PREFACE

With its grounding in the "guiding pillars of Access, Equity, Equality, Affordability and Accountability," the New Education Policy (NEP 2020) envisions flexible curricular structures and creative combinations for studies across disciplines. Accordingly, the UGC has revised the CBCS with a new Curriculum and Credit Framework for Undergraduate Programmes (CCFUP) to further empower the flexible choice based credit system with a multidisciplinary approach and multiple/ lateral entry-exit options. It is held that this entire exercise shall leverage the potential of higher education in three-fold ways – learner's personal enlightenment; her/ his constructive public engagement; productive social contribution. Cumulatively therefore, all academic endeavours taken up under the NEP 2020 framework are aimed at synergising individual attainments towards the enhancement of our national goals.

In this epochal moment of a paradigmatic transformation in the higher education scenario, the role of an Open University is crucial, not just in terms of improving the Gross Enrolment Ratio (GER) but also in upholding the qualitative parameters. It is time to acknowledge that the implementation of the National Higher Education Qualifications Framework (NHEQF), National Credit Framework (NCrF)and its syncing with the National Skills Qualification Framework (NSQF) are best optimised in the arena of Open and Distance Learning that is truly seamless in its horizons. As one of the largest Open Universities in Eastern India that has been accredited with 'A' grade by NAAC in 2021, has ranked second among Open Universities in the NIRF in 2024, and attained the much required UGC 12B status, Netaji Subhas Open University is committed to both quantity and quality in its mission to spread higher education. It was therefore imperative upon us to embrace NEP 2020, bring in dynamic revisions to our Undergraduate syllabi, and formulate these Self Learning Materials anew. Our new offering is synchronised with the CCFUP in integrating domain specific knowledge with multidisciplinary fields, honing of skills that are relevant to each domain, enhancement of abilities, and of course deep-diving into Indian Knowledge Systems.

Self Learning Materials (SLM's) are the mainstay of Student Support Services (SSS) of an Open University. It is with a futuristic thought that we now offer our learners the choice of print or e-slm's. From our mandate of offering quality higher education in the mother tongue, and from the logistic viewpoint of balancing scholastic needs, we strive to bring out learning materials in Bengali and English. All our faculty members are constantly engaged in this academic exercise that combines subject specific academic research with educational pedagogy.We are privileged in that the expertise of academics across institutions on a national level also comes together to augment our own faculty strength in developing these learning materials. We look forward to proactive feedback from all stakeholders whose participatory zeal in the teaching-learning process based on these study materials will enable us to only get better. On the whole it has been a very challenging task, and I congratulate everyone in the preparation of these SLM's.

I wish the venture all success.

Professor Indrajit Lahiri
Authorised Vice-Chancellor
Netaji Subhas Open University
(NSOU)

Netaji Subhas Open University

Four Year Undergraduate Degree Programme

Under National Higher Education Qualifications Framework (NHEQF) &

Curriculum and Credit Framework for Undergraduate Programmes

Course Type : Honours in Zoology (HZO)

Course Title : Animal Diversity

Course Code : NEC-ZO-01

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THEORY

Course Type : Honours in Zoology (HZO)
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Unit - 1 ❑ Basics of Animal Classification– Concept of Classification, Systematics and Taxonomy ; Hierarehy, Taxonomic types ; classification outline of Animal Kingdom

Structure

1.1 Objectives

1.2 Introduction : Concept of Taxonomy, Systematics and Classification

1.3 Hierarchy (Linnaean Hierarchy)

1.4 Taxonomic Types

1.5 Classification outline of Animal Kingdom

1.6 Questions

1.7 Suggested Readings

1.0 Objectives

By studying this unit learners will have a concept about taxonomy, systematics and classification, hierarchy (Linnaean hierarchy), different kinds of taxonomic types and outline classification of animal kingdom.

1.2 Introduction : Concept of Taxonomy, Systematics and Classification

The term taxonomy is derived from the Greek words taxis meaning arrangement, and nomos meaning law. It was first coined by the pioneer plant taxonomist. Augustin Pyramus de Candolle in 1813 for the plant classification. Taxonomy clearly means arranging of organisms on the basis of some laws. To understand those laws and procedure of arrangement one should know the theory and then apply them. Hence taxonomy has been defined by Ernst Mayr (1982) as "Theory and practice of classification, including its bases, principles procedures and rules." Christofferson (1995) has defined taxonomy as "the practice of recognising, naming, and ordering taxa into a system of words consistent with any kind of relationships among taxa that the investigator has discovered in nature.” The prcoess of taxonomy involves two district steps— (a) correct recogniion and definition of the organisms and their relationships and (b) application of suitable designation for the organisms and to different group which include them. The former is called classification which includes study of characters and grouping of individuals while the latter is termed as nomenclarure.

The term systmatics, on the other hand, originated from Latinized Greek word ‘systema’ meaning to put together. The systematics partly overlap with taxonomy and originally used to describe the system of classification prescribed by early biologists. Linnaeus applied the term ‘Systematics’ for the systems of classification in his famous book, ‘Systema Naturae (4th edition) in 1735. This was later defined by Simpson (1961) as “the scientific study of the kinds and diversity of organims and of any and all relationships among them.” The other simple definition by Mayr (1969) is “systematics is the science of diversity of organisms”. Systematics is broader term than taxonomy. Systematics deal with the evolutionary realtionships between organisms. Systematics try to determine which organisms share a recent ancestry with others. Study on systematic include quite a broader areas of reserach which include not only morphology and anatomy, but also genetics, behavioural aspects and population study (including poperties of each species, common characters of certain taxa and the variation within taxa are the products of systematics that ultimately help to construct a phylogeny. Systematics is sometimes incorrectly used as taxonomy. Taxonomy, as mentioned earlier, is actually the study of the principles and practices of classification and as such it is only a part of systematics which consists of both taxonomy and evolution. Taxonomy is thus one of the components of systematics. Taxonomy is concerened with describing and naming the many kinds of organisms that exist today, those that have been extinct. The second part of systematics, i.e. evolution, is concerned with understanding just all of the organisms arose in the first place and what processes are at work to maintain or change them.

Classification is a logical system that consists of several categories or ranks each of which contains some number of organisms such that by the name of a category one can immediately imagine about the structure and other aspects of those organims . That the organisms are to be placed under a specific category require the study of their relationships. The term relationship is vital and means phylogenetic and all biological relationships. Relationships will show how they are related to each other and how they differ from others. This again will show the path of origin and evolution of the group. Hence Zoological Classification can be defined as “the ordering of animals into groups or sets on the basis of their relationships" (Simpson, 1961). Here ordering means arranging the animals into groups. According to Mayr and Asholock (1991), "a biological classification is the ordered grouping of organims according to their similarities and consistencies with their inferred descent." Thus biological classification is the scientific procedure of arrangement of living organisms into groups. It is done on the basis of their similarities and dissimilarities and placing the groups in a hierarchy of categories. Classification is the result of taxonomic studies because the taxonomists "classify" organisms based on certain principles and the end result is the classification. The purpose of classification is identification and arrangement of different types of organisms into groups on the basis of relationships and to express the degree of genetic relationships or affinity between different types of organisms. The first pioneer work on biological classification was done by Carolus Linnaeus in the mid-18th century, and it is accepted by all with some modification till date.

1.3 Hierarchy (Linnaean Hierarchy)

Simpson (1961) has defined hierarchy as "a systematic framework for animal classification with a sequence of classes (or sets) at different levels in which each class except the lowest includes one or more subordinate classes."

In nature the number of animal and plant species is very large and it is necessary to arrange them into categories and taxa of different grades, and then arranging those categories and taxa in an ascending order, so that a higher taxa includes one or more lower taxa.This arrangement is called *hierarchy of classification* or *Linnaean Hierarchy*. Linnaeus recognised only five hierarchic levels within the animal kingdom.These were *classis (class),*ordo (order), *genus*, *species* and *varietas* (variety). Later, two additional categories- *family* (by Butschli in 1770) between genus and order, and *phylum* (by Haekel in 1886) between class and kingdom were added. The term varietas used by Linnaeus was subsequenty either discarded or replaced by the *subspecies.*

The above discussed categories from the basic taxonomic hierarchy of animal, and any given species belong to these seven obligatory categories:

Kingdom

Phylum

Class

Order

Family

Genus

Species

Howerver, as the number of known species increased, our knowledge of the degree of relationship of these species also increased, there was a need for a more precise indication of the taxonomic position of a given species. This was achieved by splitting the original seven basic categories and inserting additional ones. These additional categories are fromed by adding prefixes, designate as *super* above various of the basic levels and as *sub* and *infra* successively below them. Thus there are *superclass*, *subclass, infraclass, superorder, suborder* etc.More recently two other additional categories have become in use. These are *tribe*,between genus and family, used in entomology, and *cohort*, between order and class, in case of vetebrate classification. Some authors use terms for additional subdivisions,such as *cladus, legio* and *sectio*.There are as many as 33 categories presently in use in the hierarchic classification, of which *only18* (marked with asterisk below) are generally followed. The standardised endings are shown in parentheses.

Kingdom*

Subkingodm*

Infrakingdom

Superphylum

Phylum*

Subphylum*

Infraphylum

Superclass*

Class*

Subclass*

Infraclass

Supercohort

Cohort*

Subcohort

Infracohort
Super order*
Order*
Suborder*
Infraorder
Superfamily (oidea)
Family* (-idea)
Subfamily* (-inae)
Infrafamily
Supertribe
Tribe* (-ini)
Subtribe (-ina)
Infratribe
Supergenus
Genus*
Subgenus*
Super speices
Species*
Subspicies*

1.4 Taxonomic Types

In zoological nomenclature, a 'type' is a zoological object on which the original publised description of a name is based. It is the objective basis to which a given zoological name is permanently linked. In other words, it is the nucleus of a taxon and foundation of its name. Once designated the type cannot be changed, not even by the original author who first described it, except by exercise of the plenary powers of the commission (Article 79) through the designation of a Neotype (Article 75). Types may be considered as secured standard of reference tied to the taxomic names. The method of typing names to taxa is called *type method* or *typification.* A type is purely a nomenclature concept and has no significance for classification.

In case of zoological code a type is always a zoological object, never a name. The type of a family group taxon is a genus, the type of a genus group taxon is a species and the type of species group is a specimen.

The primary purpose of designating a type is to enable scientists in the future to definitely identify a described species.When attempting to describe a new species, rather than depending solely on the published description, it is improtant to physically examine previously described species to definitely conclude that a specimen we have on hand is in fact new to science. Thus, it is critically improtant for type species to be placed in a well maintained, universally accessible repository.

***KINDS OF TYPES* :**

Several kinds of types are recognised by the code. Some of which are briefly discussed.

(i) *Holotype* : A single specimen of any sex selected as the "type" by the original author at the time of publication for the original description of the species.This is the true type and most important of all types.The holotype is the key in the nomenclature of the species and settles many resolved questions in the name of the species. Zoological codes recognise the holotype.

A holotype is usually a preserved specimen or fossil,but in rare case it may consist of an illustration, a live specimen or a tissue sample.

As per recommendations 73c of the code, the following data are required for the holotype—

(a) Specimen's size (b) Locality with date and other relevant data (c) Sex (d) Stage of development or form (e) Name of the host species in case of a parasite. (f) Name of the collector (g) Height in meters for terrestrial species. (h) Depth in meters for marine species. (i) In case of fossil species, the geological age and stratigraphic position, if possible in meters. (j) Register number assigned to the collection.

(ii) *Allotype* : A single specimen of the same species as the holotype,being the opposite sex of the holotype. For example, if in holotype, the sex of the species is male,the female species is considered as *allotype*.It is often used to illustrate morphological characters not seen in the holotype.The zoological code does not favour the use of allotype which is viewed as a mere paratype.

(iii) *Paratype* : A specimen other than the hologype used by the original author in his description. While describing a new species the author selects a number of specimens for study of characters of the species. He or she marks or selects one of the specimens as holotype and marks rest of the specimens as paratypes (i.e. specimens of paratype status).

(iv) *Syntype :* When a species description is based on two or more specimens and where no holotype is designated, all the specimens are considered as syntypes. Recently the zoological codes do not approve the designation of syntype.

(v) *Lactotype :* A lactotype is a specimen later selected to serve as the single type speciemen for species originally described from a set of syntypes. In other words a lactotype is an element selected subsquently from amongst syntypes to serve as the nomenclature type.

(vi) *Neotype :* It is a substitute specimen that is selected subsequent to the description of a species to replace a preexisting type that has been lost or destroyed or damaged beyond recognition. Neotype stands for the species in asbence of its holotypic, lectotypic or syntypic specimens.

(vii) *Plastotype :* A plaster cast of a type of a species forms the plastotype of that species. It is extensively used in paleozoology.

(viii) *Paratype :* While describing a species on the basis of a good number of specimens, its author selects several specimens for basing the description of the species. The author marks one of these as the holotype and a sexual opposite of the holotype as the allotype and then labels the remaining specimens as paratypes.

(ix) *Topotype :* It is a specimen of a species which is earmarked as "collected from type-locality" (the place where from the type speciemen was collected) of the species by a reviser or a subsequent worker who may collect and identify the sample himself. It is quite a valuable type specially when original type get lost or become inaccessible.

(x) *Homotype :* A specimen compared with the type by a person other than the describer and determined by the said person as conspecific with the type. A homotype is important as a holotype and selected when original type is damaged or lost.

(xi) *Monotype :* A holotype based on a single specimen. However, when holotype is correctly designated, it is synonymous with it.

1.5 Classification outline of Animal Kingdom

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1.6 Questions

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1.7 Suggested Readings

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Unit - 2 ❑ Codes of Zoological Nomenelature : Principle of priority ; Synonym and Homonym

Structure

2.1 Objectives
2.2 Introduction
2.3 Codes of Zoological Nomenclature
2.4 Rules of Zoological Nomenclature
2.5 Principles of Priority
2.6 Synonym and Homonym
2.7 Questions
2.8 Suggested Readings

2.1 Objectives

By studying this unit learners will have a concept about codes of zoological nomenclature, rules of zoological nomenclature, principles of priority, synonym and homonym.

2.2 Intoduction

The International Code of Zoological Nomenclature is a widely accepted convention in zoology that rules the formal scientific naming of organisms treated as animals. Names are given to all animals. The name of a particular animal differs in different languages. Even within the same country one animal is known in different names in different regions. To avoid this intricacy of names, it was proposed to give them a scientific name. Such scientific names are Latinised words given as per the International Code of Zoological Nomenclature (I.C.Z.N.).

Nomenclature (Latin words- 'nomen' meaning name; 'clature' meaning to call) means a system of name and, thus, is the language of zoology and the rules of nomenclature are its grammar. Since all zoologists deal with animals and use their names for communication, it is, thus essential that the general principles of zoological nomenclature be familiar to all zoologists, irrespective of whether they are systematise or not.

2.3 Codes of Zoological Nomenclature

The International Code of Zoological Nomenclature is a widely accepted convention in zoology that rules the formal scientific naming of organisms treated as animals. Names are given to all animals. The name of a particular animal differs in different languages. Even within the same country one animal is known in different names in different regions. To avoid this intricacy of names, it was proposed to give them a scientific name. Such scientific names are Latinised words given as per the International Code of Zoological Nomenclature (I.C.Z.N.)

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The International Zoological Congress elects a judicial body, called International Commission of Zoological Nomenclature which interprets or recommends the provisions of the code for classification or nomenclatural problems of the animals. Again the International Code of Zoological Nomenclature (ICZN) formed by the International Commission of Zoological Nomenclature to see the rules and principles of nomenclature and the application of these rules for both living and fossil animals. Zoological nomenclature is independent of other systems of nomenclature, for example, botanical nomenclature. This implies that animals can have the same generic names as plants. The rules and recommendations have one fundamental aim-to provide the maximum universality and continuity in the naming of all animals, except where taxonomic judgement dictates otherwise. The code is meant to guide only the nomenclature of animals, while leaving zoologists freedom in classifying new taxa.

Parts of Code of Zoological Nomenclature

The International Code of Zoological Nomenclature contains three main parts- (i) the code proper, (ii) The Appendices and, (iii) the official glossary. The code proper includes a preamble followed by 90 articles which cover mandatory rules without any explanation. There are three Appendices, of which the first two cover the status of recommendations and the third part of the Appendices is the constitution of the commission. The glossary contains the terms used in the codes with detailed definition. Binomial and Trinomial Nomenclature. The scientific method of naming plants and animals by applying two components is called binomial nomenclature. It was evolved by Carolus Linnaeus (Karl Von Linnae), the great Swedish naturalist, and adopted by the International Code of Zoological Nomenclature. According to binomial nomenclature, the scientific name of an organism is composed of two Latin or Latinized words, the first word is called Genus (generic name or generic epithet) followed by the second word called species (specific name or specific epithet). For example, the scientific name of tiger is Panthera tigris, where Panthera is genus and tigris is species. Very rarely the generic and specific names are same. They are called tautonymes, *e.g. Gorilla gorilla, Catla catla, Naja naja, Rattus rattus, etc.* Sometimes it becomes the trinomial nomenclature.

2.4 Rules of Zoological Nomenclature

At present the naming of the animals is governed by the International Code of Zoological Nomenclature. There are many rules (Articles) concering the Zoological Nomenclature. Of these rules, some important ones are citied below: l. Zoological Nomenclature is independent of other system of nomenclature. The scientific name of animals and plants must be different, and the generic name of a plant and an animal may be same, but this should be avoided. For example, the generic name of banyan or fig tree is Ficus and the fig shell (a kind of gastropod shell) is Ficus. The scientific name of fig tree is Ficus carica or F. indica but the scientific name of the fig shell is Ficus ficus or Ficus gracilis. 2. The scientific names of a species is to be binomial (Article/Art. 5.1) and a subspecies to be trinomial (Art. 5.2). For example, the scientific name of Indian bull frog is Rana tigrina (it is binomial), while the scientific name of Indian lion is Panthera leopersica (it is trinomial). 3. The first part of a scientific name is generic (L. Genus = race) and is a single word and the first alphabet or letter must be written in capital letter. The genus must be a noun in the nominative singular. The generic part assigns a Latin noun, a latinized Greek or a Latinized vernacular word.

4. The second part of a name is species (L. species = particular kind) name and may be a single word or group of words. The first alphabet or letter of the species name must be written in small letter. The species name must be adjective form in nominative singular agreeing in gender with genus name which is in noun form; e.g.:

Ending in species name	**Ending in genus name**	**Full name of the species genus name**
Masculine ending (—i)	(-i/-us/-es)	Common mongoose *(Herpestes edwardsi)* River lapwing (*Vanellus duvaucelli*)
Feminine ending (-a/-e)	(-a/-e)	Golden cuttle fish (*Sepia esculenta*) Humpnosed viper (*Hypnale hypnale*)
Neuter ending (-um/-us. etc.)	(-um/-us, etc.)	Tusk shell (*Dentalium elephantinum*) Common crane (*Grus grus*) Lesser black-backed gull (*Larus fuscus*)

The specific name (species part) indicates distinctness while generic part shows relationship.

5. If the species names are framed after any person's name, the endigns of the species are i, ii and ae, or if the species name are framed after geographical place, the endings of the species are 'ensis', 'iensis', e.g.:

Species name after person's name

Hooded cuttle fish - Sepia prashadi (Prasad + i)

Tree frog - Rhacophorus jerdonii (Jerdon + ii)

Antarctic flying squid - Todarodes filippovae (Filippove + ae)

Species name after place

Common Indian monitor - Varanus bengalensis (Bengal + ensis) Cookiecutter shark - Isistius brasiliensis (Brasil + iensis)

Butterfly fish - Chaetodon madagascariensis (Madagascar + iensis)

6. First part of a compound species-group name is a Latin letter and denotes a character of the taxon, connected to the remaining part of the name by a hyphen (-), e.g.,

Sole (a kind of flat fish)–
Aseraggodes sinus–arabici. *L. *Sinus = recess*
China-rose (a kind of coloured rose)–
Hibiscus rosa–sinensis. *L. *rosa = rose*

7. If a subgenus taxon is used, it is included within parenthesis in between genus and species part and is not included in binomial and trinominal nomenclature, e.g. :

Name	Genus	Subgenus	Species	Subspecies
Fan shell (Bivalvia)	*Atrina*	*(Servatrina)*	*pectinata*	*pectinata*
Dussumieri's half *beak (Osteichthyes)*	*Hemirhampus*	*(Reporhampus)*	*dussumieri*	

8. The person who first publishes the scientific name of an animal, is the original auther of a name, may be written after the species name along with the year of publication. The author's name may be in its abbreviated form.

Lion– *Felis leo* Linnaues, 1758

[Lion– *Felis Leo* Linn., 1758 or *Felis leo* L., 1758]

9. Comma is only used between author's name and the year of publication (Art. 22. A. 2.1), e.g., the scientific name of **Common octopus** is *Octopus vulgaris* Cuvier, 1797. No punctuation marks are considered one to other ends of the name e.g., "*Octoups vulgaris* Cuvier, 1797" **(Not considered)**. No diacritic mark, apostrophe (i') and hypen (–) are used in names. In German word the **umlaut sign** is removed from a vowel and the letter 'e' is inserted after the vowel, e.g., *mulleri* becomes *muelleri*.

10. If the original generic name given by the first author who also reported the species name, transfers the species part from one genus to the other, the name of the orignal author is put within parenthesis, e.g.,

Tiger-*Felis tigris* Linnaeus, 1758. At first almost all the members of the cat family were placed under the genus-*Felis*. Later the genus *Felis* was divided into two genera, the genus of the larger cats (tiger, lion, leopard, etc.) is *Panthera* and smaller cats such as jungle cat, fishing cat, golden cat, etc. are placed under the genus *Felis,* e.g. :

Lion– *Felis leo* Linnaeus, 1758 **Lion**– *Panthera leo* (Linnaeus, 1758)

Jungle cat– *Felis chaus*

11. The names are not acceptable before the publication of Linnaean treatise, **Systema Naturae (10th edition)** which was published on 1st January, 1758 except the Nomenclature of spiders which starts in 1757. The book **Aranei suecici** was published by **C. Clerck in 1757**.

12. The scientific names must be either in Latin or Latinised or so constructed that they can be treated as a Latin word.

13. The scientific names must be *italicised* in printed form, or **under lined** in hand wirtten or in typed forms, e.g. :

Indian leopart–*Panthera pardus fusca* (Meyer) [in printed form]

Indian leopard–Panthera pardus fusca [in handwritten or typed forms]

14. All taxa from subgenera level and above must be **uninominal** (Art. 4.1, 4.2) and are **plural nouns** for names **above genus**, and **singular nouns** for **genus** and **subgenus**. Taxon 'species' may be used as singular or plural.

15. In case of animals some rules and practices are applied on the basis of zoological codes (Art. 29.2) for the formation of suprageneric taxa from superfamily to tribe, e.g.:

Taxon level	Endings of the name	Examples
Superfamily	–oidea (for vertebrates) or –acea (for invertebrates)	Hominoidea Genus *Homo* (Latin) = man Genitive *Hominis* Root *Homin*–of *Homo*
Family	–idae	Hominidae [Homin + idae]
Subfamily	–inae	Homininae [Homin + inae]
Tribe	–ini	
Subtribe	–ina	

16. A family name should be based on the basis of type-genus, e.g., Chitonidae– *Chiton* (type genus) + idae = Chitonidae.

17. Two species under a same genus should not have the same name.

18. Nomenclature of a **hybrid/bybrids** cannot be considered because the hybrids are normally **individuals** but not **population**. Thus such names have no status in nomenclature. Hybrids are typically **sterile** and becomes **synaptic failure** during meiosis. They are prevented from back crossing with either parental species.

19. A name published without satisfying the conditions of a availability (**nomen nudum** = naked name) has no standing in zoological nomenclature and is best never recorded, even in **synonymy**.

20. A scientific valid name which is not used about 50 years in literature, then as per zoological code's provision the unused senior valid scientific name is treated as **obliterated name** and junior name which is used continuously in literature (atleast by 10 authors in 25 publications) becomes the accepted official name.

Remark: The disadvantage of the binominal system is its instability and the name of species changes every time and is transferred to a different genus (**Mayr and Ashlock, 1991**).

21. As per the zoological code's provision (Art. 18), the species and subspecies parts of a name may be same spelling and even the second or the third component of the name repeats the generic name (**tautonomy**), e.g.:

Scandinavian red fox– *Vulpes vulpes vulpes.*

2.5 Priniciple of Priority

Of all the rules of zoological nomenclature, the most difficult to formulate was the one determining which of the two or more connecting names should be chosen. Owing to the French Revolution (1789) and the Napoleonic wars (1801-1815), there was a period of disturbed communication and taxonomists of one country were often unaware of the new species and genera described by taxonomists in other countries.

Each author used his/her own judgement as to which name to adopt. The nomenclature chaos prevalent during that period is not appreciated by those contemporary authors, who blamed the rules of nomenclature for all the evils of name changing. The fathers of modern nomenclature believed that the continuous changing of names could be prevented if priority were adopted as a basic principle of nomenclature.

Under this principle it would not be possible to change or replace an earlier name merely because it was incorrectly formed or misleading or for other personal aesthetic or even scientific reasons. It is evident from much of the earliest writings on the subject that the "priority" these authors had in mind was a priority of usage rather than priority of publication.

However, admirable though, the principle of priority of usage is it is subjective and so an attempt was made to restore objectivity by replacing priority of usage with priority of publication. This priority of publication means that when a name is given, it should be a living entity and accompanied by a description.

Reasons for the Changes of Name:

1. Changes dictated by scientific progress:

(i) Change of the generic part of binomial (binominal).

(ii) Change of specfic name.

(iii) Synonymising of currently accepted species names.

(iv) Analysis of species complex.

2. Changes dictated by rules of nomenclature:

(i) Discovery of an earlier (senior) synonym.

(ii) Discovery of an earlier (senior) homonym.

(iii) Discovery of an earlier genotype fixation.

(iv) Discovery of inapplicable type-specimen.

The Law of Priority

The Law of priority covers the period from 1st January 1758 to the present. Article 23 of the Code deals specifically with the rules and as amended at Paris in 1948. Its essential provisions are that the valid names of genus or species can only be that name under which it was first designated on the conditions :

1. That (Prior to January 1931) this name was published and accompanied by an indication or a definition or a description.

2. That the author has applied the principles of Binomial Nomenclature.

3. That no generic name nor specific trivial name published after December 31st, 1930, shall have any status of availability (hence also of validity) under the rules, unless and until it is published either–

(i) With a statement in words indicating the characters of the genus, species or subspecies concerned.

(ii) In the case of a name proposed as a substitute for a name which is invalid by reason of being a homonym with a reference to the name which is thereby replaced.

(iii) In the case of a generic name or sub-generic name, with a type species designated or indicated in accordance with the one or other of the rules prescribed for determining the types species of a genus or subgenus, upon the basis of the original publication.

4. That even if a name satisfies all the requirements specified of, that name is not a valid name if it is rejected under the law of homonymy (one name for two or more individuals).

The Law of Priority in zoological nomenclature is a basic law of International Code and promotes stability. A zoological name and name of a taxon become valid if they belong to the category of senior synonym and senior homonym.

The Law of Priority in zoological nomenclatrure applies only from subspecies to family category but not to the higher categories. Priority of the zoological name and taxon are considered from the date of publication. Priority means the oldest date, month and year of the publication.

Examples :

(i) In 1855, John Edward Gray published the name *Antilocapara anteflexa* for a new species of pronghorn, based on a pair of horns. However, it is now thought that his specieman belonged to an unusual individual of an existing species, *Antilocapra americana*, with a name published by George Ord in 1815. The older name, by Ord, takes priority; with *Antilocapra anteflexa* becoming a junior synonym.

(ii) In 1856, Johann Jakob Kaup published the name *Leptocephalus brevirostris* for a new species of eel. However, it was realized in 1893 that the organism described by Kaup was in fact the juvenile form of the European eel. The European eel was named *Muraena anguilla* by Carl Linnaeus in 1758. So *Muraena anguilla* is the name to be used for the species, and *Leptocephalus brevirostris* must be considered as a junior synonym and not be used.

Today the European eel is classified in the genus *Anguilla* (Garsault, 1764), so it's currently used name in *Anguilla anguilla* (Linnaeus, 1758).

(iii) Nunneley 1837 established *Limax maculatus* (Gastropoda) and Wiktor 2001 classified it as a junior synonym of *Limax maximus* Linnaeus 1758 from S. and W. Europe. *Limax maximus* was established fitst, so if Wiktor's 2001 classification is accepted, *Limax maximus* takes precedence over *Limax maculatus* and must be used for the species.

There are approximately 2-3 million cases of this kind for which this principle is applied in zoology.

2.6 Synonym and Homonym

Homonyms : Homonyms are names spelt in an identical manner for two or more different taxa but based on different types. If such names come into widespread use, then they create confusion. The earliest of such names are referred to as **senior-homonym**, while the later names are **junior-homonyms**. Articles 52 through 60 deal with the validity of homonyms and with replacement names for junior homonyms. They are one of the most difficult areas of zoological monenclature.

According to the Code, out of the two or more homonyms, all except the oldest (senior homonym), are excluded from use. The junior homonyms can, therefore, never be names those that have never been used for taxa in the animal kingdom.

The Zoological Code explicitly states that two identical species-group names placed in different genera that have homonymous names are not to be considered as homonymy. For example *Noctua variegata* of Insecta and *Noctua variegata* of Aves are not to be considered as homonyms.

Homonyms are of different types :

(i) **Senior homonyms :** The available name on the basis of priority.

(ii) **Junior homonyms :** A preoccupied name (not in use) on the basis of priority or by a ruling by a nomenclatorial body.

(iii) **Primary homonyms :** In a species-group (species, subspecies, etc.) these are names that are the same and were proposed in the same genus-group taxon. The junior homonym must always be replaced either by a new name or a junior synonym (if one exists)

(iv) **Secondary Homonyms :** These are species that are placed in the same genus subsequent to their publication and they have the same specific epithets. The senior secondary homonym is the older of the two names. An alternative name will have to be provided either through description or junior synonyms for the junior homonym.

Synonyms : Two or more names given to the same taxon are known as synonyms. The correct establishment of synonymies is one of the most important tasks, as elaboration of a classification and the preparation of keys depend on the correctness and completeness of the synonymies. The oldest of such names is considered to be **Senior Synonym** while the later ones as **Junior Synonyms**.

According to the principle of priority, only one name can be accepted by which the taxon may be properly known, and it is, in general, the oldest (senior synonym) one. The later or junior synonyms form what is called the synonymy of the accepted name of the taxon.

For the consultation of taxonomic works, it is thus important to disginguish clearly the name accepted as valid from those cited in the synonymy. Modern taxonomic research has to cope with frequent excess of names over taxa. This has come about in two main ways–

(i) Lack of awareness of previously published names.

(ii) Insufficient appreciation of the amount of variation that can exist within a species. This is the result due to lack of sufficient specimens.

Presently with more material available and greater opportunities for field and experimental studies, there is no dearth of species. Moreover, with modern communications, international taxonomic associations have reduced the likelihood of the same taxon being described more than once under different names. However, keeping abreast of the current literature, synonymy is still a problem in spite of the advent of computerised abstracting and data-handling services.

Taxonomic and nomenclatre synonyms : Two kinds of synonyms are generally present.

1. Nomenclature synonyms :

Nomenclature synonyms are synonyms based upon the same type. Their synonymy is said to be absolute and not a matter of taxonomic opinon. They are also known as obligate, objective or homotypic synonyms.

2. Taxonomic synonyms :

Taxonomic synonyms are synonyms based upon differnt types. They remain as synonyms only as long as their respective types are considered to belong to the same taxon. The are also known as subjective or heterotypic synonyms. Nomenclatural synonymy are indicated by the mathematical sign of congruence '≡', while the taxonomic synonymy by the sign of equality '='.

Synonyms are of different types :

(i) **Senior synonyms :** The oldest of two or more names that are considered valid by nomenclatorial codes. This is usually based on priority but may also be done on the basis of choice of names by the first revisor or by a nomenclatorial governing body.

(ii) **Junior synonyms :** The junior names are those that are considered invalid on the basis of priority or because of a choice of the first revisor, or by a governing body of nomenclature. These names, however, can be elevated to senior synonyms if new taxa are identified later and the type(s) of the new taxa are the name bearers of these names.

(iii) **Objective synonyms :** Different names that by examination of nomenclatorial literature alone are judged to refer to the same taxon. For example, any two family-group names with the same type genus or any two genera with the same type species are objective synonyms. These synonyms are generally created only by a drug or alcohol-induced stupor that lasts for days or weeks for the author or by an inadvertent error.

(iv) **Subjective synonyms :** These are different names that have been applied taxon as determined by a taxonomist or systematist. An example would include two species originally described as distinct but were later determined by a professional in the field that they are the same species. This is the most common types of synonymy and these can be the sources of confusion and great debate.

Significance of synonyms : Irrespective of the fact that the names placed by an author in synonymy are not valid, it, however, does not imply that they are of no significance. A considerable amount of information may be recorded in the literature under these invalid names. Therefore, the synonymy of a taxon is a key to information about the taxon, and it is for this reason that taxonomic research is concerned for the establishemnt of the correct synonym.

2.7 Questions

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2.8 Suggested Readings

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Unit - 3 ❑ Protozona– General characteristics and Classification up to Phylum. Study of Amocha (Structure, locomotion, reproduction & nutrition)

Structure

3.1 Objectives
3.2 Introduction
3.3 General characteristics of Protozona
3.4 Classification up to Phylum
3.5 Amoeba ; Systematic position and Structure
3.6 Locomotion in Amoeba
3.7 Reproduction in Amoeba
3.8 Nutrition in Amoeba
3.9 Questions
3.10 Suggested Readings

3.1 Objectives

From this unit learners will learn the diversity, general characteristics and classification of subkingdom Protozoa up to phylum. They will also get an idea about structure, locomotion, reproduction & nutrition of Amoeba

3.2 Introduction

Protozoa (Gr. protos = first; primitive; zoon = animal) are microscopic, eukaryotic, unicellular organisms, in which all life activities occur within the limits of a single plasma membrane. The term protozoa was coined by Goldfuss (1818) and unicellular nature of protozoa was established by von Siebold (1845). Unicellular eukaryotes are found wherever life exists. They are highly adaptable and easily distributed from place to place. They require moisture, whether they live in marine or freshwater habitats, soil, decaying organic matter, or plants and animals. They may be sessile or free swimming. There are about 8000 species of protozoa certainly belong to Protista.

Amoeba is an important member of the sub kingdom Protozoa and study of Amoeba, as a representative, is very important to get an overall idea about protozoa.

3.3 General Characteristics of Protozoa

1. Protozoa are small, generally microscopic, primitive unicellular animals with eukaryotic organization.
2. Most of them are solitary individuals but a number of them are colonial.
3. They exhibit all types of symmetry.
4. The body is bounded by cell membrane (plasma membrane). Body may be naked or is covered by a pellicle (cytoskeleton) or test (exoskeleton).
5. Body shape variable, maybe spherical, oval, elongated, flattened or irregular. Size varies from 1.0 pm to 0.25 m (some giant benthic marine amoeba), most being in between 5 and 250pm in diameter.
6. Most protozoa have a single vesicular nucleus (containing considerable nucleoplasm) while a few are multinucleate.
7. Locomotor organelles include cilia (e.g. Paramecium), flagella (e.g. Euglena) and flowing extensions of the body called pseudopodia (e.g. Amoeba). Some protozoans are sessile (attached or fixed).
8. Nutrition maybe holozoic, holophytic saprophytic, mixotrophic or parasitic.
9. Digestion occurs intracellularly within the food vacuole.
10. Respiration generally through body surface by diffusion. Some are obligatory or facultative anaerobes.
11. Excretion either through the general body surface or through contractile vacuoles, the later also serves for osmoregulation.
12. Reproduction is asexual or sexual. A sexual reproduction by binary fission, multiple fission and budding or plasmotomy. Sexual reproduction occurs either by conjugation or fusion of gametes (syngamy).
13. Protozoans exploit all types of habitat and may be free-living, commensal, mutualistic or parasitic. Free living protozoans are aquatic.

3.4 Classification of Protozoa up to Phylum

Protozoans had been classified differently by various authors like Hyman (1940), Parkar and Haswell (1949), Honiberg et al. (1964) depending upon their size, shape locomotory organs, habit and habitat, etc. But the classification of protozoa, proposed by **Levine et al. (1980)** is the recent one which was published in the Journal or Protozoology, 27(1): 37-58. This scheme of classification is widely accepted by modern zoologists. In this scheme they have uplifted the phylum protozoa of previous classification scheme to the rank of sub kingdom. Under subkingdom protozoa there are **seven phyla.**

Phylum l. Sarcomastigophora
Phylum 2. Labyrinthomorpha
Phylum 3. Apicomplexa
Phylum 4. Microspora
Phylum 5. Under Ascetospora
Phylum 6. Myxozoa
Phylum 7. Ciliophora

Classification with characters (upto phylum)

Phylum 1. Sarcomastigophora

1. Locomotory organelles are either flagella or pseudopodia or both.
2. Nucleus is of one type, except in Foraminiferida.
3. No spore formation.
4. Reproduction asexually but when sexually it is by synagamy.

The phylum includes three subphyla—(i) Mastigophora; (ii) Opalinata; (iii) Sarcodina

Examples : *Euglena, Volvox, Cryptomonas, Chilomonas, Ochromonas, Trypanosoma, Giardia, Trichomonas, Trichonympha, Leishmania. Opalina, Zelleriella, Protoopalina,Entamoeba, Amoeba, Chaos.*

Phylum 2. Labyrinthomorpha

1. Generally trophic stage with ectoplasmic network and spindle shaped or spherical nonamoeboid cells.
2. In some genera amoeboid cells move within network by gliding.
3. Unique cell-surface organelle, associated with ectoplasmic network.
4. Most species form zoospores.

This phylum includes only one class—Class 1. Labyrinthulea Examples: Labyrinthula, Thraustochytrium.

Phylum 3. Apicomplexa

1. Presence of apical complex which can be seen under electron microscope.
2. Anterior apical complex consisting of polar ring(s), rhoptries, micronemes, conoid and subpellicular microtubles at some stage.
3. Micropore(s) generally present at some stage.
4. Cilia absent
5. Reproduction generally by syngamy, some reproduce asexually.
6. All are parasitic. This phylum includes two classes-(i) Perkinsea and (ii) Sporozoa Examples: Perkinsus, Monocystis, Gregarina, Plasmodium, Eimeria, Babesia.

Phylum 4. Microspora

1. Unicellular spores, each with imperforate wall.
2. Sporoplasm with one or two nuclei.
3. Simple or complex extrusion apparatus always with polar tube and polar cap.
4. Mitochondria absent.
5. Dimorphic in sporulation sequence (often but not usually).
6. Obligatory intracellular parasites in nearly all major animal groups.

This Phylum includes two classes—(i) Rudimicrosporea and (ii) Microsporea Examples: Amphiacantha, Metchnikovella, Nosema, Amblyospora, Encephalitozoon.

Phylum 5. Ascetospora

1. Spores are generally multicellar, maybe single celled.
2. Sporoplasm maybe one or more.
3. Polar capsules and polar filaments are absent.
4. All parasitic.

This phylum includes two classes—(i) Stellatosporea, (ii) Paramyxea Examples: Marteilia, Haplosporidium, Urosporidium, Paramyxa.

Phylum 6. Myxozoa

1. Spores are of multicellar origin, with one or more polar capsules and sporoplasms.
2. Spore membrane with one, two, three or rarely more valves.
3. All are parasitic.

This phylum includes two classes—(i) Myxosporea and (ii) Actinosporea.

Examples : *Myxidium, Myxobolus, Triactinomyxon.*

Phylum 7. Ciliophora

1. Simple cilia or compound ciliary organelles are seen at least one stage of life cycle.
2. Subpellicular infraciliature present even when cilia absent.
3. Presence of two types of nuclei with rare exception.
4. Contractile vacuole typically present.
5. Nutrition heterotrophic.
6. Asexual reproduction by transverse binary fission. Budding and multiple fission also occur.
7. Sexual reproduction involves conjugation, autogamy and cytogamy.
8. Most species are free living, but many are commensal, some truely parasitic and large number found as symphorionts on variety of hosts.

This phylum includes three classes— (i) Kinetofragminophorea, (ii) Oligohymenophorea and (iii) Polymenophorea.

Examples : *Balantidium, Rasbena, Didinium, Paramoecium, Trichodina, Tetrahymena, Vorticella Exampla : Nyctotherus, Strombidium, Metopus, Ascobius.*

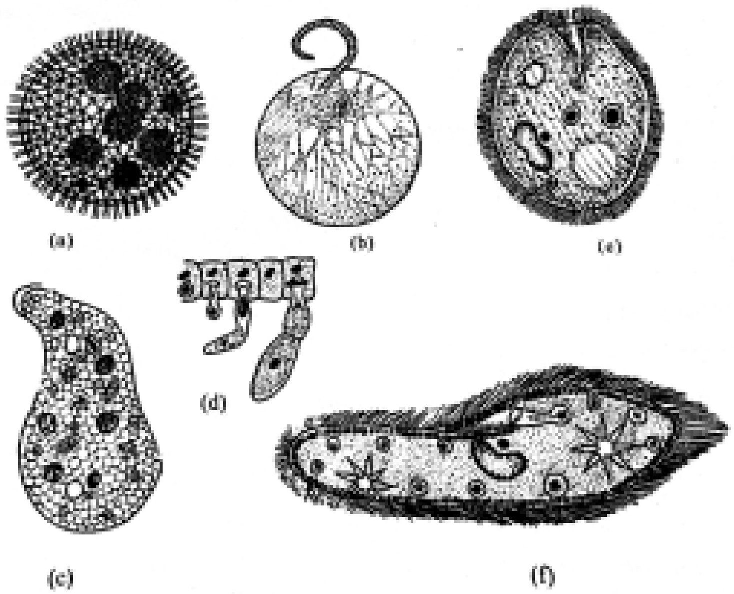

Fig. 1 : Some Important Protozoa
(a) *Volvox*, (b) *Noctiluca*, (c) *Pelomyxa*, (d) *Gregarina*, (e) *Balantidium*, (f) *Paramoecium*

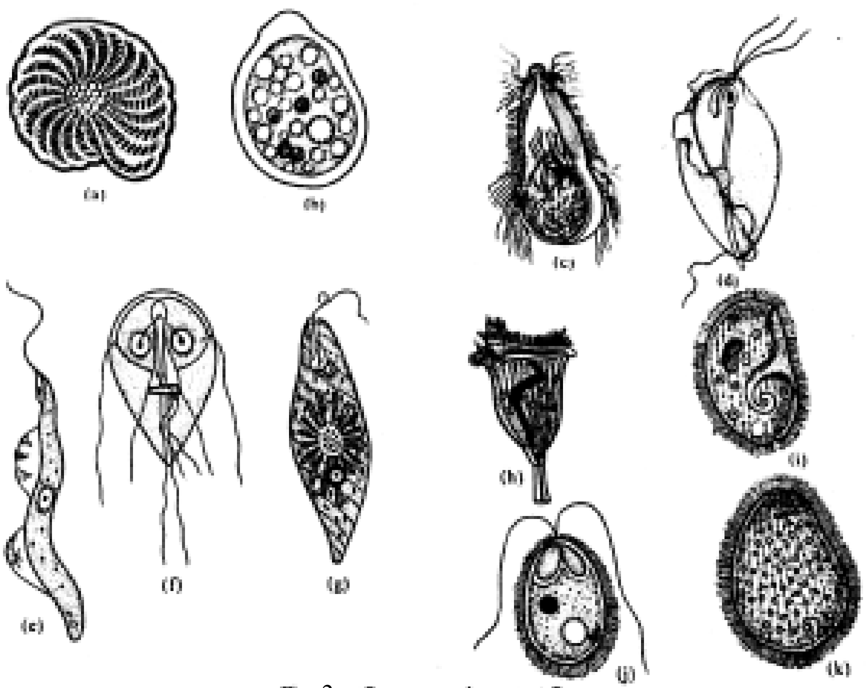

Fig. 2 : Some more Important Protozoa
(a) *Elphidium*, (b) *Entamoeba*, (c) *Trichonympha*, (d) *Trichomonas*, (e) *Trypanosoma*, (f) *Giardia* (g) *Euglena*, (h) *Vorticella* (i) *Nyctotherus* (j) *Chlamydomonas* (k) *Opalina*

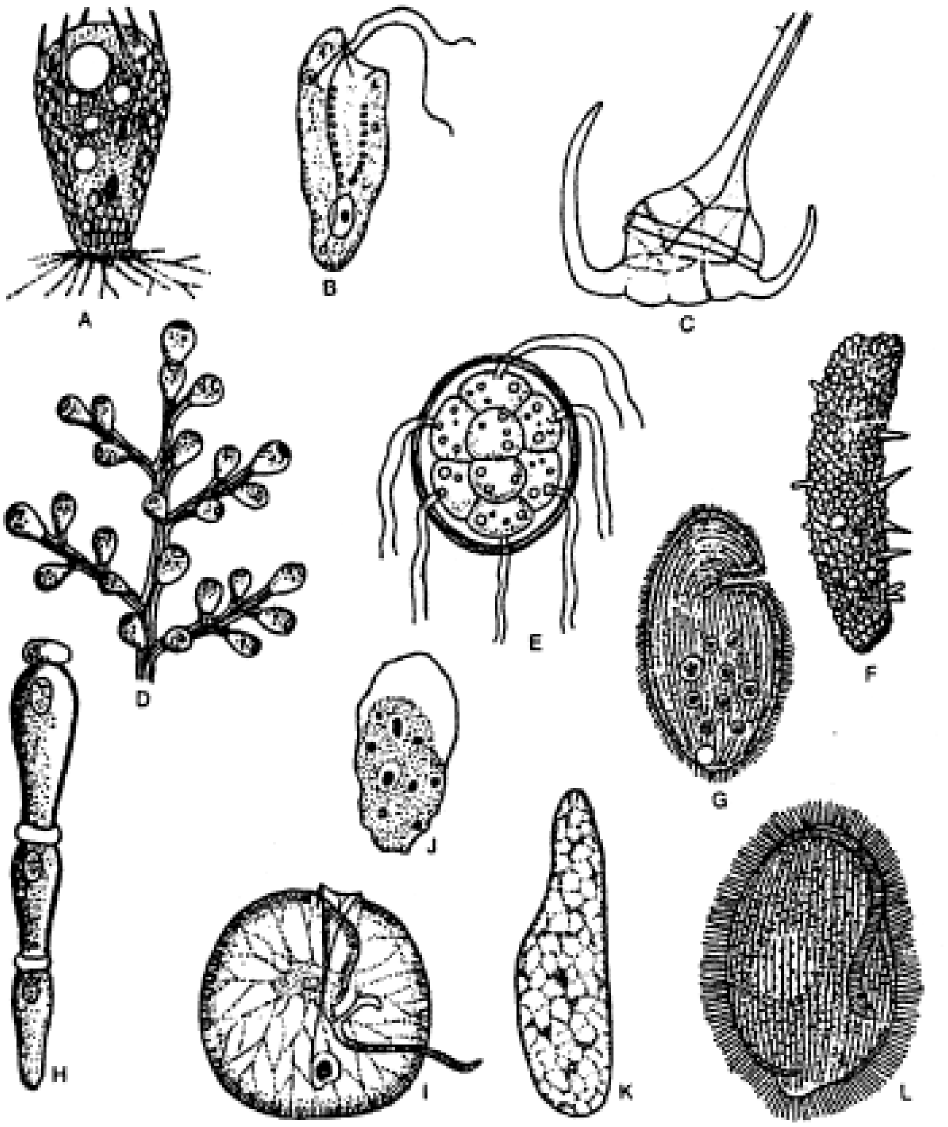

Fig. 3 Representatives of Phylum Protozoa Note the variety of forms in the Phylum Protozoa (after Hyman). A. *Euglypha.* B. *Chilomonas.* C. *Ceratium.* D. *Zoothamnium.* E. *Pandonna.* F. *Saccorhiza.* G. *Plagiopyla.* H.*Greganna.* I. *ivoctiluca.* J. *Myxidium.* K. *Sarcocystis.* L. *Nyctotherus* (nor drawn up to scale).

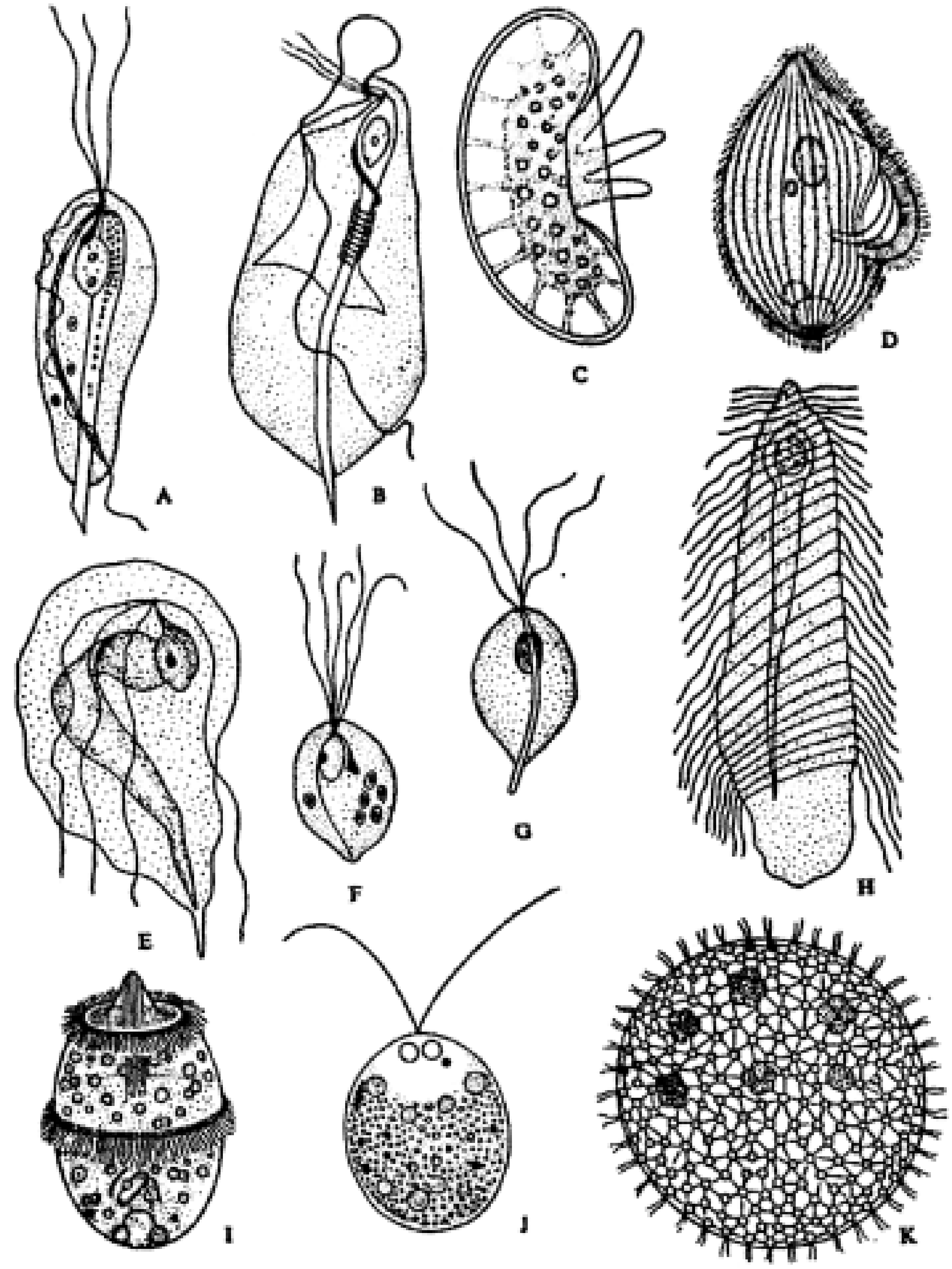

Fig. 4 : A few examples of Phylum Protozoa (after various sources). A. Tritrichomonas augusta. B. Macrotnchomonas lighti. C. Arcella vulgans. D. Belphansma latentium. E. Saccinobaculus doroaxostylus. F. Hexamastix termopsidis. G. Monocercomonas verrens. H. Holomastigoloides hemigymnum. I. Didinium sp. J. Chlamydomonas sp. K. Volvox colony.

3.5 *Amoeba*

Systematic Position :

Kingdom : Protista / Protoctista

Sub-kingdom : Protozoa

Phylum : Sarcomastigophora

Sub phylum : Sarcodina

Super class : Rhizopoda

Class : Lobosea

Genus : *Amoeba*

The genera *Amoeba* was first discovered by Russel von Rosenhoff in 1755. He called it the "little proteus" after the mythological Greek Sea God Proteus who is believed to be capable of changing his shape or form variously. Later in 1962, H.I. Hirschfield has given a full and comprehensive account of the biology of *Amoeba*.

Amoeba proteus is a minute free living protozoa occuring abundantly in the bottom of freswater ponds and other water bodies. They are always found in association with aquatic vegetations

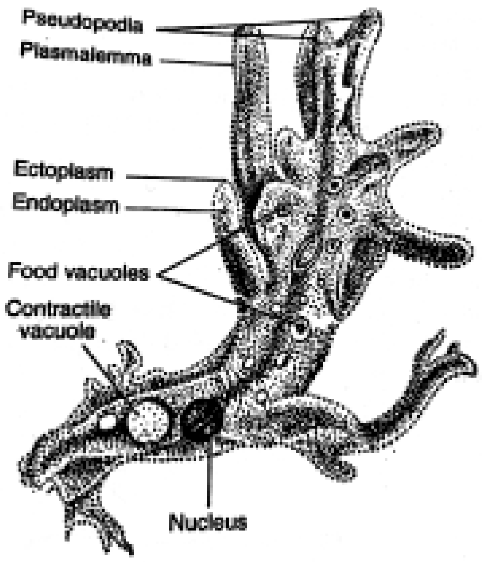

Fig. 11: *Amoeba proteus.* Note various structures like nucleus, food vacuoles, contractile vacuole and pseudopodia.

