NETAJI SUBHAS OPEN UNIVERSITY

Choice Based Credit System
(CBCS)

SELF LEARNING MATERIAL

HZO
ZOOLOGY

CC-ZO-03

Under Graduate Degree Programme

PREFACE

In a bid to standardize higher education in the country, the University Grants Commission (UGC) has introduced Choice Based Credit System (CBCS) based on five types of courses *viz. core, discipline specefic, generic elective, ability and skill enhancement* for graduate students of all programmes at Honours level. This brings in the semester pattern, which finds efficacy in sync with credit system, credit transfer, comprehensive continuous assessments and a graded pattern of evaluation. The objective is to offer learners ample flexibility to choose from a wide gamut of courses, as also to provide them lateral mobility between various educational institutions in the country where they can carry their acquired credits. I am happy to note that the university has been recently accredited by National Assessment and Accreditation Council of India (NAAC) with grade ''A''.

UGC (Open and Distance Learning Programmes and Online Programmes) Regulations, 2020 have mandated compliance with CBCS for UG programmes for all the HEIs in this mode. Welcoming this paradigm shift in higher education, Netaji Subhas Open University (NSOU) has resolved to adopt CBCS from the academic session 2021-22 at the Under Graduate Degree Programme level. The present syllabus, framed in the spirit of syllabi recommended by UGC, lays due stress on all aspects envisaged in the curricular framework of the apex body on higher education. It will be imparted to learners over the six semesters of the Programme.

Self Learning Materials (SLMs) are the mainstay of Student Support Services (SSS) of an Open University. From a logistic point of view, NSOU has embarked upon CBCS presently with SLMs in English / Bengali. Eventually, the English version SLMs will be translated into Bengali too, for the benefit of learners. As always, all of our teaching faculties contributed in this process. In addition to this we have also requisitioned the services of best academics in each domain in preparation of the new SLMs. I am sure they will be of commendable academic support. We look forward to proactive feedback from all stakeholders who will participate in the teaching-learning based on these study materials. It has been a very challenging task well executed, and I congratulate all concerned in the preparation of these SLMs.

I wish the venture a grand success.

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Vice-Chancellor

Netaji Subhas Open University

Under Graduate Degree Programme

Choice Based Credit System ((CBCS)

Subject : Honours in Zoology (HZO)

Course : Basic Concept of Taxonomy and Diversity of Non Chordates

Course Code : CC - ZO - 03

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Netaji Subhas Open University

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Unit - 1 ❑ Basic of animal classification

Structure

1.0 Objective

By studying this unit learners would be able to know about—

- Taxonomic Concept
- The basis for identification of animals
- Process of classification
- The diversity of animal world

1.1 Introduction

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." Christoffersen (1995) has defined taxonomy as "the practice of recognising, naming, and ordering taxa into a system of words consistent with any kind of relationsips among taxa that the investigator has discovered in nature.” The process of taxonomy involves two district steps– (a) correct recognition and definition of the organisms and their relationships and (b) application of suitable designations 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 ***nomenclature***.

The term ***systematics***, 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 ‘Sytematics’ for the systems of classification in his famous book, **‘Systema Naturae (4th edition)** in 1735. This was later defined by simspson (1961) as “the scientific study of the kinds and diversity of organims and of any and all relationships among them.’’ The other simple defintion by Mayr (1969) is “systematics is the science of diversity of organisms’’. Systematics is more broader term than taxonomy. Systemaics deal with the evolutionary relationships between organisms. Systematics try to determine which organisms share a recent ancestry with others. Study on systematics include quite a broader areas of research which include not only morphology and anatomy, but also genetics, behavioural aspects and population study (including population genetics, ecology and evolutionary biology). The unique properties 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 actully 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 concerned with describing and naming the many kinds of organisms that exist today, those that have been extinct for many, even millions of years and also those that are becoming 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 oragnims. That the organisms are to be placed under a specific category require the study of thier realationships. The term realationship is vital and means phylogentic and all biological realationships. Realationships 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 Ashlock(1991), "a biological classifition is the ordered grouping of organisms 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 indentification and arrangement of diffrent types of organisms into groups on the basis of realationships and to express the degree of genetic relationships or affinity beteween different types of organims. 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.

1.2 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*

1.3 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 a*s 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.

1.4 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.)

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 grammer. 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 systematist or not.

Brief history of International Code of Zoological Nomenclature

The need for a code to give a scientific name to every species was first realized by British Association for the Advancement of Science in 1842, when a set of rules were framed by it. This was also felt by American Association for the Advancement of Science in 1877. Then similar learned bodies in different countries like France, Germany and Soviet Union developed codes for their respective countries.

In 1889, at the International Congress of Zoology in Paris, discussions were made to find out some common code of nomenclature. First version of code was adopted in the Vth International Congress of Zoology in Berlin in 1901. In the XVth session held in London in 1958, the codes were rewritten and published on 6th November, 1961 and the updated version of the code (1961) was made available in 1964 (2nd edition). This code is concerned only, upto naming of super family and did not satisfy the zoologists. The latest edition (4th edition) of the code was published in 1999 and its effective use has started from 2000.

The International Zoological Congress elects a judicial body, called International Commission of Zoological Nomenclature which interprets or recomends 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 mandatary 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 sceintific 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 (specfic 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.

1.5 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 :

1. 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 leo persica* (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 spccies 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.*

1.6 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.

1.7 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.

1.8 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.

1.9 Species Concept- Biological and Evolutionary

The foremost task of a taxonomist is to know the different ‘kinds’ of organisms occuring in nature. These ‘kinds’ are actually the species. History tells us that the existence of species has been recognised by man since the dawn of civilization.

The species, like the cell and the organism, is one of the most fundamental units in biology. It is fundamental in two very important ways. On the one hand it is a basic populational and evolutionary unit. Species become transformed through time. They undergo speciation, giving rise to separate and distincit lineages that diversify through time. On the other hand, it is also a basic unit in classification. Each species is given a name, that serves as a unique identifier and has a place in a hierarchial arrangement that at once reflects its evolutionary relationships and provides a basis for biologists’ language.

Small, almost imperceptible changes in an existing species lead to the shifts that at length are manifested in the appearance of a new species. The species provides a common ground where micro- and macro evolution meet. In this role, the species is the critical unit in evolution. New species must come from old if there is to be evolution.

Biological Species Concept :

Linnaeus established species as a practical unit of classification but the notion that species are biological units, is forwarded by Buffon (1707-1788). He was the first to introduce the idea that breeding between individuals characterizes a species. By that time various concepts on species like Typological Species concept, Nomina listic Species concept, etc. had been put forwarded by various workers. But no one was universally accepted. Mayr (1940) reviewed the works of others on species problem and introduced the Biological Species Concept (BSC). It is completely different from the earlier species concepts. According to this concept, "species are groups of acutally or potentially interbreeding natural population which are reproductively isolated from other such groups (Mayr, 1940). The advantage of biological definition is that, it can be tested objectively. If two populations in the same locality do not fertilize each other and if cross fertilization occur but hybrids are not viable and fertile, then the two populations tested can be considered as two separate species.

According to Biological Species Concept the members of a species shows the following there properties. These are—

(a) ***A reproductive community*** **:** The individuals or members of an animal species recognize each other as potential mates and seek each other for the purpose of reproduction. The species-specific genetic programme of every individual ensures intraspecific reproduction. Biological species is, therefore, a *reproductive unit* in which, theoretically all individuals of the community may contribute to the procreation of descendants.

(b) ***An ecological unit*** **:** The members of a species form an *ecological unit* which regardless of the individuals that constitute it, interacts as a unit with other species with which it shares its environment.

(c) ***A genetic unit*** **:** The species finally is a *genetic unit* consisting of a large inter communicating gene pool, whereas the individual organism is merely a temporary vessel holding a small portion of the contents of the gene pool for a short period of time.

These three properties show that species do not conform to the typological or morphological definition of a class of objects. Instead, species are biological populations.

The ability of one or more populations to interbreed denotes that the members of the population or populations belong to a single species, whereas a failure of interbreeding denotes populations beloning to different species.The individual members of a population possess some cytological, genetical or ecological isolating mechanism (reproductive isolation) which maintains the gene pool of the species.

According to Dobzansky (1950 "species is the largest and most inclusive reproductive community of sexual and cross-fertilizing individuals which share a same gene pool." He worte, "species are formed when a once actually or potentially interbreeding array of Mendelian population becomes segregated in two or more reproductively isolated arrays", or more briefly, "A species is the most inclusive Mendelian population." Both Mayr's and Dobzansky's definitions treat the species as a dynamic unit, a stage in the process of evolution, and not as a fixed static entity. The emphasis lies on the achievement of reproductive isolation.

Most modern taxonomists consider the biological species concept as the widely accepted species concept, because maximum workers apply this concept during their work. This concept has no fixity, and always changable and has the potentiality for modifications required by the evolution.

Although biological species concept has wide acceptance, this concept, when applied universally, has some drawbacks or difficulties as mentioned below :

1. Although it is easy to observe the reproductive barriers (isolation) between populations found in the same locality (sympatric population) but not so in case of populations that are naturally separated or geographically isolated (allopatric population). Thus the definition does not tell whether populations isolated from each other in space or in time could actually interbreed or not.

2. To the museum taxonomists working with dead specimens, and especially to the paleontologists, who have no choice but to work with non-living materials (fossils), this concept is of no value. One can not test fossil populations as to whether they can or can not exchange genes either among themselevs or with present populations.

3. One final difficulty with the biological species definition is that it is limited to sexually reproducing species and not applicable in apomictic species (i.e. asexually reproducing groups) that do not fulfil interbreeding criterion which is the most important characteristic feature in biological species concept. Apomictic groups show uniparental reproduction by parthenogenesis, hermaphroditism apomixis, budding, etc. Uniparental reproduction is seen in lower invertebrates and lower vertebrates. The descendents of apomictic groups are termed *agamospecies or binoms* (Grant, 1957), *paraspecies* (Mayr 1987 b) but Ghiselin (1987), Mayr (1988 a) stated that these are not considered as “species”.

In spite of the difficulties inherent in the biological species definition, the biological species generally agree and the exceptional cases are most instructive.

Evolutionary Species Concept :

Not all taxonomists specially palaeontologists are not satisfied with the biological species concept. They preferred a definition of species which is related to the evolution. This concept was proposed by Simpson (1961) and had undergone many modifications. According to Simpson, “an evolutionary species is a lineage (an ancestral-descendant sequence of populations) evolving separately from others and with its own unitary evolutionary role and tendencies.”

Simpson has stated that the above defintion not only is consistent with biological or genetical concept of species but it helps to clarify and remove some limitations of the biological species concept. Simpson attempted to solve the species definition by adding to it the time dimension, which was deficient in biological species concept. According to Mayr (1982) the above definition is related to the *phyletic lineage*, not indicates a species concept. Reif (1984) and Mayr (1987) had stated that there are many demerits in evolutionary species concept. The main weakness of evolutionary species concept are—

(a) The definition is of a phyletic lineage and not of a species. There is no view as to why phyletic lines do not interbreed with each other.

(b) The concept ignores the core of the species problem as to causation and maintenance of discontinuities between contemporary species.

(c) This concept has failed to solve the problem of how to deal with the relationship of descendant populations in a single lineage.

Ideally evolutionary species concept utilizes morphological, genetic, behavioral and ecological variables. But the problem of an evolutionary definition is that it may be difficult to apply in practice. Thus the growing agreement on the concept of the biological species has resulted in a uniformity of standard and precision that has been beneficial for practical as well as theoretical reasons.

1.10 Numerical Taxonomy

Numerical taxonomy or *taximetrics*, nowadays frequently and perhaps more appropriately referred to as *phenetics*, refers to the application of various mathematical procedures to numerically encoded character state data for organisms under study. Thus, it is the analysis of various types of taxonomic data by mathematical or computerized methods and numerical evaluation of similarities or affinities between taxonomic units, which are then arranged into taxa on the basis of their similarities.

Contemporary to Linnaeus, Michel Adanson, a French botanist introduced a new system of classification in which he put forwarded a plan for assigning numerical values to the similary between organisms and proposed that equal weightage should be given to all the characters while classifying plants. He used as many characters as possible for the classification and such classifications came to be knwon as Adansonian classifications. Numerical taxonomy was, however, largely developed and popularized by Robert R. Sokal and P.H.A. Sneath (1963).

Principles of Numerical Taxonomy

Numerical taxonomy involves two aspects :

(a) ***Construction of taxonomic groups*** **:**

(i) In numerical taxonomy, first individuals are selected and their characters spotted out. There is no limitation to the number of characters to be considered. However, the larger the number of characters, better is the approach for generalization of the taxa.

(ii) The resemblances among the individuals are then established on the basis of character analysis, which can often be worked out with the help of computers, the accuracy of which depends on the appropriateness in character. The best way to delimitate taxa is, to utilize maximum number of characters, with similar weightage given to all of them.

(b) ***Discrimination of the taxonomic groups*** **:**

When the taxonomic groups chosen for the study show overlapping of characters, discrimination should be used to select them. Discrimination analysis can be done by various techniques, specially devised for such purposes.

Numerical taxonomy is based on certain principles and following *seven principles* have been enumerated by Sokal and Sneath.

(i) The greater the content of information in texa, and more the characters taken into consideration, the better a given classification system will be.

(ii) Every character should be given equal weightage in creating new taxa.

(iii) The overall similarity between any two entities is a function of the individual similarities in each of the many characters, which are considered for comparison.

(iv) Correlation of characters differ in the groups of organisms under study. Thus distinct taxa can be recognized.

(v) Phylogenetic conclusions can be drawn from the taxonomic structure of a group and from character correlations, assuming some evolutionary mechanisms and pathways.

(vi) The science of taxonomy is viewed and practiced as an empirical science.

(vii) Phenetic similarity is the base of classifications.

Merits of Numerical Taxonomy :

According to Sokal and Sneath, numerical taxonomy has the following advantages over conventional taxonomy :

(a) The data of conventional taxonomy is improved by numerical taxonomy as it utilizes better and more of described characters. The data are collected from a veriety of sources, such as morphology, chemistry, physiology, etc.

(b) As numerical methods are more sensitive in delimiting taxa, the data obtained can be efficiently used in the construction of better keys and classification systems, creation of maps, descriptions, catalogues, etc. with the help of electronic data processing systems. Numerical taxonomy has, in fact, suggested several fundamental changes in the conventional classification systems.

(c) The number of existing biological concepts have been reinterpreted in the light of numerical taxonomy.

(d) Numerical taxonomy allows more taxonomic work to be done by less highly skilled workers.

Demerits of Numerical Taxonomy :

Numerical taxonomy has, however, proved to be disadvantageous from the following points of view :

(a) The numerical methods are useful in phenetic classifications and not phylogenetic classifications.

(b) The proponents of "biological" species concept, may not accept the specific limits bound by these methods.

(c) Character selection is the greatest disadvantage in this approach. If characters chosen for comparison are inadequate, the statistical methods may give less satisfactory solution.

(d) Different taxonometric procedure may yield different results. A major difficulty is to choose a procedure for the purpose and the number of characters needed in order to obtain satisfactory results by these mechanical aids. It is necessary to ascertain whether a large number of characters would really give satisfactory results than those using a smaller number.

In spite of the above demerits this method of classification is still being used by the plant taxonomists, molecular biologistis and others. Computers and numerical taxonomic programmes are now standard resources in every museum and systematics laboratory. One of the very useful software is NTSYS.

1.11 Molecular Taxonomy

Molecular taxonomy is the classification of organisms on the basis of the distribution and composition of chemical substance in them.

The species can be differentiated on the basis of amino acid sequences in the proteins of an organism and on differences between these as found in different species. Crick (1958) called it 'Protein Taxonomy'. It is also believed that the changes in the enzyme structure can also help in the discovery of new species. Lahni (1964) coined the term 'Molecular Taxonomy' which was primarily based on the nucleotide sequnces of polynucleotides. To measure the degrees of genetic relationship it is important to look for the genetic material they are composed of and here the molecular taxonomy comes into play. Turner (1966) preferred to divide molecular taxonomy into two— *Micromolecular and Macromolecular Taxonomy*. The former gives emphasis upon the distribution and biosynthetic interrelationships of small molecular weight compounds such as free amino acids, alkacids, terpenes, flavonoides, etc. These are commonly referred to as secondary compounds. This type of approach is especially useful in resolving some systematic problems where hybridization has been a factor. The latter (macromolecular taxonomy), is concerned with the polymeric molecules. It is more or less close to the core of heriditary information, i.e. the DNA sequence, RNA, polysaccharides and proteins. This approach is useful for resolving some of the more intractable systematic problems, espeically those involving relationship among higher categories.

There are many examples where biochemical characters have been found extremely useful in solving taxonomic problems. Basu Chaudhary and Chatterjee (1969) demonstrated phylogenetic relationship among various orders of birds on the basis of the quantitative analysis of ascorbic acid. In some birds (Anseriformes, Columbiformes, etc.) it is produced in the kidney, in some (Piciformes) it is produced in the liver, while in some in both liver and kidney, and in others, in neither. Accordingly they clarified that the ancestral enzyme systems involved occured first in kidney, were somehow transferred to the liver, and in some of the more evolved passerine birds, completely lost. Similarly Brand et al. (1972) established the phylogeny of a group of fire ants using biochemical characters of the highly unique fire ant venoms. Walbank and Waterhouse (1970) corrected the phylogenetic affinities (based earlier on morphological data) of certain genera of Australian cockroaches after analysing their defence secretions.

Thus, the present biological approach is definitely helpful in solving many taxonomical problems. But this, too, is not useful in many cases. Such studies are possible only in the existing. organisms and therefore, it is difficult to trace the course of evolutionary history. It cannot lead to definite judgements with regard to the phylogeny of any organism whose fossil records are inadequate or lacking. Most of the molecular or biochemical taxonomic works are based on qualitative and quantitative differences in single chemical constituent of whole organisms or one of their tissues. Like morphological characters, chemical characters are also variable. A proper understanding of the taxonomic relationships of organisms requiers comparison of a number of biochemical characters in combination with one another to reveal the diversity on biochemical patterns rather than on a single biochemical character. Since proteins and nucleic acids provide a much reliable estimate of the degree of genetic homology among animals (Wilson and Kaplan, 1964), comparison of various characteristics of these molecules as such, are more suitable than other constituents for understanding their taxonomic relationships. The distribution of free amino acids in different organs of insects is of greater taxonomic value than their mere presence or absence or concentration in whole animals or in one of their tissues (Seshachar et al.). In mammals, the classification of species, based on amino acid sequences of the peptides, agrees in general with the accepted one based on morphological data (Blomback and Blomback, 1968).

In molecular taxonomy, studies are conducted in five ways– immunological, chromatographic, electrophoresis, infra-red spectrophotometry and histochemical studies. More recently the molecular techniques like DNA and protein sequencing, DNA-DNA or DNA-RNA hybridization methods, immunological methods are being used to establish genetic relationship between the members of different taxonomic categories. The data obtained from such studies are used to construct phylogeneic tree Fitch and Margoliash (1967) made first phylogenetic tree based on molecular data. The tree was so close to the already established phylogenetic trees of the vertebrate that the taxonomists realized the significance of molecular data and that made them understand that other traditional methods are although important but molecular evidences could be final or confirmatory evidences.

The advent of DNA cloning and sequencing methods have contributed immensely to the development of molecular taxonomy and population genetics over the last two decades. These modern methods have revolutionalised the field of molecular taxonomy and population genetics with improved analytical power and precision.

[For further reading one can consult the following Review Article on molecular taxonomy–"Molecular Taxonomy : Use of Modern Methods in the Identification of a Species", by A. K. Singh, *Indian J. L. Sci.* 2(1) : 143-147, 2012]

1.12 Questions

a) Who coined the term taxonomy?

b) How many levels of taxonomy are present?

c) Distinguish between taxonomy & systematics

d) What is the proposed hypothesis of Henig?

e) What do you mean by polytypic & Monotypic species?

f) What do you mean by type?

g) How different types are determined?

h) What do you mean by sibling species?

i) Define classification

j) What do you mean by Laws of Priority?

k) In which language naming of animals are made?

l) What is the contribution of Linneus in classification?

m) Mention the rules of nomenclature

Unit – 2 ❑ Subkingdom : Protozoa

Structure

2.1 Introduction

Protozoa (Gr. protos = first; primitive; zoon = animal) are microscopic, eukaryotic, unicelluler 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 protoza 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 swiming. There are about 8000 species of protozoa certainly belong to Portista.

2.0 Objective

By studying this unit learners would be able to know about—

- To learn the details about protozoan animals & its diversity of protozoa.

2.2 General Characteristics

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 (cytosekleton) or test (exoskeleton).
5. Body shape variable, may be spherical, oval, elongated, flattened or irregular. Size varies from 1.0 μm to 0.25 m (some giant benthic marine amoeba), most being in between 5 and 250μm 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. *Paramecuin*), flagella (e.g. *Euglena*) and flowing extensions of the body called pseudopodia (e.g. *Amoeba*). Some protozoans are sessile (attached or fixed)
8. Nutrition may be holozoic, holophytic saprophytic, mixotrophic or parasitic.
9. Digestion occurs intracellularly within the food vacuole.
10. Respiration generally through body sufrace 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.

2.3 Classification

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 Levin 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 subkingdom. Under subkingdom protozoa there are **seven phyla.**

Phylum : Sarcomastigophora

Phylum : Labyrinthomorpha

Phylum : Apicomplexa

Phylum : Microspora

Phylum : Ascetospora

Phylum : Myxozoa

Phylum : Ciliophora

Classification in outline (up to classes)

Subkingdom : Protozoa

Phylum 1. Sarcomastigophora

Subphylum 1 Mastigophora

Class 1 Phytomastigophora

Class 2 Zoomastigophora

Subphylum 2 Opalinata

Class 1 Opalina

Subphylum 3 Sarcodina

Superclass 1 Rhizopoda

Class 1 Lobosea

Class 2 Acarpomyxea

Class 3 Acrasea

Class 4 Eumycetozoea

Class 5 Plasmodiophore

Class 6 Filosea

Class 7 Granuloreticulosea

Class 8 Xenophyophorea

Superclass 2 Actinopoda

Class 1. Acantharea

Class 2. Polycystinea

Class 3. Phaedarea

Class 4. Heliozoea

Phylum 2. Labyrinthomorpha

Class Labyrinthulea

Phylum 3. Apicomplexa

Class 1. Perkinsea

Class 2. Sporozoea

Phylum 4. Microspora

Class 1. Rudimicrosporea

Class 2. Microsporea

Phylum 5. Ascetospora

Class 1. Stellatosporea

Class 2. Paramyxea

Phylum 6. Myxozoa

Class 1. Myxosporea

Class 2. Actinosporea

Phylum 7. Ciliophora

Class 1. Kinetofragminophorea

Class 2. Oligohymenophorea

Class 3. Polymenophorea

Classification with characters (upto classes)

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

Subphylum 1. Mastigophora

1. Presence of one on more long slender flagella (sing flagellum) at some or all stages in the life cycle is characteristic of the Mastigophora (Gr. mastix, whip + phoros, bearing). The flagella serve for locomotion and food capture and may be sense receptors. Some posses undulating membrane.
2. The body is usually of definite form—oval, long and spherical–covered by a firm pellicle.
3. Nucleus single.
4. Nutrition autotrophic or heterotrophic or both.
5. Reproduction usually by binary fission sexual reproduction is uncommon.
6. They may be free living, parasitic, solitary or colonial.

The subphylum includes **two classes–(i) Phytomastigophorea;**

(ii) Zoomastigophorea

Class Phytomastigophorea

1. Presence of chromatophores with typical chloroplasts.
2. Nutrition mostly autotrophic (holophytic)
3. Presence of one or two flagella.
4. Reserve food strach or paramylon
5. Sexual reproduction in some forms.
6. Mostly free living.

Examples : *Euglena*, *Volvox*, *Cryptomonas*, *Chilomonas*, *Ochromonas*, etc.

Class Zoomastigophorea

1. Chromatophores or chlorophil absent.
2. Nutrition heterotrophic (holozoic or saprozoic), Reserve food is glycogen.
3. Presence of one to many flagella. Some possess undulating membrane.

4. Parasitic, commensal or symbiotic.

Examples : *Trypanosoma*, *Giardia*, *Trichomonas*, *Trichonympha*, *Leishmania.*

Subphylum 2. Opalinata

1. Entire body surface is covered by oblique rows of cilia like organelles.
2. Cytostome or cell mouth absent. Nutrition saprozoic.
3. Two or many monomorphic nuclei.
4. Asexual reproduction by longitudine binary fission.
5. Sexual reproduction involves syngamy.
6. All are parasites or commensals.

The subphylum includes a single class-Opalinatea.

Class 1. Opalinatea

Characters are same as subphylum Opalinata.

Examples : *Opalina*, *Zelleriella*, *Protoopalina*

Subphylum 3. Sarcodina

1. Locomotory organs are pseudopodia. Flagella when present usually restricted to developmental stages of life cycle.
2. Body mostly amoeboid, naked or with external or internal skeleton or test.
3. Asexual reproduction by fission.
4. Sexual reproduction when present involves syngamy with flagellated (rarely amoeboid) gametes.
5. Most are solitary and free living, a few parasitic.

Superclass Rhizopoda

Locomotion by pseudopodia (as lobopodia, filopodia or reticulopodia) or by protoplasmic flow without production of discrete pseudodia.

The superclass includes 12 classes.

Class 1. Lobosea

1. Pseudopodia lobose type (lobopodia).

2. Usually uninucleate.

Examples : *Entamoeba*, *Amoeba*, *Chaos*.

Class 2. Acarpomyxea

1. Pseudopodia branched or sometimes reticulate.
2. Uninucleate.
3. No test
4. No spores or fruiting bodies

Examples : *Leptomyxa*, *Rhizamoeba*, *Corallomyxa*.

Class 3. Acrasea

1. Uninucleate amoeba with eruptive, lobose pseudopodia.
2. Fruiting bodies without stalk tube.
3. Sexuality unknown.

Examples : *Acrasis*.

Class 4. Eumycetozoea

1. Pseudopodia filiform type.
2. Flagella when present non mastigonemate.
3. Apical fruiting bodies with stalk tubes.

Exampla : *Protostelium*, *Dictyostelium*.

Class 5. Plasmodiophorea

1. Obligate intracellular parasites with minute plasmodia.
2. Zoospores with nonmastigonemate flagella.
3. Sexuality in some species.

Exampla : *Plasmodiophora*, *Sorosphaera*.

Class 6. Filosea

1. Hyaline, filiform pseudopodia, often branching sometimes anastomosing.

2. No spores or flagellate stages known.

Exampla : *Gromia*, *Nuclearia*, *Euglypha*.

Class 7. Granuloreticulosea

1. Delicate, finely granular or hyaline reticulopodia or, rarely, finely pointed, granular but nonanastomosing pseudopodia.
2. Test with single or many chambers.

Exampla : *Elphidium*, *Fusulina*.

Class 8. Xenophyophorea

1. Multinucleate plasmodium enclosed in branched-tube system of organic substance.
2. Fecal pellets retained outside organic tube system as conspicuons dark masses.
3. Marine.

Exampla : *Psammetta*, *Stannophyllum*.

Superclass 2. Actinopoda

1. Usually planktonic (floating) with spherical body and delicate psuedopodia.
2. Skeleton when present composed of organic matter and/or silica or of strontium sulphate.
3. Reproduction asexual and/or sexual.

The superclass includes 4 Classes—

Class 1. Acantharea

1. Skeleton is of strontium sulphate and usually composed of 20 radial or 10 diametral spines; sometimes many more spines randomly oriented.
2. Extraccllular outer and inner envelopes usually present.
3. All marine.

Examples : *Acanthocolla*, *Psuedolithium*.

Class 2. Polycystinea

1. Skeleton mostly siliceons, made up usually of solid elements.

2. Capsular membrane composed usually of polygonal plates.
3. Marine planktonic.

Examples : *Plagonium, Eucoronis, Octodendron*

Class 3. Phaeodarea

1. Skeleton (sometimes absent) of mixed silica and organic matter, consisting usually of hollow spines and/or shells.
2. Very thick capsular membrane.
3. Marine and planktonic.

Examples : *Astracantha, Sagospheera.*

Class 4. Heliozoea

1. Without central capsule.
2. Skeleton (when present) is siliceous or organic.
3. Axopodia radiating on all sides.
4. Most are freshwater, some marine.

Examples : *Clathrulina*, *Actinophrys*, *Gymnosphaera*.

Phylum 2. Labyrinthomorpha

1. Generally trophic stage with ectoplasmic network and spindle shaped or spheridal 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**

Characters are same as phylum.

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. Clilia absent
5. Reproduction generally by syngamy, some reproduce asexually.
6. All are parasitic.

This phylum includes two classes–(i) Perkinsea and (ii) Sporozoa

Class 1. Perkinsea

1. Conoid forming incomplete cone.
2. "Zoospores" flagellated with anterior vacuole.
3. No sexual reproduction.

Example : *Perkinsus*.

Class 2. Sporozoa

1. Conoid, when present, forms complete cone.
2. Locomotion of mature organisms by body flexion, gliding or undulation of longitudinal ridges. Pseudopodia ordinarily absent, if present used for feeding, not locomotion.
3. Flagella present only in microgametes of some groups.
4. Reproduction generally both sexual and asexual.
5. Oocysts generally containing infective sporozoites which result from sporogony.

Examples : *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. Diamorphic 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

Class 1. Rudimicrosporea

1. Spores with simple (rudimentary) extrusion apparatus consisting of polar cap and thick polar tube.
2. Spore spherical or subspherical.
3. Polaroplast and postorior vacuole absent.
4. Sporulation sequnce with dimorphism.
5. Hyperparasites of gregarines in annelids.

Examples : *Amphiacantha*, *Metchnikovella.*

Class 2. Microsporea

1. Spore with complex extrusion apparatus of Golgi origin, often includes polaroplast and posterior vaculoe in addition to polar tube and polar cap.
2. Polar tube typically filamentous.
3. Spore shape various, spore wall with three layers.
4. Often dimorphic in sporulation sequence.

Examples : *Nosema*, *Amblyospora*, *Encephalitozoon*.

Phylum Ascetospora

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

This phylum includes two classes—(i) **Stellatosporea**, (ii) **Paramyxea**

Class 1. Stellatosporea

1. Spore with one or more sporoplasms.
2. Haplosporosomes present.

Examples : *Marteilia*, *Haplosporidium*, *Urosporidium.*

Class 2. Paramyxea

1. Spore bicellular, consisting of parietal cell and one sporoplasm.
2. Spore imperforate (without orifice).

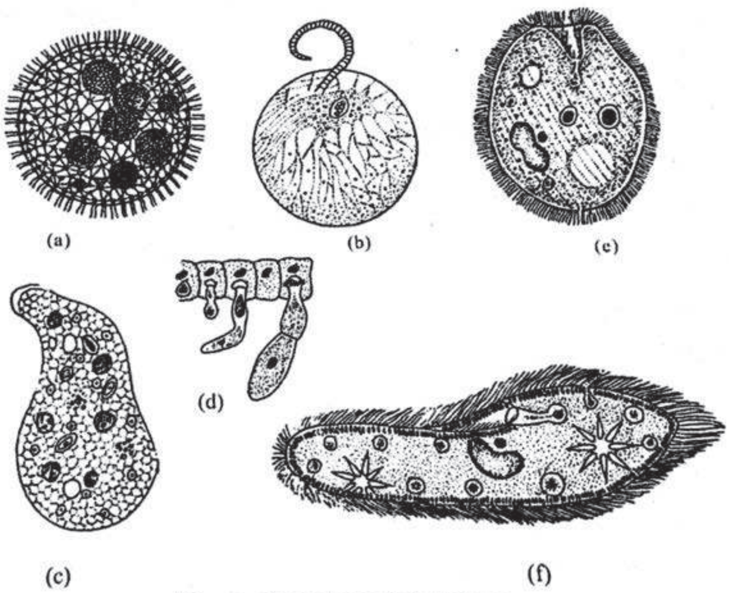


Fig. 1 : Some Important Protozoa
(a) *Volvox*, (b) *Noctiluca*, (c) *Pelomyxa*, (d) *Gregarina*, (e) *Balantidium*, (f) *Paramoecium*

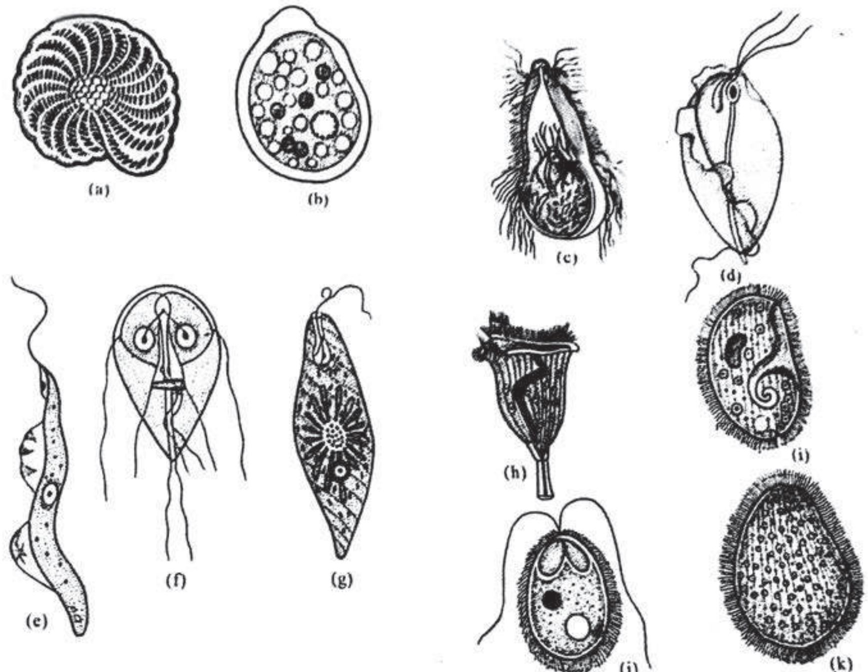


Fig. 2 : Some more Important Protozoa
(a) *Elphidium*, (b) *Entamoeba*, (c) *Trichonympha*, (d) *Trichomonas*, (e) *Trypanosoma*, (f) *Giardia* (g) *Euglena*, (h) *Vorticella* (i) *Nyctotherus* (j) *Chlamydomonas* (k) *Opalina*

Example : *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.

Class 1. Myxosporea

1. Spore with one or two sporoplasms and 1-6 (typically 2) polar capsules.
2. Each capsule with coiled polar filament which function probably anchoring.
3. Spore membrane generally with two valves (occasionally upto six valves).
4. Trophozoite stage well developed.

Exampla : *Myxidium*, *Myxobolus*.

Class 2. Actinosporea

1. Spores with three polar capsules, each enclosing coiled polar filament.
2. Spore membrane with three valves.
3. Several to many sporoplams.
4. Trophozoite stage not well developed.

Example : *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.

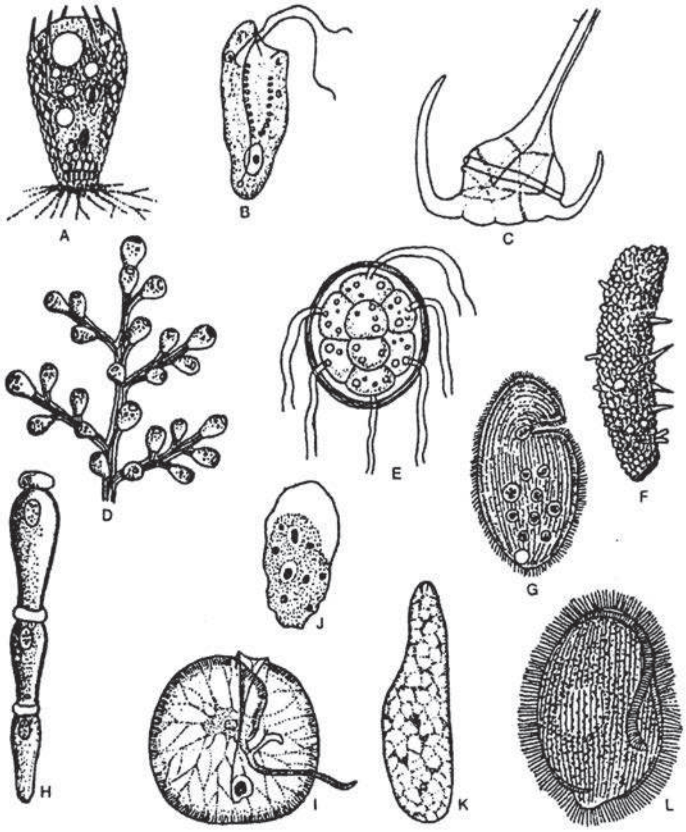


Fig. 3 Representatives of Phylum Protozoa Note the variety of forms in the Phylum Protozoa (after Hyman). A. *Euglypha.* B. *Chilomonas.* C. *Ceratium.* D. *Zoothamnium.* E. *Pandonna.* F. *Saccorhiza.* G. *Plagiopyla.* H.*Greganna.* I. *ivoctiluca.* J. *Myxidium.* K. *Sarcocystis.* L. *Nyctotherus*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

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.

Class 1. Kinetofragminophorea

1. Cytopharyngeal apparatus commonly prominent.
2. Compound ciliature typically absent.
3. Oral infraciliature only slightly distinct from somatic infraciliature.
4. Cytostome often apical (or subapical) or mid-ventral, on surface of body or at bottom of atrium or vestibulum.

Examples : *Balantidium*, *Rasbena*, *Didinium*.

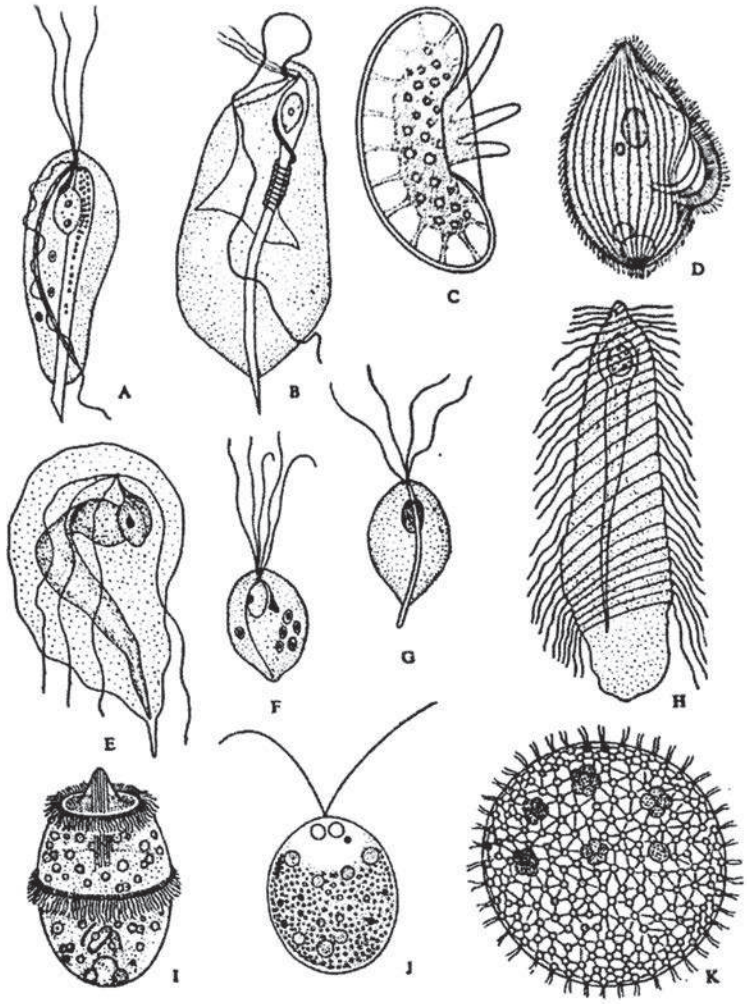


Fig. 4 : A few examples of Phylum Protozoa (after various sources). A. Tritrichomonas augusta. B. Macrotnchomonas lighti. C. Arcella vulgans. D. Belphansma latentium. E. Saccinobaculus doroaxostylus. F. Hexamastix termopsidis. G. Monocercomonas verrens. H. Holomastigoloides hemigymnum. I. Didinium sp.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

Class 2. Oligohymenophorea

1. Oral apparatus, at least partially in buccal cavity, generally well defined, although absent in one group.
2. Oral ciliature, clearly distinct from somatic ciliature.
3. Cytostome usually ventral and/or near anterior end.
4. Cysts not uncommon.
5. Colony formation common in some groups.

Examples : *Paramoecium*, *Trichodina*, *Tetrahymena*, *Vorticella*.

Class 3. Polymenophorea :

1. Well developed, conspicuous adoral zone of numerous buccal or peristomial organelles.
2. Somatic ciliature complete or reduced or appearing as cirri.
3. Cytostome at bottom of buccal cavity or infundibulam.
4. Cytoproct or cytopyge often absent.
5. Cysts common in some groups.
6. Often large and commonly free living.

Exampla : *Nyctotherus*, *Strombidium*, *Metopus*, *Ascobius*.

2.4 *Englena*

Systematic Position :

Kingdom	:	Protista/Protoctista
Sub-kingdom	:	Protozoa
Phylum	:	Sarcomastigophora
Sub-phylum	:	Mastigophora
Class	:	Phytomastigophora
Genus	:	*Euglena*

Euglena is a solitary free living (free swimming) freshwater protozoa. It is a phytoflagellate as it possess both chloroplasts as well as flagella. Euglena commonly found in ponds, pools, ditches and slowly-running streams, where there is considerable amount of vegetation. Under favorable environemtal conditions it multiplies rapidly and form green scum on water surface. The most common species of *Euglena* is *Euglena viridis.*

Structure : *Euglena viridis* is a small microscopic organism. The body is elongated and spindle-shaped with blunt anterior end and pointed posterior end. It is about 40-60 microns in length and 14-20 microns in breadth at the thickest middle part of the body. From the anterior end arises a whip-like flagellum which is seen moving when the animal is progressing forward.

The body shape is maintained by a thin flexible and strong covering membrane or pellicle that is marked spirally by parallel straitions or thicknings. The pellicle is closely followed by a plasma membrane on the inner-side. Within this there lies a thin layer of clear ectoplasm around the main mass of granular non-flowing endoplasm.

At the blant anterior end of the body there is a narrow depression–the **the gullet** or **cytopharynx** which leads to a permanent flask shaped and non-contractile cavity, the reservior. Its external opeing is called the **cell mouth** or **cytostome**.

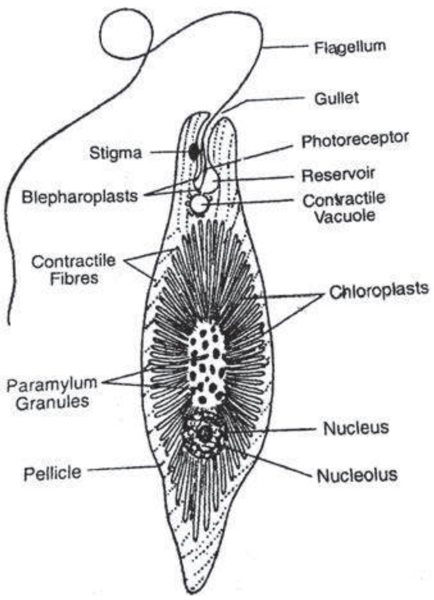


Fig. 5 : *Euglena viridis,* note the radiating disposition of its chloroplasts

The cytostome and cytopharynx are not used for ingestion of food but as a canal for escape of fluid from the, reservoir.

A large osmoregulatory body, the **contractile vacuole** lies closely associated with the reservoir. It is surrounded by several minute accessory vacuoles which probably fuse together to form the larger one. The contractile vacuole discharges the excess water along with some waste products of metabolism into the reservoir from where it goes out through the cytostome.

Near the reservoir is a large **pigment spot** or **stigma** (Fig. 6). The stigma is red in colour and is composed of small granules of carotenoid pigments embedded in colourless stroma. The stigma is sensitive to light.

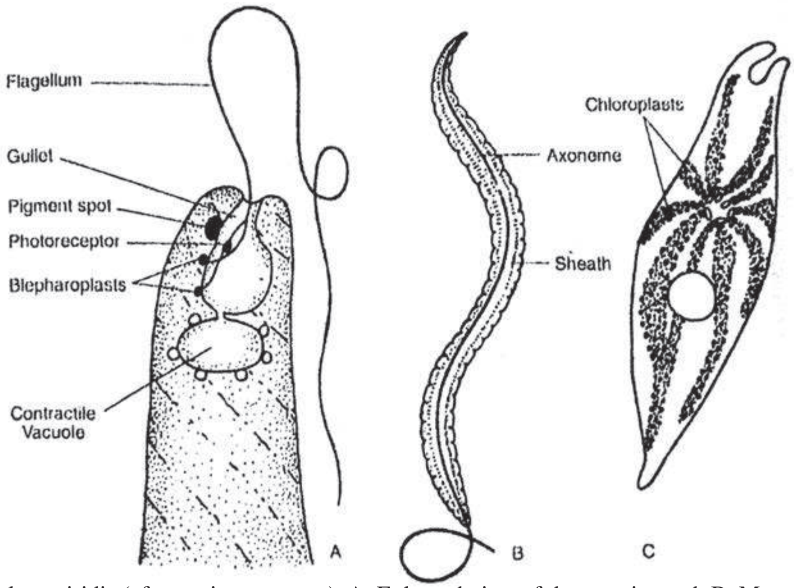


Fig. 6 : Euglena viridis (after various sources). A. Enlarged view of the anterior and, B. Magnified view of flagellum and C. Arrangement of chloroplasts.

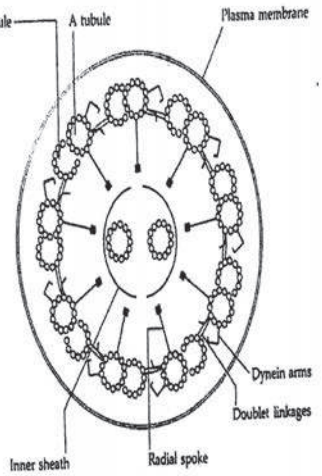


FIGURE. Schematic representation of flagellar organization.

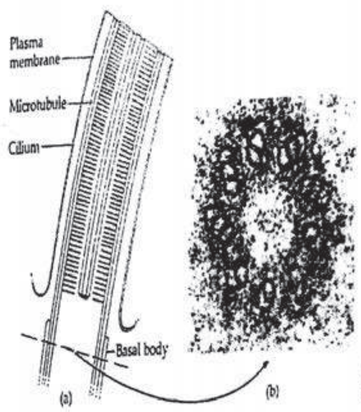
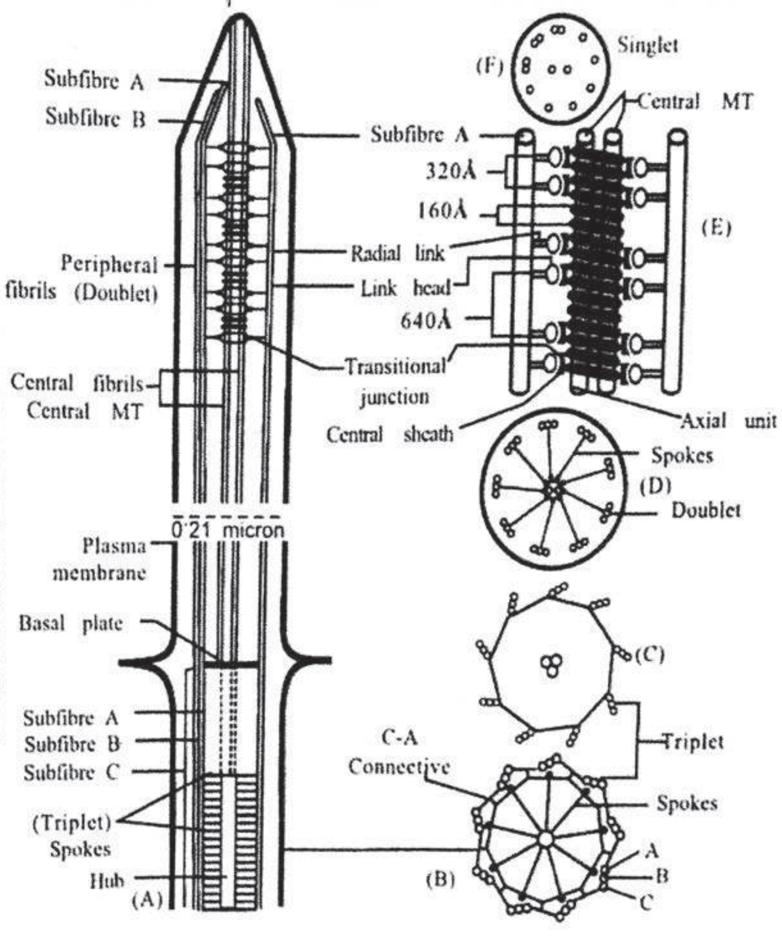


FIGURE. General structure of a cilium or flagellum. (a) Longitudinal aspect of the cilium and basal body. (b) Transmission electron micrograph of a cross section through the basal body.



A. Longitudinal view. The part below the basal plate is the basal body or kinetosome, and the part above is the shaft.
B. Transverse section through basal body region.
C. Transverse section through the transitional region.
D. Transverse section through flagellar shaft.
E. Transverse section near the tip of the flagellum.
F. Longitudinal view of 9+2 flagellar axoneme.

Fig. 7 : Details of the Structures of Flagellum under E.M.

A long whiplike **flagellum** emerges out of the cytostome through the cytopharynx. The length of the flagellum differs in different species of *Euglena but in Euglena viridis* it is almost equal in length of the body. It arises by two roots from the base of the reservoir. Each root arises from a blepharoplast or basal granule which lies embedded in the anterior part of the cytoplasm, just beneath the base of the reservoir. According to some there are two flagella–one short and one long. Each originates separately from two blepharoplasts and the shorter one soon after its origin units with the longer one. The long flagellum is thick and consists of two parts–an inner elastic axial filament, the **axoneme**, made up of several fibrils and a contractile **cytoplasmic sheath** surrounding the axoneme (Fig. 7)

Euglena has a single, large, spherical and almost centrally placed nucleus.

Radiating from the centre of the body there are a number of slender band like chloroplasts containing the green pigment Chlorophyl a, chlorophyl b and β–Carotene. *Euglena* derives its green colour from these chloroplasts which are arranged in a stellar fashion, like the rays of a star. A special type of animal strach, called **paramylum** remains scattered in the cytoplasm in the form of grains. Paramylum bodies serve as reserve food for *Euglena*. *Euglena* like green plants can synthesise carbohydrate food by photosynthesis.

Locomotion : *Euglena* exhibits following two types of locomotion– (a) **Flagellar movement**, (b) **Euglenoid movement**.

Flagellar movement : *Euglena* swims freely in water with the help of a single long flagellum. The actual mechanism involved in flagellar movement is not

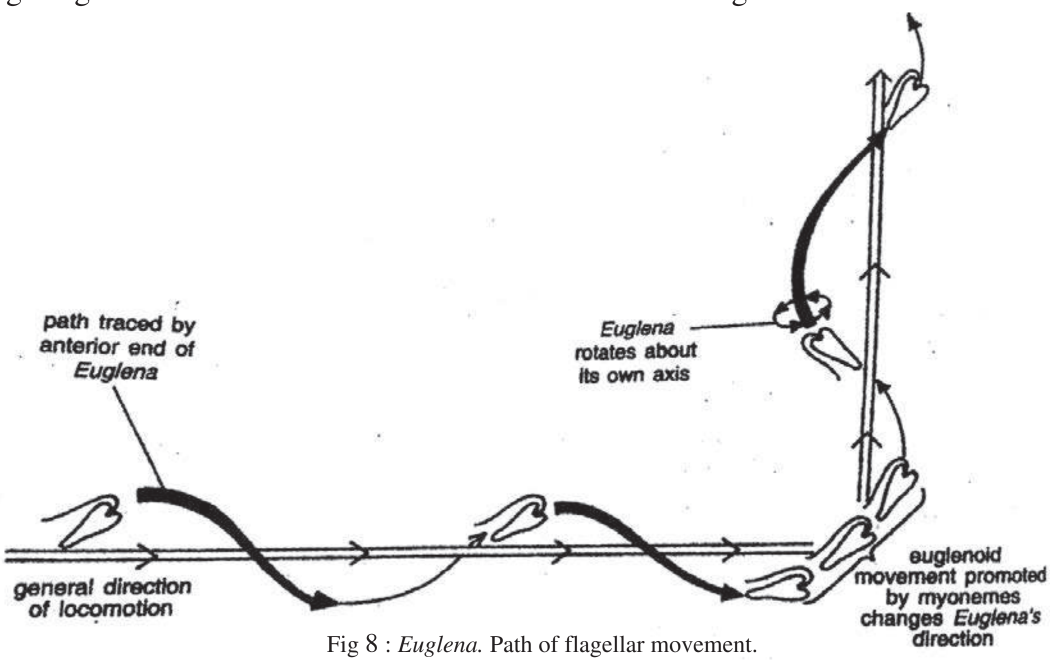


Fig 8 : *Euglena.* Path of flagellar movement.

satisfactorily known and there are varieties of flagellar movements. It has been observed that the flagellum makes a seris of *lateral movements* and as a result, a pressure is exerted on water at right angles to its surface. This pressure is resolved into two forces, one acting *parallel* and the other at *right angles* to the body axis. The parallel force causes the body to rotate while the force acting at right angles drives the animal forward. According to another observation *Euglena* moves forward by the *undulating motion* of flagellum. A series of undulating waves pass along the flagellum from base to its tip at the rate of twelve per second that push the animal forward. The flagellar action exerts forces on the surrounding water which is driven away from the stationary animal. The waves proceed along the flagellum in a spiral manner and cause the body of the animal to rotate about its axis, at about one complete body turn per second, as well as make a corkscrew pathway through water (Fig.). The rate of movement is 0.5mm per second, and it is about four times its body length. *Euglena* is able to change its direction by the action of contractile myonemes.

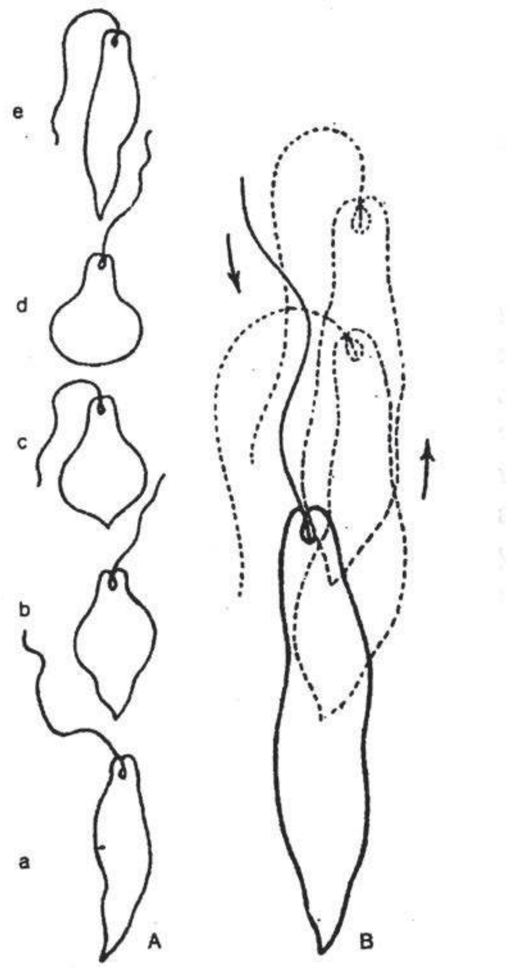


Fig. 9 : *Euglena viridis.* Types of locomotion. A. Euglenoid movement (after Buchsbaum). B. Rowing by flagellum.

Euglenoid movement : *Euglena* sometimes shows a very peculiar slow and limited movement, called metaboly or euglenoid movement. Upon a solid substratum, *Euglena* slowly wriggles like a worm by means of peristalsis. Waves of contraction and expansion sweeping over the body from anterior to posterior end and the animal creeps forward. The contractions are brought about by the localized fibrils called myonemes which are located in the cytoplasm, just beneath the pellicle.

Nutrition : The modes of nutrition in *Euglena* are *holophytic* and *saprozoic*. Such a dual mode of nutrition is referred to as *mixotrophic*. There is no evidence of animal-like nutrition or holozoic nutrition in *Euglena*. Like a true plant it assimilates carbon and synthesizes carbolydreates from carbon dioxide and water in presence of sunlight by the process of photosynthesis with the aid of chlorophyll present in the chloroplasts. Nitrogen and other minerals which remain dissolved in water are absorbed by the cell surface. Excess of carbohydrates manufactured is stored as a polysaccharide known as paramylum.

In absence of sunlight and at times when the water body becomes polluted with dead or decaying organic matter, *Euglena* gives up the holophytic mode of nutrition and switches over to saprozoic mode. Dead and decaying matters dissolved in water are digested extracellularly and then they are absorbed through the general body surface of the animal.

Some workers have reported that small organisms are forced to enter the reservoir by the movement of flagellum and they are engulfed. Such occurence of hotzoic mode of nutrition is doubtful.

Reproduction : *Euglena* reproduces asexually by longitudinal binary fission and multiple fission. Eucystment also takes place.

1. Longitudinal binary fission :

Usual mode of reproduction in *Euglena* is longitudinal binary fission. During

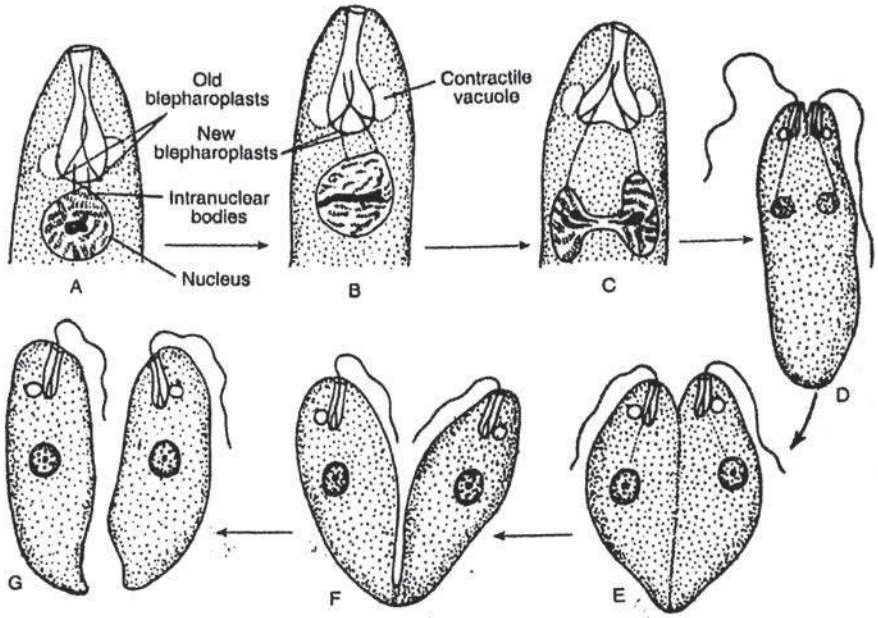


Fig. 10 : Events during longitudinal fission in *Euglena* (from various sources). A—C. Events at the anterior end. D—G. Formation of two daughter individuals. Note that the individual splits from the anterior end.
A. Nucleus comes to the anterior end within which intranuclear body divides into two, each of which splits to form a new blepharoplast and an intranuclear body. From the new blepharoplast develops a new flagellum. Two original blepharoplasts of the flagellum move one on each side of the reservoir. Contractile vacuole divides into two. B. The new flagellum unites with the old. Nucleus descends down and connections between intranuclear bodies and newly formed blepharoplasts persist. C. Nucleus, reservoir and gullet divide longitudinally.

active periods, under favourable ecological conditions such as food availability, optimum light, temperature and water, *Euglena* reproduces by this process. The fission is always *symmetrogenic*, i.e. the resulting daughter cells are exactly identical to one another (mirror image). Before fission locomotory activities are suspended and the flagellum is withdrawn in some cases. The blepharoplast is the first to divide and the two halves remain attached by a spindle-like structure or by a strand. This is followed by eumitotic division of the nucleus. Other anterior organelles flagellum, cytopharynx, reservoir and stigma–are duplicated. The body begins to divide lengthwise, from anterior end downwards to the posterior end resulting in the formmation of two daughter individuals. Regeneration of lost parts occurs immediately after division. Normally each one develops a new flagellum. In some cases the flagellum of the mother is retained by one of the daughters and a new one develops in the other.

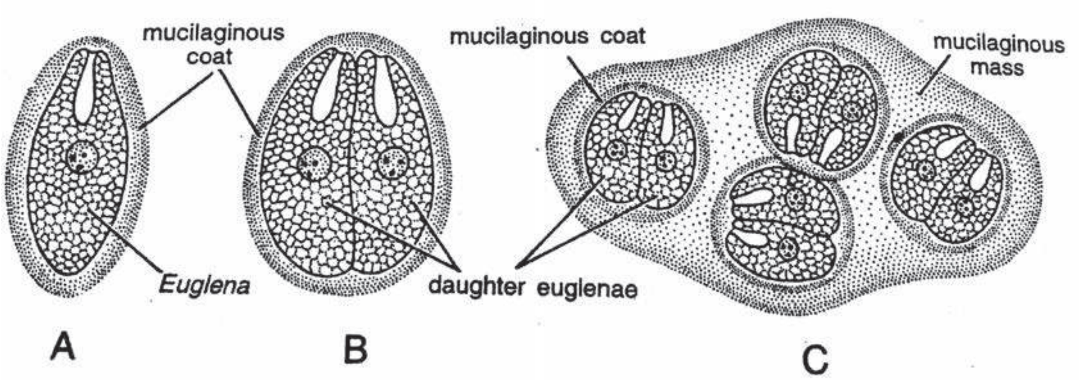


Fig. 10.1 : *Euglena* Multiple fission and encystation. A—Encysted individual. B—Fission in encysted condition. C—Palmella stage.

2. Multiple fission and palmella stage : Under unfavourable environmental conditions such as lack of food and oxygen, excessive heat or cold, draught, etc. *Euglena* becomes inactive and throws off its long flagellum and forms a protective thick mucilaginous cyst around it. A number of such encysted euglenae come close together and embeded in a common gelatinous mass on the water surface. Within the cyst,each *Euglena* divides by repeated longitudinal binary fission giving rise to several daugther individuals (16 or 32).

The latter form their own muciligenous coats within the original cyst. Such a gelatinous mass containing many cysts is called **palmella stage** which resembles the palmella stage of many algae such a *chlamydomonas*. These are often seen as green scum on ponds.Individual members of the palmella carry on their metabolic activities. When the environmental conditions become favourable these daughter euglenae, acquire normal flagella and escape out from the cyst to grow into normal euglenae and start normal and active life.

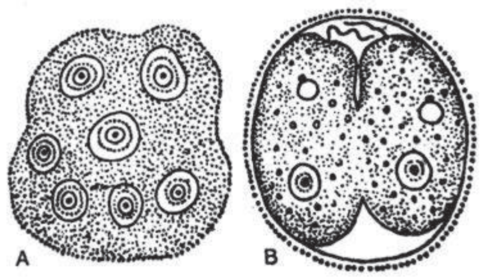


Fig. 10.2 : A. Palmella stage of *Euglena*. B. Encysted *Euglena* undergoing division.

Encystment : *Euglena* undergoes encystment during the periods of draught and extreme cold. The animal becomes inactive, withdraws its flagellum and assumes a round shape (Fig.). Gradually profective walls are secreted. The cysts are red in colour due to the presence of a pigment called **haematochrome**.

