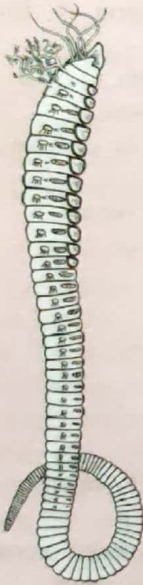




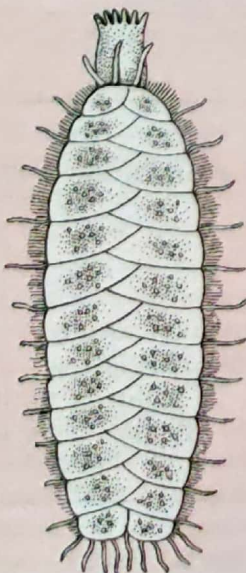
Annelida : Characters, Classification and Types



Name of phylum Annelida was first coined by **Lamarck** for the higher segmented worms (L., **annelus**, little ring+ Gr., **eidos**, form). In general, annelids are elongated, bilaterally symmetrical and highly organized animals, in which the organs have grouped into definite systems. Appearance of **metamerism** represents their greatest advancement, so that they are called **segmented worms** in order to distinguish them from flatworms (Platyhelminthes) and roundworms (Nematoda) which are not segmented. Their paired appendages, when present, are never jointed. Their coelom, nephridia and cephalization are better developed than those of the unsegmented worms. They are the first animals to have a closed vascular system. Nervous system is fundamentally similar to that of Arthropoda and embryology is not much different from that of Mollusca.

GENERAL CHARACTERS

1. Mostly aquatic, some terrestrial. Burrowing or tubicolous. Some commensal and parasitic.
2. Body elongated, bilaterally symmetrical, triploblastic, truly coelomate and **metamerically segmented** into similar metameres.
3. **Epidermis** of a single layer of columnar epithelial cells, covered externally by a thin **cuticle** not made of chitin.
4. Body wall **dermo-muscular**. Outer muscle fibres circular, inner longitudinal.
5. Locomotory organs are segmentally repeated chitinous bristles, called **setae** or **chaetae**, embedded in skin. May be borne by lateral fleshy appendages or **parapodia**.



6. **Coelom**, true, schizocoelous. Mostly well-developed except in leeches. Usually divided into compartments by transverse septa. Coelomic fluid with cells or corpuscles.
7. Digestive system straight and complete. Digestion entirely extracellular.
8. Blood vascular system closed. Respiratory pigments either haemoglobin or erythrocrurin dissolved in blood plasma.
9. Respiration by moist skin or gills of parapodia and head.
10. Excretory system consisting of metamerically disposed coiled tubes, called **nephridia**.
11. Nervous system with a pair of cerebral ganglia (brain) and a double ventral nerve cord bearing ganglia and lateral nerves in each segment.
12. Sensory organs include tactile organs, taste buds, statocysts, photoreceptor cells and sometimes eyes with lenses in some.
13. **Hermaphroditic** or sexes separate cleavage spiral and determinate. Larva, when present, is a **trochophore**. Regeneration common.

CLASSIFICATION

About 17,426 known species of Annelida are divided into four main classes, primarily on the basis of the presence or absence of parapodia, setae, metameres, and other morphological features.

CLASS 1. Polychaeta

(Gr., **polys**, many + **chaite**, hair)

1. Chiefly marine, some in fresh water.
2. Segmentation internal and external.
3. Head distinct with eyes, palps and tentacles.
4. Setae numerous, on lateral parapodia.
5. Clitellum absent.
6. Sexes separate. Gonads temporary and in many segments.
7. Trochophore larva present.

Attempts to arrange families into orders has not proved satisfactory. It is usual, therefore, to divide polychaetes into two subclasses, *Errantia* and *Sedentaria*, after **Fauvel** (1959). However

according to **Dab** (1963), this subdivision is artificial and not a natural one.

Subclass I. Errantia

1. Free-swimming, crawling, burrowing or tube-dwelling and predatory polychaetes.
2. Segments numerous and similar, except for head and anal region.
3. Prostomium distinct with sensory structures.
4. Parapodia with acicula and compound setae.
5. Pharynx protrusible, enlarged and usually with jaws and teeth.

Examples : *Aphrodite* (sea mouse), *Polynoe*, *Phyllodoce*, *Tomopteris*, *Syllis*, *Nereis*, *Glycera*, *Eunice*, *Diopatra*, *Histriobdella*.

Subclass II. Sedentaria

1. Sedentary polychaetes living in burrows or tubes.
2. Body made of two or more regions, with dissimilar segments and parapodia.
3. Prostomium small.
4. No acicula and compound setae.
5. Pharynx without jaws and teeth.

Examples : *Chaetopterus*, *Arenicola*, *Owenia*, *Sabella*, *Sabellaria*, *Terebella*, *Amphitrite*, *Pomatoceros*, *Spirorbis*, *Serpula*.

CLASS 2. Oligochaeta

(Gr., **oligos**, few + **chaite**, hair)

1. Mostly terrestrial, some in fresh water.
2. Segmentation external and internal.
3. Head indistinct, without sensory organs.
4. Setae few, embedded in skin. Parapodia absent.
5. Glandular clitellum present for cocoon-formation.
6. Hermaphroditic. Testes anterior to ovaries.
7. Fertilization external (in cocoon); development direct, no larval stages.

Order 1. Plesiopora plesiothecata

1. Mostly aquatic.
2. Male gonopores on segment immediately following that which contains testes.
3. Spermathecae in the testes-containing segments, or nearby.

Examples : *Aelosoma*, *Nais*, *Dero*, *Chaetogaster*, *Tubifex*.



Characters	<i>Nereis</i> (Clamworm)	<i>Pheretima</i> (Earthworm)	<i>Hirudinaria</i> (Leech)
23. Albumen glands	(23) Albumen glands absent.	(23) Albumen glands absent.	(23) Albumen glands present at the junction of two oviducts.
24. Copulation	(24) Copulation does not occur.	(24) Copulation takes place.	(24) Copulation takes place.
25. Fertilization	(25) Fertilization occurs in sea water, externally.	(25) Fertilization occurs in cocoon, externally.	(25) Fertilization occurs in vagina, internally.
26. Development	(26) Development indirect involving free swimming trochophore larva.	(26) Development direct. No free larval stage.	(26) Development direct. No free larval stage.

ORIGIN OF COELOM AND METAMERISM

Coelom and metamerism, and the various theories explaining their origin and evolution, have already been discussed in chapter 16 on the 'Organization of Metazoa'. Phylum Annelida represents the first group of metazoan animals developing a **true coelom** with **true metameric segmentation**.

Segmentation. When body is marked by transverse constrictions on A/P axis it is called segmentation.

(a) **Superficial.** A series of ring like creases develop in the cuticle and the body wall which facilitate the bending and telescoping of body. It is strictly ectodermal.

(b) **Metameric.** When the body is divided into smaller compartments on its A/P axis. Each compartment is separated by septum; when most of the mesodermal derivatives are also segmentally arranged.

Advantages. Enough number of structures and once the repeat pattern is available the units of the pattern can become elaborate and specialized.

ADAPTIVE RADIATION IN ANNELIDA

The evolution and spread from a single ancestral species to a variety of forms, which occupy different habitats, is called **adaptive radiation** or

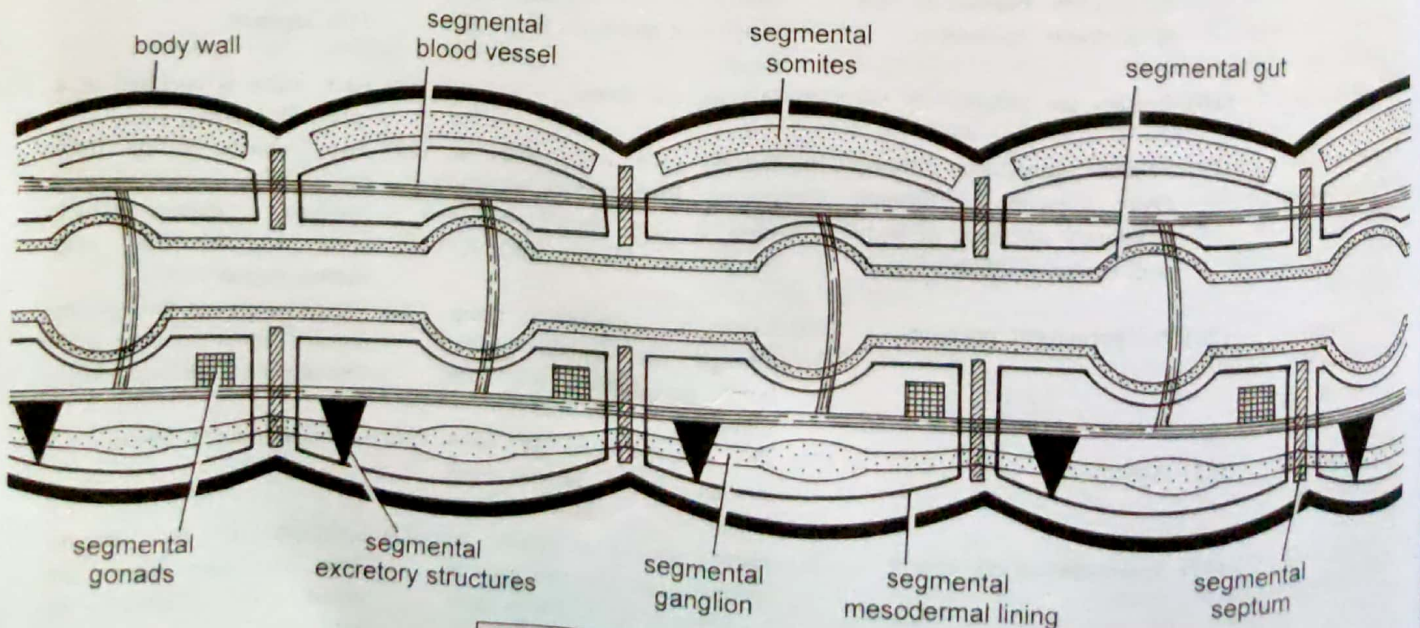
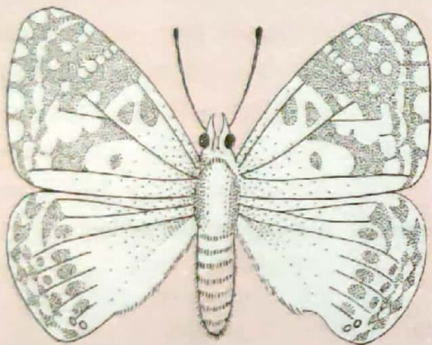


Fig. Metameric segmentation in Annelids.



Arthropoda : Characters, Classification and Types



Phylum Arthropoda (Gr., **arthros**, joint + **podos**, foot) is the largest phylum of Animal Kingdom including about 12,57,040 species in all habitats, which constitute about 83% of all the known species of animals.

