels through which water passes out from the gills
Endopodite	:	Medial ramus of a biramous appendage.
Epipodite	:	Outgrowth of the first seven thoracic coxae.
Exopodite	:	Lateral ramus of a biramus appendage.
Frontal teeth	:	True frontal teeth: those teeth originating on the front but exclusive of the inner orbital teeth.
Gastric region	:	Large median- area, in the crab carapace, bounded behind by the cervical suture, laterally by the hepatic regions, and anteriorly by the fronto-orbital regions. It is divisible into the following subregions or lobes: epigastric, protogastric, mesogastric, metagastric and urogastric.
Hand (chela)	:	Propodus and dactyl of the cheliped.

Hepatic region	:	A small (paired) subtriangular, anterolateral region, wedged between branchial and gastric regions, and either margin of carapace or margin of orbit in crabs.
Hepatic spine	:	Spine on hepatic region in prawns.
Merus (meropodite)	:	Fourth article from the distal end of a leg or maxilliped. It is sometimes called the arm of a cheliped.
Orbit	:	Cavity in the carapace containing the eye.
Orbital region	:	Narrow space bordering upper margin of orbit; not always distinguishable.
Palate	:	Roof of buccal cavity in crabs.
Palm	:	Proximal portion of propodus of chela.
Pereopod	:	Thoracic appendages behind the mouth parts, *i.e.* the appendages of somites 10 to 14.
Petasma	:	Endopodite of the first pleopods in male penaeid prawns. It takes the form of a complicated membranous plate bearing coupling hooks medially which interlock with the member of the opposite side. The petasma may terminate distally in various combinations of complex-shaped lobes. Additional complex processes may also be present.
Pleopod	:	Appendage of any of the first five abdominal somites.
Pleurobranchia	:	Gills attached to lateral wall of body dorsal to the articulation of an appendage.
Podobranchia	:	Gills attached to the coxa of an appendage.
Pterygostomiaa region	:	Triangular space on ventral surface of carapace, on either side of buccal cavity in crabs. Region at anterolateral corner of carapace in prawns.
Scaphocerite	:	Antennal scale.
Stylocerite	:	Spine or rounded lobe on lateral aspect of basal article of antennules.
Subhepatic region	:	Area below the hepatic region and below the anterolateral border of the carapace.
Suborbital spine	:	Spine on lower rim of orbit.
Supra orbital spine	:	Spine above and behind orbit.
Telson	:	Terminal somite of the abdomen in prawns and lobsters, carrying no appendages.
Tergite	:	Dorsal plate of a segment.
Thelycum	:	External seminal receptacle. Variously developed, lying on sternum of the thorax and formed by outgrowths from the last two thoracic somites.
Uropod	:	Appendage of the sixth abdominal somite.

GLOSSARY OF TECHNICAL TERMS: CEPHALOPODS

Aboral : Away from or opposite to the mouth.

Accessory nidamental glands : Glands of unknown function; consist of tubules containing symbiotic bacteria. Found in all decapodiformes except oegopsid squids.

Anal flaps : A pair of fleshy papillae involved in directing releases of ink, one flap situated at each side of the anus.

Anterior : Toward the head-end or toward the arm-tips of cephalopods.

Anterior salivary glands : Glands on or in the buccal mass that aid in preliminary digestion.

Arm : One of the circumoral appendages of cephalopods. Arms are designated by the numbers I to IV, starting with I as the dorsal (or upper) pair.

Arm formula : Comparative length of the 4 pairs of arms expressed numerically in decreasing order: the largest arm is indicated first and the shortest last, e.g. IV>III>II>I. If IV>III=II>I, then arm IV is the longest, followed by arm III which is the same size as arm II and both are longer than arm I. In octopods, the non-hectocotylized arm III is used in this formula.