2.5 *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*.

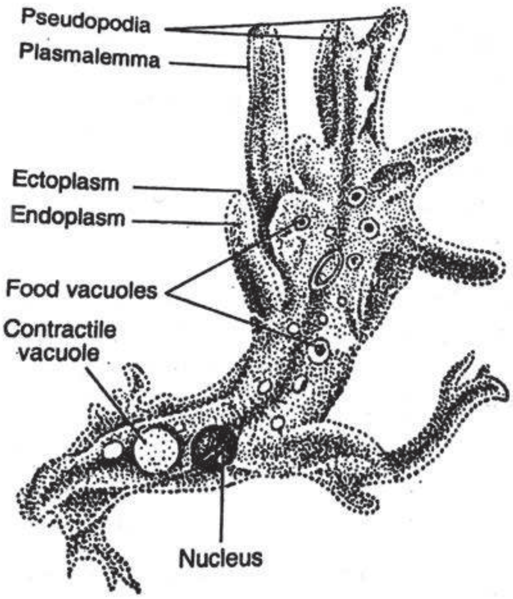


Fig. 11: *Amoeba proteus.* Note various structures like nucleus, food vacuoles, contractile vacuole and pseudopodia.

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.

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.

Locomotion :

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

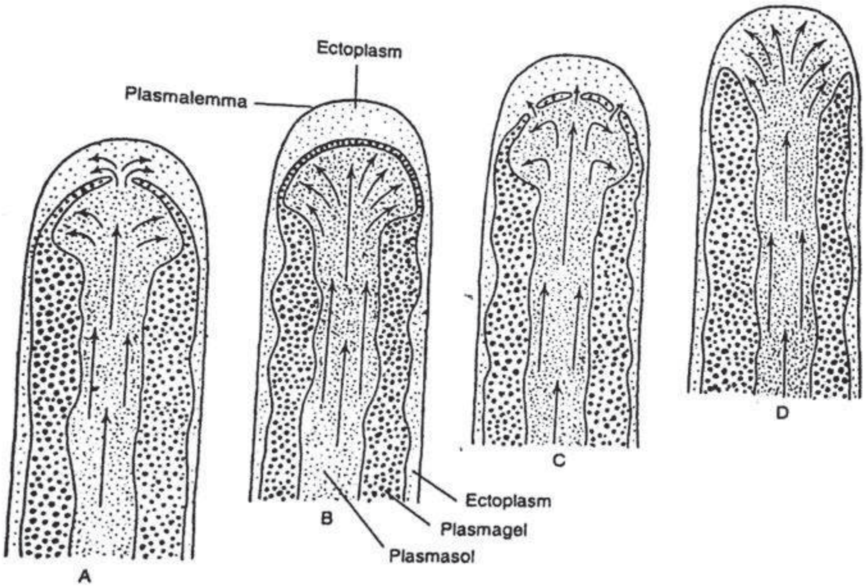


Fig. 12 : Figures illustrating the idea of Mast about the cytoplasmic flow during the formation of a pseudopodium in Amoeba proteus (after Kudo). Note that during the formation of a pseudopodium a hyaline cap appears. A. The plasmagel beneath the cap dissolves and plasmasol rushes through the gap. B.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

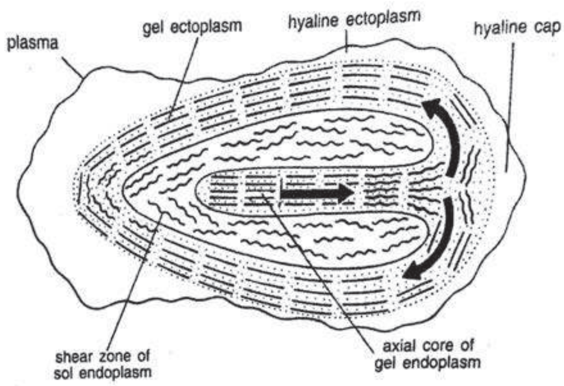


Fig. 13: Amoeboid movement on the basis of Allen's fountain zone contraction theory.

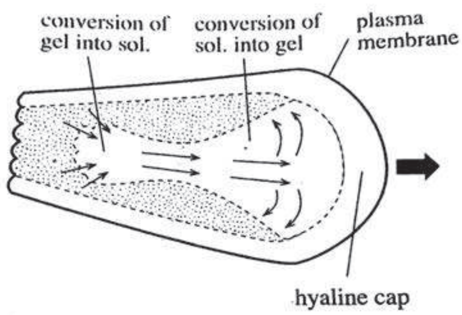


Fig. 14 : Conversion of sol and gel in Amoeba. Large solid arrow indicates the direction of movement.

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 :

(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, 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).

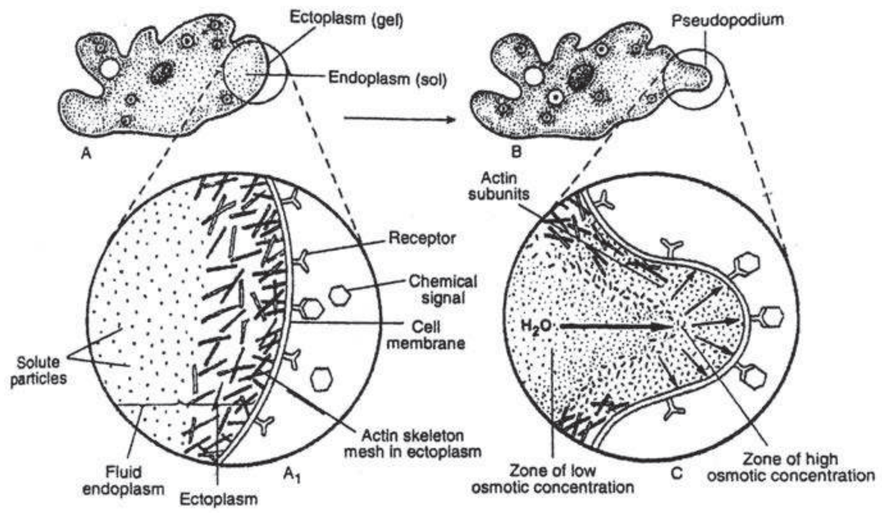


Fig. 15 : Diagrams showing the mechanism of pseudopod formation on the basis of Osmotic theory of amoeboid flow. A-A_1. Chemical signals attach to the receptors and initiate the depolymerization of the actin molecules. B-C. Osmotic concentration in the ectoplasm increases and water nows toward the periphery.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

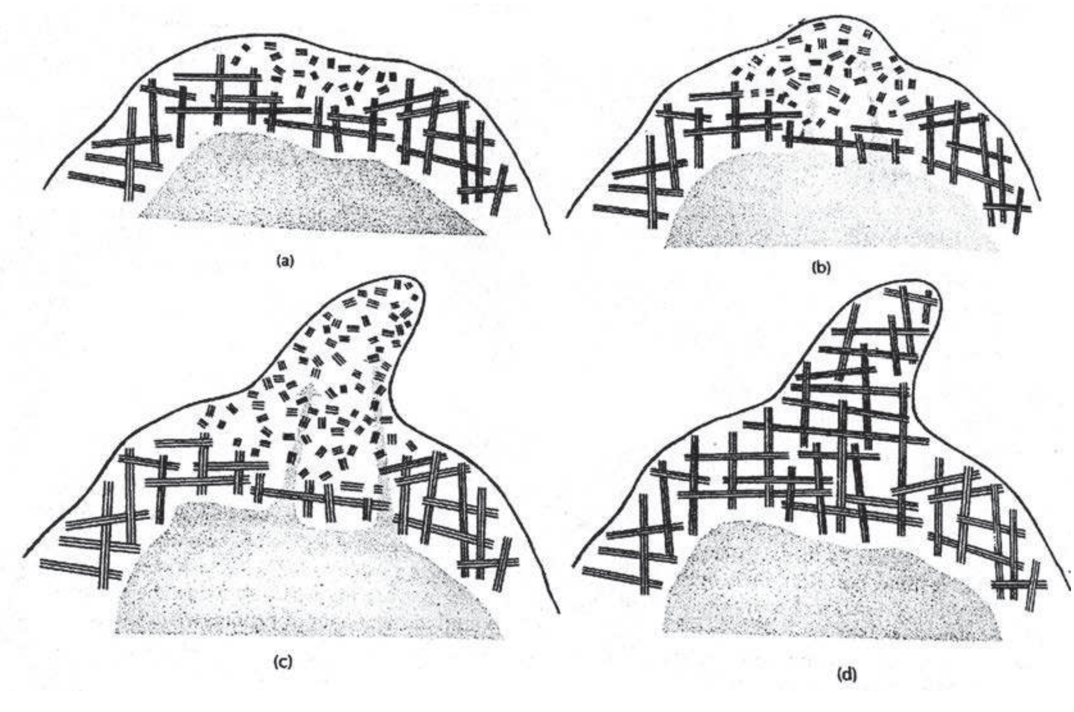


Fig. 16 : Hypothesized mechanism of pseudopod formation during amoeboid locomotion. (a) Localized breakdown of the actin network increases osmotic concentration in that part of the cytoplasm. (b) Fluid from the interior of the cell moves toward the periphery. along the osmotic gradient, forming a pseudopod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

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,

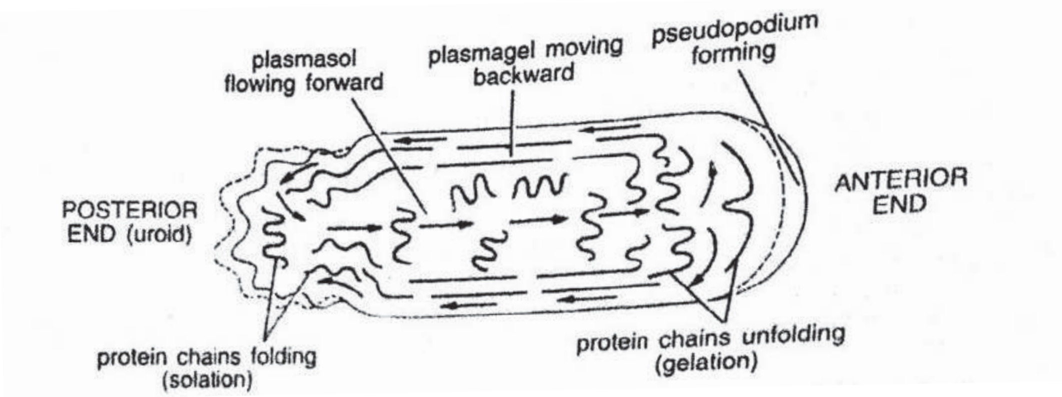


Fig. 17 : Molecular folding-unfolding during solation and gelation of cytoplasm for amoeboid movement.

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.]

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

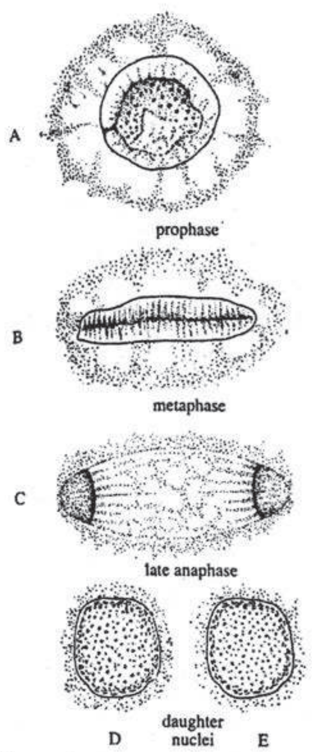


Fig. 18a: Changes in the nuclear apparatus during the binary fission of Amoeba.

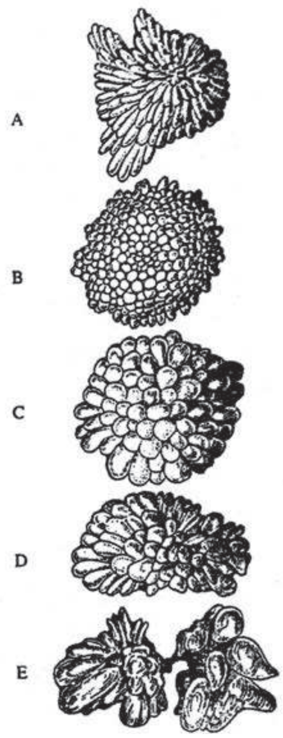


Fig. 18b: Morphological changes in Amoeba proteus during binary fission. A. In prophase. B. & C. In metaphase, D. In late anaphase, E. In telophase.

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 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.]

Reproduction :

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.

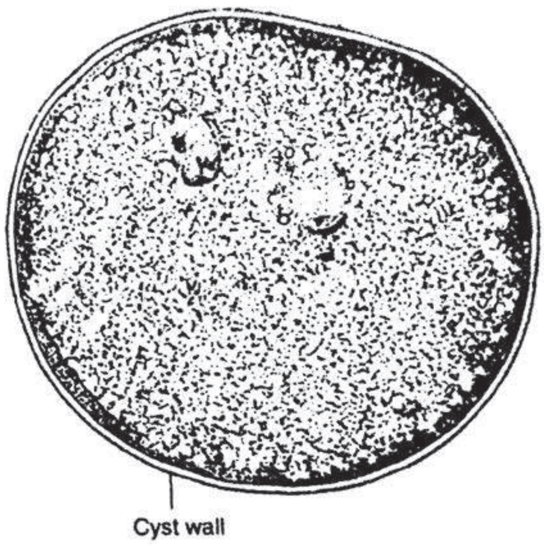


Fig. 19 : Encystment in Amoeba (after winchester). Although very common in other Amoebae. It rarely occurs in Amoeba proteus.

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.

2.5.1 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).

(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.

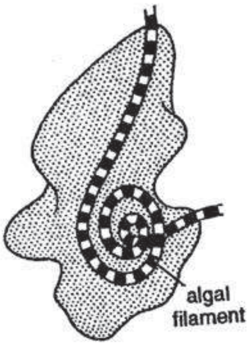


Fig. 20: *Amoeba* ingesting an alga by import.

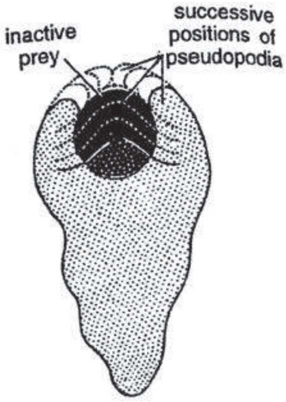


Fig. 21: *Amoeba* feeding by circumfluence.

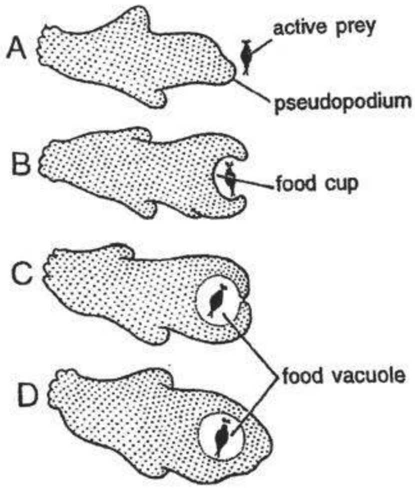


Fig. 23 :*Amoeba* ingesting a rotifer by circumvallation.

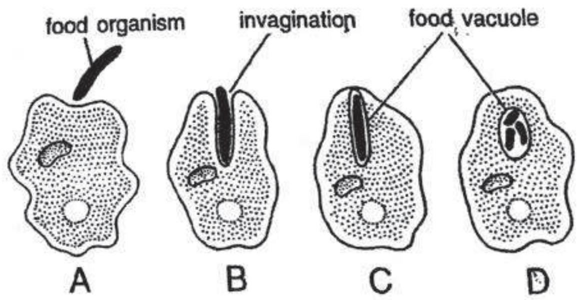


Fig. *Amoeba* ingesting food by invagination.

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*.

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.

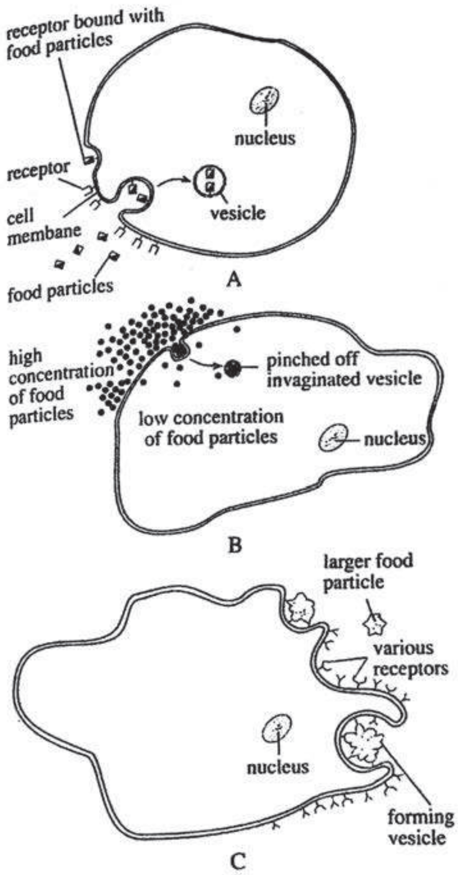


Fig. 24 : Different modes of food uptake in *Amoeba* by vesicles. A. Receptor-mediated endocytosis, B. Pinocytosis, C. Phagocytosis.

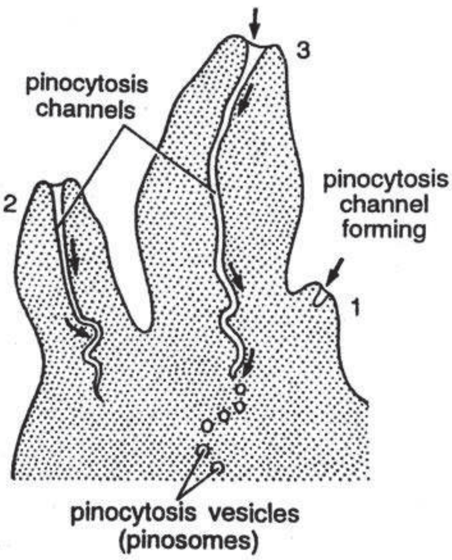


Fig. 25 : Pinocytosis in *Amoeba*.

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.

2.6 *Paramoecium & Plasmodium*

Paramecium

Systematic Position :

Kingdom	:	Protista/Protoctista
Sub-kingdom	:	Protozoa
Phylum	:	Ciliophora
Class	:	Oligohymenophorea
Genus	:	*Paramecium*

Paramecium is a typical and well know ciliate protozoa. Ciliates are characterzed by the presence of **cilia** as locomotor organelle, nuclear dimorphism and a unique type of sexual reproduction called **conjugation**. The two type of nuclei are morphologically and physiologically distinct from one another. *Paramecium* is found in stagnant water of ponds, ditches, pools, reservoirs, rivers, streams rich in organic matter. They are free living and omnivorous in habitat. They can be cultured in laboratory in hay infusions. Common species of *Paramecium* are *P.caudatum* and *P.aurelia*. The species described here is *Paramecium caudatum*.

Fig. 26: Amoeba chasing food. Note constant formation of pseudopodia towards the direction of the food.

Structure :

Size and shape : *Paramecium caudatum* is a microscopic organism and is visible to the naked eye as a minute elongated body. It appears light grey or white measuring between 170 to 290 nm in length. Its body is somewhat elongated, slipperlike in shape, hence the animal is called slipper animalcule. One end of the body is slender but rounded or blunt representing the heel of the slipper. It is anterior end as it remains foremost during locomotion. The other end is broad and pointed, representing the top of the slipper. It is posterior end. The body is asymmetrical exhibiting a well defined oral or ventral surface and aboral or dorsal surface. The flattened ventral surface is with a oral grove that always faces the substratum. The opposite aboral or dorsal surface is somewhat convex.

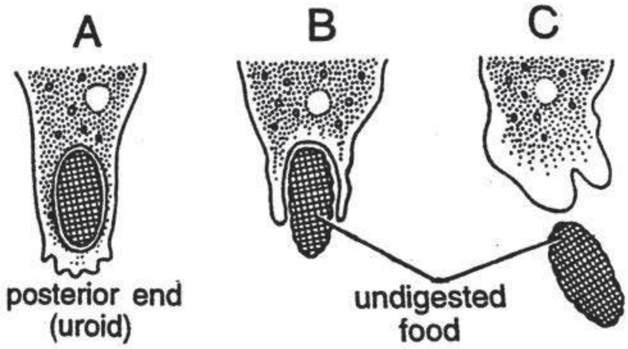


Fig. 27. Amoeba showing stages of egestion of undigested food.

Cellular body of *Paramoecium* has the following structures :

1. Pellicle : The whole body is covered by a thin, firm and flexible membrane, the pellicle. It gives the definite shape to the organism. The pellicle is sculptured into a large number of polygonal or hexagonal depressions with their raised margins (Fig. 28). The depressions are provided with holes at the centre through which the cilia project. The anterior and posterior margins of the hexagonal depressions bear the openings of trichocysts which are small spindle shaped bodies.

The electron microscopic study of pellicle by Ehret and Powers (1957) and Pitelka (1965) have revealed that the hexagonal depressions correspond to regular series of cavities, the alveoli. All alveoli collectively form a continuous aloveolar layer, which is delimited by an outer and an inner alveolar membranes. The outer alveolar layer is covered by plasma membrane which is continuous with the membrane surrounding the cilia. Thus pellicle includes outer cell membrane, outer alveolar membrane and inner alveolar membrane.

Å Cilia. Entire body surface of *Paramecium* is covered with numerous (10-14 thousands) tiny (10-12 μm in length and 0.27μm in diameter), hair like projections of cytoplasm, called **cilia** (singular **cilium**). This condition of covering whole body by cilia is called **holotrichous**. Cilia are arranged in longitudinal rows and all are

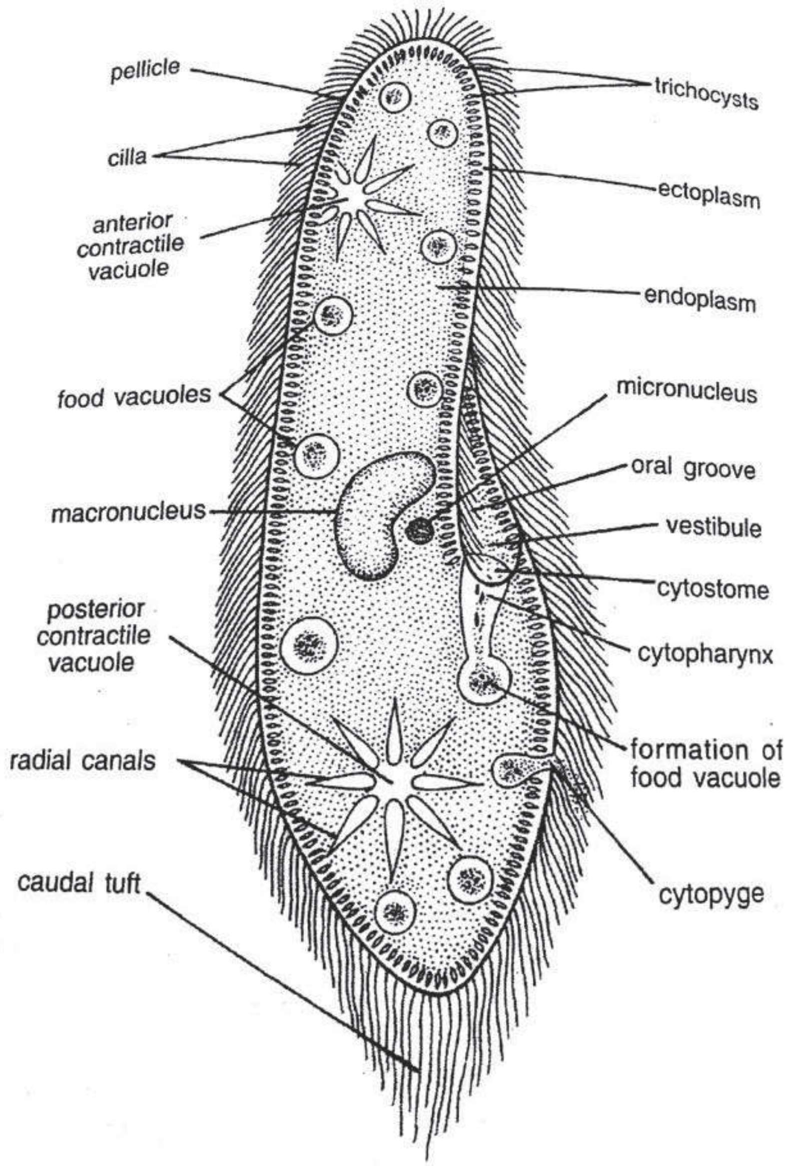


Fig. 26: *Paramecium caudatum.* (Structure).

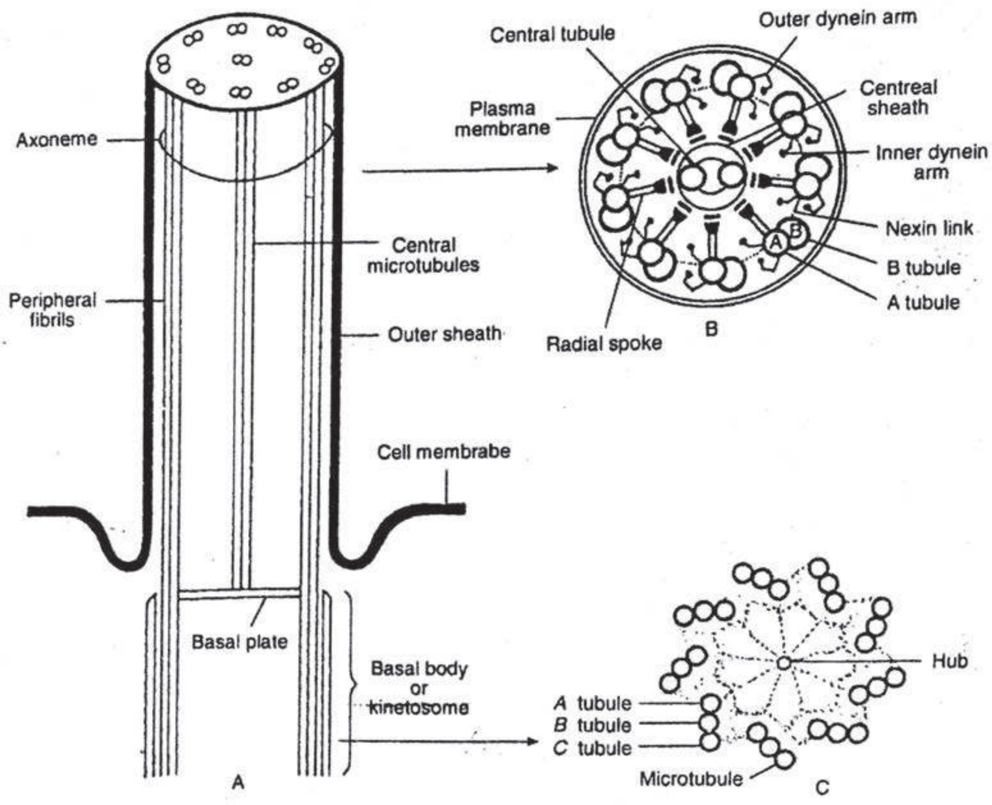


Fig. 29: A. Ultrastructure of a cilium (flagellum). B. Cross-sectional view of a shaft. C. cross-sectional view of the basal body. B. Note that the peripheral fibrils (tubules or microtubules) are doublets and each A tubule is complete and smaller and B tobule is incomplete and larger, A tubule has dynein arm. C. Note that the central tubules (microtubules) and dynein arms are absent. Peripheral tubules of a basal body are triplets.

equal size except a few at the posterior extremity which are larger and constitute the caudal tuft. In *Paramecium* the ciliature may also be diveded into body ciliature which occures over the general body surface and the oral ciliature, which is associated with the oral grove. The latter includes the larger cilia (Fig. 29). Each cilium consists of two parts–(i) a **basal body** or **kinetosome** which lies embedded in the ectoplasm and (ii) **a shaft**, short thread like structure lies above the pellicle. The basal body is a compact spherical body and homologous with the centriole. The electron micrograph (Fig. 29) of cross section of a cilium exhibits three majorparts : a central axoneme, the surrounding plasma membrane and the interposed cytoplasmic matrix. The entire ciliary projection is covered by a membrane that is contimuous with the outer plasma membrane. The core or shaft of the cilium, called **axoneme**, consists of an array of microtubules (sometimes called fibrils) that run longitudinally through the entire organelle. Axoneme has nine peripheral **doublet microtubules** or **doublets**, surrounding a central pair of single microtubules or **singlets** (i.e. typical 9 + 2 arrangement of microtubeles). The microtubules extend continuously throughout the length of the axoneme. The diameter of the axoneme is 0.02μm. The nine peripheral microtubles or fibrils are radially arranged at a distance of 200Å from each other. All the microtubules of the axonemes are composed of a globular protein, called **tubulin**.

The inner micro tubule of each doublet is called **A tubule** and the outer micro tubule is called **B tubule** of which A is small and complete and B is comparatively larger and incomplete. A tubule contains 13 protofilaments or subunits while B tubule has 10-11. The protofilaments are called tubulin subunits. Nine radially arranged spokes originate from each A tubule of the peripheral doublets and extend towards the central sheath. Extending from each A tubule are two **dynein arms**– an outer arm and an inner arm that are oriented in the same direction in all peripheral doublets, i.e. clockwise direction (when the axoneme is viewed from base to tip) towards the B tubule of the neighbouring doublet. Since dynein protein is capable of hydrolysing ATP, it acts as an ATP ase enzyme. The peripheral doublets are connected by an inter doublet bridge, called *nexin links*, composed of an eleastic protein, *nexin*. The central two singlet microtubules are called C_1 and C_2 in which dynein arms and radial spokes are absent (Fig. 29).

Cytoplasm Beneath the pellicle the protoplasm is differentiated into **cortex** and **medulla**. The cortex or ectoplasm is clear, non-granular, less extensive and contains many spindle shaped bodies called *trichocysts*. The medulla or endoplasm is granular, semi-fluid and bears nuclear apparatus, contractile vacuoles, food vacuoles, various organelles (Golgi bodies, mitochondria, ribosomes, etc.)

Following organelles or systems are found in *Paramoecium*:

1. Infraciliary System : The infraciliary system consists of basal bodies. (**Kinetosomes**) of cilia and **Kinetodesmata**, all located just beneath the alveoli of pellicle.

(i) **Basal bodies** or **Kinetosomes :** The base of each cilium is connected with a spherical basal body or kinetosome lying embedded in the ectoplasm and from which each cilium originates. Structure of the basal body is comparable to the centriole.

(ii) **Kinetodesmata (Kinetodesma) :** A single fine fibril, called Kinetodesmos or Kinetodesmal fibril, arises from each kinetosome and extendes for a distance anteriorly to its right side (Fig. 30). It joins other fibrils from

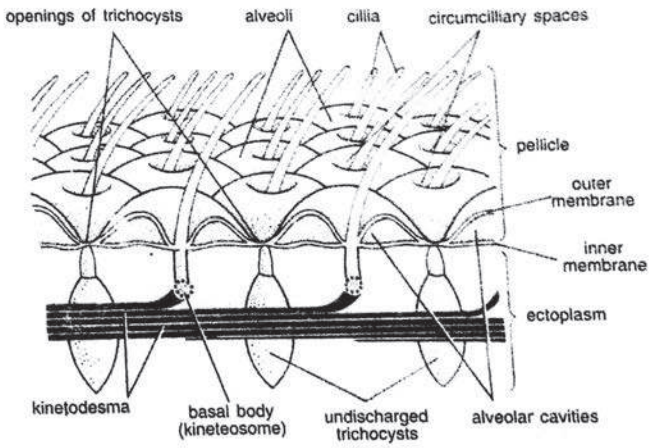


Fig. 30: Paramecium. Electron microscopic structure of pellicle, infraciliary system and associated structure.

adjacent Kinetosomes to form a longitudinal bundle of striated fibrils, called a **Kinetodesmata**. The individual fibrils do not run anteriorly farther than the five basal bodies or Kinetosomes. Thus the number of fibrils in each Kinetodesmata remains five. A longitudinal row of kinestosomes with their kinetodesma forms a collective longitudinal unit called a **Kinety**. All the kineties or kinetia together form **infraciliary system** of a ciliate. It was supposed that the infraciliary system co-ordinates the beat of cilia but the role of this system has not yet been conclusively demonstrated (Naitoh and Eckert, 1969). Infraciliature is also a tool by which the taxonomists used to distinguish the different ciliate species and the degree of differences on which the relationship is established.

2. Neuromotor system : Lund (1933) reported that some other types of fibrils remain connected to the Kinetosomes or basal bodies called **neuronemes** or **myonemes**. These are highly contractile and play the role in the movement of cilia. He also reported another dense bilobed mass of fibrils situated on the wall of the cytopharynx, called the **motorium** or **neuromotorium**. The Kinetosomes, neuronemes and motorium constitute the neuromotor system. The motorium has branches which interconnect with the fibrils of the ectoplasm and the whole fibrillar system is believed to act as controlling centre for feeding movement of oral cilia.

3. Trichocysts : Trichocysts are minute spindle shaped or bottle shaped bodies embedded in the toplasm. They alternate with basal bodies and are perpendicular to the surface of body. They open to the outside through the permanent pores existing in the ridges of hexagonal depressions of pellicle. The length of trichocyst is about 8μm and the breadth is 2μm. It consists of a spindle or an oval shaped shaft and a terminal conical **barb** or **spike** covered with a cap. The shaft is not found at the undischarged state and probably polymerised in the process of discharge. The trichocysts are filled with homogeneous, refractive and semi-fluid substances with a fibrous protein, called **trichinin** and **calmodulin**.

Upon stimulation, the ectoplasm suddenly contracts. This separates the cap of the trichocyst to let the water enter the sac and the protein of the shaft unfolds, the trichocysts themselves are expelled out of the body as a fine 40μm long striated thread like shaft having pointed sticky spike (Fig. 31). Once discharged trichocysts can not be withdrawn, they are replaced by new ones.

The function of trichocysts is not clearly known. It is be lieved that these are organelles of defence. They also serve as a means of anchorage during feeding. The secreted substance may act as adhesive and helps to anchor the animal to the substratum (Cloyd and Jones, 1951).

4. Oral apparatus : Near the anterior end of the animal and on its ventral surface is a permanent ciliated broad and shallow longitudinal groove called the **oral groove** or **peristome**. The oral grove runs obliquely backward into a funnel-like depression, called the **vestibule**. The vestibule leads into a tubular passage,

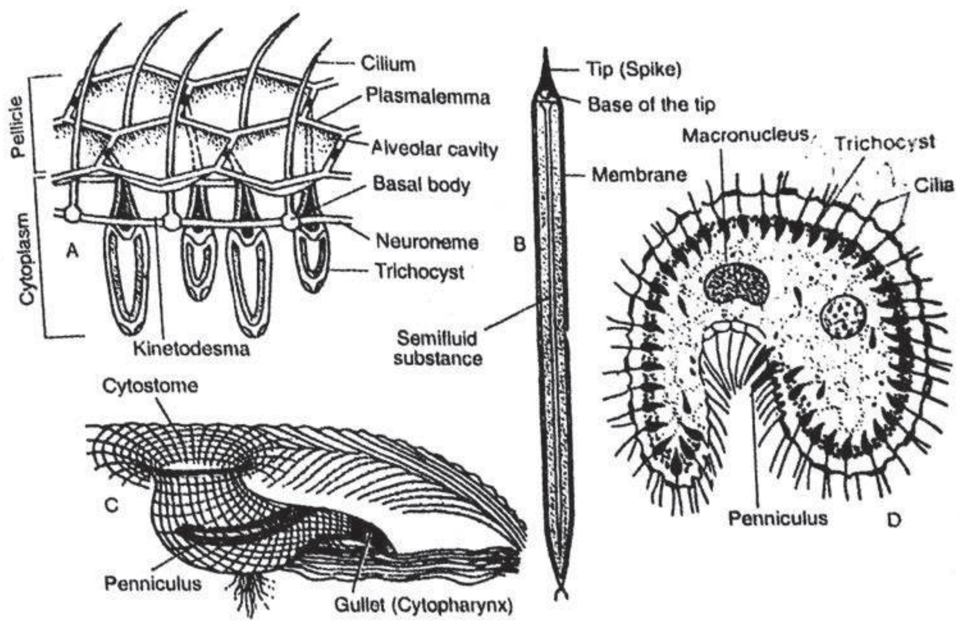


Fig. 31a: Various structures of paramoecium (modified from various sources). A. A highly magnified view of pellicle. B. A discharged trichocyst. C. The fibrillar system around cytopharynx. D. Transverse section through the cytopharynx.

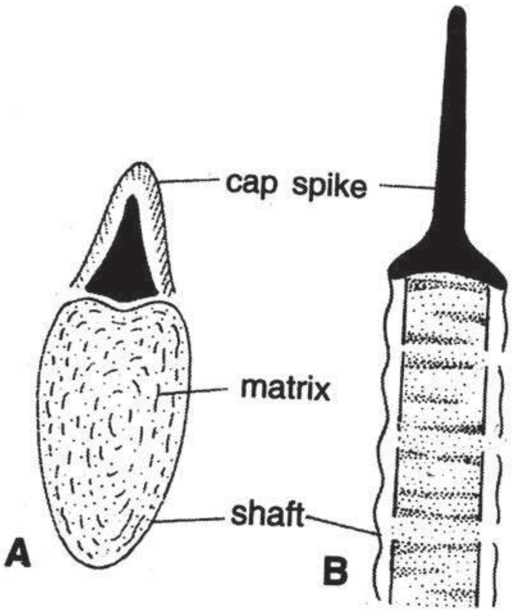


Fig. 32b : Paramecium. A—An undischaged trichocyst. A—Apical portion of a discharged trichocyst

the **buccal cavity**. The buccal cavity extends backwards and ends in a small oval aperture, the **cytostome** or **mouth**. The cytostome opens into a wide funnel shaped depression called **gullet** or **cytopharynx**, that forms a food vacuole at its proximal end. There exists a minute pore at a fixed point on the right side of the body between the posterior end of oral grove and posterior end of the body. It is called **cytopyge** or **cytoproct**. Undigested food is egested through it by active vacuolar activity (called exocytosis).

In the oral groove the cilia show a variation in size and form. The cilia in the buccal cavity are fused to form a crescentic *undulating membrane* or **endoral membrane** which runs transversely along the right wall and marks the junction of the vestibule and buccal cavity. There are three membranelles in the left wall of the buccal cavity (Fig. 33). Each membranelle is formed by adheraing four rows of cilia. These membranelles are of three types : a **dorsal peniculus,** a **ventral peniculus** and **quadrulus**. Ventral peniculus is short and ends at the cytosome. The dorsal wall (roof) of the buccal cavity, crosses over to the right wall near the cytostome.

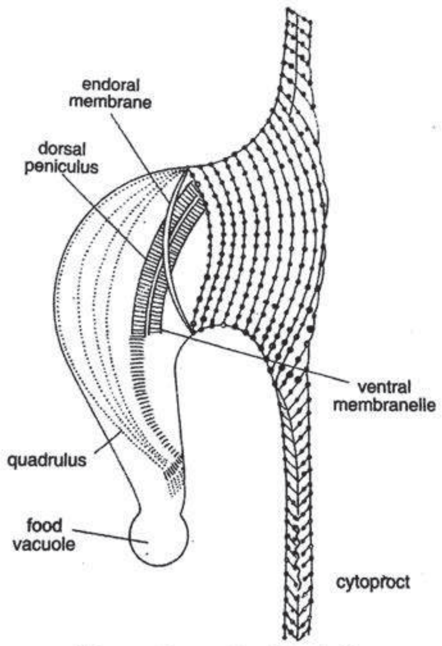


Fig. 33: ***Paramecium*. Buccal ciliature.**

5. Nuclear apparatus : The endoplasm bears at the centre the **nuclear apparatus** consisting of a large kidney-shaped mega or **macronuclues** and a small rounded **micronucleus**. Both the nuclei differ from each other not only in size and shape but also in function. The macronucleus, also called somatic or vegetative nucleus is polyploid and controls the metabolic activities of the cell. It is also concerned with the synthesis of RNA and DNA. The micronucleus, also called reproductive nucleus is diploid and controls the reproductive activities of the animal and gives rise to new micronuclei. It possesses a definite nuclear membrane and definite number of chromosomes.

Contractile vacuole : There are two star-shaped fixed contractile vacuoles in between ectoplasm and endoplasm close to dorsal surface, one at the anterior end and the other at the posterior end of the body (Fig. 33). Each vacuole consists of a large central vacuole which opens to the outside through a **discharge canal** in the pellicle on the dorsal side. Each vacuole is surrounded by 6 to 10 long and narrow **radial** or **feeder canals**. Each radial canal consists of three parts, a proximal **injector canal** which opens into the contractile vacuole, a middle **ampula** which is an inflated part and a terminal part of the radial canal. It is extended into the endoplasm and a network of minute tubules, called **nephridial tubules** or **spongiome tubules** (Rupprt and Barnes, 1994), are associated with the terminal part (Fig. 34). These tubules collect water from the surrounding cytoplasm and

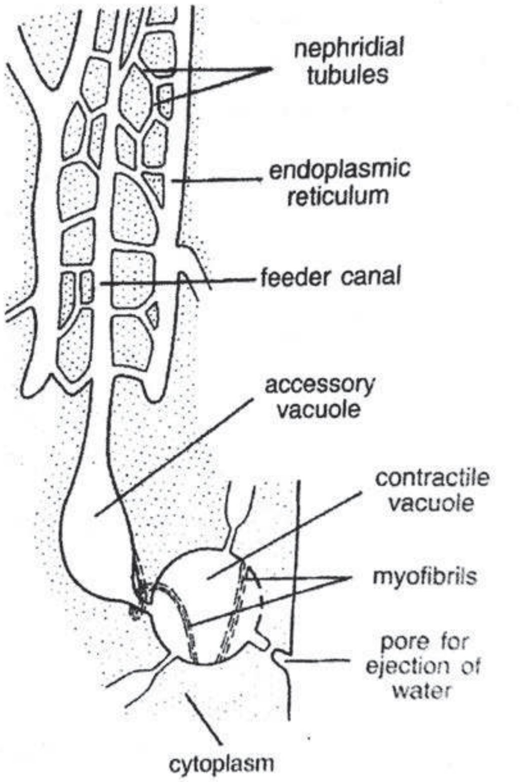


Fig. 33 : Paramecium. Contractile

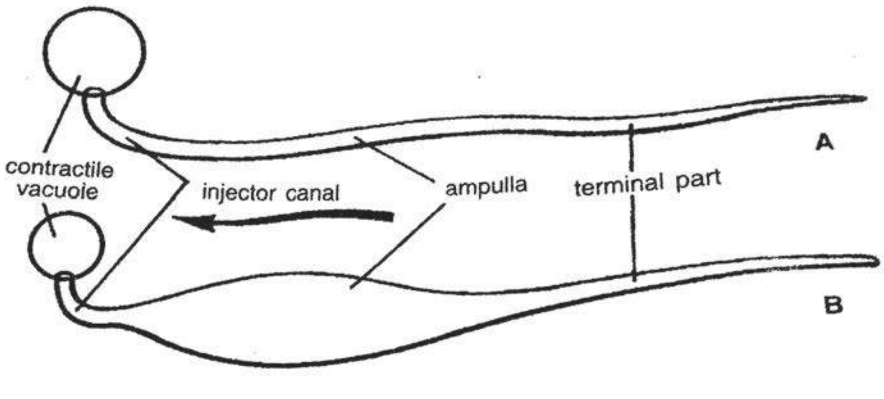


Fig. 34: Paramecium. Radial canal. A—Empty (systole); B—Full (diastole).

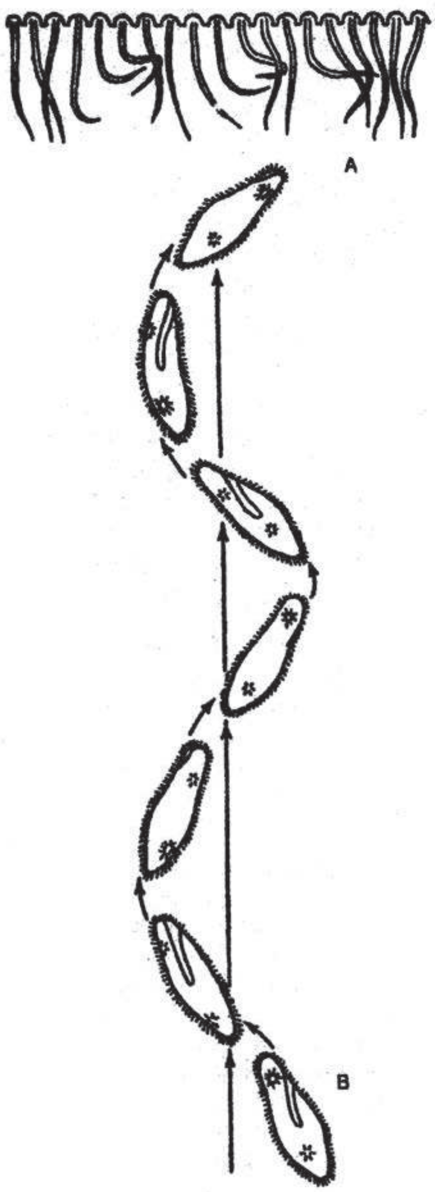


Fig. 35: Co-ordinated beating of cilla in a part of the body of Paramoecium. B. Course of progress of Paramoecium during locomotion. Note that the body rotates on its own axis during the forward movement.

transfer it to the terminal part or collecting tubule. Endoplsmic reticulum and mitochondria are also found around the spongiome tubules. The function of contractile vacuole is osmoregulation and excretion.

Food vacuole. Within the endoplasm a number of food vacuoles, with food particles at different stages of digestion, are seen. Food vacuoles move or circulate within the endoplasm by streaming movement of the endoplasm.

Locomotion : Movement of animals from one place to another is locomotion. The locomotory organelles of *Paramecium* are cilia. *Paramecium* exbibits two types of movement—(i) **Swimming** or **ciliary movement** and (ii) **Creeping movement** or **Metaboly.**

Swimming or ciliary movement : *Paramecium* can swim forwards and backwards by rhythmic beating of cilia. The cilia may be compared with the oars of a rowing boat. The cilia of a progressing *Paramecium* bend throughout its length and strike the water. Backward bending and beating of cilia in a synchronised way drive the animal forward. The backward movement of cilia is called **effective stroke**. The beating of cilia may be compared with the oscillation of a pendulum. Each oscillation consists of two strokes–(i) the **effective stroke** in which the shaft of the cilia become stiffened or rigid and slightly curved to strike the surrounding water like an oar. As a result of the effective stroke the animal drives forward, and (ii) **recovery stroke** in which there is no movement of the animal. In its recovery stroke the cilium becomes

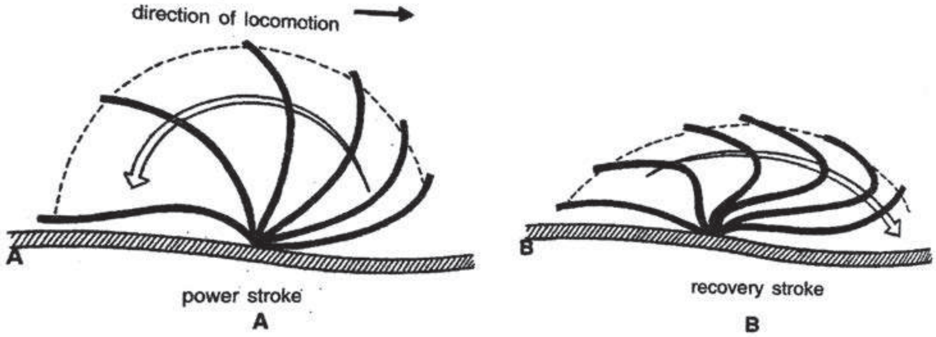


Fig. 36 : Paramecium. Two stages of cciliary movement. A —Effective or power stroke; B—Recovery stroke

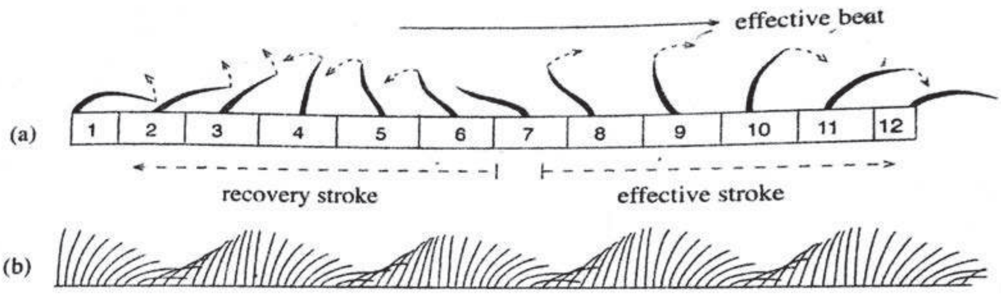


Fig. 37: Diagram to illustrate metachronal rhythm. (a) Cilia 1 and 12 are at the end of the effective stroke; 2–7 indicate successive stages during the recovery stroke; 8-11 indicate stages during the effective stroke. All the cilia 1–12 are beating in sequence. (b) Diagram illustrating the optical appearance given by a profile view of cilia beating in metachronal rhythm.

flexible, offering relatively little resistance to the medium and returns to its original position. It now becomes ready for its next effective stroke. Paramecium swims at a rate of about 1mm per second. The direction of the effective stroke is oblique to the ling axis of the body of the animal. This causes the animal to swim in a spiral course and at the same time to rotate on its lingitudinal axis (Fig. 35). In *Paramecium*, cilia do not beat simultaneously, rather group of cilia bend in a coordinated unidirectional waves. The movement of adjacent cilia occur as a result of interference effect of the surrouding water layers. Thus, the hydrodynamic forces impose a co-ordination on the cilia. This coordinated sequential activation of cilia over the surface of the animal body is seen as a wave, called metachronal waves or metachronal rhythm (Fig. 36 & 37).

The ciliary beat can be reversed and the animal can move backward. There is evidence that infraciliature and cytoplasm play a major role in the organised movement of cilia. The direction and intensity of beating of cilia are controlled by changing level of Ca^{++} and K^{+} ions. The synchronised movement of cilia is also controlled by the **neuronema** or **neuromotor system** in the body.

Creeping movement : During creeping movement, the animal uses its cilia of the oral surface as minature legs and simply glides over the obstacles. As the pellicle is thin and elastic, the animal can easily bend and squeeze through gaps narrower than its own body diameter. After this its body assumes normal shape. Such a temporary change in body shape is called *metaboly*. It is brought about by the myonemes.

Nutrition : *Paramecium* is typically a holozoic animal because it engulf's or ingests the solid food materials. It is an **omnivorous** or **microbivorous** animal and it feeds on a variety of microscopic biological materials such as bactria, algae, diatoms yeasts, small protozaoans and tiny fragments of large-sized animals and plants.

Feeding mechanism : Food is ingested through cytostome. The cilia lining the oral groove perform a great role in capturing food particles. A current of water in the form of a vortex is produced by the constant and co-ordinated beating or lashing movement of the cilia of oral groove. Due to this the food particles are swept towards the cyclostome and are carried down into the cytopharynx. These food particles are aggregated into a rounded mass (ball) by the movement of penniculi and quadrulus at the bottom of the gullet. These food balls or bolus, along with some water, pass through cytostome to form food vacuoles in the endoplasm.

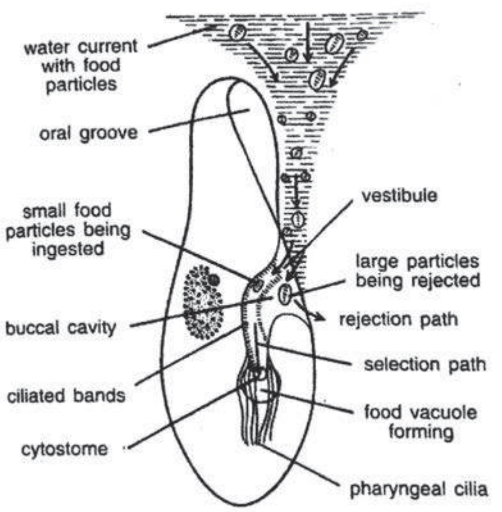


Fig. 38 : *Paramecium*. Ciliary action creating vortex (whirl pool) and drawing food particles into the oral groove with the water current.

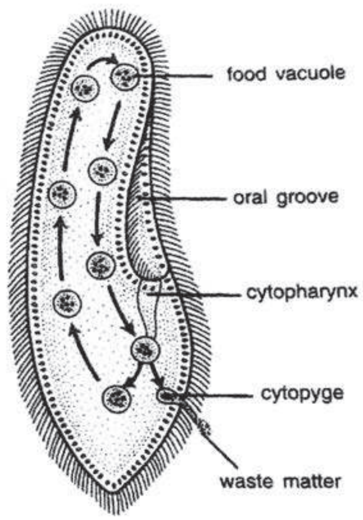


Fig. 39 : *Paramecium*. Movement of food vacuoles due to cyclosis in the endoplasm.

The formation of food vacuole is a continuous process. As soon as one food vacuole detaches from the gullet another starts forming. The food vacuoles circulate in a definite pathway. They first travel to the posterior end and then take a turn and travel anterioury. They reach the anterior border of endoplasm and travel back and come to the middle of the body to complete the circulation. This type of movement of food vacuoles in a definite course is called **cyclosis**.

During cyclosis the food materials are killed, digested and absorbed. Digestion is done by a variety of lysosomal enzymes. The food vacuole is first acidic but becomes basic later on. Digested food is absorbed and assimilated by the endoplasm during cyclosis.

The undigested food is discharged or thrown out through a definite anal spot or **cytopyge** (also called **cytoproct** or **cell anus**) situated on the ventroposterior surface. Elimination of undigested food is done by active vacuolar activity called **exocytosis**. The cytopyge is only visible during exocytosis.

2.6.1 Reproduction :

Paramecium reproduces both *asexually* and sexually. It multiplies asexually by **transverse binary fission** and sexually by **conjugation**.

1. Transverse binary fission : It is the most common mode of reproduction in *Paramecium*. In this process, a full grown individual divides into two daughter individuals. Before the beginning of fission *Paramecium* stops feeding and the body elongates to become spindle like. The oral groove disappears. The micronuclues divides **eumitotically** i.e. by passing through all the stages of mitosis and the

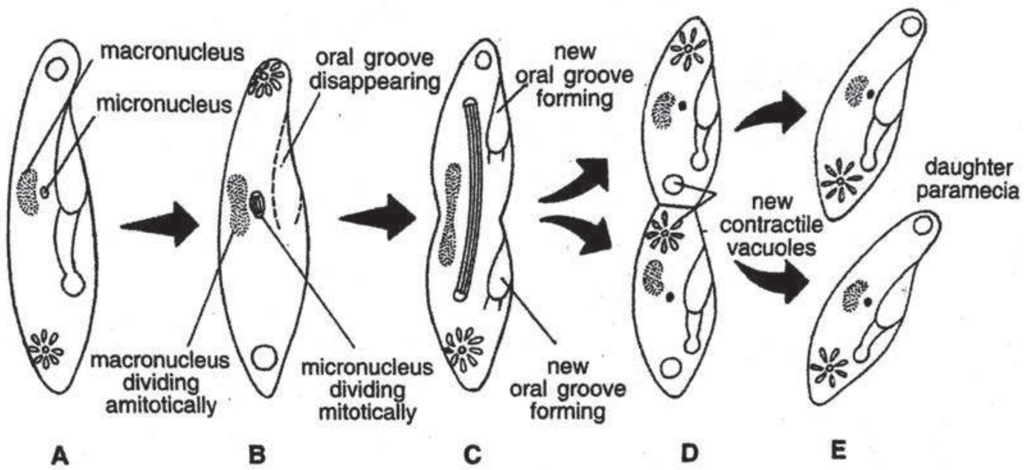


Fig. 40 :. ***Paramecium*. Asexual reproduction by transverse binary fission.**

macronucleus during this period first elongates, then divides trnsversely by amitotic process, in which the number of chromosomes may differ. The products of these divisions are two micronuclei and two macronuclei. One micronuclues and one macronucleus go to the anterior part while the other pair to the posterior part of the animal. Finally a transverse constriction appears in the middle of the body. The constriction deepens gradually, and ultimately two equal sized daughter paramecia are formed. The anterior one is called anterior daughter or **proter** and the posterior one is called posterior daughter or **opisthe**. The oral groove is usually inherited by the daughter at the anterior end. However, in both of them the division is always followed by regeneration and reorganization of lost parts.

The whole process of binary division normally takes 30-120 minutes depending on the availability of food and ambient temperature. Two to three divisions are not uncommon in 24 hours time.

Sexual reproduction : After practising binary fission for a considerable number of generations, paramecia need a nuclear reorganization by **conjugation** or **mating** in which the nuclear material of two individuals is interchanged. Conjugation may be defined as a temporary union of two individuals of same species but two different mating types for the purpose of mutual exchange of nuclear material through the formation of a temporary cytoplasmic channel.

The individuals participating in conjugation are called **conjugants.** Individuals which belong to a same species but can be differentiated on the mating behavior, are called **varieties** or **syngens**. Sonneborn reported a number of varieties wihin each species of *Paramecium*. The individuals which are morphologically alike but physiologically and genetically apart are called **mating types**. Members of same mating type never participate in conjugation, thus conjugation occures between different mating types.

During conjugation two individuals come close together and pair by their ventral surfaces. The interlocking between them is made stronger by the gullets which degenerate to form a **protoplasmic bridge** between them. A substance produced by the cilia of both conjugants probably helps in adhesion of the two. The paired conjugants are however capable of movement. Soon a series of changes occur in the nuclei of both the conjugants and that are to some extent comparable to gametogenesis of higher animals.

These nuclear changes are :

(i) The macronucleus undergoes gradual disintegration and ultimately disappears.

(ii) The micronucleus which is diploid, undergoes two successive divisions forming four haploid micronuclei (sometimes called pronuclei) in each of the conjugants. One of the divisions is probably meiotic in nature.

(iii) Three of these four micronuclei in each conjugant degenerate and the remaining one undergoes mitotic division to form two gametic nuclei. One of the gametic nucleus is large and is called **stationary** or **female** pronucleus while the small one is called **migratory** or **male pronucleus**.

(iv) The migratory or male pronuclei of two conjugants are exchanged so that the male pronuclus of one conjugant passes through the cytoplasmic bridge into the other and fuses with the stationary female pronucleus forming the **zygote nucleus** or **synkaryon** which restores the diploid condition and initiates genetic variability in both the zygotic nuclei.

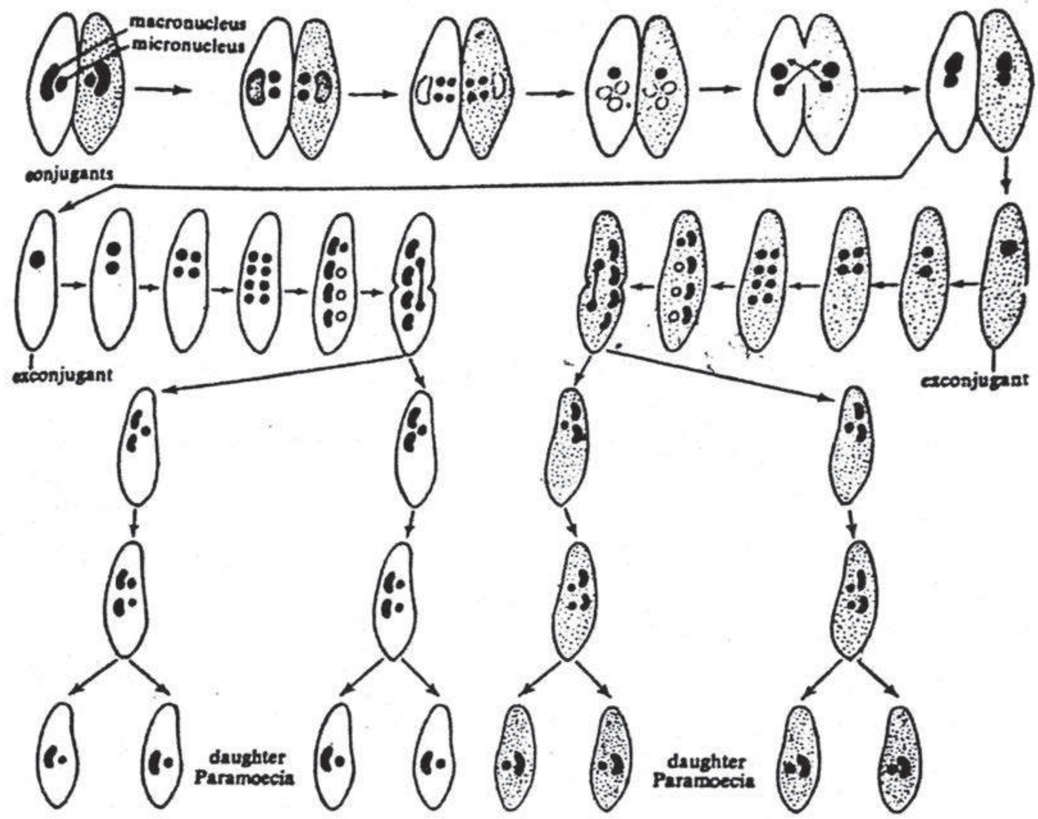


Fig. 41: Stages of conjugation in *paramoecium caudatum.* Note that two individuals (shown in different shades) come together, exchange their nuclear material and then separate. Each individual ultimately produces four daughter *paramoecia.*

(v) The conjugants with the zygote nucleus now separate (after about 12-48 hours) and are called **exconjugants**.

(vi) In each exconjugant the zygote nuclues undergoes three successive mitotic divisions to form eight daughter nuclei.

(vii) Four of the eight nuclei grow in size to become **macronuclei**. Remaining four smaller nuclei are called **micronuclei**. Later on three of the four micronuclei degenerate leaving behind one *active micronucleus*.

(viii) The micronucleus then divides mitotically forming two and at the same time the exconjugant divides by cytoplasmic division (binary fission) into two cells, each with two macronuclie and one micronucleus.

(ix) The micronuclues divides again, followed by cytoplasmic division, resulting four paramecia from each exconjugant, each with one micro and one macronuclues (Fig. 41).

(x) Thus after conjugation total eight small sized daughter paramecia are formed, each of which grow and reform lacking organelles.

Significance of Conjugation :

Conjugation resembles the sexual reproduction of higher animals in many respects. It is an important process of nuclear reorganization and nuclear exchange which recur in between the binary fission (asexual reproduction). After a number repeated binary fission, the daughter paramccia become weak. To gain vitality and physiological efficiency the role of conjugation is very important. It is the process of rejuvination by which the vigour of the species is maintained. Due to exchange of nuclear material, the macronuclus and micronuclus are totally reorganized and become a new one. Due to the reorganization the macronuclues controls the metabolic activities of the animal and the vitality and vigour of the individual are enhanced. Conjugation produces new type of **genetic resuffling**. Genetic or hereditary variations result in the formation of new combination of genes in the descendants and different mating types appear among population.

2.7 Life Cycle of *Plasmodium vivax*

Members of the genus *Plasmodium* are collectively known as **malarial parasites** because they cause a febrile disease, by the bite of the malarial parasite infected female anopheles mosquitoes, called **malaria**. The life cycle of human malarial parasites (*Plasmodium spp.*) is completed by two hosts (digenetic). The asexual cycle of the parasite is completed within the reticulo-endothelial system of human being and the sexual cycle is completed within the digestive system of female anopheles mosquito.