GENERAL CHARACTERS

1. Organ-system level of body organization.
2. Body bilaterally symmetrical, triploblastic and metamerically segmented.
3. Appendages jointed, usually one pair to a somite, and with varied functions as jaws, gills, legs, etc.
4. Exoskeleton of dead chitinous cuticle that is shed at intervals, called ecdysis or moulting, for growth and development.
5. Body divisible into head, thorax and abdomen. Head and thorax often fused to form a cephalothorax.
6. True coelom reduced and largely replaced by a blood-filled haemocoel.
7. Muscles mostly striated, usually capable of rapid contraction.
8. Digestive system complete with mouth and anus. Mouth parts adapted for various modes of feeding.
9. Circulatory system open with a dorsal often many-chambered heart, arteries and blood sinuses or haemocoel.
10. Respiration by general body surface, gills, tracheae or book-lungs.
11. Excretory organs are green glands or Malpighian tubules.





12. Nervous system typically annelidan, with a dorsal brain connected with a nerve ring to a double ventral nerve cord.
13. Sensory organs comprises of eyes (simple and compound), chemo- and tactile receptors, balancing and auditory organs.
14. Sexes usually separate (dioecious). Reproductive organs and ducts paired. Fertilization usually internal. Oviparous or ovoviviparous.
15. Development direct or indirect with one to many larval stages. Parthenogenesis in some.
16. Cilia and flagella absent except in Onychophora.
17. Parental care often well-marked.

CLASSIFICATION

Arthropoda is a much heterogeneous group including a variety of animals with divergent views concerning their phylogeny. Because of this reason, no definitive system of classifying this phylum exists. The classification adopted here is a synthesis of several views so that such a large and diverse phylum may be conveniently grouped. In fact, arthropod classification is still in a state of flux, and may always remain so.

Seven subphyla are recognized in the following classification. Of these, only Trilobitomorpha, Chelicerata and Mandibulata are definitely arthropods. Trilobitomorpha includes a number of extinct classes only. Onychophora, Tardigrada and Pentastomida show only doubtful or superficial relationships with other arthropods, so that some books treat them as independent minor phyla. We have also described the type *Peripatus* under a separate phylum Onychophora, to accommodate this view. Pycnogonida is sometimes included as a class within the subphylum chelicerata. The old class Myriapoda is retained here within the subphylum Mandibulata, otherwise, every order of Myriapoda is equivalent in status to other classes of Mandibulata.

Subphylum I. Trilobitomorpha

(Gr., **tri**, three + **lobos**, lobe + **morphe**, form)

1. Fossil trilobites. Mostly marine and bottom-dwellers. Cambrian to Permian.
2. Body 3-lobed, due to 2 longitudinal furrows.
3. Head distinct. Probably one pair of antennae.
4. Biramous appendages on all segments except the last one.

Examples : *Triarthrus*, *Dalmanites*.

Subphylum II. Chelicerata

(Gr., **chele**, claw + **keros**, horn + **ata**, group)

1. Body divided into an anterior cephalothorax (prosoma) and a posterior abdomen (opisthosoma).
2. Prosomatic appendages 6 pairs. First pair of preoral chelicerae with claws, followed by postoral pedipalps and 4 pairs of walking legs.
3. Antennae and true jaws absent.

CLASS 1. Merostomata

(Gr., **meros**, thigh + **stoma**, mouth)

1. Marine with median simple and lateral compound eyes.
2. 5 to 6 pairs of abdominal appendages with book-gills.
3. Abdomen ending in a sharp telson or spine.
4. Excretion by coxal glands. No Malpighian tubules.

Subclass 1. Xiphosura

(Gr., **xiphos**, sword + **aura**, tail)

1. Cephalothorax with large extended, convex, horseshoe-shaped carapace.
2. Abdomen unsegmented with a long terminal telson.

Example : *Limulus* (horseshoe or king crab).

Subclass 2. Eurypterida

(Gr., **eury**, broad + **pteryx**, wing)

1. Extinct marine, giant water scorpions.
2. Cephalothorax small. Carapace plain, not extended.
3. Abdomen 12-segmented and narrowed behind.

Examples : *Eurypterus*, *Pterygotus*.



SOCIAL LIFE IN INSECTS

Social Behaviour

In a broader sense, any interaction between two or more individuals constitutes **social behaviour**. Usually, social relationship implies interactions among members of the same species. The mere presence of more than one individual does not mean that the behaviour is social. Various types of associations occur among insects.

1. Solitary insects. When each individual is more or less independent, insects are called **solitary**. They forage independently and the two sexes come in contact only to mate. The female deserts her eggs or dies after laying, and does not look after the offsprings.

2. Gregarious insects. Many solitary insects are **gregarious**, that is, they form dense but temporary populations or aggregations in response to factors of physical environment or to share certain common needs or tracts. Thus, light at night stimulates large numbers of moths and other insects to collect around it. High humidity under a log causes aggregations of wood lice. Caterpillars of the same or different species may live together and act in mutual cooperation. Ladybird beetles assemble together for hibernation. Locust and may-flies come out in huge swarms. None of these groups is strictly speaking, social. Gregariousness being a temporary habit it does not involve any association of the parents and the offsprings and has nothing to do with the evolution of the social behaviour among insects.

3. Social insects. On the other hand, insects of a given species that live together in organised groups or colonies are known as **social insects**. In a social organisation many individuals of species live together in an integrated manner so that each contributes in some specialized way to the welfare of all.

Evolution of Social Habit

Among the oldest and most highly developed societies in the animal kingdom are those of

insects. Three hundred million years ago these societies were already in existence. Social habit has arisen independently in several orders of insects. Transition from solitary to social life in these usually short-lived animals was made possible by the prolongation of adult or parental life and increasing parental care. First the progeny depended on the parents, then the parents on the progeny.

Orders of Social Insects

Social species of insects belong to seven orders, namely Orthoptera (cockroaches, gryllotalpa), Dermaptera (earwigs), Isoptera (termites), Embioptera (web spinners), Psocoptera (book lice), Coleoptera (beetles) and Hymenoptera (bees, wasps and ants). About 6,000 species of insects in all exhibit social instincts, including nearly 500 species of bees, 800 species of wasps, 1,000 species of termites and 3,500 species of ants.

Gradations of Social Behaviour

Various gradations between the two extremes of solitary and social insects are evident in existing species.

Solitary insects, such as mosquitoes and dragonflies, drop their eggs anywhere and go about their business. Butterflies and fleshflies lay their eggs on food suitable for the young. Solitary digger wasp digs a hole, provisions it with food such as paralysed caterpillars and spiders, lays an egg, seals the entrance and departs, never to see its offspring which later hatches out and grows independently.

Sub-social insects represent a further step towards social habit. They provide a mass of food for each egg but remain to guard the nest or young. In some species of dung beetles female collects and rolls a ball of dung, excavates a burrow, drops the ball in, lays eggs and departs. In other species, the male assists by guarding the dung balls while the female excavates. In still another species, both sexes dig chambers, stock them with dung on which the female lays eggs, then guard them until the eggs hatch. At this time all disperse. A female earwig guards her eggs and



later the young. Cockroaches, crickets, some bugs, web spinners and book lice do likewise.

True social insects, on the other hand, forage for food for the colony continuously, the two parents live longer so as to come in association with many generations of their progeny, and the young cooperate in caring for the next generation. Only a few insect species have been able to develop social habit completely. Most highly developed and complex of insect societies are found in the termites (Isoptera), and the ants, bees and wasps (Hymenoptera).

Characteristics of Social Insects

All the social insects possess certain characteristics in common, which are as follows :

1. Large populations (colonies). Many individuals of a species of social insects live together in an integrated manner in a comparatively large group or population which is not gregarious. Term 'colony' is commonly applied to the complex society they form. Number of individuals forming a colony ranges from 35,000 to 50,000 in honey bees, upto 600,000 in ants and several millions in termites. Colonies are **matriarch**, i.e., all members of a colony are the offspring of a single female and hence all have very similar genotypes. Ordinarily, a society of social insects does not accept members from other colonies of the same species.

2. Elaborate nests. Social insects construct more or less elaborate nests for protection, storage of food and maintenance of broods. Some interesting habits of bees, ants and, termites regarding their nest and broods are summarized in the adjacent table.

3. Extra population of nests. Some small crustaceans, mites, beetles and other insects are attracted by the high temperature and surplus food of the nests of the ants and termites and get protection from their enemies. They live in close **symbiotic** relationship with the hosts. **Guests** or the outsiders feed upon the debris or waste of the nests and the dead bodies of the hosts. Slave-making ants bring eggs, pupae and adults of other ants and take from them functions of **slaves**.

Habits	Honey bees	Ants	Termites
(1) Position of nest	Trees, etc.	Leaves, wood, ground	Wood, ground
(2) Material of nest	Wax	Leaves, wood, earth	Wood, soil
(3) Shape of nest	Hexagonal cells	Chambers & galleries	Chambers & galleries
(4) Nest started by	Female & workers	Female or male and workers	Female, male & workers
(5) Number of population	35-50 thousand	600 thousand	Several millions
(6) Nature of brood	Perennial	Perennial	Perennial
(7) Food of brood	Pollen and nectar	Vegetables, wood & insects	Wood & insects
(8) Type of feeding	Progressive	Progressive	Progressive
(9) Swarming	Yes	Only in some species	Yes

Intruders or **thieves** rob the social insects of their food and brood. Some beetles (*e.g.*, *Atemeles*) live in brood chambers of the ants, where the beetle larvae eat the ant larvae with impunity. Both larvae and adults of the beetle secrete pheromone-like substances which serve to appease the aggressive tendencies of the ants.

Predator insects prey upon the social insects, stylopids attack wasps and bees, while bee moth attacks the wax of honey bee hives.

4. Polymorphism (caste system). Typically social insects have a division of labour. Members are differentiated into distinct **castes**, which are specialized in structure, function (reproduction, feeding, guarding, etc.) and behaviour. Principal castes are the **reproductives** (king and queen) and the **sterile** members (workers and soldiers). Workers are the smallest in size. Queen is the largest with a long abdomen and lays eggs. It lives for several years. Males are intermediate in size and develop parthenogenetically from unfertilized eggs. In social wasps, bees and ants, workers are only sterile females. In termites and some higher ants, workers and soldiers belong to both sexes. In termites, a special soldier-caste exists, called the **nasute**, with an elongated projection on the head. The greatest diversity of



castes (polymorphism) is found among ants, and all forms may have large and dwarf individuals.

Caste determination depends upon a number of factors. In Hymenoptera (bees, wasps and ants), genetics and nutrition form the basis of differentiation. Males are haploid and develop parthenogenetically from unfertilized eggs. Queens, workers and soldiers are diploid females which develop from fertilized eggs. Differences between queen and worker are mainly due to differences in the quantity and quality of their food. Bee larvae destined to become queens are fed on royal jelly for a few days and then are fed bee bread (honey and pollen). Bee larvae destined to become workers and drones are fed entirely on beebread.