Structure.

External structure : The body resemble a tiny mass of irregular jelly and measures about 250 to 600μ (microns) in maximum diameter. To the naked eye, the larger *A. proteus* is just visible as a whitish blob. Under microscope it appears as an irregular, colourless and translucent mass of protoplasm, continuously changing its shape by sending out and withdrawing finger like processes, called pseudopodea.

The outer boundary of the body is a very thin elastic and selectively permeable **plasma membrame** or **plasmalemma**. The thickness of plasma membrane may be between 0.5 μm to 2 μm. Recently the existence of a very thin and flexible pellicle covering the plasmalemma has been reported. Plasma membrane retains the inner contents and is permeable to respiratory gases and water. It plays important role in pseudopodia formation and food capture.

Internal structure : Inside the plasmamembrane are placed the nucleus and cytoplasm. The nucleus is disc like and slightly biconcave and occupies no fixed position in the endoplams. Cytoplasm is differentiated into ectoplasm and endoplam. The ectoplasm is less extensive, gel in nature and non-granular, though under electron microscope it shows threads and particles. It is most clearly visible at the tip of the pseudopodia where it forms a hyaline cap. Ectoplasm is responsible for maintaining the shape and also protects the inner parts. Endoplasm is the matrix within which different organelles including nucleus remain suspended. The endoplasm exists in two colloidal states. The peripheral viscid part or **gel state** beneath the ectoplasm is termed **plasmagel** and the inner fluid part or **sol state** is termed **plasmasol**. The plasmagel forms a tube through which flows the plasmasol. Conversion of plasmasol to gel and back is important in the process of pseudopodia formation. Embedded in the endoplam are the following structures :

1. **Contractile Vacuole :** A single large and transparent contractile vacuole exist in the outer part of the endoplasm near the posterior end of the body. Many tiny vacuoles of water, called accessory vacuoles, appear in the vicinity of main vacuole. The main vacuole is also surrounded by many mitochondria. The main vacuole gradually increases in size, travel to the surface and ultimately bursts to release its contents in the surrounding water and disappears. A new contractile vacuole is formed again. Contractile vacuole is involved in osmoregulation, respiration and excretion.

2. **Food Vacuole :** One or more spherical non-contractile food vacuoles containing food particles and water are present at different phases of digestion.

3. **Water Vacuole or globule :** These are several small, spherical, non-contractile vacuoles filled with colourless fluid. They control the water balance of the body.
4. **Stored Food :** Numerous granules of stored food (fats and carbohydrates) are present.
5. **Mitochondria :** These are present in the form of rods or more or less oval shape with tubular cristae.
6. **Crystals :** Crystals of different sizes and shapes are seen within the body. These are probably metabolic wastes.

3.6 Locomotion in Amoeba

Amoeba exhibits characteristic **amoeboid movement** by the formation of temporary finger-like projections of the body, *the pseudopodia* or false feet (G. pseudo = false; podium = food). Since pseudopodia of *Amoeba* are broad with rounded or blunt tips like fingers (G. lobo = a lobe), they are called **lobopodia** which bear a distinctly clear ectoplasmic area, called the **hyaline cap** near each tip. *Amoeba* use their pseudopodia to move and to feed. During locomotion in *Amoeba proteus* one or more pseudopodia are formed at a time but only one grows, becomes larger and points in the direction of movement and others are gradually withdrawn.

In contrast to flagellar or ciliary movements of protozoa, amoeboid movement has additional complexities invilving streaming movement of protoplasm which result in change in the shape and position of the amoeba along with an non-linear and irregular movement (the amoeboid movement). Starting from the latter half of the nineteenth century to the middle of part of the twentieth century, several theories or hypotheses, have been proposed to explain the mechanism of amoeboid movement. Most of the theories have been discarded today due to lack of proper evidences. However **Change of Viscocity Theory** or **Sol-Gel Theory**, first put forwarded by Hyman (1917) and later supported by Pantin (1923-1926) and Mast (1925), is the most accepted theory of psuedopodia formation. Most observed the reversible changes of protoplasm in amoeba from **Sol** (abridged form of solution) and more precisely **plasmasol** to *gel* (abridged form of gelation) and more precisely **plasmagel**. Mast then proposed that amoeboid movement is brought about by four processes occuring simultaneously :

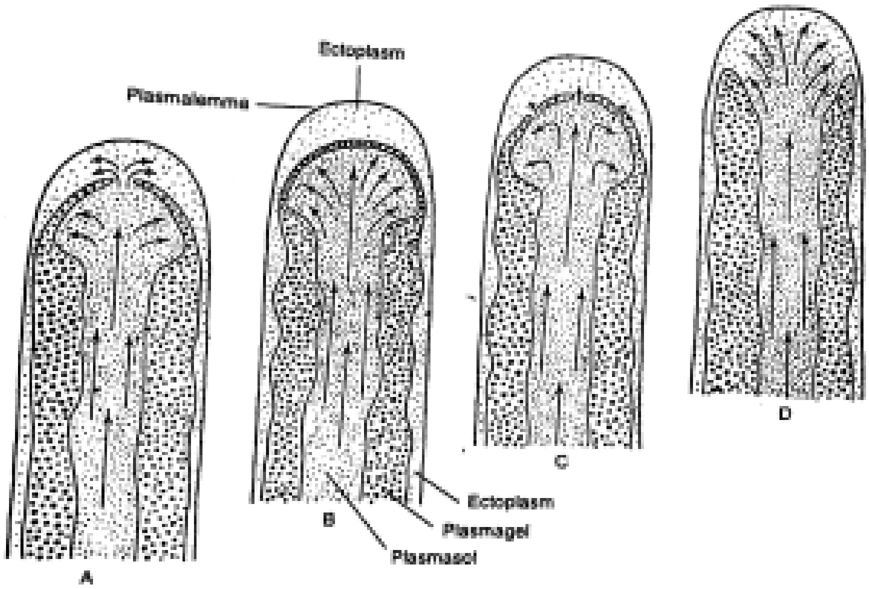

Fig. 12 : Figures illustrating the idea of Mast about the cytoplasmic flow during the formation of a pseudopodium in Amoeba proteus (after Kudo). Note that during the formation of a pseudopodium a hyaline cap appears. A. The plasmagel beneath the cap dissolves and plasmasol rushes through the gap. B. The plasmagel may persist as a thin layer. C. Break only at certain points. D. Dissolve completely.

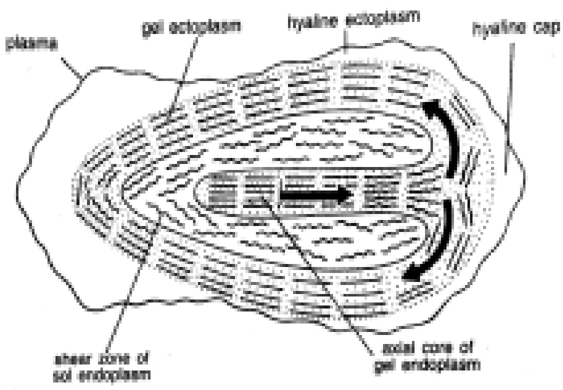

Fig. 13: Amoeboid movement on the basis of Allen's fountain zone contraction theory.

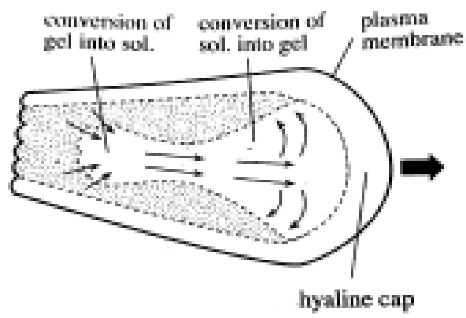

Fig. 14 : Conversion of sol and gel in Amoeba. Large solid arrow indicates the direction of movement.

(i) The outermost thin elastic cell membrane or plasmalemma becomes attached to the substratum.

(ii) A local and partial liquefaction of the plasmagel occurs at a point. This causes the central plasmasol, under tension, to flow forward and force the plasmagel against this weakened area to produce a bulge, the beginning of the psuedopodium. The pressure comes from osmotic and other forces. As plasmasol enters the newly formed pseudopodium, it rapidly changes into plasmagel around the periphery, thus forming a gelatinzed tube within which the plasmagel continues to flow forward.

(iii) At the posterior side gel or plasmagel is converted to plasmasol, so that a constant flow of plasmasol is maintained from behid forwards, in the direction of movement.

(iv) The outer tube of elastic plasmagel contracts at the posterior end to drive the plasmasol forward. As the plasmasol changes into plasmagel at the anterior end the plasmagel tube extends forward. The plasmagel thus exerts a squeezing motion from the sides and rear of amoeba, forcing the plasmalsol ahead. A thin plasmagel sheet persists in between the plasmalemma and plasmasol to prevent the plasmalsol reaching the plasmalemma through the hyaline cap. Sometimes this sheet breaks so that plasmasol streams through filling the hyaline cap, but soon the plasmasol gelates to form a new plasmagel sheet. Pseudopodia are formed because the plasmagel is elastic and under tension, it is pushed out where the elastic strength is lowest. During locomotion of *amoeba* the elastic strength of plasmagel is the highest at the sides, intermediate at the posterior end, and lowest at the anterior end. This results in the forward extension of the anterior end of the animal to bring about locomotion by psuedopodia.

Molecular basis of pseudopodia formation :

Though sol-gel theory proposed by Mast (1925) was accepted by many as a probable mechanism of a amoeboid movement but Mast himself could not explain the molecular basis of sol-gel reversion. He could not because molucular biology was little known at that time.

Molecular folding and unfolding theory propsed by Goldacre and Lorch (1950) provided a strong support to sol-gel theory and they have explained the molecular basis of solation and gelation. They propsed that the forces generated by the folding and unfolding of protein molecules are responsible for formation of psuedopodia and amoeboid movement. According to them all proteins gelate when their molecules unfold and solate when their molecules fold again. In otherwords,

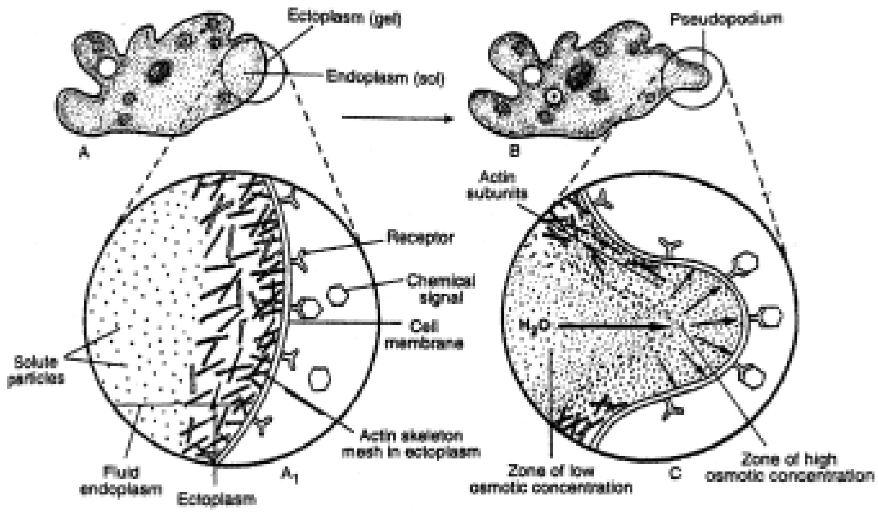

Fig. 15 : Diagrams showing the mechanism of pseudopod formation on the basis of Osmotic theory of amoeboid flow. A-A_1. Chemical signals attach to the receptors and initiate the depolymerization of the actin molecules. B-C. Osmotic concentration in the ectoplasm increases and water nows toward the periphery. Formation of pseudopodium due to the inflow of water (alter Ruppert and Bames).

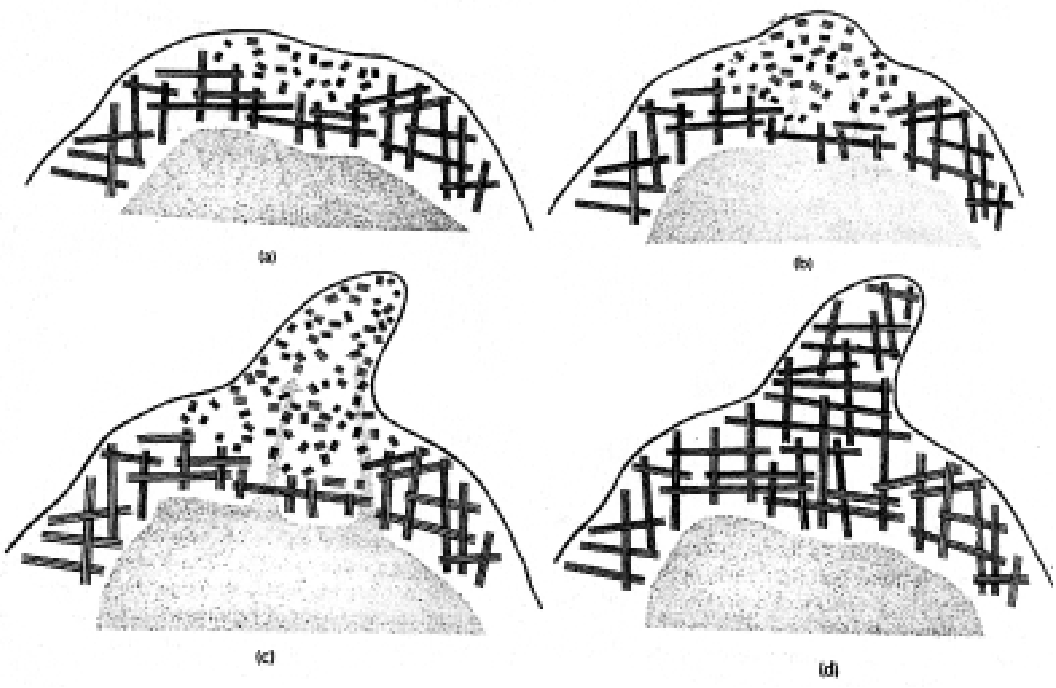

Fig. 16 : Hypothesized mechanism of pseudopod formation during amoeboid locomotion. (a) Localized breakdown of the actin network increases osmotic concentration in that part of the cytoplasm. (b) Fluid from the interior of the cell moves toward the periphery. along the osmotic gradient, forming a pseudopod 9c),. (d) Actin repolymerized, reforming a stablizing network of filaments. From T. P. Stossel, "how Cells Crowl" American Scientist, 78:408-23, 1990.

the sol state of protoplams is due to the folding of protein molecules and gel state is due to their unfolding. In the fluid endoplasm the protein molecules lie folded compactly i.e. remained at solution or sol state. At the tip of the advancing psuedopodium the protein molecules unfold i.e. they gelate to form a straightened and attached molcules. In the posterior part the protein molecules begin to fold again. This folding of protein molecules impart a contraction force. This contraction of force is confined towards the posterior end and forces the contracted protein molecules towards the anterior side. As amoeba moves, the plasmagel contracts at the posterior end, it changes into plasmasol (due to protein folding) which is forced through the central endoplasm to flow forward, and by gelation (due to protein unfolding) it forms the psuedopodium anteriorly. By analogy the psuedopodia formation can be compared with the squeezing of a tube of tooth paste to push out the paste. This squeezing can be compared with folding of the protein molecules to generate force which drives the paste (here plasmasol) to the front end where it forces out as a column of paste (here pseudopodium). For folding and unfolding of proteins a considerable amount of energy is requiered and it comes from ATP (adenosine triphosphate).

This theory appears to be satisfactory. In higher animals ATP supplies energy for muscle contraction. In this respect mechanism of pseudopodia formation and muscle contractions are to some extent similar. Quite recently, role of polymerization of action subunits (G-action) into action microfilaments (F-action) and vice-verse have been established for folding-unfolding or sol-gel theory (Karp, 1996).

View of Ruppert and Barnes (1994) on amoeboid movement :

"The theories of amoeboid movement accepted by most zoologists at present assume that cytoplasmic flow is related to the changes between the sol and gel states of the peripheral cytoplasm. The pseudopodial tip controls the change. As a result of some initial stimulus, the outer gelled ectoplasm become fluid at the, site where the pseudopod will form, and internal pressure causes the inner fluid endoplasm to flow out at this point, forming a pseudopodium. In the interior of the pseudopodium, the endoplasm flows forward along the line of progression. Around the periphery, endoplasm is converted to ectoplasm, thus building up and extending the sides of the pseudopodium like a well-starched sleeve. In the conversion of endoplasm to ectoplasm actin subunits polymerize (become longer) and bond to each other at more or less right angles, creating a mesh of filaments. It is this mesh that accounts for the rigid gelatinous state of ectoplasm. The small mesh size excludes organelles and thus accounts for the hyaline appearance. At the posterior end of the body, ectoplasm is converted to endoplasm by depolymerization. Cell membrane is also removed here, and new cell membrane is added at the psuedopodial tip.

The force for flow could be generated in one of the two ways. Bonding of myosin with the actin mesh could convert the mesh into a contractile jacket, forcing the fluid interior endoplasm forward. However, myosin has been different to demonstrate in ectoplasm. Alternatively, the initial depolymerization of the actin mesh at the pseudopodial tip would increase the number of particles (actin subunits), (Fig.). Particle increase would raise the osmotic concentration and would flow from the endoplasm out into the tip." [Invertebrate Zoology, E.E.Ruppert and R.D. Barnes (1994) Sixth Edition, pages. 42-44.]

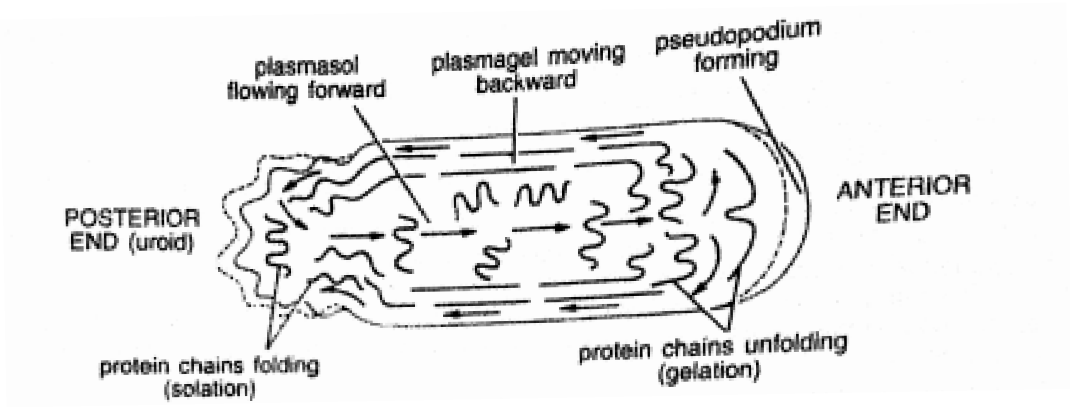

Fig. 17 : Molecular folding-unfolding during solation and gelation of cytoplasm for amoeboid movement.

View of J. A. Pechenixk (2000) on amoeboid movement :

"Amoebozoans use their psuedopodia to move and to feed. Typically, they flow into the advancing pseudopodium, a process called *cytoplasmic streaming*. The amoebozoan body is thus truely formless, lacking permanent anterior, posterior or lateral surfaces; pseudopodia can generally form at particularly any point on the body surface.The mechanism by which pseudopodia form and change shape is not certain, although it seems clear that movement involves a controlled transition of cytoplasm between the gelatinous, ectoplasmic form (*gel*) and the more fluid endoplasmic form (*sol*). The factors co-ordinating this transformation in different parts of the body are not fully understood, although the hypotheses have become wonderfully complex during the past decade. The transformation may involve the interaction of actin and myosin molecules, both abundant in amoeba cytoplasm. A model of sliding actin filaments has been proposed, in which actin and myosin interact in a way that resembles their interaction in the muscle tissue of multicellular

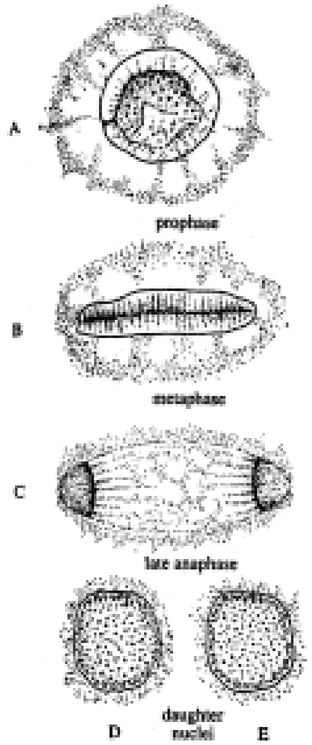

Fig. 18a: Changes in the nuclear apparatus during the binary fission of Amoeba.

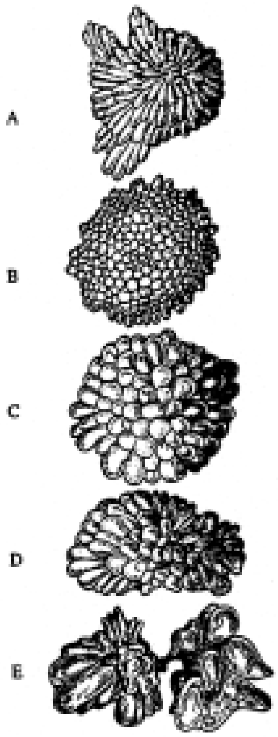

Fig. 18b: Morphological changes in Amoeba proteus during binary fission. A. In prophase. B. & C. In metaphase, D. In late anaphase, E. In telophase.

animals. Other hypotheses minimise the role of myosin in the gel-sol-gel transitions and instead emphasize the potential role of selective actin polymerization and depolymerization. In one model (Fig. 16), localized actin disassembly creates and area of increased osmotic pressure, which draws water from the more central region of the body to the periphery, forming a psuedopod. The actin is then repolymerized to form a bracing network, fixing the pseudopod's shape until the next bout of depolymerization. Whatever the mechanism, psuedopodial locomation is extremely slow, usually less than 300µm per minute." [Biology of the Invertebrates, Jan A. Pechenik (2000) Fourth Edition, pages. 53-54.]

3.7 Reproduction in Amoeba :

Amoeba proteus reproduces by asexual reproduction which takes place only by binary fission (Green et al. 1990). Other species of *Amoeba*, however, reproduce asexually by multiple fission, sporulation and cyst formation in addition to the common binary fission. Amoeba does not reproduce sexually by mating i.e. by the fusion of gametes.

1. Binary fission :

Binary fission is the most common mode of reproduction. *Amoeba* undergoes binary fission during favourable conditions of food and temperature. It results in the division of parent amoeba into two daughter amoebae. Binary fission is triggered either by the surface area to volume ratio, and/or the ratio between cytoplasmic volume and nuclear volume. Thus, when amoeba attains a maximum size i.e. 0.25 mm, it starts to reproduce. Just prior to binary fission amoeba becomes sluggish and spherical with its surface covered with small radially arranged pseudopodia. Contractile vacuole ceases to function and disappears. The division involves the nuclear division is *eumitotic* type, i.e. there is distinct chromosome formation but the presence of 500 to 600 chromosomes make the mitotic picture obscure. It has been shown that there is a definite correlation between the stages of nuclear division and external morphological changes (Fig. 18). During prophase the animal become round, studded with fine pseudopodia and in reflected light a well-defined hyaline area is seen at the cente. The hyaline area disappears in metaphase. The metaphase is marked by the arrangement of the chromosomes at the equator. During anaphase the psuedopodia become larger and irregilar in shape. The daughter chromosomes separate and move towards opposite poles. The nucleus first becomes dumbel shaped by a middle constriction and finally divides into two daughter nuclei. In telophase the body elongates, cleave furrow appears in the middle and finally divides into two daughter amoebae, each having a daughter nucleus. Gradually the pseudopodia return to normal structure. Under ideal conditions the whole process of binary fission can be completed within 30 minutes. Each daughter amoeba then proceeds to feed and grwo to maximum size.

2. Eucystment :

Encystment in *Amoeba proteus* has not yet been reported, though it is a very common feature in other amoeba.

In *Amoeba* encystment occurs for survival under unfavourable conditions, i.e. to tide over draught and extreme temperatures (extreme hot or cold). During encystment pseudopodia are withdrawn and the body becomes round. The food vacuoles are absorbed and the contractile vacuole disappears. The cytoplasm secretes a double-walled resist envelope arount the body. The cyst is a resting stage with exteremely slow metabolism. On return to favourable conditions, excystment occurs. Cyst breaks and the amoeba emerges out to lead an active life.

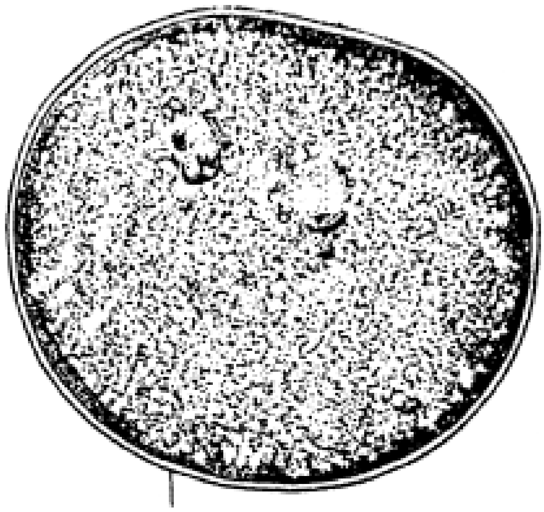

Fig. 19 : Encystment in Amoeba (after winchester). Although very common in other Amoebae. It rarely occurs in Amoeba proteus.

Now it is clear that the cyst in amoeba is protective in nature and not reproductive. Evidence in favour of amoeba undergoing nuclear division in encysted condition are rare. It is to be noted that one amoeba comes out of one cyst.

3.8 Nutrition in Amoeba

Amoeba is entirely heterotropic (the nutrition is holozoic). The food of *Amoeba* consists of algal cells and filaments, bacteria, other protozoans (smaller flagellates and ciliates), even smaller animals like rotifers and nematodes. The nutrition of Amoeba involves the following activities–

1. Ingestion : Amoeba lacks a mouth and food is ingested at any point of the body surface, but it is usually at the advancing anterior end. Food is captured by pseudopodia usually by the formation of a food cup. Ingested food along with some water occupies a vesicle, called food vacuole. According to the nature of food *Amoeba* empolys the following five methods of ingestion (Rhumbler 1930).

(i) Circumvallation : When an amoeba comes near an actively moving prey like a flagellate or ciliate, the bdoy part immediately in line with it stops moving and pseudopodia are formed above, below and on the sides of the food to form a food cup. The food cup does not touch the food but soon the edges of food cup fuse around the food to form a non-contractile food vacuole with some water within (Fig. 22).

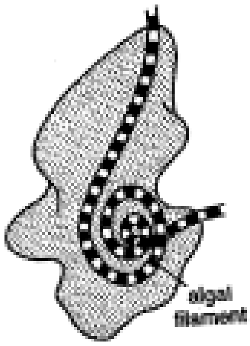

Fig. *Amoeba* ingesting an alga by import.

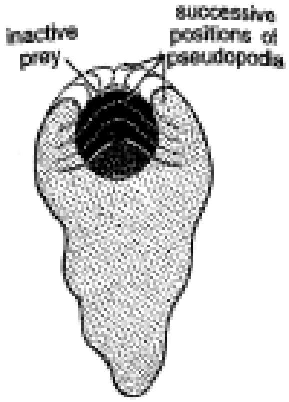

Fig. *Amoeba* feeding by circumfluence.

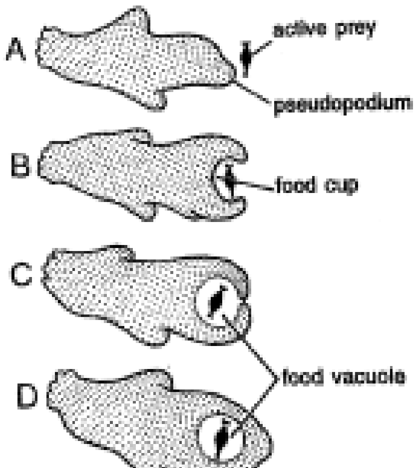

Fig. *Amoeba* ingesting a rotifer by circumvallation.

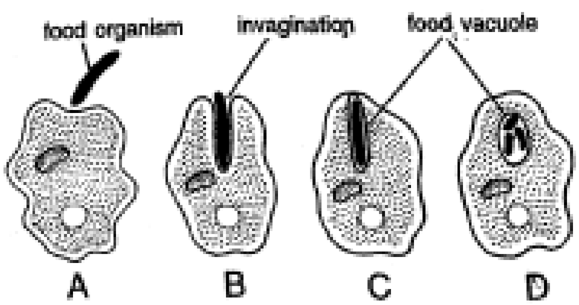

Fig. *Amoeba* ingesting food by invagination.

(ii) Circumfluence : When amoeba comes in contract with a less active or motionless organism like bacteria, the whole cytoplasm of amoeba flows around the food, encircling it into a food cup. Here the enveloping pseudopodia always maintain intimate contact with the surface of the prey.

(iii) Import : In *Amoeba verucosa* the food like algal filament when comes in contact of the animal passively sinks into the body just as a solid body sinks in a swamp (Fig. 20).

(iv) Invagination : In this method the prey is adhered by the toxic and sticky secretion of psuedopodia of amoeba (*Amoeba verrucosa*) and the plasma membrane invaginates at the point of contact forms an endoplasmic tube and the food is finally enclosed into a food vacuole.

(v) Pinocytosis : Pinocytosis (cell drinking) is the process of ingestion of liquid food material in bulk by the plasmamembrane. The process of pinocytosis was first observed by Mast and Doyle (1934) in *Amoeba proteus.* It is understood that plasmalemma along with colloidal food mateirla forms pinocytosis channels which run from surface deep into the endoplasm. The internal ends of the channels then form *pinocytosis vesicle* or *pinosomes* containing engulfed liquid food. The pinosomes then pinch off from the internal ends of pinocytic channels and sink into the endoplasm. It is yet to be confirmed whether pinocytosis is a normal means of ingestion in *Amoeba*.

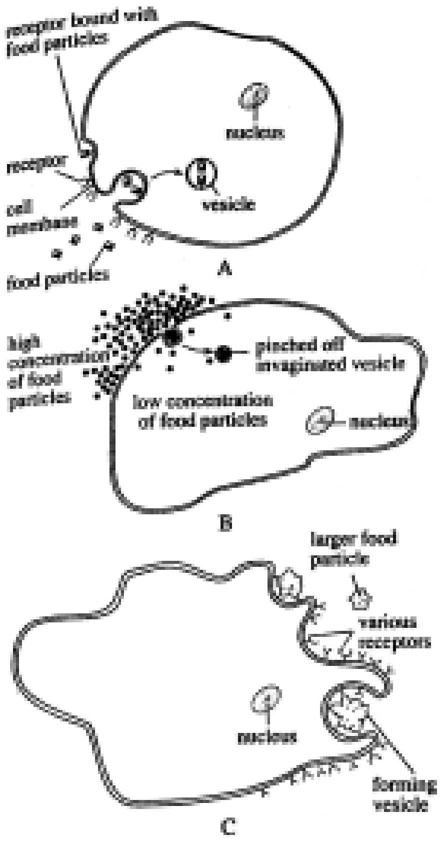

Fig. 24 : Different modes of food uptake in *Amoeba* by vesicles. A. Receptor-mediated endocytosis, B. Pinocytosis, C. Phagocytosis.

2. Digestion : Digestion takes place in the food vacuole by the help of lysosomal enzymes. The food vacuoles are analogous to the alimentary canal of higher animals except that digestion in food vacuoles is intracellular and that in alimentary canal is extracellular. Lysosomes containing digestive enzymes fuse with the food vacuoles and digestion of ingested food starts slowly. The presence of some enzymes such as proteases, amylases and lipases have been demostrated in *Amoeba*.

3. Absorption and assimilation : As digestion goes on, the food vacuoles gradually shrink in size. The food vacuoles keep on moving in the cytoplasm due to its streaming movement, called cyclosis. The digested simple food, water and minerals are absorbed by the surrounding endoplasm by simple process of diffusion and immediately get assimilated to build new protoplasm. Excess of digested food is stored as glycogen and lipid. Each food vacuole exists in cytoplasm for about 15 to 30 hours to complete digestion and assimilation.

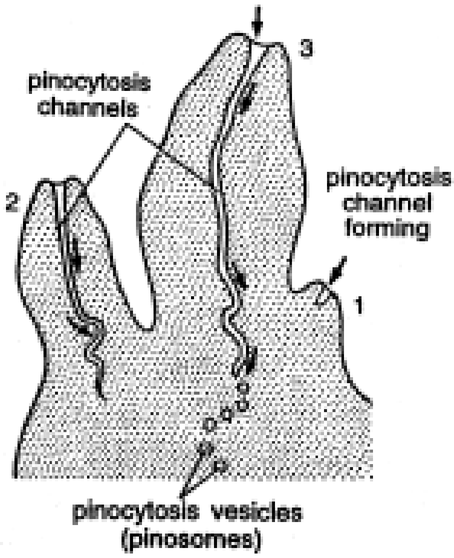

Fig. 25 : Pinocytosis in *Amoeba*.

4. Egestion : Egestion of undigested residue takes place at any point on the surface of the body. After its food contents are completely digested, a vacuole falls out of cyclosis and becomes stationary. It is simply left behind as the advancing body flows forwards (Fig. 27). As the plasma membrane of the temporary posterior end touches such a vacuole containing undigested food residue, it suddenly ruptures. Vacuolar membrane also simustaeously ruptures to allow exit of the vacuolar contents. There after, the plasmamembrane immediatly heals up to prevent any loss of cytoplasm.

3.9 Questions

? ? ? ?

3.10 Suggested Readings :

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Unit - 4 ❑ Porifera— General characteristics and Classification up to Classes : Canal system in Purifera.

Structure

4.1 Objectives

4.2 Introduction

4.3 General characteristics of Phytum Portifera

4.4 Classification of Phytum Purifera up to Classes

4.5 Canal system in Purifera

4.6 Questions

4.7 Suggested Readings

4.1 Objectives

By studying this unit learners would be able to understand about general characteristics and classification of phylum Porifera with examples. Learners will also know in detail about the canal system of phylum Porifera.

4.2 Introduction

The animals belonging to phylum Porifera are generally called the sponges. In the history of animal evolution, the sponges are regarded as the first step towards multicellularity. In otherwords, they are the most primitive of multicellular animals. The spones are distinct from the protozoans in having cellular grade of structural ortanization and from other metazoans in lacking the tissue grade of construction. Sponges have many unusal features, but the most obvious characteristic is the porous nature of the body, from which the name Porifera comes (L. porous = pore; ferre = to bear). Robert E. Grant (1836) studied the sponges quite extensively and gave the phylum name.

Sponges are aquatic, predominently marine animals (out of approximately 5000 described species of sponges only 200 species are adapted to freshwater). They occur most abundantly in shallow coastal waters, attached to the bottom or to sub-merged objects, but some groups, including most glass sponges, prefer deeper waters. Adult spongs are always attached and motionless.

4.3 General Characteristics of Phylum Porifera

1. Multicellular organisms with cellular grade of body organization without forming distinct tissues or organs.
2. All are aquatic, mostly marine, a few are freshwater (Family Spongillidae).
3. Solitary or colonial, all sessile in adult.
4. The body shape is variable–cylindrical, vase-like, tubular or branched, radially symmetrical or asymmetrical.
5. The body is perforated by a number of pores, hence the name of the phylum is Porifera (L. porous = pore; ferre = to bear).
6. Sponges posses a peculiar and vital system of passage ways and chambers through which water passes, called **Canal system**. Water enters the body through numerous small dermal or **incurrent pores**, **the ostia** and after circulating through the canal system passes out through one or more larger **excurrent pores**, the **oscula** (Singular **Osculum**).
7. The body wall with outer dermal epithelium **(pinacoderm)** inner gastral epithelium **(choanoderm)** and a non-cellular mesenchyme or **mesohyl** in between. The mesohyl consists of gelatinous proteinaceous matrix containing skeletal materials and free amoeboid cells. Sponges are **not diploblastic** as they lack true endoderm.
8. The skele ton is relatively complex and provides a supportive framework for living cells of the animal. The skeleton may be composed of clacarious spicules, siliceous spicules, protein spongin fibers or a combination of these. The spicules exist in a variety of forms and are important in identification and classification of species.
9. Sponges possess one or many internal cavities (spaces) lined by special **colared**, **flagellated cells**, the **Choanocytes**. These are most characteristic of sponge cells and also the most important of sponge cell types.
10. Digestion is entirly intracellular as in the Protozoa.
11. A functional nervous system with overall coordination is lacking.
12. Sponges are ammonotelic i.e. their chief excretory product is ammonia.
13. Gas exchange by diffusion.
14. Most sponges are monoecious (hermaphrodite) but dioeceous forms also exist. Reproduction occurs asexually by buds and gemmules and sexually by typical ova and sperms.

15. Fertilization internal but cross fertilization is the rule.
16. Cleavage is holoblastic and development is indirect through two types of free-swimming cliated larvae, the **amphiblastula** and **Parenchymula** (also called **Parenchymella**). Majority of the sponges possess the second type of larva.
17. Spongs possess great power of regeneration.

4.4 Classification of Phylum Porifera (upto class)

Opinions very regarding the classification of phylum Porifera. The classification is based almost entirely on microscopic skeletal structures, like nature and shape of spicules and presence or absence of spongin fibres. The classificaiton scheme followed here is based on Brusca and Brusca (2002) in their book "Invertebrate Zoology", 4th edition. Phylum Porifera includes three classes–**1. Class Calcarea, 2. Class Hexactinellida** and **3. Class Demospongiae**

1. Class : Calcarea or calcispongiae

Members of this class, known as calcareous spongs, are distinct in having spicules composed of calcuim carbonate (L. calcarius = limy; spongia = sponge) generally as **calcite**, although sometimes as **aragonite** (these are two distinct crystal forms of calcium carbonate). The class is also named as **Calcispongiae** (L. calcis = lime or chalk).

Characters :

1. Comparatively smaller in size, most are less than 10 cm in height, solitary or colonial.
2. Body shape is usually cylindrical or vase like but may be lamellate or massive type.
3. The osculum is narrow, terminal and provided, with oscular fringe.
4. All the spicules are of same size (not differentiated into megascleres and microscleres) and are usually separate. Spicules are **monaxons** or **tetraxons**. Tetraxon spicules loss one ray to become triradiate.
5. Spngin fibers are absent.
6. All three forms of body organization (or grades of structures) such as asconoid, syconoid and leuconoid, occur among calcarians).

7. Mostly dull coloured, although brilliant yellow, red and lavender species are known.

8. Exclusively marine, exist throughout the oceans of the world, but most are restricted to relatively shallow coastal waters.

Examples : *Leucosolenia, Clathrina* (asconoid sponge), *Grantia,* (*Scypha*) *Sycon* (*syconoid sponge*).

2. Class Hexactinellida or Hyalospongiae :

Representatives of this class are commonly known as **glass sponges**. The skeleton is of **siliceons spicules** (Sio_2) which are only **triaxon** with **six rays** (G. hex = six; actin = rays). Hence the name Hexactinellida. The class is also named **Triaxonida** due to the presence of triaxon spicules only. Furthermore, some of the spicules often are fused to form a skeleton that may be lattice-like and built of long, siliceous fibres that look like the loose fibreglass. Hence the class is also known as **Hyalospongiae** (G. hyalos = glass), and the members are called glass sponges.

Characters :

1. The glass sponges, as a whole, are the most symmetrical and most individualized of the sponges, that is, they show less tendency to form interconnecting clusters or large masses with many oscula.
2. The shape is usually cup, vase-, or urn like and the height varies from 10 to 30 cm. The colour of most sponges is pale.
3. The spongocoel is well developed and it opens through a wide osculum which is sometimes covered by a sieve-plate–a gratelike covering formed from fused siliceous spicules.
4. Dermal epithelium or pinacoderm is lacking.
5. The choanocyte cells (flagellated cells) are restricted to finger-like chambers.
6. Songin fibers are absent.
7. They are exclusively marine and occur chiefly in deeper waters of all seas and in the Antartic they are the dominant sponges.

Examples : *Euplectella* (Venus's flower basket), *Hyalonema* (glass rope sponge), *Pheronema* (bowl sponge)

3. **Class Demospongiae :** (G. demos = frame; spongos = sponges)

This largest class of phylem Porifera contains 90% of total sponge species and includes most of the common and familiar forms.

Characters :

1. Members of this class are highly organized, varying from small to large size and may be solitary or colonial.
2. The body is compact, often massive and brightly coloured. Shape is variable being rounded, oval, cup-like, funnel like or cushion like.

Fig. 1 : A few examples of Phylum Porifera (after Hyman). A. Laucosolenia, B. Oscarella, C. Hyalonema D. Craniella (A part removed to show inner radiating appearance). E. Poterion (Neptune's goblet). F. Euptectella (Venus's flower basket). G. Microciona. H. Spongilla (Freshwater sponge). 1. Haliclona. J. Halichondria (not drawn up to scale).

3. The skeleton is composed of siliceous spicules or spongin fibers or a combination of both or none i.e. skeletonless (Genus *Oscarella* is unique in lacking both spicules and spongin fibers).
4. The spicules are **monaxon** or **tetraxon**, never triaxons (hexactines).
5. The spicules (when present) may be divisible into large megascleres and smaller microscleres.
6. The canal system is complicated and of leuconoid type only.
7. Choanocyte cells are restricted to small, rounded flagellated chambers.
8. Most widely distributed sponges occuring from the tidal zone down to abyssal depths.

Examples : *Oscarella*, *Chondrilla* (chicken liver sponge), *Cliona* (boring sponge), *Plakina*, *Halichondria* (crumb-of-bread sponge), *Spongilla* (freshwater sponges), *Haliclona* (finger sponge), *Euspongia* (bath sponge), *Hippospongia* (horse sponge).

4.5 Canal System in Sponges

The passage through which water constantly flows from outside the body to the interior of the body and then outside again, collectively from the **canal system** in sponges. The structural complexities in sponges are primiarily due to possession of canal system. This system constitute the most vital system because all the cell types in sponges work on the background of this system and the entire physiolocgical activities of the animal depend on this canal system. Sponges bear a large number of pores (**Ostia**) on their body surface that lead into a system of channels permeating almost the whole body and ultimately open to the exterior through **osculum** or **oscula**. Canal system in sponges ranges from a very simple grade to highly complex type.Accordingly the system has been divided into three types :

1. **Asconoid or Ascon type**
2. **Syconoid or Sycon type**
3. **Leuconoid or Leucon type**

Asconoid Type :

The asconoid type is regarded as the simplest of all the types of canal system. This type is found in those sponges whose body is vase-like and radially symmetrical. The body wall is very thin enclosing a large central cavity, the **spongocoel**. The spongocoel opens at the free end by a narrow circular aperture, the **osculum**. The spongocoel is lined internally by flagellated collared cells or **choanocytes**, which from the choanoderm. The body wall of the sponge is pierced by numerous microscpic openings or porees, called the incurrent pores or **ostia** which extend from the external surface to the spongecoel. These pores are actully intracellular speces within tube-like cells, **the porocytes**. The asconoid type of canal system is characteized by the presence of a complete and continuous lining of choanocytes in the spongocoel, interrupted only by the porocytes (Fig. 2)

Surrounding sea water enters the canal system through the ostia. Flow of water is maintained by the beating of flagellae of the numerous choanocyte or collar cells within the spongocoel. The water finally leaves the spongocoel through the osculum.

The course of water is as follow :

Surrounding water → Ostia → Spongocoel → Osculum

Asconoid type of canal system is found in some adult calcareous asconoid sponges like *Leucosolenia*, *Clathrina*, and in olynthus stage in the development of all syconoid sponges.

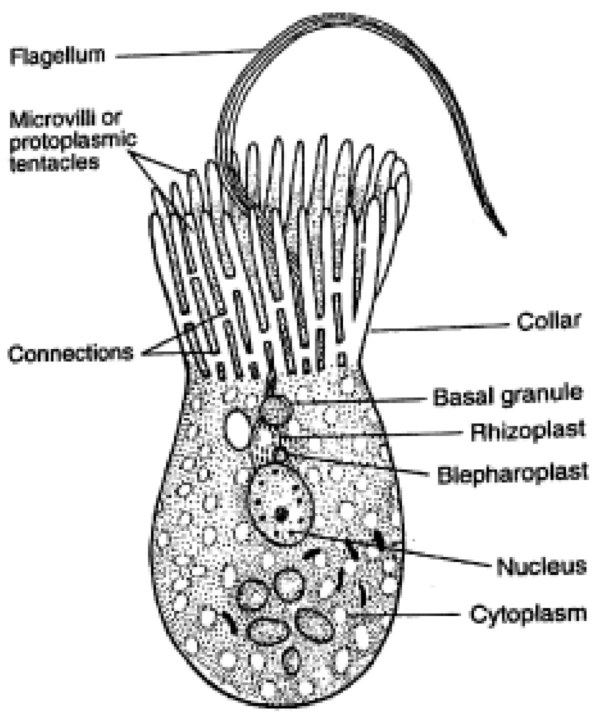

Fig. 2 : Structure of a choanocyte.

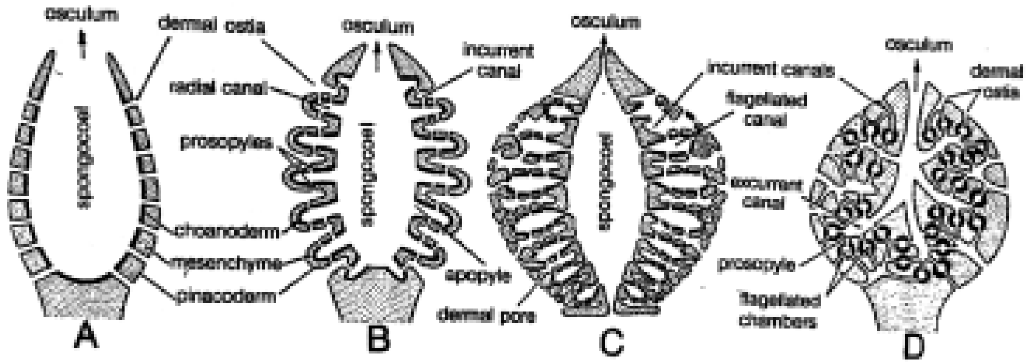

Fig. 3A: Canal system of sponges. A–Ascon type. B–Simple sycon type. C‘Complex syconoid type with cortex, D–Leucon type.

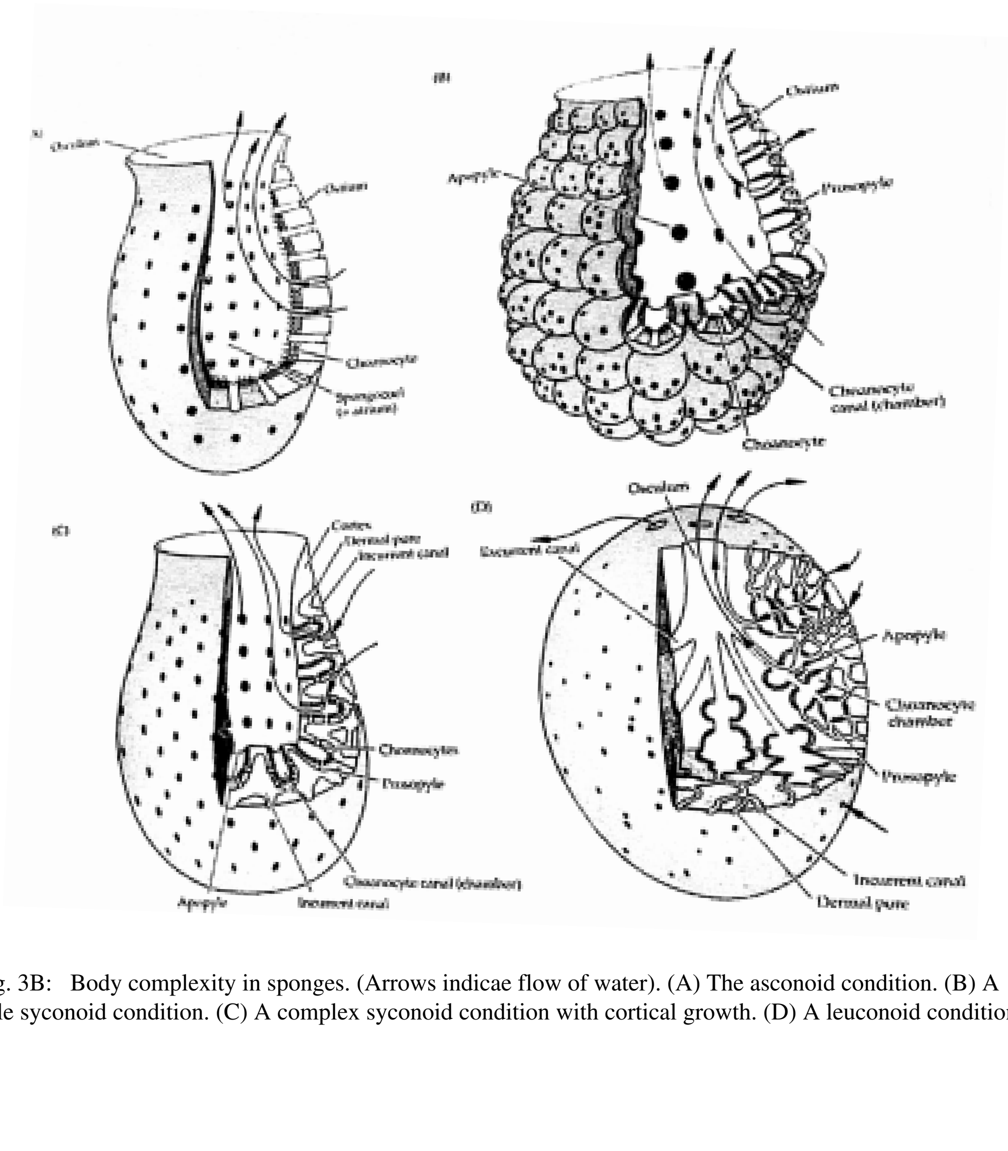

Fig. 3B: Body complexity in sponges. (Arrows indicae flow of water). (A) The asconoid condition. (B) A simple syconoid condition. (C) A complex syconoid condition with cortical growth. (D) A leuconoid condition.

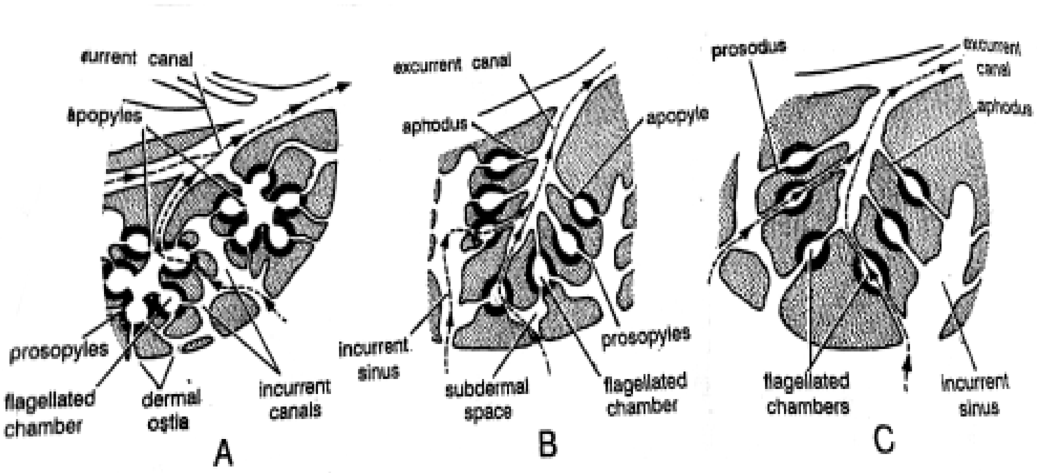

Fig. 3C : Grades in leucon type of canal system. A–Eurpylous. B–Aphodal type. C–Diplodal type.

Syconoid type :

In the canal system of sponges the syconoid type represents the transitional grade between the simplest asconoid type and more complex ones. Thus it is a step forward in the evolution of canal system. This type of canal system is formed by out pushing of the body wall at regular intervals into finger-like projections, called the **radial canals**. The radial canals being out pushings of the spongcoel are lined by flagellated collar cells or choanocytes. The radial canals are thus also called flagellated chambers.

Syconoid type canal system is represented by three grades—

(a) First grade or simple syconoid type

(b) Second grade or complex syconoid type

(c) Third grade or more complex syconoid type

First Grade :

In the simple type of syconoid canal system (first grade) the radial canals are simple out-pockeing of the spongocoel and are exposed directly to the surrounding water (outside water surround their whole length). The spaces between them are not organized into definite incurrent canals (as in higher grades), and the spaces may be

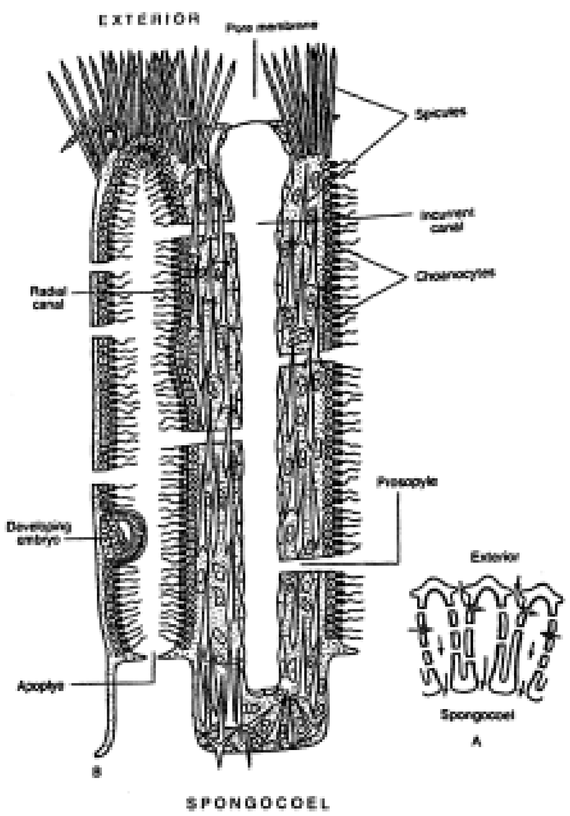

Fig. 4 : Sectional view of Sycon (Diagrammatic). A. A portion of the body to illustrate the arrangement of canals. B. Part of 'A' is magnified to show the histological details (after Parker & Haswell).

referred to as incurruent spaces (not as incurrent canals of higher grades). Here the course of water is as follows :

$$\begin{array}{ccccc} \text{Surrounding water} & \rightarrow & \text{Incurrent spaces} & \rightarrow & \text{Dermal ostia} \\ \downarrow & & & & \downarrow \\ \text{Osculum} & \leftarrow & \text{Spongocoel} & \leftarrow & \text{Radial canals} \end{array}$$

This simple type of syconoid canal system is found in a heterocoelous calcareous sponge named *Sycetta*. But most of the syconoid sponges do not have this type of canal system.