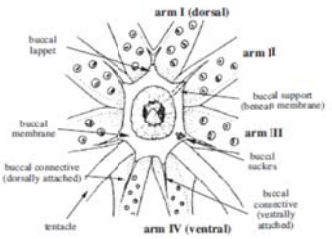
Beak : Two chitinous jaws of cephalopods, bound in powerful muscles.

Branchial : Pertaining to the gills.

Brooding : Incubation of eggs by the female. A characteristic feature of incirrate octopods, but also found in some squids (e.g. Gonatidae).

Buccal : Pertaining to the mouth.

Buccal connective : Thin muscular band that attaches the buccal support of the buccal membrane to the base of the adjacent arm. The position of attachment of the connective on the fourth arms was recognized in the early twentieth century as an important character for phylogenetic relationships among decapodiformes.

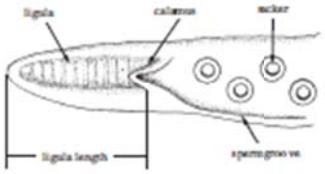


Buccal membrane : The muscular membrane that encircles the mouth like an umbrella. It connects to the buccal supports to form the buccal crown. The pigmentation of the buccalmembrane often differs from that of the adjacent oral surfaces of the arms.

Caecal sac : The sac-like, thin-walled posterior portion of the caecum in the digestive tract that lacks the internal, ciliated leaflets characteristic of the anterior portion of the caecum.

Caecum : Region of the digestive tract of all cephalopods between the stomach and intestine. It is the primary site of food absorption.

Calamus : The conical papilla or projection at the base of the ligula on the hectocotylus of octopods, at the distal terminus of the sperm groove, distal to the last sucker (see Ligula).



Cornea : Smooth, thin, turgid, transparent skin without muscles that covers the eyes to protect the eye lenses of incirrate octopods and some decapods (myopsids and sepioids)

Crop : Expansion (i.e. a broadening or a side pocket) of the oesophagus for storing ingested food, prior to entering stomach. Present in nautiluses and most octopods.

Cuttlebone (= sepion) : The calcareous (chalky) oblong, supporting protective and buoyancy shield in the dorsal part of the mantle of cuttlefishes.

Dactylus : The distal, terminal section of the tentacular club, often characterized by suckers of reduced size.

Digestive gland : Primary organ in cephalopods that secretes digestive enzymes. It is also important in

absorption and excretion.

Digestive gland duct appendages : Outpockets of the ducts leading from the digestive gland that are covered with glandular epithelium.

Dorsal : The uppermost or back surface of a cephalopod, opposite the ventral surface where the funnel is located.

Fin length : Length from anterior lobe, or anterior most attachment of lobe, to posterior most attachment of fin to mantle or tail. Extremely long, spike-like tails usually do not include fin tissue.

Fin lobe : The portion of a fin that extends anteriorly from the fin's anterior point of attachment, or posteriorly from the fin's posterior point of attachment of the fin, to the mantle. This often is called the 'free' lobe.

Fin position : Fins are located anterior to the termination of the muscular mantle (subterminal position) or mostly posterior to it (terminal position) or in an area of overlap between the two.

Fin shape : Fins are classified, somewhat arbitrarily, by their shape as sagittate, rhomboid, circular/ elliptical, lanceolate, ear-shaped, ribbed, lobate or skirt-like.

Funnel : The ventral, subconical tube through which water is expelled from the mantle cavity during locomotion and respiration (reproductive and waste products and the ink also pass through the funnel). Archaic term: siphon.

Funnel groove : The depression in the posteroventral surface of the head in which lies the anterior portion of the funnel

Funnel-locking cartilage : The cartilaginous groove, pit, pocket or depression on each ventrolateral side of the posterior part of the funnel that joins with the mantle component to lock the funnel and mantle together during locomotion and respiration, so that water is expelled only through the funnel and not around the mantle opening.

Funnel organ : The glandular structure fused to the internal surface of the funnel, generally a single W-shaped form in octopodiformes and a dorsal inverted V-shaped component with opposed ventral oblong components in decapodiformes.

