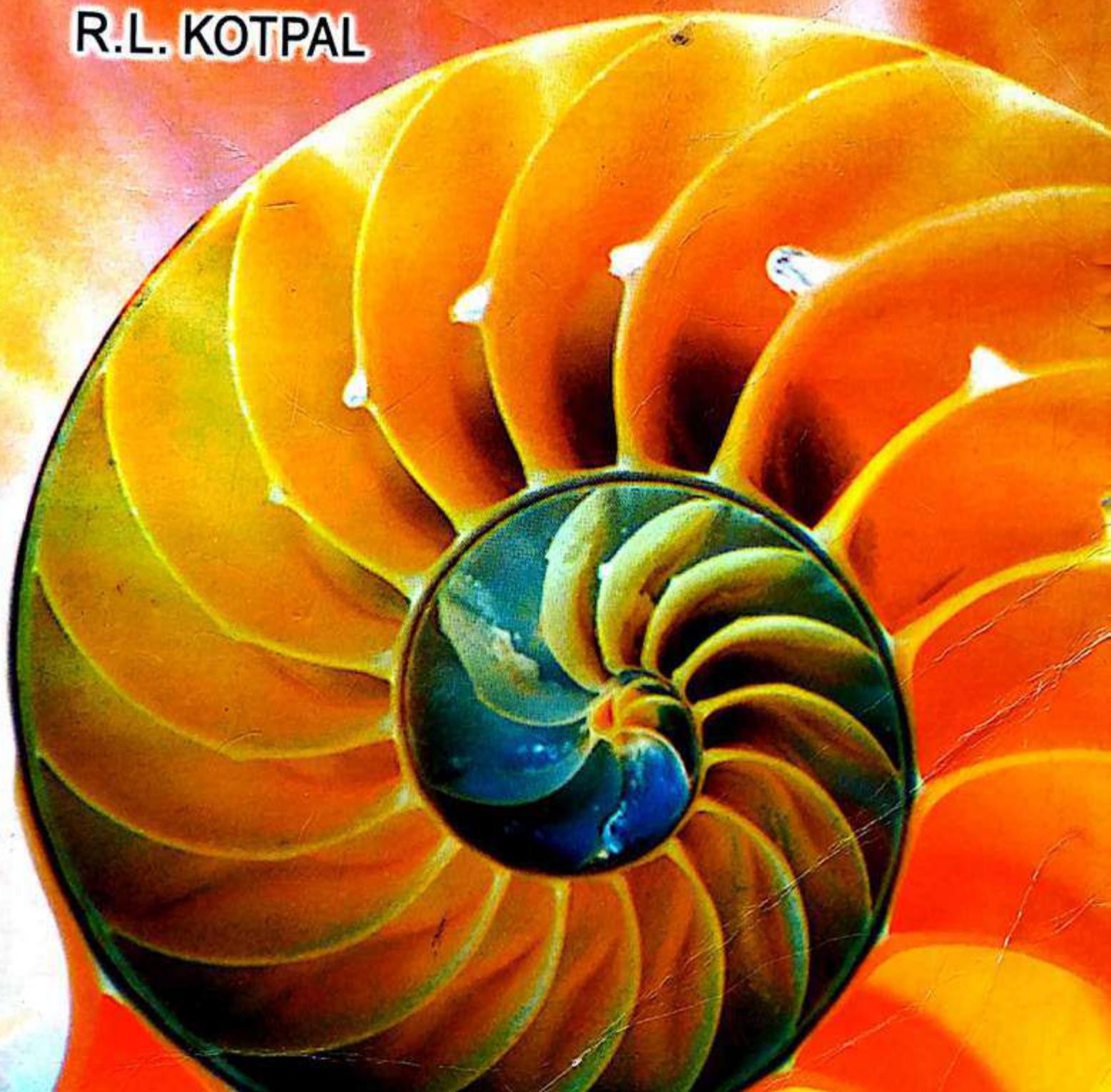


MODERN TEXT BOOK OF ZOOLOGY

# INVERTEBRATES

R.L. KOTPAL





*Author*

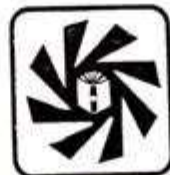
---

MODERN TEXT BOOK OF ZOOLOGY

**INVERTEBRATES**

(ANIMAL DIVERSITY - I)

---

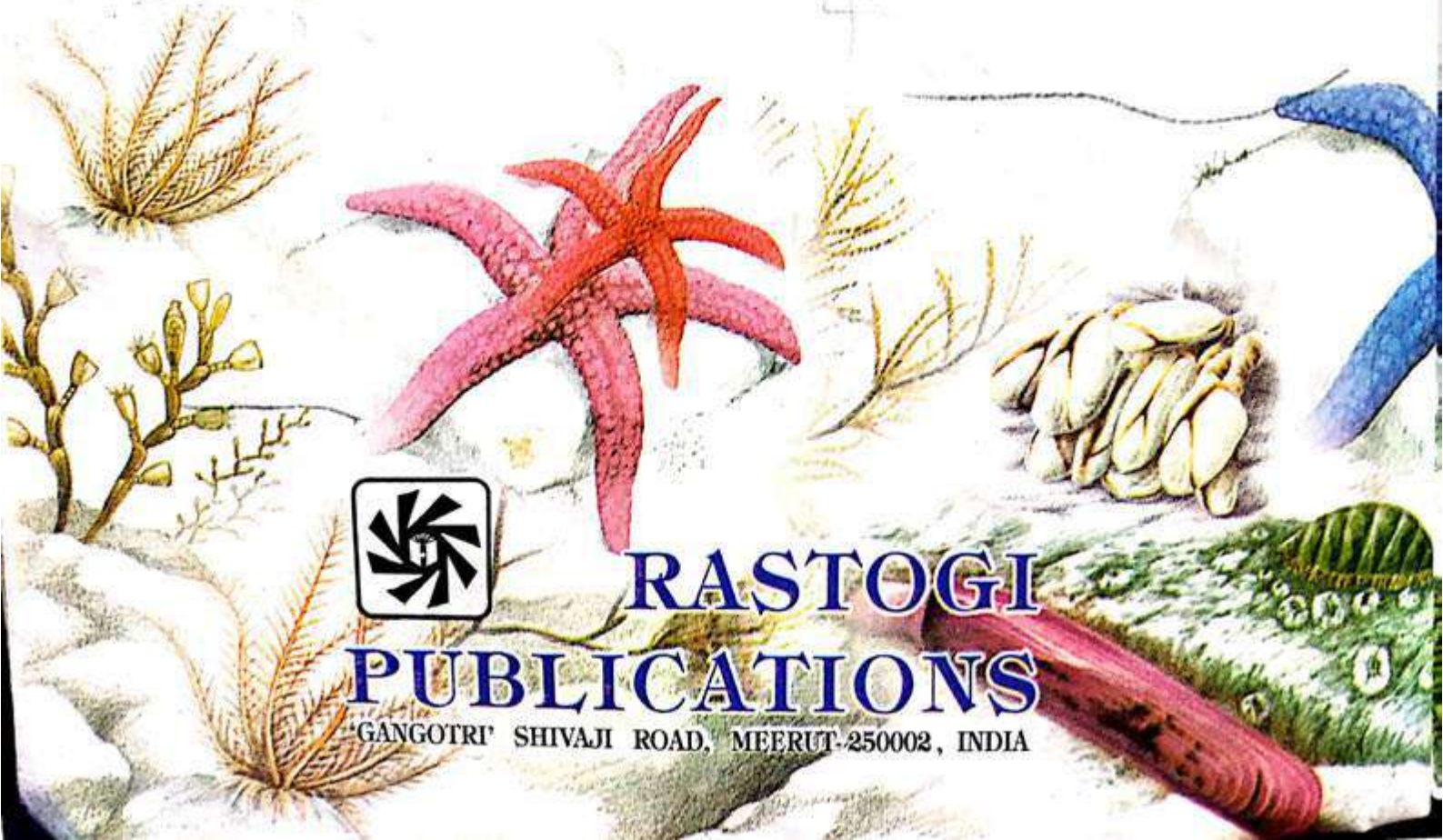
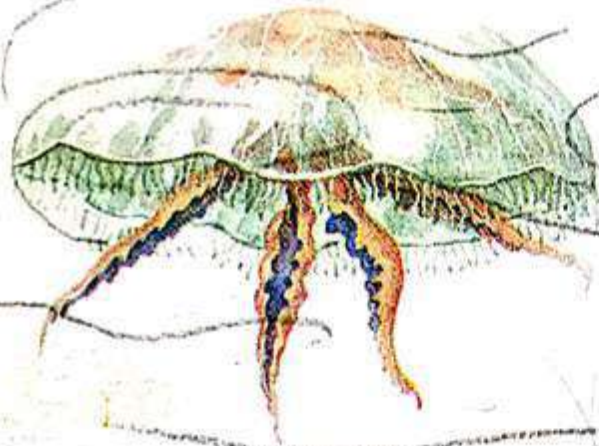


---

**R.L.KOTPAL**

*FORMERLY,*  
*PROFESSOR AND HEAD*  
*DEPARTMENT OF ZOOLOGY*  
**MEERUT COLLEGE**  
**MEERUT**

---



**RASTOGI**  
**PUBLICATIONS**

GANGOTRI SHIVAJI ROAD, MEERUT-250002, INDIA

TENTH REVISED EDITION



MODERN TEXT BOOK OF ZOOLOGY

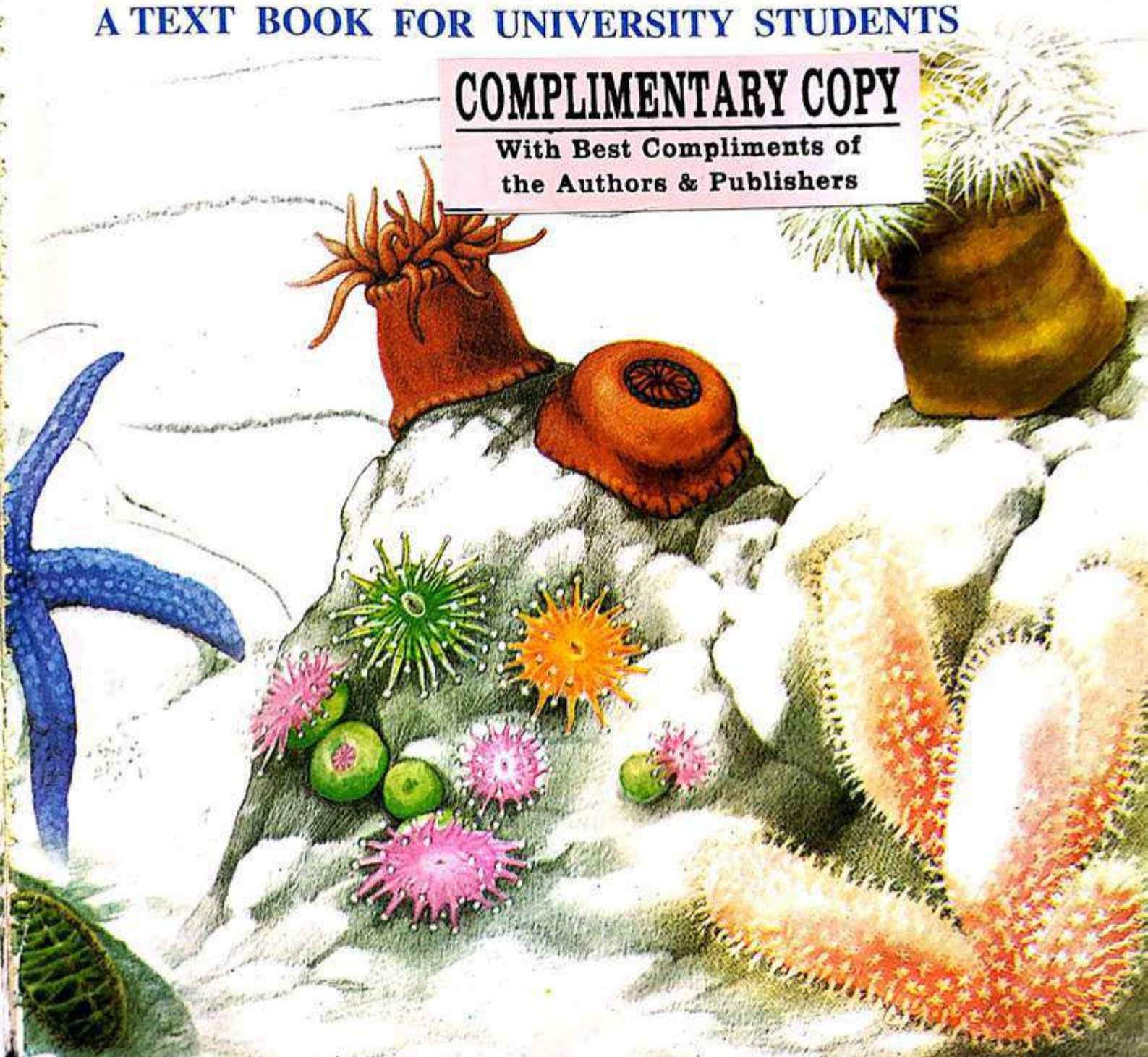
# INVERTEBRATES

(ANIMAL DIVERSITY - I)

A TEXT BOOK FOR UNIVERSITY STUDENTS

**COMPLIMENTARY COPY**

With Best Compliments of  
the Authors & Publishers



**NEW DELHI OFFICE :**  
9, RANI JHANSI ROAD  
( MOTIA KHAN )  
NEW DELHI 110055

*HINDI EDITION  
IS ALSO AVAILABLE*

**MODERN TEXT BOOK OF ZOOLOGY  
INVERTEBRATES**

ISBN : 978-81-7133-903 - 7

**© THE AUTHOR**

*All rights reserved. No part of this book (any edition / reprint) may be reproduced, stored in a retrieval system or transmitted in any form by any means, electronically or mechanically or by photocopying, recording or otherwise without the prior written permission of the Author / Publisher, except for the purposes of references and review. Infringement of copyright is a criminal offence.*

TITLE CODE NO. : Z-1

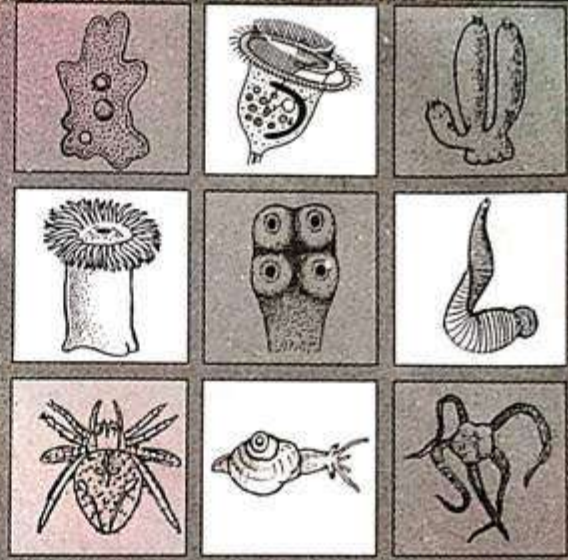
**Note:** All possible care has been taken in the editing, proof reading and printing of this book but in case of any omission/mistake which might have crept in the book, neither the author nor the publisher shall be held responsible for the same. The author & publisher shall feel grateful for the suggestions received from the readers for further improvement of the book.

SIXTH REPRINT (TENTH EDITION) : 2013

PUBLISHED BY RAKESH KUMAR RASTOGI FOR RASTOGI  
PUBLICATIONS, 'GANGOTRI' SHIVAJI ROAD, MEERUT-250 002  
PHONES : (0121) 2510688, 2515142, 2516080 FAX: 0121-2521545  
email : sales@rastogipublications.com website : www.rastogipublications.com  
PRINTED AT CAPITAL OFFSET PRESS, NEW DELHI INDIA.



# Preface to the Present Edition



We are pleased to place before the readers, the Tenth Revised Edition of the book '*Modern Text Book of Zoology : INVERTEBRATES.*' In the last few years the syllabi of many Indian universities have undergone changes in the light of UGC Model Curriculum. This has necessitated a revision of the book to include the necessary subject matter, to make the book up-to-date and more informative, fulfilling the need of B.Sc. (Pass) and B.Sc. (Hons.) students of most of the Indian universities.

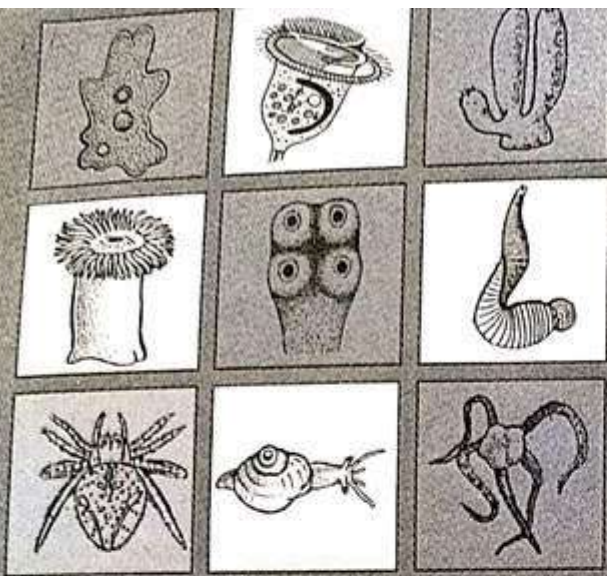
In the revised edition chapter on 'Animal Diversity and Taxonomy' has been added in the beginning of the book. Various designs of Life-cycle and Type study etc., wherever necessary have been enlarged or reduced for better understanding and presentation. After every chapter various types of questions such as—Long Answer Type, Short Answer Type, Very Short Answer Type, True and False, Matching Type and Objective Type Questions have been added as per the requirements of the new syllabi.

We hope that the students and teachers of most of the universities in India & abroad will find this new edition much more useful. Students appearing for various competitive examinations shall also find the book more informative and upto-date.

Our sincere thanks to our team of learned reviewers, editors and advisors for their valuable co-operation and help rendered in the revision of the book.

Suggestions for further improvement of this book are cordially invited and shall be incorporated in further editions.

—The Publisher



## Preface to the First Edition

We are living in an age of Science where man has reached to moon and has made remarkable achievements in various scientific spheres. A number of highly complicated and technical instruments have been devised to enable the modern researcher to evolve new ideas as theories. The electron microscope, for instance, is an indispensable companion of a growing biologist. The old concepts are being declared obsolete day by day, more so in Biology. Many a concept in Cytology and Histology has undergone a remarkable change. The fast changing face of Zoology has created a gap and has given an impetus to the authors to present the "*Modern Text Book of Zoology : INVERTEBRATES*" for the young students preparing for the degree and honors courses of various universities in India and abroad.

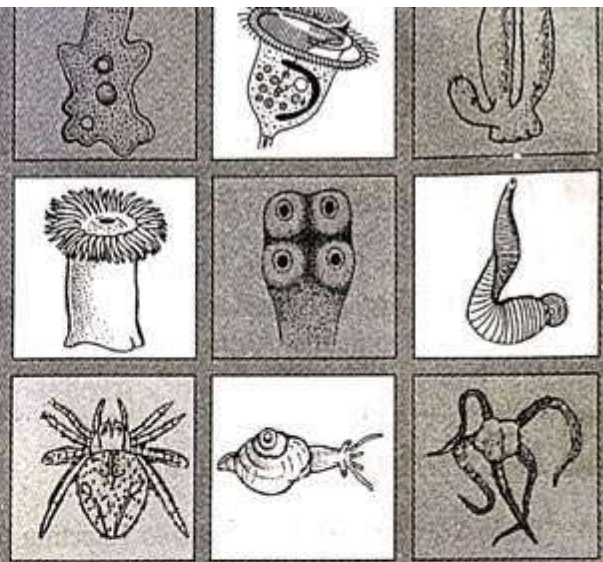
The authors, with their long teaching and writing experience, have attempted to produce a complete book on Invertebrates. For a better study of Invertebrate Phyla, introductory chapters on the basic principles of Zoology, Taxonomy and Cytology have been incorporated. The various phyla have been treated in a simple and lucid style and are in accordance with the syllabi of all the Indian universities. The approach to the discussion of all phyla is very simple so as to impart to the students a clear and vivid understanding. According to the scheme of treatment the important animal types of each phylum have been dealt with first, and efforts have been made to present their elaborate and up-to-date account. This is followed by a chapter on characters and classification and brief description of other important types of the phylum. Further, a chapter on topics of significance and general interest pertaining to the phylum has also been added to make the treatment more elaborate. Relevant comparative accounts have also been given where considered necessary.

It has been the constant endeavour of the authors to furnish maximum substance, keeping in view the limitations of size and bulk of the book. Efforts have been made to condense the matter as far as practicable. The size of print has been selected according to the needs of the text. Special attention has been paid to the preparation of illustrations, these have been designed with utmost care and accuracy and conform to the description in the text. They are quite simple and capable of being reproduced by the students without much difficulty. An exhaustive Index and a list of books suggested for further study will be of great help to the students.

Suggestions for the improvement of the book will be thankfully acknowledged and incorporated in further editions.

—The Authors

# Contents



## **1** Diversity of Animals : Modern Classification 1-12

Diversity of Animals;  
Significance of Classification;  
Brief History of Classification;  
Nomenclature of Organism;

Groups in Classification;  
Modern Classification of Animal Kingdom;  
Some Important Taxonomists.

## **2** The Invertebrates 13-29

What is an Invertebrate?  
Invertebrate Phyla;  
Invertebrata versus Non-Chordata;  
Diversity of Invertebrates;  
Major and Minor Phyla;  
Lower and Higher Invertebrates;

Contrast Between Lower and Higher Invertebrates;  
Invertebrates versus Vertebrates (Comparison);  
Phylogeny of Invertebrates;  
Major Characteristics of Invertebrates;  
Outline Classification of Animals.

### **SUBKINGDOM PROTOZOA**

## **3** *Euglena viridis* 30-40

Culture of *Euglena*;  
*Euglena* as an Animal;

Other Euglenoid Flagellates ·  
1. *Euglena*, 2. *E. gracilis*, 3. *Astasia longa*,  
4. *Peranema trichophorum*.



**4** *Trypanosoma gambiense*

Polymorphic Forms of Trypanosomes;  
Table 1 : Some Important Trypanosomes of  
Man and Domestic Animals;

41-49

Sleeping Sickness (Symptoms & Pathogenesis,  
Diagnosis, Treatment or Therapy,  
Prevention or Prophylaxis.

**5** *Leishmania donovani*

Table 1 : Species of *Leishmania* Infecting Man;

50-56

Kala-Azar or Dumdum Fever;  
(Occurrence, Symptoms, Diagnosis,  
Treatment and Prevention).

**6** *Amoeba proteus*

Culture of *Amoeba*;  
Biological Significance of *Amoeba*;

57-71

Other Species of *Amoeba* :  
1. *Amoeba verrucosa*, 2. *A. discoides*,  
3. *A. radiosa*, 4. *A. dubia*, 5. *A. terricola*.

**7** *Entamoeba histolytica*

Amoebic Dysentery or Amoebiasis  
(Symptoms, Modes of Transmission,  
Diagnosis, Therapy, Prevention);

72-78

Other Entamoebae of Man :  
1. *Entamoeba hartmanni*,  
2. *Entamoeba coli*, 3. *E. gingivalis*.

**8** *Elphidium crispum* (= *Polystomella crispa*)

79-83

**9** *Plasmodium vivax* : The Malaria Parasite

Comparative Account of 4 Species of  
Human Infecting *Plasmodium*;  
Human Malaria  
(Early History, Types of Malaria, Symptoms

84-97

and Pathogenesis, Duration of Infection,  
Relapses and Control of Malaria);  
Anti-Malaria Campaign in India.

---

**10** *Monocystis agilis* 98–105

Laboratory Study of *Monocystis*;  
Effects of Parasitism;

Comparison of *Monocystis* and *Plasmodium*.

---

**11** *Eimeria tenella* 106–110

Coccidiosis (Pathogenesis,  
Diagnosis, Prevention, Treatment).

---

**12** *Paramecium caudatum* : The Slipper Animalcule 111–127

Culture of *Paramecium*;

Cytoplasmic Particles in *Paramecium*.

---

**13** *Vorticella* : The Bell Animalcule 128–136

Comparison of Conjugation in *Paramecium*  
and *Vorticella*.

---

**14** Protozoa : Characters, Classification and Types 137–149

Definition;  
Special Features;  
General Characters;  
Classification;  
Other Types of Protozoa :  
1. *Chlamydomonas*, 2. *Volvox*, 3. *Noctiluca*,

4. *Ceratium*, 5. *Trichomonas*, 6. *Giardia*,  
7. *Arcella*, 8. *Diffugia*, 9. *Actinophrys*,  
10. *Radiolarian Ooze*, 11. *Gregarina*,  
12. *Opalina*, 13. *Balantidium*,  
14. *Nyctotherus*, 15. *Stentor*, 16. *Ephelota*.

---

**15** Protozoa : General Account 150–171

Concept of Protista;  
Status of Protozoa;  
Protozoa Unicellular or Acellular;  
Body Covering and Skeleton;  
Nucleus;  
Locomotor Organelles and Locomotion;  
Nutrition;

Contractile Vacuoles and Osmoregulation;  
Reproduction;  
Economic Importance;  
Parasitism;  
Protozoa and Human Diseases.

- 27** *Coelenterata* : Characters, Classification and Types 294-307
- General Characters;  
Classification;  
Other Types of Coelenterates :  
1. *Bougainvillea*, 2. *Hydractinia*, 3. *Tubularia*,  
4. *Pennaria*, 5. *Sertularia*, 6. *Plumularia*,  
7. *Campanularia*, 8. *Millepora*, 9. *Physalia*,  
10. *Velella*, 11. *Porpita*, 12. *Tubipora*;  
13. *Alcyonium*, 14. *Gorgonia*, 15. *Corallium*,  
16. *Pennatula*, 17. *Fungia*,  
18. *Madrepora* (= *Acropora*), 19. *Astraea*,  
20. *Meandrina* (= *Meandra*), 21. *Favea*.
- 
- 28** *Coelenterata* : General Account 308-316
- Polymorphism;  
Corals; Coral Reefs.
- 
- 29** *Ctenophora* 317-322
- General Characters;  
Classification;  
Affinities;
- Types of Ctenophora :  
1. *Pleurobrachia* and *Hormiphora*,  
2. *Velamen*, 3. *Ctenoplana*, 4. *Coeloplana*.
- 
- 30** *Dugesia* (= *Euplanaria*) : A Planarian 323-334
- Regeneration.
- 
- 31** *Fasciola hepatica* : The Sheep Liverfluke 335-351
- Features of Significance in Life History;  
Parasitic Adaptations of *Fasciola*,  
Liver Rot or Fascioliasis (Infection,  
Pathogenesis, Therapy, Prophylaxis).
- 
- 32** *Taenia solium* : The Pork Tapeworm 352-368
- Parasitic Adaptations of *Taenia*;  
Cestodiasis (Infection, Pathogenesis, Therapy,  
Prophylaxis);  
Comparative Study of *Fasciola* and *Taenia*.

### 33 Platyhelminthes : Characters, Classification and Types 369–380

Definition;

Morphological Advantages;

Phylogenetic Significance;

General Characters;

Classification;

Other Types of Platyhelminthes :

1. *Convoluta*, 2. *Bipalium*, 3. *Thysanozoon*,

4. *Diplozoon*, 5. *Polystoma*,

6. *Opisthorchis* (= *Chlonorchis*),

7. *Schistosoma*, 8. *Paragonimus*,

9. *Moniezia*, 10. *Taenia saginata*,

11. *Echinococcus granulosus*,

12. *Dipylidium*, 13. *Hymenolepis*.

### 34 Superphylum Aschelminthes : The Pseudocoelomate Phyla 381–385

Derivation of Name;

General Characters;

Classification of Major Groups;

Interrelationships.

### 35 *Ascaris lumbricoides* : The Common Roundworm 386–402

Parasitic Adaptations of *Ascaris* ;

Ascariasis

(Infection, Pathogenesis,

Therapy, Prophylaxis).

### 36 *Ancylostoma duodenale* : The Common Hookworm 403–408

Ancylostomiasis (Diagnosis, Pathogenesis;  
Therapy, Prophylaxis);

*Necator americanus*.

### 37 *Wuchereria bancrofti* : The Filarial Worm 409–412

Filariasis or Elephantiasis

(Diagnosis, Pathogenesis, Control).

### 38 Nematoda : Characters, Classification and Types 413–421

General Characters;

Classification;

Common Nematode Parasites :

1. *Trichuris trichura*, 2. *Trichinella spiralis*,

3. *Rhabditis*, 4. *Enterobius vermicularis*,

5. *Dracunculus medinensis*, 6. *Loa loa*,

7. *Tococara canus*.

**39 Helminthes : General Account**

422-427

Evolution of Parasitism in Platyhelminthes;  
Parasitic Adaptations of Flatworms;

Helminthes and Human Diseases;  
Nematode Parasites of Man and Animals.

**HIGHER INVERTEBRATES**

**40 Neanthes or Nereis : A Clamworm**

428-445

Typical Trochophore Larva;

Adaptations of *Nereis*.

**41 Pheretima posthuma : The Indian Earthworm**

446-472

Regeneration and Grafting;  
Adaptations of Earthworm;

Economic Importance of Earthworms.

**42 Hirudinaria granulosa : The Indian Cattle Leech**

473-495

Parasitic Adaptations of Leeches.

**43 Annelida : Characters, Classification and Types**

496-507

General Characters;  
Classification;

Other Types of Annelida :

1. *Aphrodite*, 2. *Polynoe*, 3. *Eunice*,
4. *Phyllodoce*, 5. *Chaetopterus*,
6. *Arenicola*,

7. *Amphitrite*, 8. *Terebella*, 9. *Megascolex*,
10. *Lumbricus*, 11. *Tubifex*, 12. *Pontobdella*,
13. *Hirudo medicinalis*, 14. *Polygordius*,
15. *Sipunculus*.

**44 Annelida : General Account**

508-525

Comparative Account of *Nereis*, *Pheretima*  
and *Hirudinaria* (1. Digestive System,  
2. Excretory System, 3. Reproductive system);  
Origin of Coelom and Metamerism;  
Adaptive Radiation;

Segmental Organs  
(Coelomoducts and Nephridia);  
Regeneration;  
Asexual Reproduction in Polychaeta;  
Economic Importance.

- 
- 45** *Palaemon* or *Macrobrachium malcolmsonii* :  
The Indian Freshwater Prawn 526-559  
*Penaeus indicus*;  
Crustaceans as Source of Food; Prawn Fishery in India.
- 
- 46** *Palamnaeus* : The Indian Scorpion 560-573
- 
- 47** *Periplaneta americana* : The Common Cockroach 574-599  
Other Cockroaches :  
1. *Blatta orientalis*,  
2. *Blatella germanica*,  
3. *Periplaneta australasiae*.
- 
- 48** Grasshopper or Locust 600-615  
Economic Importance of Grasshopper;  
Grasshopper Control; Locust Migration;  
Locust Phase Theory.
- 
- 49** *Musca domestica* : The Housefly 616-623  
Economic Importance of Housefly; Fly Control.
- 
- 50** *Culex* and *Anopheles* : The Mosquitoes 624-632  
Comparison of Life Histories of *Culex*  
and *Anopheles*; Mosquito-Borne Diseases;  
Mosquito Control.
- 
- 51** *Apis* : The Honey Bee 633-644  
Economic Importance of Honey Bee; Apiculture.
- 
- 52** *Bombyx mori* : The Silkworm 645-650  
Sericulture; Sericulture in India.
-

- 53** Arthropoda : Characters, Classification and Types 651-678
- General Characters;  
Classification;  
Other Types of Arthropoda :
1. *Limulus*, 2. Spiders, 3. Mites, 4. Ticks,
  5. *Daphnia*, 6. *Cyclops*, 7. *Cypris*, 8. *Lepas*,
  9. *Balanus*, 10. *Sacculina*, 11. *Squilla*,
  12. Lobster (*Palinurus*), 13. *Hippa*,
  14. *Eupagurus*, 15. *Cancer*, 16. Millipeds (*Spirobolus*), 17. Centipedes (*Scolopendra*),
  18. *Lepisma*, 19. *Locust*, 20. *Gryllus*,
  21. Praying Mantis, 22. Stick Insect,
  23. Termites, 24. Dragon Fly, 25. *Pediculus* (Human Louse), 26. *Cimex* (Bed Bug),
  27. Cicada, 28. Earwig, 29. Butterfly,
  30. Moth, 31. Beetle, 32. *Drosophila*,
  33. Fleas (*Pulex*), 34. Wasp, 35. Ants.
- 54** Arthropoda : General Account 679-715
- Biological Success;  
Larvae of Crustacea;  
Mouth Parts of Insects;  
Economic Importance of Insects;  
Insect Control;  
Respiration in Insect;
- Body Wall of Arthropods;  
Respiratory Organs in Arthropoda;  
Economic Importance of Arthropoda;  
Social Life in Insects;  
Crustacean Parasites.
- 55** *Peripatus* 716-721
- 56** *Pila* : An Apple Snail 722-742
- 57** *Unio* (*Lamellidens*) : Fresh Water Mussel 743-760
- Comparative Study of Respiratory Systems of *Pila* and *Unio*;
- Comparative Account of Nervous Systems of *Pila* and *Unio*.
- 58** *Neopilina* 761-768
- Discovery;  
External Features;
- Relationships of Monoplacophora and Origin of Mollusca.
- 59** *Sepia* : The Cuttle-Fish 769-779

---

**60** Mollusca : Characters, Classification and Types 780-792

- Derivation of Name;  
 Definition;  
 Evolutionary Characters;  
 General Characters;  
 Classification;  
 Few Other Types of Mollusca :  
 1. *Chiton*, 2. *Dentalium*, 3. *Patella*,  
 4. *Cypraea*, 5. *Aplysia*, 6. *Helix*,  
 7. *Doris*, 8. *Limax*, 9. *Mytilus*, 10. *Ostrea*,  
 11. *Pecten*, 12. *Pearl oyster*, 13. *Solen*,  
 14. *Teredo*, 15. *Loligo*, 16. *Octopus*,  
 17. *Nautilus*.

---

**61** Mollusca : General Account 793-813

- Podium or Foot in Mollusca;  
 Respiration in Mollusca;  
 Torsion in Gastropoda;  
 Pearl Culture;  
 Chank Fisheries;  
 Lime Fisheries;  
 Economic Importance of Mollusca;  
 Molluscan Larvae;  
 Shell in Mollusca.

---

**62** *Asterias* : A Sea Star 814-829

---

**63** Echinodermata : Characters, Classification and Types 830-839

- Historical;  
 Derivation of Name;  
 Definition;  
 General Characters;  
 Classification;  
 Few Other Types of Echinoderms :  
 1. *Pentaceros*, 2. *Astropecten*, 3. *Ophiothrix*,  
 4. *Gorgonocephalus*, 5. *Echinus*,  
 6. *Clypeaster*, 7. *Cucumaria*, 8. *Thyone*,  
 9. *Antedon*.

---

**64** Echinodermata : General Account 840-851

- Larval Forms in Echinodermata;  
 Autotomy and Regeneration;  
 Water Vascular System;  
 Symmetry in Echinodermata.

---

**65** *Balanoglossus* : A Tongue Worm 852-868

- Affinities and Systematic Position of  
*Balanoglossus* (Hemichordata).
-



**66** Hemichordata : Characters, Classification and Types 869-874

Definition;  
General Characters;  
Classification;

Other Hemichordates :  
1. *Saccoglossus*, 2. *Ptychodera*,  
3. *Rhabdopleura*, 4. *Cephalodiscus*,  
5. *Atubaria*.

Glossary

875-880

Selected References

881-884

(Z-1)

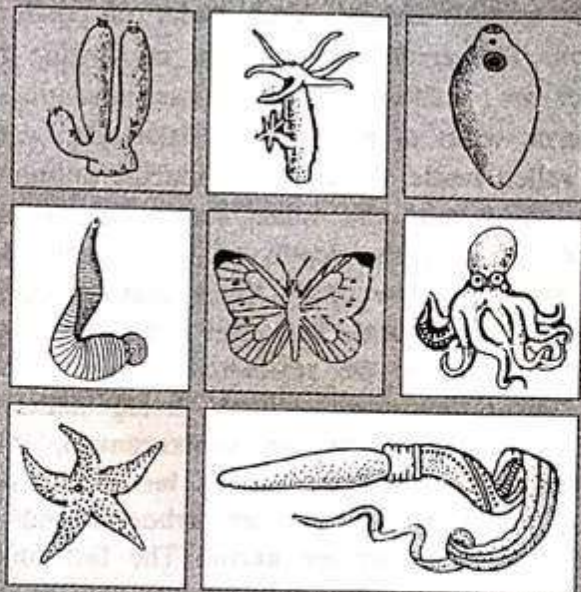
---

## List of Tables

---

- Table 2.1. Contrast between Lower and Higher Invertebrates.  
Table 2.2. Comparison (Differences) between Invertebrates and Vertebrates.  
Table 2.3. Major Characteristics of Principal Animal Phyla.  
Table 2.4. Major Groups and Phyla in Animal Classification.  
Table 4.1. Some Important Trypanosomes of Man and Domestic Animals.  
Table 5.1. Species of *Leishmania* infecting Man and other Animals.  
Table 9.1. Comparative account of 4 species of Human infecting *Plasmodium*.  
Table 10.1. Comparison of *Monocystis* and *Plasmodium*.  
Table 15.1. Comparison of Conjugation in *Vorticella* and *Paramecium*.  
Table 16.1. Differences between True Metamerism and Pseudometamerism.  
Table 24.1. Difference of Polyp (Hydranth) and Medusa of *Obelia*.  
Table 25.1. Contrast between *Obelia* and *Aurelia*.  
Table 26.1. Differences between a Hydrozoan Polyp and a Sea Anemone.  
Table 32.1. Comparative study of *Fasciola* and *Taenia*.  
Table 44.1. Comparative account of Digestive System of *Nereis*, *Pheretima* and *Hirudinaria*.  
Table 44.2. Comparative account of Excretory System of *Nereis*, *Pheretima* and *Hirudinaria*.  
Table 44.3. Comparative account of Reproductive System of *Nereis*, *Pheretima* and *Hirudinaria*.  
Table 45.0. Branchial formula of *Palaemon*.  
Table 45.1. Some important species of Prawns in the order of their abundance in landings.  
Table 45.2. Statewise landings of Prawns in India.  
Table 48.1. Differences between Solitary and Gregarious phases of Locusts.  
Table 50.1. Comparison of Life Histories of *Culex* and *Anopheles*.  
Table 54.1. Diseases transmitted by insects.  
Table 54.2. Some interesting habits of bees, ants and termites regarding their nest and broods.  
Table 57.1. Comparative study of Respiratory System of *Pila* and *Unio*.  
Table 57.2. Comparative account of Nervous Systems of *Pila* and *Unio*.
-

# Animal Diversity and Taxonomy



# 1 Chapter

## Animal Diversity

Enormously large number of animals inhabit the earth today and many more had lived here in the past. These animals vary in their shape and size, habit and habitat, colour, form and weight as well as in their distribution. A parasite causing the disease of malaria is only  $6\mu$  ( $1\mu = 1/1000$  mm) in size while whale, measures about 35 meters ( $1$  meter = 1 million micron =  $10^6$ ) in length and has a weight of 100 tons. The **smallest** living animals are probably the spores of certain tiny parasites called **Microsporidia** which measure 3 microns in diameter. A blue whale is almost  $10^7$  times longer than the smallest microsporidian spore. There are few animals which are different what they look like. For instance, a bat which looks like a bird is not really a bird but is a mammal like a man. Likewise a whale which generally known as a fish is not a fish. These things appear to be surprising to a common man.

A considerable part of animal kingdom on one hand are so small in size that they can only be observed with the help of a microscope and many of them also live in water, on the other hand giant sized animals like elephant live on the earth. Animals of all kinds i.e. round, flat, elongated, fat, zig-zag, good looking as well as ugly in shape and size exist in nature. There are certain animals which are known only by fossil remains. No one exactly knows how many and different kinds of animals are presently in existence. We know that more than one million animals (1,000,000) have been discovered by Zoologists and there are many more which are still unknown.

Diversity amongst animals does not exist in their shape and size only but also in their species, number and habitat. Starting from the indefinitely deep oceans to snow covered mountain peaks and from the poles of the earth to the equator, the animals inhabit all the places. From the point of view of habits and habita:

some animals live in **fresh water** of ponds and rivers. The animals which live in flowing river water are called **lotic** and those inhabiting the stagnant water of ponds, pools, lakes and swamps, are called **lentic**. Amongst the **marine animals**, a few living near the water surface are **pelagic**, those living in the depths of the oceanic water are **abyssal**, a few others living near the oceanic bottom are **littoral** and still other leading a sedentary life on the sea-bottom are **benthic**. In the same way some animals living under the surface of the earth are **subterranean**, others inhabiting the earth surface are **terrestrial**, some of them living on trees are **arboreal** and still others flying in air are **aerial**. The fast runners on the earth are **cursorial** while digging in habit are **fossorial** animals. It is therefore clear that with this great diversity of animals their study is not so easy. There are water areas where big rivers join the ocean, called **estuarine water** and have lesser salinity than sea water. A few fishes are unable to survive throughout their life in marine water as for example salmon and trouts. These fishes come for spawning to the estuaries and are called **anadromous** fishes in contrast to those which migrate from the estuaries to the sea for the purpose of spawning. They are called **catadromous** fishes like fresh water eels. Based on the salinity tolerance the fishes are **euryhaline**, migrating between fresh water, estuarine and salt water and have wide salinity tolerance. On the other hand fishes having a narrow range of salinity tolerance remain confined either to fresh water or salt water are called **stenohaline**.

The invertebrates are present enormously on the earth. There are approximately 14.8% micro-organisms, 4% plants and algae, 0.4% vertebrates and more than 80% invertebrates. The invertebrates have been occupying the earth for more than 400 million years. Their domination on the earth is established by the presence of their innumerable number of species and individuals. Invertebrates have also adapted to occupy practically every ecological niche. They vary in size from 18 meters long giant squid to gall mites, which are of 0.25 mm in size. Even if we exclude plants, algae and micro-organisms, the invertebrates dominance is well established. The

number of invertebrate species is staggering and new species are being discovered every day. Till date, the scientists have documented 1.7 million invertebrate species only but they estimate that the number could range up to 5-30 millions. At this rate the scientist will take unlimited time to identify all the invertebrate species. Their abundance can be judged by this example that an area of the size of a big swimming pool in a tropical rain forest may contain about three million insects.

Invertebrates play a vital role in the survival of other living organisms. These are involved in keeping the environment active and provide us with rich soil, clean water and food. Herbivory is one of these services. Herbivores help the nature by releasing their faeces on the soil which is produced by eating plants etc., after decomposition of the faeces the fertility of the soil increases. Herbivores also help in pollination, pruning the old parts of the plants and flowers. This phenomena is helpful in the growth of new organs and parts and also helps in seed dispersal and parasitism etc.

Invertebrates are widely present at every place of the earth. They have been recorded in the upper reaches of the atmosphere, in the driest deserts and in the canopies of the wettest rainforests. They can even be found in the frozen Antarctic (some mites and springtails can withstand temperature of  $-35^{\circ}\text{C}$ ) or on the ocean floor of the Abyssal Sea which reaches the depth up to 11,000 meters. Invertebrates are undisputed heavy weights of the planet. If we take the weight of the entire animal kingdom then arthropods alone will be of more than 85% of that weight.

It is estimated that five to eight million insect species have not been identified or discovered, while approximately 10,000 species of chordates awaiting the discovery and description. A good number of oceanic species diversity still remains unidentified.

### Species Estimates

An estimate of the numbers of species by group in India is given in the table (Alfred, J.R.B. : 1998)

*Faunal Diversity in India*, i-viii, 1-495. (Editors. Alfred. JRB, et al., 1998), ENVIS Centre, Zoological Survey of India, Kolkata.

The sheer number and mass of invertebrates reflects their enormous ecological impact. Admittedly, some have a negative impact on humans, either by harming us directly as disease agents, or other harmful effects. Invertebrates are the part of nearly every food chain, either directly as food for fishes, amphibians, reptiles, birds, mammals or indirectly, as agents in the endless recycling of nutrients in the soil. Insects, worms, and mites are extremely important in helping microbes to break down the dung and dead plant or animal matter. 99% of human and animal waste is decomposed by invertebrates.

Some invertebrates are "Keystone species" (small in number, form small part of the ecosystem by measures of biomass or productivity but play important role in the maintenance of biotic communities). Coral reefs are perhaps the most dramatic example, providing a wide range of niches for a diversity of plants and perhaps one-third of all fish species.

### Need of Classification

Keeping books of different subjects in different almirahs are used in a good library so that when we need a particular book of History, Geography, Hindi or English literature, Chemistry, Physics, Botany, or Zoology etc, we can atonce take that book from that section or almirah. If these books are not kept in such a systematic way, can we take out a required book out of the assemblage of thousands of books? In the same way inspite of a great diversity amongst the animals, the animal kingdom is well arranged and is very systematic. For systematic study of animals, different animals are divided into minor and major groups on the basis of similarities and differences and each group is given a particular name depending upon their characteristics. For example different kinds of birds are included in class **aves** based on their structural and physiological similarities. In the same way lizards, snakes and tortoises have been included in class **reptilia** based on definite similarities.

Taxonomic group	Indian species	% in India
PROTISTA		
Protozoa	2577	8.24
Mesozoa	10	14.08
Porifera	486	10.65
Cnidaria	842	8.49
Ctenophora	12	12
Platyhelminthes	1622	9.27
Nemertinea		
Rotifera	330	13.2
Gastrotricha	100	3.33
Kinorhyncha	10	10
Nematoda	2850	9.5
Nematomorpha		
Acanthocephala	229	28.62
Sipuncula	35	24.14
Mollusca	5070	7.62
Echiura	43	33.86
Annelida	840	6.61
Onychophora	1	1
Arthropoda	68389	6.9
Crustacea	2934	8.26
Insecta		6.83
Arachnida		7.9
Pycnogonida		2.67
Pauropoda		
Chilopoda	100	3.33
Diplopoda	162	2.16
Symphyla	4	3.33
Merostomata	2	50
Phoronida	3	27.27
Bryozoa (Ectoprocta)	200	5
Endoprocta	10	16.66
Brachiopoda	3	1
Pogonophora		
Praipulida		
Pentastomida		
Chaetognatha	30	27.02
Tardigrada	30	5.83
Echinodermata	765	12.29
Hemichordata	4952	10.22
Protochordata	119	5.65
(Cephalochordata+ Urochordata)		
Pisces	2546	11.72
Amphibia	209	4.06
Reptilia	456	7.84
Aves	1232	13.66
Mammalia	390	8.42
Total (Animalia)	868741	7.25

## Taxonomy

The study of identification and relationships among living organisms is called **systematics**. The term systematics was used by **Linnaeus** (1707-1778). The branch of biology dealing with identification, nomenclature and classification of organisms is called taxonomy. The term **taxonomy** was coined by **A. P. de Candolle** (1813). It is derived from Greek words (*taxis*, arrangement and *nomos*, law). Structural similarity or homology forms the basis of classification. The **classical systematics** (old systematics) was first employed by **Plato** and **Aristotle** and was accepted by **Linnaeus**. In this system purely morphological definition of species was employed. Species are known by a single or few specimens only. It explains **typological concept** in which one or a few individuals were thought to give information about characters of the species. According to typological concept species is **static** and remains **fixed**. Variations were supposed to be caused by imperfect expressions of traits. Individuals were considered merely expressions of the same type. Taxonomy is the one of the oldest and most fundamental branch of biology. Though enough work has been done in other branches even the importance of Taxonomy can not be ignored. New species and types of animals and plants are being identified every day and their classification and characters are studied with the help of Taxonomy. In addition to this, the use of scanning, electron microscopy and the information generated by other fields of science such as, ecology, cytology, genetics, biochemistry, molecular biology specially DNA, animals are being restudied and replaced in phylogenetic trees.

The concept of **new systematics** (neosystematics or biosystematics) was given by **J. Huxley** (1940). It deals with subspecies and populations to explain **population systematics**. New systematics considers besides morphology, other aspects also like ecology, biochemistry, physiology, cytology and genetics.

New systematics has led to new branches of taxonomy like **morphotaxonomy** based on

morphological characters, **karyotaxonomy** based on nucleus and bands on chromosomes, **cytotaxonomy** based on cytoplasm (cytochrome C), **experimental taxonomy** based on experiments determining genetic interrelationships, **biochemical taxonomy** on the basis of biochemical studies, **chemotaxonomy** based on particular chemicals like secondary metabolites and **numerical taxonomy** or **phenetic** or **adansonian taxonomy** explained by **Adanson** (1963) based on statistical methods employed in classification.

Latest in the taxonomy is the use of DNA and computers. DNA is more stable than protein in the environment; this raises the possibility of doing DNA sequencing on well preserved (in snow and amber) extinct organisms. Egyptian mummies over 2000 years old and human remains in Florida that are at least 7500 years old have yielded samples of DNA that were successfully sequenced. In 2006, a new record was reported — that the DNA was sequenced from 8,00,000 years old elephant fossils.

Protein sequencing provides a tool for establishing homologies from which genealogies can be constructed and phylogenetic trees are drawn. With such information, one can reconstruct an evolutionary history of the molecule and, thus of their respective owners. For example—Cytochrome C is an ancient molecule, and it has evolved very slowly. Even after more than 2 billion years, one-third of its amino acids are unchanged. This conservatism is a great help in working out the evolutionary relationships between distantly-related creatures like fish and humans.

Taxonomists are using the **chromosome painting** method to compare the entire genome, in which a fluorescent label to the DNA of individual chromosomes of one species (e.g., human) is attached. Then it is exposed to chromosomes of another species (e.g. chimpanzee and orangutan); regions of gene homology hybridizes taking up the fluorescent label and the "painted" chromosomes are examined under the microscope to see which species is closer to human ?

## Significance of Classification

1. **Convenience of study.** Out of millions of types of organisms it is difficult to study each of them. The study of selected animals of a particular group gives an idea about the remaining animals of that group, for example study of rabbit gives the knowledge about all animals of class mammalia.

2. **Knowledge of affinities.** The knowledge about relationships or affinities of different animals with other animal species comes from classification.

3. **Knowledge of sequence of evolution.** Classification gives the sequence of evolution of animals, like evolution of sponges from single-celled protozoa and that of arthropoda from annelida, could only be known through classification.

4. **Knowledge of connecting links.** The transitory stage between two groups of animals is known as **connecting link**. It gives the sequence of evolution of animals. With the help of classification definite position of connecting links can be made clear.

5. **Knowledge of adaptation.** By classification we come to know about such characters of animals with which they adapt to an environment.

6. **Knowledge of phylogeny.** Animals of one group are evolved from a common ancestor, is known through classification because this is based on phylogeny. We know that all animals of class mammalia have evolved from one common ancestor.

## Brief History of Classification

The Greek philosopher Aristotle (384-322 B.C.), known as Father of Zoology in his book *Historia Animalium* he classified the animals and this was followed for about 2000 years.

Following was his system of classification :

**Group I. Enaima.** It included the vertebrate animals having red coloured blood.



Fig. 1. Carolus Linnaeus ; Father of modern taxonomy.

**Class 1. Viviparous.** Animals which give birth to young ones e.g., man, whale and other mammals.

**Class 2. Oviparous.** Egg laying animals e.g., amphibians, reptiles, fishes and aves.

**Group II. Anaima.** It included the invertebrate animals without red coloured blood.

**Class 1. Cephalopoda.** It contained giant bodied molluscs.

**Class 2. Crustacea.** It included crabs and shrimps.

**Class 3. Insects and spiders.** It included different types of insects and spiders.

**Class 4. Mollusca and echinodermata.** It included other moluscs and star fishes.

**Class 5. Sponges and coelenterata.** It included sponges and sea animones.

Aristotle classified animals on the basis of their body size, habit and habitat.

## Species is a unit of classification

The word species was coined by John Ray (1628-1705). The concept of biological species was put forward by Mayer. A Swedish botanist Karl von Linne who later on became popular by the name of Carolus Linnaeus (1707-1778), wrote the book *Systema Naturae* (1735). In this book he presented the system of nomenclature for plants and animals known as **binomial nomenclature**. This book is known as the

“dictionary of classification” and Linnaeus is known as the “Father of Modern Taxonomy.”

### Nomenclature of Organisms

While classifying any animal its nomenclature is required first. There are two types of names of organisms—(i) **Common or Vernacular names** and (ii) **Scientific names**. The well known animals and plants are known by different names in different countries and language of the world. An organism may be popular by different local names in different parts of a country. This poses a great problem in the study of an organism because a man of other place or language can not understand about that organism. When Seton (1929) wanted to study a big member of cat family, he realised that in different parts of America it is known by different names. eg., painter, cougar, puma, panther, mountain lion, catamount, variment-red tiger, brown tiger, sneak cat, king cat, purple panther, mountain devil, mountain screamer and mountain demon. The easiest solution to all such problems was, only to assign one scientific name for this animal—*Felis concolor*, so that it can be studied easily throughout the world.

**Monomial nomenclature.** To assign name of one word in classification is called monomial nomenclature. While writing the names of **taxa** or **supraspecific groups**, monomial nomenclature is used e.g. name of family, order, class, or phylum, etc.

**Binomial nomenclature.** The system of writing scientific names of the organisms adopted by Linnaeus is called binomial nomenclature. He gave system of writing the name of organisms in two words. The first word of the name belongs to the **genus**, other word belongs to that specific plant or animal and is called **species**. According to the binomial nomenclature the very popular Indian bird, commonly called Gauraiya in India, is named as *Passer domesticus*, the dog as, *Canis familiaris*, the house fly as *Musca domestica*, and the lion as *Panthera leo*.

Even Linnaeus changed his real name **Karl von Linne** according to the binomial nomenclature to **Carolus Linnaeus**.

**Trinomial nomenclature.** There are certain organisms which have **subspecies**. The name of their subspecies is written after the name of their genus (generic name) and the species (specific name). These subspecies occur in different regions and have different characteristics. Therefore, the system of writing names in three words is known as **trinomial nomenclature**. The scientific name of common crow is *Corvus splendens*. It is mainly found in India, Burma and Sri Lanka but it is different in each country. It is therefore, divided into three subspecies. In India it is called *Corvus splendens splendens*, in Burma it is *Corvus splendens insolens* and in Sri Lanka it is *Corvus splendens protegatus*. In the same way the subspecific name of Indian lion is *Panthera leo persica* and the modern man is *Homo sapiens sapiens*.

**Rules of scientific nomenclature.** While writing the scientific names it is necessary to follow certain **international rules** which are :

- (1) The scientific name (generic and specific both) should be written or printed in *Italics*.
- (2) The generic name must start with capital letter and the specific name with small letter.
- (3) The generic name should be followed by the specific name.
- (4) In case different scientists have named the same genus or species differently, the name first published be accepted.
- (5) A family name is formed by suffix **-IDAE** to the names of the genus and name of a sub family by suffix **-INAE**.

### Groups in Classification

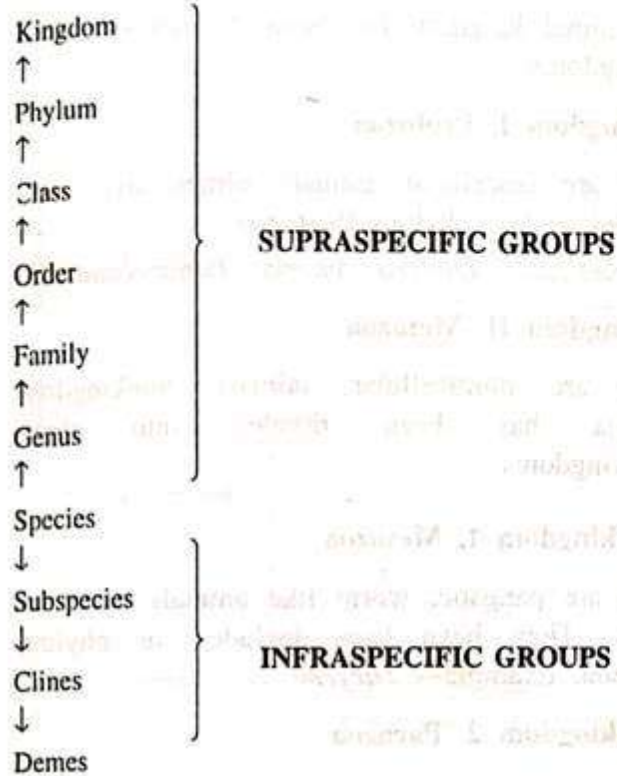
In order to classify the organisms they are divided into categories, ranks or groups of different status. The supraspecific category assigned in classification are called **taxa** (*sing. taxon*). In classification these groups or taxa are arranged in a definite order which is known as **hierarchy of classification**. There are six main **taxa**—(i) phylum, (ii) class, (iii) order, (iv) family, (v) genus, and (vi) species.

The words species, genus and family were first used by **John Ray**, word class and order



were used by **Linnaeus** and the term phylum was given by **George Cuvier**

**TAXA OR RANKS**



**Species**

In the system of classification the species (plural is also species), constitutes the small unit. It has been variously defined by different scientists. According to **John Ray** all members produced from similar parents are kept in same species. **Mayer** gave the concept of biological species as interbreeding group of organisms. **Linnaeus** described that animals with similar structural resemblance form same species.

By hybridization or cross-breeding between two almost similar species a new species resembling both the species can be produced e.g. a **mule** is formed from a female horse and male ass, a **tiglion** from a tiger and a lioness, a **zabroid** from an ass and a zebra, and **panthopard** from a female panther and a male leopard etc. The modern scientists are of the opinion that a species is a population of such organisms which have a **gene pool**, they have similar adaptation to the environment and have the capacity to change into new species through **organic evolution**.

**Modern concept of species.** The modern concept of species is biological species or genetic species. **Mayer** (1942) has defined species as a "population of interbreeding individuals. There is a free gene flow in an interbreeding" population, the genetic changes appearing in a part of population of the species can ultimately appear in the descendents of the species. The population thus tends to evolve as a whole.

An animal species may have following characteristics :

- (1) Each species possesses a common gene pool with a free gene flow.
- (2) Each species is in a process of continuous adjustment to its environment.
- (3) Each species occurs in an ecological niche not necessarily occupied by other species.
- (4) Each species possesses a constellation of isolating mechanisms that directly or indirectly prevent exchange of genes with related species.
- (5) Each species has the capacity to give rise to new species.

Often the individuals comprising a species can be subdivided into smaller groups known as **subspecies**. These differ in minor but very distinct characters. Each subspecies occupies a separate range, and the members at the borderline of two adjacent subspecies have characteristics common to both.

**Types of species.** Species can be of different types :

(a) **Agamo species.** Species reproducing asexually are called agmo species.

(b) **Gamo species or biological species.** Species reproducing sexually are called gamo species.

(c) **Sympatric species.** Two or more species living in a common habitat are called sympatric species.

(d) **Allopatric species.** Two or more species living in different habitat or different geographical conditions are called allopatric species.

(e) **Synchronic species.** Two or more species round in the same time period are called synchronic species.

(f) **Allochronic species.** Two or more species which are found in different time periods are called allochronic species.

(g) **Palaeospecies or Palaeontological species.** Such species which are now available in the form of fossils are called palaeospecies. They are also known as fossil species.

(h) **Neontological species.** Species which are found living at present are called neontological species.

(i) **Polytypic species.** Species which are found in more than one subspecies are called polytypic species.

(j) **Sibling species.** These are allopatric species which are morphologically similar but are found in different yet adjacent habitats.

**Law of priority.** If two or more than two names are given for a single animal species by different scientists at different time period, then the name first published in a scientific literature stands valid. This is the law of priority.

## Modern Classification of Animal Kingdom

The entire living world was divided by **Linnaeus** into two kingdoms :

1. **Animal kingdom.** Animal world constitutes the animal kingdom. They do not possess chlorophyll, perform locomotion and they do not possess cell wall made up of cellulose.

2. **Plant kingdom.** The plant world constitutes the plant kingdom. They possess chlorophyll, cell wall made up of cellulose and they have no power of locomotion.

**Ernst Haeckel, 1894** proposed two kingdoms but they could not get proper recognition :

1. **Monera kingdom.** Haeckel proposed it for enucleated or prokaryotic cell like blue green algae and bacteria.

2. **Protista kingdom.** Those living species which possess characters of both animals and plants were included by Haeckel in this kingdom. They include one celled eukaryotes.

Animals have been classified in various ways by various authors. The present classification is mainly based on the book, *General Zoology* by **Tracy. I. Storer** and **Robert L. Usinger**. They

have classified the animal kingdom into 23 phyla (table 1).

## Animal Kingdom

The animal kingdom has been divided into two subkingdoms :

### Subkingdom I. Protozoa

These are unicellular animals which have been included in one phylum **Protozoa**.

Examples— *Euglena*, *Amoeba*, *Paramecium* etc.

### Subkingdom II. Metazoa

These are multicellular animals. Subkingdom metazoa has been divided into three Infra-kingdoms.

#### Infra-kingdom 1. Mesozoa

These are parasitic, worm like animals and lack tissues. They have been included in phylum **Mesozoa**. Example— *Dicyema*.

#### Infra-kingdom 2. Parazoa

They are marine as well as fresh water forms and have cellular grade of body organisation. They lack-tissues, choanocyte cells are found. They have been included in phylum **Porifera**. e.g., all sponges.

#### Infra-kingdom 3. Enterozoa

Tissues and organs are found. They include all the remaining metazoans. Infra-kingdom Enterozoa has been divided into two divisions :

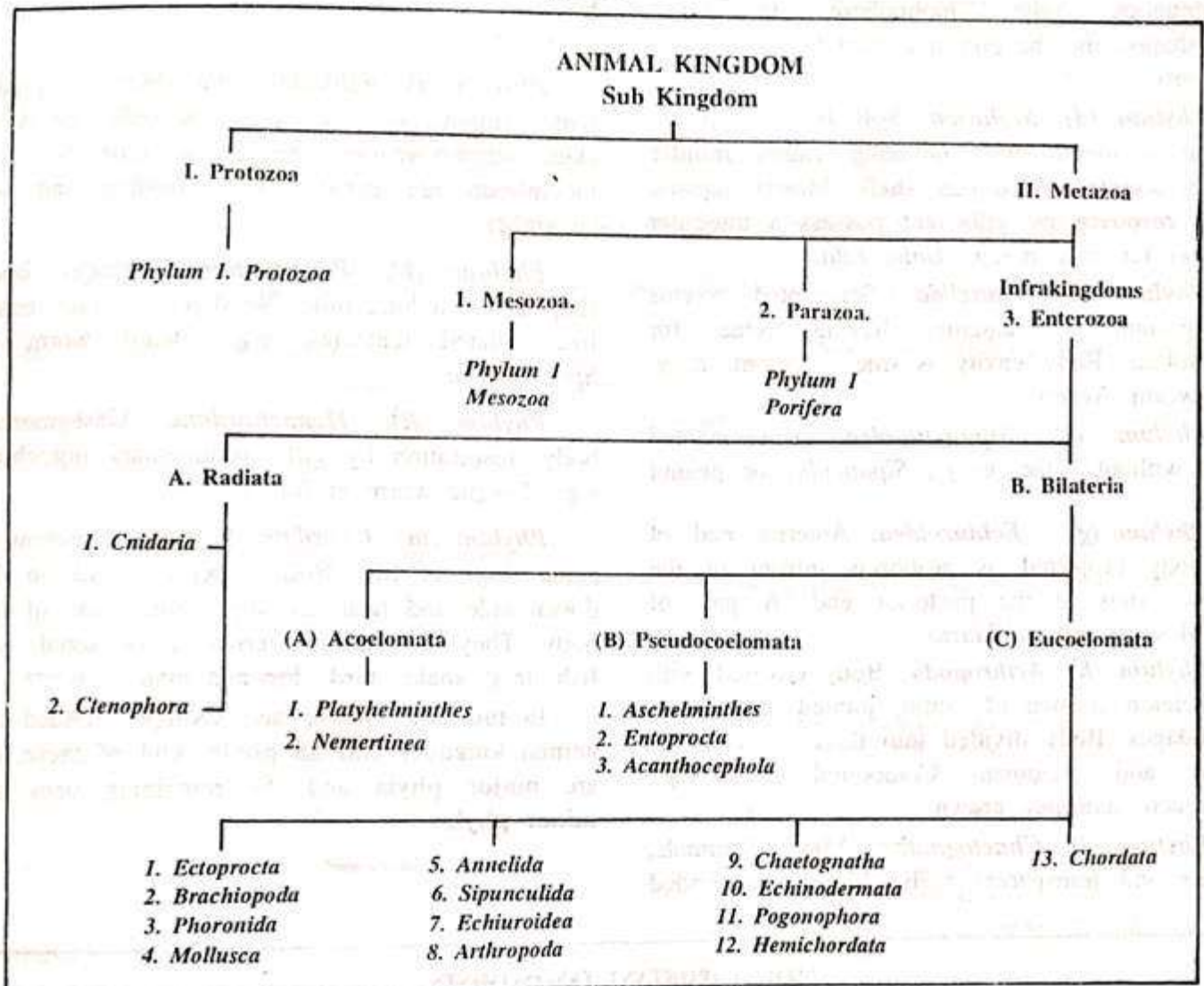
**Division A. Radiata.** Radially symmetrical animals which do not possess organs i.e. their body organization is of tissue grade. Two phyla are included in this division.

**Phylum (a). Cnidaria.** Nematoblast cells are found, tentacles present and comb plates are absent. e.g., *Obelia* and *Hydra*.

**Phylum (b). Ctenophora.** They possess comb plate which helps in locomotion. Nematoblasts and tentacles absent. e.g., *Beroe*.

**Division B. Bilateria.** Bilaterally symmetrical animals, triploblastic and have organ grade of body organisation. Bilateria has been divided into 3 sections :

Table 1. Outline classification of animal kingdom.



**Section 1. Acoelomata.** No body cavity or coelom. Space between body wall and visceral organs is occupied by mesoderm formed of parenchyma. It includes two phyla :

**Phylum (a). Platyhelminthes.** Parasitic and flat worms. e.g., tapeworm *Taenia*, liver fluke *Fasciola*.

**Phylum (b). Nemertinea (Rhynchocoela).** Thin, elongated, ribbon like aquatic animals e.g., *Stichostemma*.

**Section 2. Pseudocoelomata.** Pseudocoel found in the adult stage, parenchyma fills the spaces between body wall and visceral organs in young stage. This section includes three phyla :

**Phylum (a). Aschelminthes.** Slender, elongated and round body, mouth and anus at two different ends of the body. e.g. *Ascaris*.

**Phylum (b). Entoprocta.** Fixed and stalked animals, mouth and anus located at one end close to each other. e.g. *Loxosoma*.

**Phylum (c). Acanthocephala.** Flat bodied parasites, no alimentary canal, thorny proboscis at anterior end. e.g. *Acanthocephala*.

**Section 3. Eucoelomata.** They possess true coelom lined with mesoderm. Section Eucoelomata includes 13 phyla :

**Phylum (a). Ectoprocta or Bryozoa.** Aquatic, minute, colonial moss like animals. The digestive tract U-shaped. e.g. *Bugula*.

**Phylum (b). Brachiopoda.** Body covered with shell formed of calcium carbonate, interior with two spiral arms called **lophophore**. Commonly called **lampshells**. e.g., *Lingula*.

**Phylum (c). Phoronida.** Worm like cylindrical, unsegmented, live in self secreted

membranous tube, lophophore is horse shoe-shaped and the digestive tract U-shaped. e.g., *Phoronis*.

**Phylum (d). Mollusca.** Soft bodied animals having a membranous covering called **mantle** which secretes calcareous **shell**. Mostly aquatic forms respiring by gills and possess a muscular foot for locomotion e.g., *Unio*, *Pila*.

**Phylum (e). Annelida.** Segmented worms underground or aquatic, having setae for locomotion. Body cavity is true coelom. e. g. Earthworm, *Nereis*.

**Phylum (f). Sipunculoidea.** Unsegmented body without setae. e. g., *Sipunculus* or peanut worm.

**Phylum (g). Echiuroidea.** Anterior end of the body projected as proboscis in front of the mouth. Anus at the posterior end. A pair of ventral setae. e.g., *Echiurus*.

**Phylum (h). Arthropoda.** Body covered with exoskeleton formed of chitin, jointed and paired appendages. Body divided into three parts—head, thorax and abdomen. Compound eyes e.g., cockroach, scorpion, prawn.

**Phylum (i). Chaetognatha.** Marine animals, slender and transparent body. Mouth surrounded

by spicules, bristles or hooks. e.g., Arrow worm or *Sagitta*.

**Phylum (j). Echinodermata.** Marine animals with pentamerous body provided with spines in skin, water-vascular system and tube feet for locomotion are present. e.g. Starfish and sea cucumber.

**Phylum (k). Pogonophora.** Slender body shaped like a long tube. No digestive tract, beard like ciliated tentacles. e.g., Beard worm or *Spirobrachia*.

**Phylum (l). Hemichordata.** Unsegmented body, respiration by gills, rudimentary notochord e.g., Tongue worm or *Balanoglossus*.

**Phylum (m). Chordata.** Notochord present at some stage of life. Hollow nerve cord on the dorsal side and heart on the ventral side of the body. They are aquatic, terrestrial or aerial. e.g. fish, frog, snake, bird, dog and man.

In this way **Storer** and **Usinger** divided the animal kingdom into **23 phyla**. Out of these, **10** are **major phyla** and the remaining ones are **minor phyla**.

#### SOME IMPORTANT TAXONOMISTS

1. Aristotle	: Called as father of Zoology	10. Escholtz	: Gave the word Ctenophora.
2. Johnston	: Coined the name Mollusca.	11. Von Siebold	: Gave the name Arthropoda.
3. Leeuwenhoek	: Observed Protozoa and discovered <i>Hydra</i> in 1703.	12. Leuckart	: Coined the word Coelenterata.
4. John Ray	: Gave the term species.	13. Gegenbaur	: Coined the name Platyhelminthes.
5. Jacob Klein	: Gave the name Echinodermata.	14. Haeckel	: Formed the group Protista and Monera.
6. Carolus Linnaeus	: Father of modern taxonomy.	15. Sollas	: Gave the name Parazoa.
7. Lamark	: Coined the name Annelida.	16. Bateson	: Used the word Hemichordata.
8. Gold-fuss	: Coined the word Protozoa.	17. Mayer	: Gave the modern definition of biological species.
9. Robert Grant	: Coined the word Porifera.	18. Grobben	: Gave the name Aschelminthes.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Classify phylum Annelida upto classes giving important characters of each group.
2. Give four characters of phylum Arthropoda. On which characters class Insecta is separated from other arthropods.
3. Scorpion belongs to which class? Give its four characteristics. What is the difference between scorpion and wasp?
4. What is Zoological name of cray fish? What is the difference between cray fish and dog fish? What is the economic importance of cray fish?
5. Elephant and lion belong to which class? What are similarities between them? What are important differences between them? Give characteristics of their teeth.
6. Give important characters of Cnidaria. Classify this phylum upto orders. Jelly fish belongs to which class?

#### » Short Answer Type Questions

1. Define species giving one example.
2. Briefly describe significance of classification.
3. What is the main characteristic of phylum Echinodermata? Write zoological names of four animals of this phylum.
4. Who gave binomial nomenclature?

#### » Multiple Choice Questions

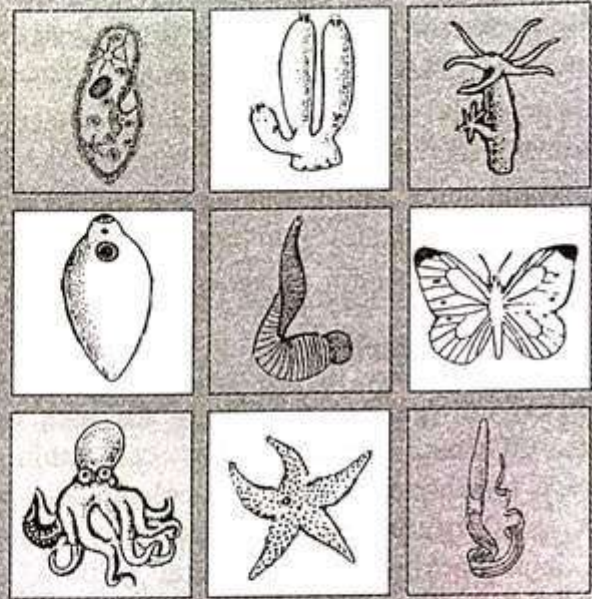
1. Linnaeus is associated with :
  - (a) inheritance of acquired characters
  - (b) binomial nomenclature
  - (c) law of independent assortment
  - (d) law of limiting factors
2. Who propounded binomial system of nomenclature :
  - (a) Carolus Linnaeus
  - (b) Gregor Mendel
  - (c) Pasteur
  - (d) Darwin
3. Radial symmetry is best seen in :
  - (a) Mollusca
  - (b) sponge
  - (c) star fish
  - (d) fishes
4. Inter-breeding animals are members of the same :
  - (a) order
  - (b) species
  - (c) genus
  - (d) family
5. One celled animals and plants have been kept in :
  - (a) Monera
  - (b) Protista
  - (c) Protozoa
  - (d) Parazoa
6. Animals living on the surface of sea water are called :
  - (a) lotic
  - (b) pelagic
  - (c) benthic
  - (d) lentic
7. Branch of biology that deals with classification :
  - (a) histology
  - (b) taxonomy
  - (c) physiology
  - (d) geology
8. Sometimes different scientists give different names of the same species, in such a situation :
  - (a) all these names are cancelled and a new name is put forward
  - (b) people are free to choose any name
  - (c) first name is considered right
  - (d) last name is considered right
9. Which is a species :
  - (a) carnivora
  - (b) *Canis*
  - (c) *Canis familiaris*
  - (d) Mammalia
10. According to the system of binomial nomenclature every organism has :
  - (a) two names one for the place to which it belongs and the other of the discoverer
  - (b) one name established by two scientists
  - (c) one scientific name of which first part is genus and other species
  - (d) two names one scientific and one common
11. A new species is formed when :
  - (a) because of new genic populations organism with new traits are born
  - (b) exchange of parts between homologous chromosomes takes place
  - (c) changes in the genotype in population leads to sexual isolation
  - (d) the exchange of parts of chromosomes during gametogenesis leads to the formation of new genotype
12. A new species can be formed when :
  - (a) individual variations leads to sexual isolation
  - (b) there is no relationship between phenotype and genotype
  - (c) an individual is produced by the combined effects of phenotypic and environmental influences
  - (d) common genotype of similar species
13. Inter-breeding animals belong to the same :
  - (a) genus
  - (b) species
  - (c) family
  - (d) order
14. In which character vertebrates differ from invertebrates:
  - (a) coelom
  - (b) tail
  - (c) dorsal tubular nerve
  - (d) brain cord
15. What is the basic unit of classification :
  - (a) order
  - (b) phylum
  - (c) genus
  - (d) species

16. Which is the matching set in classification :  
 (a) star fish, jelly fish, cuttle fish, *Octopus*  
 (b) leech, locust, sea urchin, lobster  
 (c) *Nereis*, planaria, round worm, earthworm  
 (d) millipede, crab, centipede, cockroach
17. Which animals are of similar genus :  
 (a) *Histolytica* and *coli*  
 (b) *Histolytica* and *plasmodium*  
 (c) *Histolytica* and *falciparum*  
 (d) *Histolytica* and *bancrofti*
18. Animals active at day time are called :  
 (a) nocturnal (b) herbivore  
 (c) diurnal (d) insectivore
19. Artificial system of classification was first adopted by:  
 (a) Simpson (b) Linnaeus  
 (c) Dobzhansky (d) Mayr
20. Carolus Linnaeus system of nomenclature is :  
 (a) natural (b) artificial  
 (c) phylogenetic (d) binomial
21. Which scientist made significant contribution in the field of animal classification :  
 (a) Oparin (b) Linnaeus  
 (c) Lamarck (d) Pasteur
22. Branch of science concerned with classification of animals :  
 (a) parasitology (b) ecology  
 (c) genetics (d) taxonomy
23. Who wrote the book '*Systema Naturae*' :  
 (a) Lamarck (b) Darwin (c) Buffon (d) Linnaeus
24. Protista obtain food as :  
 (a) chemosynthesis  
 (b) photosynthesis  
 (c) holotrophic  
 (d) photosynthesis, holotrophic, symbiosis
25. Phylogenetic classification is based on :  
 (a) external similarity  
 (b) common evolution  
 (c) habit and habitat  
 (d) utilitarian system
26. Radial symmetry is generally exhibited by animals :  
 (a) which are attached with substratum  
 (b) which are aquatic  
 (c) which have ciliary feeding  
 (d) which have one opening of alimentary canal
27. Taxonomically a species is :  
 (a) a group of evolutionary related populations  
 (b) population having same evolutionary basis  
 (c) category to which most taxonomic information is attached  
 (d) fundamental unit in phylogenetic history of organisms
28. Linnaeus gave natural system of classification based on :  
 (a) morphology (b) anatomy  
 (c) evolutionary trends (d) all of these
29. Radial symmetry is usually associated with :  
 (a) aquatic life (b) creeping mode of life  
 (c) lower grade of organisation  
 (d) sedentary mode of life
30. A taxon with reference to classification of organisms can be explained as :  
 (a) group of organisms based on chromosome number  
 (b) group of similar species  
 (c) group of rank of organisms  
 (d) group of similar genera
31. Taxonomy based on maximum number of phenotypic characters is :  
 (a) phylogenetic system (b) artificial system  
 (c) natural system (d) none of them
32. Who proposed artificial system of classification :  
 (a) Lamarck (b) John Ray (c) Linnaeus (d) Wallace
33. Who formed the key for identification of animals ?  
 (a) Goethe (b) Theophrastus (c) John Ray (d) Cuvier
34. Identify the correct sequence of taxa in Linnean hierarchy :  
 (a) species, genus, family, order, class  
 (b) class, family, species, genus, order  
 (c) species, genus, phylum, family, class  
 (d) phylum, class, family, species, order.

### Answers

1. (b) 2. (a) 3. (c) 4. (b) 5. (b) 6. (b) 7. (b) 8. (c) 9. (c) 10. (c) 11. (c) 12. (a) 13. (b) 14. (c) 15. (d) 16. (d) 17. (a) 18. (c) 19. (b) 20. (d) 21. (b) 22. (d) 23. (d) 24. (d) 25. (b) 26. (b) 27. (b) 28. (d) 29. (d) 30. (c) 31. (c) 32. (c) 33. (c) 34. (a).

# The Invertebrates



## 2 Chapter

### Why We Study Invertebrates ?

Famous Biologist **E. O. Wilson** has called the invertebrates as "little things which run the world." It is because of their number, variety and influence on the larger organisms and even entire ecosystem. These different creatures like butterflies, beetles, bees, ants, dragonflies, snails, lobsters and starfishes etc., are primary builders of a healthy environment. They build amazingly colourful coral reefs of the oceans, and serve as food for countless other animals.

Invertebrates are a part of nearly every food chain, either directly, as food for fishes, amphibians, reptiles, birds, mammals or indirectly, as agents in the endless recycling of nutrients in the soil. Food webs are often dependent on invertebrate species performing essential services such as pollination or seed dispersal. We can not think to live on the earth without the invertebrates.

The Animal Kingdom has categorized just over a million scientifically described species, in thirty-two phyla. The phylum Arthropoda (insects, spiders, crustaceans, millipedes, and centipedes among others) has an estimated 10,85,000 identified species, or 82% of the total identified animal species, and with all other invertebrates (excluding viruses and bacteria) the number reaches to 12,38,000 or 94%. The phylum Chordata, which includes fish, birds and mammals, contains around 45,000 (3%) species, of which only 4,000 (0.03%) are mammals. It is estimated that five to eight million insect species have not been identified or discovered, while only 5,000 to 10,000 species of Chordates may await identification and description. Certain marine taxa, particularly small deep sea organisms, are very poorly known, suggesting that oceanic species diversity still remains underestimated.

The study of invertebrates have acquainted us with their involvement in the serious effects on the sustainability of several agricultural production. The invertebrates and micro-organisms play a vital role in maintaining and enhancing the soil fertility, detoxifying of pesticides and other pollutants, and also in biological control of agricultural pests.

### What is an Invertebrate ?

The described species of animals are over one million. Of these, about 5 per cent animals possess a backbone or vertebral column and are known as "Vertebrates". The remaining animals which lack backbone or vertebral column are referred to as "Invertebrates". All such animals are included in a group, "Invertebrata". This word is a semantic blanket that covers a wide range of animals regardless of their size, shape, morphological characteristics and phylogenetic relationship. We know that worms, butterflies, sponges, corals, snails, crabs and strafishes are not alike in any specific structure, even then all have been included in 'Invertebrata'. This has been possible only due to the fact that these animals do not possess a vertebral column.

### Invertebrate Phyla

Presently there are about 30 invertebrate phyla, which are characterised by a unity of basic structural pattern in each of them. This means that in each phylum, though the members may vary in external features, the anatomical features are constructed on the same ground plan in many respects. The common anatomical ground plan implies a unique network of relationship among the groups of structural units which compose it. Other significant feature of inter-relationships among the members of same phylum is functional. All animals of a group work as efficient machines with similar functional integration. Another important feature, which binds members of the individual phylum with one cord, is the *common ancestry*. It has been confirmed by evolutionary studies that all the members of an individual phylum have been derived directly or indirectly from a common primitive ancestral type. Thus, the 30 phyla

display 30 patterns, each manifesting a characteristic, anatomical and functional integrity and common ancestry.

### Invertebrata versus Non-Chordata

Animals are often distinguished into two major categories, the "Chordates", and the "Non-Chordates". This division is based on the presence or absence of a singular character, the *notochord*, a stiff rod-like structure which serves as an internal skeleton. *Phylum Chordata* includes those animals which possess notochord during any period of their life. *Subphylum Vertebrata* includes those animals in which the supporting action of notochord is partly or wholly taken over by a segmented vertebral column.

On the other hand, animals lacking a notochord are called *Non-Chordates*, and those lacking a vertebral column are called *Invertebrates*. The terms "Non-Chordates" and "Invertebrates", are often used for each other as synonyms, but strictly speaking they are not synonymous. For example, the Protochordates are all invertebrates (due to lack of vertebral column), but they are still chordates (due to presence of notochord). Thus, all the non-chordates are invertebrates whereas all the invertebrates are not non-chordates (e.g. protochordates).

This means that the Invertebrates minus Protochordates are equal to Non-Chordates. The present book describes only those Invertebrates which are Non-chordates. It does not deal with the other Invertebrates, that is Protochordates, which have been described in a separate book along with the Vertebrates.

It must be obvious by now that it is more scientific to use the term "Non-Chordates" for animals without a notochord. But in usage, they are still called the "Invertebrates" which is a broader and older term.

### Diversity of Invertebrates

As already stated, the Invertebrates represent a heterogeneous assemblage which includes such diverse forms as sponges, corals, worms and butterflies. Accordingly, they exhibit a great



diversity of form, structure, physiology, habit and habitat, etc.

1. **Numerical strength.** About one and a quarter million species of living animals are known at present. Of these, only 5%, that is about 50,000 species belong to the chordates. The remaining 95%, that is, about 1.2 million species constitute the invertebrates. Out of these, nearly one million are Arthropoda in which the class Insecta alone includes about 900,000 species. Other major invertebrate groups include nearly 45,000 molluscs, 50,000 protozoans, 5,000 sponges, 11,000 coelenterates, 12,000 nematodes, 8,700 annelids and 6,000 echinoderms. The approximate number of described species in each of the 30 phyla is given in *Table 4*.

It has been calculated that the number of *extinct* species is around seven times the number of *living* species, and thus, there may have been some 7 to 8 million invertebrate species in all.

2. **Size.** It is a general principle that every organism is distinguished by a characteristic size. The invertebrate animals range in size from the microscopic protozoans to the large-sized cephalopods. At the lowest extremity, the malarial parasite (*Plasmodium*) is so small that it occupies nearly one-fifth of a human red blood corpuscle. At the uppermost extremity, a species of the giant squids (*Architeuthis*) of North Atlantic has been reported to have attained a total body length of 16.5 meters including the tentacles.

3. **Shape.** Animals of nearly all shapes are included amongst the invertebrates. The irregular everchanging body shape of *Amoeba*, plant-like appearance of many sponges and coelenterates, leaf-like and ribbon-shaped flatworms, elongated and vermiform annelids, nemerteans and nematodes, star-shaped star-fishes, etc., display spectra of body shapes.

4. **Symmetry.** All symmetries are represented by the invertebrates. Protozoans show bilateral as well as radial symmetry. Some are asymmetrical. Sponges are either asymmetrical or radially symmetrical. Coelenterates are radially symmetrical. Ctenophores show biradial symmetry. The members of remaining phyla are mostly bilaterally symmetrical. Spherical

symmetry too is represented in the invertebrates, principally in some spherical protozoans like *Heliozoa* and *Radiolaria*.

5. **Habits and habitat (Ecology).** Changes in morphology and function have enabled animals to live in different kinds of habitats. The invertebrates occupy a great variety of habitats and have adapted themselves to different modes of life. They are found in the seas, in fresh waters, in air and on all parts of land from snow-covered mountains to deserts. Protozoans are cosmopolitan in distribution, found in all habitats and are free living, parasitic or commensal. Sponges and coelenterates are aquatic animals, chiefly marine, but helminths again exhibit all forms of life. Annelids also occur in different habitats and some (e.g. leeches) are sanguivorous in habit. The most diverse and biologically successful among all animals are the arthropods. They live in all sorts of habitats and consume the largest amount and variety of foods and the insects are the only invertebrates capable of flight. Molluscs are mostly marine, but snails and clams live in freshwater while some species of snails and slugs are terrestrial. Echinoderms are exclusively marine.

6. **Grades of organization.** Invertebrates show all grades of organisation. *Protoplasmic grade* is found in Protozoa, as all activities at this level are confined within the limits of a single plasma membrane (plasmalemma). *Cellular grade* is characteristic of sponges because in a sponge only cells exhibit division of labour for performing specialized functions. *Cell-tissue grade* is seen in coelenterates as their cells are not only specialized for different functions but also certain similar cells gather together to form tissues as well. A noteworthy example is the nerve net formed by nerve cells and their processes. *Tissue-organ grade* appears in flatworms with the arrangement of tissues to form organs. *Organ-system grade*, where organs join together in a system to perform some function, is typical of all higher invertebrate forms.

7. **Types of coelom.** In some many-celled invertebrates, like sponges and coelenterates, the

body is a double-layered sac surrounding a single cavity, which opens to outside through a mouth. Such animals are *acoelomate* as they have no coelom. Other invertebrates have a cavity in between the body wall and the gut. This cavity is a *pseudocoelom* in nematodes as it is not lined by mesoderm. In higher invertebrates, the coelom is lined by the mesoderm and hence it is the *true coelom*.

**8. Diversified respiratory surfaces.** Protozoans, sponges, coelenterates and many worms have a direct diffusion of gases between the organism and the environment. In most annelids, the exchange of gases is through moist skin. *Gills* are common in most higher invertebrates. Echinoderms use *dermal branchiae* and *tube feet* for the purpose. In insects the *tracheal system* is adapted for aerial respiration. Sea cucumbers have *respiratory trees* acting as respiratory organs.

**9. Diversified excretory mechanisms.** In protozoans, sponges and coelenterates excretion is by *direct diffusion* through cell membranes. Flatworms possess characteristic *flame cells*, while annelids and molluscs use *nephridia* for the purpose. The excretory devices in insects are *Malpighian tubules*. Echinoderms and some other invertebrates have amoeboid cells or *phagocytes* for storage and disposal to outside of excretory products.

**10. Varied modes of reproduction.** Among invertebrates, mode of reproduction varies from simple *asexual binary fission* to most complicated *sexual reproduction*. In certain kinds, *parthenogenesis* (Gr., *parthenos*, virgin + *genesis*, origin) is also met with, in which an unfertilized egg develops into a complete individual. It occurs in rotifers, bees, some other insects and certain crustaceans. *Paedogenesis* (Gr., *pais*, a child + *genesis*, origin), in which eggs produced by immature individuals develop into larvae, is seen in some invertebrates like the gall fly, *Miastor*. In sexually reproducing invertebrates *hermaphrodites* or bisexual forms are met with, particularly in coelenterates, platyhelminths, annelids and crustaceans. Fertilization is either internal or external. Development is direct or indirect. In the latter case the development includes both larval stages and metamorphosis.

(Z-1)

## Major and Minor Phyla

It is customary to divide the invertebrate phyla into *major* and *minor* phyla. The concept of major and minor phyla depends upon two factors: (i) *Number of species and individuals*, and (ii) *their participation in ecological communities*.

On the basis of first factor, 11 phyla (*Protozoa*, *Porifera*, *Coelenterata*, *Platyhelminthes*, *Rotifera*, *Nematoda*, *Mollusca*, *Annelida*, *Arthropoda*, *Ectoprocta* and *Echinodermata* seem to be clearly major, as is evident from the species number given in *Table 4*. Whereas, the species number given in *Table 4*. Whereas, the minor phyla make up only a fraction of animal communities. On the basis of second factor, if the phyla are represented in great majority of ecological communities, they would be regarded as major phyla. On this basis, the two phyla, *Rotifera* and *Ectoprocta*, cannot be considered as major phyla. Although they are greater in species number, but they are included in minor phyla because of their limited participation in animal communities. Thus, utilizing a combination of the above two factors, we can regard only 9 as major phyla and the rest as minor phyla.

## Lower and Higher Invertebrates

The invertebrate phyla are usually referred to as *lower* and *higher* invertebrates. Lower invertebrates are generally smaller in size and simple in body organisation. They are believed to have originated, in the main lines of evolution, near the base of the phylogenetic tree of Animal Kingdom. *Protozoa*, *Porifera*, *Coelenterata*, *Platyhelminthes* and *Nematoda* fall in the category of lower invertebrates. On the other hand, the higher invertebrates are generally larger in size and complex in body organization. These take up higher positions in the phylogenetic tree of the Animal Kingdom. *Annelida*, *Arthropoda*, *Mollusca* and *Echinodermata* are higher invertebrates.

## Contrast between Lower and Higher Invertebrates

On the basis of some important features, a contrast may be made between the lower and higher invertebrates as shown in the *Table 1*.

**Table 1. Contrast between Lower and Higher Invertebrates.**

Lower Invertebrates	Higher Invertebrates
<ol style="list-style-type: none"> <li>1. Generally smaller in size.</li> <li>2. Body organization simple.</li> <li>3. Radial, biradial or no symmetry.</li> <li>4. Germ layers wanting or 2 and 3 germ layers.</li> <li>5. No coelom or a pseudo-coelom.</li> <li>6. Generally no separate mouth and anus.</li> <li>7. No muscular gut.</li> <li>8. Blood vascular system not well developed.</li> </ol>	<ol style="list-style-type: none"> <li>1. Generally larger in size.</li> <li>2. Organization complex.</li> <li>3. Bilateral symmetry.</li> <li>4. Germ layers 3.</li> <li>5. True coelom.</li> <li>6. Mouth and anus separate.</li> <li>7. A true muscular gut.</li> <li>8. A well developed blood vascular system.</li> </ol>

**Invertebrates versus Vertebrates (Comparison)**

As already mentioned earlier, in the traditional system of classification the entire Animal Kingdom has been divided into two major groups: *Invertebrata* (or Non-Chordata) and *Vertebrata* (or Chordata). The former includes those animals that do not possess a vertebral column or backbone, while the latter is characterised by its presence. No doubt, the division of animals into invertebrates and vertebrates is purely artificial, but this has a practical applicability in their systematic study.

The higher invertebrates share many structural peculiarities with the vertebrates, such

**Table 2. Comparison (Differences) between Invertebrates and Vertebrates.**

FEATURES	Invertebrates (Non-Chordates)	Vertebrates (Chordates)
1. Symmetry	1. Radial, biradial or lacking.	1. Bilateral.
2. Metamerism	2. True or pseudometamerism or lacking.	2. True metamerism.
3. Post-anal tail	3. Lacking.	3. Usually present projecting beyond anus.
4. Grade of organization	4. Protoplasmic to organ-system.	4. Organ-system.
5. Germ layers	5. 2 (diploblastic), 3 (triploblastic) or lacking.	5. 3 (triploblastic).
6. Coelom	6. Acoelomate, pseudocoelomate or truly coelomate.	6. Truly coelomate.
7. Limbs derivation	7. From same segment.	7. From several segments.
8. Notochord	8. Notochord or backbone lacking.	8. Present at some stage or replaced by a backbone made of ringlike vertebrae.
9. Gut position	9. Dorsal to nerve cord.	9. Ventral to nerve cord.
10. Pharyngeal gill-slits	10. Absent.	10. Present at some stage of life.
11. Anus	11. Opens on the last segment or absent.	11. Differentiated and opens before the last segment.
12. Bloodvascular system	12. Open, closed or absent.	12. Closed and much developed.
13. Heart	13. Dorsal, lateral or absent.	13. Ventrally placed.
14. Dorsal blood vessel	14. Blood flows anteriorly.	14. Blood flows posteriorly.
15. Hepatic portal system	15. Absent.	15. Present.
16. Haemoglobin	16. In plasma or absent.	16. In red blood corpuscles.
17. Respiration	17. Through body surface, gills or tracheae.	17. Through gills or lungs.
18. Nervous system	18. Solid.	18. Hollow.
19. Brain	19. Above pharynx or absent.	19. Dorsal to pharynx in head.
20. Nerve cord	20. Double, ventral, usually bearing ganglia.	20. Single, dorsal, without ganglia.
21. Segmental nerve roots	21. Dorsal and ventral roots not separate.	21. Dorsal and ventral roots separate.
22. Reproduction	22. Asexual reproduction predominant.	22. Sexual reproduction predominant.
23. Regeneration power	23. Usually good.	23. Usually poor.
24. Body temperature	24. Cold-blooded.	24. Cold or warm-blooded.

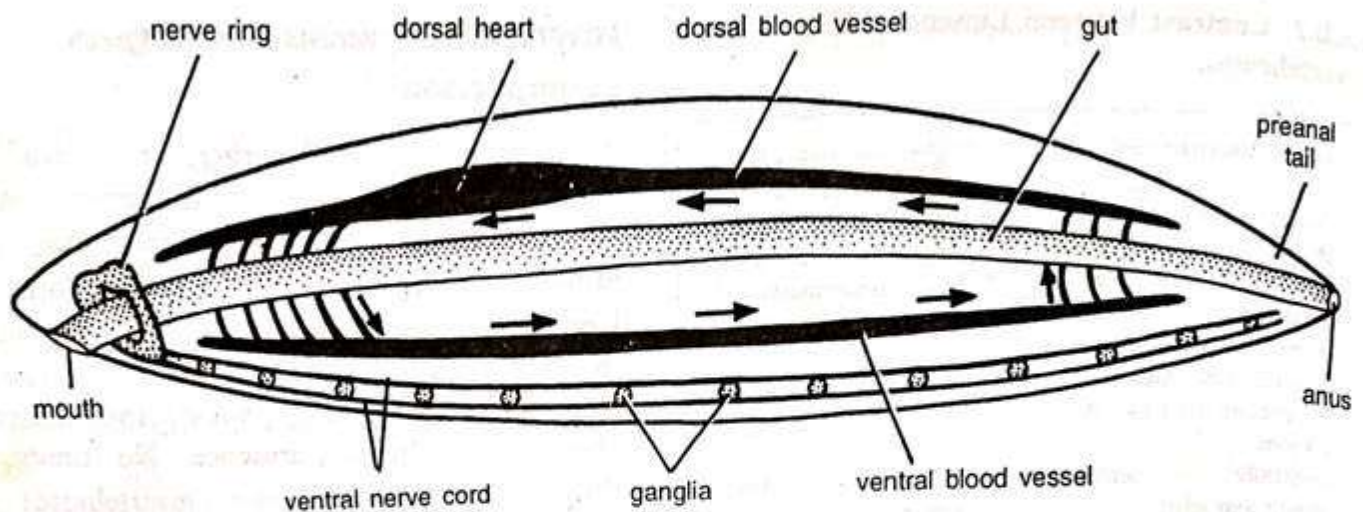


Fig. 1. Generalized invertebrate organization (diagrammatic).

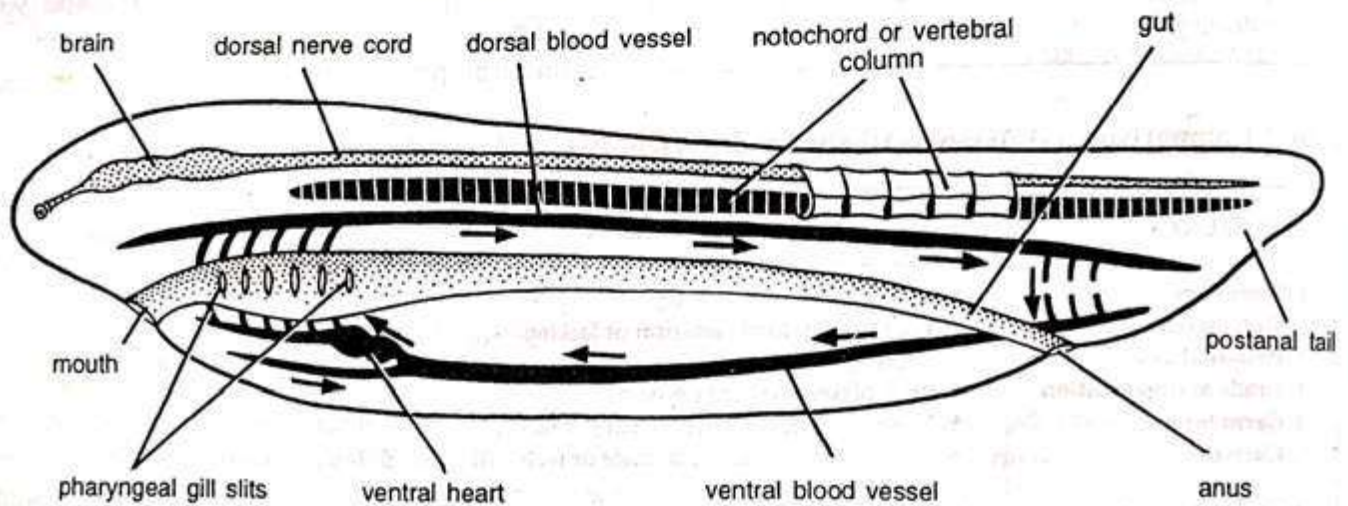


Fig. 2. Generalized vertebrate organization (diagrammatic).

as axiate body plan, bilateral symmetry, triploblastic and coelomate condition, metameric segmentation and organ-system grade of organization. However, the two groups have several fundamental differences. A comparison between Invertebrates and Vertebrates may be drawn as shown in *Table 2*.

Vertebrates can be pictured as "upside-down" invertebrates owing to the position of their nervous and circulatory systems (Figs. 1 and 2).

### Phylogeny of Invertebrates

Evolutionary history of invertebrate animals suggests that the diverse phyla of invertebrates, as we see them today, have evolved as the result of gradual changes spread over an immense period of geological time. In the absence of the fossil record of Archaozoic era, it is rather (Z-1)

impossible even to guess about the animal ancestry. Zoologists believe that the phylum Protozoa owes its origin to primitive algae from which first arose flagellate Protozoa or Mastigophora. In course of time they gave rise to other protozoans as well as the sponges (Porifera). The coelenterates are believed to have evolved from a primitive multinucleate ciliate protozoan. At first, it was syncytial in structure, but later on became cellular and achieved bilateral form. It resembled a planula larva. From such a planula-like structure probably arose the coelenterates, the ctenophores and the acael flatworms. From primitive acael flatworms arose other plathyhelminths, aschelminths and nemerteans. Since a trochophore larva appears in the development of annelids and molluscs, it is believed that a trochophore-like animal was the ancestor of both these groups. The trochophore-

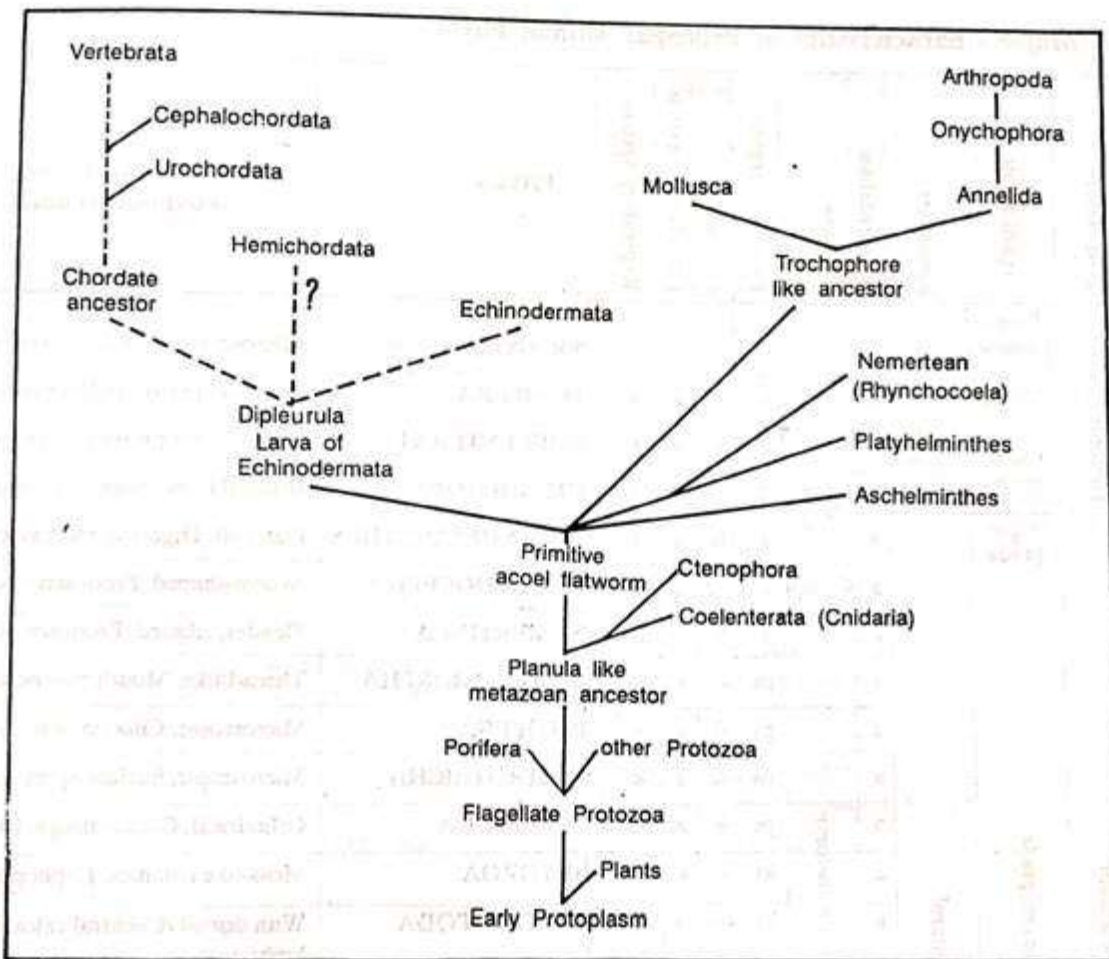


Fig. 3. Hypothetical phylogenetic tree of major animal groups.

like ancestor itself seems to have evolved from the planula-like metazoan ancestor. Further, the Onychophora, which are connecting links between Annelida and Arthropoda, have led us to presume that the arthropods have evolved from annelids.

In the development of the echinoderms, the dipleurula stage is of common occurrence. It establishes the fact that dipleurula-like creature must have been the ancestor of all the echinoderms. Like trochophore, the dipleurula-like ancestor is also considered to be derived from the planula-like ancestor.

The hemichordates and the chordates also have their ancestral links with Dipleurula.

### Major Characteristics of Invertebrates

As mentioned earlier, "Invertebrata" is not a natural group and the animals included do not show a single common character except for the absence of *notochord*. However, the zoologists often find it convenient to combine phyla under a few larger taxonomic units or categories. These are based on major characteristics or patterns because of certain common embryological and anatomical features. **Table 3** shows the major characteristics or patterns which are used in the classification of invertebrates into phyla. The table also shows distinctive features of principal animal phyla.

Table 3. Major Characteristics of Principal Animal Phyla.

Cells	Germ layers	Organization	Symmetry	Segmentation	Digestive tract	Excretory organs	Coelom	Circulatory system	Respiratory system	PHYLA	Distinctive features (exceptions omitted)					
1		Proto-plasmic								PROTOZOA	Microscopic. Single or colonies of like cells.					
Cells many Arranged in layers or tissues (METAZOA)	2. Diploblastic	Cellular		a		a	a	a	a	PORIFERA	Bodywall perforated by pores and canals.					
		Tissue grade	Radial	a	Incomplete without anus	a	a	a	a	COELENTERATA	Nematocysts present. Digestive tract sac like.					
	3. Triploblastic	Organ-system grade	Bilateral	Complete with anus. Protostomic	a		a	fc	a	a	PLATYHELMINTHES	Flat, soft. Digestive tract much branched.				
					a		a	ps	fc	a	a	ACANTHOCEPHALA	Worm-shaped. Proboscis hook-bearing.			
					a		a	fc	+	a		NEMERTINEA	Slender, ciliated. Proboscis soft, eversible.			
					a		ps	a	a	a		NEMATOMORPHA	Thread-like. Mouth may be absent.			
					a		ps	fc	a	a		ROTIFERA	Microscopic. Cilia on oral disc.			
					a		ps	fc	a	a		GASTROTRICHA	Microscopic. Surface spiny. Cilia ventral.			
					a		ps	+	a	a		NEMATODA	Cylindrical. Cuticle tough. Cilia absent.			
					a		lo	a	a	a		BRYOZOA	Moss-like colonies. Lophophore present.			
					a		lo	+	+	a		BRACHIOPODA	With dorsal & ventral calcareous shell and lophopore.			
					a		sc	+	+	+		MOLLUSCA	Soft. External limy shell of 1,2 or 8 parts.			
					+		sc	+	+	+	a	ANNELIDA	Metamerically segmented. Setae present.			
					+		ps	+	a	a		TARDIGRADA	4 Pairs of unjointed legs bearing claws.			
					a		ps	+	+	a		ONYCHOPHORA	Skin soft. Paired nephridia and tracheae present.			
					+		h	+	+	+		ARTHROPODA	Chitinous exoskeleton. Jointed appendages.			
					a		en	+	a	a		CHAETOGNATHA	Arrow-shaped. Transparent. Lateral fins.			
					Bilateral Radial	+	Complete Deuterostomic	en	+	+	+				ECHINODERMATA	5-parted radial symmetry. Tube feet. Spiny endoskeleton
															en	+

a, Absent. +, Present. en, Enterocoelom. fc, Flame cells. h, Haemocoel. lo, Lophophorate coelomata. ps, Pseudocoelom. r, Reduced. sc, Schizocoelom. v, Various or none.

Table 4. Major Groups and Phyla in Animal Classification.

Major Groups of Animals		Phyla	Number of Species	
Kingdom Animalia	Subkingdom I Protozoa.....	• 1. Protozoa	50,000	
	Branch 1. Mesozoa.....	+ 2. Mesozoa	50	
	Branch 2. Parazoa.....	• 3. Porifera (Sponges)	9,000	
	Grade A. Radiata.....	• 4. Coelenterate or Cnidaria	11,000	
	Division 1. Protostomia	(i) Subdivision Acoelomata	+ 5. Ctenophora	100
			• 6. Platyhelminthes (Flatworms)	25,000
			+ 7. Rhyhocoela / Nemertea (Ribbon Worm)	1,200
			+ 8. Acanthocephala	1,500
		(ii) Subdivision Pseudocoelomata	+ 9. Entoprocta	150
			+ 10. Rotifera	2,500
			+ 11. Gastrotricha	450
			+ 12. Kinorhyncha	150
		(iii) Subdivision Lophophorate Coelomata	• 13. Nematoda (Roundworms)	80,000
			+ 14. Nematomorpha	320
			+ 15. Phoronida	20
			+ 16. Ectoprocta	5,000
			+ 17. Brachiopoda	450
			+ 18. Priapula/Priapulida	17
			+ 19. Sipunculida	320
			• 20. Mollusca	80,000
			+ 21. Echiura/Echiurida	140
			• 22. Annelida (Segmented Worms)	15,000
		Division 2. Deuterostomia	+ 23. Tardigrada	750
	+ 24. Onychophora		110	
	+ 25. Arthropoda		11,34,000	
	+ 26. Pentastomida		70	
	+ 27. Chaetognatha		110	
	• 28. Echinodermata		7,000	
	+ 29. Pogonophora		145	
	• 30. Chordata : 49,000; • Hemichordata		120	
	* Urochordata : 1,250; * Cephalochordata		25	
	+ 31. Cyclinophora		3	
	Subdivision Enterocoelous Coelomata	+ 32. Loricifera	21	
		+ 33. Micrognathozoa	1	
		+ 34. Myxozoa	1300	
		+ 35. Orthonectida	20	
		+ 36. Placozoa	1	
		+ 37. Rhombozoa	75	
		+ 38. Xenoturbellida	2	
		+ 39. Onychophora (velvet worms)	110	
+ 40. Cyclinophora		3		

• Shows Major Phyla discussed in detail in this volume.

+ Shows Minor Phyla.

• Treated in second volume on "Vertebrates".

[Note : Approximate numbers of described living species of major metazoan phyla from Brusca and Brusca (1990) and Nielsen (1995), Alfred, J.R.B. (1998) and Wikipedia.org]

### Outline Classification of Invertebrates

Animals have been classified in various ways by different scientists and authors. It mainly depends upon what criteria and qualities the classifier has in mind. Number of phyla recognized by any particular author depends upon the extent, these are put in different classes or recognized as independent phyla. Broadly speaking the

kingdom has been divided the whole animal in to 32 phyla, with 68 classes which are further divided in to 350 orders. The following synoptic classification is based on the works of Hyman, Barnes and Storer with slight modification. Only the major taxonomic categories (subkingdoms, branches, grades, divisions, etc.) and phyla are listed with their diagnostic characters.

### Kingdom Animalia

This is the largest group of the animal classification. It includes the entire fauna (animal population) of the world. It is divided into two subkingdoms ; *Protozoa* and *Metazoa*. Their contrasting features are listed in the following table :

SUBKINGDOM I. PROTOZOA	SUBKINGDOM II. METAZOA
<ol style="list-style-type: none"> <li>1. Microscopic, unicellular animals.</li> <li>2. Structure simple with subcellular organelles.</li> <li>3. Centriole absent.</li> <li>4. Grade of organization protoplasmic.</li> <li>5. Little physiological division of labour.</li> <li>6. Life cycle with more than one generation universal.</li> <li>7. Asexual reproduction universal.</li> <li>8. Sexual reproduction rare.</li> <li>9. Conjugation occurs between adults (hologamy).</li> <li>10. When a cell divides, the daughter cells become separated as independent animals.</li> <li>11. Form of individuals may vary even in the same species.</li> <li>12. Natural death does not take place due to lack of a body, hence often termed immortal.</li> </ol>	<ol style="list-style-type: none"> <li>1. Usually large, multicellular animals.</li> <li>2. Structure complex with strong cellular differentiation.</li> <li>3. Metazoan cells contain centrioles.</li> <li>4. Grades cellular, cell-tissue, and tissue-organ-system.</li> <li>5. Physiological division of labour well marked.</li> <li>6. Life cycle comprising more than one generation is rare.</li> <li>7. Asexual reproduction occurs only in lower Metazoa.</li> <li>8. All reproduce sexually.</li> <li>9. Conjugation occurs between uninucleate sperm and ovum (syngamy).</li> <li>10. Fertilized egg repeatedly divides. Resulting daughter cells remain cohered to form an embryo.</li> <li>11. Form of body is definite for all members of a species.</li> <li>12. Natural death takes place, hence termed mortal.</li> </ol>

#### Subkingdom I. Protozoa

Unicellular, microscopic animals. No tissues.

**Phylum 1. Protozoa** (First animals). Protozoans. About 50,000 species. Solitary or colonial. Cell organelles specialized. Single to many nuclei. Nutrition holozoic, holophytic or saprozoic. Free living, commensal, symbiotic or parasitic. Freshwater, marine or moist terrestrial.

Examples : *Euglena*, *Trypanosoma*, *Amoeba*, *Paramecium*, *Monocystis*, etc.

#### Subkingdom II. Metazoa

Multicellular animals. Cells arranged in layers or tissues. Metazoans are subdivided into three branches: *Mesozoa*, *Parazoa* and *Eumetazoa*. Their contrasting features are given in the following table:

Characters	Branch 1. MESOZOA	Branch 2. PARAZOA	Branch 3. EUMETAZOA
1. Habit	1. Sessile, parasitic.	1. Sessile.	1. Mostly mobile.
2. Tissues	2. Absent. Few cells in 2 layers.	2. Poorly defined tissues.	2. Well defined tissues.
3. Organs	3. Not formed.	3. Not formed.	3. Well formed.
4. Digestive tract and mouth	4. Absent.	4. Absent.	4. Mostly with mouth and digestive tract.
5. Digestion	5. Intracellular.	5. Intracellular.	5. Mostly extracellular.
6. Body surface	6. Not porous.	6. Porous.	6. Not porous.
7. Body cavities	7. Absent.	7. One to many internal	7. Body cavities not lined by choanocytes.
8. Physiological division of labour	8. Not well marked	8. Not well marked.	8. Well marked.



**Branch 1. Mesozoa**

Digestive cells few, external, ciliated. No organs or tissues.

**Phylum 2. Mesozoa** (Middle animals). About 50 species. Worm-like, small, endoparasites of marine invertebrates. Body with an outer single layer of ciliated digestive cells enclosing one or several reproductive cells. Examples : *Dicyema*, *Rhopalura*, etc.

**Branch 2. Parazoa**

Digestive cells many, internal, flagellated. No digestive cavity and mouth. Tissues poorly defined. Organs absent.

**Phylum 3. Porifera** (Pore bearers). Sponges. About 9,000 species. Body usually irregular with numerous pores and water canals, some lined by flagellated collar cells or choanocytes. Skeleton of minute calcareous spicules or of spongin fibres. Solitary or colonial. Sessile. Marine, a few freshwater. Examples : *Leucosolenia*, *Scypha*, *Sycon*, *Euspongia*, etc.

**Branch 3. Eumetazoa**

Many-celled animals with organs, mouth and digestive cavity. Subdivided into two grades : *Radiata* and *Bilateria*. Their contrasting features are given in the following table :

GRADE A. RADIATA	GRADE B. BILATERIA
<ol style="list-style-type: none"> <li>1. Body radially or biradially symmetrical. Sometimes bilateral symmetry which is a secondary adaptation.</li> <li>2. Organ-systems are incipient, i.e., not well marked</li> <li>3. Mesoderm is not developed. Diploblastic.</li> <li>4. Coelomic cavity invariably absent.</li> <li>5. Tentacles with nematocysts. Comb plates in some.</li> <li>6. Principal external opening of digestive cavity is mouth.</li> </ol>	<ol style="list-style-type: none"> <li>1. Body bilaterally symmetrical. Sometimes radial symmetry which is a secondary adaptation.</li> <li>2. Organ-systems well marked.</li> <li>3. Mesoderm is well developed. Triploblastic.</li> <li>4. Coelomic cavity a pseudocoelom or true coelom or absent.</li> <li>5. Tentacles, if present, without nematocysts. No comb plates.</li> <li>6. External openings of digestive cavity are mouth and anus.</li> </ol>

**Grade A. Radiata**

Radially symmetrical, tentaculate, diploblastic animals with few organs. Digestive cavity opens externally through mouth.

**Phylum 4. Coelenterata** (With hollow intestine) or **Cnidaria** (Nettle-bearing). About 10,000 species. Symmetry radial or approaching bilateral. Two or three layers of cells. Mouth encircled by tentacles bearing nematocysts. Sac-like gastrovascular cavity. Sessile or free swimming. Solitary or colonial. Marine or freshwater. Examples : *Hydra*, *Obelia*, *Aurelia*, Corals, etc.

**Phylum 5. Ctenophora** (Comb-bearers). Comb-jellies. About 100 species. Symmetry biradial. 2 tentacles and 8 longitudinal rows of ciliated comb plates for locomotion. No nematocysts. No anus. Free swimming, marine. Examples : *Pleurobrachia*, *Cestum*, *Beroe*, *Ctenoplana*, *Coeloplana*, etc.

**Grade B. Bilateria**

Bilaterally symmetrical triploblastic animals with organ-systems. Digestive tract complete with anus. Mesoderm present. It is subdivided into two divisions: *Protostomia* and *Deuterostomia*. Their contrasting characters are listed in the following table:

DIVISION 1. PROTOSTOMIA	DIVISION 2. DEUTEROSTOMIA
<ol style="list-style-type: none"> <li>1. Mouth arises from blastopore or from the anterior margin of blastopore.</li> <li>2. Coelom absent, pseudocoelom persistent blastocoel or true coelom. Developed as schizocoel by a split of mesoderm.</li> <li>3. Cleavage spiral and determinate.</li> <li>4. Larva trochophore.</li> </ol>	<ol style="list-style-type: none"> <li>1. Mouth arises anteriorly some distance away from blastopore.</li> <li>2. Coelom developed as enterocoel by fusion of gut pouches.</li> <li>3. Cleavage radial and indeterminate.</li> <li>4. Larva tornaria or bipinnaria.</li> </ol>

### Division 1. PROTOSTOMIA

Cleavage spiral and determinate. Mouth arises from or near blastopore. Protostomes are divided by Barnes into 4 subdivisions : (i) *Acoelomata*, (ii) *Pseudocoelomata*, (iii) *Lophophorate coelomata* and (iv) *Schizocoelous coelomata*.

#### Subdivision (i) *Acoelomata*

No body cavity or coelom. Space between body wall and digestive cavity is occupied by mesenchyme parenchyma.

**Phylum 6. Platyhelminthes** (Flatworms). About 20,000 species. Body dorso-ventrally flattened. Digestive tract branched or absent. No anus and circulatory system. Free-living or parasitic. Marine, freshwater, a few terrestrial. Examples : *Planaria*, *Fasciola*, *Taenia*, etc.

**Phylum 7. Rhynchozoela or Nemertinea** (Ribbon worms). About 900 species. Body dorso-ventrally flattened and ciliated. With mouth and anus. Proboscis eversible. Mostly marine, few terrestrial and freshwater. Examples : *Cerebratulus*, *Lineus*, etc.

#### Subdivision (ii) *Pseudocoelomata*

Body cavity a pseudocoelom which is a persistent blastocoel, not lined by mesoderm. Anus present.

**Phylum 8. Acanthocephala** (Spiny-headed worms). About 800 species. Minute worm-like endoparasites. No digestive cavity. Protrusible proboscis with recurved spines.

Examples : *Acanthocephalus*, *Gigantorhynchus*, etc.

**Phylum 9. Entoprocta**. About 150 species. Sessile. Body of calyx and slender stalk. Digestive tube U-shaped. Mouth and anus close together and surrounded by a tentacular crown. Mostly marine. Solitary or colonial. Examples : *Pedicellina*, *Loxosoma*, *Umatella*, etc.

### Superphylum Aschelminthes

Sac worms. An assemblage of pseudocoelomates with an anterior mouth, posterior anus and straight digestive tube. Predominantly aquatic. Free living, epizoic or parasitic. Includes 5 classes (Rotifera, Gastrotricha, Kinorhyncha, Nematoda and Nematomorpha) which are also recognized as phyla.

**Phylum 10. Rotifera** (Wheel animalcules). About 2500 species. Microscopic. Anterior end with a ciliated crown. Pharynx with internal jaws. Mostly freshwater, some marine. Examples : *Philodina*, *Rotatoria*, *Hydatina*, etc.

**Phylum 11. Gastrotricha** (Hairy stomach worms). About 175 species. Microscopic. Ventral surface flattened and ciliated. Cuticle with spines, plates or scales. Freshwater and marine. Examples : *Chaetonotus*, *Macrodasys*, etc.

**Phylum 12. Kinorhyncha** (Jaw-moving worms). About 150 species. Small. Cuticle segmented and with recurved spines. Spiny anterior end or proboscis retractile. Marine. Examples : *Echinoderes*, *Pycnophyes*, etc.

**Phylum 13. Nematoda** (Round worms). About 30,000 species. Body slender and cylindrical. Cuticle tough, often ornamented. Radial or biradial arrangement of structures around mouth. Free-living or parasitic. Freshwater, marine or in soil. Examples: *Ascaris*, *Trichinella*, *Wuchereria*, *Ancylostoma*, *Enterobius*, etc.

**Phylum 14. Nematomorpha or Gordiacea** (Horsehair worms). About 250 species. Body long, thread-like. Larval stage parasitic in insects. Adult free-living in water or damp soil. Examples : *Nectonema*, *Gordius*, etc.

**Subdivision (iii) Lophophorate Coelomata**

Coelom develops as schizocoel or enterocoel. With a crown of hollow tentacles (lophophore) surrounding mouth. Head indistinct. Digestive tract U-shaped.

**Phylum 15. Phoronida.** About 15 species. Worm-like unsegmented body enclosed in a chitinous tube. Lophophore horseshoe-shaped. Marine. Examples : *Phoronis*, *Phoronopsis*.

**Phylum 16. Bryozoa or Ectoprocta** (Moss animals). About 5,000 species. Sessile moss-like colonies. Body enclosed in a gelatinous, chitinous or calcareous covering. Lophophore V-shaped or circular. Mostly marine, few freshwater. Examples : *Plumatella*, *Bugula*, *Pectinatella*, etc.

**Phylum 17. Brachiopoda** (Lamp shells). About 325 species. Body enclosed in two unequal calcareous shell valves. Lophophore W-shaped. Marine. Examples : *Lingula*, *Crania*, *Terebratulina*, etc.

**Subdivision (iv) Schizocoelous Coelomata**

Coelom is a schizocoel which originates as a space by the splitting of the embryonic mesoderm.

**Phylum 18. Priapulida.** 15 species. Sausage or cucumber-shaped marine animals with a swollen anterior introvert or proboscis. Body surface covered with spines and tubercles. Peritoneum of coelom greatly reduced. Examples : *Priapulidus*, *Halicryptus*.

**Phylum 19. Sipunculida** (Peanut worms). About 320 species. Body elongated and cylindrical with retractile anterior end (introvert). Lobes or tentacles around mouth. Anus dorsal. Marine. Examples : *Sipunculus*, *Aspidosiphon*, *Phascolosoma*, etc.

**Phylum 20. Mollusca** (Soft-bodied animals). About 80,000 species. Body soft unsegmented, with ventral muscular foot. Mantle with shell glands. External limy shell of 1, 2 or 8 parts. Terrestrial, freshwater and marine. Examples : Chitons, Snails (*Pila*), Mussels (*Unio*), Squids (*Loligo*), etc.

**Phylum 21. Echiurida** (Adder-tailed worms). About 140 species. Body cylindrical, unsegmented, with anterior retractile proboscis. One pair of large ventral setae below mouth. Marine. Examples: *Echiurus*, *Urechis*, etc.

**Phylum 22. Annelida** (Ringed worms). About 15,000 species. Body elongate, metamerically segmented. Setae for locomotion. Terrestrial, freshwater and marine. Examples : Earthworms (*Pheretima*), *Nereis*, Leech (*Hirudinaria*), etc.

**Phylum 23. Tardigrada** (Water bearers). About 750 species. Minute. Body segmented with 4 pairs of unsegmented legs terminating in claws. Freshwater, terrestrial and marine. Examples : *Echiniscus*, *Hypsibius*, etc.

**Phylum 24. Onychophora** (Claw-bearers). About 110 species. Worm-like unsegmented body covered by thin cuticle. A pair of anterior antennae. Many pairs of short stumpy legs ending in claws. Moist soil. Examples : *Peripatus*, *Peripatopsis*.

**Phylum 25. Arthropoda** (Joint-footed animals). About 1,111,34,000 species. Body segmented with jointed appendages. Exoskeleton chitinous. Coelom vestigial. Body cavity haemocoel. Terrestrial, freshwater and marine. Examples : Prawns, Scorpions, Flies, Centipedes, etc.

**Phylum 26. Pentastomida** (Tongue worms). About 70 species. Worm-like unsegmented body with two anterior appendages terminating in claws. Blood-sucking endoparasites of vertebrates. Examples : *Cephalobaena*, *Porocephalus*.

**Division 2. DEUTEROSTOMIA**

Cleavage radial and indeterminate. Mouth arises some distance away from blastopore.

**Subdivision. Enterocoelous Coelomata**

Coelom is an enterocoel which originates as pouches of embryonic gut (archenteron).