Second grade :

In the majority of the syconoid sponges the outpushings fuse by the increase in the amount of mesenchyme or mesohyl in a manner as to leave between the radial canals tubular spaces lined by pinacocytes. Such tubular spaces are called **incurrent canals** which open to the exterior between blind outer ends of the radial canals. The openings or apertures are termed **dermal ostia** or **dermal pores**, or **incurrent pores**. The radial canals and incurrent canals are arranged alternately. The wall between incurrent canal and radial canal is pierced by numerous minute pores, called **prosopyles** (G. pros = near; pyle = gate). The radial canal is lined by flagellated choanocytes, it opens into the spongecoel by an opening, called **apopyle** (G. apo = away from; pyle = gate). There may be a short passage connecting the radial canal with the spongocoel which is called **excurrent canal** (Fig. 3). Both excurrent canal and spongocoel are lined by flattened pinacocytes (endopinacocytes). The spongocoel is narrow tubular or cylindrical and it opens to the exterior through osculum. The course of water current is as follows :

Surrounding water → Dermal ostia → In current canals
↑ ↓
Osculum presopyles
↑ ↓
Spongocoel ← Excurrent canals ← Apopyles ← Radial canals

This type of canal system is seen in *Sycon* (*Scypha*).

Third grade :

The third grade of syconoid canal system is foung in many genera of Calcareous sponges like *Grantia*, *Grantiopsis*, *Heteropia*, etc. The complecation is due to further addition of mesenchyme (mesohyl) to form a thick dermal cortex which spread over the entire outer surface of body. The incurrent canals become narrowed and traverse along irregular courses through the cortex before reaching the flagellated radial canals and connect with the latter by prosopyles. Sometimes large irregular cortical spaces of **subdermal spaces** are developed.

The course of water is as follows :

Surrounding water → Dermal osita → Dermal spaces → Incurrent canals
↑ ↓
Osculum
Prosopyles
↑ ↓
Spongocoel ← Excurrent canals ← Apopyles ← Radial canal

Leuconoid type :

The most complex type of canal system in sponges is the leuconoid type. This type of canal system is characterized by–(a) folding and outpocketing of radial

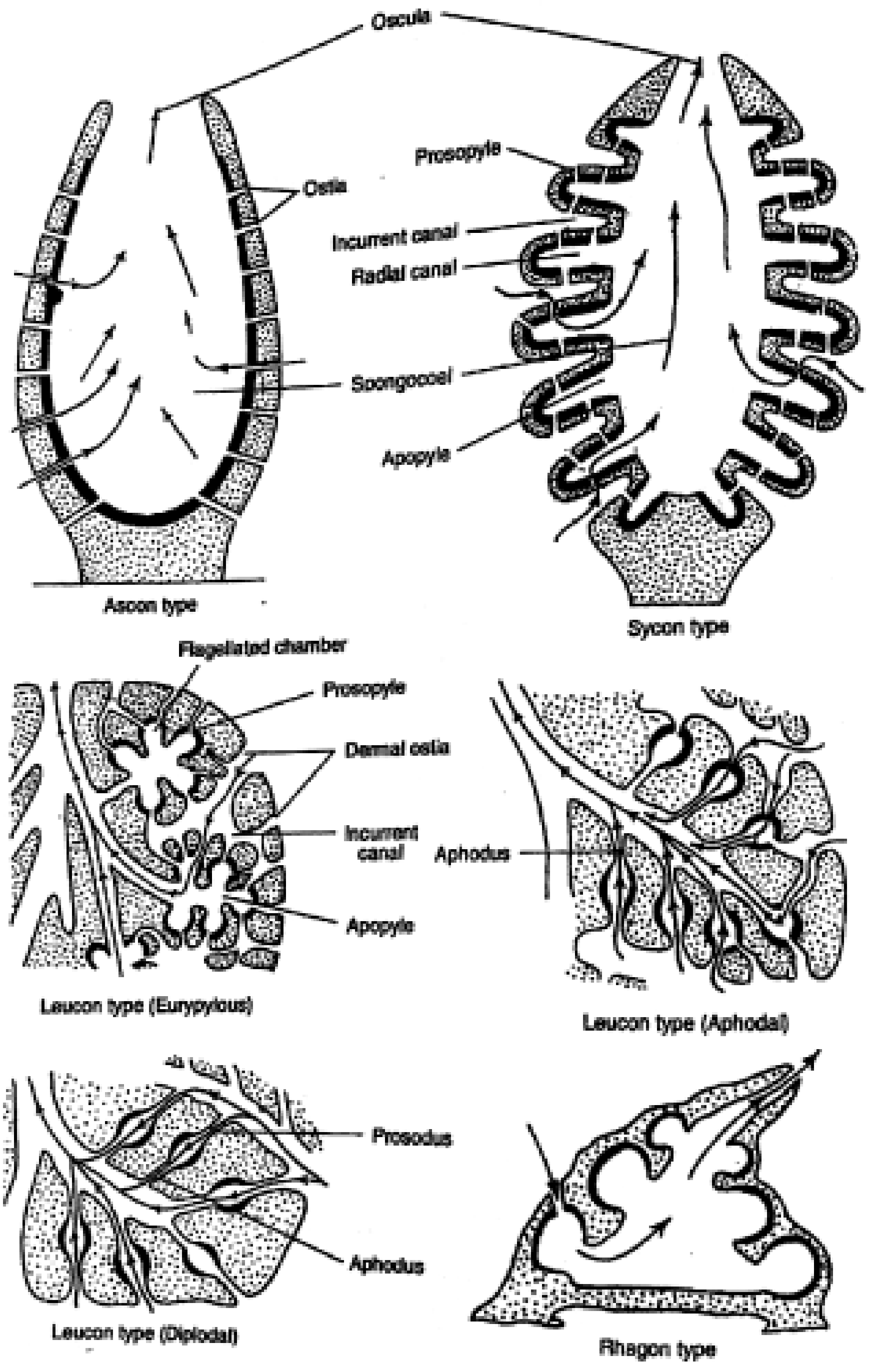

Fig. 5 : Sohematic representation of cnal system in sponges. The sycon type of canal system drawn here actually represents the syconoid (Stage 1) type. Dark bands indicate choanocyte layers nd arrows denote the course of water flow (after Hyman)

canals to maximum extent to form clusters of small and round or oval flagellated chambers or choanocyte chambers (as the choanocytes are limited to these chambers), (b) a very thick wall, thickness being increased by enormous development of mesenchyme or mesohyl forming dermal and gastral cortex, (c) a narrow or completely obliterated spongocoel and (d) complexity of incurrent and excurrent canals and flowing out of water through several oscula.

In leuconoid sponges the cortex contains a system of branching incurrent canals. In many cases dermal pores open into subdermal spaces. The subdermal spaces and incurrent canals deliver water to the choanocyte chambers by way of small pores, the **prosopyles**. The flagellated chambers, in their turn, communicate with the excurrent canals through **apopyles**. Smaller excurrent canals unite to form larger ones, all eventually unite to form a major excurrent canal through which water reaches to osculum or osucula.

The leuconoid type of canal system exhibits following three evolutionary gradations :

(i) **Eurypylous type**; (ii) **Aphodal type**; (iii) **Diplodal type**

(i) Eurypylous type : It represents the simplest type of leuconoid canal system and occurs in *Leucilla* and *Plakina*. It may be regarded as an intermediate condition called *sylleibid stage* between the syconoid and the more complex leuconoid. In euryphylous canal system the flagellated chambers are thimble shaped and open to the excurrent canal directly through wide apopyles (Fig.).

(ii) Aphodal type : In certain leuconoid sponges such as *Geodia*, *Stelleta*, the flagellated chambers do not open into the excurrent canal directly. The apopyles, instead of being wide opeings, are drawn out as narrow tubes, called *aphodus* which connect the flagellated chambers to the excurrent canals (Fig. 3)

(iii) Diplodal type : In some sponges like *Spongilla*, *Oscarella*, besides the aphodus another narrow tube, called *prosodus*, is present between each incurrent canal and flagellated chambers. Thus here both apopyles and prosopyles are drawn out into narrow tubes (Fig. 3, 4, 5)

The course of water is as follows :

Dermal ostia → Subdernal spaces and many in current canals → Prosodus (when present) → Flagellated chambers
↑ (Dermal ostia) … ↓ (Flagellated chambers)
Surrounding water … Apophyles
↑ … ↓
Osculum (Oscula) ← Large excurrent canals ← Many excurrent canals ← Aphodus (when present)

Rhagon type canal system : In Demospongiae (e.g. *Spongilla*), the existing leuconoid type canal system is not derived by way of asconoid or syconoid stages as are evident in calcareous sponges. Instead the leuconoid structure is derived from a larval stage **rhagon** whose canal system is rhagon type.

The sponge with rhagon type canal system has a flat broad base and it is conical in shape (looks like a pyramid) with a single osculum at the summit. The basal wall is termed **hyposphere** which is devoid of flagellated chambers. The upper wall with many small, oval flagellated chambers, is called **sphongosphere**. The spacions spongocoel of rhagon is surrounded by the flagellated chambers opeing into it through very wide apopyles. Between the flagellated chambers and the pinacoderm lies a

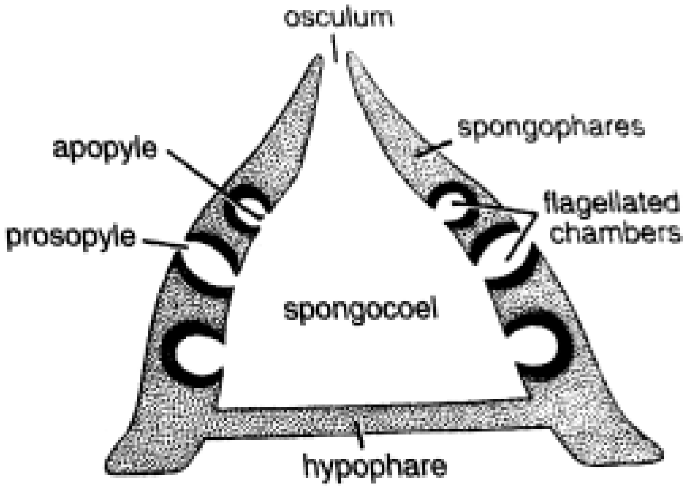

Fig. 6: Rhagon Larva. V. S. of body showing rhagon type canal system.

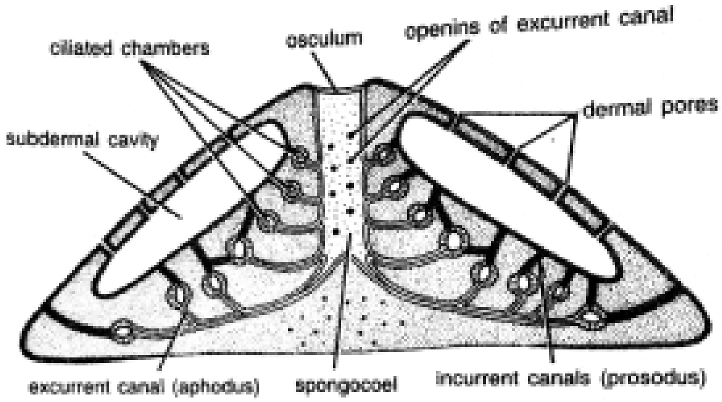

Fig. 7 : *Spongilla.* Diagrammatic V.S. of body showing rhagon type of canal system.

considerably thickened mesenchyle (mesohyl) which is traversed by incurrent canals and subdermal spaces (Fig. 5 & 6).

Functions of canal system : Canal system plays a very important or vital role in the life of sponges. All the vital physiological processes like nutrition, respiration, exeretion and reproduction are performed by this single system. The beating of flagellae of choanocyte cells create water current which flows through the canal system and brings the food and oxygen and takes away the CO_2, nitrogenous wastes and undigested food. During reproduction the water current carries the sperms from one sponge to another for fertilization of the ova.

4.8 Questions

? ? ? ?

4.9 Suggested Readings :

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Unit - 5 ❑ Cnidaria & Ctenophora– General Characteristics and Classification up to Classes : Polymorphism in Cnidarians.

Structure

5.1 Objectives
5.2 Introduction
5.3 General characteristics of Phytum Cnidaria
5.4 Classification of Phylum Cnidaria up to Classes
5.5 Polymorphism in enidarians.
5.6 General Characteristics of Phylum Ctenophora
5.7 Classification of Phylum Ctenophora up to Classes
5.8 Questions
5.9 Suggested Readings

5.1 Objectives

By studying this unit learners would be able to understand about general characteristics and classification of phylum Cnidaria and phylum Ctenophora with examples. They also learn about different types of polymorphism in cnidarians.

5.2 Introduction

The phylum Cnidaria is a diverse group with cosmopolitan distribution. It includes familiar hydras, transparent jelly fishes, beautiful and bright coloured sea annemones, and a variety of corals. While the poriferans or sponges are regarded as first group of multicellular animals, the cnidarians are definitely one more step advanced groups in having tissue grade of structural organization, i.e. tissue grade of construction first appeared in Cnidaria among the metazoans.

The members of phylum ctenophora are a small group of free-swimming, planktonic marine animals with transparent, delicate, gelatinous bodies. In the history of metazoan evolution, the ctenophores stand a step ahead of the cnidarians by having a low grade of triploblastic construction. They are commonly known as sea walnuts or comb jellies (Gr. Ktenes = combs; ophora = bearing). They are abundant in coastal water.

5.3 General Characteristics of Cnidaria :

1. Cnidarians are multicellular animals with tissue grade of organization.
2. They are aquatic, mostly marine except a few freshwater forms.
3. They are sessile or free swimming and solitary or colonial.
4. Body radially symmetrical, some are biradial.
5. Cnidarians are diploblastic with outer **epidermis** (developed from embryonic ectoderm) and inner **gastrodermis** (developed from embryonic endoderm) separated by a non-celllular jelly-like layer called **mesoglea** or partly cellular **mesenchyme** derived primarily from ectoderm.
6. The body wall encloses a single, central, blind sac-like body cavity lined by the endoderm, called **gastrovascular cavity** or **coelenteron**, with the mouth as the only opening. Mouth is encircled by short and slender tentacles arranged in one or more whorls. Mouth also functions as anus.
7. Presence of highly specialized intra-cellular structures–the **cnidoblasts** (or **nematoblasts**) containing stinging organelles called **namatocysts** or **cnidae**. Cnidoblasts are located in epidermis specially in tentacles. Cnidoblasts are unique to the members of the phylum and the phylum name Cnidaria has been cointed for them. They serve for defence, offence, food capture and adhension.
8. Cnidarians are carnivorous, digestion is both intracellular and extracellular.
9. Respiratory, circulatory and excretory organs are absent. Gas exchange is performed by diffusion.
10. Nervous stystem is of primitive type consisting of diffused network of unpolarized nerve cells.
11. In cnidaria two different body forms may exist–a **“medusa”** (representing sexual phase) adapted for pelagic existence and a **“polyp”** (asexual phase) adapted for benthic existence.
12. Reproduction by both asexual and sexual modes. Asexual reproduction by budding and sexual reproduction by the formation of ova and sperm. Development often involves a bilaterally symmetrical ciliated “planula” larva.
13. In some forms life cycle exhibits the phenomena of **metagenesis** in which the asexual polypoid, sessile generation alternates with sexual medusoid, free swimming generation, both being diploid phases.

5.4 Classification of Cnidaria

The classification scheme followed here is based on the scheme outlined by Ruppert and Barnes (1994) in their book **"Invertebrate Zoology"** (6th edition). According to them the phylum Cnidaria includes **four classes—**

Class Hydrozoa **Class Scyphozoa** **Class Cubozoa** **Class Anthozoa**

Classification with characters (upto classes)

Class Hydrozoa :

1. Exclusively polyploid or exclusively medusoid or both forms in the life cycle.

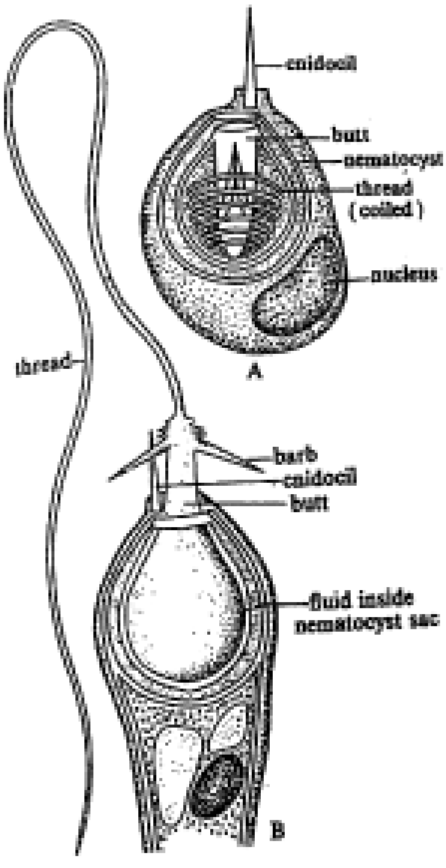

Fig. 11 : Detail structure of cnidoblast of *Hydra*.
A. Undischarged, B. Discharged.

2. Mesoglea acellular or non-cellualr and jelly like.
3. Gastrovascular cavity without stomodium, septa or nematocysts bearing gastric filaments.
4. Namatocysts are confined to the epidermis only.
5. Medusa with a true muscular velum which improves swimming efficiency.
6. Reproductive cells usually ectodermal in origin and discharged to the exterior directly.
7. Metagenesis distinct.
8. Mostly colonial and marine, a few solitary and freshwater.
9. Phenomonon of polymorphism is common.

Class Hydrozoa includes about 3000 species.

Exmaples : *Hydra*, *Obelia*, *Physalia*, *Valella*, *Porpita*

Class Scyphozoa :

1. Medusoid form is dominant in the life cycle; polypoid form is very insignificant. Medusa is bell or umbrella-shaped.

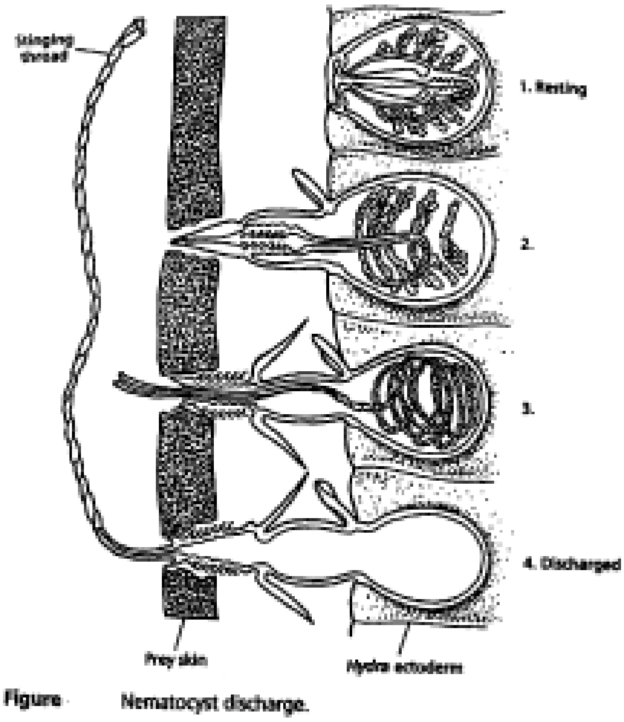

Fig. 12 : Nematocyst discharge.

Fig. 13 : Some Important Cnidarians.
(a) *Protohydra,* (b) *Stylaster,* (c) *Millepora,* (d) *Clavularia,* (c) *Clytia,* (f) *Cerianthus,* (g) *Anthomustus,* (h) *Gorgonia,* (i)*Telesto,* (j) *Praya,* (k) *Acropora,* (l) *Nausuthar,* (m) *Corallium,* (n) *Hydra,* (o) *Velella,* (p) *Physalia,* (q) *Pennatulla,* (r) *Taelia,* (s) D*urelia,* (t) *Fungia*

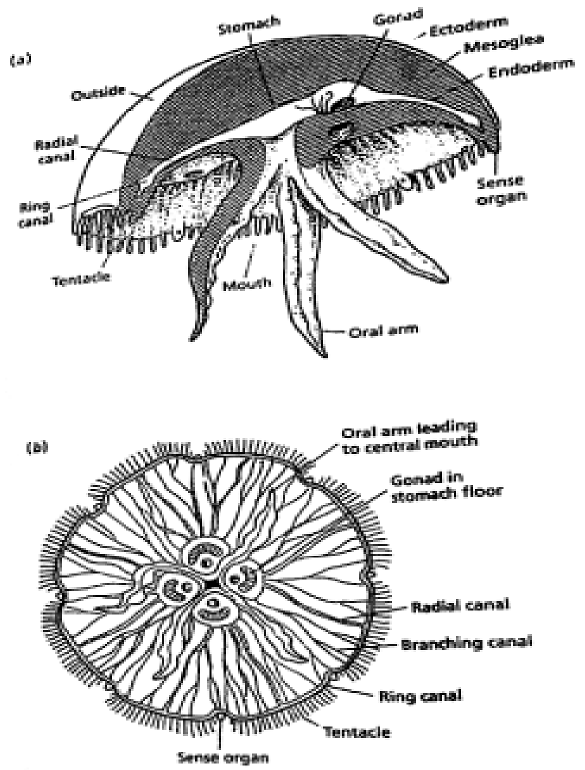

Figure 14 : The structure of a jellyfish (scyphozoan): (*a*) side view, with shaded part in section; (*b*) oral view.

2. Mesoglea is cellular and thick.
3. Endodermal gastric tentacles are present.
4. Nematocyst containing cnidoblast cells are found both in the epidermis and gastrodermis.
5. Gastrovascular cavity without stomodium but with endodermal gastric filaments or tentacles.
6. Velum absent.
7. Sense organs usually in the form of tentaculocysts.
8. Gonads are endodermal in origin and gametes are shed in the gastrovascular cavity.
9. Polypoid stage usually absent or represented by small polyp, the scyphistoma which gives rise to medusae by transverse fission or *strobilization*.
10. All are marine, solitary, free swimming or attached by aboral stalk. The class Scyphozoa includes about 200 species.

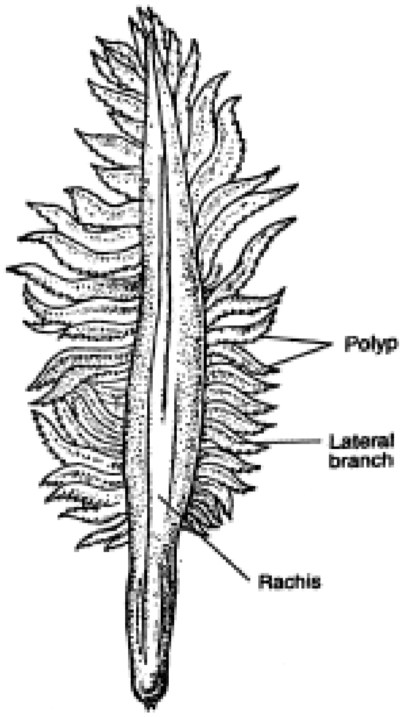

Fig. 15 : Sea-pen (*Pennatula*)—a typical example of Octocorallia.

Examples : ***Aurelia*** (Moon jelly), ***Pilema***, ***Pericolpa***, ***Cyanea***

Class Cubozoa :

1. Small medusoid cnidarians with a highly transparent cuboidal swimming bell.
2. Bell margin simple.
3. Presence of velum along the margin of the medusa.
4. There are four tentacles or four clusters of tentacles at four corners of the bell margin.

The class cubozoa includes about 20 species. The members are known as sea wasps or box jellies.

Examples : ***Tripedalia***, ***Chrybdaea***, ***Chironex***, ***Chiropsalmus***

Chironex fleckeri (sea wasp) is found in the coastal waters of Australia. It is considered one of the most deadly of all marine animals. Death takes place within 3 to 20 minutes of stinging.

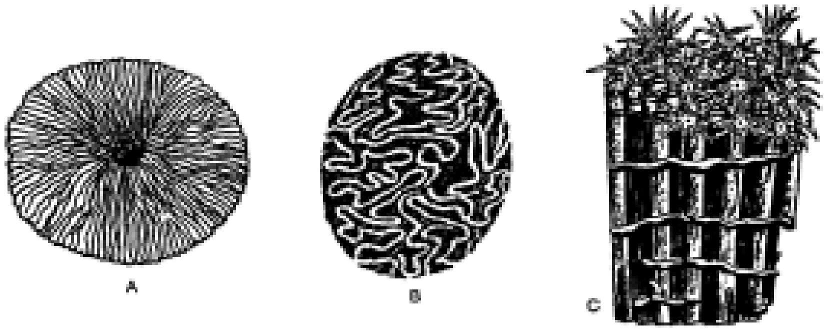

Fig. 16: Different tyhpes of Anthozoan Corals. (After Kaestner). A. *Fungia* (Mushroom coral). B. *Meandrina* (Brain coral). C. *Tubipora* (organ Pipe coral).

Class Anthozoa or Actinozoa :

1. Exist only in polypoid form, medusa phase is absent.
2. Body cylindrical with hexamerous or octamerous biradial or radiobilaterial symmetry.
3. Mesoglea cellular with fibrous connective tissue and amoeboid cells.
4. **Stomodaeum** strongly developed and posses **siphonoglyphs** (ciliated grooves in the stomodaeum).
5. The oral end of the body is expanded radially into an oral disc bearing hollow tentacles surrouding the mouth in the centre.
6. Gastrovascular cavity is divided into compartments by complete or incomplete septa or mesenteries.
7. Mesenteries bear nematocysts at their free inner edges (gastrodermal or endodermal)
8. Skeleton either external or internal. Exoskelton may be of calcium carbonate which often forms massive corals.
9. Gonads are gastrodermal (endodermal) in origin and develop in the mesenteries.
10. Gametes are discharged into coelenteron, fertilization external.
11. The fertilized eggs develop into a planula larva that metamorphoses to form the polyp.
12. Members are solitary or colonial, mostly colonial, exclusively marine.

Class Anthozoa is the largest class of Phylum Cnidaria. It includes about 6000 species of sea anemones, corals, sea fans, sea pens, etc.

Examples : ***Adamsia***, ***Metridium*** (both are sea anemones), ***Gorgonia*** (sea fan), ***Pennatula*** (sea-pen), **Tubipora** (organ-pipe coral), ***Corallium*** (red coral).

5.5 Polymorphism in Cnidaria

Polymorphism (Gr. poly = many; morphe = form) is the occurance of different types of individuals or zooids in a single species during its life cycle. It may be defined as the "phenomenon of existence of different physiological and morphological forms represented by an extensive range of variation within a single species." In polymorphism the different forms or zooids perform different functions so that there is a division of labour amongst the zooids. Amongst the cnidarians, the representatives of the class Hydrozoa provides good examples of polymorphism.

Two basic forms : In Hydrozoa (or Cnidaria), which may be solitary or colonial, there occur two main types of forms or individuals or zooids–**polyp form** and **medusoid form**

1. Polyp form : A polyp has a tubular body with a mouth opening surruounded by tentacles at one end and the other end is blind and usually atached to the substratum by a pedal disc.

2. Medusoid form : A medusa has a bowl or umbrella-shaped body with convex **exumbrellar** and concave **subumbrellar** surfaces. Subumbrellar surface with centrally located mouth on a porjection (manubrium). Medusa bears marginal tentacles.

Polyp performs vegatative or nutritive functions while the free swimming medusa are reproductive in nature. Polyps and medusae are considered as homologous

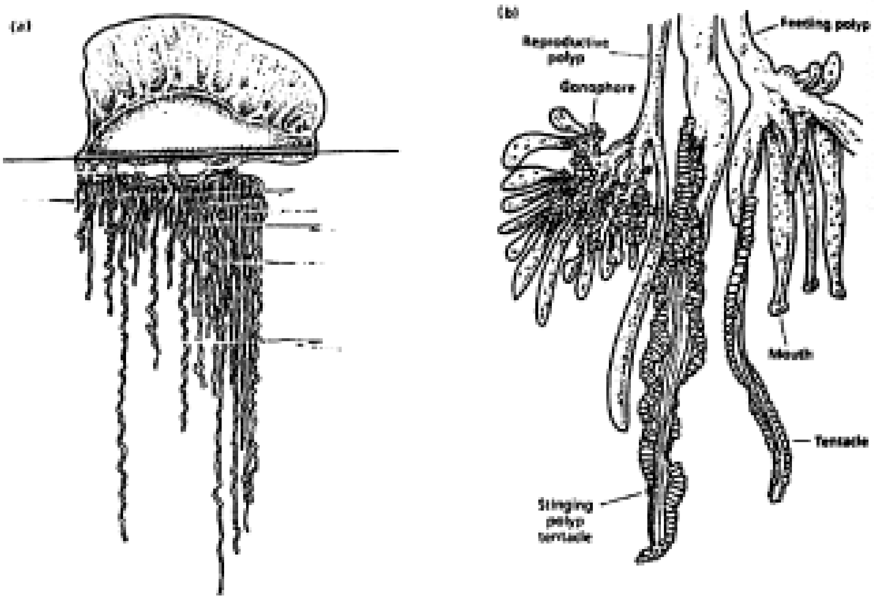

Fig. 20: (a) *Physalia,* the portuguese man-of-war, a siphonophore; (b) part of a *Physalia* colony showing the division of labour between individuals.

structures. These two forms alternate with each other in the history of a typical cnidarian–the polyp produces medusa asexually and the medusa producces polyp sexually.

Polymorphic variabilities : Polyp and medusa occur in a number of morphological variations, several of which may be found in a single species. In the class ***Hydrozoa*** both polypoid and medusoid forms occur; in the class ***Scyphozoa*** the medusoid form is predominent while in the class **Actinozoa**, zooids are exclusively polypoid. Extreme specialization and variation of forms is exhibited by the members of the order ***Siphonophora*** (Fig. 21) and suborder ***Chondrophora*** of the class **Hydrozoa**. Their colonies exhibit the highest degree of polymorphism, which is not found anywhere else in the animal kingdom.

Modifications of polypoid form.

The polypoid zooids are as follows :

1. **Gastrozoooids or Trophozoids** or **Nutritive zooids :** These are tubular or cylindrical zooid with a mouth and a long contractile hollow tentacle arising at or near the base. Tentacle bears lateral fine contractile branches called **tentilla**.Each tentilla terminates in a knob or coil of nematocysts. Gastrozooids are also called siphonozooids.
2. **Dactylozooids or Tasters or Feelers :** These zooids are actually derived from the gastrozooids by reduction or total loss of mouth. They are elongated and highly extensible usually with a long unbranched basal tentacle. They are protective zooids as they bear many nematocysts. They exhibit many

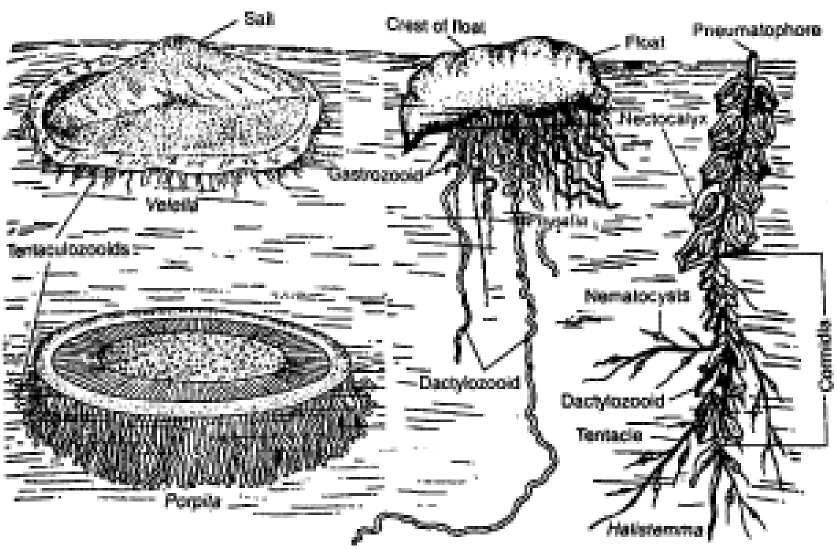

Fig. 21: A few representatives of the order Siphonophora

structural variations and are also called **tentaculozooids**, **palpons**, **testers** or **feelers**. Modified dactylozooids associated with genophores of gonozooids are termed **gonopalpons**. In *Vallela* and *Porpita* the dactylozooids arise from the margin of the colony in the form of long, hollow tentacle like fringing bodies (tentaculozooids). In *Physalia* the dactylozooids are excessively long.

3. ***Gonozooids* or *Blastostyles* or *Gonangia* :** These are reproductive zooids of the colony. They have club-shaped bodies without mouth and tentacles. Gonozooids give rise to male and female medusa buds, called gonophores, by budding. The living tissue of gonozooid is called **blastostyle** (Fig.) They are enclosed by gonotheca. In *Physalia*, gonozooids take the form of branched stalks, called **gonodendra** and bear grape like clusters of gonophores or medusae. Gonodendra are usually provided with a long retractile **gonopalpon**. In *Valella* and *Porpita* (Fig. 22) the gonozooids resemble gastrozooids and may even possess a mouth.

Modifications of Medusoid form :

The medusoid individuals exist in following forms :

1. **Nectophora or Nectocalyx or Swimming bell :** These are bell-shaped medusoids with a velum and radial canals and circular canal. They have no mouth, manubrium, tentales and sense organs. A nectocalyx is muscular and brings about locomotion of the colony by swimming. This form is present in Siphonophora except *Physalia*.
2. **Bracts or Hydrophyllium or Phyllozooid :** These forms do not resemble the medusa, though they are actually medusoid in origin. They have thick gelatinous shield-like, leaf-like, helmet-shaped or prismatic appeaance. The gastrovascular catity is simple or branched. Bracts are studded with nematocytes, serving for protection of other zooids of the colony, as found in Siphonophora.
3. **Pneumatophore or Float :** These are bladder-like or vesicle-like structures filled with gas. Each pneumatophore represents an inverted medusa bed; it is devoid of mesoglea and consist of an outer (exumbrellar) wall called *pneumatocodon* and an inner (subumbrellar) wall called *pneumatosaccus* or *air sac*. The opeing of the air-sac is directed upwards and reduced to a small pore, the *pneumatopore* which is guarded by a sphincter muscle. At the bottom (orginal roof) of the air sac, the epidermis is modified into a *gas gland* that secretes gas having composition similar to that of air. The air sac or float keeps the colony affloat. Float shows great variation in its structure and size in different siphonophores (*Physalia*, *Halistemma*, *Agalma*).

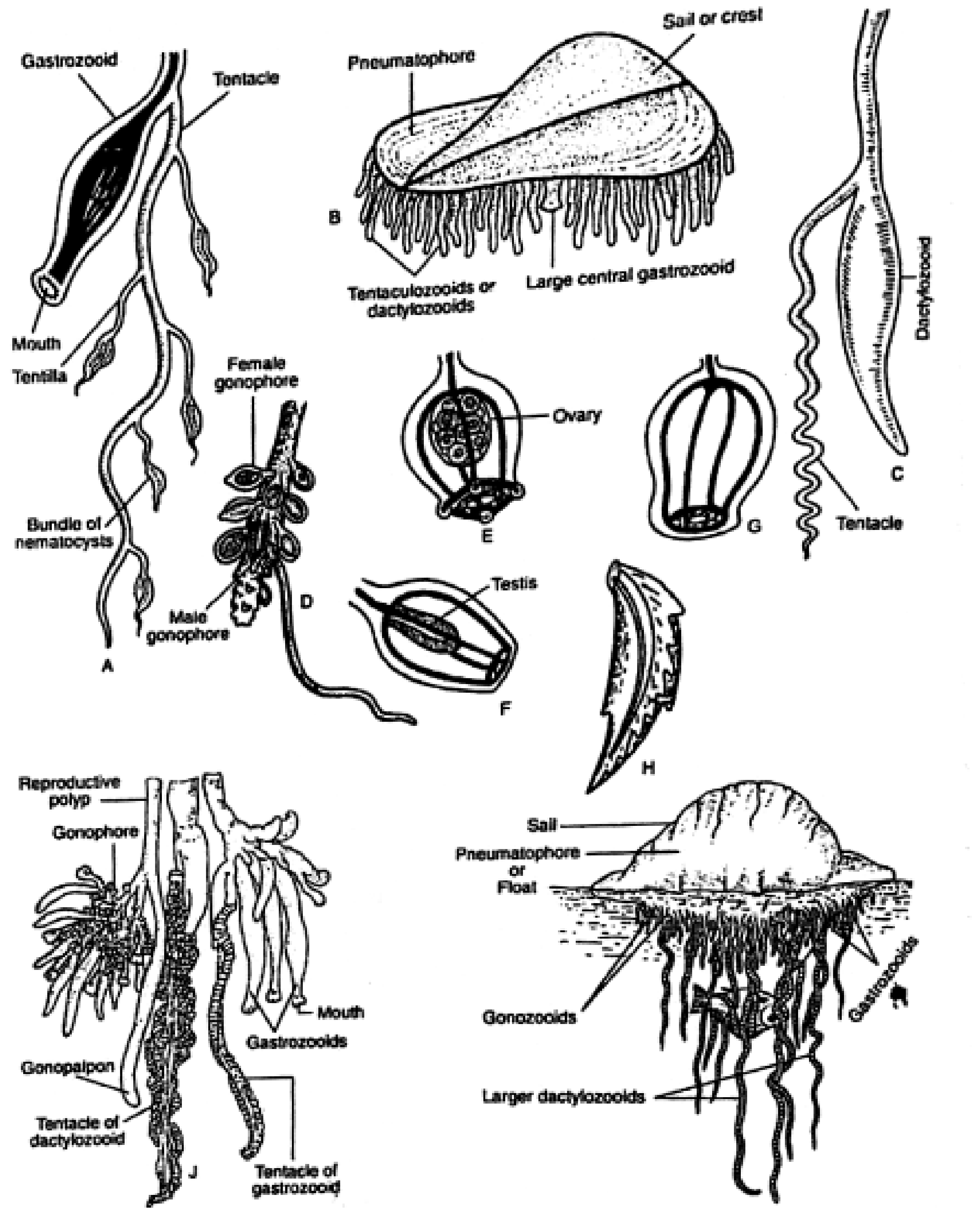

Fig. 22 : Differenttypes of zooids (after various sources). A. Gastrozoold with tentacle and bundle of memstocysts. B. Central gastrozooid of *Velella*. C. Dactylozooid with tentacle. D. Conozooid. E. Female Gonophore (medusold form). F. Male gonophore (medusold form). G. Nectophore or swiming bell. H. Bract or hydrophyllum. l. Physalie, Portuguese man-of-war, showing the pneumatophore of float. J. Part of Physalia.

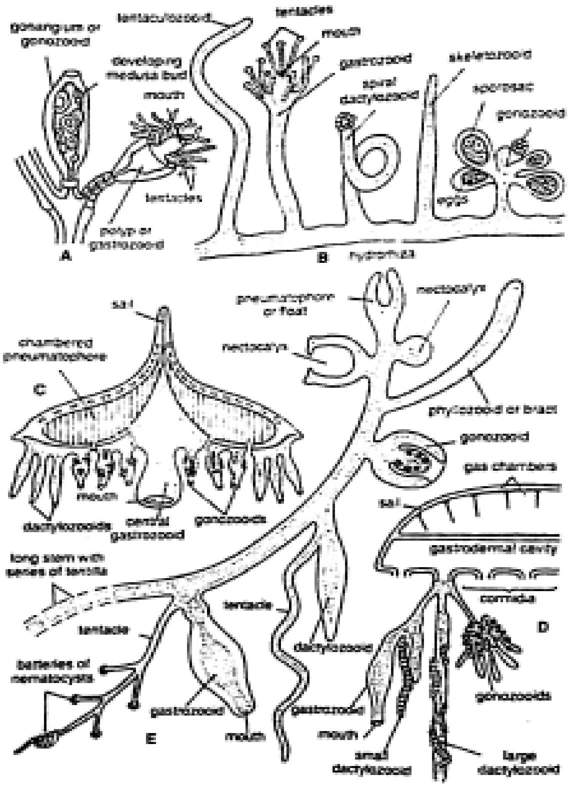

Fig. 23: Polymorphic colonies of onidaris. A—*Obeliad,* B—*Hydractina;* C—*Velella;* D—A single connidum of *Physalia;* E—Generalized calycophoran Siphonophora showing different zoolds.

4. **Gonophores :** These reproductive zooids may occur singly on separate stalk or in clusters (e.g. *Velella*). They look like medusae in having bell, velum, radial canals and manubrium but lack mouth, tentacles and sense-organs. Gonophores are dioecious but the colonies are hermaphroditic bearing both type of gonophores in the same or separate clusters. In some cases, the female gonophores are medusa-like (e.g. *Physalia*, *Porpita*) but the male gonophores are sac-like. The gonophores produce gamates.

Significance of Polymorphism : Polymorphism is essentially a phenomenon of division of labour in which different funtions are performed by diffeerent members or zooids of the colony viz. the polypoid forms are related to feeding and asexual reproduction, while the medusoid forms are related to sexual reproduction.

Amongst all Cnidarians the members of the order Siphonophora (*Halistemma*, *Physalia*, *Vellela*, *Porpita*, etc.) represent the most specialized of class Hydrozoa, attaining the highest degree of polymorphism and presenting the greatest number of medusoid and polypoid zooids.

5.6 General characteristics of Phylum Ctenophora

1. Ctenophores are exclusively marine and most are planktonic.
2. Body is soft transparent, pear-shaped, cylindrical or flat or ribbon like and biradially symmetrical with oral-aboral axis.
3. Body wall consists of an outer epidermis, inner gastrodermis and a middle gelatinous and thick mesoglea containing **mesenchymal muscle cells**.
4. Cnidocytes absent but special adhesive cells, called **colloblasts** or **lasso cells** are present on the tentacles and help in food capture.
5. Eight meridional rows of ciliary plates or **comb plates** are present that help is locomotion.
6. They are predatory (carnivorous) animals feeding on other planktonic forms. Digestion both extracellular and intracellular.
7. Nervous system is diffuse having a sub epidermal nerve net and aboral end bears sense organ, **the statocyst**.
8. Skeletal, respiratory, circulatory and excretory systems are absent.
9. Mostly hermaphroditic (monoecious), gonads endodermal.
10. Development indirect with a distinctive **cydippid** larva.
11. Nearly all ctenophores are bioluminescent.

5.7 Classification of Phylum Ctenophora

It was Hatschek (1839) who put all the ctenophores under a distinct phylum. The scheme of classification followed here is based on the scheme outlined by **Ruppert and Barnes (1994)** in their book **"Invertebrate Zoology"**, 6th edition.

The Phylum Ctinophora is divided into two classes—**Class 1. Tentaculata;**

Class 2. Nuda

Class Tentaculata :

1. Adults nearly always with two long aboral tentacles. In some only the larva has tentacles, while adults possess oral lobes.
2. Mouth narrow and pharynx small.

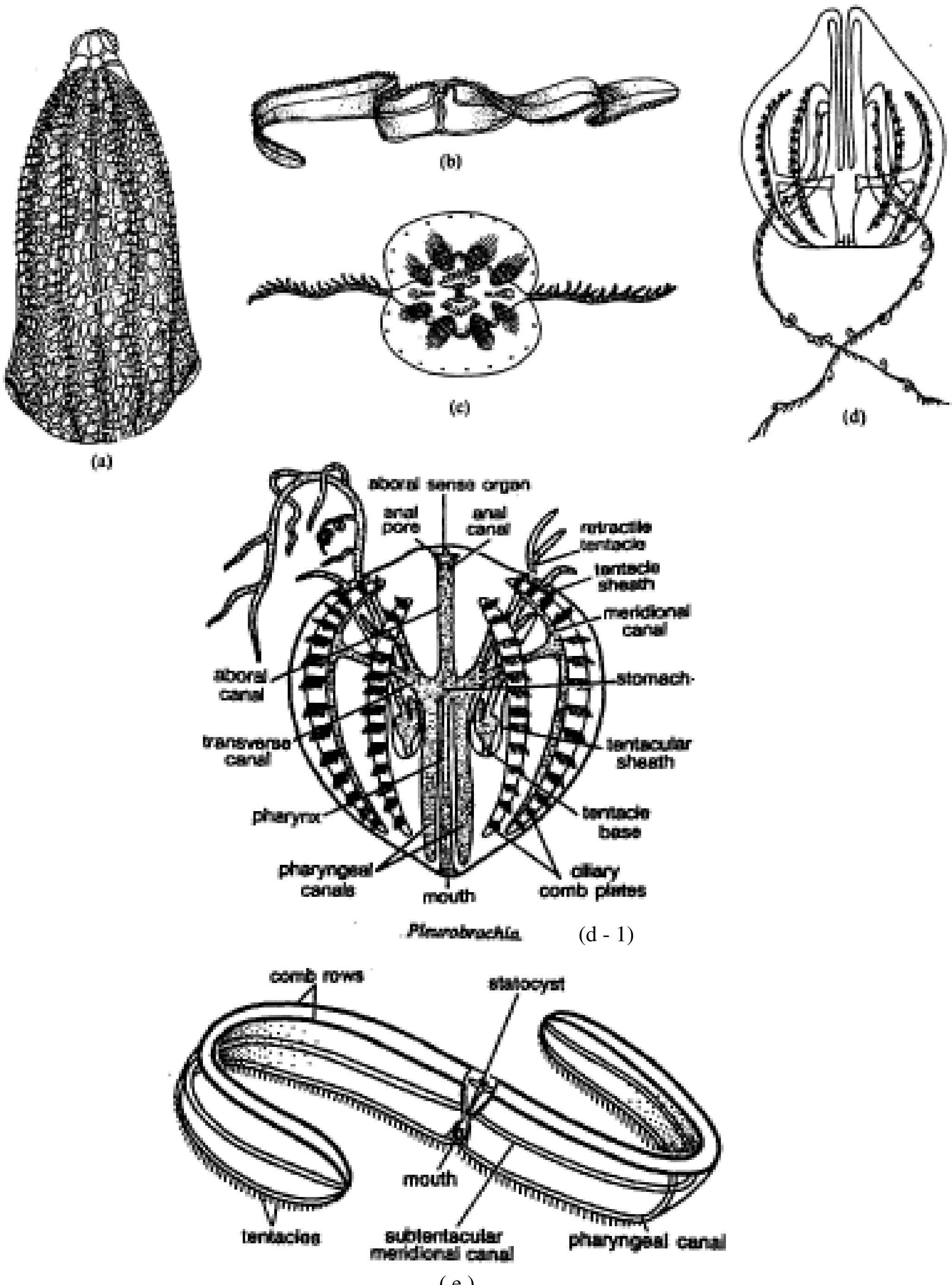

Fig. 17: Some Important Ctenophorans

3. Body may be round or oval or elongated, may be laterally compressed or ribbon like.

Example : *Hormiphora*, *Pleurobranchia*, *Velamen*.

Class Nuda :

1. The members of this class lack tentacles and oral lobes.
2. Body large, conical and laterally compressed.
3. Mouth wide and pharnx or gullet is large occupying greater portion of the interior of the body.
4. Voracious feeders feeding on other ctenophores.

This class includes only one one order and only one genus of that order is **Beroe**. *Beroe* is available in all seas and measures about 20 cm in height (Fig. 17)

5.8 Questions

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Unit - 6 ❑ Platyhelminthes & Nemathelminths– General characteristics and Classification up to Classes : Life cycle of *Taenia salium* and *Ascaris lumbricoides.*

Structure

6.1 Objectives

6.2 Introduction

6.3 General characteristics of phylum Platyhelminthes

6.4 Classification of phylum Platyhelminthes

6.5 Life cycle of *Tuenia solium*

6.6 General characteristics of phylum Nematoda

6.7 Classification of phylum Nematoda

6.8 Life cycle of *Ascaris lumbricoides*

6.9 Questions

6.10 Suggested Readings

6.1 Objectives

By studying this unit learners would be able to learn about general characteristics and classification of the more advanced metazoan animals like platyhelminthes(flat worms) and nematodes(round worms) which are triploblastic but acoelomate and pseudocoelomate,respectively, in nature.

6.2 General Characteristics of Protozoa

The term **Platyhelminthes** was first proposed by Gangenbaur (1859) meaning flatworms, because of their characteristic contour of flattened body. The term has been derived from two Greek words, platys means flat and helminthes means worms. They are a diverse group comprising of about 18500 living species, exhibiting evolutionary achievements over the diploblasts in having a structural body plan based on bilateral symmetry, in having a third layer of cells, the mesoderm and in having definite organs or system of organs. The platyhelminthes are thus first triploblastic animals. They, however, lack coelom, the body being compact (acoelomate) and the blood vascular system is absent.

The representative of the phylum Nematoda are commonly called nematodes or roundworms and they form the largest aschelminth phylum (12,000 described speices but there are probably many more undescribed than described species) and include some of the most wide spread and numerous of all multicellular animals (Ruppert and Barnes, 1994). Free living nematodes are found in the sea, in fresh water, and in the soil, and there are many parasitic species. They occur from the polar regions to the tropics, in all types of environments, including deserts, high mountain elevations, and great ocean depths. They may inhabit some unusual aquatic environment like hot springs in which the water temperature may reach 53°C. The parasitic forms display all degrees of parasitism and attack virtually all groups of plants and animals. The numerous species that infest food crops, domesticated animals, and humans make this phylum one of the most important of the parasitic animal groups. The phylum also contains one of the most intensely studied laboratory animals, Caenorhabditis elegans, whose every cell has been traced throughout the course of development, and whose genome is one of the best known of any organisms.

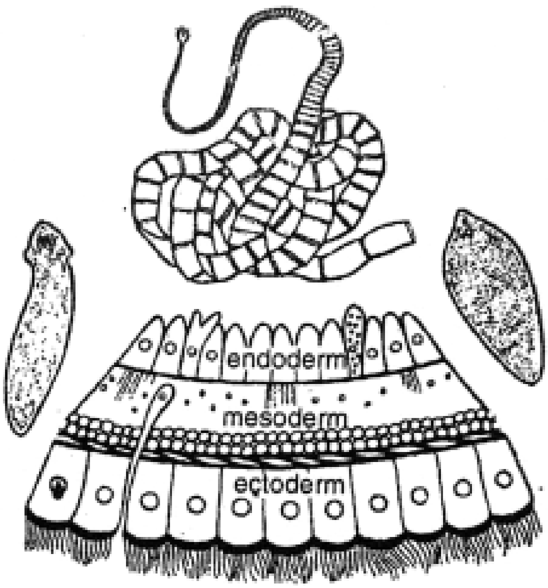


Fig. 1 : Three representatives of Platyhelminthes with a part of their body wall to show triploblastic organsation.

6.3 General Characteristics of Phylum Platyhelminthes

1. Triploblastic, acoelomate (without a body cavity) and bilaterally symmetrical animals.
2. Body soft, unsegmented and dorsoventrally flattened.
3. Body shows organ grade organization.
4. Body shape varies from moderately elongated flattened shape to long flat ribbon-like and leaf-like. Length of the body may be extremely elongated in some and may reach as much as 10 to 15 metres.
5. Metameric segmentation and skeletal structures are absent. Psdudometamerism is seen in some members.

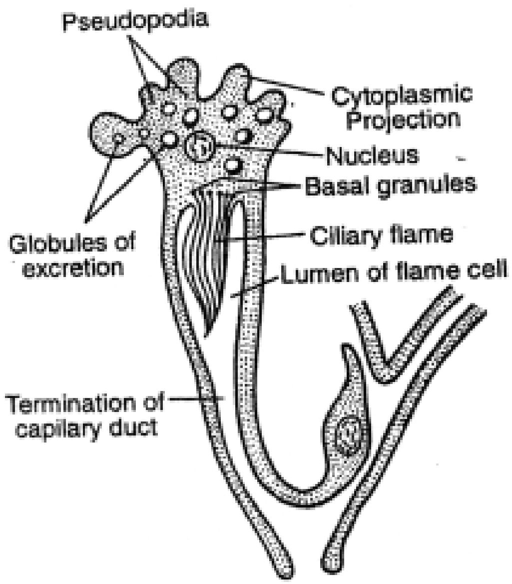


Fig. Structure of a flame cell.

6. The anterior and of the body is differentiated into a head.
7. Body is covered with syncytial one layered partly ciliated epidermis; while in parasitic forms (trematodes and cestodes) the outer body covering is cuticle.
8. Adhesive structures like hooks, spines and suckeers and adhesive secretions common in parasitic forms.
9. Mouth is the single opeing of the digestive tract and the anus is absent. Digestive tract is totally absent in some.