Mosquito is considered as **primary host** or **definitive host** (because sexual reproduction occurs there) and human being is considered as **secondary** or **intermediate host** (because asexual reproduction takes place here).

Life Cycle of a Plasmodium vivax:

The life cycle of Plasmodium vivax, is divided into following two stages—

(1) **Asexual cycle in human** and (2) **Sexual cycle in mosquito.**

Asexual cycle in human. Classically the asexual life cycle of *P. vivax* is divided into 3 stages–

(i) **Pre-erythrocytic cycle,** (ii) **Erythrocytic cycle** and (iii) **Exo-erythrocytic cycle.** But Cheng (1986) has divided it into two stages—(i) **Exo-erythrocytic schizogony** including pre-erythrocytic and exo-erythrocytic cycles and (ii) **Erythrocytic schizogony**. For the convenience of discussion the classical divisions are discussed here.

1. **Pre-erythrocytic cycle :** It begins with the inoculation of the parasite as **sporozoites** by the bite of the infected female *Anopheles* mosquito in the blood stream of a healthy person. The sporozoites are slender and spindle shaped, measuring 15 μm in length and 1μm in breadth. At the anterior end of the sporozoite there is a cup like depression with three concentric rings which forms a complex structure called **apical complex**. Within half an hour of their entry into the blood streams of human, the sporozoites take refuge in the liver parenchyma cells (Shortt, 1948). They remain within the parenchymal cells for about seven days and during this period each of them develops into an oval shaped biologically organised structure, called **Schizont**. It is about 42μm long and the nucleus is peripherally situated. The schizont carries on multiple fission (asexual reproduction) or **Schizogony**. This phase of multiplication within liver parenchyma cells is

called **pre-erythrocytic cycle**. Each schizont produces about 1200 genetically identical **merozoites** or **cryptozoites** within 8-9 dyas. Each merozoite measures about 1.5 to 1.75 µm in length and 0.5µm in breadth. It is oval in shape and the nucleus is distinct and centrally placed. These pre-erythrocytic merozoites are set free by the rupture of the schizont. The newly produced merozoites travel to liver sinusoids from where they invade fresh parenchyma cells or red blood corpuscles to inititate the erythrocytic cycle of development.

2. **Exo-erythorcytic cycle :** The pre-erythrocytic merozoites or cryptozoites enter the fresh hepatic cells (hepatocytes) and multiply by a second phase of asexual multiplication known as **exoerythrocytic schizogony**. This produces about 1000 exo-erythrocytic merozoites. The merozoites of the second generation produced in the liver cells are also called **metacryptozoites**

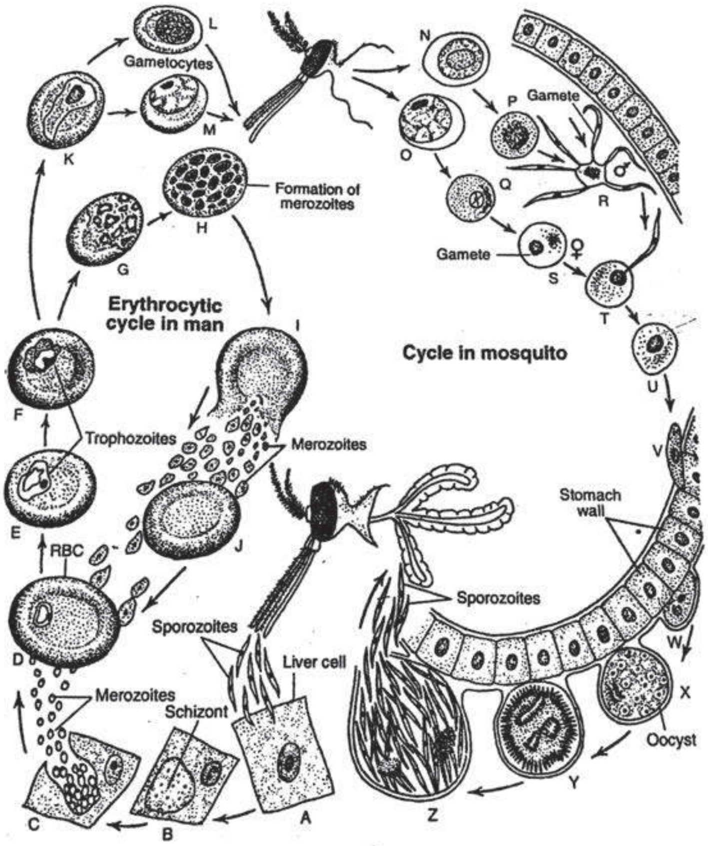


Fig. 42: Life cycle of a malaria parasite *(Plasmodium vivax*). A—C. Pre-erythrocytic cycle in liver cells. D—J. Erythrocytic cycle. K—S. Sexual cycle (begins in man and completes only within mosquito). T. Fertilisation. U. Zygote. V. Ookinete (piercing the stomach wall of mosquito). W—Z. Development of sporozoites.

or **phanerozoites**. These merozoites invade fresh RBC. The exo-erythrocytic schizogony may be repeated several times and each time new liver cells are infected.

Pre and exo-erythrocytic phases of parasite remain immune to the resistance of the host and the parasites are not susceptible to the action of any anti-malarial drug. Also little damage to the host is done during this phases.

It is supposed that the merozoites of second generation i.e. metacrytozoites are of two types. Smaller and more numerous are **micro-metacryptozoites** while larger and less in number are **macro-metacrytozoites**. In fact, the micrometacrytozoites invade the red blood corpuscles and start erythrocytic schizogony, while the macro-metacryptozoites enter fresh liver cells to continue exo-erythrocytic schizogony.

3. **Erythrocytic cycle (Erythrocytic Schizogony or Gametogony) :** Micro metacryptozoites, after escaping into blood stream, invade the erythrocytes. They can penetrate the RBCs with mediated receptor sites. Inside the RBCs they assume the shape of a rounded disc-like structure with a single large nucleus, called the **trophozoites**. The trophozoite measures about 1/

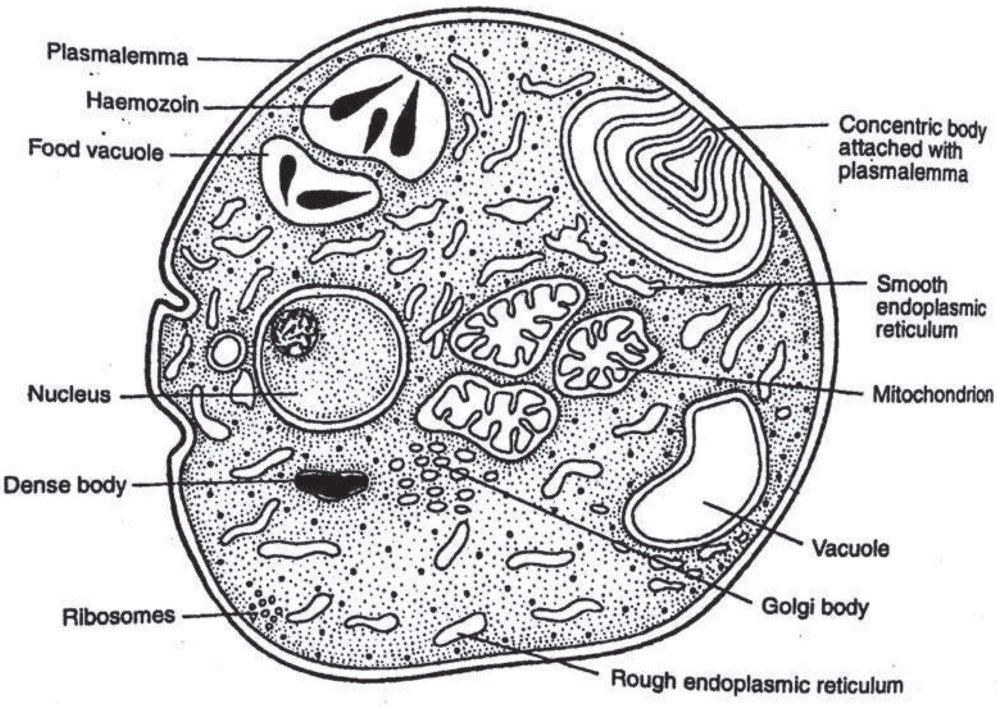


Fig. 43 : Scanning electron micrograph of trophozoite of *Plasmodium* in RBC

3rd of the RBC and is approximately 2.5-3.00μm in diameter. The young trophozoite possesses pseudopodia and show amoeba like movement. The young trophozoite grows at the expense of haemoglobin of the RBC. It absorbs haemoglobin both by general body surface and pseudopodia. Within the trophozoite a non-contractile vacuole develops and the nucleus is pushed to one side. The shape of the trophozoite at this stage resembles a ring and it is called **signet-ring stage**. It takes about 36 to 40 hours for the trophozoite to be fully grown and it occupies the whole of the RBC. During the signet ring stage the parsites ingest the haemoglobin of the RBC and haemoglobin is decomposed into amino acids and haematin. The amino acids are used by the trophozoites and the unusual yellow-brown or black coloured haematin part, a kind of toxic malarial pigment is stored in the cytoplasm as **haemozoin pigments**. Another kind of closely packed fine granules are seen on the surface of RBCs. These granules, as seen under light microscope after Romanovsky's staining, are called **Schuffner's dots** (named after the discoverer). As the trophozoite grows in size the RBC also enlarges considerably. In about 48 hrs. a trophozoite becomes full grown, almost completely fills the enlarged corpuscle.The full grown trophozoit is now called **Schizont** which is round in shape. The schizont multiplies asexually by **schizogony** or **merogony**. This is also called **erythrocytic schizogony**. When the schizont bursts a number of erythrocytic merozertes (approx. 16) are set free into the plasma from where they enter new erythrocytes and repeat the erythrocytic schizogony once every 48 hours. However, some merozoites may again go from the blood to the liver cells and invade them to undergo another phase of asexual multiplication, called **post-erythocytic schizogony**.

Formation of gametocytes : After many generations of schizogony in the blood some of the merozoites behave differently from those which repeat schizogony in RBCs. At the end of their trophic phase they do not divide but come out into the plasma by rupturing the blood cells. Some of them are transformed into rounded structures, called **gametocytes** or **gamonts**. Within 96 hours the haploid gametocytes become full grown and reach in the superficial or peripheral blood vessels. There are two forms of full-grown gametocytes—the **feamle** or **macrogametocytes** and **male** or **microgametocytes**.

The macrogametocyte is larger in size (10-12 μm) than the microgametocyte, take deep stain and contain many pigment granules with a compact peripheral nucleus. The male or microgametocyte is smaller in size (9-10 μm) with a centrally placed large diffused nucleus. It takes faint stain. Further development of the gametocytes does not take place within human body. They remain in the human blood for several weeks and it is necessary for them to be taken into the body of a female *Anopheles* mosquito. If they are not ingested by a mosquito, they degenrate and die within several weeks. Thus the sexual cycle of *Plasmodium* starts in the blood of human host with the formation of gametocytes.

B. Sexual cycle in female Anopheles mosquito :

In order to complete the life cycle *Plasmodium* requires another definite or primary host-the female *Anopheles* mosquito within which the sexual cycle is completed.

Transfer to mosquito : When a female *Anopheles* mosquito bites an infected person, the ingested blood containing gametocytes fills her stomach.

Gametogony–All other stages, except the gametocytes, are destroyed in the stomach of the mosquito by the digestive juice. Within the stomach, the macrogametocyte become spherical and transformed into the **macrogamete** or **female gamete**. The macrogametes are less active and are ready to be fertilized. The microgametocyte undergoes marked changes. Five minutes after ingestion by the mosquito the microgametes become spherical and undergo a process, called **exflage llation**, in the midgut of mosquito. The drop in temperature, due to transfer from warm-blooded human to cold-blooded insect, provides the stimulation for the process. In each microgametocyte, the nuclues divides by mitosiso produce 6-8 haploid daughter nuclei which assemble at the periphery. The cytoplasm of the microgametocyte pushes out forming long and thin flagella–like projections having a daughter nucleus in each. Thus 6-8 filamentous motile projections, calles **male gametes** or **microgametes** are formed from each microgametocytes. The microgametes, measuring 20-25 μm in length, become free and start moving in search of female gametes for fertilization.

Fertilization : The microgametes are attracted towards macrogametes by a process of chemotaxis and fusion or fertilization takes place within the stomach of the mosquito. The other name of fertilization is **syngamy** meaning complete fusion of male and female gametes. Here the gametes are dissimilar (anisogametes), hence their fusion is called **anisogamy**.

Ookinete : Fertilization results in the formation of *zygote* with a single diploid nucleus or **synkaryon**. The zygote remains rounded and motionless for about 24 hours. Then it becomes elongated in shape having pointed ends and motile in habit. In this new state it is called **ookinete** (G. oon = egg; knietos = motile). It performs wriggling or gliding movement. It measures 15-22 μm in length and 3μm in breadth.

Migration of ookinete : Owing to the natue of its worm-like movement it is often called a **travelling vermicule**. Ookinete bores its way through the internal lining of the mosquito's stomach, penetrates into the tissues and finally comes to rest just under the outer layer of the stomach wall. The ookinete in this new site becomes rounded and encased in a covering or cyst derived partly from the stomach tissue and partly from its own secretion. It is now termed the **oocyst** or **sporont**. Oocyst formation becomes complete after 48 hours of ingestion. The oocyst increases

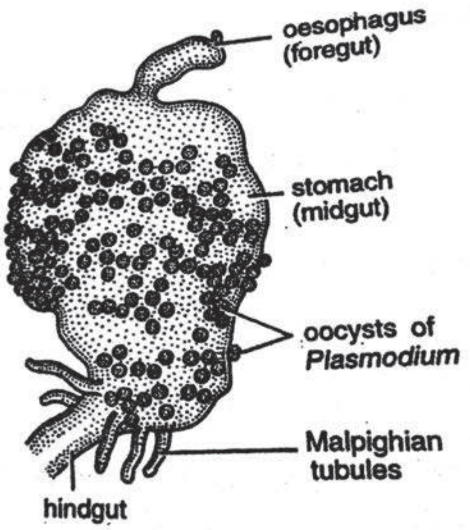


Fig. 44 : Stomach or midgut of an infected female *Anopheles* mosquito with cocysts of *plasmodium.*

in size and measures 6-7 μm. It bulges on the outer wall of the stomach towards the haemocoel and renders the stomach wall blisterred. As many as 50 or more such oocytes can be seen on the stomach of the host-mosquito. Howard (1906) observed that the ookinetes which do not succeed in boring the stomach wall pass out from mosquito's body with faecal matter.

Sporogony : Each oocyst now enters a phase of asexual multiplication known as **sporogony**. After about 7 days a number of lobes are formed in the oocyst and sporogony starts. The nucleus of the mature oocyst divides first by meiosis and then by mitosis several times (Bano, 1959) producing an enormous number of

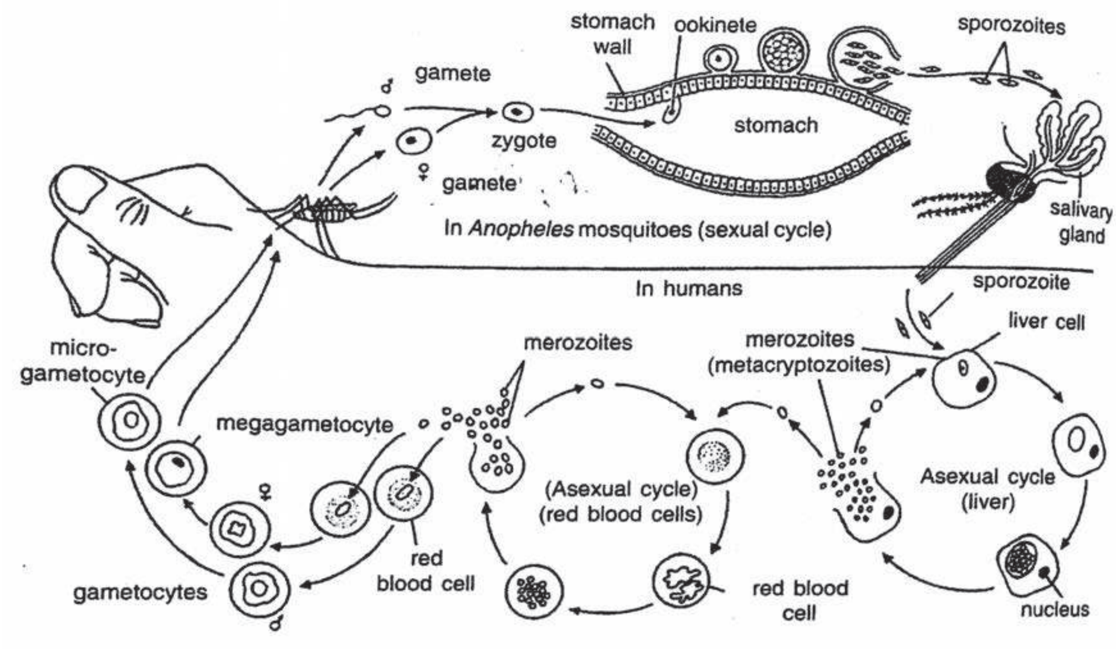


Fig. 45: The life cycles of Plasmodium in a mosquito and in a human, Reinvasion of liver cells in the tissue cycle does not occur in *Plasmodium falciparum.*

small haploid nuclei. Each daughter nucleus gets surrounded by a mass of cytoplasm of the oocyst. The resulting cells are called the **sporozoites**. Each oocyst may have 10000 sporozoites. Sporozoites have minute slender and sickled-shaped bodies with pointed ends. Each measures 15µm in length and 1-2 µm in breadth with a central nucleus. At the end of sporogony the muscular wall enveloping the oocyst bursts and cluster of sporozoites are liberated in the haemocoel of the mosquito, from where they find their way into the salivary glands of mosquito. In mosquito, whole sexual cycle is completed within 10-20 days dependng upon the temperature. The sporozoites within the salivary glands wait for their transmission into the human blood. The mosquito now becomes infective. According to one estimation salivary glands of a single infected mosquito may contain as many as 200,000 sporozoites. The infective sporozoites are introduced into a healthy person when the infected mosquito injects saliva during a bite and the life cycle of the parasite is repeated again.

Pathogenicity : Malaria caused by *Plasmodium* is one of the most prevalent and debilitating diseases afflicting humans and it has played a major role in shaping history and civilizations. More than 50 species of *Plasmodium* infect a wide variety of animals, but only four, *P. vivax*, *P. falciparum, P. malariae* and *P. ovale,* commonly cause malaria in humans. Regardless the species responsible, certain facets of the disease, such as life cycle of the infective organisms and epidemiology are more or less similar enough but the dissimilaries are medically significant.

2.8 Types of Humans Malaria

The following **four types** of human malaria are recognized on the basis of period of recurrence of fever.

1. **Tertian, benign tertian or vivax malaria.** The causative agent of this type of malaria is *P. vivax.* It is characterzed by the recurrence of fever every third day, i.e. after 48 hours. This appearance of fever paroxysm is related with rupture of merozoites from the infected erythrocytes synchronously every 48 hours. This type of malaria does not result in death of the patient. The incidence of the disease is worldwide, mainly in temperate regions.

2. **Ovale or mild tertian malaria.** This type of malaria resembles very much to the tertian malaria and is caused by *P. ovale*. Here also the fever recurs every third day or at interval of 48 hours. Ovale malaria is less harmful and is confined mainly to tropical Africa.

   Both *P. vivax* and *P. ovale* have a predilection for immature erythrocytes (reticulocytes). Less than 1 percent of the total erythrocyte population in each victim is parasitized by *P. vivax* or *P. ovale*. A diagnostically significant characteristic is the larger size of these infected erythrocytes, probably due to the fact that the parasites prefer to invade relatively larger reticulocytes. This enlargement of infected cells is less pronounced in *P. ovale* malaria than in *P. vivax* infections.

3. **Quartan malaria. *P. malariae*** is the causative organism of quartan malaria, which is characterzed by the recurrence of fever every fourth day, i.e. at intervals of 72 hours. It is well known for its longevity, 40 years or more in untreated persons. Though it ordinarily does not proove fatal to the patient, the chronic infections sometimes give rise to lethal kidney conditions. The disease is common in temperate regions. Unlike *P. vivax* and *P. ovale*, this parasite shows an affinity for older erythrocytes, parasitizing about 0.2 percent of the victim's total erythrocyte population.

4. **Malignant tertian malaria.** The causative organism is *P. falciparum.* The parasite is responsible for most cases of human malaria worldwide (80 percent) and is deeply extrenched in tropical Africa. Examination of blood smears of infected patients shows that the parasite differs significantly

from the preceding three species. Infected erythrocytes are not enlarged and represent about 10 percent of the total erythrocyte population. *P. falciparum* infects the erythrocytes of any stage indiscriminately. Multiple infections of single erythrocyte is not unusual. Rupture of merozoites from infected erythrocytes is erratic, with accompanying fever paraoxysms occuring at 48- to 72- hours intervals.

Symptoms of malaria first appear several days after the infection of the malaria parasite in man. This interval of time or the incubation period is utilized by the parasites to increase their progeny. The incubation period varies from 11-14 days in *P. vivax* and 9-13 days in *P. falciparum*. To establish malarial symptoms, it is necessary that a large number of parasites must continue erythrocytic cycle at a time. The symptoms of malaria at the end of the incubation period are head aches, loss of appetite, limb pains, nausia, vomiting and sweating, Finally, the disease is characterized by *peroxysm* (attack of fever) which shows **three** successive stages :

1. Cold stage : At the onset of malaria fever, the patient suffers from a severe shaking chill. The patient feels so cold that his/her teeth chatter though he/she may covered with a huge pile of blankets. Cold stage lasts for 20 minutes to one hour.

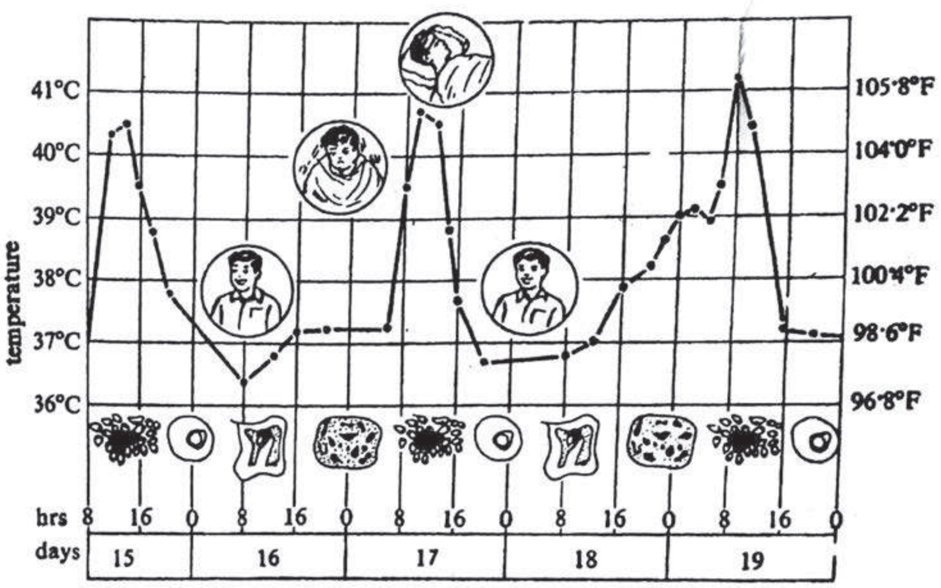


Fig. 46: Temperature cycle in malaria caused by *plasmodium vivax* (after Sharman). note the changes in the erythrocytic trophozoites corresponding to the changes in body temperature.

2. Hot stage : As the chill subsides, the body temperature rises as high as 41ºC or 106ºF. The patient feels very hot with a terrible headache. It last one to four hours.

3. Sweating stage : As the temperature lowers down, the patient sweats profusily. Finally the fever comes down, temperature becomes normal and the patient becomes comfortable until the next attack which takes place at regular interval of 48 hours in case of P. vivax malaria. The total duration of peroxysm is 6 to 10 hours depending on the spceies of *Plasmodium*.

Malaria fever occurs when schizonts in red blood corpucles burst and set free their contained merozoites and malarial pigment (haemozoin) along with cellular debris and parasites' metabolic wastes in the blood plasma. Bursting out of schizonts tends to be synochronous as they all burst out at the same time. Haemozoin is said to be toxic and induces high fever and shivering.

In infections with *Plasmodium* species, anaemia is inevitable. The reasons for anaemia are as follows:

(a) Destruction of erythrocytes on liberation of merozoites.

(b) Infected erythrocytes become more fragile, rupture easily and are destroyed.

(c) The enlarged spleen due to malarial infection releases a lytic substances, lysolecithin, which destroys erythrocytes.

(d) Malarial parasites produce haemolysin (an antibdoy), which brings about haemolysis of normal erythrocytes.

In malaria infection the spleen becomes palpable and enlarged. As spleen is considered as the graveyard of erythrocytes, due to destruction of large number of them, the function of spleen increases many fold leading to its enlargement.

The falciparum malaria infection (malignant malaria) often results in thrombosis of visceral capillaries. Death takes place when the capillaries of brain become plugged with both the parasites and malarial pigments. Another very serious outcome of the falciparum infection is **black-water fever**, which is characterized by massive destruction or lysis of patient's erythrocytes, abnormally high levels of haemoglobin in urine and blood. Fever, vomiting with blood and jaundice also occur, and there is a 20 to 50 percent mortality rate, usually due to renal failure.

In case when death does not occur, the host's immune system destroys all or most of the erythrocytic schizonts, and symptoms of malaria gradually disappear. However, the parasites persist either in the liver cells (*P. vivax*, *P. ovale*, *P. malariae*), or in the capillaries of various viscera (*P. falciparum*).

2.9 Life Cycle of *Entamoeba histolytica*

Systematic Position : (According to Levine et al. 1980)

Sub-kingdom	:	Protozoa
Phylum	:	Sarcomastigophora
Sub phylum	:	Sarcodina
Super class	:	Rhidopoda
Class	:	Lobosea
Genus	:	*Entamoeba*
Species	:	*histolytica*

Entamoeba histolytica is an amoeba-like microscopic disease-producing (pathogenic) endoparasite of human beings. The parasite was first of all reported by a Russion Zoologist Losch (1875), but he described it as *Amoeba coli*. Schaudinn established the species *Entamoeba histolytica* in 1903 and he differentiated the pathogenic and non-pathogenic types. The parasite has a very wide, almost cosmopolitan distribution and occurs especially in the tropical countries where sanitation is in bad state. It inhabits mainly in the mucuos and sub-mucous layer of large intestine of human beings. The endoparasite causes a serious disease known as *amoebiasis* or *amoebic dysentery*, the medical importance of which is well established. The name *histolytica* (Gr. histos = tissue; Luein = to disolve) is given to the parasite because of its power of dissolving (lysis) the tissues.

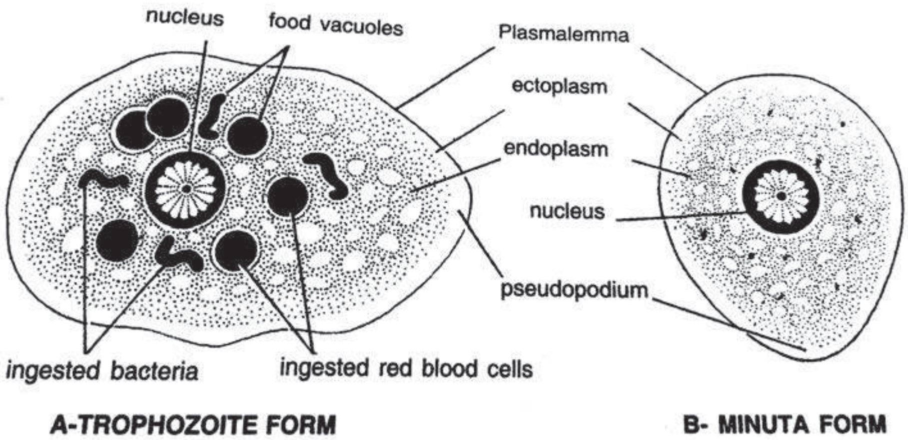


Fig. 47 : *Entamoeba histolytics.* A–Trophozoite or magna form; B–Minuta form.

The endoparasite has also been recorded in orang-utang, gorilla, chimpanzee, gibbon, donkey, dog, cat, rat and pig.

There are three stages in the life cycle of *E.histolytica*, namely **trophozoite, pre-cystic** and **cystic** stages.

1. **Trophozoite or Vegetative Stage :** The mature or adult, harmful and active stage of the parasite is called *trophozoite* (Gr. trophe = food; zoon = an animal. The growing or feeding stage). They are large, hence called *magna*, usually 20-30μm in diameter. They live in the intestinal mucosa and feed on fragments of tissue cells, erythrocytes, leucocytes and bacteria. Dobell (1919) and others have shown that the parasite has got two races, one large and the other small. Active or motile trophozoites resemble *Amoeba* in some structural details. Pseudopodia are either long finger like or short and rounded in shape (Fig. 48 & 49).

2. **Pre-cystic Stage :** When the parasite encounters shortage of food or any unsuitable environment, it assumes a colourless, round or slightly ovoid body with a blunt pseudopodia at one end (Fig. 48). The pre-cystic form is much smaller in size, measuring 10-12 μm in diameter. Owing to its small size it is also called *minuta form*. At this stage motility becomes slow and finally stops, the food vacuoles disappear. The precystic forms develop into mature cystic forms but if they are ejected in the stool no further development can take place.

3. **Cystic Stage :** The precystic form secretes a thin, tough and transparent covering around it and that is called cyst wall. The process of enclosing in a cyst is called **encystment** or **encystation**. The cysts of *E.histolytica* vary in size from 10-20 μm in diameter. At the early stage the cyst contains a single nucleus (i.e. mononucleate). The single nucleus divides mitotically forming two nuclei. This is called **binucleate cystic stage**. Ultimately the two nuclei divides again mitotically producing four nuclei. The nuclear divisions take place without cytoplasmic division and this **tetranucleate cyst** is called **mature cyst**.

Presence of black rod like **chromatid bodis** is the characteristic of the cysts of *E.histolytica*. They occur either singly or in multiples of two or more. These chromatid bodies occur in the early stages of the cysts but disappear in the mature quadirnucleate cysts. Pitelka (1963) has suggested that the chromatid bodies are made of ribonucleoprotein and Neal (1966) believes that the disappearance of chromatid bodies occurs because of the dispersion of their nucleoprotein in the substance of mature tetranucleate cystic form. In young cysts glycogen masses as reserve food are seen within the cytoplasm. The whole process of encystment takes a few hours and the mature cysts live in the lumen of intestine of host only two days.

Life Cycle : *Entamoeba histolytica* is monogenetic parasite as it completes its whole life cycle within one host only and the host is human. Its life cycle consists of three stages, **trophozoite** or **vegetative stage**, **pre-cystic stage** and **cystic stage** (discussed earlier). The mature quadrinucleate cysts are the infective forms of the parasite. Encysted forms pass out with the faecal matter of the host.

Transfer to new host. The infective cysts remain viable for a considerable length of time outside the human body, if environmental conditions are favourable. Infection of fresh human host takes place by swallowing the infective cysts with

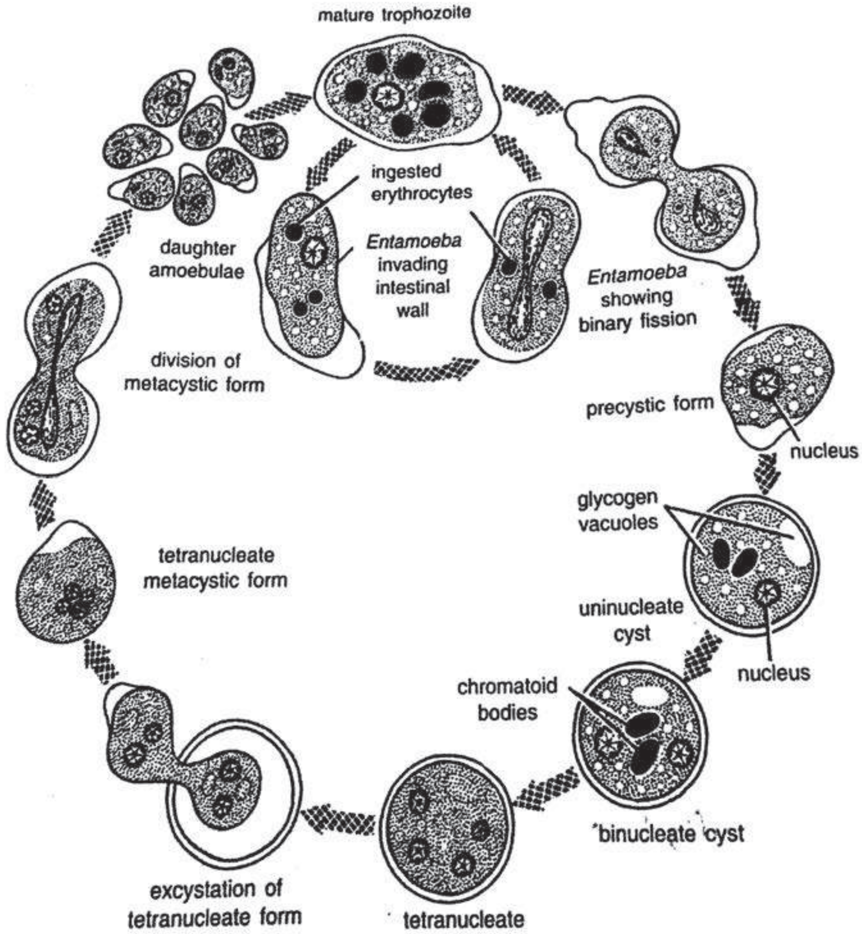


Fig. 48 : *Entamoeba histolytica.* Life cycle.

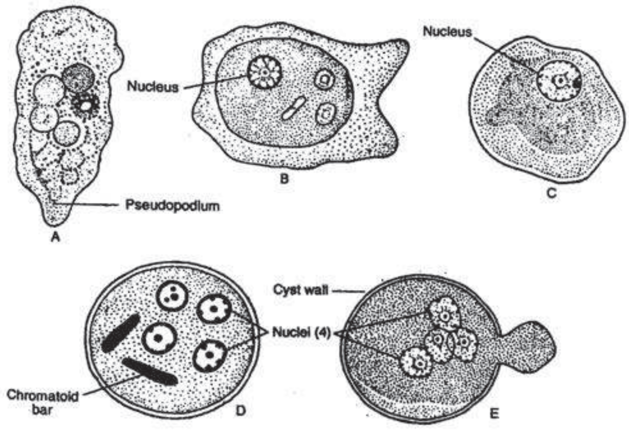


Fig. 49: *Entamoeba histolytica* (from various sources). A. Living trophozoite. B. Stained trophozoite. C. pracystic stage. D. Cystic stage. E. Excystment.

contaminated or unprotected food, drinks and vegetables. Houseflies generally carry the cysts from the faeces to the foods. Cockroaches have also been found to transport cysts. Food-handers are also responsible (sometimes) for the contamination of food through touch by dirty fingers carrying the cysts under the nails.

Excystment : In the new human host, the ingested cysts pass unaltered through the stomach, as the cyst wall is resistant to the action of gastric juice. When the cysts reach the small intestine of the host excystment occurs, as the cyst wall is digested by the action of trypsin. The cyst wall ruptures and the terranucleate entamoeba, called **metacystic form** emerges out. According to Dobell (1924) the metacystic entamoeba emerges from the cyst through a minute pore in the cyst wall. The tetranucleate metacystic form produce a new generation of trophozoites by a series of nuclear and cytoplasmic divisions which result in the formation of eight uninucleate amoebulae. These are called **metacystic trophozoites**.

The young, motile trophozoites pass into the large intestine, invade the tissues and enter through the crypts of Lieberkuhn, penetrate the muscularis mucosae and lodge themselves in the submucous tissue. They grow at the expense of living tissues to form the trophozoites of the next generation and after a particular period start the life cycle again.

Pathogenicity : *Entamoeba histolytica* is cosmopolitan with an estimated incidence of human infection exceeding 50 million cases. The infection caused by the parasite is known as **amoebiasis** or **amoebic dysentery**. Symptoms of amoebiasis vary greatly, due to the strain of *E.histolytica* and the host's resistance and physical condition. Commonly the disease develops slowly with intermittent diarrhoea, cramps, vomiting and general body weakness and discomfort. Some infections may mimic appendicitis. Broad abdominal pain, fulminating diarrhoea, dehydration and loss of blood are typical of severe cases. Acute infections can result in death from peritonitis, the result of gut perforation, or from cardiac failure and exhaution. Hepatic amoebiasis

Fig. 50: Section of human colon showing chronic amoebic ulcer.

results when trophozoties enter the mesenteric veins and travel to the liver through the hepato-portal system. They digest their way through the portal capillaries and form abscesses in the liver. The first sign of hepatic involvement is the formation of an early hepatic abscess containg a matrix of necrotic hepatic cells that eventually become liquefied. Hepatic abscesses may be single or multiple. Hepatic amoebiasis is the most serious consequnce, since abscesses may perforate the abdominal wall or extend through the diaphragm into the lungs. Any of these manifestations may be fatal. Apart from liver and lung other organs such as heart, brain, spleen, gonads and skin may also be invaded, resulting in secondary amoebiasis (Invasion of tissues other than the intestinal mucasa is known as secondary amoebiasis.

It should be mentioned here that the term "amoebiasis" is used clinically to denote all those conditions which are produced in the human host by the infection with *E.histolytica* at different areas of its invasion. The term "amoebic dysentery" signifies a condition in which the infection is confined to the intestinal canal and is charaterized by the passage of blood and mucous in the stool. Thus "amoebic dysentery" is not a synonym of "amoebiasis". Dysentery is a symptom characteristic of extensive intestinal ulerations.

The trophozoites of *E. histolytica* penetrate the mucosa and submucosa of intestine, rapidly multiply and causes necrosis of that part and form small wounds or abscesses which later become bleeding ulcers. The cavity of the ulcers is generally filled with mucous, bacteria, amoebae and cell-debris. The abscesses pour their contents into the lumen of the intestine. It has also been reported that the trophozoites secrete a battery of proteolytic enzymes, one of which is called hystolysin, that enables the organism to invade the submucosal tissue and to utilize the cytolysed material as their food. The mucosal ulceration may penetrate deeper into the intestinal tissue, causing vast areas of tissue to be destroyed. The overlying mucosal epithelium may be sloughed off, exposing those necrotic areas.

2.10 Evolution of Symmetry

A fundamental aspect of an animal's bauplan ("a structural plan or design") is its overall shape or geometry. Symmetry refers to the regular arrangement of the body structures relative to the axis of the body. In other words symmetry means an arrangement of body parts into geometrical designs. The concept of symmetry is fundamental to understanding animal organization. Symmetry describes how the parts of an animal are arranged around a point or an axis. Body symmetry can be generally determined from the external appearance of an animal but other features of a body plan typically require a more detailed examination. Animals that can be bisected or split along at least one plane, so that the resulting halves are similar to one another, are said to be *symmetrical*. For example, a prawn can be bisected vertically through its midline, head to tail, to produce right and left halves that are mirror images of one another. A few animals have no body axis and no plane of symmetry and they can not be divided into like parts by a plane, and are said to be *asymmetrical*. All animals are either asymmetrical or symmetrical. Examples of asymmetical animals are most sponges, some protists, particularly the amoeboid forms, and few others.

In animal kingdom five types of symmetry are recognized. These are–

1. Asymmetry
2. Spherical symmetry
3. Radial symmetry
4. Biradial symmetry
5. Bilateral symmetry

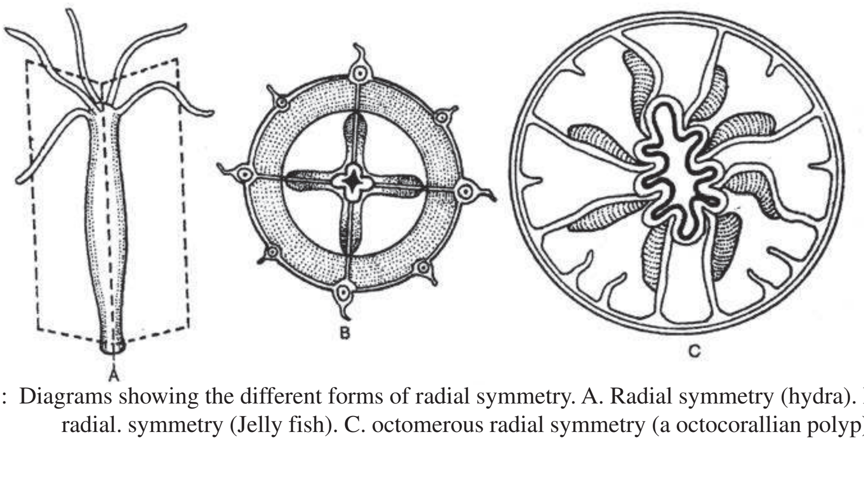


Fig. 51 : Diagrams showing the different forms of radial symmetry. A. Radial symmetry (hydra). B. Tetramerous radial. symmetry (Jelly fish). C. octomerous radial symmetry (a octocorallian polyp).

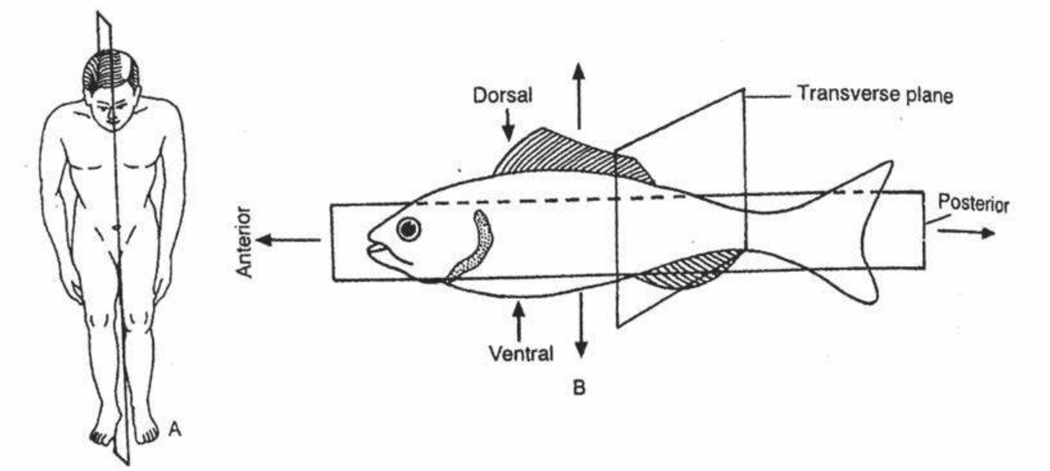


Fig. 52 : A diagram showing the bilateral symmetry in man. B. A fish showing the different planes of bilateral symmetry.

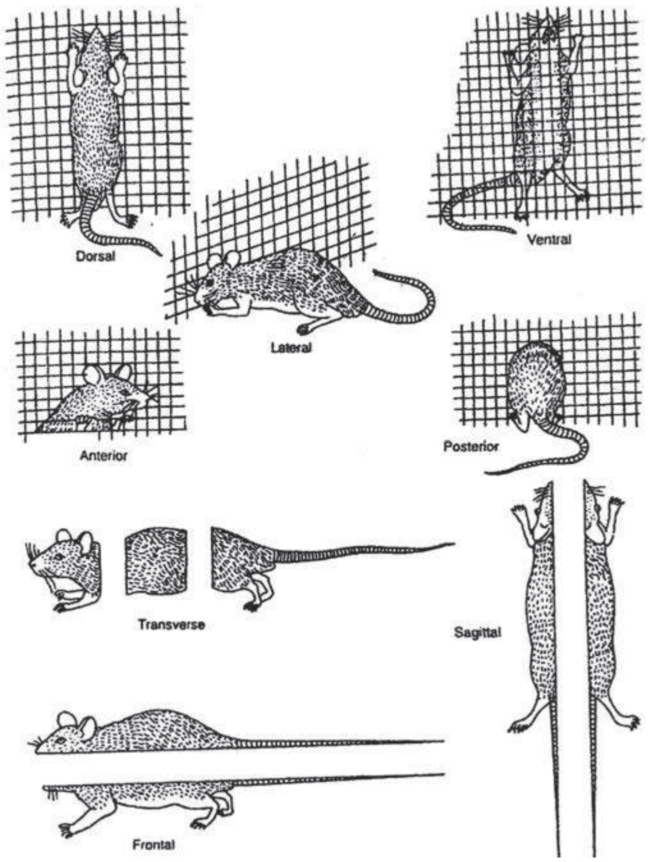


Fig. 53 : For the convenience of study, the animal body is divided into a number of regions–dorsal, ventral, lateral anterior and posterior. The entire body may also be divided into three planes, transverse, frontal and sagittal.

1. **Asymmetry or asymmetrical animals :** Discussed earlier.

2. **Spherical symmetry :** It is seen in animals whose bodies lack an axis and have the form of a sphere, with the body parts arranged concentrically around or radiating from, a central point (Fig. 54). Here any plane passing through the centre divides a body into equivalent or mirrored halves. Spherical symmetry is rare in animals and is seen chiefly among some unicellular animals e.g. radiolarian protozoa. Spherical forms are best suited for floating and rolling. Organisms with spherical symmetry share an important functional attribute with asymmetrical organisms, in that, both groups lack polarity. That is, there exist no clear differentiation along an axis. In all other forms of symmetry, some level of polarity has been achieved; and with polarity comes specialization of body regions and structures (Brusca and Brusca, 2003).

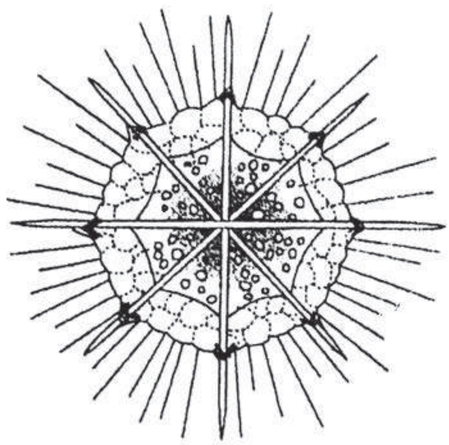


Fig. 54 : Diagram of a radiolarian showing the spherical symmetry.

3. **Radial symmetry :** A body displaying radial symmetry can be divided into two roughly equal halves by any one of many vertical planes passing through the central axis (Fig. 54), like the spokes of a wheel. The animal exhibiting radial symmetry has the general body form of a cylinder with one main axis around which the

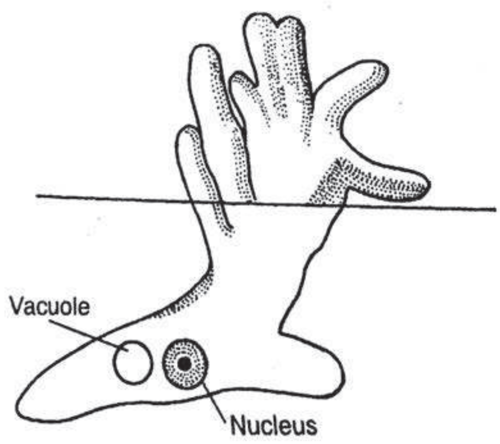


Fig. 55 : Diagram of *Amoeba* showing the asymmetrical symmetry.

various body parts are arranged equally around the axis in such a way that any plane passing through the central axis divideds the organism into equal or similar halves or antimeres. The animals with radial symmetry do not have anterior and posterior sides or dorsal and ventral surfaces. They have a mouth bearing *oral side* or *oral surface* and the opposite side (side away from the mouth) is called *aboral side* or *aboral surface*. In the animal kingdom, radially symmetrical phyla are Porifera, Cnidaria, Ctenophora and Echinodermata. Out of these only Cnidaria and Ctenophora exhibit a fundamental radial symmetry. Both the phyla were grouped together under the Division *Radiata*. Special forms of radial symmetry are observed in different groups of animals such as–

Tetramerous radial symmetry. Exhibited by many jelly fishes possessing four radial canals and the body can be divided into four equal parts (hence tetramerous).

Pentamerous radial symmetry. Most echinoderms possess pentamerous radial symmetry where the body can be divided into five roughly equal parts.

Hexamerous radial symmetry. Exhibited by the sea anemones and true coral polyps belonging to the subclass Hexacorallia (class Anthozoa). The mesenteries and tentacles are arranged in the multiple of six.

Octamerous radial symmetry. This type of symmetry is exhibited by the octocorallian polyps (subclass Octocorallia) having tentacles and mesentaries in multiple of eight.

4. Biradial Symmetry :

It is variant form of radial symmetry in which, because of some specialized portions of body, only two planes passing through the longtudinal axis can divide the animal into two similar halves. Common examples of biradial animals are ctenophores and many sea anemones.

Radial and biradial animals are usually sessile, free-floating or weakly swimming. Radial animals, with no anterior or posterior end, can interact with their environment in all directions.

5. Bilateral symmetry :

Bilateral symmetry is the arrangement of body parts in such a way that a single plane (mid sagittal plane) passing between the upper (anterior) and lower (posterior) surface and through the longitudinal axis of an animal, divides the animal into right and left mirror images (Fig. 52). Bilateral symmetry is characteristic of active, crawling or swimming animals and the animals which exhibit bilateral symmetry are called the *Bilateria*. They include acoelomates, psuedocoelomates and eucoelomates among invertebrates and both lower chordates and vertebrates.

Because the bilateral animals move primarily in one direction, one end of the animal is continually encountering the environment. Associated with bilateral symmetry and unidirectional movement is a concentration of feeding and sensory structures at the anterior end of the body. The evolution of a specialized "head", containing those structure and the nervous tissues that innervate them is called *cephalization* (differentiation of a head). This is an obvious advantage to an animal moving through its environment head first. Cephalization is always accompanied by differentiation along an anteroposterior axis, although the evolution of this axis preceded cephalization.

The entire body of a bilaterial animal can be divided into three planes such as––(a) Mid sagittal, (b) Frontal and (c) Transverse (Fig. 53). A longitudinal plane that passes along the axis of the body to separate the animal in right and left halves, is called the *mid sagittal plane*. Any longitudinal plane passing perpendicular to the mid-sagittal plane and separating the upper (*dorsal*) from the underside (*vental*) is called a *frontal plane*. Any plane that cut across the body perpendicular to the main body axis and the mid sagittal plane is called a *transverse plane* (or simply, a cross section). In bilaterally symmetrical animals the term *lateral* refers to the sides of the body, or to structures away from (to the right and left of) the midsagittal plane. The term *medial* refers to the midline of the body, or to structures on, near, or toward the mid sagittal plane. Besides lateral (right and left sides), an upper or *dorsal* surface and a lower or *ventral* surface, an *anterior end* (the end which usually moves forward during locomotion and bears head and mouth) and posterior end (the end opposite to anterior) are also recognizable in most bilateral animals.

Grade of Organization :

In addition to body symmetry other patterns or grades of animal organization are recognizable. In a broad context, these patterns may reflect evolutionary trends although these trends are not exact sequences in animal evolution. Followings are the grades of organization :

(1) **The unicellular or protoplasmic grade of organization :** Protoplasmic (also called cytoplasmic) grade of organization characterizes unicellular organisms. All the functions are confined within the boudaries of a single cell, the fundamental unit of life. Unicellular body plans are characteristics of the protista. Some zoologists prefer to use the designation *cytoplasmic*. Unicellular organization is not "simple".

All unicellular organisms must provide for the functions of locomotion, food collection, digestion, water and ion regulation, sensory perception and reproduction in a single cell. Within a cell protoplasm is differentiated into organelles capable of performing specialized functions.

2. Cellular grade of organisation : Cellular organization is an aggregation of cells that are functionally differentiated. A division of labour is evident, so that, some cells are concerned with, for example, reproduction and others with nutrition. Some flagellates, such as *Volvox*, that have distinct somatic and reproductive cells are placed at the cellular level of organization. Many zoologists (authorities) also place sponges at this level.

3. Cell-tissue grade of organization : A step beyond the preceding is an aggregation of similar cells into definite patterns or layers and organized to perform a common function, to form a tissue. Sponges are considered by some authorities to belong to this grade, although jelly fishes and their relatives (Cnidaria) more clearly demonstrate the tissue plan. Both groups are still largely of the cellular grade of organization because most cells are scattered and not organized into tissue. An excellent example of a tissue in cnidarians is the nerve net, in which the nerve cells and their processes form a definite tissue structure, with the function of coodination.

4. Tissue-organ grade of organisation : An aggregation of tissues into organs is a further step in complexity. Organs are usually composed of more than one kind of tissue and have a more specialized function than tissues. This is the organizational level of flatworms (Platyhelminthes), in which well-defined organs such as eyespots, probosis and reproductive organs occur. In flat warms, the reproductive organs transcend the tissue organ grade and are orgnized into a reproductive system.

5. Organ-system grade of organization : When organs work together to perform some functions, we have the highest level of organization—an organ system. Systems are associated with basic body functions such as circulation, respiration and digestion. Most animal phyla demonstrate this type of organization.

In addition to these grades of organization there are *diploblastic* organization and *triploblastic* organization.

Diploblastic organization is the simplest tissue level organization. Body parts are organized into layers derived from two embryonic tissue layers. *Ectoderm* (Gr. ektos = outside; derm = skin) gives rise to the epidermis, the outer layer of the body wall. *Endoderm* (Gr. endo = within) gives riese to the gastrodermis, the tissue that lines the gut cavity. Bewteen the epidermis and gastrodermis is a noncellular layer called *mesoglea*. In some diploblastic organisms, cells occur in the mesoglea, but they are alwys derived from ectoderm or endoderm. Cnidarians and Ctenophores exhibit diploblastic condition.

Next to diploblastic organization, rest of the metazoans (from Platyhelminthes to Chordata) are *triploblastic* (Gr. treis = three; blaste = to sprout); that is their tissues are derived from three embryonic layers. As with diploblastic animals, ectoderm forms the outer layer of the body wall, and endoderm lines the gut. A third embryological layer is sandwitched between the ectoderm and endoderm. This layer is *Mesoderm* (Gr. meso = in the middle), which gives rese to supportive, contractile and blood cells. Most triploblastic animals have an organ-system level of organization. Tissues are organized to form excretory, nervous, digestive, reproductive, circulatory and other systems. Triploblastic animals are usually bilaterally symmetrical (or have evolved from bilateral ancestors) and are relatively active.

2.10.1 Segmentation of Metazoa

Segmentation, also called *metamerism*, is a common feature of metazoans. Segmentation is a serial repetition of similar body segments along the longitudinal axis of the body. Each segment is called a *metamere* or *somite*. In forms such as earthworms and other annelids, in which metamerism is most clearly represented, the segmental arrangement includes both external and internal structures of several systems.

Although in the past zoologists considered that true segmentation was found in only three phyla, namely the annelids, the arthropoda and the chordates, it is widely recognized that segmentation is more widespread than previously thought. Some other animals, such as onychophores (velvet worms), tardigrades (water bears), and kinorhynchs (mud dragons) are also segmented.

Discussions of the evolution of segmentation are complicated by the fact that there does not appear to be a concensus on what constitute a "segmental" body plan. Generally a distinction is made between true segmentation and serial repetition. Serial repetition includes simple repeated structures. For example, a strobilizing cnidarian (e.g. scyphozoan) is composed of repeated units, each of which will bud off to become a complete individual. Also, rotifers have an annulated outer cuticle and chitons contains serially repeated shell plates. "True" segmentation includes repeated units along with anterpor-posterior body axis of an animal and each unit is composed of combination of structures from both ecdoderm and mesodermal origin such as excretory organs, muscles, gonads, blood vesssls, nerves, appendages, coelomic cavities and septa (Scholtz, 2002). This definition suggests a certain amount of integration of a reiterated developmental program that is not likely have arisen by fragmentation or simple modification of existing structures. The body plans of annelids, arthropods and chordates are usually distinguished from other animals with serial repetition and are known as the "eusegmented" animals.

Among the distnict proposals explaining the origins of segmentation is the hypothesis that there is a single origin of segmentation in the Metazoa. In this case, the *Urbilateria*, the ancestral primitive bilateral animal that gave rise to both the protostomes and the deuterostomes (De Robertis and Sasai, 1996), was a segmented animal. Monophyly of segmentation has been proposed historically and has recently received support based upon molecular data of developmental characters (Kimmel, 1996; De Roberitis, 1997; Carroll et al. 2001). But if segmentation is monophylatic, we are faced with the challenge of explaining loss of segmentation in numerous taxa throughout the Metazoa.

Independent origins of segmentation have also been proposed, in which chordates evolved segmentation independently from annelids and arthropods, which shared a common segmented ancestor. This theory has had support through most of the 20th century. Support for an independent origin of segmentation between chordates and annelids/arthropods has been based in part on functional arguments, in which segmentation arose for distinct locomotory purposes in the ancestor of modern day annelids and arthropods and chordates (Clark, 1964). In annelids, a segmented body plan has been cited as advantageous for burrowing, because the hydroskeletal advantages of isolating a subset of segments from the rest of the body. This proposal is also not universally accepted i.e. not beyond criticism.

2.11 Questions

a) What is the important characters of Protozoa?

b) How many phylums are present in Levine classification?

c) What are the locomotary organs in protozoa?

d) Why conjugation in Paramoècium is considered as a type of sexud reproduction?

e) What is the difference between multiple fissicn and sporulation in Amoeba?

f) What is the locomotery organ in Paramoècium?

g) What is the function of contractile vacuole in Paramoècium

h) What is the difference between Ookinete and Oocyt in Plasmodium?

i) Distinguish between hypnozoite, trophozoite and mesozoite

j) How Plasmodiums are infected in human?

Uni –3 ❑ Porifera, Cnidaria and Ctenophora

Structure

3.0 Objective

By studying this unit learners would be able to understand about primitive metazoan animals.

3.1 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 submerged objects, but some groups, including most glass sponges, prefer deeper waters. Adult spongs are always attached and motionless.

3.2 General Characteristics

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.

3.3 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.

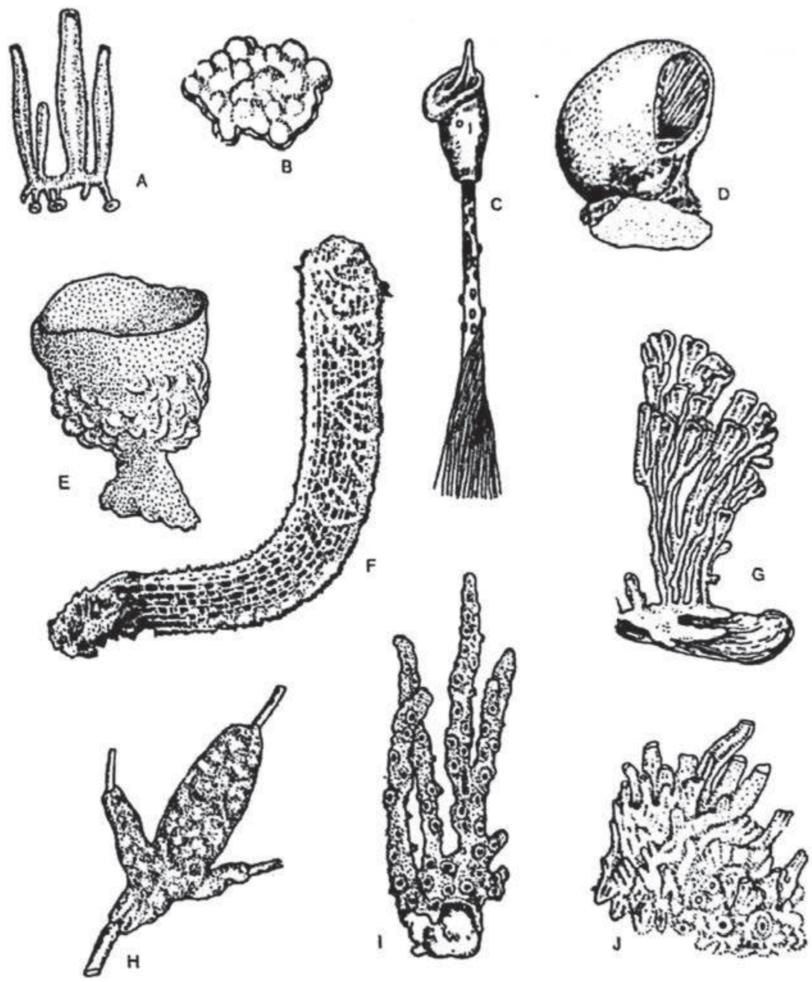


Fig. 1 : A few examples of Phylum Porifera (after Hyman). A. Laucosolenia, B. Oscarella, C. Hyalonema D. Craniella (A part removed to show inner radiating appearance). E. Poterion (Neptune's goblet). F. Euptectella (Venus's flower basket). G. Microciona. H. Spongilla (Freshwater sponge). 1. Haliclona. 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).

3.4 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.

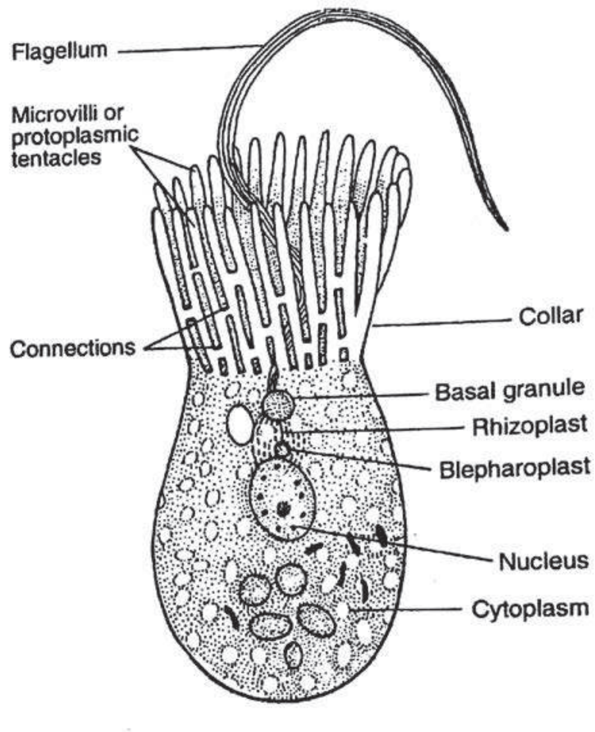


Fig. 2 : Structure of a choanocyte.

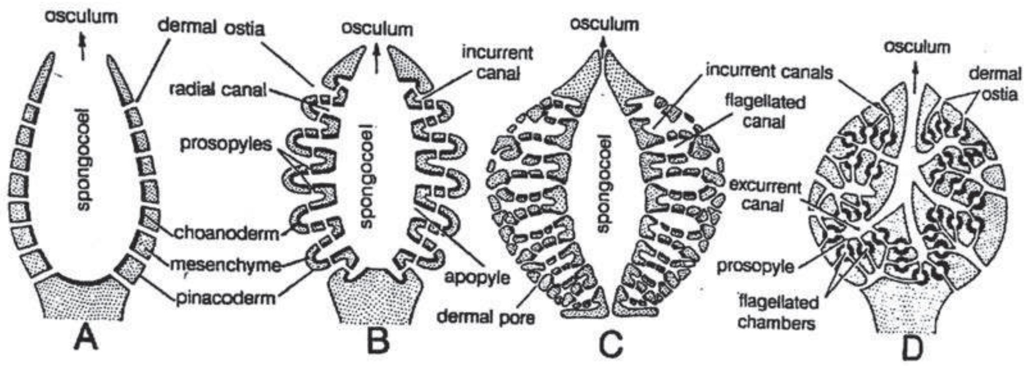


Fig. 3A: Canal system of sponges. A–Ascon type. B–Simple sycon type. C‘Complex syconoid type with cortex, D–Leucon type.