In Isoptera (termites), determination of castes is due to extrinsic factors rather than to genetical ones. Reproductives and soldiers secrete ectohormones containing inhibitory substances. When fed to nymphs, these substances prevent them from developing into like forms (soldiers and reproductives).

5. Cohesiveness of colony. Division of labour or separation of function requires great coordination, for the group must perform as a biological unit. All the members of an insect society live in an integrated or cohesive manner, subordinated to the life of the community. As a result, various castes, which differ in structure and physiology, can not live independently. They work in cooperation and with mutual benefit. For instance, many females mutually cooperate so that one worker looks after an egg (larva) laid by another female (queen) and so on. Success with them is measured in terms of the colony and not of the individual. Different castes are bound together by chemical and physiological mechanisms rather than structure.

6. Parental care. Basis for the family relationship is the provision of shelter, food and defence for the young. Thus social life in insects is correlated with the lengthening of the adult or parental life and increasing parental care. It provides, greater association of parents and young. Parental care includes various activities such as provisioning of food, cleaning and feeding of

young and queen, removal of debris and bodies, taking away and putting eggs in proper chambers, cooling of chambers in summer and protecting queen from winter by clinging and clustering about her, by workers. Parental care is instinctive behaviour.

7. Progressive provisioning of food. Stingless bees and potter wasps lay their eggs singly or in small groups and provide sufficient mass of food at the same time for the complete development of the larvae which hatch out from the eggs. This is known as **mass provisioning of food**. But true social insects (bees, ants and termites) feed their young extensively and continuously from day to day until they metamorphose into the adults. This is known as **progressive provisioning of food**.

Ants show a progression of food habits such as probably occurred in man's history. Lowest kinds (army ants) hunt insects or flesh. Pastoral ants feed on the honey dew produced by aphids. They carry these 'ant cows' (aphids) into overwintering quarters and protect them from predators. Harvester ants gather and store seeds in summer to tide them through the winter. Finally, the leaf-cutter or fungus growing ants (*Atta*) grow their own pure crops of fungi in underground gardens fertilized with organic debris. These ants cut leaves and carry them underground to serve as a substrate for growing pure strains of fungi on which they feed. A young queen, upon setting out to find a new colony, carries a seed stalk of fungal hyphae in a pouch below the mouth.

8. Trophallaxis. Exchange of food between one insect and other is known **trophallaxis**. Ants and termites feed one another from mouth to mouth. Young exchange food with the adult. Some ants feed some beetles, coccids and aphids and in return imbibe a fluid secreted by them.

In termites, trophallaxis plays an important role in the regulation and determination of castes. Ectohormones containing inhibitory substances are secreted by the reproductives and the soldiers. During mutual feeding (trophallaxis), these are passed on to the nymphs, and prevent them from developing into individuals of the same sex or

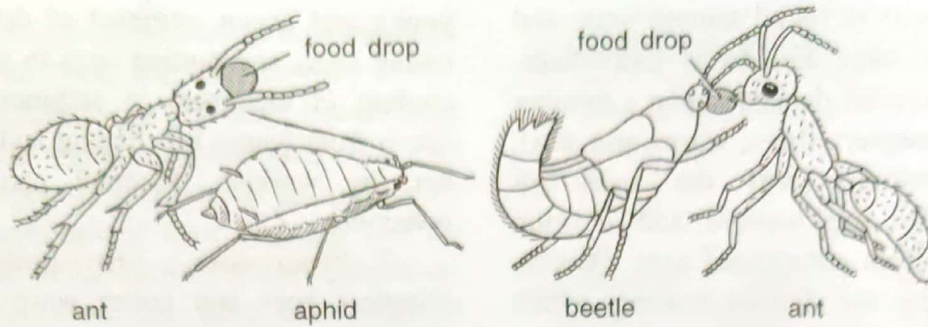


Fig. 23. Trophallaxis.

caste. This tends to keep caste numbers within bounds. Some undifferentiated nymphs may not come under the influence of trophallaxis and may become additional members of the same caste.

9. Swarming. Swarming occurs as a means of alleviating congestion in the overcrowded colony, or as a means of distribution. In many, swarming occurs for feeding, migration and mating. Mostly mating takes place between the queen and the males during swarming, called the **nuptial** or **marriage flight**. Honeybees propagate colonies by swarming. Each swarm consists of an old queen and many workers and produces a new colony. **C.G. Butler** (1961) found that the queen has over her body a so-called queen substance, secreted by her mandibular glands. It inhibits workers from becoming queens when they share this substance (trophallaxis). Swarming may come about in an overcrowded colony because this substance may not be distributed properly to all workers.

10. Protective devices. Social insects develop several devices. **Stings** are developed in most bees and certain ants. **Jaws** are highly developed in stingless bees and soldiers of ants and termites to ward off enemies. Sometimes, a few **guards** are posted at certain convenient places near the nests. Guards protect the nest and attack the intruders in a few cases. Nests are also made in **protective localities** such as ground, hollow trees, mud, paper etc., and have numerous side exits through which rapid escape is possible at the time of danger.

11. Communication. Both social and non-social insects utilize chemical, tactile, visual and auditory signals as methods of communicating with each other. Chemical communication occurs with

the help of body secretions called **pheromones**. These are secretions of exocrine glands that pass to the outside of the body and play an important role in regulating and coordinating the activities of a colony of the same species (**E.O. Wilson**, 1965). Pheromones include sex attractants, the queen substance and other types whose influences are useful to the colony. Substances deposited on the ground by ants returning from a foraging trip serve as a trail marker for other ants. Substances released by the dead body of an ant within the colony stimulate other workers to remove the body.

In honey bees, a **queen substance** produced by the queen's mandibular glands, controls nursing behaviour of the workers, caste determination and swarming. **Language** of the bees (**Von Frisch**, 1950) represents a most revealing method of communication known among insects. Some aspects, such as the tail wagging dance, set the honeybees apart from all other social insects.

Comparison of Human and Insect Societies

Highly evolved organization and cohesiveness of insect societies often prompts comparison with human societies.

1. Similarities. Some notable similarities are as follows :

- (1) Human societies originally began as discrete families (one female and her offspring), but this is not repeated phylogenetically. Insect societies also arise from discrete families and by swarming frequently found new colonies.

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Mollusca : Characters, Classification and Types

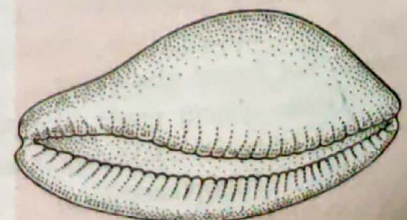
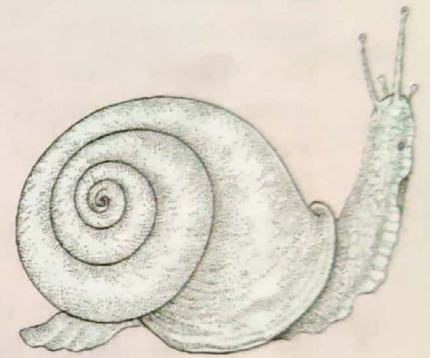
'Mollusca' is derived from Latin word **mollis** or **molluscus** which mean soft bodied. This term was first applied by **Aristotle** to the cuttle-fish of the Aegean Sea.

DEFINITION

Mollusca which include clams, snails, slugs, squids, octopods and nautili are triploblastic, bilaterally symmetrical animals with anus and coelom and without segmentation. They usually have shell and a characteristic ventral muscular foot. There are 84,978 known living species in this phylum.

DERIVATION OF NAME

In Latin, **mollusca** is the name of a soft nut with a thin shell, referring to the bivalve shell and the soft bodied animal within the shell. The term Molluscs are among the most **abundant** of all animals. In number of species, the Mollusca is the second largest phylum after Arthropoda. It is not possible to assess accurately the total of the known species. But probably 100,000 living and a good number of fossil species (35,000) exist, as compared with ten times as many insects but only half as many vertebrates. Three quarters (80,000 species) of the Mollusca are the gastropods with about 1,700 genera. Molluscs have no uniform plan as well as no specific shape. In an





evolutionary sense they are plastic material as the out lines of the body are freely altered as new habitats are acquired and new structures are needed. Most of them are slow moving and confined to rather special habitats.

EVOLUTIONARY CHARACTERS

Molluscans exhibit few evolutionary characteristics which are :

1. Some molluscs are herbivorous while others are carnivorous. The digestive system is largely extracellular.
2. They mostly have ganglionated nervous system and the ganglia have a tendency to become concentrated at the anterior end.
3. The nephridial wall tends to become evaginated and folded to effect an increase in the surface area for tubular secretion of waste picked up from circulatory blood.
4. The gonads have lost their primitive association with the pericardial cavity and have mounted on special axis to the outside.

GENERAL CHARACTERS

Molluscs range from limpets clinging to the rocks, to snails which crawl or dig or swim, to bivalves which anchor, burrow or bore, to cephalopods which torpedo through water or lurk watchfully on the bottom. They penetrate all habitats : the abysses of the sea, coral reefs, mudflats, deserts and forests, rivers, lakes and underground. They may be hidden as parasites in the interior of other animals. They feed on every possible food and vary in size from giant squids and clams to little snails, a millimeter long. They form one of the most definitely characterized group of animals. They have atleast two characters 'radula and mantle' not found elsewhere.

1. Tissue-system grade of body organization.
2. Triploblastic, coelomate, unsegmented (except in Monoplacophora) and bilaterally symmetrical.

3. Body divisible into head, mantle, foot and visceral mass.
4. Shell, when present, usually univalve or bivalve, constituting an exoskeleton, internal in some.
5. Coelom reduced and represented mainly by pericardial cavity, gonadial cavity and kidney.
6. Digestive system complete with a digestive gland or liver (hepatopancreas); a rasping organ, the radula, usually present.
7. Circulatory system mainly of closed type, but some emptying into sinuses; heart with one or two auricles and one ventricle; blood with amoebocytes and haemocyanin.
8. Respiration direct or by gills or lungs or both.
9. Excretion by paired metanephridia (kidneys).
10. Nervous system of paired ganglia, connectives and nerves. Ganglia usually form a circumenteric ring.
11. Sense organs include eyes, statocysts and receptors for touch, smell and taste.
12. Dioecious or monoecious; one or two gonads with gonoducts, opening into renal ducts or to exterior.
13. Fertilization external or internal; development direct or through free larval forms.
14. Terrestrial or aquatic (freshwater or marine).

CLASSIFICATION

Molluscs are classified into six classes according to their symmetry and the characters of food, shell, mantle, gills, nervous system, muscles and radula.

CLASS 1. Monoplacophora

(Gr., **monos**, one + **plax**, plate + **pherein**, bearing)

1. Body bilaterally symmetrical, with a dome-shaped mantle.
2. Flattened limpet-shaped shell with spirally coiled protoconch.
3. Foot broad and flat, with 8 pairs of pedal retractor muscles.
4. Five pairs of gills in pallial grooves.
5. Six pairs of nephridia, two of which are gonoducts.