10. No respiratory and circulatory systems. Respiration is **aerobic** in free living forms but **anaerobic** in parasitic flatworms. Gaseous exchange by diffusion.
11. The nervous system is most primitive type, ladder like, comprising of a pair of anterior gaglia with longitudinal nerve cords connected by transvers nerves.
12. Sense organs in the form of eye spots and chemoreceptors in free living forms.
13. The excretory system consists of *protonephridia* with **flame cells**. Absent in some primitive forms.
14. Sexes are mostly united; i.e. **hermaphrodite** or **monoecious**, but the digenean flukes are **gonochoristic** (separte sexes).
15. Reproductive system is complex and highly evolved in most forms. Asexual reproduction by fission also occurs in many free living forms.
16. Fertilization internal, may be cross or self fertization.
17. Development may be direct or indirect. In some parasitic forms development is very elaborate, involving several larval stages and hosts.
18. **Parthenogenesis** and **polyembryony** are common in trematodes and cestodes.
19. Flatworms are either **free-living** (turbalarians) or **ecto** or **endocommensals** or **endoparasites**.
20. They occur in all major habitats, aquatic and terrestrial and in the tissues of other animals.

6.4 Classification of phylum Platyhelminthes

In this text the classifactory scheme followed is based on the scheme outlined by Ruppert and Barnes (1994) in their book "Invertebrate Zoology" (6^{th} edition). According to them the phylum Platyhelminthes is devided into four classes.

1. **Class Turbellaria**
2. **Class Trematoda**
3. **Class Monogenea**
4. **Class Cestoidea**

Classification with Characters (upto Classes) :

Class Turbellaria (L. turbella = a little string)

1. Turbellarians are mostly free-living and aquatic, great majority are marine and mostly benthic, a few are terrestrial but confined to humid areas. Some are brightly colourd.
2. Body size ranges from a few milimetres to 50 centimetres.
3. Body unsegmented, flattened and covered with ciliated cellular or syncytial epidermis, containing mucous secreting cells and rod-shaped bodies called **rhabdites**.
4. Locomotion by cilia and muscular undulations.
5. Presence of epidermal gland cells which help in adhesion, mucous secretion and other secretory functions.
6. Mouth opeing ventral, located at the end of an eversible pharynx which leads into a sac-like lobed or much branched intestine. Suckers absent.
7. Respiration by body surface.
8. Several pairs of longitudinal nerve cords, associated with peripheral nerve nets and cerebral ganglion constitute the nervous system.
9. Number of pigment cups, ocelli and statocysts are the sensory organs.
10. Excretory system includes flame cells in most cases.
11. Mostly **hermaphrodite**, with internal fertilization. Many reproduce asexually by means of budding or transverse fission and show high power of regeneration.
12. Development is direct in most speices. A free-swimming larval stage **Muller's larva** is present in some forms (in a few polyclads).

Examples : ***Planeria*** (fresh water flatworm), ***Bipalium*** (land planarian), ***Oligoclado*** (marine polyclad flatworm), ***Bdelloura*** (commensal on book gills of horse-shoe crabs), ***Dugesia*** (fresh water flatworn).

Class Trematoda : (Gr. trematodes = perforated/having pores)

1. All are parasites, occuring especially in vertebrates.
2. Unsegmented dorsoventrally flattened leaf-like body, hence they are called **"flukes".**

3. Body covering is cuticle, cilia and rhabdites are absent Cuticle or **tegument** is thick and protects the parasite against hosts enzyme action.
4. One or more well developed suckers are present. **Oral sucker** for feeding and **Ventral sucker** (**acetabulum**) for attachment.
5. Mouth is anteriorly placed, gut well developed, with phrynx and branched intestine.
6. Excretion by flame cells.
7. Three pairs of longitudinal nerve cords. Sense organs are poorly developed.
8. Mostly monoecious or hermaphrodites. In most cases the testes are two or many but always single ovary. No asexual reproduction.
9. Development direct (in ectoparasites) or indirect (in endoparasites) with alternation of hosts, involving many larval forms.

Examples : ***Fasciola hepatica*** (liver fluke), ***Schistosoma*** (blood fluke), ***Aspidogaster***, ***Cotylapsis***.

Class Monogenea : (Gr. monos = single; genos - a race)

1. Mostly ectoparasites (some endoparasites) of aquatic vertebrates particularly on fishes and also on amphibians and reptiles (turtles).
2. Body dorsoventrally flattened and the posterior end of the body is provided with large attachment organ or adhesive disc, called **opisthaptor** or **haptor**. It bears hooks and suckers, allowing the parasite to cling tenaciously to the skin of the host.
3. Anterior end also has adhesive organ, called prohaptor, with adhesive glands and suckers.
4. Gut present but mouth lacks a sucker. The pharynx secretes a protease that digests the host's skin.
5. Inconspicuous protonephridia having paired excretory pores situated anteriorly on the dorsal side.
6. All are hermaphrodite.
7. Life cycle simple with single host i.e. no intermediate host. One egg gives rise to one adult worm, hence the name "*Monogenea*", meaning "one generation".

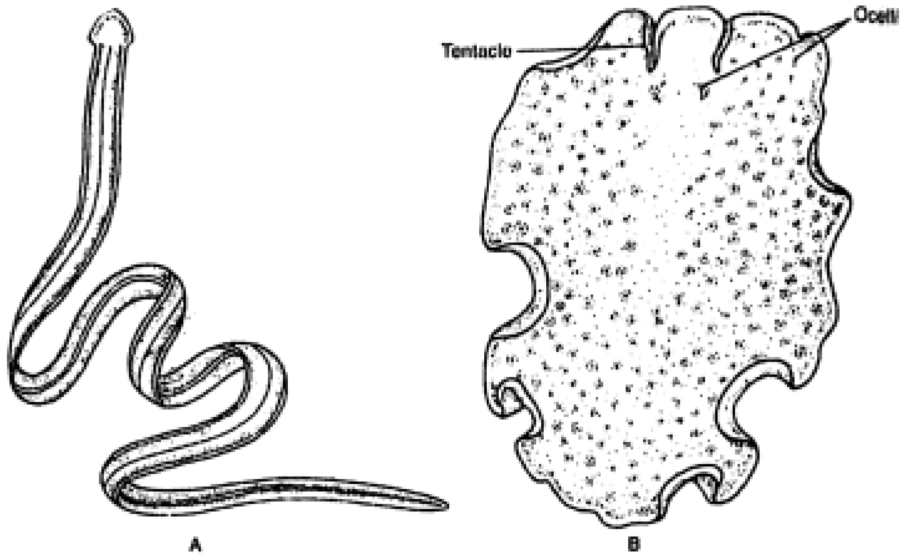


Fig. 5A : A terrestrial triclad flatworm, Bipalium, B. A marino Polyclad flatworm, oligoclado.

8. Ciliated "**oncomiracidium**" larva in the life cycle.

Examples : ***Polystoma*** (in urinary bladder of frogs and toads), ***Polystomoidella*** (in urinary bladder of turtles), ***Dactylogyrus*** (on the gills of freshwater fishes), ***Gyrodactylus***.

Class Cestoidea : (Gr. kestos = a girdle, L. cestus = ribbon; eidos = form)

1. All are highly specialized endoparasites of vertebrates, and are commonly called **tapeworms**.
2. Body flat elongated and ribbon like, covered by a non-ciliated syncytial tegument (cuticle) having microvilli-like projectons. Rhabdites are absent.
3. Body is differentiated into three regions-head or **scolex**, **neck** and **strobila** or body.
4. Scolex usually with hooks and suckers for adhesion or attachment to the host.
5. Neck is very short and narrow. It is proliferative giving rise to the body or strobila.
6. Strobila consists of linearly arranged number of segment-like sections called **proglottids**.

7. Mouth, digestive tract and sense organs are absent.
8. Each mature proglottid contains one or two sets of male and female sex organs. Thus tapeworms are hermaphrodite.
9. Life cycle complicated with one or more intermediate hosts.
10. Embryos and larvae posses hooks.

Examples : ***Taenia solium*** (pork tape worm), ***Taenia saginata*** (beef tapeworm), ***Echinococcus granulosus*** (hook worm), ***Diphyllobothrium*** (fish tapeworm), ***Hymenolepis nana*** (dwarf tapeworm in the intestine of man).

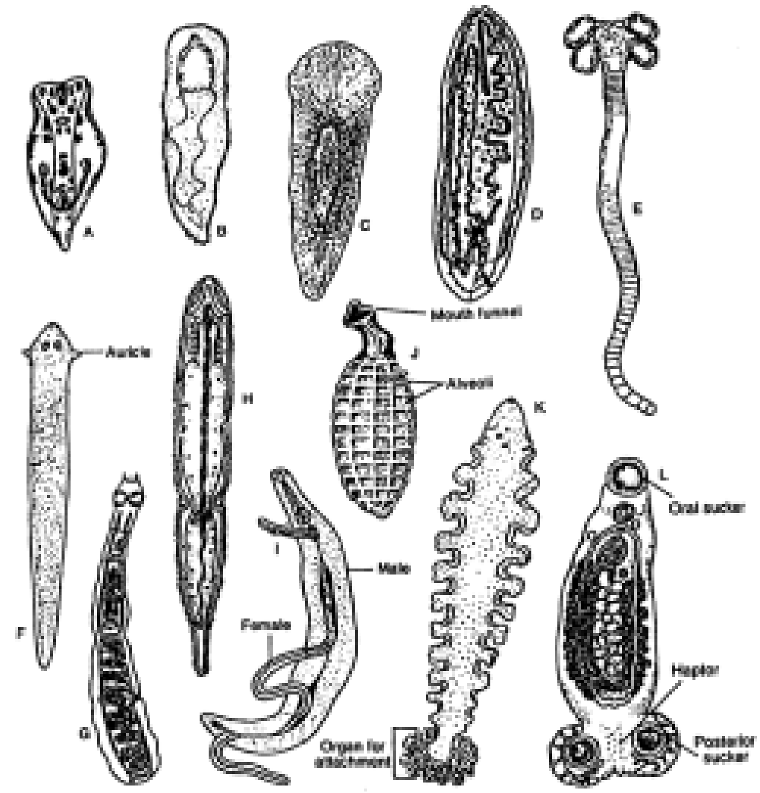


Fig. 4 : Representatives of Phylum Platyhelminthes (not drawn up to scale). A. *Convolute.* B. *Plaglostomum.* C. *Notaplana.* D. *Amphiline.* E. *Phyllobothrium.* F. *Dugesia.* G. *Echinococcus.* H. *Stenomum. I. Schislosoma.* J. *Aspidogaster.* K. *Gyrocolyle.* L. *Sphyranura.*

6.5 Life Cycle of *Taenia solium* (Pork tape worm)

Taenia solium is commonly known as pork tape worm. It is an endoparasite, the adult lives in the intestine of human beings. It has a cosmopolitan distribution. *Taenia solium* is a digenetic cestod (class Cestoda under phylum Platyhelminthes) i.e. its life cycle is completed in two hosts, human being is the **primary host** and pig is the **secondary host**. *Taenia* is found attached to the intestinal mucosa of humans by its **scolex** (head region) while the rest of the body lies free. It is most common in pork eating population of tropical and subtropical regions where pork is consumed as food without being properly cooked.

The body is very elongated (varies from 3-5 metres), dorsoventrally flattened and looks like a ribbon or tape. The body of tapeworm is differentiated into three regions– **head** or **scolex**, **neck** and **strobila**. Scolex bears hooks and suckers for attachement to the host, neck is very short and proliferative, strobila consists of a large number lineraly arranged segments-like sections called **proglottids**.

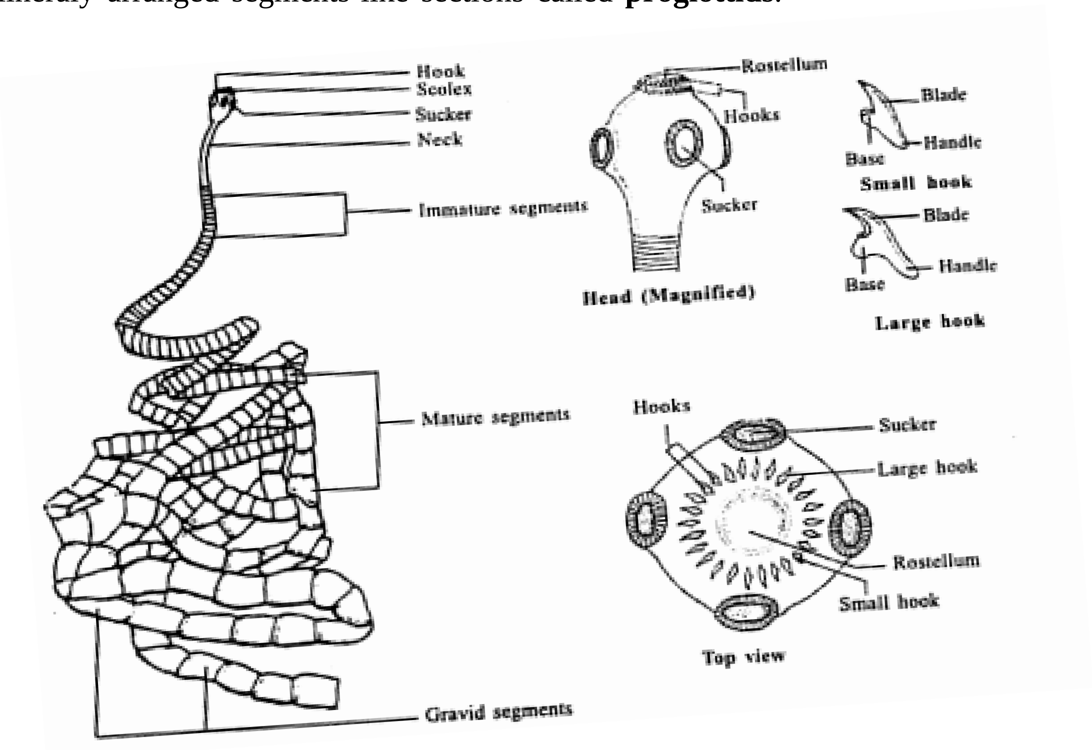


Fig. 18 : Taenia solium. An adult tapeworm.

The life cycle of *Taenia solium* may be described under the following headings :

1. **Copulation and fertilization :** *Taenia* is hermaphrodite. Each mature proglottid, after first 200, contains a complete set of male and female reproductive organs. *Taenia* practices self-fertilization, i.e. eggs are fertilized by sperms from the same proglottid or one proglottid may be inseminated by a proglottid situated anterior to it. *Taenia*, in fact, is **protandrous**, and

its male reproductive organs develop first in the anterior most mature segments. Thus, the anterior mature proglottids can copulate with the posterior proglottids. This is achieved by the bending of the strobila into folds. The possibility of cross fertilization is remote as no host is in a position to house two adult and large tapeworms at a time. Sperms injected into the vagina swim down to the seminal receptacle where they are stored temporarily till ova are released by the ovary. Fertilization occurs inside the ootype.

2. **Formation of egg capsules :** Just after fertilization, the fertilized egg or zygote gets surrounded by yolk cells in the ootype, received from the vitelline glands through the vitelline duct. The fertilized egg and yolk cells are subsequently enclosed in a thick, resistant **egg shell** secreted by the shell glands. The egg capsule or egg shell then passes into the uterus. The secretion of Mehlis's gland facilities the passage of capsule in the uterus. The uterus grows in size and becomes branched laterally as it receives more and more egg capsules. The egg capsules are very small, about 40 µm in diatmeter.

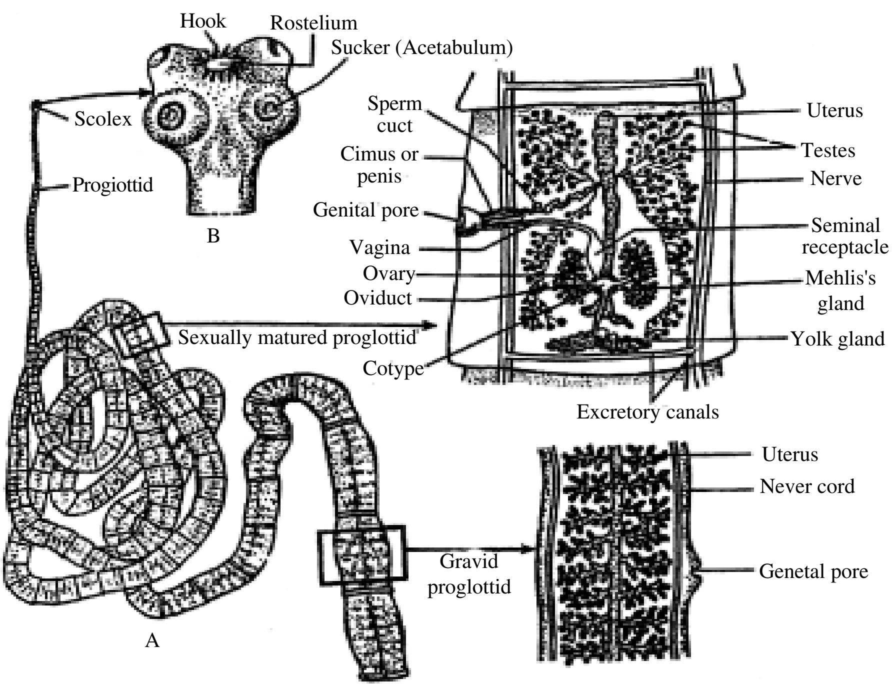


Fig. 19 : *Taenia solium*–entire specimen and enlarged view of different parts (after various sources)

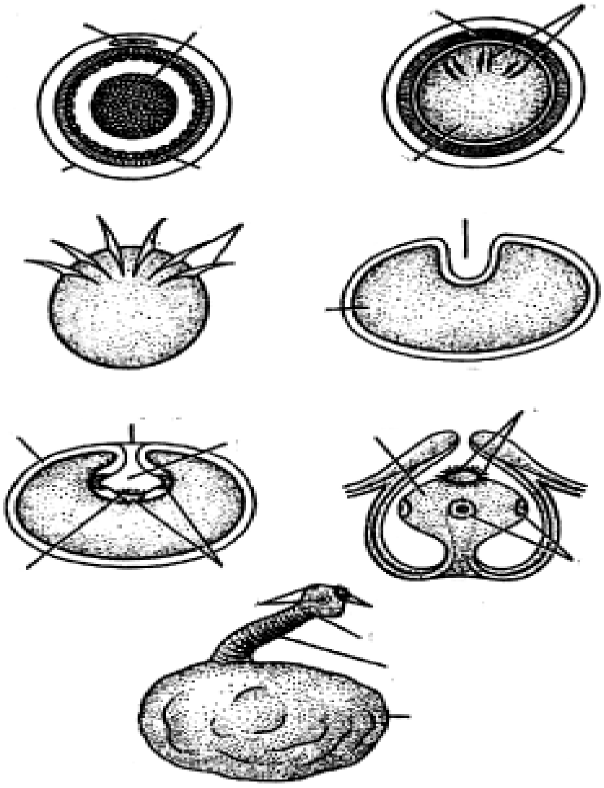


Fig. 20 : *Taenia solium.* Stages in life cycle. A–Young onchosphere; B'Mature onchosphere; C–Free hexacanth; D–Bladderworm with invagination; E–Bladderworm with proscolex; F–Bladder worm with evaginated scolex; G–Cysticercus with neck budding off proglottids.

3. **Development (Onchosphere formation) :** In *Taenia solium* development is indirect and includes a single larval stage. Development of fertilized egg starts in the uterus. The first cleavage is unequeal, producing a large **megamere** and a small **embryonic cell**. The megamere divides repeatedly to form many megameres. The embryonic cell divides repeatedly and produces two types of cells, larger **mesomeres** and smaller **micromeres** (Fig. 20). The micromeres form a ball of cells, called *morula*, in the centre. Mesomeres forms an envelope around the morula, while the megameres form an outer covering around the mesomere envelop. The megameres absorb yolk from the yolk cell and supply nourishment of the developing embryo. The large yolky megmeres fuse to form an syncytial nutritive envelope. With time the yolky envelope reduces and gradually disappears.

   As development proceeds, the middle mesomere layer forms a thick, hard cuticularized and striated **inner embryonic membrane** called **embryophore**, around the morula. Beneath the embryophore a thin basement membrane is formed. The morula forms the embryo proper. Later on six **chitinous hooks** develop in the posterior pole of the embryo. These hooks are secreted by the onchoblast cells of the embryo. This six-hooked embryo is called **hexacanth embryo**. It also possesses a pair of large penetration glands in between hooks. Hexacanth is surrounded by two **hexacanth membranes**.The hexacanth embryo together with all the membranes surrounding it is known as **onchosphere**. The onchosphere loses the outer shell so that the embryophore forms its outermost covering.

By the time onchospheres are formed, the proglottid becomes gravid and increases in size. Its uterus forms 7-13 lateral branches on each side and fills the entire proglottid. The uterus of a gravid proglottid contains 30,000 to 40,000 onchospheres.

Infection to secondary (intermediate) host : The gravid proglottids containing onchospheres at the posterior most part of strobila detach or break off (apolysis) in groups of 4 to 5 and pass out of the body of the host (human) along with the faeces. A newly shed proglottid wriggles for sometimes but eventually disintegrates setting

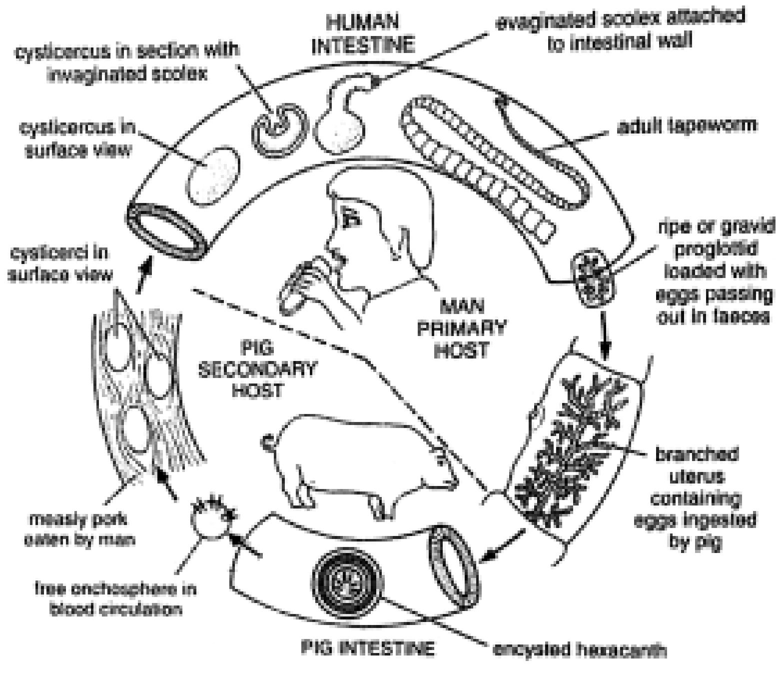


Fig. 21 : *Taenia solium.* Diagrammatic life cycle.

free thousands of onchospheres. The secondary host pig acquires infection by ingesting the human faceal matter containing the onchospheres. On reaching the stomach of pig, the egg-shell and the embryophore get digested by the gastric juices and the hexacanth embryo is released. The hexacanth then passes into the small intestine. It is now activated by the presence of bile salts, bores its way through the intestinal opithelium to reach the sub mucosal blood vessels. This is accomplished, jointly by the penetration glands and six hooks. Hooks merely anchor the hexacanth to the intestinal wall, while secretion of penetration glands dissolves the intestinal tissues. Entire process takes about 10 minutes, after which the hooks are of no use and are shed off. Submucosal blood vessel carries the hexacanth to liver via hepatic portal vein. From liver it reaches heart and enters the arterial circulation. It finally reaches the striated muscles in any part of the body. They usually settle in the muscles of the tongue, neck, shoulder, thigh,heart etc. Once settled in muscle each embryo absorbs a large amount of watery fluid from host tissue and grows to sphrerical, pea-size sac like cyst, called **bladderworm** or **cysticercus larva**. The cysticercus of *Taenia solium* is called **cysticercus cellulosae**. The flesh of pig or pork containing many cysticerci appear white spotted resembling something that of measles, hence it is characteristically called **measly pork**.

Cysticercus or bladderworm : The hookless bladderworm gradually becomes encysted by the connective tissue of the host (pig). All cells of the cysticercus larva fall into two layers around the fluid-filled central cavity. Cells of the outer layer coalesce to form a syncitial **tegument** (layer of thick syncitial protoplasmic mass). The inner layer of cells is **mesenchymal layer** or **germinal layer**. At the future anterior end (opposite to the side where hooks were present) the wall of the larva thickens and then invaginates into the cavity (Fig. 21), as hollow nob. The invaginated knob develops four suckers on its inner surface and hooks and rostellum are developed at its bottom. Now this inverted knob is called **proscolex**. In fact, the embryo at this stage is called cysticercus or bladderworm, whose further development does not take place unless it is eaten up by the primary host. Thus fully formed cysticerci or bladderworms are infective to human hosts. They usually survive (in dormant state) in the flesh for several years. It has been seen that one kilogram of measly pork may contain 500 or more cysticerici.

Infection to primary host (human) : Pork eating people get the infection of *Taenia solium* by eating raw or imperfectly cooked measly pork. The cysticercus becomes active on reaching the small intestine. Actually their bladder is digested and the proscolex everts or evaginates (tunred inside out) so that the suckers and rostellum come to lie on the outer surface as in the adults. Thus a scolex and a small neck is formed. The scolex anchors itself to the mucous membrane of the intestine by the help of suckers and hooks. The neck begins to proliferate proglottids and gradully a series of proglottids are formed as strobila and ultimately an adult tapeworm is developed. In about 10 to 12 weeks the parasite attains adult condition with gravid proglottids.

The life cycle of *Taenia solium* is not so complicated becaue it does not involve any asexual generation. The complete life cycle may be represented with the help of the following flow-chart :

Adult tapeworm in human gut → Fertilized egg in mature proglottids → Egg capsules within gravid proglottids → Oncospheres in gravid proglottids → Gravid proglottids or onc spheres in human faeces → Onchospheres outside human body in faeces → Hexacanths in the gut of pig → Hexacanths in the intestinal blood vessels → Hexacanths in the heart → Hexacanths in the muscle → Cysticercus in the strited muscles → Measly pork → Cysticercus in the gut of human beings → Adult tapeworm in human intestine.

Pathogenicity of *Tacnia Solium*

The infection of adult *Taenia* causes a disease called **taeniasis** in human beings while the condition caused by the infection of its cysticerici is called **cysticercosis**. The armed scolex may cause irritation of the mucosal lining and there have been cases in which the scolex perforated the intesitne leading to pertitonitis. Taeniasis is characterized by abdominal discomforts like pain, indigestion, vomiting, constipation, excessive appetite, diarrhoea, increase of eosinophil cells in blood and above all nervous disorders like nervousness, insomina, nausea and epileptic fits, etc. These disorders are caused by toxins produced by the parasite. Mechanical injury caused by hooks and suckers may initiate irritation in intentime, causing reverse peristalsis which lead to auto infection. Usually a single tapeworm is found to parasitize a host. This is because of the presence of one tapeworm provides a kind of immunity to the host against fresh infection.

Cysticercosis is far more dangerous than taeniasis. Self infection or auto infection with eggs can result either from contaninated fingers or from eggs hatching in the intestine and carried to the stomach by reverse peristalsis (Cheng 1986). The bladder worms may reach different parts of the body through circulation. Cysticerci in humans may form in the muslces or subcutenious tissues, where they do little damage, although tissue responses generally occurs. If cysticerci develop in the eys, heart, spinal cord, brain, or some other important organ, the mechanical pressure exerted by these larvae (cyst) may cause, severe neurologic symptoms. Violent headaches, convulsions, epileptic behaviour, local paralysis, vomiting and optic disturbances are common, sometimes so severe that death results.

When a cysticercus dies, it elicits a severe inflametory response which in brain can cause death. Rarely a cysticerecus may become proliferative, developing branches that infiltrate and destroy the surrounding host tissues. Because of the ability of the cysticerci of *T. solium* to develop in practicelly every organ in the body, and because of the severity of the resulting pathology, this tapeworm must be considered among the most pathogenic of the human-infecting species.

6.6 General Characteristics of phylum Nematoda

1. Nematoda (G. nema = thread; eidos = form) include widely distributed aquatic or terrestrial, free living or parasitic roundworms.
2. Body is slender, elongated and cylindrical (hence the name roundworm) with both ends gradually tapering.
3. Bilaterally symmetrical, triploblastic unsegmented animals.
4. A thick and flexible cuticle enclosed the body and lines the pharynx, hindgut and other body openings. Cuticle moulted periodically.
5. Mouth is located at somewhat rounded anteror end and is surrounded by lips and sensila of various sorts. There may be six lip like lobes in primitive marine forms and only three lips in terrestrial and parasitic species. Primitively the anteriour end and lips bear 18 sensilla.
6. Body wall without circular muscles and made entirely of longitudinal muscle fibres arranged in four bands.
7. Body cavity is pseudocoel filled with parenchyma in most cases. Pseudocoel is small or non-existent in most small free living species but voluminous in large forms (e.g. *Ascaris*).
8. Complete digestive tract with distinct mouth and anus. Digestion extracellular.
9. Blood vascular system and respiratory orgns absent.
10. Excretory system without flame cells or nephridia. Excretion is performed by general body surface, excretory canal system or by excretory gland cells (called *renette cells*).
11. Nervous system comprises of a brain in the form of a circumpharyngeal nerve ring with dorsal, ventral and lateral nerves.

12. Principal sense organs (sensillae) are papillae, setae, amphids and phasmids, all of which are associated with cilia.
13. Sexes are separate (dioecious) but hermaphrodites, such as the well studied *Caenorhabditis elegans*, are not uncommon. Males are often smaller than females, and the posterior end of the male may be curved like a hook or broadened into a fan-shaped copulatory aid, called a *bursa*.
14. Fertilization internal, sperms lack flagella and are amoeboid.
15. Cleavage pattern neither spiral or radial but strongly determinate. Development is direct.
16. Nematodes have successfully adapted to nearly every ecosystem and are very widely distributed invertebrates.

6.7 Classification of phylum Nematoda

The classification of phylum Nematoda presented below is based on Ruppert & Barnes (1994). They classified the phylum into **two classes** and 20 orders.

1. **Class Adenophorea (Aphasmida)**
2. **Class Secernentea (Phasmida)**

Class Adenophorea (Aphasmida) :

1. Phasmids (caudal sensory organs) are absent.
2. Presence of variously shaped amphids (paired chemosensory pits) behind the lips.
3. Presence of cephalic setae and papillae.
4. Excretory organs are only renette cells but without collecting tubules.
5. Usually two testes in male.
6. Most representatives of this class are free living, some are parasitic. The free-living species include terrestrial and freshwater forms and almost all of the marine forms.

Examples : ***Euoplus*, *Monochus*, *Enophus*, *Dorylaimus*, *Trichordis***

Class Secernentea (Phasmida) :

1. Presence of pore-like amphids in the lateral lips (amphids open to outside by pores).

2. In the caudal region presence of paired phasmids.
3. Excretory system canal-like and comparatively more complex.
4. Males possess single testis.
11. Many parasitic forms are members of this class and the free-living speices largely inhabit soil.

Examples : ***Ascaris lumbricoides*** (human round worm), ***Wuchereria bancrofti*** (filaria worm), ***Ancylostoma duodenale*** (hook worm), ***Loa loa*** (eye-worm), ***Rhabditis***, ***Dracunculus medinensis*** (guinea worm)

6.8 Life Cycle of *Ascaris lumbricoides*

Systematic Position :

Phylum : Nematoda

Class : Secernentea or Phasmida

Genus : *Ascaris*

Species : *lumbricoides*

Ascaris lumbricoides is one of the most familiar endoparasite in the small intestine of man. The worm may migrate to other neighbouring areas. It has also been reported from apes, pigs, cattle, sheep and squirrels. It remains free in the intestine and feeds on partly digested food (chyme) of the host. It is common particularly among children and has a cosmopoliton distribution but is much more common in tropical and subtropical coutries.

The body of *Ascaris* is fairly large, males measure about 15-25 cm in length and 3-4 mm in diameter, while femals are 25-40 cm in length and maximum 5 mm in diameter. The body is elongate, cylindrical and grdually tappring at both ends. The adult worms are light brown or pinkish in colour when alive, but gradually changes to white outside the intestine. The mouth opening is guarded by three conspicuous lips-one dorsal and two ventral.

The tail of male is shaprly curved ventrally while in female it is nearly straight. In female a little in front of the tail end lies a mid-ventral transverse aperture or anus, guarded by thick lips. Females can also be distinguished by the presence of separate and independent genital aperture situated on the ventral surface at about one-third of body length from the anterior end. In male there is a cloacal aperture at the curved portion of the tail and pair of needle-like chitinous **penial setae** protrudes through the cloacal aperture.

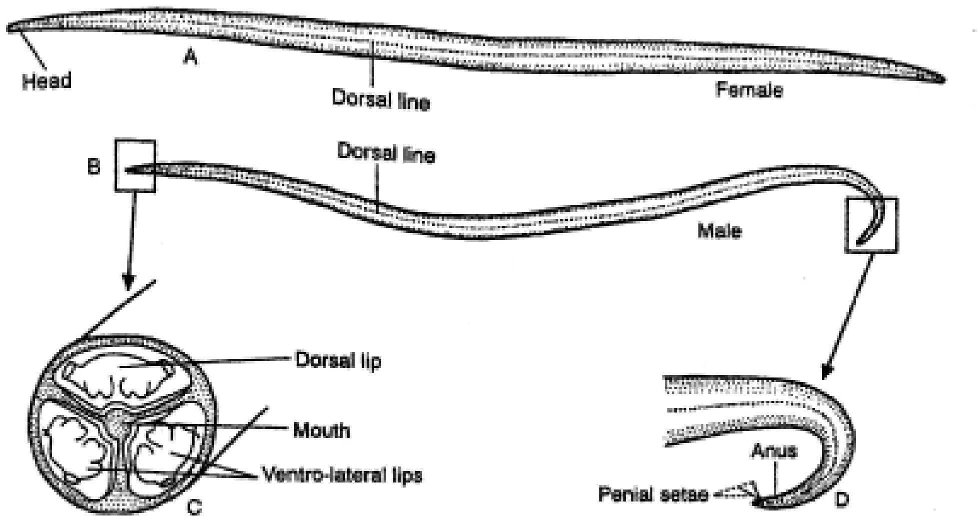
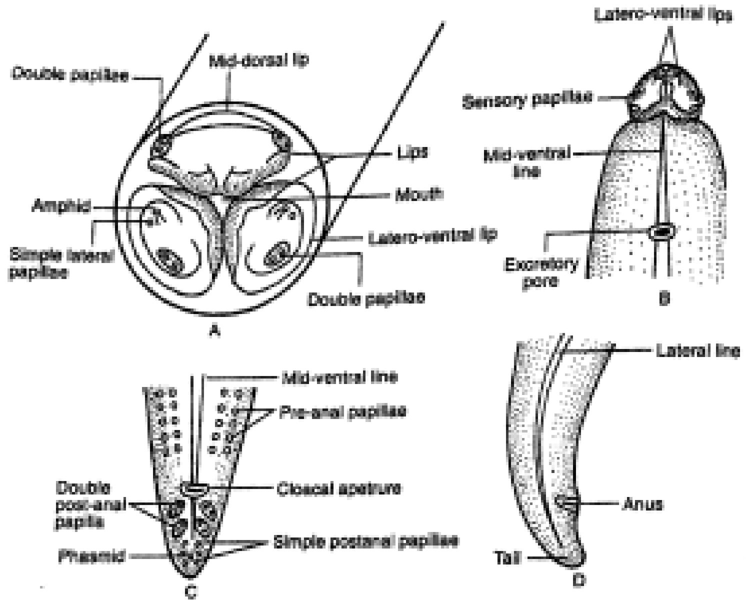


Fig. External features of *Ascaris* (after various sources). A. Male. B. Female. C. Enlarged view of head end. D. Enlarged view of posterior end of male.

Life Cycle : *Ascaris* passes its life cycle (Fig. 4) in one host and no intermediate host is required (hence it is a monogenic parasite). Human being is the only host.

Eggs are produced in large numbers by the mature females (prodigious egg producer), depositing about 20000 eggs daily and the uterus may contain upto 27 million eggs at a time. Copulation or mating takes place when the parasites remain in the intestine of the host (human). Penial setae of male help to open the female genital pore and transfer of sperms to the oviduct of female. Eggs are fertilized in the upper part of the uterus. When the fertilized eggs move downwards through the uteri, they are surrounded by a highly resistant chitinous egg shell and an outer irregualar albuminous coat. Actually the tough covering of the fertilized egg consists of three layers—(i) an inner **lipoid layer** formed by the fat globules of the egg, (ii) a middle **chitinous layer** formed by the glycogen globules of the egg and (iii) an outer quinone-tanned **protein layer** formed by the secretion of uterine wall when the fertilized egg passes down through the uteri. This protein layer represents as wart-like structure. A fine net-like fibrous layer is also present outside of the protein layer. The eggs at this stage are elliptical and measure about 60-70 µm in length and 40-50 µm in width (Cheng, 1986).



External features of *Ascaris*. A. Enlarged view of head end. B. Anterior and in ventral view. C. Posterior end of the male (Ventral view). D. Posterior end of a female.

The fertilized eggs leave the mother's body through gonopore into the host's intesitne and finally pass out with the host's faeces. The outer covering of the egg is now golden brown in colour due to bile pigment adsorbed from faeces. Among the oval fertilized eggs are found numerous unfertilized eggs, indetifiable by their elongated shape and absence of the albuminous coat. When the fertilized eggs are expelled from host's body, the zygote is uncleaved, and it remains in this state until the eggs reach soil. Eggs deposited in soil are resistant to desiccation but are, at this stage of development, very sensitive to environmental temperatures. The zygote within the eggshell develops at an environmental (soil) temperature between 15.5ºC and 35ºC and development ceases at temperatures below 15.5ºC, and eggs can not survive temperatures more than slightly above 38ºC (Bogitsh et.al.2005). Other factors such as moist soil and oxygen are necessary for development of embryo. Smyth (1994) reported that development of the embryo takes place between the temperatures of 22ºC to 33ºC and eggs gradually degenerate above 38ºC. They can remain alive for years in moist soil.

The cleavage is spiral and determinate type. The 16-celled embryo attains the form of a hollow ball the ***blastula***. Its cavity is blastcoel. Blastula transformed in to **gastrula** by the processes on invagination and eipboly and ultimately develops into a tiny active **juvenile** in about 10-14 days from the beginning of cleavage. Structurally the juvenile possesses an alimentary canal, a nerve ring and a larval exeretory system. This juvenile resembles very much with **Rhabditis** (a soil nematode), hence it is also termed **rhabditiform larva** or **rhabditiod** (first stage). This larva moults within the egg shell in about seven days and becomes the *second stage* **juvenile** or **second stage rhabditoid**. This stage of the life history of *Ascaris* is infective to the host. The larva remains in coiled condition within the egg shell. Under suitable conditions of moisture, oxygen and temperature, infective eggs of *Ascaris lumbricoides* are known to remain viable in the soil for two years or longer. The larva remains quiescent within the egg shell until it reaches a new host.

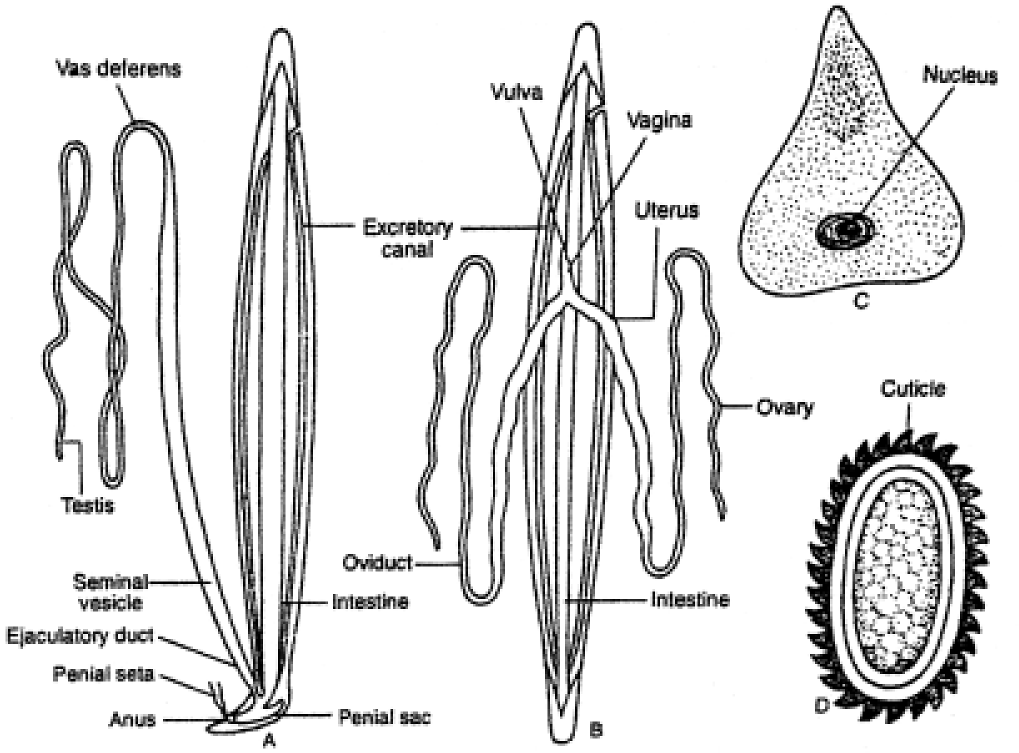


Fig. A. Showing the excretory system and male reproductive system of *Ascaris*. B. Female reproductive system of *Ascaris*. C. Spermatozoon of *Ascaris*. D. Egg of *Ascaris*.

As there is no intermediate host, man acquires infection directly by ingesting *Ascaris* eggs with contaminated food or water. The infective eggs are not hatched until they reach the small intestine (duodenum). They hatch within two hours of reaching the intestine. The larvae measures about 0.2 to 0.3 mm in length and 13 to 15 µm in breadth. The newly hatched larvae burrow their way through the mucous membrane of small intestine and enter the circulatory system, and are carried via the venous system to the liver. Here they live for a period of 3 to 4 days. Then after passing through interlobular veins, central veins, sublobular veins and hepatic veins, they are drained into the inferior vena cava which opens into the right atrium of the heart. From heart they are transported to the lung via pulmonary artery. In the lung they enter the alveoli and settle down for sometimes. Here they moult twice, the first moulting takes place after 5-6 days (third stage larva) and second moulting after 10 days.

From the alveoli of lungs the larva reach bronchi, trachea, larynx and finally to pharynx, from where they are coughed up (irritation causes caughing) and then

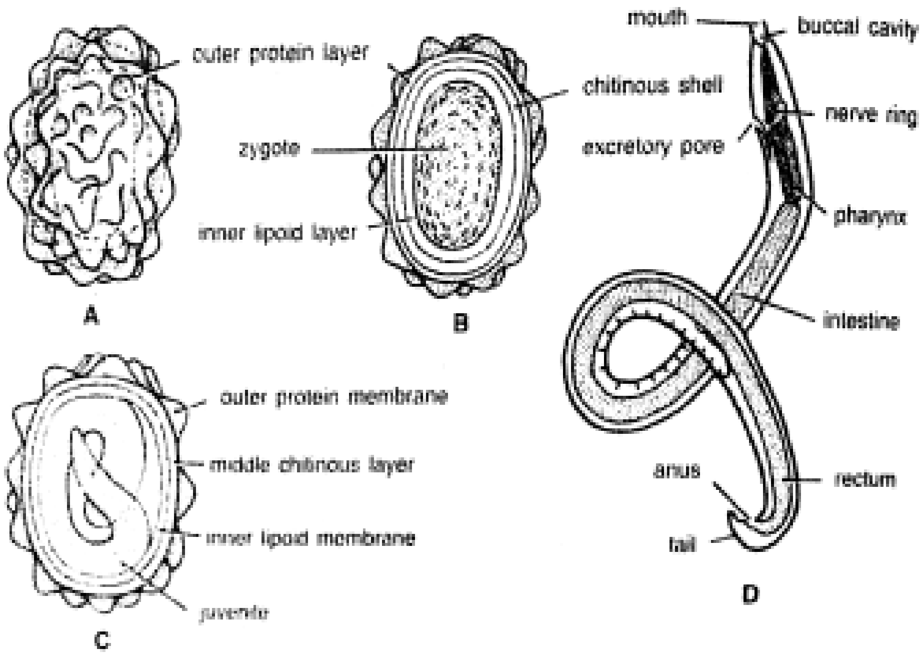


Fig. *Ascaris*. A—An entire mammilated egg; B—T.S. of a mammilated egg; C—Embryonated eg in section; D—Rhabditiform larva.

swallowed for second time and pass again to the small intestine. In the intestine they moult for the fourth and last time to become adult. During this migration the worms increase their lenght about 10 times from their initial length (from 0.2 to 0.3 mm to 2 to 3 mm). The young *Ascaris* becomes sexually mature adult within 8-10 weeks, and begins its life cycle again. The interval from ingestion of infective eggs to the

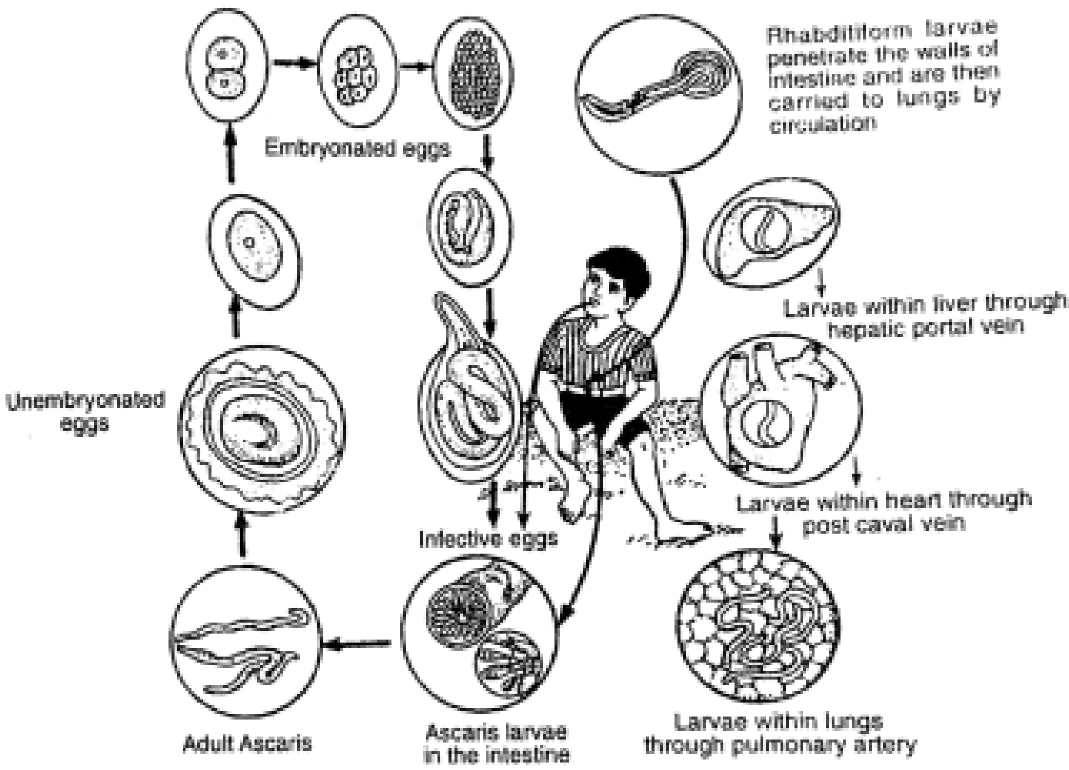


Fig. Life cycle of *Ascaris lumbricoides*.

apperance of sexually mature worms in the small intestine is about three months (Bogitsh et.al. 2005).

Pathogenicity of *Ascaris*

Infection of *Ascaris lumbricoides* in human is known as **ascariasis**. Children are more susceptible to ascariasis than adults. The symptoms attributed to Ascaris infection may be divided into two groups : (a) those produced by migrating larvae and (b) those produced by the adult worms.

Symptoms due to the migrating larvae : Little damage is associated with the penetration of host's intestinal mucosa by newly hatched larvae. However, aberrant larvae migrating in such organs as the spleen, liver, lymph nodes and brain (through general circulation) usually elicit inflametory responses and unusual clinial symptoms. When the larvae escape from capillaries in the lungs and enter the respiratory system, they cause small haemorragic foci accompanied by coughing, fever and difficulty in breathing. Larvae in large numbers can produce many small blood clots, leading to Loffler's pneumonia (or Asaris pneumonitis). If large areas of lungs are affected it may lead to potentially fatal pneumonitis. Disturbances have been reported due to presence of larvae in the brain, spinal cord, heart and kidneys.

Symptoms due to the adult worms : As the adulworms inhabit the upper part of the small intestine, the symptoms are therefore mostly related to the gastro-intestinal tract. Unless large number of adulworms are involved, there is little pathology associated with their presence, but symptoms such as abdominal pain, asthma, insomnia and eye pain may occur. Except for abdominal pain, these symptoms represent allergic responses to metabolic excretions and secretions by the worms. "Toxins" produced by the worm may cause irritation of mucous membrane, nervous symptoms like convulsions, delirium (light headedness), coma (deep sleep), and nervousness. Antienzymes liberated by the parasite interfare with protien digestion which leads to protein deficiency and stunted growth especially among children. Loss of appetite and insufficient absorption of digested food also occur as a result of heavey infections. When large numbers of adults are present, mechanical blockage of the intestinal tract may occur. The worms frequently migrate and may enter the stomach and may be vomitted out or pass up through the oesophagus at night, coming out through the mouth or nose. During migration *Ascaris* may accidentally enter into the respiratory passage causing suffocation or they may even enter into a bronchus. Furthermore, worms may penetrate through the intestinal wall or may enter the lumen of appendix, causing appendicitis. If peritonitis develops, death is common. The adult worm may even wander up the bile duct to the liver, causing abscesses, or down the pancreatic duct, causing fatal, haemorrhagic pancreatitis.

6.7 Questions

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6.8 Suggested readings

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Unit - 7 ❑ Annelida– General characteristics and Classification up to Classes ; Metamerism in annelids.

Structure

7.1 Objectives

7.2 Introduction

7.3 General characteristics of Annelida

7.4 Classification of Annelida up to class

7.5 Metamerism in annelids

7.6 Questions

7.7 Suggested Readings

7.1 Objectives

From this unit learners will learn the diversity, general characteristics and classification of phylum Annelida up to class. They will also learn about metamerism in annelids.

7.2 Introduction

The phylum Annalida comprises the segmented worms and includes the familiar earthworms, leeches and a number of marine and freshwater speices. A distinguishing characteristics of the phylum is segmentation (metamerism), the division of the body into similar parts, or segments which are arranged in a linear series along the anteroposterior axis. They range from a deep sea species measuring less than 1 mm in length to giant tropical earthworms (of Australia) which measure upto 4 metres in length. Annelids are soft-bodied, elongated, cylindrical, bilaterally symmetrical, metamerically segmented coelomate worms having a thin covering of cuticle often with segmental chitinous setae.

7.3 General characteristics of Annelida

1. Triploblastic and bilaterally symmetrical coelomates.

2. Body soft, elongated, vermiform (worm-like) and ringed appearance (L. annellus = a ring).
3. Metamerically segmented body (i.e. body is divided into similar parts or segments which are arranged in a linear series along the anteroposterior axis). The segments are marked externally by transverse groovs and internally by transverse septa.
4. The body cavity or coelom serves as a hydrostatic skeleton against which muscles contract.
5. Body wall consists of a fibrous collagenous **cuticle**, glandular **epidermis** in which the nerve fibres are situated, and a connective tissue **dermis** of varying thickness. Below the dermis there are outer layer of circular muscles and inner layer of longitudinal muscles.
6. Head comprised of prostomium and peristomium. Prostomium contains brain and in some forms sensory appendages. Terminal part of body is **pygidium** that bears the anus.
7. Locomotory organs are segmentally arranged, paired chitinous lateral bristles called **setae** or **chaetae**. They are absent in leeches and in some polychaetes.
8. Digestive tract is a straight tube running from the anterior mouth to the posterior anus. Digestion extracellular.
9. Respiration through general body surface (provided that it is kept moist) and/or by gills in some tube dwellers.
10. Circulatory system is well developed and closed type. Blood is usually confined to small vessels but larger sinuses may also occur.
11. Respiratory pigments in blood are red haemoglobins or green chlorocruorins. Both pigments are found in blood plasma, not in blood cells, as found in vertebrates. Haemerythrin (a non haem red protein pigment lacking porphyrin) is also present in some polychaetes.
12. Nervous system consists of a pair of cerebreal ganglia (supra pharyngeal ganglia) or brain and a double ventral cord bearing ganglia and lateral nerves in each segment.
13. Excretory system consisting of metamerically disposed and paired coiled tubes, called **nephridia**.
14. Annelids are often provided with **coelomoducts** which are channels for the outward passage of reproductive elements.

15. Gonads develop from coelomic epithelium.
16. Sexes may be united (monoecious or hermaphrodite) or separate (dioecious).
17. Development is direct in monoecious forms and is indirect with **trochophore larva** in dioecious marine forms.
18. Cleavage spiral and determinate.
19. Power of regeneration is well noticed in many annelids.
20. Mostly aquatic, some terrestrial, burrowing or tubicious (living in tubes), sedentary or free living. Some commensal and parasitic.

7.4 Classification of Annelida

The annelids were previously termed as "worms" and were grouped under the old phylum Vermis. Cuvier in 1798 pointed out the fundamental difference and separated them from Vermis. Later in 1909, Lamarck coined the name Annelida. Phylum Annelida includes about 17000 living species. The classification described here is according to the classification scheme outlined by Ruppert and Barnes (1994) in their book "Invertebrate Zoology", 4th edition.

Phlylum Annelida includes three classes–

1. **Class Polychaeta**; 2. **Class Oligochaeta**; 3. **Class Hirudinea**

Class Polycheata (G. poly = many; chaete = bristles).