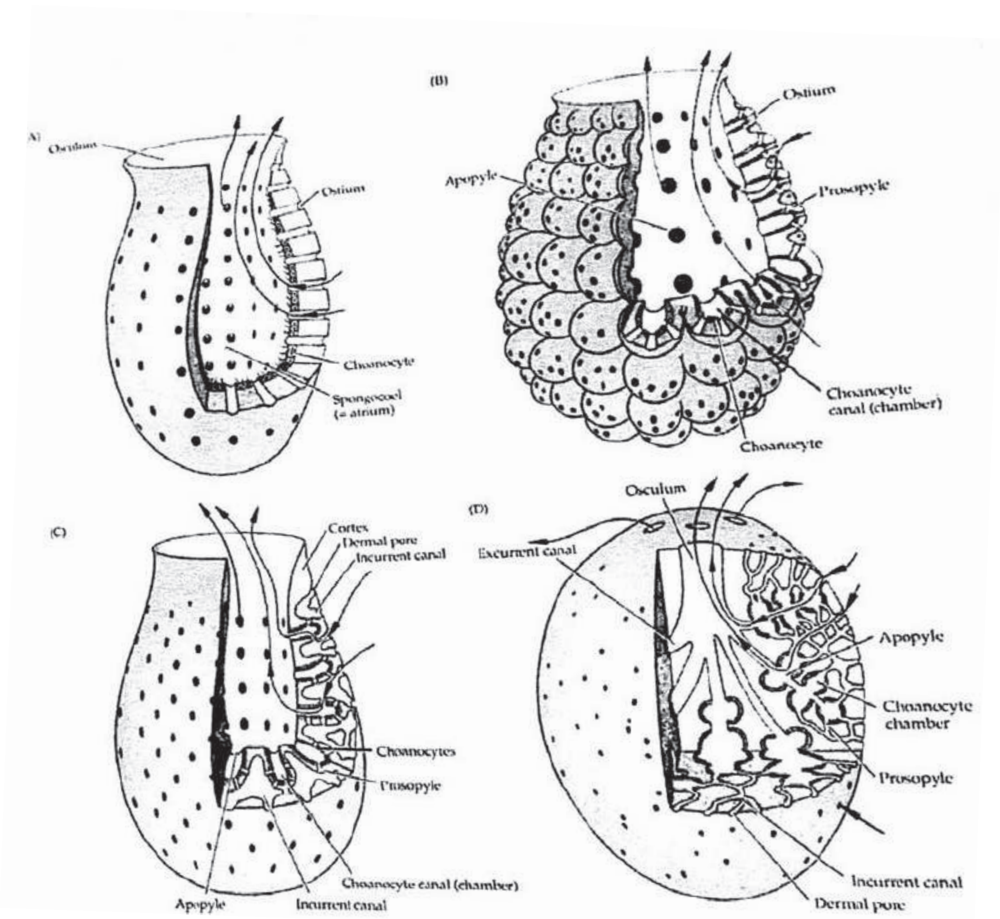


Fig. 3B: Body complexity in sponges. (Arrows indicae flow of water). (A) The asconoid condition. (B) A simple syconoid condition. (C) A complex syconoid condition with cortical growth. (D) A leuconoid condition.

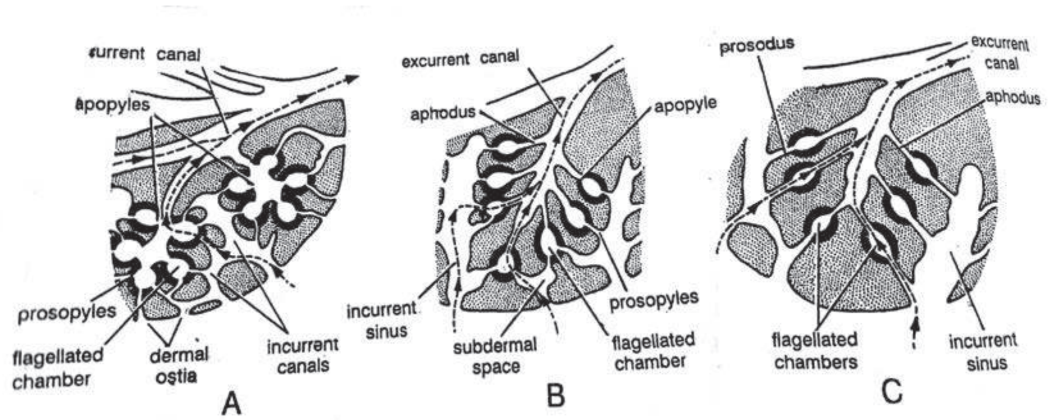


Fig. 3C : Grades in leucon type of canal system. A–Eurpylous. B–Aphodal type. C–Diplodal type.

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

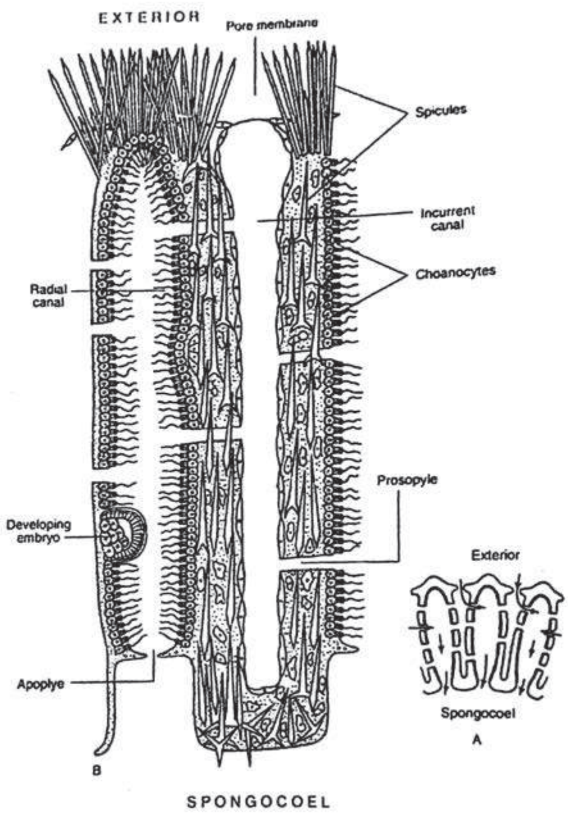


Fig. 4 : Sectional view of Sycon (Diagrammatic). A. A portion of the body to illustrate the arrangement of canals. B. Part of 'A' is magnified to show the histological details (after Parker & Haswell).

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

Surrounding water → Incurrent spaces → Dermal ostia
↓ ↓
Osculum ← Spongocoel ← Radial canals

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

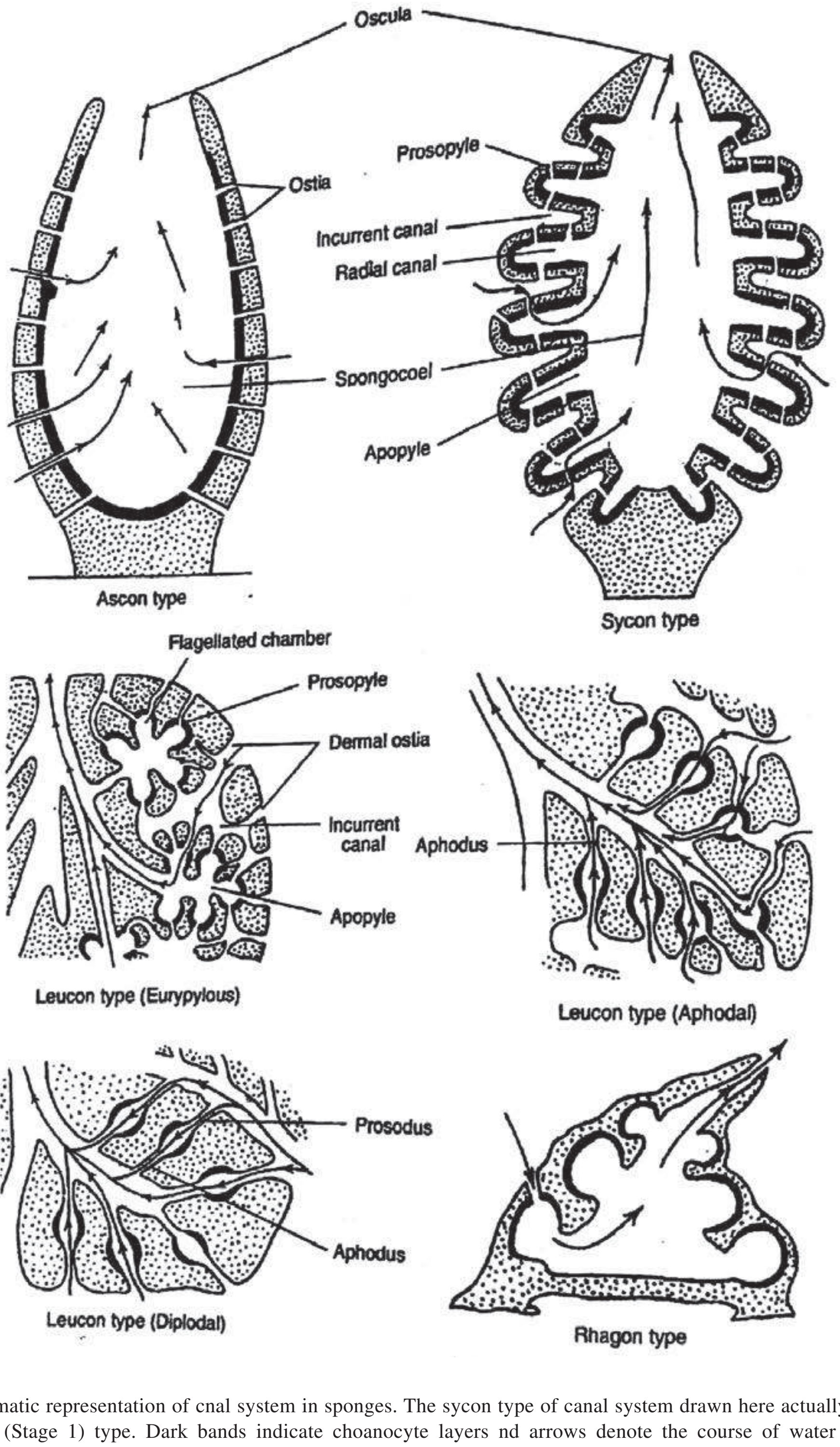


Fig. 5 : Sohematic representation of cnal system in sponges. The sycon type of canal system drawn here actually represents the syconoid (Stage 1) type. Dark bands indicate choanocyte layers nd arrows denote the course of water flow (after Hyman)

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
↓
Apophyles
↓
Aphodus (when present) → Many excurrent canals → Large excurrent canals → Osculum (Oscula)
↓
Surrounding water → Dermal ostia

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

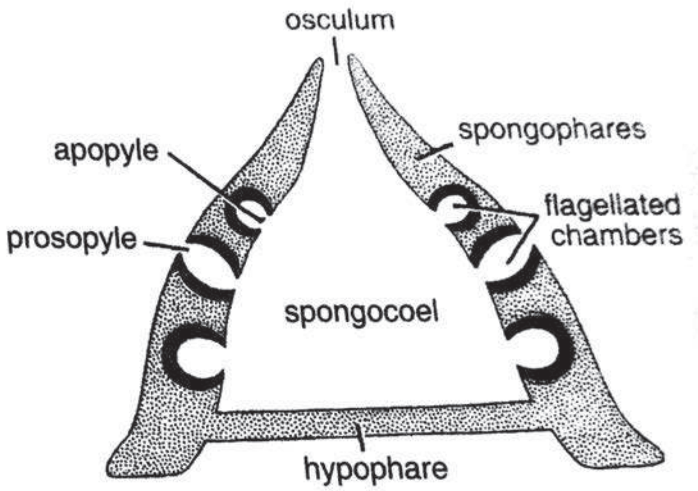


Fig. 6: Rhagon Larva. V. S. of body showing rhagon type canal system.

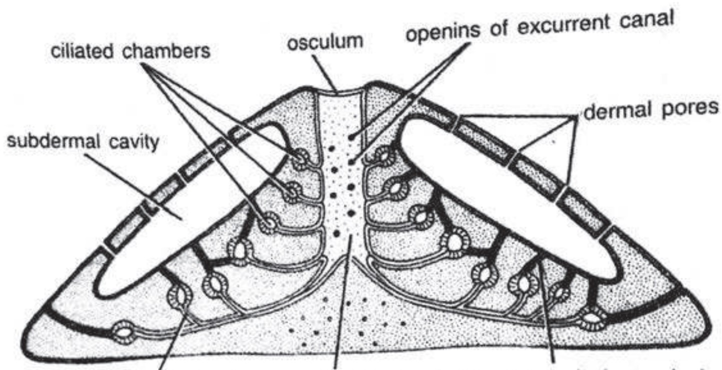


Fig. 7 : *Spongilla.* Diagrammatic V.S. of body showing rhagon type of canal system.

lies a 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.

3.5 Spicules in sponges

The skeleton of sponges is relatively complex and provides a supporting framework for the living cells of the animal. It is formed of spicules or spongin fibres or a combination of both, and serves as the basis of identification and classification of sponges. Spicules are crystalline shiny needle-like structures primarily located in the mesohyl but they frequently project throgh the pinacoderm, in some forms. The spicules (or sclerites) have definite bodies consisting of spines or rays that radiate from a point. These are secreted by specieal mesenchymal amoebocytes called **scleroblasts**. All kind of spicules have a core or central axis of organixc substances around which inorganic substances are deposited either in the form of **calcium carbonate** (calcite or aragonite) or **hydrated silica** (hydrated silicon dioxide). Thus spicules are basically of two types–calcareous spicules and siliceous spicules, based on their chemical nature. Calcareous spicules are characteristic of the class Calcarea and siliceous spicules are characteristic of the class Hexactinellida or glass sponges.

Based on their size spicules are divided into two types–**Megascleres** and **Microscleres**. The megascleres are large structural specules, constituting the main skeleton. Microscleres are small to minute reinforcing (or packing) spicules occuring interstitially within the mesohyl. The demosponges and hexactinellids have both types but calcareous sponges often have only megascleres. The suffix–axon refers to the number of axes a spicules has, while–actine refers to the number of rays or points.

A. Megascleres : Megascleres or larger "skeletal spicules" may be divided into following **six types** based on their shape.

1. **Monaxons :** These spicules have single axis and are shaped like straight needles or rods or may be curved. Their ends may be pointed, kuobbed or hooked. When growth of spicules take place in one direction only, the spicules are called **monactinal monaxons** (Fig. 8) or **styles**. Styles are

typically rounded at one end (called **strongylote**) and pointed at the other end (called **oxeote**). Styles in which broad end is knobbed are called **tylostyles**; those with minute spines or thorny processes on surface are called **acanthostyles**.

Monaxon spicules that develop by growth in both direction from a central point are named **diactinal monaxons**, or simply **diactines** or **rhabds**. These may be of following four types : (i) **Oxeas** which are pointed at both ends, (ii) **Tornotes** which are lance-headed on both ends, (iii) **Strongyles** which are rounded at both ends, (iv) **Tylotes** which are knobbed at both ends like pin heads.

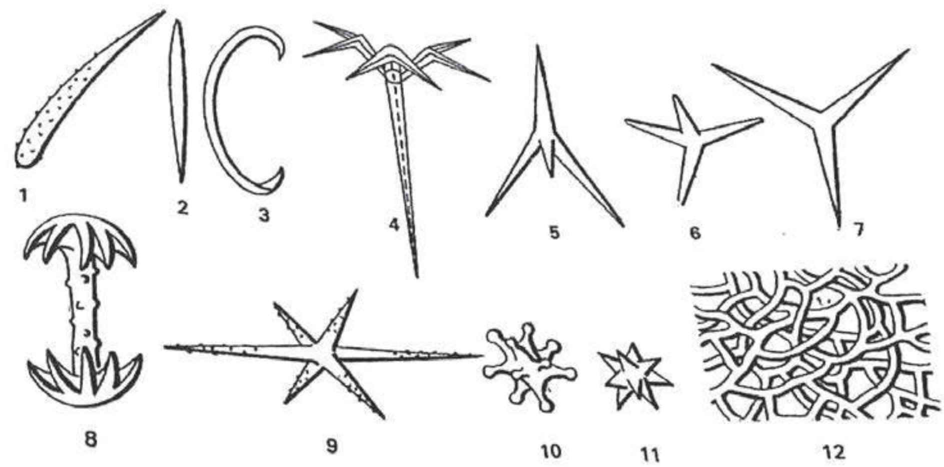


Fig. 8: Spicules and spongin 1 to 9—Megascleres. 10, 10–microscleres. 1–monactinal monaxon. 2–Diactinal monaxon 3–Curved monaxon. 4–Triacnes. 5 & 6–Tetraxon calthrops. 7–Triradiate. 8–monaxon with ends hooked (anphidise0. 9–hexactinal triaxon. 10 & 11–polyaxons. 12–Spongin fibres.

2. **Triaxon spicules :** The triaxon (three-axes) or hexactional (six-rayed) spicule consists of three axes crossing at right angles, producing six rays extending at right angles from a central point. These spicules can be modified secondarily to produce many varieties by loss or reduction of rays. Triaxon spicules occure only in the class Hexactinellida.
3. **Tetraxon spicules :** These four-rayed spicules are also called **tetractines** or **quadriradiates**. Four rays of a tetraxon spicule radiate from a common point but not in the same plane. When four rays are more or less equal in size, the spicule is called **calthrops**. When one ray is elongated (called **rhabdome**) bearing three smaller rays (**cladome**), the tetraxon spicule is called **triaene**. If one smaller ray is lost it becomes **diaene**. When the elongated ray or rhabdome bears disc at both the ends, it is called

amphidisc. Loss of elongated ray results into a **triradiate** or **triactinal** spicule, called a **triod** and it is characteristic of calcareous sponges.

4. **Polyaxon spicules :** In polyaxon spicules several equal rays radiate from a central point.
5. **Spheres :** These are almost round spicules in which growth takes place concentrically around a centre.
6. **Desma :** Desma is a special kind of megascleres consisting of an ordinary minute monaxon, triradiuate or tetraxon spicules called **crepis** on which

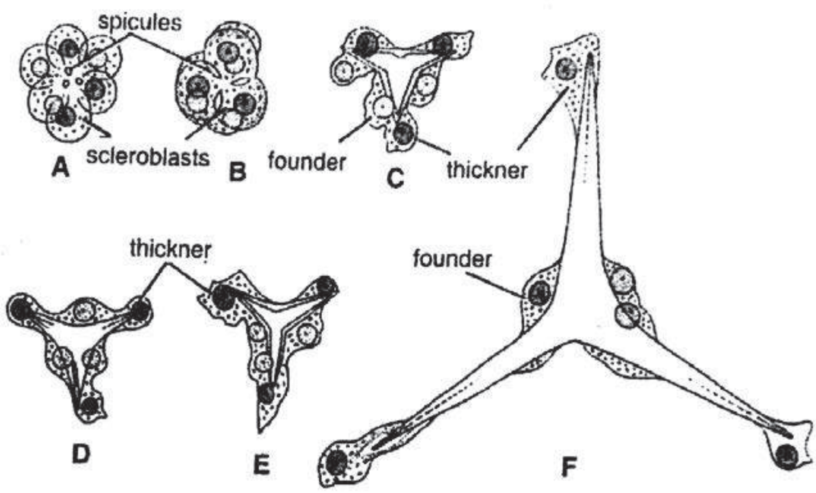


Fig. 9 : **Formation of a triaxon spicule.**

layers of silica are irregularly deposited. Based on different shapes of crepis, desmas may be named **monocrepids**, **tricrepids** and **tetracrepids**. In the begining silica deposition follows the crepis but later develops elaborate branches and when they are united into a network then it is called **lithistid**.

B. Microscleres

Microscleres are minute flesh spicules which are scattered in the mesohyl and sometimes are seen projecting in the canals. They support the pinacoderm lining the water canals. Microscleres are of following types :

1. **Spires :** Spires are curved in one plane or spirally twisted. They exhibit many shapes. The most common types are the C-shaped forms, called **sigmas**. Spirally twisted sigmas are called **sigmaspires**. Bow shaped spires

are called **toxas**, **chelas** have curved hooks or plates at both ends, when two ends are alike the chelas are called **isochelas**, when unlike they are **anisochelas.**

2. **Asters :** Asters include types with small centres and long rays. Among the small centered asters are ***oxyasters*** with pointed rays, **strongylaster** with rounded ends and ***tylaster*** with knobbed rays. The large centered forms include **spherasters** with definite number of rays and **sterrasters** with rays reduced to small projections. Short spiny microscopic monaxons are known as **streptasters**.

3.6 Phylum : Cnidaria

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

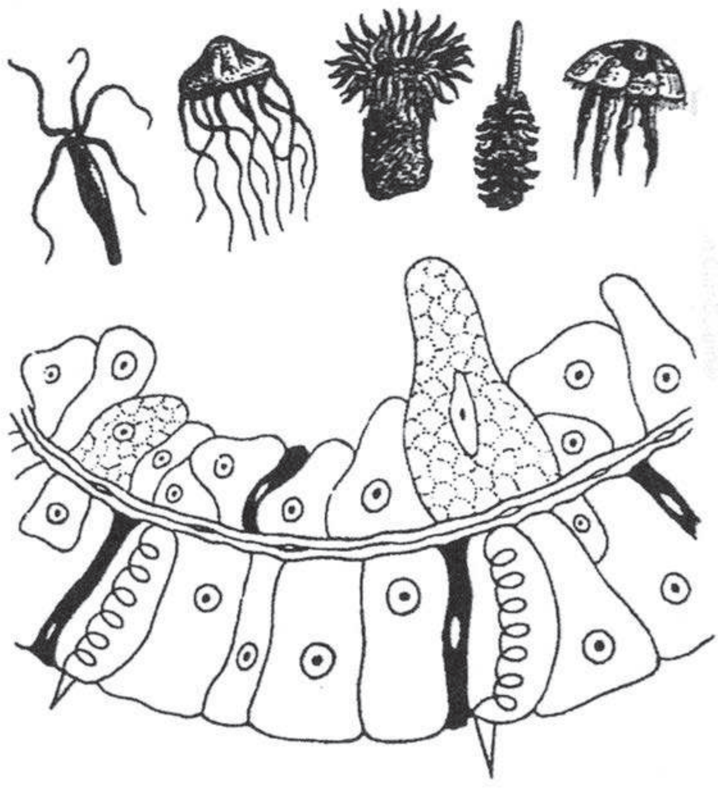


Fig. 10 : All cnidarians have two layers of cells.

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.

General Charadcteristics 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.

3.7 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.

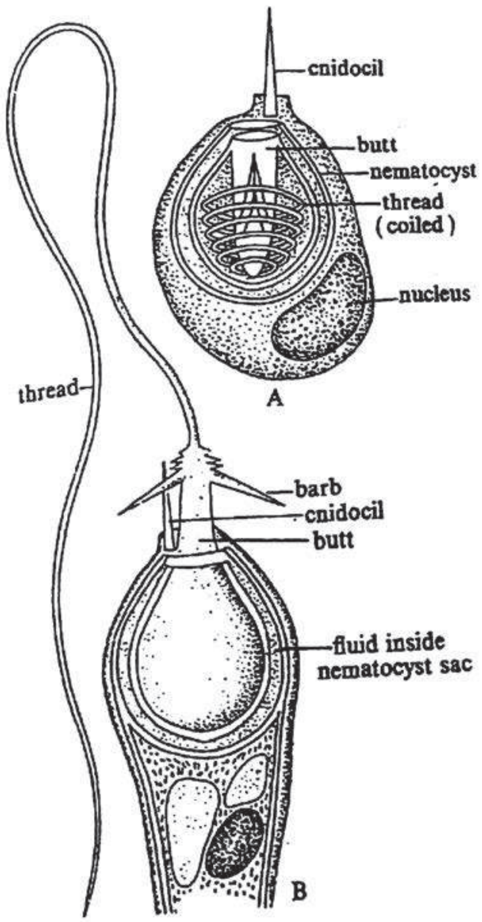


Fig. 11 : Detail structure of cnidoblast of *Hydra*.
A. Undischarged, B. Discharged.

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.

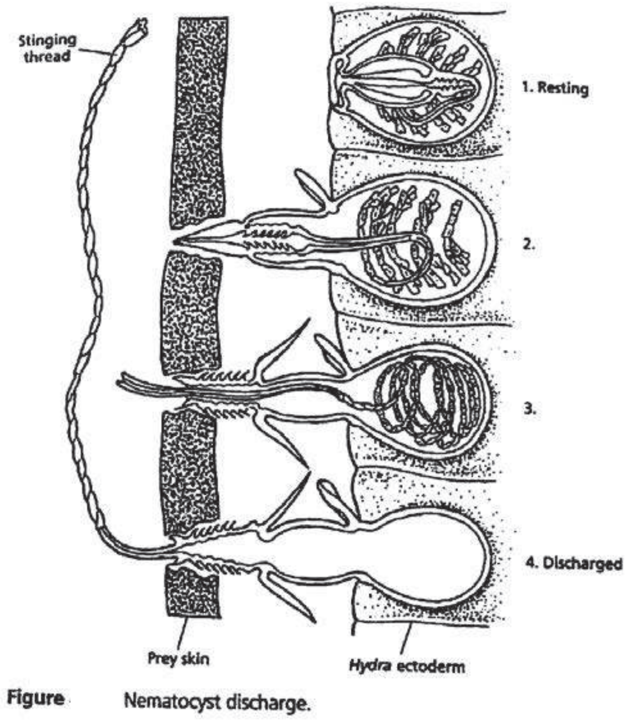


Fig. 12 : Nematocyst discharge.

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) Durelia, (t) *Fungia*

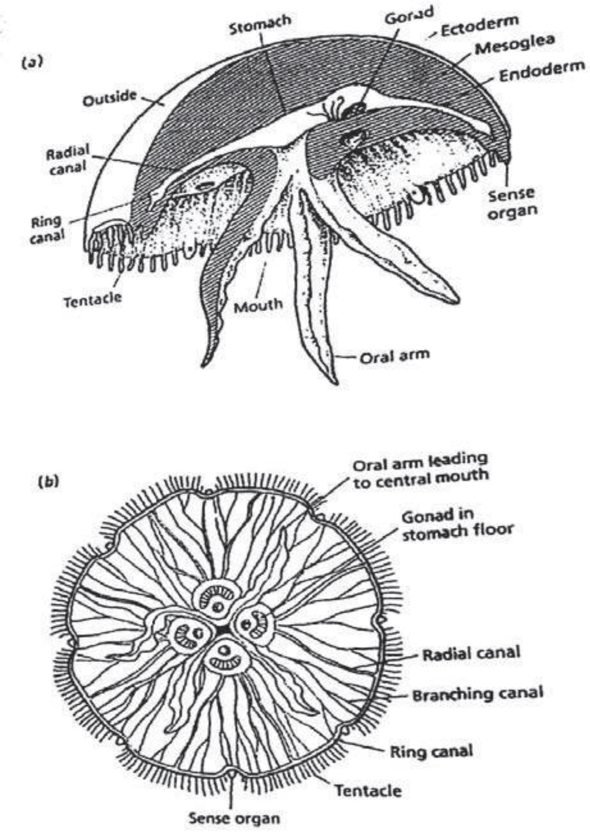


Figure 14 : The structure of a jellyfish (scyphozoan): (a) side view, with shaded part in section; (b) oral view.

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.

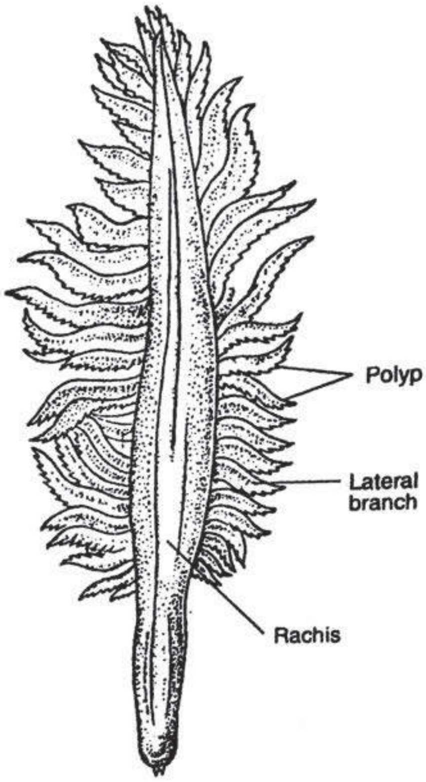


Fig. 15 : Sea-pen (*Pennatula*)—a typical example of Octocorallia.

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.

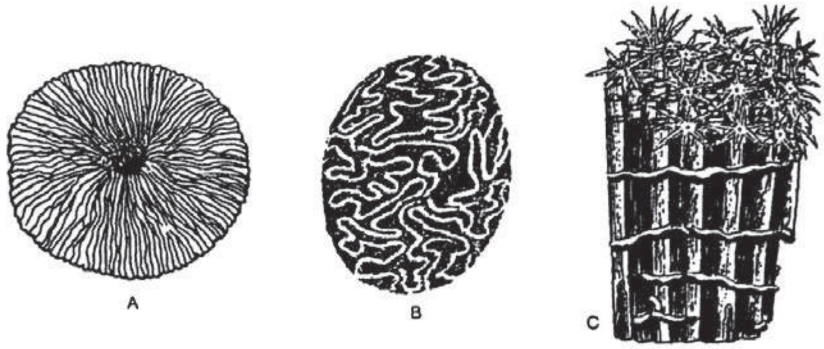


Fig. 16: Different tyhpes of Anthozoan Corals. (After Kaestner). A. *Fungia* (Mushroom coral). B. *Meandrina* (Brain coral). C. *Tubipora* (organ Pipe coral).

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).

3.8 Phylum : Ctenophora

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.

General Characters :

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.

Classification :

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"**, 6^{th} edition.

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

Class 2. Nuda

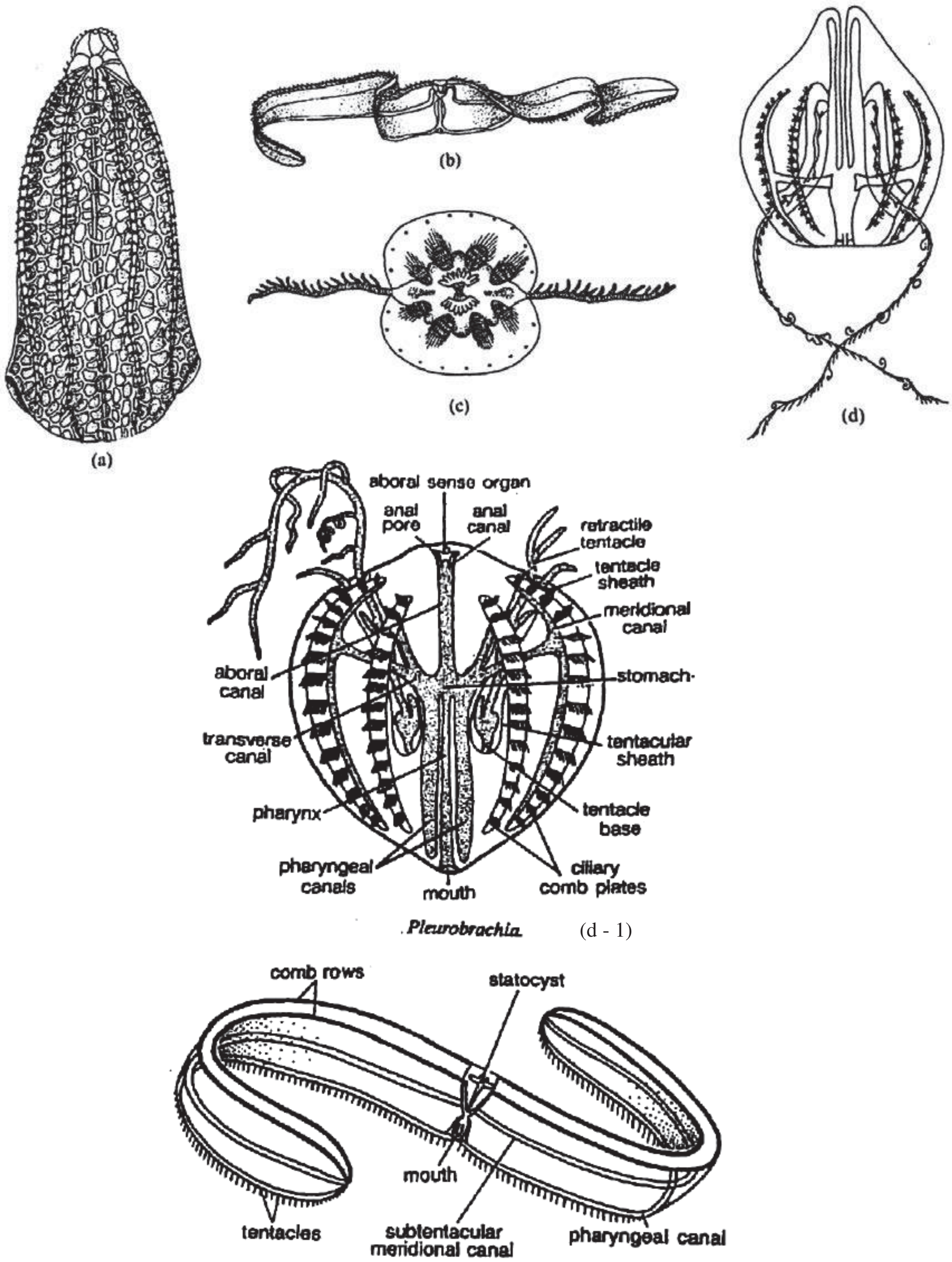


Fig. 17: Some Important Ctenophorans

(a) *Beroe,* (b) *Cestum,* (c) *Ctenoplana,* (d) *Pleurobrachia,* (e) *Velamen*

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.
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)

3.9 Metagenesis in *Obelia*

The term metagenesis was first introduced by Haeckel in 1866. Metagenesis is a phenomenon where diploid (2n) sexual and diploid (2n) asexual generations alternate each other cyclically to complete the life cycle of a sexually reproducing individual. Amongst Cnidarians this phenomenon of metagenesis is excellently shown by *Obelia*.

The *Obelia* colony represents the fixed hydroid or asexual stage (2n) which produces medusa buds (2n) by budding (Fig.). These medusa-buds subsequently transform into full-fledged medusae which represent the solitary, free swimming sexual stage (2n) and possess male or female gonads. The male and female gametes (n) are produced in the respective gonads. Fertilization of mature egg with sperm results into the formation of zygote (2n), which in turn passes through the usual development stages. The zygote ultimately gives rise to a free swimming larval stage, the **planula larva**, which, after a brief period settles down and fixes itself to the substratum and transforms into the next stage, the *hydrula stage*. The hydrula then forms the obelia colony. So in the life-cycle of *Obelia*, there is a distrinct alternation of **two diploid phases** (Fig.). One phase is completely engaged in the growth of the colony, the asexual phase or polyp phase, while the other phase is engaged in the

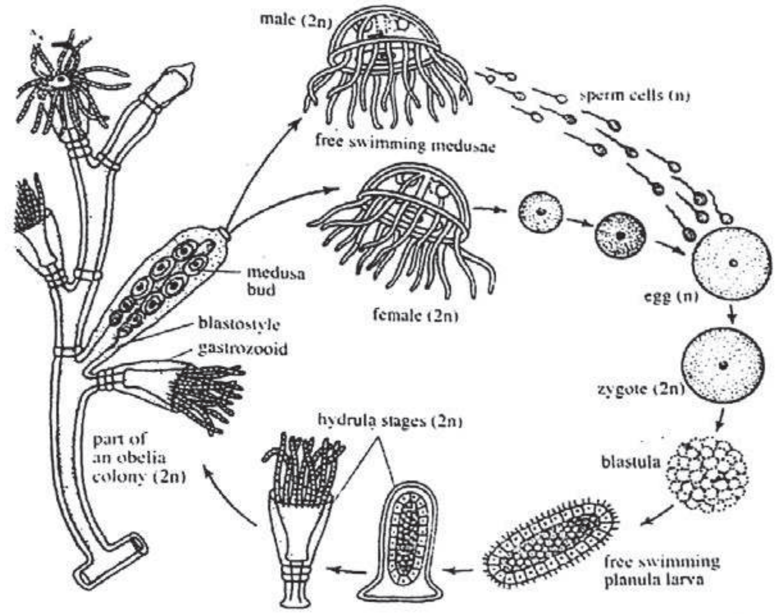


Fig. 18: Life-history of Obelia. Note the presence of asexual and sexual phases in life-history. The free-sdwimming medusae and planula larva assist in the dispersal

production of haploid (n) gametes, the sexual phase or medusa. Such a phenomenon is called **metagenesis.**

The life cycle of *Obelia* does not represent the alternation of generations because alternation of generation is a phenomenaon where diploid (2n) asexual generation alternates with the haploid (n) sexual generation cyclically to complete the life cycle.

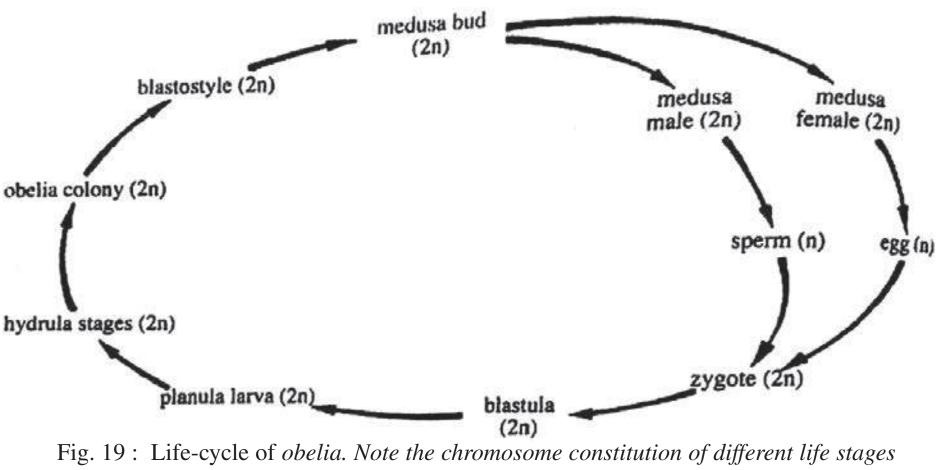


Fig. 19 : Life-cycle of *obelia. Note the chromosome constitution of different life stages for understanding metagenesis*

3.10 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

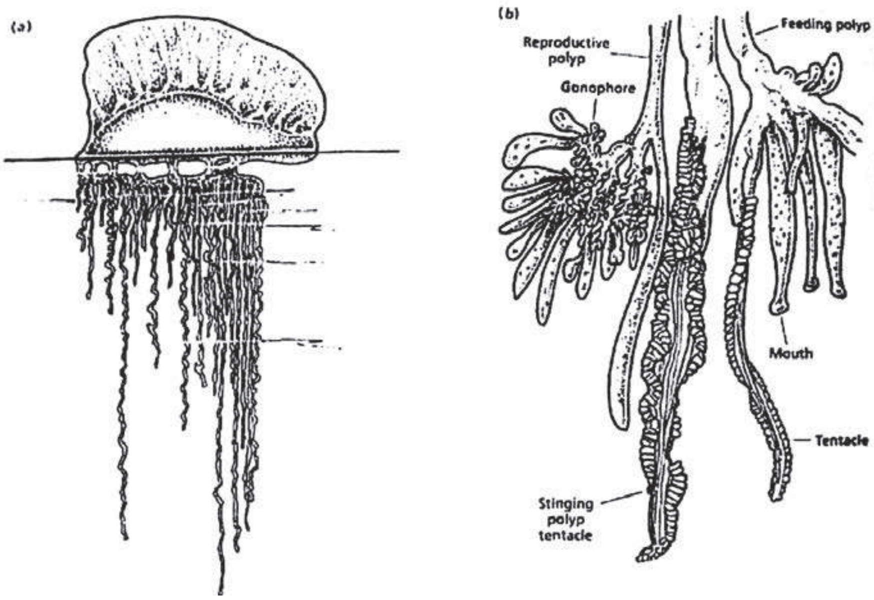


Fig. 20: (a) *Physalia,* the portuguese man-of-war, a siphonophore; (b) part of a *Physalia* colony showing the division of labour between individuals.

homologous structures. These two forms attemate 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 structural variations and are also called **tentaculozooids**, **palpons**, **testers** or **feelers**. Modified dactylozooids associated with

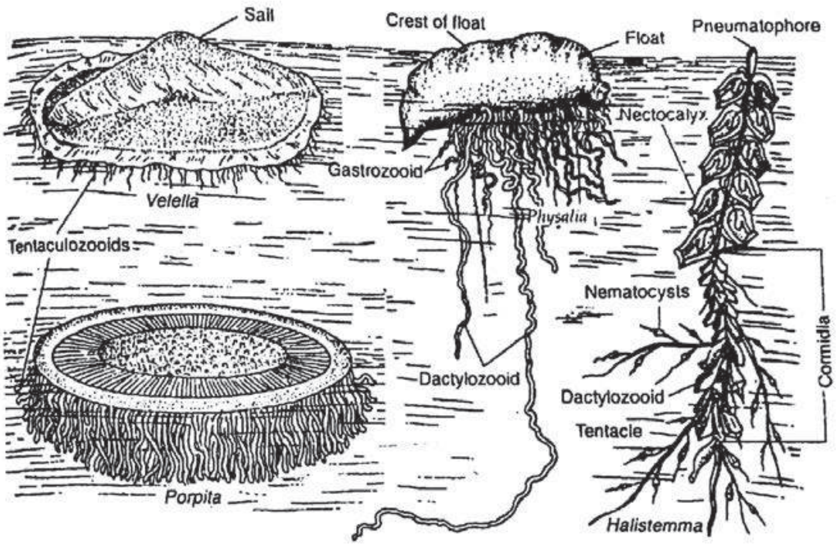


Fig. 21: A few representatives of the order Siphonophora

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*).
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,

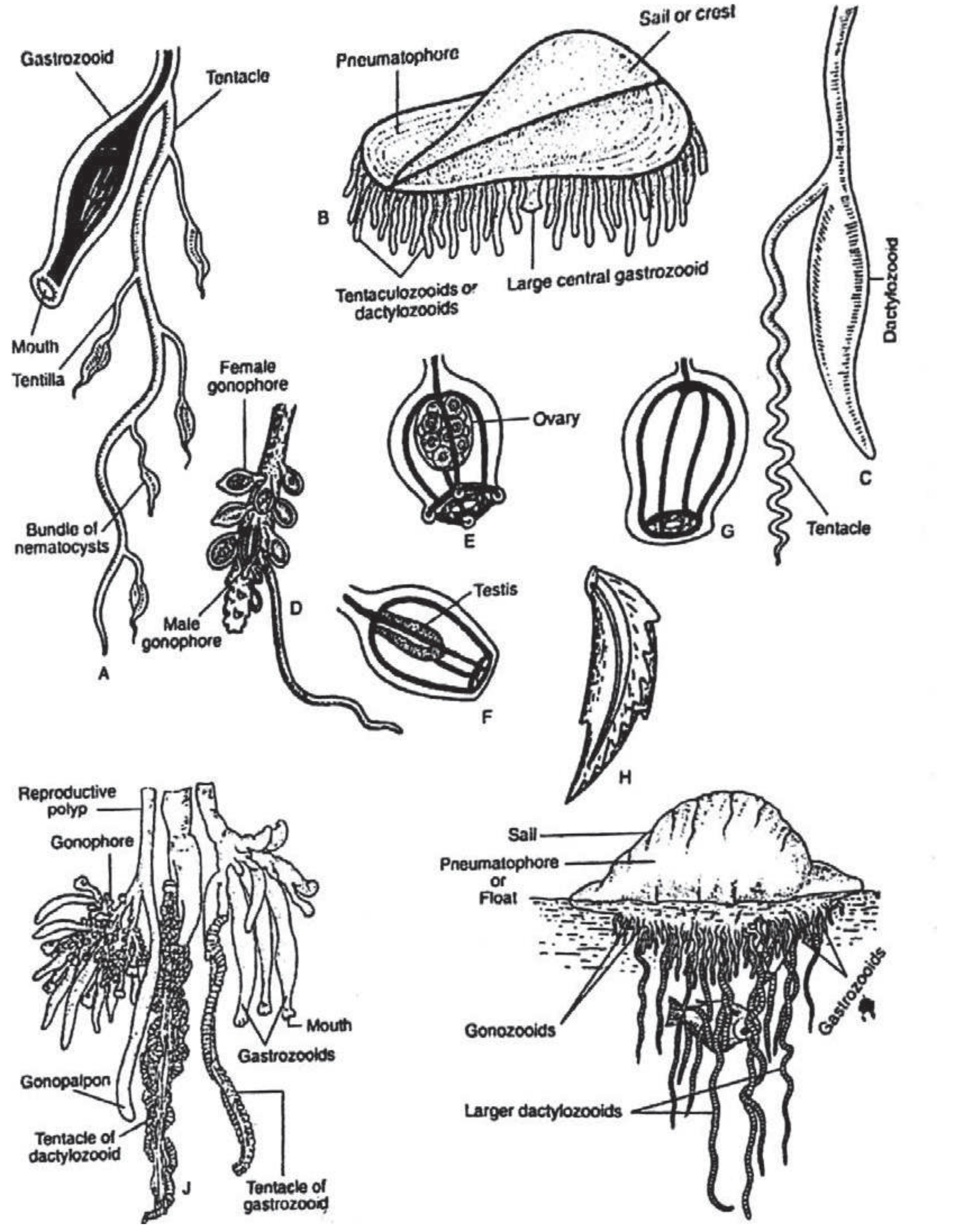


Fig. 22 : Differenttypes of zooids (after various sources). A. Gastrozoold with tentacle and bundle of memstocysts. B. Central gastrozooid of *Velella.* C. Dactylozooid with tentacle. D. Conozooid. E. Female Gonophore (medusold form). F. Male gonophore (medusold form). G. Nectophore or swiming bell.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

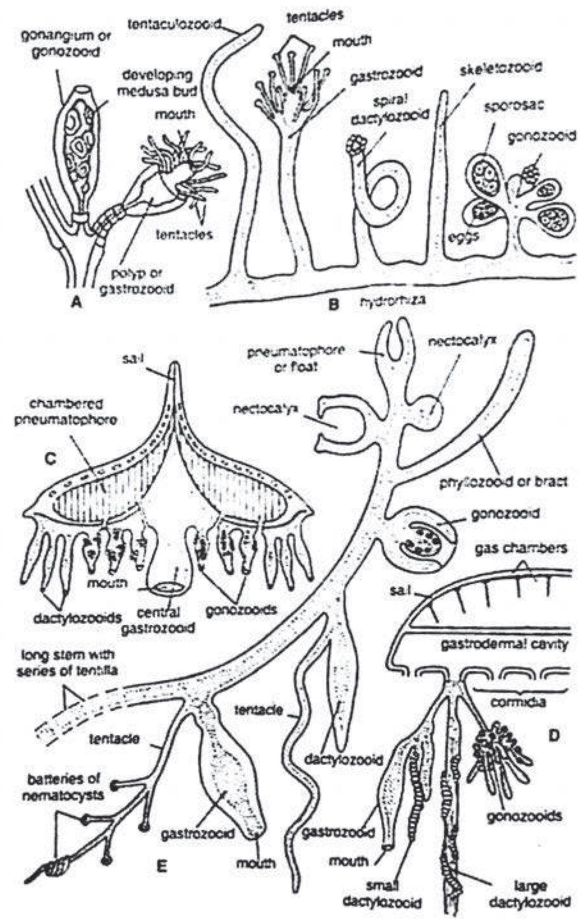


Fig. 23: Polymorphic colonies of onidaris. A—*Obeliad,* B—*Hydractina;* C—*Velella;* D—A single connidum of *Physalia;* E—Generalized calycophoran Siphonophora showing different zoolds.

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.

3.11 Corals and Coral Reefs

Coral animals or corals are a group of marine, mostly colonial, polypoid (occur only in polyp stage) cnidarians, looking like miniature sea anemones and living in a secreted skeleton of their own. Their calcarious horny skeleton is commonly known as coral. The skeleton of a single polyp is known as **corallite** and many corallites combine to form the skeleton mass which as a whole, is known as **corallum**.

Structure of a coral polyp : In structure the coral polyp is much like a small sea anemone except the skeleton portions. A typical coral polyp is cylindrical in shape, about 10 mm long and 1-3 mm in diameter. Actually the soft part of the body is somewhat like sea anemone but the basal disc is absent because the basal region of the polyp is surrounded by a calcareous skeleton cup. The basal cup is called ***theca***. From the theca the polyp projects outside and into which it can be retracted. The oral disc bears a crown of tentacles, arranged in several rows around an elongated, oval or circular mouth. Tentacles are simple and of moderate length ending in a terminal knob bearing nematocysts. Pharynx or stomodaeum is short and without siphonoglyphs. There are complete and incomplete septa or mesentaries restricted to the upper part of the gastrovascular cavity.

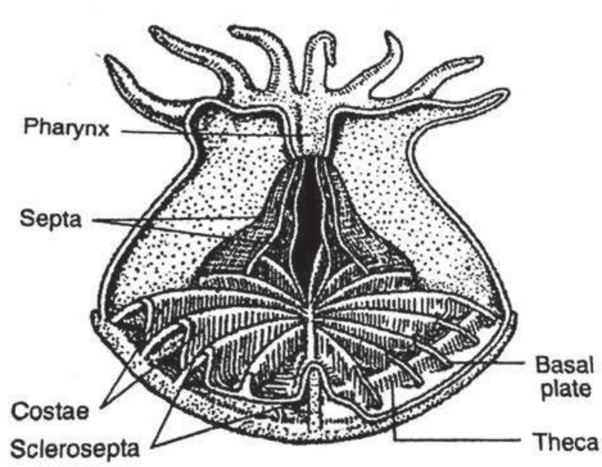


Fig. Structure of a corallite, Astroides. (After Kaestner).

The polyps of colonial corals are all interconnected but the attachment is lateral rather than aboral. The column wall folds outward above the skeletal cup and connects with the similar folds of adjacent polyps. Thus, all the members of the colony are connected by a horizontal sheet of tissue which represents folds of body-wall and so it contains an extension of the gastrovascular cavity with endoderm and ectoderm. The living coral colony thus lies entirely above the skeleton masses or coral masses i.e. they are found only on the surface layer of coral masses.

Structure of Coral Skeleton : Skeleton of an individual coral polyp is known as ***corallite***. It is a calcareous exoskeleton secreted by the ectoderm or epidermis of the polyp and it increases gradually during the life of the animal. In a colonial coral, corallites of individual polyps fuse together to form a skeletal mass, called ***corallum***. According to Voucoch, the skeleton of coral is made up of calcareous crystals in a collodal matrix secreted by the ectodermal cells outside the body wall for the protection of the polyp. Each corallite is like a stony cup (Fig.) having the following parts :

1. **Basal plate :** The bottom of the skeleton cup of a polyp is ***basal plate***. The wall of the cup enclosing the aboral portion.
2. **Theca :** The wall of the cup enclosing the aboral portion of the polyp is *theca*. From the ***theca*** the polyp projects outside and into which it can be retracted.
3. **Sclerosepta :** The cavity of the theca contains a number of calcarious ridges or partitions arranged vertically or projecting radially inwards. These ridges are called skeleton septa or **sclerosepta**, and these are connected at the base by basal plate and at the sides with the theca. The sclerosepta usually alternates with the mesenteries of the polyp and are commonly spiny or throny with toothed upper edges.
4. **Columella :** It is a pillar-like central skeletal mass which may arise independently as the outgrwoth from the basal plate or may be formed by the union of central ends of the sclerosepta. The columella formed by latter process is termed **psuedocolumella**. The collumella may be solid or trabeculae.
5. **Epitheca :** It is a distinct calcareos layer which surrounds the base of the theca in a ring like manner.
6. **Costae :** The epitheca is separated from the theca by a space and this space is crossed by continuations of the sclerosepta, called **costae**.

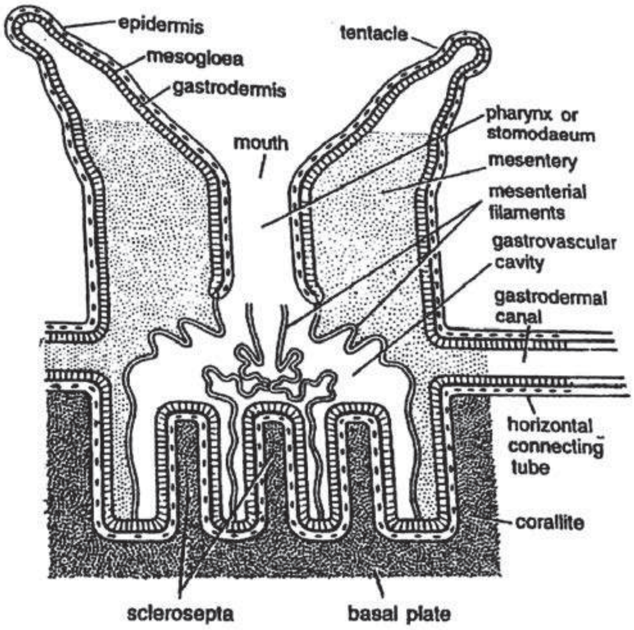


Fig. 25 : Diagrammatic V.S. of a coral polyp with its corallite.

7. **Pali :** Small ridges between the columella and the main parts of the sclerosepta are called **Pali**.
8. **Synapticula :** These are skeleton bars connecting adjacent sclerosepta.
9. **Dissepiments :** These are horizontal plates between sclerosepta, which, when incomplete, are called **dissepiments**.
10. **Trbeculae :** When the horizontal plates between sclerosepta are large and extend completely across the corallite, they are termed as **trabeculae**.

In living condition, the polyp fills the whole of the interior of the corallite and project beyond its edge. The proximal portion of its body wall is in contact with the theca which is a product of the epidermis. The free part of the body-wall of polyp is folded over the edge of the theca so as to cover its distal portion.

Coral Reefs

Vaughan (1917) has defined coral reef as "a ridge or mound of lime stone, the upper surface of which is near the surface of the sea and which is formed of calcium carbonate by the action of organisms, chiefly corals." The coral reefs are, in fact,

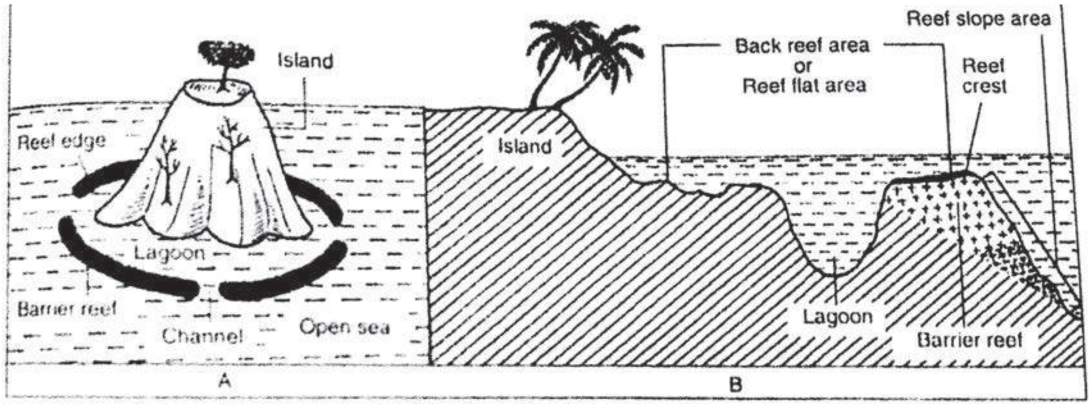


Fig. 26 A : Barrier reet, B. Sectional view of a barrier reef.

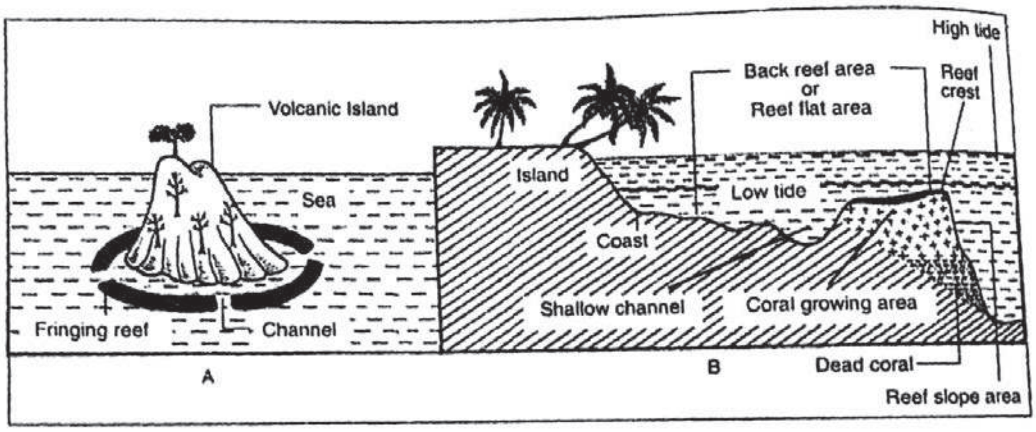


Fig. 26 B. Fringing reef. B. Sectional view of fringing reef

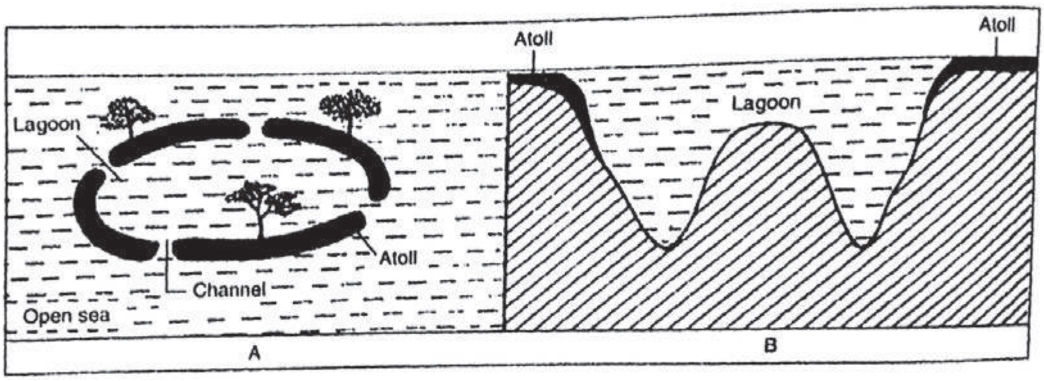


Fig. 26C. Atoll, B. Sectional view of an atoll.

produced by corals belonging to class Anthozoa, particularly by stony corals belonging to order Madreporaria. Hence the stony corals are considered as principal builders of coral reefs although other important contributors are the hydrocorallines, alcyonarians, coralline algae and foraminifera (shelled portozoa). In addition, sponges, starfishes, sea-urchins, crabs, some snails and bivalves also take part in the formation of compact structure of the coral reefs. The coral reefs are formed by incrusting their skeletal parts on the deposited lime. Coral reefs composed of multiple organisms vary in shape and colour. Reef building or hermatypic corals contain gastrodermal symbiotic algae (zooxanthellae) and thse are responsible for the rich colouration of corals which may be brown, yellow or green.

Formation of coral reefs needs some particular environmental conditions. As the symbiotic algae require light for photosynthesis, the vertical distribution of living reef corals is restricted to the depth of light penetration. Hence coral reefs occur in shallow water, ranging to depths of 60 meters. Because of their dependence on light, reef corals require clear water. Thus, coral reefs are found only where the surrounding water contains relatively small amount of suspended material, that is, in water of low turbidity and low productivity. Reef building corals are further restricted by water temperature and occur in tropical and semi-tropical seas, where the average minimum water temperature is not less than 20ºC. Thus the reef building corals require warm, clear and shallow water. They can tolerate salinities between 30 to 40 ppt. Distribution of coral reefs is limited to continental and island shores in tropical and semitropical regions (latitude 28ºN-28ºS. i.e. about 28º on either side of the equator). Reef development is greatest in the Indo-Pacific region. The coral reefs grow very slowly. Most of them expand at the rate of 10-200 mm per year. The existing reefs seem to have been formed in 15,000 to 30,000 years.

Coral reefs are estimated to cover 284,200 km^2, about 0.1% of the oceans' surface area. The **Indopacific region** (including the Red Sea, Indian Ocean, Southeast Asia and the Pacific) account for 91.9% of this total. Southeast Asia accounts for 32.3% of that figure, while the Pacific including Australia accounts fot 40.8%. **Atlantic** and **Caribbean** coral reefs account for 7.6%. Coral reefs are thus limited to the Indopacific, the Central-Western Pacific and the Caribbean regions north of Bermuda. The **Great Barrier Reef** of north east Australia, extending from the east coast of Africa to the northeastern coast of Australia, is the largest barrier reef of the world. Six of world's seven species of marine turtle, over 1500 species of fish and almost 5000 species of mollusc have been recorded in this reef. It comprises over 2900 separate reefs and 900 islands streatching over 2600 km and covering over 348,000 km^2. Besides Fiji islands of Pacific Ocean and those situated in Bahama islands region are the best known coral islands of the world. Bermuda is a coral island where houses are built of coral blocks. Around India, coral reefs are found off Port of Okha and Dwarka in the Gulf of Kutch and also off Rameshwaram in the Gulf of Mannar between India and Sri Lanka. The coral reefs are also located at Andaman and Nicobar Islands and at Lakshadweep Islands.

Types of Coral Reefs :

On the basis of structure and underlying substratum Charles Darwin (1831) classified three types of coral reefs–(i) **Fringing reefs or shore reefs**, (ii) **Barrier reefs**, (iii) **Atolls.**

Fringing reefs : The fringing reefs, also referred to as **shore reefs**, lie close to the shores of some volcanic island or part of some continent. A fringing reef may extend from the shore a few metres to 400 metres. (1/4 mile) seaward. The fringing reef consists of mainly three regions, namely (i) **reef front** or **fore reef slope** (ii) **reef crest** and (iii) the **back reef**, sometimes referred to as the **reef lagoon** or **reef flat area**. The seaward side of the fringing reef has a reef edge, called **reef front** or **fore reef slope** where the most active coral growth occurs. The coral growing areas represent a narrow belt like structure and is about 20 to 40 meters wide and subject to continuous surf. Below to this zone contains dead corals, rubble and sand. At the upper part of the reef front there is an elevated or emergent part, called **reef crest**. The seaward side of the reef crest takes the brunt of the wave action. Between the reef crest and the shore there lies a more or less flat area often eroded and uncovered at low tide, called **back reef area** or reef flat area. This area is shallow

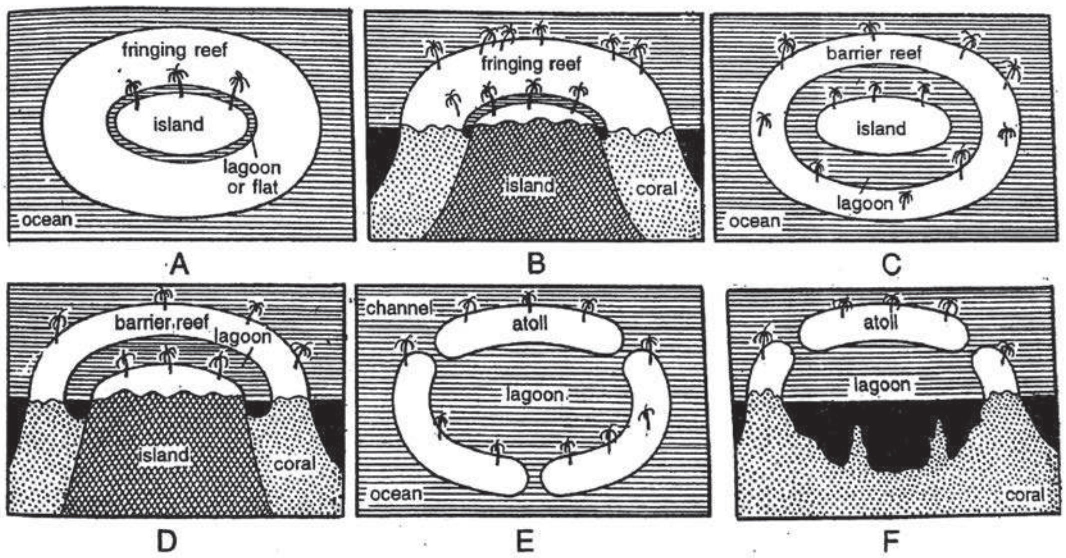


Fig. 27: Coral reefs. A – Fringing reef. B – Fringing reef in section. C – Barrier reef. D – Barrier reef in section. E – Atoll. F – Atoll in section.

and is usually 50 to 100 metres or more broad (it may be a few kilometer). Fringing reefs are quite common in East Indies.