C. Pulmonary Respiration

In terrestrial pulmonates (*Limax*, *Arion*), a true ctenidium disappears and the mantle cavity is transformed into a pulmonary sac or lung for aerial respiration. Roof of pulmonary sac is richly supplied with vessels. Pulmonate lungs are an adaptation for terrestrial existence. Alternate muscular contraction and relaxation of mantle floor, lower or raise it, causing the air to rush in and out of mantle cavity. Air can enter or leave the sac through a small rounded pulmonary aperture on right side provided with a valve. Compression of mantle cavity increases the partial pressure of O₂ and facilitates its absorption. Some pulmonates derive O₂ from water in the mantle cavity and do not come to the surface to breathe. Majority of lower pulmonates (*Lymnaea*, *Planorbis*, etc.) is amphibious and their mantle cavity serves both for aerial and aquatic respiration. They are said to drown if prevented from coming periodically to the surface to fill the lung with air. In some amphibious Prosobranchia (*Pila*, *Ampullaria*, *Siphonaria*, etc.), mantle cavity is divided by an incomplete septum (epitaenia) into a left pulmonary chamber and a right ctenidial chamber containing a gill. Animal can breathe in water by its gill and by its lung in the air.

TORSION IN GASTROPODA

All the living molluscs, except the Gastropoda, retain ancestral bilateral symmetry of the body, with mantle cavity lying posteriorly or laterally. Gastropods, on the other hand, possess an asymmetrical body with mantle cavity lying anteriorly, and the shell and the visceral mass coiled spirally and directed posteriorly. In spite of their asymmetry, Gastropoda are generally believed to have descended from an unsegmented and bilaterally symmetrical ancestor with a low conical shell, a straight alimentary canal ending in a posterior anus, and mantle cavity posterior, that is, lying behind the visceral dome. Anterior

situation of the mantle cavity in gastropods is due to **torsion** or **twisting** of the visceral mass during development.

What is Torsion ?

Torsion or **twisting** is a process, during larval development of gastropods, which rotates the visceropallium anti-clockwise through 180° from its initial position, so that mantle cavity, with its pallial complex, is brought in front of the body, in adult.

Site of Torsion

In larval gastropods, only visceral mass undergoes rotation through 180°, whereas head and foot remain, fixed. Actual site of torsion is neck, behind the head-foot, through which oesophagus, rectum, aorta, visceral nerve loop and shell muscles pass. Thus, actual twisting involves the neck tissue and structures within it.

Torsion Versus Coiling

Torsion is often confused with spiral coiling of visceral mass and shell, but the two are entirely distinct and quite independent. Torsion is not coiling of the shell which starts even much before coiling.

Coiling is achieved by a more rapid growth of one side of the visceral mass than the other. Torsion and coiling are, therefore, separate evolutionary events. Torsion was a much more drastic event than the spiralling of shell.

How Torsion Occurs ?

Torsion is not merely an evolutionary hypothesis. Its occurrence can be seen in the embryogeny of living gastropods. Before torsion, larva is quite symmetrical, the mantle cavity faces backwards and downwards, alimentary canal is straight and anus opens posteriorly in middle line. A ventral **flexure** of the body results in looping of alimentary canal and approximation of mouth and anus. Shell and visceral mass, originally saucer-shaped, become first cone-shaped and later spirally coiled. Shell lies dorsally and forms a coil on the anterior side; such a shell is called **exogastric**.

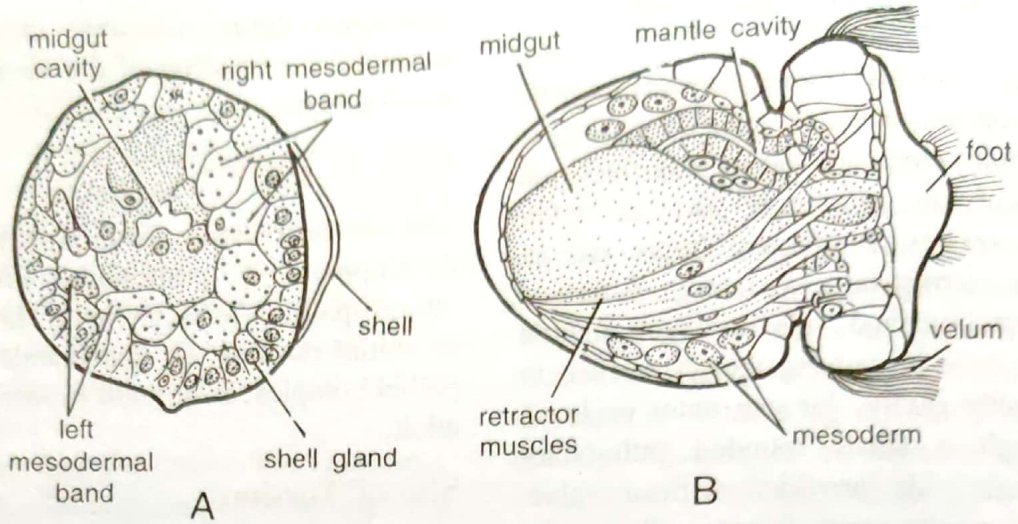


Fig. 12. Mechanism of torsion. A. T.S. early veliger of *Haliotis* showing disproportionate growth of right mesodermal cells. B. 48 hour larva of *Patella vulgata* showing a symmetrical retractor muscle.

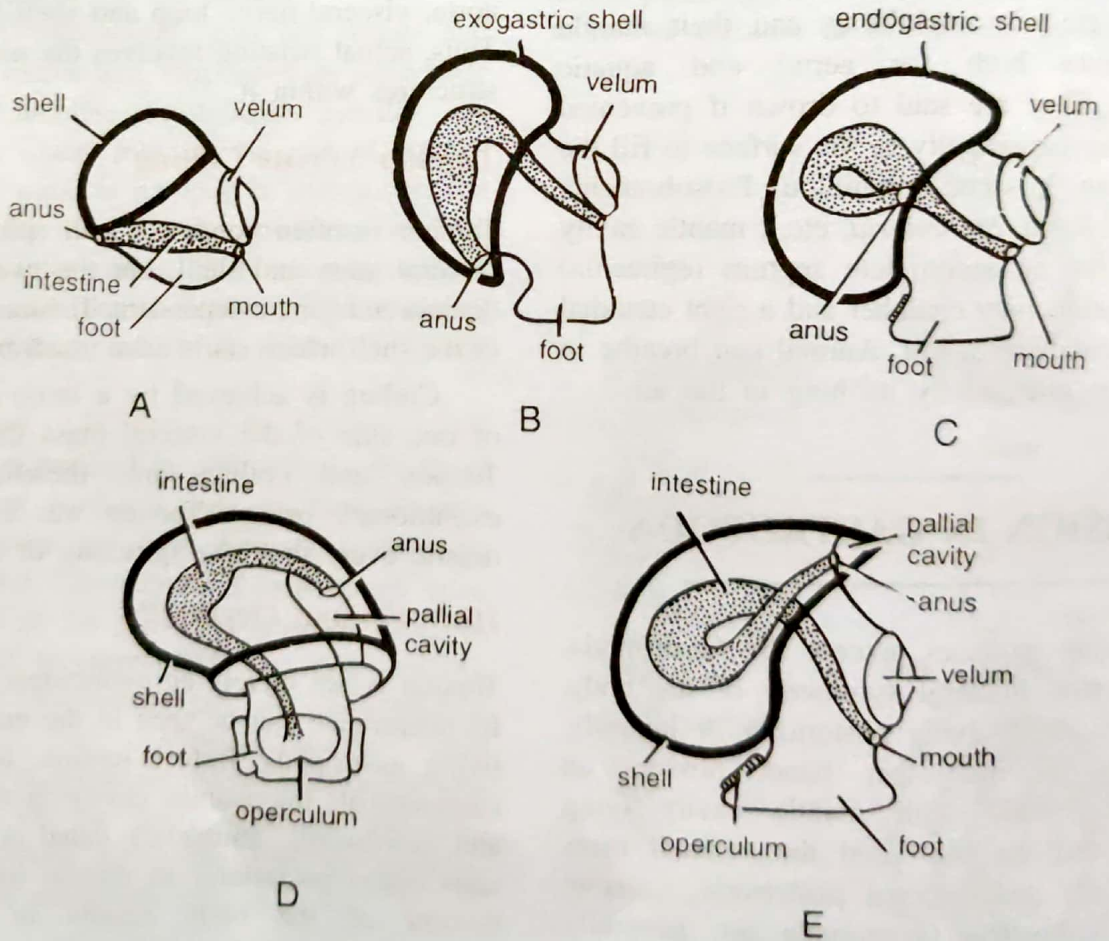


Fig. 13. Five successive stages in the development of a gastropod to show occurrence of torsion. A. Early veliger larva or pretorsional stage in lateral view. B. Larva with ventral flexure and an exogastric shell in lateral view. C. Stage showing 90° of lateral anticlockwise torsion. Shell becomes endogastric. Mantle cavity and anus move on to right side. D. 90° torsion stage in posterior view. E. Adult stage with complete or 180° torsion in lateral view.



Ventral flexure is followed by a lateral **torsion**, so that dorsal or exogastric shell becomes ventral or **endogastric**. Lateral torsion is probably due to arrest of growth on one side and active extension on the other. Generally, growth of the right side becomes retarded so that mantle cavity and pallial complex gradually pass round to right side, and so to the anterior side, on account of greater growth of the visceral sac towards the left. But the whole process completes in 2 or 3 minutes in *Acmaea*, so that it cannot be regarded due to differential growth. On the contrary, it is due to muscular contractions. Actual mechanism of torsion is supposed to be the asymmetrical position and pull of the larval retractor muscles running from the velar lobes to the shell. They are present only on the right side, there being no related muscles on the left side. Contraction of larval retractor muscles brings about the rotation or torsion. Only narrow neck of the larva is actually twisted. Consequently, everything between the head and anus undergoes an anticlockwise rotation or torsion through an angle of 180° around a vertical axis passing in a dorso-ventral direction.

Thomson (1958) after careful study recognises five ways in which torsion can be brought about :

- (1) Complete or 180° rotation, achieved by muscles contraction alone, is known only for *Acmaea* (Archaeogastropoda).

- (2) 180° rotation achieved in two stages, first 90° movement by contraction of larval retractor muscles and later a slower 90° rotation by differential growth. It is the commonest mechanism which is known today, e.g., *Haliotes*, *Patella*.
- (3) 180° rotation by differential growth processes alone, e.g., *Vivipara*.
- (4) Rotation by differential growth processes, with anus coming to a position appropriate to adult state, e.g., *Aplysia*.
- (5) Torsion no longer recognisable as a movement of visceropallium, the organs in post-torsional position from their first appearance, e.g., *Adalaria*.

Effects of Torsion

Torsion is a fundamental feature of gastropods and represents their greatest departure from the ancestral molluscan plan. Peculiarities of organization of gastropods due to torsion were first realized by **Spengel** (1881).