- Phylum 27. Chaetognatha** (Arrow worms). About 110 species. Small elongated transparent body bearing postanal tail and lateral fins. Anterior end with grasping spines. Planktonic and marine.  
Examples: *Sagitta*, *Spadella*, etc.
- Phylum 28. Echinodermata** (Spiny-skinned animals). About 7,000 species. Secondarily pentamerous radial symmetry. Calcareous endoskeleton of plates bearing external spines. A part of coelom as water vascular canals. Locomotion by tube feet. Examples: Starfish, Brittle stars, Sea urchins, Sea lilies, etc.
- Phylum 29. Pogonophora** (Beard worms). About 145 species. Body long, enclosed in a chitinous tube. Anterior end with one to many tentacles. No digestive tract. Deep water and marine.  
Examples: *Siboglinum*, *Spirobrachina*, *Polybrachia*, etc.
- Phylum 30. Hemichordata** (Acorn worms). About 120 species. Body worm-like divided into proboscis, collar and trunk. With gill slits. Embryo lacking a typical notochord. Marine.  
Examples: Acorn worms (*Balanoglossus*), *Cephalodiscus*, etc.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. What is an invertebrate? On what basis the animals have been classified as invertebrates and vertebrates?
2. Give a historical account of assigning the invertebrate animals to various taxonomic phyla. Name the present invertebrate phyla mentioning the approximate number of species contained by them.
3. Elucidate the concept of major and minor phyla. Which phyla of invertebrates are treated as major phyla and why?
4. Give the main points of differences between invertebrates and vertebrates.
5. Outline the phylogenetic account of the invertebrates.
6. Give an outline classification of animals enumerating characteristic features of different phyla.
7. Distinguish between – (i) Protozoa and Metazoa. (ii) Coelomata and Acoelomata. (iii) Radiata and Bilateria. (iv) Protostomes and Deuterostomes.

#### » Short Answer Type Questions

1. Give four important characters of phylum Protozoa. On which characters classification of Protozoa is based?
2. Write names of two invertebrate animals found near your house. Classify then upto orders.
3. Classify these animals –  
(i) mosquito, (ii) liver fluke, (iii) leech.
4. Give natural habitat of –  
(i) *Entamoeba* (ii) *Hydra* (iii) *Ascaris* (iv) *Plasmodium*.
5. Give characteristics of phylum Arthropoda. Give four examples of this group.
6. Classify any two animals upto class –  
(i) tapeworm (ii) Star fish, (iii) Locust,  
(iv) Earthworm, (v) Honey bee.
7. Give two important characteristics of each –  
(i) sponge, (ii) *Hydra*.
8. Classify these animals upto class giving one character of each –  
(i) *Octopus*, (ii) grass hopper,  
(iii) *Hyla*, (iv) *Nereis*.

#### » Very Short Answer Type Questions

1. Differentiate between jelly fish and starfish.

#### » Multiple Choice Questions

1. Organellae of defence in *Paramecium* are :  
(a) nematocyst (b) oocyst  
(c) sporocyst (d) trichocyst  
Moultling is not found in the development of :  
(a) polychaete (b) snake  
(c) insect (d) all of them  
Which animal would not survive, if there were no ponds of water :  
(a) *Fasciola* (b) *Ascaris* (c) *Entamoeba* (d) *Taenia*
4. Which group includes all marine animals :  
(a) Mollusca (b) Porifera  
(c) Echinodermata (d) Coelenterata
5. Which of the following has no alternative host :  
(a) *Ascaris* (b) *Plasmodium*  
(c) tapeworm (d) *Periplaneta*
6. Platyhelminthes are generally called :  
(a) round worms (b) flat worms  
(c) tubiculous worms (d) blind worms

7. Which structure is found in male cockroach but is absent in female :  
(a) anal cerci (b) anal style  
(c) antennae (d) gonapophyses
8. Myriapod has :  
(a) chitinous exoskeleton, ventral nerve cord, three pair of antennae  
(b) chitinous exoskeleton, ventral nerve cord, many body segments, one pair of antennae  
(c) soft body, ventral nerve cord, many body segments, two pair of antennae  
(d) chitinous exoskeleton, dorsal nerve cord, three body segments, one pair of antennae
9. Which is an annelid :  
(a) ant (b) crab (c) *Nereis* (d) *Octopus*
10. Chitinous exoskeleton is found in :  
(a) birds (b) turtle (c) insects (d) fishes
11. Corals are formed by :  
(a) Molluscs (b) Coelenterates  
(c) Protozoans (d) Echinoderms
12. Primary host in the life history of *Fasciola* :  
(a) pig (b) sheep (c) man (d) snail
13. Medusae are found in the life history of :  
(a) *Obelia* (b) *Hydra*  
(c) star fish (d) none of them
14. Conjugation in *Paramecium* is for :  
(a) binary division (b) sexual reproduction  
(c) asexual reproduction (d) metamorphosis
15. Larva is not found in the life history of :  
(a) *Ascaris* (b) *Taenia* (c) frog (d) *Pheretima*
16. Alimentary canal is not found in :  
(a) Arachnida (b) Apoda (c) Gastropoda (d) Cestoda
17. Active movement is not found in *Taenia* because :  
(a) body is segmented  
(b) hooks and suckers, are found  
(c) it is parasite  
(d) alimentary canal is absent
18. Sessile (attached) animals are marine because :  
(a) for protection from terrestrial animals  
(b) protection against bacteria  
(c) they can produce water current to obtain food and oxygen  
(d) can enjoy water life
19. Disease filariasis is caused by :  
(a) *Fasciola* (b) *Wuchereria* (c) *Taenia* (d) *Ascaris*
20. The light blue colour of blood in arthropods may be due to :  
(a) haemopoitin (b) haemoglobin  
(c) haemocyanin (d) none
21. Secondary host of tapeworm is :  
(a) cat (b) man (c) horse (d) pig
22. Why *Amoeba* has been kept in protozoa :  
(a) due to contractile vacuole  
(b) because of nutrition being insectivorous  
(c) cell wall  
(d) acellular body
23. Tapeworms do not have alimentary canal because they get food from :  
(a) suckers (b) mouth  
(c) body surface (d) all of them
24. *Palaemon* belongs to which phylum :  
(a) Crustacea (b) Insecta (c) Arthropoda (d) Mollusca
25. Which is not an insect :  
(a) mosquito (b) spider (c) housefly (d) bedbug
26. Ovo testis is found in :  
(a) snail (b) housefly (c) cockroach (d) prawn
27. Which of the following is colonial insect :  
(a) mosquito (b) locust (c) bed bug (d) termites
28. The desert locust would be living in isolation or near locality will depend upon :  
(a) its species (b) its kind  
(c) its genes (d) its food and climatic conditions
29. Common character of mosquito, rat flea, bedbug and leech is :  
(a) all have nephridia  
(b) saliva contains anticoagulant  
(c) lay eggs in stagnant water  
(d) all are insects
30. Body is unsegmental in :  
(a) earthworm (b) glow-worm and scorpion  
(c) *Ascaris* and hook-worm (d) tape-worm
31. Ecdysis is not found in :  
(a) insect (b) polychatete (c) snake (d) all
32. Turbellarians are :  
(a) independent round-worms  
(b) independent flat-worms  
(c) parasitic tape worms  
(d) parasitic-worms
33. *Sepia* and *Octopus* are two common marine animals. They show active movement in water by :  
(a) movement of oral arms  
(b) jet of water propelled through siphon  
(c) attachment with other animals through its suckers  
(d) undulating movement of lateral fins
34. Skin is covered in Arthropoda with :  
(a) mucous (b) chitinous cuticle  
(c) unstriated muscles  
(d) shell formed of calcium
35. The blood in the body of insects :  
(a) flows in open circulation  
(b) contains haemoglobin in erythrocytes  
(c) flows in arteries and veins  
(d) resembles human beings in colour
36. Mesogloea is found in which group of animals :  
(a) Porifera (b) Coelenterata  
(c) Hydrozoa (d) Annelida
37. Which animal has fixed number of legs :  
(a) *Hydra* (b) ant (c) *Amoeba* (d) earthworm
38. Class in which the animals have 3 pair of jointed legs:  
(a) Arthropoda (b) Crustacea  
(c) Insecta (d) Gastropoda

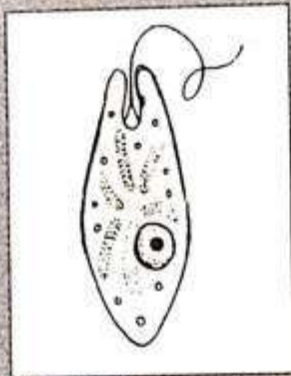
39. Which phylum has highest number of species :  
 (a) Protozoa (b) Metazoa  
 (c) Arthropoda (d) Insecta
40. Respiratory pigment in insects :  
 (a) haemoglobin (b) cytochrome  
 (c) haemocyanin (d) none
41. All worms are :  
 (a) radially symmetrical (b) asymmetrical  
 (c) triploblastic (d) diploblastic
42. Wasp, gilamonster, centepede, scorpion and honey bee are :  
 (a) terrestrial (b) viviparous  
 (c) social (d) poisonous
43. Main characteristic of Arthropoda :  
 (a) chitinous exoskeleton, external segmentation, jointed legs  
 (b) external segmentation, hair, 3 pairs of jointed legs  
 (c) external skeletal scales, segmentation, one pair antennae  
 (d) external segmentation, one pair chelicerae, one pair pedipalpi.
44. Filaria pathogen is a :  
 (a) bacterium (b) mosquito  
 (c) Protozoan (d) Helminth
45. Protozoan considered link between plants and animals :  
 (a) *Paramecium* (b) *Amoeba*  
 (c) *Euglena* (d) *Plasmodium*
46. Glow worm is a :  
 (a) Mollusc (b) Annelid  
 (c) insect (d) Helminth
47. Bladder worm stage found in the development of :  
 (a) liver fluke (b) planaria  
 (c) thread worm (d) tapeworm
48. Which is a coelenterate :  
 (a) sea cucumber (b) sea cow  
 (c) sea anemone (d) sea horse
49. Character of sporozoa :  
 (a) aquatic life (b) holophytic nutrition  
 (c) spore formation (d) holozoic nutrition
50. Metazoa includes :  
 (a) Sporozoa (b) Sarcodina (c) Cnidaria (d) Protista
51. Pearl oyster belongs to :  
 (a) Gastropoda (b) Cephalopoda  
 (c) Scaphopoda (d) Pelecypoda
52. Match the species of the same phylum :  
 (a) scorpion, spider  
 (b) scorpion, *Obelia*, *Hydra*  
 (c) cockroach, earthworm, *Taenia solium*  
 (d) starfish, *Obelia*, *Hydra*
53. In starfish which has dual function of locomotion and respiration :  
 (a) axial sinus (b) ampullae  
 (c) tube feet (d) tiedmann's body
54. Classification of phylum Porifera is based on :  
 (a) canal system (b) spicules  
 (c) shape of choanocytes (d) ascocytes
55. Aristotle's lantern is found in :  
 (a) starfish (b) brittle star  
 (c) sea urchin (d) sea anemone
56. Collar cells are characteristic of :  
 (a) earthworms (b) roundworms  
 (c) Coelenterata (d) sponges
57. Which set of animals have larva in embryonic development :  
 (a) lizard, frog, cockroach (b) *Ascaris*, frog, housefly  
 (c) mosquito, earthworm, housefly  
 (d) honey bee, mosquito, *Hydra*
58. What is common between earthworm, leech and centipede :  
 (a) they have malpighian tubules  
 (b) they are hermaphrodite  
 (c) they have vertral nerve cord (d) they have no legs
59. Transfer of wild type *Escherischia coli* from medium of normal glucose to lactose involves which change :  
 (a) it stops dividing (b) lac operon is repressed  
 (c) lac operon is induced  
 (d) all operons are induced
60. Mollusca-gastropoda is as :  
 (a) Arthropoda-Arachnida (b) Chordata-Mammalia  
 (c) both (a) and (b) (d) none of these
61. Class Cephalopoda includes animals which have :  
 (a) head located on foot  
 (b) notochord extends upto head  
 (c) foot located on head  
 (d) head fused with thorax
62. Silk is obtained from :  
 (a) *Lacifer lacca* (b) *Nosema bombycis*  
 (c) *Bombyx mori* (d) none of them
63. Osculum is related with :  
 (a) starfish (b) *Hydra* (c) silverfish (d) sponge
64. Class bivalvia is characterised by :  
 (a) coiled shell (b) absence of head  
 (c) absence of gills  
 (d) presence of tentacles around mouth
65. Useful insect which no longer exists in wild form is :  
 (a) *Musca domestica* (b) *Bombyx mori*  
 (c) *Lacifer lacca* (d) *Drosophila melanogaster*
66. Which is common to different types of canal system in sponges :  
 (a) apopyle (b) prosopyle  
 (c) radial canal (d) paragastric cavity
67. Term metagenesis is related to :  
 (a) asexual reproduction (b) polymorphism  
 (c) alternation of generation in *Obelia*  
 (d) sexual reproduction in *Paramecium*
68. Swarming generally occurs in :  
 (a) pyrilla (b) mosquito (c) house fly (d) locust
69. An anthozoan animal is :  
 (a) *Fungia* (b) *Sertularia* (c) *Dugesia* (d) *Aurelia*
70. Cell tissue grade of organization occurs in :  
 (a) Platyhelminthes (b) sponges  
 (c) Protozoa (d) Coelenterata

- 71. Shell of molluscs is derived from :  
(a) foot (b) mantle (c) ctenidia (d) placoid
- 72. Ephyra larva belongs to :  
(a) physalia (b) aurelia (c) obelia (d) sea anemone

- 73. Turkish bath sponge is :  
(a) *Cliona* (b) *Hyalonema*  
(c) *Euspongia officinalis*  
(d) *Euplectella*

**Answers**

1. (d) 2. (a) 3. (a) 4. (c) 5. (a) 6. (b) 7. (b) 8. (b) 9. (c) 10. (c) 11. (b) 12. (b) 13. (a) 14. (b) 15. (d) 16. (d) 17. (c) 18. (c) 19. (b) 20. (c) 21. (d) 22. (d) 23. (c) 24. (c) 25. (b) 26. (a) 27. (d) 28. (c) 29. (b) 30. (c) 31. (b) 32. (b) 33. (b) 34. (b) 35. (a) 36. (b) 37. (b) 38. (c) 39. (c) 40. (d) 41. (c) 42. (d) 43. (a) 44. (d) 45. (c) 46. (c) 47. (d) 48. (c) 49. (c) 50. (c) 51. (d) 52. (a) 53. (c) 54. (b) 55. (c) 56. (d) 57. (b) 58. (c) 59. (c) 60. (c) 61. (c) 62. (c) 63. (d) 64. (b) 65. (b) 66. (d) 67. (c) 68. (d) 69. (a) 70. (d) 71. (b) 72. (b) 73. (c).



# 3

## Chapter

## *Euglena viridis*

There are a large number of small protozoans which move with the help of one or more whip-like structures, called *flagella*. All these unicellular organisms are included in the superclass *Mastigophora* (Gr., *mastix*, whip + *pherein*, to bear) or *Flagellata* (L., *flagrum*, a whip). The flagellates are either *plant-like* typically having chlorophyll-bearing plastids, the *chloroplasts* or *chromatophores*; or *animal-like*, with no such plastids. The former are *autotrophic* due to their capacity to synthesize organic food by photosynthesis, whereas the latter are *heterotrophic* as they utilize pre-synthesized food of their environments. These two groups of flagellates belong to two separate classes : *Phytoflagellata* or *Phytomastigophorea* and *Zooflagellata* or *Zoomastigophorea*, respectively.

*Euglena* is a typical example of *Mastigophora*. It is a *phytoflagellate* as it possesses both

chloroplasts as well as flagella. It is autotrophic in sunlight, but becomes heterotrophic in dark. Because of its two-fold nutritional abilities, it is usually studied as a plant as well as an animal. This plant-animal organism is important as it serves as a key organism in research on photosynthesis, chloroplast structure, photoreception and flagellar activity. The species of *Euglena* which is commonly used for classroom study is *Euglena viridis*.

### *Euglena viridis*

As the name implies, *Euglena viridis* is a green organism with an eye-like photoreceptive structure (Gr., *eu*, true + *glene*, eyeball or eye pupil + L., *viridis*, green).



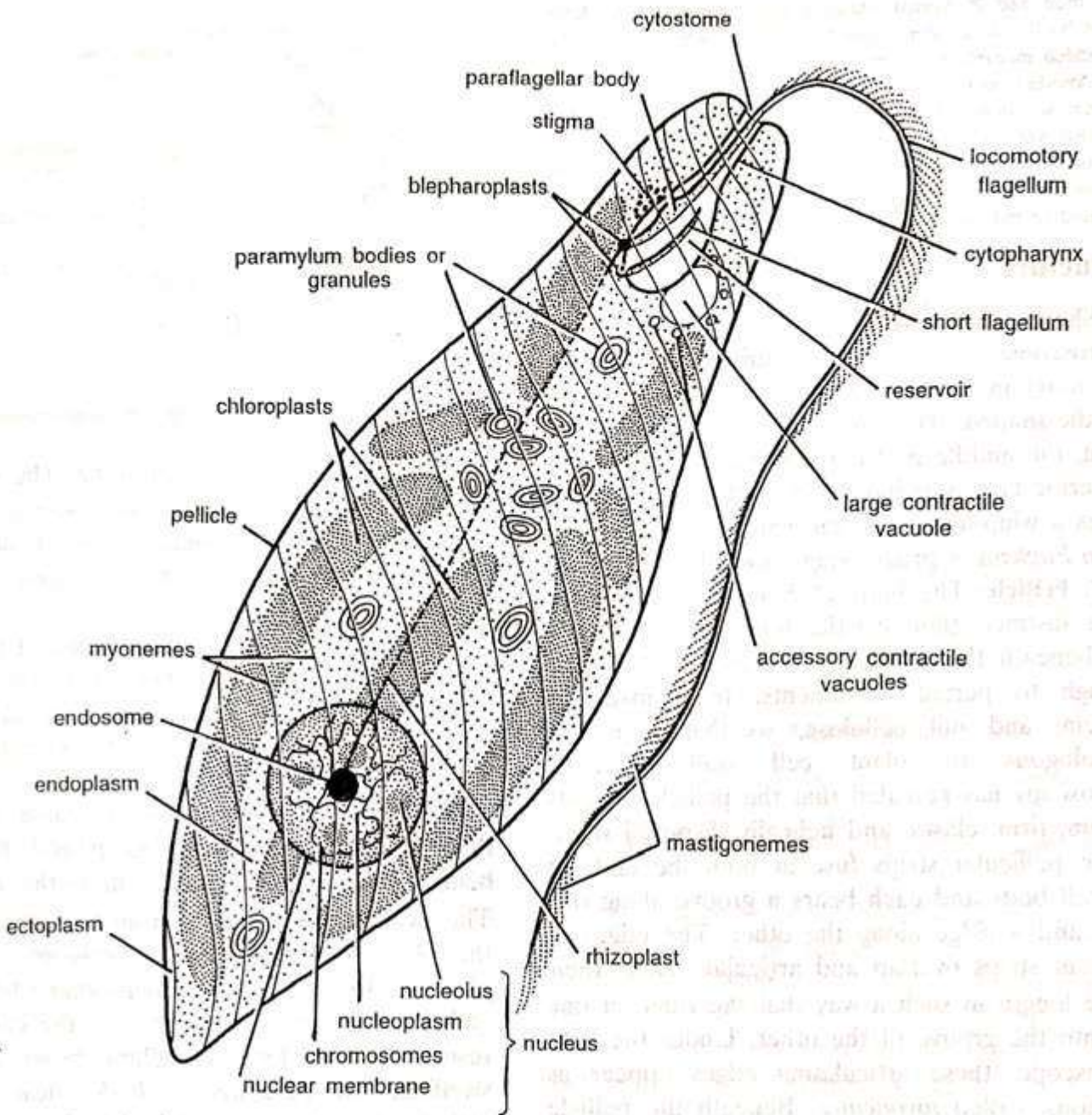


Fig. 1. *Euglena viridis*.

### Systematic Position

Phylum	Protozoa
Subphylum	Sarcomastigophora
Superclass	Mastigophora
Class	Phytomastigophorea
Order	Euglenida
Genus	<i>Euglena</i>
Species	<i>viridis</i>

### Habits and Habitat

*Euglena viridis* is a solitary and free-living freshwater flagellate. It occurs in freshwater ponds, pools, ditches and slowly-running streams, where there is a considerable amount of

vegetation. It is fairly active and often found at various depths below the surface of water. Ponds in well-maintained gardens, containing decaying nitrogenous organic matter, such as faeces of animals, leaves, twigs, etc., are good sources of this organism. Sometimes it is so abundant that the water appears green in colour and it seems as if a film of scum is present on the pond surface.

### Culture of *Euglena*

*Euglena* can be cultured and studied easily in the laboratory. An easy way to prepare a culture is to fill clean and wide-mouthed large bottles with boiled tap or pond water

and then add 20 boiled wheat grains to each bottle. Keep these bottles in a sunny place for a week. Wheat grains may be added monthly to maintain the culture.

Another method is to prepare a culture of *Euglena* in manure solutions. Horse or cow manure is boiled in pond or distilled water. These manure solutions are allowed to stand 36 to 48 hours and then inoculated with euglenae. In the laboratory, the euglenae grow and multiply well in a jar exposed to indirect sunlight.

## Structure

**1. Shape and size.** *E. viridis* is a small microscopic organism measuring about  $60\mu$  (microns) in length. The body is elongated and spindle-shaped. The anterior end is rounded or blunt, the middle part is somewhat wider and the posterior end is pointed. From the anterior end arises a whip-like flagellum which is seen moving when *Euglena* is progressing forward.

**2. Pellicle.** The body of *Euglena* is enveloped by a distinct, thin, elastic, tough *pellicle* which lies beneath the plasma membrane. It is flexible enough to permit movements. It is made of protein, and not cellulose, so that it is not homologous to plant cell wall. Electron microscopy has revealed that the pellicle consists of thin, firm, elastic and helically disposed *strips*. These pellicular strips fuse at both the ends of the cell body and each bears a groove along one edge and a ridge along the other. The edges of adjacent strips overlap and articulate along their entire length in such a way that the ridge of one fits into the groove of the other. Under the light microscope, these articulating edges appear as striations, called *myonemes*. Beneath the pellicle are present a row of mucus-secreting *muciferous bodies* and bundles of *microtubules*.

**3. Cytoplasm.** The pellicle encloses the cytoplasm which is divisible into two zones:

(a) *Ectoplasm.* It is the clear dense narrow peripheral zone containing microtubules and muciferous bodies.

(b) *Endoplasm.* It is the more fluid-like granular central zone containing the nucleus and several types of inclusions.

**4. Reservoir.** At the blunt anterior end of the body, there is an invagination forming a permanent flask-shaped cavity. It consists of a wide *reservoir* or *flagellar sac* which leads through a short tubular canal, the *cell gullet* or *cytopharynx*, to outside. Its external opening is

(Z-1)

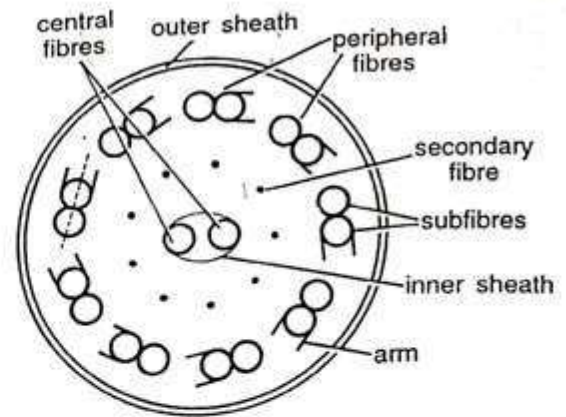


Fig. 2. *Euglena*. T.S. flagellum (diagrammatic).

called the *cell mouth* or *cytostome*. The reservoir is lined by plasma membrane without pellicle beneath it. The names "cytostome" and "cytopharynx" are misnomer because *Euglena* does not ingest solid food.

**5. Flagellum.** At the anterior end of the body, a single thread-like flagellum arises through the cytostome. Typically it is made of an axial elastic filament or *axoneme*, covered by a protoplasmic sheath.

Electron microscopy has revealed that the flagellum is not just one but paired, the other being smaller and confined within the reservoir. The two flagella originate from two tiny granules, the *blepharoplasts* (Gr., *blepharon*, eyelid + *plastos*, formed) or *kinetosomes* which lie embedded in the cytoplasm near the base of the reservoir. The long flagellum bears a lateral swelling, the *paraflagellar body*, near its base within the reservoir. This body acts as a photoreceptor and probably contains *lactoflavin* as sensitizer.

Each flagellum consists of 2 *central* and 9 *peripheral fibres*. The central fibres are enclosed in an inner membranous sheath. Each central fibre is single, whereas the peripheral fibres are paired, that is, each made of two *sub-fibres*. Of each peripheral fibre, one of the two sub-fibres bears a double row of short projections, or *arms*, all pointing in the same direction. The whole flagellum is enveloped by an outer sheath which is continuous with the plasma membrane. In the space between the peripheral and central fibres lie 9 *secondary fibres* which are somewhat inconspicuous. Alongside the bundle of fibrils runs a rod-like structure. On the long axis of the flagellum is found a unilateral row of hair-like contractile processes, called *mastigonemes*. According to the investigation of Manton (1959), these processes arise laterally from two of the nine peripheral fibres. This type of flagellum is known as *stichonematic*.

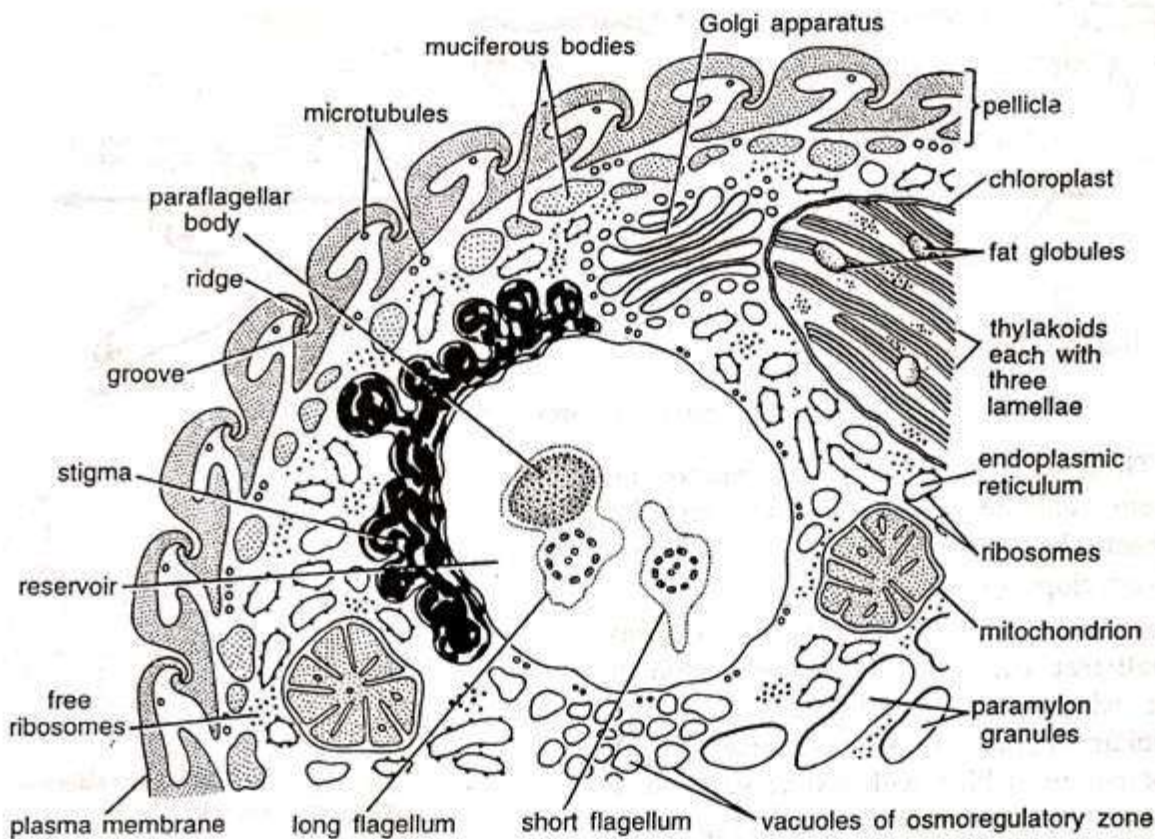


Fig. 3. *Euglena*. An electron micrograph (diagrammatic) of a portion of the T.S. body, passing through the reservoir.

**6. Nucleus.** A single, large, spherical or oval, vesicular nucleus lies near the centre of endoplasm, usually towards the posterior end of the body. It contains a large solid central body or nucleolus of chromatin, called *endosome* or *karyosome*. Its function remains controversial. The nuclear membrane is a double membrane which is perforated by pores. According to electron microscope, the nucleoplasm contains several nucleoli and a large number of granular and thread-like chromosomes.

**7. Contractile apparatus.** Associated with the reservoir occurs a dense osmoregulatory zone. It includes a large central contractile vacuole. It is surrounded by several smaller accessory vacuoles, which probably fuse together to form the larger vacuole. These vacuoles play a role in the discharge of water along with some waste products of metabolism to outside, via the reservoir, cytopharynx and cytostome.

**8. Stigma.** Lying near the reservoir, on side opposite to that of contractile vacuole, is a discoid or shallow cup-shaped red pigment spot, the *eye-spot* or *stigma*. According to Leedale (1966), the stigma is composed of a plate of lipid

droplets, each charged with a red pigment, the *carotenoid*.

The stigma and the paraflagellar body together form a photoreceptor apparatus. When *Euglena* is moving toward light, the receptor is illuminated. When it changes direction, the shadow of pigment falls on the receptor. Thus, the animal, which depends upon sunlight for photosynthesis, can orient itself towards light.

**9. Endoplasmic inclusions.** Besides contractile apparatus and stigma, the endoplasm has other important inclusions which are as follows :

(a) **Chromatophores or chloroplasts.** Suspended in cytoplasm are a number of green bodies, the *chromatophores* or *chloroplasts*, they give the *Euglena* its green colour because they contain the green pigments, chlorophyll a and b, along with  $\beta$ -carotene. Chloroplasts of *E. viridis* are slender and radiate from a central point so as to form a star-shaped grouping. In the centre of each chloroplast is a single proteinaceous *pyrenoid*, which is probably the centre for the formation of a starch-like substance, called *paramylum*.

A chloroplast contains groups of chlorophyll-bearing lamellae or *thylakoids*, each with three

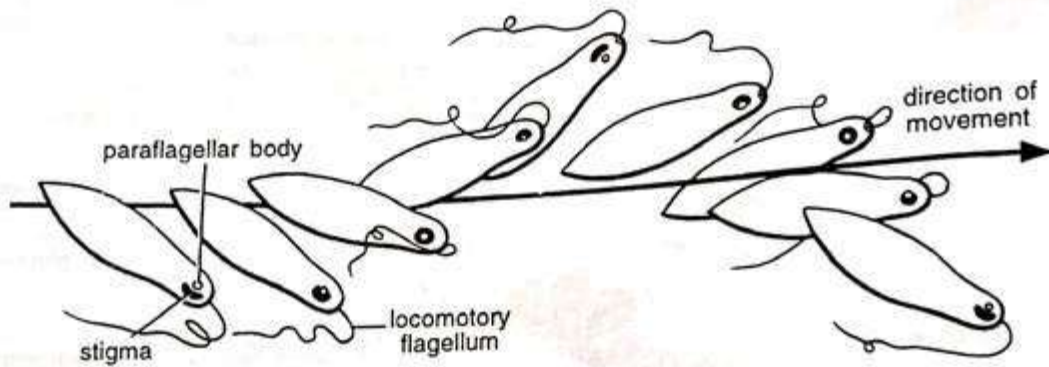


Fig. 4. *Euglena*. Successive stages in the flagellar movement.

lamellae. These are placed in the *matrix* or *stroma*, also containing ribosomes and fat globules. Each chloroplast is bounded by a triple membrane envelope (Sleigh, 1973).

(b) *Paramylon*. The endoplasm contains several small free oval granules of paramylon or paramylum which is a polysaccharide ( $\beta$ -1, 3 glucan) similar to starch but not identical with it, as it is not coloured blue with iodine solution. It is produced by photosynthesis and represents reserve food material.

(c) *Other cytoplasmic structures*. The cytoplasm contains other subcellular organelles as well. The *Golgi bodies* are piles of large flattened sacs with minute vesicles pinching off from them. The *endoplasmic reticulum* is in the form of small interconnecting tubules and vesicles. The *mitochondria* are with tubular cristae and are more in number near the reservoir. The *ribosomes* occur scattered freely in the endoplasm and also on the endoplasmic reticulum and in the chloroplasts.

## Locomotion

*Euglena viridis* performs two different kinds of movements: (1) *flagellar*, and (2) *euglenoid*.

1. **Flagellar movement.** *Euglena* swims freely in water with the help of a single, long locomotory flagellum. During swimming, the flagellum is directed obliquely backward towards the side bearing the stigma. It undergoes spiral undulations, with waves, that are transmitted from the base to the tip, causing its beating or the sideways lashing. The flagellum beats, on an average, at the rate of 12 beats per second. The beating of flagellum drives water backward and induces the whole body to move forward. Each

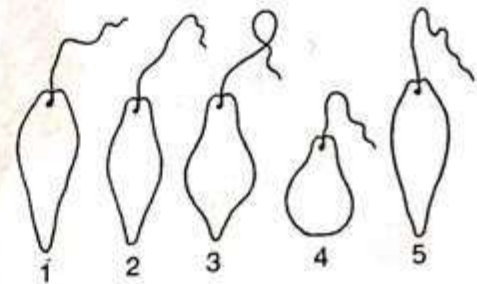


Fig. 5. *Euglena*. Successive stages in euglenoid movement.

beat not only throws the body forward but also to one side. Thus, when the beats are repeated over and over, the *Euglena* revolves in circles or *gyrates*. As the flagellum is directed obliquely backward to the long axis of the body, the organism also *rotates* on its axis. It has been calculated that *Euglena* rotates at the rate of one turn per second.

Movement of a flagellum involves contraction of its nine peripheral fibres (Fig. 2). Their position is ideal for the undulating actions as they could exert bending around the flagellar axis. The energy for the contractile action of fibres is supplied by ATP (adenosine triphosphate) formed in the mitochondria, which are included in the blepharoplasts. The function of mastigonemes, present on the flagellum of *Euglena*, is not yet known.

2. **Euglenoid movement.** The pellicle possesses considerable flexibility that enables *Euglena* to perform peristaltic activity. This activity brings about worm-like wriggings or writhing movements while the animal creeps on the bottom. As the peristaltic waves pass, the body becomes shorter and wider first at the anterior end, then in the middle and later at the posterior end. This characteristic movement, found in *Euglena* or some other Protozoa, is commonly known as the *euglenoid* or *metabolic movement*.

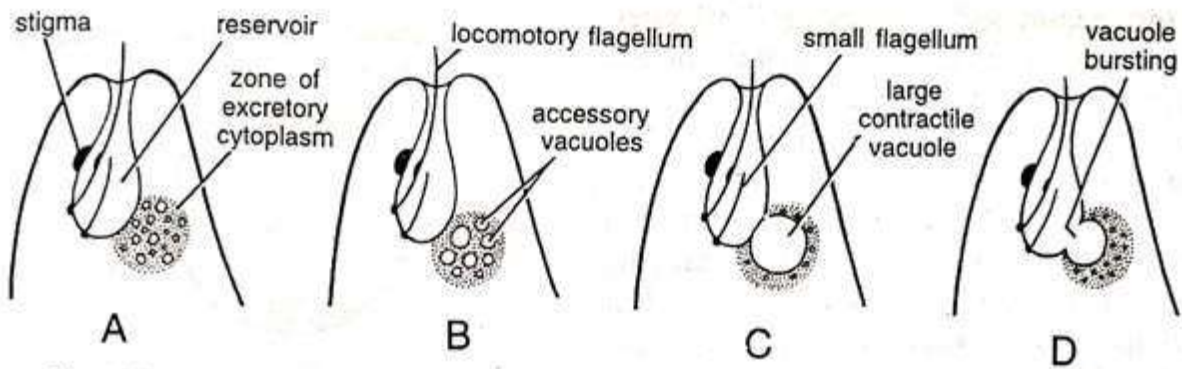


Fig. 6. *Euglena*. Successive stages of diastole and systole of contractile vacuole during excretion and osmo-regulation.

During the euglenoid movement, the adjacent pellicular strips bend and move against one another, probably the ridge of one sliding in groove of the other. The sliding of the ridges in the grooves is lubricated by the secretion of underlying muciferous bodies.

## Nutrition

In *E. viridis*, nutrition is *autotrophic* or *holophytic* as well as *saprophytic*. Such a dual mode of nutrition is frequently referred to as *mixotrophic*. There is no evidence of animal-like or *holozoic* nutrition in *Euglena*.

**1. Holophytic or autotrophic nutrition.** The chief mode of nutrition in *Euglena* is *holophytic* or *autotrophic*. That is, like green plants, it can manufacture its own food, in the presence of sunlight, by the process of *photosynthesis* with the aid of the chlorophyll present in the chloroplasts. The chlorophyll absorbs energy from sunlight. With this energy water reacts with  $\text{CO}_2$  in a series of steps forming a hexose sugar. This is then transferred into a kind of polysaccharide, called *paramylum* or *paramylon*. It differs from the true starch in that it does not become blue with iodine solution. It is stored up for future use either scattered in the form of refractile granules in the endoplasm, or deposited around one or more proteinaceous bodies, the *pyrenoids*. Paramylon is found more abundantly in well-fed individuals.

**2. Saprophytic or saprozoic nutrition.** In prolonged darkness, *Euglena* loses its chlorophyll and green colour. It becomes *etiolated*, that is, becomes pale or white, yet it continues to live and perform all the life activities. In the absence of sunlight, *Euglena* lives by the *saprophytic* or

*saprozoic* method, which means the products of decaying organic substances dissolved in surrounding water are absorbed through its general body surface. It seems that *Euglena* secretes digestive enzymes that are typically animal-like in nature.

Generally, the chloroplasts lost in dark are regained in the light. But in *E. gracilis*, the change is permanent; the lost chloroplasts can never be recovered.

*Pinocytosis* has also been observed to take place at the base of the reservoir for the intake of proteins and other large molecules.

## Respiration

*Euglena* respire with the help of free oxygen dissolved in water, which diffuses in through the pellicle. This oxygen brings about oxidation reactions catalysed by enzymes present in the mitochondria. The energy so liberated is entrapped in the high energy phosphate bonds of ATP, which supplies energy for metabolic activities. As a result of oxidation reactions, water and  $\text{CO}_2$  are formed as by-products. In sunlight, it is likely that this  $\text{CO}_2$  is utilized for photosynthesis, but in dark it is liberated to outside by diffusion through the general body surface.

## Osmo-regulation and Excretion

The osmo-regulatory function, that is, the removal of excessive water entering into the body by endosmosis, is performed by an anteriorly placed *contractile apparatus*. Outer pellicle is permeable to surrounding water, which continues to enter into *euglena's* body by endosmosis which is the result of differential concentrations

of body protoplasm and surrounding freshwater. In *E. viridis*, the contractile apparatus consists of a large contractile vacuole surrounded by numerous small accessory vacuoles. The cytoplasm secretes the excessive water into these smaller vacuoles which, in their turn, drain into the larger vacuole. It is also likely that the accessory vacuoles are first formed which when fully extended, fuse together forming the larger vacuole. The larger vacuole finally empties into the reservoir. The process involves the *diastole* (increase in volume), and *systole* (decrease in volume) of the large contractile vacuole. In diastole, the contractile vacuole is filled with water, while in systole it is emptied to throw its watery content into the reservoir. It is believed that the postero-lateral wall of the contractile vacuole, adjacent to the reservoir, is very unstable and it bursts at the systole.

Ammonia, the nitrogenous waste product, resulting from catabolism, passes out by diffusion through the general surface of the body. Excretory substances may also be emptied by the contractile vacuole into the reservoir. It has been suggested that the dense zone of cytoplasm around the contractile apparatus is both *osmoregulatory* and *excretory* in function. It secretes water as well as excretory products into the lumen of the vacuole.

## Behaviour

*Euglena* reacts to a variety of stimuli in the same manner as other Protozoa do.

**1. Reaction to light.** It avoids strong lights as well as shady areas, but reacts positively to a moderately intense light such as that from a window. Like most motile and free-living unicellular organisms containing chlorophyll, it orients itself parallel to a beam of ordinary light and swims towards the source of illumination. In a dish containing culture, most of the individuals are found to aggregate on the side towards the light. If the dish is placed in direct sunlight and one half of it is covered, the animals avoid the region of direct sunlight as well as the shade but gather in between the two in a small band.

**2. Shock reaction.** Investigations of Mast and his pupils have clearly revealed the part played by the photoreceptive stigma in the orientation of

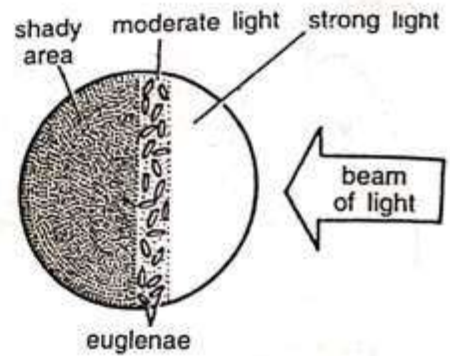


Fig. 7. *Euglena* showing reaction to light.

*Euglena*. Being positively phototactic, *Euglena* swims towards the source of light. It adopts a spiral course, rotating and gyrating around its body axis so that the paraflagellar body remains continuously exposed to light and uniformly illuminated. However, if the front source of light is screened and a new lateral beam of light is thrown, then *Euglena* produces a *shock reaction* and, by *trial and error*, reorients itself towards the new source of light. This shock reaction is explained as follows :

When the stigmal side of body faces a lateral beam of light, the paraflagellar body is shaded by the stigma once in each rotation. Thus, the base of flagellum is alternately darkened and

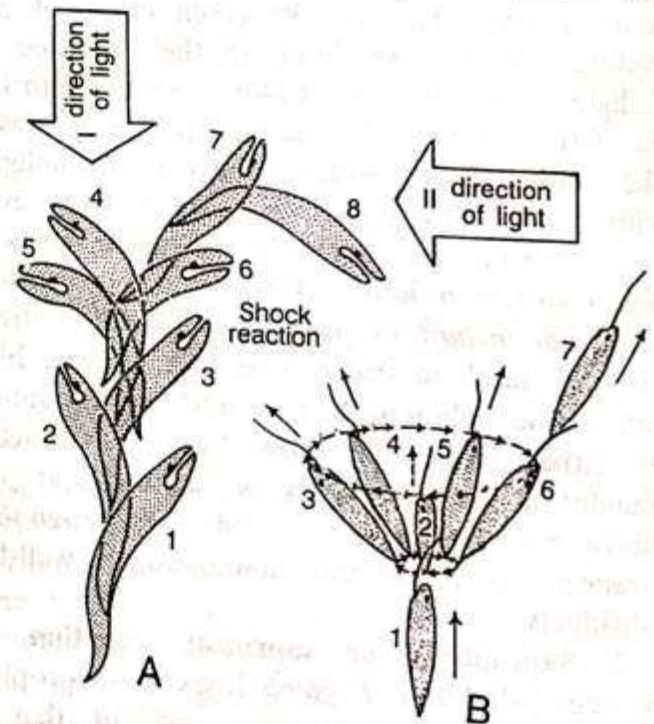


Fig. 8. *Euglena*. A—Positions 1-4, when moving towards I direction of light. Position 5, in shock reaction. Positions 6-8, when moving towards II direction of light. B. Avoiding reaction on a trial and error pattern.

illuminated in lateral light. Each darkening of the paraflagellar body excites its photoreceptor to produce a minor shock reaction. This effects flagellar action in such a way that the body bends at right angles, turning the flagellar end gradually towards the new light source. Light being essential for photosynthesis, this specialization brings the animal into light which is of distinct advantage in its nutrition.

**3. Avoiding reaction.** *Euglena* also responds to mechanical, thermal and chemical stimuli showing an *avoiding reaction* on a *trial and error* pattern (*phototaxis*). In most cases the animal slows down, stops or even moves backwards. The posterior end of body may act as a pivot, while the anterior end traces wider circles of gyrations and swims forward in a new spiral path.

## Reproduction

There is no evidence of sexual reproduction in *E. viridis*. It multiplies asexually by *binary* and *multiple* fissions and undergoes *encystment*.

**1. Binary fission.** Transverse binary fission is unknown in *Euglena*. Under favourable conditions of water, temperature and food availability, *Euglena* divides by a simple *longitudinal* binary fission. The longitudinal division is always *symmetrogenic*, that is, the parental *Euglena* divides into two daughter individuals, where one is the plane mirror image of the other. First the nucleus divides into two by *mitosis* which is followed by the division of

cytoplasm (*cytokinesis*). The unusual feature which is observed in nuclear division is the persistence of nuclear membrane. In *prophase* stage, all the nucleoli (endosomes) fuse together into a single *nucleolar body* and each chromosome splits longitudinally into two daughter chromosomes or *chromatids*. In *metaphase* stage, the paired chromatids come to lie in a longitudinal plane. The microtubules are present in nucleus but they do not form a spindle. In *anaphase* stage, the paired chromatids separate and move towards their respective poles. It has been suggested that the movement of chromatids is autonomous, with mutual repulsion. The nuclear membrane begins to constrict longitudinally. In the *telophase* stage, constriction in nuclear membrane deepens and finally separates the nucleus into two daughter nuclei. The nucleolar body also splits into two halves, each taking its place in the daughter nucleus of its own side. Next follows the *cytokinesis*. A longitudinal furrow appears in the cytoplasm, beginning at the anterior end, which deepens and finally divides *Euglena* into two daughter euglenae.

Organelles of the anterior end, such as the reservoir, cytopharynx, cytostome, flagella, stigma and contractile vacuole duplicate by the formation of a new set of these structures. However, a new set of flagella arises from new basal bodies which appear in the vicinity of old basal bodies. Multiplication of basal bodies usually precedes cell division.

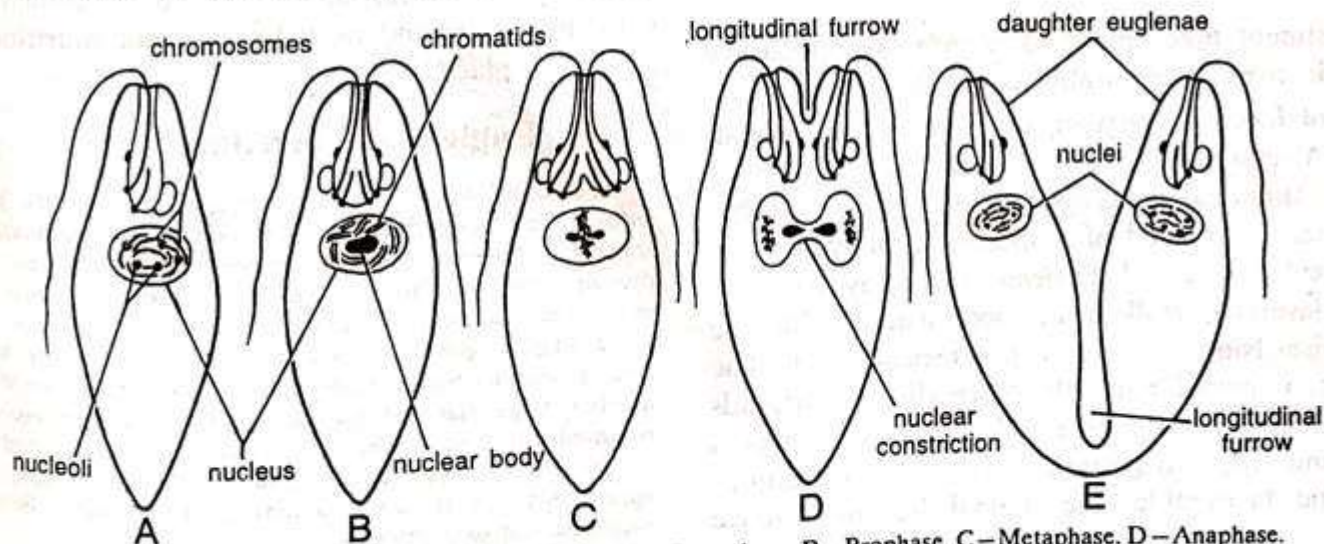


Fig. 9. *Euglena*. Stages of longitudinal binary fission. A—Interphase. B—Prophase. C—Metaphase. D—Anaphase. E—Telophase and Cytokinesis.

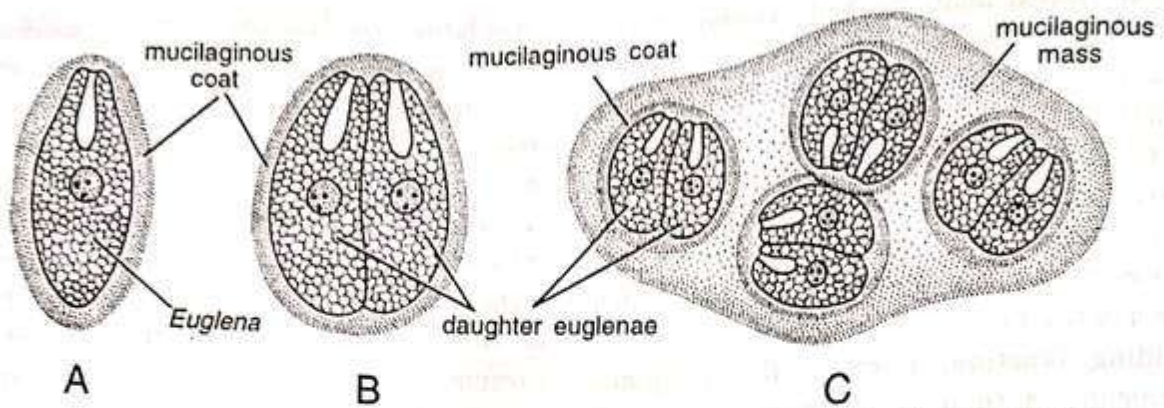


Fig. 10. *Euglena*. Multiple fission and encystation. A – Encysted individual. B – Fission in encysted condition. C – Palmella stage.

**2. Multiple fission and palmella stage.** Under inactive periods, *Euglena* undergoes multiple fission in an encysted condition. Movement ceases altogether, flagellum is thrown off and *Euglena* becomes rounded and embedded in an extensive, thick and mucilaginous coat or cyst which is secreted by the muciferous bodies. Encystment is usually followed by repeated longitudinal binary fissions with the formation of several daughter individuals (16 or 32), embedded within a mucilaginous mass. The daughter individuals within the mucilaginous mass secrete their own mucilaginous coats or cysts. This resembles the palmella stage of many algae, such as *Chlamydomonas*. Later these daughter individuals acquire flagella and escape to grow into adult euglenae.

### Encystment

Encystment takes place as a protective measure to tide over unfavourable conditions such as the lack of food and oxygen, draught, excessive heat, etc. A cyst-wall is secreted in the form of a thick, spherical, yellowish brown and gelatinous covering, composed of a special carbohydrate. In different species of *Euglena*, cyst may be thick (2-4 layered), stalked or operculated with the organism lying centrally or eccentrically in it. The encysted animal not only successfully withstands the adverse conditions of life, but also enjoys a far and wide dispersal. When the conditions become favourable, the animal becomes active

and emerges from the cyst to resume its normal free-swimming life.

As already stated above, the individual may undergo a single or several divisions, resulting in two or many new individuals (*palmella stage*).

### *Euglena* as an Animal

*Euglena* is studied as an animal as well as a plant. It is more an animal than a plant because of the following reasons :

- (1) Absence of a cellulose cell-wall overlying the plasma membrane.
- (2) Presence of centrioles forming the blepharoplasts or kinetosomes.
- (3) Reserve food is paramylon which is not a true starch.
- (4) Presence of paraflagellar body, a sensory (photoreceptive) organelle.
- (5) Moves from place to place like an animal.
- (6) Responds to various stimuli like an animal.
- (7) Pinocytosis and probably holozoic nutrition takes place.

### Other Euglenoid Flagellates

1. *Euglena spirogyra*. It is a large *Euglena*, about  $100\mu$  long, with a spindle-shaped body. Posterior end of body is somewhat tail-like. Chloroplasts are numerous, small and discoid. Pyrenoids are wanting. There are two large and many small paramylon bodies scattered in the cytoplasm.

2. *Euglena gracilis*. It is a small *Euglena* about  $50\mu$  long, with a spindle-shaped body. Chloroplasts are about 10 in number, large, flat and plate-like each with a proteinaceous pyrenoid. Once in darkness for a few days, the chloroplasts are bleached off permanently and the chlorophyll does not appear again. Cytoplasm contains many paramylon bodies, each attached to a chloroplast.



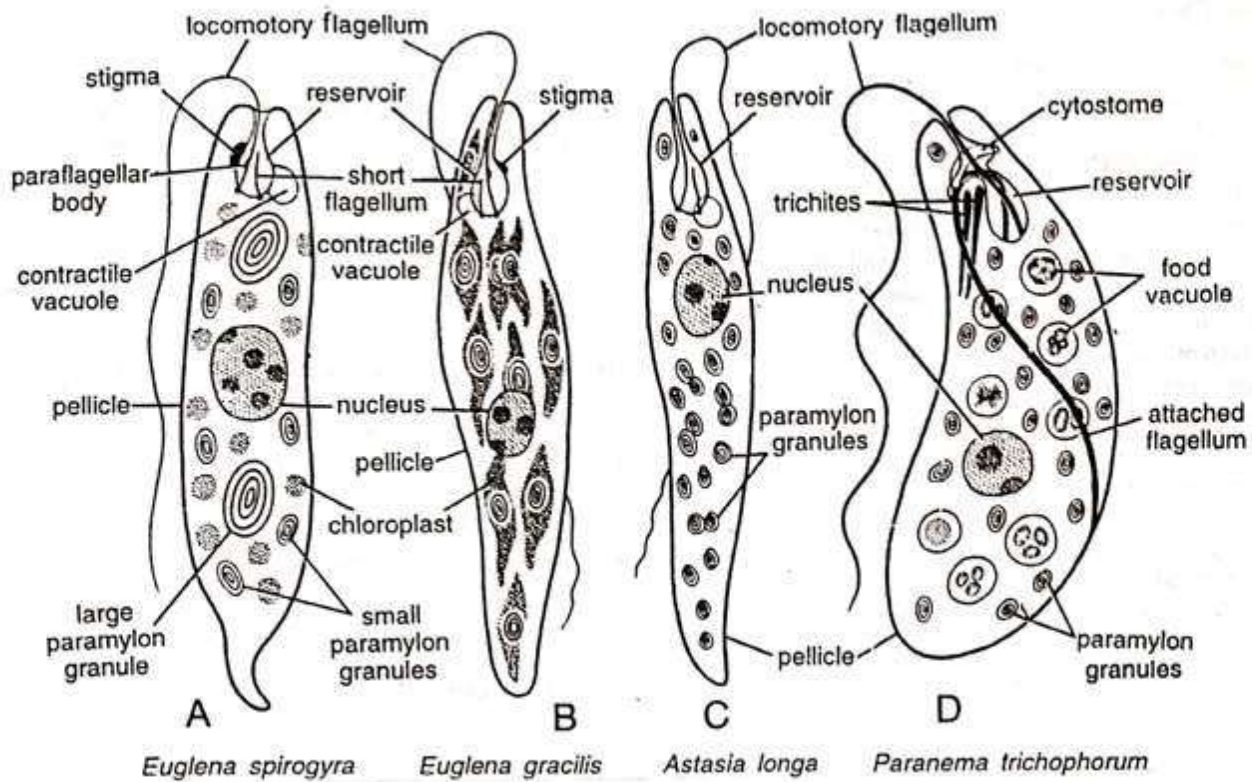


Fig. 11. Some euglenoid flagellates. A- *Euglena spirogyra*. B- *Euglena gracilis*. C- *Astasia longa*. D- *Paranema trichophorum*.

3. *Astasia longa*. It is a euglenoid flagellate, which feeds by osmotrophy in the absence of chloroplasts. Stigma and the paraflagellar body are also wanting. Cytoplasm contains numerous small free paramylon bodies. Zoologists believe that *Astasia longa* is the bleached form of *E. gracilis*.

4. *Paranema trichophorum*. It is another euglenoid flagellate which is holozoic and feeds by phagotrophy upon

quite large organisms. Of the two flagella, one is long and locomotory, while the other is trailing and adhered to the body surface. The stigma and paraflagellar body are absent. Cytopharynx or gullet bears an accessory rod apparatus, the *trichites*, for puncturing the body wall of a large prey. Cytoplasm contains food vacuoles and numerous small free paramylon bodies.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Describe the occurrence, structure and modes of locomotion, nutrition and reproduction of *Euglena*...
2. Draw a magnified view of the anterior end of *Euglena* and describe the structures present therein.
3. Give the detailed structure of *Euglena* as revealed by electron micrographs.
4. Describe the different modes of nutrition in *Euglena*.
5. Justify the statement that *Euglena* is more an animal than a plant.
6. Give arguments for treating *Euglena* as an animal, as a plant and as a protist.
7. Write short notes on : (i) Euglenoid movement, (ii) Encystment of *Euglena*, (iii) *Euglena gracilis*, (iv) Mixotrophic nutrition, (v) Palmella stage, (vi) *Paranema trichophorum*, (vii) Structure of flagellum, (viii) Stigma.

#### » Short Answer Type Questions

1. Describe the pyrenoid bodies in *Euglena*.
2. What is the type of nutrition in *Euglena* ?
3. What is the palmella stage in reproduction in *Euglena* ?
4. Encystment in *Euglena* is essential, why ?
5. Describe the flagellum of *Euglena*.
6. Give at least two reasons each for considering *Euglena* (a) as an animal, (b) as a plant, (c) as a protist.
7. What is the structure and function of stigma in *Euglena*?
8. Write on the binary fission in *Euglena*.
9. Name an animal which able to heterotrophic as well as autotrophic nutrition ?
10. Name the animal which show palmella stage ?

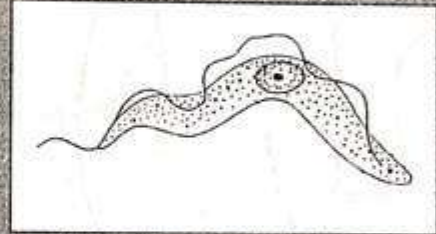
## » Multiple Choice Questions

1. Coprozoic nutrition is found in :  
(a) *Balantidium* (b) *Euglena*  
(c) *Noctiluca* (d) *Copromonas*
2. Holophytic (autotrophic) nutrition :  
(a) *Paramecium* (b) *Balantidium*  
(c) *Euglena* (d) *Nyctotherus*
3. Saprophytic or saprozoic nutrition is found in :  
(a) *Euglena* (b) *Leishmania*  
(c) *Amoeba* (d) *Monocystis*
4. Photoreceptor organ of *Euglena* is :  
(a) stigma near reservoir  
(b) paraflagellar body at the base of flagellum  
(c) stigma and paraflagellar body  
(d) chromatophore
5. Lactoflavin (sensitizer) found in :  
(a) eye spot (b) paraflagellar body  
(c) Golgi bodies (d) mitochondria
6. *Euglena* is green in colour which is due to :  
(a) chromatophores (b) leucoplasts  
(c) carotene (d) pyrenoid and paramylum
7. *Euglena* belongs to class :  
(a) Phytomastigophorea (b) Zoomastigophorea  
(c) Rhizopodea (d) Actinopodea
8. Connecting link between plank and animal kingdom :  
(a) *Paramecium* (b) *Euglena*  
(c) bacteria (d) virus
9. Which is oldest one of the animals :  
(a) *Amoeba* (b) *Paramecium*  
(c) *Euglena* (d) *Opalina*
10. Osmoregulation in *Euglena* occur with the help of :  
(a) vacuole (b) food vacuole  
(c) contractile vacuole (d) none
11. Reserved food in *Euglena* is in form of :  
(a) starch (b) glycogen  
(c) fatty acids (d) paramylon
12. Encystment take place in condition of :  
(a) lack of food  
(b) drought  
(c) excessive heat  
(d) all of them

## Answers

1. (d) 2. (c) 3. (a) 4. (c) 5. (b) 6. (a) 7. (a) 8. (b) 9. (c) 10. (c) 11. (d) 12. (d)

# *Trypanosoma gambiense*



## 4

### Chapter

The animal-like flagellates, or *zooflagellates*, include great many types of protozoans, free-living as well as parasitic. They differ with *phytoflagellates* in the absence of chlorophyll-bearing chloroplasts and the paramylon granules. But they definitely show resemblance in having one or more flagella. The parasitic zooflagellates include a number of organisms, which inhabit the blood and tissues of man and other vertebrates. The most common ones are the trypanosomes, belonging to the genus *Trypanosoma* (Gr., *trypanon*, auger + *soma*, body). They parasitize mostly the blood of vertebrates. They are characterized by the possession of a *flagellum* which arises near the posterior end of the body, extends forward as the border of an *undulating membrane*, and emerges as a free filament at the anterior end. Some species are nonpathogenic doing little or no harm to the host. Others, such as *T. gambiense*, are highly

pathogenic producing severe diseases in man and animals.

### *Trypanosoma gambiense*

#### Systematic Position

Phylum	Protozoa
Subphylum	Sarcomastigophora
Superclass	Mastigophora
Class	Zoomastigophoréa
Order	Kinetoplastida
Genus	<i>Trypanosoma</i>
Species	<i>gambiense</i>

#### Polymorphic Forms of Trypanosomes

At least four forms of trypanosomes are recognized on the basis of the positions of kinetoplast and blepharoplast and the course taken by the flagellum. Two or more such forms occur either in one or both the hosts in the life cycles of various species of *Trypanosoma*. These forms are as follows :

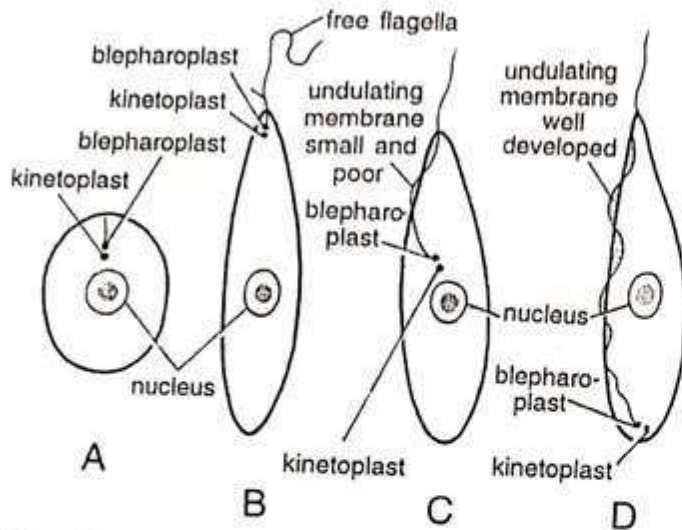


Fig. 1. Polymorphic forms of trypanosomes. A - Leishmanial. B - Leptomonad. C - Crithidial. D - Trypanosomid.

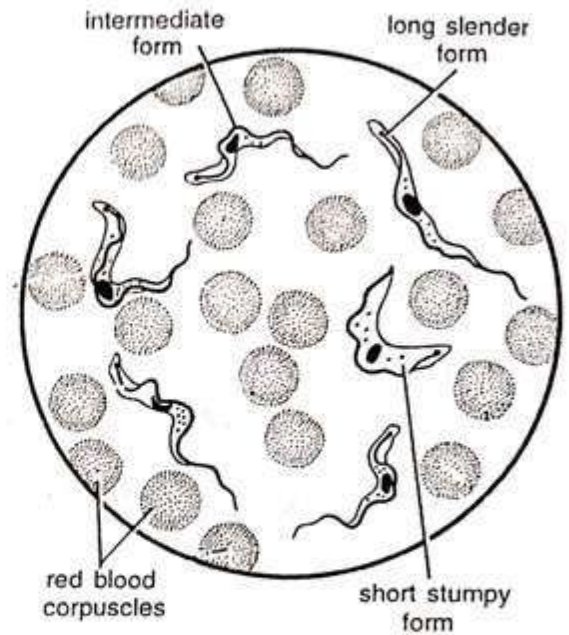


Fig. 2. *Trypanosoma gambiense*. Various forms in human blood plasma.

1. **Leishmanial (amastigote)**. Round or oval form with a nucleus, blepharoplast and kinetoplast. Flagellum reduced and fibril-like, embedded in cytoplasm.

2. **Leptomonad (promastigote)**. Body elongate, nucleus large and anteriorly located blepharoplast and kinetoplast. Flagellum short and unattached.

3. **Crithidial (epimastigote)**. Body elongate. Blepharoplast and kinetoplast placed immediately anterior to nucleus. Undulating membrane inconspicuous.

4. **Trypanosomid (trypomastigote)**. Body elongate and slender. Blepharoplast and kinetoplast situated at or near posterior end. Undulating membrane conspicuous.

1. **Ecology discovery**. *T. gambiense* as a human parasite was first observed by Forde in 1901. Sir David Bruce (1895) discovered that sleeping sickness is transmitted by tsetse fly.

2. **Distribution**. *T. gambiense* is confined mainly to Central and West Africa particularly in Nigeria and Congo. Areas near the rivers and lakes have the greatest incidence of infection, since the insect vector, the tsetse fly, lives there in low and thick vegetation.

3. **Habits and habitat**. *T. gambiense* causes the dreaded disease of African sleeping sickness in man. The parasite lives in the blood stream and in the lymph glands of infected persons in early stages of disease. Later, it invades the cerebrospinal fluid of the central nervous system causing fever, anaemia, lethargy and death. The chief vector which transmits the trypanosome from man to man is the tsetse fly, *Glossina palpalis*, but *G. tachinoides* is also known to be an important transmitter.

Occasionally, the trypanosome utilizes domestic and wild mammals, such as monkeys,

dogs, pigs, antelopes, buffaloes and reed bucks, as *temporary* or *reservoir hosts*. In these hosts, the parasite does not undergo any developmental cycle but simply waits for its introduction into the human organism. Entry into and exit from reservoir hosts are always through the bite of tsetse fly, which feeds upon the blood of man as well as the reservoir hosts.

## Morphology

1. **Shape and size**. Unicellular body of *T. gambiense* is microscopic, elongate, leaf-like, flattened and tapering at both ends. It measures 10-40 $\mu$  in length and 2.5-10 $\mu$  in width. The anterior end, which marks the emergence of free flagellum, is pointed, while the posterior end is blunt.

*T. gambiense* is a polymorphic species and occurs in two developmental forms, the *trypanosome* form and *crithidial* form. In blood stream of its vertebrate host (man), the *trypanosome* form may be long slender or short stumpy or intermediate between the two. In invertebrate host (tsetse fly), the *trypanosome* form is long slender in midgut, and short stumpy in salivary glands. *Crithidial* form is represented only in salivary glands of tsetse fly.

2. **Pellicle**. The whole body is surrounded externally by a thin, elastic and firm covering the *pellicle*. It is supported by the fine fibrils, called

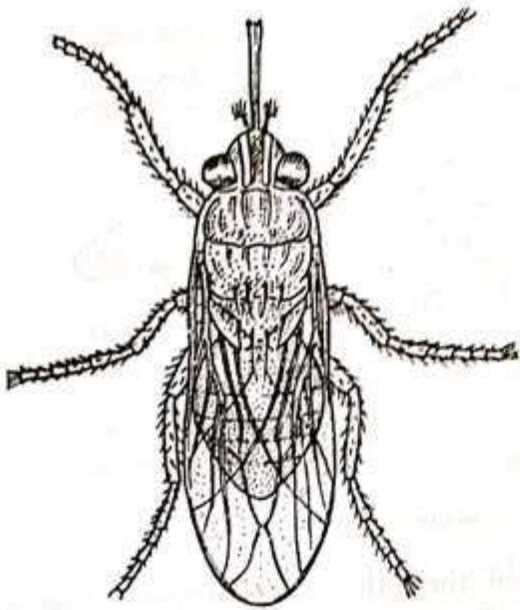


Fig. 3. Tsetse fly.

*microtubules*, which run along the whole length of body. It is believed that microtubules help to maintain the shape of the organism while it swims in the blood plasma.

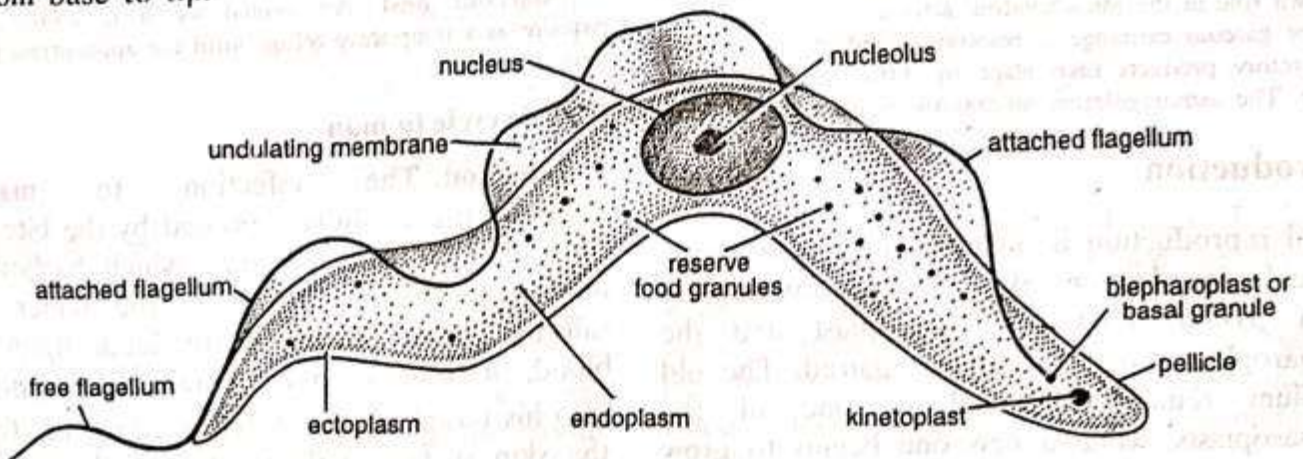
**3. Flagellum.** Trypanosome is uniflagellate as it bears a single flagellum. It arises from a *basal body (kinetosome)*, situated near the posterior end of body. It runs forward, attached along the entire length of body, and becomes free at the anterior end. In a transverse section, seen under electron microscope, the flagellum shows the usual 9+2 internal fibril arrangement, as in case of *Euglena* (Fig. 2). It also bears unilateral hair as in *Euglena*. No special structures attaching the flagellum with pellicle have been observed. When the trypanosome moves in blood, the undulating waves pass from tip to base of flagellum, a condition unlike that of *Euglena* in which waves pass from base to tip.

**4. Undulating membrane.** When the flagellum beats, the pellicle, to which it is attached, is pulled up into a membranous fold called *undulating membrane*. This is believed to be an adaptation for locomotion in the viscous fluid (blood).

**5. Cytoplasm.** The cytoplasm is enclosed within the pellicle. It has not been observed to be differentiated into ectoplasm and endoplasm.

Electron microscopy has revealed that there is present a reservoir corresponding to the *reservoir* of *Euglena*, but at the posterior end of body. The *basal body* or *blepharoplast* of flagellum is located at the base of this reservoir. An elongated and uneven *mitochondrion*, with tubular cristae, is present in the cytoplasm extending from one end of the body to the other. Just near blepharoplast, the mitochondrion forms a disk-like structure, the *parabasal body* or *kinetoplast*. It includes a double-stranded DNA helix, which lies antero-posteriorly within the disc. A *Golgi apparatus* is present in between the reservoir and nucleus. *Endoplasmic reticulum* is present throughout the cytoplasm. *Ribosomes* occur on the endoplasmic reticulum as well as scattered freely in cytoplasm. Cytoplasm also contains numerous greenish refractile granules, sometimes called *volutin granules*. These are supposed to be stored food particles, chiefly glycogen and phosphates. Various small *vacuoles* are also seen in the cytoplasm, some with hydrolytic enzymes (lysosomes).

**6. Nucleus.** Within the cytoplasm is present a large, oval and vesicular nucleus. The nuclear membrane is a double unit membrane and bears pores. The *nucleolus* or *endosome* is centrally

Fig. 4. *Trypanosoma gambiense*. Structure under light microscope.

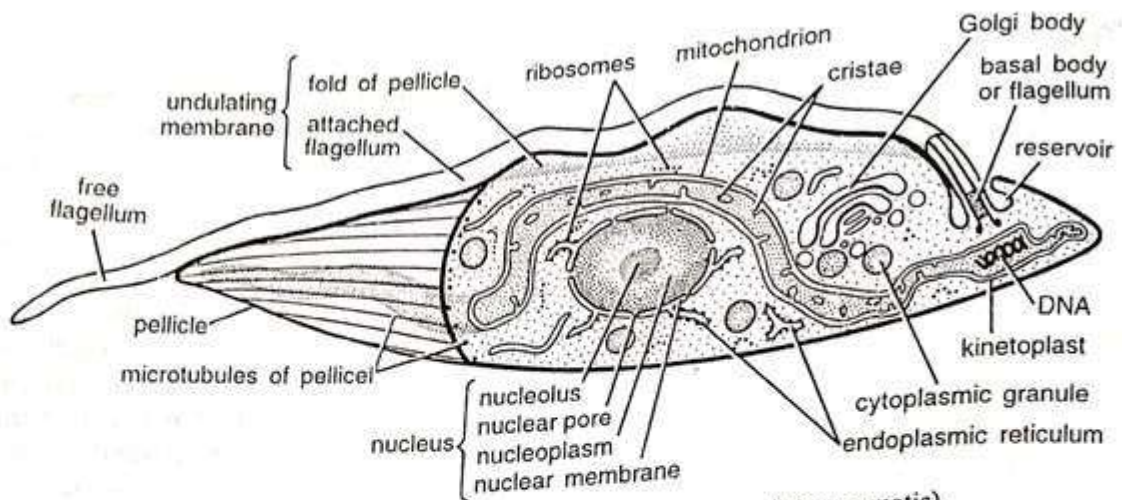


Fig. 5. *Trypanosoma*. Structure under electron microscope (diagrammatic).

placed, surrounded by a clear space. Numerous chromosomes remain scattered within the nucleoplasm.

### Metabolism

In the absence of mouth, the trypanosome obtains its nourishment by osmotrophy from blood plasma. Its long slender form, in the human blood stream, absorbs a large quantity of blood glucose that undergoes glycolysis (anaerobic) to release energy necessary for metabolism. At this stage, the mitochondrion is without cristae and thus inactive. Under conditions, when blood produces antibodies to prevent absorption of glucose, the mitochondrion develops cristae and becomes active to synthesize a series of enzymes. The enzymes in Krebs cycle oxidise pyruvic acid (a product of glycolysis) to  $\text{CO}_2$  and water and yield energy (aerobic). At this stage, trypanosomes stop multiplying and take up first the intermediate forms and then short stumpy forms. In the body of tsetse fly, the trypanosome forms in mid-gut and crithidial forms in salivary glands have extensive network of cristae-containing mitochondrion as the parasite ceases to get blood glucose and thus depends wholly on pyruvic acid. The metacyclic trypanosomes, in salivary glands, do not feed and their mitochondrion assumes a cristae-less tube possibly indicating reversion to mitochondrial inactivity at this stage. The DNA of kinetoplast plays some yet unknown role in the mitochondrial activity.

The gaseous exchange in respiration and the elimination of excretory products take place by diffusion through the pellicle. The osmoregulatory mechanism is altogether absent.

### Reproduction

Sexual reproduction is unknown in *T. gambiense*. Asexual reproduction takes place by *longitudinal binary fission*. First, the kinetoplast and the blepharoplast divide to become paired. The old flagellum remains attached to one of the blepharoplasts, while a new one begins to grow

out from the other blepharoplast. The nucleus divides by mitosis into two daughter nuclei. Finally, the body splits mid-longitudinally, from the anterior end backwards, forming two daughter trypanosomes.

### Life Cycle

**1. Hosts.** *T. gambiense* is *digenetic* that is, it completes its life cycle in two hosts. (Gr., *di*, double + *genos*, race). The *primary* or *principal* or *definitive host* is man and the *intermediate host* or *vector* is a blood-sucking insect called tsetse fly (*Glossina palpalis*). The mammals, like antelopes, pigs, buffaloes, etc., often act as *reservoir hosts* harbouring the parasite.

**Principal, primary or definitive host.** An animal in which the parasites feed and attain sexual maturity.

**Intermediate host or vector.** An animal which transmits the parasite from one individual of principal host to another. It is termed *mechanical* when the parasite does not undergo developmental changes in it. If the parasite undergoes developmental changes, it is termed *biological*. In such a host the parasite passes the sexual phase of its life cycle.

**Reservoir host.** An animal which is utilized by the parasite as a temporary refuge until the appropriate principal host is reached.

#### [I] Life cycle in man

**1. Infection.** The infection to man by *T. gambiense* is always initiated by the bite of the tsetse fly, *Glossina palpalis*, which harbours the infective *metacyclic* forms in the lumen of its salivary glands. When the fly feeds upon man's blood, it releases the contained trypanosomes into his blood stream. While feeding, the fly grips the skin surface with its claws and punctures it

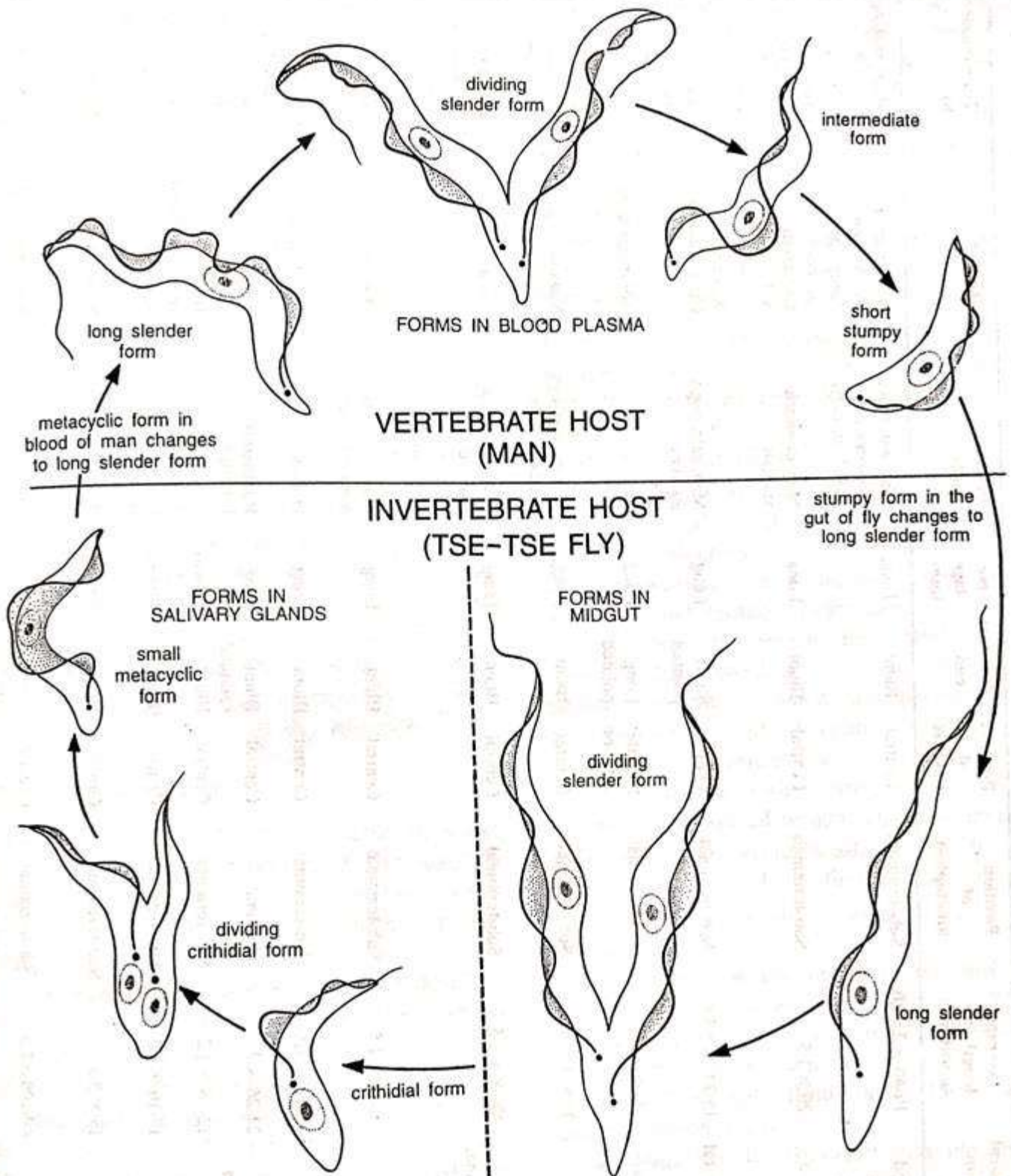


Fig. 6. *Trypanosoma gambiense*. Stages of life cycle in man and tsetse fly.

with its proboscis. To prevent the clotting of blood, the fly first introduces some saliva containing an anticoagulant, along which the infective trypanosomes too are inoculated.

**2. Multiplication.** All stages of parasite in man are extracellular as they are present in the blood

plasma and not inside blood cells. In human blood, the metacyclic forms, which are devoid of a free flagellum, become transformed into *long slender* forms with flagella. These swim freely by the beating of their free flagellum and the vibratile movements of the undulating membrane

Table 1. Some Important Trypanosomes of Man and Domestic Animals.

Species	Geographical distribution	Average length in $\mu$ width	Position of kinetoplast	Position of nucleus	Posterior end	Free flagellum	Primary hosts	Disease	Transmission by
1. <i>T. gambiense</i>	Central and W. Africa	10-40 $\times$ 2.5-10	Sub-terminal	Central	Blunt	Long	Man, antelope, monkeys, pigs, buffaloes, dogs	Gambian or W. African Sleeping sickness	Blood sucking tsetse fly <i>Glossina palpalis</i>
2. <i>T. rhodesiense</i>	Central and E. Africa	20 $\times$ 1.5	Sub-terminals	Central	Blunt	Long	Man, domestic animals	Rhodesian or E. African Sleeping Sickness	Biting of <i>Glossina</i> spp.
3. <i>T. cruzi</i>	S. and Central America	15-24 $\times$ 1.5	Sub-terminal	Central	Short pointed	Long	Man, cats, dogs, monkeys	Chagas disease	Faeces of kissing bug <i>Triatoma</i>
4. <i>T. lewisi</i>	N. America	21-36 $\times$ 2	Not terminal	Slightly anterior	Long pointed	Long	Rats	Non-pathogenic	Faeces of infected rat-flea <i>Glossina morsitans</i>
5. <i>T. brucei</i>	Africa	30 $\times$ 1.5	Sub-terminal	Central	Blunt	Long	Horses, donkeys, mules, camels, cattle	Nagana	<i>Glossina morsitans</i>
6. <i>T. evansi</i>	N. Africa, Asia, S. China, N. and S. America, India	20-28 $\times$ 1.5	Sub-terminal	Central	Blunt	Long	Horses, camels, mules, donkeys, cattle, dogs, elephants	Surra	Biting of Tabanid fly
7. <i>T. equiperdum</i>	S. America	20-28 $\times$ 1.5	Sub-terminal	Central	Blunt	Long	Horses, mules, donkeys, cattle	Dourine	During coitus
8. <i>T. equinum</i>	S. America	20-28 $\times$ 1.5	Sub-terminal	Central	Blunt	Long	Horses	Mal de caderas	Biting of Tabanid fly
9. <i>T. vivax</i>	W., Central and E. Africa	21-26 $\times$ 2	Terminal	Central	Blunt rounded	Long	Ruminants, Equines	Virulent	Biting of <i>Glossina</i> spp.
10. <i>T. congolense</i>	W. Central E. Africa	12-18 $\times$ 1.2	Sub-terminal	Central	Blunt	Absent	Cows, other domestic animals	Bovine trypanosomiasis	Biting of <i>Glossina</i> spp.
11. <i>T. simiae</i>	Africa	17-18 $\times$ 1.2	Sub-terminal	Central	Blunt	Absent	Pigs, monkeys, sheep, goats	Virulent	Biting of <i>Glossina</i> spp.
12. <i>T. suis</i>	Tanzania, Congo	15 $\times$ 3.5	Sub-terminal	Central	Very short pointed.	Short	Pigs	Virulent	Biting of <i>Glossina</i> spp.
13. <i>T. theileri</i>	N. America	60-100 $\bar{\sigma}$ 2.3	Sub-terminal	Central	Long pointed	Short	Cattle	Non pathogenic	Faeces of tabanids.



and multiply actively by longitudinal binary fission. The multiplying trypanosomes obtain energy by anaerobic glycolysis.

**3. Metamorphosis.** When the absorption of glucose ceases due to antibodies produced in blood, the glycolysis is hampered and the trypanosomes stop multiplying. They now shrink to short *stumpy* forms, which are devoid of a free flagellum. During transformation from long slender forms to short stumpy forms, the *intermediate* forms with somewhat shortened body and a small free flagellum also appear. The intermediate as well as the short stumpy forms depend on their energy supply upon the aerobic oxidation of pyruvic acid.

The stumpy forms do not feed and ultimately die if they are not sucked up by the tsetse fly along with the blood meal.

**4. Relapse of infection.** It has also been reported that some of the long and slender trypanosomes do not undergo transformation, but change the antigens of blood to which the host has produced antibodies. These unaltered slender forms survive and continue to multiply in blood leading to future relapses of the infection.

## [II] Life cycle in tsetse fly

**1. Transfer to tsetse fly.** When tsetse fly sucks the blood of an infected person, it also takes in the short stumpy forms along with the sucked blood. It is the stumpy forms which continue development in the vector.

**2. Development in mid-gut.** Further development proceeds in the insect's mid-gut within *peritrophic membrane*. Here the parasites transform into long slender forms and multiply by longitudinal binary fission. The kinetoplast moves farther from the posterior end of body. The energy-yielding process is related to mitochondrial oxidation of pyruvic acid.

**3. Development in salivary glands.** Later, the long slender forms make their way into salivary glands via the oesophagus and mouthparts of insect. Here they metamorphose into the *crithidial* forms with shortened body, reduced free flagellum and the kinetoplast in front of the nucleus. The mitochondrion develops an

extensive network of cristae and the parasite respire more economically as the blood glucose gradually declines. The crithidial forms multiply in the lumen of salivary glands and transform into slender *metacyclic* forms. At this stage, the mitochondrial activity is again suppressed. When the tsetse fly bites a healthy person, it transfers the metacyclic forms, along with saliva into his blood where they initiate another infection.

## Sleeping sickness

*T. gambiense* causes the disease of West African Sleeping Sickness or Gambian trypanosomiasis in man. It is different from Encephalitis or the so called American Sleeping Sickness which is caused by a filterable virus.

**1. Symptoms and pathogenesis.** Bite of tsetse fly causes local irritation which subsides after a few days. Infection is caused by the inoculation of trypanosomes into human blood stream. Besides undergoing development in blood plasma, they also invade the lymphatic glands causing their swelling. The disease Sleeping Sickness is caused when the parasites invade cerebrospinal fluid of central nervous system. An irregular recurrent fever is the first symptom of the disease. Other symptoms which follow are weakness, loss of weight, anaemia, increase in pulse rate and severe headache. In due course the patient falls asleep, first at regular intervals and then lies prostrate in coma. Death is always the ultimate fate.

The cause for the injury of the host by the parasite is not known, but Laveran (1913) and Rondoni (1913) attribute it to toxicity. The toxic effect is produced when the trypanosomes die in the cerebrospinal fluid and their autolytic decomposition starts.

**2. Diagnosis.** In laboratory, trypanosomes may be detected in fresh or stained blood films, or in extracts of enlarged lymph glands. In Sleeping Sickness stage, examination of cerebrospinal fluid, obtained by lumbar or cisternal puncture, becomes necessary.

**3. Treatment (Therapy).** The *Gambian* or *African trypanosomiasis* can be treated in its early stage, but once the parasites have entered the

cerebrospinal fluid, it is very hard to control it. A number of drugs have been used for the purpose. *Suramin sodium*, *Bayer 205*, *Atoxyl* and *Tryparsamide* have been useful in early stages. *Parsenophenyl butyric acid*, *germanin* and *pentamidine* are also effective in treatment of early cases. *Orsanine* is fairly effective in cases where the central nervous system is involved. *Melarsen oxide* is rapid in action and is less toxic.

No one should begin treatment for Sleeping Sickness until the diagnosis has been confirmed by laboratory studies on blood and the treatment is prescribed by a doctor.

**4. Prevention (Prophylaxis).** Prevention of African Sleeping Sickness depends upon the eradication of vector, i.e., the tsetse fly. The flies can be eradicated by clearing out bushes and low trees along rivers in the endemic areas. Spraying of DDT over bushy areas in the vicinity of villages is effective in controlling the tsetse flies. Domestic and wild animals, which act as reservoir hosts, may be put to wholesale slaughter, but this method is not practicable to operate. Further protection is obtained by injecting one gm. of *Suramin* (Antrypol) every two or three months.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Describe the structure and life history of any trypanosome studied by you.
2. Give the detailed structure of a trypanosome as revealed by the electron microscope.
3. What is African Sleeping Sickness? How it is caused? Describe its transmission and pathogenesis. Suggest methods for its control.
4. Write an essay on *Trypanosoma* and diseases.
5. Give the classification, characteristics and life-history of the Protozoa causing Sleeping Sickness.

#### » Short Answer Type Questions

1. What is the zoological name of the vector of *Trypanosoma gambiense*?
2. Name the natural reservoirs of *Trypanosoma gambiense*.
3. Name the vertebrate which retains *Trypanosoma* without any harmful effects to its own self.
4. With reference to *Trypanosoma*, explain polymorphism.
5. With the help of labelled diagram explain the changes taking place in *Trypanosoma gambiense* in the body of tse-tse fly.
6. Give the name all forms of *Trypanosoma* which shows polymorphism.
7. Name the primary host and intermediate host of *T. gambiense*.

#### » Multiple Choice Questions

1. *Trypanosoma gambiense* causes the disease :  
(a) beri beri (b) scurvy (c) sleeping sickness (d) malaria
2. Some times trypanosome passes into internal organs like spleen, lungs where they lose flagella and become oval shaped. What is its name ?  
(a) parabasal body (b) latent bodies  
(c) Rhizoplast (d) *Leishmania*
3. In the body of tse tse fly, three morphological forms of *Trypanosoma gambiense* are observed; they are metacyclic form, long and slender form and :  
(a) megalospheric form (b) microspheric form  
(c) crithidial form (d) primary form  
(e) secondary form
4. Tse tse fly is the vector of the disease :  
(a) typhoid (b) kala azar  
(c) gambian fever (d) oriental sores
5. *Trypanosoma* is transmitted by :  
(a) contamination (b) inoculation  
(c) contagious (d) touch
6. The reservoir host for *T. gambiense* is :  
(a) rat (b) pig  
(c) man (d) tse-tse fly
7. Chagas disease is caused by :  
(a) *T. gambiense* (b) *T. cruzi*  
(c) *T. evansi* (d) *T. rhodesiense*
8. *Trypanosoma gambiense* lives in the human body in :  
(a) lymph (b) blood  
(c) cerebrospinal fluid  
(d) blood and in cerebrospinal fluid
9. The main symptom for Gambian fever is :  
(a) headache (b) dysentery (c) diarrhoea (d) insomnia  
(e) pain at the joints

10. The infective stage of *Trypanosoma* is :
  - (a) long and slender form
  - (b) crithidial form
  - (c) metacyclic form
  - (d) intermediate form
11. *Trypanosoma* causing sleeping sickness belongs to class :
  - (a) Rhizopoda
  - (b) Mastigophora
  - (c) Sporozoa
  - (d) Ciliata
12. Who discovered the disease sleeping sickness :
  - (a) Ronald Ross
  - (b) Forde
  - (c) David Bruce
  - (d) Lamble
13. The vector for *Trypanosoma* :
  - (a) *Glossina palpatris*
  - (b) *G. tachinoides*
  - (c) both
  - (d) none
14. Nourishment in *Trypanosoma* :
  - (a) autotrophy
  - (b) chemotrophy
  - (c) osmotrophy
  - (d) none
15. Which is nonpathogenic :
  - (a) *T. gambiense*
  - (b) *T. lewisi*
  - (c) *T. cruzi*
  - (d) *T. evansi*
16. Chagas disease due to infection of :
  - (a) *T. gambiense*
  - (b) *T. rhodesiense*
  - (c) *T. cruzi*
  - (d) *T. brucei*
17. Osmoregulatory mechanism absent in :
  - (a) *Paramecium*
  - (b) *Amoeba*
  - (c) *Euglena*
  - (d) *Trypanosoma*
18. Caused of surra disease in cattle :
  - (a) *T. evansi*
  - (b) *T. brucei*
  - (c) *T. lewisi*
  - (d) *T. cruzi*

**Answers**

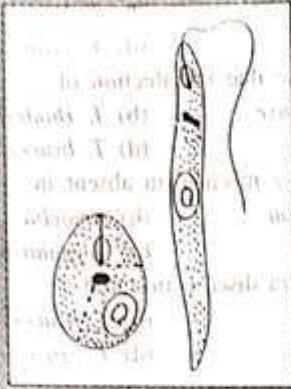
1. (c) 2. (d) 3. (c) 4. (c) 5. (b) 6. (b) 7. (b) 8. (b) 9. (a) 10. (c) 11. (b) 12. (c) 13. (c) 14. (c) 15. (b) 16. (c) 17. (d) 18. (a)

*Trypanosoma gambiense*

**Systematic Position**

- |            |                    |
|------------|--------------------|
| Kingdom    | Animalia           |
| Phylum     | Protozoa           |
| Subphylum  | Excavata           |
| Superclass | Excavates          |
| Class      | Excavates          |
| Order      | Excavates          |
| Genus      | <i>Trypanosoma</i> |
| Species    | <i>gambiense</i>   |

*Trypanosoma* is an important pathogenic flagellate genus closely related to *Trypanosoma*. Various species of *Trypanosoma* (This is most common in the dog, sheep, horse, etc. and cause various diseases collectively known as trypanosomiasis. All types are caused by the blood-sucking gnats of the genus *Glossina* (tsetse) and all are unicellular parasites of vertebrates of blood in the cells of liver and spleen. *Trypanosoma* *gambiense* causes a malaise-like chronic disease in man called Kala-azar. *Trypanosoma* *evansi* or Black fever.



# *Leishmania donovani*

## 5 Chapter

*Leishmania* is an important pathogenic zooflagellate genus closely related to *Trypanosoma*. Various species of *Leishmania* (Table 1) infect man, cattle, dog, sheep, horse, etc. and cause serious diseases collectively known as *Leishmaniasis*. All types are carried by the blood-sucking sandflies of the genus *Phlebotomus*, and all are intracellular parasites in leucocytes of blood or in cells of liver and spleen. *Leishmania donovani* causes a malaria-like oriental disease in man called Kala-azar, Dumdum fever or Black fever.

### *Leishmania donovani*

#### Systematic Position

Phylum	Protozoa
Subphylum	Sarcomastigophora
Superclass	Mastigophora
Class	Zoomastigophora
Order	Kinetoplastida
Genus	<i>Leishmania</i>
Species	<i>donovani</i>

*Leishmania donovani*

1. Ecology Discovery. Genus *Leishmania* was created by Ross in 1903. The species *L. donovani* was reported simultaneously by Leishman from London (1903) and Donovan from Madras (1903), hence the name *Leishmania donovani*.

2. Distribution. *L. donovani* infects man in India, China, Russia, Mediterranean countries, and in parts of Africa and South America. In India, it is endemic in Assam, Bengal, Bihar, Orissa, Tamilnadu and eastern parts of Uttar Pradesh.

3. Habits and habitat. In man, *L. donovani* lives as an intracellular parasite in leucocytes or cells of liver, spleen, bone marrow, lymphatic glands, etc. It is the causative agent of the disease known as Kala-azar resulting in fever, enlargement of spleen and a reduction in the number of white corpuscles in blood. It is transmitted through the bite of sandflies.

**Morphology**

1. Shape and size. The genus *Leishmania* occurs only in two forms or stages, *leishmanial* and

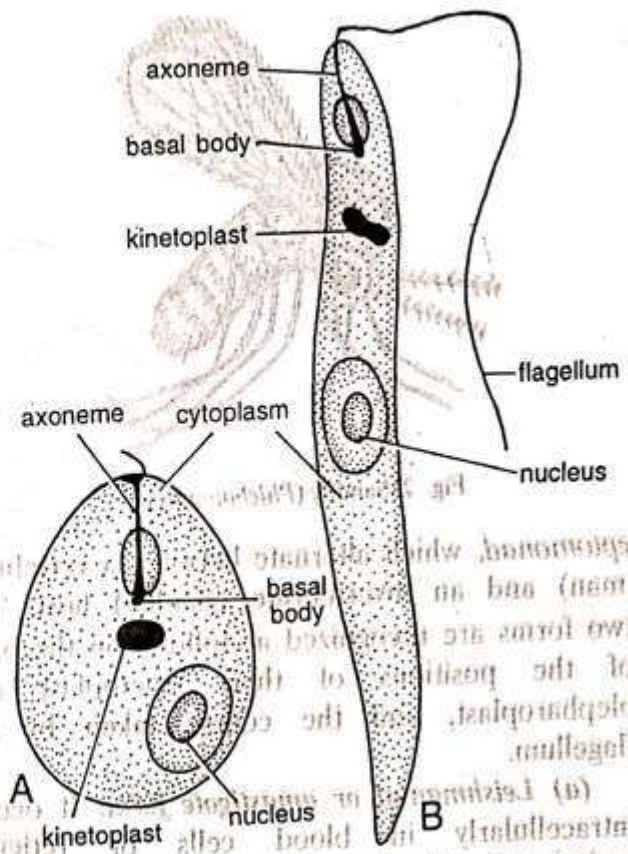


Fig. 1: Two forms of *Leishmania*.  
A- Amastigote or leishmanial form in man.  
B- Promastigote or leptomonad form in sandfly.

Table 1. Species of *Leishmania* infecting man

Species	Geographical distribution	Primary hosts	Position	Disease produced & symptoms	Transmission in host
1. <i>Leishmania donovani</i>	India, China, North Africa, South Europe, Russia, South America	Man, dogs, cats, etc.	Intracellular in leucocytes and cells of spleen, liver, bone marrow and lymph glands.	<b>Kala-azar</b> or <b>Dumdum fever</b> with fever, anaemia, enlargement of spleen and liver and darkening of skin. Also <b>Dermal leishmanoid</b> .	Cyclic, through bite of blood-sucking sandfly <i>Phlebotomus argentipes</i> in India.
2. <i>L. infantum</i>	Mediterranean areas. Considered identical to <i>L. donovani</i>	Children	Intracellular	Infantile Kala-azar with enlargement of spleen.	Bite of sandfly.
3. <i>L. chagasi</i>	South America. Identical to <i>L. donovani</i>	Man	Intracellular	S. American <b>Kala-azar</b>	Bite of sandfly
4. <i>L. canis</i>	Mediterranean areas. Identical to <i>L. donovani</i>	Dogs	Intracellular	similar to visceral leishmaniasis or kala-azar	Bite of sandfly
5. <i>Leishmania tropica</i>	Syria, Arabia, Iraq, Iran, Central Asia, Central and Western India	Man, dogs, cats, etc.	Intracellular in skin	Skin lesions called <b>Oriental sores</b>	Bite of Sandfly <i>Phlebotomus</i>
6. <i>Leishmania brasiliensis</i>	Mexico, Central and South America	Man, dogs	Intracellular in mucous membrane of nose & throat	<b>Naso-pharyngeal leishmaniasis</b> called <b>Espundia</b> in Brazil, Uta in Peru, etc.	Blte of <i>Phlebotomus intermedium</i>



Fig. 2. Sandfly (*Phlebotomus*).

*leptomonad*, which alternate between a vertebrate (man) and an invertebrate (sandfly) host. The two forms are recognized as follows on the basis of the positions of their kinetoplast and blepharoplast, and the course taken by the flagellum.

(a) *Leishmanial or amastigote form*. It occurs intracellularly in blood cells or reticulo-endothelial cells of the vertebrate host or man. It is microscopic, rounded or oval, with a central or eccentric nucleus, blepharoplast and kinetoplast, but no free flagellum. It measures  $2\mu$  to  $4\mu$  in diameter.

(b) *Leptomonad or promastigote form*. It is found in the midgut of the invertebrate host or sandfly. It is elongated, slender and spindle-shaped with a large centrally placed nucleus, blepharoplast, kinetoplast and a long free flagellum. A fully formed promastigote stage measures  $15-20\mu$  in length and  $1-2\mu$  in width.

2. **Cell membrane.** The whole body is covered externally by a very thin, delicate, elastic and firm covering or *pellicle*. It gives definite shape to the body and does not form an undulating membrane.

3. **Flagellum.** *Leishmania* is uniflagellate, bearing a single flagellum. In the leptomonad form of parasite in sandfly, the flagellum is long and free. It arises from a minute *basal body* or *blepharoplast* situated near the anterior end. Closely associated with the blepharoplast lies a disc-shaped *parabasal body* or *kinetoplast*. There is, however, no cytostome. In the leishmanial form of parasite in man, there is no free flagellum, as it is greatly reduced, fibril-like and lies embedded in cytoplasm. A transverse section of flagellum under electron-microscope shows the

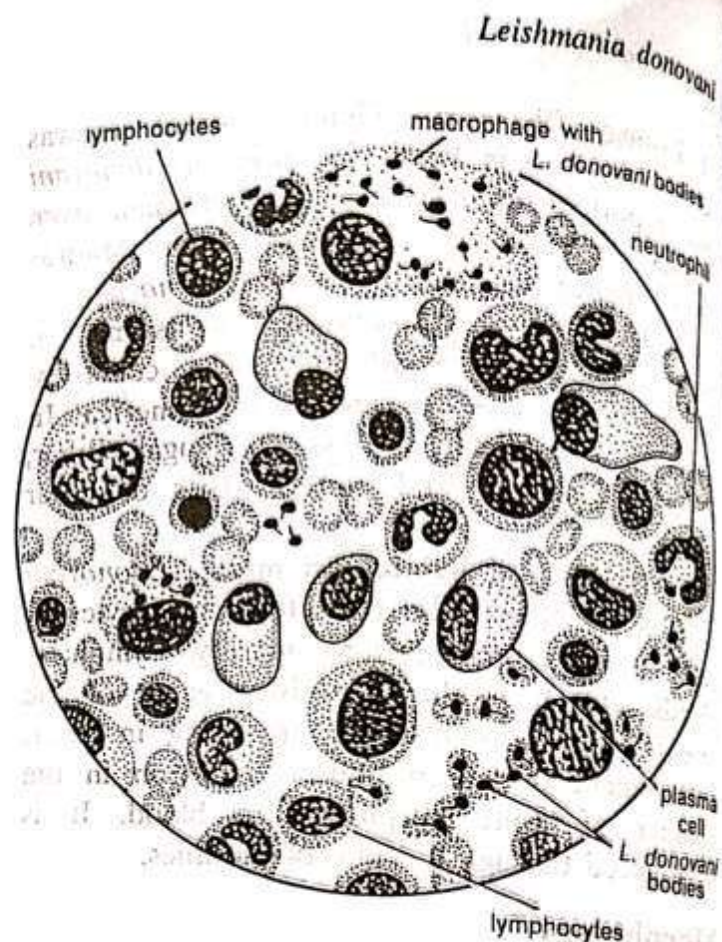


Fig. 3. Smear of bone marrow fluid showing free and phagocytosed amastigote forms of *L. donovani*.

typical 9+2 internal fibril arrangement, as in case of *Euglena* (Fig. 2).

4. **Cytoplasm.** Underneath pellicle, the body cytoplasm is colourless, homogeneous and not differentiated into ectoplasm and endoplasm. Electron microscopic studies show that cytoplasm is marked by longitudinal *striations* or *microtubules* which may be contractile. Other structures present in cytoplasm are the blepharoplast, kinetosome, rhizoplast, Golgi body, mitochondrion, vacuole and nucleus.

5. **Nucleus.** A single large spherical nucleus lies eccentrically or in the middle of the body. It is vesicular and with a distinct central *karyosome* or *nucleolus*. It is covered by a double unit membrane with pores and measures about  $1\mu$  in diameter.

## Metabolism

As in *Trypanosoma*, a mouth or cytostome is also lacking in *Leishmania*, so that *nourishment* is obtained saprozoically through body surface from host cells. Gaseous exchange in *respiration* and *elimination* of excretory products also occur by diffusion through body surface. *Sexual*

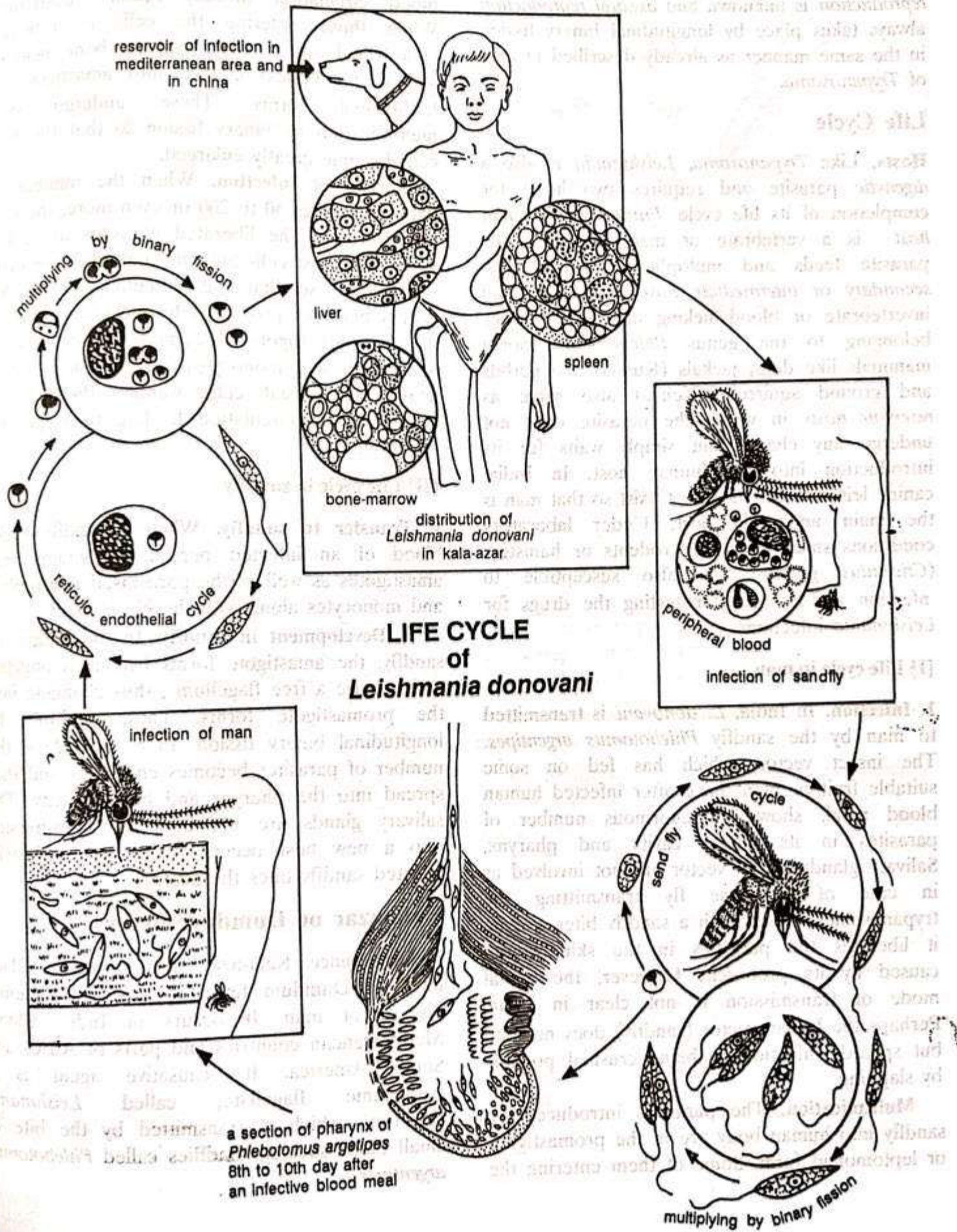


Fig. 4. *Leishmania donovani*. Complete life cycle.

reproduction is unknown and asexual reproduction always takes place by longitudinal binary fission in the same manner as already described in case of *Trypanosoma*.

### Life Cycle

**Hosts.** Like *Trypanosoma*, *Leishmania* is also a digenetic parasite and requires two hosts for completion of its life cycle. Primary or principal host is a vertebrate or man, in which the parasite feeds and multiplies asexually. The secondary or intermediate host or vector is an invertebrate or blood-sucking insect or sandfly, belonging to the genus *Phlebotomus*. Some mammals like dogs, jackals (Russia) and gerbils and ground squirrels (Kenya) also serve as reservoir hosts in which the parasite does not undergo any change but simply waits for its introduction into the human host. In India, canine leishmaniasis does not exist so that man is the main and sole host. Under laboratory conditions small burrowing rodents or hamsters (*Cricetulus griseus*) are also susceptible to infection and utilized for testing the drugs for *Leishmania* infections.

#### [I] Life cycle in man

**1. Infection.** In India, *L. donovani* is transmitted to man by the sandfly *Phlebotomus argentipes*. The insect vector, which has fed on some suitable fruit or plant juice after infected human blood meal, shows an enormous number of parasites in its buccal cavity and pharynx. Salivary glands of the vector are not involved as in case of a tsetse fly transmitting the trypanosomes. When such a sandfly bites a man, it liberates the parasites in the skin wound caused by its proboscis. However, the actual mode of transmission is not clear in India. Perhaps the Indian vector (sandfly) does not bite but spreads infection by being crushed possibly by slapping.

**Multiplication.** The parasites introduced by sandfly into human body are in the promastigote or leptomonad form. Some of them entering the

blood circulation directly become destroyed. While those entering the cells of reticulo-endothelial system (liver, spleen, bone marrow and lymph nodes) change into amastigote or leishmanial forms. These undergo slow multiplication by binary fission so that the host cells become greatly enlarged.

**Spread of infection.** When the number of parasite reaches 50 to 200 or even more, the host cell ruptures. The liberated parasites are taken up by new host cells and the multiplication cycle is repeated so that the reticulo-endothelial system becomes progressively infected. Some of the free amastigotes become phagocytosed by neutrophils and monocytes (macrophages). These heavily parasitised cells wander through the general blood circulation leading to a general infection.

#### [II] Life cycle in sandfly

**1. Transfer to sandfly.** When a sandfly sucks blood of an infected person, it obtains free amastigotes as well as the parasitised neutrophils and monocytes along with the blood-meal.

**2. Development in sandfly.** In the midgut of sandfly, the amastigote forms become elongated and acquire a free flagellum, thus changing into the promastigote forms. These multiply by longitudinal binary fission. In 6 to 9 days, the number of parasites becomes enormous and they spread into the pharynx and buccal cavity. The salivary glands are not infected. Transmission into a new host occurs when such a heavily infested sandfly bites the host.

### Kala-azar or Dumdum Fever

**1. Occurrence.** Kala-azar, also known as Black fever or Dumdum fever, is a serious oriental disease of man. It occurs in India, China, Mediterranean countries and parts of Africa and South America. Its causative agent is a pathogenic flagellate, called *Leishmania donovani*, which is transmitted by the bite of small blood-sucking sandflies called *Phlebotomus argentipes*.



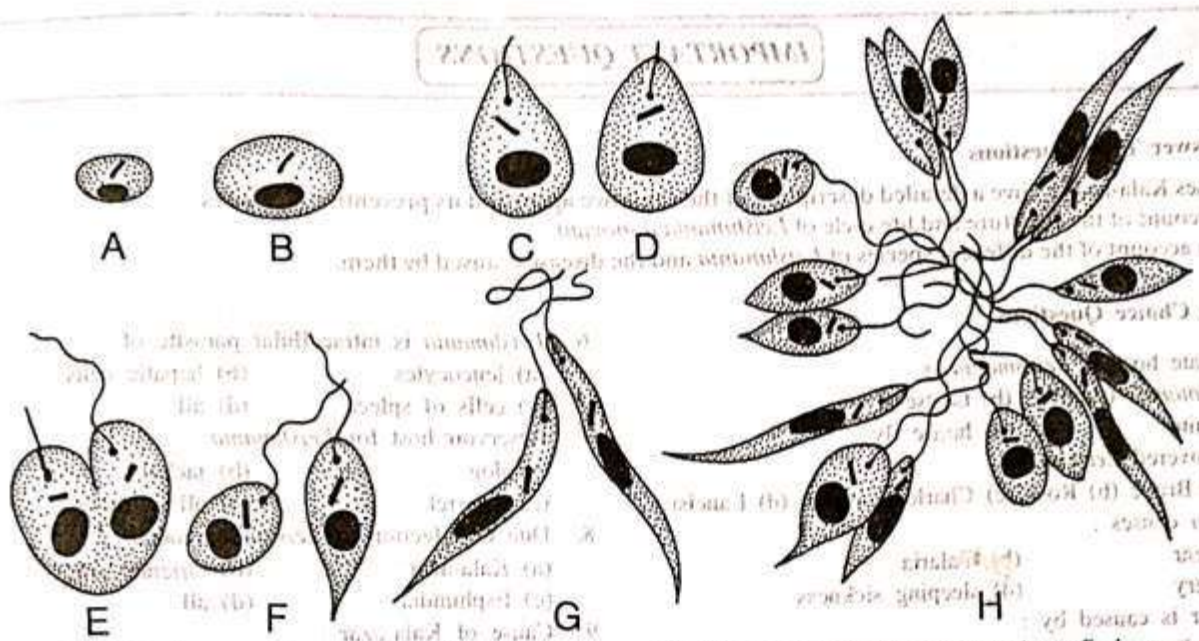


Fig. 5. *L. donovani*. Stages of development from amastigote to promastigote form and binary fission.

**2. Symptoms and pathogenesis.** Incubation period is long, from 3 to 6 months, and symptoms may appear even after 2 years. Early symptoms of Kala-azar include swelling, high fever and enlargement of spleen and liver. It is followed by general weakness, emaciation, anaemia due to reduction in number of blood cells, and a peculiar darkening of skin. The word "Kala-azar" has been derived from two Indian words, *kala* and *azar*, meaning "Black sickness". In advanced stage, skin becomes dry, rough and dark or pigmented. Hair becomes brittle and falls out. If not properly treated, the patient dies within 2 years. Death is generally due to secondary infections by bacteria or viruses. The defense mechanism of body becomes so weak that the patient is unable to resist them.

**3. Diagnosis.** Kala-azar can be diagnosed by microscopical examination of blood film or biopsy material taken from spleen or bone marrow of patient, for the presence of amastigote forms of *L. donovani*. Examination of W.B.C. count shows decrease of neutrophils but increase of lymphocytes and monocytes.

Number of erythrocytes (R.B.C.) is also decreased.

**4. Treatment (Therapy).** For treatment of Kala-azar, two groups of drugs are used. Pentavalent antimony compounds extensively used are sodium-antimony tartrate and gluconate, urea stibamine, aminostiburea, neostibosan, etc. Pentamidine isethionate is also used.

**5. Prevention (Prophylaxis).** Preventive measures include :

(a) **Eradication of the insect vector, i.e., sandfly.** In endemic areas, low trees and bushes, etc. should be cleared out. Periodic fumigation and spray of insecticides of sleeping quarters should be done.

(b) **Attack on the parasite.** In areas where dogs act as reservoir hosts, all street dogs should be killed. Control measure in India should be proper treatment campaign.

(c) **Personal defense.** For avoiding bite of sandflies, use mosquito-nets or screens and avoid sleeping on ground floors.

## IMPORTANT QUESTIONS

### » Long Answer Type Questions

1. What causes Kala-azar? Give a detailed description of the causative agent and its preventive measures.
2. Give an account of the structure and life cycle of *Leishmania donovani*.
3. Provide an account of the different species of *Leishmania* and the diseases caused by them.

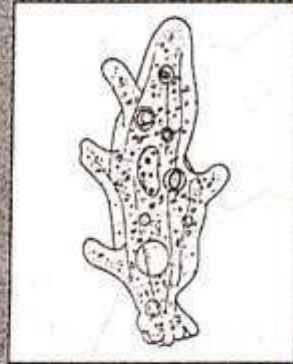
### » Multiple Choice Questions

1. Intermediate host of *Leishmania* is :  
(a) *Phlebotomus* (sandfly) (b) tse-tse fly  
(c) mosquito (d) house fly
2. Who discovered *Leishmania* :  
(a) David Bruce (b) Ross (c) Charles Laveran (d) Lancisi
3. *Leishmania* causes :  
(a) kala azar (b) malaria  
(c) dysentery (d) sleeping sickness
4. Black fever is caused by :  
(a) *Plasmodium* (b) *Trypanosoma*  
(c) *Giardia* (d) *Leishmania*
5. Leptomonad form of *Leishmania* is found in :  
(a) man (b) sandfly  
(c) tse-tse fly (d) bed bug
6. *Leishmania* is intracellular parasite of :  
(a) leucocytes (b) hepatic cells  
(c) cells of spleen (d) all
7. Reservoir host for *Leishmania* :  
(a) dog (b) jackal  
(c) squirrel (d) all of these
8. Due to infection of *Leishmania* occur :  
(a) Kala-azar (b) Oriental sore  
(c) Esphundia (d) all
9. Cause of Kala-azar :  
(a) *Leishmania donovani* (b) *L. infantum*  
(c) *L. chagasi* (d) *L. canis*
10. General body surface of *Leishmania* perform :  
(a) nourishment (b) respiration  
(c) excretion (d) all

### Answers

1. (a) 2. (b) 3. (a) 4. (d) 5. (b) 6. (d) 7. (d) 8. (d) 9. (a) 10. (d)

# *Amoeba proteus*



# 6

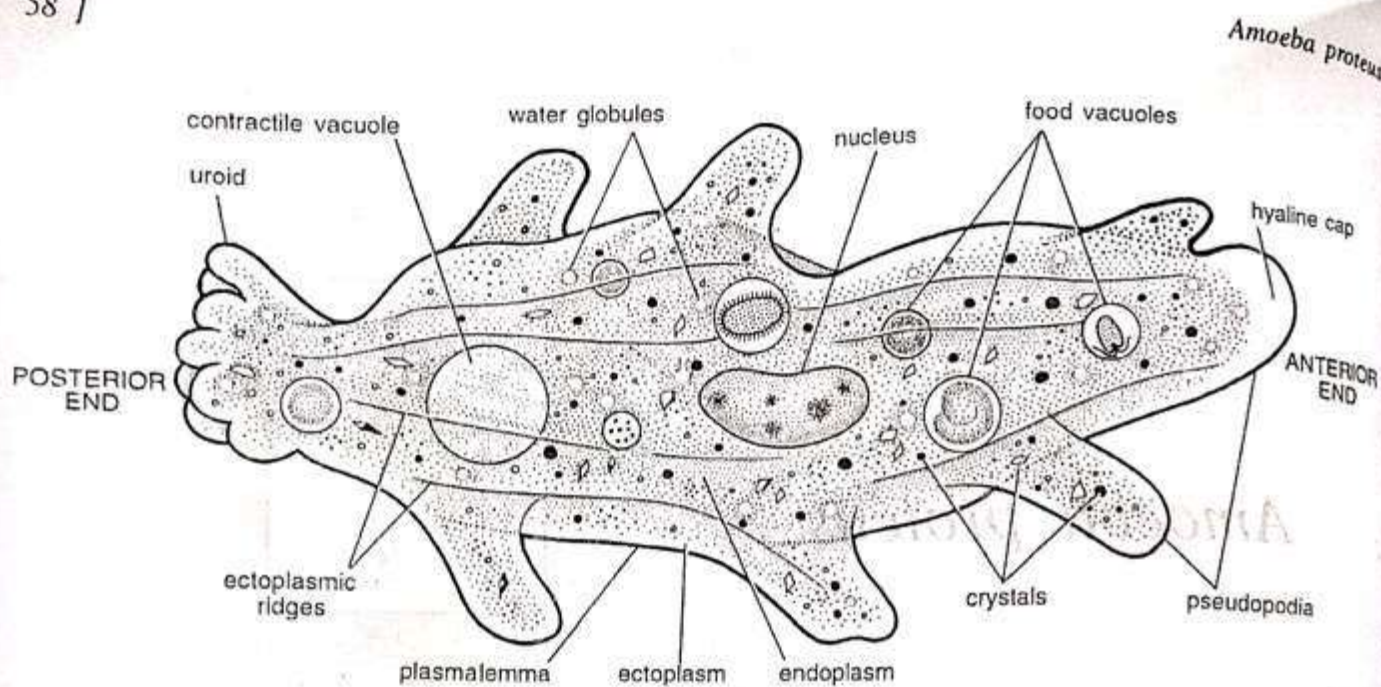
## Chapter

### *Amoeba proteus*

The name *Amoeba proteus* has been derived from two Greek words—*Amoeba* from *amoibe* which means change, and *proteus* after the name of the mythical Greek sea-god Proteus, who could change into any shape. Thus, the interesting feature associated with this animal is that it has no shape, or rather, its shape is constantly changing. *Amoeba* was first described by Rosenhof in 1755. H.I. Hirschfield (1962) has given a full and comprehensive account of the biology of *Amoeba*.

*Amoeba* is the most popular, free-living available protozoan. It is regarded as the lowest form of animal, as its body consists of a mere speck of protoplasm. The body resembles a tiny blob of jelly, and yet it contains all the equipment required by the organism to perform all the vital functions of life, such as movement, nutrition, respiration, excretion, reproduction, etc. It serves as an interesting and suitable material for laboratory studies by the students because it is a large protozoan, very slow in locomotion and easy to obtain.

*Amoeba* belongs to the superclass *Sarcodina*. There are several species of *Amoeba*, but most commonly studied, is the large freshwater species *Amoeba proteus*. This is also a useful experimental animal.

Fig. 1. *Amoeba proteus*.

### Systematic Position

Phylum	Protozoa
Subphylum	Sarcomastigophora
Superclass	Sarcodina
Class	Rhizopodea
Subclass	Lobosia
Order	Amoebida
Genus	<i>Amoeba</i>
Species	<i>proteus</i>

### Habits and Habitat

*Amoeba proteus* is widely distributed. It is commonly found on the bottom mud or on underside of aquatic vegetation in freshwater ponds, ditches, lakes, springs, pools and slow-running streams. It is rarely found in free water as it requires a substratum to glide on from place to place. It occurs in abundance in those waters which contain bacteria and organic substances such as aquatic vegetation, leaves and twigs. Sides of lotus ponds and water troughs are good places for their collection. It moves and feeds with the help of false feet or *pseudopodia*, formed as a result of streaming flow of cytoplasm. *Amoeba* has great power of regeneration. If an individual is cut into pieces, accidentally or in a laboratory, every piece containing a part of nucleus grows into a complete amoeba.

### Culture of *Amoeba*

*Amoeba* may be obtained for class study by scraping decaying vegetation from bottom of a pond. When the scraping is allowed to settle in a wide-mouthed container, amoebae of different kinds may be found in the sediment and sorted with the help of a fine pipette under a binocular microscope.

A temporary culture of amoeba can be prepared in laboratory by hay-infusion method. Decaying aquatic weeds or other organic substances such as hay, dry leaves, twigs, seeds, etc., are taken and boiled with sufficient amount of fresh water. To prepare culture medium, tap water should not be used because it is usually chlorinated. After boiling for about 15 minutes, water is filtered and the filtrate is allowed to cool. To this filtrate a few amoeba-rich water drops are added and the amoebae are allowed to multiply for 2 or 3 days. A culture can also be maintained in laboratory by keeping amoebae in small covered petri dishes containing a few boiled wheat grains. The latter serve as food for bacterial growth on which other micro-organisms feed and which in turn serve as food for amoebae. New culture should be started from time to time by putting together fresh wheat grains and a few amoebae from older cultures.

### Structure

1. **Shape and size.** *Amoeba* is a unicellular, microscopic animalcule and measures about 250 to 600 $\mu$  (microns) in maximum diameter. To the naked eye, the larger *Amoeba proteus* is just visible as a whitish blob. Under the microscope it appears as an irregular, colourless and translucent mass of protoplasm, continually

changing its shape by sending out and withdrawing finger-like processes, called *pseudopodia*. When it withdraws all its *pseudopodia*, it becomes spherical in shape.

Far from being shapeless, *Amoeba* is considered to have a definite polarity, i.e., it has definite anterior and posterior ends. At the anterior end, the animal puts out *pseudopodia*, while the posterior end is marked by a wrinkled region, called *uroid*.

**2. Pseudopodia.** *Pseudopodia* or *false feet* (Gr., *pseudo*, false + *podium*, foot) are irregular blunt processes of the cell body. These are of variable size and are capable of protruded or retracted, often with considerable speed. These are formed as a result of liquefaction and flowing forward of the cytoplasm. As many *pseudopodia* are formed simultaneously *A. proteus* is a 'polypodial' species. Its *pseudopodia* are large and broad with rounded tips. Such *pseudopodia* are called *lobopodia*. They move by 'pressure flow' mechanism and assist the animal in locomotion and food ingestion.

**3. Plasmalemma.** *Amoeba* possesses no pellicle or cell wall. The body is covered by a very thin, delicate plasma membrane or unit membrane, called *plasmalemma*. This membrane is selectively permeable, i.e., water and some small solute molecules can pass freely through it in both directions, but certain large molecules cannot pass. An unusual feature associated with *plasmalemma* is the presence of numerous fine, ridge-like extensions on its outer surface. Zoologists believe that these have adhesive properties and serve to bind the animalcule to the substratum.