Characters :

1. Predominantly marine, mostly carnivorous with errant (free-moving) or sedentary habit. Sedentary forms are either burrowers or tube-dwellers.
2. Body usually elongated, cylindrical and distinctly segmented into many similar metameres.
3. Anterior end is modified into a distinct head which bears many, sensory structures like eyes, tentacles, cirri and palps.
4. Each body segment carries a pair of fleshy, lateral paddle-like outgrowths or appendages called **parapodia** which bear many large setae or chaeta (in bundles). Parapodia are locomotory organs.
5. Clitelum absent.
6. Alimentary canal is usually straight with an eversible buccal region and a muscular protrusible pharynx.

7. Cirri or branchiae (gills) are highly vascular and act as respiratory organ. In some parapodia are used for gas exchange.
8. Blood vascular system well developed and does not communicate with coelom. Respiratory pigments are haemoglobin (most common), Chlorocruorin and haemerythrin.
9. Principal specialized sense organs are *eyes*, *nuchal organs* and statocysts. Nuchal organs consists of a pair of ciliated sensory pits or slits, often eversible, situated in the head region of most polychaetes. Statocysts are found in many sedentary burrowers or tube dwellers.
10. Segmental metanephridia for excretion. Protonephridia in some.
11. Sexes separate in most. Gonads are localized, may be temporary, exetending throughout whole body.
12. **Epitoky**, a reproductive phenomenon, seen in some polychaetes.
13. Fertilization external. Free swimming larval forms is **trochophore**. No cocoon formation.

Examples : ***Nereis***, ***Aphrodite*** (sea mouse), ***Chaetopterus***, ***Arenicola***, ***Sabella***, etc.

Class Oligochaeta (G. oligos = few; chaete = bristles)

1. Mostly terrestrial and fresh water forms with secondarily marine representatives.
2. Head indistinct, prostomium small, without eyes and other sensory structures.
3. Body segmented, parapodia absent but possess segmentally arranged setae embedded in the integument.
4. Clitelum present. It is glandular and secretes cocoon for the eggs.
5. Usually no respiratory organ except a few. Gas exchange through moist body wall by diffusion.
6. Most are scavengers, feed on dead organic matters, particularly vegetation. Digestive tract straight.
7. Excretory system metanephridial type.
8. Circulatory system well developed (basically similar to that of polychaetes). Respiratory pigment haemoglobin, dissolved in plasma.
9. Hermaphrodites with well developed reproductive systems, limited to a few anterior segments.
10. There is copulation and reciprocal transfer of sperm (cross fertilization occurs externally within a cocoon).

11. Development direct and takes place within cocoon secreted by the clitellum.

Examples : *Pheretima*, *Lumbricus*, *Tubifex*, *Chaetogaster*, *Dero*, *Megascolex*.

Class Hirudinea (L. hirudo = leech)

1. Most are freshwater, some are marine or terrestrial some are ectoparasites, blood suckers or carnivorous (predaceous).
2. Dorsoventrally flattened and elongated body with definite number of segments. Each segment subdivided externally into 2 to 4 secondary rings or annuli. Head indistinct.
3. Parapodia, setae and cephalic appendages are absent.

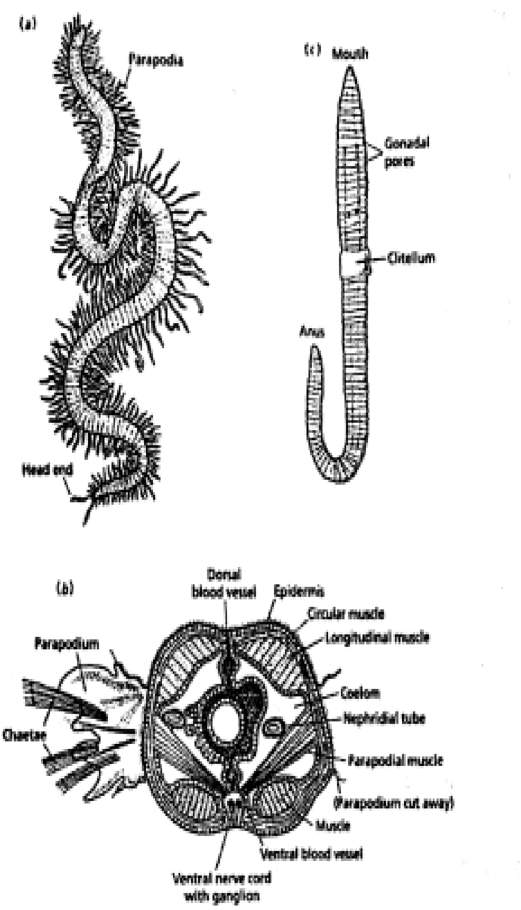

Fig. 1 : External views and transverse section (T.S.) diagrams to show the characteristic features of the three main classes of annelids: (a) *Trypanasyllis zebra*, a polychaete; (b) T.S. *Nereis;* (c) *Lumbricus terrestris*, an obligochaete.

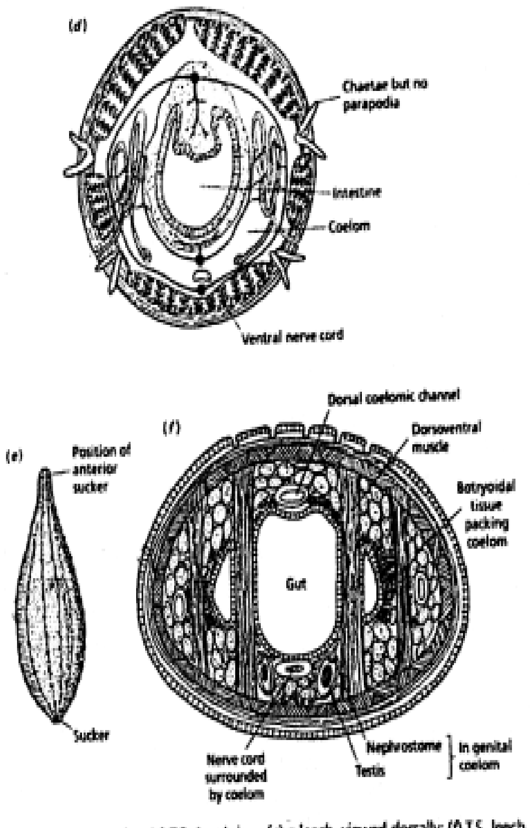

Fig. 1 : (cont.) (d) T. S. Lumbricus; 9e) a leech, viewed dorsally; (f) T. S. leech.

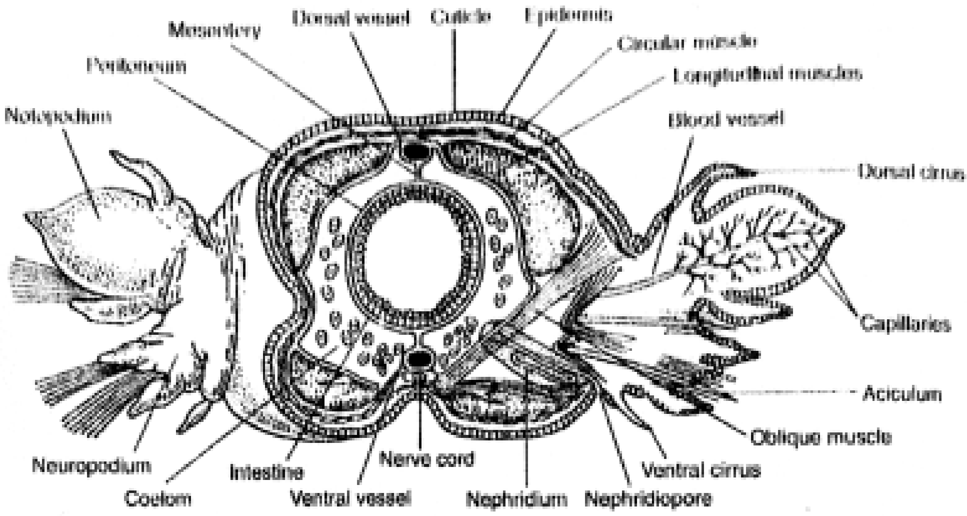

Fig. 2 : Diagrammatic view of different structures in a segment of *Nereis*. Left side of the figure depicts an entire parapodium and the remaining part is shown in cross section (after various sources).

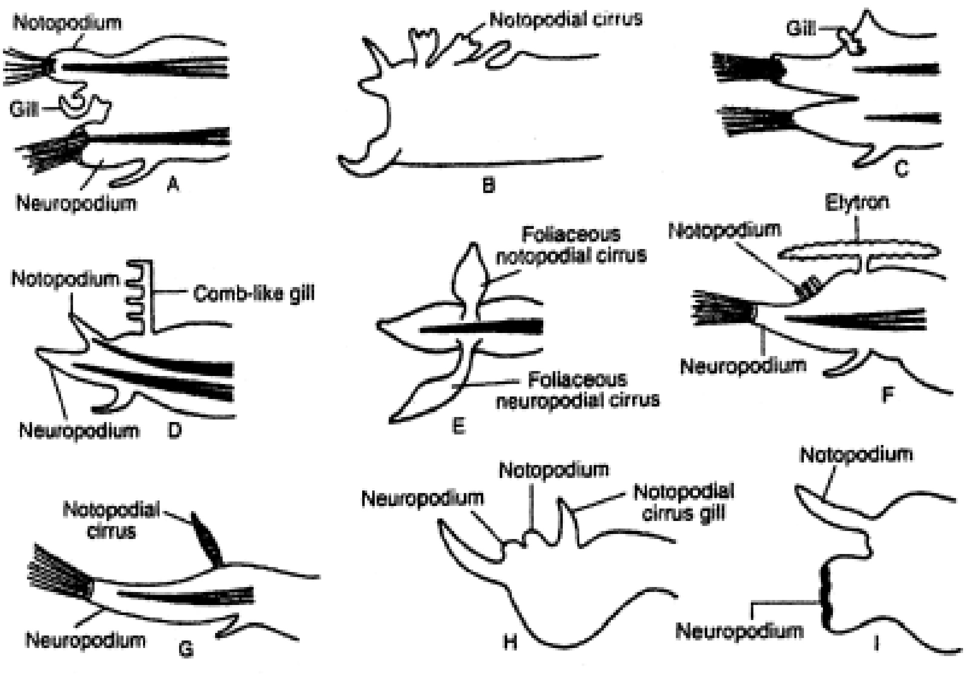

Fig. 3 : Showing the modification of parapodia in different annelids. A. Parapodium of *Nepthys*. The notopodium gives a curved gill on its underside. B. Parapodium of *Amphinome*. The notopodium is indistinct. C. Parapodium of *Glycera*. D. Parapodium of *Eunice*. It is uniramous with reduced notopodium. The notopodial cirrus acts as the comb-like gill. E. Parapodium of *Phyllodoce*. The cirri are foliaceous. F. Parapodium of *Polynoe*. The notopodium is not developed. An elytron is present. G. Parapodium of *Syllis*. Notopodium is entirely absent. H. Parapodium of *Scoloplos*. Both the neuropodium and notopodium are reduced. I. Parapodium of *Sebella*. Cirri are absent.

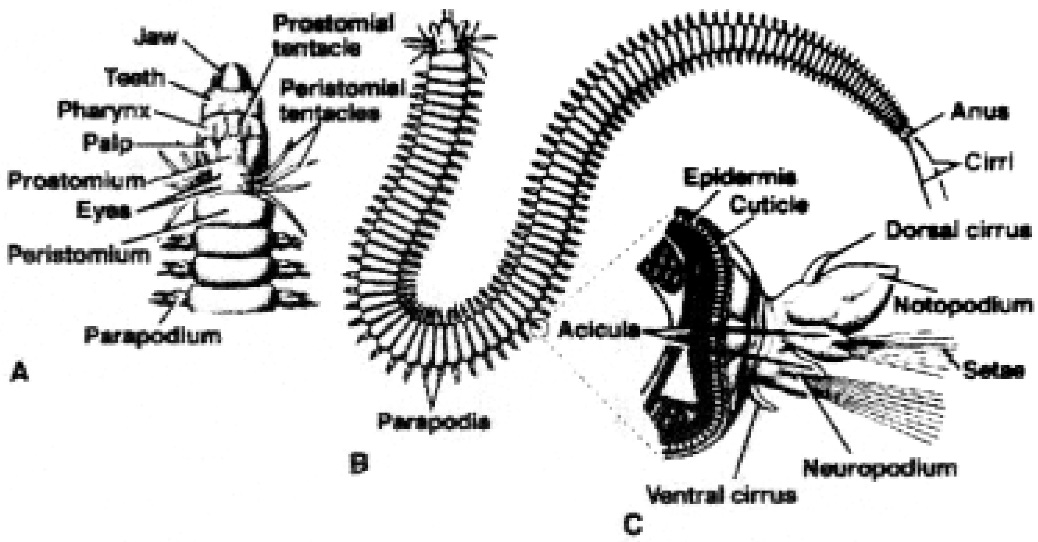

Fig. 4 Polycheat body Part: A. Prosotomium, B: Neries, C: Parapodium

4. Presence of two suckers–a small **anterior or head sucker** surrounding the mouth and a large powerful **posterior sucker**, both are situated ventrally. Clitellum present but never conspicuous except during reproductive periods.
5. Mouth opens on the ventral surface of anterior sucker, while anus opens dorsal to the posterior sucker. Just within the mouth cavity are three large, oval blade—like jaws each bearing a large number of small teeth along the edge. As the animals suck blood their salivary glands secrete an anticoagulant called **hirudin**. In most forms the stomach is provided with 1 to 11 pairs of **lateral caeca**.
6. Coelom is greatly reduced due to the presence of connective tissue, called **botryoidal tissue** and is represented by haemocoelomic sinuses.
7. The septa are greatly reduced. Metamerism is shown by paired nephridia and ganglia of the ventral nerve cord.
8. Hermaphrodite, with several pairs of testes, a pair of ovaries and a single genital opeing. Gonads and gonoducts restricted to anterior few segments.
9. Fertilization internal (cross fertilization).
10. Development direct (no larval form), eggs are usually laid in cocoons, secreted by the clitellum.

Examples : ***Hirudinaria***, ***Hirudo***, ***Acanthobdella***, ***Glossiphonia***, ***Placobdella***, ***Pontobdella*** etc.

7.5 Metamerism in annelids

? ? ? ?

7.6 Questions

? ? ? ?

7.7 Suggested Readings

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Unit - 8 ❑ Artheopoda – General characteristics and Classification up to Classes : Social life in insects.

Structure

8.1 Objectives

8.2 Introduction

8.3 Characteristic Features of of Arthropods

8.4 Classification of the Phylum Arthropoda

8.4.1. Subphylum Trilobita

8.4.2. SubphylumChelicerata

8.4.3. SubphylumCrustacea

8.4.4. SubphylumUniramia

8.5 Social life in insects.

8.6 Questions

8.7 Suggested readings

8.1 Objectives

From this chapter learner will learn the detail story about the biggest of Phylum of the Animal Kingdom. This chapter also deals with the diversity among arthropodan animals. After studying this unit, learners would be able to understand the characteristic features and classification of Arthropoda, characteristic features and classification of subphylum Trilobita, subphylum Chelicerata, subphylum Crustacea and subphylum Uniramia up to classes with examples and diagrams. The learners will also learn about an interesting topic in zoology i.e. the social life in insects

8.2 Introduction

Phylum Arthropoda is the largest phylum in the animal world and this phylum represents a vast assemblage of animalswith hard exoskeletons and jointed appendages. The phylum includes more species and more individuals than all other groups of animals combined. Over 85 percent of all known animal species described to date are belong to the phylum Arthropoda (Fig.). No other phylum of animals can rival the arthropods in success i.e. theyare considered the most successful animals on Earth and it is due to the tremendous adaptive diversity that has enabled them to survive in virtually every habitat. Its members occupy a large ecological niche and inhabit virtually all types of environments on the planet i.e.from snow covered mountain peaks to the depth of the ocean. In other words, they have been most successful in colonizing terrestrial, aquatic, and aerial habitats. They consume the greatest varieties of food. Their success as terrestrial animal is probably due to the evolution of water conserving excretory sysems and gaseous exchange organs and the development of a desiccation resistant impermeable epicuticle. Many members of this phylum are closely related with different aspects of human life like food, health, etc. and thus have great economic importance.Many familiar species belong to the phylum Arthropoda—insects, spiders, scorpions, centipedes, and millipedes on land; crabs, crayfish, shrimp, lobsters, and barnacles in water. The class Insecta by itself represents almost three quarters of all described animal species (Fig.).

Arthopods are eucoelomate, protostomic organisms. The word Arthropoda comes from Greek “arthron” means joint and “podos” or “podos” means foot or leg *i.e.* “animals with jointed legs.”

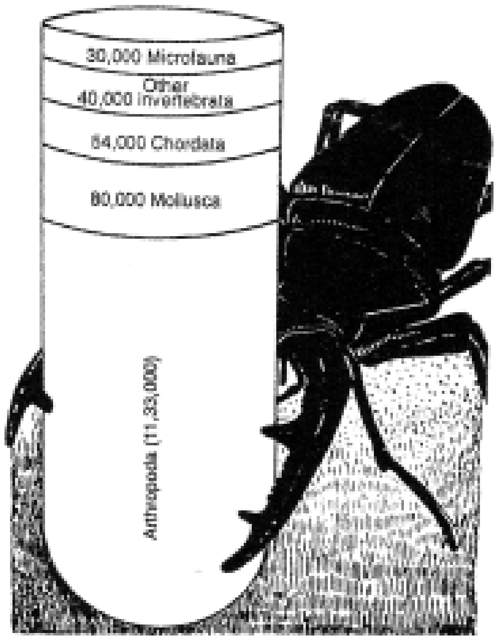


Fig. 1 : In the animal world, the Phylum Arthropoda includes the largest number of species. All of them possess metameric segmentation, hard chitinous exoskeleton and jointed legs. Number shown against each group denotes the approximate number of species.

8.3 Characteristic features of Arthropoda

1. Arthropoda are triploblastic, bilaterally symmetrical, coelomate and metamerically segemented animals.
2. Presence of paired externally joined appendages usually in each segment (Greek "arthran" means joint and "podos" or "pous" means foot or leg). Appendages are variously modified.
3. Anterior segments are specialized to form a distinct head and tagmatization (body segments grouped into specialized regions) is highly developed (e.g., head, thorax and abdomen).
4. Body is covered with a thick chitinous cuticle forming the exoskeleton (usually composed of carbohydrate and protein) with sclerotized plates.
5. Arthropods exhibit ecdysis or moulting. They shed off the old exoskeleton periodicallyand a new one develops from the underlying epidermis.
6. A pair of externally jointed appendages is usually present in each segment.
7. Musculature is not continuous but comprises of separate striped muscles. Muscles are attached to the inner surface of the skeletal system(in vertebrates the muscles are attached to the outer surfaces of the endoskeleton).
8. The body cavity is a haemocoel. True coelom is represented by spaces within the gonads and excretory organs. Thus coelom is much reduced.
9. Mouth and anus are present at the two terminal ends of the body.
10. Circulatory system is open type (e.g., blood or haemolymph opens within haemocoelthrough which it circulates to the internal organs) with a dorsallyplaced tubular hearthaving paired lateral ostia.
11. Respiration by general body surface, gills, trachea, book gills or book lungs. Haemocyanin is the usual respiratory pigment..The terrestrial forms perform respiration through trachea or book lungs. Aquatic forms use gills or the body surface.
12. Arthropods possess two types of excretory organs—Malpighian tubules (found in many terrestrial arthropods) and paired saccules (end sacs). Saccules take thename of the appendage with which they are associated, like coxal glands, green glands, antennal or maxillary glands and so forth.

13. Central nervous system consists of a dorsally placed anterior ganglionic mass(brain) connected to double ventral nerve cords running through all segments and forming paired ganglia in each segment.
14. Sensory organs comprise of simple or compound eyes (found in many crustaceans and most insects) and chemoreceptors, tactile receptors, balancing and auditory organs. Each compound eye is made up of several visual units or omatidia (sing.omatidium).
15. Cilia are entirely absent from all parts of the body.
16. Sexes are usually separate (dioecious or gonochoristic); some hermaphrodite. Sexual dimorphism is seen in many
17. Eggs are centrolecithal and cleavage usually superficial.
18. Fertilization usually internal. Oviparous or ovoviviparous.
19. Development is usually indirect involving one or more larval forms. Absence of ciliated larvae.
20. Parthenogenesis is seen in some members of Insecta, Branchiopoda and Copepoda.
21. Parental care is well marked in some species.

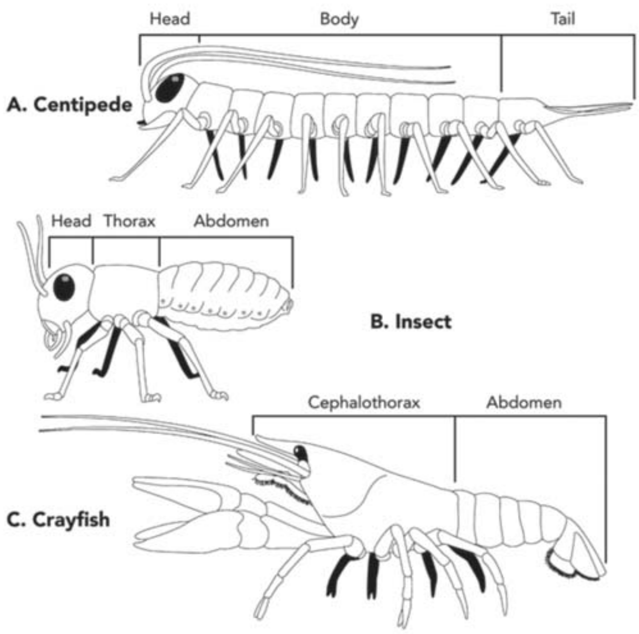
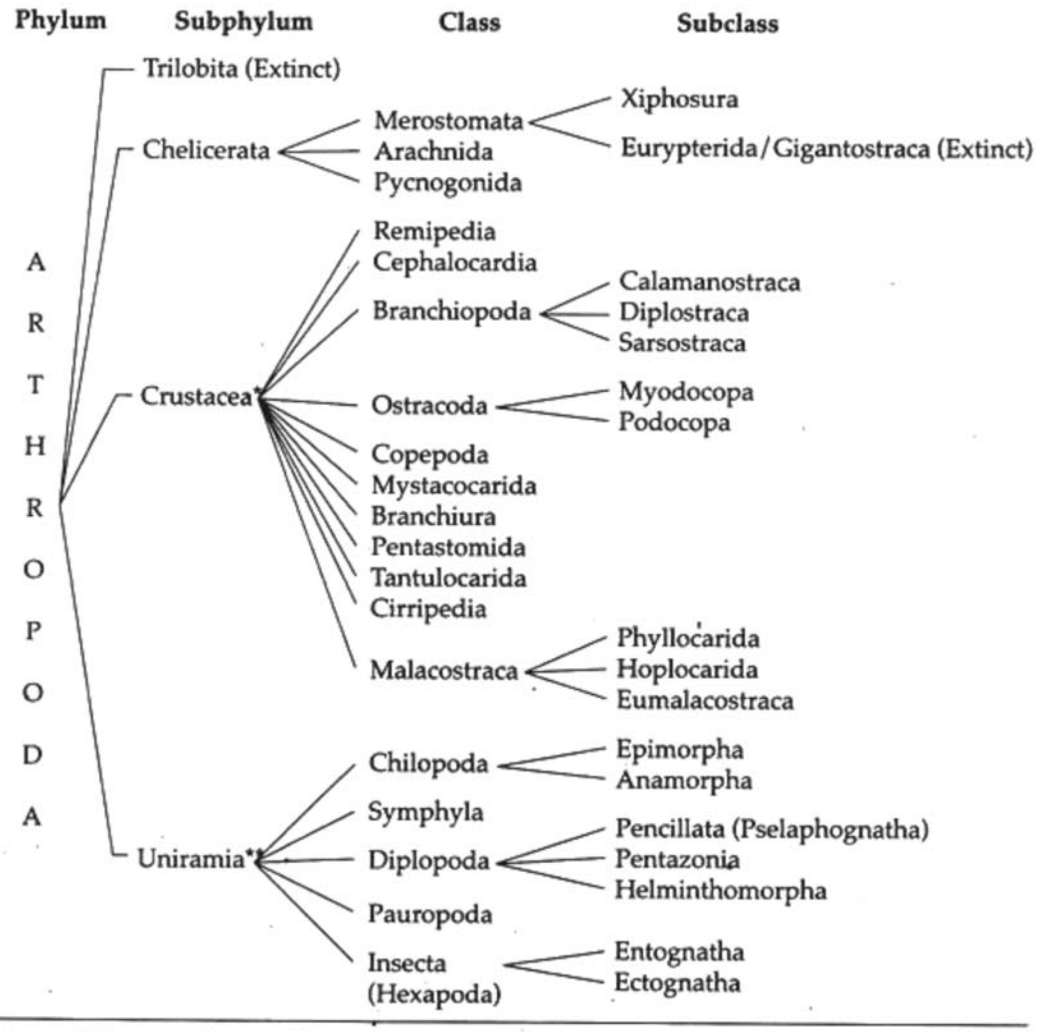


Fig. 2 : Examples of arranagement of segments in three types of arthropods (A) Centipede (B) Insect (C) Crayfish

8.4 Classification of the Phylum Arthropoda

Modern zoologists believe that there are probably four main lines of arthropod evolu-tion. These lines are represented by the extinct Trilobita and the three living-Chelicerata, Crustacea and Uniramia. The uniramia contains the flourishing insecta. The first three groups have marine origin, while uniramia appears to have evolved on land.



* Except Malacostraca, the rest of the crustacean classes had been grouped under Entomostraca in older literature.

** The four groups of uniramians — Chilopoda, Symphyla, Diplopoda and Pauropoda — Comprising of about 10,500 species were formerly considered within a single class, the Myriapoda. Modern zoologists, however, have abon-doned the Myriapoda, except as a convenient collective name.

The classification scheme followed here is based on the scheme outlined by Ruppert and Barnes (1994) in their book “Invertebrate Zoology” (6th edition). They divide the phylum Arthropoda into four subphyla—Subphylum Trilobita, Suhphylum Chelicerata, Subphylum Crustacea, and Subphylum Uniramia.Except the first one (i.e. Trilobita) all three subphyla are living. The uniramia includes the flourishing insects. The first three subphuyls have marine origin, while the members of untramia appears to have evolved on land.

Scheme of Classification (As outlined by Ruppert and Barnes, 1994).

8.4.1. Subphylum Trilobita

Classification with Characters :

l. Subphylum Trilobita (or Trilobitomorpha)[Gk. tri = three, lobos = lobe, morphe = shape = three-lobed form]

Trilobites were abundant and widely distributed in Paleozoic seas. They reached their height during Cambrian and Ordovician period and disappeared at the end of Palaeozoic era. From fossil specimens about 3900 species have been described.

Characters :

1. Extinct marine arthropods.
2. Body more or less oval and flattened from above downwards.
3. Body is divided into three regions:

   (i) The anterior head or cephalon, (ii) The middle region trunk or thorax and (iii) a posterior pygidium.
4. Each region of the body is divided into 3 lobes by two longitudinal furrows, hence the animals derive their name Trilobites or three-lobed form.
5. Size varies from 10 mm to 60 cm.
6. Head and pygidium were covered by an un-jointed calcareous exoskeleton, called carapace.
7. Presence of a pair of compound eyes, found laterally on the anterior part of the body.
8. A pair of many-jointed antennae represents the pre-oral appendage.
9. Post-oral appendages are uniform, biramous and unspecialized. The innermost branch of each appendage was without long setae and was probably adapted for walking and the outermost branch had long filaments used for swimming or filtering food materials. The two branches are sometimes called endopodite and exopodite also.

10. Each leg has 8 segments.
11. The anal opening was on the last segment of the pygidium.

    The subphylum includes about 3900 species which are grouped under 5 classes and the class Trilobita includes the largest number of species.

Examples :

Agrestus, Ampyx, Mesonocis, Holmia, Trinucleus, etc.

Chelicerata (Greek: chele, talon; cerata, horns)

8.4.2. Subphylum Chelicerata

Chelicerata (Greek : *chele,* talon ; *cerata,* horns)

Classification with Characters:

1. Heterogenous group of arthropods, in all of which pre-oral antennules or first antennae are absent (nonantennate).Chelicerates are the only arthropods which lack antennae.
2. Bilaterally symmetrical. Body shape varying from elongated to almost spherical.
3. Body is divided into two parts— anterior cephalothorax or prosoma, which is wholly or partly covered by a dorsal carapaceand a posterior abdomen (or opisthosoma) with no distinct head.Opisthosoma without legs.
4. Appendages uniramous.Cephalothorax possesses five postoral segments, each with a pair of appendages. First pair of appendages on the first postoral segment is called chelicerae(helps in feeding),one pair of chelate leg-like or feeler like 'pedipalps'

   (helps in various functions) and four pairs of walking legs.. The chelicerae become pre-oral in positionand bears a terminal chela.
5. Chelicerates have no jaws (mandibles); hence may be called amandibulates.
6. Each chelicera is jointed and bears a terminal chela.
7. Abdomen (opisthosoma) consists of 12-13 segments and a telson (telson and many abdominal segments are absent in certain forms).
8. Second abdominal segment bears genital aperture which remains covered by a modified abdominal appendage, called operculum.
9. Compound eyes in most cases degenerated.
10. Median ocelli or simple eyes present.
11. Mouth anteroventral. Gut straight. From the mid gut region arise two to many

pairs of digestive diverticula which secrete enzymes that intraeellularly digest and absorb food.

12. Development generally direct, juvenile with the full complement of limbs.
13. Primarily marine arthropods, although most living forms are terrestrial.

Chelicerata contains about 63,000 described species placed in three classes.

(i) Class Merostomata

(ii) Class Arachnida

(iii) Class Pycnogonida.

Class 1. Merostomata [Gk. meros = the thigh; stomatos, genitive of stoma = mouth] :

Characters :

1. Marine forms with fairly developed compound eyes, present laterally.
2. Head and thorax are fused into a single unit—the prosoma or cephalothorax covered by a single sheet of exoskeleton, the carapace.
3. First pair of appendages on the prosoma, first one is the Chelicerae followed by 5 pairs of appendages, the walking legs.

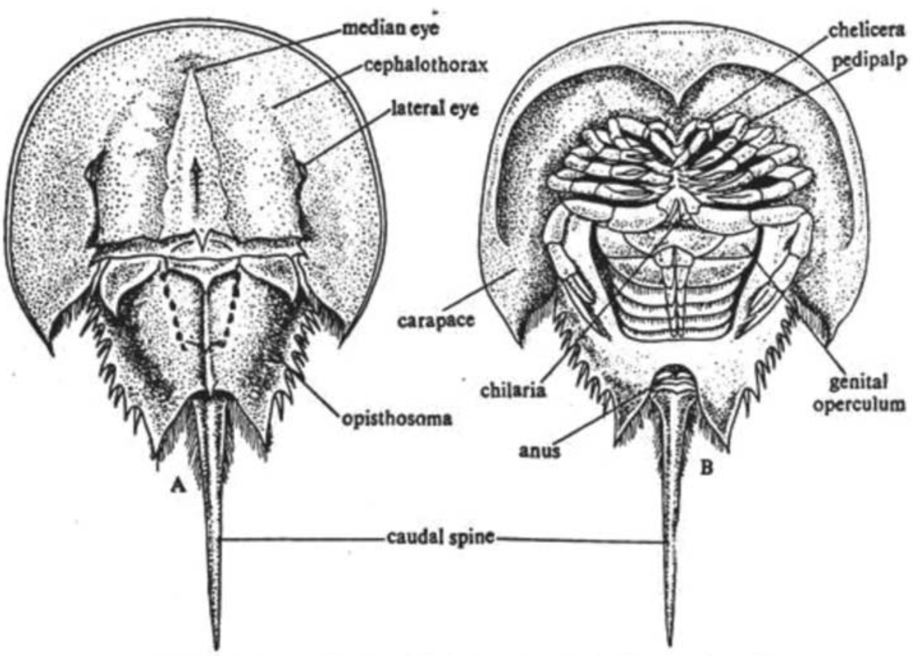


Fig. 1.101 : External features of *Limulus*. A. Dorsal view. B. Ventral view.

4. Prominent caudal spine, called telson, present at the end of the body, used as a lever in pushing and balancing during locomotion.
5. Respiratory organs are gills (book- gills), which are borne on the plate-like appendages of the mesosoma.
6. Adults crawl on earth with the face downwards, but young can swim actively.

Examples :

Limulus, Tachypleus, Carcinoscorpius.(These marine, bottom dwellers are commonly called horse-shoe crabs).

Class 3. Arachnida [Gk. arachne = spider] About 70,750 species; Size: 0.25 mm-18 cm.

Characters :

1. Body divided into two regions— cephalothorax (Prosoma) and abdomen. Prosoma un-segmented, usually covered dorsally by a solid carapace. In some arachnids (ticks and mites), the prosoma and opisthosoma have fused together and the entire dorsal surface is covered by a single carapace.
2. Eyes usually simple. Compound eyes when present are degenerated.
3. Two pairs of jointed cephalic appendages-chelicerae and pedipalpi present. The first pair of cephalic appendages, known as chelicerae, which are preoral and the 2nd pair, the pedipalps, are postoral and serve partly as jaws.
4. Four pairs of thoracic legs present.
5. Abdomen generally without appendages but modified appendages in some. Some arachnids (the spiders) bear up to 4 pairs of small abdominal appendages called spinneret.
6. Antennae absent.
7. Large arachnids (scorpions, some spiders) possess book lung as respiratory organs; small forms (psuedoscorpions, some spiders, mites) possess tracheae. In some arachnid species, both book lungs and tracheae and book lungs are present.
8. Eyes usually simple. Compound eyes either absent or degenerated. For most arachnids the sensory hairs are the primary sense organs
9. The heart is highly developed in large species with book lungs and the blood contains haemocyanin.
10. Excretory organs are Malpighian tubules or coxal glands or both.
11. Sexes separate. Single or paired gonads that lie in the abdomen. Fertilization is internal.

12. Eggs yolky and centrolecithal.
13. Development direct, not accompanied by metamorphosis.
14. Arachnids are carnivorous and except a few secondarily aquatic forms, most of them are terrestrial.
15. Predator arachnids use poison or silk in prey capture.e.
16. About 98% of the living chelicerates (Subphylum Chelicerata) belong to class Arachnida.

Examples : *Buthus (scorpion), Palamnaeus (scorpion),Scorpio,Chelifer (pseudoscorpion), Aranea (spider), Lycosa (wolf-spider), Latrodectus (black widow spider),*

Tarantula,Sarcoptes (mites), Ixodes (ticks), Dermacentor (ticks), Chorioptes (mites).

Examples :

Mesobuthus,, Mastigoproctus, Trithyreus, Eukoenenia, Argiope, Aranea (orb-web spider), Latrodectus, Cryptocellus, Ricinoides,Chelifer, Neobisium, Galeodes, Eremobates, Caddo, Phalangium, Trogulus, Mitobates,Tetranychus, Demodex, Hoplophorella, Annectacarus, Sarcoptes.

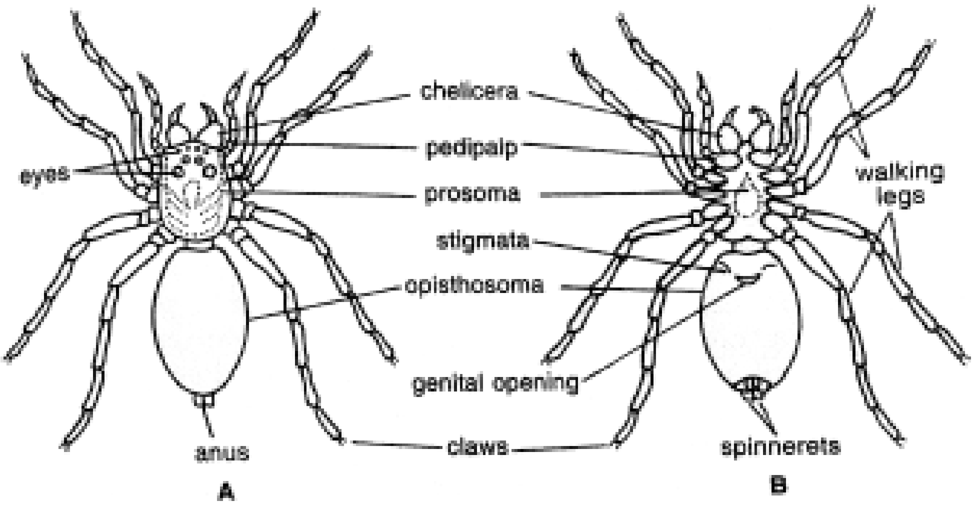


Fig. A spider. A—Dorsal view; B—Ventral view.

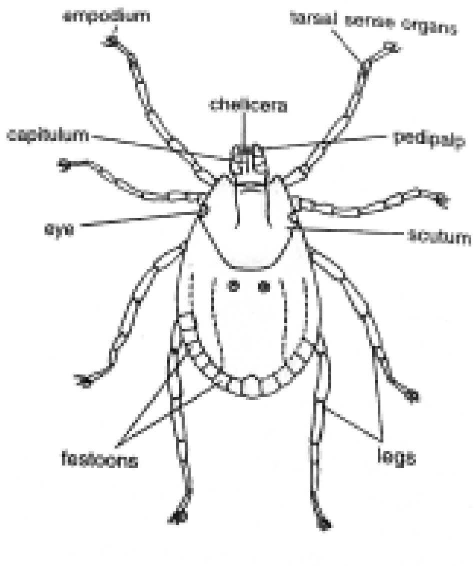


Fig. A tick. Dorsal view.

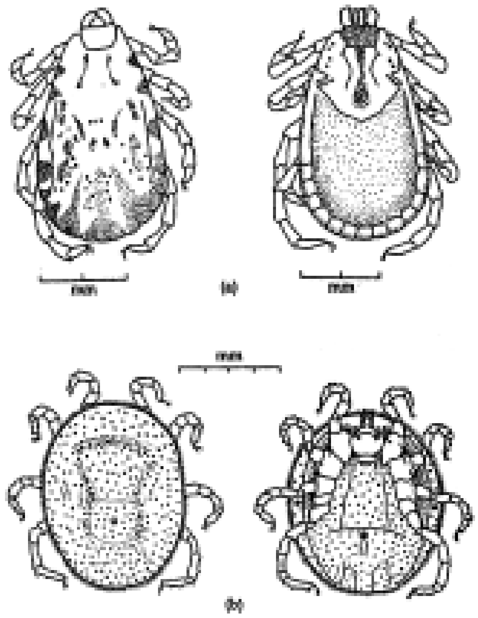


FIGURE 6 : Ticks. (a) Hard tick, Dermacentor andersoni (male left, female right). (b) Soft tick; Omithodoros moubata (dorsal aspect left, ventral aspect right).

Additional readings :

Although the earliest members of the class Arachnida were undoubtedly marine, the than 70000 living arachnid species so far described are primarily terrestrial, se speices that are aquatic (some mites) represent a secondary return to rreshwater or the sea. This class includes many familiar but generally unpopular organisms, including spiders, mites, ticks and scorpions. Nearly half of all arachnid species are spiders and most of the remaining species, about 9000, are mites and ticks. Scropions, the most primitive arachnids have long, segmented abdomens. The highly specialized mites have lost all external evidence of metamerism and the cephalothorax and abdomen are broadly joined together. Arachnids are largely predatory chelicerates and other arthropods are their principal prey. Spiders are major insect eater and used to control insect populations. Ticks and mites are mostly parasites. Some are blood sucking ectoparasites on vertebrates. Mites and ticks have economic and medical importance despite their small physical size.

Class 3. Pycnogonida (= Pantopoda): About 1,000 described species (about 16 Indian species). Size: 1 mm-10 cm.

Characters :

1. Small, benthic, marine, partially sedentaric chelicerates, commonly called sea spi-ders.
2. Youngs are parasitic on different soft bodied invertebrates.
3. Opisthosoma much reduced with a terminal anus.
4. Chelicerae short and pedipalpi segmented.
5. The head or cephalon bears four eyes at its anterior end and a cylindrical pro-boscis.
6. Third pair of appendages in the male carries the eggs and is called the ovigers.
7. Trunk of 3-6 segments with long walking legs.
8. No special organs for gas exchange and excretion are present.
9. Reproductive openings present on the leg segments (present on the ventral side of coxae) and not abdominal.
10. Dioecious. Development usually through a larva called protonymphon.

Examples :

Nymphon, Pycnogonum, Colossendeis.

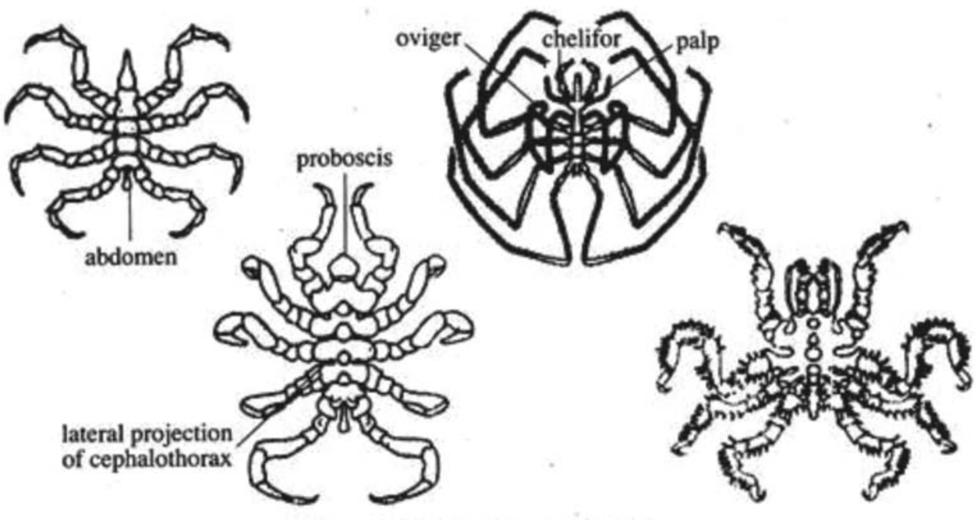


Fig. 1.103 : Pycnogonan body forms.

8.4.3. SubphylumCrustacea

Crustacea:(In Latin crusta means a hardshell) :

This subphylum includes copepods, shrimps, prawns, barnacles, lobsters crabs, etc.

Classification with Characters :

1. Body is divisible into head, thorax and abdomen. Head is fused with thorax in many to form cephalothorax which is covered dorsally by carapace.

   Carapace covers all or part of the body.Exoskeleton often calcareous
2. Head bears five pairs of appendages. Crustanceans are unique among arthropods in having two pairs of antennae (first pair of antennae is called antennules).
3. Presence of two pairs of antennae isa distinguishing feature of crustaceans. Other cephalic appendages are a pair of mandibles and two pairs of maxillae.
4. Thorax usually with eight pairs and abdomen usually with six pairs of appendages. Appendages undergo various modifications. Last segment of abdomen is telson.
5. Thoracic and abdominal appendages are typically biramous i.e. the two branches are of different size and shape, and become adapted for different functions.
6. Head bears a pair of compound eyes (in some located on movable jointed stalk) and a small median dorsal naupliareye (a characteristic feature of the naupliar larva of crustaceans and therefore referred to asthe naupliar eye).
7. Sense organs, other than eyes include statocysts, sensory hairs and proprioceptors.
8. Brain formed by the fusion of first four embryonic ganglia and is connected with ventral nerve cord by oesophageal connectives.
9. Vascular system consists of a contractile heart, arteries and haemocoelomic spaces.
10. Respiration by means of gills or by general body surface. Gills are typically associated with the appendages but the location, number and form vary greatly.
11. Excretory organs are a pair of blind sacs in the haemocoel of the head and they open onto the bases of the second pair of antennae (antennal glands or green glands) or the second pair of maxillae (maxillary glands). These are the modification of coelomoducts.
12. Most crustaceans are dioecious (sexes separate). Distinct sexual dimorphism present. Copulation and egg brooding are very common.
13. Eggs are mostly centrolechithal i.e., yolk present in the central part of the egg.
14. Cleavage is superficial. Development through various larval forms like Nauplius, Cypris, Megalopa, Zoea, etc. The earliest hatching stage is a naupliar larva bearing a single median eye and three pairs of body appendages.

15. Mainly aquatic, mostly marine, many freshwater and some have invaded into terrestrial condition.

Examples : *Palaemon (prawns), Cancer (crabs), Squilla,Penaeus, Macrobrachium, Eupagurus (hermit crab), Daphnia, Artemia (brine shrimp), Triops, Cypris,*

Cyclops, Argulus (fish louse), Lepas (goose barnacle), Balanus (rock-barnacle or acorn barnacle), Sacculina.

Crustanceans are one of the most popular invertebrate groups, even among non-biologists, for they include some the world's most delicious food items, such as lobsters, crabs and shrimps. There are more than 67000 descirbed living species of Crustacea (Brusca and Brusca, 2003). They exhibit an incredible diversity of form, habit and size. The smallest known crustaceans are less than too pm in length and live on the antennules of copepods (a group of Crustacea). The largest are Japanese spider crabs (Macrocheira kaempferi), with leg span of 4 metres and giant Tasmanian crabs (Pseudocarcinus gigas) with carapace width of 46 cm. The heaviest crustaceans are probably American lobsters (Homarus americanus), which attained weights in excess of 20 kilograms. Crustancens are found at all depths in every marine, brackish and freshwater environment on Earth. A few have become successful on land, the most notable being sow bugs and pill bugs (the terrestrial isopods). Crustaceans occupy an important position in aquatic food chains.

The subphylum Crustacea is divided into 11 classes :

1. ClassRemipedia,
2. Class Cephalocarida,
3. Class Branchiopoda,
4. Class Ostracoda,
5. Class Copepoda
6. Class Mystacocarida,
7. Class Branchiura,
8. Class Pentastomida,
9. Class Tantulocaride,
10. Class Cirripedia and
11. Class Malacostraca.

Class 1. Remipedia :

This group was first recognised in 1983 with twelve known species.They were first discovered in 1981 and is represented by nine species.

Characters :

1. Marine animals with small (range up to 30 mm in length), elongated, worm like and translucent body.
2. Body comprises of a short, carapace-less cephalothorax, followed by a trunk of 20-30 similar segmentseach with a pair of leaf-like, lateral biramous appendages.
3. They are carnivorous and the first pair of trunk appendages are modified as pre-hensile maxillipeds for feeding. Other trunk appendages help in swimming.

4. Eyes absent

4. Telson with caudal rami.

5. Hermaphrodite.Development still unknown.

They are the inhabitants of tropical marine caves.

Examples :

Lasionectes, Speleonectes.

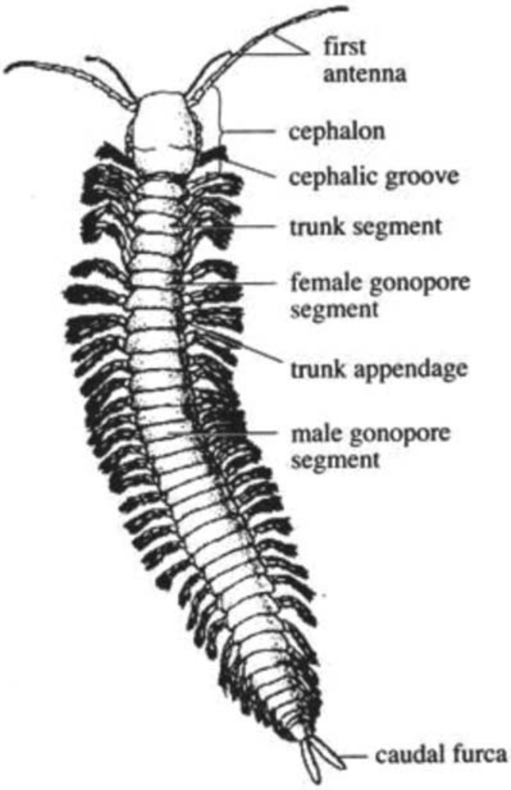


Fig. 1.104 : *Speleonectes tulumensis.*

Class 2. Cephalocarida [Approx. 9 species]

The members of this group are considered to be most primitive among living crustaceans and the first member was discovered in Long Island Sound in 1955. The all species are marine and have collected in the soft sediments of the bottom up to the depths of over 1,500 m.

Characters :

1. Bottom dwelling, marine animals and are detritus feeder.
2. Body small, (about 3.7 mm in length), horse-shoe shaped head followed by an elongated and cylindrical trunk (thorax and abdomen) terminating in a telson with a long furca. No cephalothorax or carapace.
3. First 8 thoracic segments bear biramous appendages which are identical in appearance.
4. The appendages are tripartite.
5. Exopodites of these appendages are four-jointed and leaf-like and bear lateral pseudoepipodite.
6. Endopodites are segmented and cylindrical.
7. Movements of the limbs produce water current for locomotion and also for collecting food.
8. Although compound eyes are present they are blind as these eyes are buried in the head.
9. Hermaphrodite and development includes metanauplius stage.

Examples:

Hutchinsoniella, Lightiella.

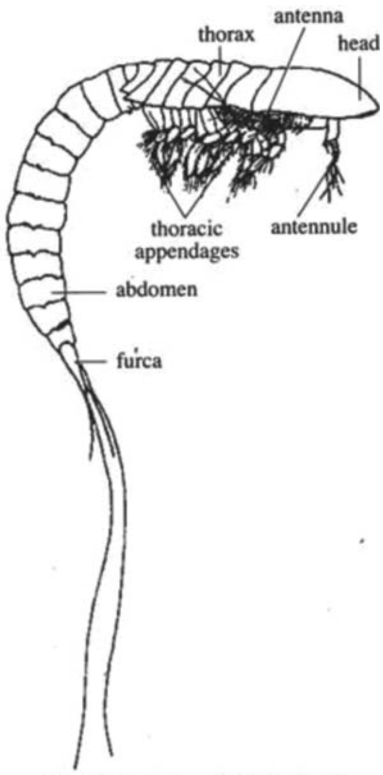


Fig. 1.105 : *Hutchinsoniella* (lateral view).

Class 3. Branchiopoda(Gk. branchiona fin)

Characters :

1. Small crustaceans mainly restricted to fresh water, a few are marine.
2. Trunk appendages are uniform, flattened and leaf-like.
3. Coxa is provided with a flattened epipod that serves as a gill and hence the name “gill feet”.
4. Presence of one pair un-jointed or jointed caudal styles.
5. Carapace either absent or shield-like or bivalve.
6. First antennae and maxillae are small or vestigial and in some cases absent.
7. Mandibular palp either rudimentary or absent.
8. Excretion by maxillary glands or shell glands.
9. Branchiopods brood their eggs.

Examples : *Lynceus* (clam shrimp), *Daphnia* (water flea), *Artemia* (brine shrimp), *Branchinecta* (fairy shrimp) *Triops* (tadepole shrimp).

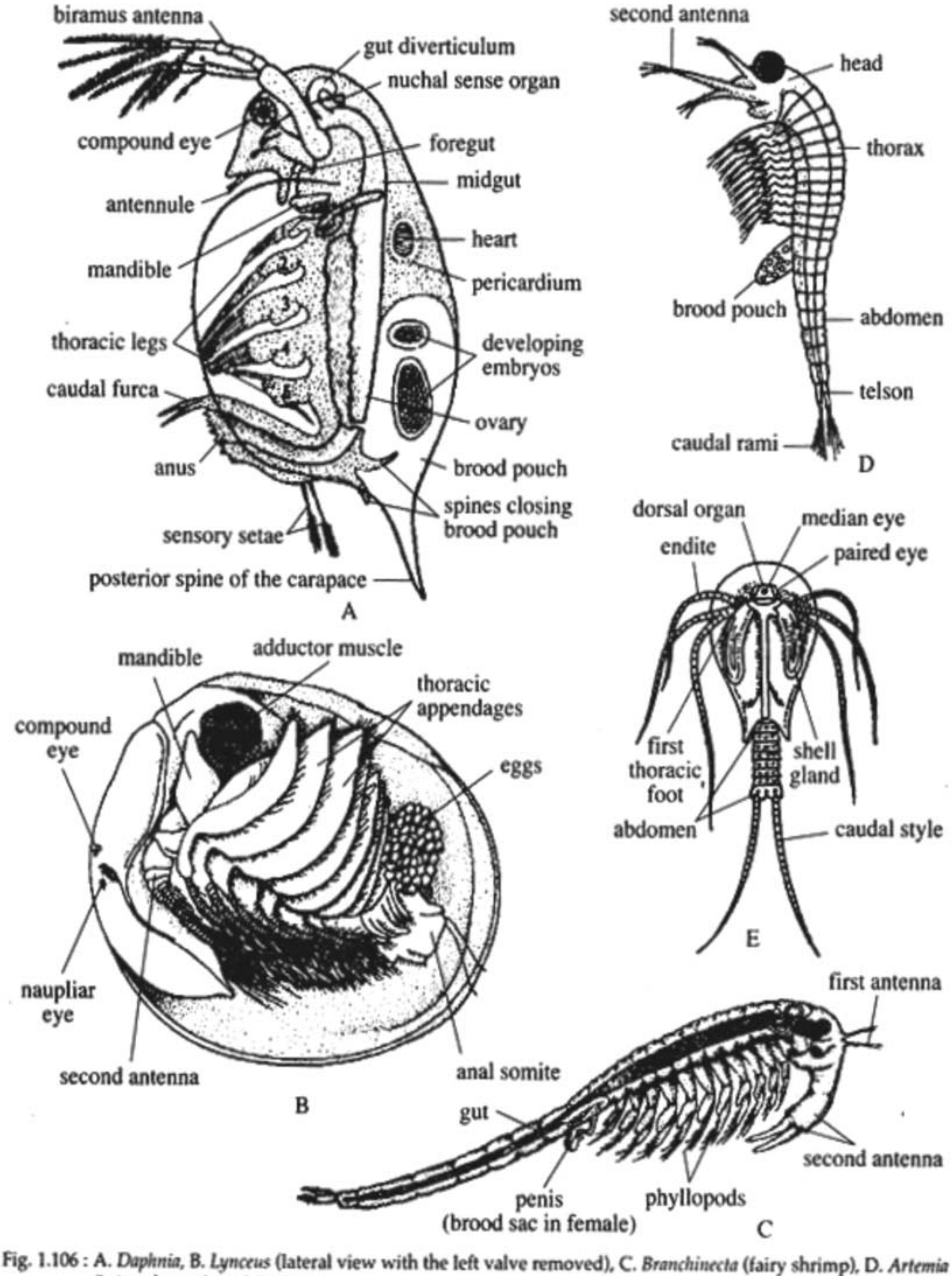


Fig. 1.106 : A. *Daphnia*, B. *Lynceus* (lateral view with the left valve removed), C. *Branchinecta* (fairy shrimp), D. *Artemia* (brine shrimp), and E. *Triops*.