1. Displacement of mantle cavity. Mantle cavity was primitively posterior in position. Increase in length of ventral foot, which primitively was very short, tends to remove the mantle cavity and pallial complex away from the head. After torsion the mantle cavity opens just behind the head and its associated parts are shifted forwards.

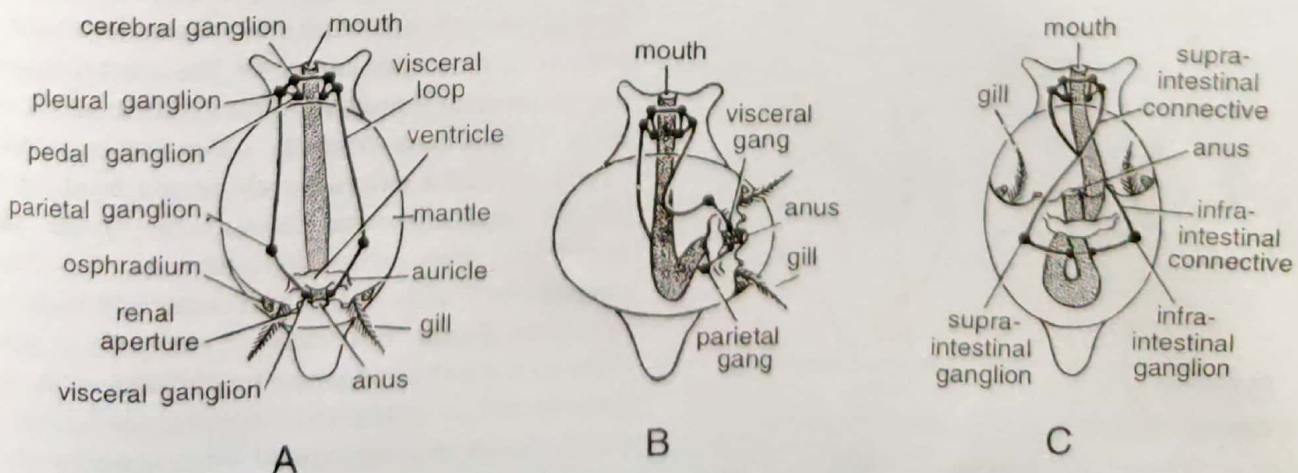


Fig. 14. Effects of torsion upon position of gills, digestive tract and nervous system, **A.** Hypothetical primitive stage before torsion. **B.** Intermediate stage showing 90° torsion with mantle cavity and pallial complex displaced to the right side of body. **C.** Final stage showing 180° torsion.



2. Changes in relative positions. Before torsion, anus, ctenidia and renal orifices point backwards, and the auricles lie behind ventricle. After torsion, anus, ctenidia and renal orifices project forward, and the auricles lie in front of ventricle. Original posterior face of visceral sac becomes the actual anterior face, so that visceral organs morphologically of the original right side become placed topographically on the left side, and vice versa.

3. Looping of alimentary canal. Digestive tract, which was originally straight from mouth to anus, is thrown into a loop.

4. Chiastoneury. Long, uncoiled pleuro-visceral nerve connectives become twisted into a figure of 8. Right connective with its ganglion passes over the intestine to become supra-intestinal, while left connective passing underneath the intestine to become infra-intestinal.

5. Endogastric coil. Coil of visceral sac and the shell, which primitively was dorsal or **exogastric**, becomes ventral or **endogastric**, after torsion.

6. Loss of symmetry and atrophy. Anus is displaced towards right side of the pallial cavity so that original symmetry of organisation disappears. Another characteristic feature involving asymmetry is reduction or atrophy of the paired parts of primitively left or topographically right side. In primitive Archaeogastropoda or Diotocardia (*Patella*, *Haliotis*, *Fissurella*, etc.)

maximum symmetry is preserved by retaining two gills, two auricles and two kidneys, but the right kidney serves as a gonoduct. In more specialized Mesogastropoda or Monotocardia (*Pila*, *Buccinum*, *Littornia*, etc.), ctenidium, auricle, osphradium, hypobranchial gland and kidney of the topographically right side disappear in dextral forms, but reverse process occurs in the sinistral forms. Remaining gill may bear one row of filaments (monopectinate gill).

Significance of Torsion

According to **Garstang** (1928), torsion first occurred as a larval mutation of advantage to the larva adapted to pelagic life but of little direct use to the adult. Before torsion, the untwisted swimming larva fell an easy victim to its predators because the posterior mantle cavity could receive the delicate head and velum only after the foot was already inside. After torsion, the mantle cavity became anterior, so that the sensitive parts *i.e.*, head and velum could withdraw first followed by the foot. Operculum sealed the aperture, the cilia of velum stopped beating, so that larva could fall to the sea bottom and avoid its enemies swimming in the water.

According to **Morton** (1958), main advantage of torsion must be to the adult. Firstly, torsion promotes stability in the adult by placing bulky mass of animal nearer the substratum. Secondly, in primitive Molluscs, the mantle cavity containing gill was situated posteriorly, so that when the animal moved upstream, the water-flow and the current due to movement of the animal opposed the respiratory current entering the mantle cavity from behind the animal. After torsion, mantle cavity is curled anteriorly above the head, so that all the three currents now flow in the same direction, thus flushing the mantle cavity continuously with fresh clean water and increasing its ventilation. Thirdly, anteriorly placed chaemoreceptive organs (osphradia) can also continuously sample the sediment and incurrent water stream and the animal orients itself properly with the help of the sense organs on the head. Once the shell is lost, gills become exposed to the external currents and their anterior position remains of no advantage, so that the mantle cavity

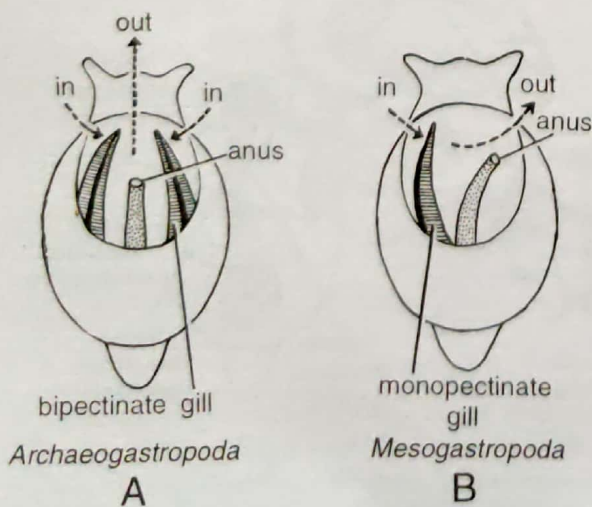


Fig. 15. Diagrams to illustrate the loss of symmetry and atrophy due to torsion. The arrows indicate the course of respiratory water currents.

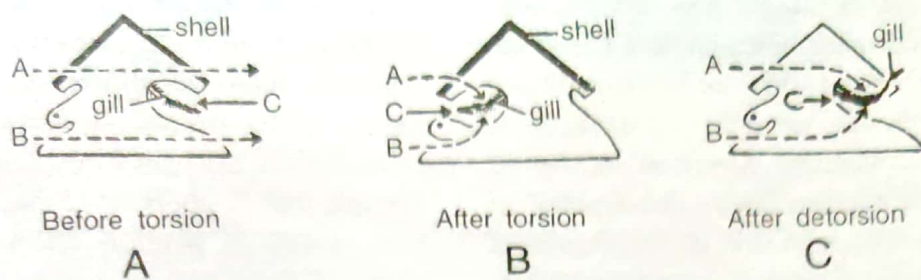


Fig. 16. Diagrams illustrating the possible advantage of torsion. A. Current due to flow of water. B. Current due to movement of gastropod. C. Respiratory current.

and the pallial complex shift back to their original posterior position (**detorsion**).

Detorsion

Changes occurring in torsion are to a certain extent reversible. This reversion is known as **detorsion** and it is very characteristic of the whole group of the **Euthyneura**. As a result, pallial complex travels back towards the posterior end along the right side, ctenidia point backwards, auricles move behind the ventricle, and the visceral loop becomes untwisted and symmetrical. In this way, a secondary external symmetry is re-established. Torsion must be disadvantageous to adult snails, as many of them have undergone detorsion processes. Various degrees of detorsion are met within the Euthyneura. In the least specialized Opisthobranchia and Pulmonata (*Acteon*, *Bulla*, etc.), detorsion is not complete, so that the visceral loop remains partly twisted and the anus and ctenidium are directed laterally, instead of anteriorly. Formerly, this condition was looked upon as an arrested stage in the torsion, but there is the same reduction of the paired parts of the pallial complex as in the specialized **Streptoneura**. Total detorsion, as shown by the typical **Opisthobranchia** (*Aplysia*), is accompanied by a reduction or disappearance of the shell. In extreme cases, as in *Pterotrachea*, the mantle and the visceral sac also disappear and the body elongates to become worm-like. The mantle cavity, visceral hump, external shell and even ctenidia may be lost, as in **Nudibranchia** (*Eolis*, *Doris*, etc.).

The phenomenon of detorsion can thus be elaborated as follows :

- (1) In some cases the right ctenidium (originally left) and the osphradium are absent.
- (2) In *Eolis*, there is veliger larva with a coiled visceral hump that undergoes torsion but adults do not show any sign and the pallial complex is posteriorly placed in adult. Naturally, the detorsion must have occurred during the course of further development.
- (3) In **pulmonata**, the pallial complex is shifted but there is no chiasmoneury as a result of shortening of visceral commissures. The pleurovisceral mass and so the chiasmoneury is secondarily lost.

PEARL CULTURE

Pearl is also called 'Moti'. It is white, highly shining globular in shape and made by the clam, a mollusc called *Oyster* within its shell. Pearls are prized as gems from ancient times. Pearls are among the most beautiful and valuable of our jewels. **Kokichi Mikimoto** of Toba (Japan) is known to be the father of Pearl Industry. He discovered a method to induce foreign particle between the mantle and the shell of the pearl *Oyster* and thus stimulated pearl formation.

Pearl Formation or Pearl Fisheries

A pearl is a result of an injury to molluscs. It is secreted by the mantle as a means of protection against some foreign body. Whenever a foreign body such as a particle of sand or a small parasite (a trematode or cestode larva), a small animalcule



or alga or even bit of shell, gets between the mantle and the shell it becomes enclosed in a sac of mantle epithelium which is thus irritated. Irritation stimulates the mantle epithelium to secrete nacre thin concentric layers of mother of pearl all around the foreign body. The amount of deposition is in direct proportion to the degree of irritation. At the end of several years, a pearl is formed.

Pearl Molluscs

Pearls are often found in clams and edible oysters but these are not nacreous and therefore, they are of little value. Most precious pearls are found in pearl oysters of the genus *Pinctada*. Important species for pearls are *P. vulgaris*, *P. chemnitzii*, *P. margaritifera*, *P. anomioides* and *P. atropurpurea* found in Indian waters. *P. vulgaris* which is closely allied to freshwater mussel is common species distributed in gulf of Kutch, gulf of Mannar and the Palk Bay and Baroda.