**4. Cytoplasm.** Inside the *plasmalemma*, there is a dense mass of cytoplasm containing several organelles. It is differentiated into two fairly distinct zones, an outer *ectoplasm* and an inner *endoplasm*.

(a) *Ectoplasm.* Lying immediately beneath the *plasmalemma*, *ectoplasm* is thin, clear and transparent. It is somewhat rigid, contractile and under tension. It is most clearly visible at the tip of a *pseudopodium* where it forms a *hyaline cap*.

(b) *Endoplasm.* Completely surrounded by *ectoplasm*, the *endoplasm* forms the bulk of the animal. It is fluid-like, granular and

semi-transparent. As the *ectoplasm* is under tension, the *endoplasm* must also be under pressure of the *ectoplasm*.

According to Mast, *endoplasm* occurs in two colloidal states. The peripheral viscid or *gel state* is termed *plasmagel* and the central flowing or *sol state* is termed *plasmamol*. *Plasmagel* forms a tube, through which flows the *plasmamol*. The two colloidal states of *endoplasm* are inter-changeable. However, the electron microscope has not revealed the occurrence of two colloidal phases in *endoplasm*. It is believed that it is the *ectoplasm* which is in *gel state*, while the *endoplasm* is in *sol state*. According to De Bruyn, *protoplasm* can be thought of as a "three-dimensional network" of protein chains, linked together by cross-linkages of side chains. *Gel state* is due to protein chains fully expanded and *sol state* is the result of contraction of such chains.

**5. Endoplasmic organelles.** A number of organelles, visible under light microscope, are found within the *endoplasm*. These organelles comprise the nucleus, contractile vacuole, food vacuoles and water globules, etc.

(a) *Nucleus.* In *A. proteus*, nucleus is a single large flattened, discoidal and slightly biconcave disk like a human erythrocyte. It may be lying anywhere in the *endoplasm*. It may be difficult to see the nucleus in a living animal, but it can be easily seen with the phase contrast microscope or after fixing and staining the amoeba in a drop of *methyl green acetic acid*. The nucleus is granular and refractive to light. It is bounded by a thin *nuclear membrane* which is double and intercepted by pores. A honeycomb-like lattice is found below the inner nuclear membrane. It probably plays some part in maintaining the flattened form of the nucleus. The *nucleoplasm* is a clear achromatic substance with scattered refringent *chromatin granules*. A few nucleoli are seen in the nucleus of fixed and stained specimen, but they do not exist in the living animal.

(b) *Contractile vacuole.* The *endoplasm*, at its posterior end, contains a single, clear rounded and pulsating *contractile vacuole*, filled with a watery fluid and enclosed by a unit membrane. Surrounding this membrane is a region containing many tiny feeder vacuoles and mitochondria. It helps in the osmoregulatory and excretory activities of the animal.

(c) *Food vacuoles.* A number of spherical spaces, small and large, containing water and

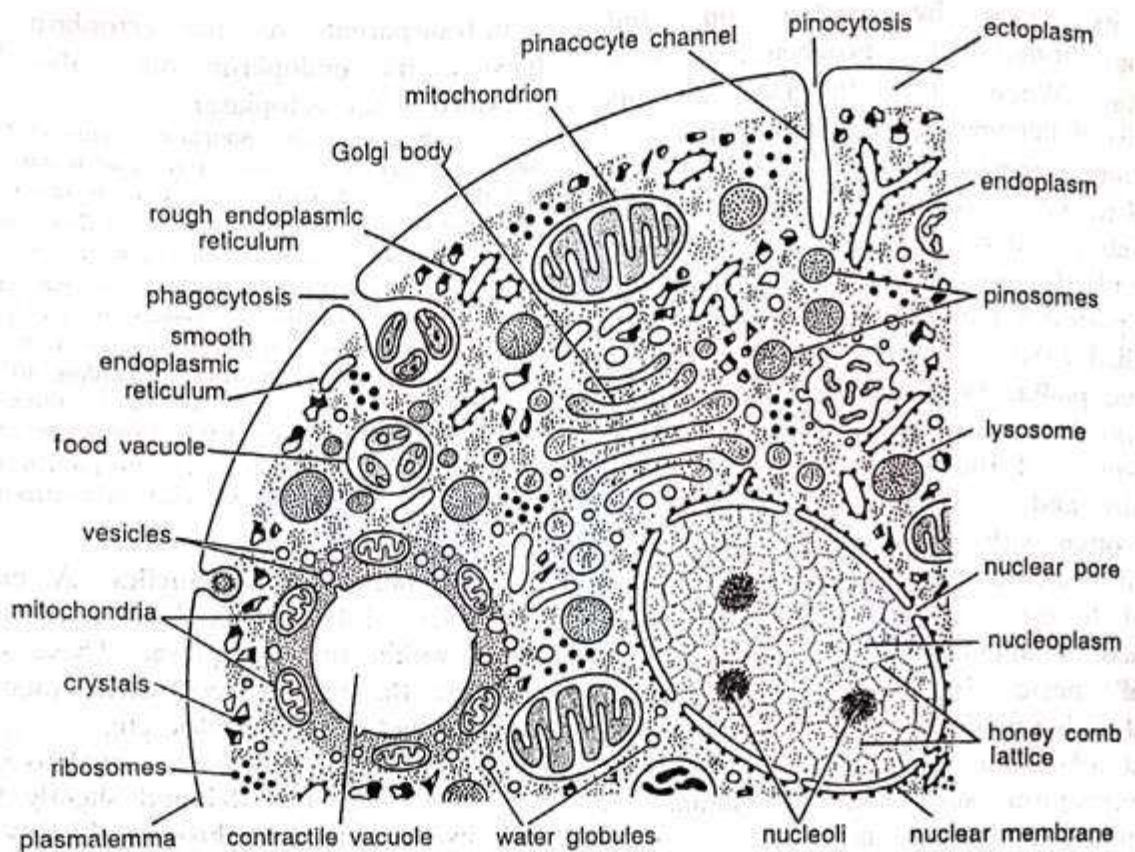


Fig. 2. *Amoeba*. A diagrammatic representation of the structure of a portion as revealed by electron microscopy.

food in various phases of digestion, occur in the endoplasm. These are the *food vacuoles*. These are formed when *Amoeba* engulfs food with a drop of water. Digestion takes place inside these *food vacuoles*. They disappear with the egestion of non-digestible food from the body.

(d) *Water globules*. These are several, small and spherical vacuoles filled with a colourless fluid.

(e) *Other organelles*. In addition to these organelles, the endoplasm shows, in electron microscope, various inclusions characteristic of an animal cell. The *endoplasmic reticulum*, besides forming a network of tubules, occurs as vesicles. The *ribosomes* occur on some of the endoplasmic vesicles as well as scattered in the endoplasm. The *Golgi bodies* are present as several groups of sac-like tubes. The *mitochondria* are more or less oval and have *tubular cristae*. Plate-like or bipyramidal *crystals* and stored food abound in the endoplasm. The *lysosomes* are membrane-bound spherical bodies, scattered in the endoplasm. Thin filamentous microtubules abound in the endoplasm.

## Locomotion

*Amoeba* shows characteristic *amoeboid movement* by the formation of finger-like temporary processes, the *pseudopodia*. These are broad and with rounded tips and are called *lobopodia*. These are formed as a result of flowing forward of cytoplasm. When moving, *Amoeba* may put out several pseudopodia but eventually progresses through just one broad anterior pseudopodium. *Amoeba* moves with an average speed of  $1\mu$  or one micron per second. Amoeboid movement is considered to be the most primitive kind of animal movement.

## Theories of amoeboid movement

How the cytoplasmic flow is effected and the pseudopodia are formed is not clearly known. Since the first observation of amoeboid movement by *Rosel von Rosenhof* in 1755, several theories, or hypotheses, have been proposed to explain the mechanism of *amoeboid movement*, but the evidence supporting them is unfortunately insufficient. A brief description of these theories is as under.

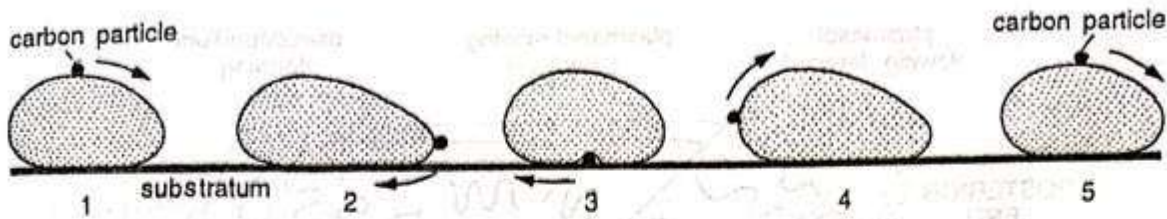


Fig. 3. *Amoeba verrucosa* showing rolling movement.

**1. Contraction-hydraulic theory.** Schultze (1875) was of the view that plasmagel (ectoplasm) undergoes contraction at the posterior end and causes protoplasmic currents to flow forwards, pushing the more fluid-like plasmasol (endoplasm) forward. This results in the formation of pseudopodium and propelling the body ahead.

**2. Surface-tension theory.** Berthold (1886) explained that the amoeboid movement is due to a difference in surface tension between the physical characteristics of body surface and substratum. According to this view, amoeboid movement is comparable with the movement of a fluid globule, like a mercury droplet. A pseudopodium is formed by an out flow of protoplasm (so-called fountain streaming) from a weak point where surface tension becomes reduced by external or internal factors. This theory had been supported by Rhumbler and Butschli (1898), but it is not supported now-a-days. The theory assumes a liquid nature of body surface, but in majority of amoeboid forms outer body surface remains rigid and gelatinized.

**3. Rolling movement theory.** Jennings (1904), with his investigations on *Amoeba verrucosa*, explained that amoeboid movement takes place due to rolling movement of body surface comparable to rolling movement of a fluid-filled sac on a substratum. He observed in *A. verrucosa* that a carbon particle on amoeba's upper surface first passes forward and then turning downwards along the anterior tip, remains on the lower surface for a time as the body rolls forward, and then passes upward at the posterior end to repeat the cycle.

Jenning's finding may be correct for *A. verrucosa* which is devoid of pseudopodia, but it cannot be applied to *A. proteus* which moves with pseudopodia.

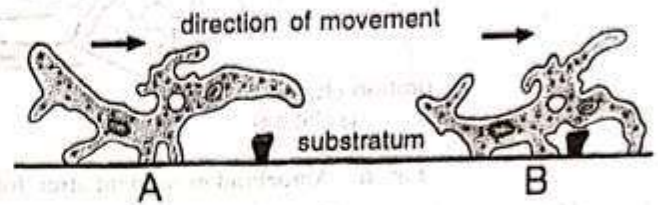


Fig. 4. *Amoeba* showing walking movement.

**4. Walking movement theory.** Dellinger (1906) studied locomotion in *A. proteus* and came to the conclusion that a contractile substance present in the cytoplasm is mainly responsible for the amoeboid movement. According to this theory, the extended pseudopodia become attached to the substratum and then contract to pull the body forward. Seen in a profile, amoeba appears to walk on its leg-like pseudopodia.

**5. Sol-gel theory.** This theory, first put forward by Hyman (1917) and later supported by Pantin (1923-26) and Mast (1925), is the most widely acceptable view, now-a-days. It attributes amoeboid motion to a change in the consistency of cytoplasm. Based on spontaneous sol-gel phenomenon of protoplasm, it offers the best explanation for amoeboid locomotion.

According to this theory, cytoplasm of amoeba is differentiated into a clear outer *ectoplasm* and a granular inner *endoplasm*. The latter is further distinguished into an outer stiffer and jelly-like region, the *plasmagel*, and an inner fluid region, the *plasmasol* (Mast, 1925).

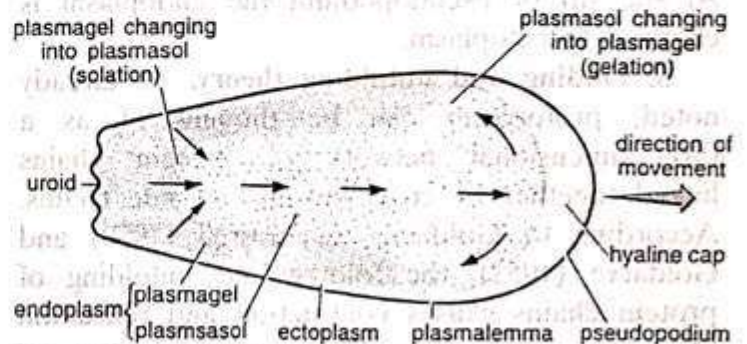


Fig. 5. Amoeboid movement after 'sol and gel' theory by Mast.

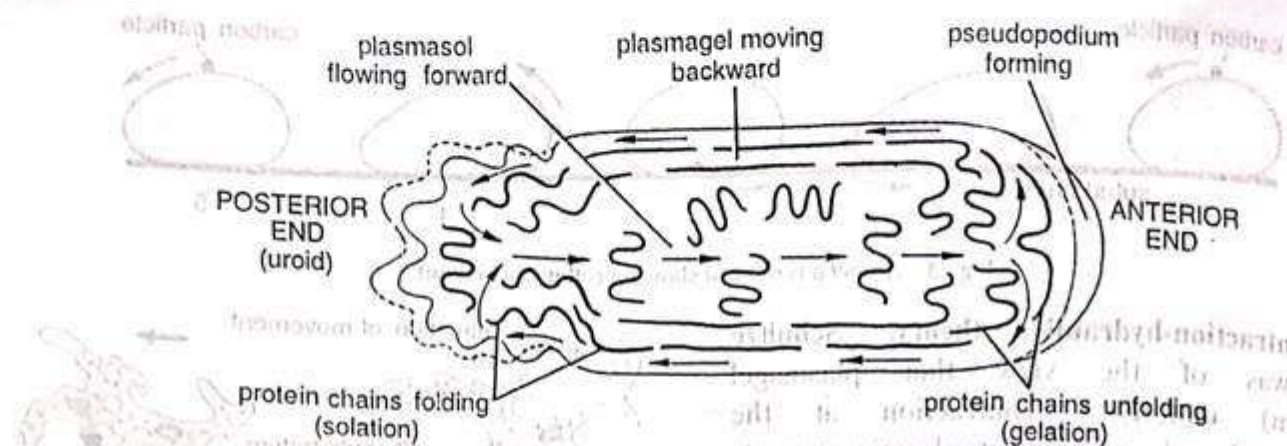


Fig. 6. Amoeboid movement after 'folding and unfolding' theory by Goldacre and Lorch.

According to the *sol-gel* or *change of viscosity theory*, amoeboid movement involves four processes occurring simultaneously: (i) The outermost thin, elastic cell membrane or *plasmalemma* becomes attached to the substratum. (ii) There is a local partial liquefaction of the plasmagel at the anterior end. 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 pseudopodium. As plasmasol enters the newly formed pseudopodium, it rapidly changes into plasmagel around the periphery, thus forming a gelatinized tube within which the plasmagel continues to flow forward. (iii) Posteriorly, inner surface of contractile plasmagel undergoes *solation*, so that a constant flow of plasmasol is maintained from behind forwards, in the direction of movement. (iv) The outer tube of elastic plasmagel contracts and moves from in front backwards, while the main bulk of body travels forwards. The plasmagel thus exerts a squeezing motion from the sides and rear of amoeba, forcing the plasmasol ahead. At the tip of pseudopodium the endoplasm is changed to ectoplasm.

**6. Folding and unfolding theory.** As already noted, protoplasm can be thought of as a three-dimensional network of protein chains linked together by cross linkages of side chains. According to Goldacre and Lorch (1950) and Goldacre (1952), the folding and unfolding of protein chains causes contraction and relaxation of protein molecules. They suggested that *sol*

state of protoplasm is due to the folding of protein molecules and *gel* state is due to their unfolding. When amoeba progresses, the cortical plasmagel at the posterior end contracts (*folding*). It is then liquefied to form *plasmasol* which is forced through the central endoplasm to flow forward. At the anterior end the plasmasol is converted back into plasmagel (*unfolding*), which forms the advancing pseudopodium. For the folding and unfolding processes, a considerable amount of energy is invested which comes from ATP (adenosine triphosphate).

**7. Front or fountain-zone contraction theory.** Allen (1961) suggests that, on the molecular level, amoeboid movement is a type of slow contraction, similar in many ways to muscle contraction. The endoplasm is believed to contain long protein chains, which undergo contraction at the anterior end of the body so that the amoeba is pulled forward. It visualises the axial stream of endoplasm diverted in regular streamlines, thus creating a *fountain zone*; the endoplasm is constantly converted to ectoplasm anteriorly and ectoplasm to endoplasm posteriorly.

**8. Reversible gel-sol transformation theory.** Advocated by Yagi (1961) and Marsland (1964), this theory is the most accepted explanation of amoeboid movement. This theory suggests that *solation* at the anterior end occurs into which endoplasm flows under pressure generated by contraction of the cortical plasmagel at the posterior end. This results in propulsion of amoeba.



**Nutrition**

**Food and selection of food.** *Amoeba* is carnivorous and its mode of nutrition is *holozoic*, i.e., it feeds by *phagocytosis*, a mechanism in which food is engulfed in a solid form. The food consists of bacteria, diatoms, desmids, flagellates, ciliates and rotifers. *Amoeba* is able to select its food even in the absence of special sense organs. It displays its preference for certain kinds of organisms whom it approaches, and avoids others. It is also able to distinguish organic food particles from inorganic sand particles.

**2. Ingestion.** *Amoeba* captures and engulfs its prey by means of pseudopodia. Pseudopodia are formed at the points, where the food comes in contact with the surface of the body.

According to Rhumbler (1930), *Amoeba* can ingest food in four possible ways, depending on the nature of food.

**1. Import.** This method involves the taking in of food, such as an algal filament, on contact. The food passively sinks into the body by rupturing the plasmalemma and ectoplasm at the point of contact. The ruptured site soon heals up.

**2. Circumfluence.** When amoeba comes in contact with a less active or motionless organism, like bacteria, it extends its pseudopodia around the organism and envelops it completely in a *food vacuole* within cytoplasm. The enveloping pseudopodia always maintain intimate contact with the surface of prey.

**3. Circumvallation.** By this method, amoeba engulfs an active prey like a flagellate or ciliate. *Amoeba* sends out pseudopodia around the prey forming a cup-like structure, called *food cup*. The pseudopodia are not in intimate contact with the prey during engulfment. The opening of food cup constricts, leaving a pore which soon closes. In this way, a non-contractile *food vacuole* is formed with the prey in a considerable amount of water.

**4. Invagination.** In this method the food is adhered by the toxic and sticky secretion of the ectoplasm. The food organism is sucked in, upon contact with the ectoplasm, by the formation of an *ectoplasmic tube*. This tube, upon engulfment, takes the form of a food vacuole.

**5. Pinocytosis.** Pinocytosis is the 'cell drinking' phenomenon also round to occur in *A. proteus*. It assists in the ingestion of liquid food. It has been experimentally demonstrated that pinocytosis is induced by proteins, inorganic ions and certain dyes. When an amoeba, which has been starved for two days, is placed in one per cent sodium acetate solution, it becomes star-shaped with pseudopodia-like projections. Many of these projections show to contain *pinocytosis channels* running from the surface deep into the body. It is thought that plasmalemma bound with colloidal material flows into the pinocytosis channels. From the inner ends of these channels, *pinocytosis vesicles* or *pinosomes*, containing engulfed liquid material, become separated off. It has not yet been confirmed whether this

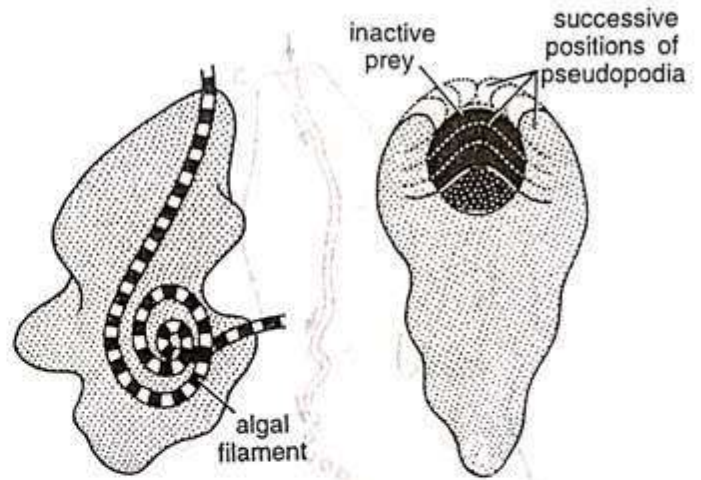


Fig. 7. *Amoeba* ingesting an alga by import.

Fig. 8. *Amoeba* feeding by circumfluence.

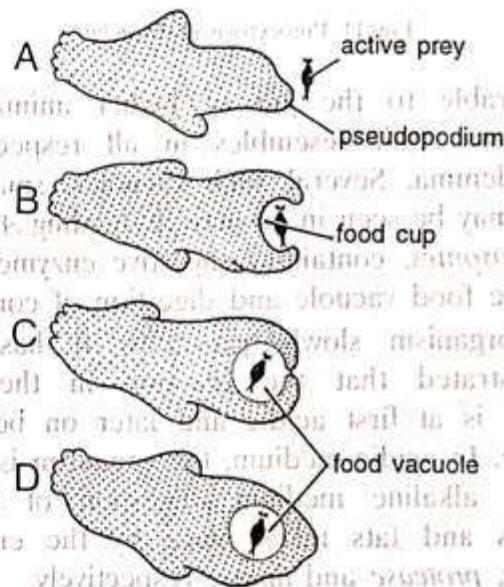


Fig. 9. *Amoeba* ingesting a rotifer by circumvallation.

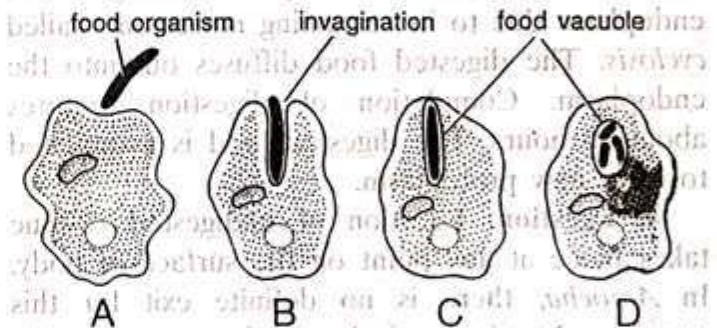


Fig. 10. *Amoeba* ingesting food by invagination.

This phenomenon is one of the means of ingestion of food in *Amoeba* under normal conditions.

**2. Digestion.** The *food vacuole* or the *gastric vacuole*, formed by the extension and joining of the pseudopodia that capture the prey, is

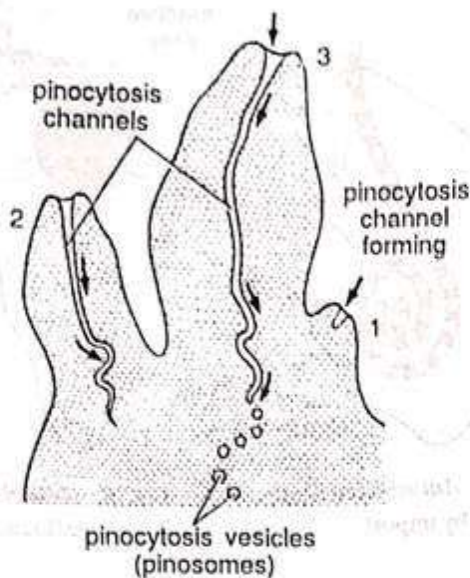


Fig. 11. Pinocytosis in *Amoeba*.

comparable to the gut of higher animals. Its membrane wall resembles in all respects the plasmalemma. Several such vacuoles, small and large, may be seen in an actively feeding *Amoeba*.

**Lysosomes**, containing digestive enzymes, fuse with the food vacuole and digestion of contained food organism slowly proceeds. It has been demonstrated that the reaction in the food vacuole is at first acidic and later on becomes alkaline. In acidic medium, the organism is killed and in alkaline medium, digestion of starch, proteins and fats takes place by the enzymes *amylase*, *protease* and *lipase*, respectively.

**3. Absorption and assimilation.** As digestion goes on, the food vacuoles gradually shrink in size. The food vacuoles keep on moving in the endoplasm due to its streaming movement, called *cyclosis*. The digested food diffuses out into the endoplasm. Completion of digestion requires about 30 hours. The digested food is assimilated to form new protoplasm.

**4. Egestion.** Egestion of undigested residue takes place at any point on the surface of body. In *Amoeba*, there is no definite exit for this purpose. In the actively moving amoeba the much reduced food vacuoles, containing undigestible residue, are shifted backwards and discharged at the posterior end, as the animal moves on.

(Z-1)

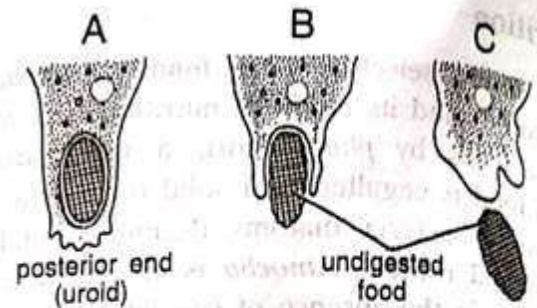


Fig. 12. *Amoeba* showing stages of egestion of undigested food.

## Respiration

Interchange of oxygen coming inwards and carbon dioxide going outwards forms the process of respiration. *Amoeba* has no special respiratory organs and no respiratory pigments but there is a free exchange of gases by diffusion through the general body surface (plasmalemma) which is permeable to the gases dissolved in water. Oxygen constantly diffuses into the cytoplasm for its concentration in water is always higher than in the cytoplasm. The oxygen brings about enzymatically assisted oxidation of carbohydrates, fats and even proteins and breaks them into simpler compounds. The energy liberated in the oxidation reactions is stored in the high energy bonds of adenosine-triphosphate or ATP, like that of any other cell. The oxidation of carbohydrates and fats results in the formation of metabolic wastes (carbon dioxide and water).  $\text{CO}_2$  diffuses out in the surrounding water as well as in the water discharged by the contractile vacuole.

## Excretion

In the body, metabolism of fats and carbohydrates produces  $\text{CO}_2$ , whereas metabolism of proteins produces ammonia. Removal of nitrogenous wastes from body is called *excretion*. *Amoeba* is an *ammonotelic* animal because it excretes nitrogenous wastes in the form of ammonia. As no special organelles are present for excretion, ammonia is excreted by diffusion from the general body surface in the surrounding water. Some amount of ammonia is

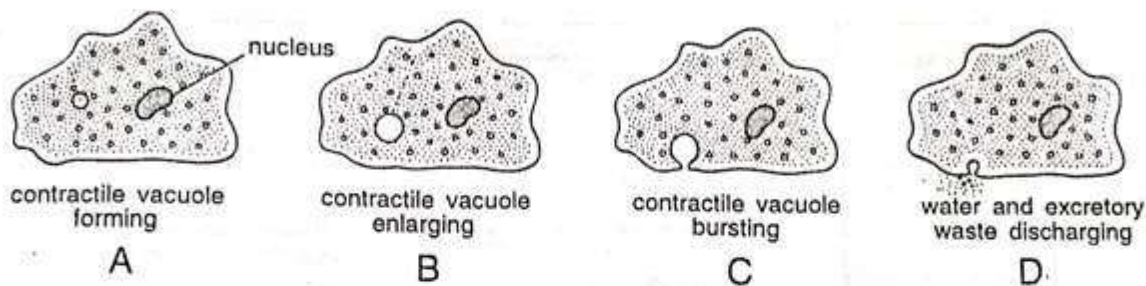


Fig. 13. *Amoeba* showing various stages of osmoregulation and excretion.

dissolved in water which is discharged through the contractile vacuole.

### Osmoregulation

The protoplasm of *A. proteus* is of higher concentration than the freshwater of its environment. This causes the entrance of water into the body of amoeba by *endosmosis* through the semi-permeable plasmalemma. Not only does water enter in by endosmosis but also some water is formed within the cytoplasm as a result of metabolic activity and some gets in along with ingested food organisms. This necessitates to get rid of excess water to prevent swelling and rupture of amoeba's body. The mechanism which effects the water regulation is called *osmoregulation*. It takes place through the contractile vacuole. The main function of contractile vacuole is osmoregulation, although  $\text{CO}_2$  and nitrogenous waste substances are also excreted through it.

The exact nature regarding the working of contractile vacuole is not known. Amoeba is *hypertonic* to the surrounding water, so that water is actively secreted into contractile vacuoles by endosmosis through vacuolar membrane. Tiny membrane-bound water-filled feeder vacuoles also get incorporated into contractile vacuole filling it with water. As water continues to fill the vacuole, it increases in size. When the vacuole becomes fully expanded, it comes to lie in the zone of gelated ectoplasm, where the ectoplasmic pressure results in its contraction and bursting. This contractile vacuole disappears and a new one begins to form in the endoplasm. Due to force of contraction, the contents of contractile vacuole, that is  $\text{H}_2\text{O}$ ,  $\text{CO}_2$ , ammonia, etc. are discharged to outside.

### Behaviour

Behaviour involves the manner in which an animal responds to the environmental conditions. The responses to stimuli are called *taxes* (singular, *taxis*). A taxis may be either *positive*, in which the organism moves towards the stimulus, or *negative*, in which the organism moves away from the stimulus. *Amoeba proteus* shows both types of taxes, positive as well as negative, specifically to different stimuli. There are two views as to the effectiveness of the responses. According to one view, the response of *Amoeba* to a given stimulus is automatic or directed (*topotaxis*), that is, amoeba either moves towards the stimulus or avoids it, depending upon the nature of the stimulus. Another view holds that response to a stimulus is undirected (*phobotaxis*), that is, amoeba always avoids a stimulus and moves here and there to get a favourable environment (Fig. 14).

Taxes are named according to the nature of stimulus. With respect to the kinds of stimuli, taxes are classified as follows :

1. **Thermotaxis** (response to heat). *Amoeba* responds negatively to both low and high temperatures. Optimum temperature lies between  $20^\circ\text{C}$  and  $25^\circ\text{C}$ . It ceases all activities at temperatures above  $35^\circ\text{C}$ .
2. **Phototaxis** (response to light). *Amoeba* avoids both direct sunlight and total darkness. It responds positively to normal or weaklight.
3. **Thigmotaxis** (response to contact). A floating *Amoeba* responds positively to those objects upon which it glides or rests. It will back away from contact with a foreign object or a probe while crawling or resting.
4. **Chemotaxis** (response to chemical substances). *Amoeba* is negatively chemotactic to strong solutions of alkalis, salts and sugars. It also avoids sand particles or some other obstacles in the way. It responds positively to the food organisms.

TAXIS	REACTION	
	NEGATIVE	POSITIVE
THERMOTAXIS (temperature)	<p>10°C      35°C</p> <p>moves away</p>	<p>25°C</p> <p>optimum temperature</p>
PHOTOTAXIS (light)	<p>strong light      dark</p> <p>moves away</p>	<p>weak light</p> <p>attracted</p>
THIGMOTAXIS (touch)	<p>pricked with a probe when settled</p> <p>avoided</p>	<p>leaf      floating</p> <p>attracted</p>
CHAEMOTAXIS (chemicals)	<p>acetic acid</p> <p>quickly withdraws</p>	<p>food</p> <p>attracted</p>
GALVANOTAXIS (electric current)	<p>anode (+)</p> <p>avoided</p>	<p>cathode (-)</p> <p>attracted</p>
GEOTAXIS (gravity)	<p>floating</p>	<p>settles to bottom and moves away</p>
RHEOTAXIS (water current)	<p>float along water current</p>	

Fig. 14. *Amoeba*. Reactions to various stimuli.

5. **Rheotaxis** (response to current of air or water). *Amoeba* prefers to be drifted along the flowing water.

6. **Galvanotaxis** (response to constant electric current). When an electric current is passed through water, containing *Amoeba*, it stops moving, withdraws pseudopodia and becomes globular. In a weak electric current it moves towards negative pole (cathode) and avoids positive pole (anode).

7. **Geotaxis** (response to gravity). The response of *Amoeba* to gravity is mostly positive as it drops to the bottom of container filled with water.

(Z-1)

*Amoeba* does not have a nervous system and special sense organs for the condition and perception of stimuli. The sensitivity is solely the function of the protoplasm.

### Reproduction

*Amoeba proteus* does not reproduce sexually by mating, that is, by the fusion of sex cells or gametes. Reproduction is essentially asexual and

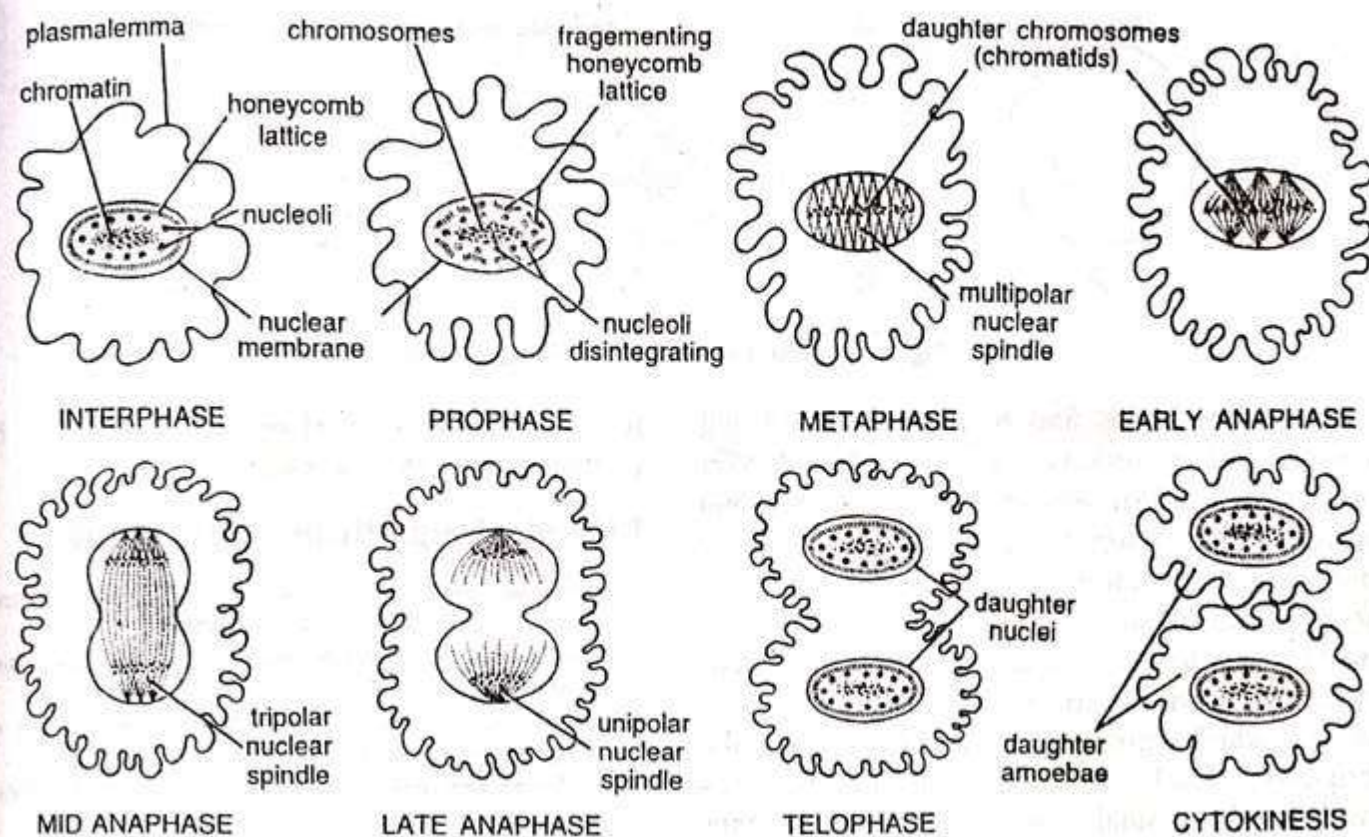


Fig. 15. *Amoeba*. Stages in binary fission.

takes place by various methods such as binary fission, multiple fission and sporulation.

1. **Binary fission.** It is the most common mode of reproduction. It results in the division of parent amoeba into two daughter amoebae. Division involves the nuclear division followed by cytoplasmic division. The animal divides by mitosis and involves the stages prophase, metaphase, anaphase and telophase. (Fig. 15).

(a) **Prophase.** In the prophase stage, amoeba withdraws its pseudopodia and becomes somewhat rounded. Cytoplasm loses its transparency to a large degree and contractile vacuole disappears. The honeycomb-like lattice underneath nuclear membrane first fragments and then disappears. The nucleoli disintegrate. A very large number (500 to 600) of very small chromosomes emerge in the central nucleoplasm.

(b) **Metaphase.** The metaphase stage is marked by the arrangement of chromosomes at the equator. Each chromosome splits longitudinally and becomes paired. Daughter chromosomes, on each side, become attached to the spindle fibres arising from multiple poles, situated within the nuclear membrane.

(c) **Anaphase.** In the anaphase stage, daughter chromosomes move towards opposite poles and constriction of nuclear membrane begins in the middle. Nuclear spindle, which was *multipolar* at metaphase, becomes *unipolar* at the end of anaphase.

(d) **Telophase.** During telophase stage, the constriction of nuclear membrane is completed and the nucleus is finally divided into two daughter nuclei. In each daughter nucleus the lattice is formed underneath the nuclear membrane and the nucleoli reappear.

(e) **Cytokinesis.** Next follows cytokinesis. Amoeba stretches and constricts in the middle. Large pseudopodia are formed at opposite poles, drawing both the daughter amoebae in opposite directions. It ultimately divides parent amoeba into two daughter amoebae which grow, and in their turn, repeat the same cycle of binary fission.

In *Amoeba*, reproducing by binary fission, the parent becomes wholly merged in the offspring. Thus, there exists a continuity of life, so that *Amoeba* is potentially immortal. However, death may come by starvation, accident or some other misfortune.

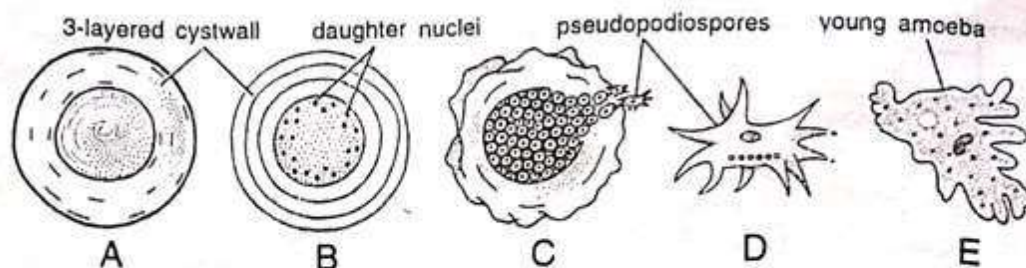


Fig. 16. *Amoeba*. Encystment and multiple fission.

**2. Multiple fission and encystment.** According to some earlier workers, such as Scheel (1899) and Carter (1915), *Amoeba* forms a cyst and reproduces by *multiple fission*, during adverse environmental conditions. The animal secretes a three-layered, protective, chitinous cyst around it and becomes inactive. Inside the cyst, the nucleus repeatedly divides to form several daughter nuclei, which arrange themselves near the periphery. Each daughter nucleus becomes enveloped by a small amount of cytoplasm, thus forming a daughter amoeba, called *amoebula* or *pseudopodiospore*. When favourable conditions arrive, the cyst breaks off liberating the young pseudopodiospores, each with fine pseudopodia. They feed and grow rapidly to become adults and lead an independent life.

Multiple fission, preceded by encystment is no longer believed to occur in *Amoeba* by modern workers, some of them maintained *A. proteus* for 28 years without ever forming a cyst.

**3. Sporulation.** According to Taylor, during unfavourable conditions, *A. proteus* multiplies by sporulation without encystment. Nucleus breaks into several small fragments or *chromatin blocks*. Each block develops a nuclear membrane, becomes surrounded by a little cytoplasm and develops a *spore-case* around it. With the disintegration of parent body, about 200 such spores are liberated, each hatching into a small *amoebula* under favourable conditions. However, evidence has been lacking in support of sporulation in *Amoeba*.

**4. Conjugation.** Some observers have described a temporary fusion between two amoebae. After some time they become separated again. It is said that this temporary union enables the two amoebae to lead a more active and vigorous life. This phenomenon is

termed *rejuvenation*. However, it has not been confirmed by other workers.

### Biological Significance of *Amoeba*

- (1) *Amoeba* depicts organization of a protoplasmic mass or a single cell into a complete organism.
- (2) Binary fission of *Amoeba* gives a clear-cut understanding of the mitotic division of a cell.
- (3) The taxes or responses of *Amoeba* represent the early beginning of sensitivity in animals.
- (4) Different organelles of *Amoeba* give the first indication of division of labour concerning vital activities.
- (5) The great number of chromosomes (500 to 600) present in the nucleus of *Amoeba* suggests the occurrence of isolated genes, which in higher animals are located in chromosomes.
- (6) *Amoeba* gives a faint idea regarding the anatomical structures of higher animals. For example, the food cup is comparable to the buccal cavity, food vacuole to gut, pseudopodia to legs, contractile vacuole to urinary bladder or kidney, and so on.

### Other Species of *Amoeba*

Numerous species, marine as well as freshwater, belong to the genus *Amoeba*. They greatly vary in their shape, size and in the characters of the nucleus and pseudopodia.

**1. *Amoeba proteus*.** First described by Leidy in 1877, is perhaps the commonest and one of the largest freshwater species. This species is also used for teaching and demonstration of living protozoans in the class. The body is about 0.6 mm in diameter and provided with a few large and blunt pseudopodia. A characteristic feature is the presence of definite longitudinal ectoplasmic ridges. The nucleus is biconvex, lens-shaped or disc-like, and may become folded and convoluted in older forms. According to Taylor, this species forms endogenous spores in an unencysted condition. It does not normally feed upon diatoms.

**2. *Amoeba verrucosa*.** It is another common freshwater species. The body, having a wrinkled surface, is nearly 0.2 mm. in diameter. The pellicle is tough and the pseudopodia are many, short and blunt. The nucleus is ovoid and contains a large endosome. The movements of this species are very sluggish. It covers the distance of about 0.5 $\mu$  in a second.

**3. *Amoeba discoides*.** It has a body about 0.4 mm in diameter and with only a few blunt pseudopodia. The biconcave, discoidal nucleus never becomes folded like that of *A. proteus* and the ectoplasmic ridges are also not known.

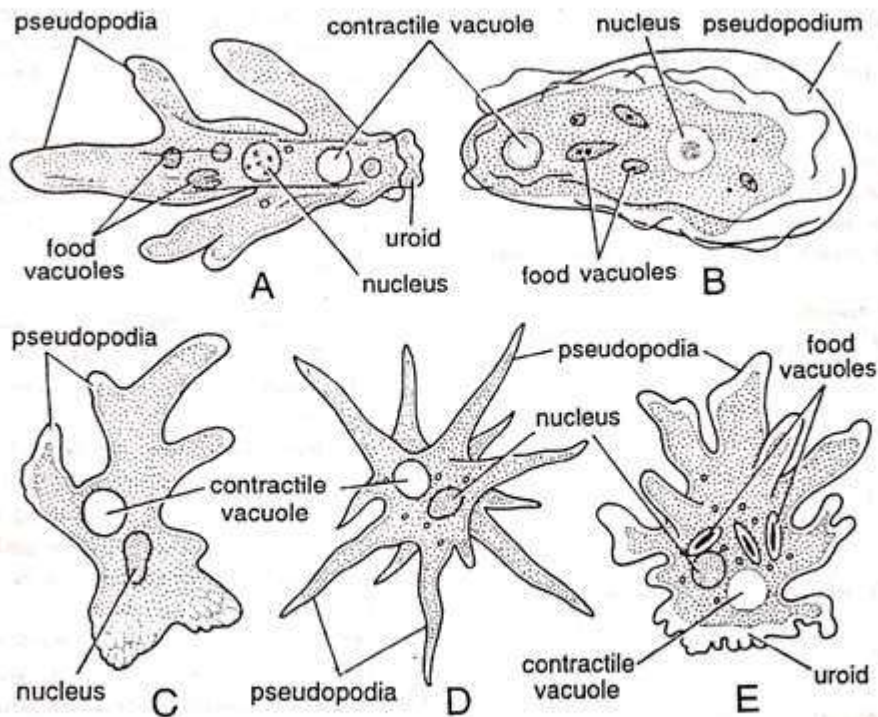


Fig. 17. Some common species of *Amoeba*. A—*A. proteus*. B—*A. verrucosa*, C—*A. discoides*. D—*A. radiosa*. E—*A. dubia*.

4. *Amoeba radiosa*. It is also a small freshwater species up to 0.04 mm in diameter. The body is oval but the animal looks star-shaped on account of the presence of slender, radiating pseudopodia, which may be stiff and straight or curved and tapering.

5. *Amoeba dubia*. It is about 0.4 mm in diameter with a smooth body surface and forming several flat pseudopodia. The nucleus looks spherical in front view but oblong in

profile. The endoplasm is laden with a few large particles of various shapes. Diatoms form an important item of their diet.

6. *Amoeba terricola*. This species occurs in damp earth.

The atmosphere contains the spores or cysts of *Amoeba* in large numbers. Several species of allied genera are also commonly known as amoebae e.g., *Entamoeba histolytica*, *Pelomyxa palustris*, etc.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

- Describe the habit, structure, physiology and behaviour of *Amoeba*.
- Give an account of the structure of *Amoeba proteus* as seen under the electron microscope. How would you distinguish *Amoeba* from a typical animal cell?
- Write detailed notes on : (i) Locomotion in *Amoeba*, (ii) Modes of reproduction in *Amoeba*, (iii) Nucleus of *Amoeba*, (iv) Osmoregulation in *Amoeba*,
- Justify the statement that "binary fission in *Amoeba* is essentially an act of mitosis."
- Discuss the biological significance of *Amoeba*.
- Write short notes on : (i) Amoeboid movement, (ii) Circumvallation, (iii) Contractile vacuole, (iv) Holozoic nutrition, (v) Lobopodia, (vi) Pinocytosis, (vii) Plasmalemma, (viii) Phototaxis.

#### » Short Answer Type Questions

- What is the mode of nutrition in *Amoeba*?
- What is the function of contractile vacuole in *Amoeba*?
- What are the pseudopodiospores in *Amoeba* and why they are essential in reproduction?
- Explain the formation of pseudopodia basing on the sol-gel theory.
- How *Amoeba* feeds on flagellates and ciliates?
- Describe sporulation in *Amoeba*.
- Who was describe *Amoeba* first?
- How are the culture of *Amoeba* in laboratory?
- What is a hyaline cap?
- Who was observed first to amoeboid movement?

## » Multiple Choice Questions

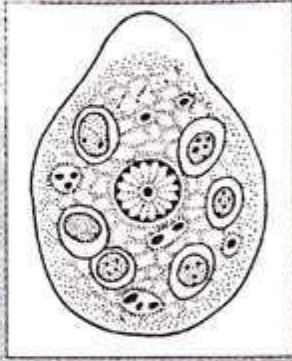
- The fresh water *Amoeba* and intestinal *Amoeba* are alike in :
  - the possession of single contractile vacuole
  - the absence of cilia
  - the structure of the cyst
  - their mechanism of dispersal
- Amoeba* is capable of regeneration. This is possible only from :
  - a nucleated bit of *Amoeba*
  - an anucleate bit of *Amoeba*
  - a young *Amoeba*
  - an old *Amoeba*
- Name a digenic parasite from protozoa :
  - Entamoeba histolytica*
  - Polystomella*
  - Plasmodium*
  - Copromonas*
- Amoeba* was discovered by :
  - Ross
  - Rosenhoff
  - Lamble
  - Loesch
- During extreme heat a fresh water *Amoeba* living in a pond :
  - will form a gamete
  - will form a cyst
  - change to parasitic phase
  - will eliminate large parts of DNA
  - elimination of excessive food
- The food capturing organelle of *Amoeba* is :
  - food vacuole
  - contractile vacuole
  - pseudopodia
  - nucleus
- Which is the most widely accepted theory of locomotion in *Amoeba*?
  - Walking movement theory
  - Rolling movement theory
  - Sol-gel theory
  - Surface tension theory
- Which type of pseudopodium is found in *Amoeba*?
  - Rhizopodium
  - Actinopodium
  - Reticulopodium
  - Axopodium
- Surface tension theory explains the theory of :
  - amoeboid movement
  - caterpillar movement of *Hydra*
  - ciliary beat
  - jerking movement of *Euglena*
  - tension development on the surface during the movement of *Paramecium* in water
- Many genera of foraminifera are dimorphic. What is meant by dimorphism :
  - existence of an animal in many forms
  - presence of two types of pseudopodia in foraminifera
  - existence of an animal in two forms which differ in characters
  - presence of different types of organelle in the same animal
  - alternation of generation is known as dimorphism
- Sol-gel theory was first given by :
  - Pantin
  - Hyman
  - Mast
  - Mast & Pantin
- Pseudopodia are formed in an *Amoeba* :
  - when it comes in contact with a food particle
  - by the movement of the surrounding water
  - by exchange of salts with the medium
  - by sol-gel transformation of the cytoplasm
- Amoeba* is placed in phylum Protozoa, because of :
  - presence of cell wall
  - phagocytic mode of nutrition
  - acellular body
  - presence of contractile vacuole
- Egestion of undigested food in *Amoeba* takes place through :
  - circumvallation
  - a temporary rupture of its surface membrane
  - the hyaline cap formed at its advancing end
  - pinocytosis
- Amoeba* reacts :
  - negatively to both weak and strong light
  - positively to strong light and negatively to weak light
  - positively to both weak and strong light
  - negatively to strong light and positively to weak light
- '*Amoeba* is immortal', it can be explained by Germplasm theory of :
  - Heitzman
  - Schultz
  - Berthold
  - Weisman
- Amoeba* belongs to class Sarcodina, which is characterised by :
  - acellular body
  - pseudopodia for locomotion
  - uninucleate body
  - presence of contractile vacuole
- Normally *Amoeba* is not found :
  - crawling
  - feeding
  - secreting a cyst
  - responding to stimuli
- Body of *Amoeba* has permanent :
  - shape
  - organelle for locomotion
  - anterior end
  - food vacuole
- A contractile vacuole is developed when :
  - fresh water *Amoeba* is placed in sea water
  - fresh water *Amoeba* is placed in salt free water
  - marine *Amoeba* is transferred in hypotonic medium
  - sea water enters in body of marine *Amoeba*
- Amoeba* shows positive response for :
  - dim and intense light
  - solid objects
  - cathode
  - chemicals
- Minimum number of daughter amoebae are produced when surrounding water has :
  - no food
  - less food
  - plenty of food
  - high temperature
- Simplest mode of locomotion is :
  - swimming
  - creeping
  - floating
  - walking
- Plasmalemma of *Amoeba* is :
  - impermeable
  - least regenerative
  - site for excretion
  - not for respiration
- If an *Amoeba* is kept in distilled water its contractile vacuole will :
  - disappear
  - become swollen and full of water
  - work faster
  - have no effect
- Regarding locomotion in *Amoeba* Hymen (1917) postulated :
  - theory of rolling movement
  - surface tension theory
  - walking movement theory
  - sol-gel theory
- If an *Amoeba* is put in medium A from fresh water its contractile vacuole disappeared but when it is transferred



- to medium B its contractile vacuole reappeared. What is the difference between medium A and B :
- (a) medium A is hypotonic  
 (b) medium B is hypertonic  
 (c) medium A is hypertonic  
 (d) medium A is isotonic
28. Nitrogenous wastes in *Amoeba*, are excreted through :  
 (a) plasmalemma (b) food vacuoles  
 (c) contractile vacuole (d) none of these
29. When the prey is very active, *Amoeba* ingests it by :  
 (a) circumfluence (b) circumvallation  
 (c) invagination (d) none of these
30. When *Amoeba* is subjected to weak and steady electric current :  
 (a) it dies (b) it remains at anode  
 (c) it moves towards the cathode  
 (d) it remains in the middle
31. Sol-gel Theory was proposed by :  
 (a) Mast (b) Hymen  
 (c) Pantin (d) Mast & Pantin
32. Mode of nutrition in *Amoeba* is :  
 (a) holozoic (b) mixotrophic  
 (c) saprophytic (d) holophytic
33. Medium inside food vacuole of *Amoeba* is :  
 (a) acidic (b) alkaline  
 (c) I acidic then alkaline (d) I alkaline then acidic
34. *Amoeba* respire through its :  
 (a) plasmalemma (b) general body surface  
 (c) cytoplasm (d) pellicle
35. Excretion in *Amoeba* occurs by :  
 (a) contractile vacuole (b) food vacuole  
 (c) plasmalemma (d) all of these
36. In *Amoeba* binary fission occurs when :  
 (a) food is abundant (b) temperature is suitable  
 (c) both (d) pond water dries up
37. Regarding locomotion in *Amoeba* Pantin supported :  
 (a) theory of rolling movement (b) surface tension theory  
 (c) walking movement theory (d) sol-gel theory
38. An *Amoeba* living in fresh water respire by means of :  
 (a) nucleus (b) food vacuole  
 (c) plasmalemma (d) pseudopodia
39. A full-grown *Amoeba* undergoes binary fission. The total surface area of one daughter *Amoeba* soon after division is likely to be :  
 (a) slightly less than that of parent *Amoeba*  
 (b) equal to the half of that of the parent *Amoeba*  
 (c) slightly more than half of that of the parent *Amoeba*  
 (d) less than half of that of the parent *Amoeba*
40. What is common between an *Amoeba* and a leucocyte ?  
 (a) contractile vacuole (b) sporulation  
 (c) encystment (d) pseudopodia
41. Locomotory organelles in *Amoeba* are :  
 (a) lobopodia (b) cilia  
 (c) flagella (d) myonemes
42. *Amoeba* was discovered by :  
 (a) Lancisi (b) Leeuwenhoek  
 (c) Rosenhoff (d) Ross
43. During digestion in *Amoeba* the medium is first :  
 (a) acidic (b) highly alkaline  
 (c) neutral (d) slightly alkaline
44. The function of the contractile vacuole in *Amoeba* is :  
 (a) excretion (b) osmoregulation  
 (c) none (d) both
45. A 'lobopodia' is derived of :  
 (a) undulating membrane (b) pseudopodia  
 (c) flagella (d) cilia
46. Gel-sol transformation theory put founded by :  
 (a) Yogi and Marsland (b) Allen  
 (c) Hymen (d) Jenning
47. *Amoeba* is :  
 (a) ammonotelic (b) ureotelic  
 (c) ureotelic (d) all
48. *Amoeba* shows :  
 (a) phototaxis (b) chemotaxis  
 (c) thertotaxis (d) all
49. Destruction of nucleus in *Amoeba* result in :  
 (a) no change (b) Quick locomotion  
 (c) slowing down of metabolic (d) immediate death
50. Nuclear DNA of *Amoeba* is :  
 (a) a double helix (b) single stranded  
 (c) circular (d) like a clover leaf
51. Pseudopodia *Amoeba* is composed of :  
 (a) ectoplasm  
 (b) endoplasm  
 (c) both  
 (d) none

### Answers

1. (b) 2. (a) 3. (c) 4. (b) 5. (b) 6. (c) 7. (c) 8. (a) 9. (a) 10. (c) 11. (b) 12. (d) 13. (c) 14. (b) 15. (d) 16. (d) 17. (b) 18. (d)  
 19. (b) 20. (b) 21. (c) 22. (c) 23. (b) 24. (c) 25. (b) 26. (d) 27. (c) 28. (a) 29. (b) 30. (c) 31. (b) 32. (a) 33. (c) 34. (b) 35. (c)  
 36. (c) 37. (d) 38. (c) 39. (b) 40. (d) 41. (a) 42. (c) 43. (a) 44. (d) 45. (b) 46. (a) 47. (a) 48. (d) 49. (c) 50. (a) 51. (c).



# 7

Chapter

## *Entamoeba histolytica*

Apart from free-living forms, certain amoebae lead a commensal or parasitic life in the intestine of man and other animals. The common parasitic genera are *Entamoeba*, *Endamoeba*, *Endolimax*, *Iodamoeba* and *Dientamoeba*. Of the species belonging to these genera, *Entamoeba histolytica* (Gr., *entos*, within + *amoeba*, change + *histos*, tissue + *lysis*, dissolve), which is the causative organism of *amoebic dysentery* or *amoebiasis* in man, is undoubtedly the most studied of all parasitic amoebae.

### *Entamoeba histolytica*

*Entamoeba histolytica* was first discovered by Lambl in 1859, and its pathological nature was described by Friedrich Losch, a Russian zoologist in 1875. He discovered this protozoan in the faeces and intestinal ulcers of a dysentery patient and succeeded in transferring it to puppies.

### Systematic Position

Phylum	Protozoa
Subphylum	Sarcomastigophora
Superclass	Sarcodina
Class	Rhizopodea
Subclass	Lobosia
Order	Amoebida
Genus	<i>Entamoeba</i>
Species	<i>histolytica</i>

### Distribution and Incidence

*Entamoeba histolytica* is cosmopolitan (world-wide) in distribution, but its prevalence is greater in tropics and subtropics than in the temperate zones. It has been reported that incidence of infection is high in Mexico, China, India and parts of South America. The incidence is considerably higher in rural and densely-populated urban areas. Infants under a year old are rarely infected with it, while children and young adults are very susceptible to the parasite.

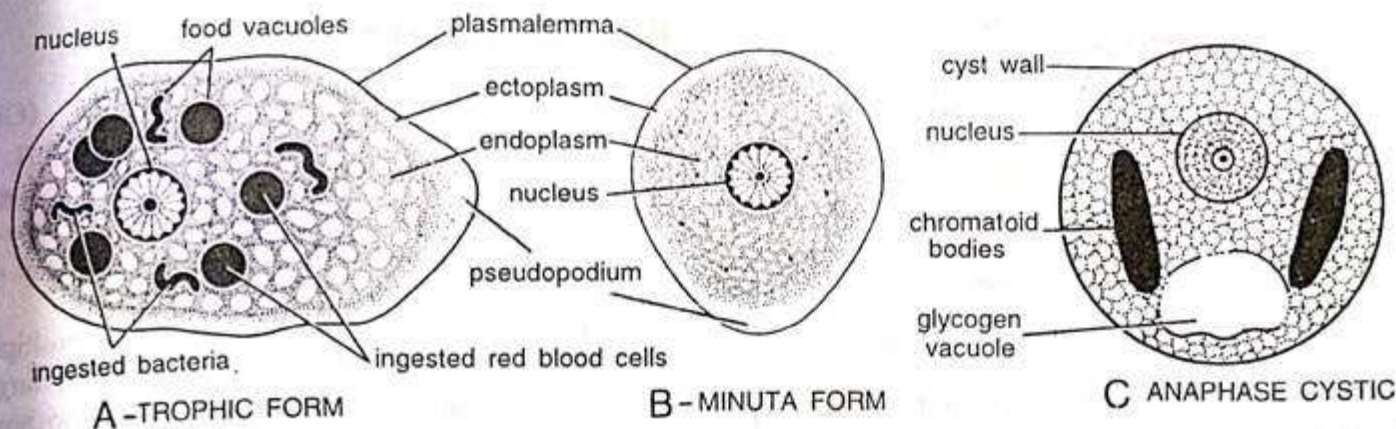


Fig. 1. *Entamoeba histolytica*. Structure of three stages of life cycle.

It is estimated that 10% of world population is suffering from amoebiasis.

### Habits and Habitat

*Entamoeba histolytica* is a microscopic endoparasite of man. It is commonly found in the upper part of the large intestine (colon) and is very often lodged in the liver, lungs, brain and testes. Parasitologists believe that this parasite lives as a harmless commensal but, for reasons which are unknown, it invades the mucosa and sub-mucosa of the intestinal wall and causes *amoebic dysentery* or *amoebiasis*. In a person suffering from this disease, the intestinal wall exhibits, in large numbers, minute *ulcers* which are formed as a result of the dissolution and destruction of the mucous lining of intestine. This is accomplished with the aid of a tissue-dissolving substance secreted by the parasite.

### Morphology

*Entamoeba histolytica* is a small microscopic parasitic amoeba. In its life cycle, it occurs in three distinct forms : (i) *trophozoite* or *magna* form, (ii) *precystic* or *minuta* form, and (iii) *cystic* forms.

**1. Trophozoite or Magna.** Trophozoite of *E. histolytica* is also known as the *trophic* or *magna* form. It is the most active, motile and feeding form which is pathogenic to man. It lives in the mucous and submucous layers of the large intestine of man. It usually measures 20 to 30 $\mu$  in diameter and, more or less, resembles the common amoeba in all structural details. The outermost body covering or *plasmalemma* is a thin, elastic and semi-permeable membrane. The

cytoplasm is differentiated into the outer clear and non-granular *ectoplasm* and the central more fluid and granular *endoplasm*.

(a) **Nucleus.** Endoplasm contains a nucleus which is seldom visible in a living organism. After being fixed and stained, it appears as a vesicular structure 4 to 6 $\mu$  in size. It is bound by a thin and delicate *nuclear membrane*, whose inner surface is encrusted with fine *chromatin granules*, arranged in a peripheral ring. In the centre of nucleus is a small dot-like *endosome* or *karyosome*, often surrounded by a clear area or 'halo'. The fluid-filled space between nuclear membrane and endosome is marked by spoke-like striations of *chromatin material*.

Other inclusions of the endoplasm are *food vacuoles* that enclose the ingested red blood corpuscles (erythrocytes), white blood corpuscles (leucocytes), fragments of epithelial cells and bacteria. *Contractile vacuoles* are wanting in *E. histolytica* since it inhabits an isotonic environment. The osmotic concentration of its body protoplasm equals to that of the intestinal fluid of the host and hence no water enters the organism by osmosis. Thus, there is no need for osmoregulation.

(b) **Pseudopodium.** When moving, *E. histolytica* produces anteriorly a large, broad and blunt pseudopodium. Hence the parasite is typically *monopodial* (Gr., *monos*, single + *podos*, foot). It is only at this anterior end that the outer clear ectoplasm is sharply differentiated from the inner granular endoplasm. With a single pseudopodium the trophozoite moves with a forward-flowing movement. This resembles the crawling of a garden slug (*Limax* spp.) and hence the

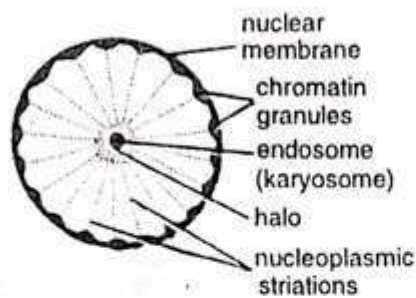


Fig. 2. *Entamoeba histolytica*. Vesicular nucleus.

movement is sometimes called 'imax-type movement'.

Nutrition in trophozoite is *holozoic*. It feeds by phagocytosis. Food particles are engulfed at the posterior end, where plasmalemma is more sticky. Food particles adhere to it and plasmalemma is invaginated into cytoplasm carrying the food particles along with it. The invaginated plasmalemma now separates off from the main plasmalemma to become food vacuole.

2. **Precystic or minuta.** Precystic or minuta form of *E. histolytica* is small, spherical, non-motile and non-feeding form. It measures 12 to 15  $\mu$  in diameter. In structural details it resembles the trophozoite except that it is smaller in size and the food vacuoles are absent. It lives in the lumen of large intestine and is non-pathogenic to man. But when resistance of host's body is low, it changes into magna form and invades the tissues of intestine.

3. **Cysts.** Under normal condition, minuta forms undergo encystation. It becomes rounded and surrounded by a thin, highly resistant and refractile *cyst wall*. A mature cyst is a spherical body 10 to 12  $\mu$  in diameter. Its cytoplasm is clear and contains one or two *glycogen masses* (reserve food) and one or more characteristic, refractile, bar-like *chromatoid bodies* or *chromidial bars* with rounded ends. Both glycogen masses and chromidial bars gradually disappear. Chromidial bars are made of ribonucleoprotein which disperses throughout cytoplasm with their disappearance. Nucleus retains the characters of the trophozoite. To start with, the cyst is *uninucleate* but its nucleus divides to form a *binucleate* and finally a *tetranucleate* or *quadrinucleate* cyst.

## Reproduction and Life Cycle

1. **Hosts.** *E. histolytica* is *monogenetic* (*Gr. monos, one + genos, race*), i.e., only one host is required for its complete life cycle. Pigs, dogs, rats and rabbits are supposed to be the *reservoir host*. It undergoes reproduction and completes its life cycle only in man.

2. **Binary fission.** Trophozoites multiply asexually by *binary fission* within the wall of large intestine. Its nucleus undergoes *mitosis* without the disappearance of the nuclear membrane. The mitosis is followed by *cytokinesis* or division of the cytoplasm. As a result, two daughter organisms are formed. They grow rapidly in size, feeding upon bacteria and host tissue elements, and, in their turn, again multiply by binary fission. Some of them invade fresh host cells, while others become the precystic or minuta forms.

3. **Encystation.** The *precystic* or *minuta* forms encyst only in the lumen of the intestine and not in the tissues. They round up and secrete a thin, refractile, tough and flexible *cyst wall* around them. The cysts at this stage are *uninucleate*. The single nucleus of the cyst soon undergoes a mitotic division to form two nuclei, leading to the formation of *binucleate* cysts. A second mitotic division divides the two nuclei into four and thus *tetranucleate* cysts are formed. The whole process of encystation is completed within a few hours.

Tetranucleate cysts constitute the transmissive or infective stage. They do not develop further but pass out of the host in the faeces. They can remain alive for 10 days in moist stool. They are very susceptible for desiccation and die at a temperature of 50°C.

4. **Transmission and infection.** Infection depends upon intake of food or water contaminated with faecal matter containing tetranucleate cysts of *E. histolytica*. The food handlers, like cooks, sweetmeat sellers, hawkers, etc., who themselves are infected and are unhygienic by nature, act as cyst passers. Untreated human faeces voided by children and adults on open grounds or in crop and vegetable fields (which is the usual practice in rural areas

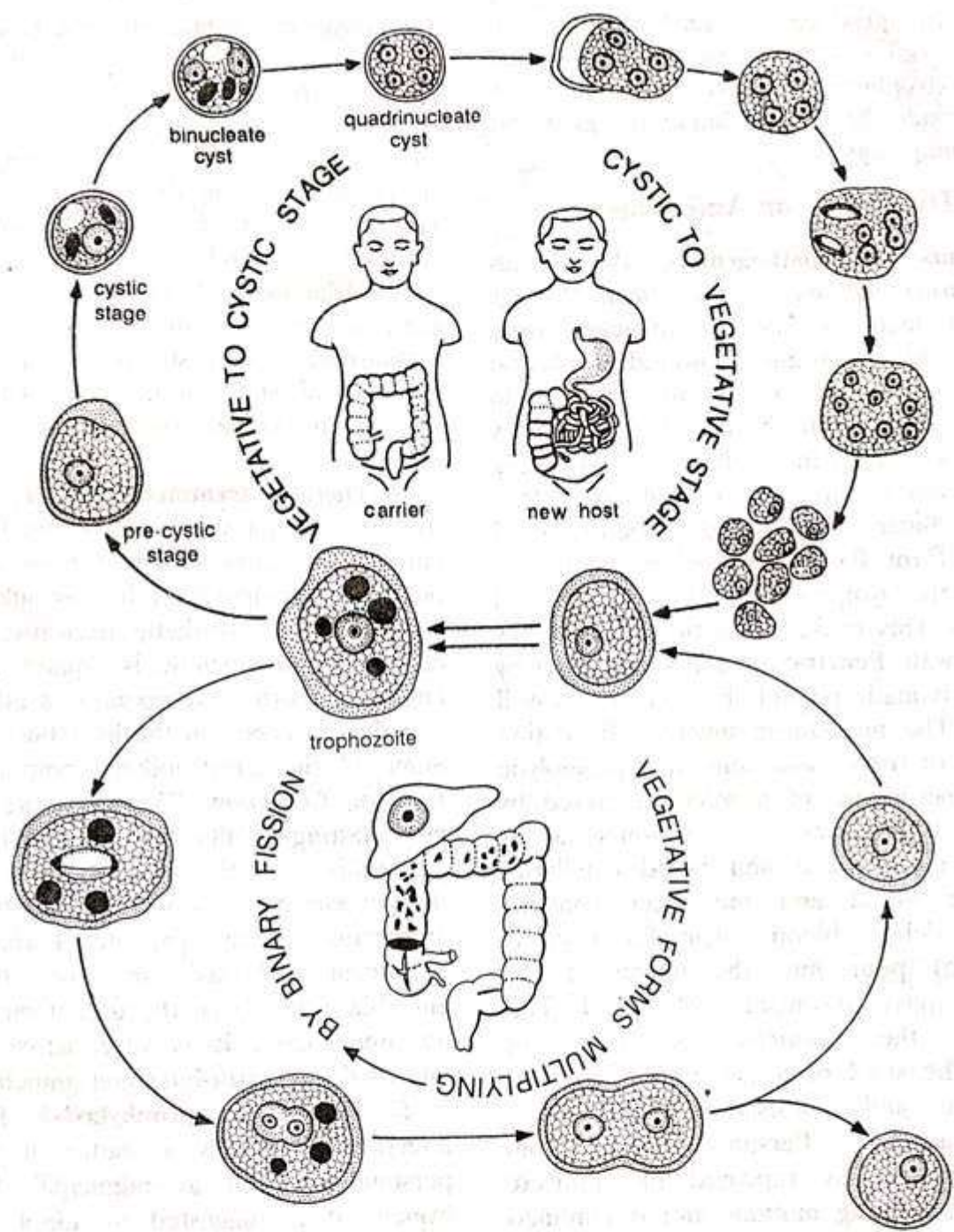


Fig. 3. *Entamoeba histolytica*. Reproduction and life history.

in India) is a common source of infection. Houseflies and cockroaches, which are coprophagous (feeding upon faecal matter), carry viable cysts on their legs or in their intestine and transfer them to unprotected foodstuffs.

**5. Excystation.** In the new host, the ingested cysts pass down the alimentary canal and reach the small intestine. The cyst wall protects them from the action of host's gastric juice during

their passage through the stomach. After 5 or 6 hours, excystation takes place as the cyst wall is digested by trypsin in small intestine releasing the tetranucleate amoeba, called the *excystic amoeba* or *metacyst*.

**6. Metacystic development.** Each metacyst immediately proceeds to divide by binary fission. Its nuclei divide in a specific pattern, accompanied by simultaneous cytoplasmic

divisions, to produce 8 small, uninucleate amoebulae or *metacystic trophozoites*. These metacystic trophozoites pass into the large intestine, invade the mucous lining and grow into mature trophozoites.

### Amoebic Dysentery or Amoebiasis

**1. Symptoms and pathogenesis.** As already noted, *E. histolytica* lives in the lumen of large intestine of man as harmless minuta forms. Whenever resistance of gut is lowered in infected people, these become pathogenic, change to magna forms and invade the intestinal wall. They make their way deep into sub-mucosa by eating through mucosa of the intestinal wall. Here they multiply by binary fission and spread radially outward to form flask-shaped *ulcers* containing cellular debris, lymphocytes, blood corpuscles and bacteria. This causes formation of *abscesses* in intestinal wall. Penetration into sub-mucosa by trophozoites is made possible by *histolysis* as well as *cytolysis*. The mechanism involves dissolution and necrosis of tissues and cells by a proteolytic enzyme of the nature of *histolysin* secreted by trophozoites themselves. As sub-mucosa is eroded, the ulcers burst and blood capillaries rupture. The blood and the ulcer contents (mucus, cell debris, blood corpuscles, bacteria and amoebae) pour into the lumen of the intestine and pass to outside with stool. This characterizes the *amoebic dysentery* or *amoebiasis*. The stool of a dysenteric person is usually acidic and consists of swarms of entamoebae as well. Person suffering from amoebic dysentery has repeated blood-mixed, slimy and foul-smelling motions and is confined to the lavatory.

Sometimes, the trophozoites make their way, through blood circulation, into the brain, liver, spleen, lungs and gonads. Here also they destroy the tissues and cause formation of *abscesses*, or cavities containing pus. The affected liver becomes enlarged, congested and painful to touch. This pathological condition is referred to as *amoebic hepatitis*. Formation of abscesses in lung and brain usually prove fatal.

**2. Modes of transmission.** It mainly occurs by ingestion of cysts in food or drinks. The contamination of food or drinks occurs by :

(i) unhygienic habits of food handlers who by habit scratch the anus and then put their fingers in the food which they serve, (ii) habit of defecating in open fields causing contamination of vegetables and then washing the bottoms in ponds causing the contamination of water, (iii) transmission of cysts from stools to food and drinks by flies and cockroaches.

**3. Diagnosis.** Diagnosis, in a simple way, consists in the microscopical detection of trophozoites or cysts in faecal smears. The presence of white, stone-shaped 'Charcot-Leyden' crystals in faeces suggests the *E. histolytica* infection.

**4. Therapy (treatment).** Treatment of amoebic dysentery is not very difficult but the permanent cure is sometimes hard to achieve as relapses do occur. For temporary relief, an alkaloid *Emetine* is effective. A synthetic derivative of Emetine, called *Dehydroemetine*, is equally effective. The antimalaria drug, *Chloroquine* is effective against amoebic abscesses in the liver but not elsewhere. Some of the latest iodine compounds, such as *Vioform*, *Chiniofon*, *Diodoquin*, etc., have shown more lasting results. Certain antibiotics, such as *Fumagillin*, *Terramycin*, *Erythromycin* and *Aureomycin* have proved to be effective in the eradication of the parasite. Perhaps the most significant advance in the treatment of amoebiasis has been the use of *metronidazole* as an amoebicide. It is very active against both intestinal and extra-intestinal amoebiasis.

**5. Prevention (prophylaxis).** Prevention of infection is entirely a matter of hygiene, both personal as well as municipal. For personal hygiene it is suggested to adopt the following habits :

- (1) Washing hands with soap and water after handling dirty articles, before taking meals and after using toilet.
- (2) Cutting finger nails regularly.
- (3) Avoiding use of unboiled water and improperly washed vegetables and raw salads.
- (4) Protection of foods and drinks from contamination by houseflies, cockroaches, etc.
- (5) Avoiding passing out of stool on open grounds, street sides or vegetable fields. The municipal hygiene is the responsibility of the town areas, municipalities or other local

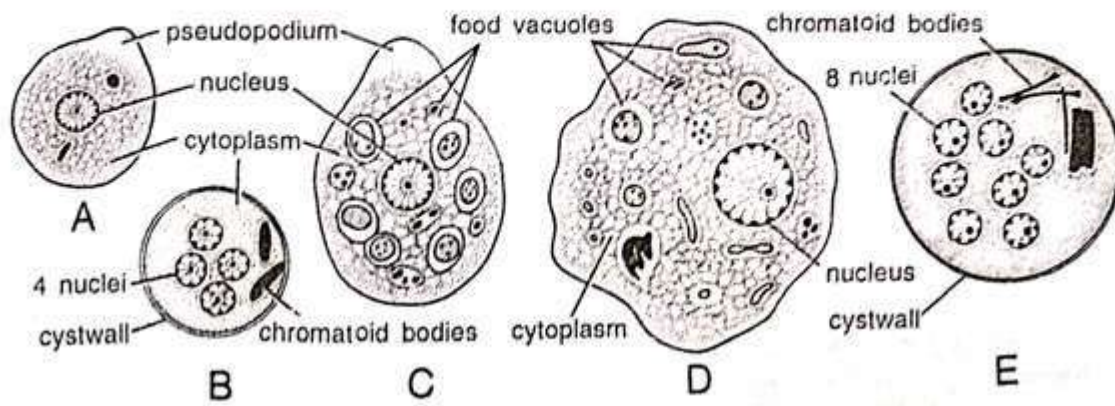


Fig. 4. Other entamoebae of man. A—Trophozoite of *E. hartmanni*. B—Cyst of *E. hartmanni*. C—Trophozoite of *E. gingivalls*. D—Trophozoite of *E. coli*. E—Cyst of *E. coli*.

bodies. They must take the following preventive measures :

- (1) Proper sanitation of roads, streets, lanes and open drains.
- (2) Purification of drinking water.
- (3) Proper disposal of sewage.
- (4) Covering of the food articles by the traders.
- (5) Chemical treatment of human faeces to be used as fertilizer.
- (6) Periodical examination of food handlers to find out whether they are infected with *E. histolytica*. On positive findings they should be treated properly.

### Other Entamoebae of Man

1. *Entamoeba hartmanni*. This *Entamoeba* closely resembles the minuta form of *E. histolytica*. It also lives in the lumen of large intestine and invades intestinal tissue. Trophozoites measure 9 to 14 $\mu$  in diameter. Nucleus is more dense. Mature cysts are tetranucleate and are less than 10 $\mu$  in diameter (smaller than the cysts of *E. histolytica*). *E. hartmanni* too causes amoebic dysentery but is supposed to be less harmful.

2. *Entamoeba coli*. This *Entamoeba* is said to be non-pathogenic as it does not invade the host tissue. Living

in the lumen of intestine it may produce digestive complications. Trophozoite of this species measures between 20 and 40 $\mu$  in diameter. It is less active and forms a small pseudopodium. Cytoplasm never contains red blood corpuscles. Central karyosome or endosome of nucleus is minute and is generally eccentric. Cysts measure between 15 and 20 $\mu$  in diameter and contain eight nuclei. Chromatoid bars are thin with sharp ends.

*E. coli* occurs in the intestine of about 50% of human population. Infection takes place when cysts in stools are voided by infected persons to outside and these are then taken by other men with contaminated food and water.

3. *Entamoeba gingivalls*. This *Entamoeba* dwells in mouth, usually between teeth and gums. Trophozoite measures about 12 to 20 $\mu$  in diameter. Ectoplasm is crystal clear and central granular endoplasm is vacuolated. Endoplasm contains a vesicular nucleus with a large central endosome, and numerous food vacuoles containing bacteria and nuclei of leucocytes. Pseudopodia are usually many with broad and rounded ends.

*E. gingivalls* occurs in mouths of nearly 70% of human population. Its incidence is high in those persons who suffer from pyorrhoea. It has been the belief for a long time that *E. gingivalls* is the causative organism for pyorrhoea, but it has now been established that pyorrhoea is caused as a result of bacterial infection. *Entamoeba*, of course, aggravates pyorrhoea by destroying tissues in gums. The species does not form cysts, since it is directly transmitted from mouth to mouth by contact during kissing or in feeding.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Give an account of the bionomics, morphology, life history and economic importance of *Entamoeba histolytica*.
2. Describe the life history and pathogenicity of the organism causing amoebic dysentery. Suggest methods for the control of the disease.
3. Distinguish between *Amoeba* and *Entamoeba*. Justify the statement that *Entamoeba histolytica* is not pathogenic but behaves as a pathogenic organism.
4. Write short notes on :  
(i) Chromatoid bodies. (ii) Encystment. (iii) *Entamoeba coli*. (iv) *Entamoeba gingivalls*. (v) Metacysts. (vi) Minuta. (vii) Nucleus of *Entamoeba*.

## » Short Answer Type Questions

1. Name the rhizopodan parasite causing dysentery.
2. What are two types of reserve food materials found in the cyst of *Entamoeba histolytica* ?

## » Multiple Choice Questions

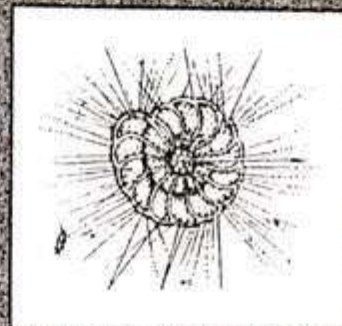
1. R.B.C. is present in the food vacuole of :  
(a) *Entamoeba histolytica* (b) *Amoeba proteus*  
(c) *Trypanosoma gambiense* (d) *Leishmania donovani*
2. What disease is caused by *Entamoeba histolytica* :  
(a) Amoebic dysentery (b) Gambian fever  
(c) Typhoid (d) Malaria
3. Pathological nature of *Entamoeba histolytica* was discovered by :  
(a) Lamble (b) Losch (c) Grassi (d) Lavern
4. The infective stage of *Entamoeba histolytica* is :  
(a) uninucleate cyst (b) binucleate cyst  
(c) tetranucleate cyst (d) minuta form
5. Besides the bead-like chromatin granules what is present inside the nucleus of *Entamoeba histolytica* :  
(a) parabasal body (b) contractile vacuole  
(c) micronucleus (d) Karyosomes
6. *Entamoeba histolytica* is found in :  
(a) the rectum of man (b) the intestine of man  
(c) the oral cavity of man (d) the stomach of man ✓
7. Amoebic dysentery is caused by :  
(a) *Amoeba proteus* (b) *Entamoeba histolytica*  
(c) *Plasmodium vivax* (d) *Taenia solium*
8. *Entamoeba histolytica* causes :  
(a) kala-azar (b) filaria  
(c) dysentery (d) sleeping sickness
9. *E. histolytica* is found in :  
(a) colon (b) intestine (c) both (d) none
10. *Entamoeba histolytica* is without :  
(a) pseudopodium (b) contractile vacuole  
(c) food vacuole (d) nucleus
11. Cysts of Amoebic dysentery spread by :  
(a) housefly (b) mosquito  
(c) men (d) none of these
12. Amoebic dysentery in man is caused by :  
(a) *Amoeba proteus* (b) *Entamoeba histolytica*  
(c) *Entamoeba coli* (d) *Entamoeba gingivalis*
13. In *Entamoeba histolytica* the normal trophozoites are called :  
(a) sporulets (b) minuta forms  
(c) monogenetic forms (d) magna forms
14. *Entamoeba histolytica* has no need for :  
(a) feeding (b) growth  
(c) osmoregulation (d) reproduction
15. Precystic stage of *Entamoeba* is called :  
(a) magna form (b) minuta form  
(c) feeding trophozoite (d) growing trophozoite
3. What is amoebiosis ? What are its pathological effects ?
4. Compare the structure of pseudopodia of *Entamoeba histolytica* and *Elphidium*.
16. *Entamoeba histolytica* is a human parasite usually found in :  
(a) intestine (b) liver  
(c) blood (d) none of the above
17. The minuta form of *Entamoeba histolytica* differs from *Amoeba proteus* in having :  
(a) one pseudopodium formed of ectoplasm  
(b) one pseudopodium formed of endoplasm  
(c) no food vacuoles (d) small contractile vacuole
18. *Entamoeba histolytica* differs from *Amoeba proteus* in having :  
(a) no pseudopodium (b) no food vacuoles  
(c) reproduction only by encystment  
(d) no contractile vacuole
19. Encysted stage is not known to occur in life of :  
(a) *Entamoeba gingivalis* (b) *Entamoeba coli*  
(c) *Entamoeba histolytica* (d) *Amoeba*
20. Monopodial locomotion does not occur in :  
(a) *Entamoeba histolytica* (b) *Entamoeba coli*  
(c) *Entamoeba gingivalis* (d) *Entamoeba*
21. Most active form of *Entamoeba histolytica* :  
(a) trophozoite (b) pericyclic  
(c) cystic (d) all
22. *Entamoeba histolytica* has :  
(a) one contractile vacuole  
(b) two contractile vacuole  
(c) three contractile vacuole  
(d) no contractile vacuole
23. Which of the following has only one host :  
(a) *E. histolytica* (b) *T. gambiense*  
(c) *T. solium* (d) *P. vivax*
24. The excretion in *Entamoeba histolytica* take place :  
(a) food vacuole (b) contractile vacuole  
(c) general body surface (d) endosome
25. How many young amoebae hatch out from a cyst of *E. histolytica* :  
(a) one (b) two (c) four (d) six
26. Cyst of *E. histolytica* spread by :  
(a) mosquito (b) bed bug  
(c) mouse (d) house fly
27. Chromatoid body in *Entamoeba histolytica* are found in :  
(a) cyst (b) trophozoite (c) meta cyst (d) minuta
28. For prevention against amoebiosis we should :  
(a) eat more food (b) use mosquito net  
(c) drink boiled water (d) eat plenty of food
29. The meta cyclic form has .... nucleus :  
(a) one (b) two (c) four (d) eight

## Answers

1. (a) 2. (a) 3. (a) 4. (c) 5. (d) 6. (a) 7. (b) 8. (c) 9. (a) 10. (b) 11. (a) 12. (b) 13. (d) 14. (c) 15. (b) 16. (a) 17. (c) 18. (c) 19. (a) 20. (c) 21. (a) 22. (d) 23. (a) 24. (c) 25. (a) 26. (d) 27. (a) 28. (c) 29. (c)



*Elphidium crispum*  
(= *Polystomella crista*)



# 8

## Chapter

Not all Protozoa are naked, some are enclosed in shells. The most common shelled protozoans are *foraminiferans* belonging to the order *Foraminiferida* (L., *forare*, pores + *ferre*, to bear). Their shells are typically many-chambered and perforated all over with small pores, through which extend long and fine pseudopodia. Almost all the members of the order are marine. When they die, their shells fall in a steady rain to the ocean floor and contribute to the formation of bottom sediments, called *ooze*.

*Elphidium crispum*  
(= *Polystomella crista*)

Many foraminiferans exhibit the phenomenon of *dimorphism*, i.e., individuals of a single species occur in two distinct forms, which differ in the

structure of shell, number of nuclei and mode of reproduction. *Elphidium* (= *Polystomella*) is a typical representative of the dimorphic forms. The most common species is *Elphidium crispum*, whose biology is dealt here in detail.

### Systematic Position

Phylum	Protozoa
Subphylum	Sarcomastigophora
Superclass	Sarcodina
Class	Rhizopodea
Subclass	Granuloreticulosa
Order	Foraminiferida
Genus	<i>Elphidium</i>
Species	<i>crispum</i>

### Occurrence: Habit and Habitat

*E. crispum* is a free-living marine foraminiferan and occurs in the littoral zone of the sea down to about 600 meters. It is commonly found creeping about on sea weeds.

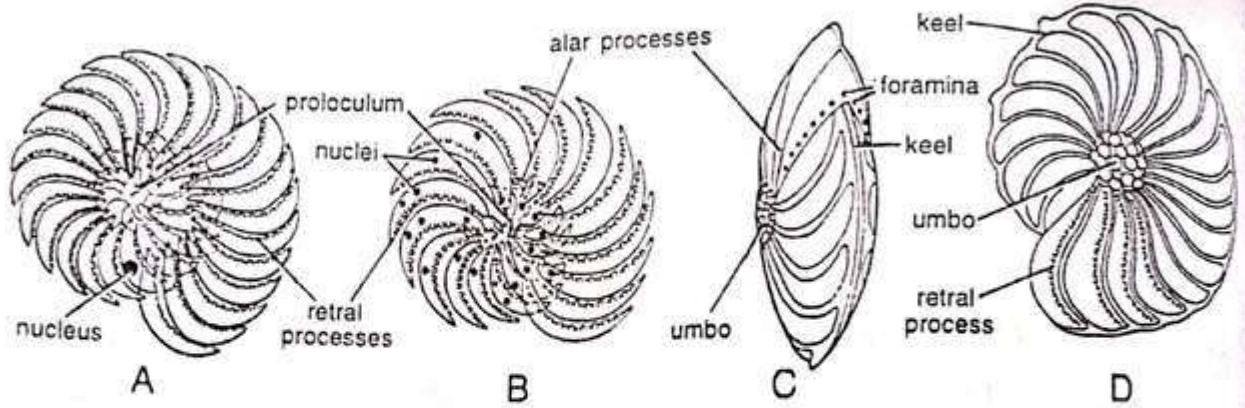


Fig. 1. *Elphidium crispum*. Decalcified and stained specimens. A - Megalospheric individual. B - Microspheric individual. C - Endon view of the shell. D - Lateral view of the shell.

**Structure**

1. **Dimorphic forms.** *E. crispum* is a dimorphic species, the two forms being the *microspheric* and *megalospheric*. The microspheric form is small, multinucleate, with a smaller initial chamber and asexual mode of reproduction. The megalospheric form is large, uninucleate, with a larger initial chamber and sexual mode of reproduction.

2. **Shell.** Shell of *E. crispum* is small, translucent, pale yellow in colour and spherical or oval in shape. It measures 1 mm in diameter. The shell consists mainly of calcium carbonate with small amounts of other inorganic compounds such as silica and magnesium sulphate. The shell is *polythalamus* or *multilocular*, i.e., it consists of many chambers. It is coiled in a *planospiral* manner, i.e., all the coils lie in the same plane or a flat spiral. All

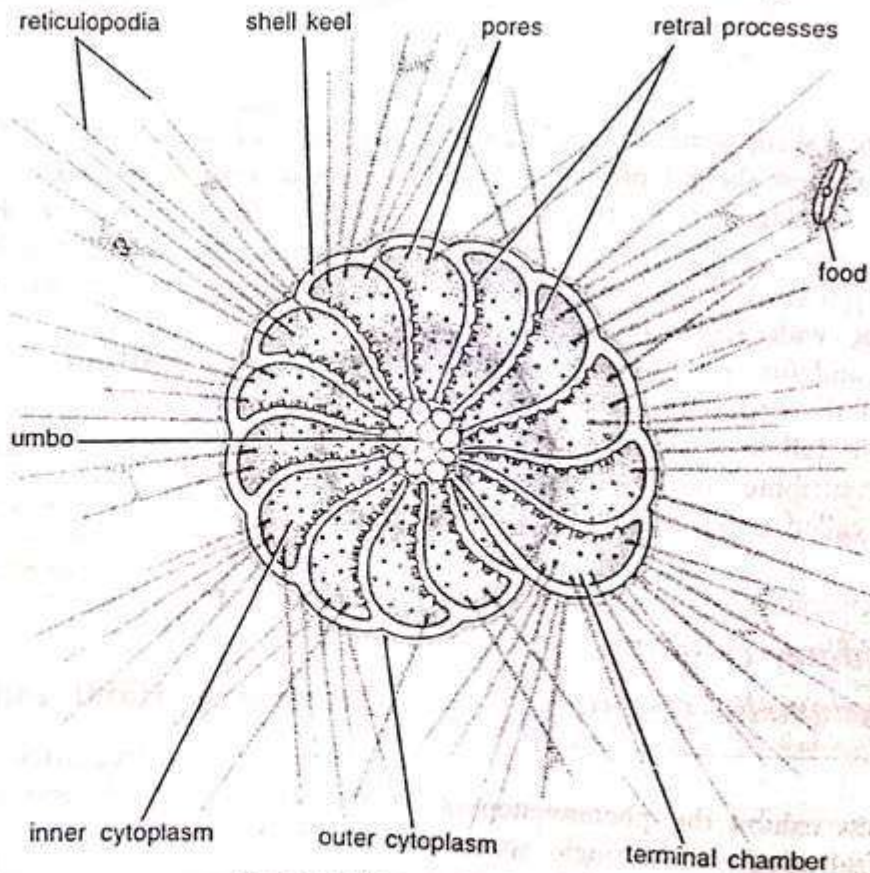


Fig. 2. *Elphidium crispum* (living).

(Z-1)

the chambers are filled with cytoplasm. The shell is *perforate*, that is, the walls of chambers bear minute pores through which cytoplasm becomes continuous from one chamber to another, and also extends to outside forming pseudopodia.

Each chamber of shell is somewhat elongated laterally. Its anterior surface is convex while the posterior surface is concave. The concave posterior surface bears *retral processes* filled with cytoplasm. Minute pores occur in the spaces between retral processes which act as open doors for the emergence of the pseudopodia to outside. Peripheral part of shell is rigid and consists of a continuous rim, called *keel*, whereas the central part is the rounded *umbo* which becomes prominent due to deposition of more calcium carbonate.

Formation of shell begins with an initial single chamber, the *proloculum*. As the animal grows in size, successive chambers are laid down in a spiral manner, forming whorls. Each chamber is larger than the preceding one and each new whorl partially overlaps and conceals the older one. Thus, only the last whorl, which is the largest and most recently formed, is visible from outside. The overlapping portions of the chambers are referred to as *alar processes* (Fig. 1).

**3. Cytoplasm.** All the shell chambers of living *E. crispum* are filled with a mass of *inner cytoplasm*. Besides, a thin layer of *outer cytoplasm* invests the entire shell, which makes the shell internal rather than external. Part of cytoplasm within the shell is also called *endoplasm* and that outside it, the *ectoplasm*. Endoplasm contains nucleus, (or nuclei), food particles, minute vacuoles, Golgi bodies, mitochondria, endoplasmic reticulum, ribosomes and colour granules or *xanthosomes*.

**4. Nucleus.** Inner cytoplasm or endoplasm contains a single nucleus in megalospheric individuals and many nuclei in microspheric individuals. The nucleus is vesicular and contains many nucleoli embedded in nucleoplasm.

**5. Reticulopodia.** Pseudopodia of *E. crispum* are typically foraminiferan because of their thread-like branching and anastomosing nature. Such pseudopodia are known as *reticulopodia* or

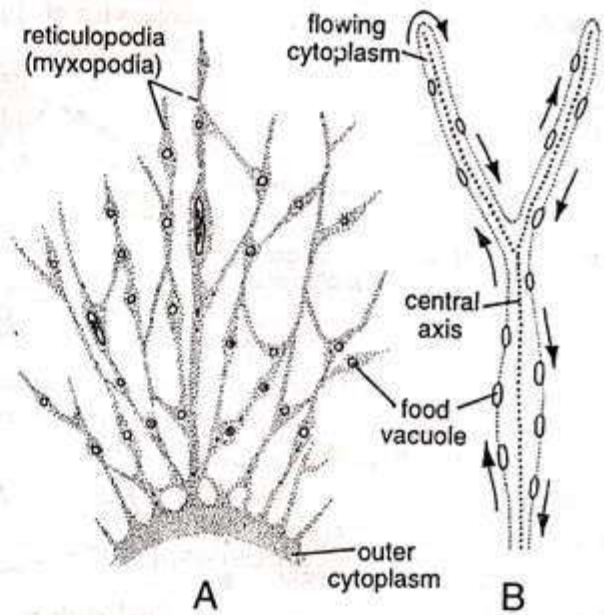


Fig. 3. *Elphidium*. Reticulopodia. A—A group of reticulopodia. B—A reticulopodium showing streaming circulation of cytoplasm.

*myxopodia*. Each consists of two regions—inner fibrillar *axis* and outer fluid-like *cortex*. It has been observed that in the network of reticulopodia cytoplasm shows streaming circulation, as is evident from the movement of granules in opposite directions along the two sides of axis. Pseudopodia may be withdrawn within the shell at lightning speed or may be extended out a short distance in water like little rockets and wave about bending, undulating, quivering and putting out side branches, which meet and fuse and so establish a reticulum. Reticulopodia help the organism in locomotion, nutrition and in the construction of shell and cyst walls.

### Locomotion

*E. crispum* creeps slowly over the substratum on the sea bottom with the help of its reticulopodia, which are arranged in bundles around the shell. With the contraction of distally placed bundles the body is pulled or dragged forward.

### Nutrition

*E. crispum* is typically *holozoic*. It feeds upon minute organisms like diatoms, other protozoans, crustacean larvae, etc. The net-like reticulopodia are thought to secrete an external mucous layer to trap the food organisms. The mucous layer

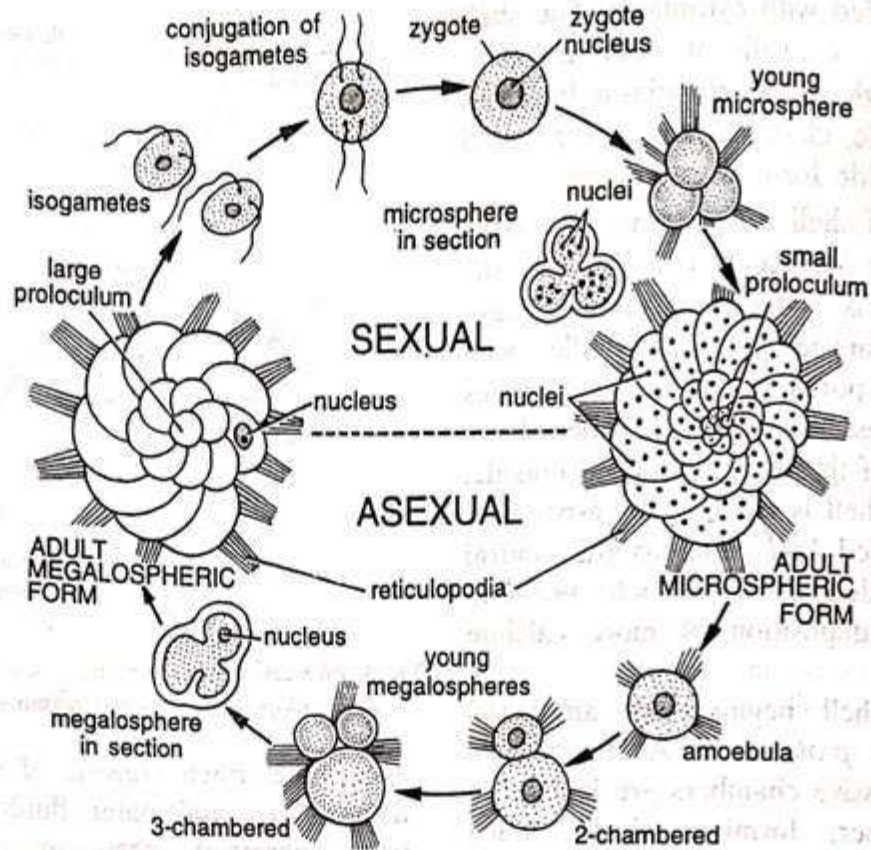


Fig. 4. *Elphidium*. Reproduction and life cycle.

contains proteolytic secretions which paralyze the prey and initiate its digestion even during capture. The captured food, enclosed in a food vacuole, is drawn into endoplasm by the withdrawal of reticulopodial filaments towards the interior of body. Digestion is normally completed outside the shell and the products of digestion pass into the endoplasm.

### Reproduction and Life Cycle

The two distinct forms of *E. crispum* actually display the phenomenon of *sexual dimorphism*. Megalospheric forms or *gamonts* are the sexual forms. They reproduce by the formation of gametes (gamogony), which unite in pairs and form zygotes. Microspheric forms or *agamonts* are the asexual forms which reproduce by multiple fission (agamogony). In the life cycle, the two forms display a definite alternation of generations. According to Jepps, the entire cycle of sexual and asexual phases is completed in about two years.

(Z-1)

### [I] Sexual phase (gamogony)

1. **Megalospheric form or gamont.** The sexual megalospheric form or gamont is somewhat larger in size and possesses a large embryonic chamber, the *proloculum*. It remains uninucleate throughout its life.

2. **Isogamy.** Each gamont produces numerous identical biflagellate gametes or *isogametes*. The formation of gametes take place inside the parent shell. The single nucleus divides repeatedly by mitosis which is accompanied by the fragmentation of entire cytoplasm. Each fragmented cytoplasmic portion, along with a daughter nucleus organizes into a gamete. Each gamete is a spherical bit of cytoplasm and possesses two motile flagella, a nucleus and a fairly large fat globule.

3. **Fertilization.** The gametes are released into the surrounding sea water through the shell pores. They swim about freely for some time and then elongate to become conical in shape. Later

the gametes, originating from different gamonts, unite and fuse in pairs, resulting in diploid zygotes.

**(II) Asexual phase (agamogony)**

1. **Microspheric form or agamont.** The zygote secretes the shell around a small initial chamber or proloculum and becomes a young *agamont* or *microsphere*. Its diploid nucleus divides first by meiosis and then by mitosis to give rise to several haploid daughter nuclei. With further growth and development, new chambers are successively added, resulting in a multinucleate and multilocular adult agamont or *schizont*. The nuclei are found in cytoplasm of all the chambers and they are encircled by numerous chromatidial granules. The microspheric individuals are scarce

in occurrence because of the remote chances of the fusion of gametes.

2. **Schizogony.** Microsphere or agamont reproduces asexually by schizogony. Entire cytoplasm containing several nuclei creeps out of the shell and takes the form of a lump around it. This lump now organizes into a large number of small uninucleate amoeba-like cells, called *amoebulae* or *agametes*.

3. **Development of agametes.** The agametes now become detached from the parental shell. Each one secretes a shell around a large proloculum and becomes a young gamont or *megalosphere*. It repeatedly secretes additional chambers and transforms into a uninucleate and multilocular adult gamont or megalospheric individual.

**IMPORTANT QUESTIONS**

» Long Answer Type Questions

1. Give a detailed account of the structure and life history of a foraminiferan studied by you.
2. Describe the phenomenon of dimorphism in *Elphidium crispum*. Give a brief account of its life history.
3. Give an account of the structure and formation of shell in *Elphidium* (= *Polystomella*).
4. Describe the asexual phase of reproduction in *Polystomella*.

» Short Answer Type Questions

1. Mention the two forms of *Elphidium*.
2. Mention two differences between the nuclei of microspheric and megalospheric forms of *Elphidium*.
3. What is the type of shell in *Elphidium*.

4. What is metagenesis ? With the aid of diagrams illustrate the phenomenon with reference to *Elphidium*.
5. Explain alternation of generation in *Elphidium*. How it differs from *Amoeba* and *Paramecium* ?

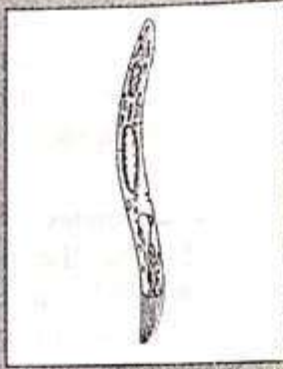
» Multiple Choice Questions

1. The mode of nutrition in *Elphidium* is :  
(a) saprozoic (b) holophytic  
(c) coprozoic (d) mixotrophic (e) holozoic
2. Locomotion in *Elphidium* is by :  
(a) filopodia (b) lobopodia  
(c) axopodia (d) reticulopodia
3. Dimorphic form occur :  
(a) *Paramecium* (b) *Euglena*  
(c) *Polystomella* (d) *Amoeba*

4. Which one of them have shell :  
(a) *Paramecium* (b) *Polystomella*  
(c) *Trypanosoma* (d) all
5. The free living marine protozoan is :  
(a) *Paramecium* (b) *Amoeba*  
(c) *Euglena* (d) *Polystomella*
6. *Polystomella* belong to order :  
(a) Foramaniferida (b) Euccosida  
(c) Amoebida (d) Eugregarinida

**Answers**

1. (e) 2. (d) 3. (c) 4. (b) 5. (d) 6. (a)



# 9

Chapter

## *Plasmodium vivax:* The Malaria Parasite

Members of subphylum Sporozoa are all parasites and without organelles of locomotion as adult. These are either intra or intercellular parasites of both invertebrates and vertebrates and many of them are causative organisms of dreadful diseases like malaria, various cattle fevers, coccidiosis in chickens, epidemic deaths in cultivated honeybees and silkworms, etc. The most interesting sporozoan genus is *Plasmodium* whose 60 known species cause malaria in man and other animals. Because of their malaria-causing abilities, the species are commonly referred to as *malarial parasites*.\* All these reside in the red blood corpuscles,

reproduce in them and destroy them. Mosquitoes are the transmitting agents or *vectors* of the malarial parasites.

### *Plasmodium vivax*

Four species of *Plasmodium* are known to cause different types of malaria fever in man. They are *P. vivax*, *P. ovale*, *P. malariae* and *P. falciparum*.

The following description belongs to *P. vivax* in particular, which is the most common type of malarial parasite.

---

According to some, the term 'malarial parasite' is incorrect. The correct term is 'malaria fever parasite'.

## Systematic Position

Phylum	Protozoa
Subphylum	Sporozoa
Class	Telosporea
Subclass	Coccidia
Order	Eucoccida
Suborder	Haemosporina
Genus	<i>Plasmodium</i>
Species	<i>vivax</i>

## Distribution of *Plasmodium*

Geographical distribution of the species of *Plasmodium* is widespread in tropical and temperate countries. Where the migratory birds are hosts, the parasites are spread all over the world. Of the human infecting parasites, *P. vivax* is the most widely distributed. It prevails mainly in temperate regions of the world. *P. falciparum* is confined to the warmer parts only. *P. malariae* follows *P. vivax* in distribution. *P. ovale*, though widespread, is the rarest of the four.

## Life Cycle of *Plasmodium vivax*

*P. vivax* is the most common of the human infecting malaria fever parasites. It is the causative organism of *benign tertian* or *vivax malaria*, which is characterized by a 48-hour cycle between the first malaria fever and subsequent recurrence of chills and fever. It is an intracellular parasite in man, living in the red blood corpuscles and liver cells, while extracellular in mosquito, living in its alimentary canal and salivary glands.

**Hosts.** The life cycle, undergone by *P. vivax*, is very complicated. Being *digenetic*, it is completed in two hosts, man and mosquito.

(a) **Man.** Asexual cycle is passed in man in two phases. First phase in liver cells is called *liver schizogony*. It involves multiple fission forming *merozoites* at the end. Second phase is

completed in red blood corpuscles. It is known as *erythrocytic schizogony* which forms *gametocytes* at the end.

(b) **Mosquito.** Sexual cycle is completed in female *Anopheles* mosquito. It also involves two phases, gametogony and sporogony. *Gametogony* is concerned with the production and fusion of *gametes*, whereas *sporogony* is postzygotic multiplication resulting the formation of infective individuals, the *sporozoites*.

## [I] Asexual cycle of *P. vivax* in man

**1. Infection.** A healthy person acquires infection when a female *Anopheles* mosquito, containing infective stages of parasite (sporozoites) in its salivary glands, bites him for sucking his blood. The mosquito punctures the host's skin by its proboscis and first introduces some saliva into blood stream. Along with saliva, thousands of sporozoites contained therein are also inoculated. Purpose of pouring saliva is to check clotting of blood, as it contains an anticoagulant.

**2. Sporozoites.** Sporozoites represent the infective forms of parasite. These are small spindle-shaped, slightly curved or sickle-shaped, and uninucleate organisms, measuring 11-12 $\mu$  in length and 0.5-1 $\mu$  in width.

Electron microscope reveals the complicated gross anatomy of sporozoite. External covering is the firm and elastic *pellicle*, which contains longitudinally arranged contractile *microtubules* for its wriggling movements. At the anterior end is the *apical cap*, made up of three or more concentric rings, into which open the secretory *paired organelles*. These are supposed to secrete lytic juice to facilitate penetration into liver cells. A *micropyle* represents the cytostome of other protozoans. Many *convoluted tubules* of unknown function are found along the whole body of sporozoite. There is a single vesicular *nucleus* with a centrally-located nucleolus and a *mitochondrion* with tubular cristae.

**3. Liver schizogony.** Once within the human blood, the sporozoites circulate for about half an

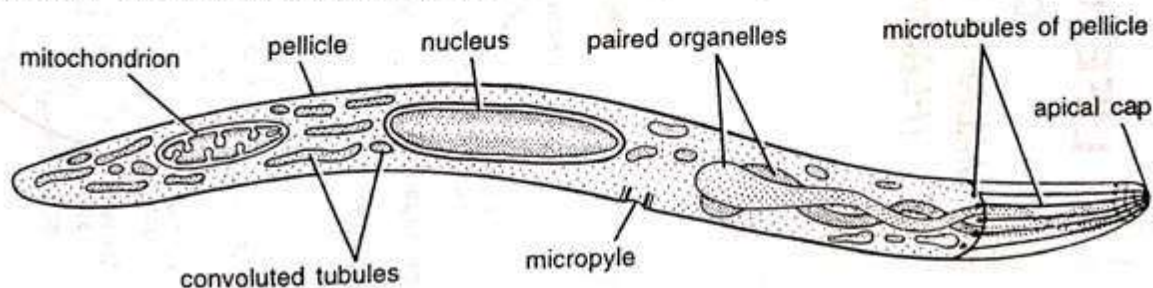


Fig. 1. *Plasmodium*. Structure of a sporozoite as revealed by electron microscope.

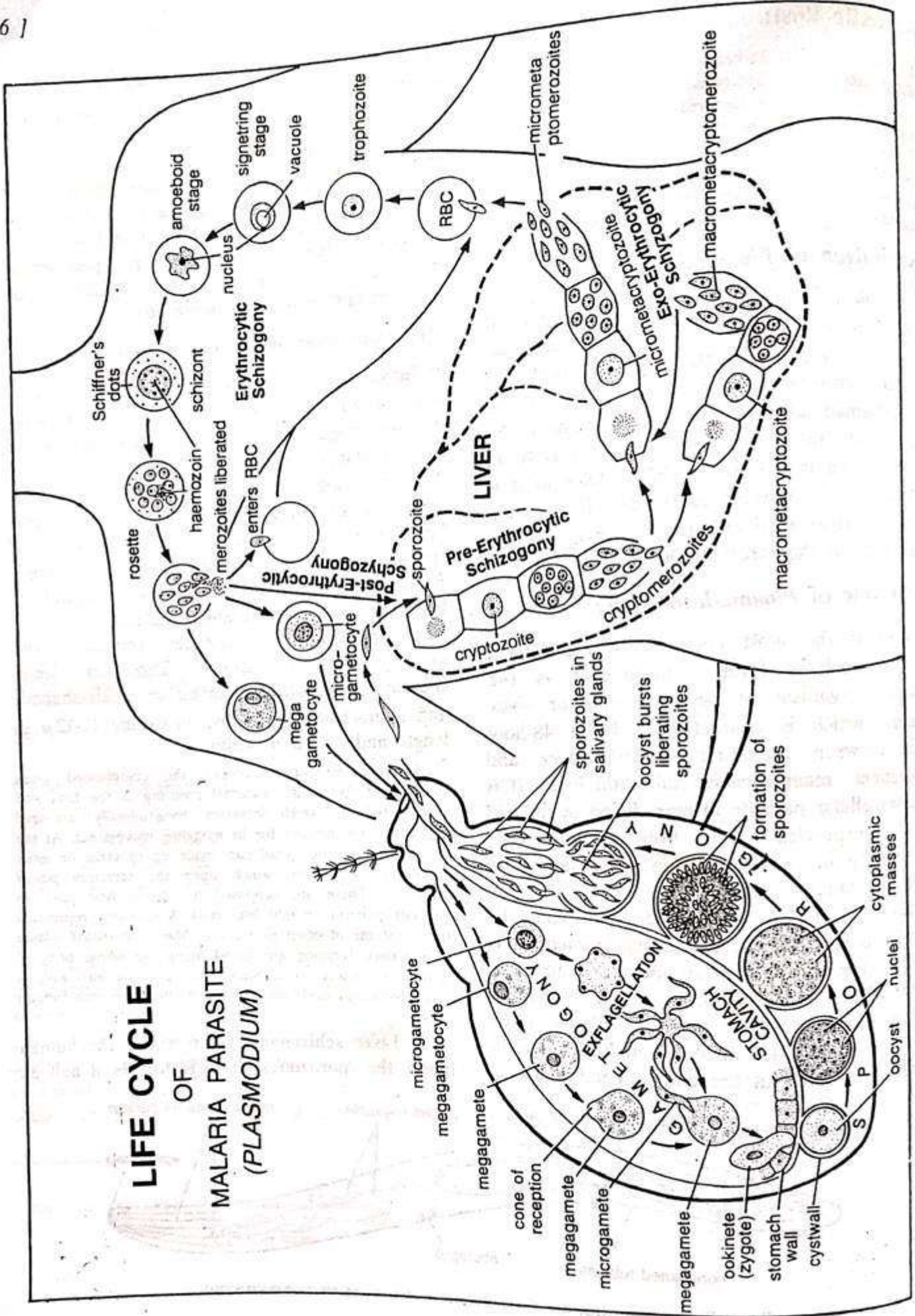


Fig. 2. Life cycle of *Plasmodium vivax*.



hour and then get into liver to invade the hepatic cells. Here they multiply asexually by schizogony. Liver schizogony has two phases, *pre-erythrocytic* and *exo-erythrocytic*.

(a) *Pre-erythrocytic phase*. After penetrating a hepatic cell each sporozoite becomes a *cryptozoite*. It grows for a number of days and becomes a spherical and non-pigmented *schizont*. It divides by schizogony (multiple fission) and forms a large number of uninucleate cells, the *cryptomerozoites*. Their reported number varies from one thousand to several thousands. They are liberated when the liver cell bursts. This is the end of *pre-erythrocytic phase*. During *pre-erythrocytic schizogony*, blood remains sterile and its inoculation does not produce infection.

(b) *Exo-erythrocytic phase*. *Cryptomerozoites* enter fresh liver cells to become *metacryptozoites*. They undergo schizogony similar to the previous one producing enormous number of *metacryptomerozoites*. This may be repeated several times and each time new liver cells are infected. All these succeeding schizogonic divisions are referred to as *exoerythrocytic* or *phanerozoic schizogony*.

It has been reported that *metacrypto merozoites* produced are of two types. Smaller and more numerous are *micro-metacrypto merozoites*. They enter the red blood corpuscles to start the erythrocytic stage. Larger and less numerous are *macro-metacrypto merozoites*. They invade fresh liver cells to continue the *exo-erythrocytic schizogony*. Both types of schizogony continue side by side.

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

(c) *Pre-patent and incubation periods*. The duration between initial sporozoite infection and first appearance of parasites in blood is termed the *pre-patent period*. It varies from species to species, being of about 8 days in *P. vivax*. The period between infection and appearance of first malarial symptoms is the *incubation period* which is of about 10-17 days (average 14 days) in *P. vivax*.

4. *Erythrocytic schizogony*. *Micro metacryptomerozoites*, after escaping into blood stream, invade the erythrocytes or red blood corpuscles.

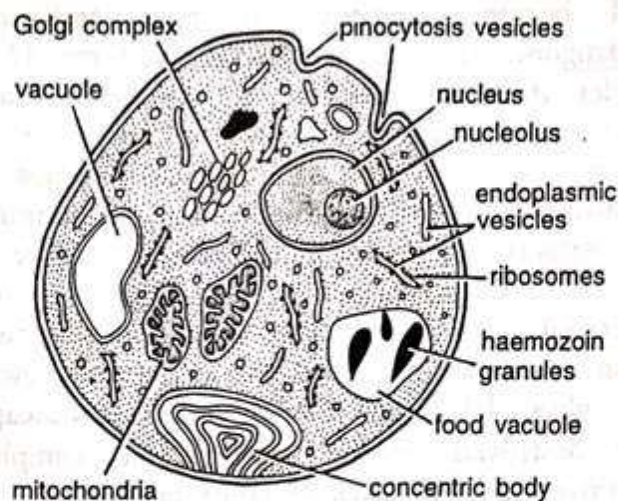


Fig. 3. *Plasmodium*. Electron micrograph of a trophozoite.

This starts the erythrocytic schizogony which includes the following stages.

(a) *Trophozoite stage*. Inside R.B.C., the micro-metacryptomerozoite becomes rounded and modified into a young *trophozoite*.

(b) *Signet ring stage*. As the trophozoite grows in size, a central vacuole is developed so that the nucleus is pushed to one side into peripheral cytoplasm. This stage is clinically referred to as *signet ring stage* as it resembles the signet ring with the peripherally located nucleus looking like the gem of the ring.

*Signet ring trophozoite* ingests a large portion of cytoplasm of red blood corpuscle forming a food vacuole into which it secretes digestive enzymes. Besides, a number of pinocytotic vesicles are also formed around the periphery of parasite into which digestion takes place. The enzymes bring about proteolysis of blood haemoglobin, which breaks down into its protein component and *hematin*. Protein is used as food by the trophozoite, while the unused hematin forms the toxic malarial pigment, called *haemozoin*.

(c) *Amoeboid stage*. Meanwhile, the signet ring trophozoite develops into an active *amoeboid trophozoite*. It sends pseudopodial processes into cytoplasm of the blood corpuscle. At this time, small red eosinophilic granules appear in the cytoplasm of the host corpuscle which are known as *Schuffner's granules*.

(d) *Schizont*. The amoeboid trophozoite, after active feeding, becomes rounded, grows in size

and becomes *schizont*. It now undergoes schizogony. Its nucleus divides to form 12-24 nuclei which get arranged at the periphery and cytoplasmic masses surrounding them. Each cytoplasmic mass with one nucleus becomes an oval-shaped *merozoite*. The haemozoin granules are gathered at the centre. With the rupture of the red blood corpuscle, the merozoites are liberated into the blood plasma. These invade fresh corpuscles to repeat the erythrocytic cycle. The 'ghost', left behind after the merozoites escape, are destroyed in the spleen. One complete erythrocytic cycle takes 48 hours in *P. vivax*.

**5. Post-erythrocytic schizogony.** Sometimes some merozoites produced in erythrocytic schizogony reach the liver cells and undergo schizogonic development in liver cells. This is referred to as *post-erythrocytic schizogony*.

**6. Formation of gametocytes.** When the impulse to multiply asexually by schizogony is exhausted, the merozoites do not proceed ahead with erythrocytic cycle, but, after entering the red blood corpuscles, increase in size to become rounded *gametocytes*. These show sexual dimorphism, being of two types. The male or *microgametocyte* is smaller and contains a large diffused nucleus. The female or *megagametocyte* is larger with a small compact peripheral nucleus. The gametocytes do not divide, but remain as intracellular parasites within their host's blood corpuscles, until they either die or are ingested by the vector, in which they continue their development.

## [II] Sexual cycle of *P. vivax* in mosquito

**1. Ingestion by mosquito.** When a female *Anopheles* mosquito sucks blood of the infected person, containing gametocytes in R.B.C., any other phases of the parasite and R.B.C.s are digested. The gametocytes however survive. These are liberated and become lodged in the cavity of gut.

**2. Gametogony.** Development of gametes from gametocytes is known as *gametogony* or *gametogenesis*. Like gametocytes, the gametes are also of two types—*microgametes* and *macrogametes*. In other animals and most Protozoa, reduction division occurs during the formation of gametes. Thus only gametes are haploid while zygote and other stages are diploid. But in

*Plasmodium*, according to some workers (Bano, 1959), meiosis or reduction division takes place in the first divisions of zygote. Consequently, only zygote is diploid, while gametes and all other stages of life cycle are haploid, as in higher plants.

**(a) Microgametes.** The male or microgametocyte begins to undergo a process, called *exflagellation*, in the midgut of mosquito. The drop in temperature, due to transfer from warm-blooded human host to cold-blooded insect, provides the stimulation for the process. In each microgametocyte, nucleus divides by mitosis to produce 6-8 haploid daughter nuclei, which assemble at the periphery. The cytoplasm outgrows into long, thin and flagella-like projections and a daughter nucleus enters each one of them. These projections break away as mature male or *microgametes* (sperms). Each measures from 20-25 $\mu$  in length.

**(b) Megagametes.** The female megagametocyte undergoes some reorganization and becomes a female gamete, that is, *megagamete* or *macrogamete* (ovum) which is ready for fertilization.

**3. Fertilization.** The megagamete gives out a small cytoplasmic projection, the *cone of reception* or *fertilization cone*. Nucleus of megagamete comes to lie near its receptive cone. When a lashing microgamete comes in contact with a megagamete, the former penetrates the latter through its receptive cone and *fertilization* or *syngamy* takes place. A complete fusion of nuclei and cytoplasm of two gametes occurs, resulting in the formation of *zygote* with a single diploid nucleus or *synkaryon*. Syngamy is *anisogamous* as the uniting male and female gametes are dissimilar.

**4. Ookinete.** The zygote remains rounded and motionless for some time, but soon it becomes elongated, vermiform and motile. It performs wriggling or gliding movement, and is known as the *vermicule* or *ookinete*. It measures about 15-22 $\mu$  in length and 3 $\mu$  in width. It moves exhibiting gregarine gliding-bending movements and peristaltic contractions and comes to lie against the peritrophic membrane of gut.

Electron microscope has revealed the presence of a central irregular nucleus, dense

Table 1. Comparative Account of Four Species of Human Infecting *Plasmodium*.

Characters	<i>P. vivax</i>	<i>P. malariae</i>	<i>P. ovale</i>	<i>P. falciparum</i>
1. Geographical distribution	Worldwide, in tropical, sub-tropical and warmer temperate regions.	Worldwide, in tropical and sub-tropical regions.	Tropical Africa.	Worldwide, in tropical, tropical, subtropical and warmer temperate regions.
2. Duration of pre-erythrocytic cycle (pre-patent period)	8 days	7-12 days	9 days	5-6 days
3. No. of metacryptozoites formed per schizont.	10,000	2,000	15,000	40,000
4. Duration of erythrocytic cycle	48 hours	72 hours	48 hours	36-48 hours
5. No. of merozoites formed per schizont.	12-24	6-10	6-12	18-24
6. Incubation period (average)	14 days	18-24 days	14 days	12 days
7. Signet ring form in R.B.C.	About 1/3 diameter of R. B. C. Large ring with vacuole and usually one chromatin dot.	About 1/3 diameter of R.B.C. Usually one ring and one chromatin dot.	About 1/3 diameter of R.B.C. Usually one ring and one chromatin dot.	Small ring situated at edge of R. B. C. Sometimes 2 chromatin dots.
8. Late trophozoite in R.B.C.	Amoeboid and large.	Compact and often band-shaped, small.	Compact and small slightly amoeboid.	Compact and medium-sized. Rarely seen in peripheral blood.
9. Schizont in R.B.C.	Large, 10 $\mu$ diameter, With 2-24 merozoites.	Medium sized, 7 $\mu$ diameter. With 6-12 merozoites.	Medium sized, 7 $\mu$ diameter. With 6-12 merozoites.	Small, 5 $\mu$ diameter. Not seen in peripheral blood.
10. Gametocytes in R.B.C.	Round. Fill R.B.C. Male 9 $\mu$ , Female 10-11 $\mu$ . Pigment granules evenly distributed.	Round or ovoid, Fills R.B.C., 7 $\mu$ . Pigment granules at centre and periphery.	Round or ovoid. Fill 3/4 of R. B. C., 9 $\mu$ . Pigment granules, evenly distributed.	Crescentic. Male 9-11 $\mu$ . Female 12-14 $\mu$ . Pigment granules around nucleus.
11. Host R.B.C.	Enlarged, Red Schuffner's dots usually seen.	Not enlarged. Ziemann's dots seen.	Slightly enlarged, Schuffner's dots seen.	Not enlarged. Greenish Maurer's dots or clefts seen.
12. Pigment (haemozoin)	Yellowish-brown. Fine granules and rodlets.	Dark brown to black. Abundant as coarse granules.	Dark brown. Less abundant coarse granules	Dark brown or black. Coarse granules in a compact mass.
13. Microgametes formed	4 to 8	2 to 5	---	4 to 8
14. Duration of sexual cycle at 25°C.	10 days	25-28 days	16 days	10-12 days
15. Type and effects of Malaria fever	Benign tertian. Death rate low	Quartan. Severe.	Ovale or mild tertian Severe	Malignant tertian. Death rate high.

\* A sporoblast stage, as found in *Monocystis*, is absent in *Plasmodium* in which the sporozoites are formed directly from the oocysts.

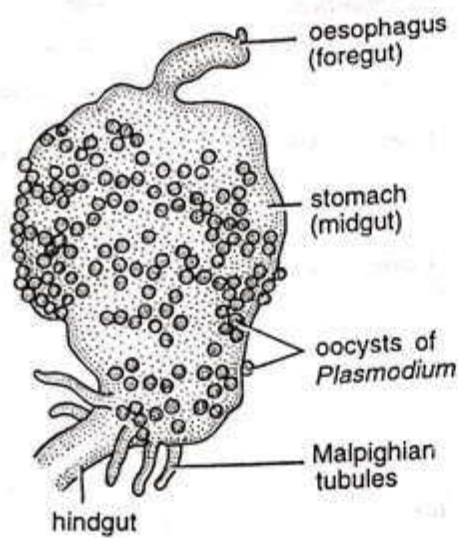


Fig. 4. Stomach or midgut of an infected female *Anopheles* mosquito with oocysts of *Plasmodium*.

cytoplasm, brown pigment granules, many mitochondria and ribosomes in the ookinete. This suggests that a very rapid synthesis of protein takes place within this stage of the parasite. Motile nature of ookinete is due to the presence of ectoplasmic contractile fibrils, the microtubules.

**5. Encystment.** Ookinete penetrates through the wall of midgut (stomach) to settle down just under the thin membrane that separates midgut from haemocoel. Here it becomes spherical and begins to encyst. The cyst wall is thin, membranous and elastic, secreted partly by ookinete and partly derived from mid-gut tissues of mosquito. The encysted zygote is called oocyst or sporont. The oocysts grow in size and they can now be seen on the outside of midgut or stomach as transparent rounded structures. These may be 50 or more in number (Fig. 4).

**6. Sporogony.** Each oocyst now enters a phase of asexual multiplication known as sporogony. Its nucleus divides first by meiosis (post-zygotic) and subsequently by mitosis (Bano, 1959), forming an enormous number of small haploid nuclei. At the same time, the cytoplasm develops large vacuoles and takes up a sponge-like structure, in which numerous irregular cytoplasmic masses are formed

connected by protoplasmic strands. The daughter nuclei arrange themselves along the free margin of cytoplasmic masses. Later, slender and finger-like processes are given out from these cytoplasmic bodies and a daughter nucleus migrates into each of them. In this way, about 10,000 minute, slender and sickle-shaped bodies, called sporozoites, are formed in each oocyst. Each sporozoite has tapering ends and a broad middle part containing a single nucleus. When mature, oocysts rupture and are separated from residual cytoplasm which look like a tangled mass within the oocyst. These sporozoites are liberated into haemocoel or body cavity of mosquito. Being motile, they move to different organs in the body of mosquito, but many of them penetrate the salivary glands. In mosquito, whole sexual cycle is completed within 10-20 days depending upon temperature.