Gill lamellae : The leaf-like convoluted individual components of the gill through which gas exchange occurs.

Gladius (= pen) : The feather or rod-shaped chitinous supporting structure in the dorsal midline of squids; the homologue of the shell of ancestral forms.

Gladius length (GL) : Sometimes used as a measurement of the body (= mantle) length when direct measurement of the mantle is unreliable (usually due to deformation).

Head length (HL) : A standard measurement within species growth stages and for species comparisons; measured from posterior limit to V-notch at base of Arms I.

Hectocotylus : One (or more) modified arm in male cephalopods used to transfer spermatophores to the female; modifications may involve suckers, sucker stalks, protective membranes, trabeculae .

Ink sac : The structure that manufactures and stores the ink of cephalopods; it lies parallel with the intestine and empties via a duct into the rectum.

Ligula : The spatulate to spoon-shaped, terminal structure of the hectocotylus of many incirrate octopods, that contains the calamus basally (proximally) and usually a series of transverse ridges and grooves on the oral surface (see Calamus, Hectocotylus). Spermatophores transferred along the sperm groove of the hectocotylized arm are presumably gripped by the ligula. Details of the function of the ligula are unknown.

Mantle : The fleshy (muscular) tubular or sac-like body of cephalopods; provides propulsion through jet-like expulsion of water; contains the viscera.

Mantle cavity : Space enclosed by the mantle. In cephalopods the mantle cavity contains the visceral sac,

gills, anus, openings of the gonoducts, nephridial pores and various muscles and septa.

Manus : Central or 'hand' portion of club between the dactylus distally and the carpus proximally.

Needham's sac (spermatophore/ spermatophoric sac) – : The elongate, membranous organ of males where completed, functional spermatophores are stored. It opens into the mantle cavity or directly into the water through the penis.

Nidamental glands : Large glandular structures in females of most decapods and nautiluses that lie in and open directly into the mantle cavity. The glands are composed of numerous lamellae that are involved in secretion of egg cases or the jelly of egg masses.

Ocellus : Apigmented spot or patch that usually consists of a central locus of concentrated chromatophores with one or more outer concentric rings of chromatophores. Ocelli occur on some octopuses, and their normally vivid iridescence and pigmentation cause them to stand out against the background coloration of the skin. Also called 'false eyespot'.

Oviduct : Female gonoduct(s). The oviduct conducts eggs from the visceropericardial coelom, that encompasses the ovary, to the mantle cavity and often is used to store eggs. In some argonautid octopods eggs are fertilized and undergo either partial (*Argonauta*) or complete (*Ocythoe*) embryonic development within the oviduct.

Oviducal gland : Glandular structure that surrounds the anterior end of the primary oviduct and secrets some of the external coatings around spawned eggs.

Penis : The long, muscular terminal section of the male gonoduct that serves to transfer spermatophores to the female. Apparently, in species with a hectocotylus, the penis transfers spermatophores to the hectocotylus which in turn transfers them to the female.

Pocket, tentacular : An open depression in the anteroventral surface of the head between the bases of arms III and IV of decapods, except myopsid and oegopsid squids, into which the ejectable feeding tentacles are retracted when not in use.

Rostrum (= **spine**) : A spike-like posterior projection of the gladius or cuttlebone, exterior to the conus.

Semelparous : A reproductive strategy in which females spawn once then die. Sometimes called terminal or 'big-bang' spawners. Many cephalopods are semelparous but in some species reproduction is prolonged (up to 50% of the ontogenesis). Nautiluses are iteroparous and spawn repeatedly over a period of years.

Sperm duct (= **seminal duct**) : The duct of males which joins the testis with the spermatophoric organ

Sperm mass : The mass of sperm held within the spermatangia of everted spermatophores.

Sperm receptacle : A bulbous structure in the buccal region or at the openings of the oviducts in females of certain cephalopods for deposition of spermatangia.