Artificial Pearl

Japanese have developed a technique of producing pearls artificially by inserting foreign bodies, such as glass beads, into the mantle of oysters. The oysters are retained in wire cages or crates until pearls are produced, which can be later removed and sold in markets. This was Mikimoto's discovery which had made him a wealthy person. It takes about 3 to 4 years to produce a pearl of

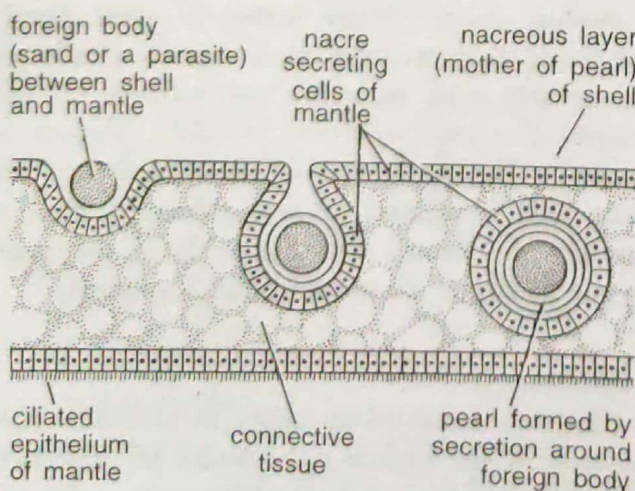


Fig. 17. Stages in pearl formation.

considerable size but a large one takes 7 years. Cultured pearls are genuine pearls but are less valuable than uncultured pearls which can be identified by experts. Imitation pearls are beads coated with an iridescent substance called pearl essence that is obtained from scales of fishes. The best quality of pearl is known as 'Lingha pearl' obtained from marine oysters.

Culture of Oysters

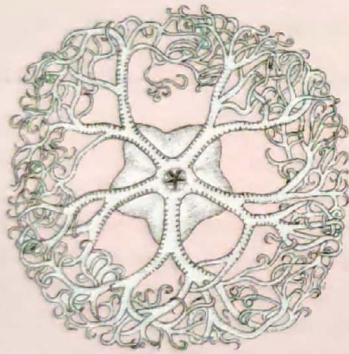
The woman divers in Japan are called 'The Girls of the Sea'. From early morning till noon, they collect the oysters from the bottom of the sea with the help of nets. Collection of oysters is best done in the two months of the summer season when the sea is calm and the water is nearer the shore. Oysters are collected, stocked and reared in rearing cages. Each cage is divided into 4-6 smaller chambers and is covered with metal mesh provided with cotton netting. The oysters are cleaned before being placed in the culture cages for about 10 to 20 days for acclimatizing them to shallow water conditions. After which they are processed for artificial pearl formation.

CHANK FISHERIES

Chank Fishery, a great source of revenue is based on a turbinellid gastropod, *Xanichus pyrum*, the shell of which is called the chank. Chank is used as trumpet in temples and is considered sacred in our country. It is a raw material for the manufacturing of ladies bangles and thus supports a number of industries especially in Nadia, Bangkura and Burdwan. Raw material for industries in West Bengal is obtained from South. Tuticorin shell is the best for bangles. Chanks or *Xanichus pyrum*, feed on polychaete worms and hence inhabit sandy bottoms. Breeding months are January to March. Fishing is done from October to May, by divers picking by hand about 100 shells per day. Chank beds on southeast coast are confined to Ramnad, Tanjore, Tirunelveli, Chingleput and Nellore districts. Chanks are abundantly found in Palk Bay and Gulf of Mannar.



Echinodermata : Characters, Classification and Types



Echinoderms are one of the most beautiful and most familiar sea creatures. Forms such as the sea stars have become a symbol of sea life. Other forms such as brittle stars, sea urchins, sea cucumbers and sea lilies are also quite well known to the visitors on the sea-shore. There are 7,550 sps known in Echinodermata.

HISTORICAL

Echinoderms are known since very ancient times. Name of this phylum was introduced by **Klein** in 1734 for sea urchins. For many years echinoderms and coelenterates were included as a class among Radiata, largely because of the radial symmetry of the adults. **Echinodermata** were first recognized as a group distinct from the Radiata by **Leukart** in 1847.

DERIVATION OF NAME

Echinodermata literally means 'spiny or prickly skinned' (Gr., **echinos**, hedgehog; **derma**, skin) and refers to the conspicuous spines possessed by their test or skin. **Jacob Klein** (1734) first used this name for echinoids. The Greeks applied the name **echinos** to the hedgehog as well as the sea urchin, both having a prickly appearance. Term **echinus** has been used for a certain sea urchin. Possession of spines is not diagnostic of the phylum because only better known members, such as sea urchin, brittle stars and starfishes, have spines.



DEFINITION

Echinoderms are exclusively marine and largely bottom dwellers enterocoelous coelomate, triploblastic animals. They have a pentamerous radial symmetry derived from an original bilateral symmetry. They possess an endoskeleton of calcareous plates or spicules embedded in the skin; a peculiar water-vascular system of coelomic origin; numerous podia or tube feet; an ectodermal nervous system; no definite head or brain; no nephridia; gonads open directly to the exterior by special ducts.

GENERAL CHARACTERS

Phylum Echinodermata contains some 5300 known species and constitutes the only major group of deuterostome invertebrates. **Bather** (1900) stated the phylum as "one of the best characterised and most distinct phyla of the animal kingdom". Echinoderms are distinguished from all animals by a number of characteristics.

1. Organ-system grade of body organization.
2. Triploblastic, coelomate and radially symmetrical; often pentamerous.
3. Body unsegmented with globular, star-like, spherical, discoidal or elongated shape.
4. Head absent; body surface is marked by five symmetrically radiating areas (**ambulacra**) and five alternating interradial (**inter-ambulacra**).
5. Endoskeleton of dermal calcareous ossicles with spines, covered by the epidermis.
6. Water-vascular system of coelomic origin, including **podia** or **tube feet** for locomotion and usually with a **madreporite**.
7. Coelom of enterocoelous type constitute the perivisceral cavity and cavity of the water-vascular system; coelomic fluid with coelomocytes.
8. Alimentary canal straight or coiled.
9. Vascular system and haemal system, enclosed in coelomic periaemal channels.

10. Respiratory organs include dermal **branchiae**, **tube feet**, **respiratory tree** and **bursae**.
11. Nervous system without a brain and with a circumoral ring and radial nerves.
12. Poorly developed sense organs include tactile organs, chemoreceptors, terminal tentacles, photoreceptors and statocysts.
13. No excretory organs.
14. Usually dioecious, gonads large and single or multiple; fertilization external; development indirect through free-swimming larval forms.
15. Regeneration of lost parts, a peculiarity.
16. Exclusively marine.

CLASSIFICATION

Subphylum I. Eleutherozoa

(Gr., **eleutheros**, free + **zoios** = **zoon**, animal)

Free-living echinoderms.

CLASS 1. Asteroidea

(Gr., **aster**, star + **eidōs**, form)

1. Starfishes or sea stars.
2. Arms 5 or more and not sharply marked off from the central disc.
3. Tube feet in orally placed ambulacral grooves; with suckers.
4. Anus and madreporite aboral.
5. Pedicellariae present.
6. Free-living, slow-creeping, predaceous and scavengerous.

Subclass 1. Somasteroidea

Fossil Palaeozoic sea stars. *Platasterias latiradiata* is the only living species.

Subclass 2. Euasteroidea

Living sea stars.

Order 1. Phanerozoia

1. Body with marginal plates and usually with papulae, on aboral surface.
2. Pedicellariae sessile, not crossed.
3. Tube feet without suckers.

58. (Z-1)

Echinodermata : General Account

LARVAL FORMS IN ECHINODERMATA

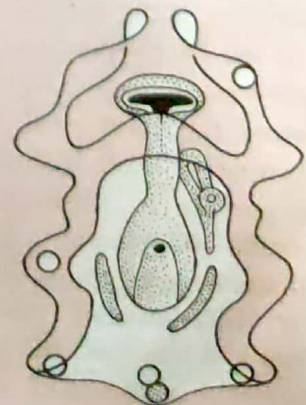
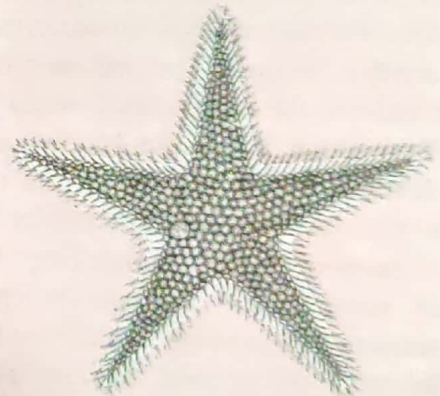
No other group of animals has such complicated metamorphosis in the course of development. Development may be direct or indirect. In direct one, the larval stages are missing while in indirect one, various types of free-swimming larvae are formed. In each class, a few members, are viviparous, that is, they brood their young in a sort of brood pouch on the surface of their body. The development of larva takes place in a typical deuterostomous fashion. In most cases the characteristic free swimming larvae develop externally which are of great phylogenetic significance.

Echinoderm larva is strikingly bilaterally symmetrical in marked contrast to radially symmetrical adult. It swims about by means of a ciliated band, which may be complicated by a number of short or long slender projection or arms from the body wall. Based upon the nature and position of the arms or their absence, larvae of different classes of Echinodermata may be distinguished. After a free-swimming planktonic existence, the bilateral larva undergoes a metamorphosis, in which the radial symmetry of the adult is developed. In different classes of echinoderms, different types of larvae complete the development.