The mosquito now becomes infective. According to one estimation, salivary glands of a single infected mosquito may contain as many as 200,000 sporozoites. When it bites a healthy person, thousands of sporozoites are injected in his blood along with saliva and start the cycle again.

## Human Malaria

Of all the contagious diseases caused by Protozoa, malaria diseases are the most destructive for man. They are widespread in the tropics and subtropics and also in certain areas of the temperate zones.

### [I] Early history

In the past, malaria was thought to be caused by foul gases emanating from marshes, hence the disease was named malaria (Italian; mala = bad; aria = air) meaning "bad air". In 1716, Lancisi established a connection between abundance of mosquitoes and malaria. In 1880, a French doctor, Charles Laveran, discovered the malaria parasite *Plasmodium* in human blood. In 1885-86, Golgi studied the erythrocytic schizogony of malarial parasite in man. In 1897, Ronald Ross discovered the oocysts of *Plasmodium* on the stomach of female *Anopheles* mosquito. In 1898, Ross worked out the life cycle of avian malarial parasite (*P. paraecox*) in mosquito while Grassi, Bignami *et. al.*, demonstrated the life cycle of human malarial parasite (*P. vivax*). In 1902, Ronald Ross was

\* A sporoblast stage, as found in *Monocystis*, is absent in *Plasmodium* in which the sporozoites are formed directly from the oocysts.



Fig. 5. Ronald Ross (1857-1932). In 1897, he proved that malaria is caused by a protozoan blood parasite (*Plasmodium*) transmitted by female anopheline mosquito. In 1902, he received the Noble Prize in Medicine and Physiology.

awarded the Noble Prize in Medicine and Physiology. In 1948, E. Short worked out the pre-erythrocytic schizogony of *P. vivax* in liver cells. In 1966, P.C.C. Garnham wrote a detailed monograph of malarial parasites, while their fine structure was reviewed in 1969 by M. Rudzinska.

### [II] Types of malaria

The following four different types of human malaria are recognized on the basis of the 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 characterized by the recurrence of fever every third day, i.e., after 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. **Quartan malaria.** *P. malariae* is the causative organism of quartan malaria, which is characterized 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 prove fatal to the patient, the chronic infections sometimes give rise to lethal kidney conditions. The disease is of worldwide occurrence, but it is mainly confined to tropical and subtropical regions.

3. **Ovale or mild tertian malaria.** This type of malaria resembles very much to the tertian malaria and is caused by *P. ovale*. The fever recurs every third day or at intervals of 48 hours. Ovale malaria is not greatly harmful and is mainly confined to tropical Africa.

4. **Aestivo-autumnal, malignant tertian or pernicious malaria.** The causative organism of this malaria is *P. falciparum*. In this also the fever cycle is of 48 hours. The fever is often fatal to the patient as it affects the brain. Its incidence follows that of *P. vivax*.

5. **Quotidian malaria.** When more than one species of *Plasmodium* infect the patient, or when 2 or 3 generations of parasites mature on successive days, the fever is repeated daily with an interval of 24 hours.

### [III] Symptoms and pathogenesis

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. To establish malarial symptoms, it is necessary that a large number of organisms must continue erythrocytic cycle at a time.

Malaria is quite a dramatic disease. Each attack of fever shows three successive stages :

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

2. **Hot stage.** As the chill subsides, the body temperature rises as high as 41°C or 106°F. The patient feels very hot with a terrible headache. It lasts one to four hours.

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

Malaria fever occurs when schizonts in red blood corpuscles burst and set free their contained merozoites and malarial pigment

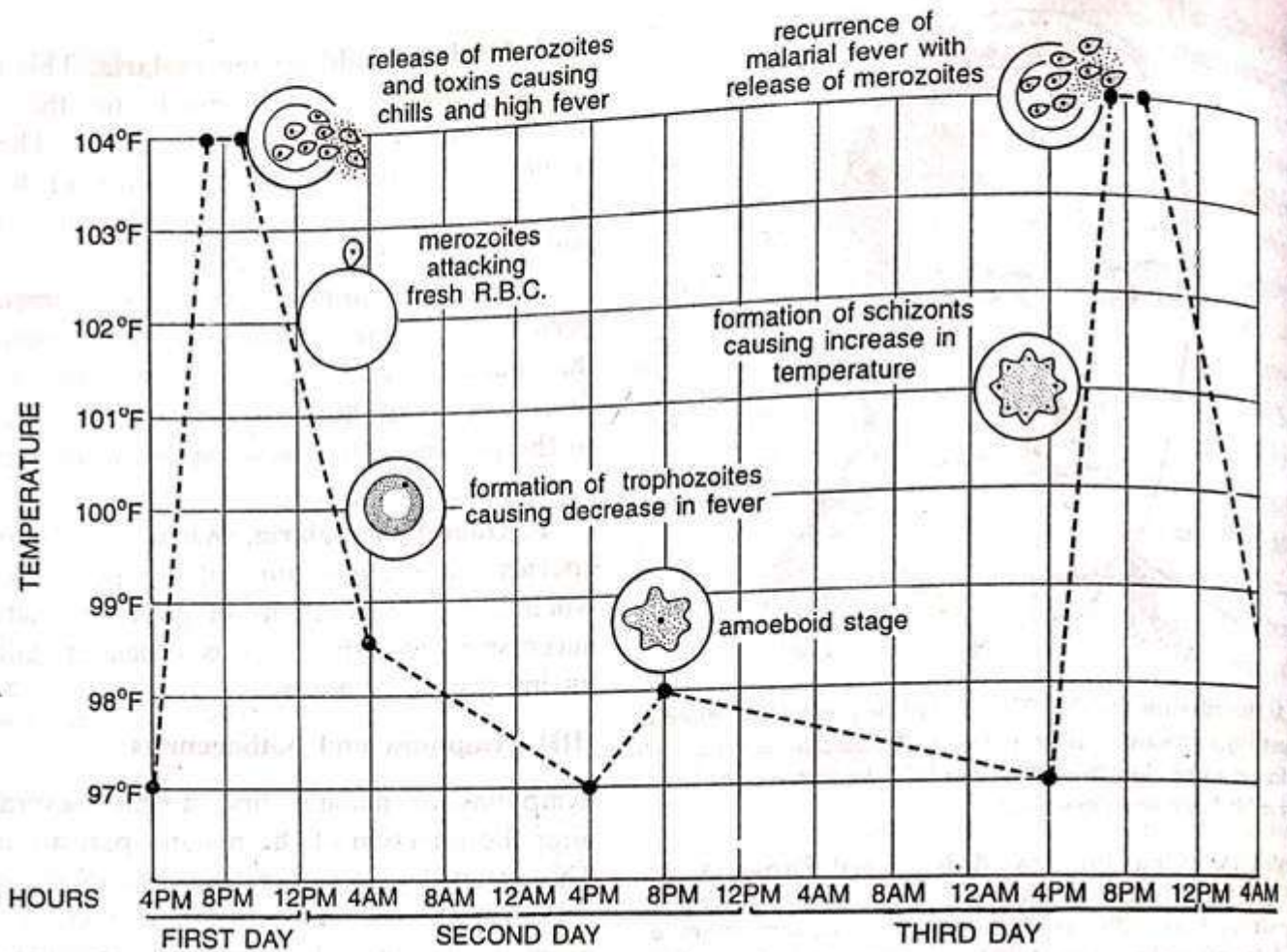


Fig. 6. *Plasmodium*. Fever cycle in vivax malaria.

(haemozoin) in the blood plasma. Bursting of schizonts tends to be synchronous as they all burst at the same time. Haemozoin is said to be toxic and so induces high fever and shivering (Fig. 6).

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

- (1) Destruction of erythrocytes on liberation of merozoites.
- (2) Infected erythrocytes become more fragile, rupture easily and are destroyed.
- (3) The enlarged spleen due to malarial infection releases a lytic substance, *lysolecithin*, which destroys erythrocytes.
- (4) Malarial parasites produce *haemolysin* (an antibody), which brings about haemolysis of some normal erythrocytes.

In chronic cases, spleen becomes enlarged and fibrosed so much that it ruptures under the influence of trauma.

The falciparum infection often results in thrombosis of visceral capillaries. Death takes place when capillaries of brain become plugged with both the parasites and malarial pigment. Another very serious outcome of the falciparum infection is *black-water fever*, which is characterized by the wholesale destruction of patient's erythrocytes and excretion of liberated haemoglobin in urine.

#### [IV] Duration of infection

If the patient is not given any treatment and death does not result rapidly, after a variable number of erythrocytic schizogonic cycles, the host's antibodies will destroy all or most of the erythrocytic schizonts. This will result in the disappearance of the malarial symptoms and occurrence of latency. However, the parasite persists either in the liver cells (*P. vivax*, *P. ovale*, *P. malariae*), or in the capillaries of various viscera (*P. falciparum*). In case of vivax malaria the infection persists for atleast two years,

quartan malaria for five years and in malignant malaria for six months.

#### [V] Relapses

Malarial relapses are fairly common in the human malarias except the ovale malaria. In tertian malaria relapses have been observed to occur after 6-12 months of primary infection. The short term relapses have been reported in malignant malaria. In quartan malaria relapses occur after long periods of latency.

#### [VI] Control of malaria

Malaria has posed a whole series of biological problems. Symptoms of malaria were recognized atleast 2000 years ago. Even at that time people realized that the disease was more prevalent among people, who lived close to marshy grounds. No further progress was made until the 17th century when the bark of *Cinchona* tree, growing in the New World, was found to be excellent for the treatment of this disease. Its active ingredient was *quinine* and this was in use well upto present century. Now medical science has gone a long way to control this disease.

In India, prevention and control of malaria is treated as a national problem and the anti-malaria department of the government deals with it. The war waged on malarial parasite is fought by attacking it simultaneously on three major fronts. In other words, all the control measures fall under the following three categories :

- (1) *Elimination* or destruction of vector, i.e., *Anopheles* mosquito.
- (2) *Prophylaxis*, i.e., prevention of infection.
- (3) *Treatment* of the infected patient.

#### A. Destruction of *Anopheles*

If Anopheline mosquitoes are completely destroyed, the infection from one person to another can be checked. It is the most effective and the surest way of controlling malaria. It is achieved by using effective insecticides and by draining swamps to destroy the breeding places of mosquitoes.

1. **Destruction of adult mosquitoes.** Adult mosquitoes can be most effectively combated in

dwellings. The following methods can be employed to kill them :

(a) **Killing by hands.** The mosquitoes which approach or bite may be killed by hands to save oneself as well as others.

(b) **Traps.** These are small boxes made of wire gauze and internally lined by black paper or cloth. The mosquitoes tend to enter the boxes and then can be killed by closing them.

(c) **Fumigation.** Mosquitoes can be driven out of the houses or killed by fumigation. Sulphur, pyrethrum, cresol, tarcamphor or other derivatives of naphtha are burnt to produce poisonous fumes. Smoke of garlic is now considered to be effective in driving the mosquitoes out.

(d) **Spraying.** Mosquitoes can be killed inside human dwellings by using *mosquito-bombs* or by spraying DDT, flit, pyrethrum and other insecticides.

(e) **Sterilization.** Sterilization of mosquitoes is now being achieved in some parts of the world, particularly Japan. This method is very effective in controlling mosquito population.

2. **Elimination of breeding places.** Swampy areas, marshes and stagnant waters, such as pools, ponds, pits and ditches must be drained off as they are breeding places of mosquitoes. If possible, the breeding grounds may be filled up with earth or stones, etc. Domestic species can be largely controlled by eliminating receptacles that hold water, such as tin-cans, buckets, cisterns, barrels, etc. Bushes and shrubs should be cleared off. Open drains should be closed or made underground.

3. **Destruction of larvae and pupae of mosquitoes.** It is easier and more convenient to kill the aquatic larvae and pupae than the winged adults of mosquitoes.

(a) **Proper drainage.** The young stages of mosquitoes can be prevented from flourishing by not allowing water to stand in drains, streams, ditches, etc. A speedy flow of water can be maintained, so that the developing forms get away into larger streams and rivers, where they generally die.

(b) **Oil screens.** Surface of water may be covered by spreading petroleum, paraffin oil, crude oil or kerosene oil. The thin surface oil film prevents the larvae and pupae from carrying on their normal respiration and they die.

(c) **Chemical larvicides.** Oil solutions or emulsions of DDT, DDD and Benzene hexachloride are effective larvicides. Dusts containing Paris green, DDT or BHC are effective in the control of surface feeding *Anopheles* larvae. Larger bodies of water can be sprayed with these poisonous substances by aeroplanes. Extracts of aquatic weed *Ceratophyllum demersum* control mosquito larvae in ponds. When tulsi (*Oscimum sanctum*) seeds are introduced in water they swell and the mucilage coating attracts and traps the mosquito larvae which eventually die.

(d) **Biological methods.** Larvicidal fishes, like stickle-backs, minnows (*Gambusia*) and trouts, etc., ducks and aquatic nymphs and adult insects like dragon-flies, which are natural enemies of mosquito, may be introduced in ornamental fountains, ditches, ponds, lakes, canals, tanks, etc. They feed upon mosquito larvae and pupae.

### B. Prevention of Infection

Protection of healthy persons in malaria prone areas from being infected can be done through the use of new insect repellents, nets, gloves and by screening the bedroom windows.

#### 1. Defence against mosquito bites.

Mosquitoes can be prevented from biting by adopting various protective measures, like :

- (1) Building houses on high grounds.
- (2) Screening of doors, windows and ventilators.
- (3) Use of mosquito nets.
- (4) Use of anti-mosquito creams (repellents) on exposed parts of the body.

2. **Use of prophylactic drugs.** Certain anti-malaria drugs, such as *Quinine*, *Paludrine*, *Daraprim*, *Proguanil* and *Pyrimethamine*, if taken in small daily or weekly doses, are effective in keeping off malaria. They kill sporozoites before they become established in liver.

3. **Reduction of susceptibility to infection.** Chances of infection can be greatly minimized by maintaining proper health. It can be achieved by

getting proper nourishment, by avoiding exposure to bad conditions and by following regularity in life.

### C. Treatment of Malaria

*Plasmodium* does not produce antibodies or antitoxins in human blood like germs of other infectious diseases, such as cholera and smallpox, etc. Therefore, treatment of malaria by inoculations or vaccinations is out of question. Value of *quinine* has been known for a long time. *Quinine*, which is extracted from the bark of *Cinchona* tree grown in Java, Peru, Ceylon and India, was used effectively for as long as 300 years to cure malaria. But, during World War II, Japan got control of the major quinine-producing areas in the East Indies. Scarcity of quinine led to the production of various synthetic drugs. In allopathy, various synthetic drugs, such as *Quinine*, *Atabrin*, *Camoquin*, *Chloroquine*, *Mepacrine* (*Atebrin*), *Paludrine*, *Resochin*, *Pamaquine* (*Plasmoquine*), and *Primaquine*, etc., are used as suppressants of various stages of the parasites.

*Daraprim* is the most potent drug invented so far for a malaria patient. It is a pyrimidine and a single dose of 25 mg. causes the schizonts of *P. vivax* and *P. falciparum* to disappear. But we are still looking for an ideal drug.

### Anti-malaria campaign in India

About two decades ago malaria was the most widespread disease in India. With the assistance of World Health Organization (WHO), the Ministry of Health of the Government of India launched a National Malaria Control Programme in 1962 and almost controlled it by destroying the mosquitoes with D.D.T. and other insecticides. For the last few years the mosquitoes have appeared again in plenty and the malaria infection has begun. The D.D.T. seems to have become ineffective as mosquitoes have developed immunity for it. Also a change in the behaviour of the mosquitoes has been noted. They now bite and rest outdoors instead of biting humans indoors and resting on the walls. The Vector Control Research Center, Pondicherry,



the Indian Medical Research Board is now busy in finding out the alternative means for the eradication of mosquitoes. It has discovered a species of water-bug (fam. Notonectidae) which feeds on the eggs and larvae of mosquito. The National Institute of Communicable Diseases, Delhi, and the Postgraduate Medical Institute, Chandigarh, are busy in developing the vaccines

for malaria. Two such vaccines are being testified.

With new strategies adopted by Government of India such as increased financial allocation to the anti-malarial operations and the treatment of every fever case with drugs readily made available, there has been decline in the incidence of malaria recently.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Give an account of the life history of the malarial parasite in man and suggest methods for controlling malaria.
2. What do you understand by 'Intermediate Host'? Describe the life cycle of the malarial parasite in mosquito.
3. Give an illustrated account of the life cycle of *Plasmodium vivax*.
4. How does malaria spread from one man to another? What steps would you suggest to protect your household from this disease?
5. Describe briefly the life-history of *Plasmodium* and compare it with that of *Monocystis*.
6. Write an essay on *plasmodium* and Malaria.
7. Write short notes on : (i) Control of malaria, (ii) Exoerythrocytic cycle, (iii) Incubation period, (iv) Ookinete, (v) Prepatent period, (vi) Schizogony, (vii) Sporogony.

#### » Short Answer Type Questions

1. Mention the names of human body cells which are prove to the attack of *Plasmodium*.
2. Mention the four species of *Plasmodium* and the types of malaria caused by them.
3. What is meant by signet-ring stage ?
4. To which order does malarial parasite belong ?
5. Define schizogony.
6. How is malaria transmitted from one person to the other? Give an illustrated description of the cycle of Ross.
7. What are the Tertian and Quartan agents ? What are their causative agents ?
8. Write a brief account of the contributions made by Ronald Ross giving an approximate date.
9. Distinguish between the schizont and cryptoschizont stages of *Plasmodium*.
10. Differentiate between pre-patient and incubation period.
11. Compare the micro- and macro-gametocytes of *Plasmodium*.
12. Distinguish between four species of human malarial parasites based on the type of malaria they produce.
13. Describe the sexual cycle of the malarial parasite.
14. Draw a labelled diagram to illustrate sporogony in *Plasmodium*.

#### » Multiple Choice Questions

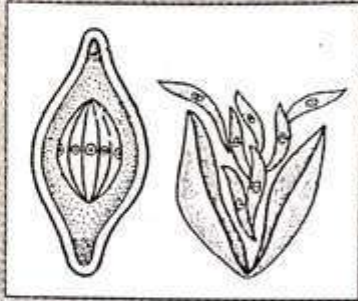
1. The shivering characteristic of malaria occurs when :
  - (a) merozoites are liberated from RBC with toxin
  - (b) when schizonts enter the RBC
  - (c) when the schizonts are on the reticulo-endothelial cells
  - (d) when the signet ring is formed
2. Besides R.B.C. *Plasmodium* attacks one more type of human body cells during its normal course of life cycle. Name that human body cells :
  - (a) liver cells
  - (b) muscle cells
  - (c) columnar cells of intestine
  - (d) nerve cells
3. What is cryptomerozoite of *Plasmodium* ?
  - (a) product of sporogony in the gut of mosquito
  - (b) product after sexual fusion of gametes in the gut of mosquito
  - (c) product of schizogony
  - (d) product of hologamy in RBC
  - (e) product of gametogamy in RBC
4. The intermediate host of malarial parasite is :
  - (a) man
  - (b) female *Anopheles*
  - (c) *Culex*
  - (d) tse-tse fly
5. In the life history of *Plasmodium* exflagellation occur in the :
  - (a) merozoite
  - (b) microgametocyte
  - (c) macrogametocyte
  - (d) cryptozoite
6. Malaria is transmitted by the :
  - (a) female *Culex* mosquito
  - (b) male *Anopheles* mosquito
  - (c) female *Anopheles* mosquito
  - (d) male *Culex* mosquito
7. Vegetative phase of *Plasmodium* in R.B.C. of man is called :
  - (a) sporozoite
  - (b) trophozoite
  - (c) merozoite
  - (d) cryptozoite
8. One of the following species of *Plasmodium* is not found in India :
  - (a) *fulciparum*
  - (b) *ovale*
  - (c) *malariae*
  - (d) *vivax*
9. *Plasmodium* is the causative agent of malaria was discovered by :
  - (a) Lavern
  - (b) Ross
  - (c) Golgi
  - (d) Lamble

10. Which species of *Plasmodium* show longest incubation period ?  
 (a) *vivax* (b) *falciparum*  
 (c) *malariae* (d) *ovale*
11. The malarial parasite is introduced into the blood of man as a :  
 (a) metacryptozoite (b) cryptozoite  
 (c) schizont (d) sporozoite
12. *Plasmodium* belongs to the class :  
 (a) ciliophora (b) rhizopoda  
 (c) mastigophora (d) sporozoa
13. Trophozoite of *Plasmodium* lives in :  
 (a) red blood corpuscle (b) lymph  
 (c) liver (d) blood plasma  
 (e) lung cavity
14. Malaria is caused by :  
 (a) *Ascaris* (b) foul air  
 (c) *Plasmodium* (d) mosquito
15. Shivering in malaria occurs when :  
 (a) liver cycle is completed  
 (b) merozoites and toxins are released into blood  
 (c) gamonts are formed  
 (d) mosquito ingests infected human blood
16. The infective stage of *Plasmodium* in man is :  
 (a) schizont (b) merozoite  
 (c) sporozoite (d) trophozoite
17. Infective stage of *Plasmodium* is :  
 (a) trophozoite (b) ookinete  
 (c) sporozoite (d) schizont
18. The formation of gametocyte of malarial parasite takes place :  
 (a) in the stomach of female *Anopheles*  
 (b) in the stomach of male *Anopheles*  
 (c) in the blood of man  
 (d) in the salivary gland of *Anopheles*
19. Schizont is a stage in the life history of malarial parasite occurring in :  
 (a) red blood cells of man  
 (b) stomach of *Anopheles*  
 (c) salivary glands of *Anopheles*  
 (d) blood of *Anopheles*
20. Sporogony of malarial parasite occurs in the :  
 (a) liver of man (b) R.B.C. of man  
 (c) stomach wall of mosquito  
 (d) salivary gland of mosquito
21. Malignant malaria is due to infection of :  
 (a) *Plasmodium ovale* (b) *P. falciparum*  
 (c) *P. malariae* (d) *Wuchereria bancrofti*
22. Prepatent period is :  
 (a) time required by sporozoite to become cryptomerozoite  
 (b) time required to complete I liver cycle  
 (c) 10 days (d) all of these
23. In the life-cycle of *Plasmodium vivax*, the microgametocyte undergoes exflagellation in the :  
 (a) stomach of the female *Anopheles*  
 (b) erythrocyte of man  
 (c) liver cells of man  
 (d) blood plasma of man
24. The erythrocytic phase in the life-cycle of *Plasmodium vivax* is completed in :  
 (a) 24 hours (b) 36 hours  
 (c) 48 hours (d) 72 hours
25. Asexual reproduction during schizogony of malarial parasite is :  
 (a) sporulation (b) binary fission  
 (c) multiple fission (d) amitosis
26. In life cycle of malarial parasite, amoeboid stage is found :  
 (a) inside the gut of mosquito  
 (b) inside the cyst attached to the wall of mosquito stomach  
 (c) inside the liver cells of man  
 (d) in RBCs of man
27. The zygote of *Plasmodium vivax* divides repeatedly to produce :  
 (a) sporozoites (b) cryptomerozoites  
 (c) micrometacryptomerozoites  
 (d) metacryptozoites
28. In life cycle of *Plasmodium vivax* after a number of erythrocytic cycles, some merozoites invading fresh RBCs grow to :  
 (a) macrometacryptozoites (b) schizonts  
 (c) gametocytes (d) signet ring stage
29. The incubation period of *Plasmodium vivax* is :  
 (a) 48 hours (b) 72 hours  
 (c) 120 hours (d) 240 hours
30. In life history of malaria the cells produced by Schizogony are :  
 (a) sporozoites (b) schizonts  
 (c) cryptozoites (d) merozoites
31. Life cycle of Malarial Parasite is :  
 (a) monogenetic (b) digenetic  
 (c) not in *Anopheles* (d) none of these
32. Infective stage of *Plasmodium* to man is :  
 (a) gamont (b) sporozoite  
 (c) trophozoite (d) merozoite
33. Schizont of *Plasmodium* is found in :  
 (a) liver (b) blood  
 (c) both (d) mosquito
34. The stage of *Plasmodium* that appears in human blood during night only :  
 (a) schizont (b) sporozoite  
 (c) gamonts (d) microgametocyte
35. Charles Laveran :  
 (a) confirmed discovery of malaria  
 (b) discovered malaria (c) first observed oocysts  
 (d) described life cycle of *Plasmodium*
36. Black water fever is caused by :  
 (a) *Plasmodium ovale* (b) *Plasmodium falciparum*  
 (c) *Plasmodium vivax* (d) *Plasmodium malariae*
37. *Plasmodium* is a parasite of human :  
 (a) blood (b) liver  
 (c) spleen (d) bone marrow
38. *Plasmodium* belongs to class sporozoa which is characterised by :  
 (a) pseudopodia (b) myonemes  
 (c) no distinct locomotory organelles  
 (d) flagella

39. Asexual reproduction called sporogony occurs in *Plasmodium* :  
 (a) in man only (b) in mosquito  
 (c) both in man and female mosquito  
 (d) in female mosquito only
40. Sporozoite of *Plasmodium* is :  
 (a) amoeboid and uninucleate  
 (b) pelliculate, uninucleate and with numerous mitochondria  
 (c) capable to pass across a blood capillary  
 (d) multinucleate
41. Prepatent period in Malarial infection is :  
 (a) interval between inoculation and fever  
 (b) duration between inoculation and start of blood cycle  
 (c) interval between two liver cycles  
 (d) duration between repetition of fever
42. What is cryptomerozoite of *Plasmodium* ?  
 (a) a product of gametogamy  
 (b) a product of schizogony  
 (c) a product of sporogony in mosquito  
 (d) none of these
43. An intracellular parasite is :  
 (a) *Entamoeba* (b) *Ascaris*  
 (c) *Trypanosoma* (d) *Plasmodium*
44. Most dangerous species of *Plasmodium* is :  
 (a) *malariae* (b) *falciparum*  
 (c) *ovale*  
 (d) *vivax*
45. In India, urban malaria is transmitted by :  
 (a) *Culex quinquefasciatus*  
 (b) *Anopheles annularis*  
 (c) *Anopheles subpictus* (d) *Anopheles stephensi*
46. What is the duration of incubation period of *P. falciparum* :  
 (a) 12 days (b) 10 days  
 (c) 14 days (d) None of the above
47. Erythrocytic cycle of *P. vivax* completed in :  
 (a) 24 hours (b) 48 hours  
 (c) 72 hours (d) 96 hours
48. Active feeding stage of *Plasmodium* :  
 (a) trophozoite (b) sporozoite  
 (c) merozoite (d) metacryptozoite
49. Malaria parasite can best obtained from its patient :  
 (a) one hours before rise the temperature  
 (b) five hours after temperature  
 (c) when temperature rise with rigor  
 (d) any time
50. Schuffner's dots in a patient of malaria, are found :  
 (a) RBC (b) gametocyte of *Plasmodium*  
 (c) liver cells (d) signet ring trophozoite
51. Toxic material formed after proteolysis of Hb :  
 (a) haematin (b) hemozoin  
 (c) heam (d) Schuffner's dot
52. Sexual phase in the life cycle of *Plasmodium* occurs in :  
 (a) gut of mosquito (b) salivary gland of mosquito  
 (c) blood of man (d) body cavity of mosquito

**Answers**

1. (a) 2. (a) 3. (c) 4. (b) 5. (b) 6. (c) 7. (b) 8. (b) 9. (a) 10. (c) 11. (a) 12. (d) 13. (a) 14. (c) 15. (b) 16. (c) 17. (a) 18. (b)  
 19. (a) 20. (c) 21. (b) 22. (a) 23. (a) 24. (c) 25. (c) 26. (d) 27. (a) 28. (c) 29. (a) 30. (c) 31. (b) 32. (c) 33. (a) 34. (a) 35. (b)  
 36. (a) 37. (a) 38. (c) 39. (d) 40. (c) 41. (a) 42. (b) 43. (a) 44. (b) 45. (d) 46. (a) 47. (b) 48. (a) 49. (c) 50. (a) 51. (b) 52. (a)



## *Monocystis agilis*

# 10

Chapter

Unlike digenetic *Plasmodium*, there are some sporozoan types which are parasitic in one host only. The *gregarines*, parasitic in invertebrates and ascidians, fall into this category. These are most commonly found in the coelomic epithelial cells, gut and reproductive organs of their hosts. Among those gregarines that exhibit sexual reproduction only, two forms are recognized, *acephaline*, and *cephaline*. In *acephaline* forms, body is not divided into chambers and anterior end does not bear an organ for attachment. *Cephaline* forms possess the chambered body as well as the organ for attachment. *Monocystis* (Gr., *monos*, single + *kystis*, bladder) is an *acephaline* gregarine. The most common species are *M. agilis*, *M. lumbrici*, *M. magna*, *M. beddardi*, *M. pheretimi*, *M. lloidi* and *M. bengalensis*. A generalized account of the genus *Monocystis* has been given here, with particular reference to *M. agilis*.

(Z-1)

## *Monocystis agilis*

### Systematic Position

Phylum	Protozoa
Subphylum	Sporozoa
Class	Telosporea
Subclass	Gregarinia
Order	Eugregarinida
Genus	<i>Monocystis</i>
Species	<i>agilis</i>

### Habits and Habitat

Species of *Monocystis* are typically endoparasites of earthworms and occur in their coelom and seminal vesicles. Besides *Monocystis*, there are also found the life cycle stages of other allied

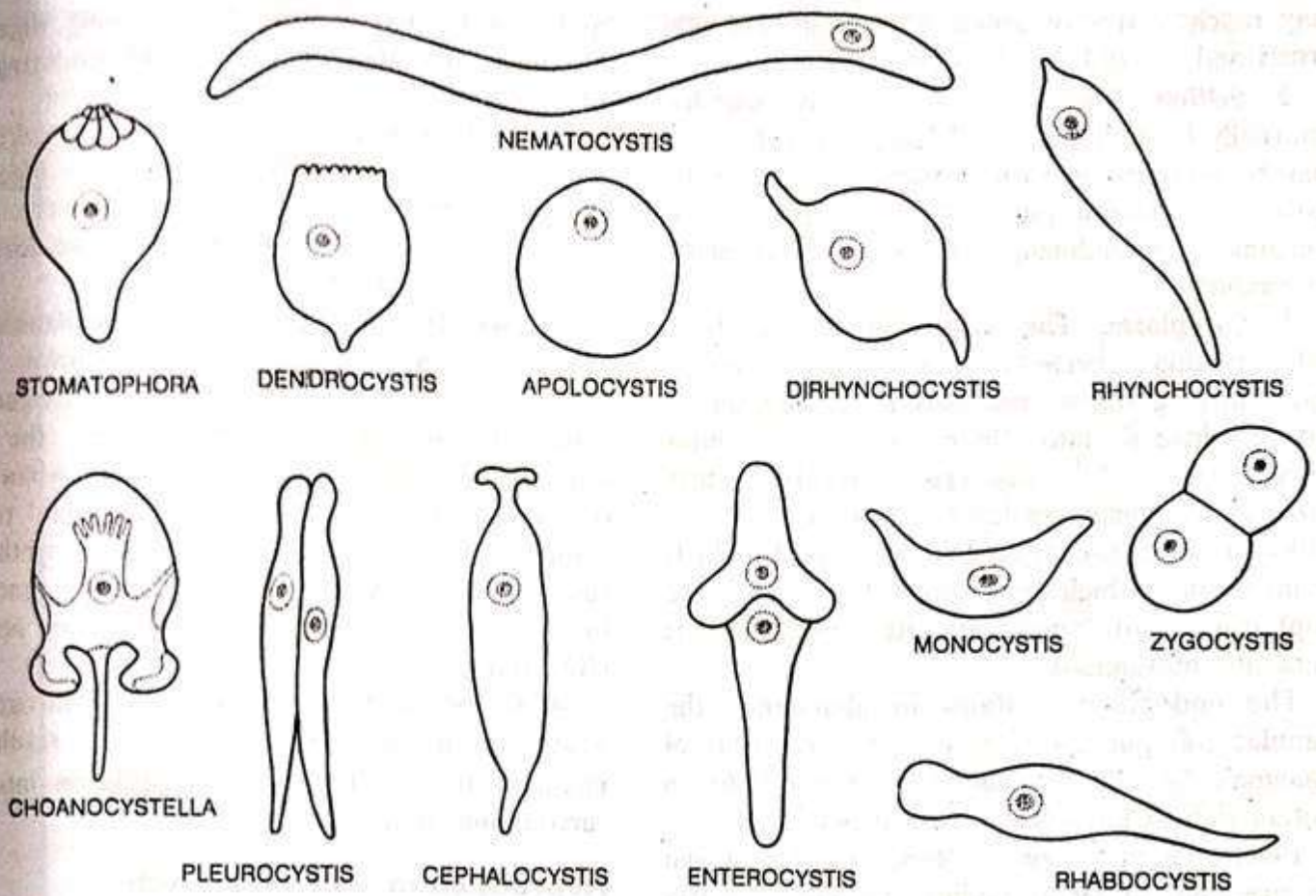


Fig. 1. Trophozoites of a few allied genera of *Monocystis* and their shapes.

genera, such as *Enterocystis*, *Rhabdocystis*, *Apolocystis*, *Nematocystis*, *Dirhynchocystis*, *Dendrocystis*, *Cephalocystis*, *Rhynchocystis*, *Zygocystis*, *Pleurocystis*, *Stomatophora*, *Choanocystella*, and so on. When an earthworm is infected with several species of these parasites, it becomes rather impossible to relate the stages of the parasites with their respective genera. However, the trophozoites of different genera have characteristic shapes by which they may be identified (Fig. 1).

### Study of *Monocystis* in Laboratory

*Monocystis* is easily obtained for study in the laboratory. Get a living, sexually mature earthworm and narcotise it by adding a few drops of *chloretone* in water containing the animal. Pin it down and then make a slit in the dorsal body wall from about X to XV segments. You will observe yellowish-white bodies extruding through the slit. These are the seminal vesicles. Pinch off these bodies with forceps and keep in a watch-glass in 0.7% NaCl solution. Make a paste of the seminal vesicles with *corrosive sublimate* (mercuric chloride in water). Spread a drop of the paste on the cover-slip which should then be placed on the glass slide.

Examine it under the microscope for trophozoites, cysts, spores and other developmental stages of the parasite. A permanent slide can also be prepared by the usual method of staining and dehydration, etc.

### Structure of Trophozoite

Trophozoite is the adult and feeding stage of parasite. It is found in seminal vesicles of earthworm. It develops within the sperm ball (*sperm morula*) which is a group of developing sperms or spermatozoa of the host. Sometimes, it is seen surrounded by a thin layer of degenerating sperm morula, to which the tails of dead spermatozoa are attached giving it a strongly ciliated appearance. When sperm tails are separated, the trophozoite becomes free.

**1. Shape and size.** Trophozoite is microscopic and unicellular. The actual shape and size differ according to the stage of development. The youngest stages are usually rounded or oval and about  $5\mu$  long. A full grown mature trophozoite is elongated, spindle-shaped, flattened and worm-like organism with tapering body ends. It

may reach a size of about  $500\mu$  long and  $40\mu$  broad and is visible to the naked eye.

2. **Pellicle.** Body of trophozoite is bounded externally by a definite thick and firm *pellicle*. It may be modified in various ways, i.e., it may be striated or thrown into ridges and furrows. It contains longitudinally arranged contractile *microtubules*.

3. **Cytoplasm.** The cytoplasm has a sharp differentiation between outer clear *ectoplasm* and inner granular *endoplasm*. Ectoplasm is further divided into three layers: (i) outer epicyte, (ii) middle *sarcocyte* and (iii) inner *myocyte*. The innermost layer, or myocyte consists of longitudinal and transverse contractile fibrils or *myonemes*, which are supposed to enable the trophozoite to perform its characteristic metabolic movements.

The endoplasm contains in abundance the granules of *paraglycogen* (a special form of glycogen), fat globules and sometimes *volutin*, a protein rich in phosphorus and nucleic acid.

Electron micrograph of *Monocystis* has shown the presence of Golgi bodies and mitochondria as has already been noted in various protozoans. The mitochondria are more in number at the periphery.

4. **Nucleus.** Nucleus is single and vesicular with spherical or ellipsoidal form. It contains usually one *nucleolus* or *karyosome*, (sometimes more), which stains deeply with iron haematoxylin. Nuclear membrane is delicate and bears pores. Nucleoplasm contains four chromosomes (haploid number).

## Physiology

1. **Locomotion.** *Monocystis* does not possess special organs for locomotion. It shows wriggling or gliding movements brought about by the rhythmic contractions and relaxations of myonemes. Such a type of movement, characteristic of a monocystid gregarine, is known as *gregarine movement*. This is similar to the *euglenoid movement* of *Euglena*.

2. **Nutrition.** Nutrition in *Monocystis* is *saprophytic*. It absorbs its nourishment from the fluid of the seminal vesicle by osmotrophy through the general surface of the body. It is

quite likely that it may be secreting digestive enzymes upon the outer fluid and rendering the protoplasmic particles soluble for their absorption. In some species, like *M. buccalis*, the anterior end of the body is modified for ingesting the nutrient from its vicinity. Reserve food material is stored in endoplasm in the form of *paraglycogen granules*.

3. **Respiration.** The actual mechanism of respiration in *Monocystis* is not known. It is believed that the parasite obtains oxygen by diffusion through its pellicle from the cell contents of host's sperm morula, when the trophozoite is within it, or from the fluid of the seminal vesicle. The mitochondria synthesize respiratory enzymes for oxidation reactions involved in aerobic conversion of pyruvic acid to  $\text{CO}_2$  and water.

4. **Excretion.** Carbon dioxide and nitrogenous waste products, produced as a result of metabolism, are eliminated by diffusion into the surrounding fluid.

## Reproduction and Life Cycle

*Monocystis* is *monogenetic*, i.e., its life cycle is completed in a single host which is earthworm. Only zygotes are diploid while all other stages (gamonts, gametes, etc.) are haploid. Asexual multiplication by schizogony does not occur. The life cycle proceeds as follows :

1. **Gamontogamy.** This is a method of sexual reproduction which involves the pairing of gamonts, formation of gametes and fertilization. It takes place as follows :

(a) **Syzygy.** After a period of feeding, growing and wandering about, each trophozoite becomes an oval reproductive body, the *gamont* or *gametocyte*. The gametocytes become shortened and spherical and associate in pairs. The two then secrete a common resistant and protective cyst wall, the *gametocyst* or *gamontocyst*, around themselves. The cyst wall has two layers, an outer thick and rigid *ectocyst* and an inner thin *endocyst*. Within the cyst wall, the gametocytes never fuse or conjugate. This type of pairing of the gametocytes is referred to as *syzygy*.

(b) **Gametogony.** Within the gametocyst, each gametocyte undergoes nuclear multiplication by

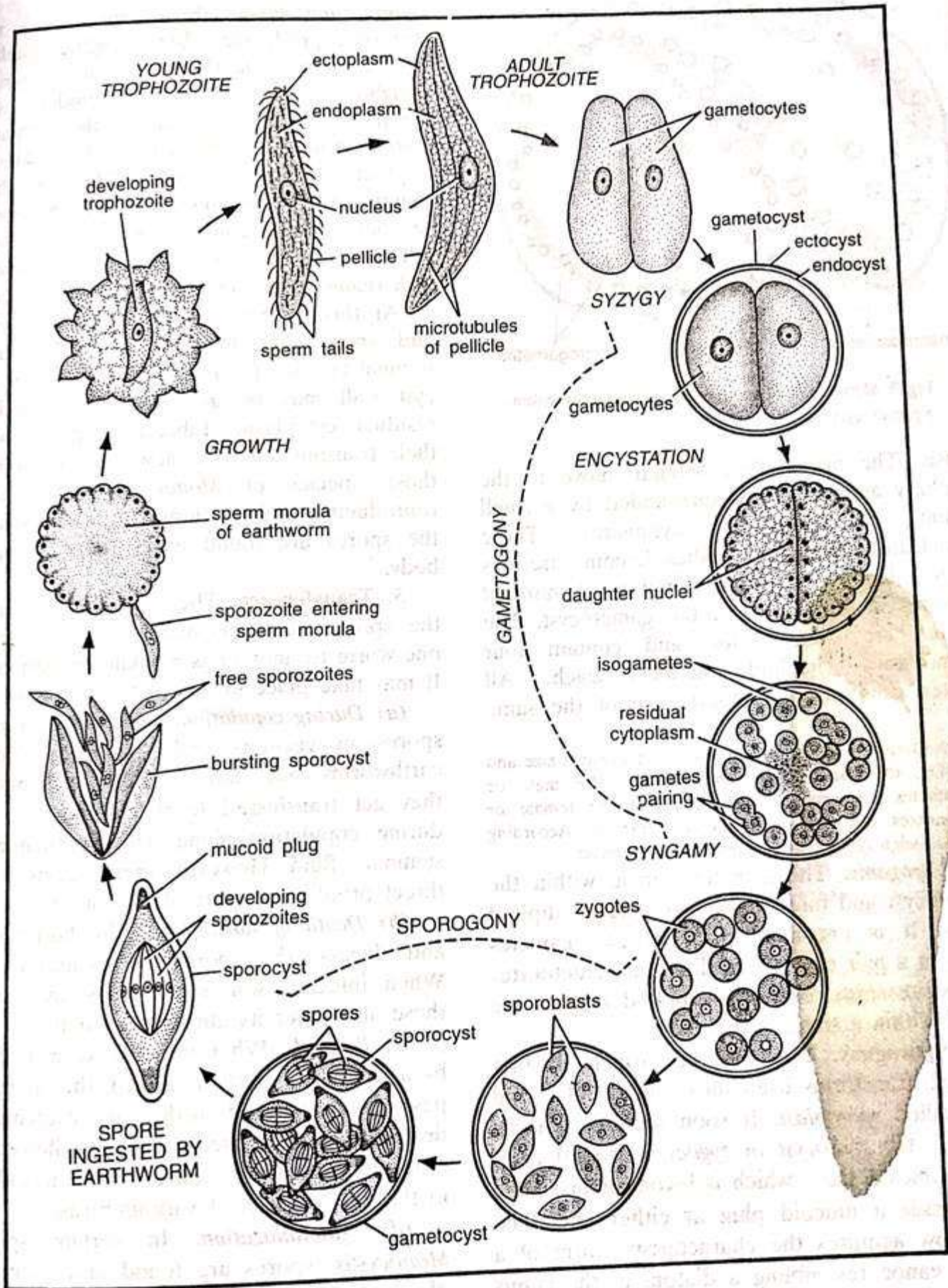


Fig. 2. *Monocystis*. Life cycle.

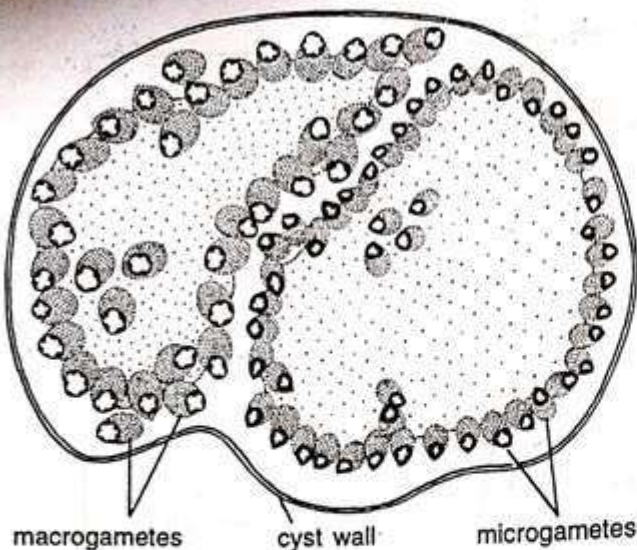


Fig. 3. *Monocystis*. Formation of anisogametes within a gametocyst.

mitosis. The nuclei, thus formed, move to the periphery and each gets surrounded by a small amount of cytoplasm (cytomere). These uninucleate cytoplasmic bodies become free as gametes, leaving a certain amount of residual cytoplasm in the centre of the gametocyst. The gametes are anisogametes, and contain four chromosomes (haploid number) each. All gametes from one gametocyte are of the same sex.

According to Hahn, the gametes are of unequal size and shape i.e., the gametes are anisogamous. The male or microgametes are small and pointed and the female or macrogametes are large and rounded (Fig. 3). According to M. A. Sleight (1973), the gametes are isogametes.

(c) *Syngamy*. The gametes mingle within the gametocyst and fuse in pairs to produce diploid zygotes. It is presumed that the two gametes uniting in a pair come from different gametocytes of opposite sexes. Numerous diploid zygotes are formed within a single gametocyst.

2. *Sporogony*. Each zygote, which is first spherical, transforms itself into a unicellular oval body, called *sporoblast*. It soon secretes a thick cyst wall, the *sporocyst* or *zygocyst*, around itself and becomes a *spore* which is biconical in shape. It possesses a mucoid plug at either end. The *spore* now acquires the characteristic form of a boat or canoe resembling a diatom of the genus *Navicella*. This stage is therefore frequently referred to as *pseudonavicella* (Gr., *pseudo*, false + *navum*, boat). Within the sporocyst the

spore undergoes three successive nuclear divisions, producing eight daughter nuclei, the first division being the reduction division. Each daughter nucleus gets surrounded with a cytoplasmic mass, resulting in the formation of eight minute, elongated and sickle-shaped haploid *sporozoites* or *zoites*. These are bundled together within the sporocyst. The 8 sporozoites or zoites can be counted only in cross-sections. All these changes occur within the original cyst wall (gametocyst) formed at the time of syngamy.

At this stage the original cyst wall ruptures and spores are liberated into the cavity of seminal vesicle of earthworm. Rupture of original cyst wall may be assisted by the swelling of residual cytoplasm. Liberated spores wait for their transmission to a new earthworm host. In those species of *Monocystis*, which undergo reproduction and development in coelomic cavity, the spores are found in posterior segments of body.

3. *Transference*. The exact manner in which the spores of *Monocystis* are transmitted from one worm to another is not known with certainty. It may take place in any of the following ways:

(a) *During copulation*. Occasional presence of spores in cocoons and sperm ducts of earthworms had led to the presumption that they get transferred from one host to another during copulation along with spermatozoa and seminal fluid. However, there seems to be no direct proof in support of this theory.

(b) *Death of host*. When the host-worm dies and decays, the spores get scattered in soil. When infected soil is eaten by another worm, these also enter its alimentary canal.

(c) *By birds*. When infected worm is devoured by a predator, such as a bird, the spores would pass out unaltered with its excrement or droppings and subsequently swallowed up by other worms. Spores have been actually found in the gut contents of various birds.

(d) *Autotomization*. In certain species of *Monocystis*, spores are found in coelomic cavity of posterior segments of earthworm. When posterior body is autotomized, the spores are liberated in soil. With ingestion of contaminated soil, by a fresh earthworm, spores too are



Table 1. Comparison of *Monocystis* and *Plasmodium*.

<i>Monocystis</i>	<i>Plasmodium</i>
1. <i>Monocystis</i> is a parasite in seminal vesicles or in coelomic cavity of posterior segments of earthworm.	1. <i>Plasmodium</i> is a blood parasite living in the liver and red blood cells of man or gut of female <i>Anopheles</i> mosquito.
2. Life cycle is simple, involving a single host (earthworm). No alternation of generations.	2. Life cycle is complicated involving two phases- asexual and sexual alternating in two hosts a vertebrate (man) and an invertebrate (mosquito).
3. Young trophozoite is intracellular in sperm morula of earthworm, but adult becomes extracellular, living freely in the cavity of seminal vesicles.	3. Trophozoite is always intracellular living either in liver cells or blood corpuscles of vertebrate host.
4. Adult trophozoite is elongated worm-like, active and motile.	4. Adult trophozoite is rounded and non-motile.
5. During growth, the trophozoite does not pass through ring and amoeboid stages.	5. During growth the trophozoite passes through signet ring and amoeboid stages.
6. Trophozoites do not multiply asexually by schizogony.	6. Trophozoites multiply asexually by schizogony producing numerous merozoites.
7. Gametocytes are all alike and formed directly by a modification of the mature trophozoites.	7. Gametocytes are differentiated into male and female and formed by a modification of some of the merozoites.
8. Gametogony and conjugation or syngamy take place in the same host (earthworm).	8. Gametocytes and conjugation occur when gametocytes are transmitted into the gut of mosquito.
9. Before gametogony, gametocytes arrange in pairs (syzygy) and secrete a common cyst wall around each pair.	9. Gametocytes do not associate in pairs (syzygy) and do not undergo encystment.
10. Gametes formed by the two gametocytes of each pair are gamous, non-motile and many.	10. Gametes are anisogamous. A macrogamete forms a single motile macrogamete, while a microgamete produces 2 to 8 microgametes.
11. Zygotes are non-motile, each secreting a sporocyst around itself while still inside the original gametocyst, and thus turning into a sporoblast and later into a spore.	11. Zygotes are motile which bore into the gut wall of the host and undergo encystment to form oocysts. Sporoblasts are not formed.
12. A large number of spores are produced having a thick resistant covering to withstand unfavourable conditions of the outside world and the high mortality, during transference from one host to another.	12. A smaller number of oocysts are produced having a thin and non-resistant covering because these never pass to the outside world to face dangers and destruction.
13. Each spore produces 8 sporozoites which remain protected inside the spore membrane during transmission.	13. Each oocyst forms hundreds of sporozoites which remain naked, i.e., without a spore membrane because they never live outside the host body.
14. Exact mode of transmission from one host to another is unknown. Probably a fresh "host" worm ingests them with contaminated soil or droppings of a bird.	14. Transmission from one man to another takes place through the bite of the female <i>Anopheles</i> mosquito by direct inoculation.
15. There is no prepatent period as the sporozoites do not develop until they reach the seminal vesicles and enter the germ cells of earthworm.	15. There is a prepatent period during which sporozoites multiply asexually in liver cells for a few days before attacking red blood corpuscles.

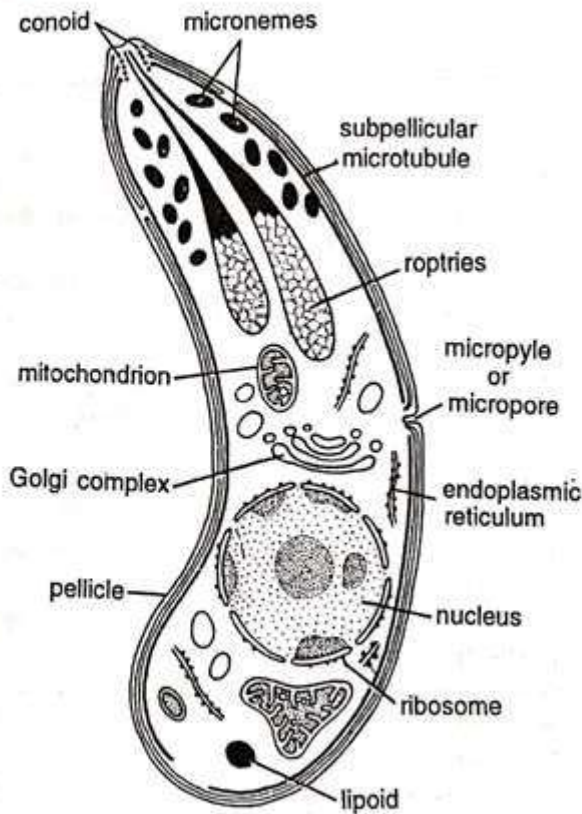


Fig. 4. *Monocystis*. Sporozoite as revealed by electron microscopy (diagrammatic).

ingested. Within the alimentary canal of a new host, the sporocyst breaks or possibly dissolves by the action of the digestive enzymes liberating sporozoites into lumen of alimentary canal.

**4. Sporozoites.** The sporozoites are minute spindle-shaped protoplasmic bodies resembling in some detail the sporozoites of *Plasmodium*. Each contains a single nucleus, one or more mitochondria, Golgi complex and granules of reserve food, chiefly carbohydrate. Outer pellicle has longitudinally arranged sub-pellicular contractile microtubules. At the anterior region is a pair of secretory organelles or *roptries*. Their secretion helps in penetration through the tissues. Anterior end also bears *conoids* and *micronemes*, whose functions are not well understood.

**5. Invasion of seminal vesicles.** With the help of contractile action of sub-pellicular microtubules, the sporozoites make active movements. They make their way into the epithelial cells of the gut mucosa, one sporozoite entering one cell. Here they grow in size and then escape into the

seminal vesicles. In the seminal vesicles, each sporozoite enters a central cell of the sperm morula (a group of sperm mother cells).

**6. Development of trophozoite.** In the sperm morula, the sporozoite feeds and grows into a young *trophozoite*. It exhibits hair-like sperm tails around its body, which are the remnants of degenerating sperms. With the degeneration of the sperm tails as well, the trophozoite becomes free in the cavity of the seminal vesicle as an adult trophozoite. Thus, the trophozoites are at first intracellular and later extracellular.

### Effect of Parasitism

**1. On the host.** Although every worm is infected with *Monocystis*, its fertility is not greatly impaired, since most of the seminal vesicles are not involved. The trophozoites invade and grow inside sperm morulae, inhibiting the development of spermatogonia and spermatids. The worm is apparently able to combat some of the parasites by forming a resistant envelope around the trophozoites or by phagocytosing and killing the resistant spores.

**2. On the parasite.** With an abundance of food and almost no competition inside seminal vesicles of earthworm, the adult trophozoite of *Monocystis* undergoes an extreme retrogression or simplification of structure. Under the most favourable, easy and uniform conditions of life, the parasite has no need to develop the various vegetative organelles, such as the mouth, gullet, locomotory structures, contractile vacuoles, etc. But the entire life cycle is passed within the same host and to continue the race, transmission to another host worm becomes essential. This is done by the production of sporozoites contained within spores having resistant coverings. During transmission the spores pass through the outside world, where danger, enemies and competition abound, resulting in their destruction on a large scale. To compensate this high mortality, huge numbers of potential individuals are produced to ensure that a sufficient number may survive to continue the race.

» Long Answer Type Questions

1. Describe the structure, physiology and life history of *Monocystis*.
2. Compare the main events in the life cycle of *Monocystis* and *Plasmodium*.
3. Write short notes on : (i) Gametogony in *Monocystis*, (ii) Gregarine movement, (iii) Nutrition in *Monocystis*, (iv) Syzygy

» Short Answer Type Questions

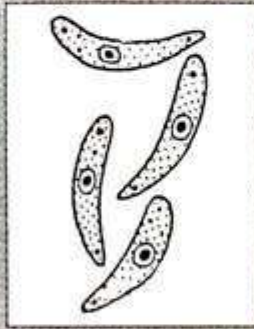
1. What is pseudonavicella?
2. Which is the host for *Monocystis* ?
3. Give the structure of trophozoite in *Monocystis*.
4. Describe the syzygy in *Monocystis*.
5. Give the description of sporozoites in *Monocystis*.
6. Give an account of autotomization in *Monocystis*.
7. Distinguish between isogamy and anisogamy.
8. Distinguish between cephaline and acephaline forms.

» Multiple Choice Questions

1. Life cycle of *Monocystis* includes :  
(a) gametogony and sporogony  
(b) schizogony and gametogony  
(c) syzygy and gametogony  
(d) sporogony only
2. *Monocystis* belongs to the order :  
(a) Coccidia (b) Gregarinida  
(c) Haemosporidia (d) Myxosporidia
3. *Monocystis* trophozoite is found in :  
(a) seminal vesicles of earthworm  
(b) seminal vesicles of cockroach  
(c) both (d) none
4. Monogenetic parasite is :  
(a) *Trypanosoma* (b) *Plasmodium*  
(c) *Monocystis* (d) *Leishmania*
5. *Monocystis* is a parasite of :  
(a) man (b) cattle  
(c) earthworm (d) mosquito
6. Trophozoite of *Monocystis* is a stage :  
(a) nutritive  
(b) genetic  
(c) infective  
(d) transform

Answers

1. (a) 2. (b) 3. (a) 4. (c) 5. (c) 6. (a)



# 11

Chapter

## *Eimeria tenella*

*Eimeria*, *Isospora* and related genera belong to subclass Coccidia of protozoan subphylum Sporozoa. These coccidians are parasites of various invertebrates and vertebrates. They are generally intracellular parasites of epithelial lining of host's alimentary canal. They cause a severe disease condition known as *coccidiosis* in their respective hosts. Two species of *Eimeria* cause heavy losses to the poultry industry in India. *E. tenella* affects the caeca of chicken and causes *caecal coccidiosis*. Another species, *E. mitis*, attacks the anterior part of ileum of adult birds. Some important mammalian species are *E. stiedae* (in bile duct of rabbit), *E. bovis* (in intestine of cattle), and *E. canis* (in small intestine of dog). The life cycle of *E. tenella* is dealt here in detail as a representative type of the group.

### *Eimeria tenella*

#### Systematic Position

Phylum	Protozoa
Subphylum	Sporozoa
Class	Telosporea
Subclass	Coccidia
Order	Eucoccida
Suborder	Eimeriina
Genus	<i>Eimeria</i>
Species	<i>tenella</i>

#### Life Cycle

*E. tenella* is *monogenetic*, i.e., its life cycle involves only one host (fowl). Various stages of

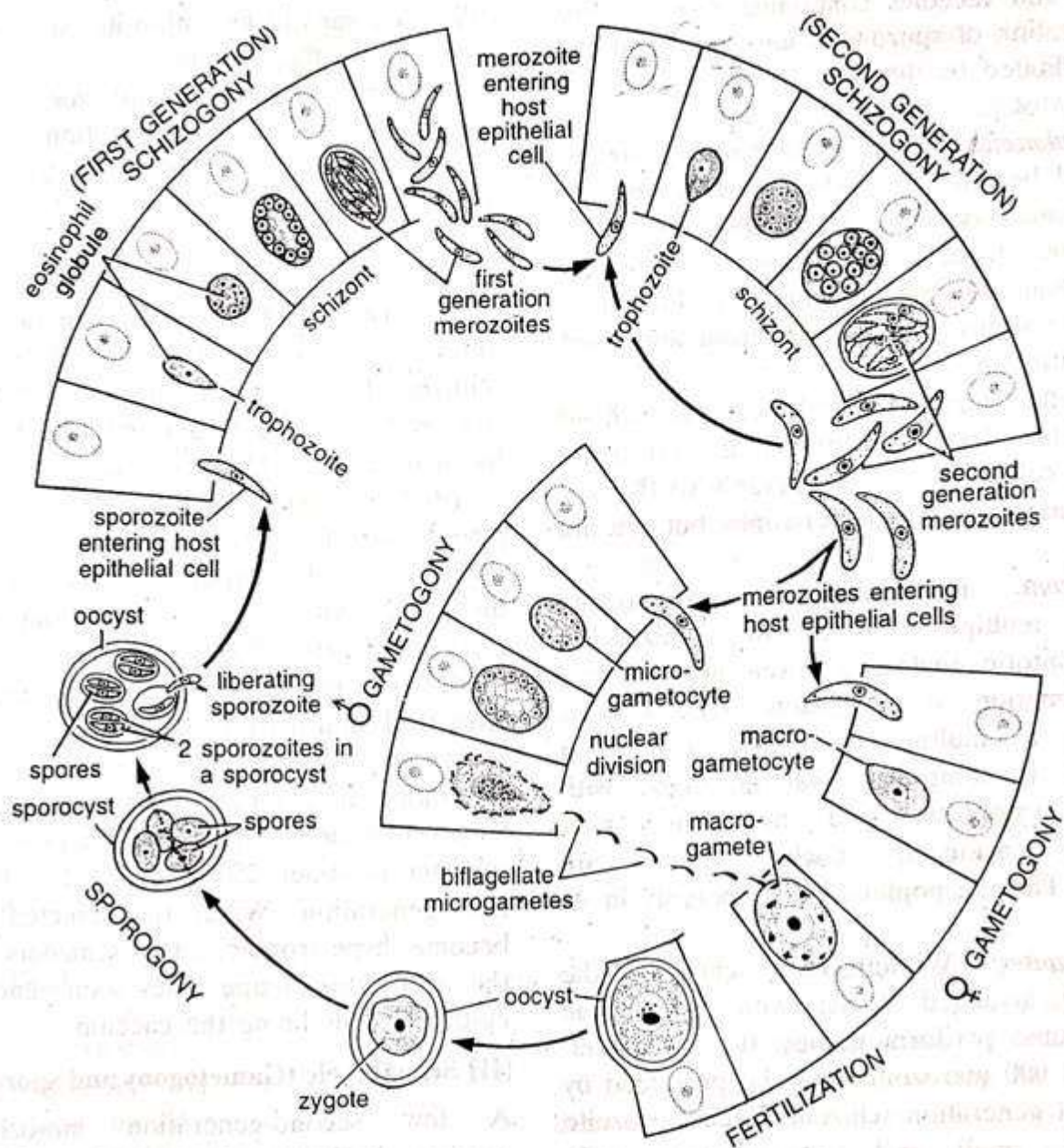


Fig. 1. *Eimeria tenella*. Life cycle.

complicated life cycle may conveniently be described under two phases, asexual cycle or *schizogony* and sexual cycle involving *gametogony* and *sporogony*. Much of the life cycle is intracellular.

### [I] Asexual cycle (Schizogony)

There are 2 (sometimes 3) generations of schizonts and merozoites which are morphologically distinguishable.

1. **First generation schizogony.** The beginning of complex life cycle of *E. tenella* may be taken to be initiated by the infection of epithelial cells of host caecum by sporozoites.

(a) **Infection by sporozoites.** The infected fowl passes out oocysts or zygocysts with faecal

matter. When these oocysts are swallowed by a new or healthy bird, its digestive juices dissolve the cystwall and release the sporozoites (or zoites) which enter the gut epithelial cells. Within the epithelial cells, the sporozoites grow in size and multiply by schizogony.

(b) **Sporozoite.** It is the earliest intracellular stage of parasite. It is elongated, slightly curved, microscopic unicellular organism with one end pointed and the other end blunt. The pellicle, forming external envelope, contains longitudinally arranged contractile microtubules which help in wriggling movements of the organism. Cytoplasm includes a vesicular nucleus, a mitochondrion, Golgi bodies, endoplasmic reticulum, ribosomes,

lysosomes and vacuoles containing reserve food, etc. Penetration of sporozoite into host epithelial cell is facilitated by the lytic secretion stored in the roptries of parasite.

(c) *Trophozoite*. The sporozoite soon increases in size and becomes pear-shaped. This stage of the parasite is called trophozoite. The characteristic feature of trophozoite is the presence of an *eosinophil globule* at its blunt end. This globule stains brightly with eosin and black with haematoxylin.

Trophozoite absorbs nourishment through its general surface from the surrounding cytoplasm of the host cell. It grows considerably so that the host cell and its nucleus hypertrophy but are not destroyed.

(d) *Schizont*. Eventually, the trophozoite undergoes multiple fission by schizogony. Repeated mitotic nuclear divisions are followed by the formation of cytoplasmic masses. This results in a multinucleate first generation *schizont*. It is somewhat oval in shape with vacuolated cytoplasm and numerous small peripherally arranged nuclei which are ill-defined. The eosinophil globule persists in its cytoplasm.

(e) *Merozoites*. Within the schizont, the peripherally arranged nuclei with cytoplasmic masses become pyriform bodies, the *merozoites*. As many as 900 merozoites may be produced by a single first generation schizont. Each merozoite is a very small and inconspicuous body, measuring about  $2-4\mu$  in length and  $1-1.5\mu$  in width. Its one end is pointed while the other end is rounded. The pointed end contains a terminal granule and the rounded end bears a number of cytoplasmic granules. The vesicular nucleus takes up the central position. The host cells containing schizonts are hypertrophied and are finally extruded into the lumen of the caecum. The schizonts burst and the first generation merozoites escape to invade other epithelial cells.

2. **Second generation schizogony.** The liberated merozoites set up new infections and schizogony may be repeated several times causing serious damage to epithelial cells.

(a) *Invasion of fresh host cells.* A first generation merozoite invades a fresh epithelial

cell and comes to lie within its cytoplasm. It soon grows into a trophozoite.

(b) *Trophozoite*. The trophozoite resembles its counterpart of the first generation, except that it lacks an eosinophil globule. It feeds upon the host cytoplasm and its nucleus undergoes repeated mitotic divisions forming a multinucleate schizont.

(c) *Schizont*. The second generation schizont differs very much from the first generation schizont. It is larger in size and the nuclei are scattered throughout its cytoplasm. Each nucleus has a distinct nucleolus or karyosome.

(d) *Merozoites*. Within the schizont the cytoplasmic divisions result in the aggregation of cytoplasmic bits around each nucleus. These nucleated cytoplasmic bits metamorphose into the second generation merozoites.

A second generation merozoite is also elongated and pyriform with a rounded and a blunt end. They are larger than the first generation merozoites, measuring about  $16\mu$  in length and  $2\mu$  in width. Their number in a single schizont is about 250 which is less than in the first generation. When the infected host cells become hypertrophied, the schizonts burst and the merozoites escape. They soon penetrate other epithelial cells lining the caecum.

## [II] Sexual cycle (Gametogony and Sporogony)

A few second-generation merozoites may produce third-generation schizonts. These are not common, small and each produces 4 to 30 merozoites. These probably lead to the formation of infective oocysts discharged with the faeces.

However, most of the second generation merozoites do not repeat schizogony. Instead, for reasons not understood, they initiate the sexual cycle. They develop into *gametocytes* which produce *gametes*.

1. **Gametogony.** The gametocytes or gamonts are sexually distinguished into two types: male or *microgametocytes* and female or *macrogametocytes*. Gametes also differ in size and number. Thus *anisogamy* is well-marked.

(a) *Microgametocytes*. After invading the host epithelial cells, some of the merozoites become male gamonts or microgametocytes immediately.

A microgametocyte is small, oval and measures about  $5.5-18\mu$  in length. It shows repeated nuclear divisions and gives rise to numerous small, comma-shaped biflagellate male cells or *microgametes*. Each of them bears a nucleus, a mitochondrion and two flagella.

(b) *Macrogametocytes*. The female gamont or *macrogametocyte* is oval but comparatively larger, measuring  $8-25\mu$  in length. Their cytoplasm, especially near periphery, bears irregular masses of basophil reserves. Each *macrogametocyte* develops into a single female cell or *macrogamete*.

2. **Fertilization.** Details of fertilization are not known. The *microgametes* escape from the host cell and invade the adjoining cells containing the *macrogametes*. A *microgamete* fuses with a *macrogamete* and thus fertilization takes place inside the host cell. The resulting fertilized cell or *zygote* is diploid.

3. **Oocyst.** The *zygote*, while still within the host cell, secretes a thick double-layered cyst wall around itself. It has a thick outer and a delicate inner layer. According to Monne and Honig (1954), the outer thick layer is quinone-tanned protein, while the inner layer is a lipo-protein layer. The *zygote* now is referred to as the *oocyst* or *zygocyst*.

The mature *oocyst* is oval in shape and measures  $20-26\mu$  by  $16.5-23\mu$ . It does not undergo further development in the host cell. The completed *oocysts* fall in the cavity of the intestine by the rupture of the host cells. From here they are expelled outside the bird's body in faeces. The passing out of *oocysts* in enormous numbers may be seen on the seventh or eighth day of infection. The *oocysts* survive for a longer time under aerobic conditions.

4. **Sporogony.** Within 24 hours the *zygote*, within *oocyst* divides by meiosis into four haploid cells, called the *sporoblasts* or *zoitoblasts*. Each *sporoblast* then secretes a tough wall, the *sporocyst* or *zoitocyst* around itself and becomes a *spore*. Each *spore* divides mitotically to produce two *sporozoites* or *zoites*. Thus a mature *oocyst* includes eight *sporozoites*, two within each *sporocyst*. *E. tenella* is thus *tetrasporous* and *dizoaic*. Division of encysted *zygote* into

*sporozoites* generally takes place outside the host after the *oocysts* pass out with faecal matter. Under suitable temperature and moisture conditions, each *oocyst* sporulates in about 21 hours and becomes infective.

5. **Transference of oocysts.** The infective *oocysts* are easily passed on into other members of the flock through direct ingestion of droppings (faecal matter) or contaminated food.

6. **Liberation of sporozoites.** Into the gut lumen of new host, the *sporozoites* liberate out through a pore or micropyle in the *oocyst*, under the influence of mechanical pressure and the enzymes pepsin and trypsin, and set up new infections.

## Coccidiosis

1. **Pathogenesis.** *E. tenella* causes a fatal disease of chickens called *caecal coccidiosis*. It is caused due to extensive destruction of the caecal epithelium, with sloughing off the walls and severe haemorrhage. The symptoms include bloody droppings, pale face and shanks, bloody vent and enlarged caeca distended with blood or with yellowish grey cheese-like ceres. In advanced stages, the infected birds show restlessness, drooping wings, suffled feathers and unsteady gait. Both the young and the old birds are susceptible to coccidiosis, but the infants are more severely injured as compared to the adults.

2. **Diagnosis.** Correct diagnosis of coccidiosis caused by *E. tenella* is possible by observing the symptoms and determining the presence of *oocysts* in the droppings. The microscopical examination of the faecal smear is done to confirm the presence of the *oocysts*.

3. **Prevention.** Infection of young chickens may be prevented through proper hygienic conditions and with good range management. Floors of poultry houses, yards and ranges must be cleaned periodically by scrubbing them through the hot lye solution. Equipment used for rearing birds should also be subjected to cleaning with the same solution.

As moist litter is favourable for keeping the *oocysts* viable, it is recommended that the litter should be heaped to develop its temperature to  $125^{\circ}\text{F}$ .  $\text{NH}_3$  destroys the *oocysts* in dry litter.

Coccidiostatic drugs, which mostly include sulpha drugs, are added in prescribed doses in the poultry feed and water for a few days, mostly at the time when infants are being reared, or when coccidiosis is apprehended. These drugs help the birds to develop immunity from the coccidial organisms.

**4. Treatment.** The chickens who have caught coccidiosis are treated with sulpha drugs. *Sulphamezathene* and *sulphaquinoxaline*, taken at the rate of 0.5% with drinking water for about a week, promise complete relief. Because of its low toxicity, *sulphaquinoxaline* is generally recommended.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Give an illustrated account of the life history of *Eimeria*.
2. How is Coccidiosis caused in poultry? Suggest measures for its control.

#### » Short Answer Type Questions

1. Name the sporozoan parasite causing caecal coccidiosis in chickens.
2. What is the coccidiosis?
3. What are gametogony and sporogony?
4. Give the name of protozoan which known as parasite of birds.

#### » Multiple Choice Questions

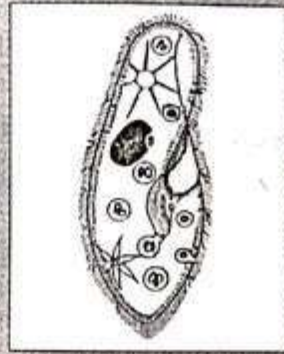
1. *Eimeria* belongs to :  
 (a) plasmodroma (b) ciliopora  
 (c) cnidospora (d) sporozoa
2. *Eimeria* caused :  
 (a) kala azar (b) dysentery  
 (c) coccidiosis (d) no any disease
3. Sexual cycle involving :  
 (a) gametogony (b) sporogony  
 (c) both (d) none the above
4. The symptoms of caecal coccidiosis chickens are :  
 (a) drooping wings (b) suffled feathers  
 (c) unsteady gait (d) all
5. The best treatment for coccidiosis :  
 (a) antiviral drugs (b) antibiotics  
 (c) sulpha drugs (d) antipyretic

### Answers

1. (d) 2. (c) 3. (c) 4. (d) 5. (c).



# *Paramecium caudatum*: The Slipper Animalcule



## 12 Chapter

### *Paramecium caudatum*

#### Systematic Position

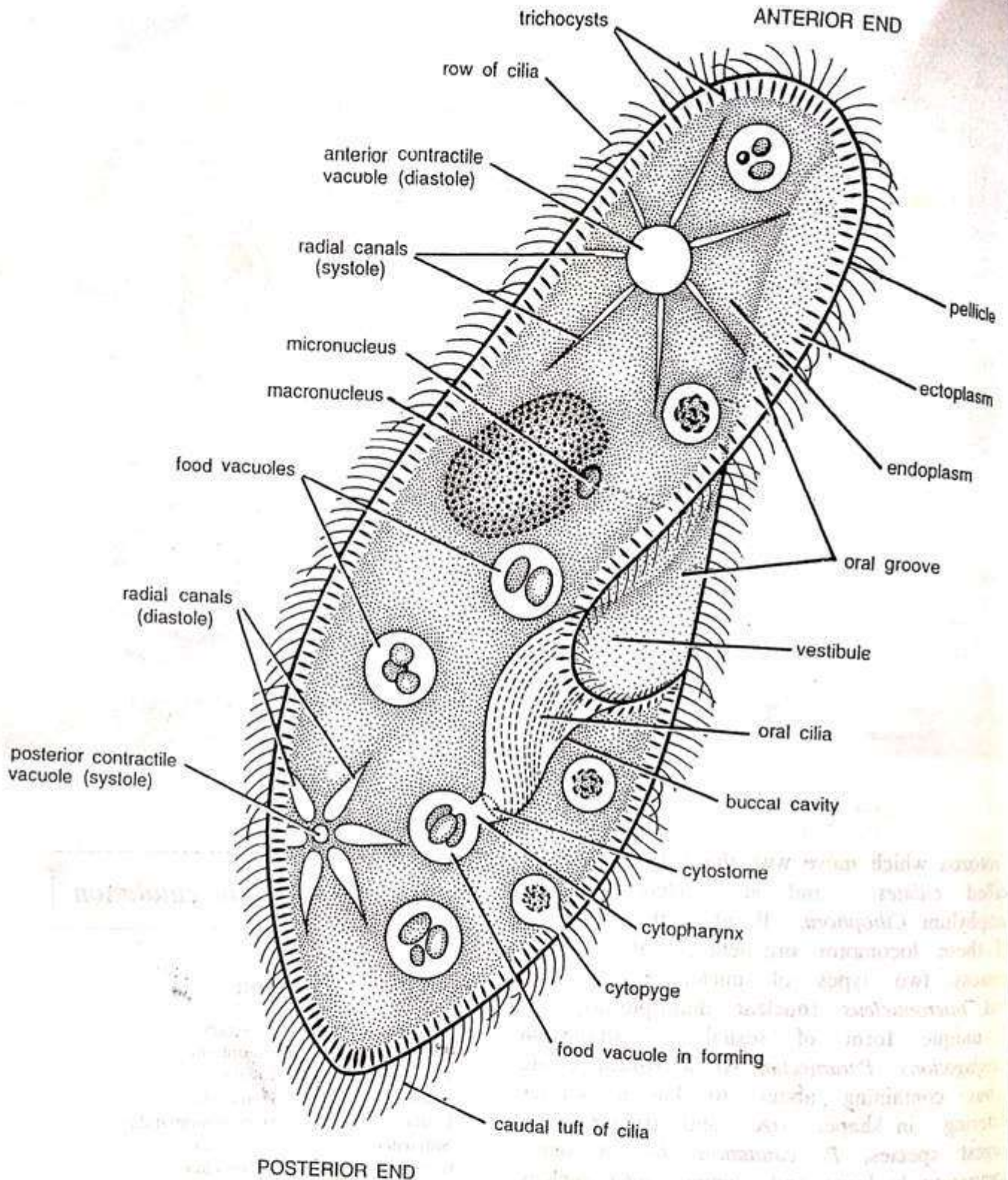
Phylum	Protozoa
Subphylum	Ciliophora
Class	Ciliata
Subclass	Holotricha
Order	Hymenostomatida
Suborder	Peniculina
Genus	<i>Paramecium</i>
Species	<i>caudatum</i>

#### Occurrence

*Paramecium caudatum* (Gr., *paramekes*, ablong + L. *caudata*, tail) is one of the most common species of paramecium having worldwide distribution. It is found in freshwater ponds,

(Z-1)

Protozoa which move with the help of *cilia* are called *ciliates* and are included in the subphylum *Ciliophora*. Besides the possession of these locomotor organelles, all ciliates possess two types of nuclei, *macronucleus* and *micronucleus* (nuclear dimorphism), and a unique form of sexual reproduction (*conjugation*). *Paramecium* is a typical ciliate genus containing about 10 known species differing in shape, size and structure. The largest species, *P. caudatum*, has a single comparatively large and compact micronucleus with chromatin material scattered throughout the nucleoplasm. It occurs widely and abundantly. *P. aurelia* has two micronuclei while *P. multimicronucleatum* has many micronuclei. *P. bursaria* is green due to presence of symbiotic alga, *zoochlorella*. In the following text, the biology of *P. caudatum* is treated in detail.

Fig. 1. *Paramecium caudatum*.

pools, ditches, streams, rivers, lakes, reservoirs, etc. It is usually abundant in those waters which contain a great deal of decaying organic matter. It thrives well in ponds or slowly running streams containing aquatic plants. The paramecia often gather near the surface in scum, but are usually seen actively swimming throughout the water in which they live.

(Z-1)

### Culture of *Paramecium*

*Paramecium* is easily grown in wide mouthed jars with glass covers, three-quarter filled with boiled pond water or Chalkey's medium (NaCl 80 mg, NaHCO<sub>3</sub> 4 mg, KO 4mg, CaCl<sub>2</sub> 4mg, CaH<sub>4</sub> (PO<sub>4</sub>)<sub>2</sub>H<sub>2</sub>O 1.6mg, dissolved in one litre of distilled water), and with 7-12 drops of skim-milk added weekly. The jars are kept away from direct light to allow bacteria to flourish which serve as food for the multiplying paramecia.

## External Structure

1. **Size.** *Paramecium* is a microscopic, elongated organism which is visible to the naked eye as a whitish or greyish spot. Its species vary in length from  $80\mu$  to  $350\mu$ . *P. caudatum*, the largest species, measures between  $170\mu$  and  $290\mu$ . The greatest diameter of the cylindrical body is about two-third of its entire length. *P. aurelia* is about  $120\mu$  to  $250\mu$  long. Usually the individuals of the same species may exhibit minor morphological and physiological differences. Jennings was able to find in one species of *Paramecium* eight races differing in total length and size.

2. **Shape.** *Paramecium* is often described as slipper shaped, cigar-shaped or spindle-shaped. Its shape is usually constant and in general asymmetrical. Because of its slipper-like shape, the *Paramecium* is sometimes called the *slipper animalcule*. Joblot assigned the name 'chausson' to *P. caudatum* which means slipper-shaped animalcule. The body is elongated, blunt and rounded at the anterior end and somewhat pointed at the posterior end. In cross section, it is circular with greatest diameter behind the centre of body. The anterior half of body is slightly twisted. The body is distinguished into an oral or ventral surface and an aboral or dorsal surface.

3. **Oral groove.** Ventral surface of body bears a prominent, oblique and shallow depression, called *oral groove*. It originates from the middle of body and extends to the left side of anterior end. Posteriorly, the oral groove leads into a deeper conical *vestibule* which in turn communicates with a *buccal cavity* having a basal mouth or *cytostome*.

4. **Pellicle.** External envelope of body is a living, clear, firm and elastic cuticular membrane, the *pellicle*. When stained specimens are observed under light microscope, the pellicle appears to be a regular series of polygonal (or hexagonal) depressions with their raised rims. A single cilium emerges out from the middle of each polygon or circumciliary space. Electron microscopic studies by Ehret and Powers (1959) have revealed that the polygons are defined by a corresponding regular series of cavities, the

*alveoli*. In fact, it is the pit in the centre of each *alveolus* which forms a polygon. All the *alveoli* collectively form a continuous *alveolar layer*, which is delimited by an *outer alveolar* and *inner alveolar membrane*. The outer alveolar layer lies in close contact beneath the outer cell membrane (not shown in the diagram). Thus, the pellicle of *Paramecium* includes a series of three membranes: (i) outer cell membrane, (ii) outer alveolar membrane, and (iii) inner alveolar membrane.

5. **Cilia.** The entire body surface is covered by numerous, tiny, hair-like fine projections,

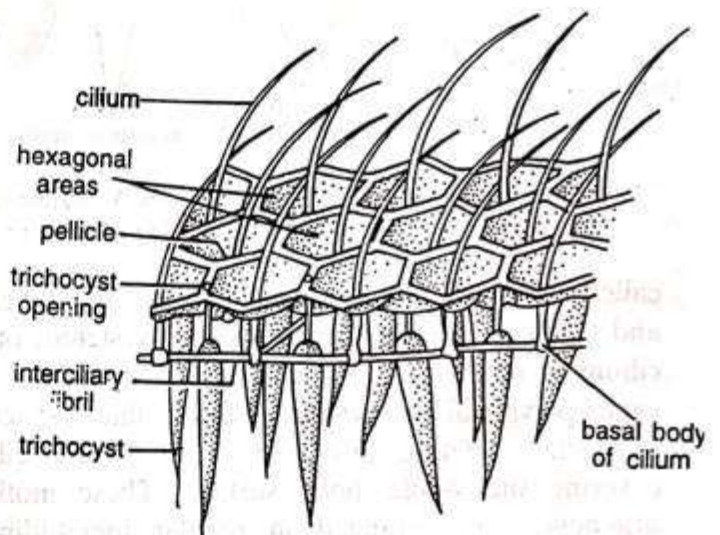


Fig. 2. *Paramecium* Diagrammatic surface view of a small area of pellicle.

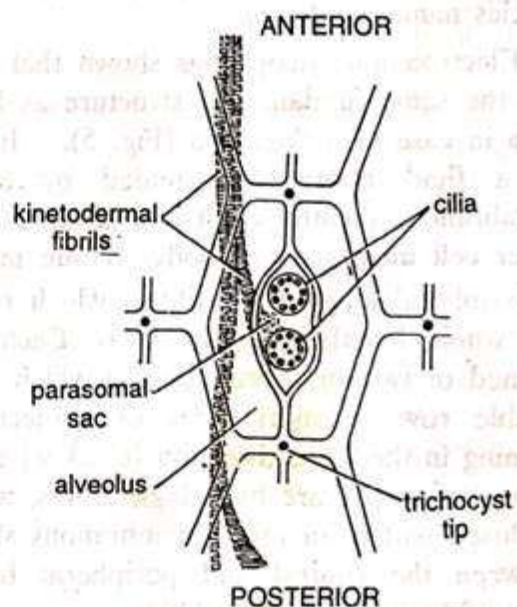


Fig. 3. *P. aurelia*. Diagram of a hexagonal area or ciliary field.

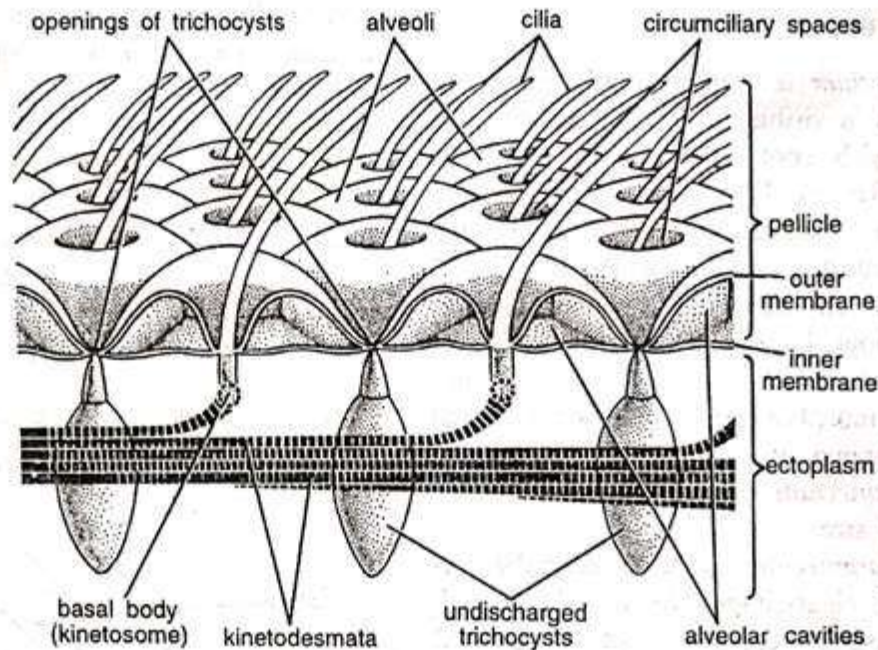


Fig. 4. *Paramecium*. A diagrammatic three-dimensional electron microscopic representation of a portion of pellicle and infraciliary system.

called *cilia*. These measure  $10-12\mu$  in length and  $0.27\mu$  in diameter. As already stated, one cilium (2 in *P. bursaria*) arises from the centre of each polygonal depression (circumciliary space) of pellicle. There are 10,000 to 14,000 cilia covering the whole body surface. These motile organelles are arranged in regular longitudinal rows. Their length is uniform throughout, except for a few longer cilia at the extreme posterior end of the body, forming a *caudal tuft*, hence the species name *caudatum*.

Electron microscopy has shown that a cilium has the same fundamental structure as has been seen in case of a flagellum (Fig. 5). It consists of a fluid matrix, surrounded by an outer membranous sheath, which is continuous with the outer cell membrane of body. Within matrix are 9 peripheral longitudinal fibres, which run along the whole length of cilium body. Each fibre is formed of two sub-fibres, one of which carries a double row of short arms or projections, all running in the same direction (clock-wise). In the centre of matrix are two single fibres, which are enclosed within an inner membranous sheath. In between the central and peripheral fibres are nine additional accessory fibres.

(Z-1)

## Internal Structure

1. **Cytoplasm.** Within pellicle, the cytoplasm of body is clearly differentiated into two regions.

(a) **Ectoplasm.** The narrow, peripheral, clear and dense zone is called the *ectoplasm* or *cortex*. It includes the structure of the infraciliary system and the trichocysts.

(b) **Endoplasm.** The large, central, granular and semi-fluid zone is the *endoplasm* or *medulla*. It includes the usual cell components like *mitochondria*, *Golgi bodies*, *ribosomes*, *crystals*, *reserve food granules*, etc. In *P. bursaria*, the endoplasm is filled with symbiotic *Zoochlorella*, a unicellular chlorophyll-bearing alga. Prominent endoplasmic inclusions are *nuclei*, *contractile vacuoles* and *food vacuoles*.

2. **Infraciliary system.** Immediately beneath the pellicular alveoli is located the infraciliary system constituted by the basal bodies and kinetodesmata.

(a) **Basal bodies.** The base of each cilium is produced into a tube-like structure, called *basal body* or *kinetosome*. It is formed by the thickened basal ends of peripheral fibres of cilium. The central fibres do not enter into it.

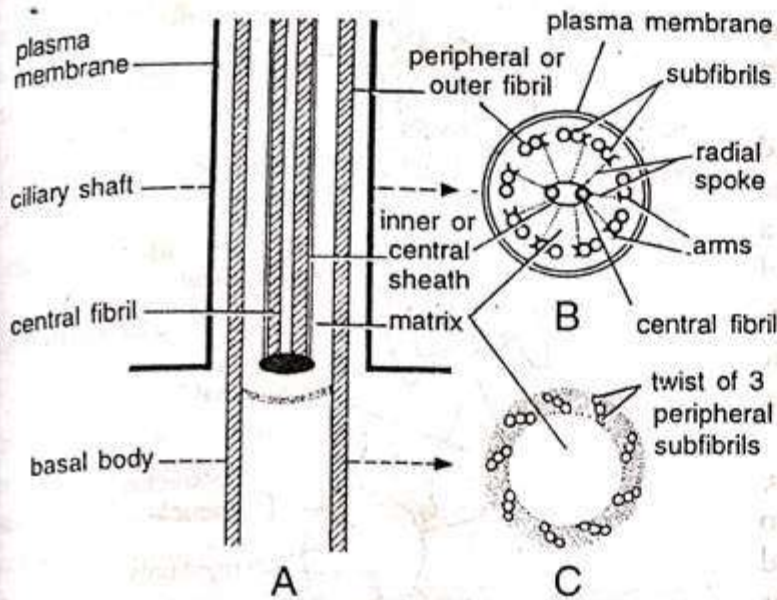


Fig. 5. Structure of a cilium and its basal body. A—Cilium in L.S. B—Free part of cilium in T.S. C—Basal body in T.S.

The wall of basal body consists of 9 triplets of sub-fibres. The basal bodies are 'self duplicating units and progenitors of new cilia. Each basal body is either a centriole or its derivative.

(b) *Kinetodesmata*. Associated closely with basal bodies of cilia and lying in the ectoplasm is a system of specialized striated fibrils, called *kinetodesmal fibrils*. A single fibril or *kinetodesmos* arises from the kinetosome or basal body of each cilium and runs anteriorly somewhat tapering along the course. It joins its counterparts from the posterior kinetosomes, forming a bundle of overlapping longitudinal fibrils, called *kinetodesma* (plural, *kinetodesmata*). The number of fibrils in each *kinetodesma* remains constant (5), because the individual fibrils do not run anteriorly farther than 5 basal bodies. It has been suggested that fibrils coordinate ciliary beat and movement, but the evidence is very conflicting.

The kinetosomes of a longitudinal row plus their *kinetodesmata* constitute a structural unit, called the *kinety*. A *kinety* system is apparently characteristic of all ciliates. It is said that the pattern of infraciliature plays an important role in the morphogenesis of Protozoa. For example, in *Paramecium*, one set of *kinety* is solely responsible for the development of mouth structure. A new mouth fails to develop if this *kinety* is removed experimentally.

**3. Trichocysts.** Trichocysts are peculiar rod-like or oval organelles present throughout the ectoplasm alternating with basal bodies and oriented at right angles to the body surface. These were first seen in *Paramecium* by Elis.

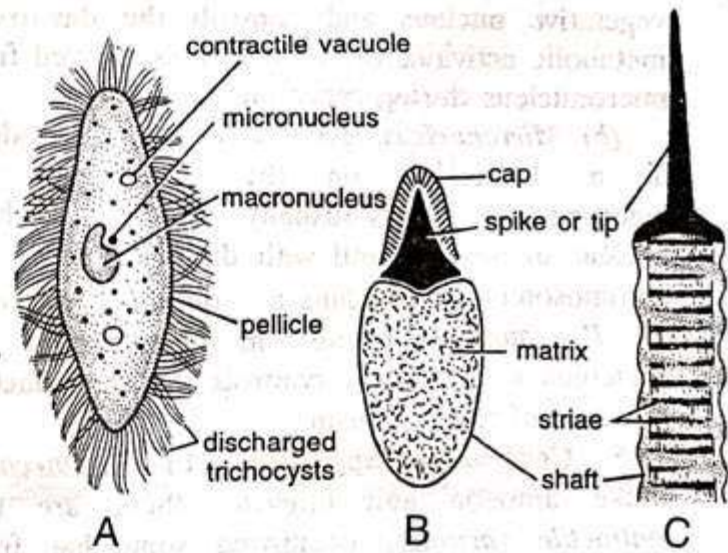


Fig. 6. *Paramecium*. A—Animal with discharged trichocysts. B—Undischarged trichocyst. C—Apical portion of discharged trichocyst.

These are very small in size, measuring about  $4\mu$  in length. Each trichocyst consists of an elongated *shaft* and a terminal pointed *tip*, called the *spike* or *barb*, covered by a *cap*. The matrix of shaft consists of a dense mass of a fibrous protein, called *trichinin*. Its fibres remain condensed forming a cross-striated lattice work.

Function of trichocysts is not well known. It is believed that these discharge and anchor the animal to a firm substratum when it feeds upon bacteria. Others believe that these are organelles of defence.

Discharge of trichocysts is triggered by mechanical, chemical or electrical stimulation. It occurs in a span of a few milliseconds. When fully discharged the shaft becomes a long cross-striated rod and measures about  $40\mu$  in length. It is believed that the discharge process consists of an unfolding of the lattice of trichinin fibres.

**4. Nucleus.** *Paramecium* is heterokaryotic as it possesses two types of nuclei. In *P. caudatum*, there is a large *macronucleus* and a small *micronucleus*. Besides the macronucleus, two micronuclei are present in *P. aurelia* and many in *P. multimicronucleatum*.

(a) *Macronucleus*. The *macronucleus* is roughly kidney-shaped and with inconspicuous nuclear membrane. It is polyploid and possesses many nucleoli and much more chromatin material (DNA). Macronucleus is the somatic or

vegetative nucleus and controls the day-to-day metabolic activities of the cell. It is derived from micronucleus during reproductive processes.

(b) **Micronucleus.** The *micronucleus* is lodged in a depression on the surface of the macronucleus. It is usually spherical, with a nuclear membrane and with diploid number of chromosomes. It contains a definite nucleolus in *P. aurelia*, while in *P. caudatum* the nucleolus is absent. It controls the reproductive activities of the organism.

**5. Contractile apparatus.** In *Paramecium*, unlike amoeba and *Euglena*, there are two *contractile vacuoles*, occupying somewhat fixed positions in endoplasm. One vacuole lies near each end of body, close to the dorsal surface. Each of them is surrounded by a cirlet of 6 to 10 long, narrow, spindle-shaped *radial canals* (afferent pulsating canals) extending far into cytoplasm. Each contractile vacuole opens to outside through a permanent pore in pellicle of dorsal side of body. The two contractile vacuoles do not lose their identity when water is expelled.

Electron microscopy has revealed that each contractile apparatus includes some of the tubules of the endoplasmic reticulum, nephridial tubules, feeder canals, accessory vacuoles (radial canals) and the main contractile vacuole. The accessory vacuoles or radial canals are, in fact, the ampullae of feeder canals.

**6. Food vacuoles.** Numerous non-contractile food vacuoles, recently termed *gastrioles* by Vokovsky, can be seen moving with the streaming endoplasm (cyclosis). They differ in shape and size according to the nature of ingested food particles, but mostly they are rounded in form.

**7. Oral apparatus.** In *Paramecium*, oral groove leads ventrally and posteriorly as a tubular structure, called *vestibule*. It leads directly into a wide tubular passage, the *buccal cavity*. In its turn it opens into a narrow gullet or *cytopharynx* through a narrow aperture, the *cytostome*. The cytopharynx, at its proximal end, forms a *food vacuole*.

Buccal cavity, at right side, is bordered by a row of cilia forming the *endoral membrane*. At left side are three groups of four rows of cilia, extending from the rim of the opening to the posterior end of buccal cavity. These are *ventral*

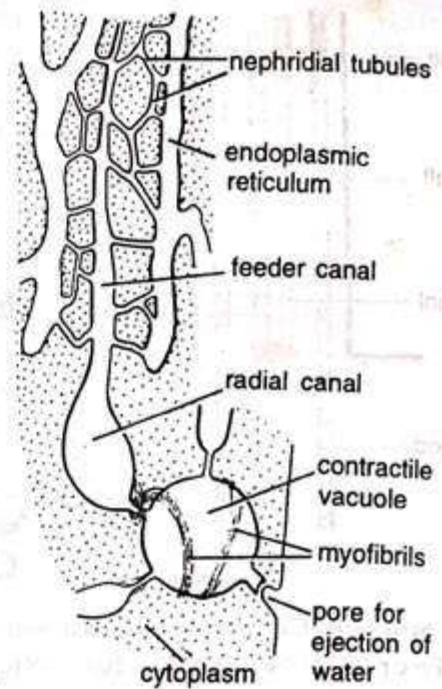


Fig. 7. *Paramecium*. Contractile apparatus.

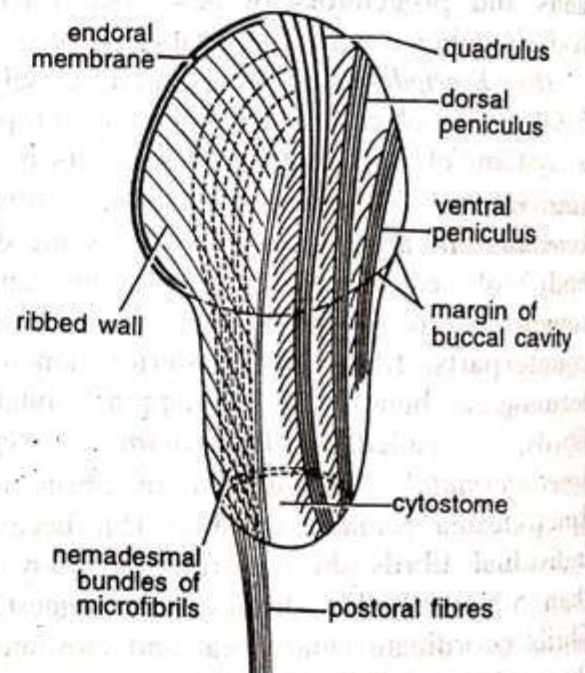


Fig. 8. *Paramecium*. Oral apparatus showing buccal ciliature.

*peniculus*, *dorsal peniculus* and *quadrulus*. These ciliary rows constitute the *membranelles*. From endoral membrane a ribbed pellicle extends upto cytostome. *Nemadesmal fibres* run dorsal to the ribbed pellicle and extend as *post-oral fibres* around cytopharynx. Rows of normal somatic cilia line the wall of vestibule.

**8. Cytopyge.** Near posterior end of body, a little behind cytostome and a little to the right

*Paramecium caudatum* : The Slipper Animalcule

side, a small portion of ectoplasm and pellicle is somewhat weak. Here, at the time of egestion, a minute aperture called *cell anus*, *cytopye* or *cytoproct*, is visible. It is, however, difficult to say whether it is a permanent opening with tightly-closed lips or a temporary opening formed at the time of egestion.

**Locomotion**

*Paramecium* has a streamlined body which enables it to swim about in water with a minimum amount of friction. The rapid swimming is facilitated by the beating of fine and hair-like cellular organelles, called *cilia*, that cover the animal's entire cell-body. *Paramecium* moves with a speed of 1500  $\mu$  or more per second.

**1. Ciliary beats.** During movement, a cilium oscillates like a pendulum. Each oscillation comprises a fast *effective stroke* and a slow *recovery stroke*. During the *effective stroke* or the strong backward lash, the cilium becomes slightly curved and rigid and strikes the water like an oar, so that body is propelled forward in opposite direction of stroke. The *recovery stroke* which follows immediately brings the cilium again into position for the next effective stroke.

All the cilia of body do not move simultaneously and independently but progressively in a characteristic wave-like manner, called *metachronal rhythm*. The cilia in a longitudinal row beat in a characteristic wave beginning at the anterior end and progressing backwards. Consequently, a cilium in a longitudinal row always moves in advance of the one behind it. All the cilia of a transverse row beat simultaneously or synchronously. During forward movement of *Paramecium* the metachronal waves pass from the posterior end forwards.

**2. Mode of swimming.** The animal does not follow a straight tract but rotates spirally like a

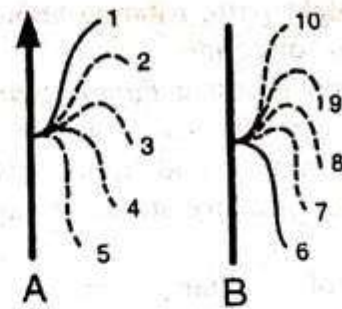


Fig. 9. Diagrams illustrating ciliary movements of a single cilium (after Gray). A - Effective stroke. B - Recovery stroke.

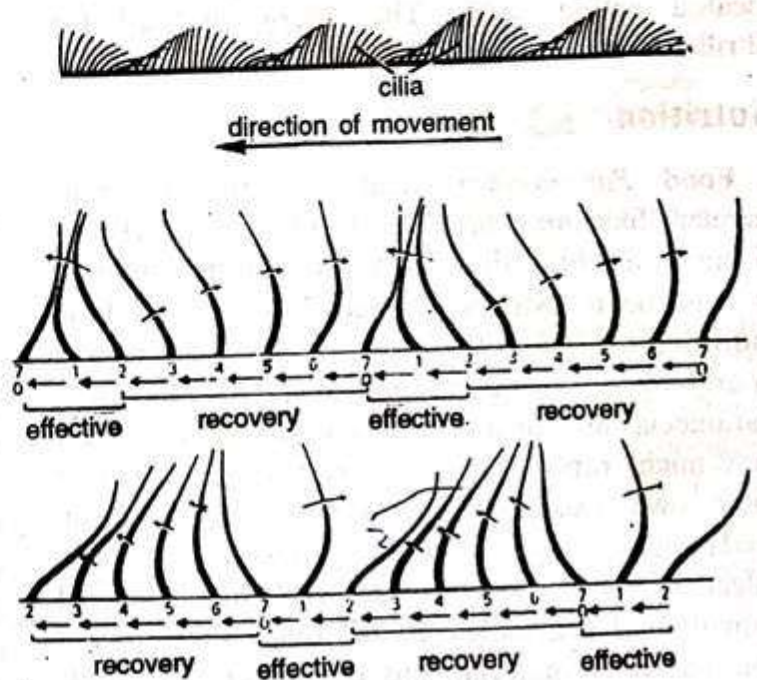


Fig. 10. A - A single row of cilia showing metachronal rhythm. B - Cilia 1-7 indicate recovery stroke. Cilia 8-12 indicate effective stroke.

rifle bullet along a left-handed helix. The reason for this is twofold. Firstly, the body cilia do not beat directly backwards but somewhat obliquely towards right, so that the animal rotates over to the left on its long axis. Secondly, the cilia of oral groove strike obliquely and more vigorously so as to turn the anterior end continually away from the oral side and move in circles. The combined effect causes the movement of animal

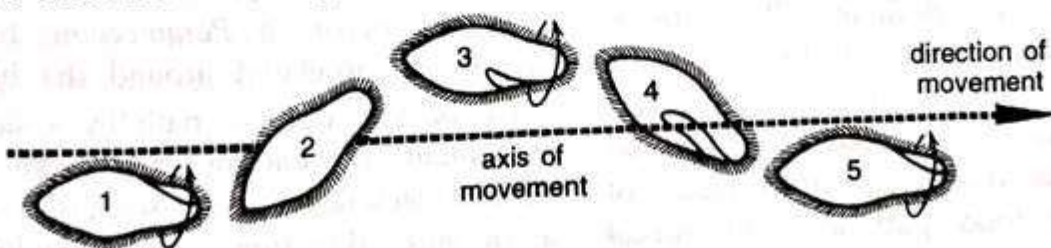


Fig. 11. Anticlockwise spiral path followed by a swimming *Paramecium*.

along a fairly straight path, rotating about its axis in an anticlockwise direction.

In backward movement a *Paramecium* follows a straight course. In this case the metachronal wave passes from anterior end backwards. This is due to the fact that effective stroke is carried out anteriorly.

Mechanism of ciliary movement in *Paramecium* is little studied. It is now known that cilia are moved in a coordinating system. They move by the contraction of peripheral fibres located within them. The energy needed for fibrillar contraction is supplied by ATP.

## Nutrition

1. **Food.** *Paramecium* feeds in the *holozoic* manner, like *Amoeba*. The food consists chiefly of bacteria which float in water in which it lives. It has been estimated that 2 to 5.5 million individuals of *Bacillus coli* are devoured in 24 hours by a single *Paramecium*. In a sense, paramecia are also beneficial to bacteria, lest they might reproduce too rapidly as to endanger their own existence by overcrowding. It also feeds upon small Protozoa, unicellular plants (algae, diatoms, yeasts, etc.) and small bits of animals and vegetables. It will reject most of the non-digestible material and devour certain kinds of food. One species, *P. bursaria*, is interesting, being green in colour due to the presence of numerous unicellular alga, the symbiotic *Zoochlorella* in its endoplasm. It can thus live holophytically for long periods on food substances manufactured by *Zoochlorella*. During scarcity of food, it can digest even its own *Zoochlorella* and can live apparently indefinitely without them.

2. **Feeding mechanism.** *Paramecium* swims to places where it can get its food. Its food catching apparatus is much more specialized than that of *Amoeba* and *Euglena*.

Food is ingested by a definite cell mouth or *cytostome* lying at the bottom of buccal cavity. The constant lashing movements of cilia of oral groove drive a current of water with food particles towards the vestibule. Ciliary tracts of vestibule direct the food particles into buccal cavity. *Paramecium* is a selective feeder.

## *Paramecium caudatum* : The Slipper Animalcule

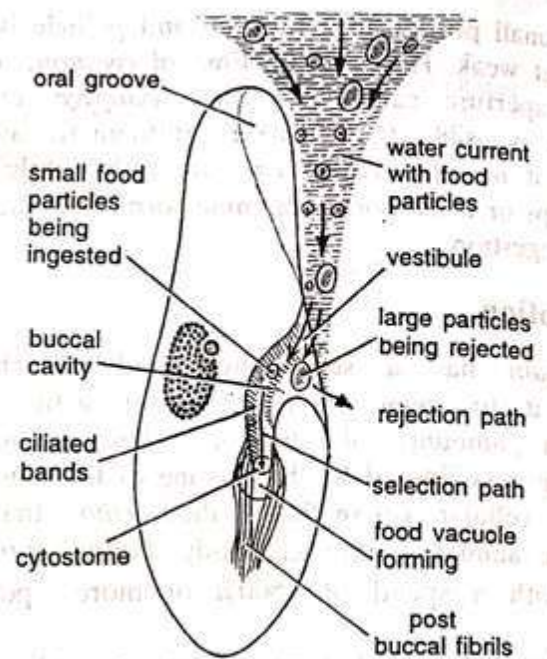


Fig. 12. *Paramecium* receiving food particles with water current drawn into buccal cavity by ciliary action.

According to Mast (1947), many kinds of particles may be carried with water current into vestibule, but only selected ones are passed on inside the buccal cavity. Rest of particles are rejected, that is, discharged to outside. Passage along which ciliary action drives selected food particles, is termed the *selection path*, whereas passage along which unwanted food particles are driven outside vestibule, is the *rejection path*.

Beating of cilia of membranelles of buccal cavity drives the selected food particles through cytostome into cell gullet or cytopharynx. The food now gradually collects at the bottom of cytopharynx into a membranous vesicle which is later nipped off as a *food vacuole*. Another food vacuole may be formed within 1 to 5 minutes depending upon the supply of food and the rate of feeding.

3. **Digestion.** Each food vacuole consists of food particles surrounded by a thin film of water. Rapid and irregular movement of endoplasm does not occur in *Paramecium*, but the food vacuole is circulated around the body along a more or less definite path by a slow streaming movement of endoplasm, known as *cyclosis*. Several vacuoles may be seen thus circulating in a definite direction in the endoplasm of a well-fed *Paramecium*. The vacuoles are carried



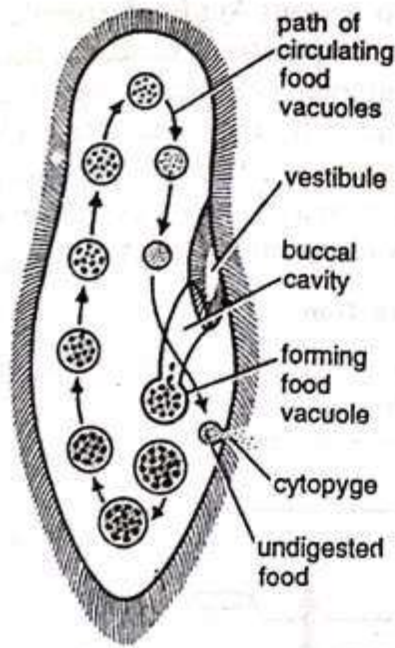


Fig. 13. *Paramecium* showing cyclosis and path of food vacuoles in endoplasm.

first posteriorly, then forward and aborally and again posteriorly and orally up to cytopharynx. Digestion and assimilation of food take place during this journey. Digestive enzymes (proteases, carbohydrases, lipases) are secreted by the lysosomes into the food vacuoles. As in *Amoeba*, the contents of a vacuole first become increasingly acidic, but later gradually become alkaline. This can be demonstrated with the help of Congo Red and other indicator dyes. The alkaline phase results from the secretion of enzymes within an alkaline medium into the vacuole. Products of digestion (glycogen and fat globules) are diffused into the surrounding cytoplasm and either stored or used for vital activity and growth.

4. **Egestion.** The vacuole gradually becomes smaller as digestion and absorption proceed. Finally, the undigested residual matter is eliminated from body, through a definite *anal spot* or *cytopharynx* on ventral surface, posterior to cytostome. The cytopharynx is of the nature of a potential cell anus as the undigested matter is always discharged at this spot.

### Respiration and Excretion

Respiration takes place, as in *Amoeba* and other freshwater Protozoa, by diffusion through the semi-permeable pellicle. Oxygen dissolved in

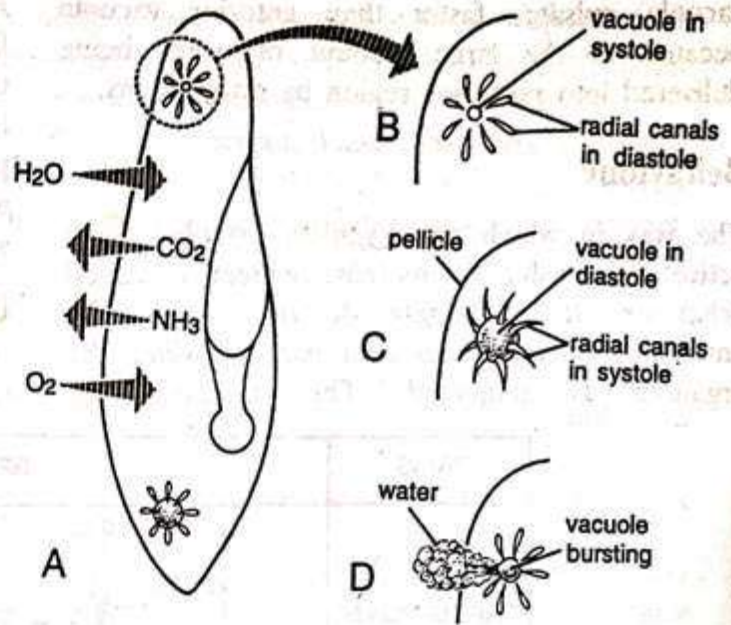


Fig. 14. *Paramecium*. Diagrammatic representation of respiration, excretion and osmoregulation.

water is diffused in and used for oxidation of protoplasmic molecules. Catabolic waste products such as CO<sub>2</sub> and nitrogenous matter (NH<sub>3</sub>) simply diffuse out into external water because their concentration is always higher in body. Crystals present in cytoplasm are in fact excretory products, which get dissolved and eliminated with the fluid of contractile vacuoles.

### Osmoregulation

The function of the contractile vacuoles in *Paramecium* is *osmoregulation*.

An excess of water accumulates in body because of continuous endosmosis, the concentration of body cytoplasm being higher than that of external medium. Small quantities of water are also taken in along the ingested food. This excess of water is got rid off by means of contractile vacuoles which contract (*systole*) and expand (*diastole*) at regular intervals, assisted by the contractility of *myofibrils* (Fig. 7).

Water from cytoplasm is secreted into some of the tubules of endoplasmic reticulum from where it flows down the nephridial tubules into feeder canals to accumulate in latter's ampullae (radial canals). The ampullae converge and discharge into contractile vacuole. When vacuole has grown to its maximum size, it contracts and discharges to the exterior, through a pore in pellicle on dorsal side. Posterior contractile

vacuole pulsates faster than anterior vacuole because of the large amount of water being delivered into posterior region by cytopharynx.

**Behaviour**

The way in which an organism establishes an active relationship to its environment is called *behaviour*. It is largely determined by the environmental influences or *stimuli* to which the organism is subjected. The responses of

*Paramecium caudatum* : The Slipper Animalcule

*Paramecium* to various kinds of stimuli, such as light intensity, temperature, concentration of O<sub>2</sub>, CO<sub>2</sub> and different chemicals in water are interesting. These produce definite behavioural patterns or *reactive behaviour*. The response is *positive* if the animal moves towards a stimulus, and *negative* when it moves away.

[I] Avoiding reaction

It is perhaps the most important mode of behaviour exhibited by *Paramecium*. If a fast

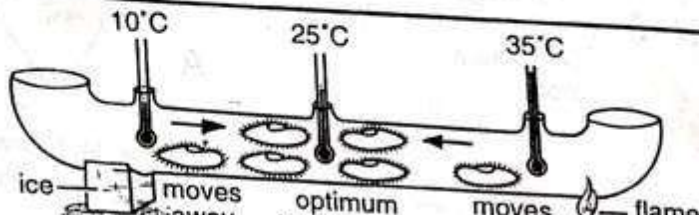
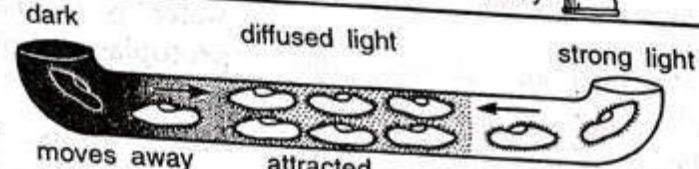
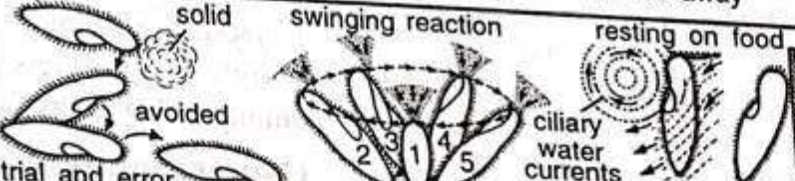
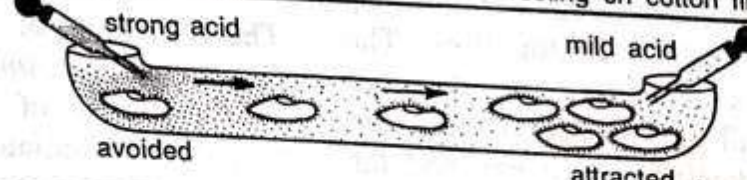


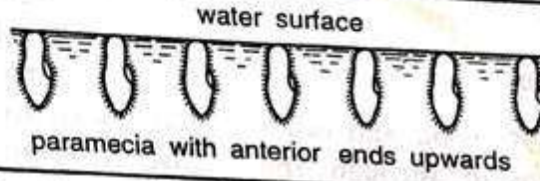
TAXIS	REACTION
THERMOTAXIS (temperature)	 <p>10°C 25°C 35°C ice moves away optimum temperature moves away flame</p>
PHOTOTAXIS (light)	 <p>dark diffused light strong light moves away attracted moves away</p>
THIGMOTAXIS (touch)	 <p>solid swinging reaction resting on food avoided trial and error ciliary water currents resting on cotton fibre</p>
CHAEMOTAXIS (chemicals)	 <p>strong acid mild acid avoided attracted</p>
RHEOTAXIS (water current)	 <p>← moves upstream → → slow water current →</p>
GALVANOTAXIS (electric current)	 <p>+ anode cathode - avoided attracted</p>
GEOTAXIS (gravity)	 <p>water surface paramecia with anterior ends upwards</p>

Fig. 15. *Paramecium*. Responses to different stimuli.

swimming individual strikes a solid object, it moves back for a short distance, turns on its side and swims forward again but at an angle to its original path. If it again collides with an obstacle, it shows the same negative reaction which is repeated until the animal passes the obstacle or becomes exhausted.

### [II] Trial and error reaction

*Paramecium* can also learn by *trial and error reaction*, involving a series of experiments on the part of animal. It constantly tests water just ahead by drawing it in its oral groove in the form of a cone. If water is too hot or too cold or if it contains an irritating chemical substance, the animal shows an avoiding reaction. It immediately backs up and pivots upon its posterior end, while the anterior end swings in a circle. Again it swings forward but in a different direction. If this avoiding reaction once more brings it into the region of the stimulus, it is repeated. These reactions help the animal to avoid undesirable environment without actually getting into it. Moreover, these bring the animal sooner or later, into the most favourable part of environment.

The responses of *Paramecium* to different stimuli may be summarised as under :

1. **Temperature.** Response to temperature is *thermotaxis*. Optimum temperature for *Paramecium* lies between 24°C and 28°C. An avoiding reaction is given to the temperatures higher or lower than this, until the animals escape or get killed.

2. **Light.** Response to light is *phototaxis*. *Paramecia* do not respond to ordinary changes of light, but a negative response is shown to strong light, darkness and ultra-violet rays.

3. **Touch.** Response to contact or *thigmotaxis* is variable. If the more sensitive anterior end is strongly touched with a solid object, the avoiding reaction is given. But a slow-moving *Paramecium* frequently comes to rest in contact with an object, such as an alga or a plant stem, which can provide rich supplies of food.

4. **Chemicals.** *Chemotaxis* or response to chemicals is negative in most of the cases. The animals show a definite avoiding reaction and do not enter a drop of weak salt solution. However,

a positive reaction occurs with a drop of weak acid solution. The animals also find and select their food in this manner.

5. **Water current.** *Paramecia* show a positive *rheotaxis*, orienting themselves with their anterior ends upstream and swimming against the current.

6. **Electric current.** A positive *galvanotaxis* is shown to weak electric current, the animals moving towards the negative pole (cathode). A strong current, however, causes them to move backward towards the anode, finally to disintegrate and die.

7. **Gravity.** *Paramecia* generally show a negative *geotaxis* or response to gravity as seen in a culture contained in a test tube, where they gather close to the surface film with their anterior ends pointed upwards. If *paramecia* are introduced in an inverted water-filled U-tube stoppered at both ends, they immediately move upward into the horizontal part of the tube. When, in moving across the tube, they find their path going downward, they reverse their direction of movement.

### Reproduction

*Paramecium* reproduces asexually by transverse binary fission and also undergoes several kinds of nuclear reorganisations, such as conjugation, endomixis, autogamy, etc. Under certain conditions of food and temperature, it undergoes encystment.

#### [I] Transverse binary fission

During favourable conditions, *Paramecium* commonly reproduces by transverse or horizontal *binary fission*, which is at right angles to the longitudinal axis of body. *Paramecium* stops feeding and its oral groove and buccal structures begin to disappear. While this is happening, the *micronucleus* starts dividing by the complicated process of mitosis, the nuclear membrane remaining intact. Micronucleus first increases slightly in size and then chromosomes, numbering from 36 to 150, depending upon the race, begin to appear. Each chromosome splits longitudinally to form two chromatids (*prophase stage*). Paired chromatids now get arranged on the nuclear spindle at its equatorial plane (*metaphase stage*).

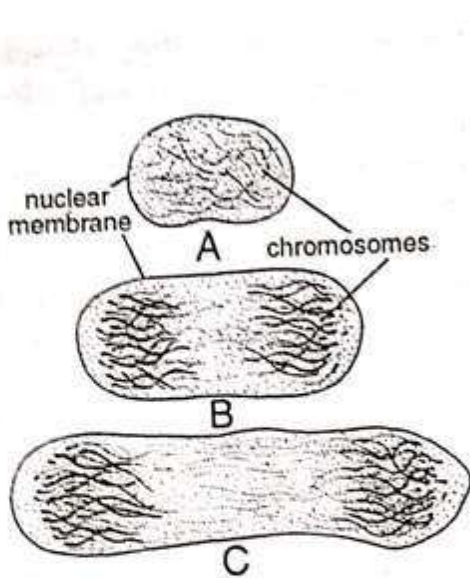


Fig. 16. *Paramecium*. Chromosomal movement in mitosis of micronucleus.

This is followed by separation apart of chromatids and elongation of micronucleus (*anaphase stage*). By the last stage (*telophase stage*), micronucleus becomes very much elongated and its two ends become organised into two daughter micronuclei. The daughter micronuclei then separate. Simultaneously, the *macronucleus* divides amitotically by simply becoming elongated and constricted in the middle. Two oral grooves now begin to form, one in the anterior half and the other in the posterior half. Two original contractile vacuoles remain, one in each half of the dividing parent individual. Two new contractile vacuoles are later formed. Two new buccal structures also appear. In the meantime, a constriction furrow appears near the middle of body. It deepens and ultimately the cytoplasm is completely divided, resulting into two daughter *paramecia*. Of the two daughter *paramecia*, the anterior one is called *proter* and the posterior, *opisthe*. These grow to full size and divide again by fission.

*P. caudatum* divides 2-3 times in a day by binary fission. The process is completed in about 30 minutes, though separation of daughter *paramecia* takes about one hour or more. The term *clone* is used to refer to all the individuals that are produced asexually from one parent *paramecium*. All the members of a clone are genetically alike.

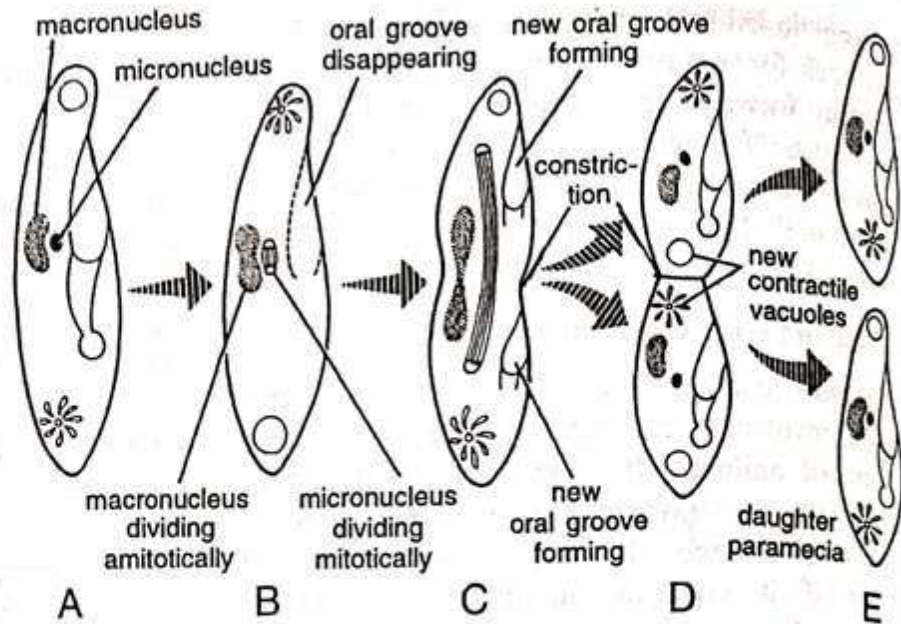


Fig. 17. *Paramecium*. Stages showing binary fission.

## [II] Conjugation

*Paramecium* undergoes a sexual phenomenon, which is called *conjugation*. It is frequently referred to as sexual reproduction, but it is simply a temporary union of two individuals of one and the same species for the purpose of exchanging a part of their micronuclear material. This remarkable process in *Paramecium* occurs frequently between binary fissions and is necessary for the continued vitality of the species.

**1. Process of conjugation.** The details of this process differ slightly in different species of *Paramecium*. The following account refers to *P. caudatum*.

In conjugation, two individuals or *preconjugants*, from two different mating types, come in contact ventrally and unite by their oral grooves. They stop feeding and their buccal structures disappear. The pellicle and ectoplasm degenerate at the point of contact and a *protoplasmic bridge* is formed between the two individuals, which are now called the *conjugants*. While so united, like the 'Siamese twins', the conjugating pair continues to swim actively and a sequence of complicated nuclear changes takes place in each animal.

The vegetative *macronucleus* simply breaks up into fragments, which are later absorbed by cytoplasm. The diploid *micronucleus* of each conjugant first grows in size and then divides by

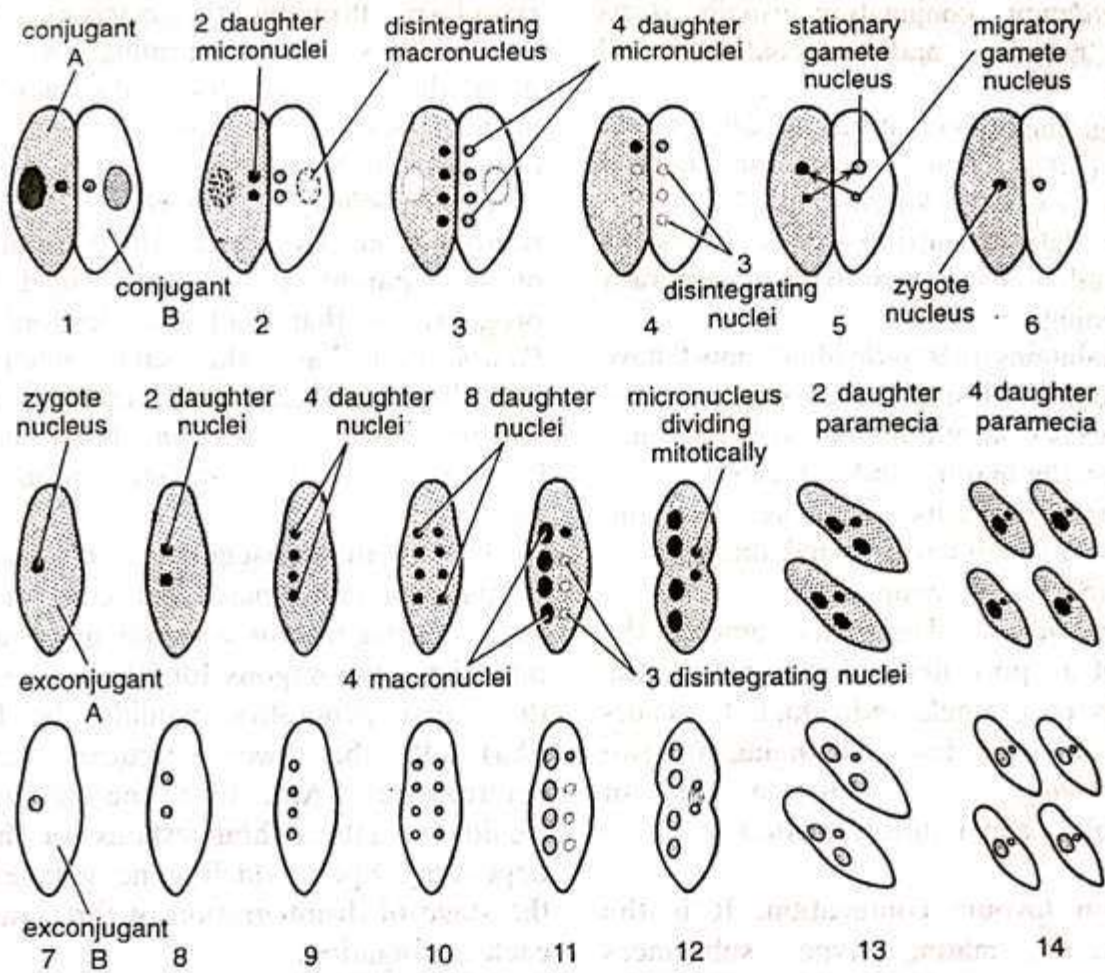


Fig. 18. *Paramecium*. Stages in conjugation. (See text for details).

meiosis. Thus, 4 haploid daughter micronuclei are produced of which 3 degenerate or become pycnotic and disappear in each conjugant, while the remaining one divides by mitosis forming 2 unequal *pronuclei* or *gamete nuclei*. The smaller one is the active *migratory gamete nucleus* and the bigger one is the passive *stationary gamete nucleus*. The migratory nucleus of one conjugant then passes through the protoplasmic bridge into the other individual and fuses with its stationary nucleus, forming a single diploid *zygote nucleus* or *synkaryon*. The complete fusion of two nuclei from two different individuals forming a zygote nucleus is termed *amphimixis*.