Spermatangium (pl. **spermatangia**) : Extruded, exploded, evaginated spermatophore/s, often in the form of a round bulb.

Spermathecae : Specialized sperm-storage structures found in the skin of some female decapodiformes or as pockets of the oviducal gland in octopods.

Spermatophore : A tubular structure manufactured by male cephalopods for packaging sperm; capable of holding millions of sperm, it is transferred and attached to the female until fertilization begins. It forms a spermatangium after the spermatophoric reaction occurs and the spermatophore has everted.

Spermatophoric complex : The unit formed by the sperm duct, the spermatophoric organ, the spermatophoric sac, the spermatophoric duct and the penis.

Spermatophoric duct : The duct of males through which the spermatophores, once formed, pass from the spermatophoric organ to the spermatophoric sac.

Spermatophoric organ : Male organ where the spermatophores are formed.

Spermatophoric reaction : The evagination of a spermatophore with the extrusion of the sperm mass, caused by the penetration of water inside the spermatophoric cavity, where the osmotic pressure is higher.

Stomach : The muscular organ of the digestive system where primary digestion occurs.

Sucker/s : Muscular, suction-cup structure/s on the arms and tentacles (occasionally on the buccal membrane) of cephalopods. It consists of a cup-shaped portion, the acetabulum, and a flat, distal ring, the infundibulum, that contacts the substrate. They usually are counted either in longitudinal rows or in transverse (oblique) series.

Sucker ring : Chitinous, often serrated or toothed, ring that encircles the opening of suckers of squids and cuttlefishes.

Tentacles : Modified fourth pair of appendages in decapods, used for prey capture and capable of considerable extension and contraction.

Tentacular club : The distal, terminal, usually expanded, part of the tentacle that bears suckers and/or hooks. Used for capturing prey.

Total length (TL) : Length measured from the posterior tip of the mantle to the anterior tip of the outstretched tentacles (squids and cuttlefishes) or arms (octopuses).

Web : A membranous sheet of greater or lesser extent that extends between the arms of many octopods, giving an umbrella-like appearance when the arms are spread out, e.g. on cirroteuthids. It is reduced or absent in most decapods.

GLOSSARY OF TECHNICAL TERMS: BIVALVES

Anterior : Region situated near the head. In bivalves: region opposite to the siphons, consequently, opposite to the shell sinus.

Beak/ Umbo (pl. umbones) : Projected portion of the hinge. Obs: first-formed part of the bivalve shell.

Bivalve : Molluscs that have, among other features, shell comprised of 2 halves, or valves.

Byssal : Position relative to byssus.

Byssal gap : Gap or opening sometimes present on the ventral margin of bivalve shells for passage of byssus.

Byssus : Bundle of fibers secreted by some bivalves attaching the animal to the bottom. Mussels, some arks, and pen shells are attached to the substrate by byssus.

Cancellate : Cross-barred sculpture. In bivalves, radial and concentric elements will cross to produce a cancellate sculpture.

Chondrophore : Depression in spoon-like form housing the internal ligament of some bivalve shells.

Chomata : Marginal crenulations in Ostreidae and Gryphaeidae, occurring all around the inner side of valves or only near the hinge, composed of small tubercles or ridgelets on the right valve, and corresponding pits on the left valve.

Compressed : Outline of bivalves which are flattened laterally.

Concentric : Feature of sculptural elements curving about the umbo in bivalves.

Cord / Cordlet : Element of gastropod shell sculpture, usually spirally oriented, thicker than lines.

Corrugated : Appearance of surfaces forming wrinkles.

Crenulated : Appearance of surfaces which are delicately notched or corrugated. Usually applied to wrinkled shell margin or edge.

Crenulations : Notches, or wrinkles which are small and delicate.

Depressed : Outline of low, pressed-down gastropod shells. Obs: term usually applied to some top shells or baby ear.

Dorsal : In bivalves, the region of the hinge.