Class 4. Ostracoda(Gk. ostrakodes – testaceous resembling a shell)

Characters :

1. Body enclosed within a hinged bivalved (often calcareous) carapace.
2. Head large, forms half of the body volume and contains four appendages-antennules, antennae, mandibles and first maxillae. Antennae modified for swimming.
3. Trunk reduced having no more than two pairs of appendages.
4. Gills absent. Gas exchange is integumentary (cutaneous).
5. Eyes may or may not be present.
6. Males are rare and the second antennae of the males serve as clasping organs.
7. Ostracods are small crustaceans sometimes referred to as mussel or seed shrimp. They are widely distributed in the sea and in all types of freshwater habitats.

Examples : *Cypridina, Gigantocypris. Cypris, Pontocypris, Candona, Cypridopsis.Cypris* sp., *Vargulahilgendorfii* (bioluminescent species, known as sea firefly)

Class 5. Copepoda(Gk. kope = handle)

Characters :

1. Mostly small with cylindrical bodies.
2. Body with well-marked segments.
3. Head is either rounded or pointed and with well-developed mouth parts and antennae. Head-shield present but no carapace.
4. First pair of antennae longer than second pair and held outstretched.
5. Trunk composed of a thorax bearing five pairs of biramous appendages and a five segmented appendage-less abdomen. Appendages are used for swimming.
6. Presence of a pair of caudal styles.
7. Absence of gills in free living copepods.
8. Single median nauplius eye present but paired compound eyes absent.
9. Excretion by maxillary glands.
10. Seventh segment of the body bears the reproductive apertures.

Most copepods are aquatic and free living, and there are many parasitic species also. About 8,400 species have been identified of which over 1,000 species are parasitic.

Examples :

Cyclops (water flea), *Mesocyclops sp.* (feeds on mosquito larva and used in biological control of mosquito), *Ergasilus* (parasite), *Diaptomus, Misophria, Harpacticus, Lernaea, Lernaeocera, Caligus, Eudactylina.Pennella sp.* (largest copepod and parasitic,parasite on flying fish)

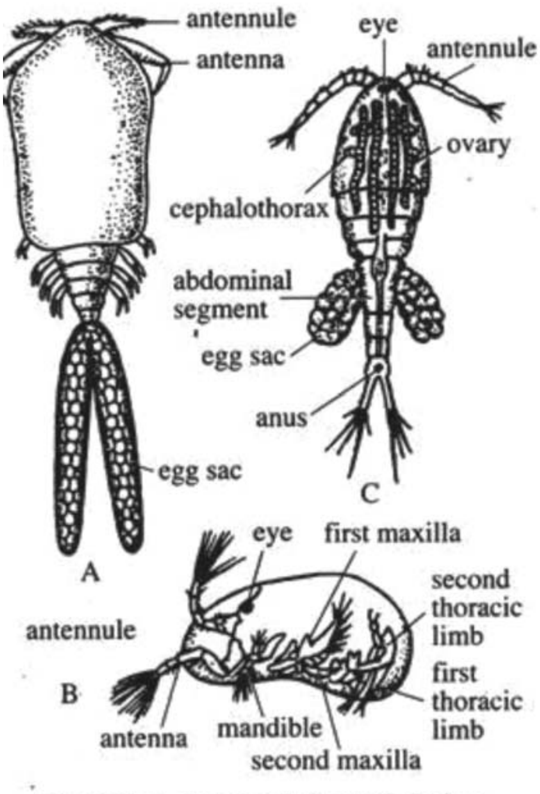


Fig. 1.107 : A. *Ergasilus*, B. *Cypris*, C. *Cyclops*.

Class 6. Mystacocarida

This subclass was created after the discovery of several crustaceans in the year in 1943 and twelve species have been identified.

Characters :

1. Marine interstitial crustaceans with elongated, pigment less body.
2. Length of the body always within 1 mm.
3. Head is divided into a small anterior and a large posterior portion.
4. Cylindrical bodies with distinct cephalic appendages.

5. Trunk is made of ten segments of which the first five bear appendages, the first one being the maxilliped. Two caudal styles work as pincers.
6. Only nauplius eye persists and the compound eyes absent.
7. Sexes separate, development through nauplius stage.

Mystacocarida was first described in 1943 and twelve species have been identified.

Examples :

Derocheilocaris sp., Ctenocheilocharis sp. These are the only two genera with eight and five species respectively.

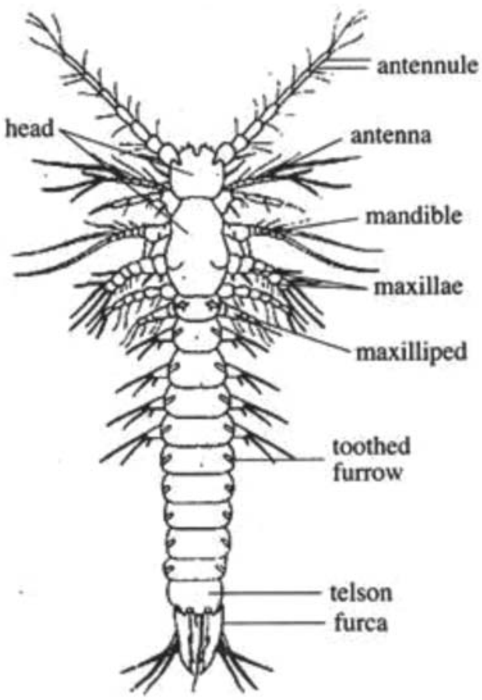


Fig. 1.108 : *Derocheilocaris.*

Class 7. Branchiura

Characters:

1. Dorsoventrally flattened body with suctorial mouth.
2. Broad shield-like carapace covers the cephalothorax.
3. Both pairs of antennae reduced and modified for attachment.
4. Sessile compound eyes present.

5. 5 pairs thoracic appendages.
6. Abdomen small, bilobed and un-segmented.
7. Flagella present in the appendages of some body segments.
8. Fifth body segment bears the genital apertures.
9. Males have two testes but females possess a single ovary.
10. Branchiurans are small, ectoparasites of marine and fresh water fishes. Commonly called fish lice.

Examples :

Argulus, Dolops, Chonopelti, Dipteropeltis.

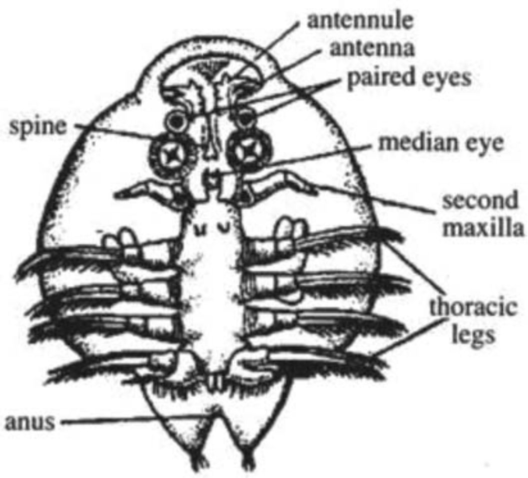


Fig. 1.109 : *Argulus*.

Class 8. Pentastomida

There are about 90 parasitic species of pentastomids.

Characters :

1. Body worm like, and bears five short, anterior protuberances. Four of these projections are leg-like bearing chitinous hooks or claws, used for clinging to the host tissues. The central projection is a snout-like process bearing the mouth.
2. Length ranges from 2 to 13 cm, the females are 10 cm in length.
3. Body covered by a non-chitinous cuticle and exhibits annular markings over the abdomen in the adult.

4. Most of the systems, such as digestive, excretory and reproductive are modified to adapt the endoparasitic life.
5. They are gonochoristic, i.e., the sexes are separate. Fertilization internal.
6. Larva possesses 2-3 pairs of un-jointed Legs.
7. Completion of the life history requires intermediate host.
8. Pentastomids are popularly known as Tongue worms or sometimes referred to as “five mouths”.

All the members are parasitic and live mainly in the lungs and nasal passages of vertebrates which include about 90% reptiles.

Remarks :

The taxonomic status of Pentastomids has long been uncertain. Previously this group was treated as a separate phylum. But recently the sperm ultrastructure and analyses of DNA sequences coding for 18s ribosomal RNA indicate the similarities with crustaceans and suggest that Pentastomids are closely related to marine crustaceans, especially with branchiurans and copepods.

Examples:

Raillietiela, Cephalobaena, Armillifer,Linguatula(Tongue worm), Porocephalus sp.

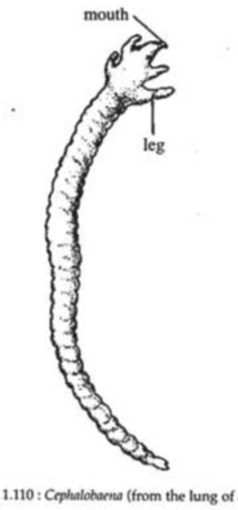


Fig. 1.110 : *Cephalobaena* (from the lung of a snake).

Class 9. Tantulocarida— Approx. 5 known species : About twelve species have been identified under this class.

Characters :

1. Tantulocarids are minute ectoparasites on other deep water marine crustaceans.
2. The adult male remains permanently attached to the host by an oral disc.

3. Thorax six segmented bearing five pairs of biramous limbs and a posterior uniramous one.
4. Abdomen two to six segmented and limbless.

Examples :

Basipoplella ,Tantulacusdieteri(It is the world's smallest arthropod).

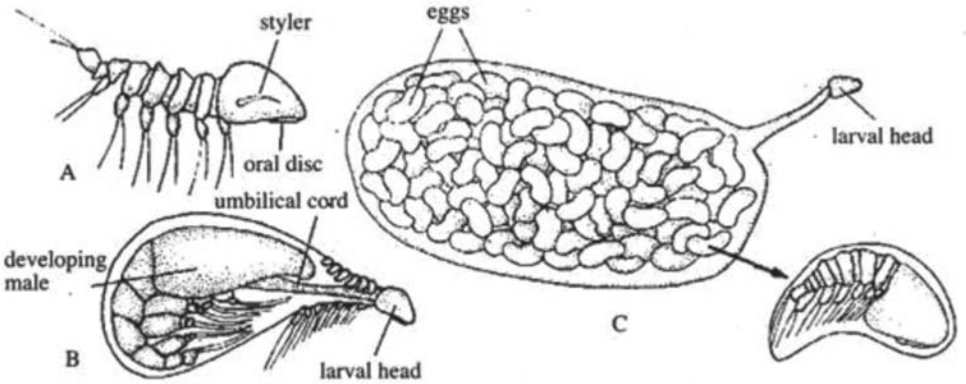


Fig. 1.111 : Body form of tantulocarids : A. tantulus larva, B. male developing within larval body and attached to the host via the larval head and 'umbilical cord', C. adult female filled with eggs, together with detail of larva developing within an egg.

Cl ass 10. Cirripedia(L. cirrus = curled, pedis = foot)

Characters :

1. Cirripedes are either sessile or parasitic marine animals.
2. Adults are sedenteric.
3. Body is poorly segmented and abdomen almost absent, with only a pair of caudal style.
4. Both pairs of antennae reduced or absent.
5. Six pairs biramous filamentous appendages present.
6. Body enclosed within a bivalved carapace with calcareous plates on it.
7. Adults without eyes and antennae.
8. Gills are lacking and the excretory organs are maxillary glands.
9. Usually hermaphrodite.
10. Development comprises of the nauplius larva that passes through a second larva, the cypris.
11. Cirripedes are familiarly known as barnacles.

Examples :

Lepas (Goose barnacles), *Balanus* (Acorn barnacles) *Dendrogaster, Sacculina* (parasite), *Verruca, Trypetesa*

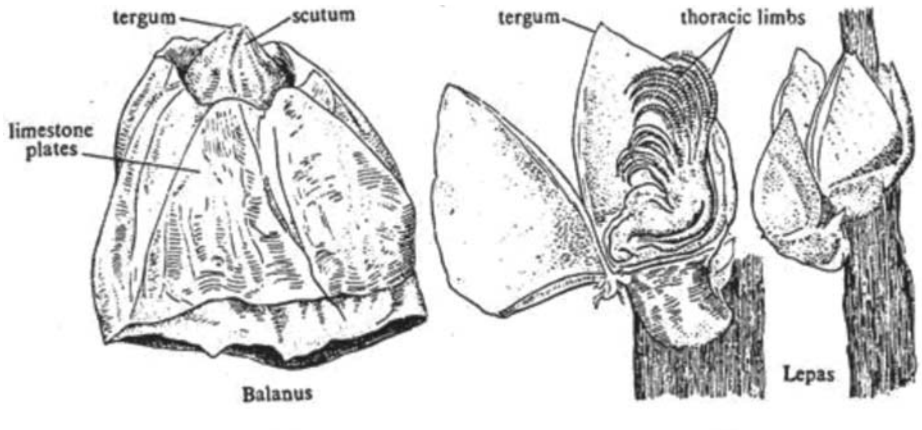


Fig. 1.112 : A. *Balanus* and B. *Lepas*.

Remarks:

Recent trend of the crustacean classification shows that the subclasses Mystacocarida, Copepoda, Branchiura, Tantulocarida and Cirripedia are included under the class Maxillopoda for the characteristic features—6 thoracic and 5 abdominal segments and the first pair of trunk appendages are maxillipeds.

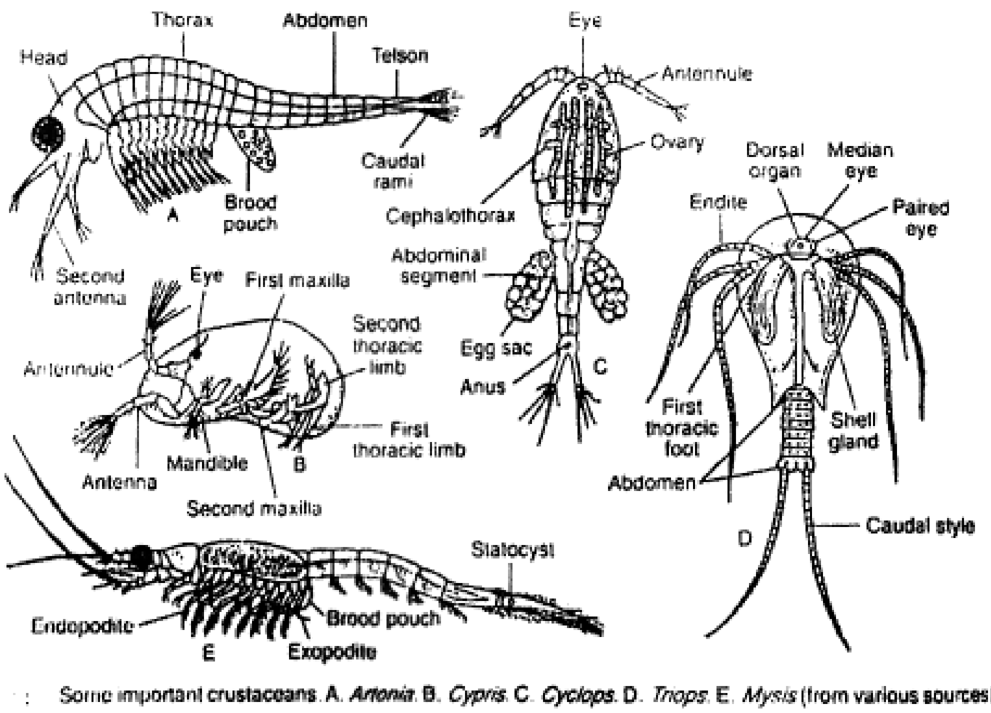


Fig. : Some important crustaceans. A. *Artemia*. B. *Cypris*. C. *Cyclops*. D. *Triops*. E. *Mysis* (from various sources)

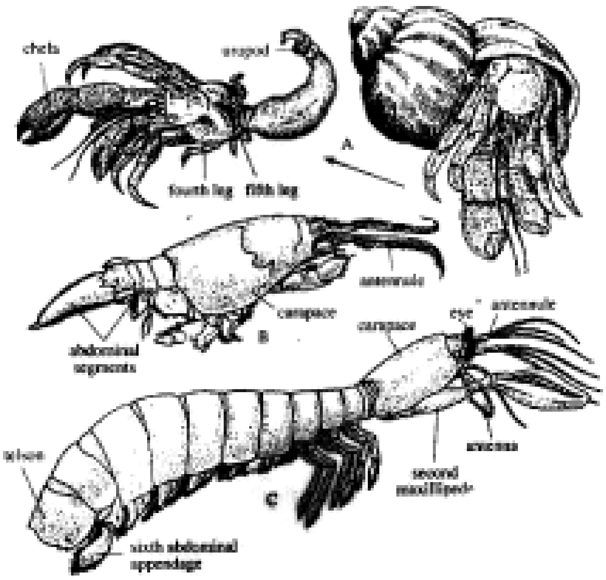


Fig. : A. Eupagurus (Arrow indicates the body of Eupagurus outside the molluscan shell), B. Hippa, C. Squilla, D. Mysis.

Class 11. Malacostraca (Gk. malakos = soft + ostracon = a shell)

Characters :

1. Body comprises of a head, an eight segmented thorax and a six segmented abdomen. All the fourteen segments bear appendages.
2. Thoracic and abdominal appendages distinct from one another.
3. The posterior thoracic limbs being walking legs (pereiopods), the first five pairs of abdominal ones forming swimming organs (pleopods).
4. Antennule with two-many-jointed flagella.
5. Carapace covers the head and at least some thoracic segments.
6. Mandible with a palp.
7. The foregut in most malacostracans is modified as a two-chambered stomach bearing triturating teeth and comb-like filtering setae.
8. Compound eyes present in most species.
9. Male and female gonopores on the bases of 6th and 8th thoracic appendages.This is the largest class of Crustacea, containing about 40,000 living species. The class displays a great diversity of body forms and include crabs, lobsters, crayfish, shrimp, krill, woodlice, amphipods, mantis shrimp and many other less familiar animals.

This class comprises of about 23,000 species divided into three subclasses.

Examples :

Macrobrachiumrosenberghii (giant fresh water prawn), *Penaeusmonodon* (giant tiger prawn), *Squilla* (mantis shrimp), *Panulirus* (lobster), *MysisEupagurus* (hermit crab), *Scyllaserrata* (mud crab), *Carcinusmaenas* (shore crab - one invasive species) *Cancer Euphausia* (Antarctic krill), *HippaOniscus, Nebalia, Paranebolia. Penaeid shrimps* (*e.g.,* Penaeus, Funchalia, Parapenaeus, Metapenaeopsis, Metapenaeus), *Sergestid shrimp* (Sergestes, Lucifer, Acetes).

The penaeid shrimps (fam. Penaeidae) are characterised by the well-developed and toothed rosturm, carapace without postorbital spine, 3rd and 4th pairs of pleopodsbiramous and telson sharply pointed with or without spines. They are found in sandy, mud estuaries, back water and near shore areas. The penaeids are the most valuable commercial shrimps exploited in many parts of the world.

8.4.4. Subphylum Uniramia (Latin: unus, one; ramus, branch)

Classification with Characters:

1. Body divided into head and trunk. The trunk either bear pairs of walking legs, or it may be differentiated into thorax and abdomen, with the abdominal appendages greatly reduced or missing.
2. Appendages strictly uniramous i.e. appendages have only one branch. Head appendages comprise of one pair each of antennae, mandibles and maxillae and in some groups a second pair of maxillae.
3. Mandibles un-jointed and without palp.
4. Presence of a single pair of antennae is an important character.
5. Gas exchange takes place with the help of tracheal system.
6. Excretory organs are Malpighian tubules.

Most are terrestrial, but some are aquatic for part or all of their life cycles.

This is the largest subphylum with maximum species including insects, millipedes, centipedes, and their relatives.

They are by far the most common and diverse major group of arthropods, and in fact comprise over three-fourths of all known animal species on the planet — and probably an even greater proportion of the total number of species, known and unknown.

The subphylum is divided into 5 classes :

These are :

1. Class Chilopoda,
2. Class Symphyla,
3. Class Diplopoda
4. Class Pauropoda,
5. Class Insecta or Hexapoda.

The first four classes i.e. Chilopoda, Diplopoda, Symphyla and Paropoda are commonly called Myriapoda and some Scientists considered these four altogether in a separate taxon.

Class 1. Chilopoda [Gk. Cheilos = a lip]

About 3000 living species; about 100 Indian species. Size: 5 mm to almost 30 cm

Features :

1. Body usually elongated and dorsoventrally flattened.
2. Head bears a pair of antennae, a pair of mandibles and two pairs of maxillae.The antennae are long filiform (long and thin).
3. Trunk comprising of 15 to more than 181 segments each bearing a single pair of uniramous walking legs, the last two segments being legless.
4. The paired appendages of the first trunk segment modified into prehensile (grasping) poison claws or pincers, known as forcipules.
5. The sense organ, 'Organs of Tomosvary' is present as a single pair at the base of the antennae.
6. Segment in front of telson is called genital segment.
7. The genital segment of both sexes usually carries a pair of small appendages (gonopods) which help in reproduction.
8. Respiration takes place by trachea.
9. Excretion by a pair of Malpighian tubules.
10. Sexes separate.
11. Members of this class are nocturnal, carnivorous (usually predatory and mostly venomous) and terrestrial, distributed throughout the world in both temperate and tropical regions, residing in soil and humus, beneath stones, bark and logs. Generally called centipedes or hundred-leggers.

Examples : *Scolopendra, Theatops, Geophilus, Strigamia, Scutigera, Lithobius, Bothropolys.*

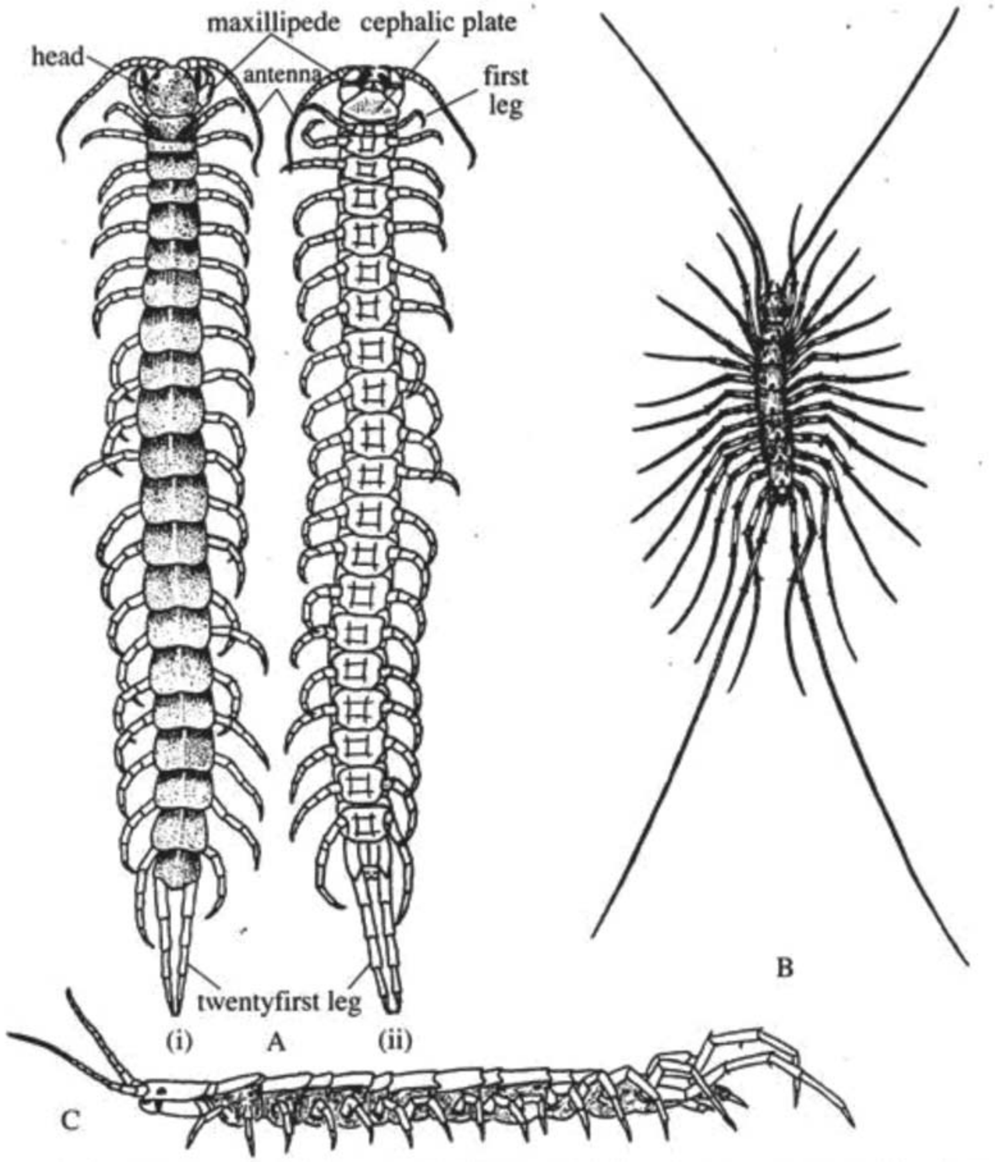


Fig. 1.114 : A. External features of *Scolopendra* (i) Dorsal view, (ii) Ventral view, B. *Scutigera*, C. *Lithobius*.

Class 2. Symphyla : About 160 living species, 4 Indian species. Size: l–8 mm

Characters :

1. Body small, comprises of a head and a long trunk with twelve leg bearing segments and two terminal segments without leg. The last segment bears a pair of long sensory hair (trichobothria).
2. Mouth parts comprise of a pair of mandibles, a pair of long, first maxillae and a second pair of maxillae. Second maxillae are united together to form the labium, similar to that of insects.
3. There are more dorsal tergal plates (15 to 24) than the number of segments. This permits increased flexibility of the body.
4. Presence of a single pair of spiracles that open on the sides of the head and trachea extends posteriorly only up to first three anterior trunk segments.
5. Eyes are lacking.
6. Genital openings are located on the fourth trunk segment.
7. Telson absent.
8. Sexes separate. Parthenogenesis is common.

The symphylans are herbivorous or detritivorous. They are terrestrial, live in soil or leaf litter, found throughout the world.They are also known as garden centipede or pseudocentiped.

Examples : *Scolopendrilla, Scutigerella.*

Class 3. Diplopoda (Millipedes) [Gk. diplos = double]

About 10,000 living species. Size: 2 mm–28 cm

Characters :

1. Elongated and segmented forms.
2. Trunk with a large number of leg- bearing segments.
3. First trunk segment (collum) is legless and next three segments with a single pair of legs in each segment and the rest double segments (diplosegments formed from the fusion of two originally separate somites) bear 2 pairs of legs in each.
4. Antennae club shaped and seven segmented.
5. Maxillae are united to form gnathochilarium. Second pair of maxillae is absent.

6. Eye simple; consist of several simple flat-lensed ocelli arranged in a group or patch (ocellaria) on each side of the head. Eyes may be totally absent (flat-backed millipedes). Many possess 'Organs of Tomosvary'.
7. Tracheae are mostly un-branched tubes.
8. Gonads unpaired but reproductive ducts are paired.
9. Gonopores are located at the anterior end of the trunk (third trunk segment).

Diplopods are commonly known as millepedes (thousand leggers), usually herbivorous or detritivorous (a few are predatory) and terrestrial, live beneath leaves, stones, barks, logs and in soil. They are mainly distributed in the tropics.

Examples : *Polyxenus, Lophoproctus,Glomeridesmus, Glomeris, Julus, Polyzonium, Polydesmus, Orthoporus, Narceus, Thyropygns.*

The species, *Illacmeplenipes,* has the greatest number of legs (750) among the entire animal kingdom (Marek and Bond, 2006).

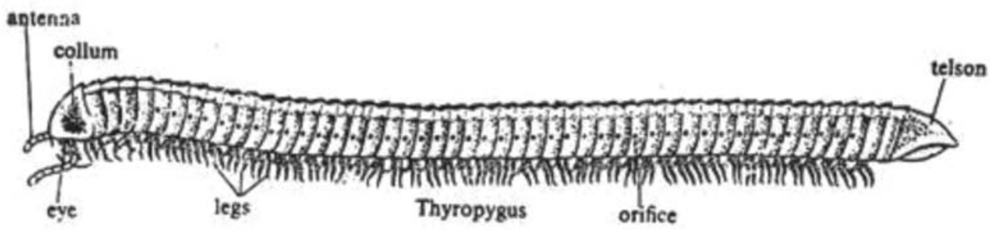


Fig. 1.115 : *Julus.*

Class 4. Pauropoda (Pauropods):

About 500 described species; probably no known Indian species. Size: 0.5–1.5 mm

Characters :

1. Body soft, grub-like, comprises of a head and twelve segmented trunk, nine of which bear a pair of legs. The first and last two trunk segments are legless.
2. The tergal plates present on the dorsal surface of trunk, are large and overlap adjacent segments. Five of them carry a pair of long, laterally placed setae.
3. Head bears five segments, maxillae single pair.
4. The floor of the preoral chamber is formed by the fused pair of maxillae, called the gnathochilarium.
5. Head lacks median ocelli but bears the 'Organs of Tomosvary'.
6. Heart and tracheae absent (except in some primitive species).

7. Gonopores on 3rd trunk segment.

Pauropods are Saprophytic, live under dead leaves, stones, and rotten wood and feed chiefly on fungi and decaying organic matter.

They are widespread in both tropical and temperate regions.

Examples : Pauropus,Decapauropus

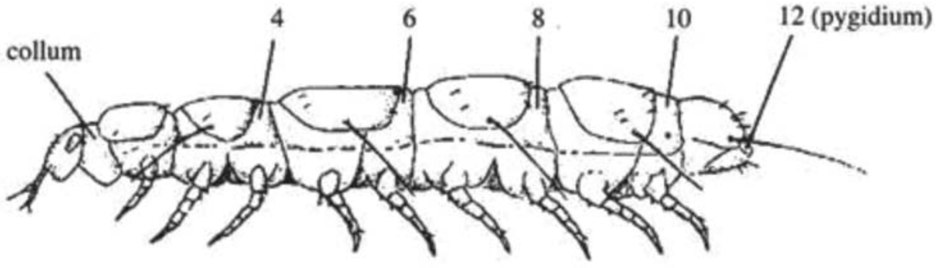


Fig. 1.116 : *Pauropus* (lateral view).

Class 5. Insecta or Hexapoda [L. in = into, sectus – cleft, cut or L. insecti = an insect; Gk. hexa = six, podos, genitive of pous = a foot]:

At least 1 million described species. Size: 0.25 mm–33 cm

Characters :

1. Body consists of three distinct tagmata (regions)—head, thorax and abdomen.
3. Head is formed by the fusion of six segments and its appendages are a single pair of antennae, a pair of mandibles and two pairs of maxillae. .

   Each body segment has four basic regions. The dorsal surface is called the tergum (or notum), the two lateral regions are called the pleura (singular: pleuron) and the ventral aspect is called the sternum.
4. In adults, the thorax includes 3 segments—prothorax, mesothorax and metathorax and each segment bears one pair of walking legs.

   Hence, called Hexapoda for the three pairs of thoracic legs.
5. In winged insects, the mesothorax and metathorax bear a pair of wings in each segment.
6. A pair of compound eyes present.
7. Paired appendages absent in the adult abdomen.
8. Foregut is commonly subdivided into an anterior pharynx, an esophagus, a crop and a narrow proventriculus. The proventriculus is variable in structure and function, in different insects depending upon the nature of food taken.

9. Most insects possess a pair of salivary or labial glands.
10. Respiratory organs are in the form of tracheae which are extensively developed.(Insects breathe by taking in air through spiracles into tracheal tubes.

    These tubes branch into smaller networks of tubes called tracheoles that branch directly into the tissues of the insect for gas exchange.

    There is no active pumping of air, but any small movement in the insect body leads to airflow throughout the trachea.)
11. The chief excretory organs are Malpighian tubules which remain closely associated with alimentary canal.
12. Gonoducts open at the posterior end of the abdomen.
13. Development usually pass through complicated metamorphosis but in some cases it may be direct.

Examples:

Wingless : *Lepisma* (Silver fish), *Machilis. Podura* (springtail), *Isotoma* (Springtail)

Winged : *Periplaneta* (cockroach), *Carausius* (stick insect), *Bombyxmori* (silk moth), *Anopheles* (mosquito), *Apis* (honey bee), *Formica* (ant), *Acheta* (house cricket), *Phyllium* (leaf insect), *Tachardia* (lac insect). *Anax* (dragonfly) *Muscadomestica* (house fly), *Gesonula* (grasshopper), *Phasmatodea* (stick insect), *Coccinella* (lady bird beetle)

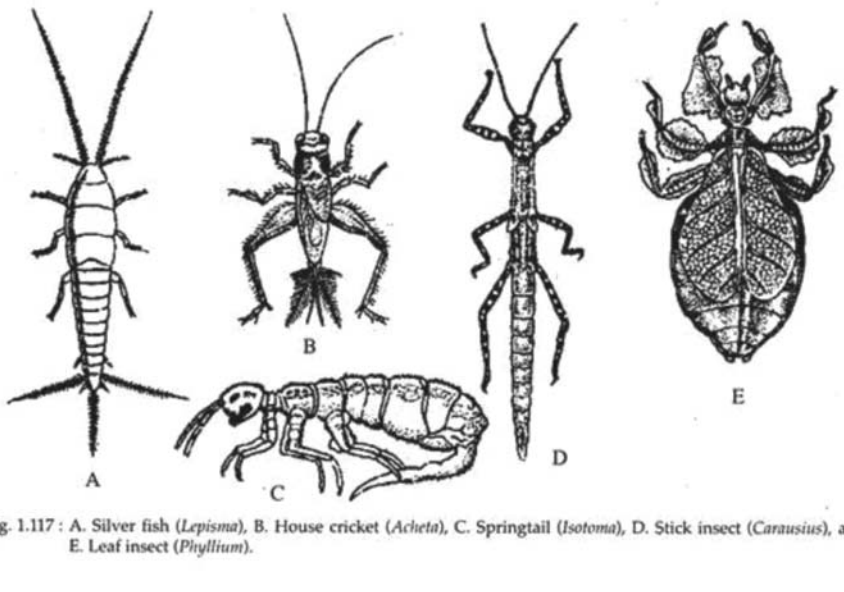


Fig. 1.117 : A. Silver fish (*Lepisma*), B. House cricket (*Acheta*), C. Springtail (*Isotoma*), D. Stick insect (*Carausius*), and E. Leaf insect (*Phyllium*).

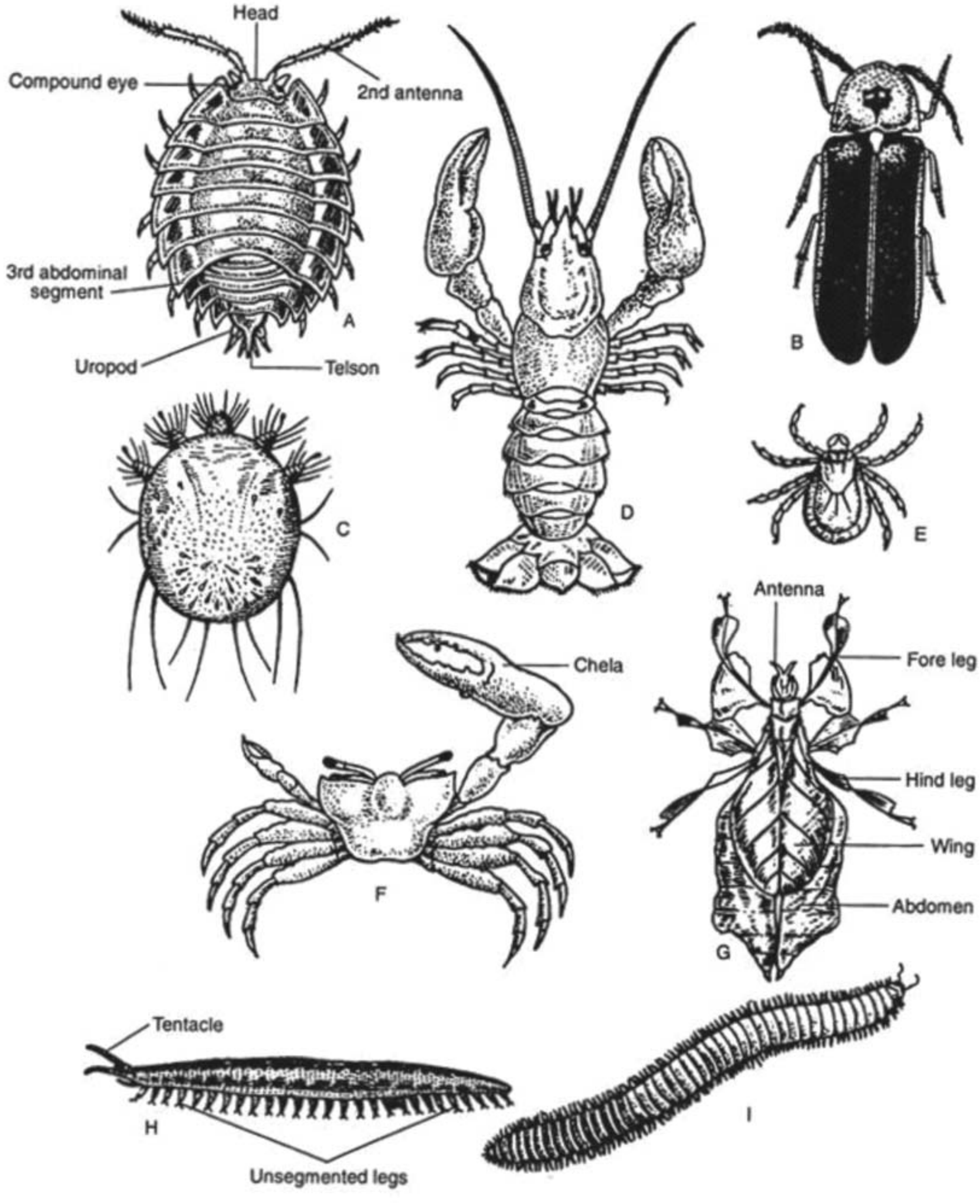


Fig. 18.119: Representative of Phylum Arthropoda (not drawn up to scale). A. *Oniscus* (wood louse). B. *Photinus* (fire-fly). C. *Sarcoptes* (itch mite). D. *Astacus* (cray-fish). E. *Tick*. F. *Gelasimus* (fiddler-crab). G. *Phyllium* (leaf-insect). H. *Peripatus*. I. *Julus* (millipede).

8.5 Social Life in Insects

8.6 Questions

8.7 Suggested Readings

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5. Study material Under Graduate Zoology (Paper: CC-ZO-03), Basic Concept of Taxonomy and Diversity of Non Chordates, 2022. Published by Registrar, Netaji Subhas Open University.
6. Arup Kumar Sinha, Simananda Adhikari, Banku Behari Ganguly and Bharati Goswami (2010) Biology of Animals (Volume-I), New Central Book Agency, Kolkata.
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Unit - 9 ❑ General characteristics and Classification up to Classes : Pearl Formation

Structure

9.1 Objectives

9.2 Introduction

9.3 General characteristics of phylum Mollusca

9.4 Classification of phylum Mollusca up to class

9.5 Pearl Formation

9.6 Questions

9.7 Suggested readings

9.1 Objectives

From this unit learners will learn the diversity, general characteristics and classification of phylum Mollusca up to class. They will also know about pearl and formation of pearl within the body of some mollusca.

9.2 Introduction

Members of the phylum Mollusca are among the most conspicuous and familiar invertebrate animals and include such forms as calms, oysters, snails, slugs, mussels, squids, octopus, etc. In abundance of spieces molluscs constitute the second largest invertebrate phylum after the arthropods. Over 50,000 living species have been described (Ruppert and Barnes, 1994). In addition, some 35000 fossil spieces are known because the plylum has had a long geological history. Mollucs are found in in the abyssal depths of the ocean and above high tide line, and are common in freshwater everywhere. A few of them are terrestrial. The biggest of all invertebrates (giant squid) and probably the most intelligent invertebrate (*Octopus*) are the molluscs. Molluscan shells including pearls always been economically important and some molluscs are important food items, and thus are also economically important.

9.3 General Characteristics

1. Triploblastic, coelomate, unsegmented (except Monoplacophora) and bilaterally symmetrical animal.

2. Soft body (L.mollis = soft) covered by a thick muscular fold or sheet of skin, the mantle or *pallium* which forms a cavity, the mantle cavity. It encloses the visceral mass and secretes the shell. Presence of mantle is the unique feature of all molluscs.

3. Exoskeleton, in the form of calcareous shell, is present in most, in some forms shell absent and in some shell is internal.

4. Presence of ventral muscular foot which helps in locomotion and may be secondarily modified in some forms.

5. Cephalization well marked in class Gastropoda and class Cephalopoda but in other classes the head is small or poorly differentiated.

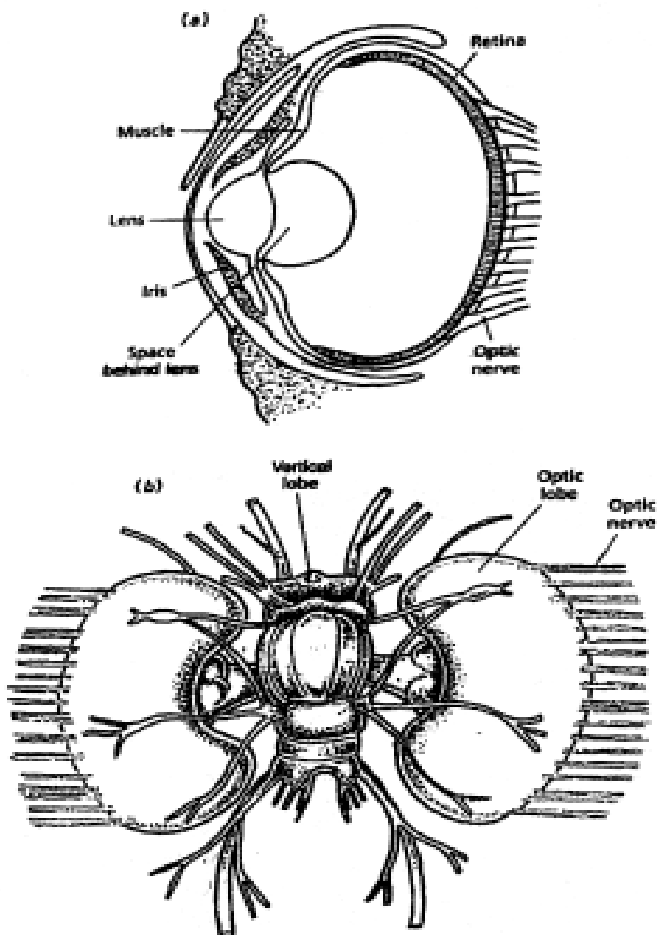

Figure 1 A, B : (a) The eye of a cephalopod; (b) the brain of an octopus in dorsal

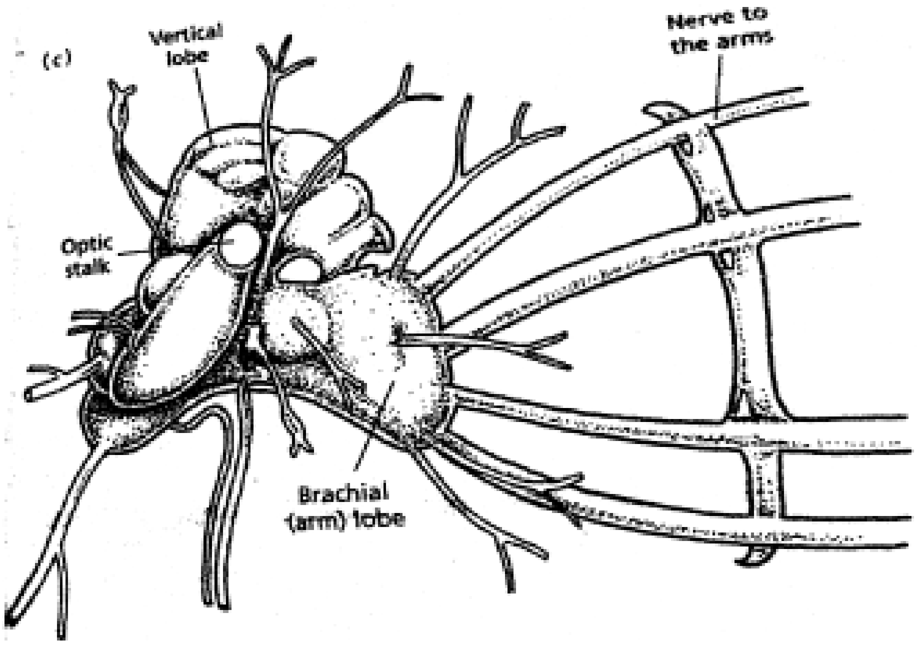

Figure (cont.). 1C : (c) the brain of an octopus in lateral view.

6. Head carries mouth, eyes and tentacles (eyes and tentacles absent in Pelecypoda and Scaphopoda).
7. Many molluscs possess a toothed, chitinous, tongue like ribbon, the ***rudula*** which assists in feeding (rasping organ).
8. Coelom is reduced, confined to the lumen of pericardial cavity, gonads and kidney. Body cavity is haemocoel.
9. Respiration is done by one or many ***ctenidia*** *or* ***gills*** enclosed in the mantle cavity. Respiratory pigment is usually ***haemocyanin.***
10. Circulatory system is of open type with dorsal heart and few bloood vessels. However, cephalopods shows some tendency towards a closed system.
11. A chemoseceptor of tactile receptor organ, called the ***Osphradium,*** generally located adjuscent to the *Ctenidium.* Other sense organs are eyes, tentacles, and statocysts in most forms.
12. Excretion is by one or two pairs of kidenys (metanephridia) communicating the coelom with mantle cavity by nephridiopore.
13. Nervous system consist of paired ganglia, connectives, commissiures and nerves.

14. Sexes usually separate (gonochoristic or dioecious) but a few are hermaphrodite.
15. Fertilization is either external or internal. Development direct or through free larval forms (veliger larvae, trochophore larvae). Direct development mainly in Gastropoda and Cephalopoda.
16. Cleavage generally spiral and determinate.

9.4 Classification :

Phylum Mollusca has been classified differently by different authors depending upon the characters of foot, mantle, shell, respiratory organs, nervous system, etc. The classificatory scheme followed here is based on as outlined by E.E.Ruppert and R.D. Barnes (1994) in their book "Invertebrate Zoology", 6th Edition.

Phylum Mollusca is divided into following *seven classes:*

(1) Class Aplacophora;

(2) Class Polyplacophora;

(3) Class Monoplacophora;

(4) Class Gastropoda;

(5) Class Bivalvia;

(6) Class Schaphopoda;

(7) Class Cephalopoda.

Classification with Characters (upto Classes) :

Class Aplacophora (G. a = without, plakos = a sheet of wood) **:**

1. Primitive worm like marine molluscs with no shell.
2. Elongated bilaterally symmetrical body covered by cuticle.
3. Foot absent or reduced to a ventral ridge.
4. Mantle thick with calcareous spiculaes or scales.
5. Head is poorly developed, without eyes or sensory tentacles.
6. Digestive tube straight, radula may be present or not.
7. Gills are either absent or reduced to a pair and located in posterior mantle cavity.
8. Nervous system primitive with distinct brain and nerve cords.
9. No separate excretory organs, vascular system rudimentary.

10. Most aplacophorans are hermaphrodites. Development direct or through trocophroe larva.

Examples : *Chaetoderma*, solenogasters such as *Neomenia*, *Proneomenia*.

Class Polyplacophora [G. poly = many; placos = a sheet of wood] (meaning bearer of many plates)

1. Body oval or elliptical (somewhat elongated) and dorsoventrally flattened (convex dorsally and flattened ventrally). Bilaterally symmetrical.
2. Dorsal side is covered by eight transverse and overlapping *shell plates* held together by a surrounding fleshy thick girdle.
3. A broad muscular *creeping foot* is present on the ventral surface.
4. Head inconspicuous, eyes and tentacles asbent.
5. Gills 6 to 8 pairs, persent in the pallial groove on the lateral sides of foot.
6. Alimentary canal coiled with well developeed radula bearing many teeth.
7. A pair of shaped kidneys present.
8. Sexes separate, development through a free swimming trochophore larva in most, but veliger larva is absent.

They are called the armadillos of the sea.

Examples : *Chiton*, *Lepidochiton*, *Chaetopleura*, *Lepidopleurus*.

Class Monoplacophora (G. mono = single; plakos = a sheet of wood) **:**

1. Body bilaterally symmetrical and metamerically segmented but the segmentation is internal.
2. Dorsal side is covered by a single piece of shield-like shell (hence the name Monoplacophora).
3. Foot ventral with a flat creeping sole and with 8 pairs of pedal retractor muscles.
4. Mouth antero-median and anus postero-median.
5. Head is without eyes and tentacles.
6. Mantle covers the dorsal surface of body.
7. Radula well developed.
8. 5 to 6 pairs of gills (monopectinate ctenidia) are serially arranged in pallial groove on either side of the foot.

9. Six pairs of nephridia and two pairs of gonads.
10. Sexes separate, fertilization external.
11. Development indirect.

Monoplacophorans are regarded as primitve molluscs and are believed to be ancestral to the gastropods (snails) and cephalopods (squids and octopods). This group was thought to have become extinct in the Devonian but only a few living species represent the class.

Examples : ***Neopilina galatheae***, ***Vema***, ***Micropilina***.

Class Gastropoda (G. gastros = stomach; podos = foot)

1. A muscular and broad foot is present below the digestive system and visceral mass.
2. Visceral mass is twisted at 180º in an anticlockwise direction **(torsion),** relative to the head and foot.
3. Shell single, spirally twisted. Shell reduced or absent in some.
4. Head well differentiated with one or two pairs of tentacles and eyes.
5. Mantle cavity contains a single pair of bipectinate ctenidia. In some ctenidia absent and mantle cavity functions as ***pulmonary sac*** or ***lung*****.**
6. Buccal cavity with an *odontophore* and a redula bearing rows of chitinous teeth.
7. Anus is usually situated anteriorly close to mouth.
8. A chemo-receptive sense organ, called *osphradium* is present in the mantle cavity.
9. Nervous system contains distinct paired cerebral buccal pleural, pedal, parietal and visceral ganglia.
10. On the upper surface of the foot in some forms there may be an operculum which closes the shell aperture.
11. Sexes separate (dioecious) in most forms while some are monoecious (hermaphroditic).
12. Development includes trochophore and veligar larval stages.

Gastropods are mostly marine, some freshwater, some terrestrial. The class Gastropoda is the largest class of Mollusca.

Examples : ***Pila*** (apple snail), ***Patella*** (limpet), ***Aplysia*** (sea hares), ***Doris***, ***Planorbis***, ***Lymnaea***, ***Achatina*** (garden snail), ***Limx*** (grey slug).

Class Bivalvia (Pelecypoda or Lamellibranchiata)

This class includes such common molluscs as clams, oysters and mussles. (L. bi = two; valvae = folding doors; G. pelekys = a hatchet; podos = foot).

1. Bivalves are laterally compressed and possess a shell composed of two valves, hinged together dorsally, that completely enclose the body.
2. The foot, like the remainder of the body, is laterally compressed, usually hatchet or plough-share shaped, hence the name Pelecypoda, meaning "hatchet foot". Foot is antero-ventral, commonly used for crawling or burrowing purposes.
3. There is no cephalization i.e. head, tentacles and eyes are absent.

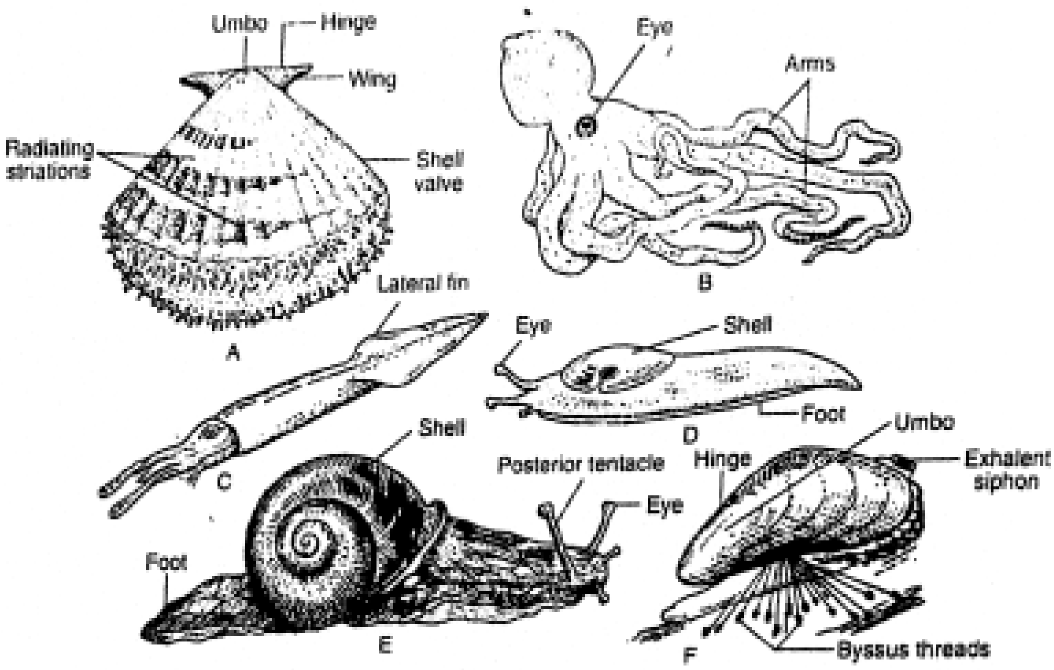

Fig. 2 : Some members of Phylum Mollusca (not drawn up to scale), A. Pecten (scallop), B. Octopus. C. Loligo (squid). D. Limax (slug). E. Helix (Roman snail). F. Mytilus (sea-mussel).