The two pairing paramecia, after a union of about 12 to 48 hours, separate and are now called *exconjugants*. In each exconjugant, the zygote nucleus divides by mitosis three times in rapid succession producing 8 nuclei, of which 4 enlarge to become *macronuclei* and other 4 become *micronuclei*. Three micronuclei disintegrate and disappear, while the remaining

micronucleus divides, with binary fission of exconjugant. Thus, from each exconjugant two daughter paramecia are obtained, each containing 2 macronuclei and one micronucleus. The micronucleus again divides with the division of each daughter paramecium, forming two individuals each containing one macronucleus and one micronucleus. Thus, each conjugant produces four daughter individuals at the end of conjugation.

**2. Factors and conditions of conjugation.** Conjugation is very complex physiologically. The factors and conditions governing conjugation are several and these may also vary with the species.

- (1) Conjugation does not occur under favourable living conditions. Starvation or shortage of food and a particular bacterial diet or certain chemicals are said to induce conjugation in some species.
- (2) A certain range of light and temperature, differing with species, is said to be essential for conjugation to occur.

- (3) In *P. caudatum*, conjugation usually starts early in morning and is continued till afternoon.
- (4) The conjugating individuals are usually smaller in size ( $210\mu$  long) than the normal individuals ( $300-350\mu$  long).
- (5) A definite state of nutrition is indispensable since starved or overfed individuals generally will not conjugate.
- (6) Maupas maintains that individuals must have passed through a desirable number of asexual generations (period of immaturity) before they become sexually mature and conjugate.
- (7) The pairing conjugants are *isogamous* and there is no morphological sexual dimorphism into male and female conjugants.
- (8) Conjugation never takes place among the members of a "pure line", that is among the descendants of a single individual. It occurs only between individuals belonging to two different *mating types*. Thus, a sort of physiologically sexual differentiation exists in *Paramecium*.
- (9) Agglutination favours conjugation. It is the interaction of mating type substances (proteins) which are localized in cilia.

**3. Significance of conjugation.** The significance of conjugation has been much discussed but it still remains uncertain. The following functions or effects are attributed to this process :

(a) **Rejuvenation.** If binary fission continues repeatedly for several generations, the *Paramecium* loses its vigour and enters upon a period of depressed physiological efficiency and senescence. The individual ceases to multiply, reduces in size, degenerates in organization and eventually dies off. To avoid this senile decay of race, conjugation is resorted to and the process seems to rejuvenate and revive the lost vigour for asexual reproduction.

However, Woodruff and Jennings do not support the view that conjugation helps in rejuvenescence. Woodruff succeeded in maintaining a culture of paramecia for nearly 36 years, resulting in hundreds of thousands of generations without resort to conjugation.

(b) **Nuclear reorganization.** During conjugation the nuclear apparatus is reorganized and a readjustment occurs between it and the

cytoplasm. Probably the macronucleus loses its potentialities in performing its metabolic activities. Its replacement by a new macronucleus brings renewed vigour and vitality to accelerate the metabolic activities.

(c) **Hereditary variation.** During asexual reproduction by fission, the hereditary material of the parent passes unchanged on to the progeny, so that all the descendants of one *Paramecium* have the same inheritance. The periodic occurrence of conjugation, however, ensures *inherited variation*. It brings about the blending of two lines of ancestry just as bisexual reproduction does.

**4. Genetic consequences of conjugation.** If conjugation takes place between two paramecia, one homozygous for a dominant gene (AA) and the other homozygous for its recessive gene (aa), the first generation would be heterozygous (Aa). If the two conjugants are already heterozygous (Aa), then the resulting progeny would be either homozygous or heterozygous, depending upon which gene gets eliminated at the stage of disintegration of three micronuclei in each conjugation.

### [III] Autogamy

W.F. Diller (1936) described a process of nuclear reorganization in *P. aurelia*, resembling conjugation, but taking place within a single individual. He called it *autogamy* or *self-conjugation*.

**1. Process of autogamy.** During autogamy in *P. aurelia*, the 2 diploid micronuclei divide by meiosis to form eight haploid daughter nuclei. Seven of them disintegrate, while the remaining haploid micronucleus undergoes a mitotic division forming 2 gamete nuclei. Meanwhile, the macronucleus grows into an irregular skein-like mass, which breaks into pieces later to be absorbed in the cytoplasm. The two gamete nuclei enter a protoplasmic cone temporarily formed near cell mouth and then fuse together to form a completely homozygous diploid zygote nucleus or *synkaryon*. This divides twice to yield 4 nuclei, 2 of which become macronuclei and 2 micronuclei. The cell body and the micronuclei then divide to form two daughter individuals, each with a new macronucleus and 2 micronuclei. Autogamy rejuvenates *Paramecium*.

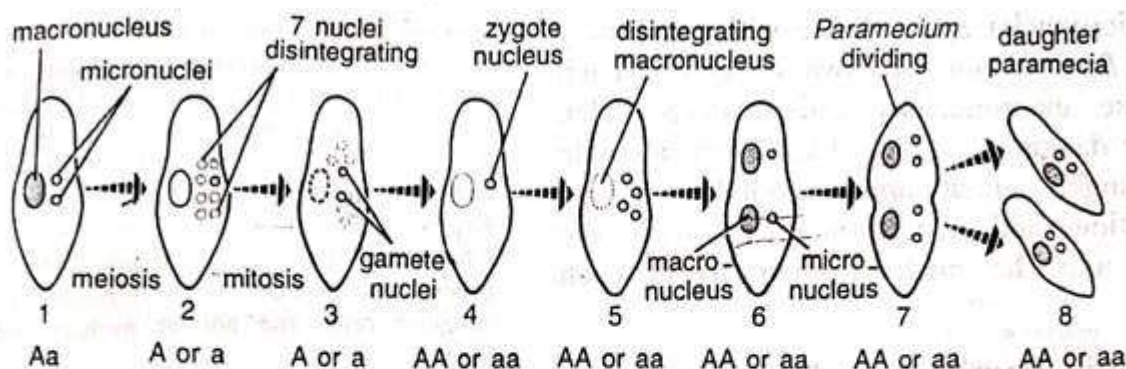


Fig. 19. *Paramecium aurelia*. Stages in autogamy

**2. Genetic consequences of autogamy.** If autogamy takes place in a *Paramecium* heterozygous for a dominant gene (Aa), the resulting progeny will depend upon the survival of the gene A or a. If the gene A survives, it will lead to AA individuals or vice versa. Thus, autogamy always results in homozygosity.

**[IV] Cytogamy**

In 1940, R. Wichterman reported, in *P. caudatum*, a sexual process without nuclear exchange, termed *cytogamy*. The process resembles *conjugation* in that two small paramecia (200μ long) temporarily fuse by their oral surfaces. The early nuclear divisions are also similar to those of conjugation; but there is no nuclear exchange between the individuals (*cytogamonts*). But, two haploid *gamete nuclei* in each individual are said to fuse to form a *synkaryon*, as in *autogamy*. The process is completed in about 13 hours.

**[V] Endomixis**

Endomixis (Gr., *endon*, within + *mixis*, mingling) is an interesting phenomenon involving a total internal nuclear reorganization within a single individual in a culture of a pedigreed race of *Paramecium*, taking place in the absence of conjugation. Woodruff and Erdmann, in 1914, first of all reported endomixis in the bimicronucleate species, *P. aurelia*, occurring periodically at regular intervals of about 30 days. The whole process may be summarized as follows :

The vegetative *macronucleus* degenerates and disappears, while the *micronuclei* divide twice by mitosis forming 8 *daughter nuclei* of which

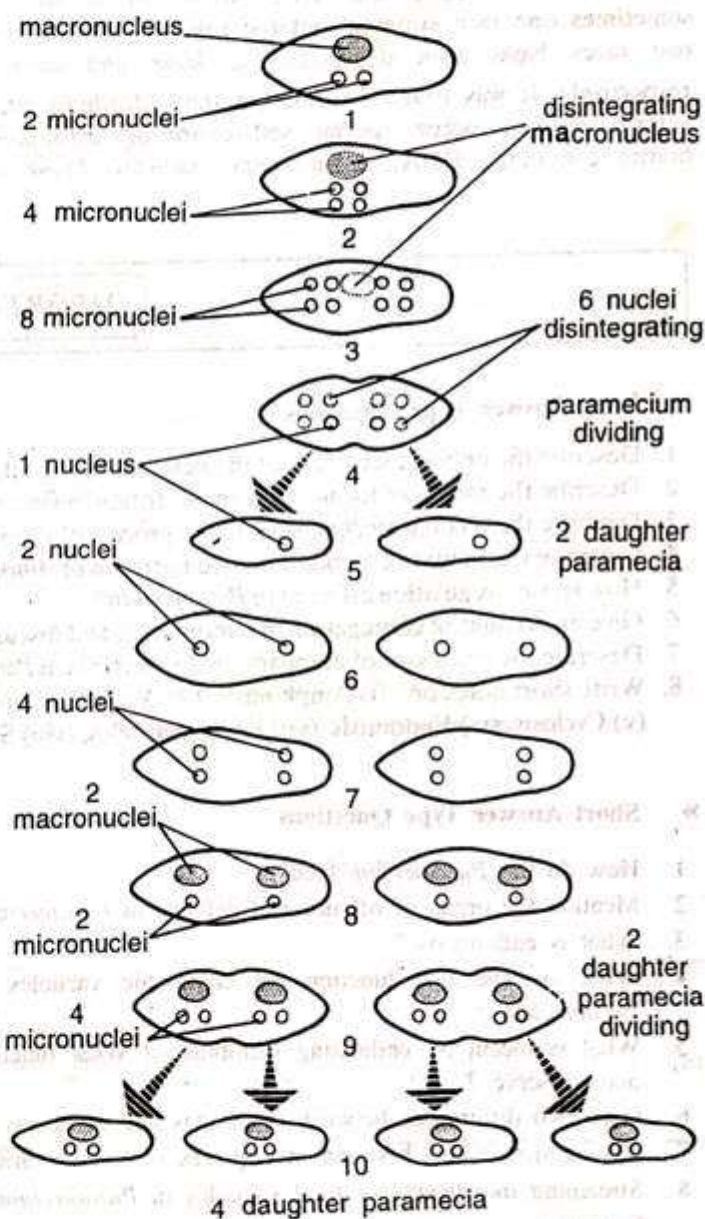


Fig. 20. *Paramecium*. Stages in endomixis.

6 degenerate. At this stage *Paramecium* also divides, each daughter receiving one micronucleus. This micronucleus divides twice forming 4 nuclei, 2 of which become macronuclei and 2 micronuclei, in each individual.

The micronuclei again divide with the binary fission of *Paramecium* into two daughters, each getting one macronucleus and 2 micronuclei. Thus, four daughters are produced from a single parent bringing about an intracellular nuclear reorganization and readjustment between the cytoplasm and the nuclear apparatus in each individual.

### Cytoplasmic Particles in *Paramecium*

1. **Kappa particles.** At the time of mixing two races of *Paramecia* for conjugation, T.H. Sanneborn found that sometimes one race survives and the other dies out. These two races have been designated as *killer* and *sensitive*, respectively. It was found out that in the individuals which survive (*killers*) occur special self-replicating cytoplasmic bodies containing DNA, called *kappa particles*. These are

associated with the production of a killing substance, *paramycin*. This substance diffuses out into the surrounding water and causes the death of the sensitive (*kappa free*) individuals. In the course of studies about the *kappa* particles, it was found that a dominant gene (K) in nucleus is necessary for *kappa* to exist, multiply and produce *paramycin*. *Kappa* particles provide an example of cytoplasmic inheritance. They are transmitted directly by cytoplasmic genes (*plasmagones*) from cytoplasm of parent cell to the daughter cells, and not by nuclear genes as in ordinary heredity.

2. **Pi particles.** These are mutant forms of *kappa* particles. They do not release any toxic substance meant for killing those which are without such particles, that is, the sensitives.

3. **Mu particles.** These particles are also killers and kill the mate without such particles, during conjugation.

4. **Lambda particles.** These particles are borne by killer *paramecia* and cause the sensitive *paramecia* to lyse or disintegrate.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Describe the detailed structure of the pellicle and the infraciliary system of *Paramecium*.
2. Describe the modes of locomotion and nutrition in *Paramecium*.
3. Describe the feeding mechanism and the process of digestion in *Paramecium*.
4. Compare the modes of locomotion and nutrition of *Amoeba*, *Euglena* and *Paramecium*.
5. How is osmoregulation effected in *Paramecium*?
6. Give an account of conjugation in *Paramecium* and discuss its significance.
7. Describe the processes of autogamy and endomixis in *Paramecium*.
8. Write short notes on : (i) Amphimixis, (ii) Autogamy, (iii) Binary fission in *Paramecium*, (iv) Buccal ciliature of *Paramecium*, (v) Cyclosis, (vi) Endomixis, (vii) *Kappa* particles, (viii) Synkaryon, (ix) Trichocysts.

#### » Short Answer Type Questions

1. How do the *Paramecium* feed ?
2. Mention the organ of offence and defence in *Paramecium*.
3. What is endomixis ?
4. What are the two functions of contractile vacuoles of *Paramecium* ?
5. What is meant by undulating membrane ? What function does it serve ?
6. Give two differences between endomixis and autogamy.
7. Conjugation occurs between mating type of the .... variety.
8. Streaming movements of food vacuoles in *Paramecium* is known as ....
9. The descendants of a single individual *Paramecium* is known as ....
10. Define conjugation.
11. Write the food procuring mechanism exhibited by *Paramecium*.
12. What is a trichocyst ? What are its functions ? Describe the mechanism of its discharge.
13. Distinguish between conjugation and autogamy.
14. What is nuclear dimorphism ? Explain the phenomenon with reference to *Paramecium*.
15. Differentiate between cytogamy and autogamy, and endomixis and hemixis.
16. Give an account of nuclear reorganization processes in *Paramecium*.
17. Distinguish between synchronous and metachronous beating of cilia in *Paramecium*.
18. Distinguish between macro- and micro-nucleus of *Paramecium* on the basis of their functions.
19. Distinguish between effective stroke and recovery stroke of a flagellum.
20. With reference to plane of division distinguish binary fission in *Paramecium* and *Trypanosoma*.
21. Describe cyclosis.

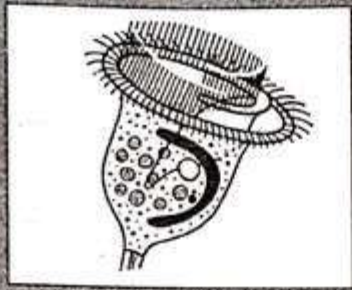


» Multiple Choice Questions

1. Movement of food vacuole in *Paramecium* along a definite path is known as :  
(a) cytokinesis (b) cyclosis  
(c) endomixis (d) metagenesis
2. In *Paramecium* the division of Macronucleus during Binary fission is :  
(a) mitotic (b) amitotic  
(c) meiotic (d) prenuclear
3. The functions of the Trichocysts are :  
(a) offence and defence  
(b) narcotising prey  
(c) to attain resting condition  
(d) all of the above mentioned
4. The main functions of the contractile vacuole is :  
(a) pumping out excess water (b) excretion  
(c) osmoregulation (d) respiration
5. What is a trichocyst ?  
(a) spindle shaped structure below pellicle  
(b) interlacing  
(c) fusion of cilia and flagella  
(d) modification of the contractile vacuole a structure concerned with photosynthesis
6. Mention a function of the neuro-motor system of *Paramecium* :  
(a) co-ordination of ciliary beat  
(b) co-ordination of various stimuli  
(c) control of digestion  
(d) co-ordination of respiratory movement  
(e) control of osmoregulation
7. Which of the following helps in anchorage and defence of *Paramecium* ?  
(a) nematocyst (b) oocyst  
(c) trichocyst (d) statocyst
8. Autogamy and conjugation are sexual processes, because :  
(a) recombination of genes takes place  
(b) the individual is rejuvenated  
(c) two individuals are involved  
(d) fusion of haploid nuclei occurs
9. The number of nucleus in *Paramecium* is :  
(a) one (b) two  
(c) three (d) four
10. Who discovered *Paramecium* :  
(a) Hill (b) Ross  
(c) Lavine (d) Grassi
11. 'Hay-infusion method' use for the culture :  
(a) *Amoeba* (b) *Paramecium*  
(c) *Euglena* (d) all
12. 'Caudal tuft' present in :  
(a) *Amoeba* (b) *Paramecium*  
(c) *Euglena* (d) *Trypanosoma*
13. Vegetative function control by :  
(a) Micronucleus (b) Macronucleus  
(c) both (d) none
14. How many food vacuole present in *Paramecium* :  
(a) one (b) two  
(c) four (d) numerous
15. Among them which one is filter feeder :  
(a) *Paramecium* (b) *Amoeba*  
(c) *Trypanosoma* (d) *Monocystis*
16. A protozoa feeds on protozoans :  
(a) *Paramecium* (b) *Amoeba*  
(c) *Trypanosoma* (d) *Plasmodium*
17. Protozoa which able to creep on a substratum :  
(a) *Amoeba* (b) *Paramecium*  
(c) *Euglena* (d) none
18. How many paramecia produce after the conjugation :  
(a) two (b) four  
(c) eight (d) sixteen
19. Autogamy occurs only in :  
(a) *Paramecium cadatum* (b) *P. aurelia*  
(c) *Amoeba* (d) *Trypanosoma*
20. Cytogamy occurs in :  
(a) *Paramecium caudatum*  
(b) *P. aurelia*  
(c) *Amoeba* (d) none

Answers

1. (b) 2. (a) 3. (d) 4. (c) 5. (a) 6. (a) 7. (c) 8. (b) 9. (b) 10. (a) 11. (b) 12. (b) 13. (b) 14. (d) 15. (a) 16. (a) 17. (a) 18. (b) 19. (b) 20. (a)



# 13

## Chapter

### Vorticella: The Bell Animalcule

Unlike *Paramecium*, certain ciliates occur as sessile individuals, attached by a stalk to the substratum. *Vorticella* (L., vortex, a whirlpool) is such a ciliate. Its body is almost bell-shaped or campanulate with free anterior end surrounded by cilia. The following text is generalized and mostly relates to *V. microstoma*, *V. campanula* and *V. nebulifera*.

#### Systematic Position

Phylum	Protozoa
Subphylum	Ciliophora
Subclass	Peritricha
Order	Peritrichida
Suborder	Sessilina
Family	Vorticellidae
Genus	<i>Vorticella</i>

#### Habits and Habitat

*Vorticella* is an extremely common, solitary and stalked ciliate, often found in freshwater ponds, lakes, rivers, streams, etc. Several individuals often occur socially in large groups anchored by (Z-1)

their large contractile stalks to aquatic plants, animals, stones, twigs, etc. The contractile stalk permits the body to expand and contract frequently. Under certain conditions the body becomes detached from its stalk and swims freely. There are about 200 species, all of which are solitary. They occur in large groups but are never colonial. They are found abundantly in stagnant water containing decaying organic matter, feeding largely on bacteria. But some species, such as *V. campanula* and *V. nebulifera*, can live only in uncontaminated waters, where bacterial growth does not become too great. Some species are marine, some are epizoic and a few are parasitic. *V. microstoma* is the one which is more frequently seen in laboratory infusions.

#### Structure

##### [1] Shape, size and colouration

*Vorticella* has a campanulate or bell-shaped asymmetrical body. To its base is attached a

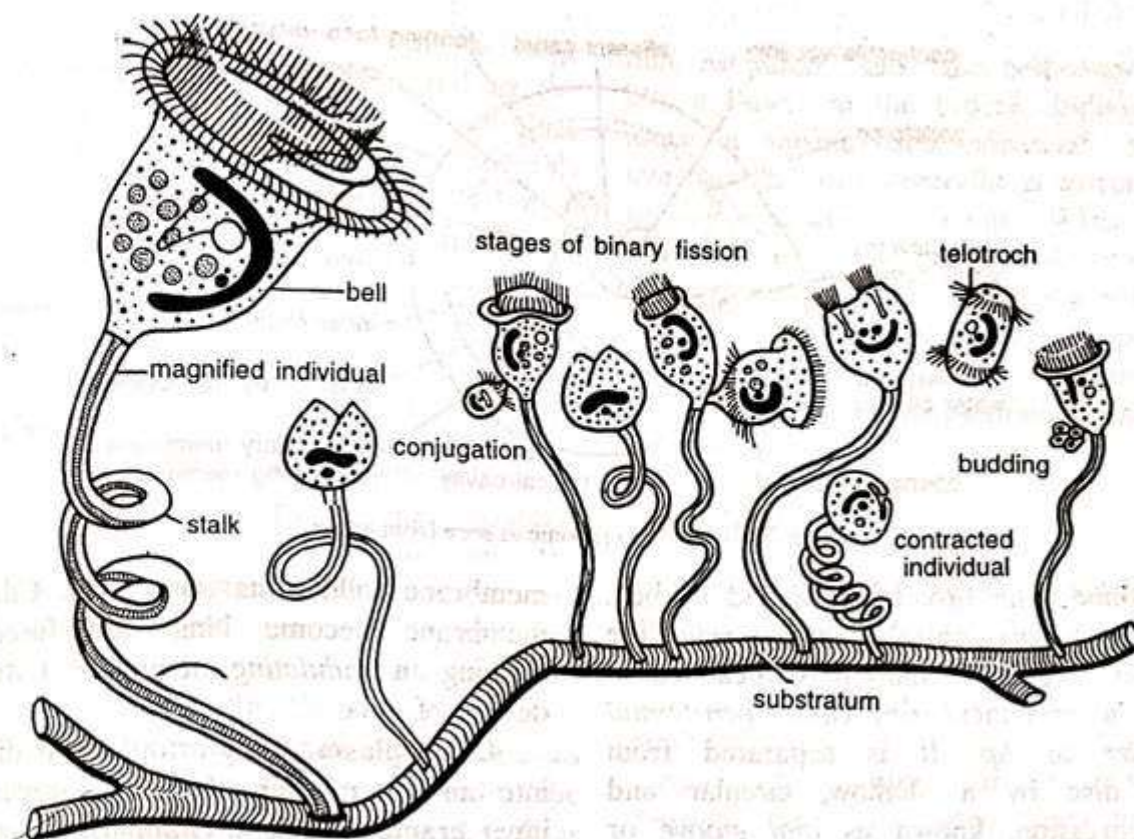


Fig. 1. *Vorticella*. A group of individuals in different states.

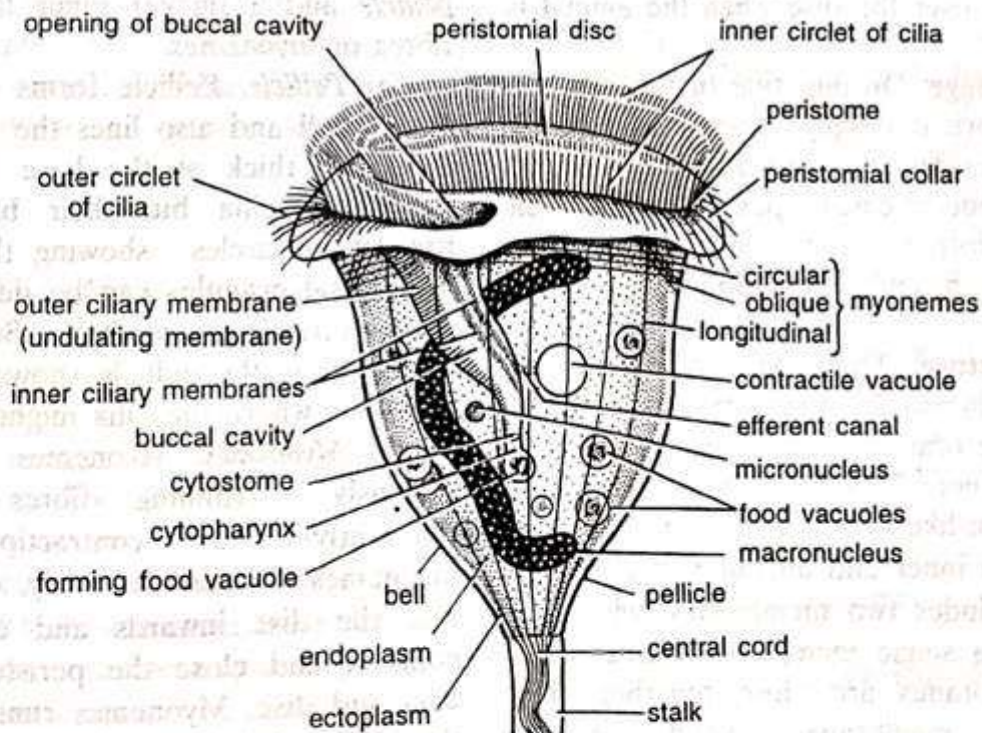


Fig. 2. *Vorticella*. The bell of an individual (magnified).

contractile stalk. Both body and stalk are capable of great individual variations in size and form. The bell of largest species (*V. campanula*) varies in size up to  $157\mu$  long and  $99\mu$  broad, while the length of stalk varies from  $53$  to  $4150\mu$ . Body of the smaller species, *V. microstoma*, measures

about  $55\mu$  by  $35\mu$ . *V. nebulifera* is greenish and *V. campanula* bluish in colour.

### [II] Bell

The body proper of each individual is shaped like a solid inverted bell. Its detailed structure is as follows :

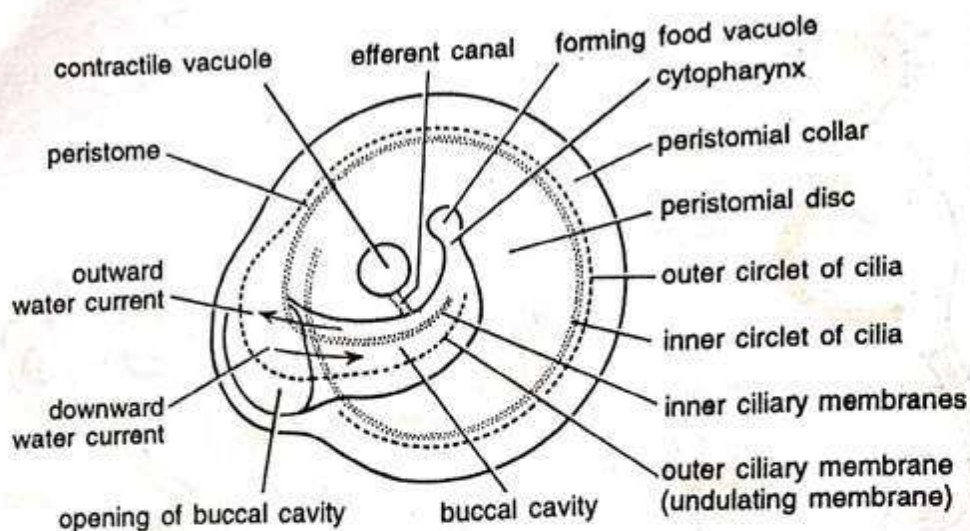


Fig. 3. *Vorticella*. Peristome as seen from above.

1. **Peristome.** The broader free end of bell, with a slightly convex central area, is termed the *peristomial disc*. Its outer margin is thickened so as to form a prominent rim called *peristomial collar*, *border* or *lip*. It is separated from peristomial disc by a shallow, circular and marginal depression, known as *oral groove* or *peristome*. Cilia are inserted in this groove. The collar can close over the disc when the animal is retracted.

2. **Food passage.** On one side of the disc the peristomial groove is deeply invaginated forming a funnel-like *vestibule* or *buccal cavity*. At its inner end, the buccal cavity opens through a cell mouth or *cytostome* into cell gullet or *cytopharynx*, which ends in a *food vacuole* in endoplasm.

3. **Oral ciliation.** There are no somatic or body cilia in *Vorticella*. Only the peristomial groove bears the oral or aboral cilia arranged in a whirlpool manner. They form three concentric rows of ribbon-like membranes, which are arranged into an inner and an outer circlet. The inner circlet includes two membranes, while the outer circlet is a single membrane. Bases of all the three membranes are close together. The three ciliary membranes wind in a counter-clockwise direction around the margin of disc and then continue downward into buccal cavity. Inside buccal cavity the ciliary membranes separate. Two inner membranes run along the inner wall of buccal cavity, and the outer

membrane follows its outer wall. Cilia of outer membrane become long and fused together forming an *undulating membrane*. Cytopharynx is devoid of cilia.

4. **Ectoplasm.** Body cytoplasm is differentiated into an outer layer of clear *ectoplasm* and an inner granular fluid of *endoplasm*. Ectoplasm has no trichocysts. It consists of an elastic outer *pellicle* and a thicker inner layer of contractile fibres or *myonemes*.

(a) **Pellicle.** Pellicle forms an outer envelope of the bell and also lines the buccal cavity. It is especially thick at the base of the bell. It is devoid of cilia but their basal granules are present in circles showing that their cilia are lost. Basal granules can be demonstrated by the *Klein silver-line\* method*. Besides, on closer examination, the pellicle shows indistinct circular striations where the cilia might have been.

(b) **Myonemes.** Myonemes form a system of variously running fibres which function differently on contraction. Longitudinal myonemes shorten the body, oblique myonemes pull the disc inwards and circular myonemes contract and close the peristomial border over cilia and disc. Myonemes running parallel down the sides of bell are more visible at the base where they converge before entering the stalk.

5. **Endoplasm.** The granular endoplasm contains nuclei, contractile and food vacuoles, etc.

(a) **Nuclei.** Endoplasm contains a large elongated, rod-like and horseshoe-shaped *macro-*

\*Klein (1926) used silver nitrate to demonstrate a complicated silver-line system, consisting of a network of fibrils, blackened.

nucleus. It is highly polyploid with a large amount of chromatin material scattered in the nucleoplasm. A tiny *micronucleus* occurs in close association with the macronucleus. It is rarely seen in living animals. To see the micronucleus it is very necessary to stain it with acetocarmine or any of the more permanent stains.

(b) *Contractile vacuole*. Located near buccal cavity is a clear and permanent pulsating space or contractile vacuole. It is about  $7\mu$  in diameter when fully distended. It shows diastole (expansion) and systole (contraction) in a rhythmic manner and pours its contents into an *efferent canal*, which leads into the buccal cavity. In some species there are two contractile vacuoles as in *V. picta* and *V. monilata*.

(c) *Food vacuoles*. In the endoplasm are present many large and small food vacuoles containing food particles. They are formed at the inner end of cytopharynx and constrict off as rounded spheres into the endoplasm.

(d) *Cytopyge*. The undigested food particles are passed into buccal cavity through a temporary or permanent opening, the *cytopyge* or *cytoproct*, formed at a weaker spot of the ectoplasm.

### [III] Stalk

The bell-shaped body of *Vorticella* remains attached to the substratum by a long, uniformly thin, unbranched and highly contractile *stalk*. It is also devoid of cilia. The older view is that the stalk is formed only by ectoplasm. But, electron microscopy has revealed that the stalk consists of two parts, central canal and outer sheath. Central canal consists of endoplasm, a contractile cord which is a specialized myoneme, called *spasmoneme*, and some granules, possibly mitochondria. Spasmoneme is a bundle of spiral fibrils continuous with the myonemes of the bell. It is believed that contractility of stalk is due to contractile ability of spasmoneme. On the stalk may be present commensal bacteria.

### Locomotion

Normally, the cilia remain very active and movements of stalk are frequent and rapid. When the animal is feeding, its stalk remains

fully extended and the bell sways to and fro like a flower in the breeze. Individuals do not move in unison; each individual sways to its own rhythm. But *Vorticella* is extremely sensitive to any mechanical stimulus. When irritated, all activities cease instantly. Stalk is retracted into a close and delicate spiral, cilia are stilled, disc is pulled in and closed over by peristomial lip and the rounded body is brought close to bottom, where it rests motionless until the danger has passed.

### Nutrition

Nutrition is holozoic as in *Paramecium*. A water current produced by adoral cilia of peristome brings bacteria and other small organic particles into the peristomial groove, from where they are further carried into buccal cavity. Within buccal cavity the water current flows downward between inner and outer ciliary membranes and outward between inner wall of buccal cavity and inner ciliary membranes. Food particles are driven towards cytostome along the outer membrane helped by undulations of two inner membranes. Terminal end of cytopharynx with food particles is pinched off along with some water into the endoplasm forming food vacuoles one after the other. Formation of food vacuoles may be compared with the formation of soap bubbles at the end of a pipe. In endoplasm, the food vacuoles move in an irregular cyclosis and not in a regular cyclosis like that of *Paramecium*. Digestion is similar to that of *Paramecium* and the medium of food vacuoles is first alkaline, then acidic and then it becomes alkaline till absorption. Excess of digested food forms refractile glycogen granules stored in endoplasm.

### Respiration, Excretion and Osmoregulation

Respiration and excretion take place by diffusion as in *Paramecium*.

A single, large and pulsating contractile vacuole is present in endoplasm between the disc and buccal cavity. It opens into buccal cavity through a permanent opening and pulsates rhythmically showing diastole and systole phases. At diastole phase, the excess water from

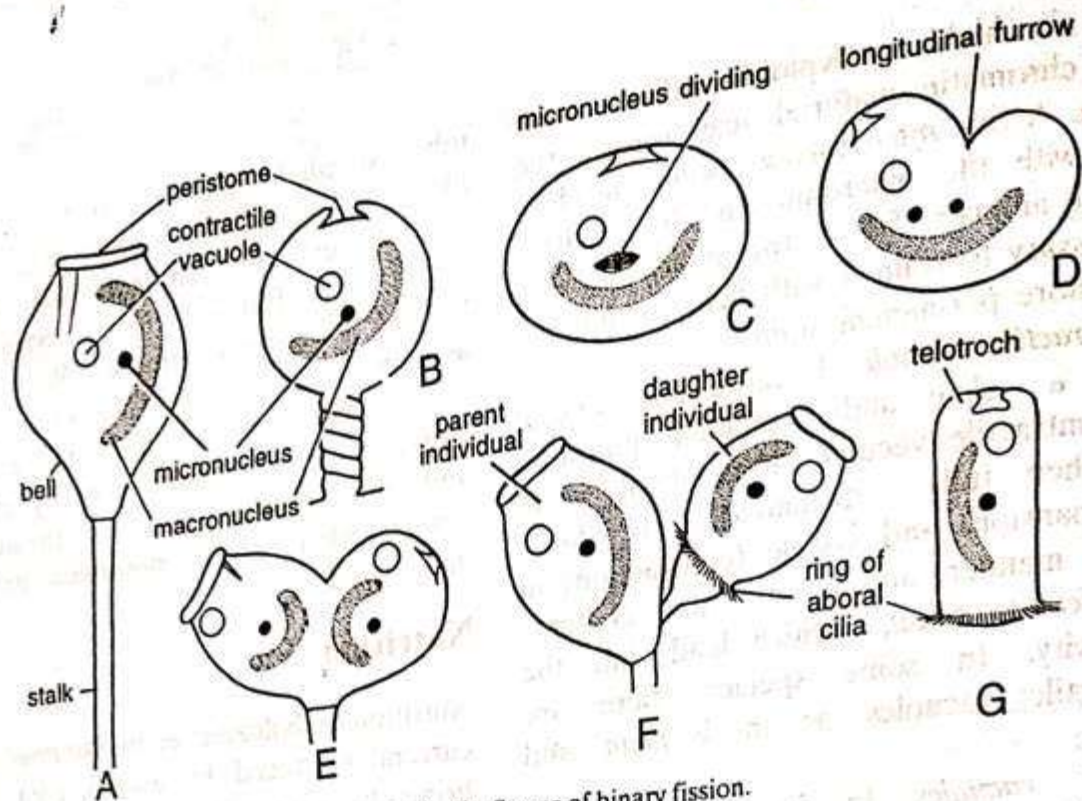


Fig. 4. *Vorticella*. Stages of binary fission.

endoplasm is secreted into it and at systole phase, the water is expelled into buccal cavity.

### Contractility and Irritability

The striking characteristic of *Vorticella* is its extreme irritability. It very readily responds to external stimuli. Even a flash of change in its surrounding water or the touch of a minute particle will bring about change in the relative position of its parts. First to respond is always the stalk, which becomes coiled into a close spiral to reduce its size. Then the disc is withdrawn and peristome closes over it. As a result the body form becomes somewhat globular.

### Reproduction

Reproduction takes place asexually by longitudinal binary fission and at intervals by conjugation. Encystment also occurs under unfavourable conditions.

1. **Longitudinal binary fission.** The organism splits into two by longitudinal binary fission. During fission, *Vorticella* closes its peristome over the disc and the body becomes depressed and transversely elongated. The elongated, curved macronucleus shortens to become straight and comes to lie transversely in the middle of body. Macronucleus now divides into two daughter nuclei amitotically, whereas the tiny micronucleus divides by mitosis. Meanwhile, a vertical

constriction develops at the free distal end, and then passes down the length of bell to one side of stalk. It divides the animal into two somewhat unequal parts or daughter individuals. Smaller daughter individual is without a stalk, while the larger daughter individual retains the parental stalk. Smaller individual acquires a ring of aboral cilia and develops a new contractile vacuole. It becomes cylindrical, gets detached basally and is now called a *telotroch*. It swims about rapidly by its posterior cirlet of cilia keeping its posterior or aboral end foremost. Later, it settles down by its aboral end, which also has a short adhesive disc or *scopula*, which is a concavity bordered by a projecting rim and stiff cilia-like projections. Scopula secretes a stalk by which the telotroch gets fixed. Now the scopula is lost, the bell expands and a new peristomial disc is formed so that it metamorphoses soon into an adult. The whole process of binary fission is completed in about 20 to 30 minutes. The larger individual, retaining old disc, may be called the *parent*, while the smaller individual, or telotroch, the *offspring*.

2. **Conjugation.** In *Vorticella*, sexual reproduction takes place by conjugation. It is known as *anisogamontogony* because the two conjugating individuals (*anisogametes*) are dissimilar in size. *Macroconjugant* is the larger, stalked and sessile individual (the female), looking like an ordinary vegetative individual.

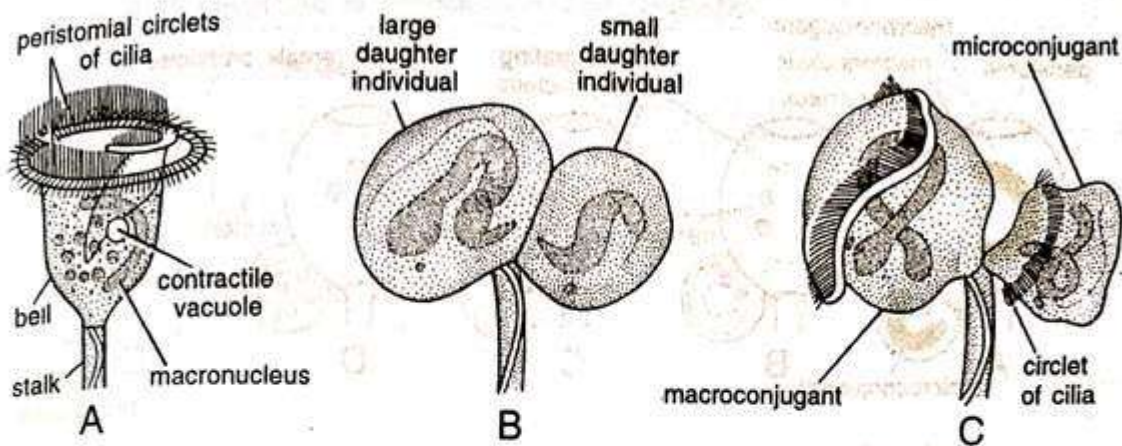


Fig. 5. *Vorticella*. Stages showing formation of micro- and macroconjugants.

*Microconjugant* is the smaller motile male which arises by special divisions.

(a) **Formation of micro and macroconjugants.**

*Vorticella* first divides asexually by longitudinal binary fission into two very unequal parts without being separated. The larger part is the ordinary somatic individual, while the smaller part is called the *microconjugant*. In some species (*V. nebulifera*), more than one *microconjugant* are produced by repeated fissions. Each *microconjugant* acquires a girdle of cilia at the posterior end, becomes detached from stalk and swims about actively in water. Swimming is an adaptation ensuring conjugation in sessile species. *Microconjugant* differs from telotroch in being much smaller in size, in never metamorphosing into adult and in never forming a stalk. *Microconjugants* never feed or encyst and survive only for about 24 hours after which they die. *Macroconjugants* are produced by the normal stalked individuals, in which certain nuclear modifications have taken place. They are morphologically similar to the normal trophic individuals, but are specialized physiologically and can attract *microconjugants* for about two hours. *Macroconjugants* are stationary and passive, while *microconjugants* are motile and active.

(b) **Fusion of conjugants.** A *microconjugant* swims and fuses by its aboral end with a *macroconjugant* in the lower third of its body. After attachment, *microconjugant* loses cilia and throws off its pellicle. The two conjugants differ in their further development. *Macronuclei* of

both conjugants disintegrate and finally disappear. In *microconjugant*, three nuclear divisions take place forming 8 nuclei, out of which 7 disintegrate and the remaining one becomes the *male pronucleus*. In *macroconjugant*, *micronucleus* undergoes two divisions forming 4 nuclei, 3 of which disintegrate and the remaining one becomes the *female pronucleus*. In both cases, first division is reduction division and hence the male as well as female pronuclei are haploid.

Later, the male pronucleus of *microconjugant* migrates into cytoplasm of *macroconjugant* and fuses with its female pronucleus, resulting in a diploid *zygote nucleus* or *synkaryon*. After this the *microconjugant* shrivels and perishes. Fertilized *macroconjugant* is now termed as *zygote*.

In case of some species, like *V. monilata*, one more division of the remaining pronucleus in both the conjugants takes place, so that each conjugant contains two pronuclei, one stationary and the other migratory. The mutual exchange of migratory pronuclei takes place. However, the *synkaryon* is formed only in the *macroconjugant*, whereas the *microconjugant* along with its contained nuclei is perished and absorbed.

(c) **Post-zygotic development.** *Synkaryon* of *zygote* undergoes three mitotic divisions to form 8 nuclei. Out of these, 7 nuclei become *macronuclei* and the remaining one, the *micronucleus*. *Micronucleus* now divides mitotically producing two daughter nuclei followed by cytokinesis. Thus, two daughter cells are formed, one with 4 *macronuclei* and one *micronucleus* and the other with 3 *macronuclei* and one *micronucleus*. Each daughter cell and its

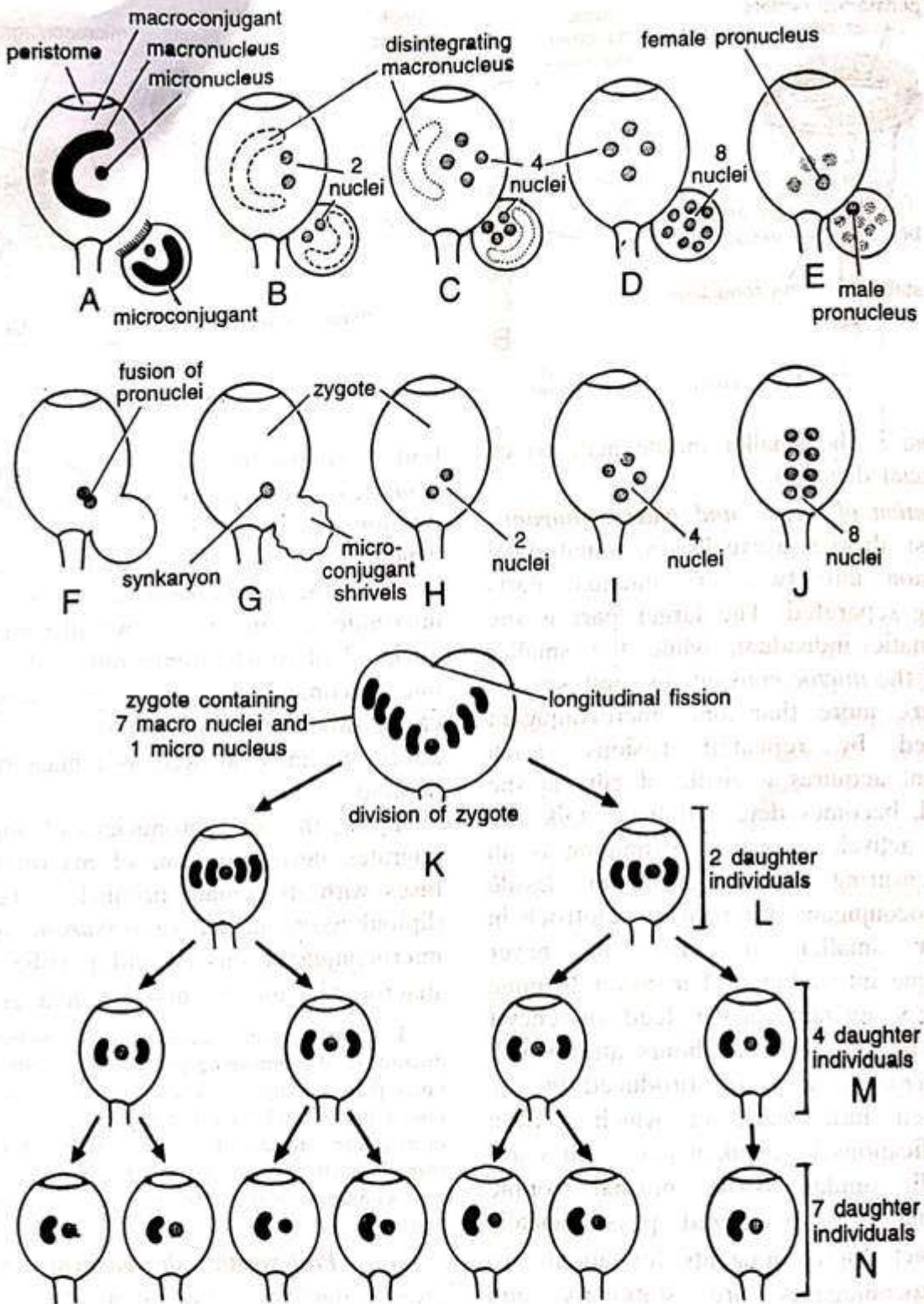


Fig. 6. Vorticella. Stages showing conjugation.

micronucleus divide twice. Daughter cell with 4' macronuclei forms 4 daughter individuals, and daughter cell having three macronuclei gives rise to only three individuals, each having one

micronucleus and one macronucleus. 7 daughter cells thus produced begin to acquire stalks and finally become adults.

The grow.



Table 1. Comparison of Conjugation in *Paramecium* and *Vorticella*.

Characters	<i>Paramecium</i>	<i>Vorticella</i>
1. Conjugants	1. Conjugants are <i>isogamous</i> , i.e., similar in size.	1. Conjugants are <i>anisogamous</i> , i.e., dissimilar in size.
2. Dimorphism of pre-conjugants	2. No morphological sexual dimorphism in male and female pre-conjugants.	2. Dimorphism distinct. Male or <i>microconjugant</i> is smaller than female or <i>macroconjugant</i> .
3. Formation of conjugants (Parentage)	3. Conjugating individuals are smaller $1250\mu$ in size than normal individuals ( $300\text{--}\mu$ ) and come from different parents.	3. Produced by unequal longitudinal binary fission of a single parent.
4. Motility	4. Pairing conjugants continue to swim actively while attached together like siamese twins.	4. Male or microconjugant swims actively before fixing upon a macroconjugant which is stalked and sessile.
5. Mating types	5. Conjugation occurs between two conjugants belonging to two different mating types which are physiologically different.	5. Both conjugants show morphological as well as physiological differences and come from two different parents.
6. Union	6. Two conjugants unite temporarily for exchange of nuclear material.	6. Union of two conjugants is permanent.
7. Exchange of nuclei	7. As in <i>Vorticella</i> male pronucleus of one conjugant enters the other conjugant and fuses with its female pronucleus (amphimixis) to form synkaryons.	7. As in <i>Paramecium</i> , mutual exchange of pronuclei takes place but synkaryon is formed only in macroconjugant.
8. Post-conjugants	8. After amphimixis, both conjugants separate as exconjugants.	8. After amphimixis, macroconjugant absorbs the contents of microconjugant whose pellicle falls off.
9. Further divisions	9. Each exconjugant undergoes further nuclear and cytoplasmic divisions, independently.	9. Microconjugant degenerates. Only macroconjugant undergoes further divisions.
10. Offsprings	10. Each exconjugant produces 4 daughter paramecia on completion of conjugation.	10. Only macroconjugant gives rise to 7 daughter individuals or <i>Vorticella</i> .
11. Nature of conjugation	11. Conjugation is not a sexual reproduction. It is merely an exchange of nuclear material. There is no fusion of cytoplasm.	11. Conjugation involves fusion of nuclei and cytoplasm of both conjugants. It is intermediate between conjugation and syngamy.

## Dispersal and Encystation

Under unfavourable conditions a normal individual of *Vorticella* may also grow a posterior ring of cilia to become a *telotroch*. The telotroch then breaks loose from its stalk, swims away to a more favourable spot and there becomes fixed again by growing a stalk. *Vorticella* is also known to tide over adverse conditions by undergoing *encystation*. The whole bell-body encysts on the stalk from which it finally breaks off. The stalk contracts to its maximum and the bell-body loses water, rounds off and secretes around it a gelatinous *ectocyst*. It soon becomes a wrinkled membrane and underneath it develops a

double-layered *endocyst*. Myonemes become indistinct and pulsating rate of contractile vacuole goes very low, till it disappears. After some time, peristome is absorbed. Completed cyst of *V. microstoma* measures about  $38\mu$  in diameter and its poles are marked by two scars. One scar represents the point of attachment with stalk, while the other scar indicates the last point of escape for excreted water. On the return of favourable conditions excystation takes place. Contractile vacuole becomes enlarged and the organism grows an aboral circlet of cilia to become a telotroch. After some free swimming, the telotroch gets fixed to some substratum and grows into an adult *Vorticella*.

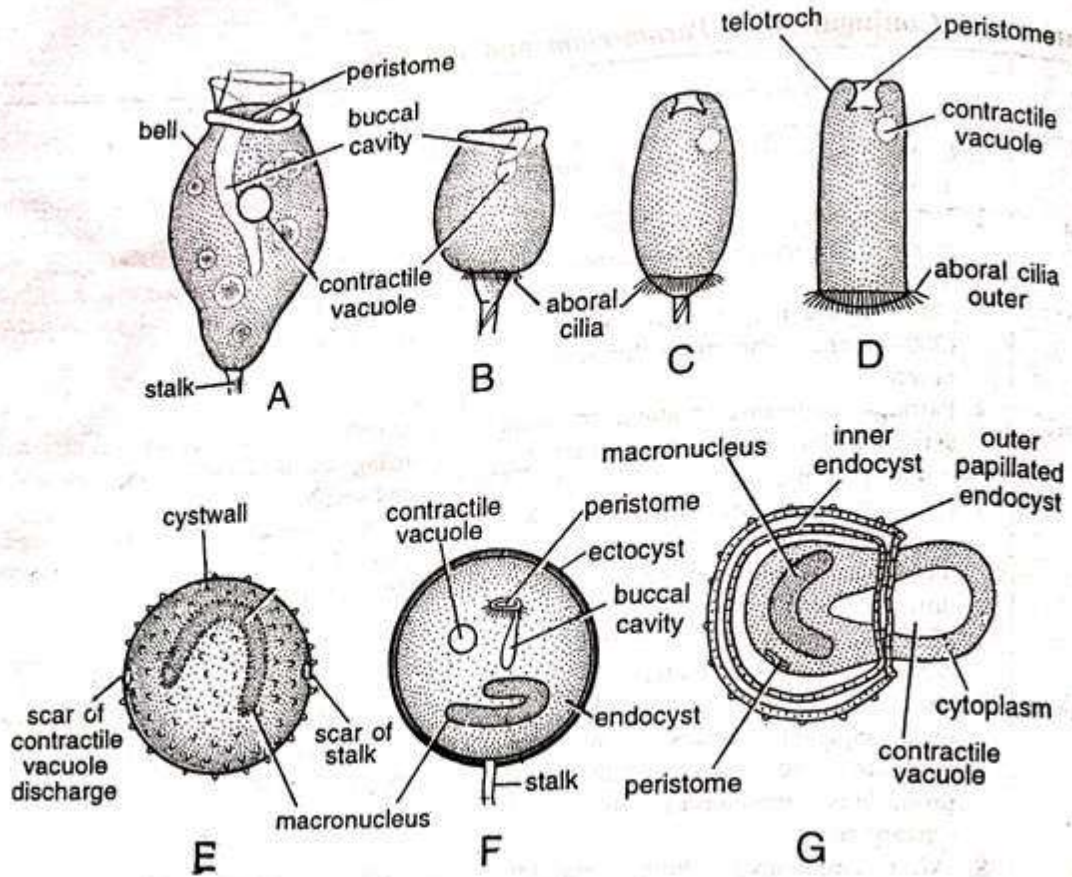


Fig. 7. *Vorticella*. A-D – Formation of telotroch. E – Complete cyst. F – Cyst in section. G – Excystation.

**IMPORTANT QUESTIONS**

» Long Answer Type Questions

1. Give an illustrated account of the structure of *Vorticella*.
2. Describe the process of conjugation in *Vorticella* and compare it with that of *Paramecium*.
3. Write short notes on : (i) Peristome, (ii) Scopula, (iii) Telotroch.

» Short Answer Type Questions

1. Name any one distinguishing feature of *Vorticella* organism.
2. Describe the telotroch of *Vorticella*.
3. Give the structure of bell in *Vorticella*.

4. Write on the conjugation in *Vorticella*.
5. Distinguish between micro- and macro-conjugants in *Vorticella*.

» Multiple Choice Questions

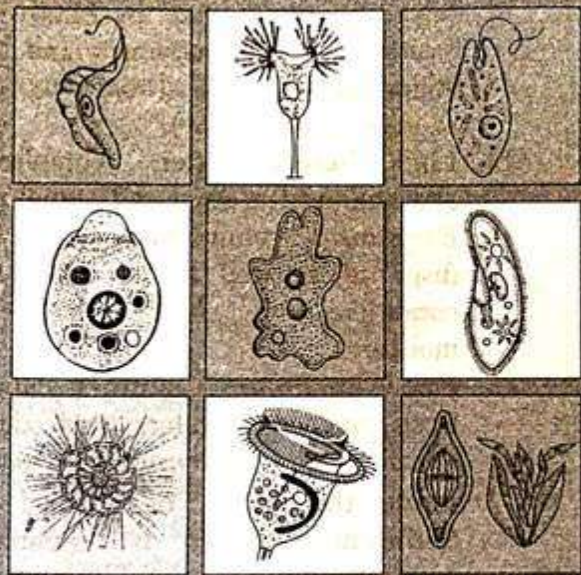
1. *Vorticella* belongs to the order :  
 (a) spirotricha (b) oligotricha  
 (c) chonotricha (d) peritrichida
2. Common name of *Vorticella* :  
 (a) whorl animalcule (b) bell animalcule  
 (c) ball animalcule (d) both
3. Contraction of body occurs by :

- (a) pellicle (b) myonemes
- (c) cytoplasm (d) none
4. Fresh water Protozoa :  
 (a) *Euglena* (b) *Amoeba*  
 (c) *Vorticella* (d) all
5. Telotroch present in :  
 (a) *Paramecium* (b) *Vorticella*  
 (c) *Euglena* (d) all

**Answers**

1. (d) 2. (b) 3. (b) 4. (b) 5. (b)

# Protozoa: Characters, Classification and Types



# 14

Chapter

## Definition

Protozoa may be defined as microscopic and acellular animalcules, without tissues and organs, having one or more nuclei, but no nucleus ever in charge of a specialized part of cytoplasm. They exist either single or in colonies which differ from a metazoan in having all the individuals alike except when engaged in reproductive activities.

## General Characters

1. Small, usually *microscopic* animalcules, ordinarily not visible without a microscope.
2. Simplest and most *primitive* of all animals, with protoplasmic grade of organization.
3. Body *unicellular*, containing one or more nuclei which are monomorphic or dimorphic.
4. *Solitary* or forming loose *colonies* in which individuals remain alike and independent.
5. Body symmetry none, bilateral, radial or spherical.

6. Body *naked* or bounded by a *pellicle* and often provided with simple to elaborate *shells* or *exoskeletons*.
7. Body form usually constant, varied in some, while changing with environment or age in many.
8. The single cell body performs all the essential and vital activities, which characterize the animal body; hence only *subcellular physiological division of labour*.
9. Locomotor organelles are finger-like *pseudopodia* or whip-like *flagella* or hairlike *cilia* or absent.
10. Nutrition *holozoic* (animal-like), *holophytic* (plant-like), *saprophytic* or *parasitic*. With or without definite oral and anal apertures. Digestion occurs intracellularly inside food vacuoles.
11. Respiration and excretion through general surface or through *contractile vacuoles*, which serve mainly for *osmoregulation*.

12. Reproduction *asexual* by binary or multiple fission and budding, and *sexual* by conjugation of adults (hologamy) or by fusion of gametes (syngamy).
13. Life history often complicated with alternation of asexual and sexual phases.
14. *Encystment* commonly occurs to help in dispersal as well as to resist unfavourable conditions of food, temperature and moisture.
15. *Free-living* Protozoa mostly aquatic, inhabiting fresh and sea waters and damp places. *Parasitic* and *commensal* Protozoa live over or inside the bodies of animals and plants. Sufficient moisture is essential in their environment.
16. The single-celled individual not differentiated into somatoplasm and germplasm; therefore, exempt from natural death which is the price paid for the body.
17. About 50,000 known species.

### Classification

Phylum Protozoa is a large and varied group and poses a number of problems in its classification. The conventional scheme followed by Hyman (1940), Hickman (1961) and Storer (1965) etc. recognizes 2 subphyla on the basis of organs of locomotion and 5 classes, briefly outlined as follows :

#### Subphylum A. Plasmodroma

Locomotory organelles are flagella, pseudopodia, or none. Nuclei of one kind.

**Class 1. Mastigophora.** Move by one to many flagella. Ex. *Euglena*.

**Class 2. Sarcodina.** Move and capture food by pseudopodia. Ex. *Amoeba*.

**Class 3. Sporozoa.** No locomotory organs. All parasitic. Spore-formation common. Ex. *Plasmodium*.

#### Subphylum B. Ciliophora

Cilia or sucking tentacles throughout or at certain stages. Nuclei of 2 kinds.

**Class 4. Ciliata.** Move by cilia throughout life. Ex. *Paramecium*.

**Class 5. Suctoria.** Move by cilia as young and by tentacles as adult. Ex. *Podophyra*.

The following classification of Protozoa is based on the scheme given by the Committee on Taxonomy and Taxonomic Problems of the

Society of Protozoologists, and mainly proposed by B.M. Honigberg and others (1964). It divides Protozoa first into 4 subphyla : (1) *Sarcomastigophora*, (2) *Sporozoa*, (3) *Cnidospora*, and (4) *Ciliophora*. Only important orders have been mentioned here.

### SUBPHYLUM I. SARCOMASTIGOPHORA

Locomotor organelles pseudopodia or flagella or both. Nuclei of one kind (monomorphic).

#### Superclass A. Mastigophora (=Flagellata)

1. Simple, primitive, with firm pellicle.
2. Locomotor organelles flagella.
3. Nutrition autotrophic or heterotrophic, or both.

#### Class 1. Phytomastigophorea (=Phytoflagellata)

1. Chlorophyll-bearing chromatophores present.
2. Nutrition mainly holophytic by phototrophy.
3. Reserve food starch or paramylon.
4. Flagella 1 or 2, sometimes more.

#### Order 1. Chrysomonadida

1. Small, with thin pellicle, often amoeboid. Flagella 1 to 3.
2. Gullet absent. Stigma often present.
3. Chromatophores 1 or 2, yellow or brown, and discoidal.
4. Starch absent. Leucosin and fats may be present.

Examples : *Chrysamoeba*, *Synura*, *Ochromonas*, *Dinobryon*.

#### Order 2. Cryptomonadida

1. Small, with a rigid pellicle. Flagella 2.
  2. Anterior gullet reaches up to middle of body.
  3. Chromatophores 2, yellow, brown or colourless.
  4. Reserve foodstuff starch, sometimes oils.
- Examples : *Chilomonas*, *Cryptomonas*.

#### Order 3. Euglenida

1. Large, pellicle thick and firm. Flagella 1 or 2.
2. Anterior end with a gullet leading into a reservoir.
3. Chromatophores numerous, green or colourless.

4. Reserve foodstuff paramylon and oils.  
Examples : *Euglena*, *Peranema*, *Phacus*, *Copromonas*.

**Order 4. Volvocida (= Phytomonadida)**

1. Small, with rigid cellulose covering (theca).
2. No gullet. Flagella 2 to 4.
3. Chromatophore green, usually cup-shaped.
4. Reserve foodstuff starch and oils.  
Examples : *Chlamydomonas*, *Volvox*.

**Order 5. Chloromonadida**

1. Small, dorso-ventrally flat. Pellicle delicate.
2. Gullet present.
3. Chromatophores green and numerous.
4. Reserve foodstuff oils.  
Examples : *Vacuolaria*, *Coelomonas*, *Gonyostomum*.

**Order 6. Dinoflagellida**

1. Small, planktonic. Naked, amoeboid or with a thick cellulose theca.
2. Gullet present or absent. Flagella 2.
3. Chromatophores yellow or brown.
4. Reserve foodstuff starch or oils or both.
5. Some are bioluminescent.  
Examples : *Noctiluca*, *Ceratium*.

**Class 2. Zoomastigophorea (= Zooflagellata)**

1. Chlorophyll or chromatophores absent. Mostly parasitic.
2. Nutrition holozoic or saprozoic.
3. Reserve food glycogen.
4. Flagella one to many.

**Order 1. Rhizomastigida**

1. Small, amoeboid, chiefly freshwater.
2. Locomotion by 1-4 flagella and pseudopodia.  
Examples : *Mastigamoeba*, *Dimorpha*.

**Order 2. Kinetoplastida**

1. No gullet. Kinetoplast present.
2. Flagella 1 to 4. No definite pellicle.
3. Mostly parasitic forms living in blood.  
Examples : *Bodo*, *Leishmania*, *Trypanosoma*.

**Order 3. Choanoflagellida**

1. A collar round the base of a single flagellum.
2. Free-living, solitary or colonial.  
Example : *Proterospongia*.

**Order 4. Diplomonadida**

1. Bilaterally symmetrical, binucleate, with delicate pellicle and often with a cytostome.

2. Flagella 3 to 8. One often trailing or forming border of an undulating membrane.
3. Mostly intestinal parasites.  
Examples : *Hexamita*, *Giardia*.

**Order 5. Hypermastigida**

1. Highly specialized, numerous flagella.
2. Kinetosomes arranged in a circle, plate or longitudinal or spiral rows.
3. Mouth absent. Food ingested by pseudopodia.
4. Gut parasites of termites and cockroaches.  
Examples : *Lophomonas*, *Trychonympha*.

**Order 6. Trichomonadida**

1. Flagella 4 to 6. One flagellum trailing.
2. Parasites of vertebrates.  
Example : *Trichomonas*.

**Superclass B. Opalinata**

1. Entire body covered by cilia-like flagella.
2. Nuclei 2 to many, monomorphic.
3. Reproduction by symmetrogenic binary fission or by syngamy of anisogametes.
4. Parasitic mainly in frogs and toads.  
Examples : *Opalina*, *Zelleriella*.

**Superclass C. Sarcodina (= Rhizopoda)**

1. Body mostly amoeboid without definite pellicle. Some with a skeleton of some kind.
2. Locomotion by pseudopodia.
3. Nutrition holozoic or saprozoic.

**Class 1. Rhizopodea**

Pseudopodia as lobopodia, filopodia or reticulopodia, without axial filaments.

**Subclass (a) Lobosia**

Pseudopodia as lobopodia.

**Order 1. Amoebida**

1. Body amoeboid, naked, without skeleton.
2. Nucleus with honeycomb lattice.
3. Largely freshwater and free-living. Many parasitic.  
Examples : *Amoeba*, *Entamoeba*, *Pelomyxa*.

**Order 2. Arcellinida (= Testacida)**

1. Body enclosed in one-chambered shell of pseudochitin, with a single opening through which lobopodia protrude.
2. Free-living, mostly freshwater.  
Examples : *Arcella*, *Diffugia*, *Euglypha*.

**Subclass (b) Filosia**

Pseudopodia as filopodia. Naked or with a shell with single aperture.

Examples : *Allogromia*, *Penardia* (naked).

**Subclass (c) Granuloreticulosia**

Pseudopodia delicate granular reticulopodia.

**Order Foraminiferida**

Large sized with uni- or multichambered calcareous shell with one or more openings through which reticulopodia emerge.

Examples : *Globigerina*, *Elphidium* (= *Polystomella*)

**Class 2. Actinopodea**

Pseudopodia mainly axopodia with axial filaments, radiating from a spherical body.

**Subclass (a) Heliozoia**

1. Spherical protozoans, called sun-animalcules.
2. Pseudopodia (axopodia) radiating.
3. Naked or skeleton of siliceous scales or spines.

Examples : *Actinophrys*, *Actinosphaerium*.

**Subclass (b) Radiolaria**

1. Body naked or with perforated chitinoid central capsule separating ectoplasm from endoplasm.
2. Reticulopodia, axopodia or filopodia.
3. Skeleton mostly of siliceous spicules or of strontium sulphate.

Examples : *Collozoum*, *Thalassicola*.

**Subclass (c) Acantharia**

1. Imperforate non-chitinoid central capsule without pores.
2. Skeleton of strontium sulphate.
3. Pseudopodia are axopodia.

Example : *Acanthometra*.

**Subclass (d) Proteomyxidia**

1. Pseudopodia are filopodia.
2. Mostly parasites on algae.

Examples : *Vampyrella*, *Pseudospora*.

**Class 3. Piroplasmea**

Small parasites in red blood cells of vertebrates.  
Example : *Babesia* (formerly included with Sporozoa, but its species do not produce spores).

**SUBPHYLUM II. SPOROZOA**

Locomotor organelles absent. Spores usually present. Exclusively endoparasites.

**Class 1. Telosporea**

Spores without polar capsules and filaments, naked or encysted.

**Subclass (a) Gregarina**

1. Mature trophozoites large, extracellular in host's gut and body cavities.
2. Each spore produces 8 sporozoites.
3. Parasites in invertebrates.

Examples : *Monocystis*, *Gregarina*.

**Subclass (b) Coccidia / APICOMPLEXA**

1. Mature trophozoites small and intracellular.
2. Each oocyst produces many sporozoites.
3. Blood or gut parasites of vertebrates.

Examples : *Eimeria*, *Isospora*, *Plasmodium*.

**Class 2. Toxoplasmea**

Spores absent. Only asexual reproduction.

Example : *Toxoplasma*.

**Class 3. Haplosporea**

Spore cases present. Only asexual reproduction.

Example : *Ichthyosporidium*.

**SUBPHYLUM III. CNIDOSPORA**

Spores with polar filaments present.

**Class 1. Myxosporidea**

1. Spores large, developed from several nuclei.
2. Spores with two or three valves.
3. Parasites mostly in fishes.

Examples : *Myxidium*, *Myxobolus*, *Ceratomyxa*.

**Class 2. Microsporidea**

1. Spores small, developed from one nucleus.
2. Spores with a univalved membrane.
3. Intracellular parasites in arthropods and fishes. Example : *Nosema*.

**SUBPHYLUM IV. CILIOPHORA**

Presence of cilia as locomotor and feeding organelles at some stage in the life cycle. Nuclei of 2 kinds (dimorphic).

**Class Ciliata (= Infusoria)**

Locomotor organelles numerous hair-like cilia, present throughout life.

Definite mouth (cytostome) and gullet present except in a few parasitic forms. Anal aperture (cytopyge) permanent.

One or more contractile vacuoles present even in marine and parasitic types.

Mostly two kinds of nuclei, large *macronucleus* and smaller *micronucleus*.

**Subclass (a) Holotricha**

Body cilia simple and uniform.

Buccal cilia mostly absent.

**Order 1. Gymnostomatida**

Large ciliates without oral ciliature. Cytostome opens directly. No vestibule.

Examples : *Coleps*, *Didinium*, *Prorodon*, *Dileptus*.

**Order 2. Trichostomatida**

With vestibular but no buccal ciliature.

Examples : *Balantidium*, *Colpoda*.

**Order 3. Chonotrichida**

No body ciliature. A spirally coiled apical funnel contains vestibular cilia.

Examples : *Spirochona*, *Lobochona*.

**Order 4. Apostomatida**

Spirally arranged body cilia. Cytostome midventral.

Example : *Hyalophysa*.

**Order 5. Astomatida**

Body ciliation uniform. Cytostome absent.

Example : *Anoplophrya*, *Maupasella*.

**Order 6. Hymenostomatida**

Body ciliation uniform. Buccal cavity ventral with ciliary membranes.

Examples : *Colpidium*, *Paramecium*.

**Subclass (b) Peritricha**

Adult without body cilia.

Apical end with buccal cilia.

**Order: Peritrichida**

Examples : *Vorticella*, *Carchesium*.

**Subclass (c) Suctoria**

Sessile and stalked body.

Young with cilia, adult with suctorial tentacles.

**Order: Suctorida**

Examples : *Acineta*, *Ephelota*, *Podophyra*.

**Subclass (d) Spirotrichia**

1. Reduced body cilia.

2. Buccal cilia well marked.

**Order 1. Heterotrichida**

Body cilia short. Uniform or absent.

Examples : *Stentor*, *Bursaria*, *Spirostomum*.

**Order 2. Oligotrichida**

Body cilia reduced or absent. Buccal membranes conspicuous.

Examples : *Strombidium*, *Halteria*.

**Order 3. Hypotrichida**

Dorso-ventrally flattened. Fused cilia forming ventral cirri.

Examples : *Euplotes*, *Stylonchia*.

**Other Types of Protozoa**

1. *Chlamydomonas*. *Chlamydomonas* is a typical genus of the order Phytomonadida. The microscopic, unicellular and solitary individuals are found in stagnant freshwater ponds. Ovoid or flattened body is surrounded by a thick and delicate cellulose cell wall or capsule. It bears two long flagella, each arising from a blepharoplast in cytoplasm. The cytoplasm includes a vesicular nucleus, a cup-shaped chloroplast, with a pyrenoid, a red stigma, a pair of small contractile vacuoles and reserve food granules as starch and oil droplets. Nutrition is mainly holophytic but osmotrophic tendency is also seen. Asexual reproduction is by binary fission, often in palmella stage. Sexual

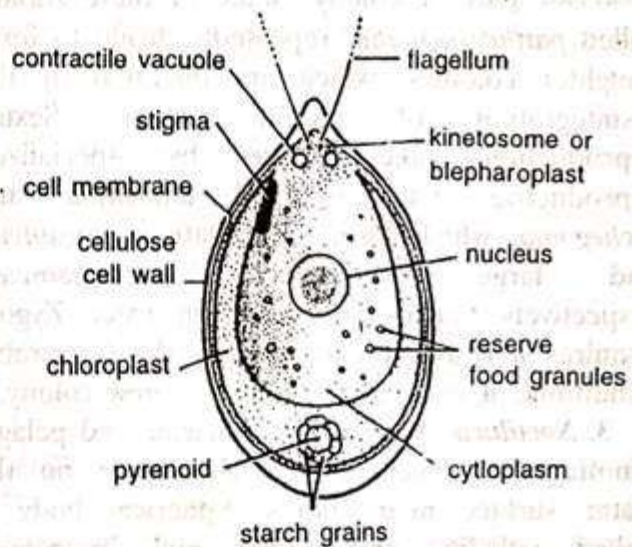


Fig. 1. *Chlamydomonas*.

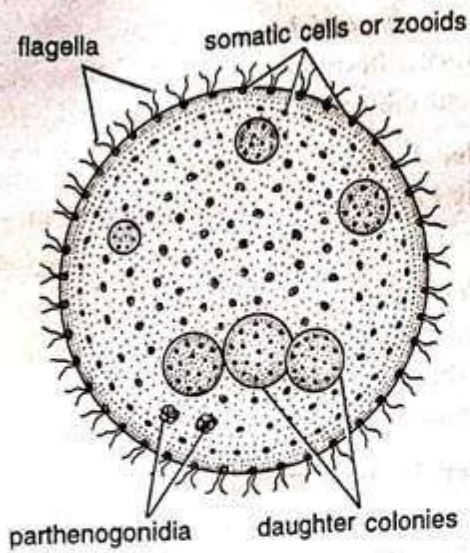


Fig. 2. *Volvox glabator*. Vegetative colony.

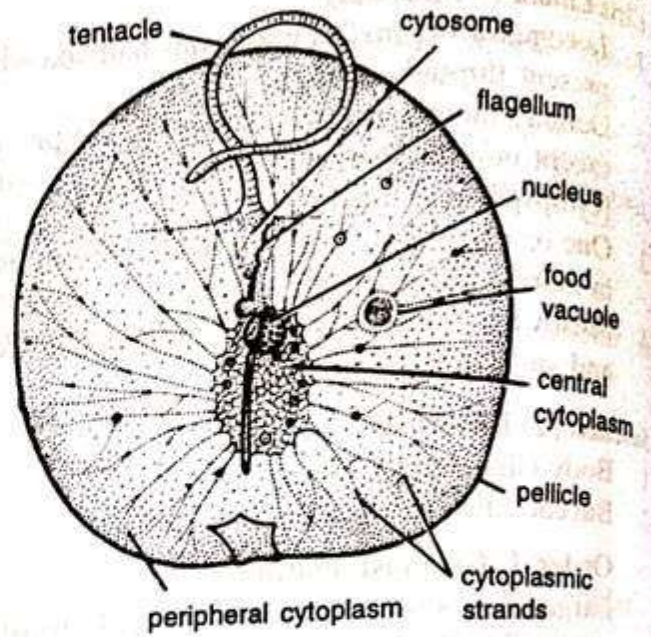


Fig. 3. *Noctiluca*.

reproduction is by isogamy, and in some, by anisogamy.

2. *Volvox*. *Volvox* is a beautiful, colonial phytomonad commonly found in freshwater ponds and lakes. Colony looks like a small green, hollow sphere filled with a watery jelly. The sphere contains thousands of zooids (somatic cells), arranged in a single peripheral layer. Each zooid has 2 flagella, 2 or more contractile vacuoles, a large cup-shaped chloroplast, a single nucleus, a red stigma but no gullet. Fine protoplasmic strands connect adjacent zooids. Colony swims by rolling due to combined action of flagella. Nutrition is holophytic. Colony increases in size by binary fission of the surface somatic cells. Asexual reproduction takes place from reproductive zooids, mostly situated in the posterior part of colony. Some of these zooids, called *parthenogonidia*, repeatedly divide to form daughter colonies, which are liberated by the disintegration of parent colony. Sexual reproduction takes place by specialized reproductive zooids, called *antheridia* and *archegonia*, which form biflagellate *microgametes* and large non-flagellate *macrogametes*, respectively. Fertilization occurs in water. Zygote acquires a resistant cyst wall. Under favourable conditions, it germinates to form a new colony.

3. *Noctiluca*. *Noctiluca* is a marine and pelagic dinoflagellate, occurring in abundance on the water surface near shores. Spherical body is naked, jelly-like and slightly pink in colour. Mid-ventrally, there is a large pouch-like

*cytostome* leading into an elongated *cytopharynx*, which bears a small delicate flagellum and a large motile *tentacle*. Cytoplasm is much vacuolated at the periphery, but is dense centrally which contains a single nucleus. Locomotion is affected by the locomotor tentacle. Nutrition is exclusively holozoic in the absence of chloroplasts. Reproduction takes place by binary fission and multiple fission (sporulation). During sporulation, cytoplasm forms a multinucleate surface disc, which by exogenous budding gives rise to numerous uninucleate and unflagellate swimmers or spores. These spores behave as *luciferin* which under the influence of an enzyme, *luciferase*, emits light.

4. *Ceratium*. *Ceratium* includes marine as well as freshwater species. The microscopic flattened body is armoured by *thecal plates*, which are sculptured with spines and pits. It is produced into an anterior and generally two posterior spines. The shell is grooved by a transverse and a longitudinal furrow, each containing a flagellum. The deep transverse groove or *annulus* encircles the body and contains the transverse flagellum. The longitudinal groove or *sulcus* is provided with large locomotor sulcal flagellum. The cytoplasm contains a large oval nucleus, numerous chromatophores and a complex system of contractile vacuoles. The animal is mainly holophytic, but a few species may be holozoic. The reproduction is by oblique binary fission.



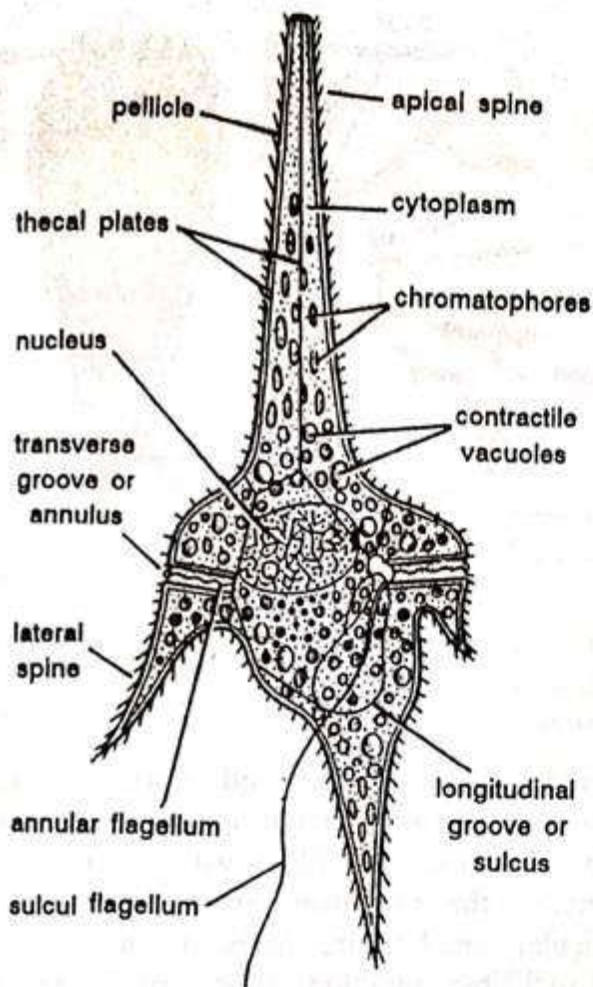


Fig. 4. *Ceratium*.

Cyst formation sometimes occurs. Several species are known to be luminescent.

**5. *Trichomonas*.** *Trichomonas* is a multiflagellate and the most common endoparasite of invertebrates as well as vertebrates. Its body is roughly egg-shaped or pear-shaped, slightly tapering posteriorly. Four flagella arise at the anterior end from a group of basal bodies forming the *basal body complex*. The recurrent or trailing flagellum is directed posteriorly bordering an undulating membrane. Two large striated *parabasal fibres* arise from the basal body complex. A contractile fibre *costa* runs along the line of attachment of undulating membrane. Body is supported by a central red or cylinder of microtubules, the *axostyle*. It frequently projects from the posterior end of body as *spike* and serves to anchor the animal while it feeds. Endoplasm contains an oval *nucleus* with few nucleoli. Broad anterior end of body bears ventrally a *cytostome* used for ingestion while feeding holozoically. Saprozoic

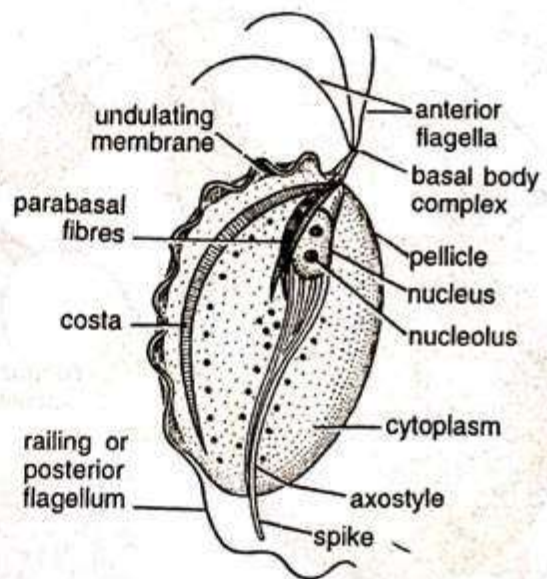


Fig. 5. *Trichomonas tenax*.

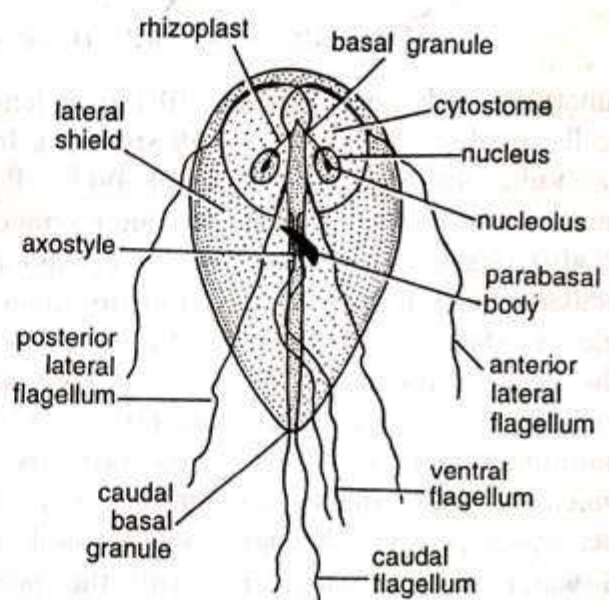


Fig. 6. *Giardia lamblia*.

mode of feeding is also met with. Reproduction takes place exclusively by longitudinal binary fission.

Parasitic human species of *Trichomonas* are *T. tenax* of mouth, *T. hominis* of colon and *T. vaginalis* of vagina. Of other animals, *T. foetus* of cattle and *T. gallinae* of doves and pigeons are important. The disease caused by species of *Trichomonas* is called *trichomoniasis*.

**6. *Giardia*.** *Giardia*, commonly nicknamed as the 'Grand Old Man of the Intestine', is a diplomonadid parasitic flagellate occurring in the intestine of man and other animals. *Giardia (Lamblia) intestinalis* of small intestine (duodenum) of man possesses a bilateral

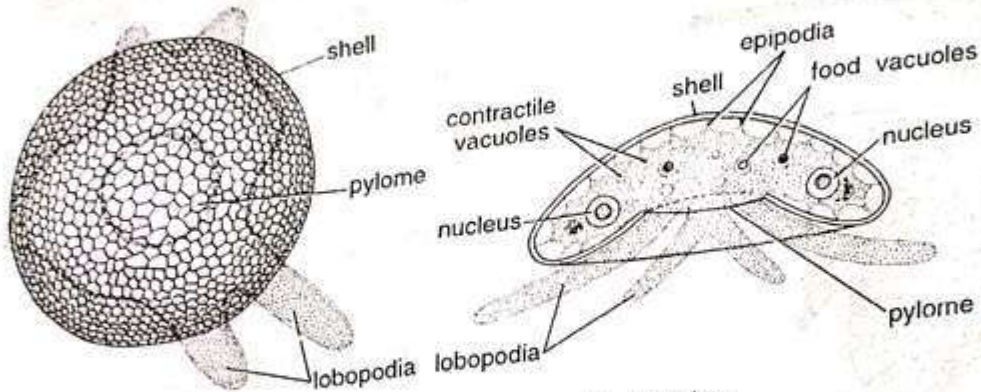


Fig. 7. *Arcella vulgaris*. A - Dorsal view. B - Side view.

symmetrical body and measures 10-18 $\mu$  in length. Flagella are four on each side, all springing from the middle and hinder region of body. Basal granules of foremost flagella are interconnected and also connected with a pair of conspicuous vesicular nuclei lying just posterior to them. A single axostyle forms the longitudinal axis of body. A parabasal body is prominent. Reproduction in human intestine takes place by longitudinal binary fission. Infection is by uninucleate cysts which pass out in faeces and infect other persons through contaminated food and water. *Giardia* interferes with the normal digestive processes.

7. *Arcella*. *Arcella* commonly occurs in stagnant fresh water containing much vegetation and also in moist forest soils. It secretes a yellow to brown, thick, hard, transparent and hemispherical or disc-shaped shell or test around itself and carries it along as it moves. The shell is made of *pseudochitin*, a proteinous substance containing silica and iron. It is finely sculptured and arched above but the ventral surface shows an inverted funnel-like depression leading to a single central opening, the mouth or pylome. One to six small, hyaline, finger-like, simple or branched lobopodia are extended through the pylome and serve as locomotor and feeding organs. Body is attached to inner wall of test by ectoplasmic strands, known as epipodia. Endoplasm contains various reserve food (Z-1)

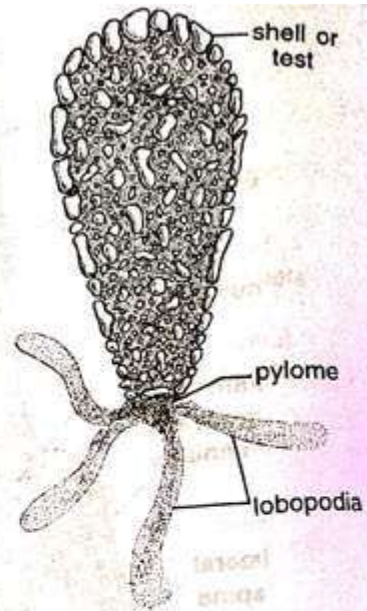
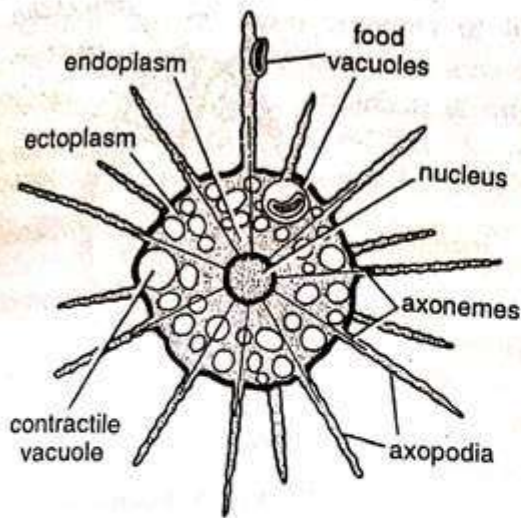


Fig. 8. *Diffflugia*.

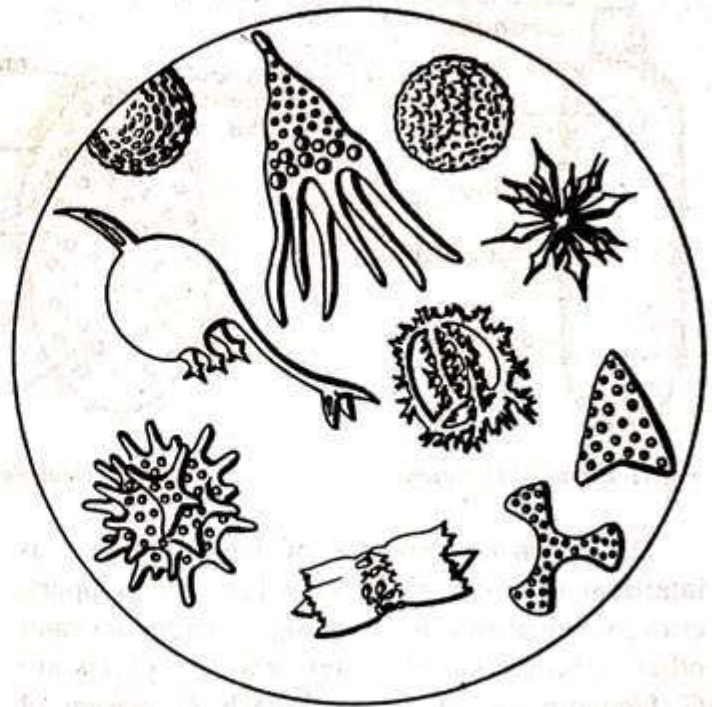
particles, food vacuoles and contractile vacuoles. One or more vacuoles are said to be non-contractile and filled with a gas, to which probably the organism owes its buoyancy. Two vesicular nuclei are present in *A. vulgaris*. Asexual reproduction takes place by binary fission. Multiple fission is also said to take place. 8. *Diffflugia*. *Diffflugia* is a free-living test-acid, occurring in small leaf-choked freshwater puddles, ponds, ditches or even in moist soil. It builds around itself a beautifully symmetrical shell or test by cementing together sand grains, diatom shells, spicules of freshwater sponges and other foreign substances by a sticky chitinous secretion. Test may be pyriform, vase-shaped or flask-shaped according to the species and has a distinct neck with a terminal mouth opening or pylome. As many as half a dozen slender lobose pseudopodia (lobopodia) may protrude out from pylome. Numerous contractile and food vacuoles are scattered around the periphery of endoplasm. A single nucleus is centrally located in endoplasm occupying the bulbous part or fundus of shell. *Diffflugia* feeds upon microorganisms and filamentous algae such as *Spirogyra*. It reproduces typically by binary fission, but multiple fission has also been reported. *Diffflugia oblongata* remains active in spring and summer, but becomes encysted within its test in late fall.

9. *Actinophrys*. A common shell-less heliozoan is *Actinophrys sol*, which lives in stagnant fresh

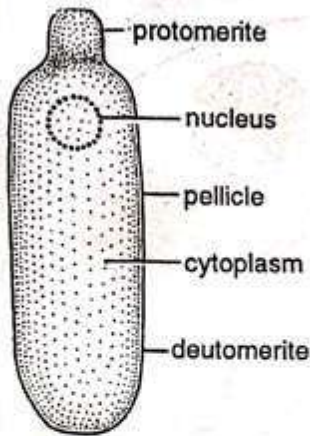
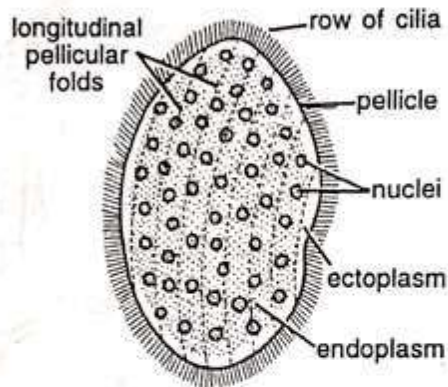
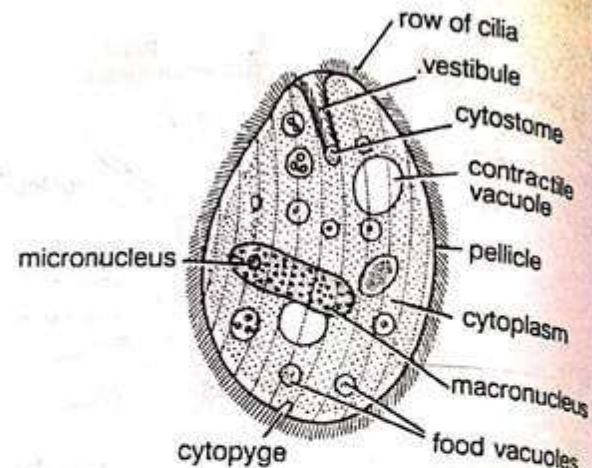
Fig. 9. *Actinophrys sol*.

water, floating about among vegetation or rolling over bottom. Mechanism of its rising or sinking in water is not well understood. Its minute spherical body measures about .05 mm. in diameter. Protoplasm is not distinctly divided into endoplasm and ectoplasm. Inner endoplasm is not vacuolated but contains a large central nucleus and food vacuoles. Outer ectoplasm is packed with numerous, blister-like vacuoles, filled with a clear fluid. Usually a single and large contractile vacuole is found near the surface of body. Numerous, slender pointed and stiff pseudopodia (axopodia) radiate from all sides of body. Their axial filaments run through cytoplasm and converge around the centrally placed nucleus. *Actinophrys sol* is commonly known as the "sun animal-cule" because the animal with radiating axopodia resembles sun surrounded by rays of light. Axopodia are used for gathering food and not for locomotion. Food organisms are paralysed when they come in contact with pseudopodia and devoured, as in *Amoeba*. Binary fission occurs with or without formation of a cyst wall. Self-fertilization (autogamy) or paedogamy takes place in encysted condition, when two daughter gametes become fused and the zygote, after resting for some time, divides into two daughter cells, which eventually emerge out of their cysts and develop into independent adults.

**10. Radiolarian ooze.** Radiolaria are exclusively marine and planktonic Sarcodina, found mostly in deep sea, particularly the tropical Pacific, floating or drifting at varying

Fig. 10. *Radiolarian ooze*.

depths. They resemble heliozoans in their outer appearance, but their cytoplasm is divided by a perforated and chitinous membrane or *central capsule*, into an intracapsular or inner *medulla*; and an extracapsular or outer *cortex*. Medulla contains one or more nuclei and oil globules. Cortex is vacuolated, pigmented and often contains yellow, unicellular and symbiotic algae. Numerous vacuoles filled with a light fluid give a frothy appearance to cytoplasm and reduce specific gravity of organism. Besides central capsule, extracapsular cytoplasm may contain scattered, siliceous spicules. In majority, however, a hard, transparent and symmetrical skeleton of silica ( $\text{SiO}_2$ ) or strontium sulphate is present, often of bizarre shape and beauty. It usually forms an intricate lattice-work, through the opening of which are extended fine, stiff and ray-like pseudopodia, usually without conspicuous axial filaments. When these animals die, their minute but hard skeletons sink to the sea-bottom and form the *radiolarian ooze*, which covers nearly 3,000,000 sq. miles of the ocean floor, particularly of the Pacific Ocean. Their fossils are abundant in rocks such as flint and chert. They also constitute a part of the "Tripoli Stone", used in abrasive powders for polishing metals.

Fig. 11. *Gregarina blattarum*.Fig. 12. *Opalina*.Fig. 13. *Balantidium*.

11. *Gregarina*. Species of *Gregarina* live as intestinal parasites of cockroaches, grasshoppers, crickets, meal-worms, crayfish, centipedes and other arthropods. The better known species are *G. blattarum* of oriental cockroach, *G. oviceps* of crickets and *G. polymorpha* of mealworm.

Body of adult trophozoite or sporont is divisible into two chambers, anterior small *protomerite* and posterior large *deutomerite*, containing nucleus. Sporonts associate in pairs (*syzygy*) and encyst within a common gametocyst. Cysts are passed out with faeces of host. Within gametocysts, gametogony takes place by production of gametes and their fusion in pairs resulting in zygotes. These encyst within sporocysts and form spores. Three rapid divisions occur within spore, resulting in eight sporozoites. Gametocysts, containing spores, are discharged with host's faeces. These rupture to liberate spores which are ingested by another host. In the gut of new host spores hatch and each of the liberated sporozoites enters an epithelial cell and grows into an intracellular trophozoite. At this stage, trophozoite has an apical cap, the *epimerite*, for attachment to host cell. Older trophozoites lose their attachment to the host cells and become extracellular.

12. *Opalina*. The best known genus of superclass Opalinata (subphylum Sarcomastigophora) is *Opalina*. It lives as an endoparasite or endocommensal in large intestine of Anura. Commonest species is *O. ranarum* which is found in rectum of frogs and toads. Its body is flattened, leaf-like and oval in outline. It may

(Z-1)

reach a length of about 1 mm. and may be seen with naked eyes. Thin but tough pellicle is uniformly covered by rows of innumerable and equal-sized cilia (flagella). Between rows of cilia, pellicle is thrown into narrow longitudinal folds, supported by microtubular fibrils. Mouth, gullet, cytophyge, food vacuoles and contractile vacuoles are absent. *Opalina* feeds by pinocytosis, ingesting liquid food contents of rectum of host through general body surface. A large number of small, spherical and similar nuclei are found evenly distributed in endoplasm, which also contains several minute spindle-like or ovoid granules of unknown character. Each nucleus has both trophochromatin and idiochromatin.

During breeding season of host, *Opalina* undergoes transverse as well as longitudinal binary fission's to produce smaller individuals each with only three to six nuclei and few rows of cilia. These encyst and pass out in faeces of host. If cysts are swallowed by tadpoles, along with weeds, they hatch in rectum as gametocytes, which divide by a series of longitudinal fissions to form uninucleate, club-shaped gametes. These include small slender microgametes and large macrogametes. These conjugate in pairs to form zygotes which encyst for a while as zygocysts. With growth and rapid nuclear division, each zygote reaches the normal multinucleate adult stage.

13. *Balantidium*. *Balantidium* is a trichostomatid ciliate parasite, inhabiting the intestine of man, pigs, sheep, guinea pigs, camels opossums, ostriches, fish, cockroaches, etc. They are present

in large numbers in rectal contents of frog. Of about 50 species of *Balantidium* only one species, *B. coli*, infects man. The organism is large and ovoid and measures about  $60-70\mu \times 40-60\mu$ . Entire outer surface is covered by longitudinal, slightly spiral rows of cilia. At the anterior end is a vestibule leading to the cell mouth or cytostome. It is lined by longer cilia. Cytoplasm includes two contractile vacuoles, a macronucleus, and food vacuoles. At the hinder end is a permanent pore or cytopye for egestion of undigested residue. Nutrition is holozoic and food is carried down vestibule into the forming food vacuole with a drop of water. Reproduction takes place by asexual binary fission. Infection takes place through cysts in contaminated food and water.

14. *Nyctotherus*. *Nyctotherus* is the intestinal, endo-commensal of amphibians and some invertebrates. Its important species are *N. cordiformis* in rectum of frogs and *N. ovalis* in intestine of cockroaches. Slightly compressed body is oval measuring about  $60-120\mu$  in length. Outer surface bears longitudinal and slightly spiral rows of cilia. On lateral side is a vestibule leading to cell-mouth or cytostome. It bears somewhat longer cilia. Cytoplasm includes a contractile vacuole, a macronucleus, a micronucleus and food vacuoles. Cytopye, a permanent pore for the egestion of food, is located at its hinder end. Nutrition is holozoic and reproduction takes place by binary fission and conjugation.

15. *Stentor*. *Stentor* is a free-swimming or sessile ciliate, mostly found in pond water contaminated with sewage. The sessile form takes a funnel or trumpet-shaped appearance. Oral surface bears a broad vestibule leading into buccal cavity, which is lined by a row of membranelles. Buccal cavity leads into cytopharynx through a cytostome. Macronucleus is greatly beaded or chained and several micronuclei lie close to it. A single contractile vacuole lies anteriorly and fed by a single and long radial canal. Nutrition is holozoic like *Paramecium* and reproduction takes place by oblique binary fission and conjugation.

16. *Ephelota*. *Ephelota* is a marine attached form of subclass Suctorina (Class Ciliatea).

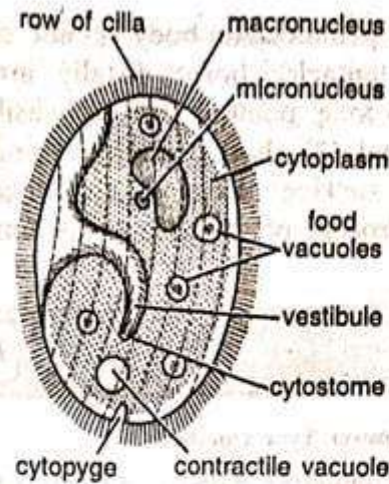


Fig. 14. *Nyctotherus*.

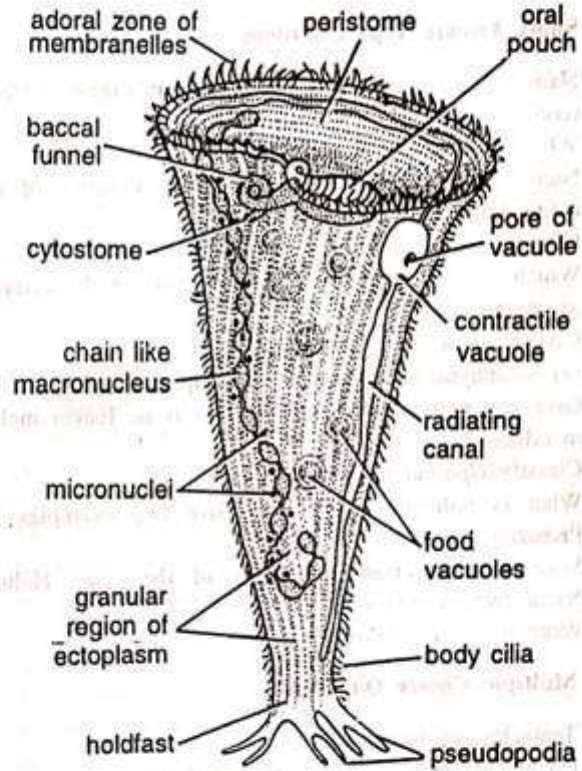


Fig. 15. *Stentor*.

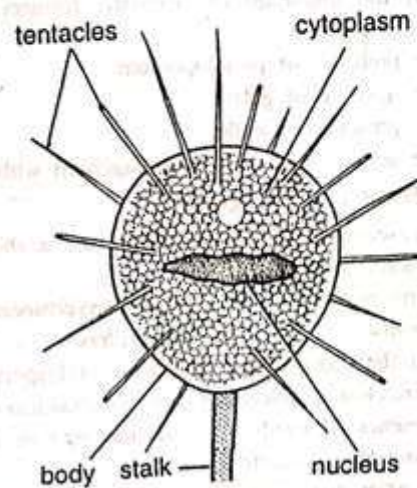


Fig. 16. *Ephelota*.

Spherical, pedunculate body is not seated in a cup. The tentacles, borne distally, are of two kinds : (1) long, pointed and prehensile, used for piercing and (2) short, cylindrical and knobbed, used for sucking. Reproduction occurs by a peculiar process of multiple exogenous budding.

In *Ephelota gemmipara*, distal end of body projects into several buds, each receiving a branch of nucleus. Finally, the buds detach and acquire cilia on one surface. After a short, active and free-swimming existence, they lose cilia and grow into tentaculate adults.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Give the distinctive characters of Protozoa. Classify the phylum up to classes giving diagnostic characters and examples.
2. What is the basis of classification of phylum Protozoa into classes ?
3. Write short notes on : (i) *Ceratium*, (ii) *Gregarina*, (iii) *Leishmania*, (iv) *Notiluca*, (v) Rectal ciliates.

#### » Short Answer Type Questions

1. Name a symbiotic protozoan present in digestive tract of termites.
2. What is the study of protozoans called as ?
3. Name the protozoan that lives in the intestine of wood eating termites.
4. Give an example for coprozoic protozoan.
5. Which order of protozoa shows division of the cytoplasm as central capsule ?
6. Give an example of a protozoan with  
(a) holophytic nutrition, (b) mixotrophic nutrition
7. Give any two reasons why *Opalina* is no longer included in ciliata ?
8. Classify *Opalina* upto order.
9. What is holozoic nutrition ? Give two examples from Protozoa.
10. State two important characters of the order Heliozoa. Name two examples.
11. Write note on *Opalina*.

#### » Multiple Choice Questions

1. Tentacles are found in :  
(a) *Stylonychna* (b) *Ephelota*  
(c) *Euglypha* (d) *Euplectella*
2. One of the important characteristic features of the order chrysoomonadida is :  
(a) the presence of pseudopodium  
(b) the absence of gullet  
(c) the presence of gullet  
(d) the attachment of a long flagellum without gullet  
(e) absence of flagellum
3. The presence of a long flagellum and a short tentacle is the characteristic feature of :  
(a) *Copromonas* (b) *Chlamydomonas*  
(c) *Noctiluca* (d) *Euglena*
4. One of the characteristic feature of Telosporea is :  
(a) uninuclear trophozoites (b) multinuclear trophozoites  
(c) presence of shells (d) presence of an eye spot  
(e) elongate sporozoite
5. Class sporozoa includes parasitic protozoa in which locomotory organelles are :

12. Write note on Heliozoa.
13. Give the distinguishing character and one example of Haemosporidea.
14. Give the taxonomic position of the following animals.  
(a) *Monocystis* (b) *Polystomella*  
(c) *Amoeba* (d) *Euglypha*  
(e) *Paramecium* (f) *Giardia*
15. With reference to their habitat distinguish between coccidia and haemosporidia.
16. What is osmoregulation ? Give an account of the process of osmoregulation in Protozoa.
17. Mention three characters to show the affinities of suctoria with ciliata.
18. Differentiate between lobopodium and reticulopodium.
19. Distinguish between dinoflagellata and hypermastigina based on their flagellar condition.
20. Conjugation is found in the class ....
21. *Balantidium coli* causes a disease called .... in man.
22. The plane of binary fission in ciliophora is ....

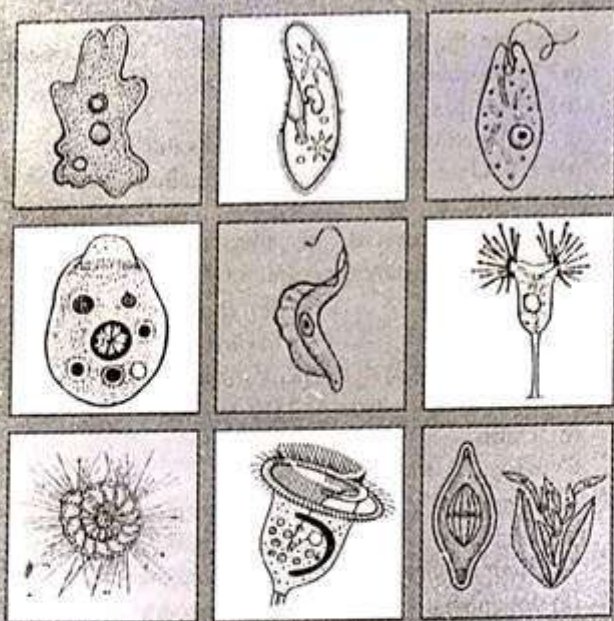
- (a) flagella (b) absent  
(c) both cilia and pseudopodia (d) of various types
6. Locomotion in young sporozoans is by :  
(a) gliding (b) ciliary  
(c) amoeboid (d) euglenoid
7. An example of sporozoan is :  
(a) *Elphidium* (b) *Monocystis* (c) *Diffugia* (d) *Vorticella*
8. Contractile vacuole is present :  
(a) in marine protozoa (b) in parasitic protozoa  
(c) in fresh water protozoa  
(d) in all protozoa
9. Which of the following do not have locomotory organelles :  
(a) Rhizopoda (b) Flagellate  
(c) Ciliata (d) Sporozoa
10. Trichocysts are found in :  
(a) ectoplasm of *Euglena* (b) ectoplasm of *Paramecium*  
(c) endoplasm of *Euglena* (d) endoplasm of *Paramecium*
11. The mononucleate form is :  
(a) *Balantidium* (b) *Chryamoeba*  
(c) *Stylonychia* (d) *Pelomyxa*

Protozoa : Characters, Classification and Types

1. *Trichomonas* belongs to :  
(a) protomonadina (b) dinoflagellata  
(c) schistoflagellata (d) polymastigina
2. The characteristic feature of class Sporozoa is the presence of :  
(a) flagella (b) parasitism  
(c) chlorophyll (d) amoeboid movement
3. The primary grouping of the protozoans is based on their :  
(a) mode of feeding (b) locomotory organelles  
(c) mode of reproduction (d) size and shape
4. Class mastigophora includes the protozoan in which locomotory organelle is :  
(a) lobopodium (b) flagella  
(c) cilia (d) absent (e) pseudopoda
5. The phylum protozoa is divided into sub-phyla on the basis of their :  
(a) nuclear structure (b) locomotory structure  
(c) mode of reproduction  
(d) mode of nutrition (e) habitat
6. The presence of slender pseudopodia with interlacing branches to form a net work is the characteristic feature of the order :  
(a) radiolaria (b) lobosoa  
(c) mycetozoa (d) heliozoa (e) foraminifera
7. Order lobosoa includes :  
(a) *Pelomyxa* (b) *Elphidium*  
(c) *Globigerina* (d) *Euglypha*
8. *Chilomonas* belongs to the order :  
(a) chrysomonadina (b) euglenodina  
(c) cryptomonadina (d) phytomonadina
9. Order suctorida includes :  
(a) *Trichonympha* (b) *Giardia*  
(c) *Lophomonas*  
(d) *Ephelota*
10. *Proterospongia* is included in order :  
(a) Euglenida (b) Rhizomastinoida  
(c) Choanoflagellida (d) Rhizomastigida
11. *Volvox* is included in order :  
(a) Phytomonadida (b) Euglenida  
(c) Chrysomonadida  
(d) Dinoflagellata
12. *Ceratium* is included in order :  
(a) Mastigophora (b) Dinoflagellata  
(c) Euglenida (d) Ciliata
13. What are the locomotor organelles of Mastigophora :  
(a) many pseudopodia  
(b) many pseudopodia and cilia  
(c) a flagellum and many pseudopodia  
(d) reticulate pseudopodia and flagellum  
(e) flagellum
14. Karyosome consists of two materials. What is the achromatic substance present in it ?  
(a) plastin (b) chromosomes  
(c) paramylum (d) eyespot
15. The shell of *Polystomella* is made up of :  
(a) calcium carbonate (b) silicon  
(c) chitin
16. *Cytopyge* is found in :  
(a) *Amoeba* (b) *Paramecium*  
(c) *Euglena* (d) *Trypanosoma*
17. The locomotory organelle of foraminifera are :  
(a) lobopodia (b) filopodia  
(c) axopodia (d) reticulopodia
18. Which of the following protozoans is unlikely to have a contractile vacuole ?  
(a) *Paramecium* (b) *Plasmodium vivax*  
(c) *Amoeba proteus* (d) *Euglena*
19. Losch discovered that :  
(a) *Entamoeba histolytica* causes amoebic dysentery  
(b) trophozoite of *Plasmodium* has brownish yellow pigment granules, called haemozoin granules  
(c) *Trypanosoma* causes sleeping sickness  
(d) digestion in *Amoeba* is similar to that of higher animals
20. Grand old man of the intestine is :  
(a) *Amoeba* (b) *Entamoeba*  
(c) *Trypanosoma* (d) *Giardia*
21. The disease caused by the infection of *Trichomonas* :  
(a) amoebiosis (b) kala-azar  
(c) sleeping sickness (d) trichomoniasis
22. 'Tripali stone' is characterise presence of :  
(a) foramaniferian (b) radiolarian  
(c) *Actinosphaerium* (d) all of them
23. Which show endocommensal form in large intestine of anura :  
(a) *Opalina* (b) *Monocystis*  
(c) *Trypanosoma* (d) none
24. *Balantidium* in housing the intestine of :  
(a) man (b) pig  
(c) sheep (d) fish  
(e) all

Answers

1. (b) 2. (b) 3. (c) 4. (a) 5. (b) 6. (a) 7. (b) 8. (c) 9. (d) 10. (b) 11. (b) 12. (d) 13. (b) 14. (b) 15. (b) 16. (b) 17. (e) 18. (d) 19. (c) 20. (a) 21. (c) 22. (a) 23. (b) 24. (e) 25. (a) 26. (b) 27. (d) 28. (b) 29. (a) 30. (a) 31. (d) 32. (d) 33. (b) 34. (a) 35. (e).



# 15

Chapter

## Protozoa: General Account

### Concept of Protista

There are certain basic differences between higher animals and higher plants. In general, plant cells are characterized by cellulose cell walls, but animal cells are devoid of cellulose cell walls. All plants synthesize complex organic foodstuffs by photosynthesis, with the help of chlorophyll present in cells, so nutrition is holophytic. But animals are unable to prepare their own food, due to lack of chlorophyll, and they have to depend on plant material, so their mode of nutrition is holozoic or saprophytic. All plants are stationary, but most animals are able to move.

On the basis of the above differences, all multicellular organisms can be clearly grouped either as animals or as plants. For example, roses, geraniums and oaks are distinctly plant-like organisms, whereas horses, lions and elephants are distinctly animal like organisms.

However, the above criteria cannot be applied to non-multicellular or non-cellular organisms (Protozoa and Protophyta) because of numerous difficulties. Sometimes it is difficult to tell whether non-cellular organisms are plants or animals. Some have characteristics of animals, some of plants, and many of both. Thus, botanists claim some, zoologists claim some, and many are claimed by both. For example, *Euglena* is treated as an animal in zoology text books, and as a plant in botany textbooks. Similarly, two genera of the protozoan order Cryptomonadina (*Cryptomonas* and *Cheilomonas*) are morphologically very similar, but chlorophyll is present in *Cryptomonas* and absent in *Cheilomonas*. Placing them in two different kingdoms on the basis of chlorophyll would mean widely separating these two closely related forms. Considering these facts, it is difficult to classify all living organisms simply in two



kingdoms, i.e., animal kingdom and plant kingdom. To remove this difficulty, as early as 1866, Ernst Haeckel proposed a third kingdom *Protista*, (Gr., *protistos*, first of all), to include all those non-multicellular organisms which are neither plant nor animal in nature. *Protista* may be defined as microscopic, acellular organisms with no definite nucleus, one nucleus or many nuclei. They may be unicellular or multicellular, their gametes are formed by single cells rather than by multicellular gonads and no embryo is formed from the zygote.

However, there is no general agreement as to which organisms should be placed in the kingdom *Protista*. Generally, it includes such forms as bacteria, slime moulds (*Mycetozoa*, *Myxophyta*) and the *Protozoa*. In the traditional classification, the animal like protists are usually lumped together in a single phylum, named "*Protozoa*", which is placed in the animal kingdom.

Whittaker, in 1969, divided all the organisms into 5 kingdoms, on the basis of cell structure, nucleus type, number of body cells and mode of nutrition, etc.

1. **Kingdom Monera.** For prokaryotic organisms, such as bacteria and blue-green algae.
2. **Kingdom Protista.** For single-celled eukaryotic organisms, such as *Protozoa*.
3. **Kingdom Fungi.** For multicellular, eukaryotes without chlorophyll, such as *Rhizopus*.
4. **Kingdom Plantae or Metaphyta.** For multicellular plants.
5. **Kingdom Animalia.** For multicellular animals.

### Status of Protozoa

In the traditional system of classification, "*Protozoa*" is treated as subkingdom or as the first phylum of the animal kingdom, as indicated by its name (Gr., *protos*, first + *zoon*, animals). However, it is a heterogeneous grouping of single-celled organisms. The principal subgroups (subphyla or classes) are similar chiefly in being unicellular, otherwise they are distinctive and dissimilar in many other respects and display extreme diversity. They display all types of symmetry, a great range of structural complexity, and adaptation for all types of environmental conditions. Their evolution parallels that of

multicellular animals and their origin is perhaps polyphyletic.

It seems improper to call protozoan organisms as "animals" because sometimes it is difficult to tell whether the members are plants or animals, as they are intermediate forms having both plant and animal characteristics. Common examples are *Euglena* and *Volvox* having chlorophyll, which are considered animals by zoologists and plants (algae) by botanists. Most of the free-living flagellates are thus placed by phycologist under different phyla of algal organisms as they contain, chlorophyll and show plant-like autotrophic nutrition. They are much more closely related to multicellular green algae than to other flagellates. Similarly, of the two structurally similar cryptomonad genera, *Cryptomonas* has chlorophyll while *Cheilomonas* is without chlorophyll. On the basis of presence or absence of chlorophyll, these two genera would be placed separately in plant and animal kingdoms, respectively, which seems unrealistic. Further, some dinoflagellates have cellulose cell wall like plants, but do not have chlorophyll and are holozoic. It would not be proper to describe some dinoflagellates as plants and others as animals.

One solution to these difficulties is to remove the protozoans from animal kingdom and place them under a new kingdom, called *Protista*, along with some algal and fungal groups. This was done by Haeckel (1866) who created *Protista*, and by Whittaker (1969) who proposed 5 kingdoms including *Protista*. In the kingdom *Protista*, the different classes of *Protozoa* (*Flagellata*, *Sarcodina*, *Sporozoa*, and *Ciliata*) become independent phyla. This arrangement justifies to abandon *Protozoa* as a phylum in the absence of any unifying characters in different protozoan classes.

However, in the present textbook, we will consider *Protozoa* representing a single phylum of animal kingdom, according to the old, classical or traditional concept, which is still adopted by most protozoologists as well as textbooks.

### Protozoa Unicellular or Acellular

Study of invertebrates begins with *Protozoa*. They were originally defined as *unicellular* animals, but

now referred to as *acellular* whether Protozoa should be considered unicellular or acellular, depends on the concept of the "cell", itself.

1. **Unicellular.** According to the "cell theory" of Schleiden and Schwann (1839), all plants and animals are made up of cells as units. If we define the cell as the unit of animal body, then Protozoa are *unicellular* animals, consisting of a single cell. According to this view, body of a free-living protozoan is morphologically equivalent to a single cell of a metazoan body. Supporters of this view claim that Metazoa evolved by the aggregation of separate unicellular protozoan individuals forming a multicellular colony (Flagellate or Colonial Theory).

2. **Acellular or non-cellular.** If we regard the animal body divisible into units, called cells, then Protozoa are *acellular* or *non-cellular* animals whose body is not divisible in cells. Due to this view a single celled protozoan body is not merely a loose cell, moving about. It is a complete animal performing all the vital functions of life, such as nutrition, excretion, respiration, reproduction, etc. In structure, a protozoan cell may be compared with an individual cell of the metazoan body, but physiologically it is equivalent to the whole metazoan body. Dobell, therefore, defines Protozoa as cellular or non-cellular rather than unicellular animals. This view implies that metazoa arose by cellularisation of a multinucleate syncytial ciliate (Syncytial Theory)

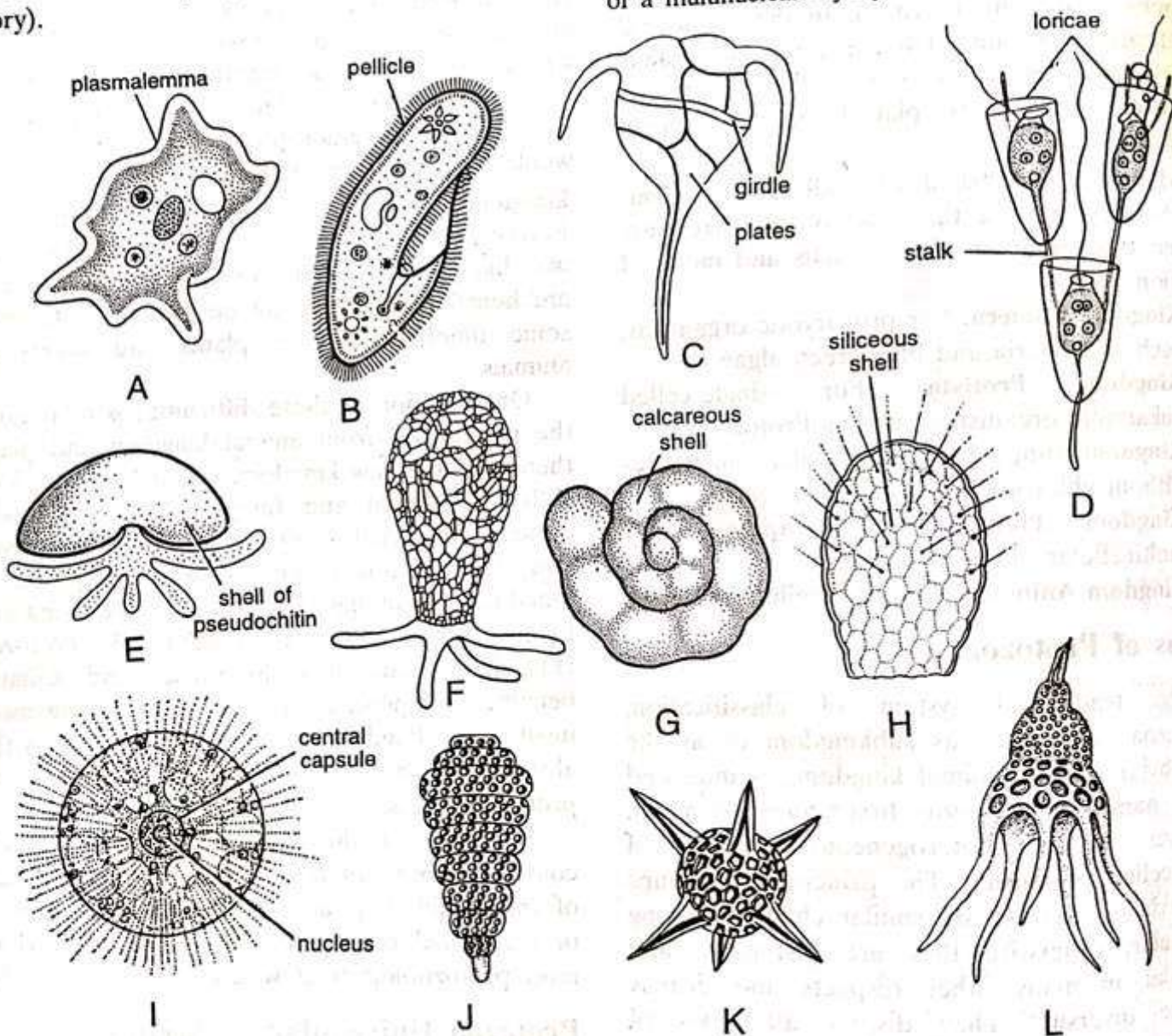


Fig. 1. Protozoan skeletons. A - Plasmalemma of *Amoeba*, B - Pellicle of *Paramecium*. C - Thecal plates of *Ceratium*. D - Lorica of *Poteriodendron*. E - Pseudochitinous shell of *Arcella*. F - Sand grain shell of *Diffugia*. G - Calcareous shell of *Discorbis*. H - Siliceous shell of *Euglypha*. I - *Thalassicola* showing central capsule. J, K - Radiolarian skeletons showing lattice network. L - Helmet-shaped radiolarian skeleton.

## Body Covering and Skeleton

In Protozoa, cytoplasm remains separated from external environment by a cell envelope. This is of special importance as this covering protects the body from harmful influences of external environment, permits a controlled exchange of substances across it, perceives mechanical and chemical stimuli and establishes contact with other cells. It may take the following forms :

1. **Plasmalemma.** In some forms, like *Amoeba*, *Chrysamoeba* and *Sporozoa* body covering is a thin plasma membrane or *plasmalemma*. It possess the typical bilayered lipid & protein ultra structure in general. Flexibility of this membrane allows change in shape. In *Amoeba*, it is provided with longitudinal ridges of mucopolysaccharides which help in adhesion to substratum.

2. **Pellicle.** In other Protozoa, like *Euglena*, the body covering is in the form of a differentiated pellicle, which is somewhat thicker and firm. It is underlined by the plasma membrane and is formed of proteins. The rigidity of pellicle gives definite shape to the body. The thickened pellicle in some of the more specialised Protozoa is variously ridged and sculptured, as in *Paramecium*, *Coleps*, etc.

3. **Skeletons.** In different groups of Protozoa, various kinds of permanent non-living external (or internal) layers are secreted. These may be composed of organic (gelatin, cellulose or pseudochitin) and inorganic (silica, calcium carbonate) materials, which are often impregnated with foreign bodies. These constitute the Protozoan skeleton and include *cyst*, *theca*, *lorica* and *test* or *shell*.

(a) **Cyst.** It is a temporary sheath, and is formed both in free-living and parasitic Protozoa when they pass into a dormant state. Exhaustion of food supply, drought and putrefaction favour encystment.

(b) **Theca.** Many dinoflagellates bear a coat of closely-fitted armour of cellulose, called *theca*. In some forms, theca is composed of two valves, while in a majority of dinoflagellates (e.g. *Ceratium*, *Glenodinium*) it is differentiated into a

number of plates laid out in a definite pattern and variously sculptured or ornamented.