Equivalve : Characteristic of bivalves that have the 2 valves or halves of same size.

Escutcheon : An area of the posterior-dorsal shell surface near a ligament that is

differentiated by sculpture and frequently demarcated by a marginal ridge or furrow.

Excavated : Appearance of a hollow, concave surface.
Foliated : Characteristic of being leaf-like.
Foot : In bivalves, hatchet-like, expandable structure involved in burrowing.
Glassy : Surface resembling glass, vitreous, transparent.
Granulated : Surface covered with minute grains, pustules, or beads.
Growth lines : Lines on shell surface indicative of alternating periods of growth and rest; sometimes corresponding to seasonal changes.
Hinge : Region of the bivalve shell where the two valves are joined together, usually including interlocking teeth and the ligament.
Hinge teeth : Projections that interlock on the inner side of the bivalve shell hinge helping to prevent the two valves from sliding sideways past each other.
Horny : Substance that is hardened, proteinaceous; partially or completely forming the ligament, shell periostracum, and possibly other structures.
Incised lines : Features of shell sculpture represented by cuts or narrow grooves on the shell surface.
Indented : Surface bearing an indentation.
Inequivalve : Characteristic of having the two valves (halves) of different size.
Inflated : Characteristic of being 'fat', rotund, and frequently lightweight.
Interspaces : Spaces between sculptural features, e.g., ribs, costae, or cords.
Knob : Large nodule, rounded projection.
Knobbed : Surface bearing knobs.
Lamella : Thin plate or blade-like projection
Ligament : Structure that is horny, proteinaceous, acting as a spring tending to keep the valves opened in bivalve shells. Usually situated in the region of the hinge, either internally or externally.
Line : Sculptural feature narrowly incised on shell surface.
Lunule : Impression on the external side of the hinge, anterior to the umbo, usually heart-shaped.
Mantle : Fleshy sheet surrounding vital organs and composed of 2 lobes, one lining and secreting each valve.
Margin : Edge of shell.
Nacreous : Characteristic of being iridiscent, like mother-of-pearl.
Nodules : Projections which are rounded as tubercules
Nodulose : Surface bearing nodules.
Notch : Cut or depression, as on a shell margin.
Opalescent : Characteristic of being whitish, but with nacreous luster.
Ovate / Oval : Characteristic of having the form of an egg.
Pallial line : Fine scar-like impression present internally; in bivalve shells produced by the edge of the mantle.
Periostracum : Layer of the outside part of the shell. It is horny and sometimes hair-like.
Posterior : In bivalves, the region of the shell sinus away from the foot.
Prodissoconch : Shell in larval state remaining on the umbonal region of well-preserved bivalve shells.
Radial / Radiating : Structures that are directed away from the umbo toward the shell margin in bivalve shells.
Reticulate / Reticulated : Feature of shell sculpture consisting of criss-crossed, net-like texture formed by the intersection of lines at right angles.
Ribs : Strucutural elements forming a well-defined, narrow ridge in gastropod shells. Term usually applied to those elements forming a plane with (or slightly oblique to) shell axis.
Riblets : Diminutive of ribs.
Scales : Sculptural elements that are small, raised, and plate-like.
Septum : Partition found in the internal side of gastropod shells; characteristic of slipper-shells.

Serrated	:	Outline resembling tiny saw teeth.
Shell sinus	:	Embayment on the pallial line of bivalve shells that correspond to the position of the siphons.
Siphon	:	Prolongation of the mollusc mantle used to convey water into or out of the mantle cavity.
Spiral	:	Direction following the coiling of the gastropod shell. Usually applied as a modifier to sculptural terms such as 'spiral cords'.
Striation	:	Fine, repeated lines or furrows on shell surface.
Varix (pl. varices)	:	Axial sculptural element that is more prominent than a costa, and usually more widely Spaced; evidence of a growth halt during which a thickened lip develops.
Valve	:	One half of the bivalve shell.
Ventral	:	Region of the animal opposite the dorsal region; usually region of the foot in bivalves.