(1) Class I. Asteroidea

Bipinnaria Larva

Two types of development occurs in asteroids. The **direct** type has large, yolky eggs and no free swimming larval stage. The **indirect**



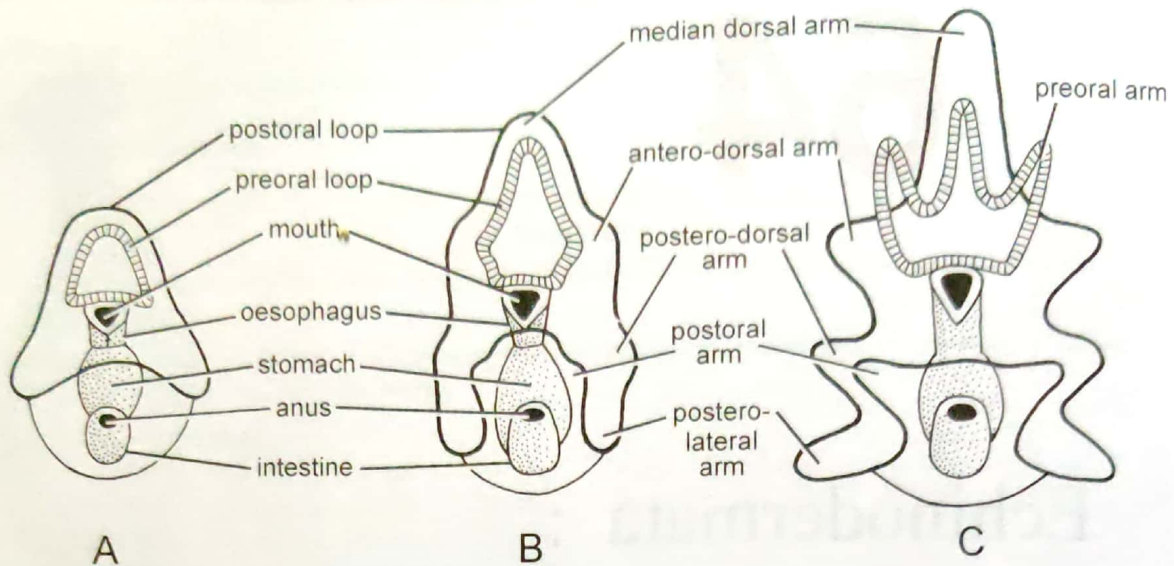


Fig. 1. Stages in development of a bipinnaria larva.

type has homolecithal eggs with little yolk and a free swimming larval stage. After hatching the larva develops cilia and begins a free-swimming life. The larva feeds on diatoms as an alimentary canal is formed. The presence of powerful ciliary band on the stomodaeal walls helps in feeding. Two lateral longitudinal locomotory ciliated bands develop which connect in front of mouth, forming a **preoral loop** and in front of the anus, to form a **preanal loop**. Preoral loop later, separates or in some cases develops independently into an anterior ciliated ring around the body. Three lateral lobes or projections are also developed on each side of the body bordered by ciliary bands. This larva is known as **bipinnaria** and develops in 2 to 7 days.

Internal development of bipinnaria. Tip of larval archenteron forms the mesenchyme and later gives rise to two lateral pouches which connect anteriorly to form a U-shaped coelom. Posterior ends of the lateral pouches pinch off to form right and left **somateocoels**. Remaining anterior portion represents the **hydrocoel** and **axocoel**, but they never separate. Left hydrocoel connects with the dorsal surface to form the **hydropore**, without ectodermal invagination. Ventrally an ectodermal invagination meets the archenteron and the larval gut is differentiated into mouth, oesophagus, stomach and intestine. Blastopore remains as larval anus. Right somateocoel and axohydrocoel get

reduced in metamorphosis, while left axohydrocoel gives rise to water ring and radial canals. Axocoel separates from hydrocoel and contributes to stonecanal. Madreporite or dorsal sac originates either from rearrangement of mesenchyme cells or from ectodermal invagination or from right axohydrocoel. Bipinnaria larva, after free-swimming existence for a few weeks, changes to next larval stage, called **brachiolaria larva**.

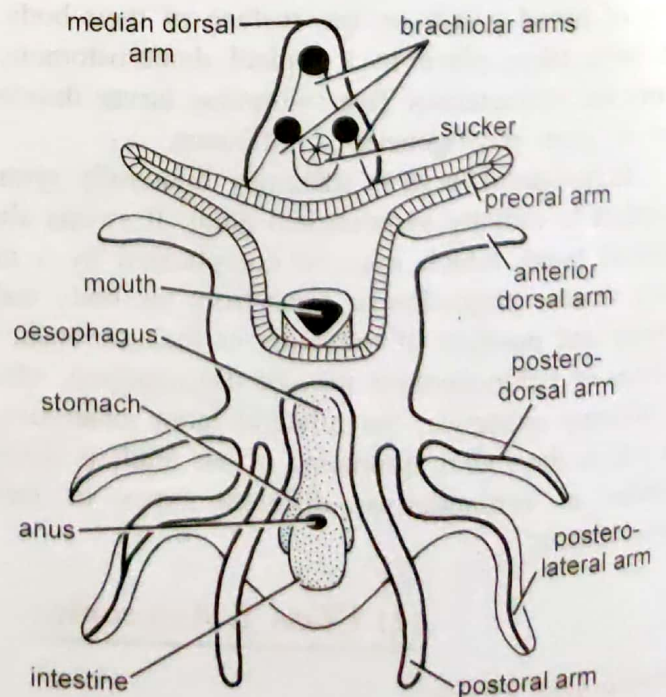


Fig. 2. Brachiolaria larva.

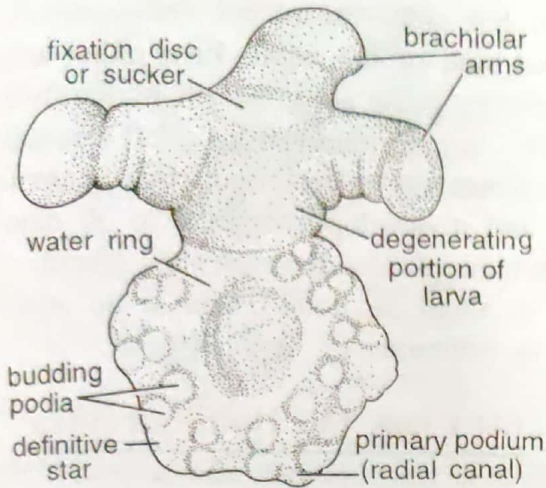


Fig. 3. Metamorphosis of brachiolaria in sea star, *Leptasterias hexactis*.

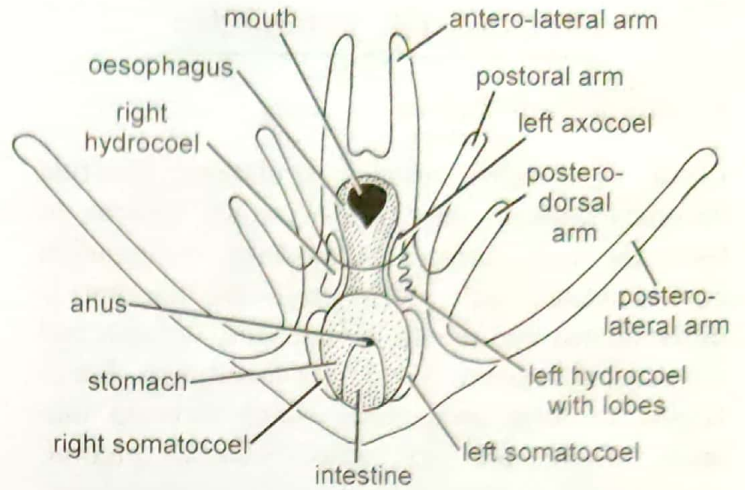


Fig. 4. Ophiopluteus larva of *Ophiocomina*.

Brachiolaria Larva

Bipinnaria transforms into brachiolaria larva which develops three short arms at preoral lobe, known as **brachiolar arms** (one median and two lateral arms). They contain coelomic extensions and adhesive cells at their tips. An adhesive glandular area at their base acts as a sucker. Appearance of the sucker marks the beginning of metamorphosis.

Metamorphosis of brachiolaria. With the help of adhesive structures it attaches to some object. Anterior region acts as stalk for sometime, while posterior part, having gut and coelomic chambers, converts into a young star. This star detaches itself and starts leading a free life.

Some species cut short the development as a result of deletion of some larval stages. In *Astropecten*, the brachiolaria stage is missed with the result bipinnaria directly metamorphoses into adult with in 2-3 months. In *Asterina gibbosa*, bipinnaria stage is omitted, larva develops an adhesive apparatus, as brachiolar arms and sucker, and undergoes metamorphosis. Still in *Luidia*, a giant and peculiar is formed which is called as **bipinnaria asterigeara**.

(2) Class II. Ophiuroidea

Ophiopluteus Larva

Pluteus is the free swimming larva in brittle stars which is known as **ophiopluteus**. It is similar to echinopluteus of echinoids with the only difference

that the former has fewer arms than the later. The posterolateral arms are the longest and directed forward. After gastrulation the arms develop gradually. Posterolateral arms are formed first. After 4, 10 and 18 days, anterolateral, postoral and posterodorsal arms develop, respectively. Ciliated bands accompany the arms edges. Internally the larva contains coelomic chambers and archenteron. Internal development proceeds in the same way as in other classes. While free swimming metamorphosis of the larva starts, there being no attachment stage. Tiny serpent star sinks to the bottom to begin its adult existence.

Amphiura vivipara, a viviparous form, omits pluteus stage. In *Ophionotus hexactis*, development takes place in ovary and the aborted pluteus larva is devoid of arms and anus.

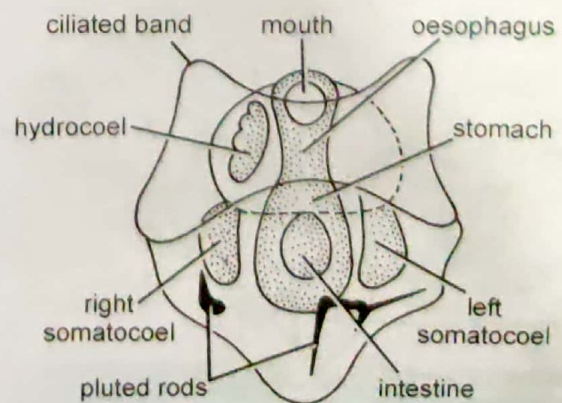


Fig 5. Aborted pluteus of *Ophionotus hexactis*.



(3) Class III. Echinoidea

Echinopluteus Larva

Larva is formed after gastrulation. Gastrula becomes conical, one side of which flattens to form the oral surface. Stomodaeal invagination communicates with archenteron and the gut is differentiated into mouth, oesophagus, stomach and intestine. Blastopore remains as larval anus. Larva begins to form projections which develop into arms. There are six arms namely, preoral, anterolateral, anterodorsal, postoral, postero-dorsal and posterolateral. Posterolateral arms are very short and directed outwards or backwards. In some cases, anterodorsal arms may also not develop. Thus a fully developed echinopluteus may have 5 or even 4 pairs of arms instead of usual six. Tips of the arms are pigmented and are supported by calcareous skeletal rods. Locomotion is by ciliated bands, which in some case become thickened and known as **epaulettes**. In *Arbacia* and *Cidaris*, larva develops special ciliated lobes, between the arm bases known as vibratile lobes, auricular lobes or auricles.