(c) **Lorica.** It is a covering which fits less closely to the organism than theca. It may be gelatinous or tectinous. It is usually a cup or vase-like structure with an opening, through which emerges the anterior part of organism's body or its appendages. Base of lorica in sessile species may be attached directly to the substratum (e.g. *Phacus*, *Salpingoeca*) or may end in a stalk (e.g. *Monosiga*). In colonial loricated individuals, one lorica may be attached to another directly (e.g. *Dinobryon*) or by means of a stalk (e.g. *Poteriodendron*).

(d) **Shell or test.** Shells or tests are widespread among Protozoa. These are coverings in loose contact with the body, provided with one or more openings, through which the animal can protrude itself. In shelled amoebae, like *Arcella* and allied forms, the shell is thin and made up of a chitinous material, called *tectin* or *pseudochitin* (a combination of proteins and carbohydrates). In *Diffugia* and others shells are formed of sand particles and other foreign substances like pieces of foraminiferan shells and sponge spicules, which are embedded in secreted matrix acting as cement. Foraminiferans secrete mostly a calcareous shell, made of calcium carbonate. It may be single chambered or multichambered and dimorphic in some cases (e.g. *Elphidium*, *Discorbis*). Siliceous shells, made up of silica, are found in some Rhizopoda (e.g. *Euglypha*). Usually the silica forms polygonal, square or elliptical plates which are formed within cytoplasm then transferred to the test. Some heliozoans also secrete siliceous pieces, which are embedded in an outer gelatinous covering.

4. **Internal skeleton.** Continuous internal skeleton is found in radiolarians. It lies in between the ectoplasm and endoplasm, forming the so-called *central capsule*. (e.g. *Thalassicola*). It consists of gelatin, pseudochitin, silica or strontium sulphate. It is perforated by one, a few or many pores. In many radiolarians the skeleton consists of a lattice network, which is variously sculptured and ornamented.

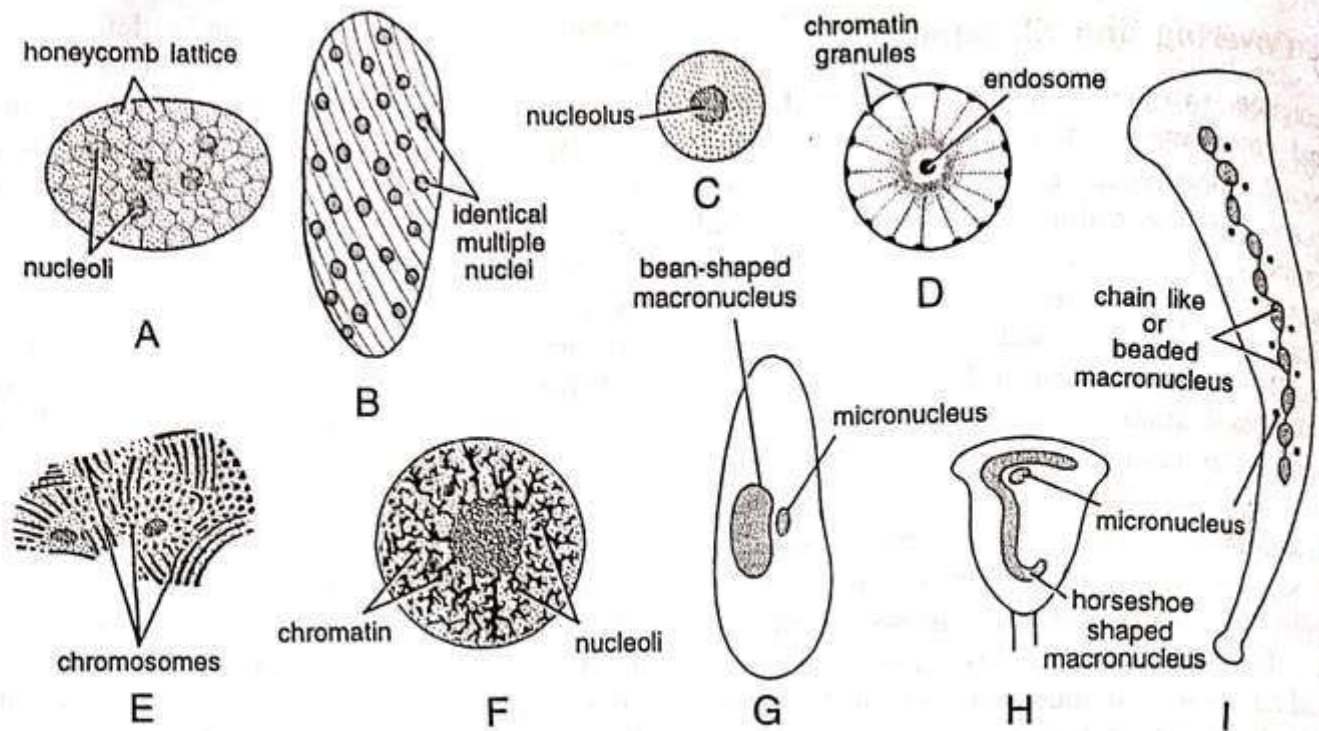


Fig. 2. Protozoan nuclei. A—Vesicular nucleus of *Amoeba proteus*. B—Multiple nuclei of *Opalina*. C—Vesicular micronucleus of *Paramecium aurelia*. D—Vesicular nucleus of *Entamoeba*. E—Chromosome nucleus of *Amoeba sphaeronucleus*. F—Polyploid nucleus of *Aulacantha scolymantha*. G—Compact macronucleus and vesicular micronucleus of *Paramecium caudatum*. H—Horseshoe-shaped micronucleus of *Vorticella*. I—Beaded macronucleus of *Stentor*.

## Nucleus in Protozoa

All protozoans possess nuclei. Mastigophora, Sarcodina and Sporozoa have single or multiple nuclei, identical in structure and function. In Ciliata, there are generally two types of nuclei, *macronucleus* and *micronucleus*, which differ in size, structure and behaviour during reproduction. Only the micronucleus takes an active part in sexual reproduction and is regarded as *generative* nucleus. Whereas the macronucleus is associated with trophic or metabolic activities and is regarded as *somatic* nucleus.

Protozoan nuclei present varying appearances. This diversity is due to differential coiling of chromosomes in a resting nucleus and also to different proportions of nuclear inclusions.

*Vesicular nucleus* is more common in distribution. It contains a distinct nuclear membrane, considerable amount of nucleoplasm and one or more prominent bodies, the *nucleoli*

or *endosomes* or *karyosomes*. This type of nucleus is usually found in most species of Sarcodina and Mastigophora. Micronucleus of *Paramecium aurelia* is also of this type. *Compact* or *massive nucleus* contains an inconspicuous nuclear membrane, and small amount of nucleoplasm with evenly distributed minute granules of chromatin material. Macronucleus of ciliates and nuclei of Dinoflagellida are of this type. Ciliate macronucleus is generally rounded, oval or bean-shaped (*Paramecium*), but often becomes elongated in the form of C (*Euplotes*), or bent like a horse-shoe (*Vorticella*). It may be moniform or shaped like a string of beads (*Stentor*, *Spirostomum*), or becomes branched (*Ephelota*).

In nucleus of Dinoflagellida and others, chromosomes are retained in interphase. In *polyploid nucleus*, chromatin material is distributed radially and nucleoli remain scattered in chromatin. This type of nucleus occurs in many radiolarians.

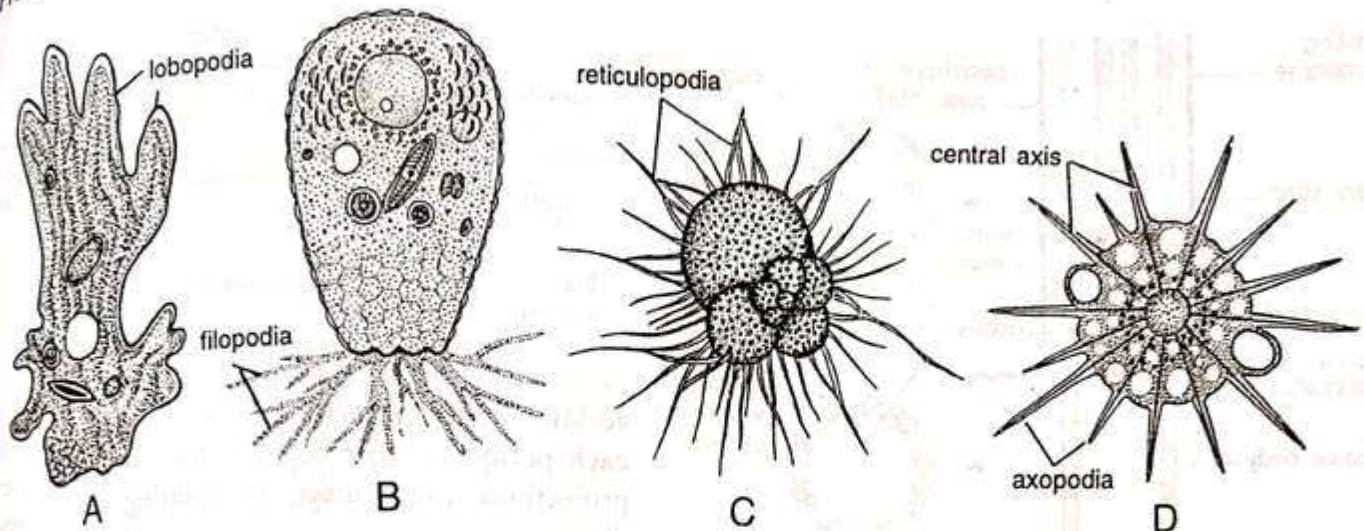


Fig. 3. Types of pseudopodia. A—Lobopodia of *Amoeba proteus*. B—Filopodia of *Euglypha*. C—Reticulopodia of *Globigerina*. D—Axopodia of *Actinophrys sol*.

## Locomotor Organelles and Locomotion in Protozoa

### (I) Locomotor organelles

Locomotor organelles in Protozoa include pseudopodia, flagella, cilia and pellicular contractile structures.

1. **Pseudopodia.** Pseudopodia or false feet are temporary structures formed by the streaming flow of cytoplasm. Sarcodina move with these structures. On the basis of form and structure, pseudopodia are of the following four types :

(a) **Lobopodia.** These are lobe-like pseudopodia with broad and rounded ends, as in *Amoeba*. These are composed of both ectoplasm as well as endoplasm. Lobopodia move by pressure flow mechanism.

(b) **Filopodia.** These are more or less filamentous pseudopodia, usually tapering from base to the pointed tip, as in *Euglypha*. Unlike lobopodia, the filopodia are composed of ectoplasm only. Sometimes they may branch and form simple or complex networks.

(c) **Reticulopodia.** The reticulopodia (rhizopodia or myxopodia) are also filamentous. Filaments are branched and interconnected profusely to form a network. This type occurs in foraminiferans (e.g. *Globigerina*). Reticulopodia display two-way flow of cytoplasm.

(d) **Axopodia.** These are more or less straight pseudopodia radiating from the surface of the body. Each axopodia containing a central axial rod which is covered by granular & adhesive

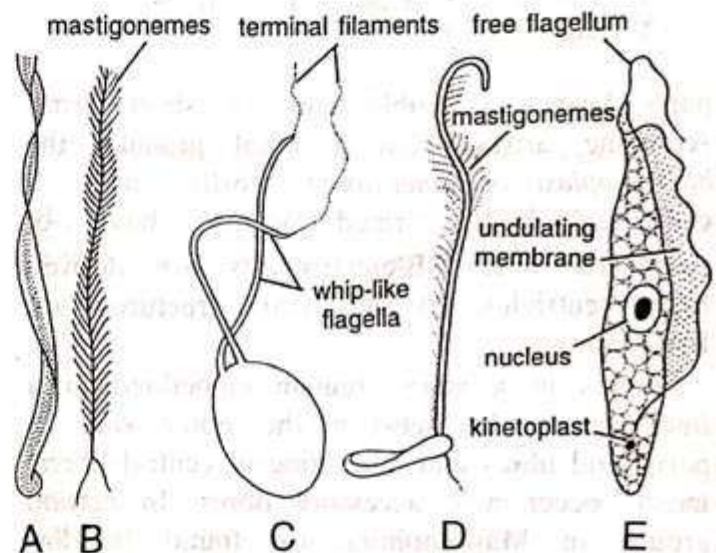


Fig. 4. Types of flagella in Protozoa. A—Flagellum of *Trachelomonas*. B—Flagellum of *Euglena* with mastigonemes. C—Whip-like flagella of *Polytoma*. D—Flagellum of *Urcoelus* with mastigonemes. E—Undulating membrane of *Trypanosoma* with a flagellum.

cytoplasm. Like reticulopodia, axopodia also display two-way flow of cytoplasm. Axopodia are characteristic of heliozoans, such as *Actinosphaerium* and *Actinophrys*.

2. **Flagella.** Flagella are the locomotor organelles of flagellate Protozoa, like *Euglena*, *Trypanosoma*, etc. These are thread-like projections on the cell surface. A typical flagellum consists of an elongate, stiff axial filament, the *axoneme*, enclosed by an *outer sheath*. In axoneme, nine longitudinal peripheral paired fibres form a cylinder, which surrounds the two central longitudinal fibres, enclosed by a membranous inner sheath. Each of the peripheral

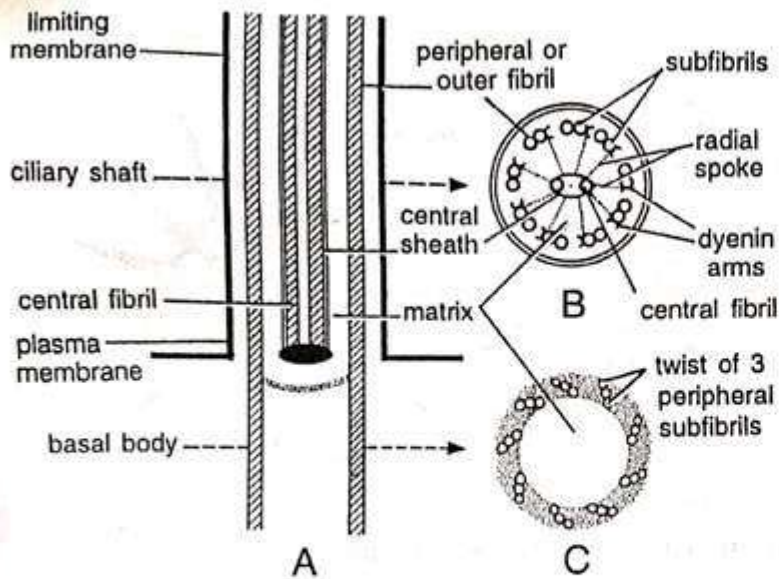


Fig. 5. Structure of a cilium. A—In I.S. B—In T.S. C—Basal body in T.S.

pairs bears a double row of short arms. Axoneme arises from a basal granule, the *blepharoplast* or *kinetosome*. Mostly, it is a cylindrical body formed by the bases of peripheral fibres. Blepharoplasts are derived from centrioles, as the two structures are homologous.

Fibres of axoneme remain embedded in a fluid matrix. In between the outer ring of peripheral fibres and inner ring of central fibres, mostly occur nine accessory fibres. In certain groups of Mastigophora are found flagellar appendages or *mastigonemes* extending laterally from the outer sheath.

Number and arrangement of flagella vary in Mastigophora from one to eight or more. Free-living species have usually one or two, while in parasitic species, the number ranges from one to many.

**3. Cilia.** Cilia, characteristic of Ciliata, resemble flagella in their basic structure. These are highly vibratile small ectoplasmic processes. Electron microscope reveals the presence of an external membranous sheath, continuous with plasma membrane of cell surface and enclosing the fluid matrix. Running along the entire length of body of cilium are nine paired peripheral fibres and two central fibres, all embedded in a structureless matrix. Central fibres are enclosed within a delicate sheath. In between the outer and inner fibre rings are

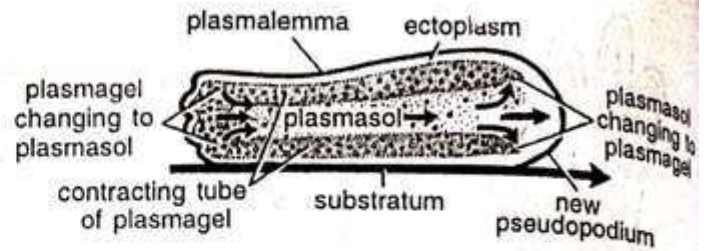


Fig. 6. Amoeba showing amoeboid movement according to sol-gel theory of Mast.

present nine spoke-like *radial lamellae*. In addition to these, one *sub-fibre* or *microfibre* of each peripheral pair bears a double row of short projections, called *arms*, all pointing in the same direction.

Each cilium arises from a thickened structure, the basal granule, basal body or blepharoplast. According to Lenhsek and Henneguy (1898), basal granules are centrioles or their derivatives. Basal granules show nine peripheral subfibre triplets, each disposed in a twist-like fashion. In many species, cilia become fused variously forming compound organelles, such as undulating membranes (*Pleuronema*), membranelle (*Vorticella*), and cirri (*Euplotes*).

**4. Pellicular contractile structures.** In many Protozoa are found contractile structures, in pellicle or ectoplasm, called *myonemes*. These may be in the form of ridges and grooves (e.g. *Euglena*), or contractile myofibrils (e.g. larger ciliates), or microtubules (e.g. *Trypanosoma*).

## [II] Methods of locomotion

Basically there are four known methods by which Protozoa move— (1) Amoeboid movement, (2) Flagellar movement, (3) Ciliary movement, and (4) Metabolic movement. Speed of locomotion varies from  $0.2\mu$  to  $3\mu$  per second in amoeboid forms,  $15\mu$  to  $300\mu$  in flagellates and  $400\mu$  to  $2000\mu$  in ciliates.

**1. Amoeboid movement.** It is characteristic of all Sarcodina and certain Mastigophora and Sporozoa. It consists in the formation of pseudopodia by the streaming flow of cytoplasm in the direction of movement. Locomotion by pseudopodia is possible only over a surface. We still do not know precisely about the mechanism involved in the formation of pseudopodia, but the most convincing theory at present is that it depends upon active contraction of the

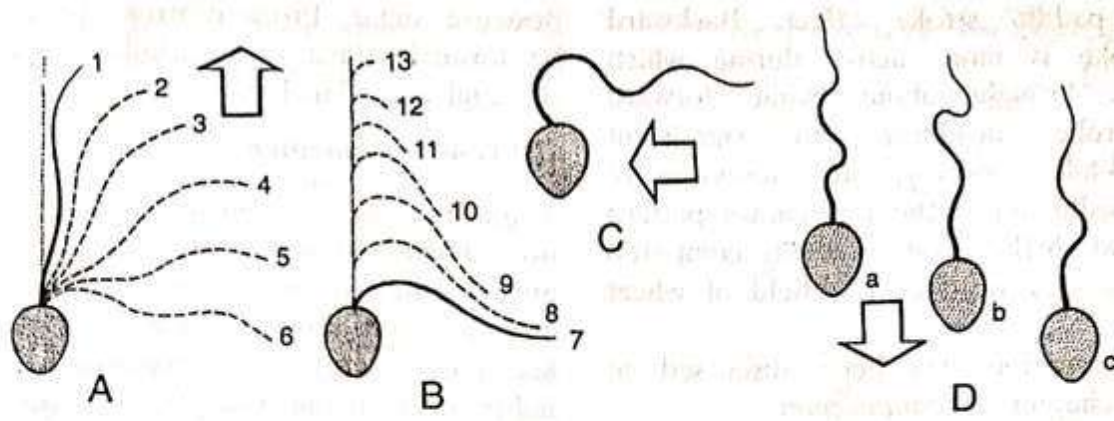


Fig. 7. Flagellar movement. A - Effective stroke. B - Recovery stroke. C - Lateral movement. D - Backward movement.

ectoplasmic tube (plasmagel) at the posterior end of the body. This leads the endoplasm (plasmasol) to flow forward into the expanding pseudopodium. This process involves continuous solation at the posterior end and gelation at the anterior end (Fig. 6). This is called *sol-gel* or *change of viscosity theory* by Mast and Pantin (1925). It was further developed by Goldacre and Lorch (1950) and by Allan and Rosalansky (1958). Other aspects and theories of amoeboid locomotion have been discussed at length in the chapter on *Amoeba*.

**2. Flagellar movement.** It is characteristic of Mastigophora which bear one or more flagella. The flagella need liquid medium for movement or locomotion. Three types of flagellar movements have been recognized :

(a) **Paddle stroke.** Ulehla and Krijnsman (1925) observed that common movement of a flagellum is sideways lash, consisting of an effective *down stroke* with flagellum held out rigidly, and a relaxed *recovery stroke* in which flagellum, strongly curved, is brought forward again. As a result, the animal moves forward, gyrates and is also caused to rotate on its longitudinal axis (Fig. 7A, B).

(b) **Undulating motion.** Wave-like undulations in flagellum, when proceed from tip to base, pull the animal forward. Backward movement is caused when undulations pass from base to tip. When such undulations are spiral, they cause the organism to rotate in opposite direction (Fig. 7D).

(c) **Simple conical gyration.** Butschli's screw theory postulates a spiral turning of flagellum

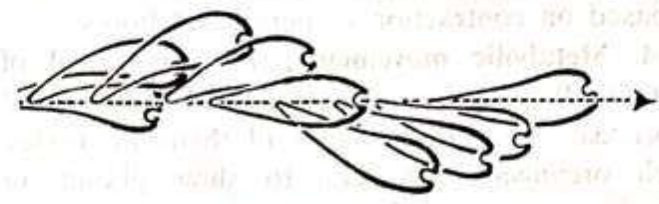


Fig. 8. Successive stages of gyrating flagellar movement.

like a screw. This exerts propelling action, pulling the animal forward through water with a *spiral rotation* as well as *gyration* (revolving in circles) around the axis of movement (Fig. 8).

The mechanism producing flagellar beat is not exactly known. It is believed that some or all of the axonemal fibres are involved. According to the latest *sliding tubule* Theory of flagellar (or ciliary) movement, adjacent doublets slide past each other, causing the entire flagellum or cilium to bend. Cross bridges are formed and energy utilized for the process is supplied by adenosine triphosphate (ATP).

**3. Ciliary movement.** Most ciliates appear to move in a spiral path, rotating on their axis as they go. Spiral movement is due to in opposite directions on the two sides of the pseudopodial filaments oblique strokes of all body cilia working together and striking in the same direction. Cordination of ciliary movement is due to fact that basal bodies of all cilia are linked by kinetodesmata. Cilia also need liquid medium for their movements. Large ciliates are the swiftest swimmers, and the champion of them may be named *Paramecium caudatum*.

Ciliary action resembles the swing of a pendulum except that it is more rapid in one direction. Backward and forward vibrations

produce a paddle stroke effect. Backward effective stroke is more active during which movement is brought about, while forward recovery stroke produces no significant movement. While moving, the succession of beats are coordinated in the well-known pattern of metachronal rhythm, conventionally compared to the passage of wind over a field of wheat (Fig. 7).

Ciliary locomotion has been discussed at length in the chapter on *Paramecium*.

As regards the essential mechanism of ciliary movement, little definite can be said. The evidences strongly suggest that ciliary movement is based on contraction of peripheral fibres.

**4. Metabolic movements.** This is typical of certain flagellates (e.g. *Euglena*) and most sporozoans at certain stages of their life cycles. Such organisms are seen to show gliding or wriggling or peristaltic movement. Contractile myonemes or microtubules, present in their pellicular walls, are responsible for this type of movement. Movements of this kind are usually also referred to as *gregarine movements* since they are characteristically exhibited by most gregarines.

## Nutrition in Protozoa

Protozoa obtain nourishment in many ways. Some synthesize their own food, others have it made for them by algae living in their cytoplasm and still other wait passively until food comes within reach, capturing it almost with the outer sheath. Some Protozoa lead parasitic life, usually doing no or little harm to their hosts, but occasionally causing serious diseases.

All types of nutrition are found in Protozoa; such as holophytic, holozoic, saprozoic, mixotrophic and parasitic, etc.

### [I] Holophytic nutrition

All those phytoflagellates possessing chloroplasts or chromatophores synthesize their food by photosynthesis. As energy is supplied by sunlight to carry on food-making activity, this method involving self-feeding is also referred to as *autotrophic phototrophy*. Carbon dioxide and water, acting as raw materials, enter into a complex cycle of chemical reactions and produce

dextrose sugar. From dextrose paramylum may be formed which is especially characteristic of the euglenoid flagellates.

### [II] Holozoic nutrition

Majority of free-living Protozoa derive nourishment by ingesting other organisms, both animals and plants. Such Protozoa are called *holozoic*, and mode of nutrition is said to be *holozoic nutrition*. All Sarcodina are strictly holozoic with the exception of some parasitic species. This mode of nutrition involves development of organelles for food capture, ingestion, digestion and egestion of indigestible residues.

**1. Food and feeding.** Food of holozoic Protozoa consists of microorganisms like other protozoans, bacteria, diatoms, rotifers, crustaceans, larvae, etc. The method involved in ingestion of these organisms is referred to as *phagotrophy* or *phagocytosis*.

Colourless *flagellates* and those who have lost their chromatophores capture their solid food by means of flagella and ingest them either through naked sites on their bodies (e.g. *Bodo*) or through specialized oral apparatus (e.g. *Euglena*). Some flagellates, like *Peranema*, capture food with the help of special rod-like structures, called *trichites*.

In *Sarcodina*, solid food is captured with the help of pseudopodia. This type of feeding is said to be *amoeboid nutrition*. According to the observations of Rhumbler (1910), amoebae are said to ingest food in four ways :

(a) *By import.* This method involves taking in food into body upon contact with very little movement on the part of organism as there is some chemical attraction between it and *Amoeba*. Passive organisms such as algae are imported like this (see Fig. 7 : Ch. 6).

(b) *By circumfluence.* By this method *Amoeba* engulfs the food organism upon contact by rolling over it in order to arrest it completely. This happens when less active organisms are fed upon such as bacteria (see Fig. 8 : Ch. 6).

(c) *By circumvallation.* This method is applied when amoeba happens to feed upon an active prey. It sends out pseudopodia to engulf the desired prey, while it is still some distance away.



The pseudopodia surround food without touching it. Later, these pseudopodia fuse at their tips and the so-called food vacuole is formed which is engulfed as a whole (see Fig. 9 : Ch. 6).

(d) *By invagination.* It is a method of sucking in the food particle upon contact with ectoplasm. The food particle then sinks into endoplasm (see Fig. 10 : Ch. 6).

*Heliozoans* (sun animalcules) and *radiotarians* hold and pull the prey that comes within reach by their axopodia which act as traps. After capture the axopodia withdraw and the prey passes into deeper cytoplasm.

*Foraminiferans* produces delicate reticulopodia forming a net. A granular mucoid film is present on the reticulopods upon which stick the food particles on contact which are then dragged into inner cytoplasm (see Fig. 3 : Ch 8).

In *ciliates*, the oral apparatus meant for food-capturing is well developed. By the beating of cilia of oral groove, food is taken into buccal cavity and then driven towards mouth or cytostome by ciliary bands (membranes, membranelles) into cytopharynx which strips off food vacuoles containing food particles into the endoplasm (see Fig. 11 : Ch. 12).

*Suctorians* feed on other ciliates with the help of their tentacles which are usually knobbed at the tip. Each tentacle consists of a rigid central tube surrounded by a contractile sheath. As soon as the prey is adhered to the tips of tentacles, it is paralysed by some toxin (hypnotoxin). It is then gradually sucked into the suctorian body through their central tubes (Fig. 9).

2. **Digestion.** Food in Protozoa is digested within food vacuoles, which usually keep on circulating in the endoplasm. Within food vacuoles, the reaction is at first acidic which later on becomes alkaline. Proteolytic and carbohydrate splitting enzymes have been demonstrated in many protozoan organisms. In the acidic medium, proteins are converted into dipeptides and, in the alkaline medium, dipeptides are converted into amino acids. Hydrolysis of carbohydrates takes place in alkaline medium. Certain Protozoa are also said to digest fats. Digestive enzymes are furnished by lysosomes which fuse with the food vacuoles.

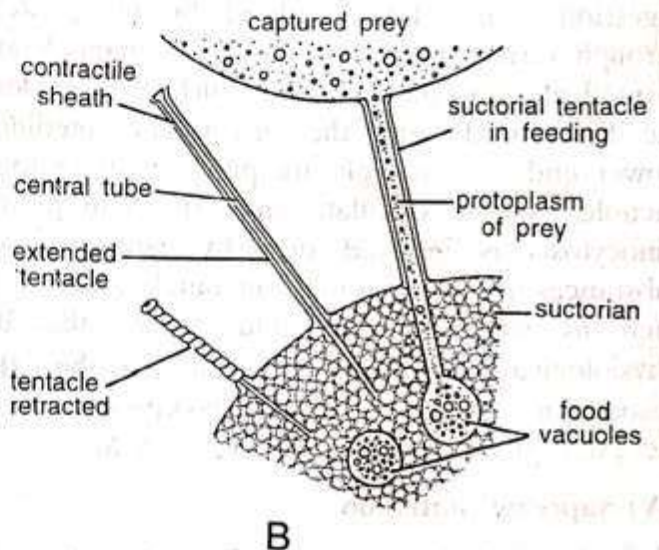
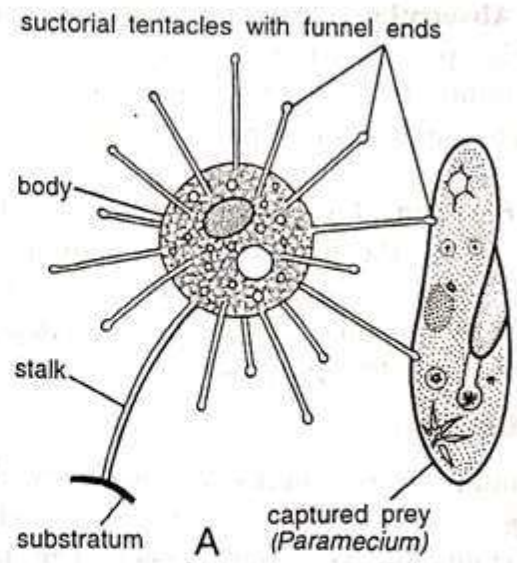


Fig. 9. Feeding in Suctoria. A—*Podophrya* sucking *Paramecium*. B—Prey's protoplasm flows into the suctorian's body through the tubular tentacle.

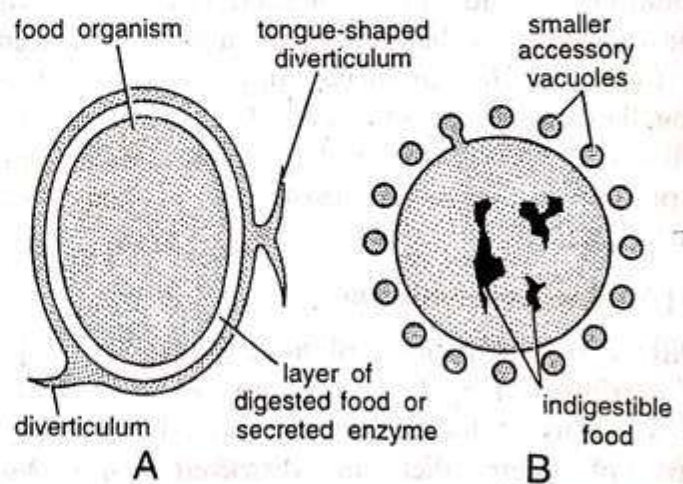


Fig. 10. Food vacuole. A—Recently formed food vacuole. B—An older food vacuole.

3. **Absorption.** Digested food gets diffused into endoplasm, where it is assimilated into protoplasm. Excess food may be stored as glycogen, paramylum, lipids, chromatoid bodies, etc.

4. **Egestion.** Indigestible residue of food is expelled from the hinder part of body in case of moving amoeba at any point. Ciliates often possess an anal opening, the *cytopyge* or *ectoproct*, for this purpose.

### [III] Pinocytosis

In addition to phagocytosis, *pinocytosis* or *cell-drinking* has been reported in *Amoeba* and certain flagellates and ciliates. This involves ingestion of liquid food by invagination through surface of body. Pinocytosis channels are formed at some parts of body surface to enclose the fluid food from the surrounding medium. Lower ends of channels are pinched off as food vacuoles which circulate into the endoplasm. Pinocytosis is induced only by certain active substances in the medium surrounding the cell, such as some proteins and many salts. Its physiological significance seems to be the absorption of high molecular compounds from the external medium (see Fig. 11 : Ch 6).

### [IV] Saprozoic nutrition

Saprozoic nutrition involves absorption of food by osmosis, i.e., through general surface of body. This method of food-getting is referred to as *osmotrophy*. Food consists in the form of solution of dead organic matter, rendered so by the decomposing bacteria. This mode of nutrition is found in *Mastigamoeba*, and some colourless flagellates (e.g., *Chilomonas*, *Astasia*, *Polytoma*). Dissolved food materials, upon which the saprozoic protozoans subsist, are proteins and carbohydrates.

### [V] Myxotrophic nutrition

This is a combination of more than one mode of nutrition. Many Protozoa using photosynthesis as a means of food-synthesis also take in some part of their diet in dissolved form by osmotrophy or solid form by phagotrophy. Flagellates like *Euglena* and *Peranema* nourish themselves by this method.

(Z-1)

### [VI] Nutrition of parasites

The food-getting mechanisms used by parasitic Protozoa are generally the same as those of their non-parasitic relatives. Many intestine-inhabiting Zoomastigophorea (*Trichomonas*) have a distinct mouth or cytostome through which food particles are ingested by phagotrophy. Many parasitic ciliates, like *Nyctotherus* and *Balantidium*, do the same. Parasitic Sarcodina of the genus *Entamoeba* feed by phagotrophy, at least at certain stage of their life cycle. Zooflagellates inhabiting blood (e.g., *Trypanosoma*) feed by *osmotrophy*. Osmotrophic forms may be either *coelozoic* or *histozoic*. *Opalina*, which is found in the rectum of frog, is coelozoic and absorbs all its food through the cell surface. The young trophozoite of *Monocystis* is histozoic within the sperm morula and it feeds upon the sperms substance by osmotrophy. Parasitic saprozoic forms may also use directly the serum of their host's blood.

### Contractile Vacuoles and Osmoregulation

Contractile vacuoles are pulsating organelles found in freshwater Sarcodina, Mastigophora and Ciliata. They also occur in marine ciliates. They are altogether absent in parasitic forms of the protozoan classes, except Ciliata, where they occur frequently.

1. **Contractile vacuoles in different Protozoa.** In *Amoeba*, the contractile vacuole is in its simplest form, being a spherical vesicle bounded by a limiting membrane of about  $0.5\mu$  in thickness. It is surrounded by a circlet of mitochondria which furnish energy for its pulsating activity. It is thought to be a temporary structure formed by the fusion of numerous small accessory or feeder vacuoles. In protozoans, with a more defined body form, like *Euglena*, the contractile vacuole has a fixed position. Formation of main vacuole is contributed by a few accessory vacuoles. Sporozoans have no contractile vacuoles. Ciliates, both marine and freshwater, have contractile vacuoles of more advanced type. *Paramecium* has two vacuoles, one located at the anterior end and

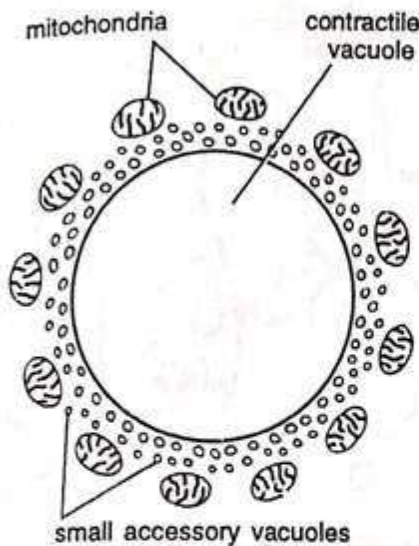


Fig. 11. Contractile vacuole of *Amoeba* surrounded by mitochondria.

other at the posterior end of body. The main larger vacuole is fed by a varying number of radial canals or afferent canals. It opens to outside through a small pore in the organism's body surface.

Electron microscopy has revealed that the bounding membrane of the contractile vacuole is a lipoprotein membrane, similar to the cell membrane.

**2. Mechanism of osmoregulation.** The function of contractile vacuole is *hydrostatic* or *osmoregulatory*. Water in freshwater Protozoa enters the organism by endosmosis and during feeding. The reason is that cytoplasm of a freshwater protozoan represents a medium denser than surrounding water and outermost plasmalemma or pellicle acts as a semi-permeable membrane. Thus water continuously flows inside to dilute the cytoplasm. If the organism does not possess a mechanism to get rid of this excess water, it will swell to the point of rupture and dissolution. The mechanism which is assumed to effect water regulation is the contractile vacuole. The vacuole periodically increases in volume (diastole) to get filled with water and contracts (systole) to discharge its water content to the surrounding environment. But the exact mechanism of its working is little understood. Three theories have been put forth to explain it. These are as follows :

(a) **Osmotic theory.** According to this theory, water from cytoplasm enters the contractile vacuole by osmosis.

(b) **Filtration theory.** According to this theory, hydrostatic pressure forces water through vacuolar membrane. But, Kitching is of the view that this theory cannot be applied to the working of contractile vacuole as it is only connected to outside medium at systole. Thus, internal hydrostatic pressure could not be relieved by filtration of fluid into vacuole, since the total volume within the limiting cell membrane would not be reduced.

(c) **Secretion theory.** This theory holds that water is actively secreted into vacuole during diastole through vacuolar wall. This theory is most widely accepted. Systole and diastole are attributed to the contractile nature of the vacuole's wall.

## Reproduction in Protozoa

### [I] Asexual reproduction

**1. Binary fission.** This involves the division of one individual into two approximately equal parts. The division is not a mere fragmentation but a complicated process of mitosis, during which nuclear division or *karyokinesis* is always followed by the division of cytoplasm or *cytokinesis* (Fig. 12). Division or fission may be either in a transverse plane (e.g. *Paramecium*), or in a longitudinal plane (e.g. *Euglena*), or in an oblique plane (e.g. *Ceratium*) or in any plane (e.g. *Amoeba*). The two daughter organisms produced as a result of binary fission carry all the cytoplasmic organelles of the parent individual. Some organelles like mitochondria, divide at the time of division, while others, like oral apparatus, flagella, and contractile vacuoles, are formed afresh by one of the daughters. In shelled sarcodina (e.g. *Euglypha*, *Arcella*) a mass of protoplasm extrudes from the opening of shell, which secretes a new shell. This double-shelled organism now divides into two. In ciliates (e.g. *Paramecium*), during fission, mega or macronucleus divides amitotically and micronucleus by usual mitotic division. Some Protozoa divide only in the encysted stage (e.g. *Colpoda*, *Tillina*).

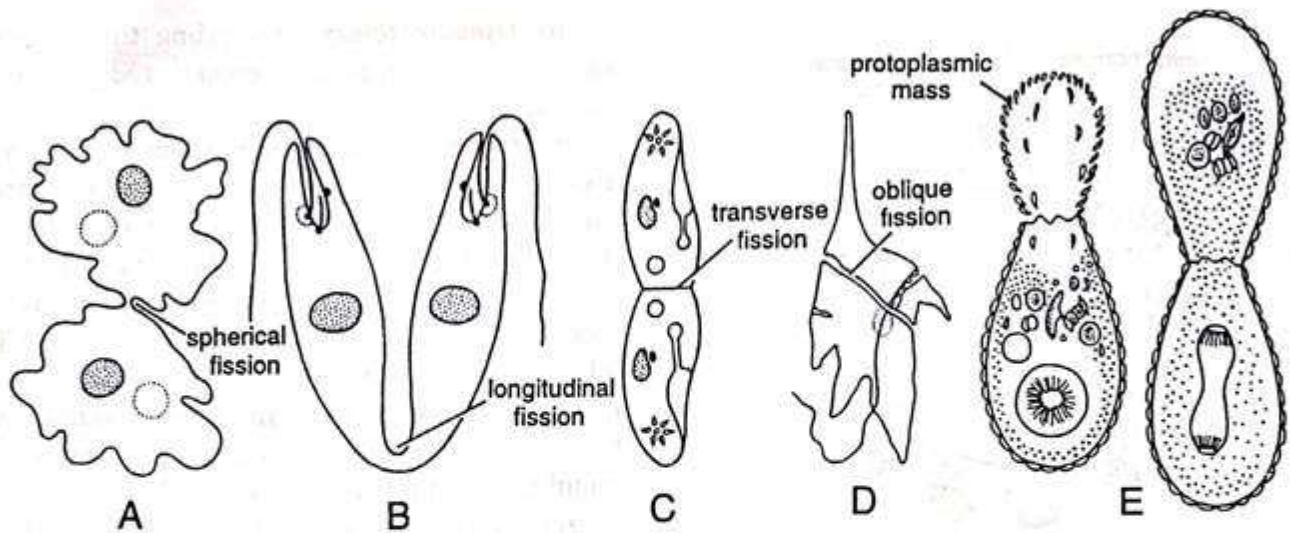


Fig. 12. Binary fission in Protozoa. A—*Amoeba* (irregular) B—*Euglena* (longitudinal). C—*Paramecium* (transverse) D—*Ceratium* (oblique). E—*Euglypha* (Two stages in fission).

2. **Plasmotomy.** It is a special type of binary fission concerned with the division of multinucleate Protozoa into two or more smaller multinucleate daughter individuals. Plasmotomy takes place in *Pelomyxa*, opalinids and some other forms, etc. (Fig. 13).

3. **Budding.** In its simplest form budding implies modified fission resulting in a small daughter individual in the form of a bud. When the bud breaks off, it grows to full size. When a parental body produces only one bud it is *monotonic* (e.g. *Vorticella*), while in *multiple budding*, several buds are formed simultaneously (e.g. *Ephelota*).

4. **Multiple fission.** During *multiple fission* or *sporulation*, nuclear division is not followed immediately by division of cytoplasm. First, nucleus undergoes a series of divisions either by repeated binary fissions as in *Plasmodium*, or by simultaneous multiple divisions, as in *Aggregata*. The body thus becomes multinucleate. Later, the body cytoplasm divides into as many parts as there are daughter nuclei which usually arrange themselves at the periphery, each getting surrounded by a fragment of cytoplasm. Thus, the parent body simultaneously divides into as many daughter individuals as there are nuclei. Parent cell usually leaves behind some residual cytoplasm which disintegrates afterwards. Number of offspring greatly varies among different and the same species and sometimes runs into thousands.

(Z-1)

Multiple fission is quite common in Foraminifera, Radiolaria, Sporozoa and certain Mastigophora. The process receives different names according to the particular period in life cycle when it occurs.

(a) **Schizogony.** In this process, a series of nuclear divisions results into numerous daughter

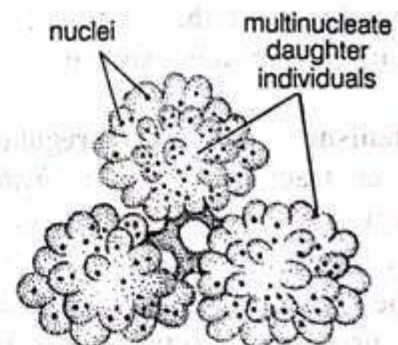


Fig. 13. Plasmotomy.

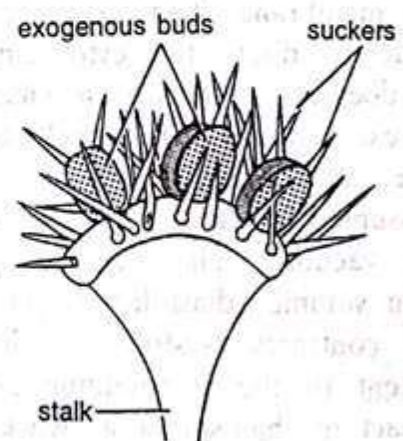


Fig. 14. Multiple budding in *Ephelota*.

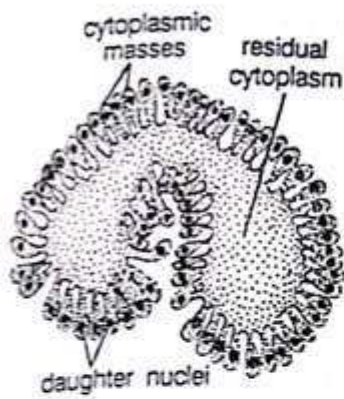


Fig. 15. Multiple fission.

nuclei. This is followed by the formation of cytoplasmic buds, each containing a nucleus. The buds are pinched off to grow directly into new organisms.

5. **Plasmogamy.** In certain Rhizopoda and Mycetozoa, two or more individuals may fuse by their cytoplasm to form a plasmodium, in which the nuclei remain distinct, and they separate again unchanged afterwards. The process, which is thus non-sexual and not syngamy, is called *plasmogamy* and sometimes serves the purpose of digestion of large prey.

### [II] Sexual reproduction

In Protozoa, sexual reproduction takes place mainly by two processes : (i) *syngamy* or fusion of two sex cells, and (ii) *conjugation* or temporary contact of two protozoans with nuclear exchange.

1. **Syngamy.** Syngamy is the complete fusion of two sex cells or gametes, resulting in the formation of zygote. The fusion nucleus of zygote is called *zygokaryon*. Depending upon the degree of differentiation displayed, by the fusing gametes, syngamy is of the following types :

(a) **Hologamy.** The two ordinary mature protozoan individuals do not form gametes but themselves behave as gametes and fuse together to form zygote. Hologamy occurs in a few Sarcodina and Mastigophora (e.g. *Copromonas*).

(b) **Isogamy.** When two fusing gametes are similar in size and shape but differ in behaviour, they are called *isogametes* and their union, *isogamy*. Isogametes are generally produced by multiple fission. Isogamy is common in Forminifera (e.g. *Elphidium*), Gregarinia (e.g. *Monocystis*) and Phytomonadida (e.g. *Chlamydomonas*).

(c) **Anisogamy.** When two fusing gametes, differ morphologically as well as in behaviour, they are called *anisogametes*. Usually small and motile gametes are the male or *microgametes* and large non-motile ones are the female or *macrogametes*. Fusion of such dissimilar gametes is *anisogamy*. This mode of sexual reproduction is widely seen in Sporozoa (e.g. *Plasmodium*) and Phytomonadida (e.g. *Volvox*).

(d) **Autogamy.** It is the fusion of gametes derived from the same parent cell, as in *Actinophrys* and *Actinosphaerium*. In *Actinophrys*, during sexual reproduction, pseudopodia are withdrawn and a cyst is formed. Now meiotic division takes place and two daughter nuclei with half number of chromosomes are formed. No cell division takes place. After sometime, gametic nuclei fuse to form a zygote nucleus.

2. **Conjugation (amphimixis).** This involves temporary union of two individuals, called *conjugants*, usually at oral or buccal regions of their body. It is characteristic of Suctoria and holotrich ciliates.

Fusion of protoplasm occurs at the place of contact. Macronuclei break up and disappear. Micronuclei undergo meiotic division now all but one micronuclei degenerate. This remaining micronucleus again divides forming two gametic micronuclei. Out of these two, one is considered *male pronucleus* and other *female pronucleus*. Male pronucleus of one conjugant moves through fused protoplasm into the other conjugant. In each conjugant, these male and female pronuclei fuse together forming a *zygote nucleus*. Now two individuals separate and are called *exconjugants*. Each exconjugant undergoes further nuclear and cytoplasmic divisions forming four daughter individuals.

Association in conjugation is not at random but indicates a high level of specialization. Sonneborn has recognized different syngens in a species of *Paramecium* and each syngen includes two mating types. Conjugation can only take place between individuals of the same syngen but belonging to opposite mating types. The unique feature of conjugation is an exchange of hereditary material so that each conjugant benefits from a renewed hereditary constitution.

Conjugation in *Paramecium* has been discussed at length in chapter 11.

### [III] Parthenogenesis

In *Actinophrys*, the gametes which fail at cross-fertilization, develop parthenogenetically. It also occurs in *Chlamydomonas* and others when syngamy has been missed. Individuals of *Polytoma*, which are potential gametes, can grow and divide parthenogenetically.

### [IV] Regeneration

Most Protozoa can regenerate their lost parts, as normally displayed at fission or encystment. Parasitic Protozoa usually have slight regenerative capacity. Nucleus plays an important role in the process. Relative quantities of nuclear and cytoplasmic materials and the size of the broken piece affect the rate and result of the process of regeneration.

## Economic Importance of Protozoa

Protozoa are unicellular microscopic organism found almost everywhere, in water, in moist soil, in air, or even within the bodies of other animals and plants. In this fast-moving Age of Mammals, dominated by man, it may appear at first glance that these minute animals would have little or no economic significance. However, such is not the case, and Protozoa exert far more influence in worldly affairs than is generally thought. They are harmful as well as useful, but the harmful species are relatively smaller in number as compared with the useful species.

### [I] Useful Protozoa

1. **Helpful in sanitation.** Numerous holozoic Protozoa feed on putrefying bacteria in various bodies of water and thus help indirectly in the purification of water. These Protozoa play an important part in the sanitary betterment and improvement of the modern civilized world in keeping water safe for drinking purpose.

2. **Planktonic Protozoa as food.** Protozoa floating in the plankton of sea provide directly or indirectly the source of food supplies to man, fish and other animals. They form one of the first links in the numerous and complicated food chains that exist in the oceans of the world.

Clams and young fish feed extensively on aquatic insect larvae, small crustaceans, worms, etc., all of which take Protozoa as food. Thus, Protozoa indirectly form the food of fish, clams and other animals, which in their turn are consumed by man.

3. **Symbiotic Protozoa.** Some protozoans are found in symbiotic relationship with other organisms. This association is usually beneficial to both the partners. The two partners become so dependent on each other, that one cannot get along without the other, and their separation results in the death of both. Most outstanding examples of symbionts among the Protozoa are several intestinal flagellates (*Trichonympha*, *Colonympha* etc.) of termites and woodroaches. According to Cleveland, these flagellates are extremely vital for the very existence of their hosts. They digest cellulose converting it into soluble glycogen substances for their hosts as well as for themselves.

4. **Oceanic ooze and fossil Protozoa.** Tiny skeletons of dead pelagic Foraminifera, Radiolaria and Heliozoa sink to the sea bottom forming the soft mud or *oceanic ooze*. These tiny skeletons are made of silica or calcium carbonate. Over countless millions of years these skeletons, deposited on the floor of ocean, became solid and fossilized and converted into some important sedimentary rock strata found all over the world. These have been put to various commercial uses, such as filtering agents, abrasives, chalk, building stones, etc. The white chalk cliffs of Dover, England, and the limestone beds of Paris, Cairo and North America are composed almost exclusively of the fossil Foraminiferida. It is hard to believe that great city of Paris is indebted to these obscure animals. Most of the buildings of Paris are made of limestone composed almost exclusively of the shells of the foraminiferan genus, *Miliolina*. Similarly, the great pyramids of Egypt were carved from the limestone deposits made by tests of an early Tertiary foraminiferan, *Nummulites*. Radiolarian fossils are abundant in the hard rocks of the nature of *flint* and *chert*. They also constitute a part of Tripoli Stone, which is used in abrasive powders of materials.

5. **Protozoa in study.** Protozoa are single-celled organisms, possessing forms

functions like those of metazoan cells. They are studied in laboratories for the comprehension and application of biological principles. Due to their minute size and quick reproduction, they are studied by geneticists for heredity and variations. Knowledge of fossil Protozoa is essential for the students of geology and palaeontology. Protozoa are the progenitors of all metazoans alive today. Their study helps in understanding the probable beginning of organic matter and the origin and evolution of life on Earth. Study of physiology of Protozoa has contributed much to our knowledge about the physiology of animal cell.

## [II] Harmful Protozoa

1. **Soil Protozoa.** Several species of Protozoa, present in large numbers in soil, feed upon the nitrifying bacteria, and thus decline their activity and consequently tend to decrease the amount of nitrogen given to soil by the nitrifying bacteria.

2. **Water pollution.** Whereas some Protozoa are helpful in water sanitation, others become responsible for water contamination or pollution. The Protozoa of faecal origin belong to this latter category. Some free-living Protozoa (e.g. *Uroglenopsis*) also pollute water by producing aromatic and oily secretions with objectionable odours, which render water unfit for human consumption.

Some bioluminescent dinoflagellates, such as *Noctiluca*, *Gymnodinium* and *Gonyaulax*, living in sea, sometimes multiply so extensively as to turn the water red with their bodies. The phenomenon is known as *blooming* and is the cause of "red tides", often experienced in the sea. Outbreaks of this "red water" often gives a foul and disagreeable odour to the ocean water. Large concentrations of these flagellate protozoans may even lead to destruction of fish and poisoning of edible molluscs, such as clams, oysters and mussels, etc., making them unfit for human consumption.

3. **Pathogenic Protozoa.** Some Protozoa cause diseases in man as well as animals and these are termed *pathogenic Protozoa*. They occur in all classes of Protozoa.

(a) **Pathogenic sarcodines.** There are two common genera of parasitic amoebae, *Entamoeba* and *Endamoeba*, which live in the intestine of man and of other animals. Only two species of *Entamoeba*: *E. histolytica* of man and other mammals and *E. invadens* of reptiles are known to be seriously pathogenic. *E. histolytica* is responsible for amoebic dysentery or amoebiasis in man, which occurs in about 60-70% Indian population. *E. invadens*, occurring in the colon of reptiles, causes reptilian amoebiasis.

(b) **Pathogenic flagellates.** Pathogenic species of parasitic flagellates are included in the genera *Leishmania*, *Trypanosoma*, *Histomonas*, *Trichomonas* and *Giardia*. Three pathogenic species of *Leishmania* have been known to cause severe diseases in man. *L. donovani* causes Kala-azar, a disease of the spleen and liver, *L. tropica* causes a peculiar type of skin lesion (cutaneous leishmaniasis) and *L. brasiliensis* causes infection of nasopharynx and skin lesion. These are transmitted by sandflies of the genus *Phlebotomus*. Parasitic species of *Trypanosoma* in mammals cause worst diseases. *T. gambiense*, is the causative agent of fatal African sleeping sickness. *T. Rhodesiense*, *T. cruzi*, *T. equiperdum*, *T. evansi*, and *T. brucei* are other common pathogenic species.

*Histomonas meleagridis* is the parasitic mastigamoeba. Of the parasitic species of *Trichomonas*, *T. vaginalis* is the causative organism of vaginal trichomoniasis or vaginitis in human females. *T. foetus* causes trichomoniasis of cattle in U.S., and *T. gallinae* is pathogenic in doves, pigeons, turkeys and chickens. Of the numerous species of *Giardia*, *G. intestinalis* (= *G. lamblia*) of man causes enterocolitis.

(c) **Pathogenic Sporozoans.** Protozoan superclass Sporozoa is exclusively of parasitic forms. Though most of sporozoans are harmless, yet some genera like *Plasmodium*, *Eimeria*, *Isospora* and *Babesia* include pathogenic species. Species of *Plasmodium* are called malaria parasites as they cause the disease of malaria. Four species of *Plasmodium*, namely *P. vivax*, *P. malariae*,

*P. ovale* and *P. falciparum* cause malaria in man. Malaria is caused by *P. cyanomolgi* in monkeys, by *P. verghei* in tree rats and by *P. gallinaceum* in jungle fowl of Asia. Pathogenic species of *Eimeria* cause coccidiosis in chickens and rabbits. *E. tenella* and *E. mitis* infect chickens, whereas *E. mana* and *E. steidae* infect rabbits. *E. canis* in dogs, *E. felina* in cats, *E. bovis* in cattle and *E. intricata* in sheep and goats are also common. *Isospora*, intestinal parasites of man and other animals, include one truly pathogenic species of man, *I. hominis*, *I. felis*, *I. bigemina* and *I. rivolta* infect cats and dogs and occur in mucous membranes of ileum. Their transmission is by cylindrical oocysts. Species of *Babesia* are intra-erythrocytic parasites of various vertebrates. *Babesia bigemina* of cattle causes the lethal haemoglobinuric fever, red-water fever or Texas fever. *B. equi* in horses, *B. rohdani* in rodents, *B. felis* in cats, *B. motasi* in goats, etc., cause malignant jaundice, anaemia and fever in their respective hosts.

(d) *Pathogenic ciliates*. *Balantidium coli* is the only important ciliate pathogenic parasite. It is found in the intestine of man and often in frogs.

## Parasitism in Protozoa

### [I] Parasite and parasitism

The word *parasite* has been derived from two Greek words, *para* = beside, and *sitos* = food, which means eating beside one another. *Parasites* may be defined as "the species which exist at the expense of certain other species, called *hosts*, and are biologically and economically closely connected with them throughout their life-span", *Parasitism* is an association between the parasites and their hosts. It may be defined as "an association between two organisms of such kinds that one (parasite) lives and feeds, temporarily or permanently, either in or on the body of the other (host)".

Parasitic species occur in all groups of Protozoa, and one of them, Sporozoa, is exclusively parasitic. A brief account of parasitism in Protozoa may be given under the following headings :

### [II] Types of parasites

1. **Ectoparasites.** Those Protozoa which inhabit the external surface of their hosts. *Hydramoeba hydroxena*, feeding on the ectodermal cells of Hydra and *Ichthyophthirius multifiliis*, burying in the epidermis of freshwater fishes, are examples of ectoparasitic Protozoa.

2. **Endoparasites.** Those parasites which live inside the body of their hosts. These are divided into four categories :

(a) *Parasites of digestive tract.* Those endoparasites which dwell inside the lumen of alimentary canal of hosts. *Giardia lamblia*, a parasitic flagellate, *Entamoeba histolytica*, a parasitic amoeba, *Isospora hominis*, a parasitic coccidian, *Balantidium coli*, a parasitic ciliate, are all intestinal endoparasites of man.

(b) *Parasites of mouth.* Those endoparasites which reside in mouth cavity of hosts. In man, *Entamoeba gingivalis* and *Trichomonas tenax* are found in pockets between the gums and teeth.

(c) *Parasites of genital tract.* Those endoparasites which inhabit the genital tract of hosts. In human female, *Trichomonas vaginalis* lives in vagina.

(d) *Parasites of body tissues.* Those parasites which live within tissues of hosts and may enter through skin or from digestive tract. Species of *Trypanosoma*, *Leishmania*, *Plasmodium* and *Babesia* are common blood parasites of vertebrates. Species of *Eimeria* and *Isospora* occur in the epithelial lining of gut of their respective hosts.

3. **Hyperparasites.** These are Protozoa parasitizing other species of parasitic Protozoa. For instance, the opalinid (*Zelleriella*) which lives in the frog's intestine, is parasitized by a certain amoeba. *Nosema notabilis* parasitizes *Sphaerospora polymorpha* which is a parasite of urinary bladder of toad fish.

4. **Pathogenic parasites.** Most of the parasitic protozoans do not cause disease conditions in their hosts except producing minor symptoms. On the other hand, certain parasites act as disease-causing organisms in man and other animals. Such parasites are referred to as *pathogenic parasites*. Important pathogenic



parasites of man are *Leishmania donovani*, *Trypanosoma gambiense*, *Plasmodium vivax*, *Entamoeba histolytica*, etc.

### [III] Host specificity

Two general trends are exhibited regarding the development of host specificity in parasitic Protozoa. Firstly, some parasites can successfully parasitize a wide variety of hosts. *Trypanosoma*, *Entamoeba* and *Eimeria* belong to this group. Secondly, some parasites have become restricted to only a few specific host. *Coccidia* of mammals (e.g. *Plasmodium*) are such parasites.

### [IV] Transmission

Protozoan parasites have different ways of infecting their hosts. *Entamoeba gingivalis* is transferred directly from one man to another through mechanical contact, like kissing (direct transfer). Some, such as *Entamoeba histolytica* and *Eimeria tenella*, are transferred by cysts in water or food (contaminative transfer). Species of *Trypanosoma*, *Plasmodium*, etc. are transmitted by certain invertebrate vectors (inoculative transfer). Transmission by invasion of ovary or egg takes place for species of *Babesia*. Placental transference has been reported for *Plasmodium* in man (congenital transfer).

### [V] Life cycle

Many parasites, such as *Eimeria* and *Monocystis*, have only a single host during their life cycle, only a part spent outside the host. These are called *monogenetic* parasites. Other protozoan parasites (e.g. *Plasmodium*, *Trypanosoma*) have two or more hosts, belonging to widely separated animal groups. The two hosts are usually designated as the *primary host*, in which the parasite's ancestors evolved and the *secondary host* or *vector*, which acts as a transmitting agent for the parasite to the other host. These are called *digenetic* parasites. If the parasite undergoes part of its life cycle in vector, its transmission is called *cyclical*, if not, it is referred to as *mechanical* transmission. Besides the two hosts, some other animals may be infected by the parasites and serve as a source for infecting other animals. These animals constitute the *reservoir hosts*.

### [VI] Effects of parasites on their hosts

Parasitic Protozoa bring about change within their hosts to a lesser or greater degree. Some prove to be injurious for their hosts, while others produce almost no effect. *Entamoeba histolytica* destroys host's large intestine causing large ulcerations. *Eimeria stiedae* is known to cause hyperplasia of the hepatic cells of rabbits. The coccidian parasite of earthworm, *Polymnia nebulosa*, brings about hypertrophy of the sperm mother cells. The malarial parasite of birds, *Plasmodium gallinaceum*, clogs the fine blood capillaries. Similar examples are not few but numerous in the world of protozoan parasites.

### Protozoa and Human Diseases

Most of the diseases affecting human beings are caused by living organisms. Of the parasitic species of *Bacteria*, *Protozoa*, *Fungi*, *Viruses*, *Helminths* and *Arthropods*, some are pathogenic for man. Diseases occur as a result of interaction between pathogens (parasites) and human host under specific environmental conditions. This interaction is referred to as *infection* or *infectious process*, the manifestation of which is always some *infectious disease*. Disease is caused when pathogenic parasites alters the human body's normal vital activities as a result of morphological and physiological damage.

Pathogenic parasites, belonging to various groups of animal kingdom, share the following common characteristic features :

- (1) All are *obligatory parasites*, i.e., they depend for their existence upon their hosts.
- (2) All show *host specificity*, i.e., they harbour selective hosts.
- (3) They secrete toxic substances which cause the particular disease.
- (4) They complete their life cycle in one or more than one host.

Parasitic species occur in all classes of Protozoa. Approximately 15 different genera have been found living as parasites within the human body. While the majority of these have relatively little effect upon their hosts, certain pathogenic parasites cause some of the worst human diseases. Some of these are described below.

**[I] Amoebiasis**

*Amoebiasis*, also known as *amoebic dysentery*, is caused by *Entamoeba histolytica* (Sarcodina). Its trophozoites, that penetrate the wall of hosts intestine (colon), secrete histolytic enzymes and feed upon its cells causing the formation of ulcers. These ulcers rupture and discharge blood and mucus into the intestine that pass with stools. The trophozoites, under certain circumstances, reach liver, lung and brain where they cause abscess formation.

No intermediate host is involved in the life cycle of *E. histolytica*. Transmission of parasite from man to man takes place through tetranucleate cysts. Prior to cyst-formation the trophozoite changes into a smaller *minuta form*, which then encysts to form a tetranucleate cyst. These cysts are avoided with faecal matter and contaminate food and water and spread into new hosts. Houseflies help in its rapid spread.

Amoebic dysentery is endemic in warm countries. *Emetin*, *Fumagillin*, *Erythromycin*, *Aureomycin*, *metromidazole* etc. are the drugs which provide quick relief.

**[II] Diarrhoea**

*Diarrhoea*, which is characterized by loose bowels, is caused by a flagellate parasite, *Giardia* (= *Lamblia*) *intestinalis*. It harbours the small intestine of man. Its cell body is pear-shaped with dorsal side convex and ventral side flattened and deepened anteriorly to form a suction groove. It bears two nuclei and four pairs of flagella arranged symmetrically.

The parasite divides by binary fission to multiply rapidly and feeds upon amino acids and vitamins contained in food within the intestine. This causes intestinal disorders leading to epigastric pain, abdominal discomfort, loss of appetite and headache.

Transmission of parasite takes place through cysts which are voided with faeces and enter new hosts in food or water. Infection of *Giardia* is more in children than in adults. *Chloroquin*, *Camoquin*, *Atebrin*, etc., are effective drugs for its treatment.

**[III] Trypanosomiasis**

*Trypanosomiasis* is caused by the species of *Trypanosoma* which are flagellate parasites of

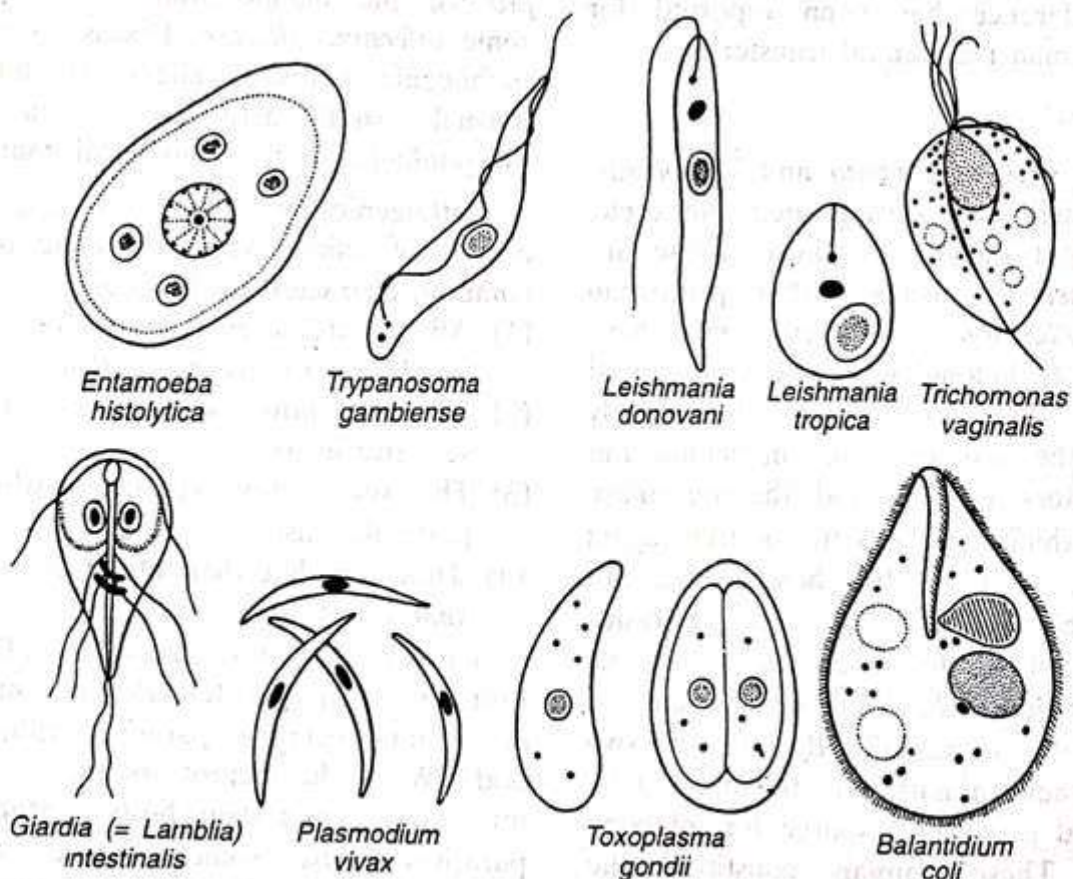


Fig. 16. Some pathogenic protozoan parasites of man.

blood (in vertebrate host) and gut (in invertebrate host). These are most dreadful of all pathogenic protozoans. *Sleeping sickness* is a dangerous disease of man in tropical Africa. Its causative agent is *T. gambiense* which is transmitted by a tsetse fly, *Glossina palpalis*. Infestation of the lymph system leads to glandular swelling which is symptomatic for sleeping sickness. Later, the parasites penetrate into cerebro-spinal fluid, cause damage to brain and bring about lethargy which is characteristic for sleeping sickness. If untreated, the disease leads to death. *Germanin* and *Lomidine* are used to treat blood and lymph infections and *Tryparsamide* for brain infection.

*T. cruzi* is the causative agent of *American trypanosomiasis* or *Chaga's disease*. It is widespread in south and central America and is more common in children. It is transmitted by bugs of the genus *Triatoma*. Transmission to man is not due to bug's bite but through its faeces. Swelling of body parts, severe headache and continuous fever are symptomatic for the disease. Anaemia and injury to heart muscles lead to death. No permanent cure has yet been suggested. *Primaquine* and *Puromycin* are used for temporary relief.

#### [IV] Leishmaniasis

*Leishmaniasis* is caused by the species of *Leishmania*, the parasitic flagellates that inhabit macrocytotic cells in body organs in vertebrates and gut in insect hosts. *Leishmania donovani* is the causative agent of *Kala-azar* or *visceral leishmaniasis*. The disease is widespread in India, South China and in Mediterranean countries. A major characteristic of the disease is a considerable enlargement of spleen due to blockage of reticulo-endothelial system by parasites. It is usually fatal, if untreated. Treatment with antimony compounds proves useful. *Sodium antimonyl gluconate*, *Neostibosan* and *Urea stibamine* are most effective medicines.

*L. tropica* is the causative agent of *skin leishmaniasis* (Oriental sore). Infection is restricted to endothelium of skin capillaries and leads to lump-like boils. Disease is endemic in warmer countries, especially south-west Asia,

Eastern Mediterranean and tropical America. Treatment includes regular cleaning and dressing of boils and injecting *Atebrine* and *Berberine sulphate* around them.

*L. brasilliensis* causes a disease called *Espundia*, producing multiple sores over large areas of body. Development of ulceration in nasal cavities, mouth and pharynx is quite frequent. Injection of antimony drugs has proved fruitful for curing the disease.

*Leishmania* species are transmitted from man to man by bites of sandflies belonging to the genus *Phlebotomus*.

#### [V] Trichomoniasis

This disease is caused by the species of *Trichomonas*, the flagellate protozoans. Its body is rounded with one nucleus, an axostyle, a parabasal body, 4-6 flagella and one backwardly directed flagellum. Most common pathogenic species is *Trichomonas vaginalis* that inhabits vagina of women and causes *vaginitis*. Disease is characterized by inflammation, burning sensation, itch and frothy vaginal discharge. Transmission is always through sexual intercourse by male members who act as intermediaries. Even in man, the infection of urethra and prostate is not uncommon. Arsenic and iodine drugs and antibiotics like *Aureomycin* and *Terramycin*, have proved helpful in combating the disease.

#### [VI] Malaria

Malaria is caused by the species of *Plasmodium*, the sporozoan parasites. It is transmitted through bite of female anopheles mosquito. In man, the parasite attacks liver cells and red blood cells. A toxic substance, *haemozoin*, released by parasite causes malaria.

Malaria is most destructive for man. It is widespread in the temperate, tropics and subtropics. It is characterized by the periodic attacks of fever. The fever is repeated in tertian malaria caused by *P. vivax* every third day; in ovale malaria caused by *P. ovale* every third day; in quartan malaria caused by *P. malariae* every fourth day, and in malignant tertian malaria caused by *P. falciparum* every third day. Various drug which are now used in the

treatment of malaria include *Quinine*, *Atebrin*, *Chloroquine*, *Camoquine*, *Pamaquine*, *Paludrine*, *Daraprim*, etc.

### [VII] Toxoplasmosis

This disease is caused by *Toxoplasma gondii*, a sporozoan parasite. It is widely distributed all over the world. The parasite occupies the cells of the reticulo-endothelial and central nervous systems. The parasites multiply by *endodyogeny* but under certain conditions large cysts are also produced. Usually the parasite remains in hosts body without causing any symptoms, but if an infected woman conceives, abortion takes place. If infection of *T. gondii* occurs during

pregnancy, in third trimester then nervous system of the developing foetus is affected and the infant dies after birth. *Daraprim*, combined with *sulphadiazine* has been found to be an effective remedy.

### [VIII] Balantidial dysentery

This disease is caused by *Balantidium coli*, an intestinal ciliate. It is characterized by diarrhoea and ulceration of the large intestine. Transmission of parasite to a new host takes place through cysts in contaminated food or water. *Carbarsone*, *Aureomycin* and *Terramycin* are ideal for curing the disease.

## IMPORTANT QUESTIONS

### » Long Answer Type Questions

1. Mention the chief types of locomotor organelles of Protozoa. Explain briefly how they bring about locomotion.
2. Describe the organs of locomotion in *Amoeba*, *Euglena*, *Paramecium* and *Monocystis*.
3. Write an essay on: (i) Nutrition in Protozoa. (ii) Parasitism in Protozoa. (iii) Protozoa and Human Diseases. (iv) Body coverings and Skeletons in Protozoa. (v) Locomotion in Protozoa.
4. Give a brief account of the modes of reproduction in Protozoa.
5. Discuss the economic importance of Protozoa.
6. Distinguish between: (i) Amphimixis and Syngamy. (ii) Cytostome and cytophyge, (iii) Gametogony and sporogony, (iv) Macronucleus and micronucleus, (v) Saprozoic and saprophytic nutrition.
7. Name some important pathogenic species of Protozoa that cause diseases in man. Describe the methods of their control.
8. Write short notes on: (i) Amoebiasis, (ii) Contractile vacuole and osmoregulation, (iii) Euglenoid movement, (iv) Holozoic nutrition, (v) Hyperparasites, (vi) Leishmaniasis, (vii) Lobopodia, (viii) Mixotrophic nutrition, (ix) Multiple fission, (x) Nucleus in Protozoa, (xi) Parasitism, (xii) Pathogenic Protozoa, (xiii) Skeleton in Protozoa, (xiv) Symbiotic Protozoa, and (xv) Trypanosomiasis.

### » Short Answer Type Questions

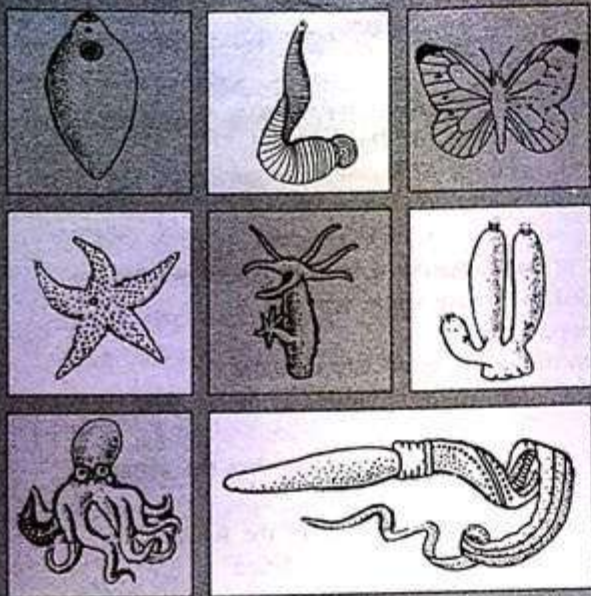
1. Which protozoan parasite exhibits schizogony?
2. What is incubation?
3. What is exflagellation?
4. Name a symbiotic protozoan present in digestive tract of termites.
5. What is the study of protozoans called as?
6. Give an example for coprozoic protozoan.
7. Give an example of a protozoan with (a) holophytic nutrition, (b) mixotrophic nutrition
8. Name the different forms of flagella found in Protozoa.
9. With reference to Protozoa, define commensalism and give an example.
10. Mention the different types of flagella found in Mastigophora.
11. Define symbiosis with reference to protozoa and give an example of a type where both organisms are animals.
12. What is holozoic nutrition? Give two examples from Protozoa.
13. With reference to Protozoa, what is meant by syngamy?
14. Distinguish between sporonts and sporozoites.
15. Describe the structure and types of cilia in ciliophora.
16. With reference to their habitat distinguish between coccidia and haemosporidia.
17. What is osmoregulation? Give an account of the process of osmoregulation in Protozoa.
18. Write the functional value of chromatophores in phytomastigina. Do the chromatophores have any bearing on the phylogenetic implications of the flagellates?
19. Differentiate between lobopodium and reticulopodium.
20. Distinguish between dinoflagellata and hypermastigata based on their flagellar condition.
21. Compare the organization of the Flagellata and Ciliophora and give reasons for believing that ciliophora are more advanced than the flagellata.
22. Distinguish between paedogamy and hologamy in Protozoa.

Multiple Choice Questions

1. Alternation of sexual and asexual generation is known as :  
 (a) digenesis (b) metagenesis  
 (c) metamorphosis (d) dimorphism
2. What is meant by intracellular parasite ?  
 (a) parasite on the outer surface of cells  
 (b) parasite between the cells  
 (c) parasite inside the cells  
 (d) parasite which interconnects neighbouring cells
3. What is a vector ?  
 (a) disease transmitting host  
 (b) natural reservoir of disease  
 (c) non pathogenic protozoa  
 (d) pathogenic protozoa
4. Down stroke and recovery stroke are the two phases of :  
 (a) movement of contractile vacuole  
 (b) flagellar movement  
 (c) movement of food vacuole  
 (d) amoeboid movement
5. The presence of slender pseudopodia with interlacing branches to form a net work is the characteristic feature of the order :  
 (a) radiolaria (b) lobosoa  
 (c) mycetozoa (d) heliozoa (e) foraminifera
6. Contractile vacuole is noticed among *Amoeba* in :  
 (a) sea water (b) fresh water  
 (c) both (d) none
7. One-celled animals reproduce by :  
 (a) budding (b) splitting  
 (c) cutting (d) regeneration
8. The contractile vacuole in protozoans is chiefly concerned with the process of :  
 (a) digestion (b) osmoregulation  
 (c) excretion (d) assimilation
9. Food capture is the function of :  
 (a) food vacuole (b) reticulopodium  
 (c) eyespot (d) paramylum
10. Karyosome consists of two materials. What is the achromatic substance present in it ?  
 (a) plastin (b) chromosomes  
 (c) paramylum (d) eyespot
11. The shell of *Polystomella* is made up of :  
 (a) calcium carbonate (b) silicon  
 (c) chitin
12. Cytopyge is found in :  
 (a) *Amoeba* (b) *Paramecium*  
 (c) *Euglena* (d) *Trypanosoma*
13. The locomotory organelle of foraminifera are :  
 (a) lobopodia (b) filopodia  
 (c) axopodia (d) reticulopodia
14. The function of contractile vacuole is increased when :  
 (a) it is needed to remove waste products  
 (b) it has stopped feeding  
 (c) the cell membrane is permeable to water  
 (d) the concentration of water outside is higher than that inside  
 (e) the pond water contains more solute than the animal's body
15. Contractile vacuole in protozoans serves the function of :  
 (a) excretion (b) osmoregulation  
 (c) digestion (d) respiration
16. What would happen if some fresh water protozoans are placed in a medium of high osmotic potential ?  
 (a) the contractile vacuole will work faster  
 (b) the contractile vacuole grows larger  
 (c) the contractile vacuole shows no change  
 (d) the contractile vacuole does not form
17. The probable function of contractile vacuole is :  
 (a) to remove salts only  
 (b) to remove excess water  
 (c) to remove undigested food particles  
 (d) to transport water from one location to the other
18. When we transfer a protozoan living in sea to a fresh water medium :  
 (a) it bursts (b) it enlarges but shrinks again  
 (c) it shrinks (d) it remains static
19. If marine protozoan is placed in fresh water its body will :  
 (a) rupture (b) shrink  
 (c) do not change (d) first enlarge then become normal
20. Cilia in *Paramecium* arise from :  
 (a) basal granules (b) pellicle  
 (c) cytopharynx (d) trichocysts
21. Bioluminescence represented by :  
 (a) *Noctiluca* (b) *Giardia*  
 (c) *Volvox* (d) *Trichomonas*
22. Subcellular physiological division of labour occur in :  
 (a) Protozoa (b) Porifera  
 (c) Cnidaria (d) all

Answers

1. (b) 2. (c) 3. (a) 4. (b) 5. (e) 6. (b) 7. (b) 8. (b) 9. (b) 10. (c) 11. (a) 12. (b) 13. (d) 14. (c) 15. (b) 16. (d) 17. (b) 18. (b) 19. (b) 20. (a) 21. (a) 22. (a)



## Organization of Metazoa

# 16

Chapter

### What are Metazoa ?

On the basis of the number of cells forming the body, the Animal Kingdom is generally divided into two Sub-kingdoms, *Protozoa* and *Metazoa*. Members of the *Subkingdom Protozoa* are unicellular or acellular animals composed of single cells or colonies of like cells. On the other hand, members of the *Subkingdom Metazoa* are multicellular animals composed of many cells, usually arranged in distinct layers, tissues and organs.

Metazoans may be defined as holozoic multicellular organisms which develop from embryos. Their body cells are generally differentiated into tissues and organs\* which are specialized for different functions. Their gametes are never formed within unicellular structures but are produced within multicellular sex organs or

at least within surrounding somatic cells. This definition holds good to differentiate the Sub-kingdom Metazoa from the Subkingdom Protozoa of the Animal kingdom.

In short, Metazoa can be defined as multicellular animals, or as cellular animals, or simply as animals.

### Metazoa versus Metaphyta

The usual concept of plants and animals does not apply satisfactorily to non-multicellular or acellular organisms. Some of them have the characteristics of animals (*Protozoa*), some of plants (*Protophyta*) while others possess both animal and plant characteristics. This difficulty is met with by regarding all non-multicellular (acellular) organisms as *Protista*. The term was proposed by Haeckel in 1866. It includes

\* Body of all Metazoans is not organized on tissue and organ level of organization. Poriferans are at cellular grade of organization and coelenterates are at tissue grade of organization.

bacteria, slime moulds (Mycetozoa) and Protozoa. However, in case of multicellular organisms, a fair and satisfactory distinction can be made between animals or *Metazoa* and plants or *Metaphyta*.

Plants or *Metaphyta* are autotrophic multicellular organisms. They possess cellulose cellwalls and contain chlorophyll for synthesis of complex organic foodstuffs by photosynthesis (holophytic nutrition). They have inconstant body form, mostly external organs and limited movement (stationary).

On the other hand, animals or *Metazoa* are heterotrophic multicellular organisms. They do not have cellulose cell walls and lack chlorophyll (holozoic or saprozoic nutrition). They have a fairly constant body form, mostly internal organs, pronounced movement and definite irritability.

In general, *Metaphyta* (plant) body architecture reflects a way of life based on photosynthesis and attachment or sessility. Whereas *Metazoa* (animal) body architecture reflects a way of life based on alimentation and locomotion.

### Lower and Higher Metazoa

In Table 3 of Chapter 2, we saw that animal phyla can be arranged in several different ways on the basis of their structural traits, as follows :

- (1) *Asymmetrical* (most Porifera), *radially symmetrical* (Coelenterata) and *bilaterally symmetrical* (all others).
- (2) *Diploblastic* (Porifera, Coelenterata) and *triploblastic* (all others).
- (3) *Acoelomate* (Porifera to Platyhelminthes), *pseudocoelomate* (Entoprocta, Acanthocephala, Aschelminthes) and *coelomate* (all others).
- (4) *Segmented* (Annelida, Arthropoda, Tardigrada, Chordata) and *unsegmented* (all others).
- (5) *Chordates* (Protochordata, Vertebrata) and *non-chordates* (all others).
- (6) *Vertebrates* (higher chordates) and *invertebrates* (all others).

1. Lower Metazoa. Porifera, Coelenterata, Platyhelminthes, Aschelminthes, Entoprocta and Acanthocephala are generally called *Lower*

*Metazoa*. They are unsegmented, radially or bilaterally symmetrical, diploblastic or triploblastic, and acoelomate or pseudocoelomate.

2. Higher Metazoa. The remaining phyla (Mollusca, Annelida, Arthropoda, Echinodermata and Chordata) are known as *Higher Metazoa*. They are triploblastic and truly coelomate animals. Except chordata, all are non-chordates or invertebrates.

However, the Lower and Higher Metazoan Phyla, based on structural traits, must not be confused with the *Minor* and *Major Phyla* which are based on different criteria, such as the number of species and individuals and their participation in ecological communities. (See chapter 2).

### Metazoan Organization

Relationships between animals, or groups of animals, are best explained by their comparative morphology and embryology. Animals show various patterns in their morphology. The gross external morphology of animals falls under a limited number of patterns (criteria). These include form of animals (*symmetry*), arrangement of body parts in segments (*metamerism*), formation of a head (*cephalization*), and progressive sequence of specialization of structure (*levels or grades of organization*). Similarly, the criteria of internal morphology are differences in formation of body cavity (*coelom*) and reproduction (*embryology*), etc.

### Symmetry and its Significance

Symmetry means an arrangement of body parts into geometrical designs. It refers to the division of body into equal parts by lines or planes. Current zoological ideas about symmetry derive chiefly from Haeckel. An animal is called *symmetrical* when a plane passing through its centre will divide it into similar halves. When an animal cannot be divided into like parts by a plane, it is called *asymmetrical*. All animals are either asymmetrical or symmetrical. Examples of asymmetrical animals are most sponges, some Protozoa (*Amoeba*) and few others.

Certain terms are often used when explaining symmetry. An *axis* is an imaginary line passing through the centre of body, such as longitudinal

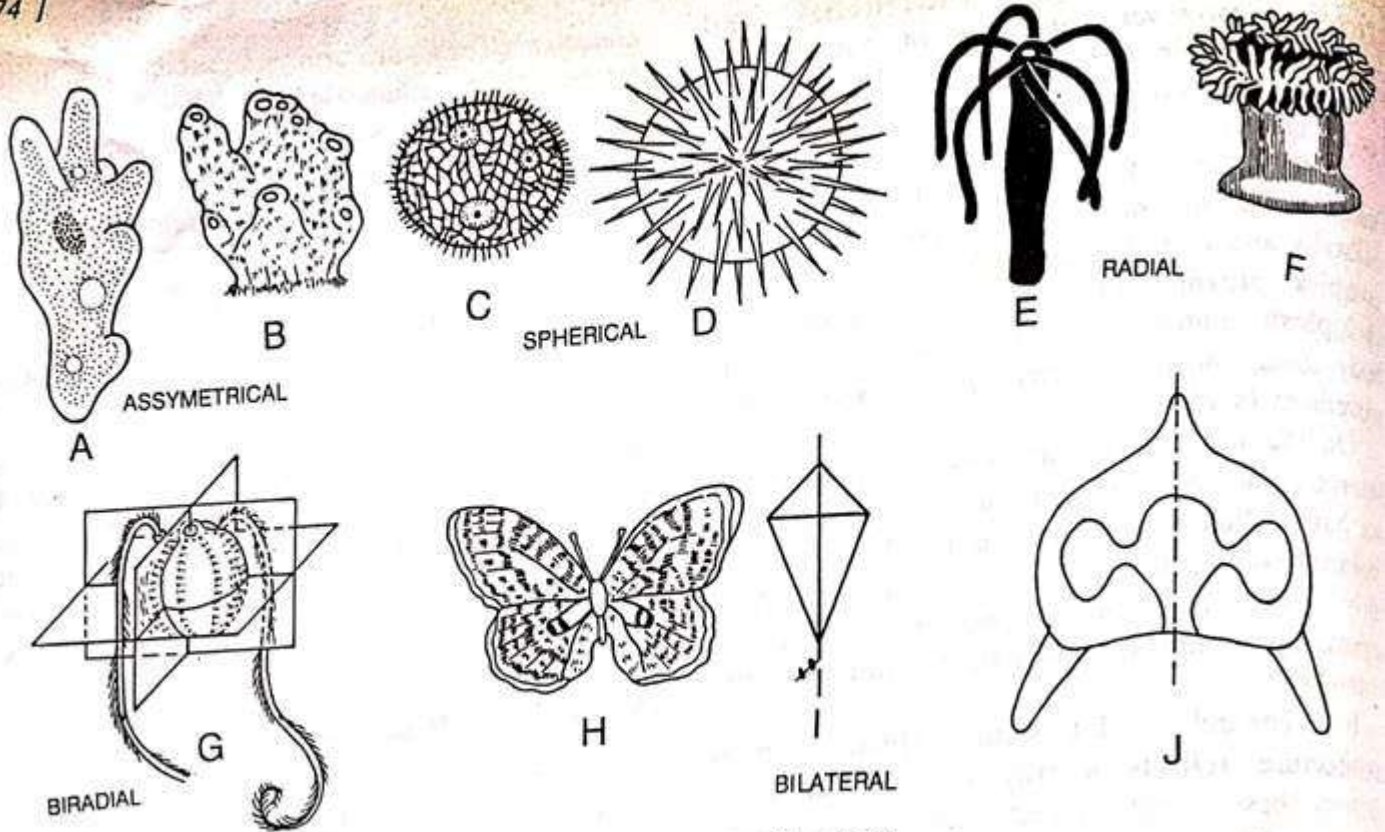


Fig. 1. Types of symmetry in animals.

axis and oral-aboral axis. Either end of an axis is termed a *pole*. Thus, each axis has two poles. A *plane* of symmetry is a straight line that divides organisms into corresponding halves.

Metazoa display only two types of symmetry, *radial* and *bilateral*. Two other types of symmetry are also recognized, *spherical* and *biradial*. Protozoa are not only asymmetrical but display all four types of symmetry in their diverse body forms.

**1. Spherical symmetry.** It is found in animals whose body has the shape of a sphere. All planes that pass through the centre will cut it into similar halves. Some protozoans (e.g. *Volvox*, *Heliozoa*, *Radiolaria*) have spherical symmetry, and it is adapted for free-floating or rolling movements.

**2. Radial symmetry.** The body is in the form of a flat or tall cylinder. Many similar body parts, called *antimeres*, are arranged around one main, central or longitudinal axis in a circular or radiating manner like the spokes of a wheel. All the lines passing through this longitudinal axis, in any plane, will divide the body into equal halves or antimeres. The surface having mouth is the *oral surface*, and the opposite surface is the

*aboral surface*. Examples are echinoderms and most coelenterates (e.g. *Hydra*).

Radial symmetry is best suited for a sessile existence. Most of them are attached by the aboral surface. Some are free-swimming but remain at the mercy of water currents. Due to similarity of antimeres, their sensory receptors are equally distributed all around the periphery. This enables them to receive stimuli and to meet the changes of the environment equally from all directions. They can obtain food or repel enemies from all sides.

In the animal kingdom, radially symmetric phyla are Porifera, Coelenterata, Ctenophora and Echinodermata. Out of these, only Coelenterata and Ctenophora display a fundamental radial symmetry. Both the phyla were grouped together by Hatschek (1888-91) under the Division *Radiata*. Adult Porifera are mostly asymmetrical but they start life from a radially symmetric larva. On the other hand, larval stage of Echinodermata has bilateral symmetry, but the adults become radially or pentaradially symmetrical.

**3. Biradial symmetry.** It is a variant form of radial symmetry found in Ctenophora and most



Anthozoa (e.g. anemones), and is best fitted for a floating life. Such symmetry has only 2 pairs of symmetrical sides. There are only 2 planes of symmetry, one through the longitudinal and sagittal axes, and the other through the longitudinal and transverse axes, which will divide the animal into equal halves.

4. **Bilateral symmetry.** In most higher animals, the longitudinal axis of body runs from the anterior end (head) to the posterior end (tail). There is a single plane, the *median longitudinal* or *sagittal* plane, through which the body can be divided into two similar right and left halves. This is called *bilateral symmetry*. Besides right and left sides, an upper or *dorsal* surface and a lower or *ventral* surface are also recognizable, which are unlike because they are exposed to different conditions.

Bilateral symmetry is characteristic of the most successful and higher animals, including the remaining invertebrates and all vertebrates. In most of them, the anterior end is differentiated into a *head*.

First phylum of animal kingdom to exhibit bilateral symmetry is the phylum Platyhelminthes. All bilaterally symmetrical metazoans were grouped together by Hatschek (1988-91) under the Division *Bilateria*. As already mentioned earlier, some Bilateria, such as echinoderms, display a radial symmetry which has been secondarily derived from bilateral ancestors due to assumption of an attached mode of life by adults.

### Cephalization and Polarity

Bilateral symmetry is correlated with the locomotor movements brought about by these animals. One end of their body, usually containing the mouth, always moves forward in a particular direction. It is the first to come in contact with the environment, so that there is great concentration of nervous tissue and sense organs at this anterior end called *head*. The posterior or rear end is usually equipped with some locomotory organ. This modification of anterior or oral end of the animal into a definite head is called *cephalization* which is characteristic of most bilateral animals.

Cephalization is always accompanied by a differentiation along an antero-posterior or oral

aboral axis. This condition is known as *polarity*, and it usually involves gradients which refers to ascending or descending activities between anterior and posterior ends.

### Metamerism

#### [I] Meaning of metamerism

When the segmentation in bilateral animals, such as annelids, involves a longitudinal division of the body into a linear series of similar sections or parts, it is termed *metameric segmentation* or *metamerism*. Each section or part is called a *segment*, *somite* or *metamere* (Gr., *meta*, after; *meros*, part). Each metamere typically repeats some or all of the various organ units. The term metamerism is applied only when organs of mesodermal origin are so arranged. The primary segmental divisions are the body wall musculature and sometimes the coelom. This in turn imposed a corresponding metamerism on the associated supply systems (nerves, blood vessels and excretory organs). Longitudinal structures such as gut, principal blood vessels and nerves extend the entire length of body, passing through successive segments. While other structures, such as gonads, are repeated in each or few segments only.

Metamerism is always limited to the trunk region of the body. The *head* (or acorn) represented by the prostomium and bearing the brain and sense organs, and the *pygidium*, represented by the terminal part of the body which carries the anus, are not metameres. New segments arise just in front of the pygidium; thus the oldest segments lie just behind the head.

#### [II] Metameric animals

Metameric segmentation of the body, encountered for the first time in Annelida, is of considerable interest because the most successful groups of animal kingdom, i.e., Arthropoda and Vertebrata, also have their parts metamericly repeated. At least one group of Mollusca (Monoplacophora) also exhibits metamerism: Metameric segmentation seems to have evolved three times independently in animal kingdom (i) in the annelids-arthropods, (ii) in the chordates and in (iii) cestodes.

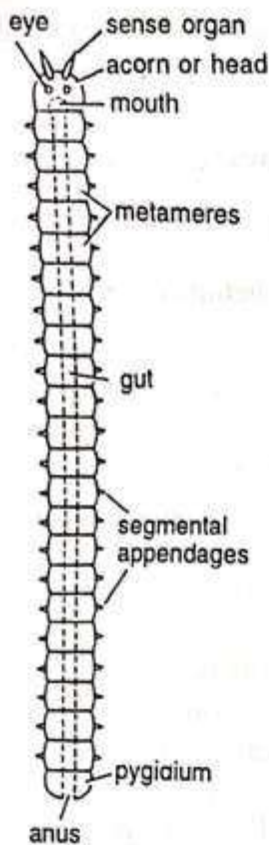


Fig. 2. A typical metameric animal, such as an annelid worm.

### [III] External and internal metamerism

Metamerism is conspicuously visible in most annelids, both *externally* as well as *internally*. The common earthworm is a good illustration of both external and internal metamerism. Its body consists of a great number of similar segments and all the body organs, such as musculature, setae of locomotion, blood vessels, nerves, ganglia excretory organs and gonads, etc., are repeated segmentally. Even the coelom is divided into segmental compartments by the intersegmental transverse mesenteries, called *septa*. Only the digestive tract remains unaffected, but it also extends through every segment. In arthropods, metamerism is chiefly *external*, while man and other vertebrates show an *internal metamerism* of body muscles, nerves, certain blood vessels, vertebrae and ribs.

### [IV] Complete and incomplete metamerism

In annelid worms, metamerism is *complete*, affecting practically all the systems. The metameres are essentially alike or *homonomous*, each having segmental blood vessels, nerves,

(Z-1)

nephridia and coelomoducts. This condition is called *homonomous metamerism*. On the other hand, higher animals such as arthropods and vertebrates, show *incomplete metamerism*. Because of division of labour, the segments or metameres of different regions of their body become greatly dissimilar. This is called *heteronomous metamerism*. However, *incomplete metamerism* should not be confused with the repetition of single organs such as shell plates or gills in certain unsegmented animals like molluscs.

In arthropods and vertebrates, metamerism is more complete and metameres are uniform and clear in the larval and embryonic stages. But, metamerism becomes obscure in the adult due to subsequent specialization or modification, so that the segments are no longer similar. It may result from simplification, by loss of metameres, by fusion of segments (cephalization), by differentiation between segments, by disappearance of organs, or by development of other structures, such as limbs. Heteronomous condition always appears first at the anterior end and progresses posteriorly. In segmented animals, varying degrees of specialization are met with some of which are extreme.

### [V] Origin and evolution of metamerism (Theories)

How metamerism has been brought about is still doubtful. No satisfactory reason can be given for the origin of metamerism. Various hypotheses have been proposed to explain the origin of metamerism, but none is acceptable in the absence of convincing evidence. The main theories concerning the origin of metamerism emphasize primarily either repetition of organs or mesodermal segmentation and correlate it with the origin of coelom.

1. **Pseudometamerism theory.** This theory stresses that metamerism developed secondarily as a result of repetition of body parts, such as muscles, nerves, nephridia, coelom, blood vessels etc., in a single individual.

Such serial repetition of organs, such as testes, yolk glands and transverse connectives or two nerve cords, is seen in some elongated turbellarians and nemertean. Later, a segmented condition was obtained by the formation

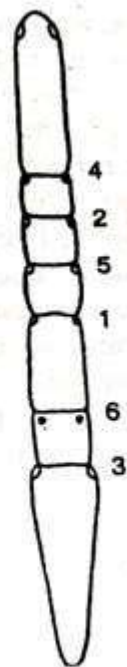
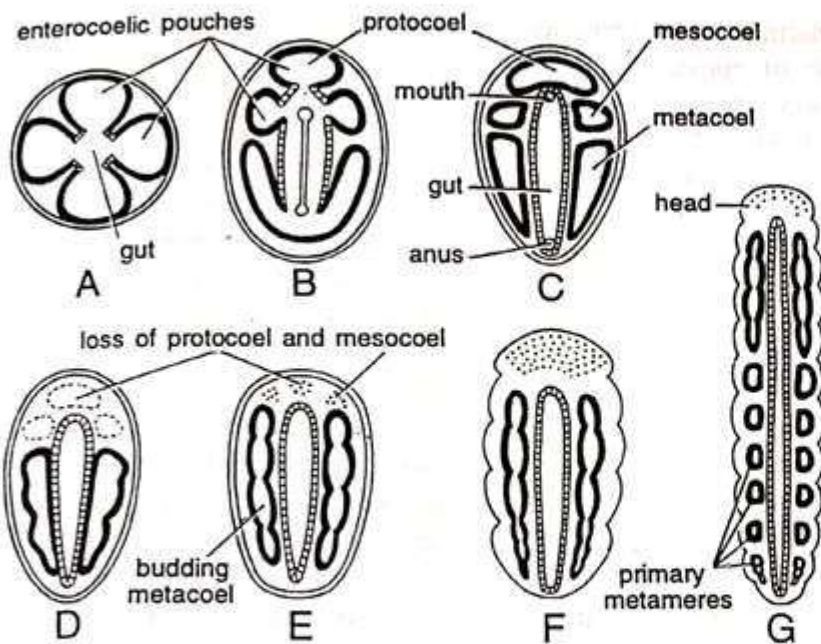


Fig. 3. Diagrams illustrating the Enterocoel-Cyclomerism theory of metamerism. A-C—Transformation of enterocoelic pouches of a radiate ancestor into coelomic pouches of a bilateral ancestor. D-E—Loss of protoceol and mesocoel. F-G—Subdivision of metacoel producing primary metameres.

Fig. 4. Diagram showing development of a chain of zooids in rhabdocoel flatworm *Stenostomum*, according to Corm Theory. Numbers indicate sequences of fission planes.

cross-partitions in between them, so that each segment received a repeated part of each system. This process is witnessed even today in the formation of somites in larval and adult stages of some Annelida, in which cross-partitions develop after the basic segmentation is already laid down. Such segmentation was probably an adaptation for an undulatory mode of swimming. However, all ribbon-like animals swim in this way, whether segmented or not. This theory is supported by Hyman (1951) and Goodrich.

**2. Cyclomerism theory.** Originally proposed by Sedgwick (1884) and greatly supported by Temane (1950, 1963), the cyclomerism theory is a corollary of the enterocoelous theory for the origin of mesoderm and coelom. This theory assumes that coelom originated in some ancestral radiate actinozoan coelenterate, through the separation of four gastric or enterocoelic pouches from the central digestive cavity or gut. Division of two pouches resulted into three pairs of coelomic cavities—the protoceol, mesocoel and metacoel, in the protoceolomate or ancestral coelomate. Loss of protoceol and mesocoel led to the unsegmented coelomates, such as molluscs and sipunculids. Later subdivision of metacoel

produced primary segments, leading to the segmented annelids. The phylogenetic implication of this theory is that all bilateral metazoans were originally segmented and coelomate, and that the acoelomate unsegmented groups (flatworms, nemerteans) have lost these characters secondarily.

**3. Corm or fission theory.** According to this theory, metameric segmentation resulted when some non-segmented ancestor divided by transverse fission repeatedly or by asexual budding producing a chain of sub-individuals or zooids, united end to end due to their incomplete separation. This occurs in some Platyhelminthes and Annelida even today. Later, with the passage of time, these subindividuals or segments gradually became integrated morphologically as well as physiologically into one complex individuality. A segmented animal, according to this view, is a chain of completely coordinate subindividuals. This theory was supported largely during the 19th century and greatly elaborated by Perrier (1882). The chief objection to this theory is the lack of gradations of age in such a chain of zooids, which is true of segments in a metameric

animal, such as an annelid. In platyhelminthes and scyphozoan strobilae the sequence of zooid formation is never serial, fission occurs always somewhere in the middle of the chain. In cestodes the proglottids are serially arranged but in a reversed order. Another objection is that reproduction by fission is usually confined to sessile animals, whereas the ancestors were probably free-swimming. Moreover, fission is a more extensive and disruptive division of body than is metamerism.

**4. Embryological theory.** It explains original metameric segmentation mainly as an embryological accident. It suggests that mechanical stresses in the mesoderm of the elongating embryo or larva resulted in its fragmentation leading to segmental repetition of mesodermal derivatives in the adult.

**5. Locomotory theory.** It is an amalgamation of pseudometamerism and embryological theories. It postulates that metamerism evolved as an adaptation to locomotion of different kinds. Annelid metamerism probably evolved as an adaptation for burrowing and chordate metamerism as an adaptation for undulatory, serpentine swimming movements.

R.B. Clark (1964) suggests that coelom evolved initially as a hydraulic skeleton to facilitate locomotion in response to the increasing body size. According to Clark, metamerism also evolved as an adaptation to burrowing in annelids. The ancestors of Annelida were in all probability elongate coelomate animals which burrowed in marine sand and mud. The evolution of compartmented coelom, due to development of septa and metameric segmentation, localized the function of the hydraulic skeleton. This allowed only part of the body to contract while other parts in the longitudinal axis relaxed. The locomotory movements can be more continuous and better controlled if the action of the bodywall muscles is localized, i.e., restricted to sections of the body. Metamerism permits such localization and accounts for the evolution of this condition in annelids. The localization enabled a strong peristaltic wave to propagate down the body, an efficient type of locomotion for worm-like burrowers. Thus, annelid metamerism is

(Z-1)

basically a modification of the coelom and the bodywall muscles. The initial segmentation of the coelom and bodywall muscles led to the subsequent segmental organization for the nervous, circulatory and excretory systems.

In chordates, metamerism evolved as an adaptation for undulating swimming movements. According to Berrill (1955), notochord evolved in the early chordates to provide support for the body, followed by metameric segmentation of bodywall musculature, so that alternate waves of contraction sweeping down the body could enable strong swimming. The initial muscle segmentation caused segmentation of the nervous and circulatory systems.

In cestodes, metamerism evolved as a response to reproduction. A reproductive package was formed which, once it had performed its function, was expendable. Proglottids are not additional to the body but are the body and so have to carry a complete series of organs.

**Conclusion.** Metameric segmentation met in one phylum is not necessarily similar to that in another. It probably arose independently in more than one line of evolution, each time in adaptation to a major advantage for the group in question. It probably evolved in response to burrowing in annelids, to swimming in chordates and to reproduction in cestodes. Therefore, we cannot devise one explanation for all the cases of segmentation or think of a common ancestor of all sorts of segmented animals.

**[VI] Significance of metamerism**

It is not clear just how and why metamerism evolved or how the primitive ancestors were benefitted by it. Probably specialization of metameres for particular functions showed an advancement.

It is possible that segmentation was initiated in the musculature of an elongated swimming worm. This breaking up of the body into metameres would facilitate swimming movements. Metamerism helps in locomotion in several ways. The coordination of muscular action in fluid-filled coelomic compartments cause efficient swimming and creeping which is an advancement over the simple ciliary and creeping

movement of lower invertebrates. Fluid-filled coelomic compartments also provide hydrostatic skeletons for burrowing. Precised movements can take place by differential turgor effected by flow of coelomic fluid from one part of the body to the other.

Another advantage of segmentation or metamerism is the opportunity for different segments to specialize for different functions, thus leading to a rapid evolution of high grade of organization. It is not clearly marked in annelids, but is well developed in arthropods. Metamerism has, therefore, contributed towards the greater complexity of animal bodies and rapid evolution of high organization in animals. Thus, some indication of primitiveness of an animal can be determined by the degree of segmentation it displays.

The fact that cestodes, annelids, arthropods and chordates have metamerism does not necessarily indicate a close relationship among them, for the metameric condition may have arisen independently by convergent evolution.

[VII] Pseudometamerism

True metamerism, as shown by annelids, must not be confused with the pseudometamerism or strobilization of the tapeworms. It refers to superficial segmentation and could be termed body annulation. True segments of annelids are laid down in the embryonic stage. Whereas proglottids of tapeworm are not true metameres

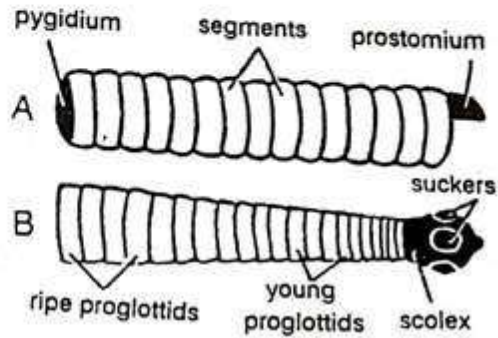


Fig. 5. Diagrams to illustrate differences between A—True metamerism of a generalized annelid. B—Strobilization of a generalized tapeworm.

but rather complete reproductive individuals produced by strobilization, a type of budding, with the buds remaining attached. Table 1 shows the important differences between the two. However, the modern view now gaining favour is that cestodes are indeed metamERICALLY segmented, although their metamerism is of a different type.

Body Cavity or Coelom

[I] Definition

A body cavity can mean any internal space, or a series of spaces present inside body. Whereas coelom or true body cavity generally refers to a large fluid-filled space (cavity) lying between the outer bodywall and the inner digestive tube. It arises as a secondary cavity between two layers of embryonic mesoderm and contains most of the visceral organs.

Table 1. Differences between True Metamerism and Pseudometamerism.

True metamerism	Pseudometamerism
<ol style="list-style-type: none"> <li>Number of segments is generally constant for each species; i.e., new segments are not added to the body after maturation except in asexual reproduction.</li> <li>Growth occurs due to simple elongation of pre-existing segments. The segments and ends of body have a fixed relationship to one another throughout life.</li> <li>All segments are of the same age and at the same stage of development.</li> <li>Segments are functionally interdependent and integrated. Working in co-ordination, they preserve the individuality of body. For example, in a worm, during locomotion, muscles of each segment contract in a regular sequence so that rhythmical waves of contraction pass over the whole body which moves forward in an orderly manner.</li> </ol>	<ol style="list-style-type: none"> <li>Number of segments or proglottids forming the body is not fixed as new segments are continually added throughout life.</li> <li>Growth occurs due to addition of new segments from a region of proliferation, just behind the scolex.</li> <li>Proglottids differ from one another in age and in the degree of development.</li> <li>Segments or proglottids are independent and self-contained units, each having a full set of sex organs and a portion of excretory and nervous systems. They are productive units developed for detachment. A tapeworm represents a sort of colony or strobila made of a linear rows of incomplete individuals.</li> </ol>

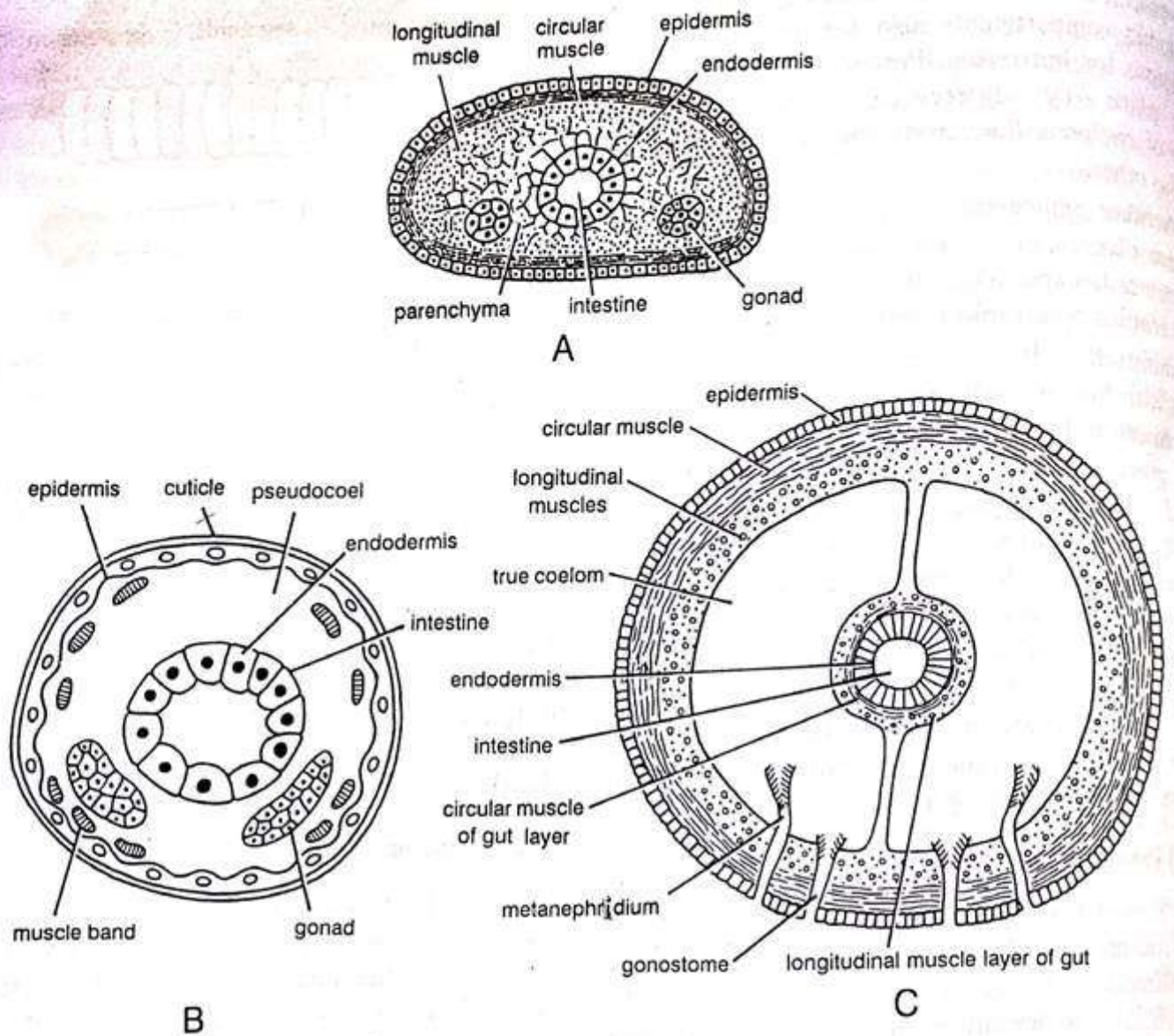


Fig. 6. Main types of body arrangements in Metazoa on the basis of coelom (In diagrammatic cross-sections).  
 A—Acoelomate, with no body cavity. B—Pseudocoelomate, with body cavity not bounded by mesoderm.  
 C—Coelomate or Eucoelomate with body cavity enclosed by mesoderm.

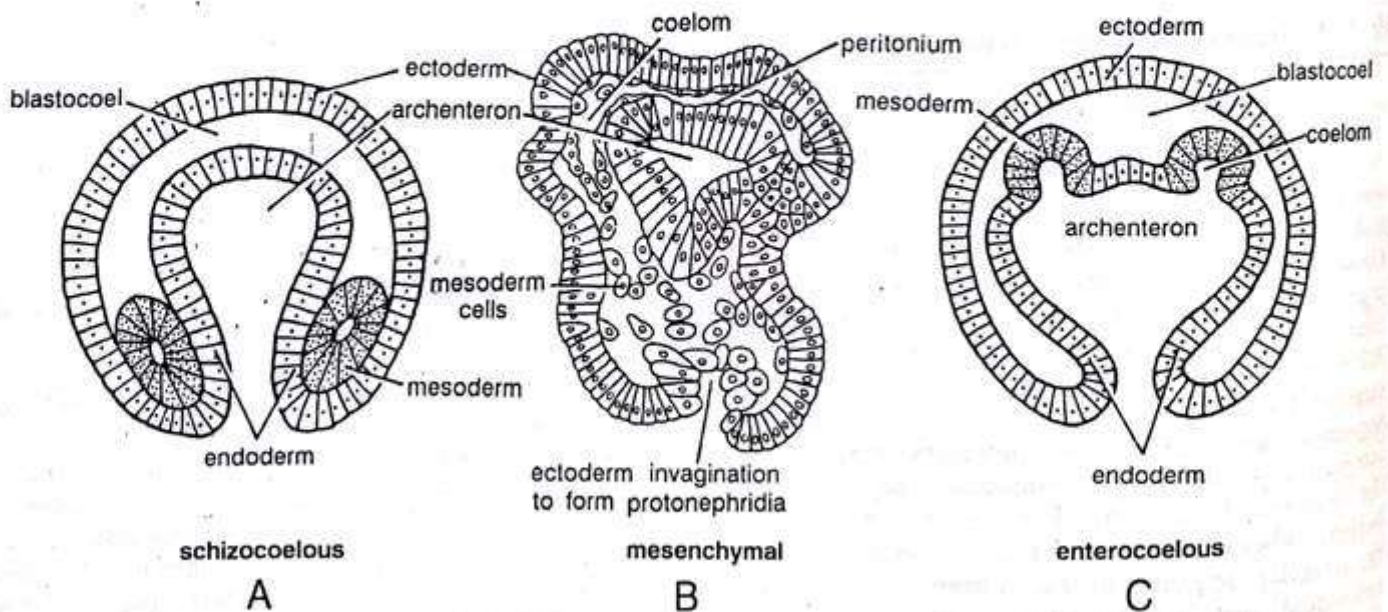


Fig. 7. Three types of mesoderm and coelom formation. A—Schizocoelous. B—Mesenchymal. C—Enterocoelous.

Thus, a true coelom may be defined as a secondary body cavity, formed by the splitting of mesoderm during embryonic development and bounded on all sides by a definite coelomic epithelium or peritoneum. It contains a colourless coelomic fluid, the excretory organs open into it and the reproductive organs arise from its walls.

However, all animals do not possess a coelom, such as sponges, coelenterates, ctenophores, flatworms and proboscis worms. They are said to be *acoelomate*.

### [II] Types of coelom

Two types of body cavities or coelom occur in Bilateria, *primary* and *secondary*.

1. **Primary coelom.** It is also called a false coelom or *pseudocoelom*. It is derived from the blastocoel of the embryo, rather it represents a persistent blastocoel? Internal organs remain free in it since it is not bound by peritoneum or mesoderm. It is a space enclosed by ectoderm on the outside and endoderm (digestive tract) on the inside, and not by mesoderm on both sides. Such a pseudocoelom occurs in many worm-like animals including rotifers and roundworms, etc.

2. **Secondary coelom.** In more highly developed Bilateria, the blastocoel is gradually obliterated by the embryonic archenteron, without forming a primary coelom. Instead, a *secondary* or *true coelom* or *eucoelom* develops within the embryonic mesoderm and lined by a characteristic layer of flattened mesodermal epithelial cells, known as *peritoneum*, which also surrounds the internal organs of the body. A true coelom probably appeared for the first time in annelids.

### [III] Coelomic division of Metazoa

On the basis of presence or absence of coelom, the Metazoa are divided into 3 major groups as follows:

1. **Acoelomata.** No body cavity or coelom is present. Embryonic mesoderm remains as a solid layer, space between endoderm (gutwall) and ectoderm (bodywall) is filled with mesenchyme and muscle fibres. Examples: Porifera, Coelenterata, Ctenophora, Platyhelminthes and Nemertinea.

2. **Pseudocoelomata.** Body space is a pseudocoelom or false coelom. It is a persistent blastocoel enclosed between outer ectoderm and inner endoderm, and not lined by mesoderm. Examples: Acanthocephala, Ectoprocta and Aschelminthes (Rotifera, Gastrotricha, Kinorhyncha, Nematoda, Nematomorpha).

3. **Coelomata or eucoelomata.** Body space is a true coelom, enclosed by mesoderm on both sides. Remaining phyla of Bilateria, from Annelida to Arthropoda, belong to Coelomata.

There are 3 different ways in which entomesoderm and coelom can arise during embryological development. Accordingly, Hyman (1951) further divides coelomate Bilateria in 3 groups as follows:

(a) **Schizocoelomata.** Coelom arises by a splitting of endomesodermal bands which originate from blastoporal region of larva and extend between ectoderm and mesoderm. It is a true coelom called a *schizocoel*. Examples: Most of the Protostomia (Annelida, Arthropoda, Mollusca, etc.).

(b) **Mesenchymal coelomata.** It is seen only in Phoronida in which mesenchymal cells rearrange to enclose a space or coelom, which is regarded an aberrant schizocoel.

(c) **Enterocoelomata.** Coelom arises in the form of mesodermal pouches from larval archenteron. After separation from endoderm, the pouches fuse and expand until they touch the gut and bodywall. Since the coelom arises from larval enteron, it is called an *enterocoel*. Example: Deuterostomia (Chaetognatha, Echinodermata, Hemichordata, and Chordata) and Brachiopoda.

### [IV] Modifications of coelom

There are modifications of coelom in different animals. As already described, in a schelminths, it forms a *pseudocoelom* not lined with mesoderm. In arthropods, it is formed by scattered spaces, collectively known as *haemocoel*, in which blood circulates. In annelids, coelom is divided by *septa* into chambers corresponding to the somites. In mammals, coelom is divided by a muscular *diaphragm* into thoracic and abdominal cavities, with a separate *pericardial cavity* around heart.

### [V] Significance of coelom

Evolution of coelom is of great significance in animals. It plays an important role in the progressive development of complexity of structure. It permits greater size and contributes directly to the development of excretory, reproductive and muscular systems of body. In a triploblastic animal (e.g. earthworm), the appearance of a perivisceral coelom between gut and bodywall leads to several advantages.

- (1) It surrounds the internal organs like a water jacket and protects them from external shocks.
- (2) It provides flexibility to the body. It provides space and gives the digestive tract and other internal organs freedom of movement and opportunity for enlargement, further differentiation and greater activity.
- (3) The coelomic fluid often functions as a hydraulic skeleton and also serves as a circulatory medium for the transport and distribution of nutritive substances and gases.
- (4) The excretory matter is collected into coelomic fluid and then passed out of the body through nephridia.
- (5) The gonads arise from its coelomic epithelium and project into coelom. Ova and sperms are extruded through special gonoducts connecting the coelom with the exterior.

No doubt, the evolution of coelom made a major advance in the evolution of Metazoa. It is evident from the great increase in size and diversity in structure and ways of life met within coelomate phyla in comparison with acoelomate and pseudocoelomate phyla.

### [VI] Evolution of coelom (Theories of Origin)

Origin of coelom in Metazoa is of great evolutionary significance. It has recently been extensively discussed by R.B. Clark (1964). There is no direct evidence of evolution of coelom available from palaeontology. There is only indirect evidence which is based mainly on the embryology of present day metazoans. This has been differently interpreted by different workers resulting in many conflicting theories about the origin and evolution of coelom. Out of these, there are 4 principal theories as follows :

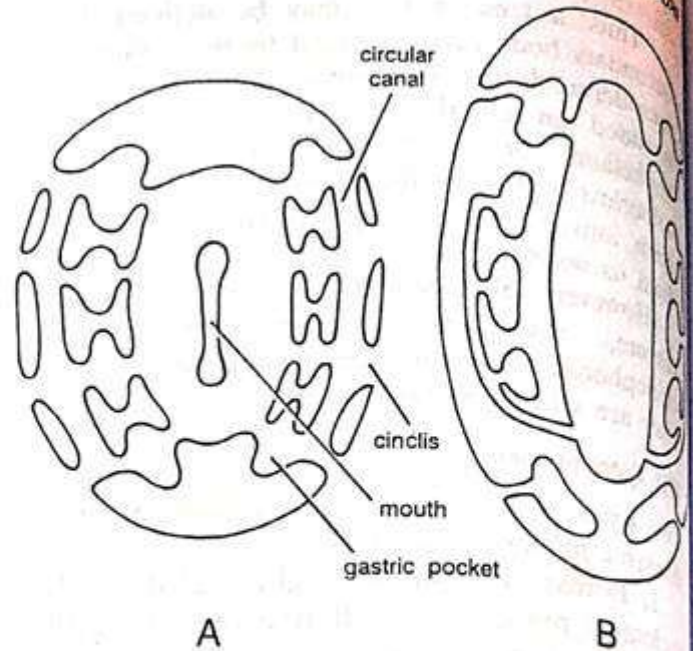


Fig. 8. Diagrammatic representation of coelom formation according to Enterocoel Theory. A—Formation of gastric pockets in an anthozoan. B—Gastric pockets become coelomic pouches.

**1. Enterocoel theory.** The theory holds that the primitive mode of coelom formation was enterocoelous. The idea was first proposed by Lankester (1875) and later modified by Sedgwick (1884) and till recently by Hartman (1963) and Ramne (1963). According to this theory, the bilateral metazoan ancestor of coelenterates had gastric pockets which become separated from the central digestive cavity to form coelomic pouches (Fig. 8). However, the theory is mainly objected on the following grounds :

- (1) Gastric pouches occur in highly organized coelenterates, such as Scyphozoa and Anthozoa, which are not suitable for ancestral types.
- (2) Sealing off of gastric pockets in the ancestor would defeat the purpose for which they were formed, that is, for increasing the surface area for digestion and absorption.
- (3) Gastric pockets of coelenterates are not evaginations of gut endoderm, but formed differently by ingrowth of bodywall-septa.

**2. Gonocoel theory.** This is the most popular theory of origin of coelom. According to this theory, coelom represents a persistent expanded gonadial cavity or gonocoel. The theory



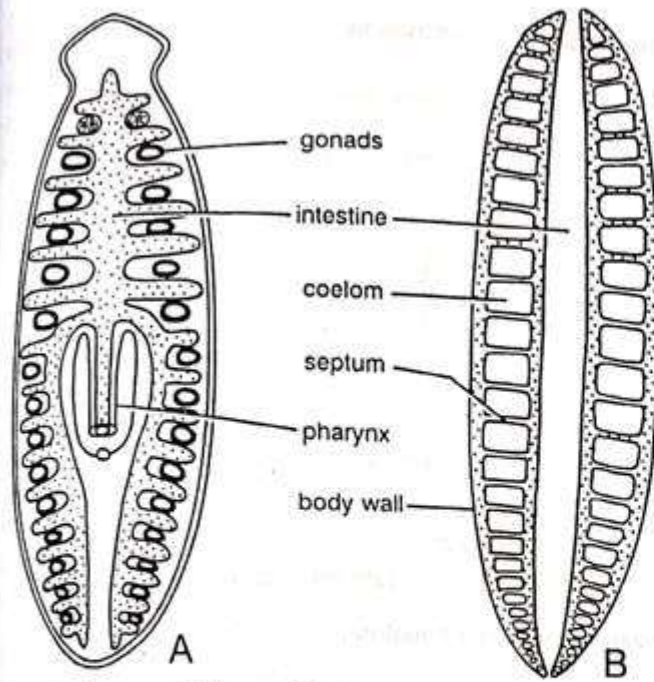


Fig. 9. Gonocoel Theory of coelom formation. A—Gonads alternating with intestinal branches in a triclad flatworm. B—Coelomic sacs or compartments in an annelid, formed by fusion of adjacent expanded gonads.

pseudometameric distribution of organs (such as gonads) in an elongated worm-like body.

**3. Nephrocoel theory.** According to this theory, proposed by Lankester in 1874, coelom originated as the expanded inner end of a nephridium. The theory is not seriously held because, (i) Protonephridia have been described in coelomates, and (ii) some coelomate groups, such as Echinodermata, do not have excretory organs.

**4. Schizocoel theory.** According to this theory, coelom has a mesenchymal origin and has no relation with nephridia and gonads of Lower Bilateria and endodermal pouches of Radiata.

**Conclusion.** None of the above theories satisfactorily explains the origin of coelom. Firstly, they do not explain the advantages of intermediate stages passed through during the course of evolution. Secondly, the connection between evolution of coelom and metamerism together, has not been made clear. Thirdly, no exact nature of a coelom has been defined. Which cavities should be regarded coelomic and which not, has not been explained. Moreover, there is no evidence showing that secondary body cavity is homologous (with same origin) throughout the animal kingdom. Probably it is polyphyletic in origin. As Clark postulates, coelom might have arisen independently a number of times and in various ways in different animal groups— as a persistent blastocoel in pseudocoelomates, as an enterocoel in deuterostomes, as a schizocoel in protostomes, and as a gonocoel, etc.