GLOSSARY OF TECHNICAL TERMS: GASTROPODS

Albino	:	Shell lacking normal pigmentation
Anterior	:	Region situated near the head. In gastropods: in front.
Anterior canal	:	Expansion looking like a groove or a tube and serving to protect the siphon in gastropod shells.
Aperture	:	Opening in gastropod shells.
Apertural	:	Position relative to the aperture of gastropod shells.
Apex/ Top of the shell	:	Extremity of a gastropod shell opposite to the anterior region; part of the shell built in earlier life.
Apical	:	Situated at or near the apex of a gastropod shell.
Axial	:	Direction forming a plane with main shell axis in gastropods.
Basal	:	Position relative to shell base.
Base	:	Part of the gastropod situated in opposition to the apex.
Bottom of the shell	:	Same as base.
Body whorl	:	Most anterior whorl of the gastropod shell, last and largest whorl.
Callus	:	Thickening of the shell, secondary, smooth, sometimes glazed, usually secreted on the parietal region of the columella.
Cancellate	:	Feature of cross-barred sculpture of some gastropod shells consisting of axial and spiral elements of same intensity crossing at right angles.
Columella	:	Column or pillar located on the centre of a gastropod shell.
Cord	:	Element of gastropod shell sculpture, usually spirally oriented, thicker than line.
Cordlet	:	Narrow cord, thicker than line.
Corrugated	:	Appearance of surfaces forming wrinkles.
Crenulated	:	Appearance of surfaces that are delicately notched or corrugated. Term usually applied to wrinkled shell margin or edge.
Crenulations	:	Notches, or wrinkles that are small and delicate.
Denticles	:	Features of sculpture elements looking like small teeth-like projections.Termusually applied to features seen on the internal part of the aperture.
Depressed	:	Outline of low, pressed-down gastropod shells. Term usually applied to some top shells
Dorsal	:	Region opposite to the foot in gastropods.
Elongate	:	Shell with length significantly larger than width.
Excavated	:	Appearance of a hollow, concave surface.
Fold/ Plication	:	Ridge spiralling on columella.
Foliated	:	Characteristic of being leaf-like.
Foot	:	In gastropods, fleshy, sole-like, muscular part of body involved in locomotion.
Furrow	:	Groove in longitudinal direction found on the dorsal region of, among other

shells, cowries and Triviidae.

Fusiform : Characteristic of being spindle-shaped.

Glassy : Surface resembling glass, vitreous, transparent.

Globular / Globose : Shape resembling a sphere or a ball.

Granulated : Surface covered with minute grains, pustules, or beads.

Growth lines : Lines on shell surface indicative of alternating periods of growth and rest; sometimes corresponding to seasonal changes.

Horny : Substance that is hardened and proteinaceous; present in or completely forming the gastropod operculum and shell periostracum.

Incised lines : Features of shell sculpture represented by cuts or narrow grooves on the shell surface.

Indentation : Cut or notch on shell edge or parietal region.

Indented : Surface bearing an indentation.

Interspaces : Spaces between sculptural features, such as ribs, costae, or cords.

Juvenile : Characteristic of being young, immature, not fully grown.

Keyhole : Apical orifice in some limpets.

Knob : Large nodule, rounded projection.

Knobbed : Surface bearing knobs.

Lamella (pl. lamellae)/ Lamellation : Thin plate or blade-like projection.

Ligament : Structure that is horny and proteinaceous, acting as a spring tending to keep the valves opened in bivalve shells. Usually situated in the region of the hinge, either internally or externally.

Line / Thread : Sculptural feature narrowly incised on shell surface.

Lip : Edges of the outer surface of the aperture in the gastropod shell.

Longitudinal : Direction parallel to the largest dimension of the shell or mollusc.

Nacreous : Characteristic of being iridiscent, like mother-of-pearl.