2. Barrier reef : The barrier reefs are somewhat like fringing reefs but they are located some distance away from the shore, in deep water. A barrier reef develops around island or along the edges of continental shelves and is separated by a wide and relatively deep channel, called *laggon*. The lagoon may be 20 to 40 fathoms deep and ½ to 10 miles or more wide through which ships can easily navigate. Like the fringing reefs the barrier reefs are divided into (i) **reef front area**, (ii) **reef crest** and (iii) **back reef area** or **flat reef area** containing lagoon. The most notable example of barrier reef is **Great Barrier Reef** on the north-east coast of Australia. It is the world's largest coral reef system composed of over 2900 individual reefs and 900 islands stretching for over 2300 km over an area of approximately 344400 km^2. It is situated nearly over 160 km away from the shore.

3. Atoll : The **atoll**, also referred to as **coral island** or **lagoon island** is more or less circular or horse-shoe shaped coral reef enclosing a central area of water, called the **lagoon**. The lagoon varies from a few hundred meters to 90 kilometers in diameter and 20 to 90 metres in depth. The atoll reef may be complete or broken by a number of channels of which a few are navigable in between lagoon and outer seas. The outer side of the reef slopes off rather steeply into the depth of the ocean. Atolls are not connected with the main land but are usually separated from the main land by hundreds or thousands of kilometers. More than 300 atolls are present in the Indopacific region and the largest atoll of the world is **Kwajalein** atoll in the Marshall island of the Pacific Ocean that surrounds a lagoon over 97 km. Lakshadweep islands are an example of Indian atoll. The atoll of Bikine, famous for atomic and hydrogen bomb tests, lies in the Pacific Ocean.

3.12. Questions

a) What is the function of Canal system in sponges?
b) Write two important difference between asconoid and syconoid canal system?
c) What do you mean by Sylibid stage?
d) Where do you find choanocyte cells in Porifera?
e) Write three important characters of phylum ctenophora?
f) What are the important characters of class Hydrozoa
g) What is the difference between Barrier and Fringing reefs?
h) What do you mean by polymorphism
i) Which class of Coelentrate animals are able to produce coral reefs?

Unit– 4 ❑ Phylum : Platyhelminthes

Structure

4.0 Objective

By studying this unit learners would be able to learn about the more advanced metazoan animals which are diploblastic and pseudocoelomate in nature.

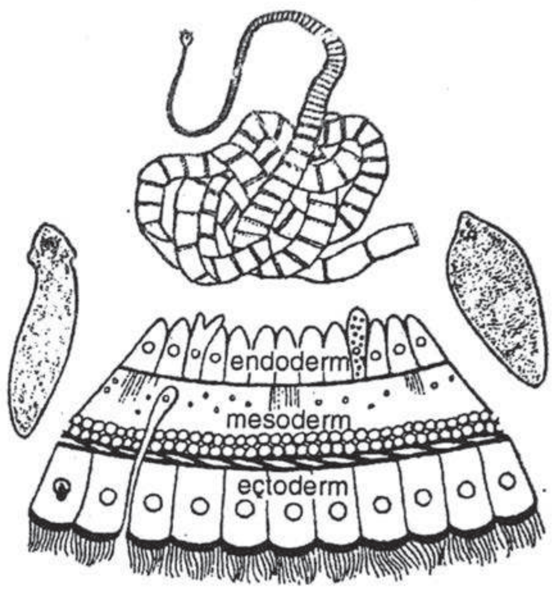


Fig. 1 : Three representatives of Platyhelminthes with a part of their body wall to show triploblastic organsation.

4.1 Introduction

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. They, however, lack coelom, the body being compact (acoelomate) and the blood vascular system is absent.

4.2 General Characters 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.

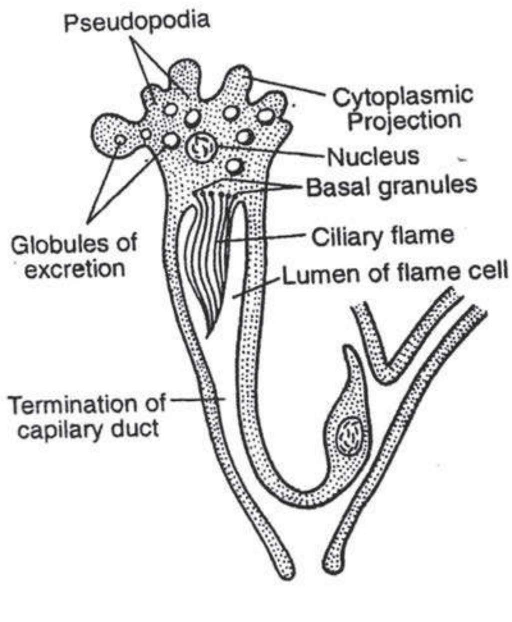


Fig. Structure of a flame cell.

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.

4.3 Classification :

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).

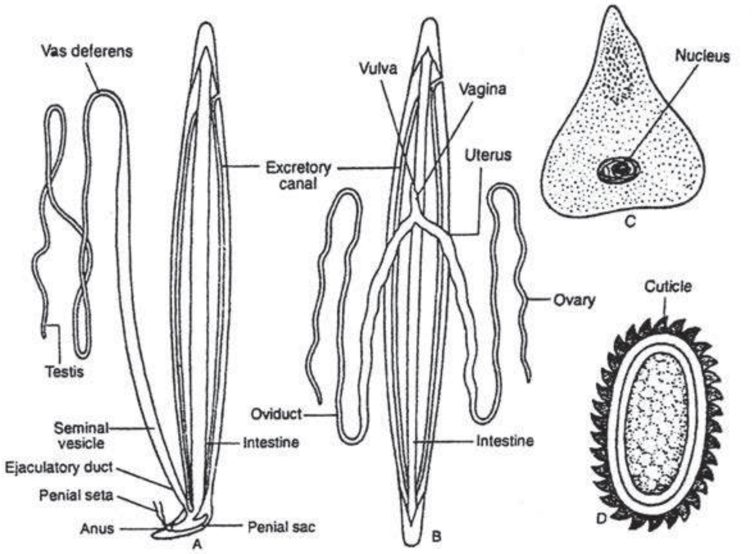


Fig. 3 : A showing the excretory system and male reproductive system of *Ascaris,* B. Female reproductive system of *Ascaris.* C. Spematozoon of *Ascanis.* D. Egg of *Ascaris.*

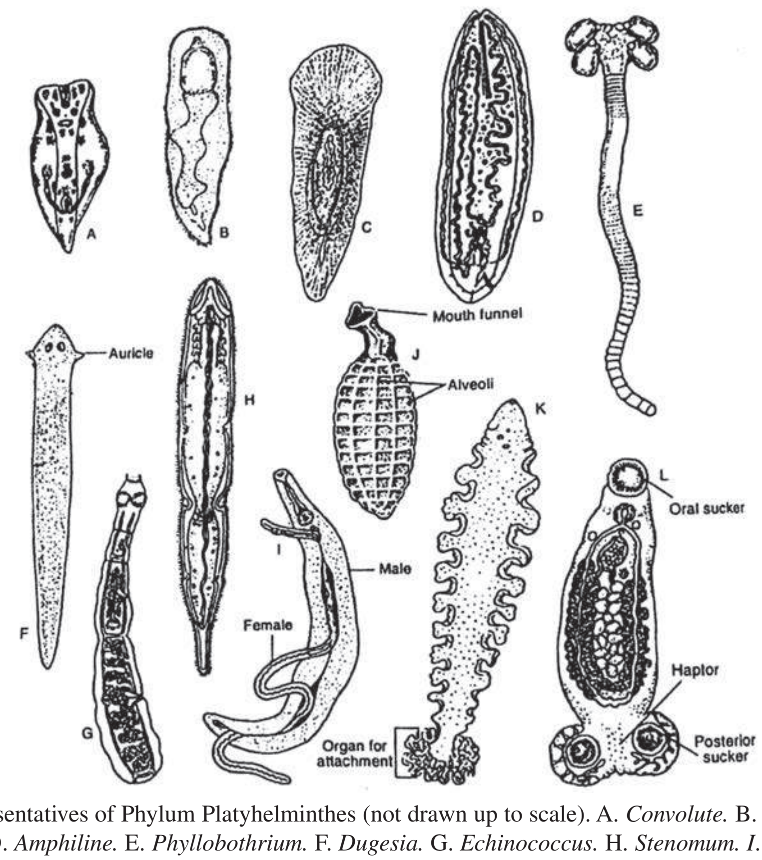


Fig. 4 : Representatives of Phylum Platyhelminthes (not drawn up to scale). A. *Convolute.* B. *Plaglostomum.* C. *Notaplana.* D. *Amphiline.* E. *Phyllobothrium.* F. *Dugesia.* G. *Echinococcus.* H. *Stenomum. I. Schislosoma.* J. *Aspidogaster.* K. *Gyrocolyle.* L. *Sphyranura.*

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.

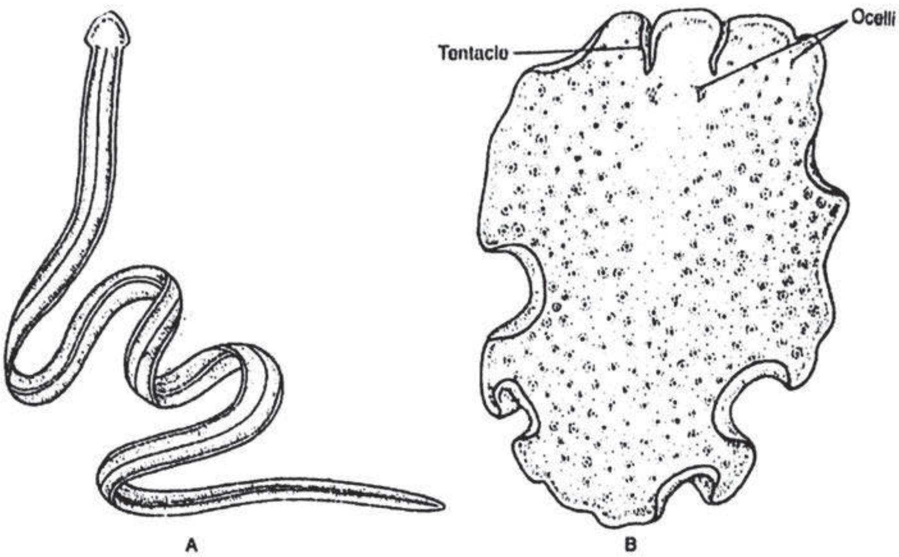


Fig. 5A : A terrestrial triclad flatworm, Bipalium, B. A marino Polyclad flatworm, oligoclado.

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".
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).

4.4 Life Cycle of *Fasciola hepatica*

Fasciola hepatica (L. fasciola = small bandage; Gr. hepar = liver), the **sheep liver fluke**, lives as an endoparasite in the bile passage of sheep. They are called flukes on account of their flat, leaf-like structure. It is the first trematode whose life history was described by A.P. Thomas in 1883. The parasite is of much importance as it causes **fascioliasis** or **liver rot—**a disease that causes immense damage to the liver tissues and bile ducts of sheep. A single sheep may harbour as many as 200 liver flukes in its liver. *F. hepatica* has a cosmopolitan distribution and is common in areas where sheep and cattle are being reared.

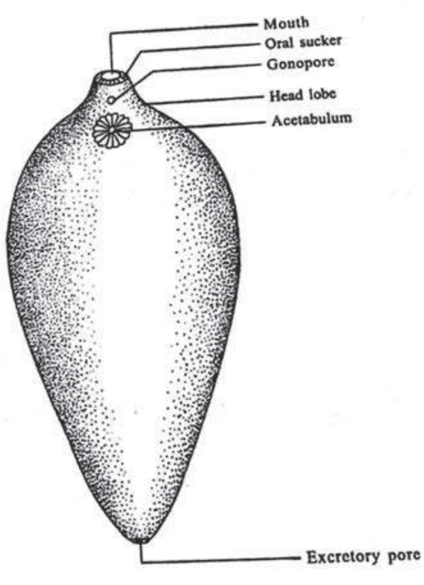


Fig. 6 : *Fasciola hepatica*

The life cycle of *Fasciola hepatica* is completed in two hosts, hence it is called a digentic trematode. The **primary host** of this animal is sheep while the **secondary host** is a snail (gastropod mollusc) of the genus *Limnaea*. Sometimes the adult fluke invade other vertebrates like goat, horse, dog, ass, ox, rabbit, monkey and even man. Development of *F. hepatica* is indirect involving four types of free-swimming and parasitic larval stages between egg and adult. The completion of life cycle depends upon transfer of the parasite from one host to the other. The life cycle can be described under the following headings :

1. **Copulation and fertilization :**

   Fasciola is hermaphrodite (monoecious) but cross fertilization is the rule, and self fertilization is very uncommon. Copulation takes place in the bile duct of the host. During copulation the cirrus or penis of of one worm is inserted into the opening of Laurer's canal of the other individual and the sperms are deposited in the oviduct. The eggs are fertilized by the biflagellate sperm in the lower part of the oviduct and then pass on to the uterus.

2. **Formation of egg capsules and release of eggs.**

   The fertilized eggs are brownish in colour, oval in shape and measure about 130-150 μm in length and 63 to 90 μm in width. The fertilized egg receives a fair amount of yolk from the yolk cells and vitelline secretions. It finally becomes enclosed in a proteinaceous shell or capsule secreted by the shell glands. The shell becomes hard when it enters the uterus. The hardening is caused by the action of quinone. One pole of the egg capsule bears a small lid or operculum for the exit of the future larva. The egg thus bccomes complete and remains for sometime in the uterus. The egg capsule then leaves the fluke's body through its gonopore and passes down the bile duct of the sheep into the intestine, from where eventually it is discharged to the exterior along with faeces of the host.

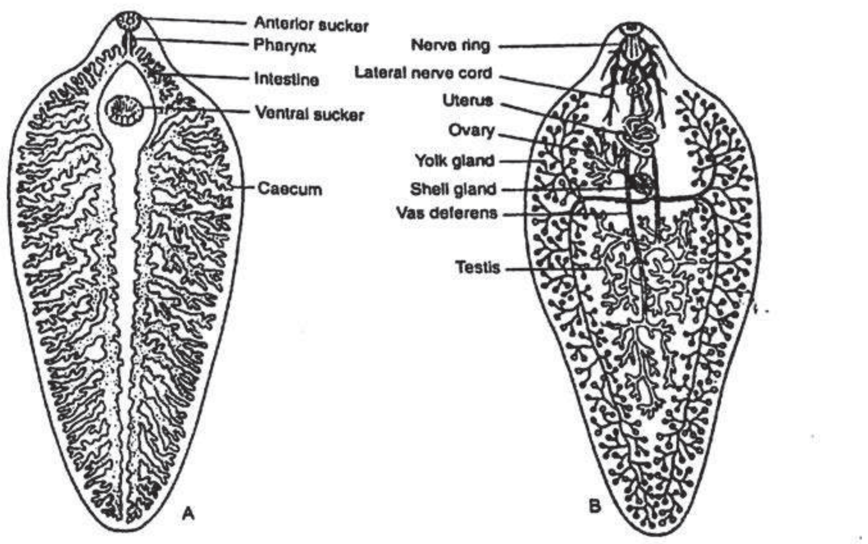


Fig. 10 : Liver fluke. A. Digestive system (after Kaestner). B. Nervous and reproductive systems (major part of the lateral nerve cords is removed).

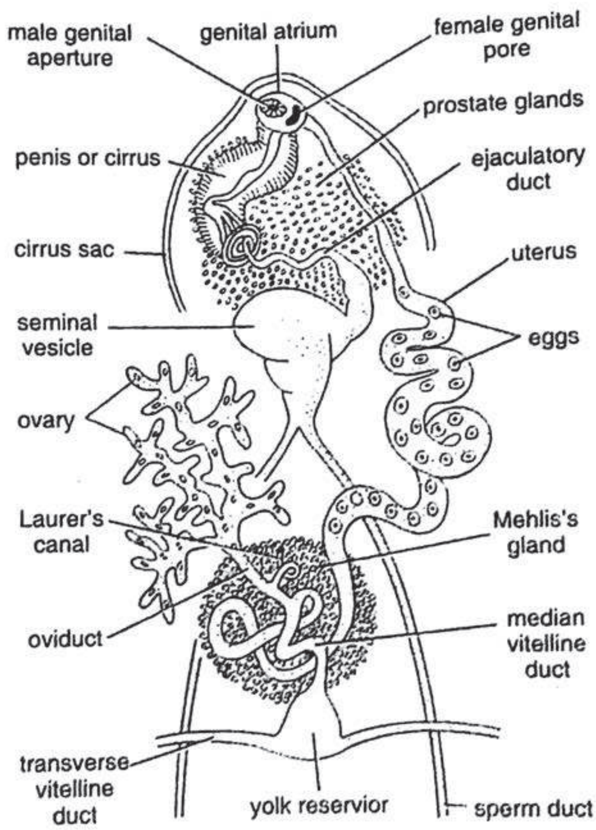


Fig. 8 : *Fasciola hepatica.* Details of male and female reproductive organs in anterior region.

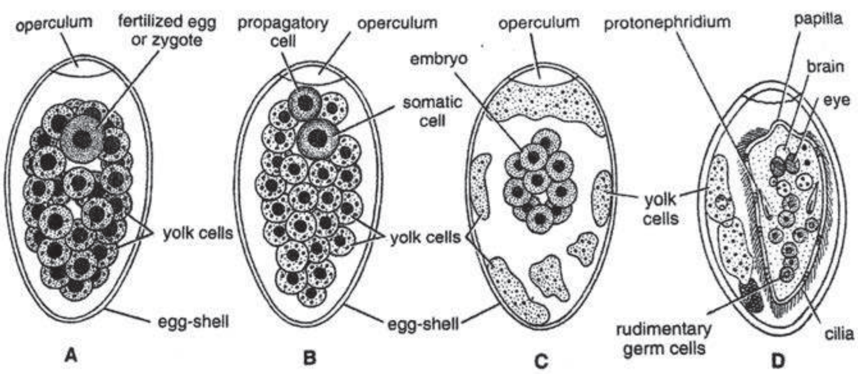


Fig. 9 : *Fasciola hepatica.* Clevage and larva formation. A–Fertilized egg; B–Two cell stage; C–Many cell stage (morula); D–Miracidium.

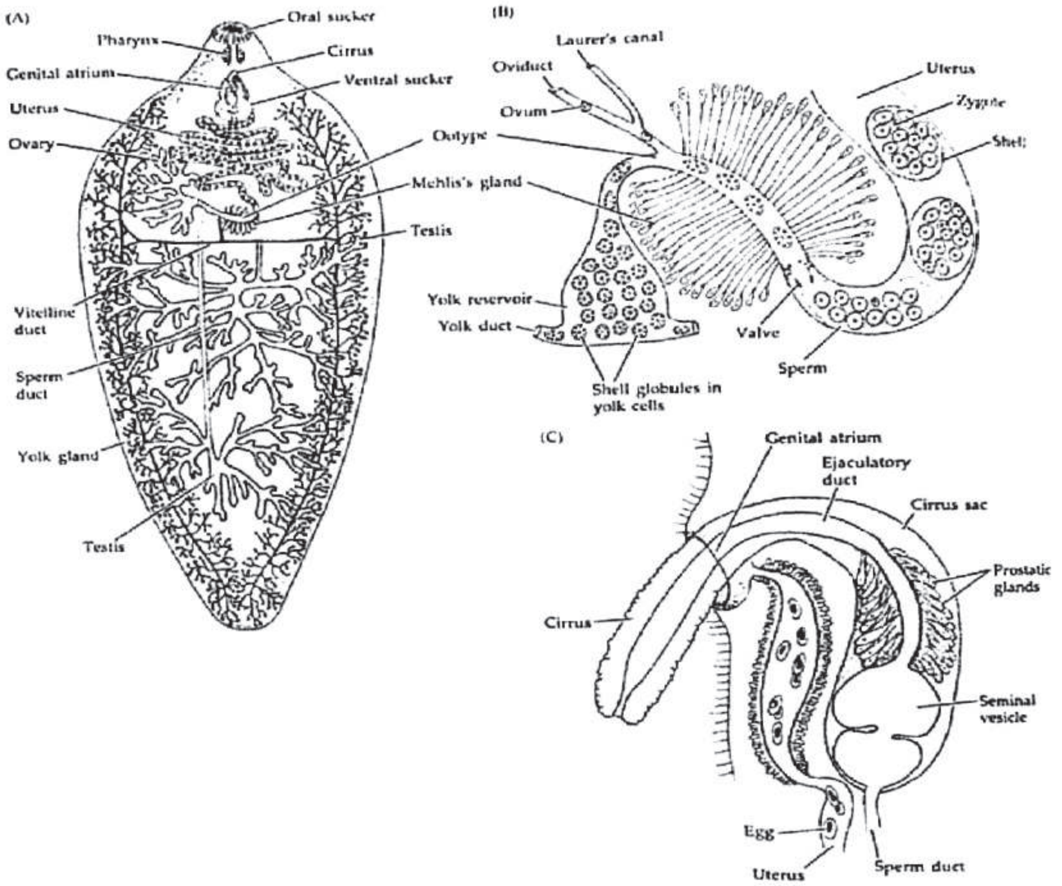


Fig. 10: Fluke reproductive systems. (A) Reproductive structures of fasciola hepatka. (B) The region of the obtype in F. Hepatica. (C) Male copulatory apparatus with cirrus extended.

The egg can survive if only it falls on damp soil or in water.

3. **Cleavage and development :**

Cleavage or segmentation of the fertilized egg starts when the egg remain inside the uterus. The first cleavage is complete but unequal and produces two unequal cells–(i) a small granular **propagatory cell** and (ii) a large **somatic** or **ectodermal** cell. The Somatic cell by repeated divisions lead to the formation of ectoderm of larva. The propagatory cell divides further and forms two group of cells—propagative cells and somatic cells. Somatic cells form the larval body and the propagative cells form a mass of germ cells at the posterior end. Encapsulated embryos or capsules or simply eggs do not develop further in flukes uterus. Further development also remains arrested while the embryos remains in the faeces and they may survive in wet fecal matter for several months. If washed free the development of the embryos proceeds. The optimun temperature for development ranges from 20-30ºC. The encapsulated embrys differentiates into a **micracidium larva** within eight to nine days at 30ºC, but at lower temperatures it may take 3 to 6 weeks. Availability of oxygen is also a factor. The miracicium hatches out of the capsule by forcing off the operculum. The larva produces a proteolytic enzyme which dissolves the cementing material by which the operculum is attached, thus releasing the operculum.

Miracidium larva:

The miracidium is a minute (0.13 mm long) somewhat oval or conical body, covered all over with cilia. The anterior end of the body is broader than the posterior end. The anterior end is produced into a non-ciliated **apical lobe** or **apical papilla** (also known as **head lobe** and **terebratorium**). The apical lobe bears openings of a pouch-like multinucleated **apical gland** and a pair of unicellular **penetration glands** or **cephelic glands.** These glands produce histolytic enzymes that help the larva during penetration in the host tissue. Behind the apical lobe there is a pair of eye spots or pigmented spots situated above the brain. These are considered as primary receptors of the larva. A large *brain* or *nerve ganglion* is situated antero-dorsally near the anterior end. Except the apical lobe the entire body of miracidium is ciliated and is covered with 21 closely fitted hexagonal epidermal plates which are arranged in five rows or tiers (Fig. 11). In the first row there are 6 plates, second

1. First row	—	Six plates (2 dorsal, 2 ventral and 2 lateral)
2. Second row	—	Six plates (3 dorsal, 3 ventral)

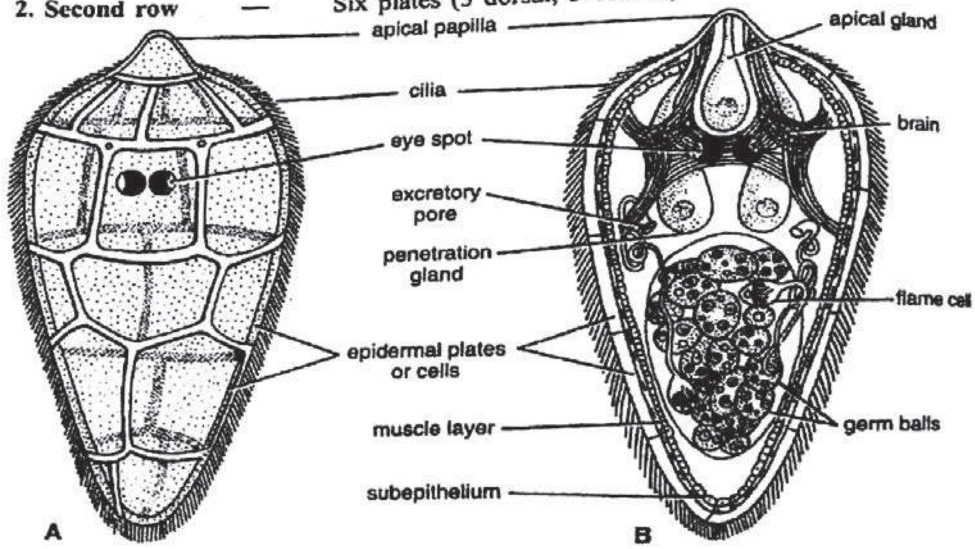


Fig. 11 : ***Fasciola hepatica*. Miracidium larva. A—External structure; B—Internal structure.**

3. Third row	—	Three plates (1 dorsal, 2 ventro-lateral)
4. Fourth row	—	Four plates (2 right, 2 left)
5. Fifth row	—	Two cells (1 right, 1 left)

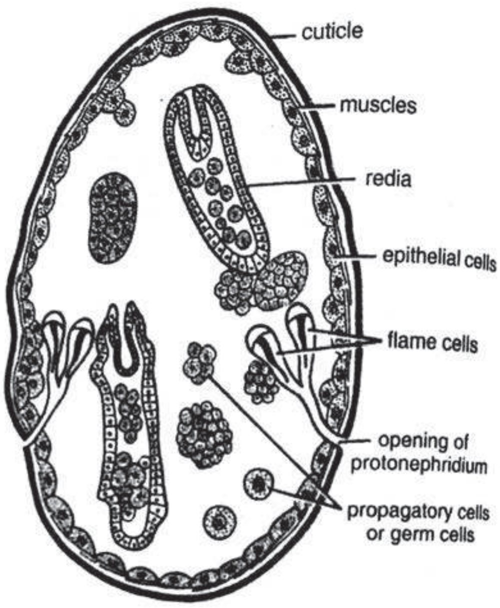


Fig. 12 : *Fasciola hepatica*. Sporocyst.

row also has 6 plates, third row consists of 3 plates, fourth row with 4 plates and fifth row has 2 plates. Within the body just below the epidermis there are delicate layers of circular and longitudinal muscle fibres. In the interior of the body, there is a pair of **protonephridia**, each with two flame cells. The protonephridia open to the exterior by two separate **excretory pores** or **nephridiopores** which are located laterally in the posterior half of the body. Towards the posterior side there are some **propagatory** or **germ cells** (or **germ balls**), which are developing embryos.

The miracicium larva does not feed, it swims freely in water or crawl over damp surface for sometimes. It dies in eight hours unless it can reach a suitable *intermediate* host, which is some species of amphibious snail, of genus *Limnaea* (or even *Bulinus* or *Planorbis*).

After getting a suitable host the miracidium adheres to it by its apical papilla, bores into the body by the operation of the penetration glands through the skin and reaches the internal organs, specially the *pulmonary sac*. From the pulmonary sac the larva penetrates into the body tissues with the help of penetration gland and finally reaches the snail's digestive gland. Within the intermediate or secondary host the miracidium casts off its ciliated epidermis, loses its sense receptors and swells up ans changes its shape to become next larval form, called **sporocyst**.

Sporocyst : This is the second larval stage of *Fasciola*. It is an elongated germinal sac about 0.7 mm long and is covered with a thin cuticle. Below the cuticle, there are circular and lingitudinal muscles and some mesenchymal cells. The hollow interior of the sporocyst has a pair of protonephridia each with two flame cells. It also has some (about 25-40) germ cells or germ balls. The sporocyst moves about the host tissues and its germ cells divide and passess through embryogenesis to give rise to third larval stage, called **radia larva**. Each sporcyst produces 5 to 8 radiae. Some of the germ cells of sporocyst are set aside within the radiae for the development of next larval forms. The radia larvae come out of sporocyst and migrate to the hepatopancreas of the host.

Radia larva : The radia is an elongated (about 1.3 to 1.6 mm in length) cylindrical sac-like larva. It has a small anterior mouth, a muscluar pharynx with unicellular pharyngeal glands and a small sac like gut or intentine. The body wall consists of cuticle, mesenchyme and muscle layers. Near the posterior end there are two ventral porcesses, called **procruscula** or **lappets**. Near the anterior end of the body there occurs a ring like muscular ridge or swelling called **collar**. Collar helps in locomotion of larva. Behind the collar is present the **birthpore**. There is a pairs of protonephridia, each with many flame cells, which open to the exterior through a single nephridiopore on each side. Within the interior of the body there are undifferentiated germ balls. These germ cells give rise to a second generation of **daughter radiae** during summer months, but in winter they produce the fourth larval stage, the **cercaria larva**. Thus, either the primary radia or daughter radia produce cercaria larvae which escape through the birth pore of the radia into the snail tissue. Each radia forms about 14 to 20 cercariae.

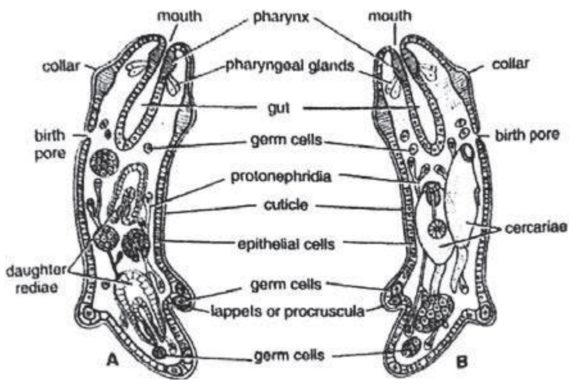


Fig. 13 : Fasciola hepatica. A–Redia with daughter rediae, B–Redia with cercariae.

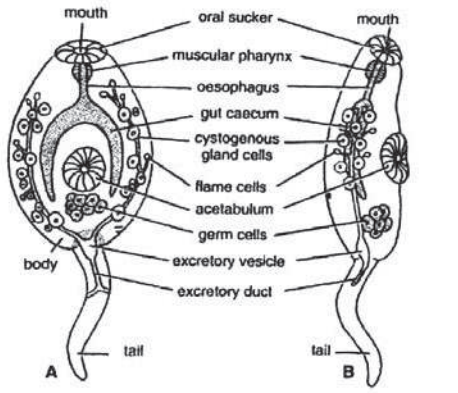


Fig. 14 : Fasciola hepatica. A–Cercarie in vertral view; B–Cercaria in lateral view.

Cercaria larva : The larva is oval in shape with a long contractile tail. It measures about 0.25 mm to 0.35 mm in length. The body is covered with a thin cuticle. Below the cuticle are muscles and cystogenous glands. It has rudiments of organs of an adult. There are two suckers (oral sucker and ventral sucker) and an alimentary canal consisting of mouth, muscular pharynx, oesophagus and a bifid intestine. There is a pair of excretory ducts each with several flame cells. These open near the hind end of the larva into a bladder that leads out through a pair of nephridiopores. Cercaria larva also contains germ cells near the hind end. Rudiments of reproductive organs develop from the germ cells. A large number of unicellular

cystogenous glands are found beneath the cuticle. Secretion of these glands forms the cyst around the larva when it is transformed into **metacercaria**. On maturation the cercariae migrate from the digestive gland of the snail to the pulmonary sac from where they pass out into the surrouding water. The time taken in snail, from the entry of miracidium to the exit of cercaria, is five to six weeks.Cercaria swims about in the surrounding water for sometimes and settles down on the blade of grass or on leaves of some other aquatic weeds or plants. It sheds off tail and a cyst is formed around it. Thus, a metacarcaria representing a juvenile fluke is formed.

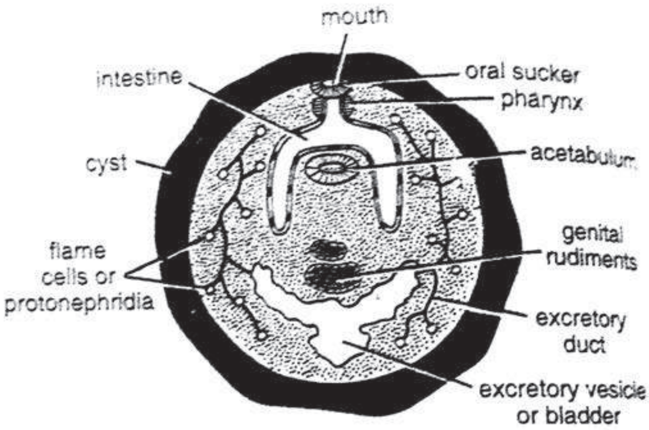


Fig. 15 : *Fasciola hepatica*. **Metacercaria.**

Metacercaria : It measures about 0.2 mm in diameter and somewhat rounded in shape. It resembels cercaria larva but differs from later in the absence of tail, cystogenous glands and presence of a thick cyst wall. Its excretory bladder opens directy through a single pore. The germ cells and genital rudiments are present as such. The cyst provides protection against short periods of desiccation. The cyst wall consists of four layers. The metacercaria on vegetation may survive one year at low temperatures but two to three weeks at 25ºC.

Infection to the final (primary) host : As mentioned earlier, the metacercaria remains attached to blades of grass or leaves of other plants. When the sheep feeds on metacercaria infested leaves or weeds, the metacercaria larva enters the gut. In the alimentary canal of the sheep, the cyst wall is digested and a young fluke emerges out and bores through the wall of the intestine and migrates to the liver through the hepatic portal system. The young fluke stay in the liver for 5 to 6 weeks feeding on its tisues and finally settles in the bile duct and grows into an adult fluke. The sexually mature fluke starts egg laying 12-14 weeks after infection. It can live in host's body for several years and a new cycle begins with the liberation of fertilized eggs.

Pathogenicity of Fasciola hepatica : Infection by *Fasciola hepatica*, the liver fluke is a common occurance in sheep and some other domestic and wild animals feeding on vegetation. In general, the disease caused by the infection of *Fasciola hepatica* is referred to as **fascioliasis**. The effect of the parasite on its vertebrate host

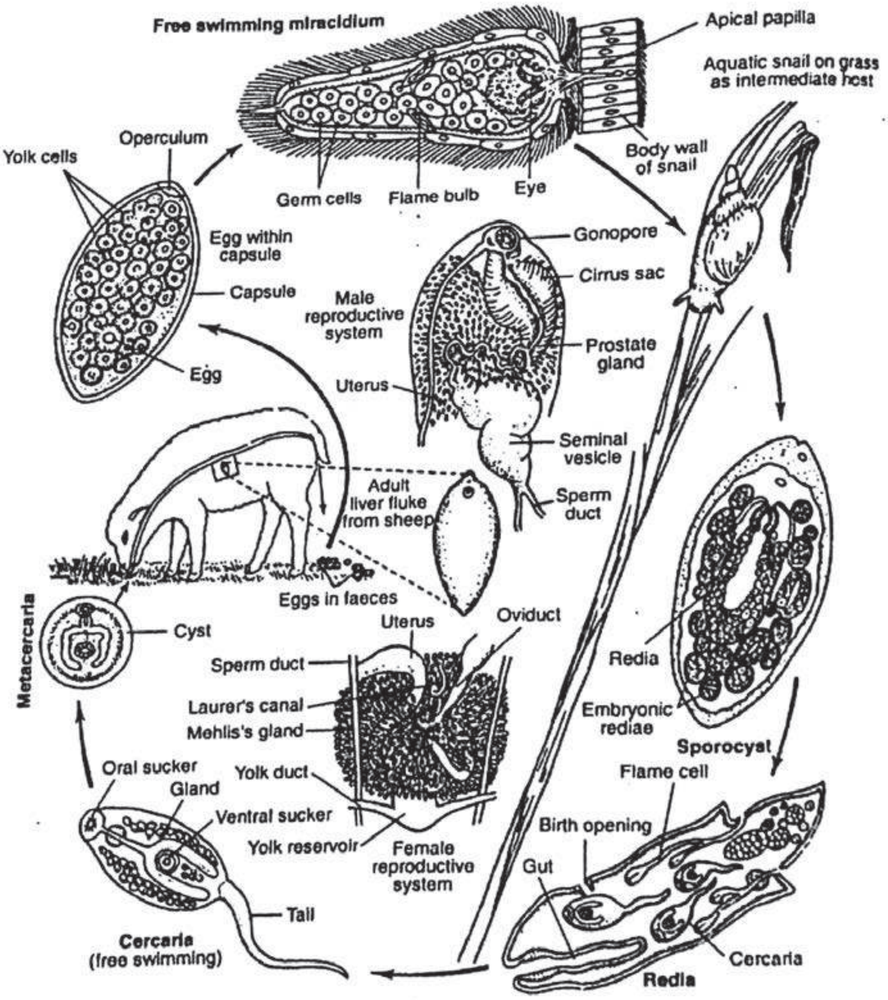


Fig. 16 : Life history of liver fluke (after various sources)

is of significant economic importance and sometimes it may cause a serious economic problem. The animal causes serious damage to the bile duct and liver of its host. During migration of young worms throgh the liver they cause extensive damage to the liver tissue and in heavy infections may lead to portal cirrhosis. This is accompanied by haemorrhage (caused by cuticular spines of the worms), inflamation and loss of parenchyma tissue of liver. Thus during heavy infection the liver fluke seriously affect the liver of sheep, upsetting the normal metabolic functions of liver. The disease thus caused is called **liver rot** or **acute fascioliasis** as it occurs during the pre adult migration of the flukes in the parenchyma of the liver for about 8 weeks.

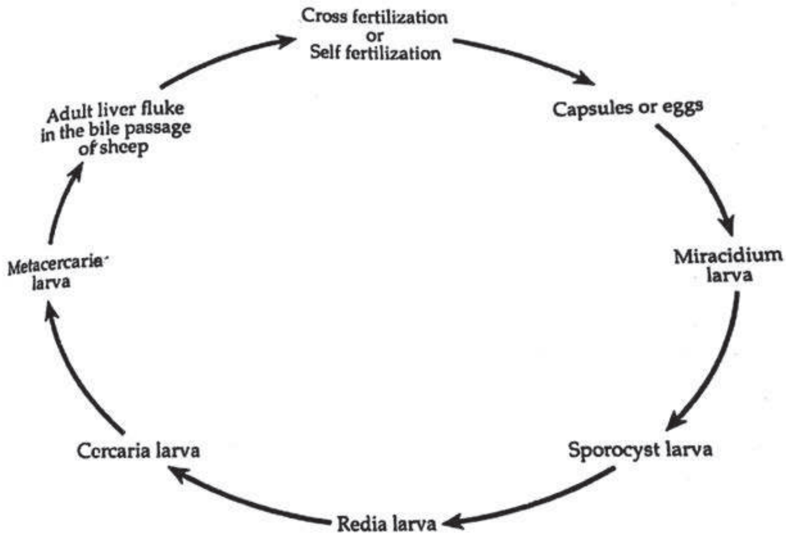


Fig. 17 : Life cycle of *Fasciola hepatica.*

Chronic fascioliasis : occurs beyond 12 weeks, when the flukes have reached the bile ducts and mature sexually. In the biliary passages, they may interfere with normal flow of bile, causing obstructive jaundice. The mature worms cause marked pathological changes in the bile ducts by mechanical irritation as well as by their toxic secretion. The bile ducts become thickend, which is followed by calcification and finally resulting in the formation of gall stones.

Symptoms of liver-rot are more acute in lambs than in sheep, and appear about a month after infection. Frequently death may soon result due to cerebral apoplexy. However, if the host survives few weeks of infection it becomes a victim of acute anaemia due to suppression in production of new red blood corpuscles. Its appetite declines, rumination (chewing the cud) becomes irregular and at times there is fever and increase in respiratory activity. There will be failure to gain weight in young animals, weight loss in older animals, reduced milk production, conjunctiva becomes whitish yellow, wool become dry and brittle and fall off. Large oedemas or swellings appear on jaws. Rarely does the host survive this period. Thus, the infection by *Fasciola hepatica* causes heavy mortality in sheep population.

In addition to cattle and sheep, *F. hepatica* has been reported from horses, goats, rabbits, pigs, dogs and squirrels. Human cases, of fascioliasis are also known. It is especially common in some Caribbean islands and South America, as well as southern France, Great Britain and Algeria. Humans become infected when they eat salads prepared by vegetables, particularly by watercress (eating raw or poorly cooked watercress with attached metacercariae).

It is to be mentiond that infection to the secondary host (snail) also causes partial and complete destruction of the affected site, which is preferably the digestive gland (liver) or gonad. Sometimes the infected snail attains gigantic size i.e. increase in size considerably.

4.5 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**.

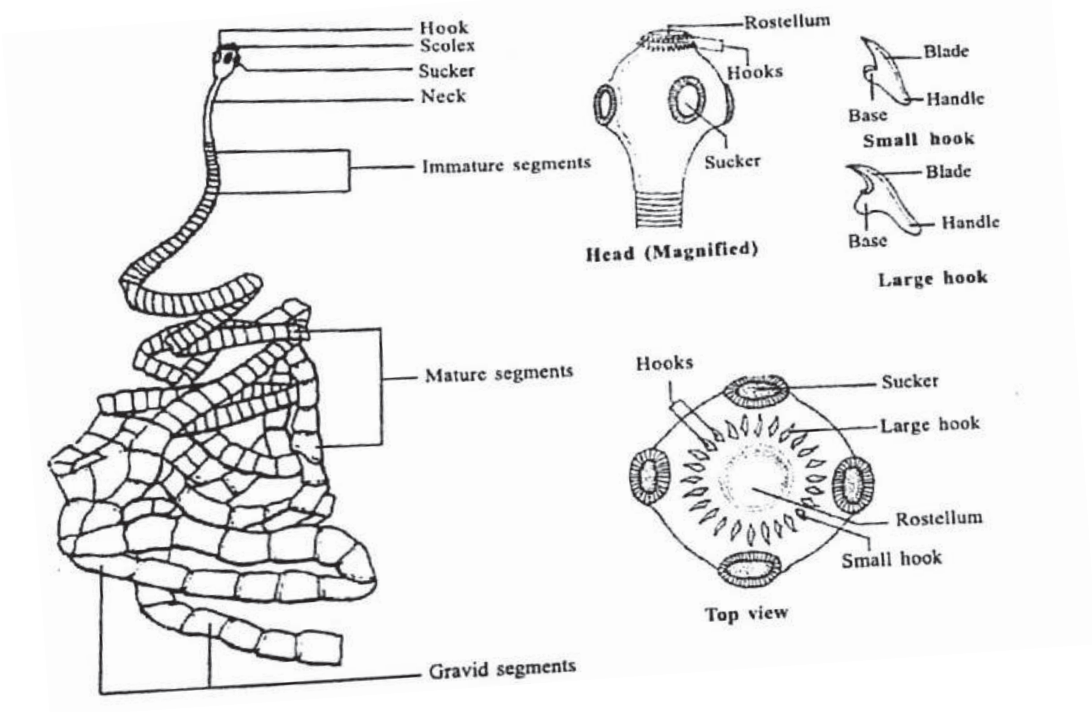


Fig. 18 : Taenia solium. An adult tapeworm.

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

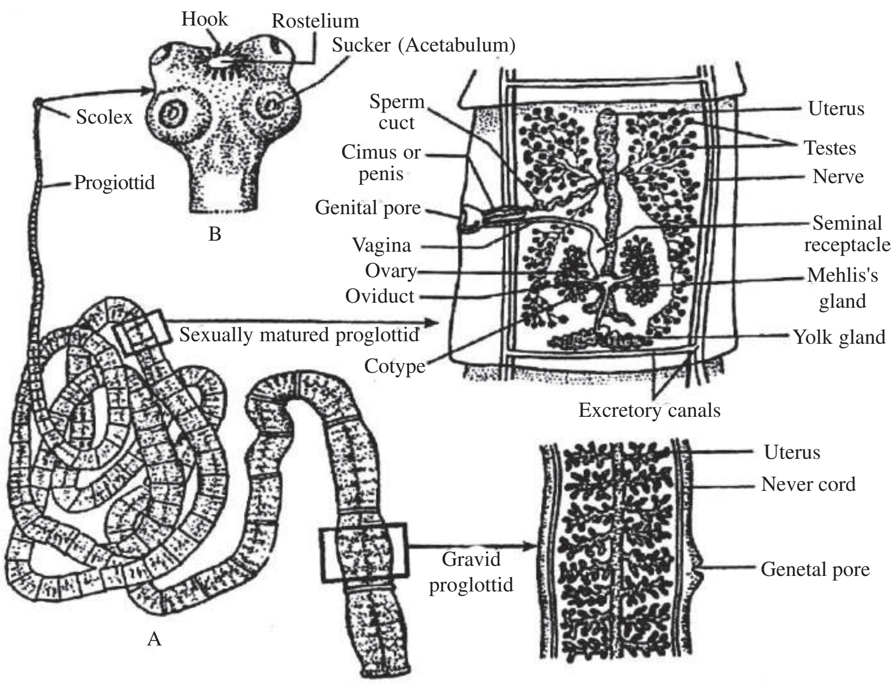


Fig. 19 : *Taenia solium*–entire specimen and enlarged view of different parts (after various sources)

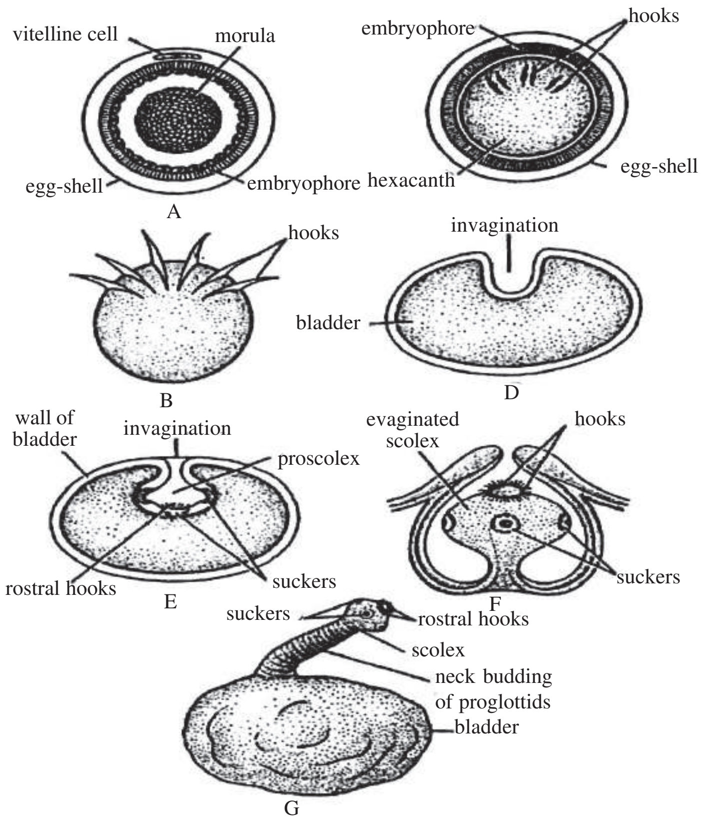


Fig. 20 : *Taenia solium.* Stages in life cycle. A–Young onchosphere; B‘Mature onchosphere; C–Free hexacanth; D–Bladderworm with invagination; E–Bladderworm with proscolex; F–Bladder worm with evaginated scolex; G–Cysticercus with neck budding off proglottids.

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.

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.

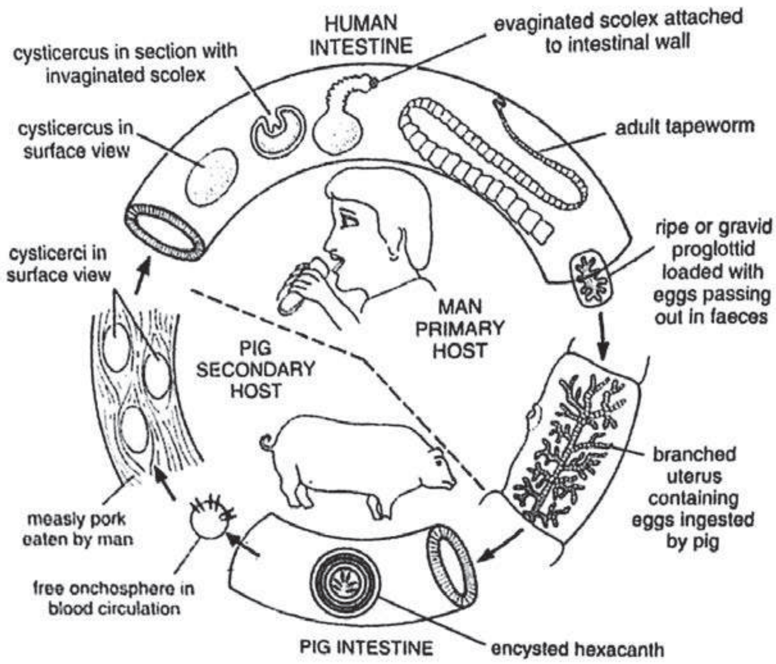


Fig. 21 : *Taenia solium.* Diagrammatic life cycle.

A newly shed proglottid wriggles for sometimes but eventually disintegrates setting 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.

4.5.1 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.

4.6 Questions

a) Describe the excretery system of Fasciola

b) What do you mean by polyembrony?

c) How many larval stages are present in Fasciola?

d) What is scolex?

e) What do you mean by qravid proglotid?

f) Write short notes on

i) Glycocalyex ii) Polyp iii) Prladder worm iv) Proscolex v) Rostellum vi) Hexacanth embryo vii) Heteromorphosis

g) What do you mean by Psendocoèlom?

Unit – 5 ❒ *Ascaris* & *Wuchereria*

Structure

5.0 Objective

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 unusal aquatic environment like hot springs in which the water temperature may reach 53ºC. The parasitic forms dispaly all degrees of parasitism and attack vitually 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 animasl 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.

5.1 Introduction

These animals are commonly known as **Nemathelminthes / Aschelminthes :** Gegenbaur (1859) created a group *Nemathelminthes* to place some groups of psuedocolomate animals. However, Grobben (1910) introduced the term *Aschelminthes* in place of Nemathelminthes. The Aschelminthes (G. askos = cavity; helmins = worm) are a heterogenous assemblage of marine and freshwater animals having some characters in common. These are : (a) possession of non coelomic body cavity, (b) distinctive types of pharyngeal and body wall construction (c) a through gut with a terminal or subterminal anus (d) lack of circulatory system (e) sexes separate (f) absence of asexual reproduction and regeneration of body segments (g) cleavage asymetrical type that is neither radial or spiral (h) determinate type of development (i) absence of a larval stage (j) many species have an invarient and genetically fixed number of cells–a phenomenaon called *eutely*. In eutelic animals, mitosis normally ceases following embryonic development and growth contnues only through increase in size of cells, not through the number of cells. These charcters had led R.S.K. Barnes (1998) to assign Aschelminthes a superphylum status with seven phyla under it. Previous authors like Parker and Haswell (1972), had given the phylum status (consisting of five classes) to Aschelminthes. However, Meglitsch and Schram (1991), Ruppert and Barnes (1994) and other recent authors do no longer consider Aschelminthes as either a superphylum or a phylum. The informal name Aschelminthes, however, is still a convenient terms of referance for the entire assemblage. Ruppert and Barnes, 1994 (6th edition) not only include all eight phylums (**Gastrotricha**, **Nematoda**, **Nematomorpha**, **Rotifera**, **Acanthocephala**, **Kinorhyncha**, **Loricifera** and **Priapulida**) of Meglitsch and Schram (1991), but also the phylum **Tardigrada**. The tardigrades or water bears, traditionally grouped with the arthropods, show evolutionary relationship and aspect of their biology very similar to some aschelminthes. For this reason Ruppert and Barnes (1994) have placed tardigrades under the assemblage of Aschelminthes.

5.2 General Characteristics

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.

5.3 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)

5.4 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.

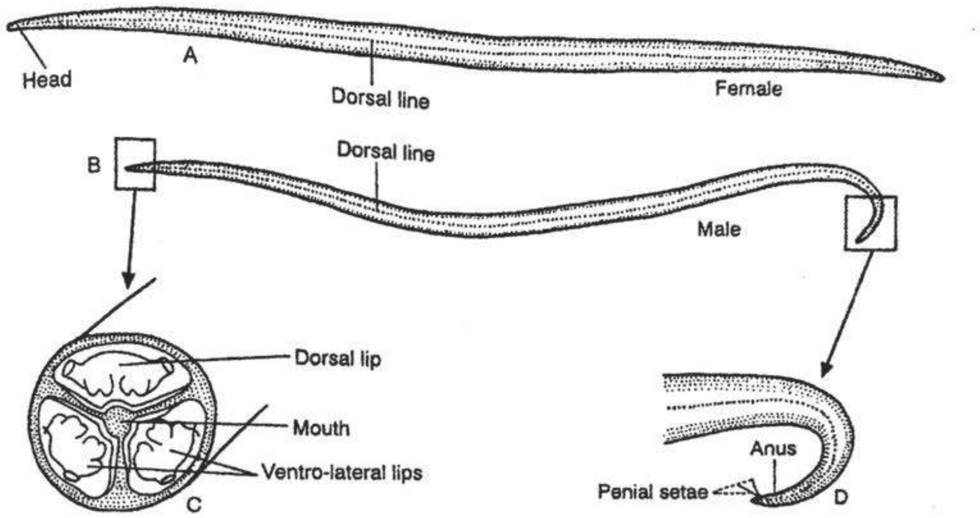


Fig. 1A : External features of *Ascaris* (after various sources). A. Male. B. Female. C. Enlarged view of head end. D. Enlarged view of posterior end of male.

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

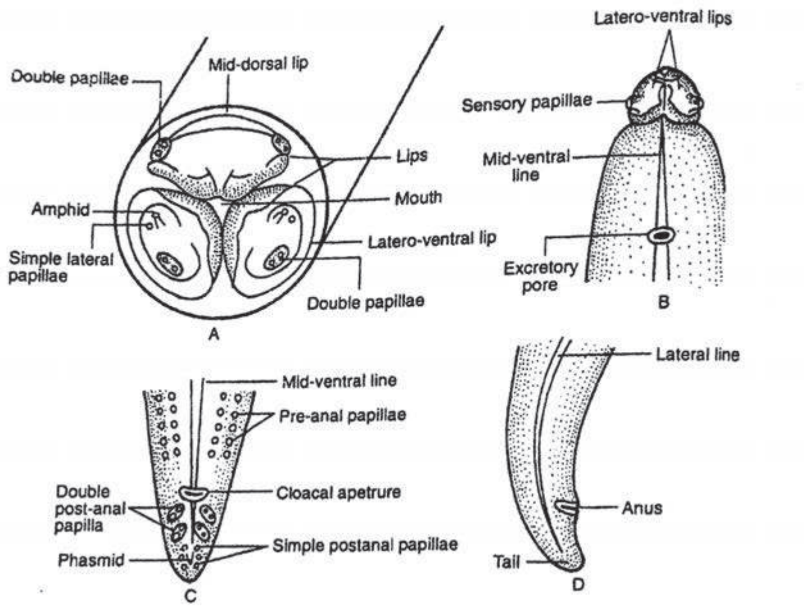


Fig. 1B : External features of *Ascaris*. A. Enlarged view of head end. B. Anterior end in ventral view. C. Posterior end of the male (Ventral view). D. Posterior end of a female.

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).

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.

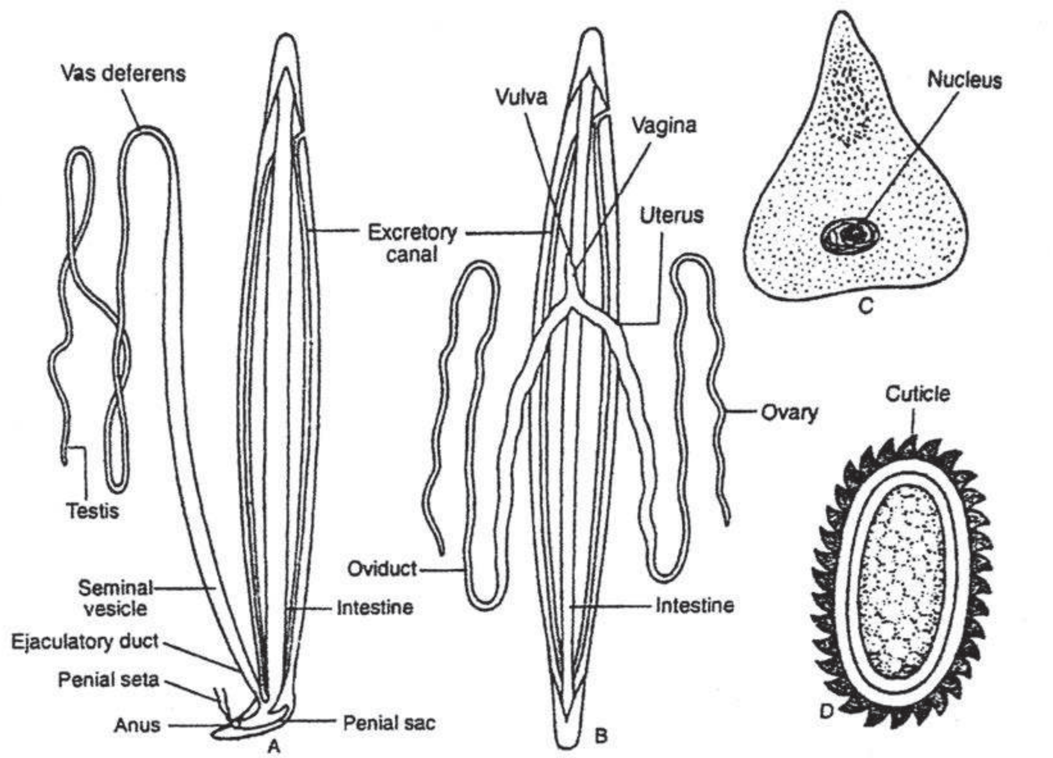


Fig. 2 : A. Showing the excretory system and male reproductive system of *Ascaris*. B. Female reproductive system of *Ascaris*. C. Spermatozoon of *Ascaris*. D. Egg of *Ascaris*.

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.

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

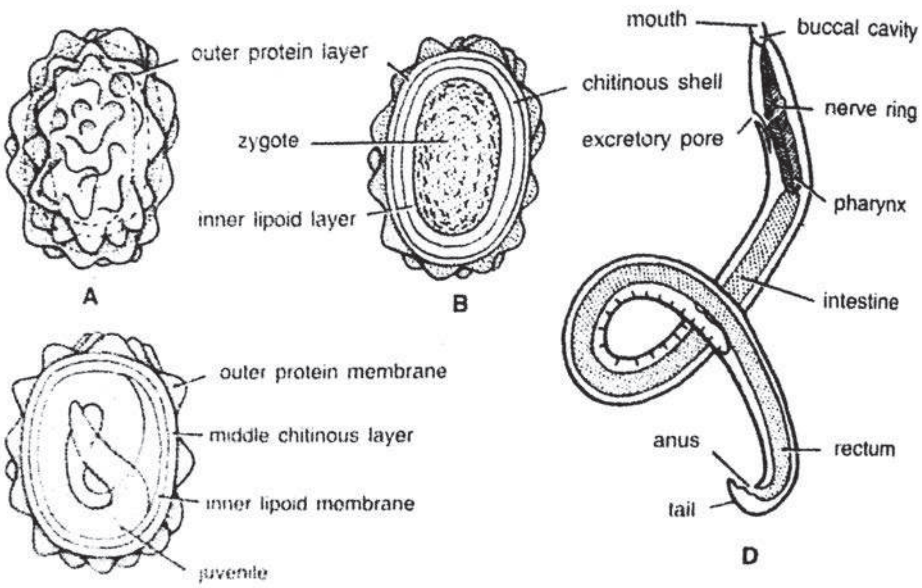


Fig. 3 : *Ascaris* A—An entire mammilated egg; B—T.S. of a mammilated egg; C—Embryonated egg in section; D—Rhabditiform larva.

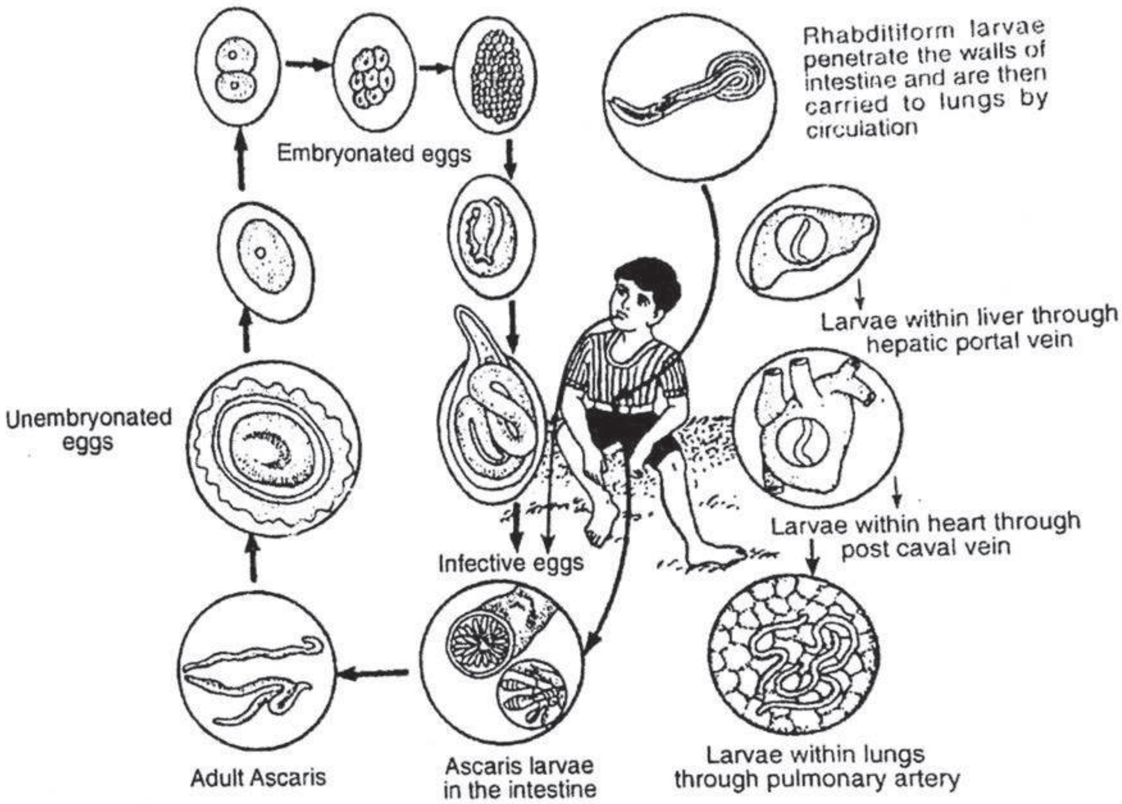


Fig. 4 : Life cycle of *Ascaris lumbricoides*.