### Levels or Grades of Organization

All living plants and animals are made of cells. A cell is the unit of structure (histology) and function (physiology) of animals and plants, so that, differentiation of cells is always accompanied by physiological division of labour. Depending on the number and degree of complexity or specialization of cells present in individuals, we can divide animals into the following patterns, levels or grades of organization : (i) protoplasmic, (ii) cellular (iii) cell-tissue, (iv) tissue-organ, (v) and organ-system. These are approximately in the order in which they have evolved. Most animals fit

proposed in 1885 by Bergh, based on an idea earlier expressed in 1878 by Hatschek.

Meyer (1890) considered coelom initially unsegmented, arising from a single large pair of gonads. However Bergh and Lang (1903) believed that coelom initially arose in a segmented condition. In nemertean and flatworms, especially in the triclad turbellarian *Procerodes lobata* (Fig. 9), they observed intestinal branches alternating with a linear series of gonads. If the intestinal branches withdraw and gonads enlarge with their walls meeting to become septa, they would resemble the row of coelomic compartments of an annelid. However, the chief defects of the Gonocoel theory are :

- (1) It links the origin of coelom with that of metamerism which is not acceptable phylogenetically.
- (2) It is not supported by embryology because gonads do not arise before coelom.
- (3) It does not account for unsegmented coelomate phyla, which are in majority, and there is no evidence that they have originated from segmented ancestors. Goodrich (1946) and Hyman (1951) have rejected the Gonocoel theory. They consider that metamerism was preceded by a

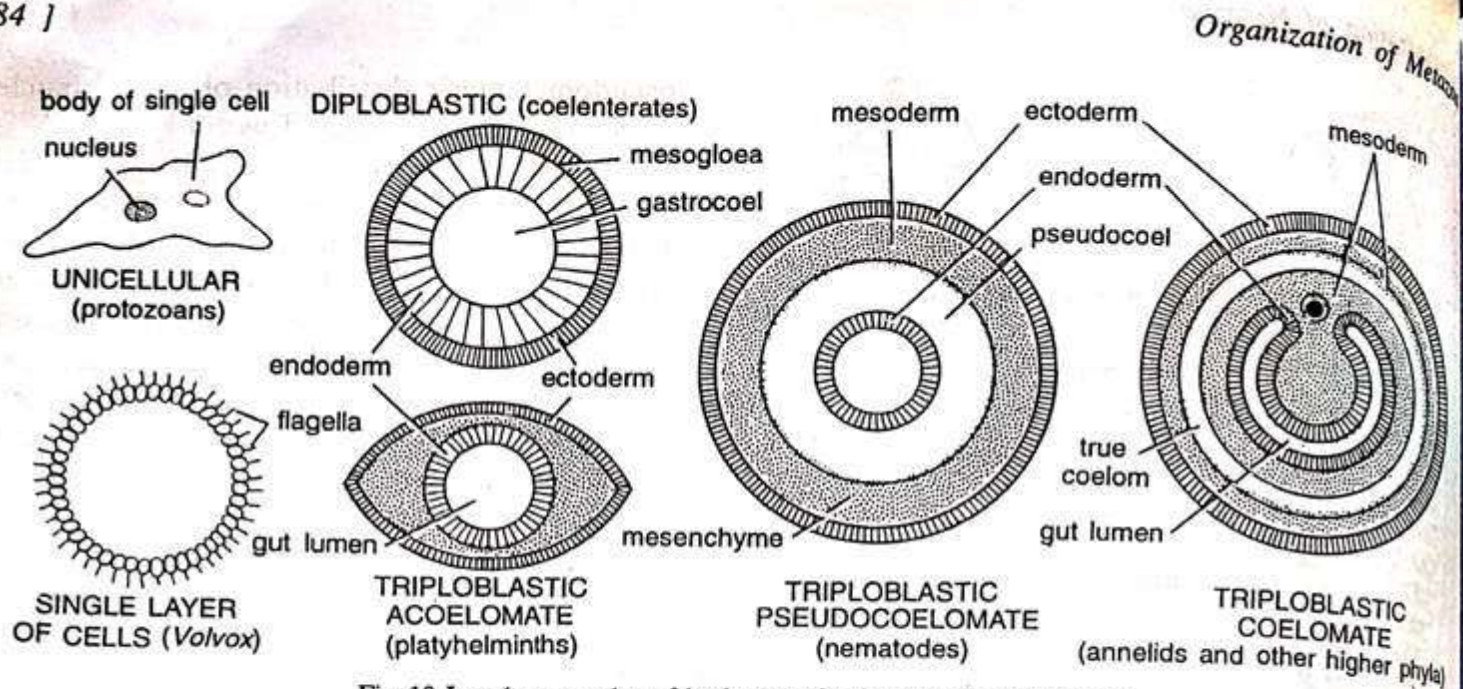


Fig. 10. Levels or grades of body organization in animal kingdom.

neatly into one of these groups or categories although some animals appear to be intermediate between certain categories. For example, sponges only show a hint of tissue (cellular level), but not true tissue as shown by coelenterates (cell-tissue level).

**1. Protoplasmic or acellular level.** This type of organization occurs in Protozoa or acellular protists. All the activities are performed by one-cell body. However, specialized cytoplasmic structures, or the organelles, carry on specific functions, thus illustrating division of labour.

Colonial protozoans, such as *Volvox*, are differentiated into somatic and sex cells. But, the somatic cells do not show specialization and division of labour. This distinguishes colonial Protozoa from Metazoa.

**2. Cellular level.** Multicellular animals such as mesozoans and sponges, are made of loose association of cells. All the cells are in direct contact with the environment, that is water, so that respiration, excretion, etc. take place by the general body surface. However, some division of labour occurs in certain cells concerned with reproduction (germ cells) and nutrition (choanocytes). But, such specialized cells do not form definite tissues. All cells act more or less independently and show little coordination. Sponges and mesozoans do not attain a higher level than this and are considered to be the simplest metazoans. Certain colonial protozoans are considered to have reached the cellular level.

**3. Cell-tissue level.** Multicellular animals, such as hydra and jelly fish, are supposed to make the beginning of the tissue plan. Most of their cells remain scattered, at the cellular level, and not organized into tissues. Nerve cells appear for the first time but nerve ganglia are absent. But the nerve cells and their processes remain interconnected forming a *nerve net* which is a good example of a tissue with the function of transmission of impulses and coordination. Thus, first truly metazoan phylum of tissue grade organization is Cnidaria or Coelenterata. Their body is generally radially symmetrical and made of only two germ layers, ectoderm and endoderm. Such animals are called *diploblastic*.

**4. Tissue-organ level.** Further step of advancement is the aggregation of tissues into organs which have a more specialized function than tissues. Platyhelminths are the first bilaterally symmetrical, acoelomate metazoans to have reached the tissue-organ level of organization. They have a number of well-defined organs such as eyespots, proboscis, gonads, etc. They are also *triploblastic* because they have a third or middle cellular germ layer, called *mesoderm*, which lies between outer ectoderm and inner endoderm.

**5. Organ-system level.** In higher animals several organs are associated to form a distinct system concerned with a specific function, such as digestion, respiration, circulation, excretion and reproduction. This is the highest level of

organization. This is first seen in a group of marine worms known as nemerteans. They have a complete digestive system separate and distinct from circulatory system.

Members of superphylum Aschelminthes, such as nematodes, are bilaterally symmetrical, triplo-

blastic and pseudocoelomate metazoans. They have a pseudocoelom but lack a true secondary coelom. On the other hand, annelids, arthropods, molluscs, echinoderms and chordates are triploblastic and eucoelomate because they possess a true coelom.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. What are Metazoa and how do they differ from Metaphyta ?
2. Define true metamerism and give the various theories of its origin and evolution in Metazoa.
3. What is coelom? Describe its condition throughout Metazoa.
4. Give an illustrated account of the various grades or levels of structure met with in the animals.
5. Write short notes on : (i) Cephalization and polarity, (ii) Enterocoel, (iii) Pseudocoelom, (iv) Pseudometamerism, (v) Schizocoel, (vi) Symmetry of animals.

#### » Short Answer Type Questions

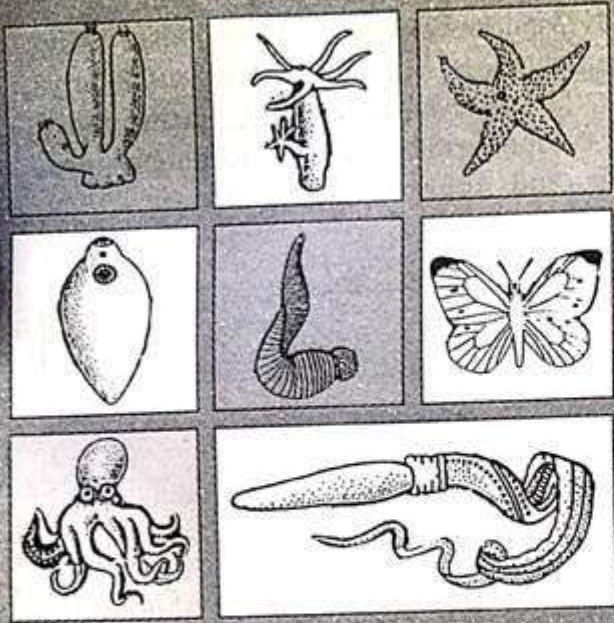
1. What are metazoa. How you define?
2. Define metaphyta?
3. Give differences between diploblastic and triploblastic.
4. Differentiate between asymmetrical and symmetrical.
5. What is radial symmetry?
6. Define pseudocoelomate?
7. What is biradial symmetry?
8. Give an account about metamerism.
9. How you define somite?
10. Define coelom?
11. Give the name of pseudocoelomate phyla?
12. What is schizocoelome.
13. Define and differentiate between schizocoelome and enterocoelome.
14. Haemocoelome present in .....
15. In mammals coelome divided by .....
16. Enterocoel theory put farward by .....
17. Protozoans are ..... grade of organism.
18. Hymen rejected the ..... theory of coelome origin.
19. Name the acoelomate group of animals.
20. Give two names of metamericly segmented animals.

#### » Multiple Choice Questions

1. Animals which develop mouth away from blastopore are called :  
(a) protostomia (b) deuterostomia  
(c) parazoa (d) metazoa
2. Which phyla are radially symmetrical :  
(a) Cnidaria and Annelida  
(b) Echinodermata and Arthropoda  
(c) Platyhelminthes and Nematoda  
(d) Cnidaria and Protozoa
3. Pseudocoelom develops from :  
(a) Mesoderm (b) Blastocoel  
(c) Archenteron (d) Gut
4. Radial symmetry generally occurs in :  
(a) Free swimming organisms (b) Sessile organisms  
(c) Terrestrial organisms (d) Parasitic organisms
5. Which is characteristic of Protostome :  
(a) Spiral and determinate cleavage and schizocoel  
(b) Spiral and determinate cleavage and enterocoel  
(c) Spiral and indeterminate cleavage and enterocoel  
(d) Spiral, indeterminate cleavage and schizocoel
6. Syncytial theory explains :  
(a) Formation of coelom (b) Symmetry of animals  
(c) Origin of life (d) Origin of metazoa
7. Which animal transforms from bilateral to radial symmetry in its life history :  
(a) *Obelia* (b) Starfish (c) Sponge (d) *Hydra*
8. True coelom is the space between alimentary canal and body wall enclosed by layers of :  
(a) Mesoderm on one side and ectoderm on the other  
(b) Endoderm on one side and ectoderm on the other  
(c) Mesoderm on both sides  
(d) Ectoderm on both sides
9. Coelom produced from mesoderm cells is called :  
(a) Hydrocoel (b) Enterocoel  
(c) Schizocoel (d) Pseudocoel
10. On the basis of body organization evolution of animals are grouped as :  
(a) Parazoa and Metazoa (b) Protozoa and Metazoa  
(c) Protozoa and Parazoa  
(d) Metazoa and Eumatozoa

### Answers

1. (b) 2. (d) 3. (b) 4. (b) 5. (a) 6. (d) 7. (b) 8. (c) 9. (c) 10. (b)



# 17

Chapter

## Origin of Metazoa

### Introduction

On a rough estimate, life began on Earth about 3.7 billion years ago. First cell to appear was a prokaryote cell without a definite nucleus. Later, the eukaryote cell developed having a well organized nucleus. The earlier unicellular or non-multicellular organisms were neither plant (*Protophyta*) nor animal (*Protozoa*) in nature. Ernst Haeckel (1866) called them *Protista* which may be defined as organisms, usually of small size, consisting of a nuclear apparatus (no definite nucleus, one nucleus or many nuclei) in a cytoplasmic body which is not divided into cells.

With the increase in complexity of life, multicellularity developed in plants and animals. As mentioned earlier, the term *Metaphyta* is used for multicellular plants and *Metazoa* for multicellular animals.

### Premetazoan Ancestors

There is no direct proof about the ancestors of Metazoa. But all zoologists agree that the metazoans have evolved from some unicellular or acellular organisms, such as Protozoa. This is strongly evident by the facts of embryonic development in which each metazoan passes from an acellular (zygote) to a cellular condition (morula, blastula, gastrula, etc.).

A unicellular protistan individual performs all of the functions of the living. From such a functionally complex single-celled protistan arose the multicellular animals. But, how single-celled Protozoa, which evolved possibly 2,000 million years ago, gave rise to the multicelled Metazoa remains one of the fundamental mysteries of evolution shrouded in complete obscurity. It is difficult to solve it because the earliest

metazoans, like most invertebrates, were soft-bodied and left no fossils.

## Theories of Origin of Metazoa

Different views have been expressed by many prominent scientists from time to time to explain the evolution of the Metazoa from different groups of Protozoa. All these views can be generalized into three principal viewpoints as below :

- (1) The ancestral metazoan originated from a colonial flagellate through increasing cellular specialization and interdependence (*Colonial Theory*).
- (2) The ancestral metazoan arose from a multinucleate syncytial ciliate which became compartmented or cellularized by the appearance of cell boundaries (*Syncytial Theory*).
- (3) The metazoans had a polyphyletic origin from different unicellular groups (*Polyphyletic Theory*).

### A. Colonial Theory

The *Colonial* or *Flagellate Theory* is the classic and most frequently repeated theory of the origin of multicellular animals. It maintains that hollow colonial flagellates, like *Volvox*, were probable ancestors of the metazoans. This idea was first conceived by Butschli, Lankester and Haeckel (1874), later modified by Metschnikoff (1886), and recently revived by Hyman (1940).

1. **Proposition.** Colonial Theory holds that multicellular animals came about through association of many one-celled flagellate individuals forming a colony. With increase in the number of individual cells, they became more and more specialized in structure and functions. Soon, individuality in the cells was lost and the whole colony itself became a single multicellular individual or a metazoan.

2. **Support.** The Colonial Theory has been greatly accepted, since it conforms best with the facts of embryonic development. The belief in the flagellate ancestry of Metazoa is also supported by the following facts.

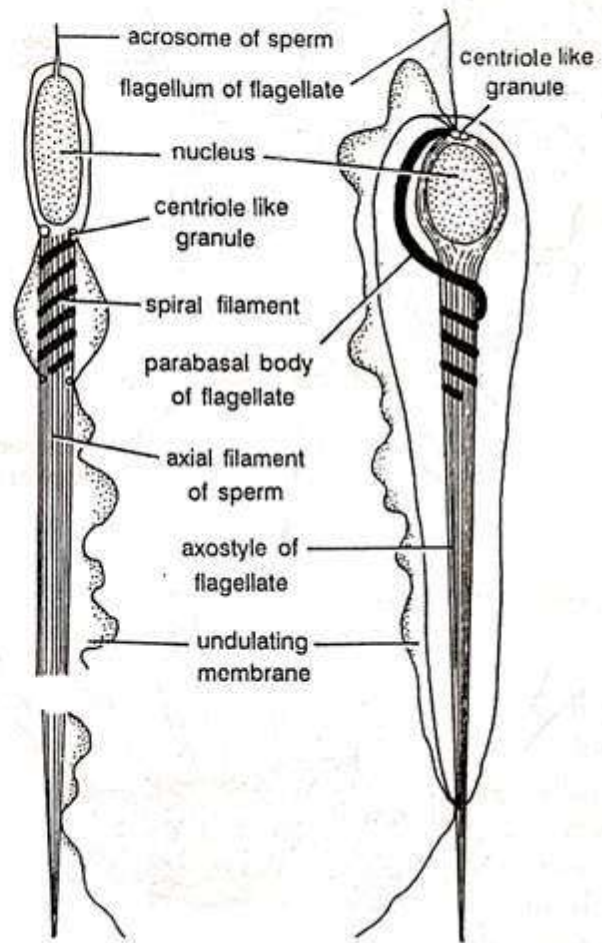


Fig. 1. Comparison of a spermatozoon (A) and a polymastigote flagellate (B).

(a) **Plastic group.** The flagellates are a highly plastic group, that is, capable of great changes. In all probability, the entire plant kingdom, and all other protozoan classes have originated from them.

(b) **Compact colonies.** The flagellates show a great tendency of forming compact colonies, and these clearly resemble various stages in the embryonic development of Metazoa.

(c) **Flagellated spermatozoa.** The metazoan tailed sperm cell very closely resembles a modified flagellate (Fig. 1). Therefore, the occurrence of flagellate or tailed spermatozoa throughout the Metazoa is a clear indication of descent of Metazoa from the Flagellata.

(d) **Flagellated body cells.** Flagellated body cells are common among the lower metazoans, that is, sponges and coelenterates.

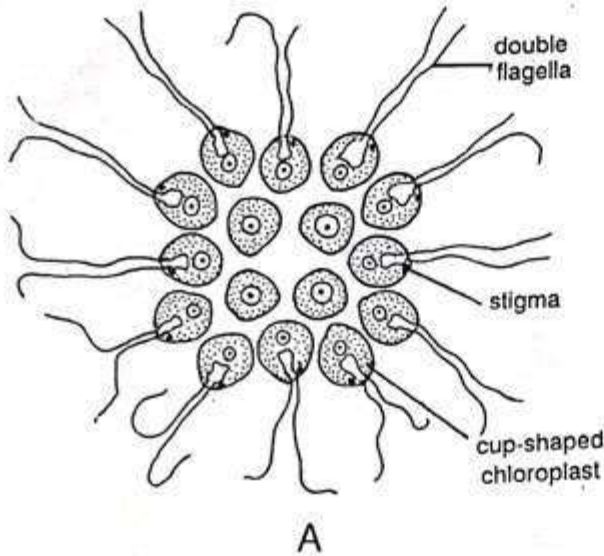


Fig. 2. *Gonium pectorale*, a Colonial phytomonad. A—From above, B—Inside view.

Sponges produce flagellated larvae (*parenchymula* and *amphiblastula*) and also possess flagellated cells or choanocytes that closely resemble a choanoflagellate (*Proterospongia*). In coelenterates, the endoderm cells have a tendency to give out flagella.

**3. Criticism.** According to the Colonial Theory, the metazoan ancestors were like existing freshwater volvocid phytoflagellates. But these are plant-like organisms having cellulose cellwalls, chlorophyll and autotrophic nutrition and undergo reduction division following fertilization. The theory does not explain how these plant-like characteristics were lost during the course of evolution of the metazoan ancestors. However, this objection is met with by holding that probably metazoans arose from some group of existing zooflagellates having colonial organization similar to the volvocid phytoflagellates.

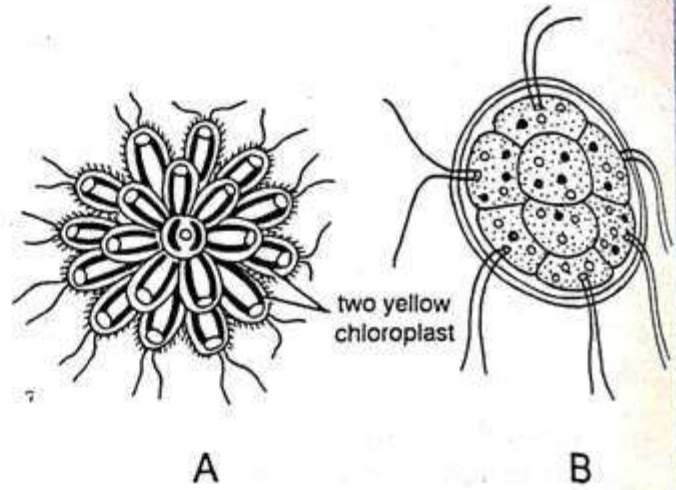


Fig. 3. A—*Synura vella*, a chrysomonad. B—*Pandorina*, a phytomonad.

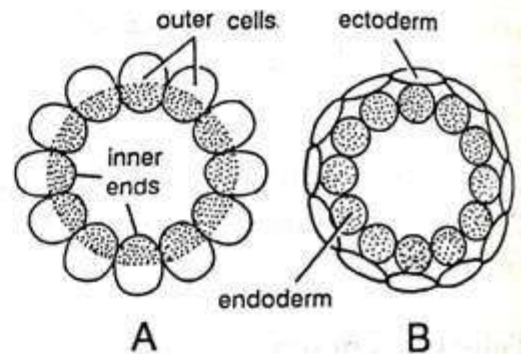


Fig. 4. A and B. Endoderm formation by primary delamination, according to Lankester's theory.

The flagellate protozoan colonies are of several types such as linear, tree-like, plate-like, spherical and solid as well as hollow. Of these which type gave rise to the ancestral Metazoa has been a subject of great speculation among scientists. Some of the noteworthy views are listed below.

**[I] Butschli's theory**

The plate-like form such as *Gonium* (Fig. 2) was favoured by Butschli as the ancestral metazoan type. He postulated that first this became two-layered by cutting off a lower plate of cells and later curved into a sphere. But this idea gets no support from the embryonic development of metazoans.

**[II] Lankester's theory**

According to Lankester, the ancestral metazoan was a morula-like solid colony, such as *Synura* or *Pandorina* (Fig. 3). Food taken by outer surface

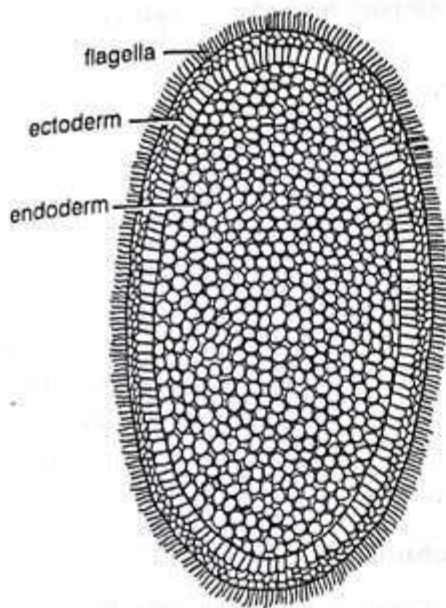


Fig. 5. Planula.

of the external flagellated cells (*ectoderm*) was passed into their inner ends, a process still seen in living sponges and coelenterates. Later, the inner ends of cells got separated forming an internal digestive layer or *endoderm* (Fig. 4). Lankester named this hypothetical ancestor as *planula* (Fig. 5), which was a solid organism. Later on, it developed mouth and digestive cavity.

**Criticism.** Lankester's theory found no acceptance, because :

- (1) Endoderm formation by primary delamination is very rare in the Metazoa.
- (2) Formation of internal digestive tube or endoderm will be of no use without a mouth for taking in food.

### [III] Haeckel's theory of blastaea and gastraea

The Colonial Theory is based mainly on E.H. Haeckel's *Gastraea Theory of metazoan ancestry*, presented in 1874.

**1. Proposition.** According to Haeckel, the metazoans evolved by aggregation of single protistan cells into a little hollow, spherical, flagellate colony, similar to *Volvox*. It possessed a distinct antero posterior axis and swam about with one pole directed forward. This hypothetical organism was named *blastaea* by Haeckel and was considered similar to the *blastula* or

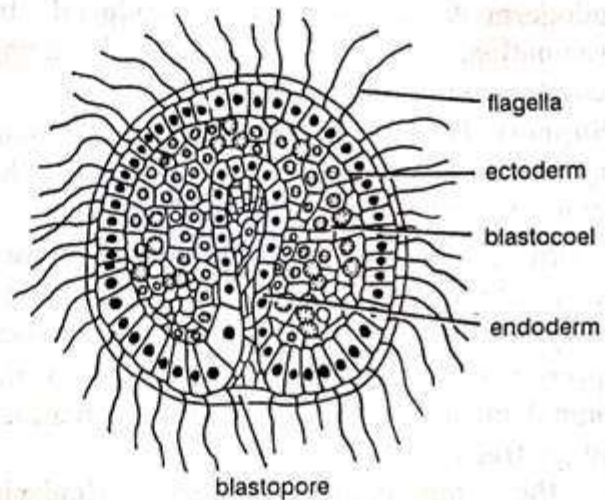


Fig. 6. A typical gastrula showing endoderm formation by embolic invagination (according to Haeckel).

*coeloblastula* stage in the embryogeny of living metazoans. Blastaea showed an early differentiation between somatic and reproductive cells. Somatic cells were meant for perception, food capture and locomotion by the action of flagella. But, certain cells were specialized to become sex cells, a process already seen in *Volvox*. The embryonic archaeocytes of sponges and interstitial cells of coelenterates, which later become reproductive cells, are reminiscent of the same phenomenon.

The blastaea invaginated at the posterior pole to become a double-walled sac termed *gastraea* by Haeckel (Fig. 6). The inner endodermal sac thus formed was termed primitive intestine or *archenteron* and its single opening to the exterior primitive mouth, *protostoma* or *blastopore* (Fig. 6). The endodermal cells lining the digestive cavity were relieved from perceptive and locomotory functions and became specialized for engulfing and digesting food for the whole colony. According to the famous *Gastraea Theory* of Haeckel :

- (1) A two-walled hollow gastraea was the hypothetical common ancestor of all the Metazoa.
- (2) It is represented in the embryonic development of Metazoa by the two-layered *gastrula* stage.
- (3) The two layers of gastraea are retained through out Metazoa as ectoderm and endoderm.

- (4) Endoderm is fundamentally produced by invagination, all other methods being secondary modifications of invagination.

**2. Support.** Haeckel's Gastraea Theory about ancestry of the Metazoa is mainly based on the embryological evidence.

- (1) According to Haeckel's recapitulation theory, the blastula and gastrula stages in the embryonic development of higher metazoans represent repetition of the adult stages of the original metazoan ancestors, that is, blastaea and gastraea.

- (2) In the nineteenth century, Cnidaria (Coelenterate) were regarded to be the first or most primitive metazoan phylum because of their radial symmetry. Haeckel also compared close structural similarity between the ancestral gastraea and lower metazoans like hydrozoan coelenterates and certain sponges. Like gastraea, they are also radially symmetrical, double-walled and with a single opening (mouth or osculum) leading into a sac-like digestive cavity.

**3. Criticism.** Gastraea theory by Haeckel was widely accepted as it simplifies the embryologic and phylogenetic history of animals and gives a convincing explanation of the stages by which complex metazoan structure might have been achieved. However, it had to face some objections.

- (1) Chief objection is that in metazoan embryology, endoderm is not always formed by *invagination*. Even in the Coelenterata, which are structurally nearest to the hypothetical gastraea, endoderm is formed by the inwandering of ectodermal cells (*multipolar ingression*), and the larva is a parenchymula or planula rather than a gastrula. Invagination is an unusual method of gastrulation which in most cases takes place by immigration or *delamination*. It is probable that invagination is a derived rather than original method and represents one of the short cuts common in embryology.
- (2) According to Haeckel, possession of radial symmetry was regarded as primitive character of cnidarians (coelenterates). But, in

echinoderms and some chordates (tunicates) it is a secondary condition derived through metamorphosis of a bilaterally symmetrical larva. Thus, radial symmetry may be an adaptation due to a sedentary or sessile mode of life rather than a phylogenetically primitive condition, so that there is no compulsion to consider the ancestral metazoan to be a radially symmetrical, two-layered and hollow sac-like organism.

- (3) Haeckelian recapitulation theory has been largely discarded now due to its many discrepancies.

#### [IV] Metschnikoff's theory

Haeckel's Gastraea theory was later modified by Metschnikoff (1866).

**1. Proposition.** Metschnikoff noted that the primitive mode of gastrulation in coelenterates is by *ingression*, and not by *invagination*, producing a solid gastrula. He also discovered that digestion is intracellular and phagocytic in lower Metazoa. According to him, certain ectodermal cells of blastaea became phagocytic and wandered (multipolar ingression) into the inner blastocoel which became filled up with amoeboid cells embedded in a gelatinous material. Therefore, he argued that the diploblastic ancestral gastraea was a solid rather than a hollow organism, and he named it *parenchymula* (Fig. 7). It would not have required a digestive sac or mouth because of phagocytic intracellular digestion. Formation of archenteron and blastopore were regarded as later, secondary processes.

**2. Support.** According to Metschnikoff, his theory of solid gastraea was strongly supported by the discovery of *Proterospongia* (Fig. 8) by Saville Kent in 1880. It is a choanoflagellate colony embedded in a gelatinous matrix. Some outer collared cells frequently lose their collars and flagella and move into the jelly as amoeboid cells, indicative of ingression.

Facts of embryonic development also support Metschnikoff's theory rather than Haeckel's because gastrulation by inwandering of cells or multipolar ingression is far more common than invagination.



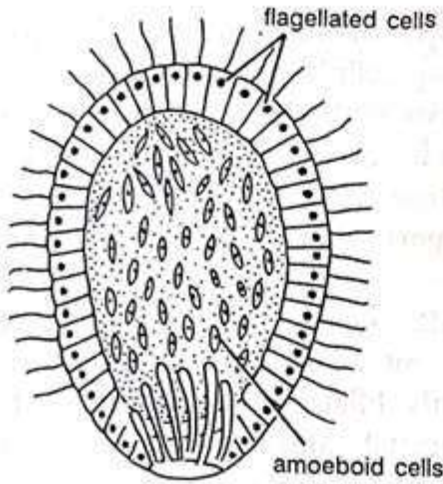


Fig. 7. Parenchymula larva.

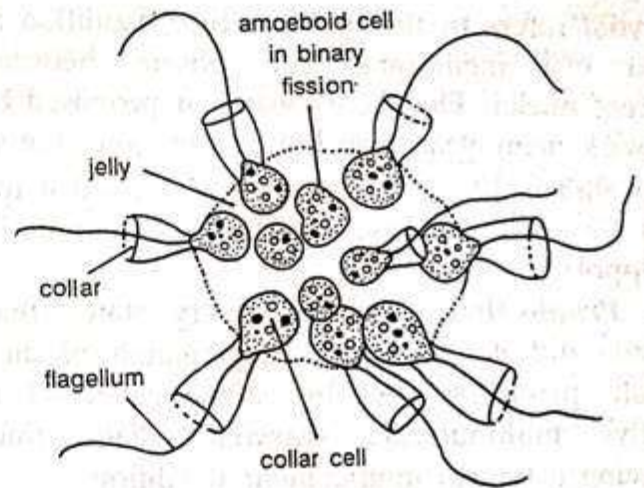


Fig. 8. *Proterospongia haeckeli*.

[V] Modern view by Hyman, etc.

Modern supporters of Colonial Theory, such as Hyman (1940), also derive Metazoa from an axiate hollow spherical flagellated colony, similar to *blastaea* of Haeckel. It showed an early differentiation into somatic and reproductive or germ cells. The somatic cells also became differentiated into locomotor-perceptive and nutritive types. Through the migration or wandering of nutritive cells inside (multipolar ingression), the originally hollow sphere became converted into a solid, ovoid and radially symmetrical *parenchymula* or *stereogastrula* (after Metschnikoff). It had no mouth and no digestive cavity. Food was caught, as in Protozoa, by the outer flagellated locomotor-perceptive cells and

passed to the inner amoeboid nutritive and reproductive cells, for intra-cellular digestion. The anterior pole probably bore special sensory cells or a tuft of sensory cilia. This hypothetical organism has been called the *planuloid ancestor* (Fig. 9) because of its close similarity with the planula larva of coelenterates. According to this view, the radial symmetry of coelenterates is primitive and derived directly from this hypothetical planuloid ancestor.

B. Syncytial Theory by Hadzi

Resemblance between multinucleate ciliates and acelous flatworms led Hanson (1958) and Hadzi (1963) to propose a ciliate origin for metazoans. Their theory may be called the *Syncytial Theory*.

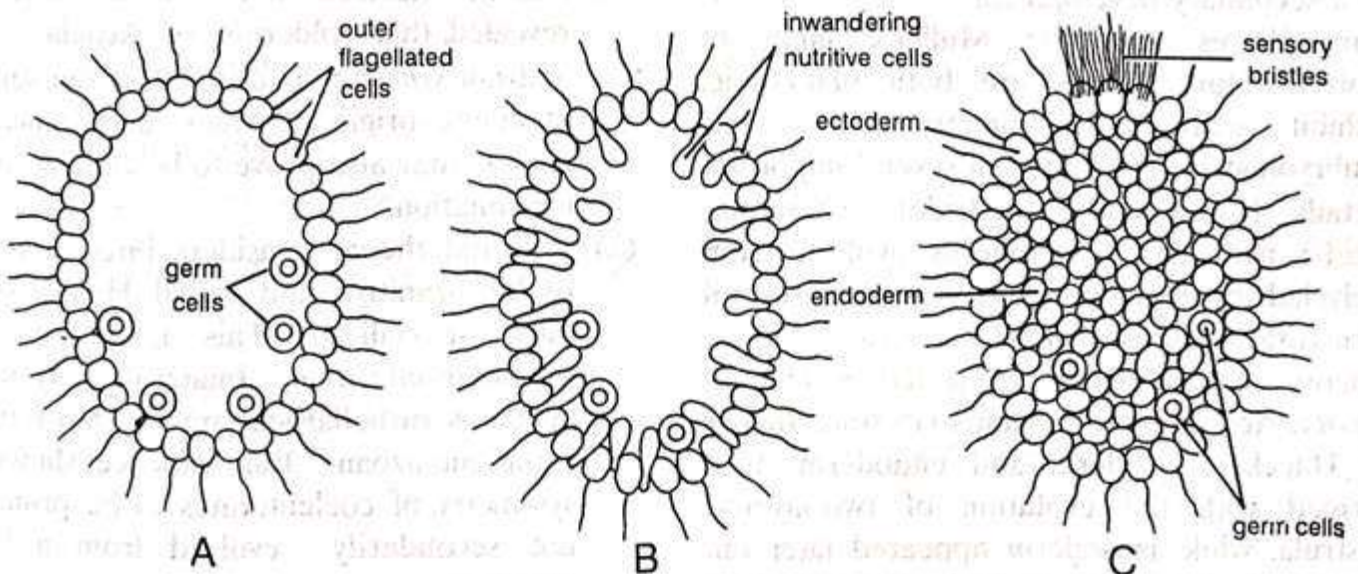


Fig. 9. Formation of endoderm according to Metschnikoff and Hyman. A—Hypothetical ancestral blastaea. B—Multipolar ingression. C—Hypothetical stereogastrula or a planuloid ancestor of Eumetazoa.

Syncytial refers to the multinucleate condition in which cell membranes are absent between adjacent nuclei. The theory was first proposed by Sedgwick many years ago but was ignored. Later, Jovan Hadzi (1963), a Yugoslavian, studied it for about 50 years and gave many logical reasons in its support.

**1. Proposition.** Hadzi's Theory states that Metazoa did not evolve by aggregation of unicellular protists, but by cellularization of a primitive multinucleate syncytial ciliate, thus producing a typical multicellular condition.

The main tenets of Hadzi's theory are as follows :

- (1) The ancestral metazoan was at first syncytial in structure and bilaterally symmetrical. It gave rise to acoel, flatworms (Turbellaria) by process of cellularization. Acoel turbellaria are, therefore, regarded to be the most primitive living metazoans and their bilateral symmetry is considered to be primitive.
- (2) Cnidaria, especially the Anthozoa, were derived from the rhabdocoel turbellarians. Anthozoa became radially symmetrical externally by adopting a sessile mode of life. However, internally they still retain some of their ancestral bilateral symmetry as shown by stomodaeum, mesenteries and muscle bands. Accordingly, the radially symmetrical Hydrozoa are not primitive but advanced than Anthozoa, and their structural simplicity is a secondary development.
- (3) Ctenophores and the Muller's larva of polyclad turbellarians are both planktonic, exhibit octoradial symmetry, and their embryology is also similar in several important details (Lang and MacBride). Therefore, Hadzi held that ctenophores evolved from polyclads by the neoteny retention of several structural features of Muller's larva.
- (4) Theory of germ layers is rejected by Hadzi's theory. According to Blastaea-Gastraea theory of Haeckel, ectoderm and endoderm were formed with the evolution of two-layered gastrula, while mesoderm appeared later on. But, in the development of Acoela, 3 regions are formed in situ without any formation of germ layers. Thus, Hadzi presumes that the three germ layers were formed

contemporaneously in the ancestral ciliate following cellularization.

- (5) It is assumed that *conjugation* in ciliates is a form of sexual reproduction equivalent to copulation in Metazoa.

**2. Support.** Hadzi compared an acoelous turbellarian, such as *Convoluta*, with certain multinucleate ciliates. Both are in the same size range, have an antero-posterior axis, are ciliated and distinctly bilaterally symmetrical. Both tend to be syncytial and lack a digestive cavity. Multinucleate ciliates practice asexual conjugation, show a differentiation into inner, middle and outer material and organelles, and possess trichocysts which are similar to turbellarian sagittocysts and cnidarian nematocysts. Central parenchyma of Acoela (*Convoluta*) looks syncytial due to imperfect cellularization. Hadzi considered these similarities as evidence in support of the primitive position of acoelous turbellarians.

According to Hadzi, all that is needed to convert such a protist to an acoelous turbellarian which has neither gut nor complete cellularization, is partial cellularization and a primitive nerve net. A hollow gut comes later.

**3. Criticism.** A number of objections have been raised against the Syncytial or Turbellarian Theory of Hadzi. It disregards the evidence of embryology, while pays too much importance to adult structural similarity.

- (1) Recent electron microscopic studies have revealed that epidermis of Acoela is cellular and not syncytial as claimed by the supporters of ciliate origin of Metazoa. Parenchyma of Acoela may also prove to be cellular on closer examination.
- (2) Syncytial theory considers biradial Anthozoa to be primitive and radial Hydrozoa to be most specialized. This is based on the presumption that bilaterally symmetrical acoelous turbellarians are the most primitive living metazoans. But evidence shows radial symmetry of coelenterates to be primary and not secondarily evolved from a bilaterally symmetrical ancestor.
- (3) Body plan of primitive groups (or phyla) is generally more variable or less fixed. Naturally, Hydrozoa being more variable

- should be considered more primitive and low in evolutionary line than Anthozoa.
- (4) Anthozoa, with few exceptions, are not hermaphroditic, although most sessile animals are. Thus, Anthozoa seem improbable descendants of hermaphroditic turbellarians, as claimed by Hadzi's theory.
  - (5) Flagellated sperms occur in Metazoa but not in ciliates. Therefore, it is difficult to explain a *de novo* origin of motile sperm in the ciliate metazoan ancestor. Hadzi's theory holds that in some ciliates, the male nucleus is already cellularized, that is, flagellated like a metazoan sperm. Thus, during conversion from Ciliata to Metazoa, cellularization of female gamete must not involve great difficulty.
  - (6) A *macronucleus* is present in ciliates but absent in acoels. It is assumed that macronucleus was absent in the multinucleate protociliate ancestor which gave rise to the metazoan ancestor. It probably developed later in the evolutionary line leading to higher ciliates.

- (7) Turbellarians, nemerteans, annelids and molluscs, etc., undergo *spiral cleavage* during embryonic development. On the other hand, coelenterates show a variety of cleavage patterns but not the spiral cleavage. Thus, derivation of coelenterates from turbellarians would require overnight abandonment of spiral cleavage which seems improbable.

Hadzi's Syncytial or Turbellarian theory has generated much discussion among zoologists, but it has failed to receive universal acceptance.

### C. Polyphyletic Theory

More recently, Greenberg (1959) and Preston (1967) held that probably all Metazoa have not originated from any single ancestor. They have suggested a polyphyletic origin for the metazoans. It is fairly certain that sponges developed by way of colonial flagellates (e.g. *Proterospongia*), whereas other multicellular groups originated from the cellularization of syncytial protociliates or perhaps the mesozoans.

## IMPORTANT QUESTIONS

### » Long Answer Type Questions

1. Write an essay on the origin and evolution of Metazoa.
2. Describe in detail the Colonial or Flagellate Theory of origin of Metazoa.
3. Give a detailed account of Hadzi's Theory regarding origin of Metazoa.
4. Discuss that flagellate protozoans are a highly plastic group from which probably all other protozoan classes have originated.
5. Write short notes on : (i) Blastaea, (ii) Gastraea, (iii) Metschnikoff's theory of origin of Metazoa. (iv) Planuloid ancestor of Metazoa.

### » Short Answer Type Questions

1. Who proposed the colonial theory of the origin of metazoa?
2. Which theory of origin of metazoa supported by Hyman?
3. Give the two failure of Lankester's theory of origin of metazoa.
4. E. H. Hackel presented a theory about evolution and origin of metazoa. What is the name of that theory?
5. What is blastaea?
6. What is gastraea?
7. What is the basic idea of the Hackel's theory of origin of metazoa?
8. Who modified the Hackel's theory?
9. Who proposed the syncytial theory?
10. What is meant by the word syncytial?
11. What is the name of the theory of Hanson and Hadzi.
12. Polyphyletic theory proposed by whom.

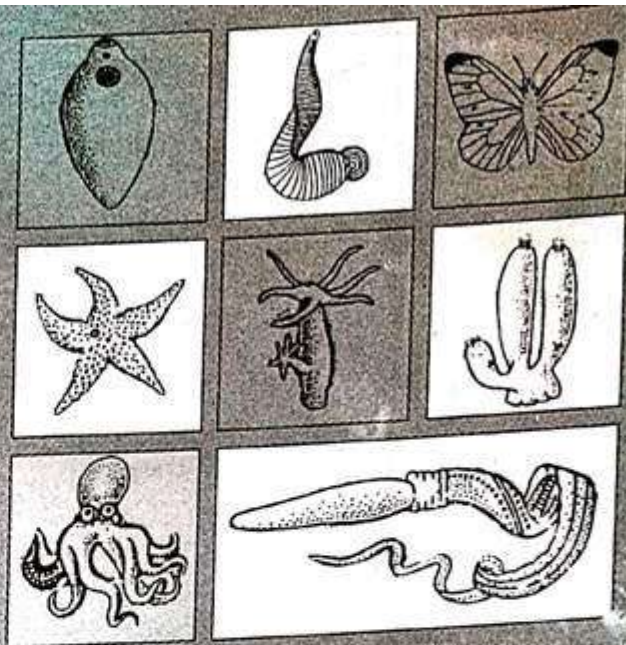
## » Multiple Choice Questions

1. Syncytial theory explains :  
 (a) formation of coelom (b) symmetry of animal  
 (c) origin of life (d) origin of metazoa
2. On the basis of body organisation evolution of animal are grouped as :  
 (a) Parazoa and metazoa (b) Protozoa and metazoa  
 (c) Protozoa and parazoa (d) Metazoa and eumetazoa
3. Polyphyletic theory given by :  
 (a) Greenberg and Perston  
 (b) Lang and McBride  
 (c) Hanson and Hadzi  
 (d) Lankester
4. Colonial theory proposed by :  
 (a) Butschli, Lankester and Haeckel  
 (b) Hanson and Hadzi  
 (c) Hymen L.H. (d) Haeckel E.H.
5. Proterosporgia discovery by :  
 (a) Hymen (b) Haeckel  
 (c) Kent (d) Metschnikoff
6. Gastraea theory of metazoan ancestry presented by :  
 (a) E. H. Haeckel (b) L.H. Hymen  
 (c) J. Hadzi (d) Lankester
7. Syncytial theory proposed by :  
 (a) Hanson and Hadzi (b) L.H. Hymen  
 (c) Lankester (d) E. H. Haeckel
8. Which group of Protozoa support and give explanation of colonial theory of origin of metazoa :  
 (a) Ciliata (b) Sarcodina  
 (c) Ciliophora (d) Flagellate

<b>Answers</b>
----------------

1. (d) 2. (b) 3. (a) 4. (a) 5. (c) 6. (a) 7. (a) 8. (d)
---

# Organization of Bilateria



# 18

Chapter

## Bilateral Phyla

Earlier workers, especially Hatschek (1881-91), divided the Eumetazoa into two super-groups, *Radiata* and *Bilateria*. This division is based on the overall symmetry of the animal bodies. *Radiata* includes only two metazoan phyla, Coelenterata and Ctenophora, which display a fundamental radial symmetry. The remaining phyla, from Platyhelminthes upto Chordata, are bilaterally symmetrical and grouped together as the *Bilateria*. A section only in *median sagittal plane* (M.L.S.) divides their body into right and left halves which are mirror images of each other. Many zoologists agree that free-living acoeloid flatworms of phylum Platyhelminthes are the most primitive of all bilateral animals.

The Bilateria are defined as *bilaterally symmetrical* Eumetazoa with a main *antero-posterior body axis*, with *organ-systems* and a well defined or true *endodermal mesoderm*. Some characteristics, not common to all but present in

many groups of Bilateria, are the presence of *coelom*, *segmentation* and a *definitive anus* or the posterior opening to the digestive tract.

In larger bilateral animals we see the gradual appearance of *excretory*, *respiratory* and *circulatory* systems which are absent in Radiata. *Fertilization* in Bilateria is usually *internal* in contrast to *external* fertilization seen in Radiata.

## Theories of Origin of Bilateria

Supporters of the Colonial Theory believe that the first Metazoa were almost certainly radial animals. When a radial ancestor gave rise to bilateral animals, there must have been a change from radial to bilateral symmetry. It is generally believed that bilateral symmetry developed in the radial ancestor when it started creeping. Several conflicting views have been put forward about the origin of Bilateria, that is, to explain the steps from the radial to the bilateral condition. Of these, the following three theories are noteworthy.

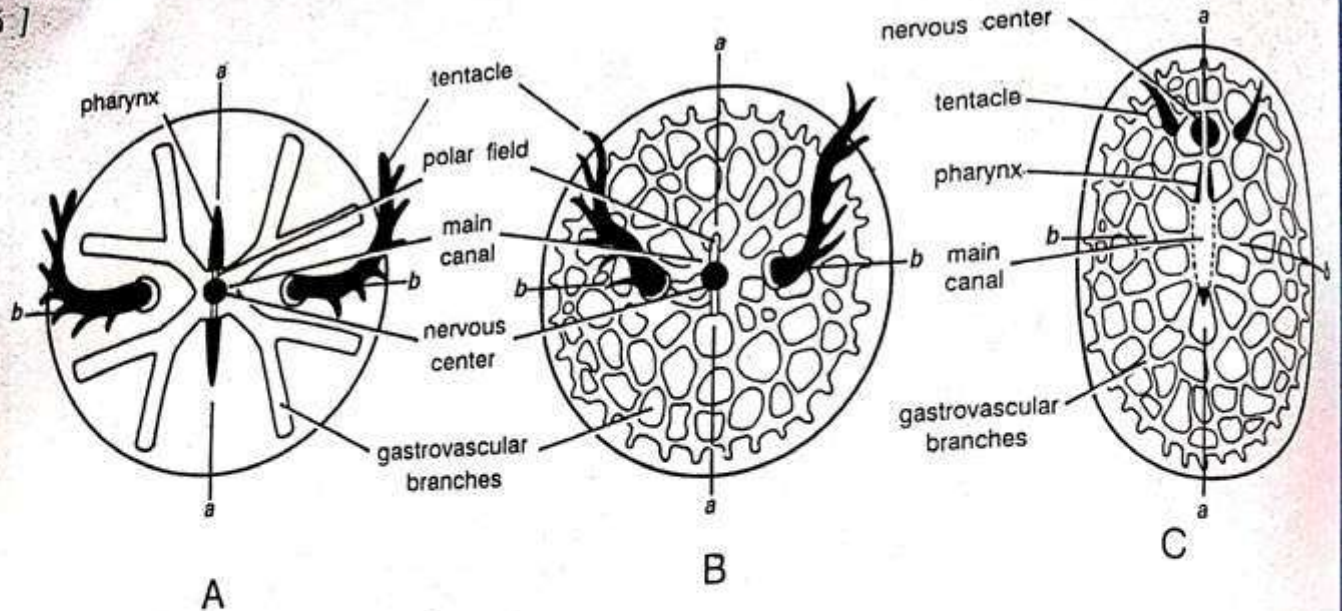


Fig. 1. Gradual change from a ctenophore to a polyclad, according to Ctenophore-polyclad theory. A—Ctenophore. B—Hypothetical intermediate stage. C—Polyclad.

### [I] Ctenophore-polyclad theory

With the discovery of aberrant creeping ctenophores, *Ctenoplana* and *Coeloplana*, this theory was first suggested by Kowalevsky (1880) and later elaborated chiefly by Arnold Lang (1881-84). According to this theory, these ctenophores provided a bridge or intermediate forms between the radially symmetrical coelenterate ancestors and the bilateral polyclad flatworms. This view is based on the following resemblances of *Ctenoplana* and *Coeloplana* with polyclads:

- (1) Oval flattened shape with dorso-ventral differentiation.
- (2) Creeping upon the entire ventral surface.
- (3) Presence of 2 dorsal tentacles.
- (4) Centrally located ventral mouth.
- (5) Branched, blindly ending digestive canals.
- (6) Radiating, anastomosing nervous system.
- (7) Determinate cleavage and a large stomodaeal invagination contributing to the ventral surface.
- (8) The swimming larval stage of many polyclads has 8 ciliated lobes comparable to 8 comb rows of ctenophores.

Fig. 1 represents the stages showing a shift of nerve centre from middle to anterior side, conversion of branching elongated tentacles into

simple small tentacles, and digestive canals branching extensively, during change from a biradially symmetrical ctenophore to a bilaterally symmetrical polyclad.

**Objections.** Lang's ctenophore-polyclad theory is rejected on the following grounds:

- (1) *Ctenoplana* and *Coeloplana* are highly aberrant ctenophores without phylogenetic significance. Their resemblances to polyclad flatworms are undoubtedly superficial.
- (2) Cleavage is biradial in ctenophores but spiral in polyclads.
- (3) According to Lang's theory, the polyclads were regarded as the most primitive Bilateria. Now a days, the acel flatworms are regarded to be most primitive.

### [II] Ctenophore-trochophore theory

This theory is based on the so-called resemblances between ctenophores and trochophore larva, and suffers from many lacunae.

- (1) The theory derives annelids and higher Bilateria from ctenophores through trochophore, but fails to explain the origin of lower Bilateria.
- (2) To bridge over this difficulty, some regard the larvae of acelomate Bilateria (flatworms and

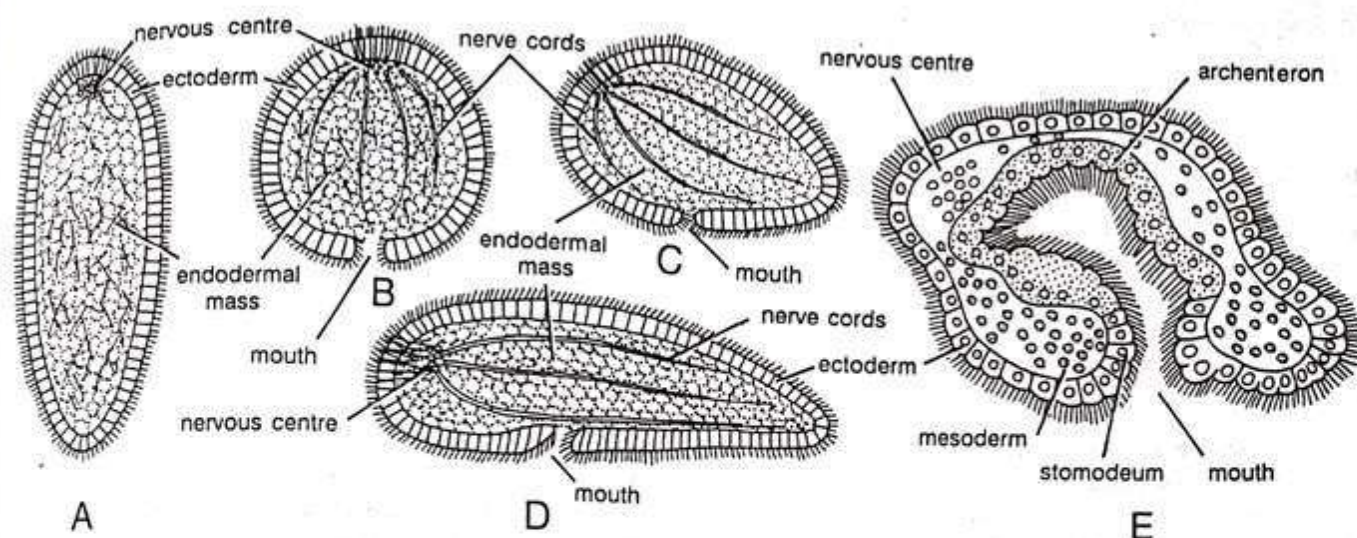


Fig. 2. Stages showing evolution of a planuloid ancestor into an acoel flatworm. A - Planula larva. B - Mouth formed. C - Body elongates and nervous centre shifts forward. D - Acoeloid stage. E - Young flatworm.

nemertines) as earlier stages of trochophore larva. But then, such stages must logically resemble a ctenophore more than a trochophore, which is not the case. Only a fully developed typical trochophore shows resemblances to a ctenophore.

- (3) Others try to justify that acoelomate Bilateria have degenerated from higher Bilateria. But free-living flatworms, especially the acoels, have been firmly established to be the most primitive Bilateria, and are not degenerated forms.

### [III] Planuloid-acoeloid theory

This theory is based upon the remarkable features of acoelous flatworms and their phylogenetic significance. Some zoologists think that acoels are secondarily degenerate and polyclads are the most primitive group of turbellarians (Lang's ctenophore-polyclad theory). While others consider acoels to be the most primitive of all the turbellarian orders. This later view forms the basis of the planuloid-acoeloid theory which was first conceived by Ludwig von Graff (1882) and most recently elaborated by Hyman (1951). The theory places acoel flatworms at the base of the Bilateria and suggests the origin of Bilateria from a planuloid ancestor through an acoeloid form.

The hypothetical planuloid ancestor was very similar to the planula larva of coelenterates (Fig. 2-A). It was elongated, radially symmetrical and without mouth or archenteron. The exterior cells were ciliated or flagellated epitheliomuscular cells, while the solid mass of interior cells were digestive as well as reproductive. There was a nerve-net under epidermis and the anterior pole had a nervous centre or an accumulation of neurosensory cells. Many of these features are already present in the acoel flatworms.

According to Hyman (1951), some of the planuloid ancestors may have adopted a creeping mode of life. This could have resulted in their flattening out in the oral-aboral axis, in differentiation between dorsal and ventral surfaces, and to the development of a ventral mouth.

The forward shifting of the nervous centre would have led to the evolution of the acoeloid ancestral stage. Later on, the hollowing out of interior mass formed an archenteron, and the greater differentiation of anterior region formed a head which also sprouted a pair of tentacles. The result is the conversion of the radial planuloid ancestor into a simple flatworm with bilateral symmetry, ventral mouth, anteriorly located brain and sense organs (Fig. 2-E).

## IMPORTANT QUESTIONS

### » Long Answer Type Questions

1. What are bilateral phyla? Discuss the theories regarding their origin.
2. What is the significance of discovery of *Ctenoplana* and *Coeloplana* in the origin of Bilateria?
3. Write short notes on : (i) Ctenophore-trochophore theory of origin of Bilateria. (ii) Planuloid-acoeloid theory.

### » Short Answer Type Questions

1. What do you mean by bilateria?
2. Explain ctenophora.
3. Describe the coeloplana?
4. What is M.L.S. ?
5. Name the systems which are absent in radiata?
6. Explain polyclad theory in brief?

7. Name the theory which conceived by Graff?
8. Eumetazoa divided into ..... and .....
9. Fertilization in bilateria is usually .....
10. Ctenophore polyclad theory was first suggested by .....
11. Planuloid acoeloid theory was first conceived by .....

### » True / False

1. According to Flymen (1951) some of the planuloid ancestors may have adopted a creeping mode of life.
2. The hypothetical planuloid ancestor was very similar to planula larva of coelenterates.

3. Cleavage is biradial in ctenophores but spiral in polyclads.
4. Ctenophore polyclad theory put forward by L.H. Hymen.
5. Eumetazoa divided into radiata and biradiata.

### » Multiple Choice Questions

1. Radiata include :
  - (a) Coelenterata & Platyhelminthes
  - (b) Porifera & Coelenterata
  - (c) Coelenterata & Ctenophora
  - (d) Porifera & Platyhelminthes
2. Most primitive among bilateral animals :
  - (a) Coelentrata
  - (b) Porifera
  - (c) Platyhelminthes
  - (d) Annelida
3. Common character of bilateria :
  - (a) coelome
  - (b) segmentation
  - (c) definitive anus
  - (d) all

4. In bilateria fertilization usually is :
  - (a) internal
  - (b) external
  - (c) internal as well as external
  - (d) in sea water
5. According to Lang's theory following were regarded : most primitive bilateria :
  - (a) Porifera
  - (b) Coelenterates
  - (c) Polyclads
  - (d) Ctenophore

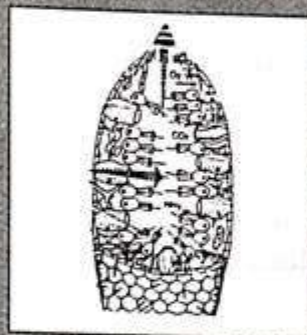
### Answers

1. true, 2. true, 3. true, 4. false, 5. false

1. (c) 2. (c) 3. (d) 4. (a) 5. (c)



# *Leucosolenia:* An Asconoid Sponge



## 19 Chapter

Phylum *Porifera* contains the most primitive of multicellular animals, called *sponges*. They are usually referred to as 'pore bearers', as their body walls contain tiny pores that are basic structures in their functional activity. The organization of sponges shows certain features to a degree not apparent in any of the other metazoan animal groups. Especially, the cell types and gross morphology are not at all comparable with other Metazoa. This led to place the sponges in an isolated branch of Metazoa, the *Parazoa*, whereas all the remaining phyla of multicellular animals are combined in the branch *Eumetazoa*.

Biology of sponges can best be understood by the study of a simple asconoid type. *Leucosolenia* is one of the simplest asconoid sponges.

### *Leucosolenia*

*Leucosolenia* (Gr., *leukos*, white + *solen*, pipe), as the name implies, has a pipe-like body. It is an *asconoid* sponge which represents the simplest and most primitive type of structural pattern. It is usually said to be the *olyntus* type as well, as its body organization resembles the *olyntus*

stage in the *ontogeny* (developmental history) of certain other sponges, like *Scypha*.

## Systematic Position

Phylum	Porifera
Class	Calcarea
Order	Homocoela
Genus	<i>Leucosolenia</i>

## Occurrence

*Leucosolenia* is a small, delicate, sessile, branching, colonial and marine sponge. It is found growing in shallow water, below low-tide mark, on seashore rocks, boulders and jetties. It does not live in calm water but is found abundantly where wave action is intense. It is very sensitive to external conditions and will die if removed from its habitat. About 100 species occur all over the world. The common species are *L. botryoides*, *L. complicata* and *L. variabilis*.

## External Morphology

The colony of *Leucosolenia* is whitish or yellowish in colour. It consists of radially symmetrical, vase-shaped, vertical, hollow and tube-like individuals or cylinders, united at their bases by irregular horizontal tubes and attached to the substratum through adhesive-discs. The upright individuals or cylinders may reach upto 25 mm in height.

The surface of each tube-like individual bears minute pores called *ostia* (singular, *ostium*) or *incurrent pores*. The pores lead into a central spacious cavity, the *paragastric cavity* or *spongocoel* (Gr., *spongos*, sponge + *koilos*, cavity). It opens to outside through a large circular opening, the *osculum*, situated at the free terminal end of the tube.

## Body Wall (Histology)

The thin body wall, which encloses the spongocoel, is relatively simple. It consists of two cellular layers, the outer *pinacoderm* and inner *choanoderm*, with a non-cellular *mesenchyme* in between.

**1. Pinacoderm.** The body is covered externally by *epidermis* or *pinacoderm*. This is a single layer of thin and flat polygonal cells, the *pinacocytes* (Gr., *pinako*, plank + *kytos*, cell). It ensures

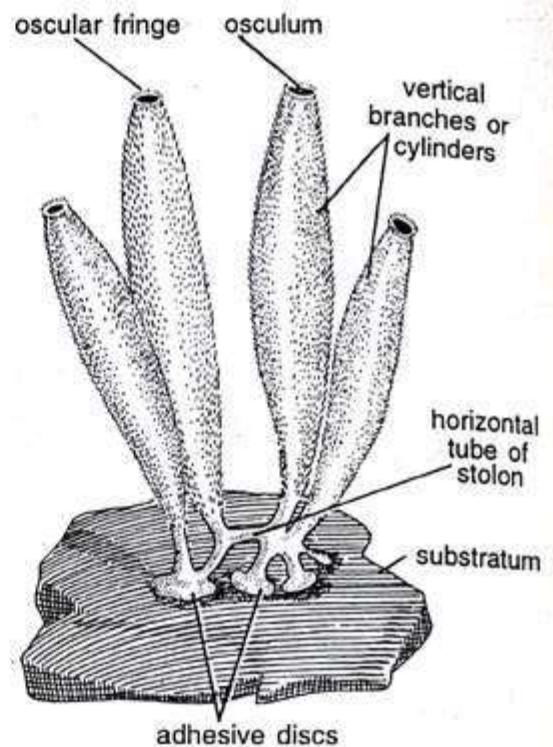


Fig. 1. *Leucosolenia*. A colony growing on a rock.

protection to the internal organization of body. Pinacocytes are hexagonal in surface view with thin margins and a bulging central part containing a nucleus. The margins show contractility, so that the sponge can increase or decrease slightly in size.

Within the body wall are special, large and tubular cells, called *pore cells* or *porocytes*. They are supposed to be modified pinacocytes. Each porocyte contains a central canal-like space, communicating with the outside as well as the spongocoel. These spaces are called *ostia* or *dermal pores* or *incurrent pores*. These permit water to flow from outside into the spongocoel.

**2. Choanoderm.** The spongocoel is lined internally by *gastrodermis* or *choanoderm*. It consists of a single layer of flagellated collar cells, the *choanocytes* (G., *choane*, funnel + *kytos*, cell). A choanocyte is an ovoid cell with its free end bearing a transparent contractile collar. It surrounds a single long *flagellum* which arises from a *basal granule* or *kinetosome*. The nucleus lies at the base or apex of its cell body. Protoplasmic processes of the cell body are embedded in the mesoglea. Choanocytes are used in feeding and for ensuring the flow of water within the animal's body by beating of their flagella.

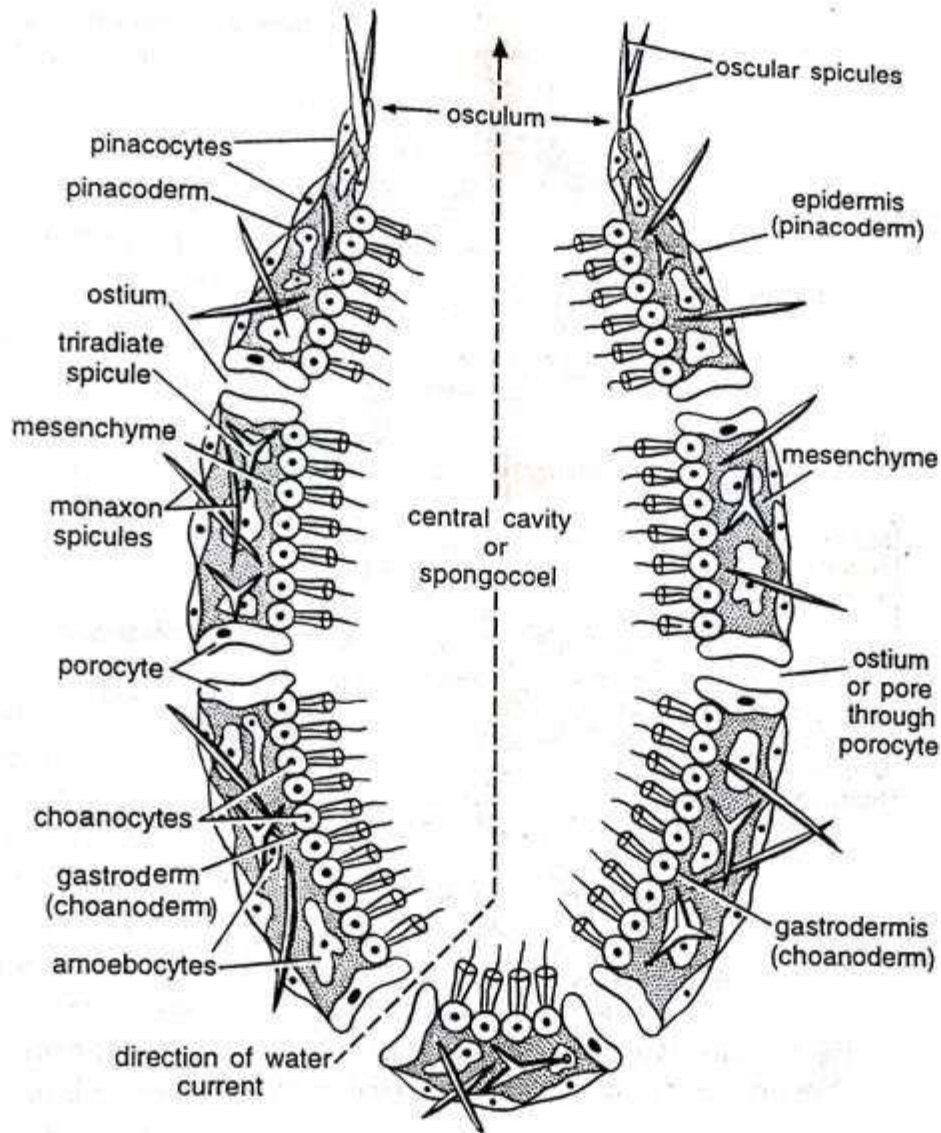


Fig. 2. *Leucosolenia*. Longitudinal section.

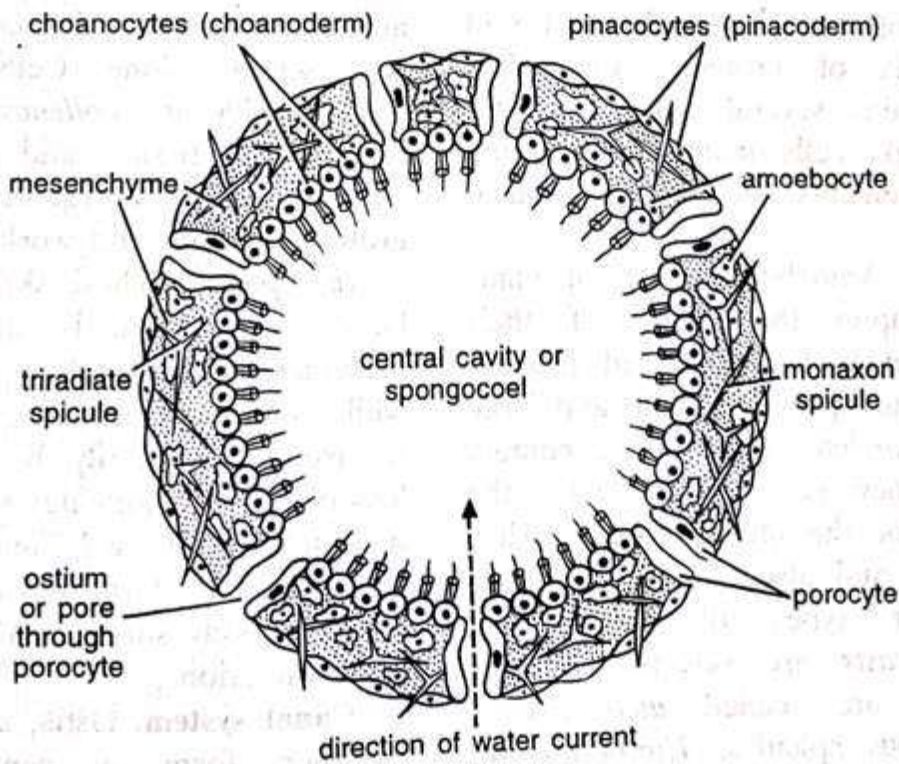


Fig. 3. *Leucosolenia*. Transverse section.

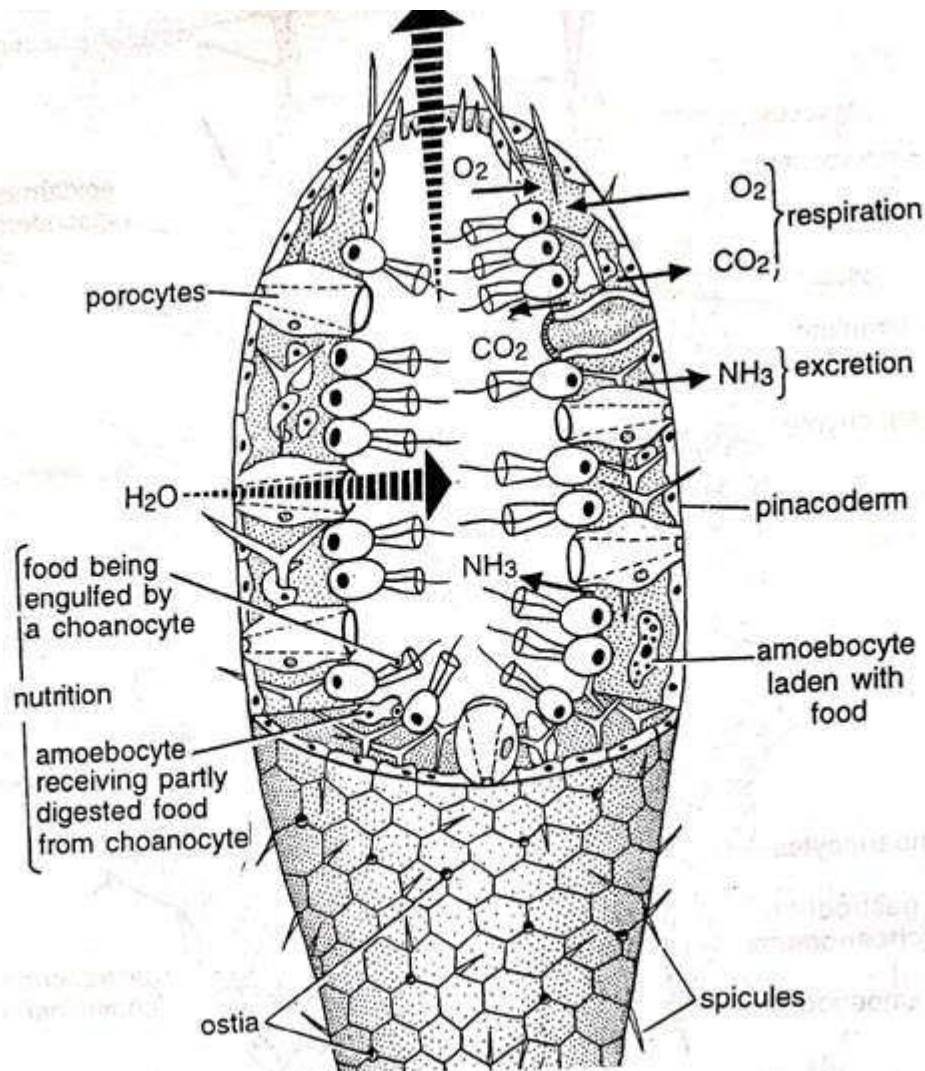


Fig. 4. *Leucosolenia*. An individual cylinder with a portion cut to show circulation of water, nutrition, respiration and excretion.

**3. Mesenchyme.** In between pinacoderm and choanoderm is present non-cellular mesenchyme. It is secreted by both body layers. It consists of a gelatinous matrix of protein, also called *mesogloea*. It contains several types of freely wandering amoeba-like cells or *amoebocytes*, and minute skeletal elements of CaCO<sub>3</sub>, called *spicules* or *sclerites*.

(a) **Amoebocytes.** Amoebocytes are of many types depending upon the shape of their pseudopodia and function. Large-sized primary amoebocytes with blunt pseudopodium and large nucleus are the *archaeocytes*. These contain much RNA and they carry on all the functions essential for the life of sponge. They are self-replicating and also capable of giving rise to all other types of amoebocytes (totipotent). *Scleroblasts* are skeleton forming amoebocytes. They are called *caloblasts* as they form calcareous spicules. *Thesocytes* are

with rounded pseudopodia and have reserve food material. *Chromocytes* carry colour pigments and are responsible for colour of sponge. *Glan cells* secrete slime. Cells with thin branching pseudopodia are *collencytes* forming a sort of connective tissue and probably nerve cells. *Myocytes* are contractile thin cells, present around osculum and work as a sphincter.

(b) **Spicules.** These skeletal elements, small or large, are formed of crystalline calcareous carbonate. Needle-like spicules are *monaxon* while some are *tetraxons* with four rays. Some tetraxons secondarily become *triradial* due to loss of one ray. Spicules remain embedded within mesenchyme, though many of them protrude through pinacoderm and impart roughness to the sponge's body surface. All spicules orient in the same direction.

**Canal system.** Ostia, spongocoel and osculum together form a canal system which

characteristic of all sponges. Canal system of *Leucosolenia* is of *ascon type*. It is the simplest type of canal system found in sponges. Water enters directly through ostia into the central spongocoel, which is lined by choanocytes, and leaves through osculum.

### Physiology

**1. Locomotion and behaviour.** *Leucosolenia* is incapable of locomotion. It is supposed to possess local contractile powers that appear to be mostly restricted to the region of osculum. Reactions to stimuli are very slow and responses are seen several minutes after the application of stimulus.

**2. Water current.** Vital life processes of a sponge are dependent upon a continuous uninterrupted flow of water through its porous body. This is essential because they are sessile and have no other means of getting food and oxygen or getting rid of wastes. Water current is caused by constant beating of flagella of millions of choanocytes. Water enters spongocoel through ostia and exits through osculum. Flow of water is controlled by the closing and opening of ostia. Flow of water through a sponge can be demonstrated by adding carmine particles to water containing a living sponge. These particles are seen to enter body of sponge through ostia and pass out through osculum. The water current brings food and oxygen and removes excretory as well as reproductive elements.

**3. Digestion.** Food consists chiefly of plankton, i.e., microscopic animals and plants and organic particles. Choanocytes capture and digest the food. Amoebocytes receive the partly digested food particles from choanocytes, complete digestion and distribute the digested food from cell to cell by diffusion. Amoebocytes digest food intracellularly within their food vacuoles. The reaction of food vacuoles is at first acidic and later alkaline. Undigested residue is eliminated by the amoebocytes into spongocoel.

**4. Respiration.** Respiration, involving exchange of  $O_2$  from sea water and  $CO_2$  produced within the living cells, is accomplished by diffusion.

**5. Excretion.** Elimination of metabolic wastes (chiefly  $NH_3$ ) also takes place by diffusion through the general surface of body.

### Reproduction and Development

*Leucosolenia* reproduces asexually as well as sexually.

**1. Asexual reproduction.** *Leucosolenia* reproduces asexually by *branching* and *budding*.

**(a) Branching.** New horizontal branches arise from stolon, grow over rocks, and give rise to new erect vase-shaped cylinders. When an upright branch or cylinder attains sufficient size, its top breaks through as an osculum.

*Regeneration* is also common and a complete individual or colony will grow from almost any broken piece of sponge.

**(b) Budding.** This is accomplished by evagination of body wall near the base of a vertical tube in the form of a *bud*. The bud grows in size and breaks off an osculum at its free end, thus becoming an additional individual of colony. This may again bud off new individuals.

**2. Sexual reproduction.** *Leucosolenia* is monoecious, i.e., male and female reproductive cells or gametes are formed in the same individual. No special gonads are formed. Sperm and ova are derived from *archaeocytes* by gametogenesis. Sperms are released into sea water and they make their way into another

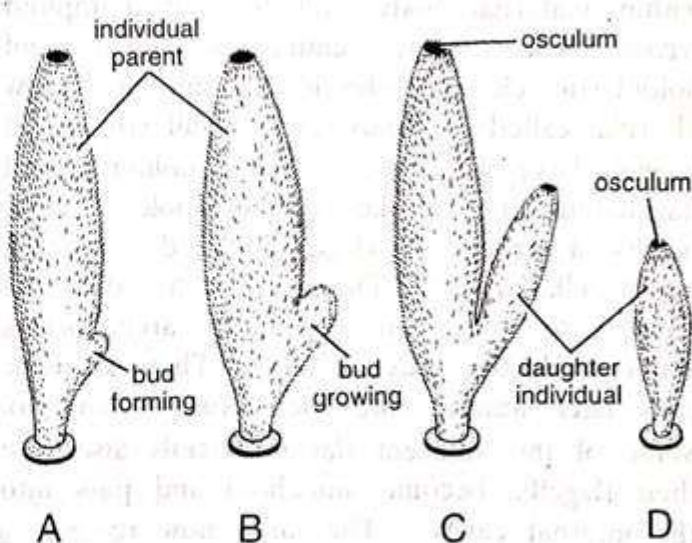


Fig. 5. *Leucosolenia*. Stages showing budding.

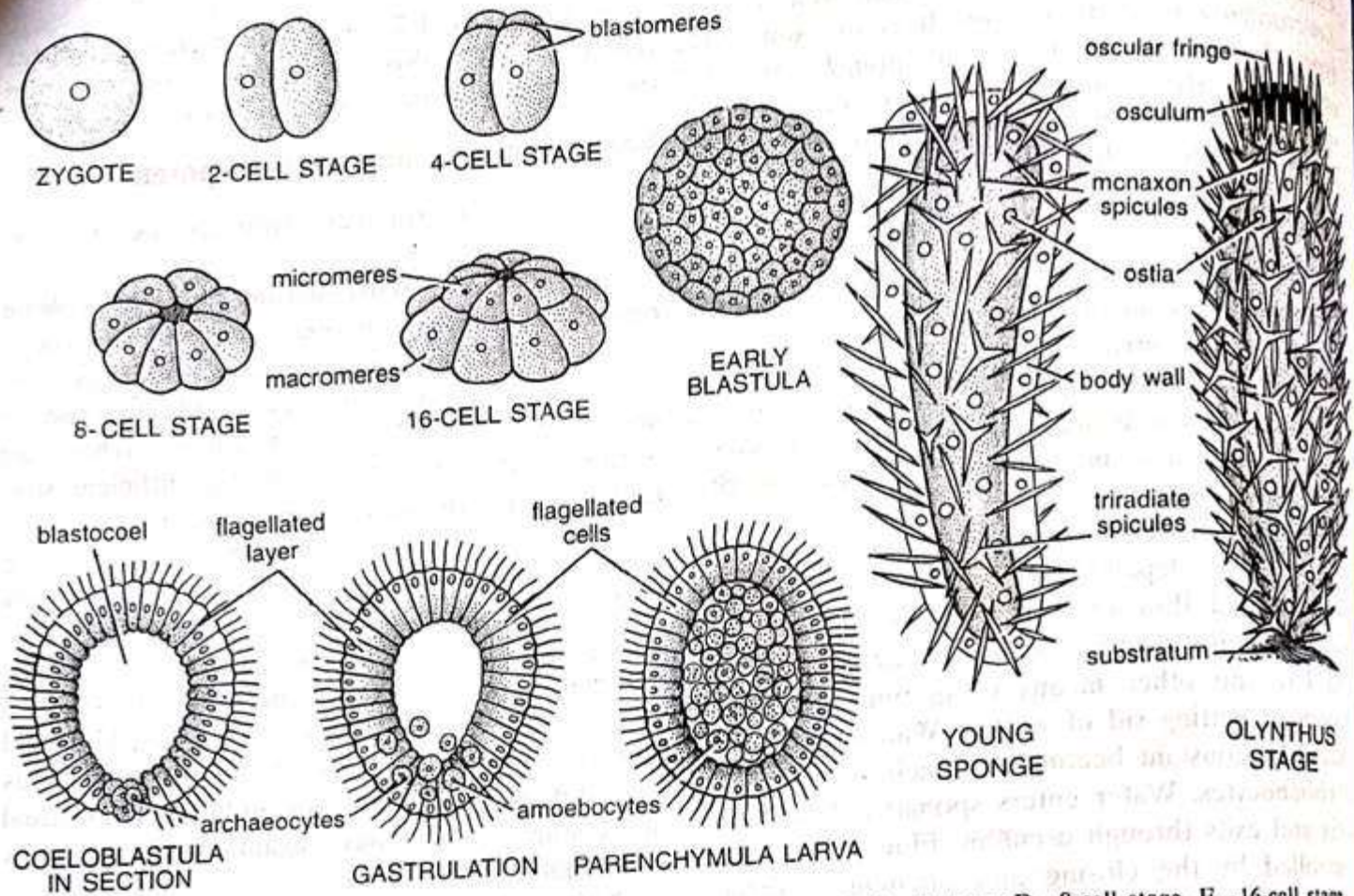


Fig. 6. *Leucosolenia*. Stages in development. A—Zygote. B—2-cell stage. C—4-cell stage. D—8-cell stage. E—16-cell stage. F—Early blastula. G & H—Coeloblastula. I—Parenchymula. J—Young sponge. K—Adult sponge.

sponge to a region of a mature ovum. Some workers believe that sperms are transported to mature ova by amoebocytes.

**3. Development.** Ovum is fertilized by a sperm within maternal body wall forming a diploid *zygote*. The *zygote* undergoes equal and holoblastic cleavage developing into a hollow blastula, called *coeloblastula*. Its wall consists of a single layer of narrow, elongated, columnar and flagellated cells. At the posterior pole of larva occurs a group of large, rounded, granular, non-flagellated cells. These are believed to be *archaeocytes* which form all future *archaeocytes* and reproductive cells of sponge. These granular cells later wander into the cavity of embryo. Some of the adjacent flagellate cells also lose their flagella, become amoeboid and pass into the internal cavity. The larva now reaches a stage corresponding to the *planula* larva of coelenterates. It is termed *stereogastrula* or

*parenchymula* and consists of an external layer of flagellated cells and an inner mass of amoeboid cells. It has no mouth opening.

*Parenchymula* swims freely for some hours. Then it becomes fixed by its anterior pole and develops into a flat plate with an irregular outline. Most of the amoeboid cells migrate to external surface, passing between flagellated cells and form the pinacoderm and mesenchyme. Flagellated cells, thus enclosed, become the choanocytes. A central cavity or spongocoel appears which increases in size, becomes lined by choanocytes and opens to outside by an osculum. Certain non-flagellated cells in the wall of sponge, or porocytes, become perforated to form incurrent pores or ostia. Monaxon and triradiate spicules are secreted by the scleroblasts of modified amoeboid cells. Within a few days of attachment, the larva is converted into the adult asconoid sponge.

**IMPORTANT QUESTIONS**

» Long Answer Type Questions

1. Give an account of the structure, physiology and reproduction of an asconoid sponge studied by you.
2. Describe, with suitable diagrams, the development of *Leucosolenia*.
3. Draw a labelled diagram of the L.S. of *Leucosolenia*.
4. What are sponges? Describe the cellular organization of *Leucosolenia*.
5. Briefly describe the structure and life history of *Leucosolenia*.
6. Write short notes on : (i) Choanoderm, (ii) Coeloblastula, (iii) Osculum, (iv) Ostia, (v) Parenchymula, (vi) Pinacoderm.

» Short Answer Type Questions

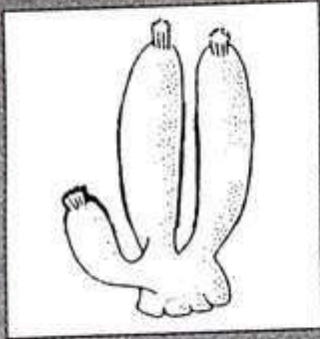
1. What is amoebocyte found in mesenchyme of *Leucosolenia*? Write its various forms and their functions.
2. Describe the ascon type of sponge.
3. What is a choanocyte? Relate its structure to its function.
4. Describe the various histological elements found in *Leucosolenia*.
5. Give the structure of pinacoderm in *Leucosolenia*.
6. Give the structure of choanoderm in *Leucosolenia*.
7. Describe the development and structure of parenchymula larva in *Leucosolenia*.

» Multiple Choice Questions

1. *Leucosolenia* is :  
(a) fresh water colonial sponge  
(b) marine and solitary  
(c) solitary  
(d) colonial and firmly attached to the substratum
2. *Leucosolenia* is :  
(a) sessile (b) marine  
(c) colonial (d) all of these
3. Which is not known to occur in *Leucosolenia* :  
(a) respiration (b) egestion  
(c) asexual reproduction (d) locomotion
4. The free swimming larva of *Leucosolenia* is :  
(a) stomoblastula (b) amphiblastula  
(c) stereoparenchymula (d) olynthus stage
5. Which type of canal system is found in *Leucosolenia* ?  
(a) ascon (b) rhagon  
(c) leucon (d) syconoid
6. In sponges food is ingested by :  
(a) scleroblasts (b) choanocytes  
(c) porocytes (d) pinacocytes
7. Digestion of food in *Leucosolenia* takes place :  
(a) in the spongocoel (b) in the amoebocytes  
(c) in the choanocytes  
(d) first in choanocytes and then in the amoebocytes
8. The internal skeleton of *Leucosolenia* is formed of calcareous :  
(a) monaxon (single-rayed) spicules  
(b) monaxon and tri-radiate (three-rayed) spicules  
(c) tri-radiate and quadri-radiate (four-rayed) spicules  
(d) monaxon, tri-radiate and quadri-radiate spicules
9. The principal cell types present in the body wall of *Leucosolenia* are the :  
(a) pinacocytes, porocytes, choanocytes, amoebocytes  
(b) pinacocytes, choanocytes, amoebocytes, nephrocytes  
(c) choanocytes, nerve cells, amoebocytes, nephrocytes  
(d) choanocytes, porocytes, nephrocytes, amoebocytes
10. The common bath sponge is :  
(a) *Leucosolenia* (b) *Euspongia*  
(c) *Sycon* (d) *Spongilla*
11. Gametes in *Leucosolenia* are derived from :  
(a) archaeocytes (b) choanocytes  
(c) porocytes (d) amoebocytes
12. Spicules of *Leucosolenia* origin from :  
(a) calcoblast (b) thesocyte  
(c) trophocyte (d) archeocyte
13. Nutrition in *Leucosolenia* is :  
(a) intracellular (b) extracellular  
(c) both (d) none
14. The chief excretory product of *Leucosolenia* :  
(a) ammonia (b) urea  
(c) uric acid (d) none
15. In *Leucosolenia* the sperm and ova develop from :  
(a) monocyte (b) amoebocyte  
(c) archaeocyte (d) gland cells
16. Young stage of *Leucosolenia* is :  
(a) coeloblastula (b) parenchymula  
(c) olynthus (d) stomoblastula

**Answers**

1. (d) 2. (d) 3. (d) 4. (c) 5. (a) 6. (b) 7. (c) 8. (d) 9. (a) 10. (b) 11. (a) 12. (a) 13. (a) 14. (a) 15. (c) 16. (c)



# 20

Chapter

The structure of *Leucosolenia*, described in preceding chapter, is of primitive asconoid type in which the body wall is not folded. In other types, the body organization is based upon the folding of the body wall and reduction in size of the spongocoel. The first stage of the folding of the body wall is displayed by sponges with syconoid type of structure in which the body wall has become folded horizontally, forming finger-like processes. Syconoid sponges include the well-known genera *Scypha* (= *Sycon*) and *Grantia*. The biology of *Scypha* has been treated in detail in this chapter.

## *Scypha* or *Sycon*

*Scypha* is commonly known as *urn sponge*, as the individuals are shaped like an urn (a water vessel). It is also called the *crown sponge*,

## *Scypha* (= *Sycon*): A Syconoid Sponge

because the fringe of long and straight spicules at the top looks like a little crown. *Scypha* differs from *Grantia*, a European genus, in not having an outer covering, or the *cortex*, a characteristic feature of the latter. The best studied species of *Scypha* are *S. coronata*, *S. ciliatum*, *S. elegant*, *S. lingua* and *S. raphanus*.

### Systematic Position

Phylum	Porifera
Class	Calcarea
Order	Heterocoela
Family	Sycettidae
Genus	<i>Scypha</i> or <i>Sycon</i>

### Habitat

*Scypha* (Gr. *skyphos*, cup) is a marine sponge which is widely distributed, but is best known from North Atlantic shores. It may be solitary or forms a colony by budding. Sessile colonies of cylindrical individuals are found permanently



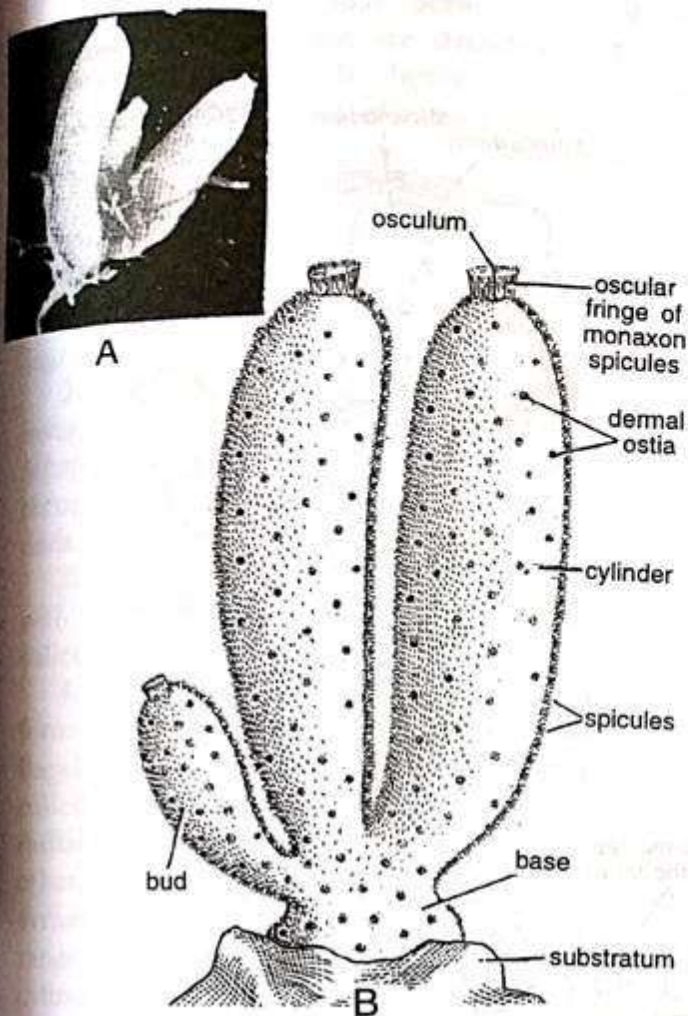


Fig. 1. *Scypha*. A - Colony in natural size  
B - One individual magnified.

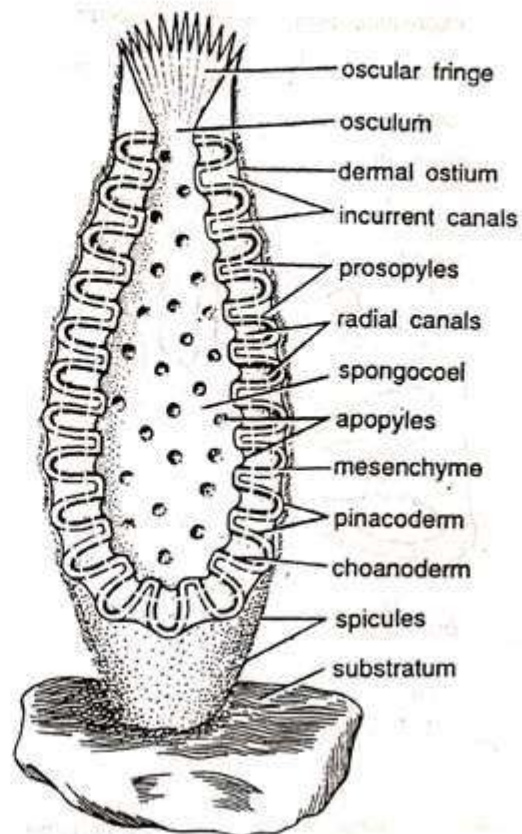


Fig. 2. *Scypha*. A diagrammatic L.S. of a cylinder showing gross internal structure and canal system.

from entering into the body. Just below osculum, the body becomes narrower forming a *collar region*. The body surface is thrown into regularly arranged polygonal elevations from which project spear-like spicules, called *oxeotes* (monaxon spicules), that impart a bristly appearance to the body. The polygonal elevations are separated by deep grooves, bearing minute pores, i.e., *ostia*, which lead into the central body cavity, the *spongocoel* or *paragastric cavity*, through a system of canals.

#### Canal system

Body of *Scypha* is organized in such a manner as to form a complex system of pores and canals. This system is generally referred to as *canal system* or *aquiferous system*. Body wall has essentially the same cellular layers, *pinacoderm* and *choanoderm*, with a non-cellular gelatinous *mesenchyme* in between. But the body wall is so folded as to form regularly arranged alternating invaginations and evaginations, establishing the sycon type of canal system. Various components of canal system are as follows :

(Z-1)

attached to submerged rocks or other solid substrata in shallow sea water along the coasts. They thrive well where wave action is not too strong and at low tide mark.

#### External Morphology

*Scypha* or *Sycon* possesses a vase-shaped and radially symmetrical body which measures from 1 to 3 cm in height and 5 to 6 mm in diameter. The colour is not specific but varies from grey to light brown. Near the attached end are found a few small tubular projections, or *buds*, which are formed not so extensively as in *Leucosolenia* or other asconoid sponges. Free end of the vase-shaped individual bears a pore, the *osculum* (*exhalent* or *excurrent* pore), which is fringed with long, straight, needle-like calcareous monaxon spicules. This *oscular fringe* checks small animals

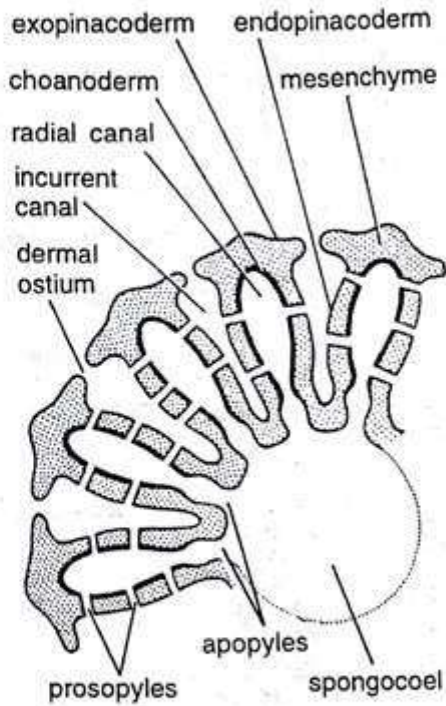


Fig. 3. *Scypha*. A portion of a T.S. (diagrammatic).

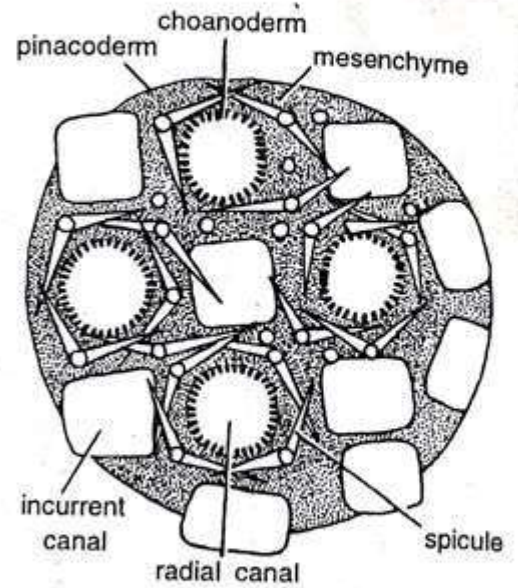


Fig. 4. *Scypha*. A tangential section of a portion of body wall showing arrangement of incurrent and radial canals.

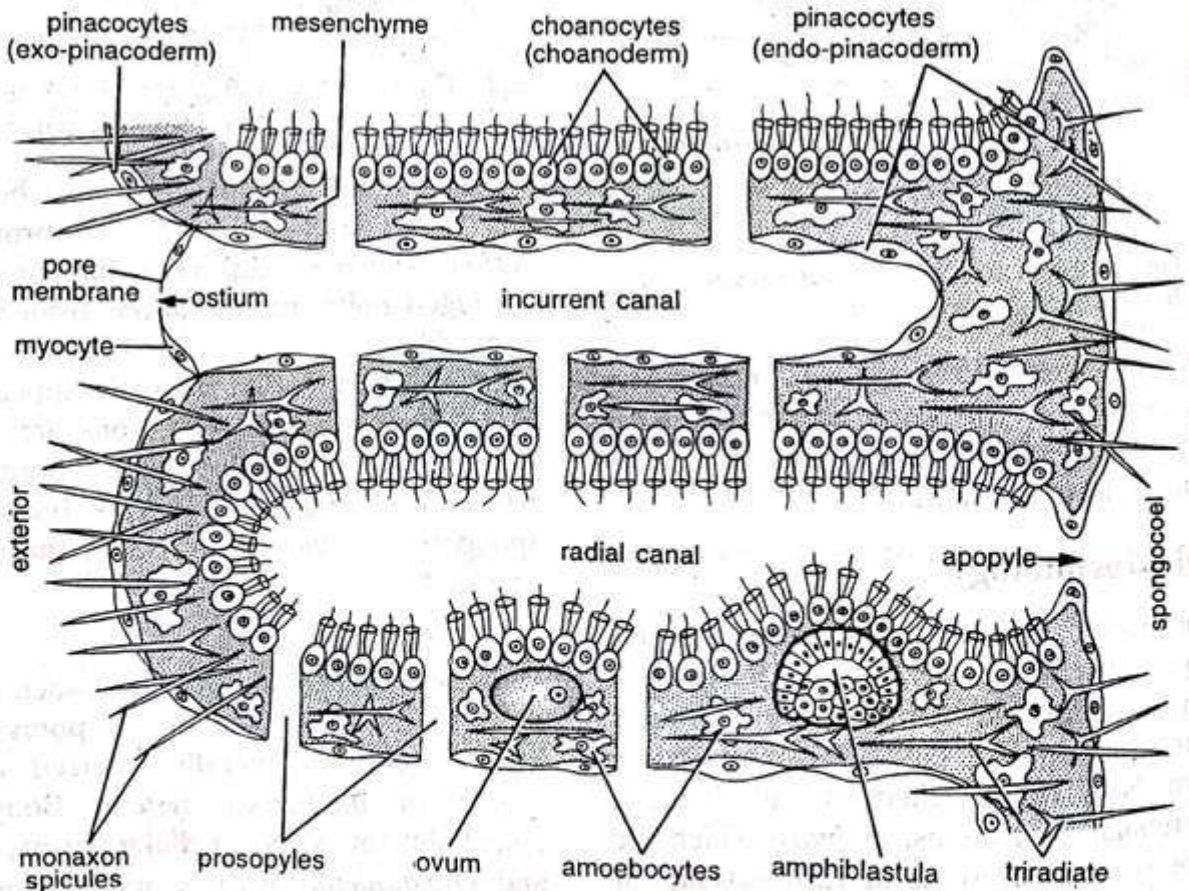


Fig. 5. *Scypha*. A diagrammatic sectional view of body wall showing one incurrent canal and one radial canal.

1. Ostia or dermal pores. The external























































































































































































































































2. Affinities with Platyhelminthes. *Platyctenea* ctenophores (*Ctenoplana* and *Coeloplana*) show certain resemblances with polyclad turbellarians (*Cestoplana*).

1. Dorso-ventrally flattened body.
2. Crawling mode of life.
3. Ectoderm ciliated.
4. Lobed gastrovascular cavity, especially in embryos.
5. Gelatinous mesenchyme with muscle fibres and cells.
6. Similar earlier stages of segmentation and gastrulation.

On account of these similarities, *Ctenoplana* and *Coeloplana* have been considered the missing links between Coelenterata and Platyhelminthes. This view is no longer supported because *Ctenoplana* and *Coeloplana* are now considered typical ctenophores adapted for a creeping mode of life.

3. Position in animal kingdom. Ctenophores have certain characteristics in common with coelenterates. Ctenophora are believed to have diverged very early from the ancestral medusoid coelenterate which was a spherical animal with concentration of cilia along 8 meridional rows which later developed into comb plates. However, they represent a blind offshoot which gave rise to no higher forms. Ctenophores also present certain advancements over Radiata, such as prominence of apical region, musculature derived from mesoderm, presence of gonoducts and determinate type of cleavage. This implies that Ctenophora are intermediate between Radiata and Bilateria and have undergone considerable specialization with many striking characteristics of their own. Therefore, it seems quite logical to treat Ctenophora as a separate phylum rather than a class or subphylum of phylum Coelenterata.

### Types of Ctenophora

1. **Pleurobrachia and Hormiphora.** *Pleurobrachia* (Gr., *pleuron*, side + *brachia*, arms) and the closely allied genus *Hormiphora*, are common marine pelagic forms, found all over the world. Body is glassy transparent and pear-shaped or walnut-shaped, hence commonly known as *sea walnuts*. *Pleurobrachia pileus* is about 20 mm. in

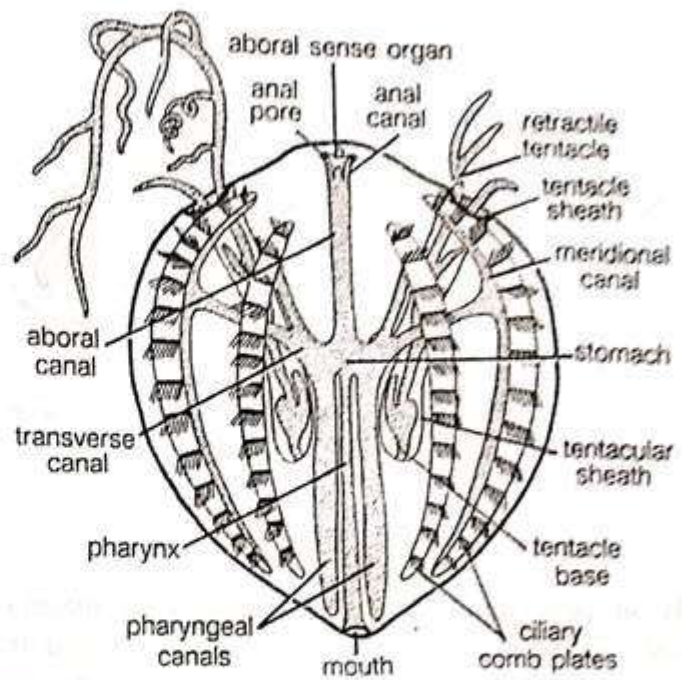


Fig. 1. *Pleurobrachia*.

diameter, while *Hormiphora plumosa* is slightly smaller and 5 to 20 mm. in diameter. External surface bears 8 equally spaced *paddle plates* or *comb plates*, each made of transverse rows of long fused cilia. For this reason they are also called *comb jellies*. Near aboral end, on opposite sides, are attached two very long (15 cm.), solid and highly extensile *tentacles* provided with lateral branches. Each tentacle can be completely withdrawn into a deep cavity or *tentacle sheath*. At the aboral end is a shallow depression with a sense organ or *statocyst*. A slit-like *mouth* is present at the oral end. It leads into a long, narrow pharynx or stomodaeum, opening into the stomach, which is connected to a system of gastrovascular canals. Comb jelly is strictly carnivorous. Food is captured by tentacles with the help of *colloblasts*. Undigested material comes out of the mouth. The animal is hermaphrodite. Gonads develop in the meridional gastrovascular canals. Development includes a free-swimming *cydippid* larva.

2. **Velamen.** *Velamen* is commonly known as 'Venus girdle'. It occurs in warmer seas, especially the Mediterranean. Body is about 45 cm long and 3 cm wide. It is laterally compressed and looks like a transparent celluloid belt or ribbon. Of 8 comb plates, 4 are very long and the other 4 are very short. Locomotion takes place by means of long comb rows and muscular undulations. At the middle of the oral surface of

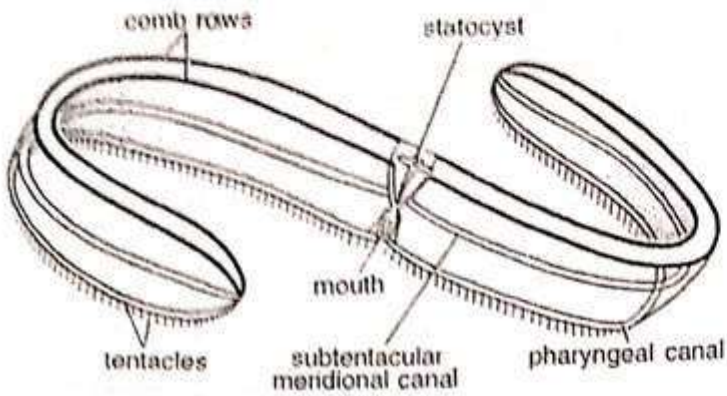
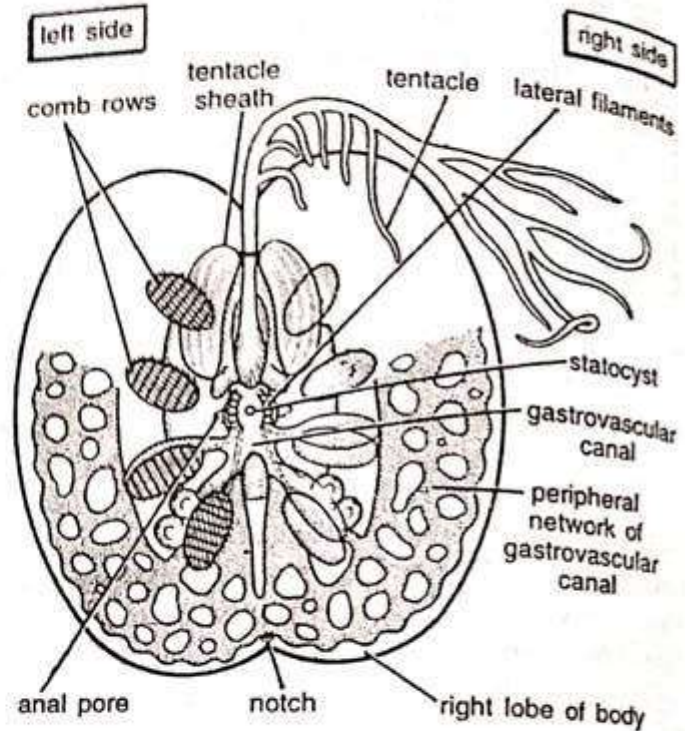
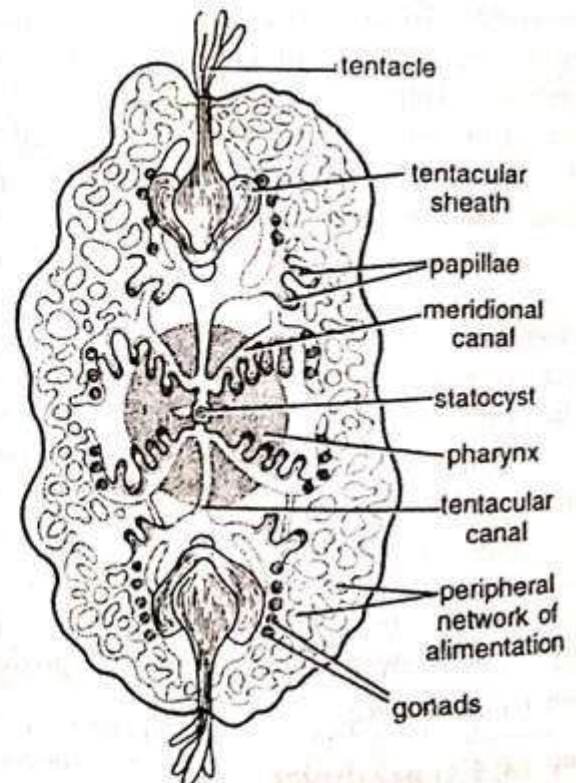


Fig. 2. Velamen.

ribbon is a mouth and the whole oral margin bears lateral tentacles. Sense organ or statocyst is present in the middle of aboral surface. Along the middle of ribbon run two sub-tentacular meridional canals and along the oral edge, the pharyngeal canals.

**3. Ctenoplana.** *Ctenoplana* is a small marine ctenophore living in the surface waters of sea. Body is flattened, oval or disc-shaped and measures about 6 mm. in diameter. Dorsal surface is mostly olive green, brown or reddish. Body has a central thick portion and two rounded lobes in sagittal plane. At each end, in the notch between two lobes, there is a long, pennate, retractile tentacle. In the centre of aboral or dorsal surface is a typical polar body or *statocyst* surrounded by a ring of sensory papillae or filaments arranged bilaterally into two groups of eight each. There are eight short comb rows of several plates, connected to the statocyst by ciliated furrows. *Ctenoplana* occurs along the coasts of Indo-China and Japan. It is a creeping animal and was first discovered by Korotneff in 1886.

**4. Coeloplana.** *Coeloplana* resemble *Ctenoplana* in most details. It is a flat oval animal, elongated in tentacular plane and about 60 mm. in length. Comb rows do not occur, although traces of ciliated furrows exist. Tentacular sheaths project only slightly. Movement takes place only by creeping and as ectocommensal on specific kinds of alcyonarians. Presence of 12 to 60 erectile papillae is the diagnostic character of animal. Gonads are found

Fig. 3. *Ctenoplana*. Other tentacle not shown.Fig. 4. *Coeloplana*.

in the walls of eight meridional canals. Development includes a typical cydippid larva with comb plates. *Coeloplana* is found on the coasts of Japan and was first discovered by Kowalevsky in 1880.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Mention the general characters of Ctenophora. What is its relationship with Coelenterata ?
2. Classify Ctenophora giving characters and examples of each group and discuss its affinities.
3. Write short notes on : (i) *Coeloplana*, (ii) *Ctenoplana*, (iii) *Pleurobrachia*, (iv) *Velamen*.

#### » Short Answer Type Questions

1. Name the larva of ctenophores.
2. Which are the animals that possess an aboral sense organ ?
3. To which class does cydippids (e.g., *Pleurobrachia*, *Hormiphora*, *Mertensia*) belong.
4. Give the common name for ctenophores.
5. Give the name of a parasitic ctenophore.
6. What are the type of animals that class Nuda includes ?
7. What is the basis on which ctenophora is divided into two subclasses ?
8. What type of diet is seen in ctenophora ?
9. What is the function of the aboral sense organ of a ctenophore ?
10. What is the function of comb plates ?
11. Mention the features in which ctenophores resemble and differ from coelenterates.

#### » Multiple Choice Questions

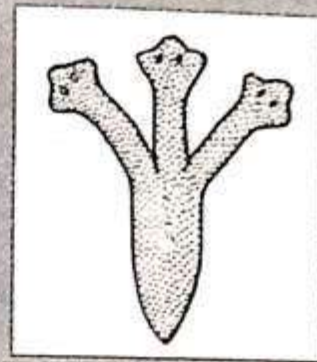
1. The free swimming larval form of *Pleurobrachia* is called as :
  - (a) Planula
  - (b) an Ephyra
  - (c) a Semper's larva
  - (d) a Cydippid
2. Select the creeping ctenophore from the following :
  - (a) *Ctenoplana*
  - (b) *Coeloplana*
  - (c) *Deiopea*
  - (d) *Hormiphora*
3. Ctenophores are :
  - (a) unisexual creatures
  - (b) hermaphrodites
  - (c) asexual creatures
  - (d) neotenic forms
4. The ctenophore *Cestum* is commonly known as :
  - (a) venus's flower basket
  - (b) dead man's fingers
  - (c) brain coral
  - (d) venus's gridle
5. Development is indirect in ctenophores and the larva is known as :
  - (a) Planula
  - (b) Miracidium
  - (c) Cydippid
  - (d) Ephyra
6. One of the following Ctenophore is without tentacles :
  - (a) *Coeloplana*
  - (b) *Ctenoplana*
  - (c) *Berve*
  - (d) *Pleurobrachia*
7. Entoprocts are :
  - (a) acoelomate
  - (b) pseudocoelomate
  - (c) coelomate
  - (d) none of the above
8. Ectoprocta is also known as :
  - (a) Polyzoa
  - (b) Bryozoa
  - (c) both of these
  - (d) none
9. The technical name of lamp shell is :
  - (a) *Phoronis*
  - (b) *Lingula*
  - (c) *Bugula*
  - (d) *Ectinorhynchus*
10. Male lives inside female body. This condition is seen in :
  - (a) *Sipunculus*
  - (b) *Bonellia*
  - (c) *Priapulius*
  - (d) *Echiurus*
11. One of these is also known as "glass worms" :
  - (a) *Urechis*
  - (b) *Glossiponia*
  - (c) *Sagitta*
  - (d) *Echiurus*
12. Chaetognaths are also called as :
  - (a) glow worms
  - (b) proboscis worms
  - (c) arrow worms
  - (d) thread worms
13. Lophophore is found in the phylum :
  - (a) Ectoprocta
  - (b) Phoronida
  - (c) Branchiopoda
  - (d) all of these
14. *Bugula* belongs to :
  - (a) Brachiopoda
  - (b) Gastrotricha
  - (c) Ectoprocta
  - (d) Nemertinea
15. Members of which phylum are called wheel animal cule ?
  - (a) Rotifera
  - (b) Gastrotricha
  - (c) Kinorhyncha
  - (d) Nematoda
16. Body cavity is absent in the phylum :
  - (a) Platyhelminthes
  - (b) Gnathostomulida
  - (c) Nemertinea
  - (d) all of these
17. Members of which phylum are called bear animalcules ?
  - (a) Pentastomida
  - (b) Tardigrada
  - (c) Chordata
  - (d) Protozoa
18. Actinotroch larva is a modified :
  - (a) veliger
  - (b) tadpole
  - (c) planula
  - (d) trochophore

19. Which is commonly known as 'Sea walnuts' :  
 (a) Porifera (b) Coelenterata  
 (c) Ctenophora (d) Echinodermata
20. 8 comb like plates for locomotion in :  
 (a) Arthropoda (b) Platyhelminthes  
 (c) Mollusca (d) Ctenophora
21. Calloblast is adhesive and sensory cells in :  
 (a) Porifera (b) Ctenophora  
 (c) Coelenterata (d) Mollusca
22. Body acoelomate and triploblastic in :  
 (a) Coelenterata (b) Ctenophora  
 (c) Annelida (d) Porifera
23. Which is commonly known as 'venus girdle' :  
 (a) *Physalia* (b) *Porpita*  
 (c) *Hyalonema* (d) *Velamen*
24. *Cestum* and *Beroe* belong to :  
 (a) Protozoa (b) Porifera  
 (c) Coelenterata (d) Ctenophora
25. Statocyst present in :  
 (a) Ctenophora  
 (b) Coelenterata  
 (c) both of them  
 (d) none

### Answers

1. (d) 2. (a) 3. (b) 4. (d) 5. (c) 6. (c) 7. (b) 8. (b) 9. (b) 10. (b) 11. (c) 12. (c) 13. (d) 14. (c) 15. (a) 16. (d) 17. (b) 18. (d)  
 19. (c) 20. (d) 21. (b) 22. (b) 23. (d) 24. (d) 25. (c)

# *Dugesia*: A Planarian



## 30 Chapter

Phylum *Platyhelminthes* includes primitive, bilaterally symmetrical and acoelomate worm-like animals, commonly known as 'filaments' (Gr., *platys*, flat + *helmins*, worm). They show many phylogenetic advances over Coelenterata and Ctenophora, such as definitely triploblastic, definite head and tissue-organ level of organization. Class *Turbellaria* includes free-living planarians, whereas the other two classes are exclusively parasitic. Class *Trematoda* includes 'flukes' and class *Cestoda*, the 'tapeworms'.

Trematodes and cestodes having undergone parasitic adaptations, the basic plan of platyhelminth organization is exhibited by turbellarians. Commonly studied turbellarians by undergraduate students, belong to the genus *Dugesia*. Following account mostly relates to *Dugesia tigrina*, formerly called *Planaria maculata*. But the account is sufficiently general to apply to species of other allied genera, such as *Planaria*, *Euplanaria*, *Polycelis*, *Dendrocoelum*.

### *Dugesia tigrina*

#### Systematic Position

Phylum	Platyhelminthes
Class	Turbellaria
Order	Tricladida
Suborder	Paludicola
Family	Planariidae
Genus	<i>Dugesia</i>
Species	<i>tigrina</i>

#### Habits and Habitat

*Dugesia* is found commonly in freshwater ponds, lakes, streams and shallow rivers of cold running water. It prefers to keep to the bottom, where it is found resting or gliding on the undersurface of stones and on aquatic leaves. Planarians are gregarious, i.e., they live in groups. They are carnivorous and extremely cannibalistic.



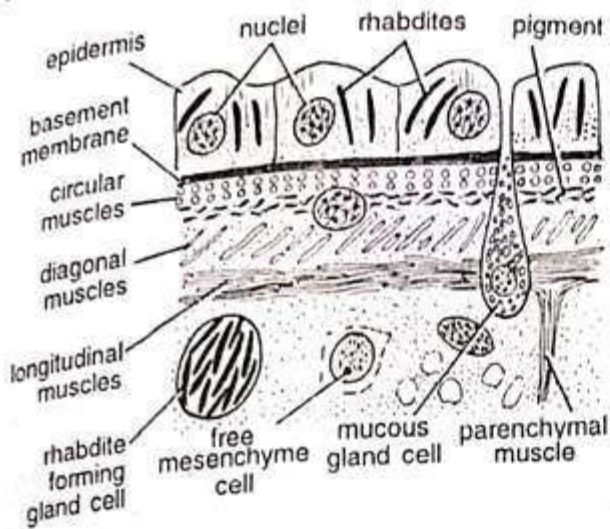


Fig. 2. *Dugesia*. V.L.S. dorsal body wall.

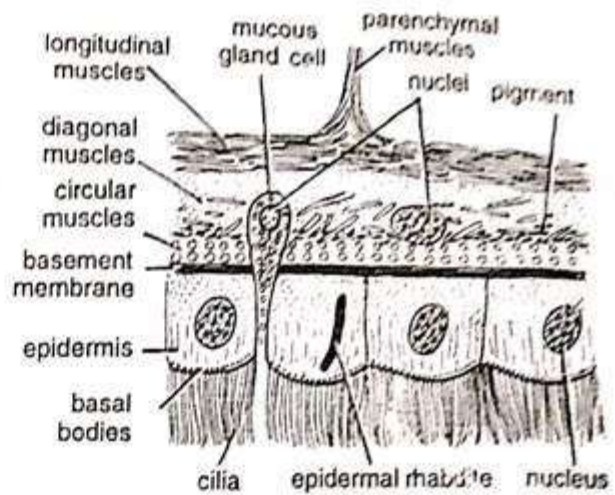


Fig. 3. *Dugesia*. V.L.S. ventral body wall.

mesenchyme. The exact function of rhabdites is still doubtful. It is, however, believed that, when epidermis is chemically irritated, say by acetic acid, the rhabdites discharge in water to form a thick, adhesive layer around the body. It protects the animal and also helps in capturing the prey.

(c) **Subepidermal glands.** Numerous *mucus gland cells* and *adhesive gland cells* of epidermal origin lie deep in the mesenchyme. They are provided with narrow ducts or necks, the openings of which lie between epidermal cells. Mucus gland cells are more abundant on the ventral surface in anterior part of body. They secrete a slime trail for locomotion. Adhesive gland cells produce a sticky secretion which helps in attachment of body and eggs to substratum, and capturing prey.

**2. Basement membrane.** It is a thin, structureless membrane on which rests the epidermal cells. It serves as a surface for attachment of the underlying muscles and for maintaining the general form of body.

**3. Muscle layer.** This layer lies below the basement membrane. It consists of elongated contractile *muscle cells* produced by special cells, called *myoblasts*, which are of mesodermal origin. Immediately below the basement membrane, the muscle cells form an outer layer of *circular muscles*, a middle layer of *diagonal muscles* and an inner layer of *longitudinal muscles*. There are present two series of diagonal muscle fibres which run at right angles to each other. Longitudinal muscle fibres are more developed on the ventral side. Extending across the body

between dorsal and ventral surfaces are also present *dorso-ventral muscles*.

Associated with the muscle layer are also present *pigment cells* that impart colouration to the body. These are more abundant on dorsal side.

**4. Mesenchyme or parenchyma.** This is a mesodermal connective tissue characteristic of Platyhelminthes. It fills up the interior of body and serves as a sort of *packing tissue* between its various organs. Mesenchymal cells are vacuolated, syncytial and have irregular processes, which form a loose network with fluid-filled intercellular spaces. These cells serve to transport digested food and excretory materials. Mesenchyme thus performs the role of circulatory system in which the animal lacks. In mesenchyme lie numerous free, amoeboid *formative cells*, or *neoblasts*, which rush to injured areas and bring about regeneration. Various gland cells are seated in mesenchyme.

## Locomotion

*Dugesia*, though aquatic, does not swim in water. It always moves in contact with some substratum or on the underside of water surface film. Movements are of two types : *gliding* and *muscular*.

**1. Gliding or ciliary movements.** These are performed with the help of *cilia*. A thin layer of mucus is first poured on substratum. *Cilia* then beat backwards in the mucous layer resulting in forward movement of body. Head is kept somewhat raised during gliding.

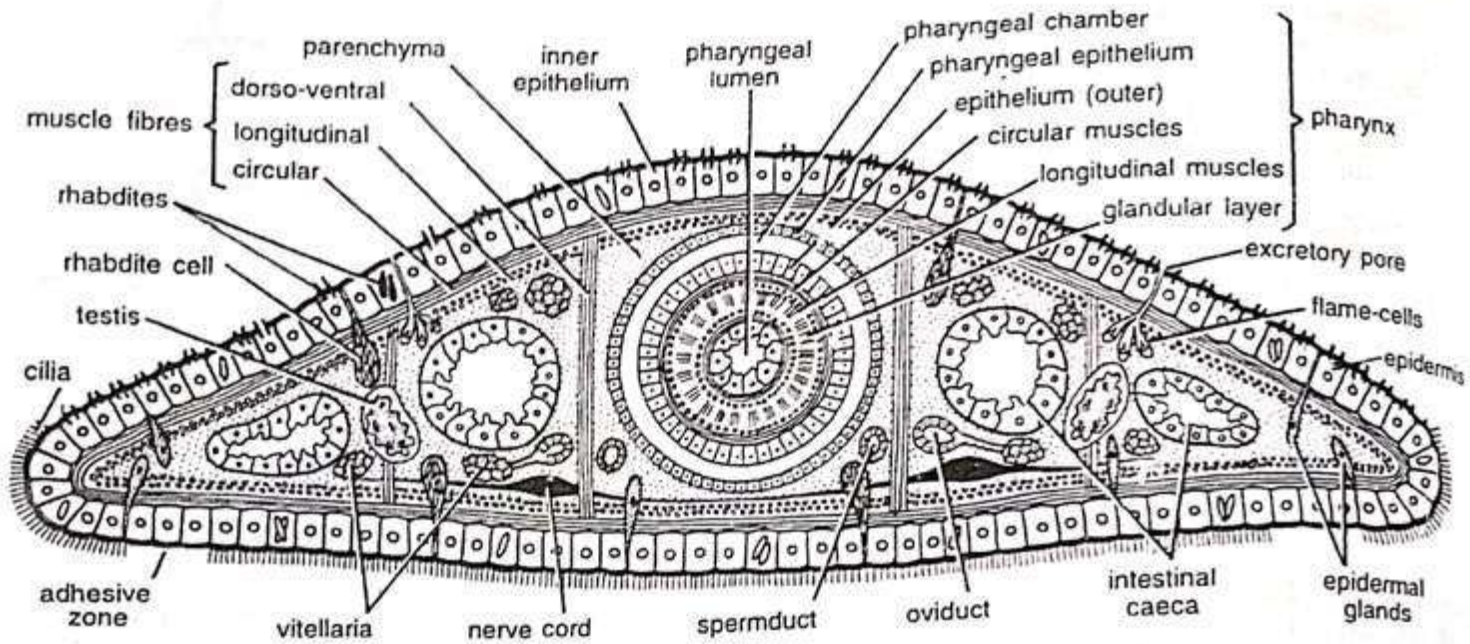


Fig. 4. *Dugesia*. T.S. through pharyngeal region (semi-diagrammatic).

**2. Muscular movements.** These are responsible for the bending and twisting of the body in different forms and for crawling.

During crawling, the body first elongates by contraction of circular muscles and the head adheres to some substratum with the help of secretion of adhesive glands. This is followed by waves of contraction of longitudinal muscles, passing from anterior to posterior end, alternately along the right and left sides, results in the forward movement of body in a wavy manner. Contraction of diagonal muscles stiffens the worm by increasing its internal turgor.