4. Mouth is provided with two pairs of labial palps, most are ciliary feeders or filter feeders radula absent.
5. Mantle consists of paired leaf-like right and left lobes which secrete the shell. Posterior-edges of mantle often fused to form inhalent and exhalent siphons.
6. Gills or ctenidia are paired, well developmed and plate-like, hence the name lamellibranchiata. They are often specialized to assist in feeding (food collection).
7. Nervous system consists of four pairs of ganglia cerebral, pleural, pedal and visceral. Cerebral and pleural of each side usually fused into a cerebropleural ganglian.
8. Sense organs are statocyst and osphradium.
9. Mostly unisexual, some bisexual. Fertilization external.
10. Development indirect through *trochophore* and *veliger* larvae.

Exampls: ***Nucula***, ***Mytilus*** (sea mussel), ***Pinctada*** (pearl oyster), ***Ostrea*** (edible oyster) ***Unio*** (fresh water mussel), ***Lamellidens, Solen*** (razor clam).

Class Scaphopoda (Tusk Shells) [G. skaphe = a boat; podos = foot]

1. Tusk-shaped tubular or conical shell, open at both ends. Anterior part of the shell is much wider than the posterior end.
2. The elongated body completely enclosed by the mantle.
3. From the wider anterior opeing of the shell protrude the narrow trilobbed (wedge-shaped) burrowing foot and buccal region.
4. Mouth surrounded by adhesive knobbed tentacles, called *captacuca* used both for feeding and as sense organs.
5. Buccal mass possess a radula.
6. Head reduced, lacks eyes.
7. Heart rudimentory, gills absent.

8. Gonad unpaired and kidneys paired.

9. Sexes separate, fertilization external.

10. Eggs planktonic, both trochophore and veliger larval stage in life cycle.

Scaphopods are exclusively marine, widely distributed in all seas. The animals remain buried on sandy or mudy sea bed with their anterior end downward, and posterior end, (through which ventilating current enters and leaves), near the surface of the substratum (see bed)

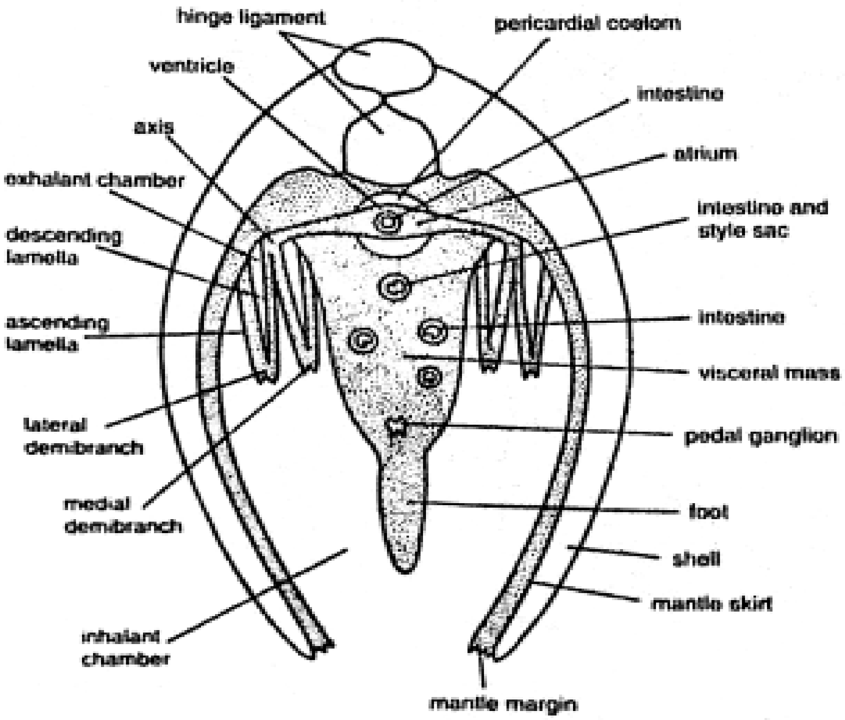

Fig. 3 : Bivalve mollusc. Cross section of a generalized Lamellibranch (after Ruppert, et al., 2004)

Examples : *Dentalium, Cadulus, Antalis.*

Class Cephalopoda (G. kephale = head; podos = foot)

1. Head well developed and projects into a circle of large, prehensive tentacles or arms modified from foot (homologous to the anterior of the foot of other molluscs). Hence the name cephalopoda.

2. Body bilaterally symmetrical.
3. Shell usually internal either reduced or absent and covered by the mantle in most species. An external shell occurs only in *Nautilus.*
4. Head bears large eyes and mouth. Mouth with horny or calcareous beak-like jaws and radula.
5. Tentacles or arms bear suckers, except *Nautilus.*
6. A funnel or siphon is present which expels water from the mantle cavity, helps in jet propulsion during swimming. Most cephalopods possess an ink gland (except *Nautilus*) associated with rectum.
7. Gills or ctenidia are bi-pectinate and are either one or two pairs.
8. Circulatory system closed, heart with two or four auricles.
9. Excretory system comprieses one or two pairs of nephridia.
10. Nervous system is highly developed and complex. There is a great cephalization. All of the typical molluscan ganglia are concentrated and more or less fused to form a brain that encircles the oesophagus and in encased in a cartilaginous cranium.
11. Sexes separate, external sexual dimorphism in some species. Gonad single. One of the arms of the male modifies as an spoon like intromittent organ, called *hectocotylus*, for transferring spermatophores to the female.
12. Cleavage meroblastic, development direct i.e. metamorphosis or larval form absent.

This class includes cuttle fishes, squids, nautiluses, octopuses, all of which are exclusively marine.

Examples : ***Sepia*** (cuttle fish), ***Loligo*** (squied), ***Nautilus***, ***Octopus*** (Devil fish), ***Architeuthis*** (giant squid, it is the largest animal not only in cephalopodes but also among the invertebrates. It may attains 20 metres in total length).

9.5 Pearl formation

Pearl is a spherical or irregular mass formed by the calcareous secretion of the nacre (mother of pearl) found in the glandular mantle of pearl oysters, deposited in concentric layers around a nucleus which is composed of foreign object causing irritation.

Pearl is a valuable gem known to mankind since ancient times. The word ‘pearl’ is derived from the Latin word pirula which means pear, that is in accordance to the pear shape of the pearls. The beauty of pearl is an object of adoration and a barometer of wealth. Pearl is counted among the nine gems and needs no cutting or polishing to bring out its lustre. The pearl, in fact, is of animal origin and produced by some specific bivalve molluscs. The pearl producing bivalves are marine oysters mainly of the genusPinctada, though some freshwater bivalves of the genus Unio and Anodonta also produce pearl but of inferior quality and rarely of any use.As the oyster grows in size, its shell must also grow. The mantle is an organ that produces the oyster’s shell, using minerals from the oyster’s food. The material created by the mantle is called nacre. Nacre lines the inside of the shell.

Today, Japan produces the bulk of pearl in the world by using pearl culture technique. However, the culture of pearl, its fishing and its commercialisation, etc., constitute a separate story. Here we are concerned only with the formation of pearl within the body of a bivalve i.e. the natural pearls.

Types of Pearls: (a) Natural pearls : Natural pearls may be formed within the oyster or mussels by either accidental entrance of a solid or accidental wound within the shell muscles or tissues. Pearls so produced are called natural pearls and are very rare because of their accidental origin. **(b) Cultured pearls :** Cultured pearls are produced by human interference, when the pearls are produced through the process of culture of pearl producing oysters or mussels.

Chemical Composition of Pearls :

1. Calcium carbonate ($CaCO_3$) or Aragonite. A special type of calcium crystal 88-90%.
2. Organic conchiolin ($C_{32}H_{98}N_2O_{11}$). A special type of scleroprotein 3.5- 5.9%.
3. Water 2-4%.4. Residue 0.1-0.8%.

Shape, Size and Colour of Pearls :

The shape, size and colour of the pearls are variable in different kinds of pearls. In most cases, the pearls are irregular in shape, and perfect round-shaped pearls are rare. The pearls may be dumb-bell-shaped, disc-shaped or elongated. The large, badly misshapen free pearls are called baroque that are mostly pear-shaped or rather flat. The size of pearls is also variable. It depends upon various factors, such as age, temperature of sea water and nutritional condition, etc., Colouration of the pearls such as cream, pink, bluish brown and black are due to the nature of the organic layers (conchiolin) and the introduction of certain pigments into the aragonite. The shape of the pearls depends upon the pattern of nacre deposition.

Formation of Pearl :

The formation of natural pearls may be considered as an accident of nature. The formation of a natural pearl begins when a foreign substance like sand particle, parasite (in most cases larval forms of trematodes), egg of trematodes and cestodes, or any object of organic and inorganic origin slips into or gets accidental entryinto the oyster between the mantle and the shell, and irritates the mantle. The pearl is secreted by the mantle as a protective measure against foreign objects. In fact, as soon as a foreign object, somehow, enters the body of a pearl oyster in between the shell and mantle, the mantle immediately gets irritated and at once encloses it within a sac, the pearl sac.As a response to the irritation caused by the foreign object, the nacre glands in the mantle begin to secrete layers of nacre around the foreign object as a pro-tection against it. Thus, the mantle wall of that particular area continuously secretes nacre around the foreign object in thin concentric layers and finally pearl is formed. The iridescence of the pearls is pro-duced by the refraction of the light rays from various nacre layers of the pearl.   The value of pearl depends upon its size, quality, etc. Duration of the pearl growth may vary according to species and usually takes a couple of years. The giant Tridacna clam which can produce a pearl of the size of a golf-ball, may take as long as 10 years.Now a days, the pearl producing bivalves are reared and pearls are produced artificially by introducing some foreign objects between the mantle and shell in the different parts of the world; Japan has surpassed all other countries in this field.

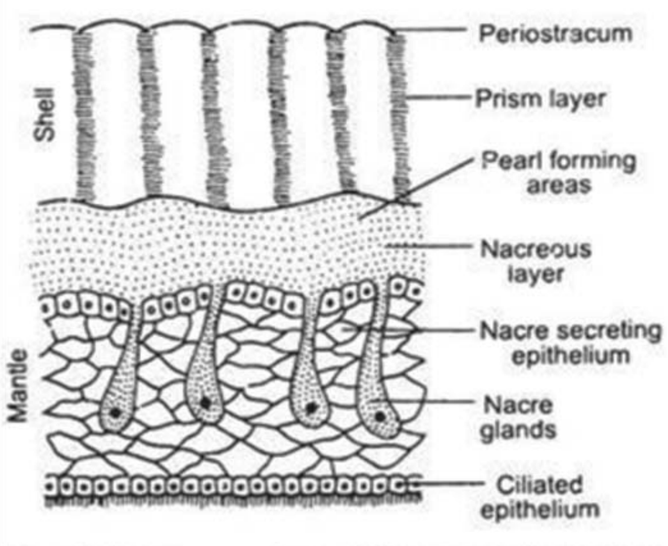

Fig. 16.76: Nacreous layer and nacre glands of pearl oyster.

Fig. 16.77: Stages (A–C) of pearl formation.

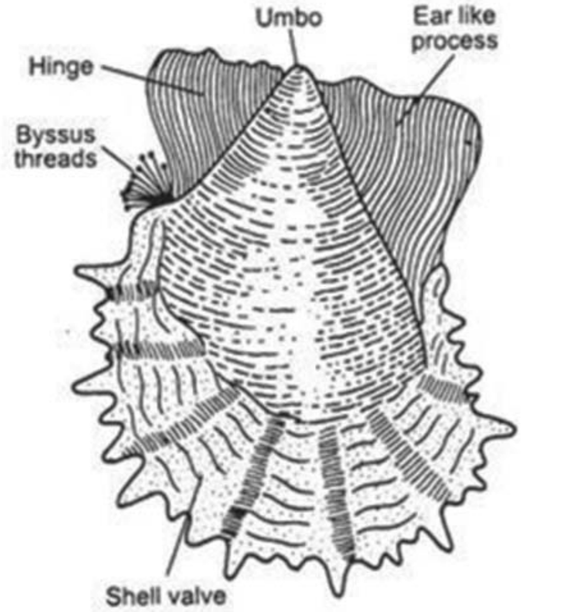

Fig. 16.78: External features of an Indian pearl oyster (*Pinctada vulgaris*).

Additional information :

Biology of pearl oysters: Pearl oysters are sedentary animals. They are attached to rocks. They have two valves. One valve is cemented to the rocks and the other free. They spawn twice in a year. The eggs are hatched into free swimming larvae. The larvae sink to the bottom of the water and develop into young oysters called spats. They grow to their maximum size in four or five years.

Distribution of Pearl Oysters in Indian Waters:Pearl oysters are usually the inhabitants of the ridges of rocks and dead corals which form the pearl banks. These oyster beds are located at a depth of 10-12 fathoms (= 18- 22 m) at a distance of approximately 10 to 20 km from the shore. The pearl oyster beds are most extensive in the east coast than the west coast. In the east coast the beds extend from Kanyakumari to Rameswaram with a most productive zone near Tuticorin.In the east coast the pearl oysters produce a best quality pearl which is spherical shaped and rainbow coloured, called lingha pearl. In the west coast the pearl oysters are found in coral reefs in the Gulf of Kachchh extending from the north of Halar district to the Jamnagar in Gujarat.Pinctadamargaritiferaoccurs in the Andaman and Nicobar Islands in good num-bers rather than the east and west Indiancoasts. Pinctadachemnitzii is found mainly in the Gulf of Mannar.Pinctadaatropurpurea and Pinctadaanomioides are found rarely in the Gulf of Mannar. Placenta (= Placuna) placenta is also found in the Gulf of Mannar, specially around Rameswaram Island, Mumbai, Kakinada (Andhra Pradesh) in which pearls of inferior quality are obtained.

History of Pearl Industry: For the first time the idea of pearl industry was evoked in Japan which was carried out in the Bay of Japan located at South coast of Hansoo. The credit for the production and development of modern pearl culture goes to Japan. The initial success was achieved in 1893 by KokichiMikimoto,(1858-1954) who is considered as the ‘Pearl King’ and the Father of Pearl Culture industry. From the initial success the technique of pearl culture was developed and perfected.

9.6 Questions

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9.7 Suggested readings

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Unit - 10 ❑ Echinodermata – General characteristics and Classification up to Classes ; Water Vascular system in Starfish.

Structure

10.1 Objectives
10.2 Introduction
10.3 General characteristics
10.4 Classification of phylum Echinodermata up to class
10.5 Water Vascular system in Starfish.
10.6 Questions
10.7 Suggested readings

10.1 Objectives

From this unit learners will learn the diversity, general characteristics and classification of phylum Echinodermata up to class. Echinoderms are considered to be the ancestor of chordata animals. Not only that these animals are the first deuterostomian animals.

Learners will also get an idea about the water vascular system in starfish, one well known and well studied echinoderm.

10.2 Introduction

Members of the Phylum Echinodermata are among the most familiar marine invertebrates, some being the most beautiful of all sea-creatures. The phylum contains some 6000 known species and constitute the only major group of deuterostome invertebrates.

Echinoderms are exclusively marine and are largely bottom dwellers. All are relatively large animals, most being at least several centimeters in diameter. The most striking characteristic of the group is their ***pentamerous radial symmetry–***that is, the body can usually be divided into five parts arranged around a central axis. Another unique feature of the phylum is the presence of of bilateral symmetry in the larval phase. The radial symmetry in adult is regarded as a secondary acquisition (derived from a bilateral ancestor), and the echinoderms are not closely related to the other radiate phyla.

10.3 General Characteristics

1. The echinoderms are exclusively marine, free living non-colonial and mostly bottm-dwellers.
2. They are triploblastic, unsegmented, enterocoelous coelomate animals.
3. Adults exhibit radial symmetry, usually pentamerous i.e. the body can usually be divided into five parts arranged around a central axis, but their larvae are bilaterally symmetrical.
4. Adults generally do not have anterior and posterior ends. Instead body is distinguishable into oral (bearing the mouth) and aboral (not bearing the mouth) surfaces, without any differentatiated head.
5. Most echinoderms possess a well developed internal skeleton composed of calcareous ossicles. Commonly the skeleton bears projecting spines or tubercles that give the body surface a warty or spiny appearnace, hence the name echinoderm, meaning "spiny skin" (Gr. echinos = hedgehog; derma = skin).
6. The oral surface of the body is marked by five equidistant radiating grooves, called ambulacra, originating from the mouth, with intervening interabmulacra.
7. Coelom spacious, developed as outgrowths of the archenteron (enterocoelous type).
8. Digestive tract is mostly a coiled tube with the anus placed on the aboral surface.
9. A characteristic coelomic Water Vascular Sysem (WVS) or ambulactal system is present. It performs many functions such as feeding, locomation and respiration, etc.
10. Presence of tubular contractile tube feet or podia used as locomotory organ and or feeding organ.
11. The blood vascular system also called haemal or blood (lacunar system) is present. It is well developed in Echinoids and Holothuroids.
12. Nervous systems simple, consisting of a circum-oral ring and radial nerve along each ambulacrum.
13. No definite respiratory and excretory system in most cases. Respiration is done through body wall, podia, respiratory tree and papulae.

14. Specialized sense organs are poorly developed.
15. Sexes are usually separate (gonochoristic). Reproductive tracts are very simple. Fertilization is usually external in sea water.
16. Eggs are typically homolecithal, cleavage radial and indeterminate, development through bilaterally symmetrial larvae which undergo metamorphosis into radially symmetrial adults.

10.4 Classification of Phylum Echinodermata

The scheme of classification presented here is based on the the classification plan outlined by *Ruppert and Barnes* (1994) in their book "*Invertebrate Zoology*", 6th Edition.

According to them phylum Echinodermata is divided into four subphyla–

Subphylum Homalozoa (Extinct)

Subphylum Crinozoa — Class Crinoidea

Subphylum Asterozoa — Class Asteriodea, Class Ophiuroidea and Class Concentricycloidea

Subphylum Echinozoa — Class Echinoidea and Class Holothuroidea

All members of Subphylum *Homalozoa* are extinct.

Subphylum *Crinozoa* includes only one class – Class Crinoidea.

Subphylum *Asterozoa* includes three classes–Class Asteroidae, Class Ophiuroidea and Class Concentricycloidea.

Subphylum *Echinozoa* includes two classes—Class Echinoidea and Class Holothuroidea.

Classification with Characters :

Subphylum Homalozoa (Extinct) :

Paleozoic echinoderms lacking any evidence of radial symmetry.

Example : *Enoploura*

Subphylum Crinozoa :

1. Radially symmetrical echinoderms with a globoid or cup-shaped theca and 5-10 brachioles or arms.

2. Mostly attached, with oral surface directed upward.

   This subphylum contains the fossil eocrinoids (class Eocrinoidea), cystoids (Class Cystoidea) and the fossil and living crinoids. Only the characters of class Crinoidea are described here

Class Crinoidea (Cambrian–Recent) [G. crinon = lily; eidos = form] About 700 speices.

1. Stalked and free moving echinoderms having the oral side of the body directed upward. Arms well developed, movable, branched and bearing pinnules.
2. Body exhibits strong pentamerous symmetry.
3. Mouth is centrally placed and anus is generally excentrically placed on the oral surface of the body.
4. The ambulacral grooves radiates from the mouth and extend along the arms and pinnules upto their tips.
5. The theca (protective covering or case) on the aboral side is differentiated into a non-porous cup-like *Calyx*.
6. Madreporite, spines and pedicllariae are absent.
7. Sexes separate, gonads are located in the arms or pinnules.
8. Barrel-shaped free-swimming larva, called *doliolaria* larva with five ciliated bands.

This class includes both extinct and living forms

Examples : ***Antedon*** (feather stars), ***Neocrinus*** (long stalked sea lilies), ***Cenocrinus*** (long stalked sea lilies), **Holopus** (very short stalked sea lilies.

Sub-phylum Asterozoa :

1. Radially symmetrical, free moving (unattached) echinoderms.
2. Body composed of a flattened central disc and radially arranged arms.
3. Oral surface directed downward. On the oral surface in the ambulacral groove, tube feet are present.
4. Anus and madreporite aboral.

The subphylum includes **three classes –** class Asteroidea, Class Ophiuroidea and Class Concentricycloidea.

Class Asteroidea (Cambrian – Recent) [G. aster = star; eidos = form] About 1800 spices**.**

1. Body star shaped, arms not sharply set off from the central disc.
2. Ambulacral grooves are open and a large coelomic cavity is present in relatively wide arms.
3. Each ambulacral groove contains two to four rows of tube feet or podia. Tube feets with or without suckers.
4. Oral and aboral surfaces are distinct. Oral surface directed downward and aboral surface upward.
5. Madreporite and anus are present on the aboral surface.

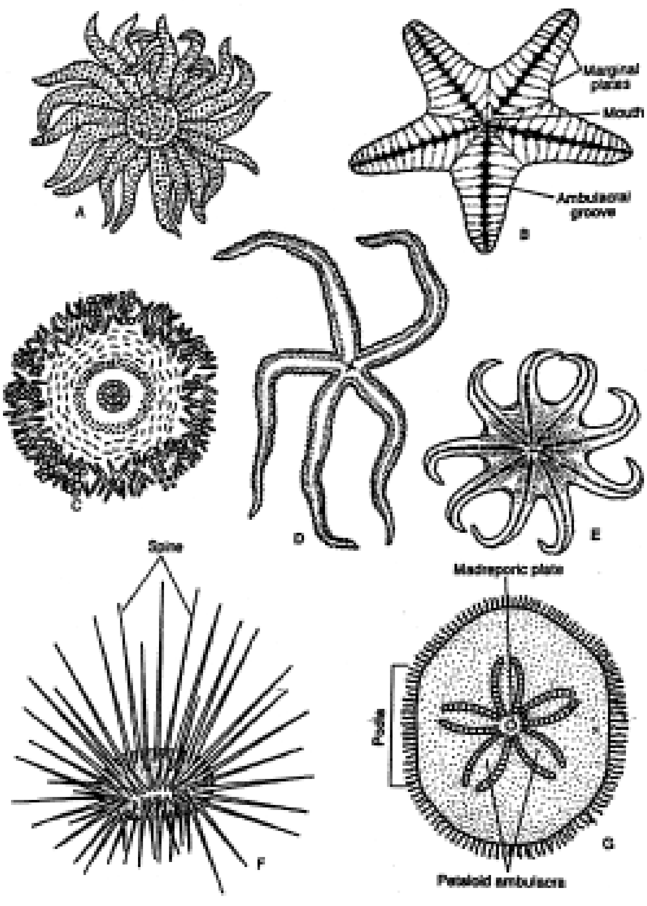

Fig. 1 : Some important echinoderms. A. *Heliaster.* B. *Ctenodiscus.* C. *Arbacia.* D. *Zoroaster.* E. *Solaster.* F. *Diadema.* G. *Clypeaster.*

6. Pedicellariae are present.
7. Larval forms are ***bipinnaria*** and/or ***brachiolaria*.**

The members of this class are generally called sea stars :

Examples : *Asterias*, *Astropecten*, *Heliaster*, *Ctenodiscus*.

Class Ophiuroidea (Carboniferous to Recent) [G. ophis = snake; oura = tail; oidos = form] About 2100 species **:**

1. Body pentamerous and star-shaped.
2. Arms sharply set off from the central disc. Arms are elongated and flexible.

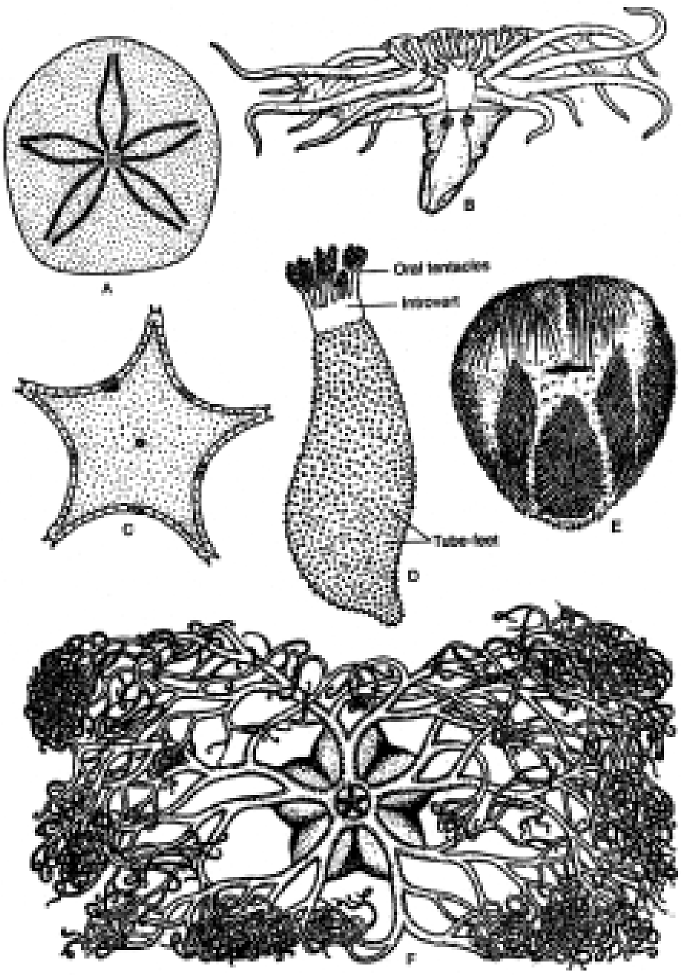

Fig. 2 : Some important Echinoderms (contd.). A *Laganum.* B. *Pelagothuria.* C. *Porcellanaster.* D. *Thyone.* E. *Echinocardium.* F. *Gorgonocephalus.*

3. Ambulacral grooves absent, tube feet without suckers.
4. No spacious prolongations of the coelom into the arms. Arms largely filled with vertical ossicles.
5. Mouth and madreporite are situated on the oral surface of the body. Anus is lacking.
6. Pedicellariae absent.
7. Larva is ***Ophiopluteus*.**

The members are commonly termed the brittle stars or serpent stars.

Examples : ***Ophiura*** (brittle stars), ***Ophiothrix*** (brittle stars), ***Ophiocoma*** (brittle stars).

Class Concentricycloidea (L. concentric rings)

1. Minute (maximum 1 cm diameter) deep water echinoderms with disc-shaped body.
2. Body covered aborally with plate-like ossicles.
3. Two concentric water rings on the outer edge of the disc. Marginal spines are located around the periphery.
4. Coelom spacious.
5. Water vascular system has two ring canals with the tube feet arising from the outer one.
6. Ambulacral system absent.
7. No larval form.

The members are called *sea daisies* and are known by a single genus and two species that were discovered in 1983 and 1984 from the coast of NewZealand and described in 1986 by Baker et al.

Examples : ***Xyloplx* medusiformis** and ***X. turnerae***.

Subphylum Echinozoa [G. echinos = a hedge hog; eidos = form].

1. Radially symmetrical globoid or discoid echinoderms without arms or brachioles (small arm-like processes).

2. Mostly unattached.
3. Madreporite and anus remain on the aboral side.
4. Hydrocoel forms a ring around the mouth.

The subphyklum comprises two classes– **Class Echinoidea** and **Class Holothuroidea.**

Class Echinoidea (Ordovician – Recent) [G. echinos = a hedge hog; eidos = form] About 900 species **:**

1. Body may be globular, heart-shaped, oval or disc shaped.
2. Body orally and aborally flattened and without arms.
3. Body is enclosed in a skeleton in the form of a continuous shell or test (corona) of closely fitted clacareous plates.
4. Movable spines are mounted on the test. The name Echinoidea means "like a hedge hog". It is called so because it contains movable spines (like the hedge hog) that covers the body.
5. Although the ambulacral grooves are absent, the body surface is divided into alternate ambulacral and interambulacral areas.
6. The ambulacral areas extend from the oral to the aboral sides of the body.
7. Ambulacral plates have pores for the passage of tube-feet.
8. Tube feets are highly extensible, provided wth suckers and locomotory in function.
9. Mouth and anus are surrounded by membraneous *peristome* and *periproct* respectively.
10. Mouth is generally provided with an elaborate chewing appartus or Aristotle's lantern with teeth.
11. Larva is ***echinoplutens*****.**

The sea urchnins, heart urchins, cake urchins are included in this class.

Examples : ***Echinus*** (sea urchins), ***Abracia*** (sea urchins), **Dendraster** (sand dollar), ***Clypeaster*** (sea biscuit), ***Echinocardium*** (heart urchins).

Class Holothuroidea (Devonian – Recent) [G. holothurion = a water polyp; edio = form] About 1200 species **:**

1. Body elongated / cylindrical along the oral / aboral axis.
2. Body exhibits somewhat bilateral symmetry.
3. Mouth and anus located at the opposite extremities of the body.
4. Skin soft, thin and leathery, without spines and pedicellariae.
5. Oral or buccal podia form a circle of tentacles around the mouth.
6. Arms are absent.
7. Alimentary canal long and coiled and cloaca usually with respiratory trees.
8. Skeleton reduced to microscopic ossicles.
9. Tube-feet locomotory in function and restricated to five ambulacral areas.
10. Larva is ***auricularia*.**

The membrs of this class are known as ***sea cucumbers.*** Some move on bottom, others live beneath stones or in crevices.

Examples : ***Cucumaria****,* ***Holothuria****,* ***Thyone****,* ***Molpadia****.*

10.5 Ambulacral System or Water Vascular System (WVS) :

The ambulacral system or water vascular sysem (WVS) is unique to the echinoderms. It is consideredd as the major unifying characteristic of the phylum Echinodermata. The system consists of a series of fluid-filled canals derived primarily from 1 of 3 pairs of coelomic compartments (the left hydrocoel) that form during embryonic development (Pechenik, 2000). The canals are lined with a ciliated epithelium (as they are derived from coelom). The ambulacral system exhibits radial symmetry from the beginning and it is equally developed in all echinoderms. This system lies just above the haemal system. It is primarily locomotory in function and also subserves the function of tactile and respiratory organs in some forms. The excretory role of this system, as suggested by some workers, is not yet fully ascertained.

General plan of ambulacral or water vascular system :

The water vascular system in different classes of Echinodermata has almost the same structural organization. It comprises of a few canals together with some appendages attached to these canals. The typical arrangement of the water vascular system is exhibited by *Asterias*. It consists of madreporite, stone canal, ring canal, radial canal, Tiedeman's bodies, lateral canals and tube feet.

The internal canals of the water vascular system connect to the outside through the button-shaped ***madreporite*** on the aboral surface covered with ciliated epithelium of the body surface. The bottom of each furrow contains many pores that open into ***pore cansls*** passing downward through the madreporite. Acutally pore canals join

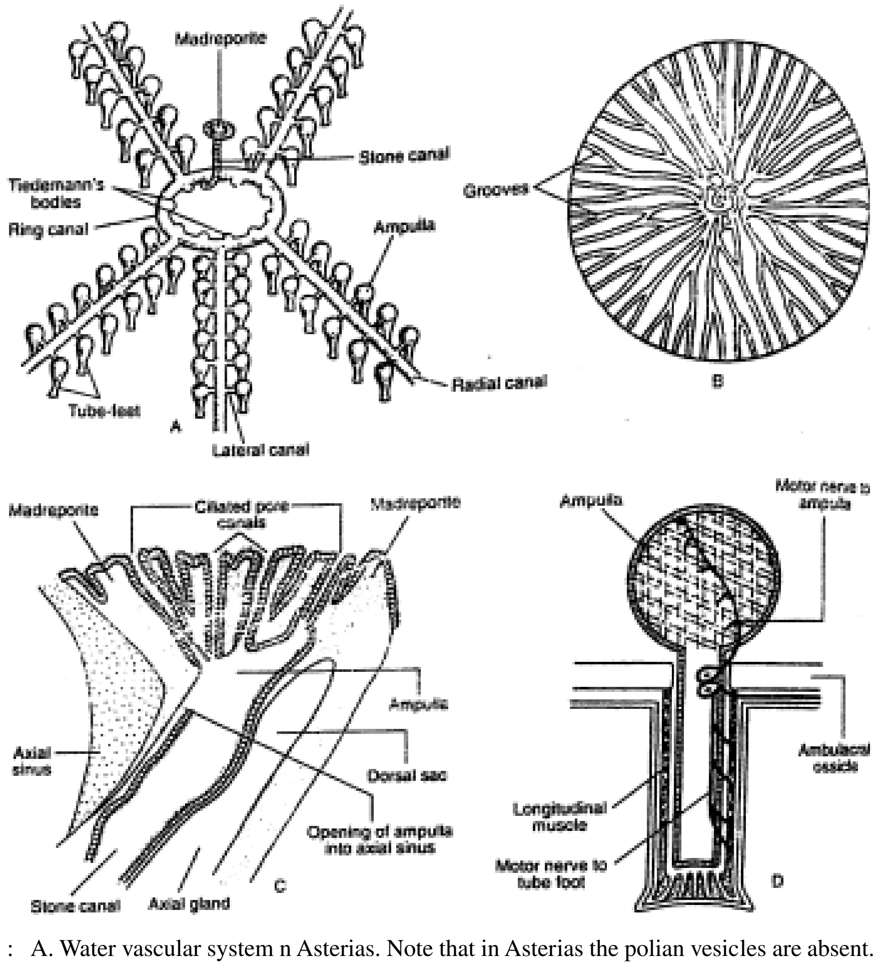

Fig. 3 : A. Water vascular system n Asterias. Note that in Asterias the polian vesicles are absent. B. Enlarged view of the madreporite of Asterias. C. Diagrammatic view of the vertical section through the madreporite in Asterias. D. Diagrammatic sectional view of a tube-foot and its nerve supply in Asterias.

to form a common canal to open into an cup like depression called ***ampulla*** beneath the madriporite. The pore canals eventually lead into a vertical ***stone canal*** that descends to the oral side of the disc (Fig.). The stone canal is so named because of the calcareous deposits in its walls. On reaching the oral side of the disc, the stone canal joins a circular canal, the ***ring canal,*** just to the inner side of the ossicles that ring or surround the mouth (peristominal ring).

The inner side of the ring canal (water ring) gives rise to four or more, usually five pairs of greatly folded pouches called ***Tiedemann's bodies*** (Fig.). Each pair of these pouches has an interradial position. Also attached interradially to the inner side of the ring canal in many asteroids (although not in *Asterias*) are one to five elongated, muscular bladder like sacs which are suspended in the coelom. These sacs are known as ***polian vesicles.*** Both Tiedemann's bodies and polium vesicles are accessory fluid-storage structures. In addtiion to storing fluid, the Tiedemann's bodies also serve to filter fluid from the water vascular system into the main body cavity (the perivisceral coelom), helping to maintain body turgor. Some zoologists are of the opinion that Tiedemann's bodes produce certain coelomocytes or phagocytic amoebocytes which are released into the water vascular system.

From the outer margin of ring canal, a long, ciliated *radial canal* extends into each arm (Fig). The radial canals run up to the tip of the arms and each ends at the lumen of the tentacle tentacle. From either side of each radial canal, ***lateral canals*** are given off atternately along its entire length. The ***lateral canals*** pass between the ambulacral ossicles on each side of the ambulacral groove (Fig.).

Each lateral canal is provided with a valve and terminates in a bulb and a ***tubefoot* or *podium.*** The *bulb* or *ampulla*, is a mall, muscular sac that bulges into the aboral side of the perivisceral coelom. The ampulla opens directly into a canal that passes downward between the ambulacral ossicles and leads into the tube foot or podium. Ambulacral ossicles are calcarious ossicles supporting the ampullae and tube feet.

The tube feet are short, tubular external projections of the body wall located in the ambulacral groove. Commonly, the tip of each tube foot or podium is flattened, forming a sucker. Like the body wall, the podium is covered on the outside with a ciliated epithelium and internally with peritonium. Between these two layers lie connective tissue and longitudinal muscle fibers. Tube foot or podium often lacks

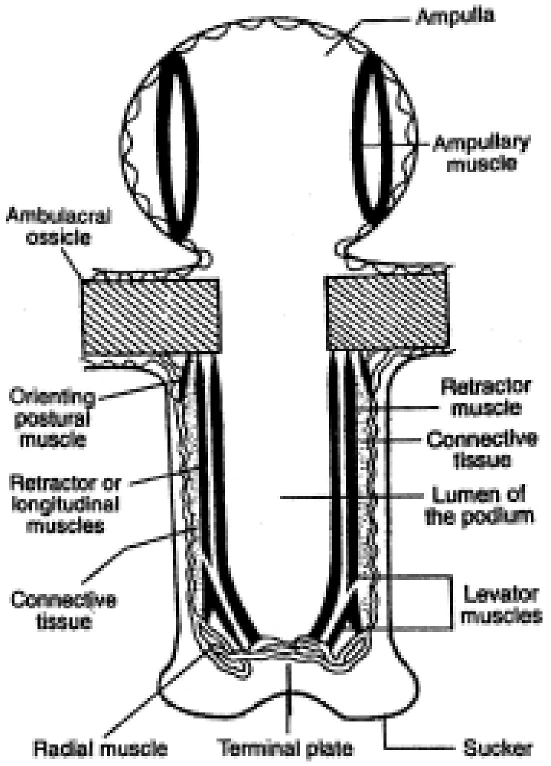

Fig. 4 : Diagrammatic view of longitudinal section through the tube-foot and ampulla of a star-fish showing the arrangement of muscles.

circular muscles and so it can not extend itself. Fluid is pumped into the tube foot hydralically. An one-way valve at the juncture of the ampulla and radial canal ensures that fluid flows from ampulla to tube foot, rather than to the radial canal, when the ampulla contracts. The tube feet or podia are arranged in two rows when the lateral canals are all of the same length or in four rows where they are alternately long and short.

The entire water vascular system is filled with fluid that is similar to sea water except that it contains coelomocytes, a little protein and a relatively high concentration of potassium ions. The system operates during locomotion as a hydraulic system. When the muscular ampulla contracts, the valve in the latgeral canal closes, and water is forced into the podium, which elongates. When the podium comes in contact with the substratum, the sucker adheres. Adhesion is largely chemical, the podium secretes a substance that bonds with surface films. Another

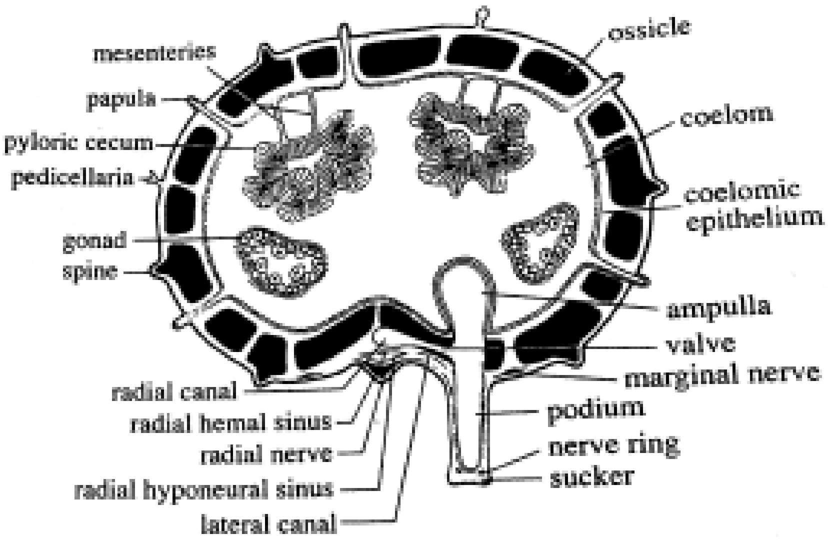

Fig. : Diagrammatic cross-section through the arm of a star fish.

secretion breaks the bonds and brings about release. This has been designated as duogland adhesion system. [one or more gland cells on each tube foot apparently secrete an adhesive that binds that tube foot to a substrate; adjacent gland cells then apparently frelease another chemical that somehow breaks those bonds.]

When attachment is prolonged, or a large force is generated, adhesion by suction probably also takes place. After the sucker adheres to the substratum, the longtudinal muscles of the podium contract, shortening the podium and forcing fluid back into the ampulla. During movement each podium or tube foot per forms a short of stempping motion. The podium swings forward, grips the substratum, and then moves backward. backword. In a particular section of an arm most of the tube feet are performing the same step, and the animal moves forward. The action of the podia is highly coordinated. During progression one or two arms act as leading arms, and the podia in all arms move in the same direction, but not necessarily in unison. A single echinoderm may possess more than 2000 tube feet.

10.6 Questions

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10.7 Suggested readings

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Unit - 11 ❑ Protochordates– Salient features and Classification

Structure

11.1 Objectives

11.2 Introduction

11.3 Salient features and Classification of Protochordates (Hemichordata, Urochordata and Cephalochordata)

11.3.1 Hemichordata

11.3.2 Salient features of Hemichordata

11.3.3 Classification of Hemichordata

11.3.4 Urochordata

11.3.5 Salient features of Urochordata

11.3.6 Classification of Urochordata

11.3.7 Cephalochordata

11.3.8 Salient features of Cephalochordata

11.3.9 Classification of Cephalochordata

11.4 Larval forms in protochordates

11.5 Questions

11.6 Suggested readings

11.1 Objectives

After studying this unit, learners would be able to understand the following—

- salient features of Protochordates(Hemichordata, Urochordata and Cephalochordata).
- classification of different protochordates with characters and examples
- larval forms in protochordates.
- an idea about tornaria and tadpole larvae.

11.2 Introduction

The word "**protochordata**" means primitive chordates. The organisms belonging to Protochordates are generally known as the lower chordates. They are also known as Acraniata because they lack a true skull. Protochordates include two subphyla-Urochordata and Cephalochordata under phylum Chordata and phylum Hemichordata (previously considered as a subphylum under phylum Chordata)**.**

The hemichordates, urochordates and cephalochordates were considered as the invertebrate members of the phylum Chordata, thus, separated as "invertebrate chordates" (Hyman, 1959).

The protochordates are a connecting link between the vertebrates and other deuterostomes (animals where the anus develops from the blastopore and the mouth is formed a new). However, the phylogenetic status of hemichordate is a subject of great controversy. According to recent classification Urochordata, Cephalochordata and Vertebrata are more closely related with each other and the chordate nature of urochordates and cephalochordates is well established though their relationships with the vertebrates and with each other are difficult to ascertain.

11.3 Salient features and classification of Protochordates

(Hemichordata, Urochordata and Cephalochordata)

11.3.1 Hemichordata

The phylum Hemichordata represents a group of lowest invertebrate chordate having profound phylogenetic significance. This phylum consists of marine worms that share some, but not all of the characteristics of chordates. These animals have pharyngeal gill slits and a dorsal nerve cord, which is usually solid. The three body parts are proboscis, collar and trunk. What was once thought to be a notochord is no longer considered homologous. This group forms a sort of structural bridge between the nonchordates and chordates. They are particularly significant because they share some characteristics of both the echinoderms and the chordates. Therefore, they are sometimes thought of as an offshoot from an early common ancestor. Along the wall of their pharynx is a series of gill slits, one of the key characteristics that identify the chordates. In addition, they have a ciliated larval stage that is very similar to that of some echinoderms.

11.3.2 Salient features ofHemichordata

1) The representatives are vermiform, unsegmented, bilaterally symmetrical and triploblastic.
2) They are solitary or colonial, mostly tubicolous, soft and fragile animals.
3) Body divisible into three regions: proboscis (protosome); collar (mesosome); trunk (metasome).
4) Body wall with a single-layered epidermis.
5) Appendages are absent; in few forms the collar may bear arms with tentacles.
6) A preoralbuccal diverticulum is considered as the stomochord (earlier considered as notochord).
7) Coelom enterocoelous, divisible into protocoel, mesocoel and metacoel.
8) Alimentary canal is complete, in the form of straight or U-shaped tube.
9) Gill-slits, when present, are paired and one to numerous.
10) Circulatory system simple and well developed; closed type; usually with a contractile heart vesicle and two longitudinal vessels, one dorsal and one ventral, interconnected by lateral vessels and sinuses.
11) Excretion is performed by a single glomerulus, present in proboscis and connected with blood vessels.
12) Nervous system is primitive, comprising mainly of an intra-epidermal nerve plexus.
13) Mode of reproduction is mostly sexual but a few forms exhibit asexual reproduction.Sexes separate or united. Gonads one to several pairs.
14) Fertilisation external. Development mostly indirect through a free swimming tornaria larva. Direct development is also found in some forms.

Mostly marine in habitat and feed on micro-organisms and debris by ciliary mode of mechanisms.

11.3.3 Classification of Hemichordata

The Phylum Hemichordata includes two classes:

1) Enteropneusta and **2) Pterobranchia**.

Authors like Marshall and Williams, 1964; Young, 1981; Romer and Parsons, 1986; Barnes, 1987; Ruppert and Barnes, 1994; Anderson, 1988; Pechemik, 2000; and Kardong, 1998, 2000 have mentioned only two classes in their books.

Class 1. Enteropneusta : (Gk., enteron=gut or intestine; pneustos, breathing; Intestine breather)

Characters :

1. Solitary and burrowing worm-like marine animals.
2. Body consists of proboscis, collar and trunk; collar without tentaculated arms. Proboscis cylindrical and tapering.
3. Alimentary canal straight; mouth and anus at opposite ends.
4. Numerous pairs of U-shaped gill-slits.
5. Two pairs of hepatic caeca present in the middle of the trunk.
6. Sexes separate; gonads numerous, sac-like. Asexual reproduction is lacking.
7. Development with or without tornaria larva.

Commonly known as **”acorn”** or **”tongue worms.”** Their conical proboscises are acorn like—hence the name acorn worms.

Examples : *Balanoglossus, Saccoglossus (= Dolichoglossus), Ptychodera. Protoglossus.*

Class 2. Pterobranchia: (Gk., pteron=feather; branchion=gill; Feather gill)

Characters :

1. Sedentary, solitary or colonial, tubicolous marine animals (Living inside secreted chitinous tubes).
2. Body short, compact, with stalk for attachment.
3. Proboscis with ciliated tentacles to produce ciliary feeding currents of water.
4. Collar with two or more tentaculated arms bearing tentacles.
5. One pair of gill-slits or none, never U- shaped.
6. Alimentary canal U-shaped with dorsal anus situated near the mouth at the same end.
7. Sexes separate or united; single or one pair of gonads.
8. Development direct, may or may not include a free swimming larval stage.
9. Asexual reproduction by budding in some.

Examples : *Rhabdopleura.Cephalodiscus, Atubaria.*

Additional information on Hemichordates :

Pterobranchia (pterobranchs) are tiny, deep-sea, colonial, moss-like animals. There is no trace of dorsal nerve cord or notochord and only one pair of gill slits in species of the genus *Cephalodiscus.* Unlike the acorn worms; they form colonies in which the individuals are interconnected by stems, or stolons. The individuals are generally small often less than 1 millimeter long. Most strikingly, almost in all pterobranch species, special glands in the proboscis secrete a collagen material from which a tube casing is made to house the animal. The proboscis is also used as an organ of locomotion (just the way a snail uses its foot), both for movement inside and outside the burrow. The tentacles secrete mucous which is driven, along with the food particles trapped in it, to the mouth by the beating of the cilia. The mucous and the accompanying food particles are then digested in a U-shaped digestive tract.

11.3.4 Urochordata (also known as Tunicata) (Gk. oura=tail)

The members of the phylum Urochordata exhibit a high degree of diversity in form, habit and habitat. The urochordates are also known as tunicates (L. tunica; an undergarment or test) or Ascidian (Gk. Askos; a leather bag).They represent the most primitive of the true chordate. In other words they are the most advanced amongst the protochordates i.e. they are more advanced than the cephalochordates and hemichordates. Urochordates are sometimes called tail chordates (notochord is confined to the tail region of the larva.).

11.3.5 Salient features of Urochordata

1) Exclusively marine, solitary or colonial, fixed or pelagic.
2) Body varies considerably in size, form and colour.
3) The notochord is confined to the tail region in the larval stage. For this characteristic feature the name of the subphylum is given Urochordata.
4) Unsegmented body wholly covered by a structure called test or 'tunic' (hence named Tunicata). The tunic is composed of a protein tunicin and a polysaccharide similar to plant cellulose.
5) Incurrent branchial siphon (mouth), and ex-current atrial siphon (atriopore), form entrance and exit portals for the water that circulates through the body.
6) Branchial siphon opens into a spacious branchial basket, *i.e.* pharynx, with pharyngeal slits or gill slits, adapted for filter feeding.
7) Coelom is not recognizable; the atrial cavity receives gonoducts, anus and gill-slits.
8) Larva has notochord in the tail. It disappears in adult during metamorphosis.
9) Alimentary canal is complete, presence of spacious pharynx.Gill slits are used to trap food particles during filter feeding.
10) Respiration by gill slits and test. Respiratory pigment is hemocyanin.
11) Circulatory system open type. Ventral heart is tube like and central in position and enclosed in a pericardial cavity.

    The heart is unusual because it periodically reverses the direction in which it pumps blood. Blood contains cells but not erythrocytes.
12) Excretion is performed by nephrocytes, neural gland and pyloric glands.
13) In adult the nervous system is represented by single dorsal ganglion.
14) Mostly bisexual (hermaphrodite). Fertilization is external. A sexual reproduction by budding.
15) Development indirect, through tadpole larva. Metamorphosis is retrogressive.

Most of the urochordates are sac like creatures inhabiting the sea bottom and are popularly called 'sea squirt' because the solitary forms spray water when they are disturbed mechanically. The life-history of urochordates passes through a dramatic change (retrogressive metamorphosis). Their chordate characters are more pronounced during larval period.

11.3.6 Classification of Urochordata

The subphylum is divided into three classes namely:

1. Ascidiacea, 2. Thaliacea and 3. Larvacea.

Class Ascidiacea

Characters :

This class is represented by the Sea Squirts and they make up the bulk of the species found within the urochordates.

1) Most of the chordate characters that were present during larval period disappear during metamorphosis into adult.In adult, nervous system transforms into a nerve ganglion.
2) Adults are sessile, but larvae are planktonic and do not feed. Tadpole-like larvae metamorphose into adults.
3) Adults having sac-like body, covered by tunic. Two openings, an inhalant siphon (where water comes in) and an exhalent siphon (where water goes out).
4) Pharynx has numerous small pores or slits in its walls for the passage of water.
5) Filter feeders.
6) Hermaphroditic - male and female reproductive organs on each organism.
7) Sessile (non-moving or staying in one place) adults.
8) Solitary or colonial in form - the colonial species may share a common exhalent siphon.
9) Translucent or whitish body colour but some species are much more colourful and can be red, brown, yellow and even blue.

Marine, most species are common coastal animals occurring in rock pools and out into deeper water to about 400 - 5,000 meters in depth. The class Ascidiacea contains about 2000 species

Examples : *Ascidia, Ciona, Herdmania.*

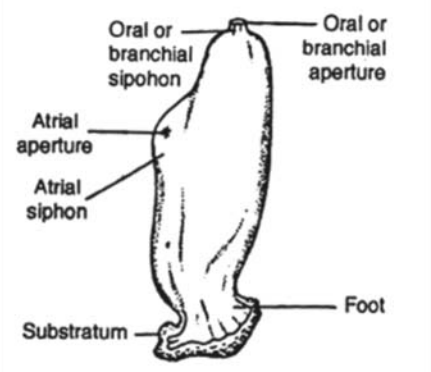

Fig. 1.8 : External organisation of adult *Ascidia*

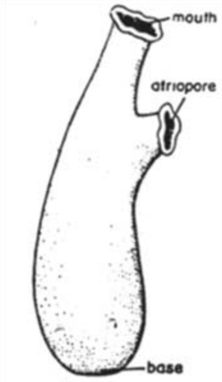

Fig. 30.1. Ascidia andamanensis

Class Thaliacea

Characters :

1) This class includes free-swimming pelagic urochor-dates.
2) Small barrel-shaped animals, the tunic is transparent and thin.
3) They possess encircling circumferential bands of muscles within the walls of the test or tunic.
4) Filter feeders, inhalant and exhalent siphons at opposite end of the body.
5) A few pharyngeal gill slits are present.
6) In the life-cycle polymorphism and clear alternation of generations are evident.

The class Thaliacea contains about 70 species.

Examples : *Salpa, Doliolum,*

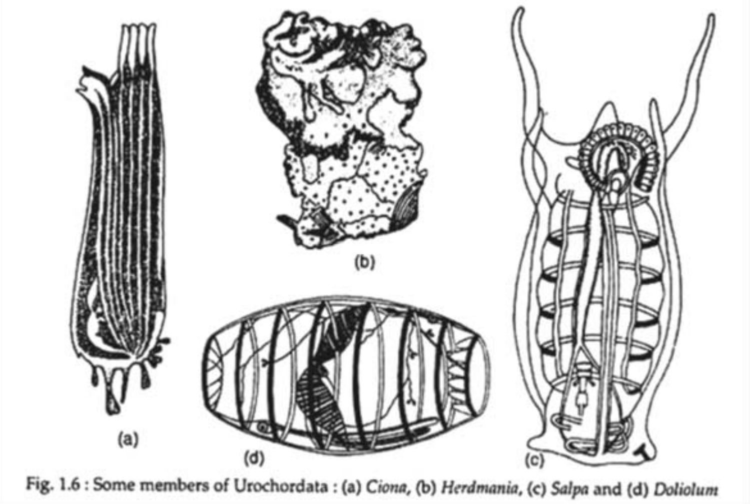

Fig. 1.6 : Some members of Urochordata : (a) *Ciona*, (b) *Herdmania*, (c) *Salpa* and (d) *Doliolum*

Class Larvacea (Apendicularia)

The Larvaceans, sometimes called the Apendicularians, are small animals quite different in form to the rest of the urochordates.