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

5.4.1 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.

5.5 Life Cycle of *Wuchereria bancrofti* (Filarial worm)

Systematic Position :

Phylum	:	Nematoda
Class	:	Secernentea or Phasmida
Order	:	Filarioidea
Genus	:	*Wuchereria*
Species	:	*bancrofti*

Wuchereria bancrofti is a widely distributed human parasitic roundworm, lives in the lymphatic vessels and lymph nodes of human and causes **lymphatic filariasis** or **Bancroft's filariasis**. It is one of the three parasitic nematodes, together with *Brugia malayi* and *B. timori*, that infect the lymphatic system to cause lymphatic filariasis. These filarial worms are spread by a variety of mosquito vectors. *W.bancrofti* is the most prevalent of the three and affects over 120 million people, primarily in central Africa and the Nile Delta, Turkey, India, South East Asia, the Philippines, many Pacific islands, Indonesia, Australia, the Caribbean islands and parts of South America.

Wuchereria is a digenetc parasite completing its life cycle in two hosts. The definitive host is human harbouring the adult worms while the intermediate host is a blood sucking insect, the female mosquito of the genus *Culex pipiens* (in India).

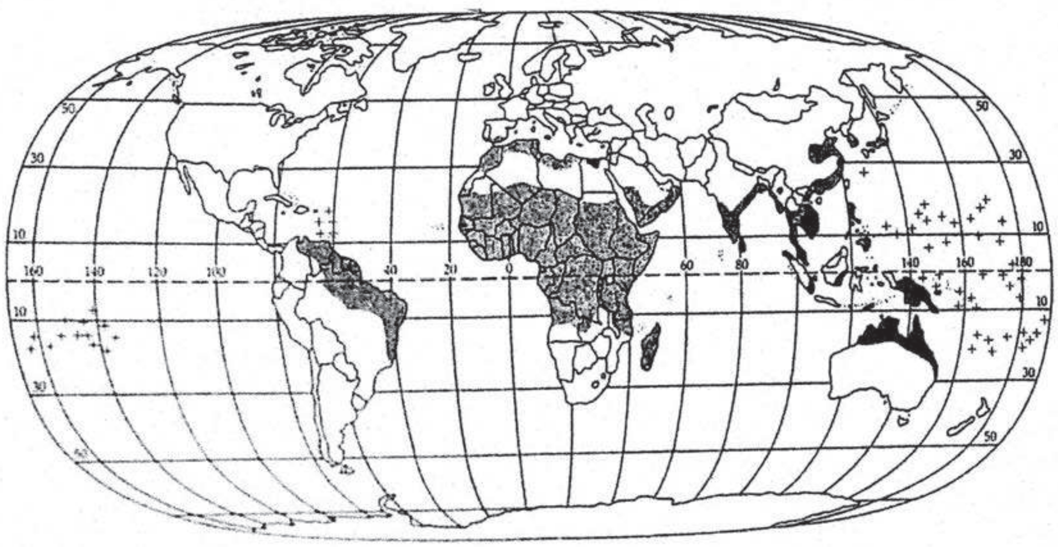


Fig. 5 : Distribution of *Wuchereria bancrofti.*
(+Islands, black areas, concurrent Brugia *Malayi)*

Unlike the malaria organisms, filarial worms show little specificity in regard to mosquito hosts. *W. bancrofti* can utilize *Culex* spp. *Aedes*. spp., *Mansonia* spp. *Anopheles* spp. and *Psorophora* spp. as vectors equally well (Cheng 1986).

As a dioecious nematode *W. bancrofti* exhibits sexual dimorphism. The adult worms are long, cylindrical with both ends terminate bluntly. They are creamy white in colour or almost transparent. Males and females can be differentiated by size and shape of their tail tips. The males are smaller measuring 40 mm in length and 0.1 mm in diameter. The tail is curved and carries two spicules of unequal length. It also contains number of genital papillae or caudal papillae. Females are 80-100 mm in length and 0.24-0.30 mm in diameter. Its tail gradually tapers and rounded at the tip. No additional sensory structures are seen. The valva or genital pore lies ventrally towards the anterior part in the pharyngeal region and is provided with a pyriform ovijector. Adult males and females are most often coiled together and are difficult to separate. Females are ovoviviparous and lay eggs containing well developed larvae. The hatched larvae or juveniles are known as **microfilariae** (Fig. 6). Though they are commonly called microfilaria larvae but they should appropirately be termed embryo (Cheng 1970) becasue their internal organization represents an early developmental stage and they are also not comparable to other nemtode larvae.

Life Cycle : The stages in the life cycle of *Wuchereria bancrofti* are depicted in Fig. As mentioned earlier the life cycle of this parasite is completed in two hosts (digentic). The primary or definitive host is human being and the secondary or intermediate host is female mosquito belonging to genus *Culex, Aedes and Anopheles. Culex quinquefasciatus (Culex fatigans)* and in some places a closely related species *Culex pipiens* play a leading role as vectors in different parts of the world.

Life cycle in human beings : The adult parasites resides in the lymphatics of the human host. They are found mostly in the afferent lymphatic channels of the lymph glands in the lower part of the body. The adult males measure 40 mm in length and 0.1 mm in diameter, while the adult females are 80-100 mm in length and 0.24-0.30 mm in diameter. Copulation takes place when individuals of both sexes are present in the same lymph node or lymphatic vessel. Adult males and females are most often coiled together. Females are ovoviviparous i.e. lay eggs with well deveolped larvae or juveniles. Each gravid female gives rise to numerous (about 1000) minute larvae or juveniles called **microfilaria** which are surrounded by delicate membranes or sheaths and measure 127-320 μm long. They are born in a very immature state. They are colourless and transparent when living. Body of a microfilaria consists of a surface covering of flattened epidermal cells and an inner column of cytoplasm containing nuclei. Important structures from anterior end to

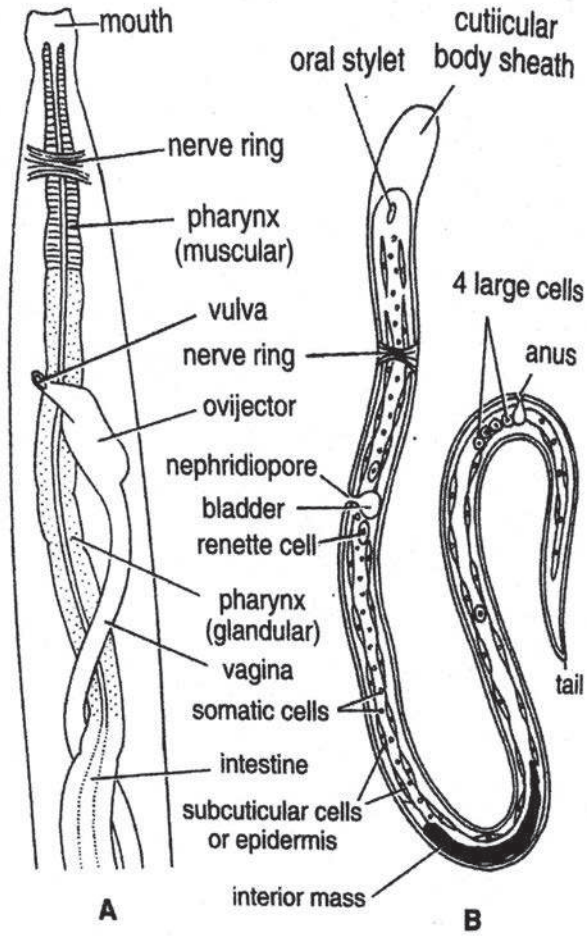


Fig. 6 : ***Wuchereria bancrofti*. A—Anterior part of female; B—Microfilaria.**

backwords are : future mouth or oral stylet, nerve ring, nephridiopore, renette cells, darkly staining inner mass, 4 large cells (G-1, G-2, G-3 and G-4) and future anus (Fig. 6). The caudal end is pointed and without nuclei.

The microfilariae, discharged into lymph vessels, soon enter blood vessels and circulate with blood showing active movements. These larvae are unable to develop futher in human body unless they are sucked up by the intermediate host, the female mosquito. If they are not ingested by mosquito they will die within 70 days (Rao 1933). In order to infect mosquitoes there must be about 15 or more microfilarie per drop of blood, a high concentration of 100 or more per drop of blood is fatal to mosquitoes.

Life cycle in mosquito : The microfilaria are sucked up by the mosquito (*Culex pipiens*/*Culex fatigans*) along with blood meal. The larvae pass to the midgut of the insect and lose their sheaths or cast off their sheaths quickly, penetrate the gut wall within an hour or two and migrate to the thoracic muscles. Here they rest and begin to grow. In the next two days the slender, snake-like organism changes to a thick, short sausage-shaped form with a short spiky tail, measuring 124 to 250 µm in length and 10 to 17 µm in breadth. This stage of development represents the **first larval stage**. It possesses a rudimentary digestive tract. Within 3 to 7 dyas the larva grows rapidly, molts (shed cuticle) once or twice and at the end of this stage measures 225 to 330 µm in length and 15 to 30 µm in breadth. This stage represents **second stage larva**. On 10th or 11th day the metamorphosis becomes complete within muscle. The tail atrophies to a mere stump and the digestive system, body cavity and genital organs are now fully developed. This is the **third stage larva** which measures 1500 to 2000 µm in length and 18 to 23 µm in breadth. At this stage the larva is infective to man and migrates to the proboscis sheath of the mosquito on or about 14th day. There may be several larvae remaining coiled up, waiting for an opportunity to infect human host while the mosquito is having its blood meal. The time taken for the complete developement of microfilaria in the mosquito varies from 10 to 20 days or more, depending however on the atmospheric temperature, humidity and also to a certain extent, on the species of the mosquito.

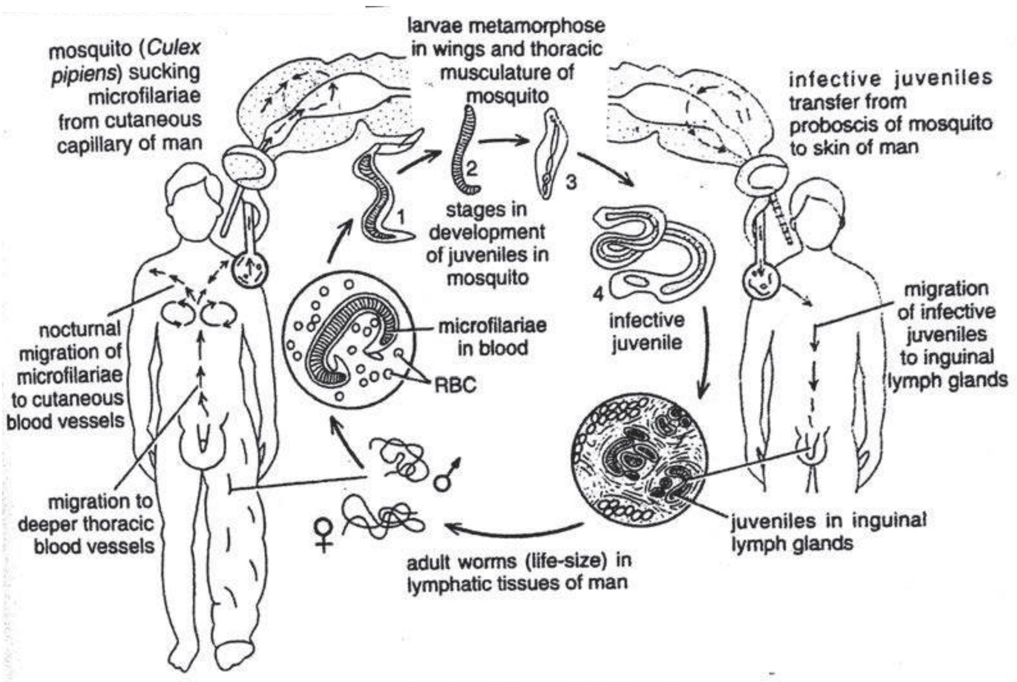


Fig. 7 : *Wuchereria bancrofti*. Life cycle.

Infection to human and development into adult worms : When the infected mosquito bites a human being, the third stage larvae are not directly injected into the blood stream like malarial parasites but are deposited on the skin near the site of puncture (the larvae creep out of the labium to the human skin). Later attracted by the warmth of the skin, the larvae either enter through the puncture wound or penetrate through the skin of host. Unlike the malaria parasites, filarial worms show little specificity in regard to mosquito hosts. *W. bancrofti* can utilize *Culex* spp. *Aedes* spp, *Mansonia* spp., *Anopheles* spp., *Psorophora* spp. as vectors eqully well (Cheng, 1986)

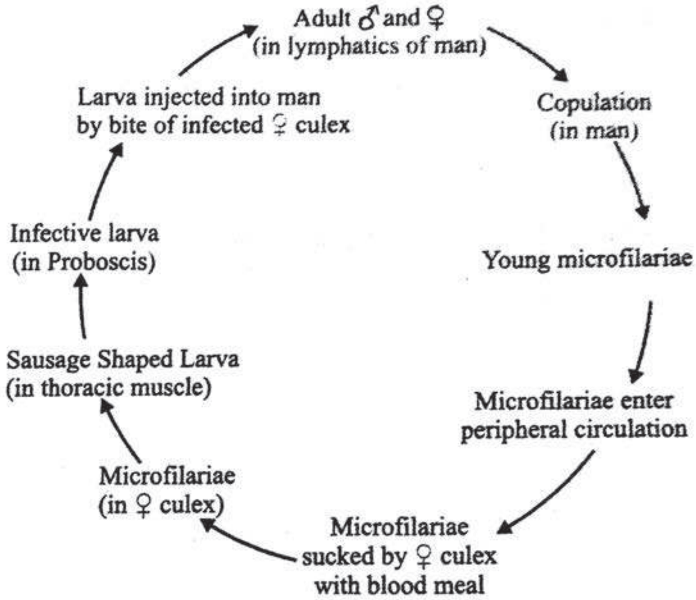


Figure - 8 : Life cycle of *W. bancrofti.*

The third-stage larvae (infective larvae) after entering through skin, reach the lymphatic channels, settle down at some spots (inguinal, scrotal or abdominal lymphatics), and begin to grow into adult forms. In course of time, probably after a period of 5 to 18 months they become sexualy mature. The male fertilizes the female and the gravid females releases the new generation of microfilariae which passess either through the throracie duct or the right lymphatic duct, to the venous sysem and pulmonary capillaries and then to the peripheral circulation (capillaries of the systemic circulation), thus completing the life cycle.

Nocturnal and diurnal periodicity : The phenomenon of **nocturnal periodicity**– that is occurence of microfilariae in the peripheral circulation of the host at night–

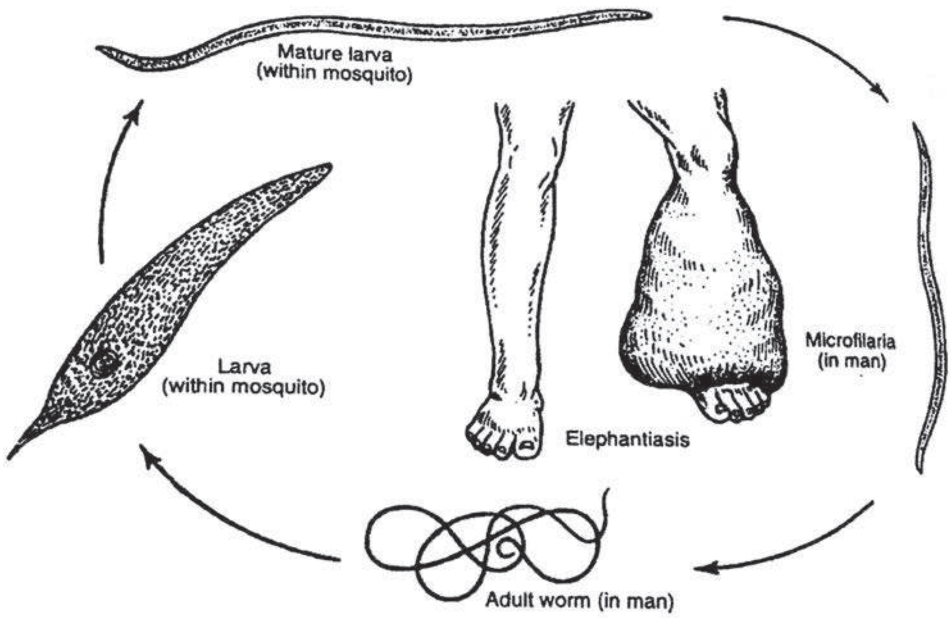


Fig. - 9 : Life cycle of *Wuchereria bancrofti* (after Storer and Usinger).

has been reported in most instances. The microfilariae of *W. bancrofti* of oriental countries (periodic strain) exhibit periodical appearance in the peripheral blood at night mostly between 10 p.m. and 4 a.m. thus showing **nocturnal periodicity**. It has been reported that during daytime they retire principally inside the capillaries of lungs, kidneys, heart and the big arteries, such as carotid. The evolution of microfilarial periodicity is of survival value, for it enhances chances for the ingestion of microfilariae by the insect vectors.

Interestingly, the so-called Pacific strain of *W.bancrofti*, unlike the periodic strain, exhibit a certain degree of **dirunal periodicity**. Here the microfilariae appear in greater numbers in the peripheral blood during the day. The South Pacific strain is said to be *subperiodic*. This opposite rhythmic pattern coincides with the feeding habit of its mosquito vectors, *Aedes pseudoscutellaris, Aedes polynesiensis*, etc. which feed on day time.

Several hypotheses have been contributed to explain nocturnal periodicity. (1) There is chemotactic attraction between the microfilariae and the saliva of mosquito hosts (vectors), which are more plentiful at night. (2) The relaxation of the host during sleep induces the microfilariae to migrate into the peripheral circulation. (3) The migration results from a response to oxygen and carbon dioxide supply. (4) The microfilariae sruvive for only a short period, and it is during the nocturnal period that they are most abundant and are readily found in the peripheral circulation. None of these hypotheses is completely satisfactory (Cheng 1986).

5.5.1 Pathogenicity of *Wuchereria*

Wuchereria bancrofti is one of the classic cousative agents of *elephantiasis* in human. Elephantiasis is also known as *filariasis* or *Bancroft's filariasis*. Pathology in *W.bancrofti* infection is due largely to living, dead and degenerating adult worms. Blocking of the lymph vessels by large number of worms results in serious short-term hymphatic inflamation and edema marked by pain and fever. Over a long period, the accumulation or deposition of connective tissue cells and fibres contributes to terrible enlargement of the legs, scrotum, breast and other extremities. Such enlargement is called **elephantiasis** (Fig. 10).

Pathogenesis in filariasis is heavily influenced by the immune responses and the degree of inflamation. Clinically, the deisese can be divided into **incubation, acute** (or inflamatory) and **obstructive** (chronic) phases. The incubation phase is largely asymptomatic and may last for a year or more. Symptoms that do appear are usually mild and may include low-grade fever caused by lymphatic inflamation. This phase lasts until the first microfilariae appear in the blood.

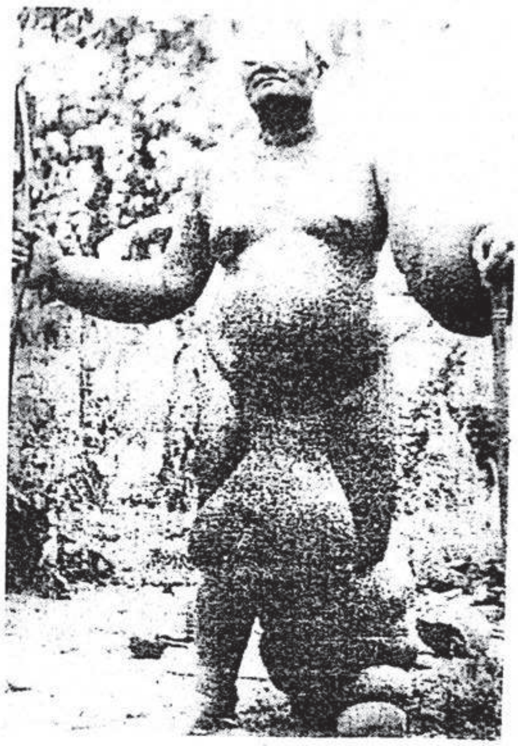


Fig. 10 : South Pacific native severely affected by Bancroft's filariasis.

The acute phase is initiated when the females reach maturity and begin to release microfilariae. This phase is actually an allargic response to the products of dying and degenerating adult worms and is characterized by intense inflamation of the lymph areas usually in the lower parts of the body of patient. In males, scrotum is frequently affected. Chills, fever and toxemia, accompanied by localized swelling in the arms and legs, may persist for days, and/or recur at frquent intervals.

The obstructive phase is characterized by blockage of lymph flow resulting from acute granulomatous response in the lymphatic system to dead and degenerating adult worms. This phase eventually lead to the condition known as elephantiasis. However, only about 10 percent of the inflected population manifests this chronic condition. Elephantiasis is rarely seen in people less than 25 years old and is more prevalent in people older than 40.

The injurious influence excited by the adult worm and developing larva on its host is an inflamentaroy reaction of the lymphatic system, known as **lymphangitis** which forms the basic lesion in classical filariasis. Lesion in occult filariasis is caused by microfilariae and is found not only in the lymph nodes but also in lungs, liver and spleen.

The metabolites of the growing larvae in highly reacting individuals may give rise to allergic mainfestation such as urticaria, "fugitive swellings" (painful, tender, red areas of the skin at the extrimites) and lymphoedema.

5.6 Parasitic adaptation in helminthes

The term helminthes is derived from Greek word "Helmins" meaning worms. The term is not correct because it is applied to all elongated invertebrates without appendages and with bilateral symmetry. The term helminthes is restricted to a few phyla of invertebrate animals all of which are superficially worm like but they differ markedly in their morphology, life history and binomics. The helminthes ae restricted to three phyla of animal kingdom. These are :

1. Platyhelminthes (flatworms)
2. Nemathelminthes (round worms)
3. Acanthocephala (spiny headed worms)

Parasitism is an association of two organisms of different sizes and differeent species, in which the smaller organism **(the parasite)** is benefited and the larger organism (the host) is harmed.

Adaptation to environments is one of the most important and dynamic features of living organisms. Adaptation may be defined as the fitness of an organism to live in its specific habitat or environment. The term is also applied to "the process of adjustment involved and to a characteristic that so adjusts an animal." Of the different categories of adaptation, parasitic adaptation is important since it presents a peculiar condition in which a fortituous freeliving existence is altered to one in which protection from enemies and a good supply of food are guaranteed. The main changes that occur in the structure and life cycle of a parasite with the help of which it is capable of leading a parasitic life successfuly in its specific environment is called *parasitic adaptation*. This parasitic adaptation has brought about profound modifications in helminthes.

Parasitism undoubtedly began as a chance of contact of one organism with another. Sooner or latter the guest began to partake the food produced by the host, becoming more and more dependent on such food and shelter and finally transformed into either an ectoparasite (outside the body of host) or an *endoparasite* (within the body of the host).

The helminthes are modified morphologically, anatomically as well as physiologically to live in their particular environments of host body. The structural and functinal modificatious in parasites depend on the degree of parasitism.

A. Morphological adaptations : Though helminthes come at the bottom of organ grade organization of animals, yet every part of the body of a helminth parasite exhibit twist due to parasitic mode of life. The structural modifications or adaptations of helminthes have taken place along two distinct directions–

(a) Degeneration or loss of organs or organ system/s. (b) Attainment of new organs.

(a) Degenerations : The endoparasites undergo loss or simplification of unused organs or parts. In helminthes loss or degeneration involves particularly the locomotory, digestive and the sensory organs

1. **Organs of locomotion :** Locomotion is actually an effort for procuring food, getting, mate and escaping from enemies. But the helminth endoparasites habitually inhabit such places in the host's body where sufficient food is available without effort. They need no protection from enemies. Hence total reduction of locomotory structures is observed in adult except in the free-

living larval forms of parasites–miracidium possesses cilia and cercariae possess tail for locomotion.

2. **Alimentary canal or organ of nutrition :** Since the helminth parasites consume digested or semi-digested food or body fluid of the host, the alimantary canal and digestive glands are partly or wholly lost. In the adult trematodes there is an incomplete gut, in adult tapeworm (cestodes) there is total disappearance of alimentary canal. In cestodes the food is readily availabe in the gut of the host. Stages such as rediae in lymph spaces of molluscs, microfilariae in blood vessels and *Trichinella and cysticercus* larva in vertebulate muscles occur in such locations that they are constantly surrounded by rich nutritious food, which is absorbed through the outer sruface of their body.

3. **Sensory organs :** The sensory organs, necessary for quick and efficient response to the stimuli are associated with free active life. In the host body the enviroment is more or less uniform and so the sense organs are not essential. Hence in helminthes they are either reduced or absent. In trematodes, sense organs are absent but are generally provided with tangoreceptors (bulb like nerve endings sensitive to touch and pressure). Nematodes have reduced or poorly developed sensory organs on the lips (amphids) and on the tail (phasmids). There are no sense organs in cestodes. Absence of complicated sensory structures can also be correlated to sedentary life in a sheltered habitat, espcically endoparasites.

4. **Circulatory system and respiratory system :** Circulatory system is absent because circulatory system is primarily meant for transporation of nutrients that is not required by the parasites. Similarly due to living in internal envirnoment without oxygen the helminthes, like other endoparasties, exhibit anaerobic respiration.

(b) New attainment or Specializations : Parasitic existence of helminthes (like other endoparasites) leads to modification of old structures and attainment of new structures helpful in food absorption, protecion, attachement and vast reproduction.

1. **Body form :** The body form of parasites is such that they offer least resistance to the fluids of the host otherwise they might be explled out, e.g. *Fasciola* is dorsoventrally flatened and leaf-like, *Schistosoma* is thin and cylindrically elongated. *Taenia* is very elongated like a ribbon and dorsoventrally flattened.

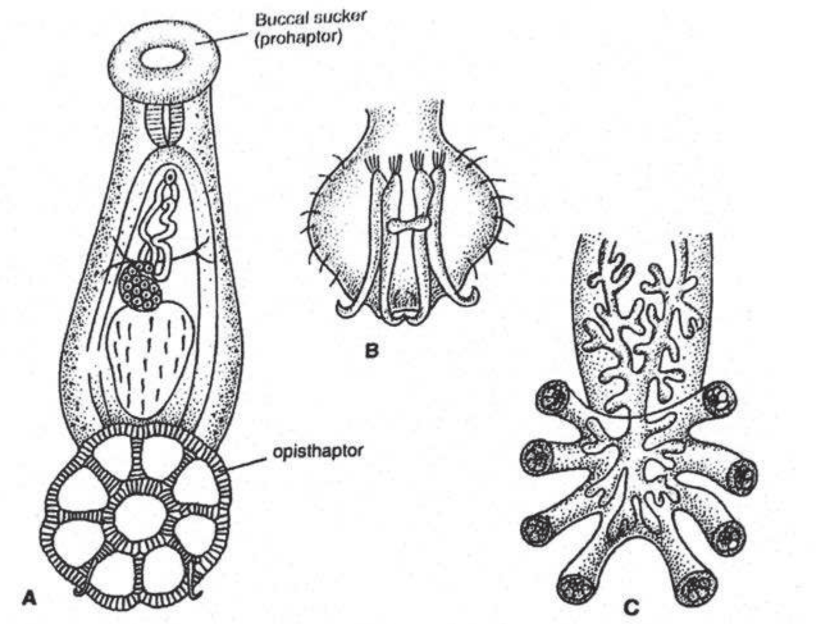


Fig. - 11 : Some attachment organs of monogenetic flukes. A—*Anoplocotyloides papillate*; B, C—Opisthaptor from monogenetic flukes.

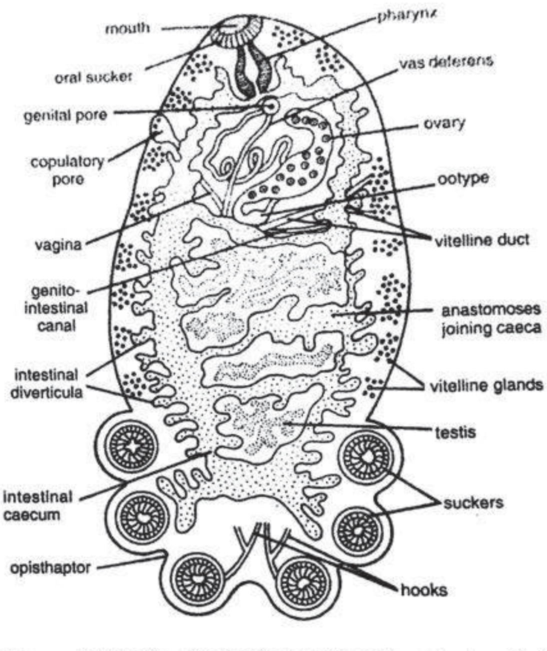


Fig. 12 : *Polystomum*—lives in urinary bladder of frogs, toads and turtles.

2. **Integument :** The integument (also called tegument) covering the body of helminthes has become greatly modified to serve the following three important functions :

(i) **Absorption :** The integument is semipermeable and allows the fluids to enter the body. It becomes thin, serving partly or wholly for food absorption in parasites living in rich nutritious environments, such as the adult liver flukes (in bile), blood flukes *(Schistosoma)* in the hapatic portal system, tapeworms (*Taenia*) in the intestine, *Trichinella* and cysticercus in vertebrate muscles and several larval forms developing in lymph spaces of mollusca or in blood stream. In *Taenia* the integument is thrown into minute projections known as microtriches which enhance the absorption by increasing the surface area.

(ii) **Protection against the digestive juice of the host :** In case of larval forms of liver fluke which have to pass through for further development, a cyst capsule is provided as a protection against the digestive juice. In the gut parasites, such as tapeworms, certain gnathostomes (nematodes in cats, dogs and horses) and amphistomes (stomach or rumen flukes in ruminats) which remain attached to the gut wall, the cuticle becomes thick, impregnated with impermeable chitin-like substances and enzyme resistant, so that it is not digestible by the host's digestive juices but is permeable to water. Some cestodes (e.g. *Taenia*) stimulate mucous lining of their host's intestine and enjoy a protective covering of mucous over them. These intestinal parasites also produce antienzymes to neutralize the action of digestive enzymes of their hosts.

(iii) **Protection against abrasion :** Many trematodes living in the intestinal tracts are provided with spinous integument to guard against the abrasive action of the food and roughage flowing around them or passing through the gut. These spines may be accicular, dentate or placoid types and are rooted into the subintegumental layer. In the chinese liver fluke, *Clonorchis sinensis*, the larval stage possesses a spinous cuticle, suggesting that it was probably a gut parasite before converting into a parasite of the bile passage.

3. Modification for attachment/Organs for attachment : Essential prerequisite for parasitic life is the possession or attainment of suitable mechanisms for attachment with their hosts. Helminths are variously modified for adhesion to the body of their hosts. Following modifications for attachment are often encountered :

(i) **Acetabula or suckers :** These are found in all adult parasitic flatworms.

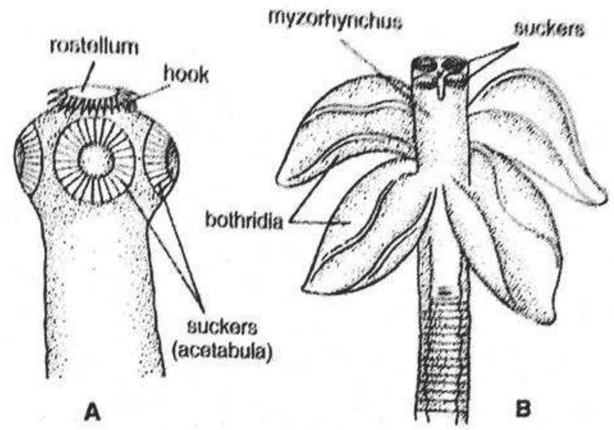


Fig. 13 : **Scoleces of two eucestodes. A—"Typical" scolex with rostellum, hooks and suckers (*Taenia solium*); B—Complex scolex with suckered myzorhynchus and leaflike bothridia (*Myzophyllobothrium*).**

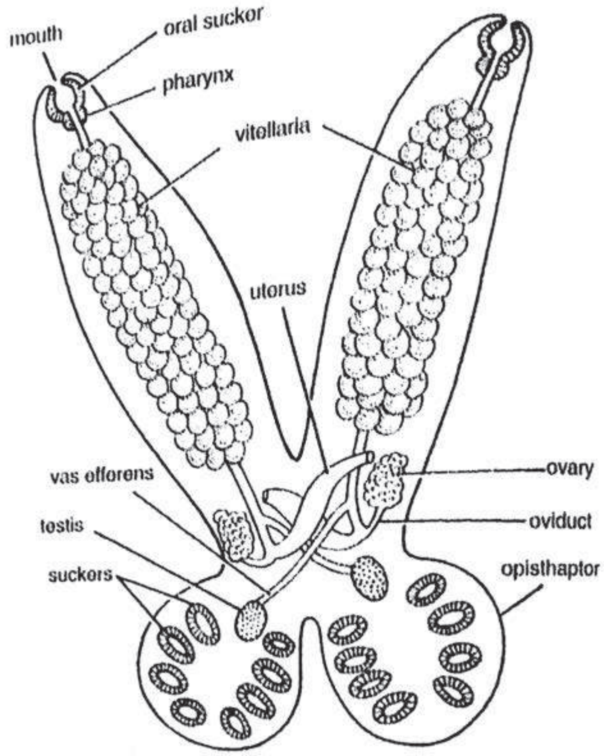


Fig. 14 : *Diplozoon.* Two individuals are permanently united in the form of a cross.

Monogenetic flukes typically have an anterior and a posterior adhesive organs called the ***prohaptor*** and ***opisthaptor,*** respectively. The prohaptor consists of suckers and adhesive pads or glands (e.g. *Gyrodactylus*). The opisthaptor is usually the major organ of attachment, and include one or more well developed suckers with hooks (e.g. *Polystomum, Polystomoidella, Diplozoon, Gyrodactylus*). The digenetic flukes possess two hookless suckers. One, the oral suckers, surrounds the mouth and the other, the ***acetabulum*** (e.g. *Fasciola hepatica*). These suckers are usually supplied with adhesive gland cells, although the well developed ones operate mainly on suction produced by muscle action. The aspidogastrean flukes lack an oral sucker but have a large subdivided ventral sucker (Fig.). *Schistosoma* (blood fluke) also possesses two suckers. In tapeworms, the scolex bears either four sucking cups or large suckers (e.g. *Taenia solium*) or accessory suckers (e.g. *Myzophyllobothrium*) or leaf-like outgrowth on the scolex, called ***bothridium***. *Phyllobothrium* has four bothridia. These leaf-like structures are often equipped with suckers on their anterior ends. Another adhesive sucker like structures are ***bothria*** which are elongate longitudinal and shallow sucking grooves on the scolex. *Echinobothrium* and *Diphyllobothrium* bear two bothria, and *Tetrarhynclus* bears four bothria.

(ii) Hooks : In some cestodes and nametodes, hook or hook-like structures also develop in or near the cephalic and, which further help in attachement. In *Taenia solium* the hooks are arranged in double circlet at the base of the rostellum. In dog tapeworm (*Diphylidium caninum*) several rows of hooks are peresent around the retractile rostellum. In *Macracanthorhynchus* (an acanthocephalan parasite) a buccal armature is present bearing tooth-like structures which serve for tissue aberration and anchorage.

In the hexacanth embryo of *Taenia solium* six hooks are there and the embryo with the help of the hooks bores into the wall of gut of host to reach the blood stream. In addition, the embryo has a pair of penetration glands which also helps in penetration.

(iii) Glands : (*Penetration glands or Histolytic glands*) : In order to penetrate into the host the helminths have develop ceratin strutures or glands. Miracidia larva of fluke has a conical process at the anterior end called apical papillae. There are a pair of penetration gland at the anterior end. These glands secrete histolytic enzymes that help in dissolving the host's tissue to penetrate into it. In hookworms (*Ancylostoma*) there are glands in

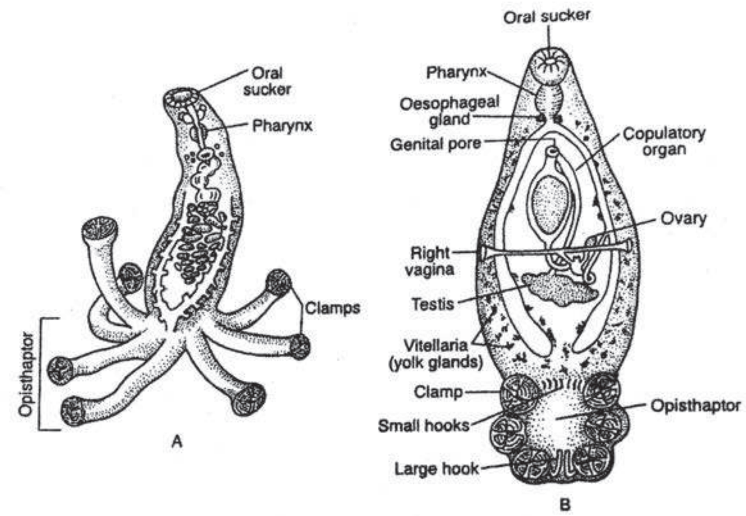


Fig. 15 : Monogenean parasites. A. Entire view of a *Choriocotyle* sp. showing the complex haptor. B. *Polystomoidella* sp. showing the hooks and haptor (From Pechenik).

the buccal region and the secretion of which are supposed to have anti-coagulative and histolytic properties.

In most cercaria a large number of dark or brown unicellular cystogenous glands are present beneath the cuticle. These glands help in secreting a protective cyst around the cercaria tranforming it into metacercaria. These cysts help the metacercaria to overcome unfavourable conditions and protect them till they are finally eaten by their host.

4. Modification for reproduction : (Vast or excessive reproduction) : Reproductive system in helminthes, like other endoparasites, is highly developed as the parasites live in the hostile environment. It can be discussed under following heads–

(i) *Enormous development of reproductive organs :* Large numbers of testes, ovaries, vitelline follicles and other associated structures are present in helminthes. In cestodes about 90% of the avaiable space of the body is occupied by reproductive organs.

(ii) *Hermaphroditism* : All tremtodes and cestodes are hermaphrodites except a few like *Schistosoma*. Hermaphroditism is an adaptation, advantageous to the parasitic mode of life, to overcome the search of the mate. Many of the parasites have adopted self-fertilization to escape the failure of cross fertilization.

(iii) *Multiplication of reproductive organs* : In cestodes reproductive organs are much more elaborate and are repeated in each proglotid. Each mature proglotid possesses one (*T. solium*) or two sets (*Diphylidium*) of male and female reproductive organs. In each gravid proglotid, all other organs of the system degenerate to make room for the uterus which is greatly enlarged and branched to accomodate a large number of eggs.

(iv) *Enormous number of egg production* : The egg production in helminthes is astronomical. The female *Ascaris lumbricoides* (round worm) lays about 2 lac eggs per day. Trematodes usually produce a few thousand eggs daily. The human hook-worm. *Ancylostoma duodenale* produces 25000-30000 eges per day. Cestodes produce very large number of eggs. Each gravid segment of tape worm *Taenia* contains 30,000-50,000 eggs and there may be 50-100 such gravid segments in one individual. Production of such an enormous number of eggs is an important adaptation of endoparsites to keep the continuity of their race because the chances of survival of most of the eggs are very remote and the parasites used to face a number of hazards to reach the host.

(v) *Larval multiplication* : In addition to large number of egg production some helminths also practice asexual reproduction at larval stage. Each sporocyst of liver fluke produces 5-8 radia, from each of which 14-20 cercaria are produced. In cestodes larval multiplication takes place in some forms, e.g. a hydatid cyst developing from a single egg may contain thousands of scolices.

B : Physiological adaptations : There are many physiological adjustments of parasites to cope up with their host or their environment. Most of the parasitic helminthes live within the body of the hosts and hence have to protect themselves from various substances produced by the host. The parasite living in the alimentary canal of the host has to protect itself from the action of diegestive juice of the host. Some cestodes stimulate mucous lining of their host's intestine and the secreted mucous then forms a protective clothing around the parasite (e.g. *Taenia*). Lime cells in the body wall of tape worms neutralize the acids formed in the host's gut. The gut or intestinal parasites also produce antienzymes to neutralize the action of digestive enzymes of their host. Green in 1957 reproted the presence of trypsin and chymotrypsin inhibitors in the body wall of *Ascaris*. *Hymenolepis diminuta* (a common tapeworm of rats and mice) releases proteins (enzyme inhibitors) that appear to inhibit trypisin activity. The tapeworms can also regulate the pH of its immediate environment to about 5.0 by secreting organic acids and this acidic output may also inhibit the activity of trypsin (Uglem and Just, 1983). Endoparasites normally possess a high range of pH tolerance of 4—11. Blood parasites are known to withstand the effects of anti-bodies and phagocytes by some mechanisms.

The intestinal parasites live in an environment completely devoid of free oxygen, the respiration is thus of anaerobic type, consisting of extracting energy from the food absorbed by the parasite. In the absence of oxygen, energy is obtained by the fermentation of glycogen which is broken through glycolysis.

Endoparasitic flatworms seem to possess a considerable osmotic adaptability, as they can live successfully in different media. Liver fluke of sheep, for example passess through the stomach, body cavity and liver before reaching the bile duct.

High fertility or excessive multiplication of helminthes, as mentioned earlier, is also a physiological adaptation to keep the continuity of the race.

In conclusition can be said that the parasitic helminthes are intelligent enough as other organisms and they have accepted the challange of changing environment of host and have constantly modified/changed during the course of their evolution in order to survive in an efficient way in the host's hostile environment. But the specializaton and degeneration of structures or organs of parasites for life in peculiar environments, make them completely unfit for life in any other environment. Thus parasitism is a highly successful way of life in itself but it is a blind alley as far as any further evolutionary change is concerned.

5.7 Questions

a) Write the Pathogenicity of Ascaris
b) What is the name of disease produced by Wuchena?
c) What do you mean by primary host and secondary host?
d) Write the name of Vector of Wucheria bancrofti
e) In which organ of human body Wucheria prefers to live?
f) Is Coèlom is present in Ascaris?
g) How humans are infested with Ascaris?
h) Write the life history of Wucheria
i) Describe the anatomy of Ascaris.

Unit – 6 ❑ Phylum : Annelida

Structure

6.0 Objective

This chapter elaborates the structure of first triploblastic animals and their structural peculiarities. From the chapter learness will learn the diversity of the animals belongs to the phylum Annelida.

6.1 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.

6.2 General characteristics

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.

6.3 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.
4. Presence of two suckers–a small **anterior or head sucker** surrounding the

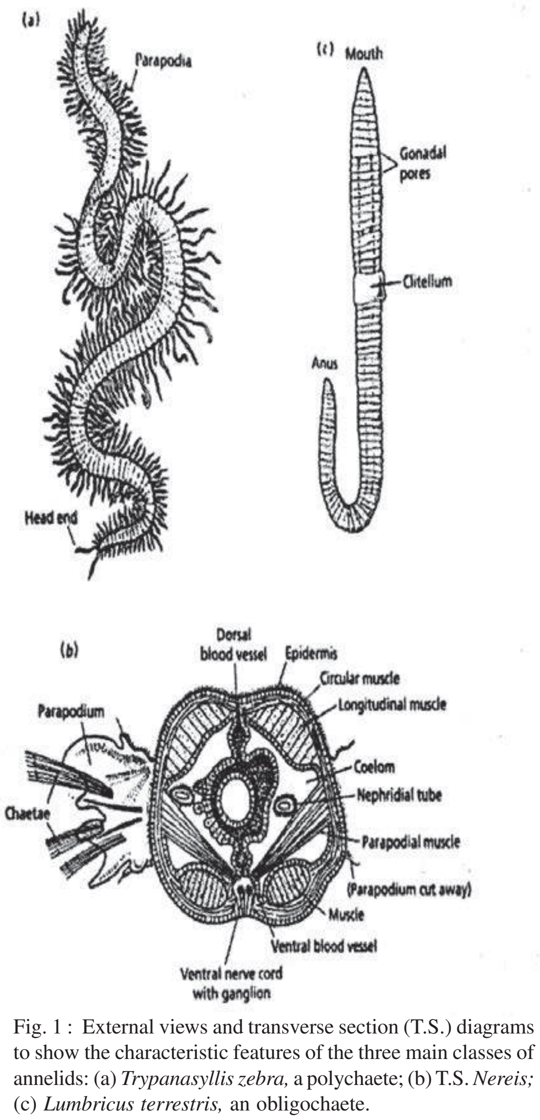


Fig. 1 : External views and transverse section (T.S.) diagrams to show the characteristic features of the three main classes of annelids: (a) *Trypanasyllis zebra,* a polychaete; (b) T.S. *Nereis;* (c) *Lumbricus terrestris,* an obligochaete.

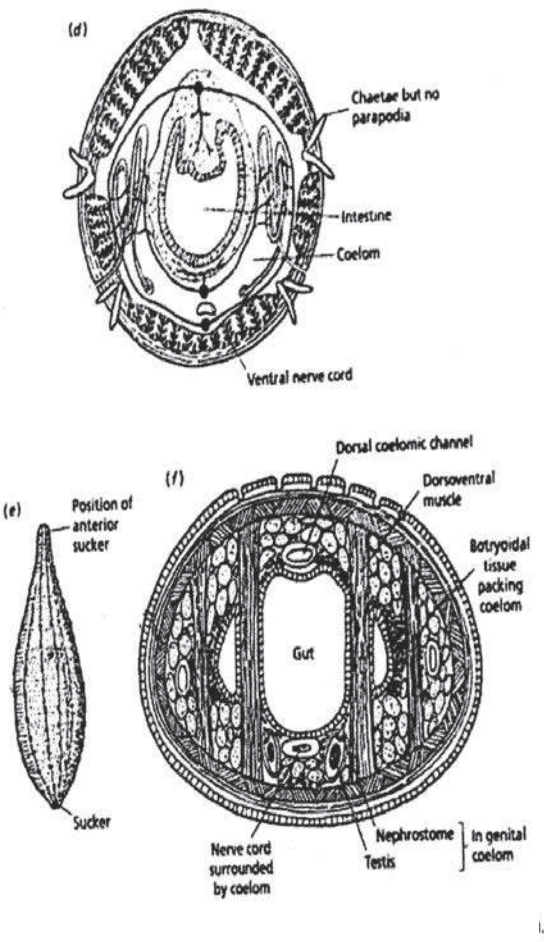


Fig. 1 : (cont.) (d) T. S. Lumbricus; 9e) a leech, viewed dorsally; (f) T. S. leech.

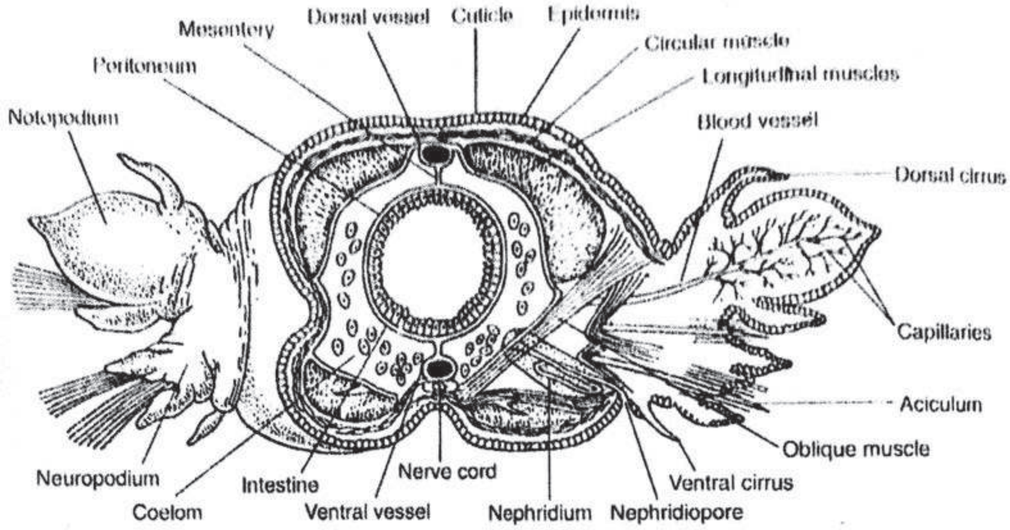


Fig. 2 : Diagrammatic view of different structures in a segment of *Nereis*. Left side of the figure depicts an entire parapodium and the remaining part is shown in cross section (after various sources).

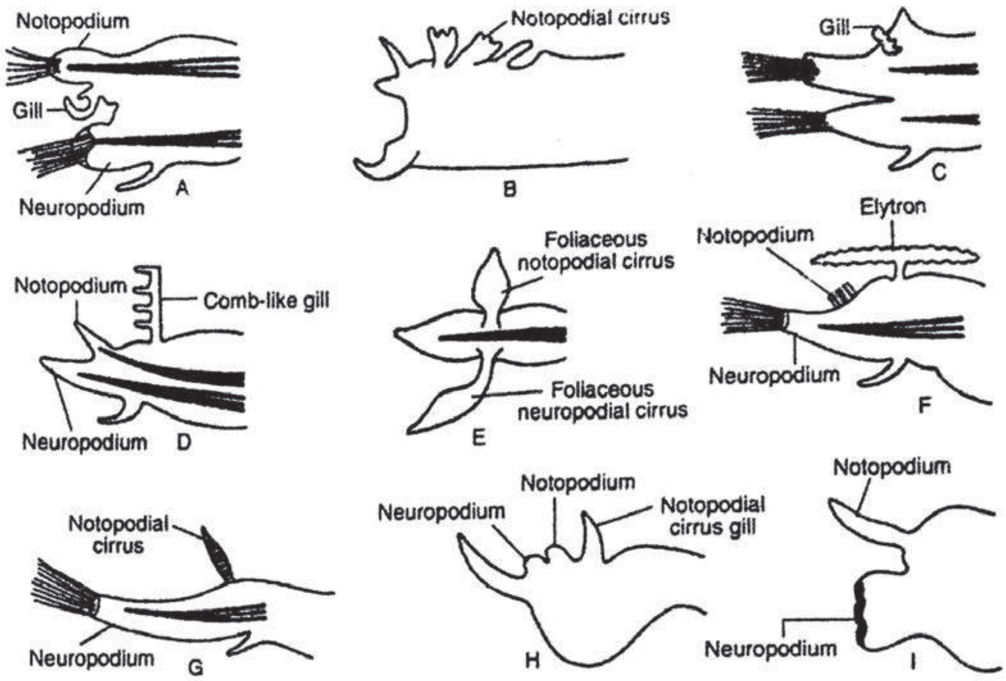


Fig. 3 : Showing the modification of parapodia in different annelids. A. Parapodium of *Nepthys*. The notopodium gives a curved gill on its underside. B. Parapodium of *Amphinome*. The notopodium is indistinct. C. Parapodium of *Glycera*. D. Parapodium of *Eunice*. It is uniramous with reduced notopodium. 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.

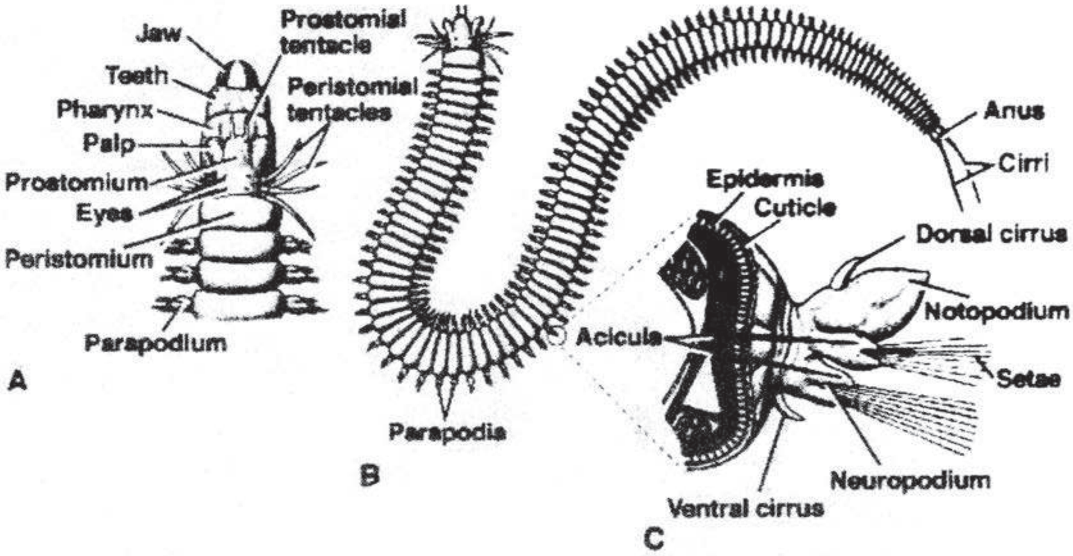


Fig. 4 Polycheat body Part: A. Prosotomium, B: Neries, C: Parapodium

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.

6.4 Locomotory *Organelles* in Annelida

The chief locomotory organelles in annelida are–**Parapodia, Setae** and **Suckers**

Parapodia :

Parapodia (Fig.) are principal locomotory organelles of free living polychaetes. Parapodia are segmentally arranged fleshy lateral hollow extensions of the body into which also extends the coelomic cavity. Each parapodium basically consists of two lobes (biramous) a dorsal **notopodium** and a ventral **neuropodium**, and each lobe bears a bundle of bristles or setae supported internally by one or more chitineous rods, each called an *aciculum.* Both notopodium and neuropodium may bear additional projected parts (dorsal cirrus and ventral cirrus) and they may be variously modified in different polychaetes (Fig. 3, 4). As the coelomic cavity extends into parapodia, the hydrostatic pressure is exerted by the coelomic fluid. Associated with parapodium are dorsal and ventral sets of *oblique muscles*, originating from the midventral line of the body wall. In addition to these muscles, there are intrinsic **protactor** and **retractor** muscles. The point of attachment of the parapodia with the body wall acts as a hinge for forward and backward movements. During movement, two parapodia of a segement always remain in opposite phases of motion and thus cause a sort of paddling activity through water. The bristiles and acicula are protruded and withdrawn through the action of the protractor and retractor muscles.

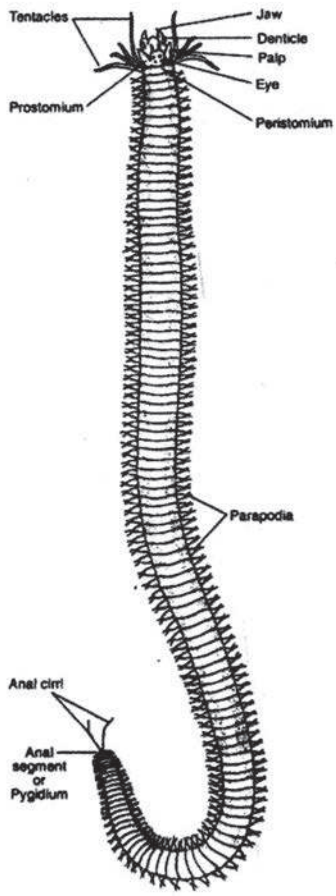


Fig. 5 : External features of *Nereis*—dorsal view (afer Bloom and Krekeler)

The parapodia exhibit variations in form among different polychaetes in accordance with the different functions they perform. Creeping and swimming forms have well developed parapodia; the burrowing forms and tube dwellers have feebly developed parapodia especially in the posterior part of their body.

Setae : Setae are the main locomotor structures in oligochaetes, but they are also present in polychaetes. Setae are implanted directly in the body muscles and are

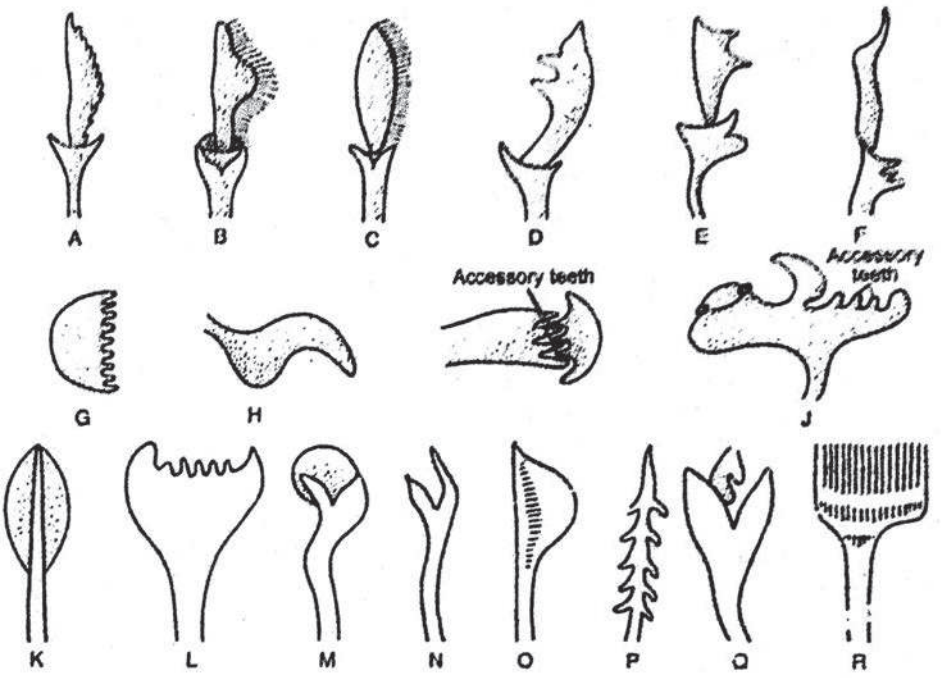


Fig. 6 : Setae of various annelids : Jointed forms : *Nereis* (A, B), Heteroneries stage (C), *Eunice* (D), *Syllid* (E), *Phyllodoce* (F), Uncini forms : Serpulid (G), Sebellid (H), Terebellid (I-J), Simple forms : Terebellid (K), Maldamid (L), Polydea (M), *Euphosyne* (N), *Polynoe* (O), *Hermione* (P, Q), *Eunice* (R). The setae may be notched (L) or hooked (M-N) or serrated (O) or comb-like (R).

mostly oriented in the ventral region of the body segments. Setae are secreted by **setal sacs**.

The extension and withdrawl of the setae during movement are caused by a pair of setal muscles and the associated circular muscles. Like parapodia, setae may also show variations in form reflecting their functional significance. Burrowing forms have short, simple and blunt setae, white the swimming forms have characteritically long, forked or plumose setae (Fig.).

Suckers : Suckers are characteristics of class Hirudinea which lack parapodia and setae. Anchorage on the substratum during locomotion is caused by two muscular suckers, one is situated at the anterior end (**anterior sucker**) and the other is located at the posterior end (**posterior suckers**) of the body. They are formed by the fusion of several body segments. Suckers are circular disc shaped and the posterior sucker is larger and more powerful than the anterior sucker. Anterior sucker bears mouth opening at its ventral surface. Adhesion or attachement of the suckers to the substratum is assisted by the secretion from the specialized epidermal sucker glands present in masses in both the suckers.

6.5 Circulatory System in Annelida

Circulatory system is one of the most important systems of the living bodies because through this system exchanges of essential elements between the tissues of the body and the external environment take place. Not only that but the transport of materials from one part of the body to different parts also take place through this system.

The circulatory system in annelids is closed type and consists of blood vessels through which blood is distributed and collected from different parts of the body. The circulatory system in annelids differs from one class to another, hence the system may be described separately classwise.

Clas Polychaeta : Circulation in most polychaetes results from fluid movement in both blood vascular system and the coelom. A common variation on this pattern occurs in many polychaetes that have reduced septa, for example, the glycerid blood worms. In these, the coelomic system replace the blood system and transport substance throughout the body. Very small species also typically lack a blood system and sometimes also the coelomic cavities.

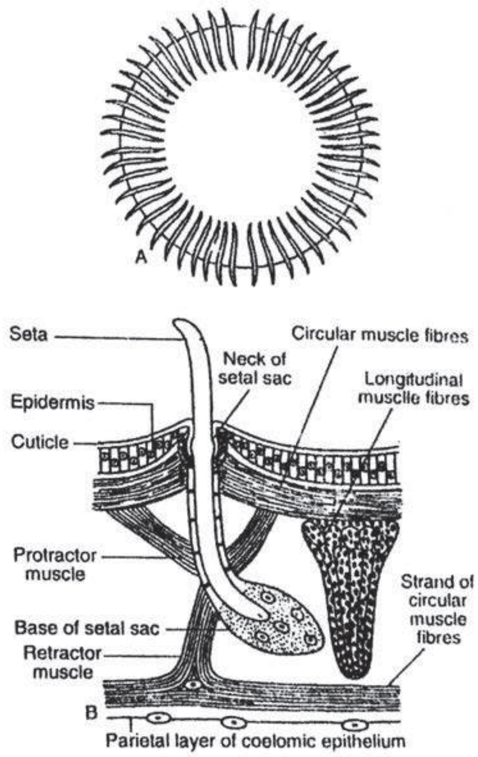


Fig. 7 : A. Geometric disposition of setae in *Pheretima* (after Bahl) B. Diagrammatic view of a portion of the body wall of earthworm (Transverse section, after Bahl).

In most polychaetes there exists a well developed blood-vascular system, in which the blood is enclosed within vessels. In a typical blood vascular system, blood flows anteriorly in **dorsal vessel** situated over the digestive tract. At the anterior end of the body, the dorsal vessel is connected to a **ventral vessel** by one to several vessels or by a network of vessels passing around the gut. The ventral vessel carries blood posteriorly beneath the alimentary tract (Fig.).

In each segment the ventral vessel gives rise to one pair of ventral, parapodial vessels, which supply the parapodia, the body, and the nephridia and to several ventral, interstinal vessels, which supply the gut (Fig.). The dorsal vessel, in turn, receives a corresponding pair of dorsal parapodial vessels and a dorsal intestinal vessel. The dorsal and ventral parapodial vessels and the dorsal and ventral intestional vessles are interconnected by a network of smaller vessels. Polychaete blood is confined to small-and large-diameter vessles and in some species, large-volume sinuses, which typically occur on the wall of the gut (Fig. 8).