Nodules : Projections that are rounded as tubercules.

Nodulose : Surface bearing nodules.

Notch : Cut or depression on any margin, canal, or on the gastropod aperture.

Opalescent : Characteristic of being whitish, but with nacreous luster.

Operculum : Trapdoor or plate which closes the aperture of gastropod shells and isolates the snail from its surrounding environment. Opercula can be horny ('soft', brownish) or calcareous ('hard', usually whitish).

Outer lip : Edge of the external part of the aperture away from the shell axis.

Ovate/ Oval : Characteristic of having the form of an egg.

Parietal : Region of the internal part of the aperture, usually set apart by differences in surface texture and/or coloration.

Parietal shield : Parietal region when markedly different from the remainder of the adjacent shell area.

Periphery : Region of the outermost part of any given whorl on the gastropod shell. The shell periphery is therefore the greatest circumference of the gastropod shell.

Periostracum : Layer of the outside part of the shell. It is horny and sometimes hair-like.

Peristome : Aperture rim or periphery.

Posterior : Region away from the siphonal canal, near the apex, in gastropods; in bivalves, the region of the shell sinus, away from the foot.

Posterior canal : Canal of small size or notch opposite to the siphonal canal on the aperture of the gastropod shell.

Protoconch : Larval shell remaining on the apex of well-preserved gastropod shells.

Radial / Radiating : Structures that are directed away from the apex toward the shell margin, in limpets.

Reticulate : Feature of shell sculpture consisting of criss-crossed, net-like texture formed by the intersection of lines at right angles.

Ribbon / Egg-ribbon : Surface consisting of an aligned sequence of egg-cases.

Ribs : Strucutural elements forming a well-defined, narrow ridge in gastropod shells. Term usually applied to those elements forming a plane with (or slightly

oblique to) shell axis.

Riblets : Diminutive of ribs.

Scales : Sculptural elements that are small, raised, and plate-like.

Septum : Partition found in the internal side of gastropod shells; characteristic of slipper-shells.

Serrated : Resembling tiny saw teeth.

Shoulder : Angled region of the whorls of gastropod shells.

Siphon : Prolongation of the gastropod mantle used to convey water into the mantle cavity.

Siphonal canal : Projection of the anterior region shell in tubular form protecting the anterior siphon.

Snails : Common name of gastropods.

Spiral : Direction following the coiling of the gastropod shell. Term usually applied as a modifier to sculptural terms such as 'spiral cords'.

Spire : Series of successive whorls in a gastropod shell, with exception of the last one.

Spire angle : Angle formed by the lines defined by the outermost points on both sides of the spire.

Striation : Fine, repeated lines or furrows on shell surface.

Suture : Line or region of junction between two adjacent whorls in the gastropod shell.

Synonym : A scientific name applied to a species that has received an earlier name. Obs: usually, the earlier name is the valid one.

Turbinate : Form that looks top-shaped, tapering evenly from base to apex.

Turreted : Form that looks tower-shaped, elongate.

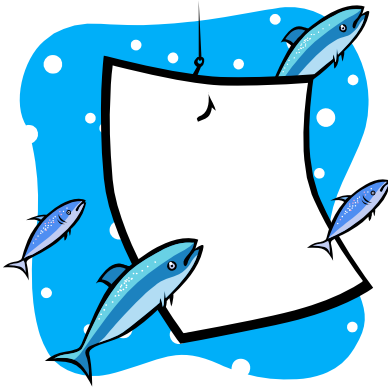
Umbilicus : Cavity at base of gastropod shells.

Uncoiled : Gastropod shell that lacks coiling.

Varix : Axial sculptural element that is more prominent than a costa, and usually more widely spaced; evidence of a growth halt during which a thickened lip develops (plural: varices).

Ventral : Region of the animal opposed to the dorsal region; region of the foot in gastropods.

Whorl : A complete turn or coil of the gastropod shell.

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