Characters :

1) These are tiny marine planktonic (mass of floating organisms) uro-chordates, found worldwide.
2) Body consists of a basically oval trunk and a relatively long thin tail. Tail is supported by notochord which is retained all through the animal's life, unlike the rest of the urochordates where it is lost before maturity.
3) The tail has large striped muscle cells attached to it and used for swimming.
4) The trunk holds major body organs.
5) They produce a remarkable feeding apparatus (house) that consists of three components: screens, filters and expan-ded gelatinous matrix.

   The 'house' encases the trunk or body, but not the tail. Disturbed or actively feeding larvaceans abandon their old house and builds a new one.
6) Larva like that of tunicates, metamorphoses to adult.
7) All species, except one, are monoecious, and most of these are protandrous.

Larvacea received their name because the adults retain larval characteristics similar in some way to the ascidian tad-pole with its tail and trunk. The general resemblance of adult larvaceans to asci-dian tadpoles suggests that larvaceans may be neotenous form.

Examples : *Oikopleura , Appendicularia.*

11.3.7 Cephalochordata (Gk. kephale = head L. chorda, cord)

The cephalochordate is an important group of animals for phylogenetic analysis and comparative anatomy of the chordates in general. Cephalochordates are small fish like marine chordates. The persistent notochord extends forward beyond the brain. Hence they are called cephalochordates.

Despite their great variety all these types show certain common features, often referred to as the typical chordate characters. It is better to regard these not as a list of isolated "characters" but as the signs of a certain pattern of organization that is characteristics of the group. The cephalochordates are the most advanced protochordates showing clearly the four primary features of chordates (notochord, dorsal nerve cord, pharyngeal gill slits and post anal tail) throughout their life. They are the closest to the vertebrates.

11.3.8 Salient features of Cephalochordata

1) Small fish like (lancet-shaped) translucent marine chordates.
2) Notochord well developed and persist throughout life of the animal. It runs the length of the animal from the tail to the tip of the head, hence the name Cephalochordata.
3) The body is laterally compressed and tapered at both ends with post anal tail. They are commonly called "lancelets" for the shape of the body.
4) Body muscles are in a series of V-shaped blocks of striated muscle fibres running throughout the body, called the myotomes which are separated from each other by sheet or layer of connective tissue, the myosepta or myocoma.
5) The body is provided with a dorsal fin, which joined to a somewhat caudal fin present round the tail. A ventral fin runs along the mid ventral line lying between caudal fin and atriopore.Paired fins absent.
6) At the anterior end an oral hood bears more than twenty stiff buccal or oral cirri or tentacles. The mouth is kept hidden within the oral hood.
7) The posterior wall of the oral hood is defined as velum.
8) On the lateral sides of the body there are numerous gill-slits (to trap food particles during filter feeding) which remain partly covered by the lateral folds of the body.
9) Presence of wheel organ adjacent to mouth.
10) Alimentary canal is long. It includes a large pharynx with many gill-slits. The anus is situated of the left side of the ventral fin.
11) The atrium opens to the exterior through a round atriopore located closed to the anterior end of the ventral fin.
12) Closed circulatory system and a specialed heart is lacking.
13) Blood is colourless without any respiratory pigment.
14) Excretory organs are paired protonephridia with solenocytes.
15) Sexes are separate. Gonads are metamerically arranged and without gonoducts.
16) Fertilization external. Fertilized eggs develop into free swimming larvae.

Marine animal, commonly found in the sandy shores of the sea. Sedentary, although it can swim in water. In spite of their streamlined shape, cephalochordates are relatively weak swimmers and spend most of their time in a filter feeding position partly to mostly buried with their anteriorend sticking out of the sand.

11.3.9 Classification of Cephalochordata

The subphylum Cephalochordata comprises a single class Lepitocardiiwith two genera:

Branchiostoma [Approx. 16 species]

1. Gonads lie on each side of the body.
2. They inhabit the tropical and subtropical seas

Branchiostoma lanceolatum (Amphioxus)

Asymmetron [Approx. 7 species]

1. Gonads lie only on the right side
2. They inhabit the tropical seas

Asymmetron cultellum

11.4 Larbal forms in protochordates

Protochordates are an informal category of animals (i.e., not a proper taxonomic group), named mainly for convenience to describe invertebrate animals that are closely related to vertebrates. This group is composed of the phylum Hemichordata, the subphylum Cephalochordata and the subphylum Urochordata. Tornaria larva is the larva of Hemichordata (Balanoglossus) and tadpole larva is the larval form of Urochordata (Ascidia).

Tornaria larva of Balanoglossus

Balanoglossus reproduces normally by sexual process. A sexual reproduction occurs very rarely. The development is indirect, i.e., the development is followed by the metamorphosis of a well-developed larval form, the tornaria larva. This larva was first discovered by Johannes Muller (1850), who gave the name tornaria due to its habit of rotating in circle.

General characteristics of tornaria larva are:

1) Oval in shape and bilaterally symmetrical body.
2) Size varies from 1 to 3 mm.
3) The mouth is present on the ventral side near the equatorial plane of the body.
4) Anterior to the mouth there is a prolonged preoral lobe.
5) There are three distinct ciliated bands on the body.
6) The preoral and postoral ciliated bands unite for a short distance at the apical plate.
7) One ciliate ring is present around the anus, which is called circumanal ciliated band or telotroch.
8) The cilia in the band are long, powerful and act as the chief locomotor organ.
9) The anus is located medially on the posterior end of the body.
10) The digestive tract is distinguishable into oesophagus, stomach and intestine.
11) Possess one pair of gill slits.
12) It undergoes morphological changes to become an adult.

Tadpole larva of Ascidia

The larval form present in the life history of Ascidia is called tadpole larva. The general characteristics of tadpole larva are—

1) Highly motile and does not take food from the outside.
2) The body is more or less oval in outline.
3) Body divisible into head and tail region.
4) The whole body is covered by tunic.
5) The head is elliptical and has three adhesive papillae or chain warts.
6) The tail is laterally compressed and pointed terminally.
7) The tail is provided with caudal fin.
8) The dorsal and ventral fins are continuous along the tail and are marked with striae.
9) The central nervous system is situated dorsal to the notochord.
10) A single median eye is present.
11) An otocyst, the organ of balance is situated in the ventral side.
12) The notochord is restricted only in the tail region.
13) Segmental muscle bands are present in the tail region.
14) The mouth is present and the alimentary canal is rudimentary.
15) Well developed pharynx is sac like.
16) A fully developed endostyle and two pairs of gill slits are present.
17) Non-functional heart with epicardia lies beneath the endostyle.
18) The paired atrial sacs are present.
19) Just after hatching the tadpole larva becomes positively phototactic and negatively geotactic.

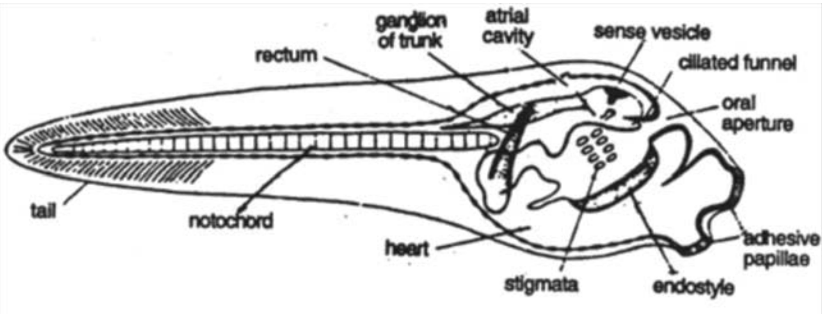

Fig. 30.5. Ascidia sp. A free swimming tadpole larva

11.5 Questions

? ? ? ?

11.6 Suggested readings

1. ? ?

Unit - 12 ❑ Pisces – General characteristics and Classification; Osmoregulation; Migration of Fishes.

Structure

12.1 Objectives

12.2 Introduction

12.3 General characteristics of Pisces

12.4 Outline Classification of Pisces

12.5 General characteristics of class Placodermi

12.6 General characteristics of class Chondrichthyes

12.7 Classification of class Chondrichthyes up to order

12.8 General characteristics of class Osteichthyes

12.9 Classification of class Osteichthyes up to order

12.10 Osmoregulation in fish

- **12.10.1 Introduction**
- **12.10.2 Types of osmoregulation**
- **12.10.3 Osmoregulation in freshwater fishes**
- **12.10.4 Osmoregulation in marine water fishes.**

12.11 Migration of Fishes

- **12.11.1 Definition**
- **12.11.2 Types of migratory movements**
- **12.11.3 Pattern of fish migration**
- **12.11.4 Factors affecting fish migration**
- **12.11.5 Different stimuli and fish migration**

12.12 Questions

12.13 Suggested readings

12.1 Objectives

After studying this unit, learners would be able to understand the following—

- Characteristics of Pisces.
- General characteristics of class Placodermi
- General characteristics and classification ofclass Chondrichthyes.
- General characteristics and classification ofclass Osteichthyes.
- Classification of Pisces up to order.
- Fish osmoregulation.
- Fish migration.

12.2 Introduction

Fishes are aquatic cold blooded vertebrates which exploit the aquatic habitat and become a "sentinel organism" of the water bodies. Fishes constitute the first group of animals that have developed the biting jaws in the phylogenetic history of vertebrates. Fishes are known for its unique characteristics, like- (i) presence of both paired and unpaired fins with dermal fin rays; (ii) presence of dermal scale; and (iii) presence of lateral line sense organ. The biology of fishes is so diverse that it is extremely difficult to give a concise account of the group.

Living fishes with jaws mostly fall into two well-marked classes- (i) the cartilaginous fish (**Condrichthyes**); and ii) the bony fishes (**Osteichthyes**). These groups arose in the late Devonian period.

Fishes are aquatic cold blooded (poikilothermic) vertebrates which exploit the aquatic habitat and become a "sentinel organism" of the water bodies. Fishes constitute the first group of animals that have developed the biting jaws in the phylogenetic history of vertebrates.They arose in the late devonion period. Fishes are known for their unique characteristics, like- (i) paired and unpaired fins with dermal fin rays; (ii) presence of dermal scale; and (iii) presence of lateral line sense organ. The Superclass Pisces (L. Piscis = fish) are the truly jawed vertebrates. All modern fishes belong to either the Chondrichthyes (cartilaginous fishes) or the Osteichthyes (bony fishes). These are diverse in morpho-logy and they are worldwide in distribution. They out number all other vertebrates com-bined and are one of the most successful groups of animals. In the earliest fishes, the ostracoderms, bone was a major part of their external design. In many later groups, there was a tendency for ossification to extend to the internal skeleton, but bone was secondarily reduced or lost in chondrichthyans and some bony fishes, such as lung fishes. Osteichthyans are not the only fishes to con-tain bone in their skeleton, but the taxonomic term 'Osteichthyes' recognises the perva-sive presence of bone, especially throughout the endoskeleton. Most bony fishes possess an adjustable, gas-filled swim-bladder that pro-vides neutral buoyancy, so they need not struggle to keep from sinking or bobbing to the surface.Fishes are hero of the vertebrate story. Ray-finned fishes have been dominant aquatic vertebrates since the mid-Paleozoic. Fleshy finned fishes gave rise to land vertebrates, the tetrapods.

12.3 General Characteristics of Pisces

1. Aquatic, either freshwater or marine, herbivorous or carnivorous, cold blooded (poikilothermous), oviparous or ovoviviparous vertebrates.
2. Body usually streamlined, spindle-shaped, some are elongated snake-like and a few are dorsoventrally compressed, and differentiated into head, trunk and tail.
3. Locomotion by paired pectoral and pelvic fins along with median dorsal and caudal fins, supported by true dermal fin-rays. Muscular tail used in propulsion.
4. Exoskeleton of dermal scales, denticles or bony plates (in Placodermi) covering body surface. Placoid in Chondrichthyes and ganoid, cycloid or ctenoid in Osteichthyes.
5. Endoskeleton is cartilaginous or bony. The notochord in usually replaced by vertebrae. Presence of well-developed skull and a system of visceral arches, of which the first pair forms the upper and lower jaws, the latter movably articulated with the skull.
6. Muscles arranged into segments called myotomes, with separate dorsal and ventral parts.
7. Lateral line system is well developed.
8. Nostrils are paired but do not open into pharynx except Dipnoi. Nasal capsules are partly separate in Chondrichthyes and completely separate in Osteichthyes.
9. Tympanic cavity and ear ossicles are absent. Internal ear with three semicircular canals.

10. Alimentary canal with definite stomach and pancreas and terminates into cloaca which serves as a common outlet for rectum, renal and reproductive ducts.
11. Organs of respiration are gills. Gill-slits 5 to 7 pairs, naked or covered by an operculum.
12. Heart is venous and two chambered, i.e., one auricle and one ventricle. Sinus venosus and renal and portal systems present. Erythrocytes nucleated.
13. Brain with usual five parts. Cranial nerves ten pairs
14. Kidneys mesonephric. Excretion mostly ammonotelic, in some ureotelic.
15. Sexes separate. Gonads typically paired. Gonoducts open into cloaca or independently.
16. Fertilisation internal or external. Females of Chondrichthyes are oviparous or ovoviviparous and of Osteichthyes are mostly oviparous and rarely ovoviviparous or viviparous. Eggs with large amount of yolk. Cleavage meroblastic.
17. Extra-embryonic membranes are absent.
18. Development usually direct without or with little metamorphosis.

12.4 Outline Classification of Pisces

About 40,000 species of fishes are known. Various workers have proposed different schemes of classification of fishes. However, no classification has been universally accepted because of confusion due to large number of fishes and great diversity in their shape, size, habits and habitat. Jordan (1923) divided fish-like vertebrates into six classes. Among the more recent authors Goodrich (1930), Berg (1940), Grasse (1958) and Romer (1959) have given a detailed classification of fishes.

Romer (1959) classified the fishes into two classes- **Chondrichthyes** (includes all cartilaginous fishes) and **Osteichthyes** (includes all bony fishes). Osteichthyes is divided into two subclasses- **Sarcopterygii** and **Actinopterygii.** Parker and Haswell (1962) have further combined all the extinct jawed fishes under a single class- **Placodermi**or Aphetohyoidea.

This simple division of superclass **Pisces** into three classes- **Placodermi, Chondrichthyes and Osteichthyes**, has been followed more or less by all the eminent authors.

12.5 General Characteristics of Class Plaeodermi (Extinct) [Gk. plaks = a flat plate; derma = skin] (Silurian — Permian)i

The earliest known jawed vertebrates are represented by a group of fossil fishes called placoderms which appeared during the Silurian period. These fossil fishes exhibit many structural peculiarities and are included under the class Placodermi or Aphetohyoidea.

The placoderms present wide range of adaptive radiation and flourished well in the Devonian and Carboniferous periods, but all of them became extinct by the end of Permian. The placoderms possess many pecu-liar and specialised characteristics and are regarded as the progenitors of the modern fishes. Although the placoderms form a heterogeneous group of fishes, the following features characterize the class.

]**The characte-ristic features are :**

1. The body is protected by heavy bony armour, a feature which has given the name 'placodermi' to the group.
2. The hyoid arch is unspecialized and does not take part in jaw suspension.
3. The jaws are attached with the skull by their own processes. This peculiar type of jaw attachment is called autostylic.(This is also called aphetohyoidean condition; because of this characteristic the placo-derms are also called Aphetohyoidea. Such type of jaw attachment is regarded as the most primitive type of jaw attachment.
4. The spiracle is typically a gill-slit which is present anterior to the unmodified hyoid arch.
5. The paired fins are usually present.

12.6 General characteristics of class Chondrichthyes (Gk., chondros = cartilage; ichthys = fish)

1. Mostly marine and carnivorous/predaceous.
2. Body fusiform and streamlined.
3. Fins both median and paired, all supported by fin-rays. Pelvic fins bear claspers in male which help in reproduction. Caudal fin or tail is heterocercal i.e. two lobes of the fin are unequal (except *Chlamydoselachus* and *Chimaera*, where tail is of isocercal type).

4. Skin is tough and covered with minute placoid scales. In some, the skin is naked and bears mucous glands.
5. Endoskeleton entirely cartilaginous often calcified, without true bones. Notochord persistent. Vertebrae complete and separate. Pectoral and pelvic girdles present.
6. In living forms, the sutures are absent in the skull.
7. Olfactory sacs do not open into pharynx. Membranous labyrinth (internal ear) with three semicircular canals. Lateral line system present.
8. Mouth ventral. Jaws are armoured with rows of sharp teeth. Teeth are modified placoid scales. Stomach J-shaped. Intestine with spiral valve.
9. by gills. Gills are of lamellar type.Gill slits are separate and without gill cover (operculum). In holocephalans the gill openings are covered by an opercular flap. Gill-slits 5 to 7 on each side. No air-bladder.
10. Respiration posterior part of kidney is excretory in function). Excretion ureotelic.
11. Heart two chambered (one auricle and one ventricle). Sinus venosus and conusarteriosus present. Both renal and hepatic portal system present.
12. Brain with large olfactory lobes and cerebellum. Cranial nerves ten pairs.
13. Kidneys opisthonephric (only Cloaca present. Its aperture serves as a common outlet for rectum, renal and reproductive ducts.
14. Sexes separate. Male usually possesses claspers. Gonads paired. Gonoducts open into cloaca.
15. Fertilisation internal. Oviparous or ovoviviparous. Eggs large, yolky. Cleavage meroblastic.
16. Development direct, without metamorphosis.

12.7 Classification of class Chondrichthyes up to orders

The Class Chondrichthyes is divided into two subclasses**:**

(i) Elasmobranchii (ii) Holocephali

Subclass 1. Elasmobranchii Characters:

Characters:

1. 5-7 pairs gill openings separately open to the exterior.
2. Body is covered by placoid scales.

3. Tail is mostly heterocercal type.
4. Spiracle is present.
5. Spiral valve present in the intestine.
6. High concentration of urea and trimethylamine oxide (TMAO) in the blood. Little water is drunk by the marine elasmobranchs and some water enters through the gills, hence little amount of urine is formed.
7. Males with pelvic claspers (Myxopterygia).
8. Jaw suspension mostly hyostylic type.

Examples: *Sharks (Scoliodon), rays {Trygon) and skates (Rhinobatus).*

They are mostly marine and highly predaceous. Some elasmobranchs have entered into the rivers and lakes, and live permanently there. Some species of *Carcharhinus* found in the Lake Nicaragua, and in the Ganges and Zambesi. Four elasmobranch species found in the Perak River in Malayasia, though they are not permanent resident but enter regularly from the sea. The Amazon sting ray, *Potamotrygon* is a permanent resident in the Amazon.

The subclass Elasmobranchii is divided into 3 orders:

(i) *Cladoselachii (Extinct)**, (ii) Selachii and (iii) Batoidea**

Order 1. *Cladoselachii (Gk. klados = branch, selakhe = a shark) Extinct

Characters:

1. They were abundant in the Carboniferous period.
2. The elongated body possessed terminal mouth.
3. Presence of two dorsal fins.
4. The large pectoral fins had broad bases.
5. The caudal fin is nearly symmetrical externally.
6. The teeth were cladodont (branched tooth) type.
7. They had no anal fin.

They were predaceous, marine shark-like fishes.

Example: *Cladoselache.*

Order 2. Selachii (Gk. selakhe = a shark)

The living sharks and rays are included under the order Selachii.

Characters:

1. The body is fusiform or elongated body.

2. Mostly cartilaginous endoskeleton.
3. Tail is heterocercal type.
4. Presence of external gill-slits.
5. First gill-slit is reduced and forms a small opening called spiracle.
6. Males with clasper.

Examples: *Sharks (Scoliodon, Squalus etc.)*

Order 3. Batoidea:

Characters:

1. The body is dorsoventraliy flattened.
2. Gill-openings ventrally placed.
3. Anterior margin of pectoral fin is fused with sides of the body or head.
4. No anal fin.
5. Dorsal fin if present placed from behind.
6. Tail is heterocercal.

Examples: *Rays (Dasyatis), Skates (Rhinobatos).*

Subclass 2. Holocephali:

Characters:

1. 4 pairs gill-openings are protected by fleshy operculum.
2. Body is naked but cephalic claspers retain placoid scales.
3. Tail is absent in the adult but is present in the young.
4. Spiracle is absent in the adult but is present in the young.
5. Spiral valve is absent.
6. Jaw suspension is holostylic type.

The subclass Holocephali is divided into two orders:

(i) Bradyodonti and (ii) Chimaerae.

Order 1. *Bradyodonti (extinct)

Characters:

1.Palaeozoic extinct forms, recorded in Upper Devonian.
2. The group is mainly represented by tooth plates.
3. The teeth are simple with broad, flat crowns.
4. The teeth are replaced very slowly than elasmobranchs.

Example: *Bradyodontus*

Order 2. Chimaerae

Characters:

1. Presence of crushing tooth plates.
2. Absence of true centra.
3. Presence of persistent notochord surrounded by partly calcified rings.
4. Palatoquadrate is fused to the neurocranium (holostylic).

Examples: *Chimaera (Ratfish), Callorhynchus (Elephant- fish)*

12.8 General characteristics of class Osteichthyes (Gk. osteon = bone, ichthys = a fish)

The class Osteichthyes includes a large assemblage of true bony fishes. There are well over 30,000 to 40,000 living species, both freshwater and marine. Some of the freshwater forms are the carp, perch, bass, trout, catfish, sucker, etc., while the marine fishes are the tarpon, meckerel, tuna, sailfish, barracula, flying fish, etc.

The characteristic features of class Osteichthyes are:

1. The skeleton is partly or largely formed of bony structures.
2. Body covered by dermal ganoid, cycloid or ctenoid scales.
3. Gills remain in a pouch, covered by a bony operculum.
4. Gills are of filamentous type.
5. Tail is mainly homocercal type.
6. Swim bladder is present in most forms except benthic feeders and deep sea forms.
7. Mouth terminal.
8. Clasper is absent in males.
9. Spiracle is absent except in some primitive forms (*Acipenser* and *Polypterus*).

12.9 Classification of class Osteichthyes up to orders

The classification of class Osteichthyes described here has been largely followed after A.S. Romer (1966) which has also been followed by most authors including Storer and Usinger. However, several new schemes of classification are also known.

The class Osteichthyes is divided into two subclasses:

(i) Actinoptrygii and (ii) Sarcopterygii.

Subclass 1. Actinopterygii (Gk., actis – ray; pteryx = fin) (Ray finned fishes)

The characteristic features are:

1. Includes all ray-finned fishes.
2. Paired fins thin, broad, without fleshy basal lobes and supported by dermal fin-rays.
3. One dorsal fin, may be divided.
4. Caudal fin without epichordal lobe.
5. Tail generally homocercal, in a few heterocereal or semi-heterocercal.
6. Body of Actinopterygii is covered by ganoid, cycloid or ctenoid scales. In some cases scales are absent.
7. Olfactory sacs not connected to mouth cavity. Internal nares absent.
8. Gill-slits covered by operculum. Spiracles generally absent.

The subclass is divided into 3 superorders:

(i) Chondrostei, (ii) Holostei and (iii) Teleostei.

Superorder 1. Chondrostei (Gk. chondros = cartilage, osteon = bone) Primitive ray finned fishes.

Characters:

1. Primitive ray-finned fish or cartilaginous ganoids. Internal skeleton is mainly cartilaginous but little bone present.
2. Notochord is persistent in between vertebrae.
3. Scales usually ganoid, covered by a layer of ganoin.
4. Heterocercal tail. Pelvic fins are posteriorly placed.
5. Spiral valve in the intestine.
6. Mouth opening large.
7. Spiracle present.

The superorder includes two orders:

Order **Polypteriformes** and Order **Acipenseriformes.**

Order 1. Polypteriformes

Characters:

1. Typical rhomboid ganoid scales.

2. Dorsal fin of eight or more finlets.
3. Pectoral fins with a small prominent scale covered fleshy lobe.
4. Ossified skeleton.
5. Spiracles present.
6. Air-bladder bilobed opening into the intestine ventrally.

Example:*Polypterus (Bichir).*

Order 2. Acipenseriformes

Characters:

1. Body covered with five rows of bony scutes.
2. Snout elongated, having barbles on the ventral surface.
3. Caudal fin heterocercal.
4. Skeleton largely cartilaginous. Endocranium cartilaginous.
5. Jaws without teeth.
6. Spiracles present.

Examples: *Acipenser (Sturgeon), Polydon (Paddle-fish) Scaphirhynchus (Shovel-nosed sturgeon).*

Superorder 2. Holostei (Gk., holos = whole/entire; osteon – bone) Intermediate ray finned fish.

Characters:

1. Internal skeleton bony.
2. Intermediate ray-finned fish, transitional between Chondrostei and Teleostei.
3. Body covered with cycloid scales in *Amia* and rhomboid scales in *Lepisosteus*. Generally the scales have lost their shiny ganoid covering.
4. Dorsal fin and pelvic fins are present very near to the caudal fin.
5. Mouth opening small.
6. Spiracle absent.

The superorder includes two orders: Order **Amiiformes** and order **Lepidosteiformes.**

Order 1. Amiiformes

Characters:

1. Body covered with thin, overlapping cycloid scales.
2. Caudal fin abbreviated heterocercal but rounded in outline.

3. Long dorsal fin.
4. Vertebral centra non-opisthocoelous.
5. Premaxillary not protractile, firmly articulated with the cranium.
6. Snout normal rounded.
7. Spiracles and clavicles absent.
8. Presence of a single swim-bladder.

Example: *Amia (Bowfin).*

Order 2. Lepidosteiformes

Characters:

1. Scales rhomboidal ganoid and in oblique rows.
2. Body elongated.
3. Nasal opening at the end of much elongated snout.
4. Caudal fin abbreviated heterocercal.
5. Vertebrae completely ossified and opisthocoelous.
6. Swim -bladder cellular.
7. Spiracle absent.

Examples: *Lepidosteus or Lepisosteus (Garpike).*

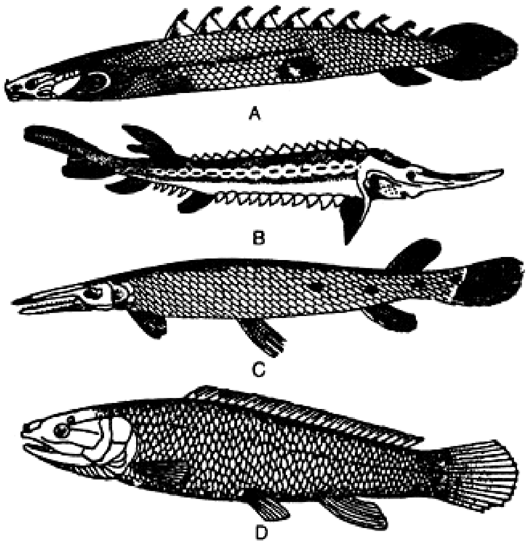

Fig. 1.44 : A. *Polypterus*, B. *Acipenser*, C. *Lepidosteus*, D. *Amia*

Superorder 3. Teleostei (Gk., teleos = complete; ostgon = bone) Specialized ray finned fish.

Characters:

1. Body covered with thin cycloid or ctenoid scales or scale absent.
2. Endoskeleton more or less bony.
3. Mouth terminal, small.
4. Tail fin mostly heterocercal.
5. Single external gill-slit on each side of the head covered over by operculum.
6. Large maxilla which takes part in the formation of upper jaw.
7. Air-bladder usually present. Spiracle is absent.
8. Conus arteriosus greatly reduced. There is an enlarged bulbus arteriosus.

The members of the teleosteans originated in the oceans but later invaded freshwater environment (Romer, 1962).

This superorder includes rest of the advanced or modem ray-finned fishes. Some examples are Rohu (*Labeo)*, Katla(*Catla*), Eel (*Anguilla*), etc.

This superorder includes following orders:

Characters:

Order 1. Clupeiformes

1. Scales cycloid and well developed.
2. Head and operculum not scaled.
3. Single dorsal and a small ventral fin without spines. Ventral fin may be absent. Pelvic fins abdominal.
4. Caudal fin homocercal.
5. Air-bladder communicate with the pharynx (Physostomous or open type swim bladder).
6. Vertebral centra completely ossified.
7. No auditory vesicles.
8. Weberian apparatus absent.

Examples: *Clupea (Herringer), Salmo (Atlantic salmon), Sardinops (Pacific sardine), Esox (Pike), Notopterus (Chital fish), Elops, Gadusia, Tenualosa ilisha (Hilsa or Ilish), etc.*

Order 2. Scopeliformes

1. Deep sea fishes having phosphorescent organs.
2. Dorsal and anal fins without spines. An adipose fin present.
3. Mouth wide and provided with numerous small teeth.
4. Air-bladder absent.

Example: *Harpodon (Bombay duck).*

Order 3. Cypriniformes

1. Fins either without spines or dorsal, anal and pectoral have a spine each.
2. Ventral (pelvic) fins abdominal.
3. Air-bladder connected with the pharynx by a duct (Physostomous or open type swim bladder).
4. A peculiar Webarian apparatus, connecting the internal ear with the air-bladder, present.

Representatives of this order are grouped in two divisions- **Cyprini, Siluri.**

Division I. Cyprini

1. Body covered with scales or naked. Never covered with bony plates.
2. Third and fourth vertebra not fused with each other.

Examples: *Labeo rohita*(Rohu), *Cirrhina mrigala*(Mrigel),*Catla catla*(Katla), *Cyprinus carpio, Puntius, Tor, Esomus, Oxygaster*, etc.

Division II. Siluri

1. Body naked, not covered by scales.
2. Maxillary bone reduced supporting the barbules.
3. Second, third, fourth and sometimes the fifth vertebrae are generally fused.

Examples: *Arius(Aar), Heteropneustes fossilis* (Singhi) *Clarius batracus*(Magur), *Wallago attu(*Boal), *Mystus* (Tengra), *Ompok, Ailia, Silonia, Bagarius*, etc.

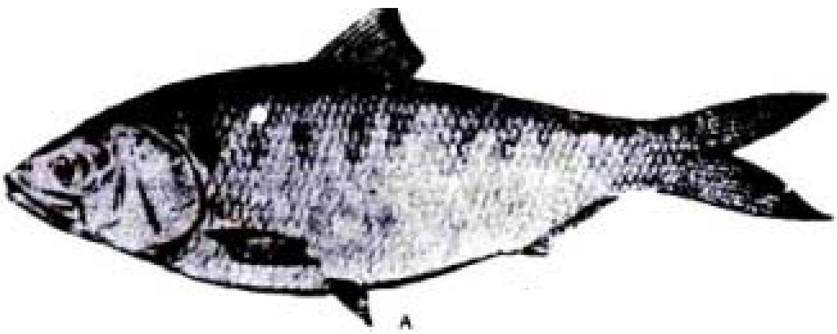

Fig. 1.45 : A. *Tenualosa ilisha*, B. *Labeo rohita*, C. *Anabas testudineus*

Order 4. Anguiliformes

1. Body elongated eel-like or snake-like.
2. Scales vestigial or absent.
3. Dorsal and anal fins long and confluent behind.
4. Pelvic fins, if present, abdominal.
5. Fins devoid of spines.
6. Air-bladder with duct (Physostomous or open type swim bladder).

Examples: *Anguilla* (Freshwater eel), *Muraena* (Moray).

Order 5. Beloniformes

1. Body elongated covered with cycloid scales.
2. Fins without spines.
3. Pectoral fins large and high on body.
4. Ventral (pelvic) fins abdominal.
5. Some of them are capable of jumping into the air and glide with the help of enlarged pectoral fins.

Examples: *Belone or Xenentodon* (Garfish), *Hemirhamphus* (Half beak), *Exocoetus* and *Cypselurus* (Flying fishes).

Order 6. Syngnathiformes

1. Body, covered with protective layer of scales or bony rings.
2. Snout tubular with suctorial mouth.
3. Pectoral fins small, pelvics absent and a single dorsal fin present.
4. Fin-rays of dorsal, pectoral and pelvic fins not branched.
5. Tail prehensile in sea horse, not in pipe fish.
6. Air-bladder closed (Physoclist bladder).
7. Males possess brood pouch for the development of the young.

Examples: *Hippocampus* (Sea horse), *Fistularia* (Flute fish), *Syngnathus* (Pipe fish).

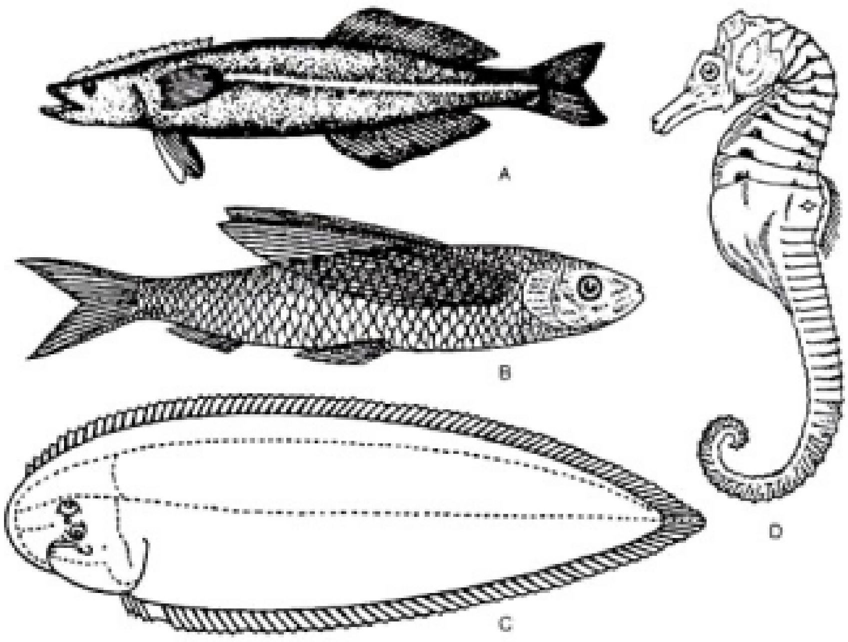

Fig. 1.46 : A. *Echeneis* (Suckerfish). B. *Exocoetus* (Flying fish). C. *Cynoglossus* (Indian flat fish). D. *Hippocampus* (Sea horse)

Order 7. Ophiocephaliformes or Channiformes

1. Body covered with cycloid scales.
2. Head depressed, covered with plate-like- scales.
3. Fins without spines.
4. Air-bladder very long and without duct (Physoclist bladder).
5. Accessory respiratory organs present.

Example: *Ophiocephalus* or *Channa* (Snake headed fish).

Order 8. Symbranchiformes

1. Body elongated eel-like or snake-like devoid of scales.
2. Dorsal, caudal and anal fins continuous. Pectoral fins absent.
3. Fins without spines
4. Gill-slits single or join to form a transverse ventral slit.
5. Air-bladder absent.

Examples: *Amphipnous*, *Symbranchus* (Eels).

Order 9. Mastacembeliformes

1. Freshwater eel-like fishes.
2. Dorsal, caudal and anal fins confluent. Sometimes a small fin separate.
3. Some free spines present in front of dorsal fin. Anal fin with three spines.
4. Ventral (pelvic) fins absent, but pectoral fins present.
5. Nostrils on tubular tentacles at the end of snout.
6. Buccal cavity enlarged for air breathing.
7. Air bladder without duct (Physoclist bladder).

Examples: *Mastacembelus, Macrognathus*.

Order 10. Perciformes

1. Two dorsal fins, ventral (pelvic) fins thoracic with not more than 6 rays.
2. Fins usually with spines.
3. Weberian apparatus absent.
4. Air bladder without duct (Plysoclist bladder).

Examples: *Anabas* (Climbing perch), *Perca* (Yellow perch), *Lates* (Bhetki).

Order 11. Scorpaeniformes

1. Enlarged heads and pectoral fins.
2. Projecting spines from gill-covering.

Example: *Pterois* (Scorpion fish).

Order 12. Pleuronectiformes

1. Bottom dwellers.
2. Body flat, lying on one side, adapted for bottom living.
3. Head asymmetrical.

4. Both eyes present on the upper or dorsal side and close to each other.
5. Dorsal and anal fins fringing the body and along the caudal encircle the body. Fins usually without spines.
6. Air-bladder absent in adults.

Examples: *Synaptura, Pleuronectes, Solea* (Flat fishes).

Order 13. Echeneiformes

1. Body covered with cycloid scales.
2. First dorsal fin modified into a flat oval adhesive disc or sucker on head for attachment. It possesses 12-28 transverse ridges which are modified spines.
3. No spines in second dorsal and anal fins.
4. Air-bladder absent.

Example: *Echeneis or Remora* (Sucker fish).

Order 14. Tetradontiformes

1. Body usually globular.
2. Body scales modified into spines. Scutes or bony plates cover the body.
3. Strong jaws with a sharp beak.
4. Gill-slits small like a hole on either side of fish in front of pectorals.
5. Ventral fines thoracic or subthoracic.
6. Air-bladder present or absent.
7. Some inflate by swallowing water.

Examples: *Diodon* (Porcupine fish), *Terodon* (Globe fish), *Ostracion* (Coffer fish or Trunk fish).

Order 15. Lophiiformes

1. First ray of spinous dorsal fin placed on the head is transformed into a fishing organ consisting of a rod (illicium) and a lure called esca.
2. Mouth large with long pointed teeth.
3. Body with minute scales or scaleless.
4. Pelvic fins present or absent. Pectorals well developed.
5. Air-bladder absent.
6. Luminescent organs present.

Examples: *Lophius* and *Antennarius* (Angular fishes).

Subclass 2. Sarcopterygii (Gk., sarcos = fleshy; pterygium = fin). Popularly called fleshy or lobbed finned fishes. (Gr. sarkos, flesh, pteryx, fin, wing)

1. Paired fins leg-like or lobed, with a fleshy, bony central axis covered by scales. Scales have a characteristic cosmoid layer.

2. Dorsal fins two, caudal fin heterocercal with an epichordal lobe.

3. Olfactory sacs usually connected to mouth cavity by internal nostrils or choanae.

4. Swim-bladder is modified into lung in some.

5. Intestine with spiral valve.

Subclass Sarcopterygii has been divided into two orders-

(i) **Crossopterygii** and (ii) **Dipnoi.**

Order 1. Crossopterygii (Primitive fleshy finned fishes and ancestors of land vertebrates)

1. Body covered with large cycloid scales with enamelled surface.
2. The tail is diphycercal with a median lobe.
3. Presence of two dorsal fins of which the posterior one has a fleshy lobe. The paired fins have also fleshy lobes.
4. Presence of an internal nostril (Choana). Internal nares present or absent.
5. Notochord persists and vertebrae unossified.
6. Teeth with labyrinthine structure.
7. Respiration is performed by gills.
8. Swim-bladder is highly reduced and is neither hydrostatic nor a respiratory organ.

Example: *Latimeria chalumnae*(Coelacanth)

Order 2. Dipnoi: (Gk., di = double; pnoe = breathing)

1. Body is covered by thin, large cycloid scales.
2. Paired fins with basal fleshy structures.
3. Caudal or tail fin symmetrical (diphycercal), with no trace of separate dorsal fins.
4. Single gill-slit on either side, covered by operculum.
5. Presence of two internal nostrils; spiracles absent.
6. Swim-bladder single or paired, modified into lung which is used in respiration.
7. Pulmonary and systemic circulation separate.

8. Small denticles are fused to form crushing tooth-plates.
9. Dermal bones on the skull.
10. Notochord remaining as an unconstricted rod.

Examples: Lung fishes - *Protopterus* of Africa, *Lepidosiren* of S. America and *Neoceratodus* of Australia.

There are three genera of Dipnoans found living till date. These lung fishes are mainly inhabitants of rivers and large lakes, they all breathe air. *Protopterus* lives in the large lakes of tropical Africa. *Neoceratodus* lives only in the Burnett and Mary rivers in Queensland, Australia. *Lepidosiren* lives in the rivers of tropical South America.

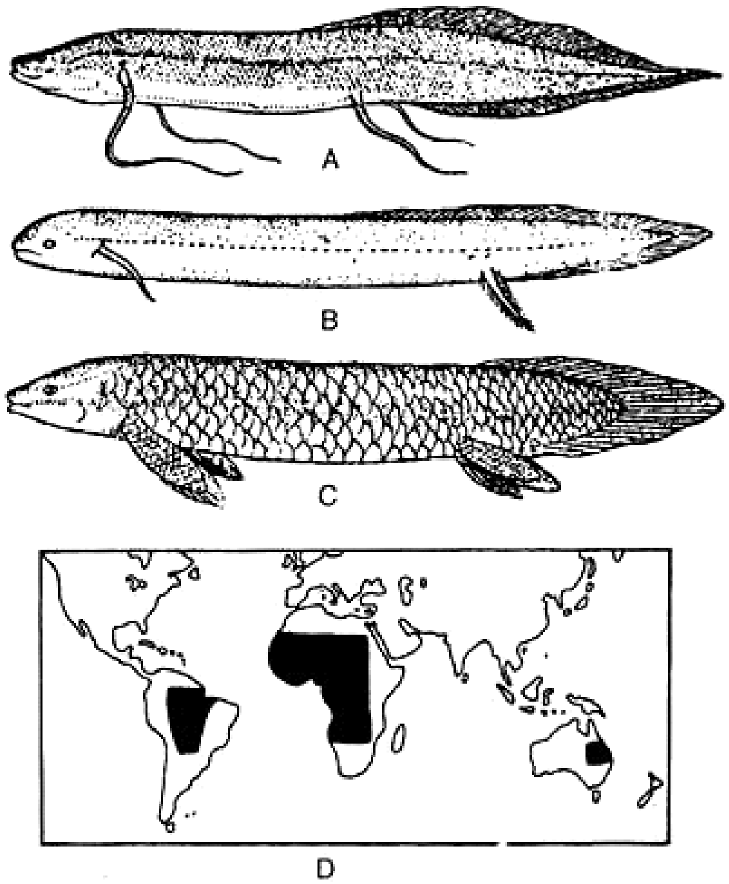

Fig. 1.47 :A. *Protopterus* (Arican), B. *Lepidosiren* (South American), C. *Neoceratodus* (Australian), D. Black areas of the map showing the distribution of three living lung fishes

12.10 Osmoregulation in fishes

12.10.1 Introduction

The water is essential component of all living cell and it is the universal biological solvent. As the life began in the water medium most of the organism live in water

medium and face the more problem of osmoregulation. Fish, migrate from freshwater to marine water and vice-versa, thus requires osmoregulation. Freshwater fish and seawater fish osmoregulate in different ways. Due to the different nature of the salinity of water in which they live, their process of osmoregulation is different. Osmoregulation is the process by which an organism regulates the water balance in its body and maintains the homeostasis of the body. It includes controlling excess water loss or gain and maintaining the fluid balance and the osmotic concentration, i.e., the concentration of electrolytes. It ensures that the fluids in the body do not get too diluted or concentrated.

12-10.2 Types of osmoregulation

There are two major types of osmoregulation-

1. **Osmoconformers:**

   Osmoconformersare organisms that keep their internal fluids isotonic to their environment, that is, they maintain an internal salinity similar to their ambient conditions. These organisms try to maintain the osmotic pressure of their body equal to their surrounding environment. Most of the marine invertebrates, hagfish, skates and sharks are osmoconformers.

2. **Osmoregulators:**

   These organisms maintain their internal osmolality, which can be extremely different from that of the surrounding environment, through physiological processes.

   Some fish have evolved osmoregulatory mechanisms to survive in all kinds of aquatic environments. When they live in fresh water, their bodies tend to take up water because the environment is relatively hypotonic. In such hypotonic environments, these fish do not drink much water. Instead, they pairs a lot of very dilute urine, and they achieve electrolyte balance by active transport of salts through the gills. When they move to a hypertonic marine environment, these fish start drinking sea water; they exerete the excess salts through their gills and their urine.

12.10.3 Osmoregulation in freshwater fishes

The body fluid of freshwater fishes is generally hyperosmotic to their aqueous medium. Thus, they are posed with two types of osmoregulatory problems- i) because of hyperosmotic body fluid they are subjected to swelling by movement of water into their body owing to osmotic gradient; ii) since the surrounding medium has low salt concentration, they are facing with continual loss of their body salts to the environment. Thus, freshwater fishes must prevent net gain of water and net loss of salts. Net intake of water is prevented by kidney as it produces a dilute, more copious urine (Fig.).

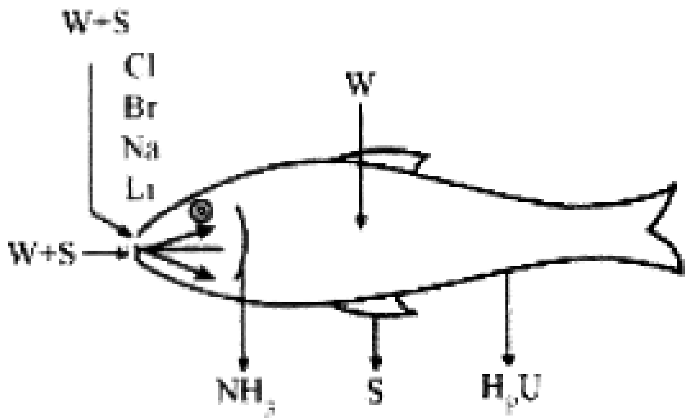

Fig. Osmoregulatory inflow and outflow of salts and water in a fresh water fish. HpU: hypotonic urine; S: salt W: water, W + S: water and salt.

On the other way, the useful salts are largely retained by re-absorption into the blood in the tubules of kidney, and a dilute urine is excreted. Although some salts are also removed along with urine which creates torrential (loss of some biologically; important salts such as KC1, NaCl which are replaced in various parts. As for example, NaCl actively transported in the gills against a concentration gradient in excess of 100 times. In these fishes the salt loss and water uptake are reduced by the integument. considerable with low permeability or impermeability to both water and salt also by not drinking the water (Fig.).

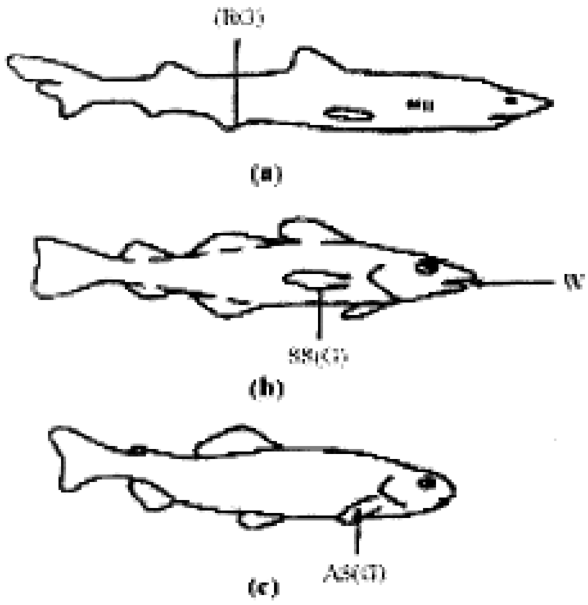

Fig: Exchange of water and salt in some fishes. (a) marine elasmohranch does not drink water and has isotonic urine; (b) marine teleost drinks water and has isotonic urine; (c) freshwater teleost drinks no water and has strongly hypotonic urine: AS(G): absorbed salt with gill: HrNaCl (RG): hypertonic NaCl

from rectal gland, SS(G): secretes salts from gill: W: water.

12.10.4 Osmoregulation in marine water fishes

In marine fishes, the concentration of body fluid and marine water is almost similar. Therefore, they do not require much energy for maintenance of osmolarity of their body fluid. As for example is hagfish, *Myxine* whose plasma is iso-osmotic to the environment. Hagfish maintains the concentration of Ca^{++}, Mg^{++} and SO^{4++} significantly lower and Na^{+} and Cl^{+} higher in comparison to sea water.

Modern bony fishes (marine teleost) have the body fluid hypotonic to sea water, so they have tendency to lose water to the surroundings particularly through gills via epithelium.

The lost volume of water is replaced by drinking salt water (Fig.).

About 70-80% sea water containing NaCl and KC1 enters the blood stream by absorption across the intestinal epithelium. However, most of the divalent cations like Ca^{++}, Mg^{++} and SO^{4++} left in the gut are finally excreted out. Excess salts absorbed along with sea water ultimately received from the blood with the help of gills by the active transport of $Na^{+}Cl^{-}$ sometimes K^{+} and eliminated into the sea water. However, divalent ions are secreted into the kidney (Fig.).

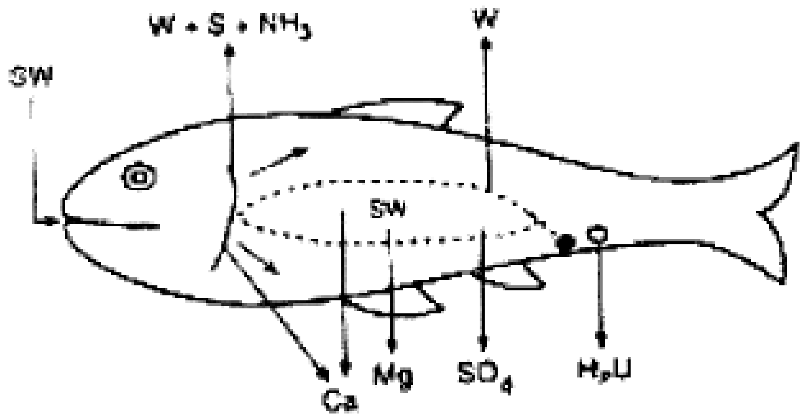

Fig. Osmotic regulation in marine bony fishes. HpU: hypotonic urine; SW: sea water; W + S + NH_3 : water, salt and ammonia; W: water.

Thus, urine is iso-osmotic to the blood but rich in those salts, particularly Mg^{2++}, prime prime Ca^{++} and SO_4^{--} which are not secreted by the gills. Combined osmotic action of gills and kidney in marine teleost resulted in the net retention of water that is hypotonic both to the ingested water and urine. By using similar mechanism some teleost species such as the salmon maintain more or less constant plasma osmolarity in-spite of being migratory between marine and freshwater environment.

12.11 Migration of fishes

12.11.1 Definition

The term migration may be applied to the cycle or periodic travels of an animal if it returns eventually to the original place of departure. Such movements can be constructed with emigrations and involves a change in location not necessarily followed by return journey. Fish exhibit migration due to searching of food, shelter and for breading purpose.

12.11.2 Types of migratory movements

According to Thompson (1942) migratory movement was grouped into the following categories:

A. **Local and seasonal movements:** There are merely changes of ground at a particular time of year. The migratory movements are sometime very small often larger but still confined within one geographical area.

B. Dispersals: The movements are more extensive only the breeding area is well defined and the movement is ideally an even and outward spread from the centre.

C. True migration: True migration is the movement between highly separated and well defined areas. The movement impels migrant to return to the region from which they have migrated.

12.0.3 Pattern of fish migration

Several authors have coined specialized terms considering the return of water current and character to designate the pattern of fish migration.

A. Movements in relation to water current: Merk (1915) introduced two terms, denatant and contranatant movements of fishes. Denatant means swimming or drifting or migrating with the current and contranatant means swimming or migrating against the current. The young stages of fish generally drift with the current to the nursery ground, the spawning migration is against the current. Again the adult fishes swim against the current to reach the spawning area.

B. Movements in relation to water character: Mayers' (1949) has proposed. some terms to designate the fish migration considering the water characteristics.

1. Diadromous: Truly migratory fishes which migrate between the sea and fresh water. This type of migration has following sub-divisions.

(a) Anadromous: Diadromous fishes which spend most of their lives in sea and migrate to freshwater for breeding, eg: Salmon, Sea lamprey, Tenulosa ilisha (Hilsa).

(b) Catadromous: Diadromous fishes which spend most of their lives in freashwater and migrate to the sea for breeding, e.g: Eeuropean eel (Anguilla anguilla) eel.

(c) Amphedromous: Diadromous fishes where migration from freshwater to the sea or vice-versa, is not for the purpose of breeding but occurs regulatory at some other definite stage of the life cycle, eg. Fresh water mullet (cestraeus plicatitis).

(d) Limnodromous: Many freshwater fishes leave the lakes to spawn in the river. This is called as limnodromous migration. e.g.: white fish (coregonus lavaretus).

2. Potamodromous: True migration of fishes whose migration occur wholely in the fresh water, e.g: Some species of salmon and trout.

3. **Ceranodromous:** Truly migratory fishes which live and migrate wholely in the sea. e.g: Harring, Cod.

12.11.4 Factors affecting fish migration

The following are the factors affecting fish migration.

Physical factor: light, temperature, turbidity, depth of water etc.

Chemical factor: Salinity, pH value of water etc.

Biological factor: Predators, competitors, Shortage of food, hormonal secretion etc.

12.11.5 Different stimuli and fish migration

Fish migration is considered to be directed by various stimuli. These stimuli have been discussed below.

A. **Chemical stimuli:** The alfaction play a vital role in finding food and locating areas which could be characterized by chemical clues. Different experiments prove that the threshold of smell of fishes is very much slower than that of test. Parker (1922) has rightly classed the alfactory organ of fishes as a distance receptor.

B. **Temperature stimuli:** Temperature may act as sensory receptor ordinate on the metabolism. In teleost the thermal receptors are scattered by spinal nerves.

C. **Water current stimuli:** So far as migration is concerned, the reaction of fish to water currents is one of the most interesting aspects of their behavior directing the course of their movements. To select the rheotactic response the visual and tactile sense organs are necessary.

D. **Light stimuli:** Fish react phototactically to light. The eye is the main receptor for light. In some fishes, in the pineal area, the dermal photoreception also occurs. Under natural conditions, most fishes often show a vertical migration from deep water by day of shallow water by night and probably the phototactic reactions are efficiently used by fish on migration.

E. **Electrical stimuli:** Regnarl (1932) was the first to suggest that the electro-magnetic force generated by moving water could have some biological significance. Thornton (1932) argued that deep sea fish could defeat the another animals by means of the electric current produced by their own motion.

F. **Celestrial stimuli:** Various evidences like compass reaction suggests that the fishes make are of celestrial clues for orientation during migration. Haster et al (1958) observed it in the White Ban (Roccus chysops). Migration of Sole

(Solea vulguris) in Southern North Sea is oriented at right as lightened by Haswell (1960).

12 Questions

12.13 Suggested readings

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