In polychaetes the blood contains few cells compared to coelomic fluid. In small polychaetes it is usually colourless but in larger species and those that burrow in soft bottoms, the blood contains respiratory pigments dissolved in the plasma. In them three of the four respiratory pigments of animals are found. **Haemoglobin** is the most common of these pigments, next common is **chlorocruorin**. It is a kind of haemoglobin but a slight difference in side chains gives it a green colour rather than a red colour. The less common respiratory pigment is **haemerythrin**. It is an iron-bearing but nonhaeme (not a porphyrin) protein pigment. Here the two iron atoms are bound directly to the protein and not to a haeme. The chlorocruorin (blood of *Serpula* contains both haemoglobin and chlorocruorin), Haemerythrin is found within enucleated blood corpuscles of *Magelona*.

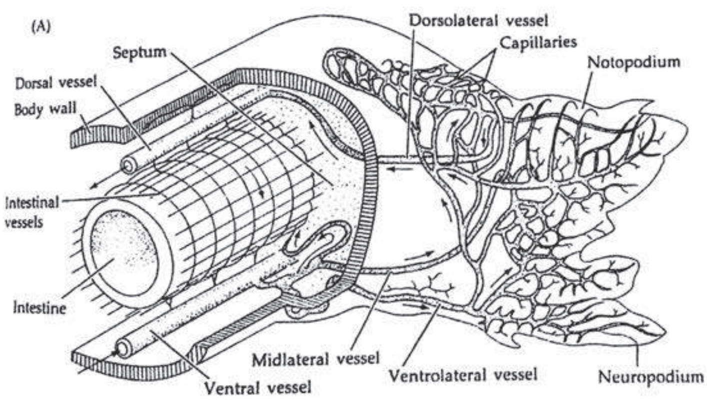


Figure Polychaete circulatory and gas exchange systems. (A) A segment and parapodium (cutaway view) of a nereid. Note the major blood vessels and blood flow pattern (arrows). Blood flows anteriorly in the dorsal vessel and posteriorly in the ventral vessel (see also Figure 13.18A). In such polychaetes the flattened parapodia serve as gills. (B–D) Circulatory patterns in an arenicolid (B), a terebellid (C), and a serpulid (D). Major modifications from the basic plan include additional vessels, sinuses associated with the foregut, and branchial vessels serving anterior gills.

Class Oligochaeta :

The circulatory system of Oligochaetes (Fig.) is basically similar to that of polychaetes with some modifications in structure and pattern of blood flow. The differences are largely adaptations to living in terrestrial and freshwater enviroments. In *Lumbricus* and many others three main longitudinal blood vessels extend most of the body length and are connected to one another in each segment by additional segmentally arranged vessles (Fig.). The largest longitudinal blood vessel is the **dorsal vessel**, the wall of which is quite thick and muscular and provides much of the pumping force for blood movement. This vessel with it valves functions as heart. It collects blood from the vascular areas of the intestine and drives it towards the anterior end. Suspended in the mesentary beneath the gut is the longitudal **ventral vessel** in which blood flows from anterior to the posterior region. The third longitudinal vessel lies ventral to the nerve cord and is called the **subneural vessel**, in which blood flows posteriorly. Exchanges between the longitudinal vessles occur in each segment through various routes supplying the body wall, gut and nephridia. Most oligochaetes also possess from two to five pairs of large, muscular circumoesophageal vessles, called **ring vessles** or **lateral hearts**. They carry blood from the dorsal to the ventral region. These vessels are conspicuously contractile and function as accessory organs for blood propulsion. These vessles are often equipped with flap valves to ensure a one way blood flow. The number of such lateral hearts varies. Five are present in *Lumbricus*, surroudning the oesophagus and only one pair in *Tubifex* and this pair is circumintestinal.

Most oligochaetes have haemoglobin dissolved in the plasma. Memebrs of some families (e.g. Naididae) lack blood pigments. Various phagocytic amoebocytes are also present in the circulatory fluid of most ot these worms.

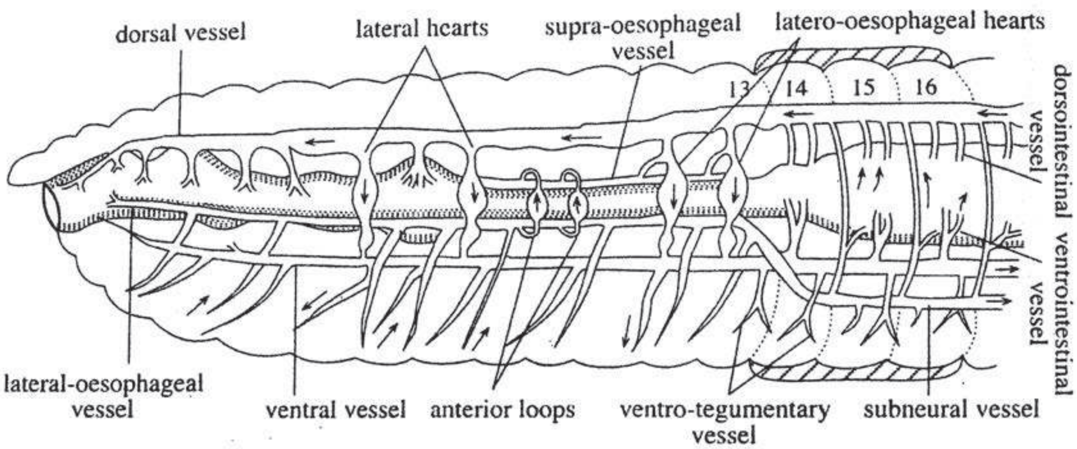
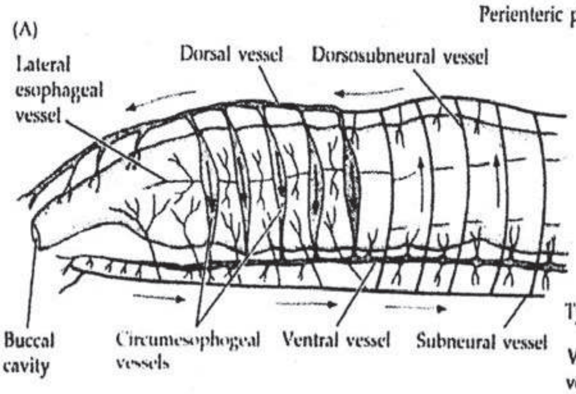
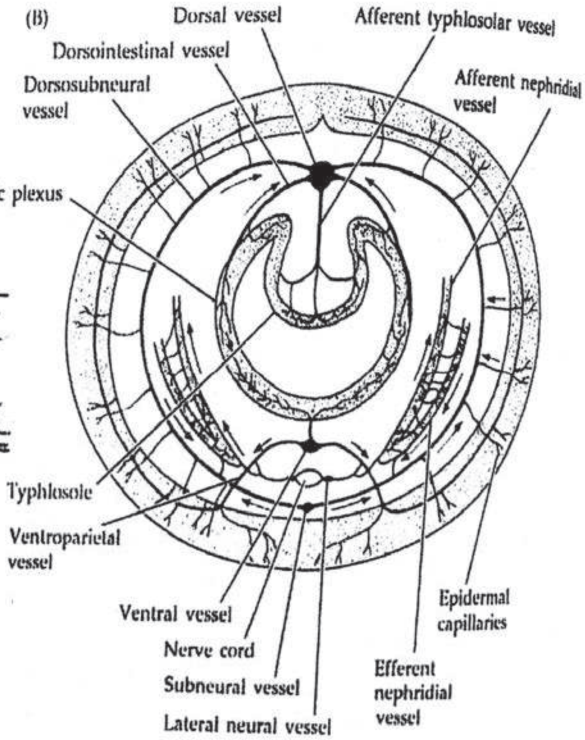


Fig. 9 : Distribution of different blood vessels in earthworm (upto 16 segments from anterior end).

Class Hirudinea : Among the euhirudineans (majority of leeches), the rhynchobdellids marine fish and turtle leeches and freshwater leeches with eversible probocis) have etain the blood-vascular system of oligochaetes, but the coelomic sinuses act as a supplimentary circulatory system. In the arhynchobdellids (leeches with a non-eversible pharynx, often bearing jaws for sucking blood or ingesting prey), the ancestral circulatory system has disappeared, and the coelomic sinuses and

Figure 10 : Circulatory system of *Lumbricus.* (A) Anterior blood vessels (lateral view). (B) The circulatory pattern in one segment (cross section).





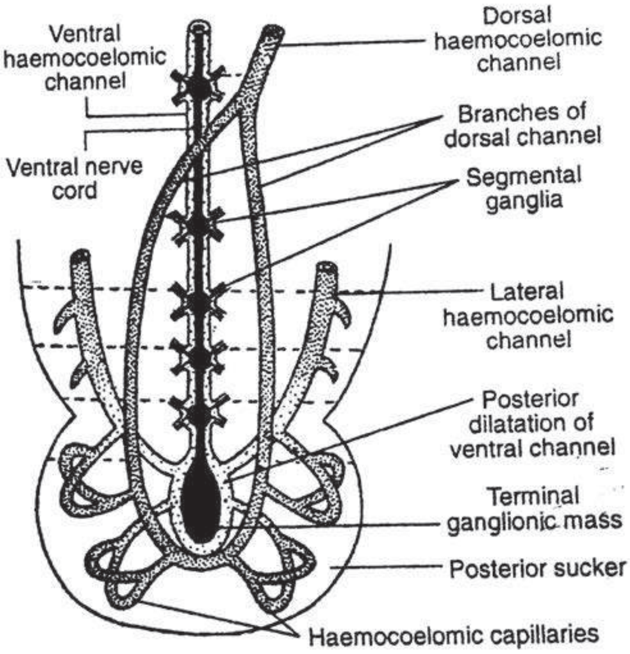


Fig. 11 : Posterior end of leech showing the union of four longitudinal haemocoelomic channels.

fluid have become the sole internal transport system, now termed the haemocoelomic system (Fig). Because the haemocoelomic system evolved from the original coelom and not the blood-vascular system, all of its vessels and channels are lined by an endothelium, the peritonium. Much of this peritonium, especially in the capillaries, is specialized into large nutrient storage cells, the **chloragogen tissue** in rhynchobdellids and the **botryoidal tissue** in the arhynchobdellids. The haemocoelomic fluid is propelled by the muscular contractions of the lateral longitudinal channels.

Respiratory pigment (extracellular haemoglobin) is found only in the arhynchobdellid leaches and is responsible for about one half of the oxygen transport (Ruppert and Barness, 1994).

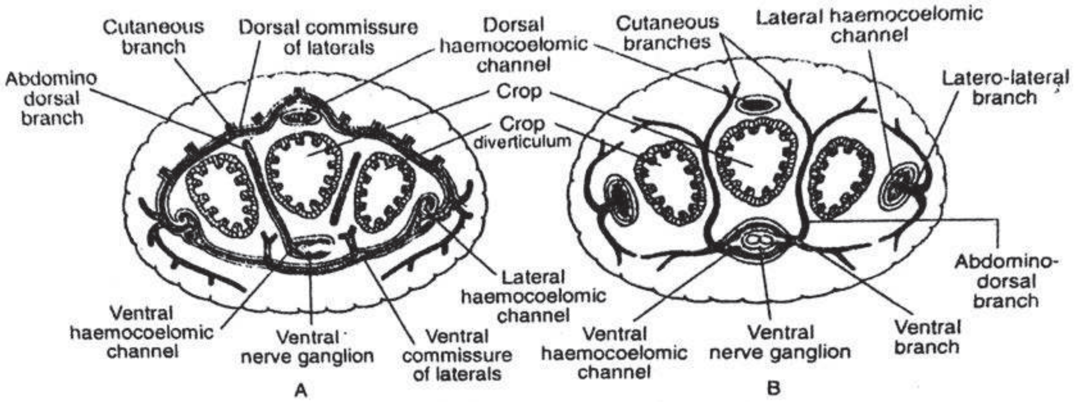


Fig. 12 : Transverse sections of leech showing haemocoelomic channels. A. Dorsal and ventral commissures of lateral channels. B. Abdomino-dorsal and ventral branches.

6.6 Reproduction in Annelida

Reproduction in Polychaetes : Polychaetes reproduce both sexually and asexually. Asexual reproduction is seen in some polychaetes (cirratulids, syllids, sabellid fan worms and spionids). It takes place by budding or division of the body into two parts or a numbr of fragments. Most of the polychaetes reproduces only sexually and the great majority of polychaetes are dioecious and hermaphroditism is known in serpulids, certain freshwater nereids and isolated cases in other families. Polychaete gonads are usually distinct organs but, depending on speices, vary in position and number. In general they remain associated with septa, blood vessels and lining of the coelom. Formation of gametes may occur throughout the body or only in particular regions of the trunk. The gametes generally mature within the coelom and are released to the outside by mechanisms such as gonoducts, coelomoducts, nephridia, or simple rupture of the parent bodywall. Many species release eggs and

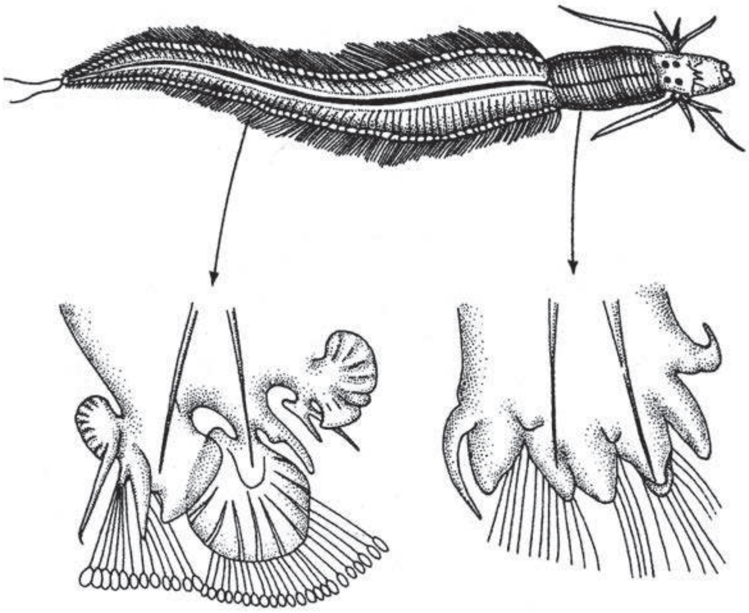


Fig. 13 : An epitokous nereid, *Neneis irrorata.* Note the dimorphic condition of the antgerior and pasterior parapodia. (Brusca and Brusca, 2002)

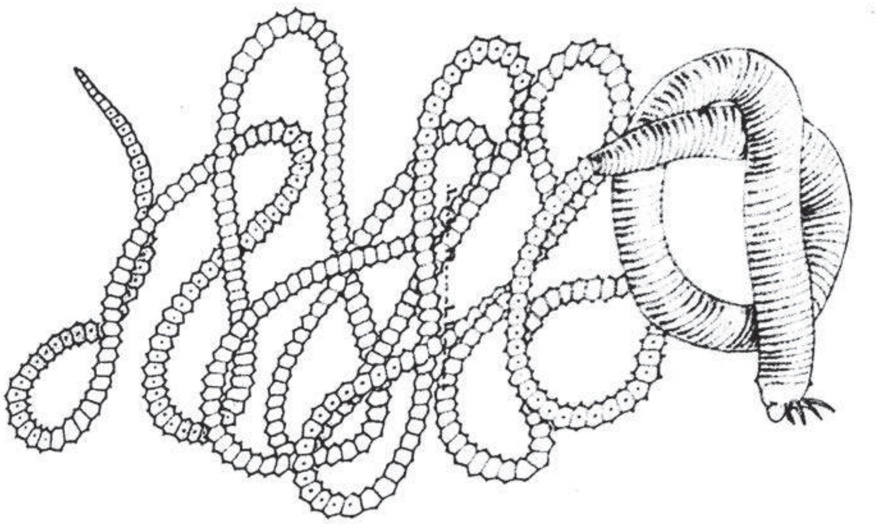


Fig. 14: The epitokous *palola viridis.* Brusca and Brusca, 2002)

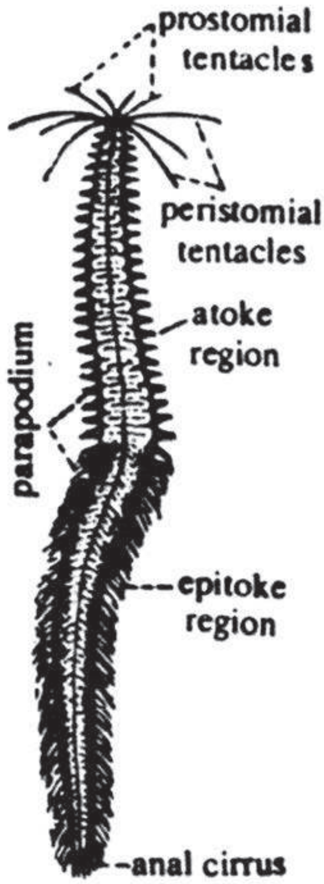


Fig. 15 : **Heteronereis**. Sexual phase, nereids

sperm into the water, where external fertilization is followed by fully indirect development with a planktotrophic larval stage. In some other forms fertilization is internal, followed by brooding or by the production of floating or attached egg capsules. In most instances the embryos are released as free-swimming larvae. Some species brood their embryos on the body surface.

Many of the free swimming polychaetes have evolved methods that ensure relatively high rate of fertilization. One of these methods is the fascinating phenomenon of **epitoky**, characteristic of many benthic syllids, nereids, and eunicids. This phenomenon involves the production of a sexually reproductive worm called an **epitokous** individual. Epitokous froms may arise from non reproductive (**atokous**) animals by a transformation of an individual worm as in most nereids and eunicids, or by the asexual production of new eiptokous individuals, as in most syllids. In some forms, the whole body may transform into a sexual individual called a **heteronereid** or **epitoke** (Brusca and Brusca, 2003) In others, only the posterior body segments (again called the epitoke) become swollen and filled with gametes, and their associated parapodia become enlarged. The gamete-bearing segments of the epitokes are the most strikingly modified, and the body of the worm appears to be divided into two markedly different regions. The gamete bearing epitokes are capable of swimming from the bottom upwords into the water column, where the gametes are released. Epitoky is controlled by neurosecretory activity, and the upward migration of the epitokes is precisely timed to synchronize spawning within a population. The reproductive swarming of epitokes is linked with lunar periodicity. This activity not only ensures successful fertilization but establishes

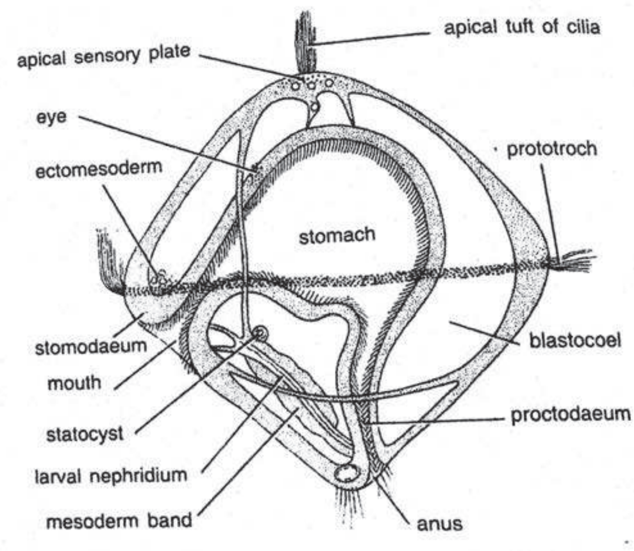


Fig. 16 : A typical trochophore larva.

the developing embryos in a planktonic habitat suitable for the larvae. Perhaps the most famous of the epitokas worms are the palola worms (*Palola viridis*) of the South Seas.

Many polychaetes shed their eggs freely into the sea water where they become planktonic. Some, however, retain the eggs within the tubes or burrows and some of them brood their eggs. A few species, such as *Nereis limnicola*, brood their eggs within the coelom. The polychaete egg contains a variable amount of yolk, depending on the species, and the cleavage is spiral and holoblastic. After gastrulation the embryo rapidly develops into a top-shaped **trochophore** larva (Fig. 16), which transforms into juvenile worm through metamorphosis.

Reproduction in Oligochaeta : The reproductive system of oligochaetes differs from that of polychaetes in a number of striking respects. Oligochaetes are all hermaphrodites and usually possess distinct and complex reproductive systems, including parmanent gonads. Furthermore, various parts of the reproductiove appartus are restricted to particular segments, usually in the anterior portion of the worm. The arrangement of the reproductive system facilitaties mutual cross-fertilization followed by encapsulation and deposition of the zygotes. The male system inclues one or two pairs of testes located in one or two specific body sgements. In most aquatic groups there is usually one ovarian segment followed by one testicular segment. In terrestrial families, two male segments may be present. Sperms are released from the testes into the coelomic spaces, where they mature or are picked up by storage sacs or spical coelomic pouches, called **seminal vesicles** derived from pouches of septal peritonium. There may be single seminal vesicle or as many as three pairs in some earthworms. When mature, the sperm are released from the seminal vesicles, picked up by ciliated **seminal (sperm) funnels**, and carried by sperm ducts to paired gonopores.

The female reproductive system consists of a single pair of ovaries located posterior to the male system (Fig. 17). Ova are released into the abjacent coelomic space and sometimes stored until mature in shallow pouches in the septal wall called

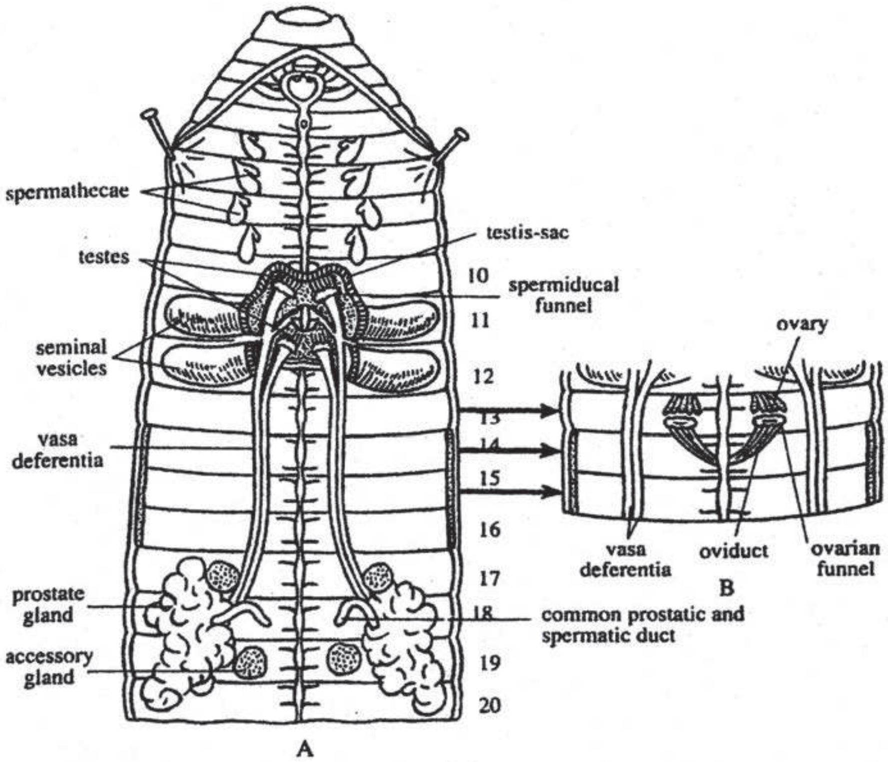


Fig. 17 : Reproductive systems of Earthworm. Male (A) and Female (B) reproductive systems are drawn separately. But it must be remembered that both are present in the same individual, the clitellum may be taken as a marker to their relative positions. Note segment number.

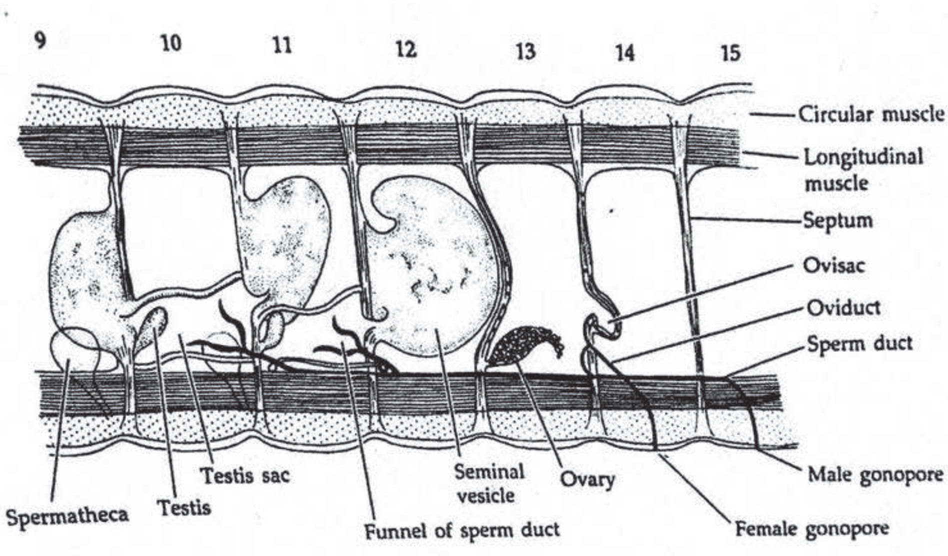


Fig. 18 : Segments 9—15 of *Lumbricus* (cemposite lateral view) (Brusca and Brusca, 2002).

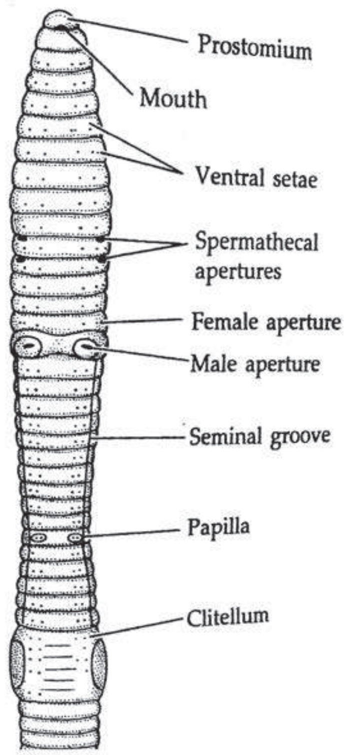


Fig. 19 : External structures associated with reproduction of *lumbricus* (ventral view). (Brusca and Brusca, 2002)

the **ovisacs**. Next to each ovisac is a ciliated funnel that carries the mature ova to an oviduct and eventually to the female gonopore. Most oligochaetes also posssess one or two or more pairs of blind sacs called **spermathecae** (seminal recaptacle) that open to the outside via separate pores.

A characteristic reproductive structure of oligochaetes is clitellum (Latin for saddle) which is a unique region of glandular tissue. This structure is a principal antomical feature unifying the Oligochaeta and the Hirudinoidea as the clitellate annelids. The clitellum has the appearance of a thick sleeve and consisting of certain adjucent segments in which the epidermis is greatly swollen with unicellular glands that form the girble, partially or almost completely encircling the body from the dorsal side downward (Fig. 19, 20) The exact positrion of the clitellum and the number of segments involved are consistent within any particular species. There are 2 cliteller segments in many aquatic forms, 6 or 7 in *Lumbricus*, 3 in *Pheretima* and as many as 60 in certain Glossoscolecidae. In freshwater forms the clitellum is located around the position of the gonopore but in most earthworms it is posterior to the gonopores. The degree of development of the clitellum varies from group to group. In aquatic species the clitellum may be only one cell thick, whereas in many earthworms it forms a thick girdle. The development of the clitellum also varies from season to season. It generally coincides with sexual maturity, but there are some worms in

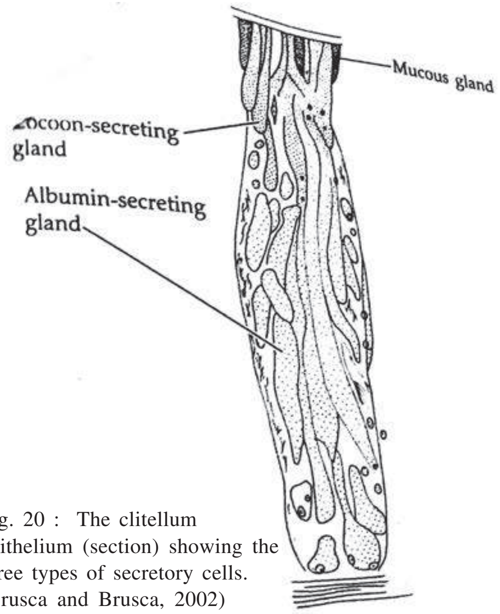


Fig. 20 : The clitellum epithelium (section) showing the three types of secretory cells. (Brusca and Brusca, 2002)

which the clitellum becomes conspicuous only during breeding season. The glands of the clitellum produce mucous for copulation, secrete the wall of the cocoon and secrete the albumin in which the eggs are deposited within the cocoon.

Though hermaphrodite, the oligochaetes practice cross fertilization. Reciprocal copulation enables the worms to pass on sperm of one worm to the other. The sperm thus recieved remain stored in the spermatheca. A few days after copulation, a cocoon is secreted for the deposition of eggs. When completely formed the cocoon slips forward over the anterior end as the worm pulls backward. Both eggs and sperms are discharged into the cocoon and fertilization is external within the cocoon. The open ends of the cocoon contract and seal as they pass off the antrior end of the body. The closed cocoons are deposited in benthic debris by aquatic oligochaetes. Terrestrial forms deposit their cocoons in the soil at various depths depending on the moisture content of the substratum. The shape and size of the cocoons are often species-specific.

The eggs are telolecithal, cleavage is holoblastic and unequal. In both terrestrial and aquatic groups development is direct, with no trace of larval stage and all the development takes place within the cocoon.

Asexual reproduction is very common among many species of aquatic oligochaetes, particularly the aeolosomatids and the naidids. In fact, there are many asexually reproducing naidids in which sexual individuals are rare or have never been observed. Some oligochaetes reproduce asexually in the summer and sexually in the fall. Asexual reproduction always involves a transverse division of the parent worm into two or more new individuals. Regeneration commonly precedes the separation of the daughter individuals.

Reproduction in Hirudinea : Unlike many other annelids, leeches do not reproduce asexully, nor can they regenrate lost parts. Like oligochaetes, all leeches ae hermaphrodites, but they are protandric, not simultaneous hermaphrodites (male reproductive organs develop first). The reproductive system is similar to that of

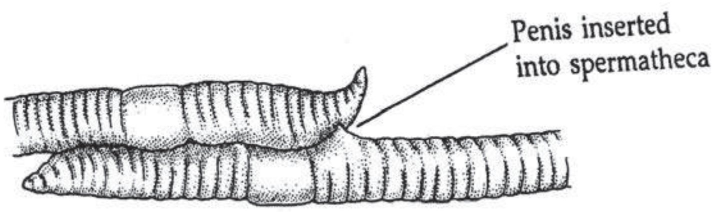


Fig. 21 : *Pheretima* transfers sperm directly from the male pare, through a penis, into the mate's spermatheca. (Brusca and Brusca, 2002)

oligchaetes. There are, however, no separate seminal receptacles (spermathecae), and there is internal fertilization. They also undergo direct development.

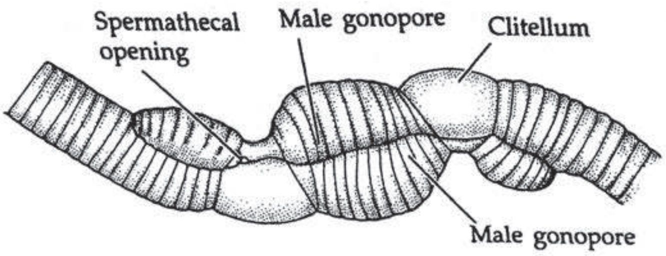


Fig. 22 : *Eisenia uses indirect sperm transfer. As in* Ljumbricus, the sperm leave the male pares and travel along paired seminal grooves to the spermathecal openings of the mate. (Brusca and Brusca, 2002)

The male reproductive system includes a varialble number of paired testes, usually from 5 to 10 pairs in leeches, arranged serially beginning in segment XI or XII. There is a pair of lingitudinal sperm ducts (vas deferens) that lead to a copulatory apparatus and a single gonopore located midventrally on segment X. The copulatory apparatus of leeches is often complex and varies in structure among species. Each sperm duct is coiled distally and enlarges as an ejaculatory duct. The two ducts join at a common glandular, muscular atrium. In arhynchobdellids, the atrium is modified as an eversible intromittent organ, the penis. The rhynchobdellids lack a penis and the atrium functions as a chamber in which spermatophores are produced.

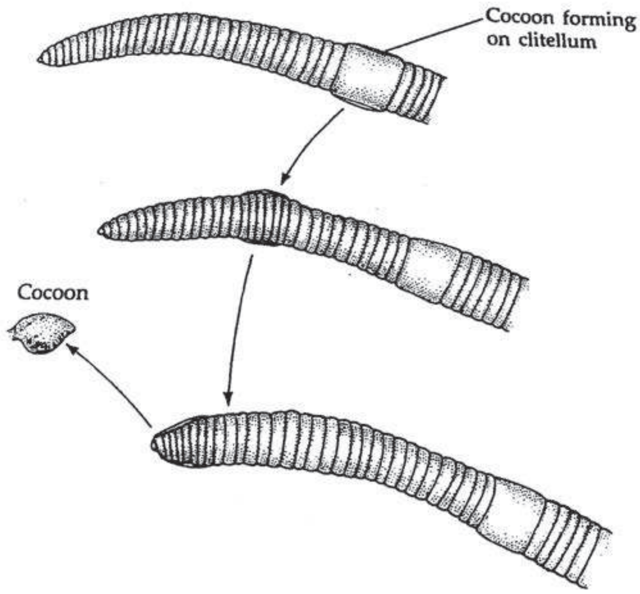


Fig. 23 : An earthworm forming and relearsing a cocoon. As the cocoon slides over the worm, it receives ova and sperm. (Brusca and Brusca, 2002).

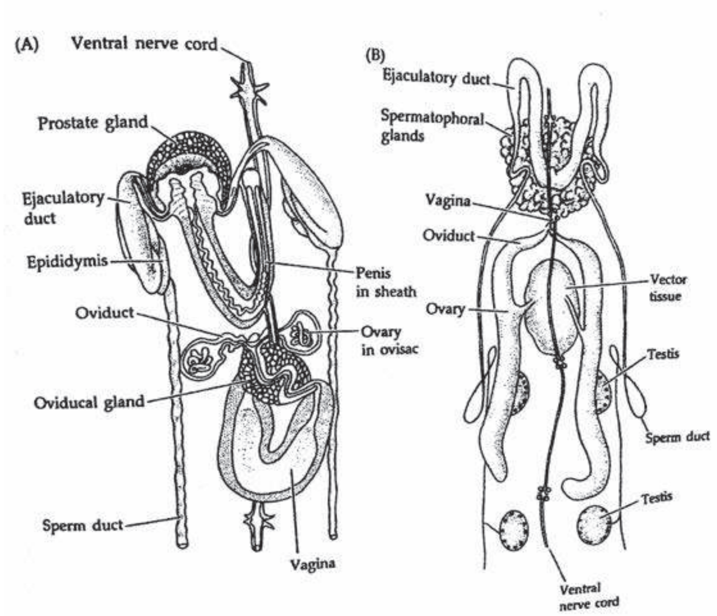


Fig. : 24 *(A, B)* Reproductive Systems of two leches. (A) *Hirudo* (Anhynohobdelle). (B) *Pisciola* (suborder Rhynchobdellae). (Brusca and Brusca, 2002).

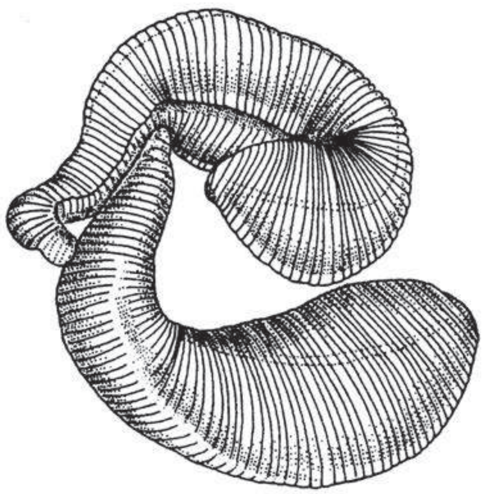


Fig. : *25* Copulating leeches. The arrangement is much like that in obligochaetes. (Brusca and Brusca, 2002)

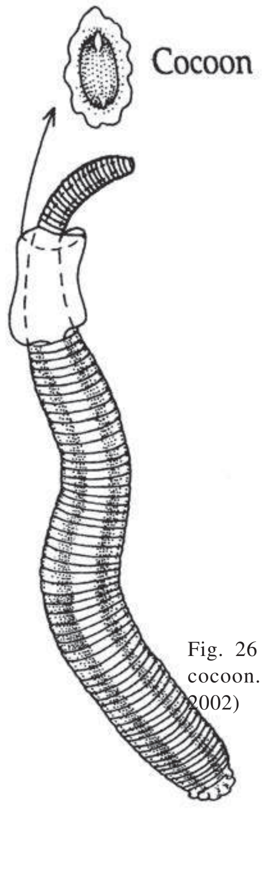


Fig. 26 : *Erpobdella* with cocoon. (Brusca and Brusca, 2002)

There is a single pair of ovaries in leeches, which may extend through several segments. Oviducts extend anteriorly from the ovaries and unite as a common vagina, which leads to the female gonopore on the midventral surface of segment XI, just behind the male pore. In some leeches, and oviducal gland surrounds a portion of the oviduct and vagina and apparently functions in egg-laying activity.

Copulation and sperm transfer differ markedly between the rhynchobdellans and arhynchobdollans, in part due to the differences in the male copulatory structures.

Cocoon formation in leeches is similar to that of oligochaetes, with the clitellum producing a cocoon wall and albumin. As the cocoon slides anteriorly over the female gonopore, it recives the zygotes or young embryos rather than separae eggs and sperm. The cocoons are deposited in damp soil by terrestrial species and even by a few aquatic forms that migrate to land for this process (e.g *Hirudo*). Most aquatic forms deposit their cocoons by attaching them to the bottom or to algae; a few attach them to their hosts (e.g. some piscicolids). A few freshwater leeches display some degree of parental care for their cocoons. The embryogeny of leeches is similar to that described for oligochaetes. Except for a few species, the amount of yolk is relatively small and development time quite short.

6.7 Questions

a) What is the difference between Seta and Parapodia?

b) What is permanent clitelleum?

c) Distinguish between Oligochaeta and Hirudinea.

d) How many types of nephridia are found in earth worm?

e) What do you mean by haemocoelomic system?

f) Why blood of earthworm is red?

g) Write the important external features of Leech.

h) Why host blood is not clotted during the feeding of Leech

i) What is nephrostome

j) What is Peristomium and Prstomium?

Unit – 7 ❐ Phylum : Arthropoda

Structure

7.0 Objective

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 animal and how they are well adapted in different ecosystem of the world.

7.0 Introduction

Arthropods are a vast assemblage of animals. At least 75% of all animal species described to date belong to the phylum Arthropoda. No other phylum of animals can rival the arthropods in success and it is due to the tremendous adaptive diversity that has enabled them to survive in virtually every habitat, (from snow covered mountain peaks to the depth of the ocean). Their success as terrestrial animal is probably due to the evolution of water conserving excretory sysems and gaseons-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.

7.2 General Characters

1. Arthropods are triploblastic, bilaterally symmetrical, coelomate and metamerically segmented animals.
2. Presence of paired externally joined appendages usually in each segment (G. arthos = joint; podos = feet). Appendages are variously modified. Anterior segments are specialized to form a distinct head.

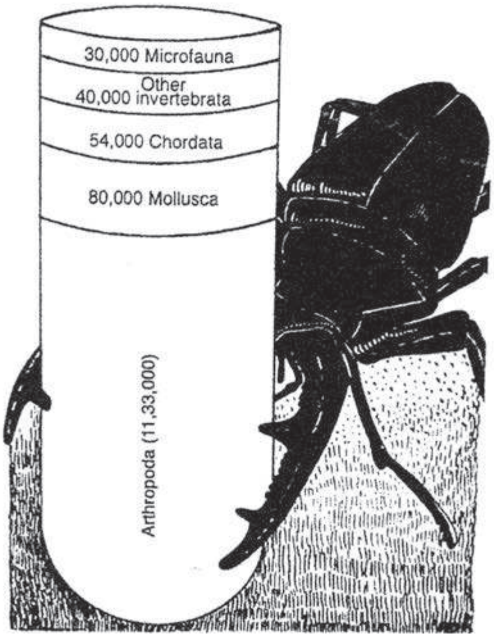


Fig. 1 : In the animal world, the Phylum Arthropoda includes the largest number of species. All of them possess metameric segmentation, hard chitinous exoskeleton and jointed legs. Number shown against each group denotes the approximate number of species.

3. Body is covered with a thick chitinous cuticle forming the exoskeleton. The exoskeleton sheds at interval (moulting or ecdysis).
4. Musculature is not continous but comprises of sepearte striped muscles.
5. The body cavity is a haemocoel. True coelom is represented by spaces within the gonads and excretory organs.
6. Circulatory system open type with a drosal tubular heart, having paired lateral ostia.
7. Respiration by general body surface, gills, trachae, book gills or book lungs. Haemocyanin is the usual respiratory pigment.
8. Excretory organs are green-glands, coxal-glands or Malpighian tubules.
9. Central nervous system includes a large bilobed dorsally placed brain and a double ventral nerve cord with one fused ganglion in each segment.
10. Sensory organs comprise of simple or compound eyes (each eye is made up of several visual units or omatidia), chemoreceptors, tactile receptors, balancing and auditory organs.
11. Cilia are entrely absent from all parts of the body.
12. Sexes are usually separate (dioecious or gonochoristic); some hermaphrodite. Sexual dimorphism is seen in many.

13. Fertilization usually internal. Oviparous or ovoviviparous.
14. Development is usually indirect involving one or more larval forms.
15. Parental care is well marked in some species.

Insects, Spiders, Scropions, Centipedes, Crabs, Prawns, Lobsters, Shrimps, and Barnacles are all arthropods.

Crustacea (L. crusta = a hard shell)

The crustancenas belong to subphylum Crustacea Phylum Arthropoda.

7.2.1 General Characteristics of Crustacea

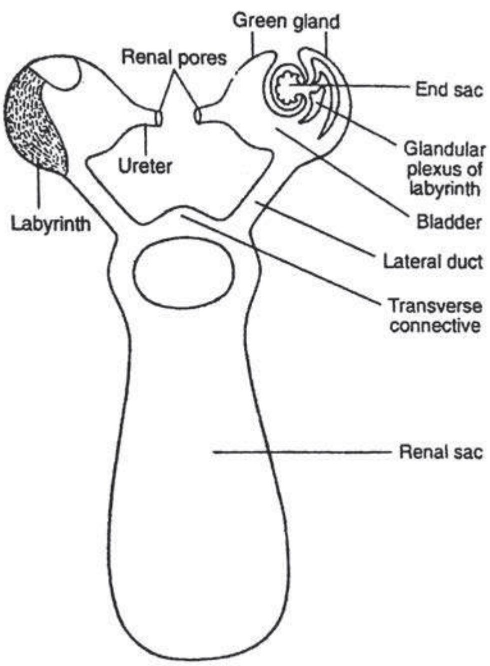


Fig. 2 : Diagrammatic view of the excretory organs of *Palaemon*. These are called green glands or antennal glands and here the gland of the right side has been dissected to show the internal structures.

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

2. They are unique among arthropods in having two pairs of antennae (first pair of antennae is called antennules).

3. Other cephalic appendages are a pair of mandibles and two pairs of maxillae.

4. Throax usually with eight pairs and abdomen usually with six paris of appendages. Appendages undergro various modifications. Last segment of abdomen is telson.

5. Throacic and abdominal appendages are typically biramous, 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 naupliar eye (a characteristic feature of the naupliar larva of crustaceans and therefore referred to as the naupliar eye).

7. 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.

8. 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 (***antenal glands*** or ***green glands***) or the second pair of maxillae (***maxillary glands***).

9. Brain formed by the fusion of first four embryonic ganglia and is connected to the ventral nerve cord by oesophageal connectives. Sense organs, other than eyes include statocysts, sensory hairs and proprioceptors.

10. Most crustaceans are dioecious Copulation and egg brooding are very common. Eggs are mostly centrolechithal and 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.

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 100 μm 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 crustancans 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, themost notable being sowbugs and pillbugs (the terrestrial isopods). Crustaceans occupy an important position in aquatic food chains.

Examples : ***Palaemon*** (prawns), ***Cancer*** (crabs), ***Squilla, Penaeus, Macrobrachium, Eupagurus*** (hermit crab), **Da*phnia, Artemia*** *(brine shrimp),* ***Triops, Cypris, Cyclops, Argulus*** *(fish louse),* ***Lepas*** (goose barnacle), ***Balanus*** *(rock-barnacle or acorn barnacle),* ***Sacculina****.*

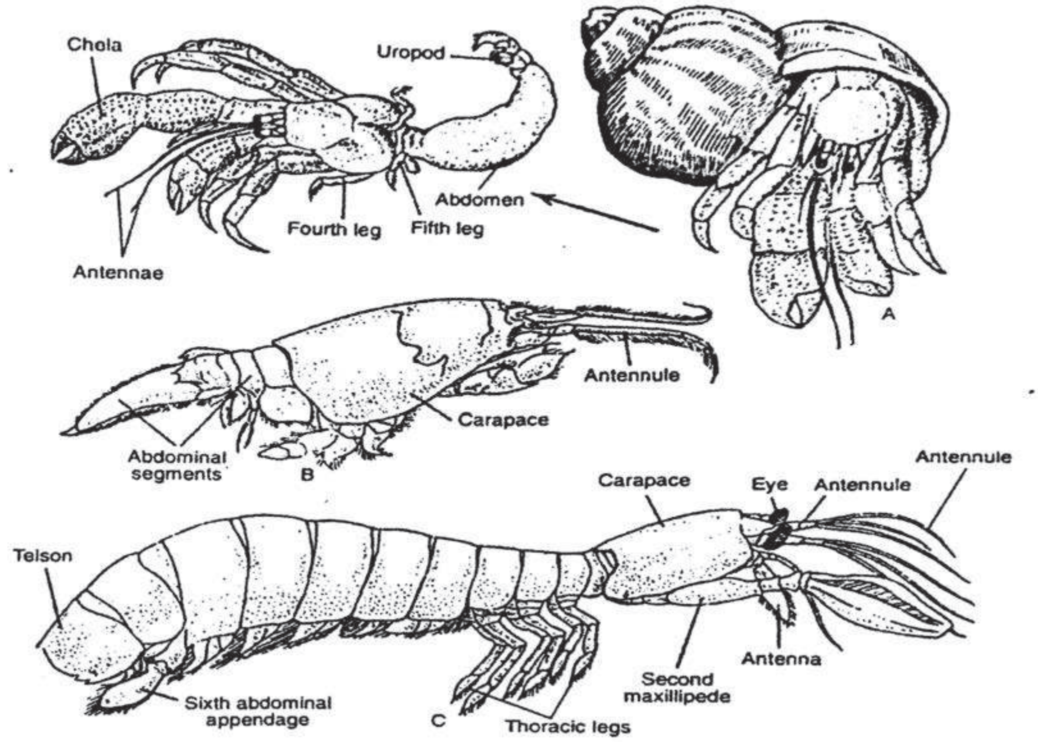


Fig. 3 : Some important crustaceans (contd.). A. *Eupagurus*. B. *Hippa*. C. *Squilla*. Arrow indicates the body of *Eupagurus* outside the molluscan shell.

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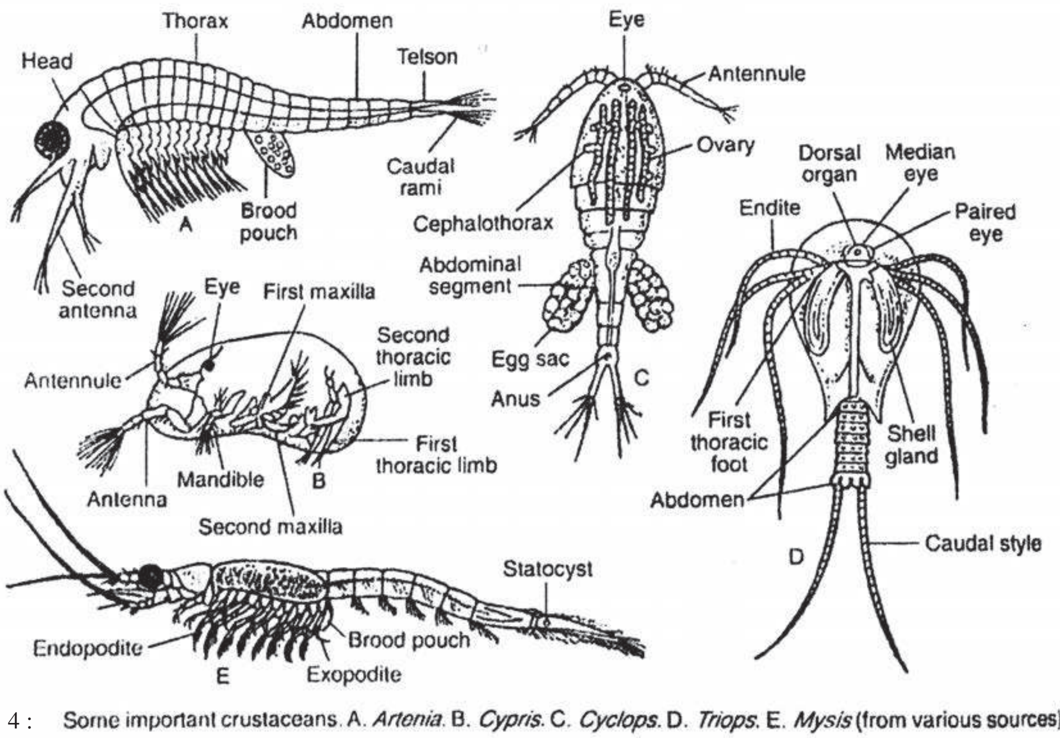

Fig. 4 : Some important crustaceans. A. *Artenia*. B. *Cypris*. C. *Cyclops*. D. *Triops*. E. *Mysis* (from various sources).

Arachnids (G. arachne = spider) **:**

The arachnids belong to **Class Arachnida** under subphylum **Chelicerata** of phylum **Arthropoda**.

7.2.2 General Characteristics of Arachnida

1. The body is divisible into **cephalothorax** or **prosoma** and **abdomen** or **opisthosoma**. Prosoma unsegmented, usually covered dorsally by a solid carapace.
2. Prosoma or cephalothorax with one pair of chelicerae, one pair of pedipalpi and four pairs of legs.
3. Antenna and true jaws are absent.
4. In some arachnids (ticks and mites), the prosoma and opisthosoma have fused together and the entire dorsal surface is coverd by a single carepace.
5. The brain is an anterior ganglionic mass lying above the oesophagus. Eyes usually simple. Compound eyes either absent or degenerated. For most arachnids the sensory hairs are the primary sense organs.
6. Abodmen generally without appendages but modified appendges in some. Some arachnids (the spiders) bear upto 4 pairs of small abdominal appendages called **spinnerets**.
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. The heart is highly developed in large species with book lungs and the blood contains haemocyanin.

FIGURE 3 A : Light microscope view of *Ixodes* spp.

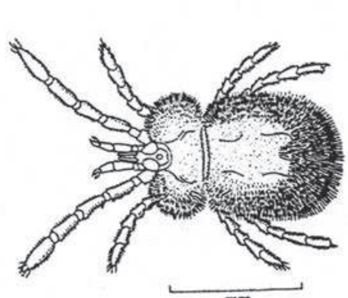

FIGURE 3 B : *Trombicula*, a mite vector of scrub typhus.

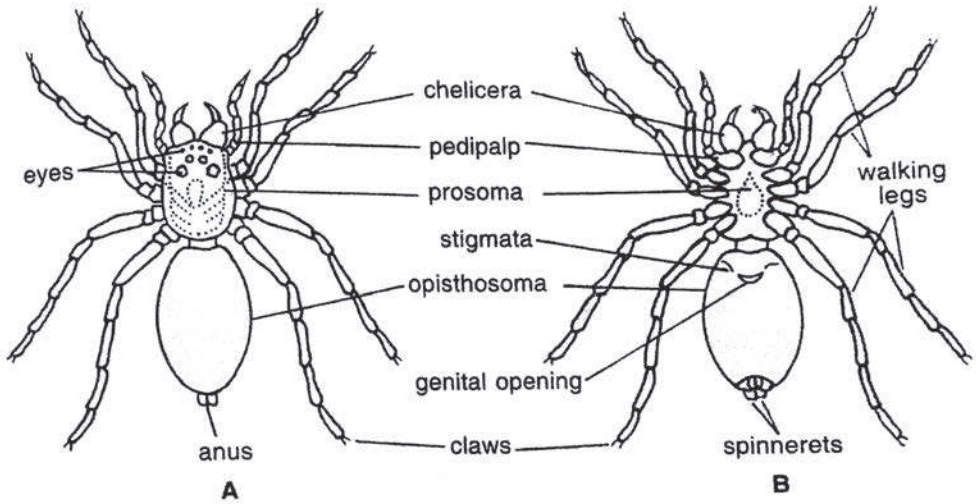

Fig. 4 A spider. A—Dorsal view; B—Ventral view.

9. Excretory organs are coxal glands or Malpighian tubules or both.
10. Sexes separate. Single or paired gonads lie in the abdomen. Fertilization is internal.
11. Eggs yolky and centrolecithal. Development direct, not accompaned by metamorphosis.
12. Arachnids are carnivorous and mostly terrestrial.

About 98% of the living chelicerates (**Subphylum Chelicerata**) belong to class Arachnida. Although the earliest members of the class Arachnida were undoubtedly marine, the more than 70000 living arachnid species so far described are primarily terrestrial. Those speices that are aquatic (some mites) represent a secondary return to freshwater 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

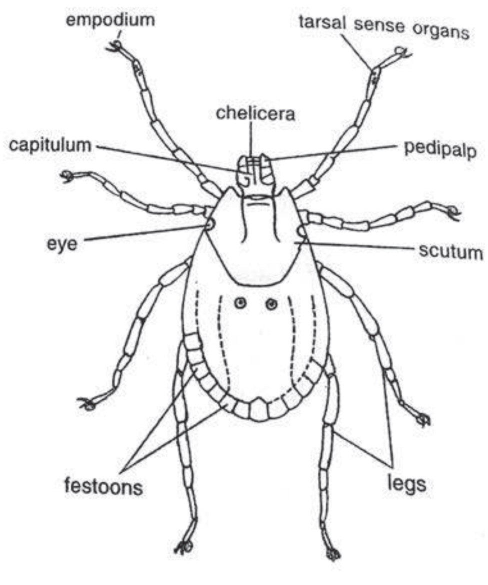

Fig. 5 : A tick. Dorsal view.

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.

Examples : *Buthus* (scorpion), ***Palamnaeus*** (scorpion), ***Chelifer*** (pseudoscorpion), ***Aranea*** (spider), ***Lycosa*** (spider), ***Latrodectus*** (black widow spider), ***Sarcoptes*** (mites), ***Ixodes*** (ticks), ***Dermacentor*** (ticks), ***Chorioptes*** (mites).

7.3 Crustacean Larvae :

Larva is a developmental stage in the life cycle of many invertebrates as well as some vertebrates. It differs from the adult both in its structure and its habit. Larvae are usually free living i.e.lead an indepedent life and subsqueutnly transform into adults. In creustacea the development is usually indirect through metamorphosis of larval stages. In some crustaceans e.g. *Palaemon, Argulus*, the larva does not come out of the egg. Transformation occures internally and young, resembling the adult, is hatched out. Within the clsss crustacea, variety of larval forms are seen and in many groups one type of larva transforms into another type and finally becomes the adult.

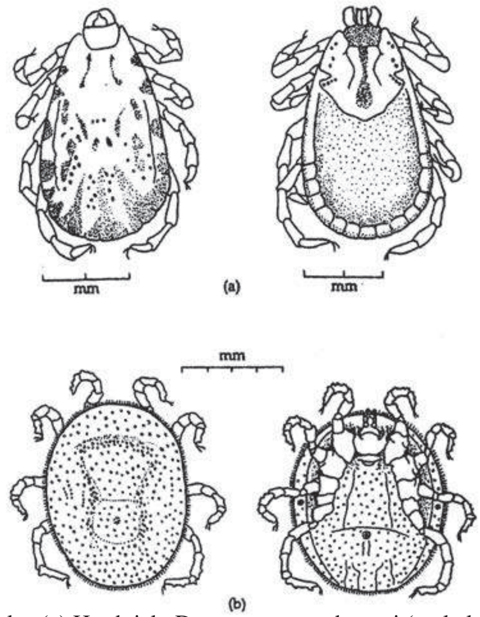

FIGURE 6 : Ticks. (a) Hard tick, Dermacentor andersoni (male left, female right). (b) Soft tick; Omithodoros moubata (dorsal aspect left, ventral aspect right).

Different types of crustacean larvae :

1. Nauplias larva : The earliest and basic type of crustacean larva is a nauplias which is found in all major groups of crustacea.

Characteristics of Nauplias larva–

1. Nauplias is a very small transparent free swimming larva.
2. The body is oval in shape, the anterior part of the body is wider than the posterior end and there is no trace of external segmentation.
3. A median frontal eye is present at the anteiror end. It is characteristic of nauplius and often referred to as the nauplius eye. The median eye may persist or degenerate in adult.
4. The body is with three pairs of appendages.
5. The anterior first pair of appendages are uniramous and placed in front of the mouth. They develop into the antennule of the adult.
6. The remaining two pairs of appendages are biramous and are present in the trunk region and act as locomotor organs. The second pair transforms into antennae and the third pair becomes the mandibles of the adult.
7. In between the trunk appendages lies the mouth which is enclosed by a prominent labrum.
8. Alimentary canal is straight and simple and terminates at the posteriormost end of the body through anus.
9. In the anterior part there is a pair of lateral projection known as lateral horn or frontolateral horn.

In allmost all crustaceans the nauplius is the first larval stage of development but its appearance varies in different forms or groups. In cladocera, nauplius stage appears inside the egg. In ostracoda nauplius, a pair of bivalved shells and uniramous appendages are present. In the cirripedia, a number of spines are present in nauplius. Alimentary canal is absent in Sacculina nauplius. In Isopoda, the nauplius is maggot-like.

In some forms the nauplius larva develops straight away into adult, but in many other crustaceans it gives rise to other intermediate larval forms like metanauplius, protozoea, zoea, cypris, mysis, megalopa, phyllosoma, alima, etc.

2. Metanauplius Larva :

The nauplius larva of Copepoda metamorphosed by a series of ecdysis and form **metanauplius** larval stage.

1. It is the second larval stage which develops from the nauplius larva.
2. The body has an anterior oval cophalothorax and an abdomen terminating in a pair of caudal forks.

3. Besiedes the three pairs of nauplius appendages, it also bears the rudiments of four pairs of appendages which are two pairs of maxillae and two pairs of maxillipedes of the adult.

Some decapods, stomatopods (mantis shrimps) and some notostracans (e.g., *Apus*) begin their life history with the free swimming metanauplias larva.

3. Cypris Larva :

In some Cirripedia (*Lepus, Sacculina*) the nauplius larva after several moults develops into cypris stage.

1. The body and the appendages are enclosed within bivalved carapace with adductor muscle to close it.
2. In addition to medium eye, a pair of compound eyes are present.
3. The antennule is large and four jointed and modified for attachment to the substratum with cement gland. The second antenna is absent.
4. Six pairs of biramous thoracic appendages are present for swimming.
5. The tip of the abdomen bears a caudal furca.
6. The larva contains a mass of germ cellls.

4. Protozoea Larva : In case of marine prawns (*Penaeus*) and some other decapods, the eraliest nauplius by growth and moulting develops into a protozoea larva.

1. Body is divisible into a braod segmented cephalothroax covered with a small carapace and a slender abdomen which is unsegmented.
2. First antenna (antennule) is four jointed, and uniramous, second antenna is biramous with three-jointed endopodite and four jointed exopodite.
3. Mandibles are small and masticatory in function.
4. Two anterior pairs of maxillipeds are biramous.
5. It still lacks compound eyes, but impressions are visible.
6. Three pairs of thoracic limbs make their appearance as buds.
7. Abdomen ends in a forked telson.
8. The seven pairs of appendages become well developed and capable of movements.

5. Zoea Larva : Zoea is the second important larva of the Crustacea after the nauplias larva. In *Penaeus*, protozoea develops into zoea. It is also the common larva of decapods and hence it has variations in its features in different species.

1. The larval body is divisible into a broad cephalothroax and an segmented abdomen.
2. The cephalothorax is covered by a helmet-like carapace which bears two long spines, a median rostral one (protrudes into a rostrum in front) and a median dorsal one.
3. Compound eyes are prominent and stalked.
4. The larva bears antennules, antennae, mandibles, maxillae and two pairs of well-developed maxillipeds.
5. Thoracic appendages appear as rudiaments.
6. Abdomen is six-segmented and curved, without appendages and has a forked telson at the tip.

6. Mysis larva or Schizopod Larva : In shrimps and some lobsters zoea transforms into mysis that resembles adult *Mysis* in general features.

1. Elongated transparent body, differentiated into cephalothorax and six segmented abdomen including a telson.
2. Carapace is produced in front into a pointed rostrum.
3. Six pairs biramous thoracic appendages for locomotion.
4. Presence of a pair of stalked compound eyes on the head.
5. The endopodites of the thoracic appendages are long but the exopodites are reduced.

In some decapods (e.g., in *Penaeus*), the egg hatches as nauplius, it passes by successive moults through zoea stage, protozoea stage and mysis stage which changes into an adult. In some lobsters, (e.g. *Homarus*) both nauplius and zoea are passed within the egg, and it hatches as a mysis larva which changes into an adult.

7. Megalopa Larva : In true crabs (brachyuran decapods), zoea metamorphoses into megalopa larva. It looks, to some extent, the adult crab.

1. It has a broad unsegmented crab-like cephalothorax and a straight abdomen. Cephalothorax is covered by a broad carapace. The carapace is produced into a median spine anteriorly.
2. Thorax is with five pairs of walking legs.
3. First thoracic appendage is chelate.
4. Large stalked eyes are distinctly visible.

5. Abdomen bears biramous pleopods.

Megalopa larva transforms into adult through moulting.

8. Phyllosoma Larva : In the rock-lobster (*Palinurus*), the newly hatched larva is called phyllosoma larva or glass crab. It is a modified mysis stage.

1. The body is more or less mysis like.
2. It is remarkably large, flattened, leaf-like delicate and glassy.
3. A narrow constriction demarcates the head from thorax.
4. A pair of compound eyes with long stalks.
5. Thorax bears six pair of appendages–first thoracic or maxillipedes are rudimentary (*Palinurus*) or absent (*Scyllarus*), second appendages are uniramous, remaining four pairs are long birammous legs.
6. Abdomen is short, segmented but limbless.

The larva undergoes several moultings and transforms into adult.

9. Alima Larva : In some malacostraca like *Squilla*, the egg directly hatches out in a young stage, called *alima larva*. It is modified form of zoea.

1. The body is divisible into cephalothorax and abdomen. The cephalothorax is covered by a short and broad carapace.
2. The body is slender, having a glass-like transparency.
3. In addition to all cephalic appendages, only first two thoracic appendages are found.
4. Abdomen has six segments with four or five pairs of pleopods.
5. The alima larva differs from zoea larva in the armature of the telson and a very large raptorial second maxillipedes.

10. Kentrogen Larva :

1. Body is sac-like and elongated.
2. Undifferentiated mass of cells is present inside the body.
3. It has a chitinous tube called dart.
4. Presence of root like processes.
5. All crustacean characteristics lost due to parasitism. Kentrogen larva is seen in the parasitic form like *Sacculina* (Cirripedia).