Internal development. Archenteron gives off hydro-enterocoels which contribute to axocoels, hydrocoels and somatocoels. A vestibule is formed by the enlargement of an ectodermal invagination

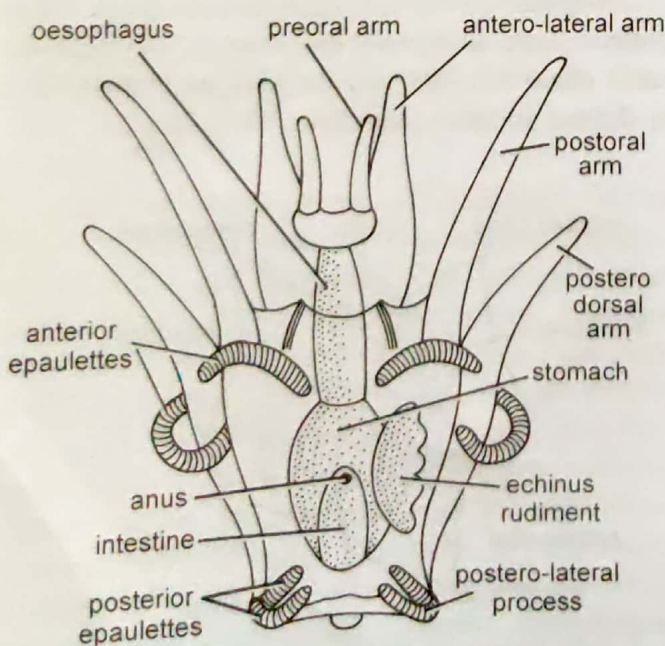


Fig. 6. Echinopluteus larva of *Strongylocentrotus franciscanus*.

on the left side. Hydrocoel and vestibule form the oral side of the adult. Five radial arms and five primary podia are given off by the hydrocoel. Lantern is formed from left somatocoel. Echinopluteus is microscopic, free swimming in water and it develops within 7 to 30 days.

Metamorphosis is extremely rapid, taking place in about an hour. There is no attachment stage in echinoids.

(4) Class IV. Holothuroidea

Auricularia Larva

After gastrulation and formation of coelomic sacs and gut, the embryo becomes a free-swimming larva called **auricularia larva**, within 3 days. It is transparent, pelagic about 0.5 to 1 mm in length. It swims about by a ciliated band which forms **preoral loop** and an **anal loop**.

Internally, larva has a curved gut with sacciform stomach, hydrocoel and right and left somatocoels.

Some giant auricularians of unknown adults reported from Bermuda, Japan and Canary islands measure about 15 mm in length and possess a frilly flagellated band.

Doliolaria Larva

It is a transitional stage from auricularia and appears barrel-shaped and alike doliolaria of crinoids.

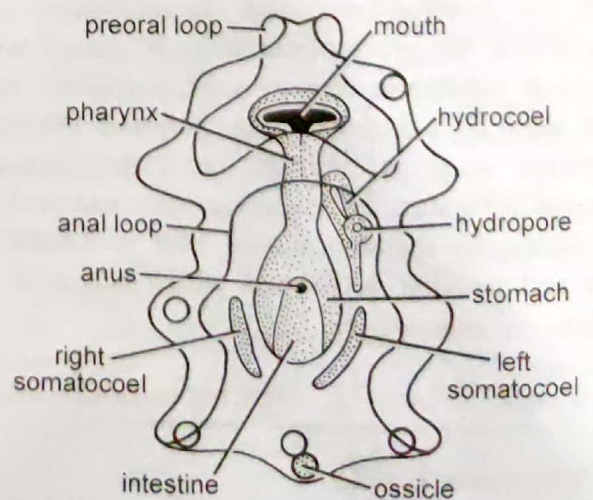


Fig. 7. Auricularia larva.

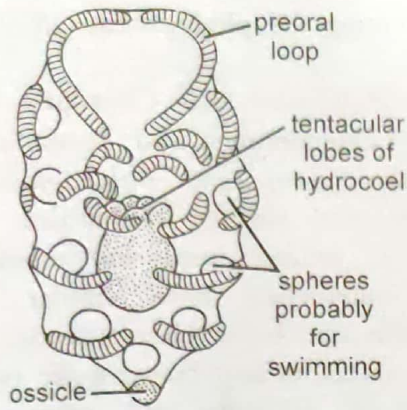


Fig. 8. Transitional stage from auricularia to doliolaria.

Continuous ciliated band breaks in 3 to 5 flagellated rings. Mouth is shifted to anterior and anus to posterior pole.

Metamorphosis is gradual during which it acquires 5 tentacles and 1 to 2 functional podia. As such it is sometimes known as 'pentactula'. After appearance of more podia and tentacles, sea cucumber settles to the sea bottom and leads an adult mode of life.

Other forms of this class show marked peculiarities in larval development. In *Cucumaria planci* and *C. quinquesemita*, etc., there is no auricularia stage and embryo directly develops into **doliolaria** larva. In others like *C. saxiola*, *C. frondosa*, both of these, larval stages are omitted and the larva only swims about having an oval ciliated shape. In *Holothuria floridana*, embryo hatches directly into a young.

(5) Class V. Crinoidea

Doliolaria Larva

It hatches as a free-swimming larva. Body has 4 to 5 ciliated bands with an apical sensory plate at the anterior end provided with a bunch of cilia. There is an adhesive pit over the first ciliated band, near the apical plate in the mid ventral line. Between second and third ciliated band lies the stomodaeum or vestibule. Skeleton also develops at this larval stage. After the differentiation into prospective organs, larva attaches itself and internal organs rotate at an angle of 90 degrees from ventral to posterior position. Larva forms a stalk and is now referred as

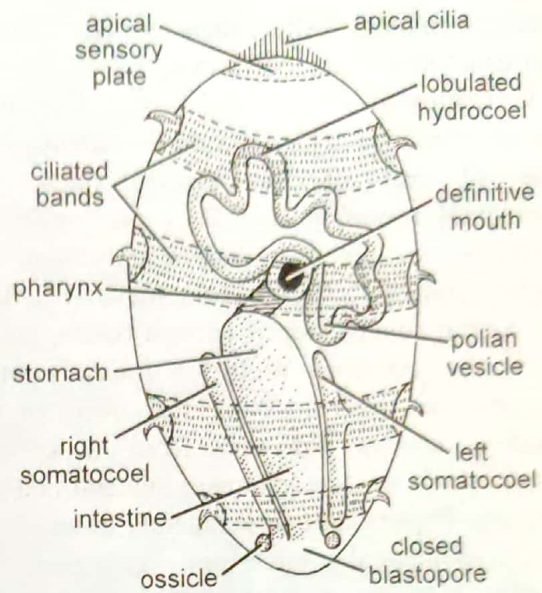


Fig. 9. Mature doliolaria larva of *Leptosynapta inhaerens*.

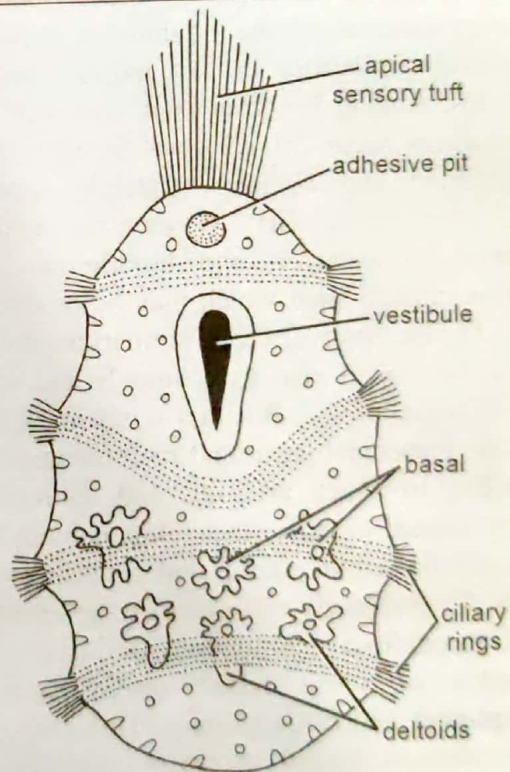


Fig. 10. Doliolaria of *Antedon bifida*.

cystidean or **pentacrinoid** larva which after sometime metamorphoses into adult.

(6) Significance of Echinoderm Larvae

It is seen that different classes of echinoderms have somewhat different larvae which are



differently named. After their study, following significant points can be drawn.

1. Common origin of classes. Except the larva of crinoidea which becomes sedentary, the larvae of rest of the classes have some fundamental resemblances. They are constructed on the same general fundamental plan with bilateral symmetry. They have somewhat flattened body, longitudinally looped ciliated bands, gut and enterocoelic coelom. With so many common characters, one may conclude the origin of their respective classes (groups) from a common ancestor which was a coelomate, bilateral and free-swimming. Dipleurula and pentactula larva are two such hypothetical ancestors suggested by zoologists. It is believed that all modern echinoderms have originated from them.

2. Taxonomic affinities. Closely looking at the classification of the phylum, it is seen that the larval similarities do not indicate taxonomic affinities. Among **Eleutherozoa**, two well marked larval forms occur : (i) **Pluteus group** is common to ophiuroids and echinoids, bilaterally symmetrical with long arms, (ii) **Auricularia group**, is common to asteroids and holothurians, has a winding ciliated band which may be produced into lobes. On the basis of larval similarities ophiuroids should be placed near to echinoids and asteroids near to holothurians. But this is not in agreement with the palaeontological and morphological result, according to which asteroids and ophiuroids are closely related to each other while echinoids seem to have followed an entirely independent evolution.

3. Phylogenetic affinities. A survey of larval types throughout echinoderms indicates several examples of close larval resemblances e.g., ophiopluteus and echinopluteus. This must be due to **convergent larval evolution**. Occurrence of convergence in development is seen among unrelated groups such as Asterozoa, Holothurozoa and Crinozoa. Similarly, larva of closely related forms such as asteroids and ophiuroid, exhibit major differences, which must be due to **divergent larval evolution**. Occurrence of divergent type of development is seen within related groups (ophiuroida). Therefore, the larval structures in echinoderms, cannot serve the purpose

of determining the phylogenetic affinities in the phylum.

4. Relationship with Chordates. Auricularia larva of Echinodermata and **Tornaria larva** of some enteropneusts (e.g., *Balanoglossus*) shows very close and striking similarities. Moreover, cleavage is indeterminate and mesoderm and coelom (enterocoel) have similar origin in echinoderms and lower chordates. Serology also indicates a relationship between the two groups. In view of all this and other evidences, echinoderms and chordates have been regarded as phylogenetically related groups.

5. Aid in dispersal and feeding. Since the adult echinoderms are somewhat sluggish, their larvae are the main dispersive phase for them. They remain in plankton for sufficient time to be swept from the place of their birth to new areas, or to restock the original areas. In addition to their dispersive function, larvae will aid the species in feeding from a different source from their adults, and thus when food is short larvae and adult will not compete.

AUTOTOMY AND REGENERATION

Breaking off the injured or unduly stimulated body parts, is termed as **autotomy** or **self amputation**. It serves as a means of protection to the animal. It is also a method of getting rid of injured body parts and replacing them with perfect ones. Replacement of the lost parts is brought about by another process known as **regeneration**. Echinoderms possess remarkable powers of autotomy and regeneration.

[I] Asterozoa

Sea star immediately shed off or break off its arm whenever it is injured or attached to some base. The arm is detached from its base at the IV or V ambulacral ossicle. This process is known as **autotomy**. Whenever caught, a starfish may throw off one or more of its arms.