Sequences of larval appearance in crustacea :

In Branchiopoda, Cladocera, Ostracoda and Copepoda only nauplius larva appears. But in Cirripedia, nauplius stage is followed by cypris stage which transforms into an adults. In the *Sacculina*, after cypris another stage called

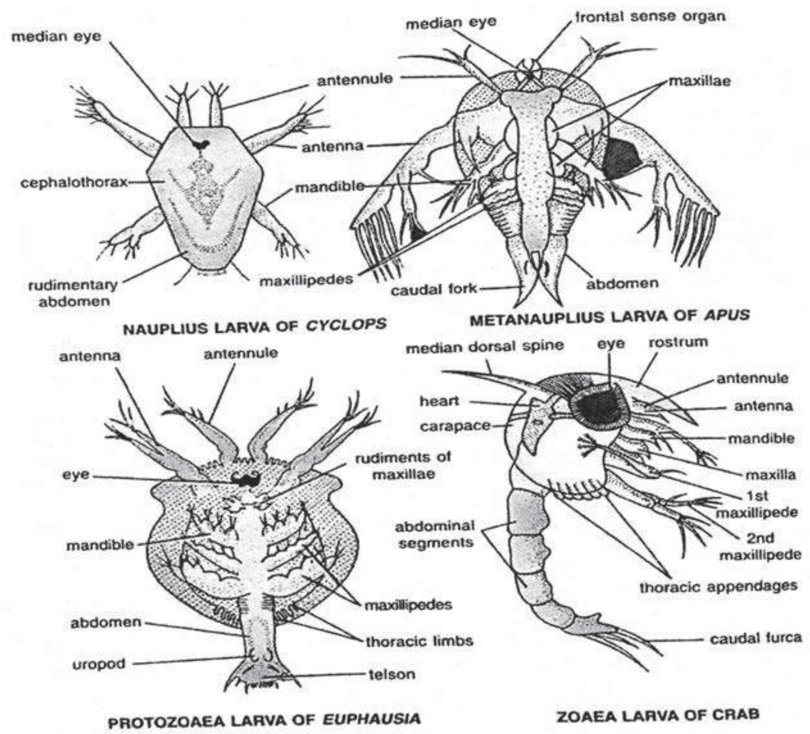

Fig. 7A : Some larval forms of Crustacea.

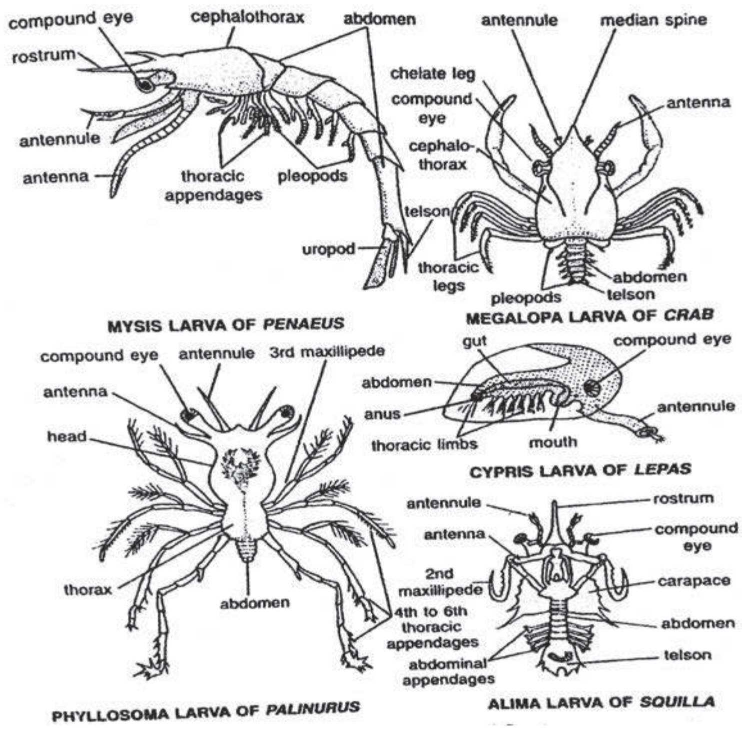

Fig. 7B : More larval forms of Crustacea.

Kentrogen stage, appears. In *Euphausia*, nauplius metamorphoses into protozoea and calyptopis before passing into the adult. In *Penaeus*, larvae pass through nauplius, protozoea, zoea and mysis stages, before becoming and adult. In the crabs, after certain transformations within the egg, the larva is hatched as zoea which changes into megalopa stage and then becomes an adult. In *Palinurus*, the larva hatches out in a modified mysis stage which is called phyllosoma larva.

7.4 Bionomics and Affinities of *Peripatus* (*Onychophora*)

Peripatus belongs to the phylum Onychophora. Previously onychophora was treated as a class and it was placed as an appendix to the phylum Arthropoda, but recently it has been given the status of a separate phylum. Peripatus is a small caterpillar-like animal and it is very important from zoological point of view because the animal displays some characteristics of annelids and some characteristics of arthropods along with some specialized features of its own. As the onychophorans have many similarities with both annelids and arthropods, they have been described as a missing link between the two groups by some zoologists but some of their special adaptations and peculier features do not confirm the "missing link" status of Onychophora by the modern zoologists.

The onychophorans have been divided into two families–Family Peripatopsidae and Family Peripatidae by Meglitsch and Schram (1991). Commonly studied genus is *Peripatus*.

Geographical distribution.

Peripatus exhibits discontinuous distribution with its species scattered in most of the warmer part of the world–Africa, Australia, New Zealand, Central America, Mexico, West Indies, Malaya Archipelago, India and other localities. More specifically, the members of family Peripatidae are distributed to the equitorial West Africa, West Indies, Mexico to the Rio de Janeiro, North East India and Southern part of South East Asia, while the members of family Peripatopsidae are distributed in Chilie, South Africa, Australia, New Zealand, Tashmania, New Britain and new Guinea. No species have been found north of the Tropic of Cancer.

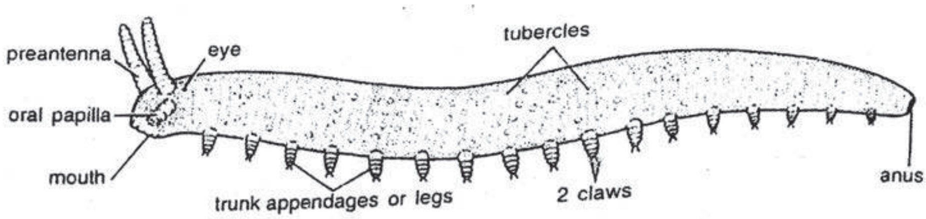

Fig. 1. *Peripatus.* External features in lateral view.

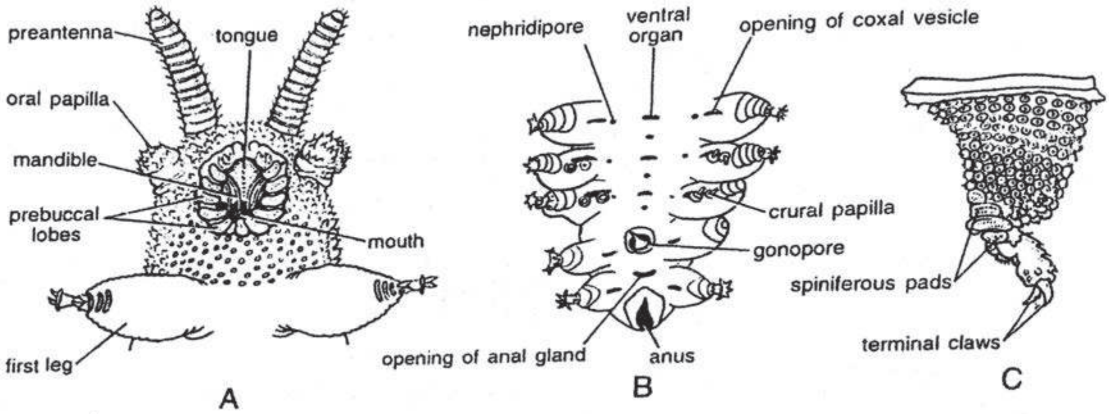

Fig.10: *Peripatus.* A—Anterior end in ventral view. B—Posterior end in ventral view. C—A leg.

Habit and habitat :

Peripatus is a terrestrial animal, living in moist or humid places, in crevices of rocks, under stones, logs and bark and other dark and damp places where it is protected both from loss of water and from the predators. It is nocturnal in nature and predaceous and carnivorous in feeding habit (feeding on insects, other small arthropods and worms).

External Morpholgy :

The body of *Peripatus* is caterpillar like (Fig 11). It is soft elongated, more or less cylindrical, measruing between 1.5 cm to 15 cm in length. The external segmentation is indistinct and marked only by the presence of paired appendages. Numerous superficial lines or annuli mark the body but such annuli do not correspond to segmentation. Head is not clearly differentiated. The body covering is thin cuticle which is soft and has velvety texture and thrown into a number of fine transverse rideges or wrinkles bearing numerous small conical papillae or tubercles armed with chitinous spines. The colouration usually varies from dark grey to brown but red, blue and green colourations are also marked.

The anterior end bears a pair of simple eyes, a pair of annulated antennae and

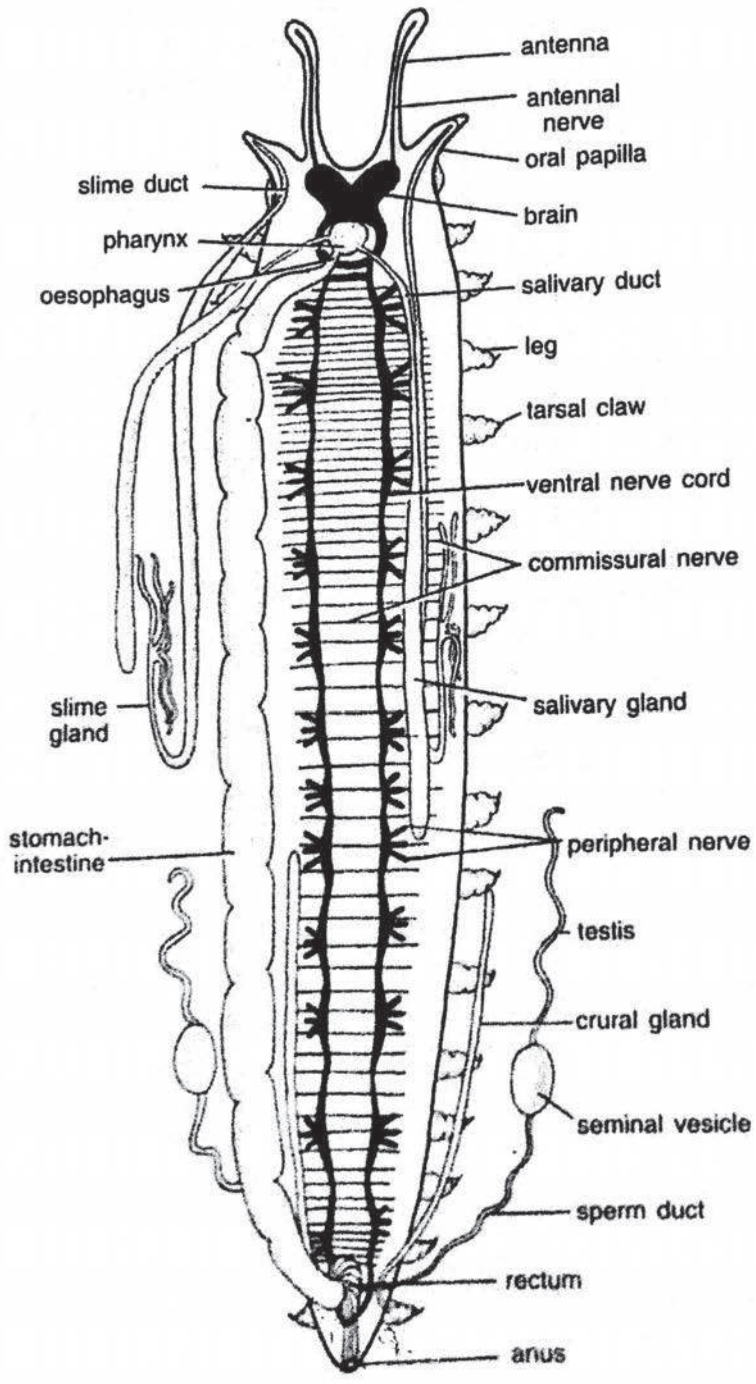

Fig. 11 : Peripatus. Internal structure.

a ventral mouth, which is flanked by a pair of mandible, each with two claw-like blades and a pair of short conical oral papillae. The body has 14-43 pairs of short, unjointed and fleshy stumpy legs, that are hollow evagination of the body bearing terminal pads, pairs of claws and muscles. The anus lies at the posterior end of the body, slightly towards the verntral side behind the last pair of legs. The genital opeing or gonopore is located just in front of the anus in between last pair of legs. A nephridiopore lies on the inner base of each leg.

Anatomical Features :

1. The body wall is dermomuscular, consisting of cuticle, epidermis, dermis, and striped circular and longitudinal muscles.
2. True coelon is reduced to the small cavities of excretory and reproductive organs.
3. The body cavity is a haemocoel and well developed, forming the hydrostatic skeleton.
4. A pair of *slime glands* are located, one on either side of the body cavity. These open on the tip of oral papillae and secrete or discharge an adhesive slime for entangling the prey, during food capture. The slime also helps in defence.
5. Digestve system includes alimentary canal and a pair of large *salivary glands* (which are modified metanephridia). Alimentary canal is a stright tube comprises of mouth, a tongue, buccal cavity with jaws, muscular pharynx, short eesophagus, long midgut or stomach-intesitine, rectum and anus (Fig.).
6. Peripatus is adapted to air breathing and the respiratory organs are simple unbranched or rarely branched tracheae. They communicate with the exterior by numerous stigma (spiracles) situalted over the surface of the body and are placed in the depressions between papillae or ridges of the integument.
7. Circularoty system open, consists of a dorsal tubular and contractile heart which runs entire length of the body and is enclosed in a *pericardial sinus*. Blood is colourless and contains phagocytic amoebocytes.
8. Excretory organs are paired segmental sac-like nephridia with a ciliated funnel and nephrostome. The nephridiopore is located on the inner base of each leg.

9. The nervous sysem consists of a bilobed brain and a pair of widely separated ventral nerve cords connected together by transverse commissures. Ganglia on the cords are indistinct.
10. Sense organs include a pair of eyes near the base of the antennae (which also act as sense organs), taste spines in and around buccal cavity and tactile spines on the surface tubercles.
11. Sexes separate (Gonochoristic), males are usually smaller than females. Reproductive organs are paird.
12. Fertilization is internal and development is direct. Most species of *Peripatus* are viviparous, eggs develop in uterus of female (females broad their eggs internally and give birth to young ones).

Affinites of Peripatus :

Peripatus, a small caterpillar-like animal, is very important from zoological point of view becaue the animal exhibits some characteristics of annelids and some characteristics of arthropods along with some specialized (unique) features of its own. Because it shares the characters of two different phyla, *Peripatus* is considered by some zoologists as *conecting link* between the two phyla. An account of its affinities (similarities) with three other large phyla, Annelida, Arthropoda and Mollusca is given below :

A. Affinities with Phylum Annelida :

1. Body is vermiform (worm like) with truncated extremities.
2. Absence of a true head.
3. Segmentation in both is homonymous.
4. Body wall dermo-muscular, consisting of a thin, flexible and permeable cuticle and underlying circular and longitudinal muscles.
5. Presence of paired nephridia which are segmentally arranged.
6. Structure of eye is similar to that of some polychaetes in having large chitinous lens and well developed retina.
7. Like the parapodia of annelids (Polychaeta), the hollow unjointed stumpy legs are the extensions of the body wall.
8. Simple, straight alimentary canal with terminal mouth and anus.
9. Presence of cilia in the excretory and reproductive ducts as in annelids.

10. Locomotion slow by contraction and expansion of body muscles as in annelids.
11. The slime and coxal glands correspond with the similar glands of polychaetes and oligochaetes.

B. Affinities with Phylum Arthropoda :

1. Presence of antennae.
2. Jaws are modified appendages.
3. Locomotion by definite legs, having definite musculature and provided with claws.
4. Cuticle has a thin deposition of chitin like that of arthropods and it is moulted periodically.
5. Body cavity is a haemocoel. True coelom is reduced to the small cavities of exeretory and repriductive organs.
6. Dorsal tubular heart with lateral ostia. Heart and circulatory system are distinctly arthropodan.
7. Respiration by tracheae.
8. Brain is large and resembles the brain of typical arthropods.
9. Excretory organs closely resemble the green gland of crustaceans.
10. General structure of the reproductive organs and pattern of development are similar to arthropods.

C. Affinities with Phylum Mollusca :

1. Slug-like appearance.
2. Ladder-like nervous system resembling that of polyplacophora (*Chiton*) and lower prosobranchia.
3. Antennae tentacle-like.

According to many zoologists these resemblances are only superficial.

D. Peculiar Onychophoran Characteristics (Its own characters) :

1. Peripatus possesses certain characteristics of its own by which they differ from other phyla. These are :
1. Body shows no or indistinct segmentation.
2. Texture of skin is different from other phyla. Cuticle is rough and velvety, permeable and with numerous processess.
3. Antennae are not homologous to that of arthropods.

4. Three segmented head of *Peripatus* exhibits a condition mid-way between that of Annelida and Arthropoda.
5. Restriction of jaws to a single pair. Jaw is modified second appendage and movement of jaws is antero-posterior.
6. Presence of non-jointed legs with claws.
7. Irregular distribution of spiracles or tracheal openings. Tracheae are not branched.
8. Two ventral nerve cords are widely separated and without distinct ganglia.
9. The structure of eye is less complicated.
10. Disposition of reproductive organs is different.

7.5 Taxonomic position of Onychophora

The characters of *Peripatus* have made it most interesting from the point of view of evolution. It is the oldest terrestrial group which probably originated from some marine ancestors. With the peculiar nature and some annelidan characters it appears that *Peripatus* probably originated from some marine polychaetes which gave up the marine habit and has become modified for locomotion on land without jointed appendages.

As discussed earlier *Peripatus* exhibits both annelidan and arthropodan characteristics. Therefore, they were regarded by some zoologists to be an intermediate stage or connecting link between Annelida and Arthropoda. According to some *Peripatus* appears to be more closley allied to arthropods than to annelids and perhaps arose as an offshoot from near the base of arthropod line. Based on such phylogenetic considerations, Manton (1970) and other contemporary zoologists have included them within Phylum Arthropoda as a subphylum or class. Marshall and Williams (1972) placed all the members of onychophora in a separate subphylum Onychophora under phylum Arthropoda. But absence of jointed chitinous exoskeleton and jointed appendages and presence of annelidan characters in onychophora do not support the inclusion of Onychophora within Arthropoda. At the same time *Peripatus* shows marked differences from all other classes of Arthropoda. In fact onychophorans are neither worms nor arthropods. At present it is believed that onychophoras are not an evolutionary link between Annelida and Arthropoda but an ancient independent group of segmented animals contemporary to Arthropoda and as such has been placed under separate phylum Onychophora.

Additional information :

- ❑ Onychophora is undoubtedly very ancient group because a mid-cambrian (about 520 million years ago) fossil, *Aysheaia*, closely resembles the modern onychophorans. *Aysheaia* was more closer to the annelids than the arthropods.

- Kaestner (1967) has stated that the Onychophora probably represents an early lateral branch of evolutionary line terminating in the arthropods.
- A cladistic analysis places the Onychophora in an intermediate position between the Polychaeta and the Tardigrade–Arthropoda clade (Brusca and Brusca, 2003).
- Onychphora represnt a sister group to the Arthropoda on the basis of morphological, palaeongtological and molecular data (Anderson, 1998).
- "Both morphological and molecular evidence argue that arthropods had a single origin, and that onychophorans are an early offshoot from an ancestor that eventually gave rise to both tardigrades and arthropods" (Pechenik, 2000).
- "Although onychophorans reflect an annelidan ancestry, their origins are obscure. Their development is somewhat similar to that of clitellate annelids (oligochaetes/leeches), and recent studies on ultrastructure of onchophoran sperm have also revealed striking similarities to the sperm of clitellates. Some zoologists postlate that clitellates and onychophorans are a monophylatic group and the sister group of the myriapod insect assemblage." (Ruppert and Barnes, 1994).

7.6 Questions

a) Write short notes on—

i) Haemocoèl ii) Living forsil iii) Connecting link iv) Book gill v) Cephalothorax vi) Epipodite

b) How many legs are present in insects?

c) Why crustaceans are also known as decapoda?

d) What do you mean by social insects?

Unit – 8 ❑ Phylum : Echinodermata

Structures

8.0 Objective

This chapter deals with those animals which are considered to be the ancester of chordate animals. You also learn why all the animals belong to this phylum lives in ocean only. Not only that these animals are considered to be the first deutostomian animal.

8.1 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.

8.2 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.

8.3 Classification

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.

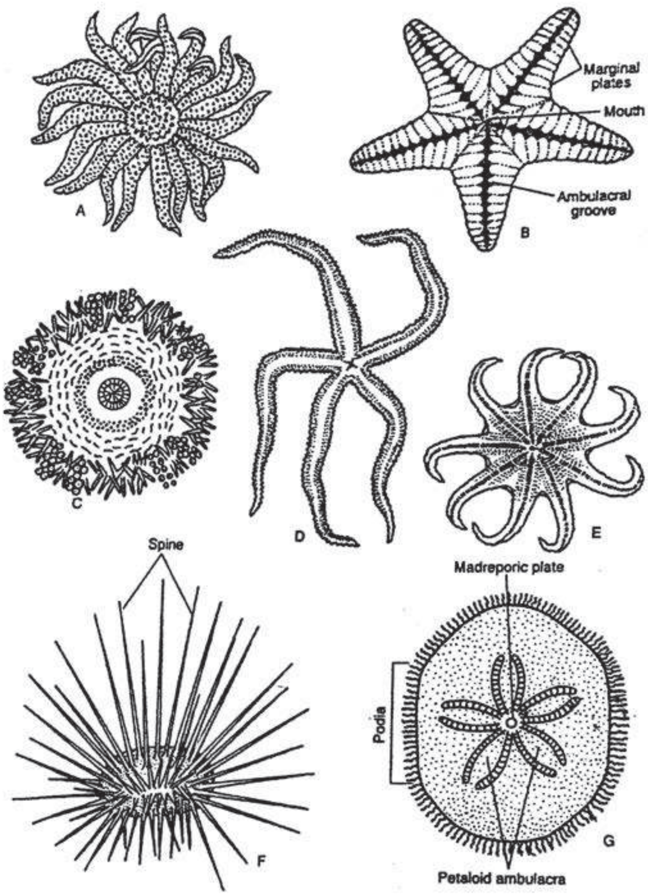

Fig. 1 : Some important echinoderms. A. *Heliaster.* B. *Ctenodiscus.* C. *Arbacia.* D. *Zoroaster.* E. *Solaster.* F. *Diadema.* G. *Clypeaster.*

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.
3. Ambulacral grooves absent, tube feet without suckers.
4. No spacious prolongations of the coelom into the arms. Arms largely filled with vertical ossicles.

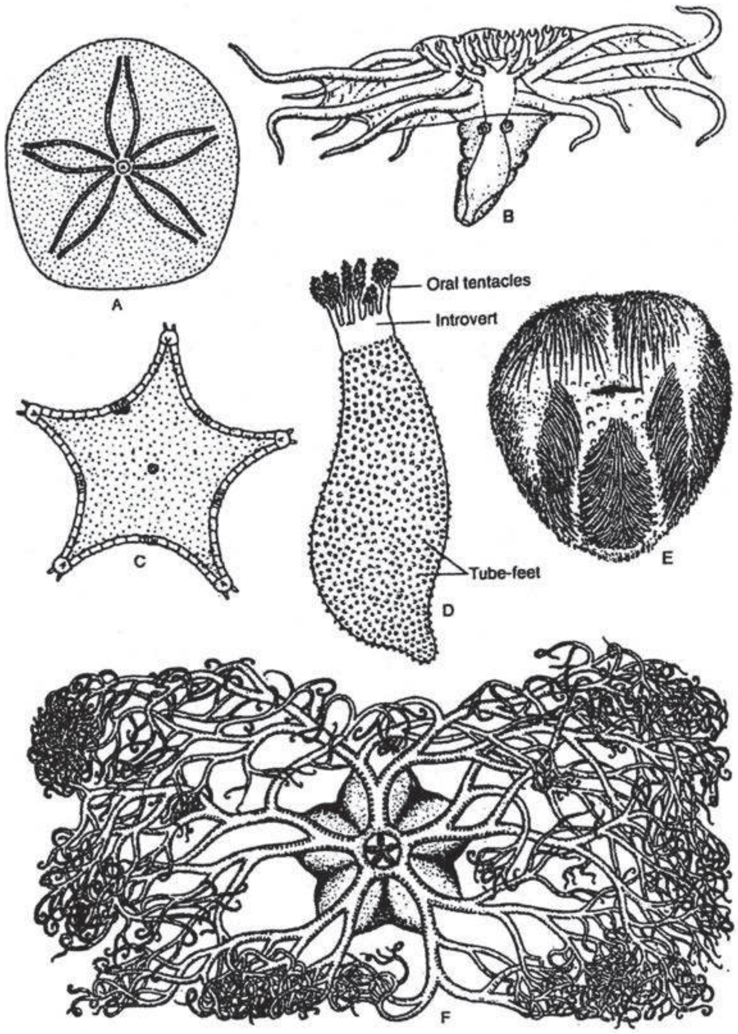

Fig. 2 : Some important Echinoderms (contd.). A *Laganum.* B. *Pelagothuria.* C. *Porcellanaster.* D. *Thyone.* E. *Echinocardium.* F. *Gorgonocephalus.*

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**.*

8.4 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 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.

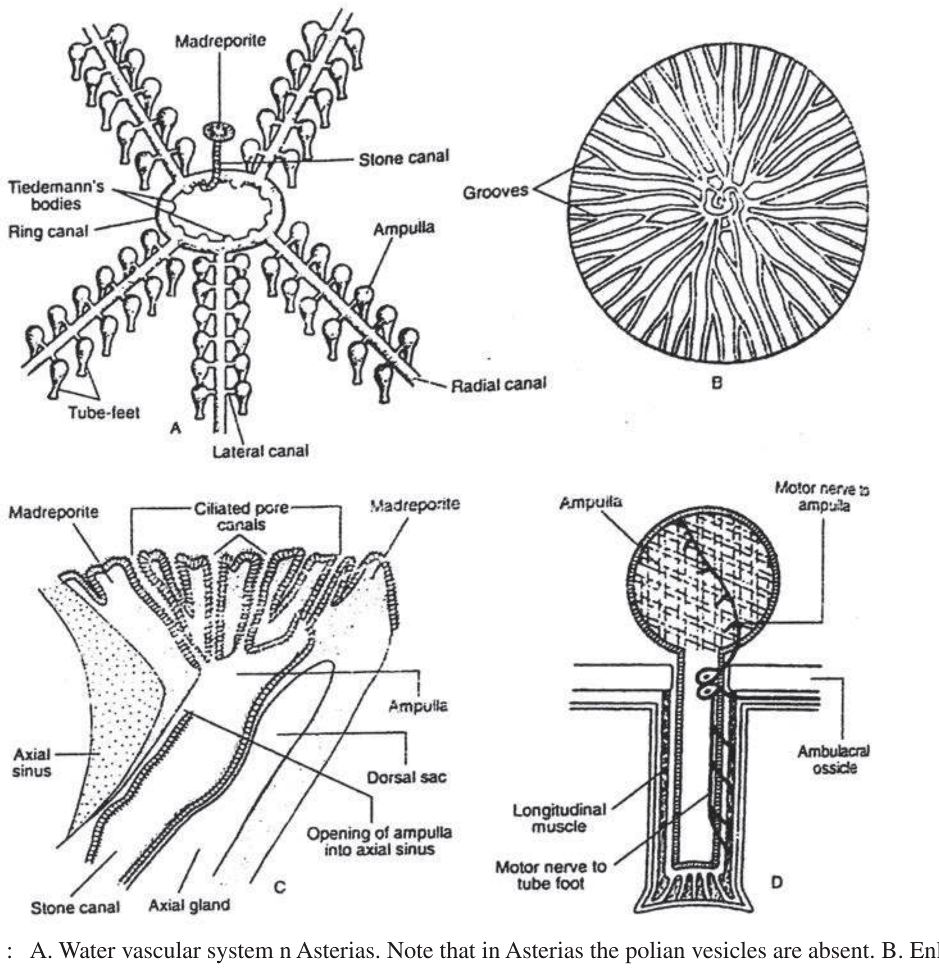

Fig. 3 : A. Water vascular system n Asterias. Note that in Asterias the polian vesicles are absent. B. Enlarged view of the madreporite of Asterias. C. Diagrammatic view of the vertical section through the madreporite in Asterias. D. Diagrammatic sectional view of a tube-foot and its nerve supply in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

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,

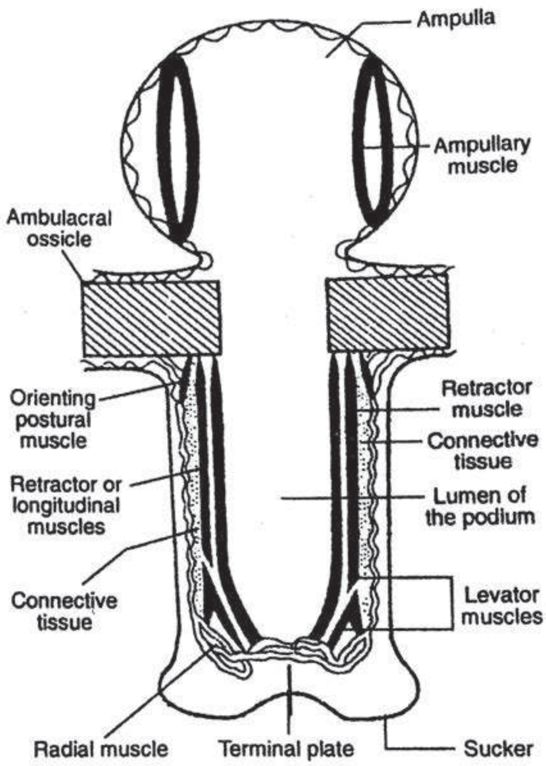

Fig. 4 : **Diagrammatic view of longitudinal section through the tube-foot and ampulla of a star-fish showing the arrangement of muscles.**

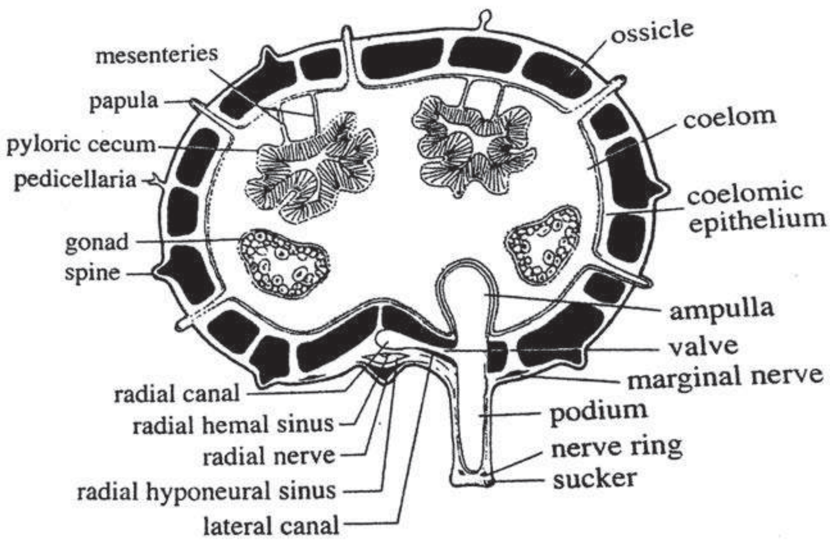

Fig. 5 : Diagrammatic cross-section through the arm of a star fish.

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 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 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.

8.5 Questions

a) What is madriporite?

b) What do you mean by stone canal?

c) How many parts are present in tube feet?

d) What are the name of larval stages in Echinoderm animal?

e) What do you mean by ambulacral system?

f) Is blood vascular system is present in Echinodermata?

g) Write the important characters of phylum Echinodermata.

Unit–9 ❒ Phylum : Mollusca

Structure

9.1 Objective

This unit deals with those animals which are externally covered with a shell or conch. From this unit you will learn that how beautifully patterned conchs are present in these animals. The study of the shells of these animals is a separate science which is known as Choncology.

9.0 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.

9.2 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.

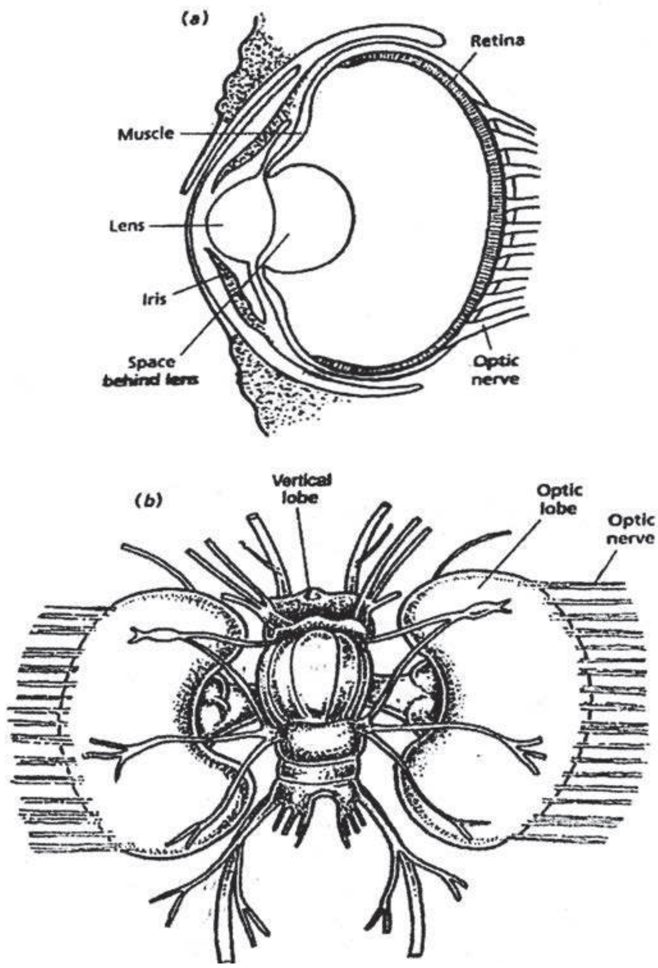

Figure 1 A, B : (a) The eye of a cephalopod; (b) the brain of an octopus in dorsal

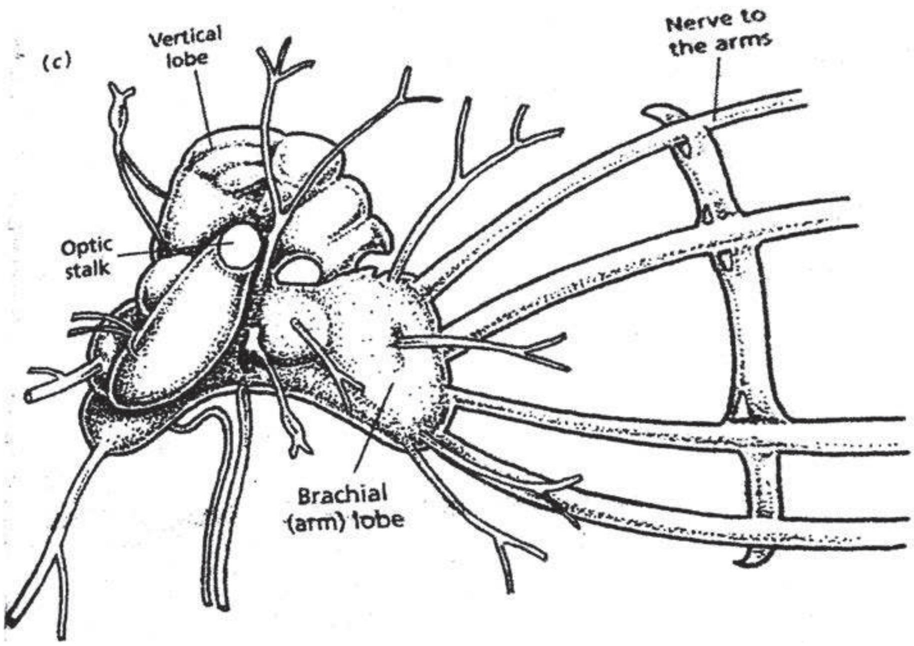

Figure (cont.). 1C : (c) the brain of an octopus in lateral view.

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.

9.3 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.

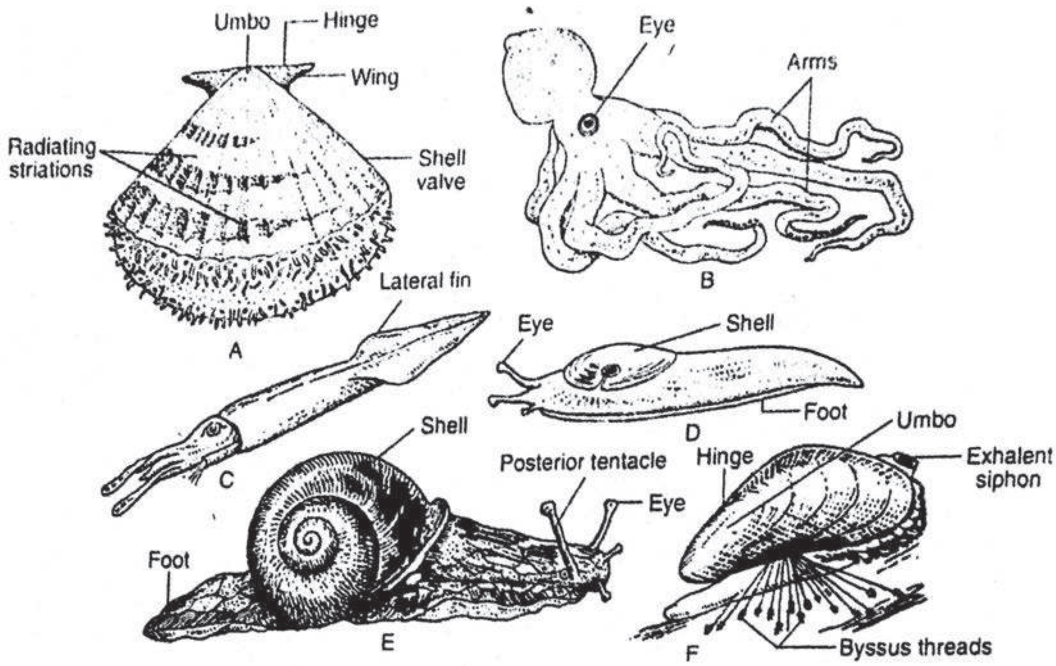

Fig. 2 : Some members of Phylum Mollusca (not drawn up to scale), A. Pecten (scallop), B. Octopus. C. Loligo (squid). D. Limax (slug). E. Helix (Roman snail). F. Mytilus (sea-mussel).

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)

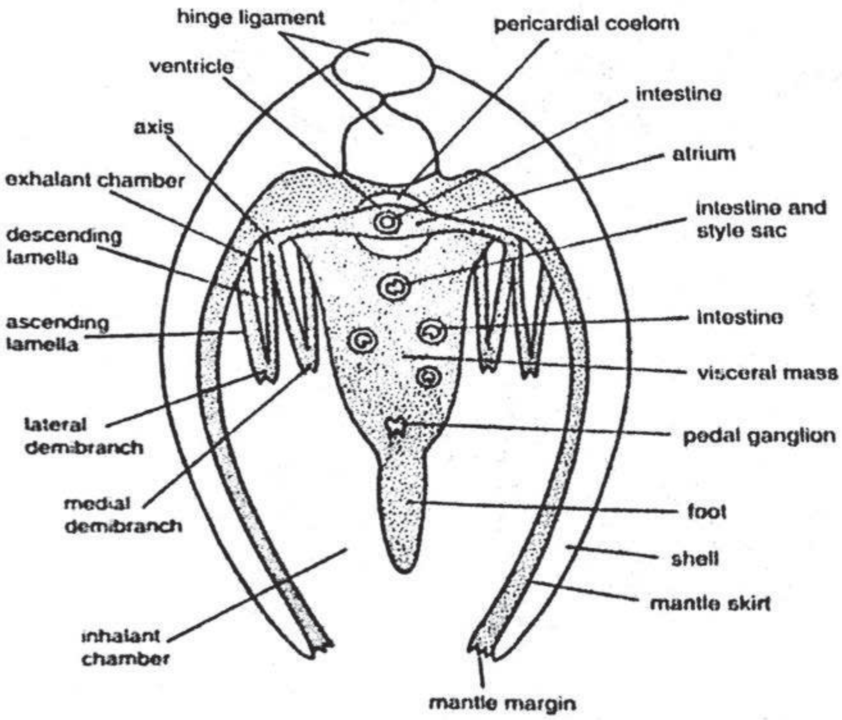

Fig. 3 : Bivalve mollusc. Cross section of a generalized Lamellibranch (after Ruppert, et al., 2004)

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).

9.4.1 Torsion in Gastropoda

All the living molluscs, except the Gastropods, retain ancestral bilateral symmetry of the body with mantle cavity lying posteriorly or laterally. Gastropods, on the other hand, possess an asymmetrical body with mantle cavity lying anteriorly and the shell and visceral mass coiled spirally and directed posteriorly. This anterior positon of the mantle cavity in gastropods is due to *torsion* or twisting of he visceral mass during development. This unique process of torsion is a characterisic feature of all living gastropods.

Torsion is the rotation of the visceral mass (containing organs of the body) and

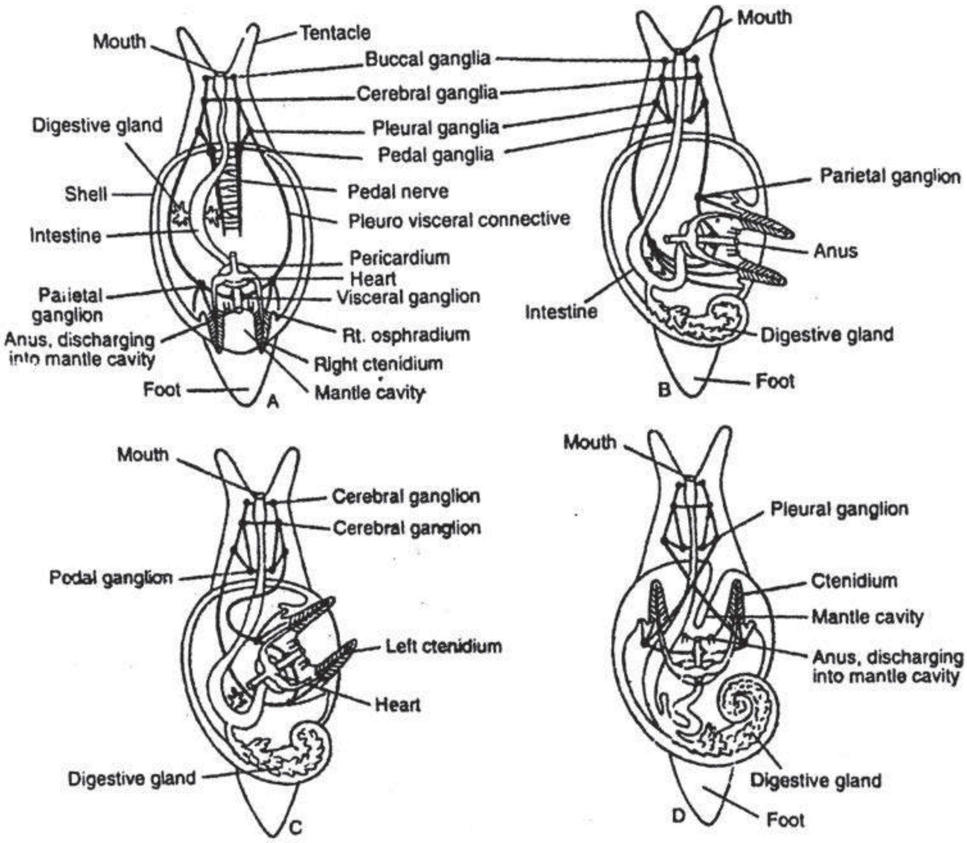

Fig. 4 : Diagrammatic representation of torsion in Gastropod. A. Hypothotical ancustral stage with symmetrical arrangement of structures. B. Displacement of the mantle cavity to the right side. C. Showing 90' torsion. D. Showing complete torsion.

its overlying mantle and shell as much as 180º with respect to the head and foot (Fig.). The twisting is always in a counterclockwise dierection (viewing the animal from above) and it is completely different from the phenomenon of coiling (Brusca and Brusca, 2002). Torsion takes place during developement of all gastropods, usually during the late veliger larval stage. During torison, the mantle cavity and the anus are moved from a posterior to a more anterior position, somewhat above and behind the head. Visceral structures and incipient organs that were on the right side of the larval animal end up on the left side of the adult. The gut is twisted into a U-shape, and when the longitudinal nerve cords connecting the pleural to the visceral ganglia develop, they are crossed rather like a figure eight. Most veligers have nephridia, which reverse sides, but the adult gills and gonads are not fully developed when torsion occurs. (Brusca and Brusca, 2002).

"The original mechanism by which torsion was brought about was probably the

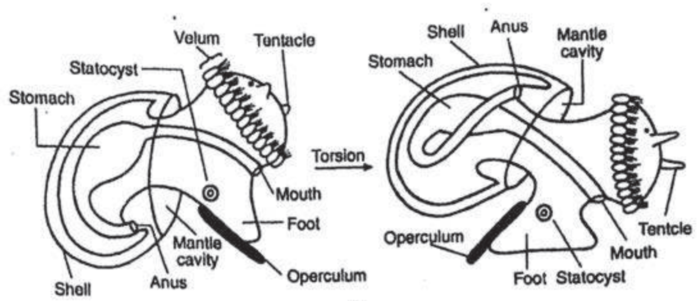

Fig. 5A: Figures showing the torsion of a free-swimming larva in a primitive gastropod (*Patella* sp.) (after Pechenlk)

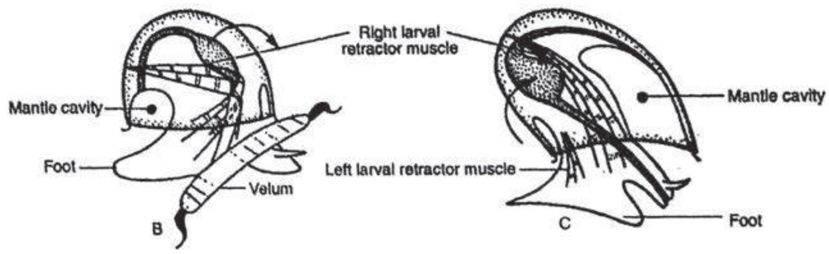

Fig. 5 B, C : Diagrammatic representation of torsion in veliger larva of a prosobranch. B. Pre-torsional stage. C. Post-torsional stage (after Parker and Haswell).

contraction of larval retractor muscles, the entire rotation being completed in a few minutes. In most of the gastropods in which torsion has been carefully studied, larval retractor muscles account for 90º of the rotation, differential growth for the rest.

Even in the very early veliger larva, the mesodermal bands develop asymmetrically. The right band is distinctly larger than the left and can be distinguished as five large mesodermal cells. As these cells elongate to form muscle cells, they gradually, displace he visceral hump to the left, emphasising the asymmetry. These cells converge on to the right side in the posterior region of larval shell and are inserted into the anterior end of the body as larval *retractor muscles*. There are no related muscle cells on the left side. As soon as the larval muscle cells have any contractile power, the process of torsion commences (Fig.). If the muscle contraction accounts for only 90º of rotation, the process usually lasts for a few hours. At the end of this *first stage*, the mantle cavity which originally lay ventrally and posteriorly now lies on the right side and the foot projects on the left."

[The above descripiton of torsion is according to Parker and Haswell (1972), Textbook of Zoology, Volume-1, Invertebrates, 7th edition]

Stage two of torsion is usually longer in duration and is the result of differential growth. It is difficult to give a generalized account on torsion in gastropods, however, Thomson (1958) distinguished five possible ways in which torsion can be brought about. These are :

1. 180º rotation of visceral hump is achieved by muscle contraction alone. This was probably the original mechanism and is known only for *Acmaea*.
2. 180º rotation achieved in two stages, an initial 90º movement (rotation) by larval retractor muscle contraction followed by a slower rotation of remaining 90º by differential growth process. This is probably the commonest mechanism of present-day forms, e.g. *Haliotis*, (Prosobranchia) *Patella* (Prosobranchia).
3. In some gastropods 180º rotation is achieved by differential growth process alone. e.g. *Vivipara* (prosobranchia)
4. Torsion achieved by differential growth processes, the change in the position of the anus being halted at a site appropriate to the adult stage, e.g. *Aplysia* (opisthobranchia).
5. Torsion no longer recognisable as movement of the visceropallium, the organs being in the post-torsional postion from their first appearance, e.g. *Adalaria* (opisthobranchia).

Whatever the mechanism involved, the post-torsional larva now has its mantle cavity placed anteriorly and whatever organs are developed will be affected in some way, particularly in their spatial relationship with each other.

9.4.2 Adaptive significance of torsion

The adaptive significance of torsion is speculative, however *three advantages* are plausible. *First,* without torsion withdrawl into the shell would proceed with the foot entering first and the more vulnerable head entering last. After torsion, the mantle cavity became anterior, so that the sensitive part like head could withdraw first followed by foot, thus avoiding the attack of potential predators. A *second advantage* of torsion concerns an anterior opening of the mantle cavity that allows clean water from in front of the animal to enter the mantle cavity, rather than water contaminated with silt stirred up by the snail's crawling. The twist in the mantle's sensory organs around the head region is a *thrid advantage* of torsion because it makes the snail more senstitive to stimuli coming from the direction in which it moves.

It should be mentioned here that placing the mantle cavity in front (with the anus and nephridia empty dorsal to the head) created a potential fouling problem relative to the situation in the ancestral molluscs with the mantle cavity in the rear. This fouling occurs because the water now passes directly into the cavity from the front, goes over the ctenidia, pickes up the wastes from the anus and nephridia and essentially exists on top of the animal's head, where it may be deposited. However, a number of evolutionary adaptations (many of the major evolutionary trends) seem to circumvent this fouling problem : In most primitive gastropods the problem is solved by having slits or holes in the shell over the mantle cavity so that water with wastes exists farther back on the shell. More advanced gastropods have solved the problem by extending the anal and nephridial openings to the far edge of the mantle cavity and developing a siphon to channel an oblique water flow through the mantle cavity. In this the water enters on one side and exits on the other side, away from the head region. Finally, in one group, opisthobranchia, the animals have undergone detorsion and the whole mantle cavity is displaced back toward the rear or is lost.

9.4.3 Detorision :

Detorsion means the reversion of the changes that had occured during torsion. Acquisition of secondary symmetry observed in some opisthobranch gastropods is regarded as the result of detorsion. As a result of detorsion the pallial complex shifts towards the posterior part along the right side. The ctenidia are pointed backwards and the auricles come behind the ventricle. The visceral loop becomes untwisted and symmetrical. In this way a secondary external symmetry is established again. Detorsion is always associated with the loss of shell and liberation of gills (ctenidia) from their enclosing case, the gills becoming exposed and subjected to external current. The organs lost in torsion are never replaced. With the result, the opisthobranches continue to have unpaired ctenidium, auricle and kidney. This indicates towards their evolution from the prosobranch gastropods.

Different gradations of detorsions are encountered in different members of opisthobranchs. Detorsion is incomple or partial in primitive opisthobranchs like *Acteon* and *Bulla* but complete in advanced forms such as *Aplysia*. Complete detorsion is accompanied by reduction or loss of the shell. In some nudibranchs (e.g. *Doris, Aeoldia*) the shell and mantle cavity are absent and the body becomes secondarily bilaterally symmetrical.

9.5 Larval Stages in Mollusca

Developent in molluscs may be direct, mixed or indirect. In fact, excepting the cephalopods development is usually indirect. In msot forms, during indirect development, the free-swimming ***trochophore larva*** that develops, is remarkably similar to that seen in annelids. Like the annelid larva, the molluscan trochophore bears an apical sensory plate with a tuft of cilia and a girdle of ciliated cells–the prototroch–just anterior to the mouth (Fig.).

In some free-spawning molluscs (e.g. Chitons), the trochophore is the only larval stage, and it metamorphoses directly into the juvenile. But in many groups (gastropods and bivalves), the trochophore stage is followed by a uniquely molluscan larval stage called a ***veliger.*** The veliger may posssess a foot, shell, operculum and other adult-like structures.

The most characteristic feature of the veliger larva is the swimming and feeding organ or *velum,* which consists of two large ciliated lobes developed from the trochophore's prototroch. In some species the velum is subdivided into four, five, or even six separate lobes. Veligers feed by capturing particulate food between opposed prototrochal and metatrochal bands of cilia on the edge of the velum. Some veligers apparently are non-feeding. Eventually eyes and tentacles appear, and the veliger transforms into a juvenile, settles to the bottom and asumes an adult existence.

Some bivalves have long-lived *planktotrophic* veligers, whereas others have short-lived *lecithotrophic* veligers. The formers have larval life of two or three months and the short-lived ones have larval life not more than a week. Many widely distributed species have very long larval life that allow dispersal over great distances. A few birvalves have mixed development and brood the developing embryos in the suprabranchial cavity throughout the trochophore period; then the embryos are released as veliger larvae. Some marine and fresh water clams have direct development, i.e. no larval form. Development of a free-swimming trochophore, succeeded by a veliger larva, is typical of marine bivalves. The veliger is bilaterally symmetrical and eventually becomes enclosed within the two valves charcterisitc of bivalve. In the fresh water mussels (Unionacea and Mutelacea) the eggs or embryos are brooded between the gill lamellae, where they develop through the veliger stage. The veligers of these groups are often highly modified for a parasitic life on fishes, thereby facilitating disparsal (the fish disperse the rather sedentary freshwater bivalves). Various names have been given to these specielized parasitic veligers. In

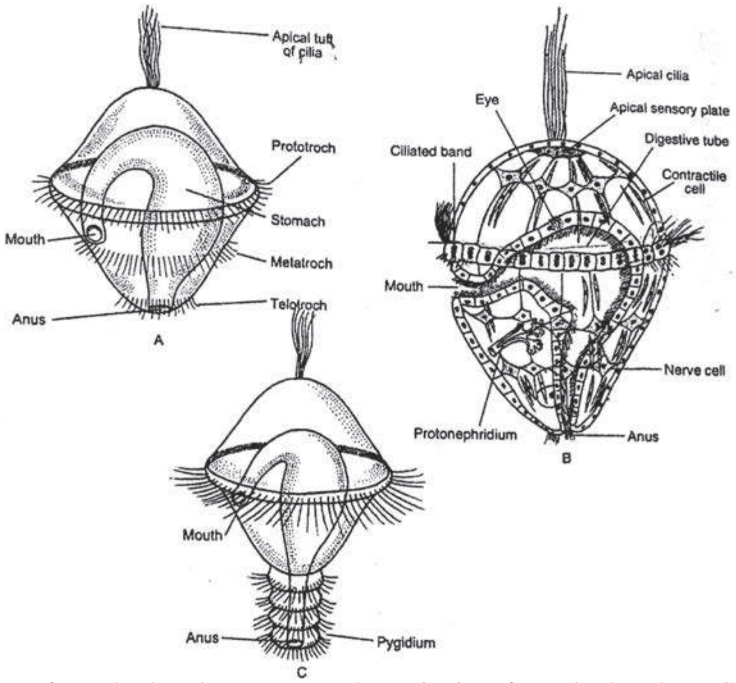

Fig. 6 : External features of a trochophore larva. B. Internal organization of a trochophore larva. C. An advanced trochophore larva showing the additional ciliated segments at the posterior end.

the Unionacea they are caleld ***glochidia*** (Fig.). They attach to the skin or gills of the host by sticky mucuous, hooks or other attachment devices. Most glochidia lack a gut and absorb nutrients from the host by means of special phagocytic mantle cells. The host tissue often forms a cyst around the glochidium. Eventually the larva matures, breaks out of the cyst, drops to the bottom and assumes its audlt life.

Among the gastropods, only the primitive archaeogastropods that rely on external fertilization have retained a free-swimming trochophore larva. All other gastropods suppress the trochophore or pass through it quickly before hatching. In many groups embryos hatch as veligers (e.g. opisthobranchs). Some of these gastropods have feeding (*planktotrophic*) veligers that may have brief of extended (to several months) free-swimming larval life. Others have short-lived, yolk-laden non-feeding (*lecithotropic*) veligers that remain planktonic only for short periods. Planktotrophic veligers feed by use of the velar cilia, whose beating drives the animal forward and draws minute planktonic food particles, into contact with the shorter cilia of a food groove. Once in the food groove, the particles are trapped in mucus and carried along ciliary tracts to the mouth.

Almost all pulmonates and many advanced marine prosobranchs (e.g.

neogastropods) have direct development, and the veliger stage is passed in the egg case, or capsule. Upon hatching, tiny snails crawl out of the capsule into their adult habitat.

It is usually during the veliger stage that gastropods undergo torsion when the shell and visceral mass twist 180 degrees in relation to the head and foot.

Cephalopods produce large, yolky, telolecithatl eggs. Development is always direct, the larval stages being lost entirly or passed within an egg case.

Scaphopod development is very similar to that of the marine bivalves. There is a free-swimming trochophore larva, succeeded by a bilaterally symmetrical veliger larva.

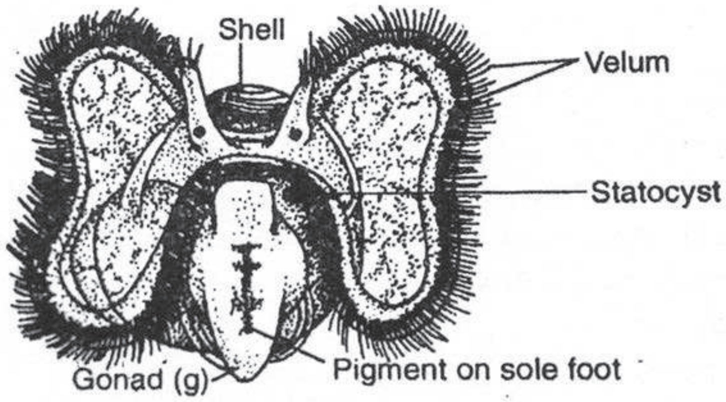

Fig. 7 : Structure of a veliger larva of Nassarius reticulatus (after Parker and Haswell).

Charcters of a typical trochophore larva :

1. Body is transparent, oval or pear-shaped with broad anterior and narrow posterior end.
2. It is bounded externally by a thin ectodermal epithelium which is thickened at two ends and also along the equatorial ring.
3. The thickned anterior end forms sensory apical plate which bears a tuft of cilia.
4. A pair of cerebral ganglia and pigmented larval eyes are present on the apical plate.
5. There is a curved gut with a mouth, ectodermal oesophagus, endodermal sac like stomach and an ectodermal hind gut opeing by anus. It feeds on microorganisms.

6. At the equatorial region a preoral band of large cilia, called pre-oral ciliary band or ***prototroch,*** develops around the body just in front of the mouth.
7. A similar band of cilia may occurs at the posterior end. This is post-oral band or ***metatroch.***
8. Close to anus another ciliated band, called *telotroch* is present.
9. A spacious blastocoel, between the gut and ectodermal epithelium, is present.
10. A pair of protonephridia and larval mesodermal cells are found in the blastocoel.

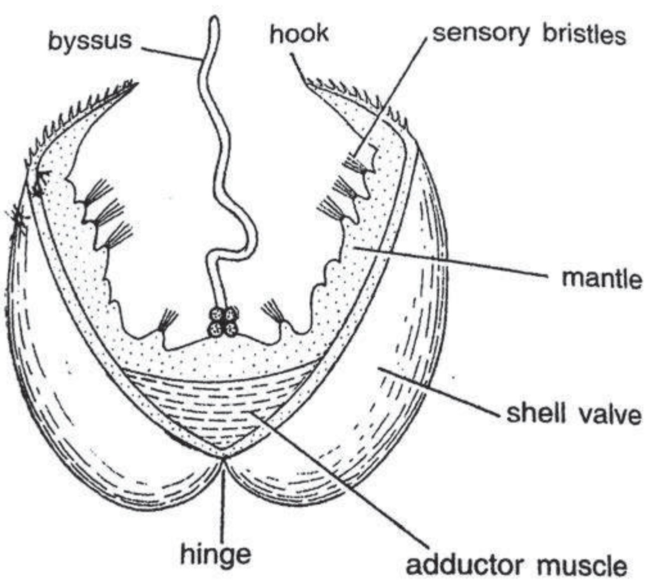

Fig. 8 : A glochidium.

Characters of veliger larva :

1. It is modified trochophore larva.
2. Presence of ciliated organ, curved gut and larval nephridia.
3. The prototroch of trochophore expands to form a ciliated disc called ***velum.***

In some gastropods velum is produced into ciliated lobes.

4. Presence of bilobed mantle and shell.
5. Foot is ventral between the mouth and anus.

Characters of glochidium larva :

1. Microscopic form (ranges from 0.1 to 0.4 mm).
2. Body is enclosed in a triangular bivalved shell with its valves united dorsally and free ventrally. The free ends bear curved hook and spines.
3. The two valves are connected together by a single large *adductor muscle*.
4. Mantle lobes are two, bearing brush-like sensory hairs.
5. A long filamentous byssus (provisional byssus) arises from the byssus gland near the adductor muscles.
6. Glochidium leads an ectoparasitic life, attaches to fish skin and gill.

9.6 Questions

a) What do you mean by hecto utylised arm?

b) What is malacology?

c) What is Choncology?

d) What type of Symmetry is found in molluscan animal?

e) What is the excretory organ in mollusca?

f) How many larval stages are found in mollusca?

g) What is the name of respiratory organ in mollusca?

Notes

মানুষের জ্ঞান ও ভাবকে বইয়ের মধ্যে সঞ্চিত করিবার যে একটা প্রচুর সুবিধা আছে, সে কথা কেহই অস্বীকার করিতে পারে না। কিন্তু সেই সুবিধার দ্বারা মনের স্বাভাবিক শক্তিকে একেবারে আচ্ছন্ন করিয়া ফেলিলে বুদ্ধিকে বাবু করিয়া তোলা হয়।

-- রবীন্দ্রনাথ ঠাকুর

ভারতের একটা mission আছে, একটা গৌরবময় ভবিষ্যৎ আছে, সেই ভবিষ্যৎ ভারতের উত্তরাধিকারী আমরাই। নূতন ভারতের মুক্তির ইতিহাস আমরাই রচনা করছি এবং করব। এই বিশ্বাস আছে বলেই আমরা সব দুঃখ কষ্ট সহ্য করতে পারি, অন্ধকারময় বর্তমানকে অগ্রাহ্য করতে পারি, বাস্তবের নিষ্ঠুর সত্যগুলি আদর্শের কঠিন আঘাতে ধূলিসাৎ করতে পারি।

-- সুভাষচন্দ্র বসু

Any system of education which ignores Indian conditions, requirements, history and sociology is too unscientific to commend itself to any rational support.

— Subhas Chandra Bose

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