## Digestive System

### [I] Alimentary canal

Alimentary canal of *Dugesia* is distinct, extensive but *incomplete*, as there is no anal opening. Since an anus is absent, it is comparable to the gastrovascular cavity of Coelenterata. It includes mouth, pharynx and intestine.

**1. Mouth.** Mouth is an oval or rounded aperture located mid-ventrally a little behind the centre of body.

**2. Pharynx.** Mouth opens into a large, elongated and non-muscular cavity, called *pharyngeal chamber*. It is bounded by an epithelium or *pharyngeal sheath*. Within the chamber lies the elongated, thick-walled, cylindrical and highly muscular *pharynx*. It is called *folded* or *plicate pharynx* and projects

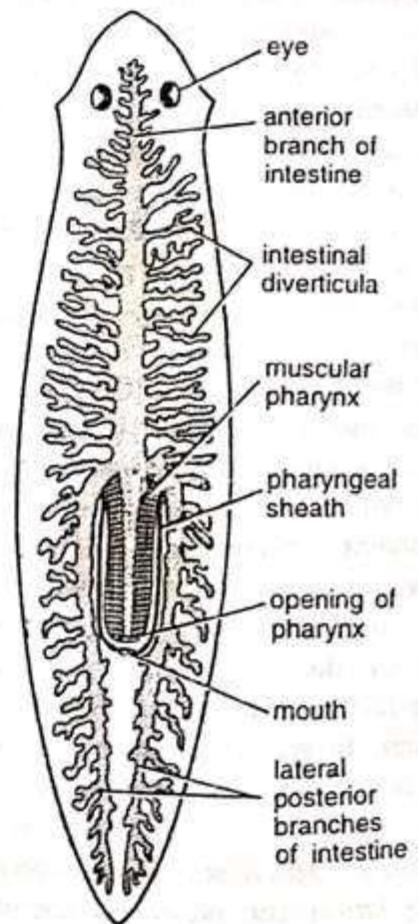


Fig. 5. *Dugesia*. Showing the alimentary canal.

behind freely into pharyngeal chamber from its anterior wall. Its free posterior end bears the *pharyngeal opening*, which lies a little in front of the mouth opening. The short space between these two openings is sometimes called the



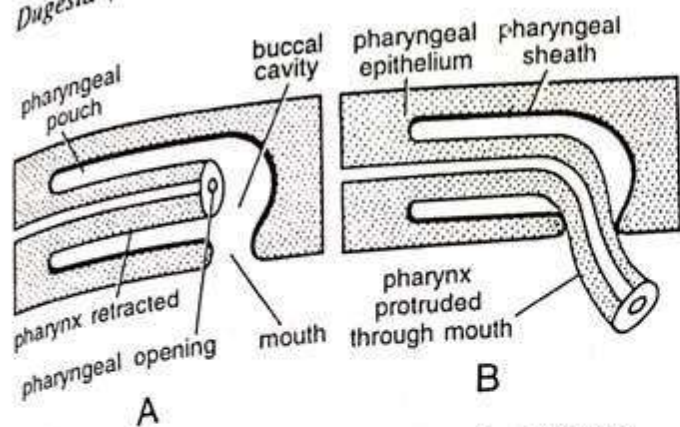


Fig. 6. *Dugesia*. Diagrammatic representation of pharynx. A—Retracted. B—Protruded.

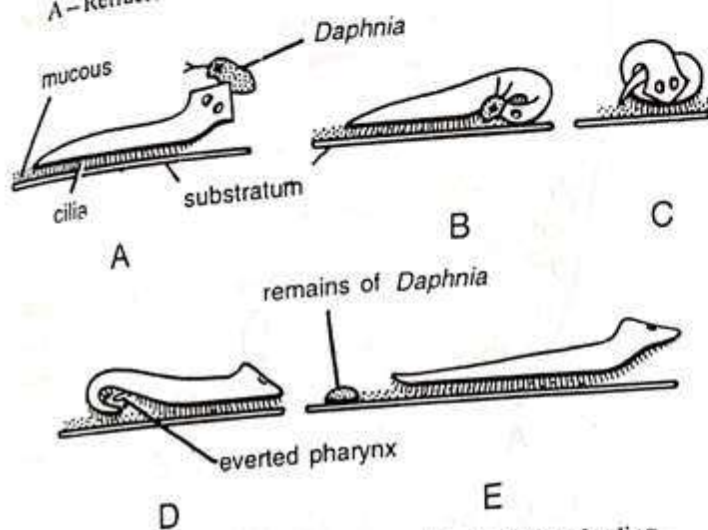


Fig. 7. A planarian capturing the prey (*Daphnia*) and feeding.

buccal cavity. Pharynx can be protruded through mouth considerably, when feeding, to form a proboscis for enveloping prey. (Fig. 6).

The pharyngeal wall consists of outer and inner epithelial layers, between which lie muscle layers, gland cells and nerve plexus (Fig. 4). Inner epithelial layer is ectodermal. Nuclei of some of these ectodermal cells lie sunk into mesenchyme and are connected with their respective cells by long branching cytoplasmic processes.

**3. Intestine.** Anteriorly, pharynx leads through an inconspicuous *oesophagus* into the *enteron* or *intestine* which immediately forms three main branches, one median and two lateral. Median branch extends to the anterior end, and each lateral branch immediately bends backwards and extends to the posterior end. This type of *three-forked* intestine is a characteristic feature of the turbellarian order Tricladida.

Each main branch of intestine gives out numerous lateral branches, the *diverticula* or *caeca*, which further branch and ramify. The

main branches and their diverticula end blindly in solid mesenchyme. Wall of intestine is made up of non-ciliated, vacuolated columnar cells, granular storage cells and gland cells, which is lined externally by a delicate muscle layer.

## [II] Nutrition

**1. Food.** *Dugesia* is a *carnivorous* animal. It preys upon small animals like crustaceans, worms, nematodes, insects, etc., and subsists also on body fragments of larger animals, dead or living.

**2. Ingestion.** Food is detected, from some distance, by special sensory cells, located at the sides of head. When it approaches the food it begins waving its head from side to side. Then it moves over the prey to trap it by pressing its body between its ventral surface and substratum, and by pouring over it the sticky secretion of adhesive glands and rhabdites. Now pharynx is everted to *ingest* the food by peristaltic movements. Smaller prey is ingested as such, while larger ones are first reduced to smaller bits by the pumping movements of pharynx aided by a digestive juice which is secreted by the pharyngeal glands.

**3. Digestion.** Digestion is both *intracellular* and *extracellular*. Fats are probably digested extracellularly in the lumen of intestine. Intracellular digestion is brought about by microscopic particles and incorporate them in food vacuoles. Digested food diffuses through the walls of intestine into surrounding mesenchyme. Highly branched intestine and mesenchyme make possible the distribution of digested food to all the parts in the absence of a circulatory system. *Reserve food*, mostly in the form of fat and sometimes as protein globules, is stored in the epithelial cells of intestine.

**4. Egestion.** There is no anus, so that undigested food is egested through the mouth.

A planarian prefers consuming its own body parts to starving. The order of preference is eggs, vitelline glands, ovaries and testes, mesenchyme, and in extreme conditions, even gut and muscles, sparing only the nervous tissues and sense organs. These substances pass on into the lumen of the gut where they are digested. A planarian under these conditions shrinks greatly in size, and body may be reduced to as little as 1/300 of the original. When it feeds again, it regenerates the lost parts and becomes normal in size.

## Excretory System

Excretory system of *Dugesia* consists of a large number of excretory cells, the *protonephridia* or *flame cells* and a system of *excretory tubules*.

1. **Flame cells.** Flame cells occur in large numbers along the length of body on each side. Each flame cell is large and gives out numerous branched protoplasmic processes (resembling pseudopodia) in the surrounding mesenchyme. In the centre of cell is a conspicuous bulbous cavity or *cell lumen*. The cytoplasm thus occurs in the periphery. It contains a rounded or oval nucleus and some excretory globules and vacuoles. Lying suspended in cell lumen is a tuft of numerous, long, hair-like *flagella* or *cilia*. Each cilium arises from a rounded body or basal granule, situated in cytoplasm. In a living animal cilia vibrates in the manner in which a candle flame flickers. This is why these excretory cells are called *flame cells*.

2. **Excretory tubules.** The bulbous cavity of flame cell narrows down into a fine vessel or *capillary duct*, which in turn opens into a lateral *longitudinal excretory duct* or *canal*. There are two such longitudinal excretory canals on each side. They extend along the entire length of body, forming a network. Longitudinal excretory canals of right and left sides are united anteriorly, in front of eyes, by a *transverse vessel*. Each longitudinal canal opens to the exterior through a number of minute *excretory pores* or *nephridiopores*, situated on the dorsal surface.

**Physiology of excretion.** Excretory materials diffuse from the surrounding mesenchyme into flame cells and eventually pass into their bulbous cavities. Frequently, loss of some useful substances like salts and sugars also occur along with the excretory materials. Vibrations of flagella or cilia cause these materials, dissolved in water, to move into longitudinal excretory canals. Walls of canals reabsorb useful substances, while excretory materials, along with excess of water, are expelled out through the nephridiopores. A considerable amount of excretory waste is also expelled through mouth. Walls of lateral excretory canals are also provided with bundles of long flagella, here known as *lateral flames*, which keep the fluids moving through them.

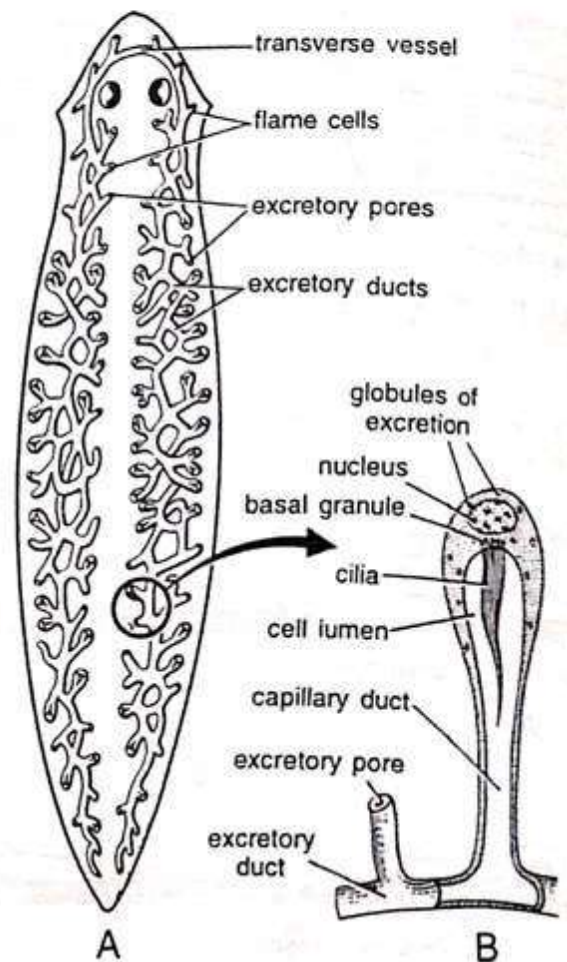


Fig. 8. *Dugesia*. A—Excretory system. B—A single flame cell in section, connected with an excretory duct.

In some turbellarians, special vacuolated cells with prominent nuclei, known as *athrocytes* or *paranephrocytes*, occur around the excretory tubules and help in transferring excretory materials into them.

3. **Osmoregulation.** Main function of flame cells or excretory system in planarians seems to be osmoregulation rather than excretion. Although direct evidence is lacking, but it is seen that flame cells or protonephridia are best developed in freshwater species but less developed or absent in marine species. As the excretory system plays an important role in getting rid of excess of water from body, it is better to call it *osmoregulatory system*.

## Respiration and Transportation

There are no special organs for respiration. Gaseous exchange takes place through general body surface by diffusion. A circulatory system is

also lacking. The function of transportation of gases within body, of digested food from intestine to different parts and of excretory wastes from different parts to flame cells, is performed by mesenchyme described earlier.

The intestine, being highly branched, is not too far from any part of body. Moreover, the body being highly flat, the various organs are not far from body surface. These features limit the scope for transportation and an elaborate system for the same would have been superfluous.

### Nervous System

Nervous system of planarians marks the beginning of a centralized nervous system encountered in higher animals.

At the anterior end, below epidermis and a little behind the eyes, is a prominent bilobed mass of nervous tissue, called *brain* or *cerebral ganglia*. Two lobes of brain are connected by several transverse fibres. From the brain arise two *lateral longitudinal nerve cords*, which extend to the posterior end along the ventral side of body. Each nerve cord is in fact a strand of concentrated nerve cells.

From each lobe of brain arise numerous *peripheral nerves* which supply the various sense organs located at the anterior end. Each nerve cord also gives out numerous branched nerves on both the sides all along its length. Those arising from the inner side frequently anastomose with similar ones from the other nerve cord to form *transverse commissures* or *connectives*. This is sometimes called the *ladder type* of nervous system.

In addition to the centralized nervous system, *Planaria* also possesses a *sub-epidermal nerve net* like that of coelenterates. Brain receives stimuli from the sense organs and conveys them to different parts of body. It, however, does not appear to exercise any control over muscular movements concerned with locomotion.

### Sense Organs

Sense organs or *receptors* occurring in *Planaria* are : (i) a pair of eyes (photo-receptors), (ii) ciliated pits, grooves and auricular organs (chemoreceptors), (iii) some scattered

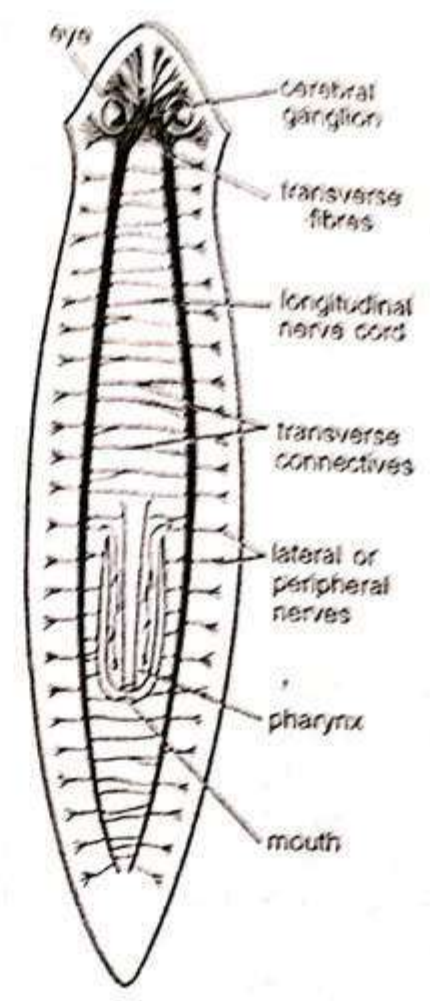


Fig 9. *Dugesia*. Nervous system.

tangoreceptors, and (iv) rheoreceptors. Most of these receptors lie concentrated at the anterior end of the body (head), which remains foremost during locomotion. Thus, planarians show the beginning of *cephalization* which is highly developed in vertebrates.

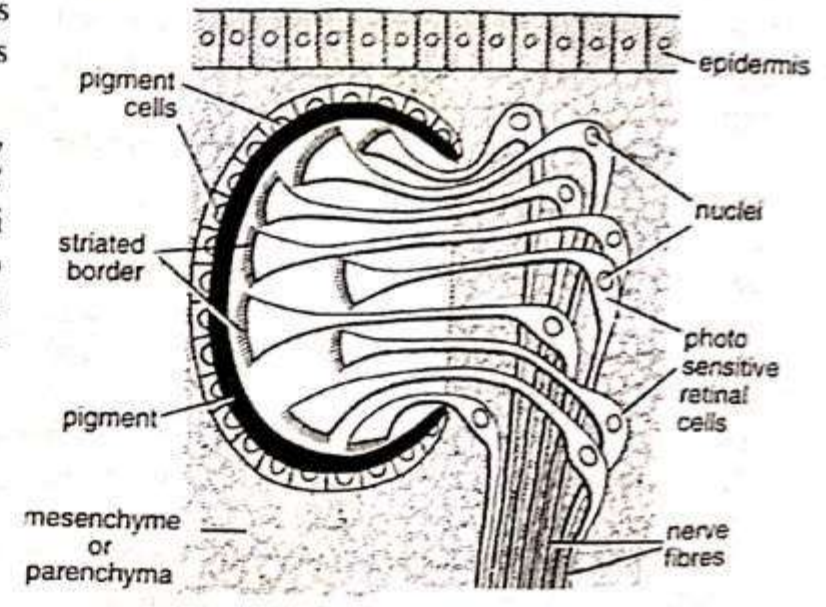


Fig 10. V.S. planarian eye.

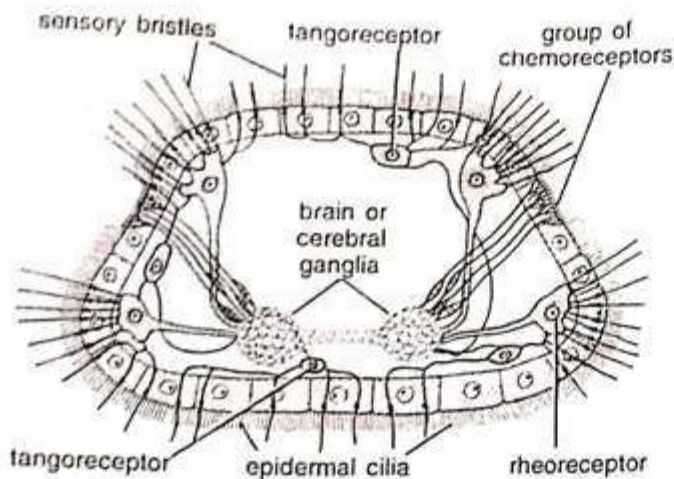


Fig. 11. A diagrammatic T.S. of the anterior end of a planarian showing the various receptors.

**1. Eyes.** Eyes or *ocelli* are a pair of conspicuous, black, rounded spots situated dorsally on head. Each eye has a cup-like form with its opening directed antero-laterally. The cup is lined by a layer of *pigment cells*. Projecting into its hollow are numerous bipolar neuro-sensory light-receptive *photosensitive* or *retinal cells*. In this type of eye, known as *inverse eye*, the light has first to pass through photosensitive cells before reaching the pigmented cells. Expanded distal end of each photosensitive cell, projecting into cup longitudinally striated forming a *striated border* of uncertain function. Proximal ends of these cells run side by side forming the so-called nerve fibres which communicate with the brain. Eye of *Planaria* lacks a lens. It cannot form an image but can perceive the difference between light and dark. Planarians with eyes removed can react to light but slower and less accurately.

**2. Ciliated pits, grooves and auricular organs.** Anterior end of body bears several grooves and pitlike depressions. A pair of whitish grooves, situated on auricles, are known as *auricular organs*. Ciliated pits, grooves and auricular organs are devoid of gland cells and rhabdites and the sensory cells lining them are *chemoreceptors*, i.e., sensitive to chemicals. Their sensory processes project just a little above the epidermis. These receptors help in detecting food and orienting the body towards it, hence are called *taste receptors*. If auricles are removed, the animal can not locate food.

**3. Tangoreceptors.** These are *touch-sensitive* or *tactile cells* found all over the body. They are distributed abundantly on ventral surface, especially around mouth, on lateral margins and at the anterior end. Their sensory processes project beyond the epidermis so that their tips lie slightly beyond the level of cilia.

**4. Rheoreceptors.** These are sensory cells sensitive to water currents. The sensory processes of rheoreceptors project much beyond the level of cilia.

## Reproductive System

*Dugesia* reproduces *sexually* as well as *asexually*.

### [I] Asexual reproduction

Asexual reproduction occurs by the appearance of a constriction behind the pharynx. It gradually deepens and finally divides the animal into two parts, each of which regenerates the wanting structures. This mode of asexual reproduction is termed *transverse binary fission*.

### [II] Sexual reproduction

In *Dugesia*, both male and female reproductive organs are present in the same individual. It is

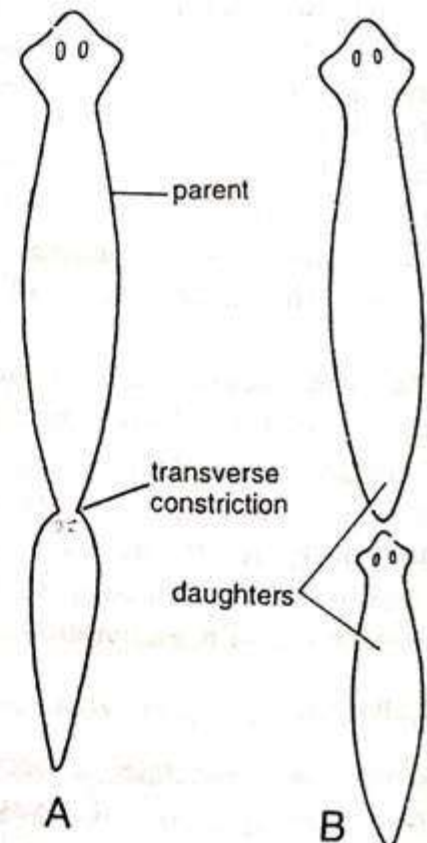


Fig. 12. *Dugesia*. Transverse binary fission.

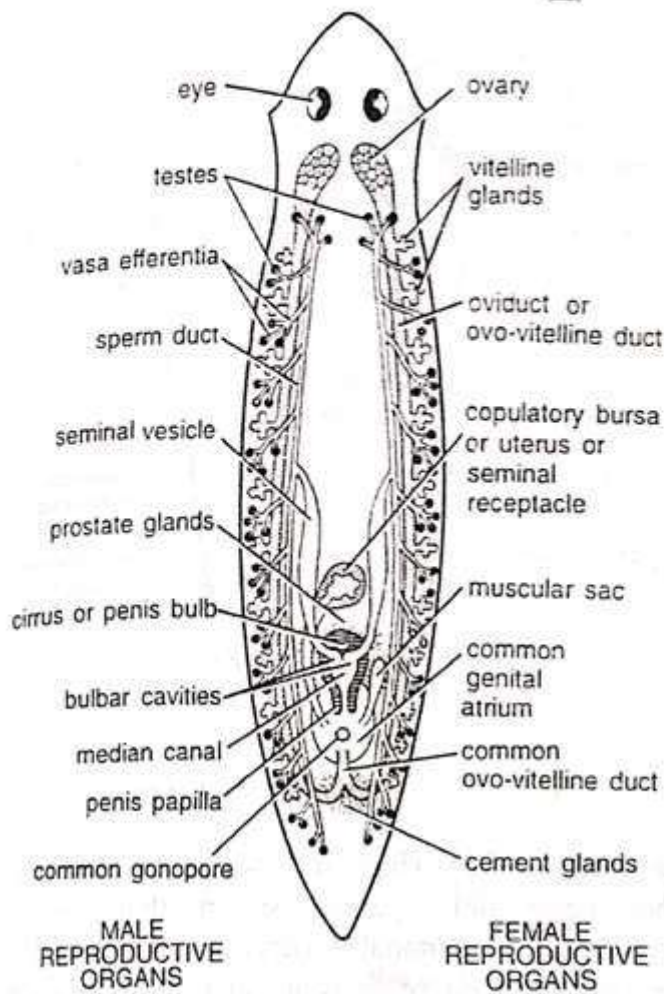


Fig. 13. *Dugesia*. Reproductive system.

thus *hermaphrodite* or *monoecious* or *bisexual*. Both male and female gonoducts open into a common chamber, the *genital atrium*, which in turn opens to the exterior by a common *gonopore*, situated ventrally in the median position, just behind mouth.

1. **Male reproductive system.** It consists of testes, vasa efferentia, vasa deferentia and a cirrus or penis. *Testes* occur as numerous, small and rounded bodies lying along either side of body. Gonads of this type are called *follicular*. From each testis arises a minute *sperm ductule* or *vas efferens*. It usually unites with a few similar ductules from the neighbouring testes before opening into the *vas deferens* or *sperm duct* of that side. *Vasa deferentia*, two in number, are narrow longitudinal tubes, one on either side. Each *vas deferens*, all along its length, receives vasa efferentia from the testes of its own side. From each *vas deferens* arises a dilated *seminal vesicle* for storage of sperms. Posteriorly, the two seminal vesicles unite together and open into a thick-walled, muscular copulatory sac, called *cirrus* or *penis*, which consists of two parts. Proximal musculo-glandular part is known as *penis bulb*. It is surrounded by numerous unicellular *prostate glands*, opening into its lumen formed by two *bulbar cavities*. Distal conical part is called *penis papilla*. Its lumen or *median canal* opens into the *common genital atrium* which opens outside through *common gonopore*. During copulation, penis papilla extends through the gonopore. *Sperms* are long, filamentous, and each provided with 2 long flagella. Arrangement of axoneme is 9-0 in the flagella of sperms.

2. **Female reproductive system.** It consists of ovaries, oviducts, vagina, uterus or bursa copulatrix and vitelline or yolk glands. *Ovaries* are a pair of rounded bodies situated at the

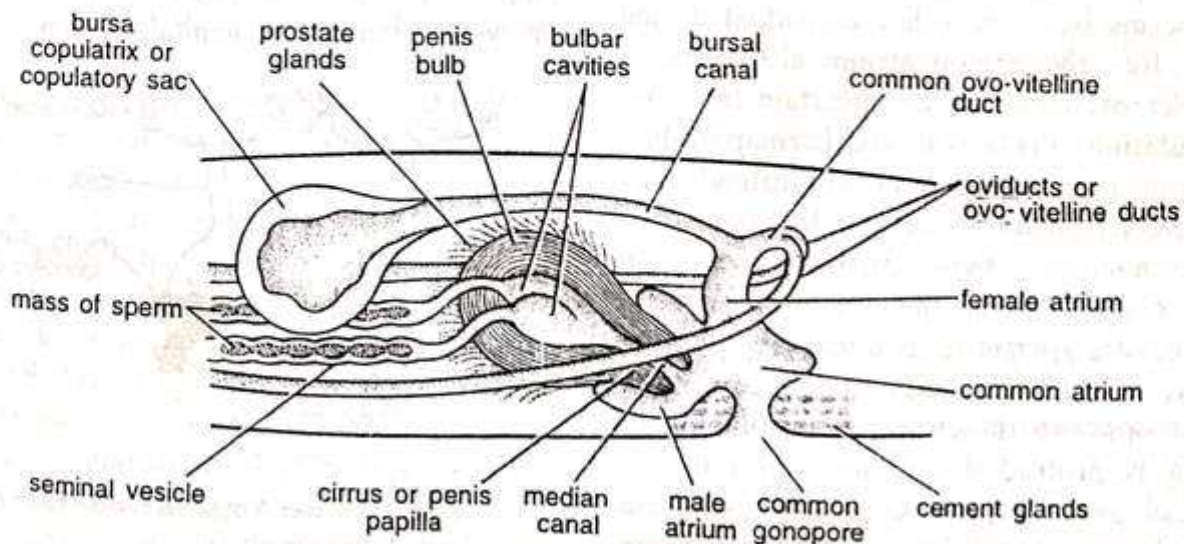


Fig. 14. *Dugesia*. A part of the reproductive system in lateral view.

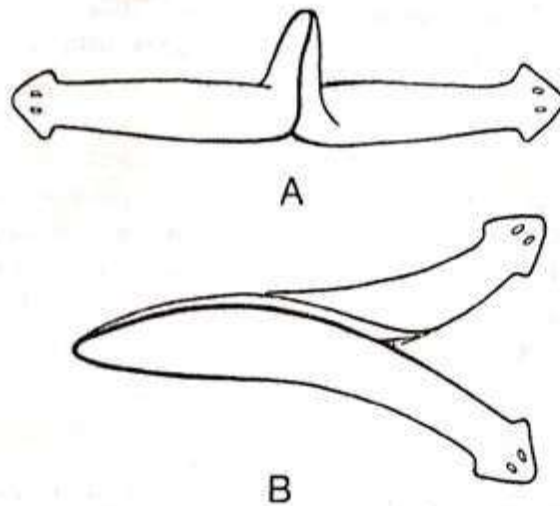


Fig. 15. *Dugesia*. Copulation. A—Head ends facing in opposite directions. B—Head ends facing in same direction.

anterior end, one behind each eye. Posteriorly, each ovary is connected with a narrow elongated tubule, the *oviduct* or *ovo-vitelline duct*, running parallel and dorsal to the nerve cord of its side. Posterior ends of two oviducts unite to form a *median vagina* or *common ovo-vitelline duct*. It opens into the genital atrium lying in front of it. Each oviduct, all along its length, is surrounded by numerous follicular *vitelline* or *yolk glands* which open into it. It is for this reason that the oviduct is also referred to as *ovo-vitelline duct*. Numerous minute *cement glands* surround as well as open into vagina and genital atrium.

An elongated and club-shaped sac, termed variously as *uterus*, *bursa copulatrix* or *seminal receptacle*, opens into the genital atrium. It receives sperms from the other individual during copulation. Into the genital atrium also opens a much smaller *muscular sac* of uncertain function.

**3. Copulation.** Planarians are hermaphrodite, but self-fertilization does not occur. Instead, they practice *crossfertilization* preceded by *copulation*. During copulation, two worms come in temporary contact along their ventral surfaces with their genital apertures (gonopores) opposing each other. Their head ends may face in the same or in opposite directions. Penis papilla of each worm is protruded and inserted into the gonopore of other worm to reach its bursa copulatrix. This is followed by a mutual exchange

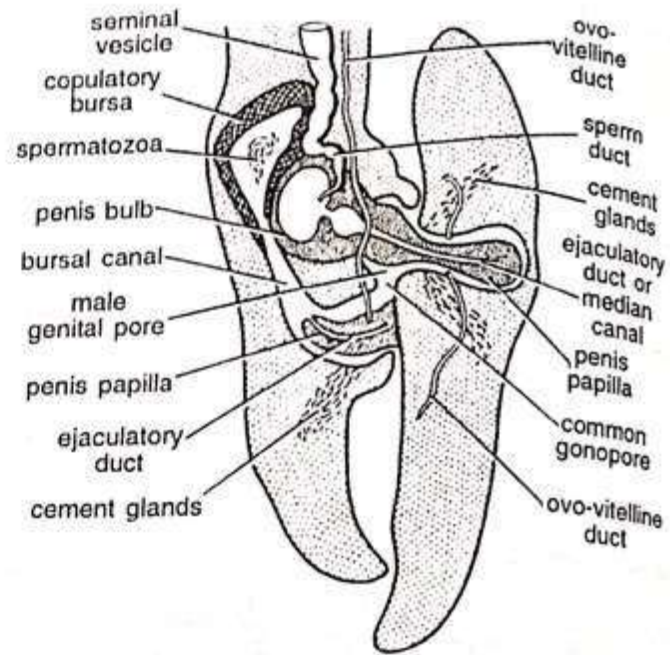


Fig. 16. *Dugesia*. A copulating pair in section.

of sperms, after which the two worms withdraw their penis and separate. Sperms thus received are stored in seminal receptacle and nourished by the secretion of prostate glands which keeps them active for fertilizing ova.

**4. Fertilization.** After copulation sperms leave the seminal receptacle and migrate into the oviducts or ovo-vitelline ducts. Here they fertilize the eggs, as they are released from the ovaries. Thus fertilization is *internal* in *Dugesia*.

**5. Cocoon-formation.** Fertilized eggs or *zygotes* move backwards through ovo-vitelline ducts along with yolk-laden *yolk cells* released by the yolk glands. In genital atrium, about ten

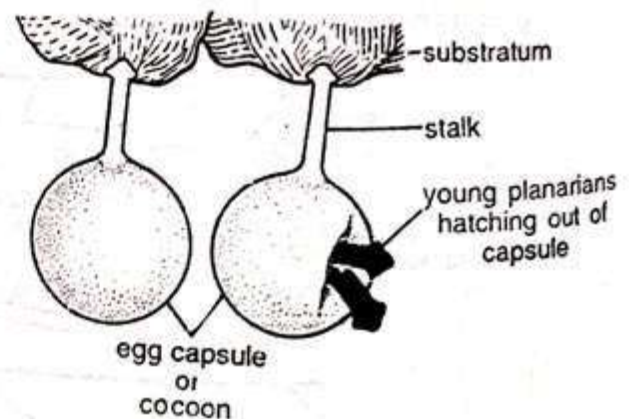


Fig. 17. *Dugesia*. Young planarians hatching from an egg capsule.

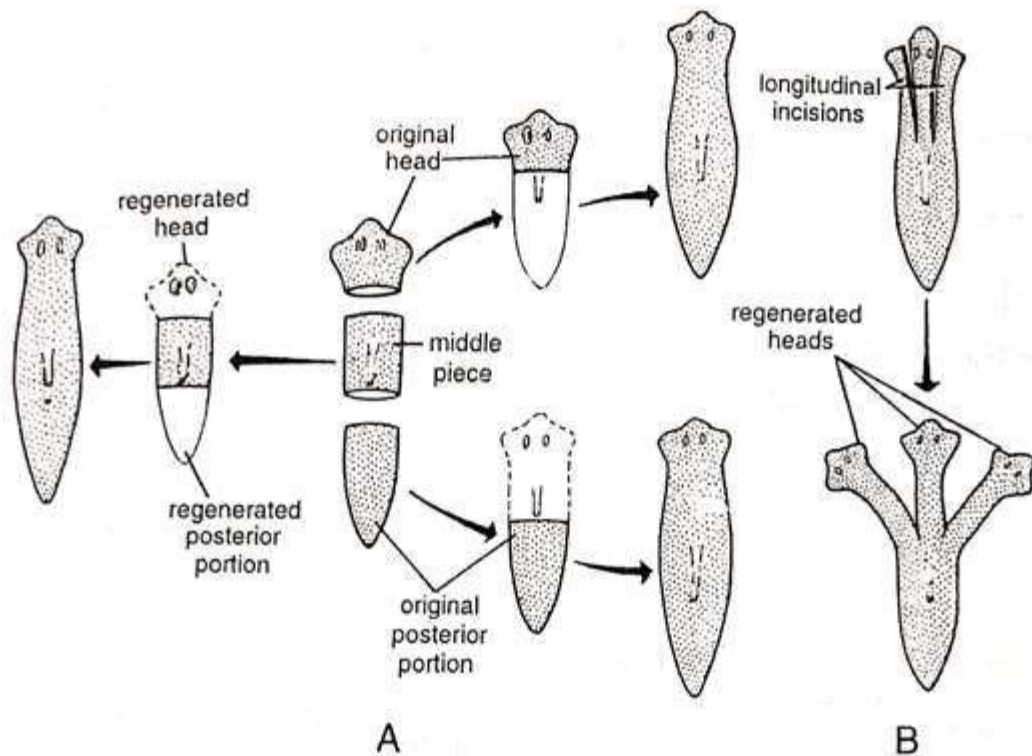


Fig. 18. Regeneration in planarians. A—Three individuals regenerate from an individual cut into three parts. B—Formation of a heteromorph with three heads.

zygotes and thousands of yolk cells get enclosed in a protective, proteinaceous shell called *cocoon* or *egg capsule*. The capsule is spherical and is provided with a little adhesive stalk secreted by cement glands. One such egg capsule is formed after every few days in a planarian copulating is frequently during the breeding season. Capsules are laid on the undersurface of some submerged object, like aquatic weed, stone, etc., to which they adhere by means of adhesive stalks.

**6. Development.** Development starts soon after the egg capsule is laid and is completed in two to three weeks. It is *direct*, i.e., without the occurrence of any larval stage. Cleavage is *spiral* and *determinate*, i.e., future of each blastomere is pre-determined. Each zygote develops into a young one. Yolk cells in egg capsule serve as food for the developing young ones. On completion of development, the egg capsule ruptures, probably along a definite line, and the young planarians or *juveniles* glide out of it. A newly-hatched planarian lacks reproductive organs and is smaller in size than the parents.

Reproductive organs degenerate and disappear after each mating, after which the

worms reproduce asexually by fission. However they develop again during the next breeding season.

### Regeneration

Planarians possess a tremendous power of regeneration. If cut across into two, three or more parts, each part regenerates into a complete and normal individual. Regeneration, thus, involves two complementary processes, viz., *epimorphosis*, in which the missing parts are formed and *morpholaxis*, in which the original parts are fit to function with regenerated parts are in the new individual.

When the anterior end of *Planaria* is cut along the length into two or more parts, each part develops into a new head, resulting in a many-headed monster or *heteromorph*.

A note-worthy observation is that a piece from the middle always regenerates a head towards its anterior side and tail towards its posterior side. In other words, each piece maintains its original *linear polarity*. This can be explained by the theory of *metabolic* or *axial gradient* by C.M. Child. The theory holds that metabolic activity is highest in head and gradually decreases towards the tail end.

Correspondingly, anterior end of each piece, having greater metabolic activity, regenerates the anterior part of body and posterior end piece, having lesser metabolic activity, regenerates the posterior part of body. Gradual difference in intensity of metabolic activity, and hence the capacity of regeneration, from anterior to posterior end of body (along the antero-posterior axis of body) is spoken of as the *axial* or *metabolic gradient*.

Regeneration, however, is not always perfect. A sexually mature *Planaria*, cut across between its pharynx and copulatory apparatus, loses its genitalia by degeneration. The two halves fail to regenerate the sex organs and each grows into an asexual individual.

Recent investigations have revealed that, when body *Planaria* is cut across, free cells from mesenchyme, the *neoblasts* or *formative cells*, migrate to the cut surface form a *blastema* that develops into the new parts. Radiation destroy neoblasts and thus prevents regeneration.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Give an account of the structure, physiology and reproduction of a planarian.
2. Draw a labelled diagram of transverse section of the body passing through the pharynx of a planarian.
3. Describe the histological structure of the body wall of *Planaria*.
4. Give an illustrated account of the reproductive system of any planarian and add a note on regeneration.
5. Write notes on : (i) Eye of *Planaria*, (ii) Feeding in *Planaria*, (iii) Flame cell, (iv) Locomotion in *Planaria*, (v) Regeneration in *Planaria*, (vi) Rhabdites.

#### » Short Answer Type Questions

1. What are the structures that produce mucus in *Planaria* ?
2. Describe regeneration in *Dugesia*.
3. Explain the female reproductive system of *Planaria* with a sketch.
4. Discuss regeneration with reference to *Planaria*.
5. Give an account of the structure and life history of a planarian.
6. Draw and label T.S. of *Dugesia*.

#### » Multiple Choice Questions

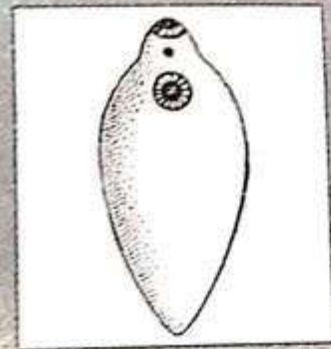
1. Planarians have extra power of regeneration due to the presence of :  
(a) parenchyma (b) rhabdites  
(c) neoblasts or formative cells (d) interstitial cells
2. Ciliated epidermis is found in :  
(a) *Dugesia* (b) *Fasciola*  
(c) *Taenia* (d) *Schistosoma*
3. Rhabdites are found in :  
(a) *Fasciola* (b) *Taenia*  
(c) *Echinoocus* (d) *Planaria*
4. Platyhelminth which live in fresh water :  
(a) *Fasciola* (b) *Taenia*  
(c) *Schistosoma* (d) *Dugesia*
5. Rhabdite occurs in epidermis of :  
(a) Turbellarian (b) Trematoda  
(c) Cestoda (d) all above
6. Oesophagus lead into intestine :  
(a) Rotifera (b) Ctenophora  
(c) Planarian (d) all
7. Cephalization start to :  
(a) Porifera (b) Coelenterata  
(c) Ctenophora (d) Planarian
8. Cocoon formation occurs in :  
(a) *Taenia* (b) *Fasciola*  
(c) *Schistosoma* (d) *Dugesia*

### Answers

1. (c) 2. (a) 3. (d) 4. (d) 5. (a) 6. (c) 7. (d) 8. (d)



# *Fasciola hepatica*: The Sheep Liverfluke



## 31 Chapter

The trematodes, belonging to the class Trematoda, are all parasitic. They are commonly called "flatworms" or "flukes" (Anglo Saxon, *floc* = flat), on account of their flat, leaf-like form. Flukes inhabit liver and bile duct of vertebrates like cattle, sheep, goat, rabbit, pig, dog and man. *Fasciola hepatica* is the common liverfluke of sheep. *F. gigantica* (= *F. indica*), the liver fluke of cattle, is however a more familiar species in India. *Fasciolopsis buski* occurs as an intestinal parasite in man and pig, while *Clonorchis* (= *Opisthorchis*) *sinensis*, the Chinese liver fluke is the causative organism of *clonorchiasis* in human beings in Oriental countries like Japan, Vietnam, Korea and South-eastern China. The present account mostly relates to *Fasciola hepatica*, the sheep liver fluke which is one of the most widely studied trematodes. Its structure and life history are well-known, but physiology is not much understood, because it is difficult to keep

the parasites outside their hosts in a situation where they may be observed and used in experiments.

### *Fasciola hepatica*

#### Systematic Position

Phylum	Platyhelminthes
Class	Trematoda
Order	Digenea
Family	Fascioliodae
Genus	<i>Fasciola</i>
Species	<i>hepatica</i>

*Fasciola hepatica*, the sheep liver fluke was the first digenetic trematode whose life history was completely worked out by Thomas in 1883. It has a cosmopolitan distribution throughout sheep and cattle raising areas of the world. It is

(Z-1)

of great parasitological and pathological importance as it is the causative organism of *fascioliasis*, a disease that causes immense damage to the liver-tissues and bile ducts of sheep.

### Habits and Habitat

*Fasciola hepatica* (L., *fasciola*, small bandage + Gr., *hepar*, liver) is an endoparasite which completes its life history in two hosts. Adult *F. hepatica* is known as the sheep liver fluke because it occurs in the liver and bile passages of sheep, the primary host. It may also occur in some other vertebrates, like goat, horse, dog, ass, ox, deer, antelope, rabbit, elephant, man, monkey, etc. A single sheep may harbour as many as 200 adult flukes in its liver, which may consequently cease to function normally. This effect is known as *liver rot*. *F. hepatica* spends a part of its life history in an intermediate host, a freshwater gastropod, which is either *Limnea truncatula* or some specific species of *Planorbis* or *Bulinus*.

### External Morphology

Structure of a fluke is more or less similar to that of a planarian.

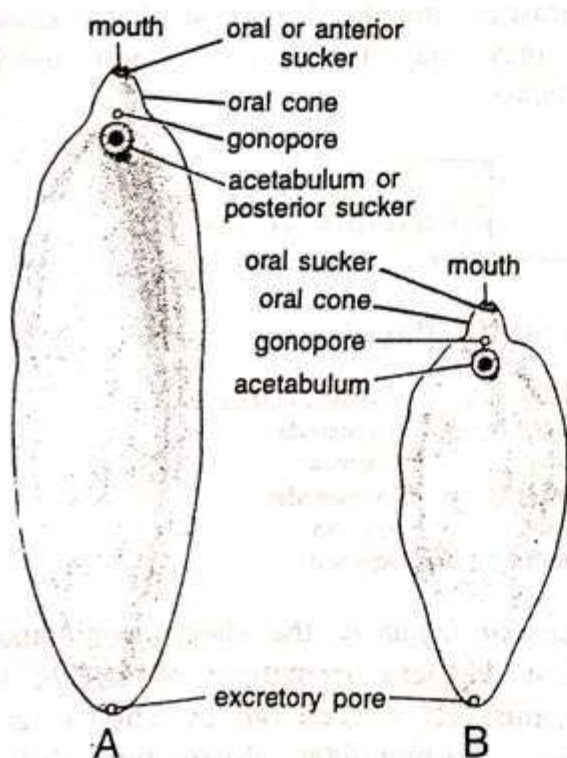


Fig. 1. Liver flukes. A—*Fasciola gigantica*. B—*Fasciola hepatica*. External features in ventral view.

(Z-1)

1. **Shape and size.** Body of *F. hepatica* is soft, oval in outline, dorso-ventrally flattened and leaf-like. It is about 1.8 to 3 cm. long. Maximum width is about 0.4 to 1.5 cm, which is a little in front of the middle region of body. From this region, body tapers away anteriorly as well as posteriorly. Anterior end is somewhat broad and rounded, while posterior end is bluntly pointed.

2. **Colouration.** Colour is usually pinkish, but the transparency of body wall enables the observer to see the blackish or brownish vitelline glands along the lateral margins, and the alimentary canal, which appears brownish due to ingested bile of the host.

3. **Oral cone.** Anterior end of body is drawn out into a prominent conical projection, termed the *oral cone* or *head lobe*, bearing at its tip a somewhat triangular aperture, the *mouth*.

4. **Suckers.** There are two small suckers, anterior and ventral. Both are devoid of hooks and spines.

(a) **Anterior sucker.** Mouth is situated at the centre and bottom of a cup-shaped muscular organ, known as the *anterior* or *oral sucker*. It has a diameter of about 1 mm. Muscles of oral sucker radiate from margin of mouth to the periphery of sucker. Oral sucker acts as an ideal suctorial organ serving for adhesion as well as ingestion.

(b) **Ventral sucker.** About 3 to 4 mm. behind the oral sucker, situated mid-ventrally, is another bowl-like adhesive sucker, the *ventral* or *posterior sucker*, also known as *acetabulum*. It is without an aperture and has a diameter of about 1.6 mm.

5. **Apertures.** In addition to *mouth*, there are two more permanent apertures on body. A small common *genital aperture* or *gonopore*, situated mid-ventrally a little in front of the acetabulum. A single *excretory pore* lies at the posterior end, slightly towards the ventral surface. During breeding season, a temporary *opening of Laurer's canal* appears on dorsal surface, a little anterior to the middle of body. The alimentary canal being incomplete as there is no *anus*.

6. **Scales.** Body of liver fluke is covered with *tegument* (cuticle), from which project numerous minute backwardly directed *spinules* or *scales*. These anchor the body to the walls of host's bile duct, protect the body and help in locomotion.

### Body Wall

Unlike turbellarians, a ciliated epidermis is absent in trematodes. Body wall of *Fasciola* consists of the following succession of layers : (1) tegument, (2) Basement membrane, (3) musculature and (4) mesenchyme.

**1. Tegument.** Body is covered externally by a thick, non-ciliated cytoplasmic syncytium, the tegument. When observed earlier with the ordinary light microscope, it appeared non-cellular and homogeneous and was regarded as a non-living cuticle. However, recent studies made with electron microscope, by Threadgold (1963) and others, have revealed that it contains mitochondria, endoplasmic reticulum, vacuoles and pinocytotic vesicles. Thus, the old term 'cuticle' is rejected in favour of 'epidermis' or 'tegument' for this outer cytoplasmic layer. It is continuous with the cytoplasmic processes of certain tegument secreting cells (earlier cuticle secreting cells) lying in mesenchyme.

Tegument is thick, tough and capable of withstanding the action of host's digestive juices. It thus serves as an ideal body covering of the endoparasite. Further, it bears all over numerous

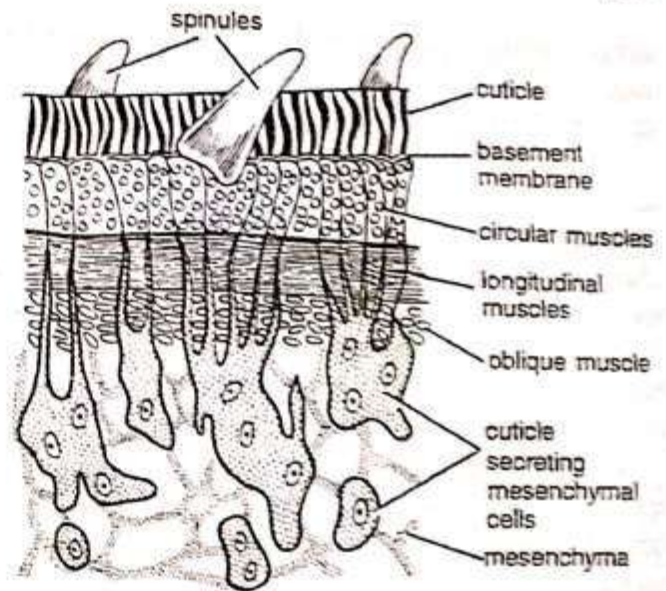


Fig. 2. *Fasciola*. V.L. S. body wall under light microscope.

microscopic and broad backwardly directed spinules or spines or scales, which anchor the fluke in host's bile passage, render protection to body and facilitate locomotion.

**2. Basement membrane.** Immediately beneath tegument, the light microscope shows a thin but well-defined acidophilic basement membrane. However, with electron microscope only its outer edge is visible, while inner edge appears to

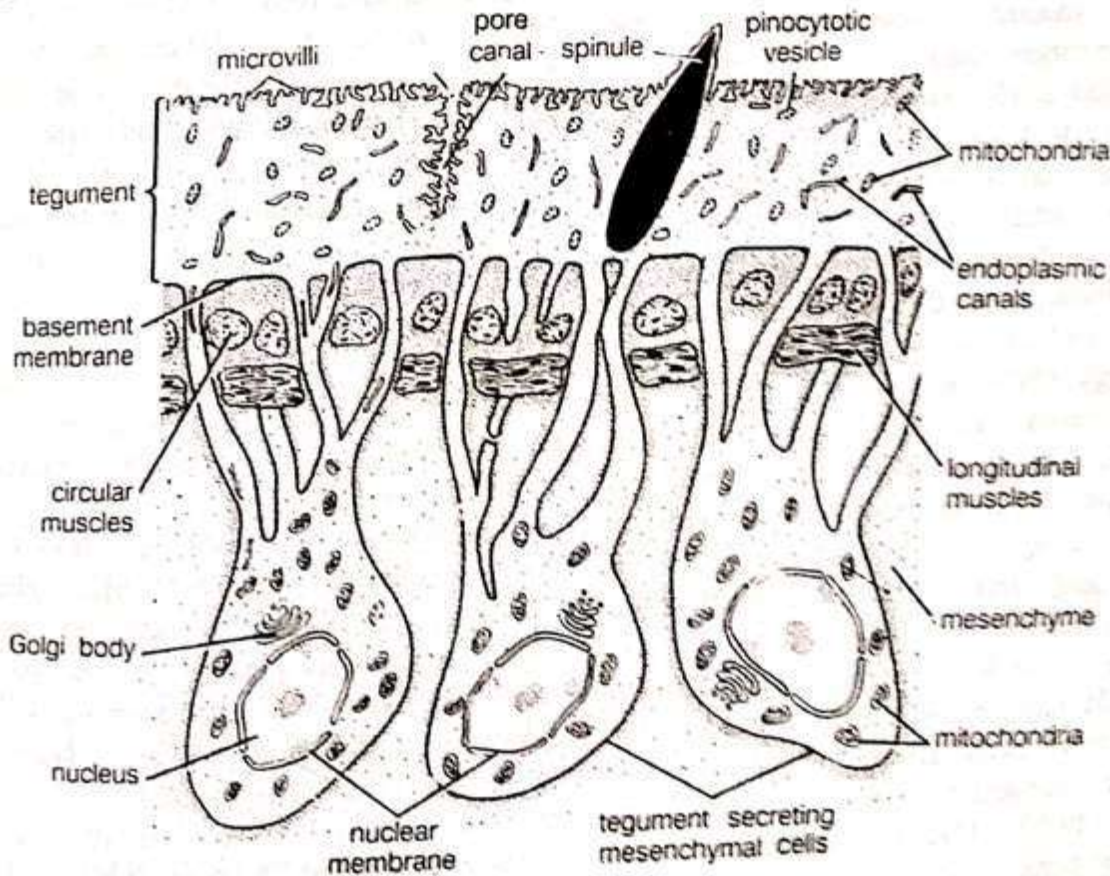


Fig. 3. *Fasciola*. V. L. S. Body wall under electron microscope.

merge imperceptively with underlying tissues. Inside the basement membrane are the integumentary muscles.

**3. Musculature.** Body wall musculature or integumentary muscles include an outer *circular layer* and an inner *longitudinal layer*. In *Digena (Fasciola)*, a third layer of *oblique or diagonal muscle fibres* is also present inside the longitudinal layer. In suckers, muscles form stout bundles of *radial fibres*, imparting radial striations to them. All muscle fibres are smooth.

**4. Mesenchyme or parenchyma.** This peculiar tissue of mesodermal origin surrounds the various internal organs serving as a sort of packing material between them. It consists of numerous loosely arranged, irregular, uninucleate and binucleate cells with large fluid-filled intercellular spaces. Some of these cells are large and have processes extending to the base of the tegument which they are believed to secrete.

In addition to its skeletal function, mesenchyme also serves as an important transport medium since flatworms are devoid of a blood vascular system.

## Digestive System

**1. Alimentary canal.** *Fasciola hepatica* has an incomplete alimentary canal as it lacks the anus. *Mouth* is situated at the anterior end surrounded by oral sucker. It leads into an ovoid *pharynx* having a small narrow lumen and thick walls provided with radial muscles and *pharyngeal glands*. It is followed by a short, narrow *oesophagus*, which is lined by a single layer of epithelial cells and opens into the large *intestine*. Intestine at once forks into right and left main branches or limbs. Each branch terminates blindly near the rear end of body and gives out numerous irregular side branches called *caeca* or *diverticula*, all along its length. Caeca of outer side are large and further branched, while those of inner side are short and simple.

Pharynx and oesophagus are coated internally by cuticle, while intestine is lined by endodermal columnar epithelial cells, around which is a thin muscle layer consisting of circular and longitudinal fibres. Caecal epithelium has secretory gland cells.

(Z-1)

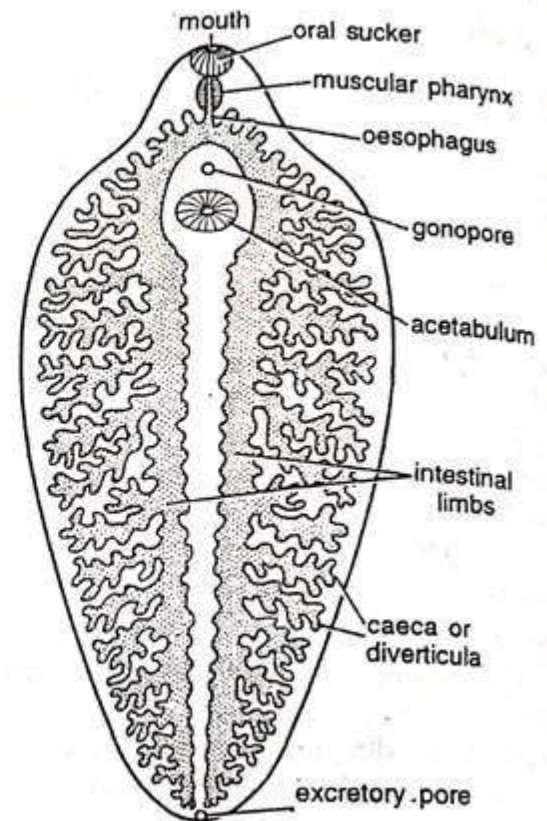


Fig. 4. *Fasciola*. Digestive system.

**2. Food and feeding.** Migration occurs during feeding. It has been found that hungry flukes migrate into smaller bile ducts and capillaries for feeding. They suck up food, lymph, bile and tissue pieces rasped off by oral sucker from the walls of bile passages. Oral sucker and muscular pharynx serve as an efficient suctorial apparatus.

**3. Digestion.** Digestion, which is *extracellular*, takes place in the intestine. Distribution of digested food is accomplished by the ramifying diverticula of intestine aided by mesenchyme, there being no circulatory system. Waste materials diffuse into the surrounding mesenchyme or egested through mouth. Monosaccharide sugars, like glucose and fructose, can diffuse directly into the body of fluke through its general surface. Absorption of some digested food and amino acids also takes place through tegument. This is facilitated by the numerous fine folds formed by the tegument on its outer surface. Food is reserved in the form of glycogen and fats in mesenchyme and muscles.

### Respiration

Oxygen content in bile being extremely low, respiration in *Fasciola hepatica* is usually anaerobic or anoxybiotic.

In this process glycogen (present as reserve food), breaks up by anaerobic glycolysis into carbon dioxide and fatty acids. Lactic acid is the end product of glycolysis. CO<sub>2</sub> diffuses out through general body surface, whereas fatty acids (lactic acid) get eliminated through excretory system. This is an exothermic reaction involving release of energy (heat). If free oxygen is available, aerobic respiration takes place.

### Protonephridial or Excretory System

This system concerned with *excretion* and *osmo-regulation* is similar to that of planarians. It comprises a large number of *flame cells* or *flame bulbs* or *protonephridia*, connected with an intricate system of *excretory ducts* of various orders.

**1. Flame cells.** Flame cells or protonephridia, which themselves are modified mesenchymal cells, are distributed throughout mesenchyme in a

specific pattern, called the *flame cell pattern* by Faust (1919). They are usually of irregular shape and send out *pseudopodial processes* into the surrounding tissue. Each flame cell has an *intracellular lumen* or *cavity*, in which hang a few long *cilia*, each arising from a *basal granule* situated in cytoplasm. In the living fluke, cilia vibrate like the flickering of a flame; hence the name "flame cell".

**2. Excretory ducts.** Lumen of flame cell is continuous with a microscopic *capillary duct*. Capillary ducts from a few protonephridia open into a narrow *collecting tubule*. Several such tubules open into larger *twigs*, which in turn open into *vessels*. Excretory vessels of anterior part of body open into four *trunks*, two dorsal and two ventral, which unite posteriorly to form a single median *longitudinal excretory canal*. It extends upto the posterior end of body where it opens out through the single *excretory pore* situated somewhat ventrally. Excretory vessels of posterior part of body open directly in the longitudinal excretory canal. All the ducts, except the single median longitudinal canal, are lined with cilia.

**3. Physiology of excretion.** Main excretory products of fluke are fatty acids, carbon dioxide and ammonia. These substances diffuse into protonephridia (flame cells) from the surrounding mesenchyme. Excretory fluids are

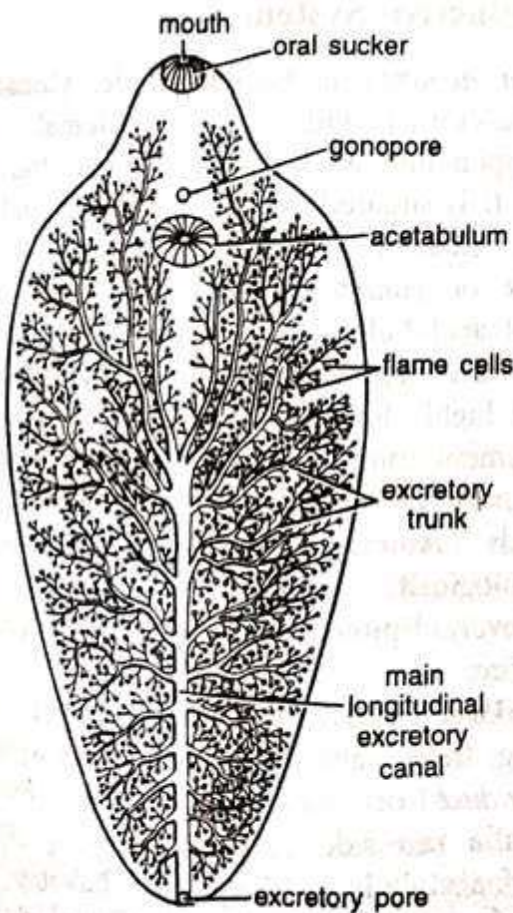


Fig. 5. *Fasciola*. Protonephridial system.

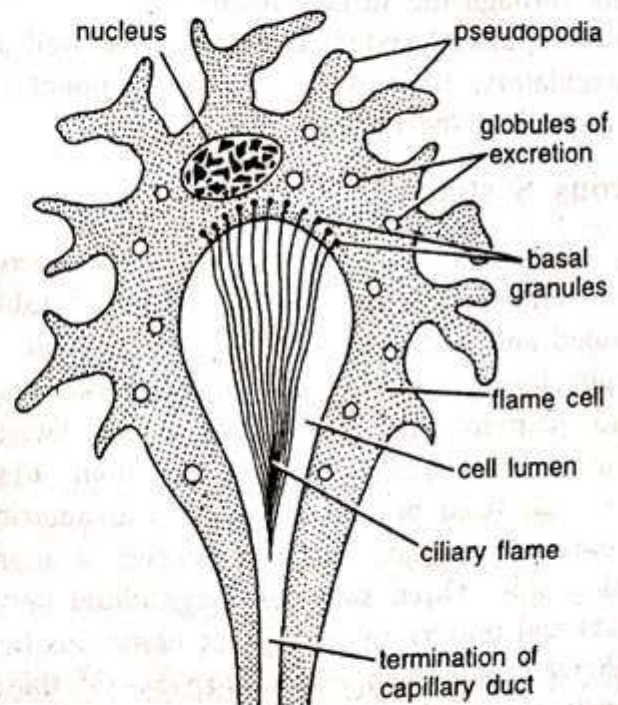


Fig. 6. *Fasciola*. A flame cell.

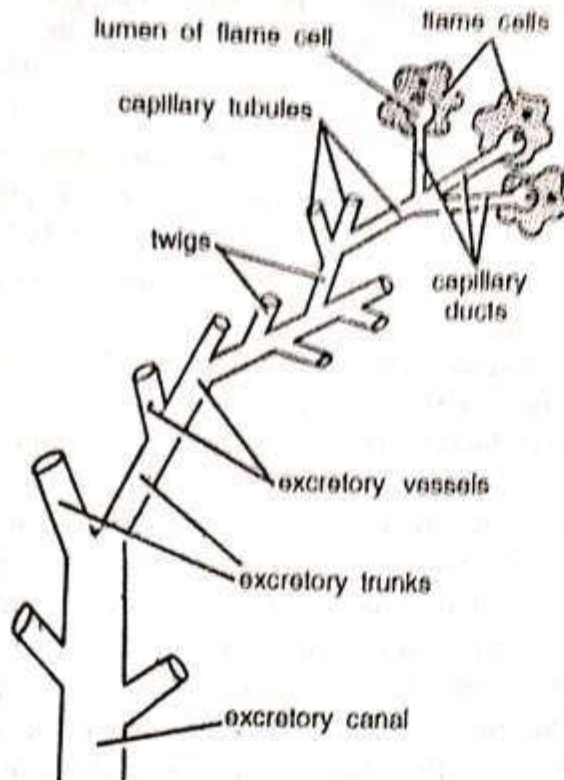


Fig. 7. *Fasciola*. Arrangement of flame cells and excretory ducts

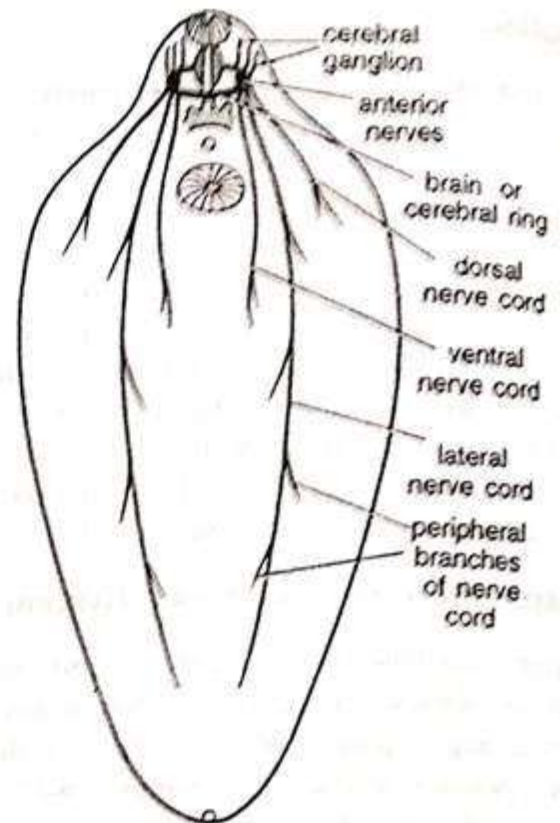


Fig. 8. *Fasciola*. Nervous system.

kept moving through tubules by the action of cilia, and finally squeezed out through the excretory pore by contractions of the body. The enzyme alkaline phosphatase, found in flame cells and collecting tubules serves in the selective transfer of chemical substances. Some nitrogenous wastes are also passed to the exterior through the surface tegument.

Protonephridial system is excretory as well as osmoregulatory, since it controls the amount of fluid (water) in the body.

## Nervous System

Being parasitic, adult fluke lacks any sense organs. Nervous system however, is considerably developed and resembles the turbellarian plan.

Brain forms a collar or ring (cerebral ring) around pharynx and bears a pair of lateral cerebral ganglia and a ventral ganglion. Fine nerves arise from brain and supply the anterior and posterior regions. Suckers receive a more liberal supply. Three pairs of longitudinal nerve cords extend posteriorly, giving out numerous fine peripheral branches to various organs. Of these, one pair is dorsal, one ventral and one lateral. Unlike dorsal and ventral cords, lateral cords are

well-developed and connected by a few *transverse commissures*.

## Reproductive System

*Fasciola hepatica* is *hermaphrodite*. Gonads are well developed and male and female genital ducts open into a common chamber, the *genital atrium*. It is situated anteriorly in body and opens to the exterior through the common *genital aperture* or *gonopore*, located ventrally just in front of acetabulum.

1. **Male reproductive system.** (a) *Testes*. A pair of highly lobed tubular testes lie in tandem arrangement (one behind the other), occupying a large space in the middle and posterior regions of body. Anterior and posterior testes are morphologically the left and right testes respectively. Epithelium lining the testis gives rise to sperms.

(b) *Vasa deferentia and seminal vesicle*. Leading from each testis is a narrow, slender sperm duct or *vas deferens*. The two vasa deferentia run side by side anteriorly upto the level of acetabulum. Where they become united and form a large pear-shaped *seminal vesicle* for storage of sperms.

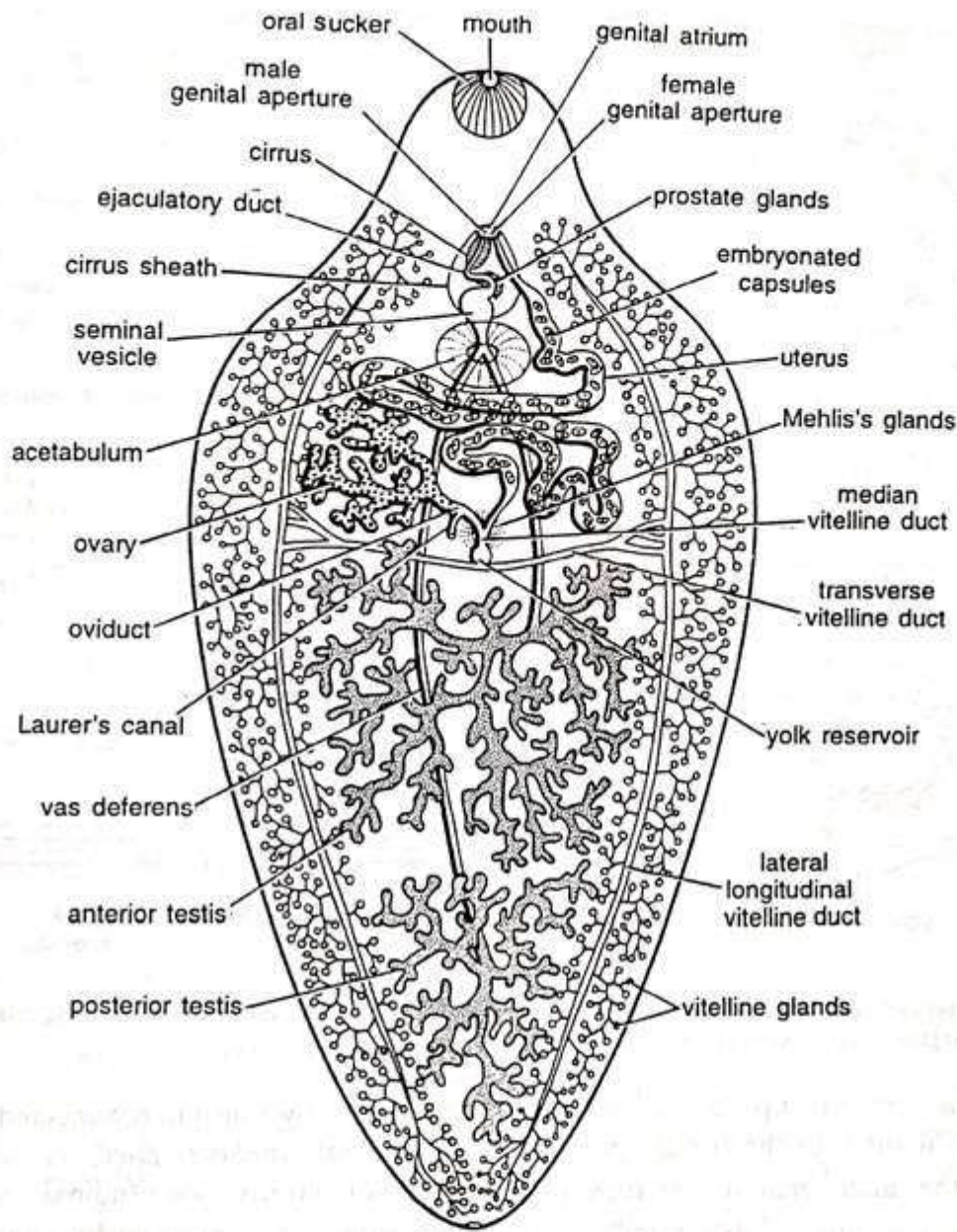


Fig. 9. *F. hepatica*. Reproductive system in ventral view.

(c) *Cirrus sac*. Anteriorly, from seminal vesicle, arises a narrow and somewhat twisted tube, the *ejaculatory duct*, which extends forward and enters a stout muscular and eversible copulatory organ, the *penis* or *cirrus*. It extends upto the common *genital atrium* into which it opens by the *male genital aperture*. Genital atrium in turn opens outside through common *gonopore*.

Numerous unicellular *prostate glands* surround and open into the ejaculatory duct. Their alkaline secretion helps in the free movement of sperms during copulation. Cirrus, prostate glands and seminal vesicle are enclosed in a *cirrus pouch* or *cirrus sac*.

2. **Female reproductive system.** (a) *Ovary*. A solitary, highly branched and tubular *ovary* or *germarium* lies anterior to the testes on right side in the anterior one-third of body.

(b) *Oviduct and uterus*. All the branches of ovary gather posteriorly to form a short narrow tube, the *oviduct*. It extends backwards towards the middle line of body, and joins the *median vitelline duct* (described ahead) to form the *ovo-vitelline duct* or *uterus*. In some species, before joining median vitelline duct, the oviduct swells up to form a small rounded central chamber, the *ootype*. However, ootype is absent in *F. hepatica*, *Uterus* is a long, wide and highly

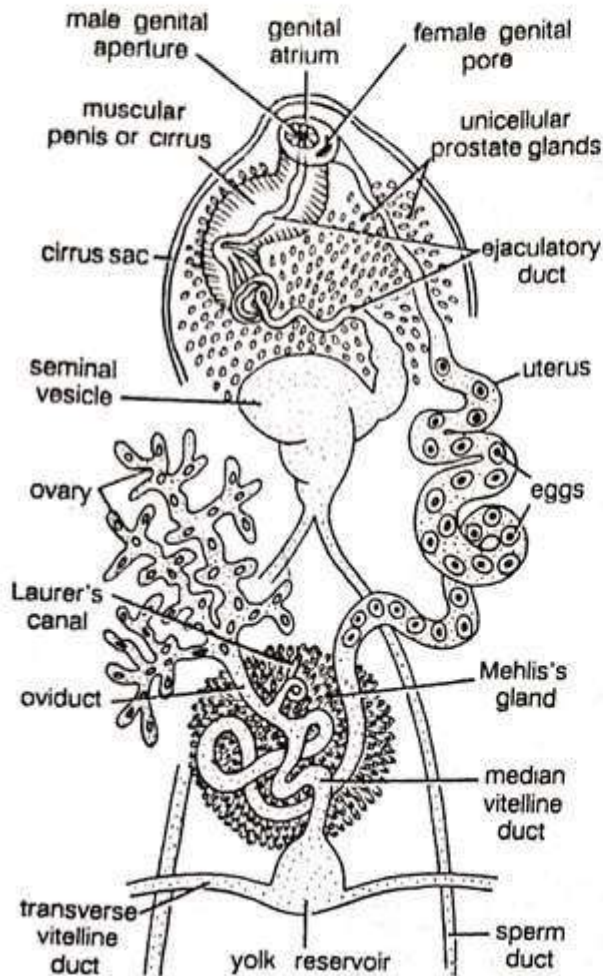


Fig. 10 *F. hepatica*. Details of male and female reproductive organs in the anterior region of body (ventral view).

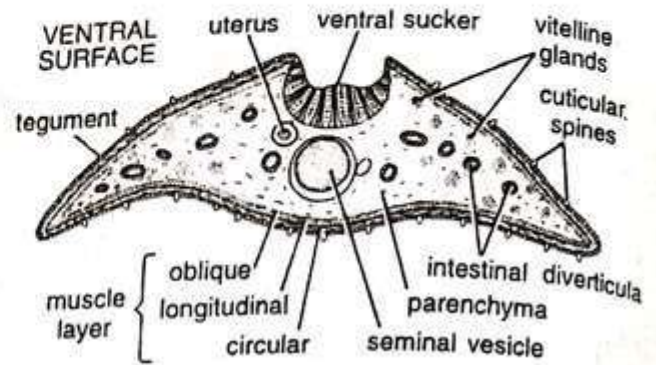


Fig. 11. *F. hepatica*. T.S. body through seminal vesicle.

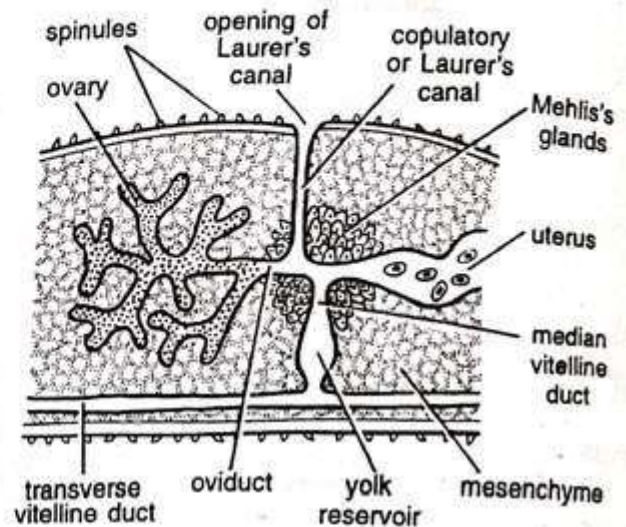


Fig. 12. *F. hepatica*. T.S. showing relations of ovary and genital ducts.

convoluted tube that extends up to the genital atrium, opening into it through the female genital aperture, close to the male genital aperture on the left side. Uterus contains a large number of *capsules* containing fertilized eggs. Enormous size of uterus is in fact correlated with the high rate of egg production, a feature characteristic of endoparasitic mode of life. A short muscular *copulatory tube*, also known as the *Laurer's canal* or *Laurer-Stiedia canal*, arises from oviduct. During breeding period it opens through a temporary median dorsal pore, a little in front of the middle of the body. It serves as a *vagina* during copulation.

(c) **Vitellaria.** Associated with female reproductive system are two important glands : (i) *vitelline glands* or *vitellaria*, and (ii) *Mehlis's glands*. Vitellaria occur as clusters of follicles on the right and left sides, almost all along the entire length of body. Follicles on each side are

connected, by fine interconnected *ductules*, to the *longitudinal vitelline duct*. A little behind the origin of uterus, longitudinal vitelline ducts of both sides are connected by a *transverse duct*, the three together form the letter "H". Parts of each longitudinal duct in front and behind the transverse duct are called anterior and posterior limbs, respectively. Transverse vitelline duct swells up in the centre to form a *yolk reservoir*. From this arises anteriorly a *median vitelline duct*, which joins oviduct to form the uterus. Vitellaria produce special *yolk cells* or *vitelline gland cells*. These cells contain abundant yolk for nourishing the embryo and numerous large *shell globules* which form egg shells.

(d) **Mehlis's glands.** *Mehlis's glands*, though also known as *shell glands*, do not play any role in shell-formation. They are a cluster of unicellular glands and surround the junction of oviduct, median vitelline duct and uterus. Their



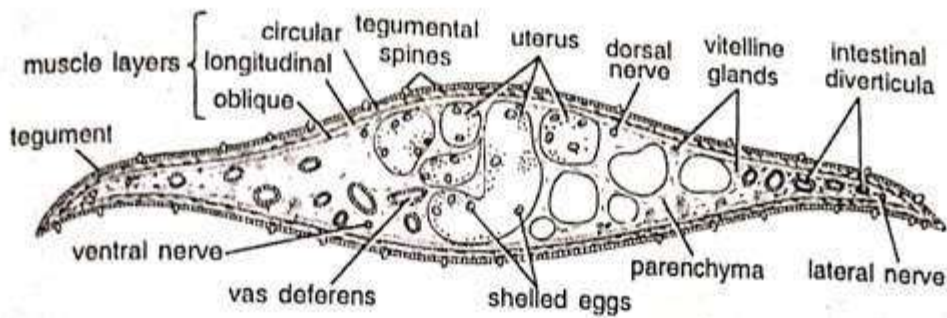


Fig. 13. *F. hepatica*. T.S. body through uterus.

secretion helps in lubricating uterus for smooth passage of eggs and in activating sperms. This secretion, perhaps, also causes release of shell globules from vitelline gland cells.

### Life Cycle and Development

1. **Digenetic life cycle.** Life cycle of *F. hepatica* is complex and completed in two hosts. *Primary host*, in which the adult fluke lives, is sheep. While the *intermediate host*, in which numerous larval stages are passed, is a snail (*Lymnaea*, *Planorbis*, etc.). This type of life cycle, involving two different kinds of hosts, is termed *digenetic*.

2. **Copulation.** Self-fertilization is of rare occurrence in liver flukes though they are hermaphrodite. *Cross-fertilization* preceded by *copulation* is of normal occurrence. In *F. hepatica*, copulation takes place in bile ducts of the host.

Two flukes in copulation bring their genital pores in opposition. Cirrus of one fluke, everted through its gonopore, penetrates the Laurer's canal of the other through the latter's temporary opening, and injects spermatozoa. Secretion of prostate glands, and perhaps also of the Mehlis's glands, keep the sperm active for fertilization.

3. **Fertilization.** Fertilization is *internal*. In *cross-fertilization*, sperms received in Laurer's canal during copulation, enter the distal end of oviduct where fertilization occurs. During *self-fertilization*, sperms enter the uterus of same fluke through female genital aperture and pass down to fertilize the eggs.

4. **Capsule formation.** Each fertilized egg or zygote is surrounded by yolk cells, which provide yolk and shell material. Shell-globules of yolk cells contain proteins and a phenol. According to Stephenson (1947), phenol is oxidized to a

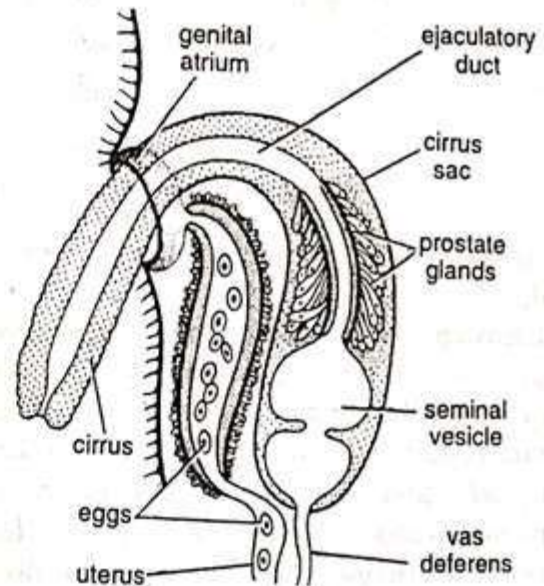


Fig. 14. *F. hepatica*. Cirrus protruding through gonopore.

quinone in the proximal part of uterus. Quinone then tans the protein, producing a hard, resistant and leathery *sclerotin* like that of insects. This sclerotin forms the shell around fertilized eggs. Above finding of Stephenson in liver flukes is perhaps true for all platyhelminths.

5. **Capsules.** Shelled eggs are termed *capsules* or simply *eggs*. A shell or capsule is yellow or brown, in colour and oval in shape. It is about 130 to 150 $\mu$  long and 60 to 90 $\mu$  wide. It is operculate, i.e., provided with a lid or *operculum*. Situated immediately beneath the operculum, at the terminal end of egg is a viscous and granular cushion. About 3,000 or more such capsules may occur at a time in the uterus of a single fluke. There may be as many as 200 flukes in the liver of one sheep. If each fluke produces 500,000 eggs (in 10 years), a single infected sheep may disperse 100 million fertile eggs. This vast capacity for egg production is necessary in view

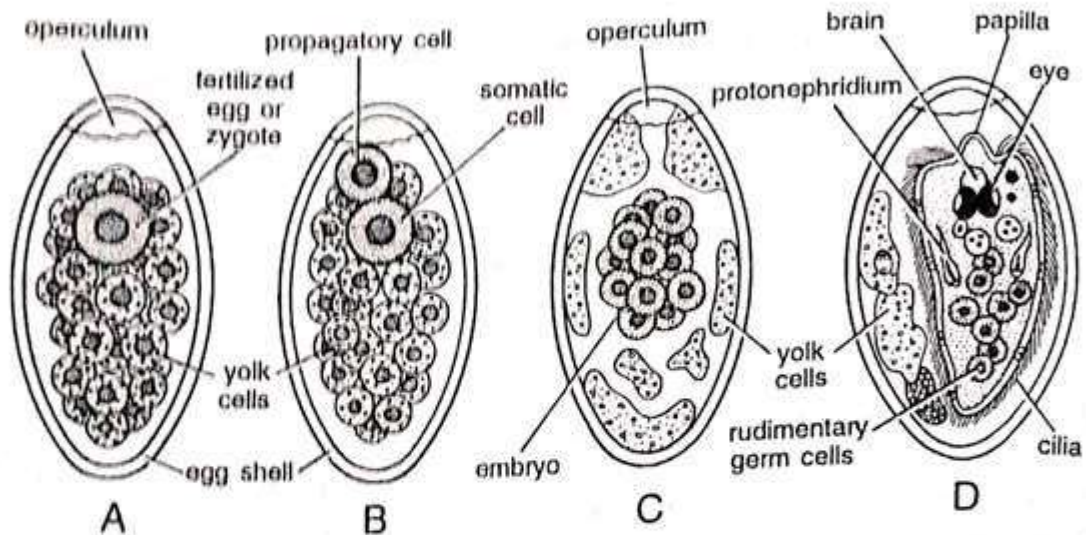


Fig. 15. *F. hepatica*. Early or embryonic development. A - Zygote in capsule. B - 2-cell stage. C - Many-cell stage. D - Miracidium in capsule.

of the complicated life cycle and slim chances of survival.

#### 6. Cleavage and embryonic development.

Cleavage starts while eggs are still in uterus. Cleavage is *holoblastic* and *unequal*. First division of zygote results in two *unequal* cells, a larger *somatic cell* and a smaller *propagatory cell*. Subsequent divisions of somatic cell form larval ectoderm and tissues. Propagatory cell divides further into two daughter cells. One daughter cell by its divisions finally produces the larval body. Other daughter cell divides several times to form a mass of smaller *germ cells* which cluster in the posterior part of larval body.

*Encapsulated embryos* or *capsules* or simply *eggs* do not develop further in fluke's uterus. A very large number of capsules leave fluke's body through its gonopore into host's intestine, and finally ejected out with its faeces. Further development takes place when capsules come in contact with water (or damp areas with at least 60% moisture content) which is slightly acidic (pH 6.5). Optimum temperature for development ranges from 22°C to 25°C.

**7. Miracidium larva.** It is the first larval stage involved in life cycle. When suitable conditions become available, the encapsulated embryo, in 4-15 days, differentiates into a *miracidium larva*. It hatches out and swims in water. Hatching is initiated by a proteolytic *hatching enzyme*. It dissolves the cementing material by which operculum is attached, thus releasing the operculum.

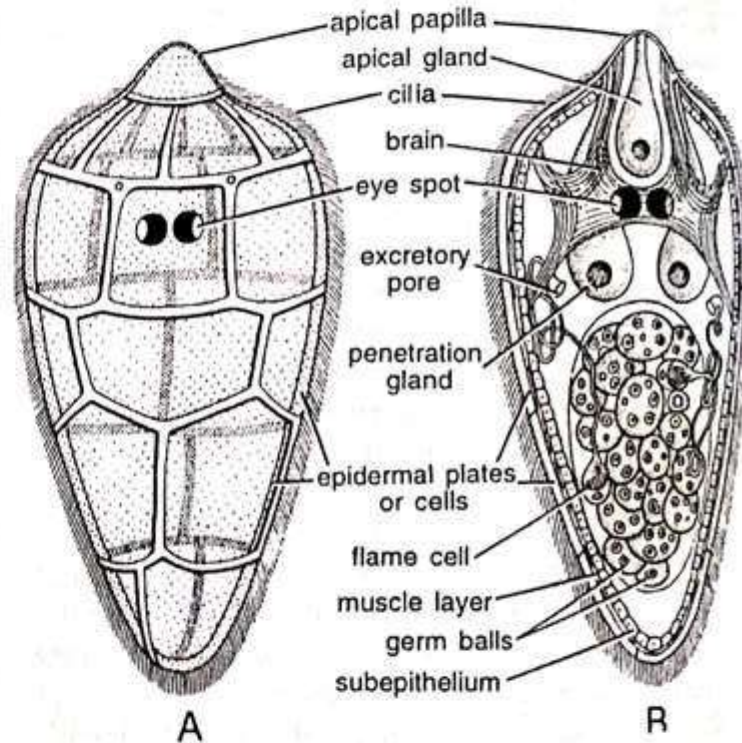


Fig. 16. *F. hepatica*. Miracidium larva. A - External structure. B - Internal structure.

(a) *External structure.* Miracidium is a minute, about 0.07 mm long, oval, elongate and richly ciliated active creature. Its broader anterior end is produced into a mobile and non-ciliated *apical papilla* or *terebratorium*. Miracidium is a multicellular organism. Its body is covered with flattened ciliated *epidermal plates* or cells, 21 in number and arranged in five rows or *tiers*.

Number and arrangement of cells in each tier is fixed. *First tier* (anteriormost) has 6 plates, two dorsal, two lateral and two ventral. *Second tier*

also has 6 plates, three dorsal and three ventral. Third tier has 3 plates one dorsal and two ventro-lateral. Fourth tier has 4 plates, two right and two left. Fifth tier (posteriormost) has 2 plates, one left and one right.

Beneath epidermal plates is a fine layer of sub-epidermal musculature, consisting of outer circular and inner longitudinal fibres. Below muscles is a layer of cells forming the sub-epithelium. Epidermal plates, sub-epidermal musculature and sub-epithelium together form the body wall of miracidium.

(b) **Internal structure.** Within the body of miracidium are present glands, nervous tissue, protonephridia and germ cells. A sac-like multinucleate mass of granular protoplasm is attached to the centre of apical papilla by a stalk. This structure, earlier thought to be rudimentary gut, is now regarded an *apical gland*.

A pair of large, unicellular *cephalic* or *penetration glands* open by their narrow ends near the apical papilla. A large *brain* with several associated nerve fibres lies dorsally below epidermal cells of second tier. Situated above the brain is an "x" shaped larval *eye*, consisting of two crescentic pigmented cells or *eye spots*, with their concavities facing away from each other. The concavities contain a clear refractile material serving as lens. (It should be noted here that a photoreceptor of any sort is absent in adult due to its or the parasitic mode of life). A pair of long tubular *protonephridia* or *flame cells* open to the exterior through two *nephridiopores* or *excretory pores*, situated laterally in the posterior half of body. *Germ cells* lie in groups, called *germ balls*, in the rear part of body.

(c) **Physiology.** Miracidium does not feed. It swims about desperately as if "*seeking something with feverish haste*" (Barlow, 1925). Miracidia tries to penetrate any object or organism they may come across, but only those succeed that come in contact with a specific intermediate snail host (*Lymnaea*, *Succinea*, *Planorbis*, *Bulinus*, *Possaria*, or *Praticolella*). Those, which do not come across the suitable host, in about 24 hours after hatching, die invariably. For penetration, miracidium attaches its apical papilla and performs boring movements together with

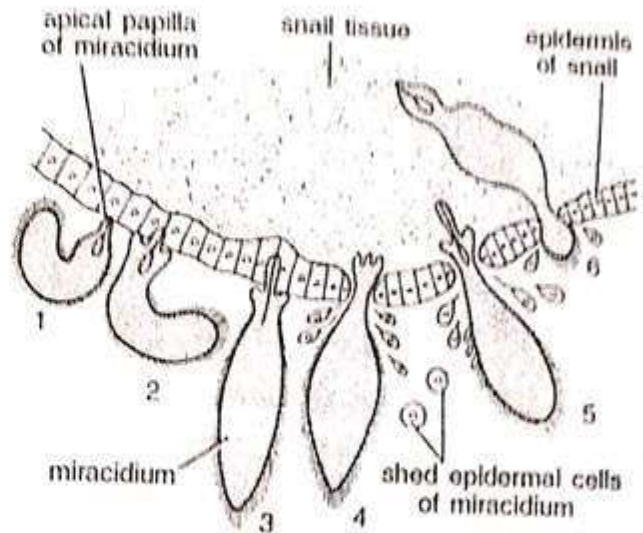


Fig. 17. Miracidia of *Fasciolopsis buski*. Stage of penetration through snail epidermis.

contractions and expansions of body. This process, aided by the action of flesh-dissolving larval secretions, results in a minute opening in the host's tissue. The larva then squeezes through this opening, casting off its ciliated epidermis while doing so. It soon makes its way into the digestive gland of snail, where it undergoes various changes and, in about 14 days, develops into the second larval stage, the *sporocyst larva*.

**8. Sporocyst larva.** It looks like an elongated sac, about 0.7 mm long. Its body wall retains all the layers of body wall of miracidium except the ciliated epidermis, which is lost in the process of

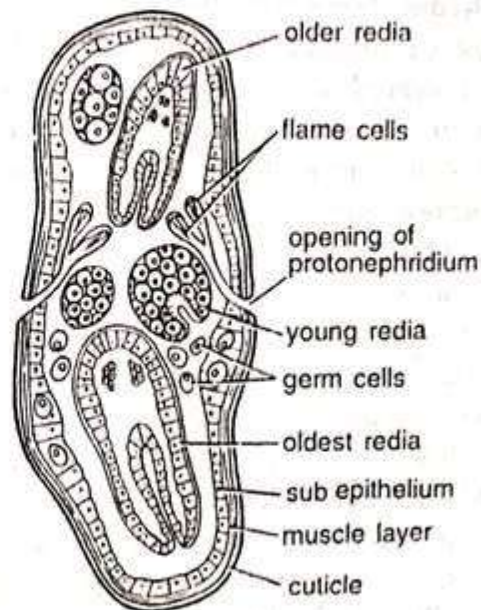


Fig. 18. *F. hepatica*. Sporocyst larva.

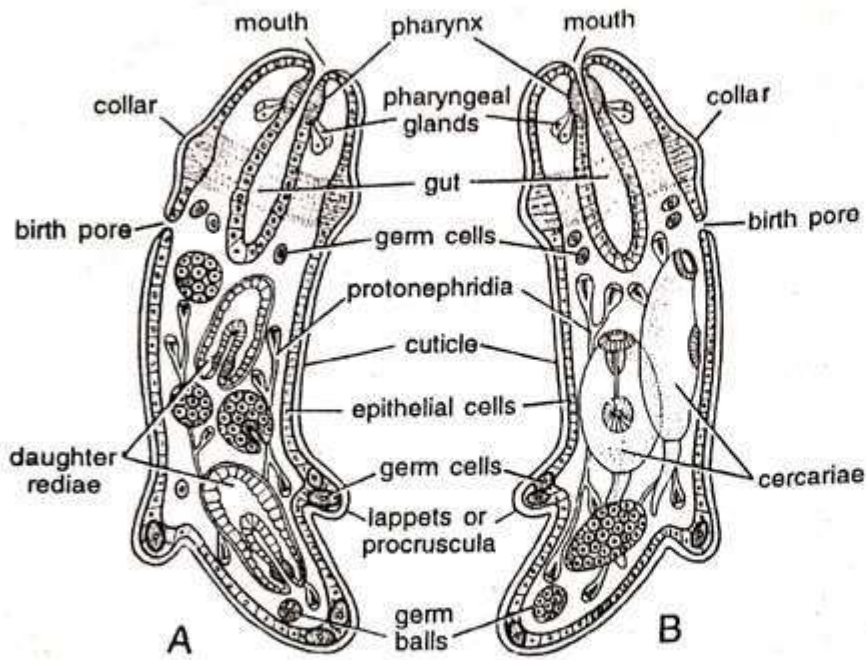


Fig. 19. *F. hepatica*. A—Redia with daughter rediae.  
B—Redia with cercariae.

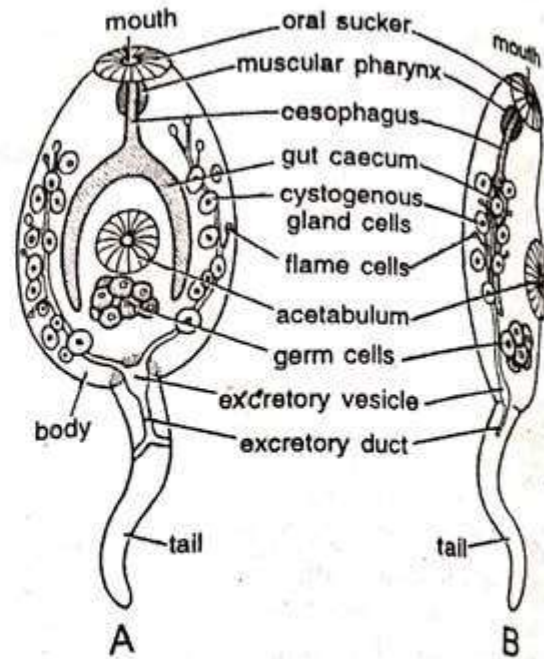


Fig. 20 *F. hepatica*. A—Cercaria in ventral view.  
B—Cercaria in lateral view.

penetration and soon replaced by a thin *cuticle*. Glands, brain, eye spots and apical papilla of miracidium degenerate and disappear in sporocyst. *Protonephridium* of each side divides into two *flame cells* which open outside by a common excretory pore. In addition, the sporocyst contains *germ balls*. Sporocyst moves about in the tissue of host, absorbing nutrition from it. Its germ balls develop into the next larval generation, the *rediae*. Each sporocyst produces 5 to 8 rediae.

**9. Redia larva.** Rediae emerges from the sporocyst by rupture of its body wall. Each redia is an elongated and cylindrical creature, about 1.3 mm to 1.6 mm long. It bears a *mouth* at the anterior end, a ring of muscular swelling or *collar* near anterior end, a permanent *birth pore* a little behind collar, and a pair of projections called *lappets* or *procruscula* ventrolaterally near the posterior end. Body wall consists of the usual layers, viz., cuticle, musculature of outer circular and inner longitudinal fibres, and subepithelium. Mouth leads into a short muscular *pharynx*, followed by an elongated sac-like *intestine*, *enteron* or *gut* lined by a single layer of cells. Numerous unicellular *pharyngeal glands* open into pharynx. *Protonephridia* divide further and form a

much branched system. However, all the flame cells of each side open out through a common excretory duct. Body of larva is packed with *germ balls* and mesenchyme cells.

Redia moves through the host's tissues on which it also feeds. Movements are brought about by muscular contractions of body, aided by the collar and lappets. Moving rediae enter various organs of snail but prefer to migrate to its digestive gland. During summer months, when sufficient nourishment is available, the germ balls of rediae give rise to a *second generation of rediae*, morphologically identical to the parents. During winters, germ balls of rediae of second generation develop into larvae of the next stage, known as *cercaria larvae*.

**10. Cercaria larva.** Each redia produces 14 to 20 cercaria larvae. They leave the body of redia through its birth pore and enters the snail's digestive gland. Morphologically, cercaria bears a close resemblance with the adult fluke. It has an oval body, 0.25 mm to 0.35 mm long, with a long simple tail for swimming. Layers of its body wall are the same as of sporocyst and redia. Cuticle bears backwardly directed spines. Below body wall lie numerous *cystogenous gland cells*, which secrete cyst for the next larva (*metacercaria*).

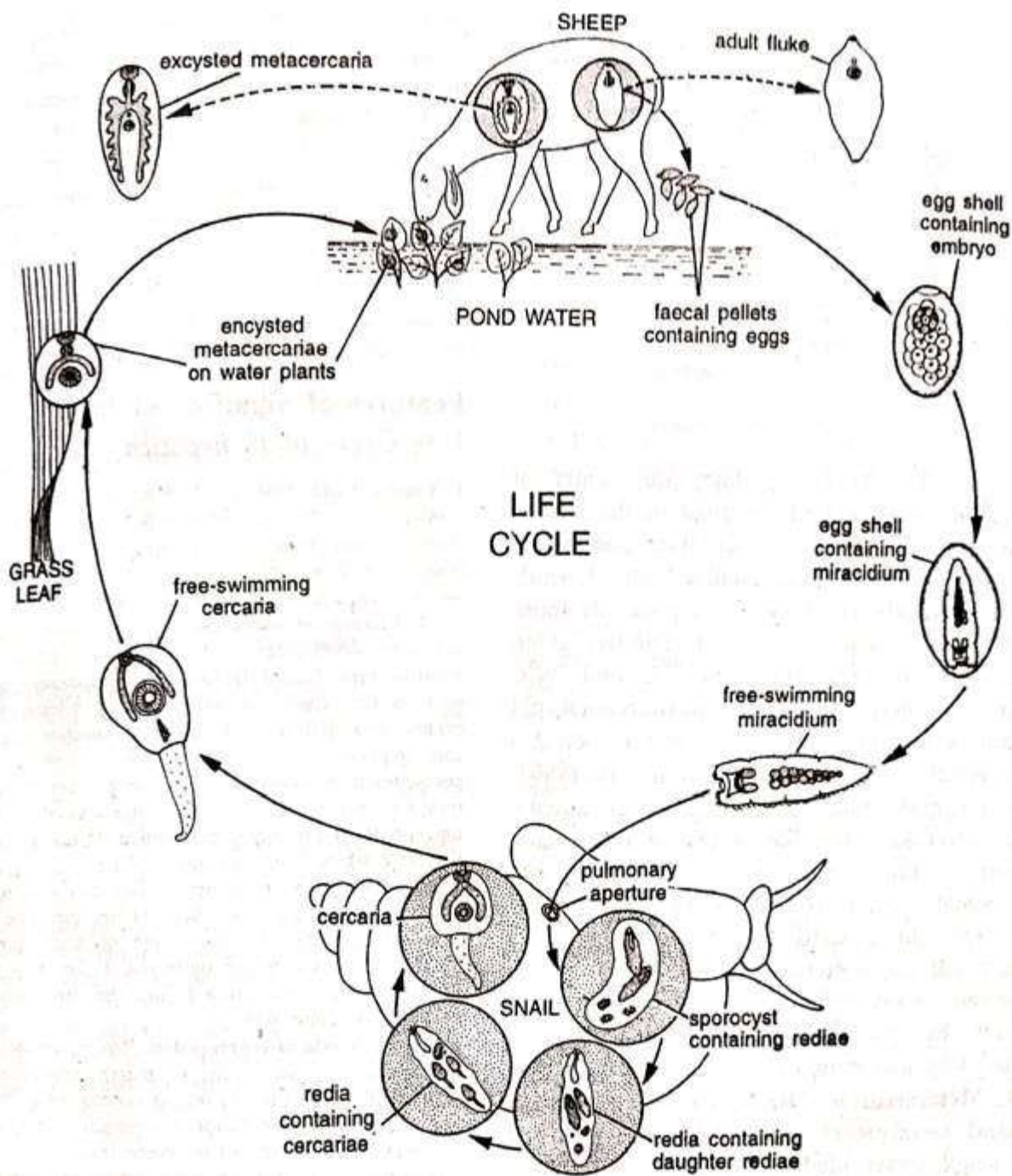


Fig. 21. *F. hepatica*. Life cycle.

Well formed anterior (oral) and ventral suckers like those of adult are present. Rudiments of adult's digestive, excretory and genital systems can be seen in cercaria. Mouth leads into a muscular pharynx, followed by oesophagus and intestine, the latter forking in front of the ventral sucker to form two tubular limbs. Flame cells occur in large numbers along the lateral zones, opening into a pair of excretory tubules, which unite in front of the tail to form an excretory

vesicle or bladder. An excretory duct arises from bladder and extends into tail, where it bifurcates and opens out through a pair of nephriopores. Lying in the body are groups of germ cells, which are direct descendants of propagatory cell of the capsule. These cells represent rudiment of adult's genital system.

Mature cercaria makes its way through the host's tissues, often migrates to its pulmonary sac, and from there escapes to the surrounding

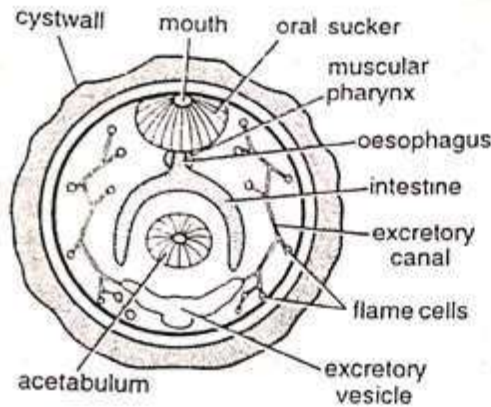


Fig. 22. *F. hepatica*. Metacercaria.

water. It takes 35 to 65 days, after entry of miracidium into the body of snail to the exit of cercariae from the host's body. Rate and extent of larval development in snail's body depends upon the availability of nutrients, primarily those stored in the hepatopancreas or digestive gland of snail. Temperature between 9°C and 26°C favours the emergence of cercaria from snail; pH of medium has no effect in the matter. Cercaria swims about in the surrounding water or crawls about on grass blades or some other aquatic plants. After an active life of two or three days, it loses its tail and undergoes encystment on some aquatic plant to become the *metacercaria larva*. The thick, hard and whitish cyst is a product of cystogenous gland cells which degenerate soon after. Unencysted cercariae ingested by the primary host (sheep) are destroyed by action of its acidic gastric juice.

**11. Metacercaria larva.** As many as a thousand metacercariae may be found attached to a single grass blade. They have a rounded form with a diameter of about 0.2 mm. Metacercaria is in fact the *juvenile fluke*, also called *marita*. It differs from cercaria in that it has a rounded form, a thick hard cyst and large number of flame cells. It lacks a tail and cystogenous gland cells and its excretory bladder opens out directly through a single pore. Germ cells or the genital rudiments are present as such. Cyst provides protection against short periods of desiccation.

**12. Infection of primary host.** Metacercaria develops into adult fluke only inside its definitive host or sheep. The latter gets infection by

grazing on leaves and grass blades to which the cysts are attached. Metacercaria survives action of host's gastric juice as its cyst is insoluble in it. Cyst wall finally dissolves in proximal part of intestine and liberates the larva. It penetrates the intestinal wall and gets into coelomic cavity. Now it infects the liver, feeds on its tissue, and grows in size in five to six weeks. It then takes up its position in the bile duct, where it finally attains sexual maturity. In 11 to 13 weeks, after entering the body of host, it starts laying eggs (capsules.)

### Features of Significance in Life Cycle of *F. hepatica*

**1. Complex life cycle.** Involvement of several larval stages complicates the life cycle of liver fluke. Further, liver fluke is digenetic, that is life cycle is completed in two alternating hosts. Primary or definitive host is sheep and secondary or intermediate host is a freshwater snail.

**2. Chances of death.** Due to complicated and prolonged life cycle, developmental stages have to encounter several hazards. First hazard is faced by *encapsulated embryos* as soon as they come out with faeces of primary host. They cannot develop further if water (or moisture), suitable pH and temperature are not available. Second hazard is encountered by *miracidia* which emerge from the capsules. If they are unable to make contact with a suitable soft part of the specific intermediate host within 24 hours, they perish. *Cercariae* which leave the intermediate host and swim into surrounding water are the next to face an uncertain future. If ingested by the vertebrate host, before they have encysted, they are destroyed by the action of host's gastric juice. Finally, *metacercariae* are destroyed if they have to face a long period of desiccation before they are ingested by a suitable vertebrate host.

**3. High rate of reproduction.** Rate of reproduction of an animal, as a general rule, is directly proportional to the chances of death it has to face at various levels. The ratio, in fact, is the deciding factor for perpetuation of a species. *Fasciola hepatica*, exposed to several threats to its survival, is highly prolific. Each fluke in its lifetime produces more than 200,000 eggs. Further, each sporocyst produces 5-8 rediae, each of which in turn produces 8-12 rediae in the second generation, each of which further produces 14 to 20 cercariae. Thus, each egg is capable of producing 1000 to 2000 cercariae but the actual number produced is far less due to high mortality. Out of those produced, a very small number successfully encysts and infects the final host.

**4. Heterogamy.** Grobben (1882) and some others believed that germ cells in the sporocysts and rediae were eggs which developed *parthenogenetically* into subsequent larval forms. This kind of asexual parthenogenetic reproduction by larval forms is known as *heterogamy*. Reproduction in immature or larval stages is called *paedogenesis* (Gr., *pais*, child; *genesis*, origin). This view, however, is now considered erroneous and has been given up in favour of the *polyembryony*, concept is described further.

5. **Polyembryony.** Germ cells in sporocysts and rediae are direct descendants of *propagatory cells* produced by first division of zygotes. These germ cells multiply mitotically and produce subsequent larval stages within sporocysts and rediae. In doing so, they (germ cells or propagatory cells) behave as several embryos. Thus, this process of reproduction in sporocysts and rediae has been looked upon as *polyembryony* by Ishii (1934), Chen (1937), Rees (1940) and Carl (1944).

6. **Metagenesis.** Life cycle of *Fasciola* involves a period of asexual reproduction during immature stages (sporocysts and rediae) followed by a period of sexual reproduction in the adult stage. Steenstrup (1942) and some others interpret this as an alternation of asexual and sexual generations in the life cycle. But Hyman is of the view that it is a continuous ontogeny (life history) involving asexual multiplication in larval stages.

7. **Advanced larval stages.** Miracidium and cercaria, being free-living larvae, exhibit more advanced features than the adult which has undergone degeneration in many respects to suit its parasitic mode of life. Body cavity, locomotory organs, sense organs, and a cellular epidermis are lacking in adult but are present in larvae.

### Parasitic Adaptations of *Fasciola*

Liver fluke has undergone great modifications, morphological as well as physiological, to suit its existence as an endoparasite in the bile ducts of sheep.

- (1) Outer *tegument* is thick, permeable to water, but enzyme-resistant, so that parasite is not digested by digestive juices of the host.
- (2) Locomotory organs are absent as not required by adult. However, free-swimming larvae, such as miracidium has cilia and cercaria has a locomotory tail.
- (3) Oral sucker, acetabulum and spines of body wall of adult worm serve as organs of attachment in the host's body.
- (4) Alimentary canal is without anus as there is no undigested food for egestion. Suctorial pharynx helps in sucking bile etc. and much-branched intestine serves to distribute digested food to all parts of the body.
- (5) Adult lacks circulatory, respiratory and sensory organs as they are not needed. Nervous system is poorly developed for the same reason. However, free-swimming miracidia has sensory eye spots.
- (6) Respiration is *anaerobic* as free O<sub>2</sub> is not available.
- (7) Reproductive system is highly developed. Number of eggs produced is enormous (about 200,000 eggs per fluke). This is necessary to offset several hazards resulting in great mortality.
- (8) Resistant egg shells around zygotes provide further safety from unfavourable environmental conditions.
- (9) Hermaphroditism ensures self-fertilization even in the absence of another companion for copulation. It is necessary for survival of the species.

### Liver Rot

When sheep are infected by the liver fluke *Fasciola hepatica*, the liver of sheep is seriously affected in structure and function. This disease is known as "Liver rot", or "Fascioliasis".

**Infection.** The vertebrate host (sheep, goat, etc.) gets the infection by grazing on grass, leaves and other vegetation to which metacercarial cysts are attached. The invertebrate host (snail) acquires infection when a miracidium, at random, establishes contact with a suitable part of its body.

**Pathogenesis or Symptoms.** Infection of invertebrate host (snail) results in a partial or complete destruction of the affected site, which is preferably the digestive gland (liver) or gonad. In case of heavy infections, snail considerably increases in size.

Of significant economic importance is the effect of *F. hepatica* on its vertebrate host, whose bile ducts as well as liver may be damaged. In bile ducts, it causes *inflammation* and *hepatitis*, resulting in loss of its epithelium and thickening of wall, followed by calcification and formation of *gall stones*. Heavy infections upset the normal metabolism of liver. This is due to *haemorrhage* caused and irritation inflicted by cuticular spines. The disease thus caused is called *liver-rot* or *fascioliasis*.

Symptoms of *liver-rot*, are more acute in lambs than in sheep, 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 falls a victim to acute *anaemia* and falls even at mild contact. Its appetite declines, rumination (chewing the cud) becomes irregular and at times there is fever and increase in respiratory activity. Conjunctiva becomes whitish-yellow, and dry and brittle wool falls off. After three months of infection comes the fatal period. Large *oedemas* or swellings ("watery poke") appear on jaws. Lactation and breeding are greatly reduced. Rarely does the host survive this period. In case it does, the fluke may migrate to the duodenum and finally escape to the outside world with faeces. When this happens, or when fluke somehow dies *in situ*, the host recovers considerably.

Infection by *F. hepatica* takes a huge toll of sheep annually. In England it caused the death of about one and a half million sheep in 1830 and about double in number in 1879-80. Ireland lost 60 per cent of its flocks in 1882.

**Therapy or treatment.** Treatment of infection is not easy because it is difficult to introduce drugs in bile passages of infected sheep. Anti-helminth drugs such as *hexachloroethane*,

carbon tetrachloride, filcin, emetine hydrochloride, phenothiazine and tetrachloroethane are being employed for treating cases of liver-rot. These drugs are fairly effective in killing stages of the parasite in liver.

**Prophylaxis or Prevention.** It is better to prevent infection by control of the vector or intermediate host. Preventive measures include : (i) killing heavily infected sheep, (ii) destroying eggs and manure of infected sheep, (iii) feeding infected sheep with salt and

little dry food, and (iv) killing or checking snail population. Snails are killed by adding copper sulphate solution in ponds and ditches or by draining their pastures as they are unable to survive long dry periods. Ducks feed on snails and can be usually employed in removing their population. Breeding of snails can be checked by removing vegetation from ponds and streams they inhabit. Man can avoid infection by consuming thoroughly washed and adequately cooked vegetables.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. What is a digenetic life cycle ? Explain it with reference to the life history of *Fasciola hepatica*.
2. Give an account of the reproductive organs of *Fasciola hepatica*.
3. Give a detailed account of the parasitic adaptation in *Fasciola*.
4. Give a detailed account of the life cycle of *Fasciola hepatica* and discuss its economic importance.
5. Describe the anatomy of *Fasciola hepatica* with special reference to its parasitic mode of life.
6. Draw neat and fully labelled diagrams of the following : (i) T.S. of *Fasciola* passing through the ovary. (ii) V.S. of Body wall of *Fasciola*. (iii) Full page, well-labelled diagrams of life history of *Fasciola*. (iv) Reproductive system of *Fasciola hepatica*.
7. Write an essay on the economic importance of *Fasciola hepatica*.
8. Write notes on : (i) Cercaria, (ii) Control measures against *Fasciola* infection, (iii) Distinction between digenetic and monogenetic parasites, (iv) Effects of infection of *Fasciola* on primary host, (v) Flame cell, (vi) Metacercaria, (vii) Miracidium, (viii) Ootype, (ix) Polyembryony, (x) Redia, (xi) Sporocyst.

#### » Short Answer Type Questions

1. What is miracidium ?
2. What are flame cells ?
3. Where can you locate flame cells ?
4. In *Fasciola* write the name of the canal that leads from the junction of the oviduct and combined vitelline duct and open to the exterior on the mid-dorsal surface.
5. Explain the structure of the body wall in *Fasciola*. Draw and mention three adaptive features.
6. Define polyembryony and mention its example.
7. Define parthenogenesis. Explain it with reference to development in *Fasciola*.
8. Draw a labelled sketch of Miracidium of *Fasciola hepatica*.
9. Draw a neat labelled diagram T.S. of liver fluke through middle region.
10. In *Fasciola*, draw neatly stages from Redia to Metacercaria and label all the parts.
11. Draw a sketch showing the reproductive system of *Fasciola hepatica* and label it fully.
12. Give an account of the reproductive system of *Fasciola*.
13. Give an account of the life history of the common liver fluke.
14. Give a detailed account of the reproductive organs of *Fasciola*. How is it adapted to the parasitic mode of life ?

#### » Multiple Choice Questions

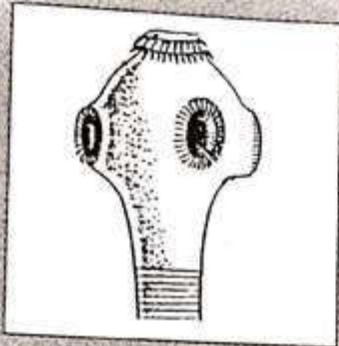
1. In *Fasciola* miracidium develops into the next stage inside :  
(a) *Bulimes* (b) *Limnea trunculata*  
(c) *Pila globosa* (d) *Planorbis*
2. *Planorbis* and *Lymnaea* are the intermediate host of :  
(a) *Fasciola* (b) *Schistosoma*  
(c) *Trichinella* (d) *Echinococcus*
3. Which of the infective stage to primary host of *Fasciola* ?  
(a) Miracidium (b) Sporocyst  
(c) Metacercaria (d) Cercaria
4. One of the following larval stage of *Fasciola* does not produce several larvae ?  
(a) sporocyst (b) secondary Redia  
(c) primary Redia (d) Cercaria
5. Which layer of *Dugesia* contains rhabdites :  
(a) epidermis (b) circular muscle  
(c) parenchyma (d) cuticle
6. Miracidium is one of the stages in the development of :  
(a) *Fasciola hepatica* (b) *Taenia solium*  
(c) *Ascaris lumbricoides* (d) *Planaria*



7. In *Fasciola* the region where the shell gland opens into is the :  
(a) oviduct (b) ovovitelline duct  
(c) uterus (d) oocyte
8. *Fasciola hepatica* is a parasite that lives in the :  
(a) intestine of sheep (b) liver of sheep  
(c) spleen of sheep (d) pancreas of sheep
9. In *Fasciola* the germ cells of the redia gives rise to :  
(a) daughter Cercaria (b) daughter Sporocyst  
(c) daughter Redia (d) daughter Metacercaria
10. Liver fluke is not affected by enzymes of host because of :  
(a) cuticle (b) suckers  
(c) epidermis (d) hooks
11. The stage of life history of the liver fluke when it infects the primary host is :  
(a) Redia (b) Cercaria  
(c) Sporocyst (d) Cysticercus
12. Which stage of Liver fluke infects the intermediate host :  
(a) Redia (b) Cercaria  
(c) Miracidium  
(d) Sporocyst
13. Primary host of *Fasciola* is :  
(a) man (b) pig (c) sheep (d) dog
14. For attachment *Fasciola* has :  
(a) four suckers and hooks (b) two suckers  
(c) two suckers & hooks (d) hooks only
15. Correct sequence of larval stages during development of *Fasciola* is :  
(a) Miracidium, Redia, Sporocyst and Metacercaria  
(b) Cercaria, Miracidium, Sporocyst and Metacercaria  
(c) Miracidium, Sporocyst, Redia, Cercaria and Metacercaria  
(d) Redia, Cercaria, Metacercaria and Sporocyst
16. In *Fasciola* germ balls of Redia give rise to :  
(a) daughter Sporocyst (b) daughter Cercaria  
(c) daughter Redia (d) Metacercaria
17. Which of the infectious stage to secondary host of *Fasciola* :  
(a) Miracidium (b) Sporocyst  
(c) Redia (d) Cercaria
18. Which is the first stage of larva of *Fasciola* :  
(a) Miracidium (b) Sporocyst  
(c) Redia (d) Cercaria
19. Protonephrodic perform the function in *Fasciola* :  
(a) excretion (b) osmoregulation  
(c) both (d) none the above
20. *Fasciola* has :  
(a) salivary gland (b) pharyngeal gland  
(c) gastric gland (d) intestinal gland
21. The cause of 'liver rot' in sheep :  
(a) *Dugesia* (b) *Fasciola*  
(c) *Taenia* (d) *Schistosoma*

**Answers**

1. (b) 2. (a) 3. (c) 4. (d) 5. (a) 6. (a) 7. (b) 8. (b) 9. (c) 10. (a) 11. (b) 12. (b) 13. (c) 14. (b) 15. (c) 16. (c) 17. (a) 18. (a) 19. (c) 20. (b) 21. (b)



# 32

Chapter

## *Taenia solium*: The Pork Tapeworm

Cestodes belong to the class cestoda of phylum Platyhelminthes and are exclusively endoparasites. They differ from turbellarians and trematodes in the total absence of a digestive tract. They are commonly known as *tapeworms* for their long, flat and ribbon-like form. Genus *Taenia* includes several species parasitizing man and domestic animals. Common examples are *T. solium* (the pork tapeworm) and *T. saginata* (the beef tapeworm).

The present text mostly relates to *T. solium*, the pork tapeworm of man.

### *Taenia solium*

#### Systematic Position

Phylum	Platyhelminthes
Class	Cestoda
Subclass	Eucestoda
Order	Taenioidea (= Cyclophyllidea)
Family	Taenidae
Genus	<i>Taenia</i>
Species	<i>solium</i>

### Habits and Habitat

*Taenia solium*, like *Fasciola hepatica*, completes its life cycle in two hosts. The adult dwells as internal parasite in the small intestine of man (primary or final host) where it is anchored to the intestinal mucosa by its scolex. It has no mouth or digestive cavity but absorbs the host's digested food through its body wall. The larval stage occurs in the tissues of a secondary or intermediate host which is usually pig and sometimes dog and sheep. A number of other animals such as goat, cattle, horse, bear and monkeys have also been mentioned as intermediate hosts.

*Taenia solium* is found in all those parts of the globe, where pig is domesticated and consumed as food. Its distribution, thus, is cosmopolitan.

### External Morphology

1. Shape, size and colouration. *Taenia solium* is usually opaque white in colour but creamish,

yellowish or greyish colouration is also common. Body is 1 to 5 meters long, and flattened like a ribbon or tape. The two flat surfaces represent the dorsal and ventral surfaces respectively, but from external examination it is not possible to identify them. Internal view reveals that surface closer to testes is dorsal and nearer the female reproductive organs, the ventral surface. Elongated body is extremely narrow anteriorly and gradually broadens towards the posterior end.

2. Segmentation. Elongated body of tapeworm is divided into a great number of parts or segments, called *proglottids*, possibly upto about 850 altogether. Segmentation of tapeworms is called *pseudometamerism* in contrast to the *true metamerism* of annelids and arthropods (chapter 15). Therefore, the term 'segment' in tapeworm is being used solely for convenience and in no way implies a true metameric segment.

Entire body is divisible into three distinct parts: (i) an anterior *scolex* or head, (ii) a short unsegmented *neck*, and (iii) a segmented *strobila*.

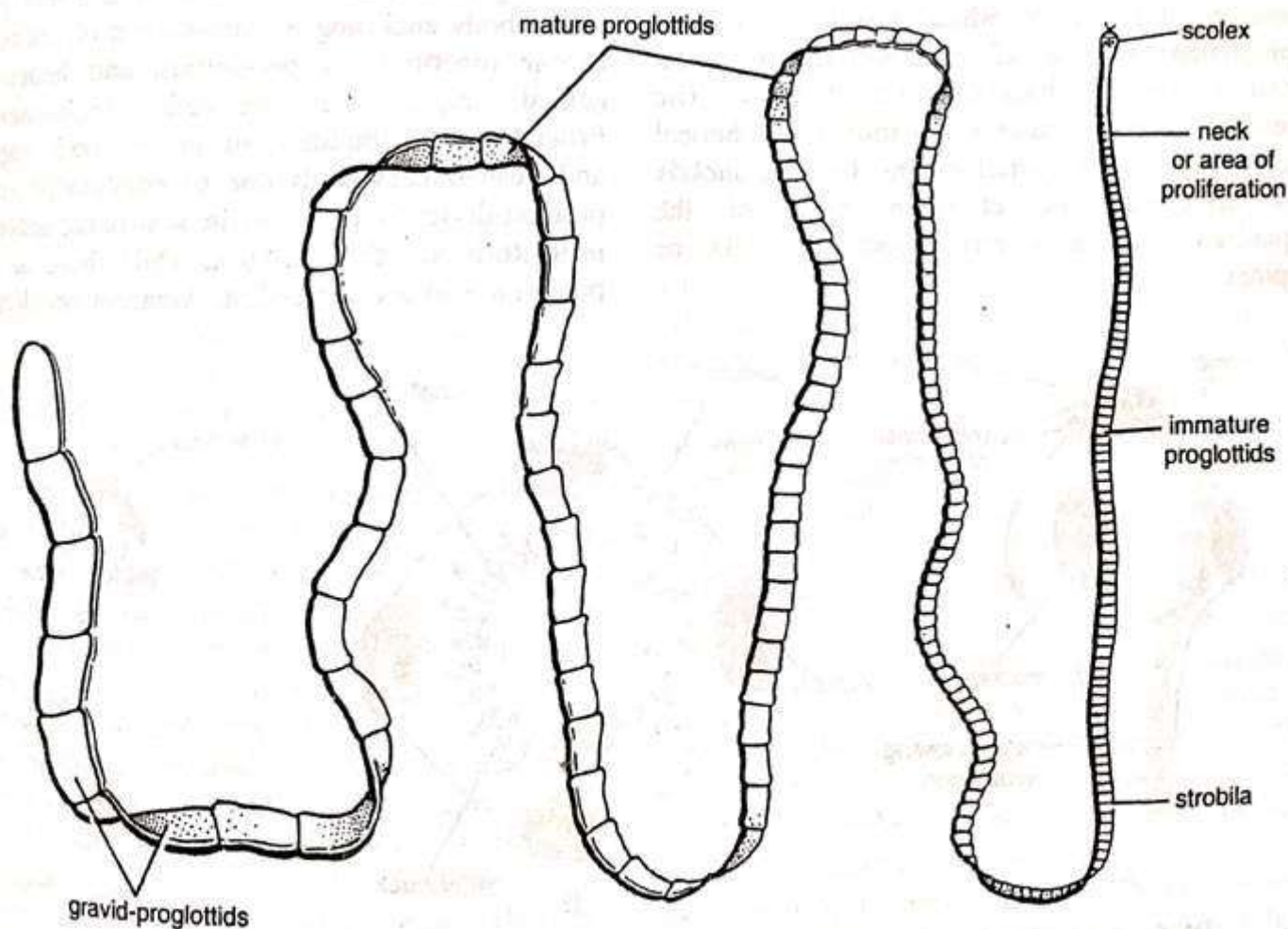


Fig. 1. *Taenia solium*. Entire animal.

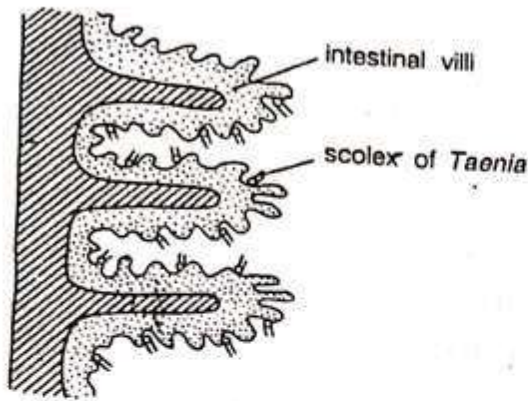


Fig. 2. Scolex of *Taenia* attached to the host's intestinal wall.

3. **Scolex.** It represents the anterior end of body. It is knob-like, biradially symmetrical and 0.6 to 1 mm wide. In en-face view it appears roughly quadrangular. At the apex is a prominent rounded mobile cone, the *rostellum*. It is armed with 22 to 32 curved chitinous *hooks*, arranged in two rows or circles around its base. Hooks of anterior circle are larger, each measuring 0.14 to 0.18 mm and those of posterior circle are smaller each measuring 0.11 to 0.14 mm. Each hook consists of a *base* by which it is fixed, a blunt projection or *handle* directed towards the apex, and a conical outwardly directed *blade*. The broadest part of scolex bears four hemispherical highly muscular suckorial organs, the *true suckers* or *acetabula*, one at each angle of the quadrangle. Suckers are devoid of hooks or spines.

The scolex with the help of its hooks and suckers, lies buried in the host's intestinal mucosa, providing firm adhesion to the body against the loosening action of peristaltic movements of the host's intestine. It is thus an organ of attachment or *holdfast*. It plays no role in perceiving or catching food. The term "head" frequently used for the scolex is, thus, inappropriate.

4. **Neck.** It is a well-defined, short, narrow and unsegmented region behind scolex. Unlike scolex, it is dorsoventrally flattened. It has been variously termed *the budding zone*, *growth zone*, *area of proliferation* and *area of segmentation*, because it is this region where the segments or proglottids, constituting *strobila*, are budded off and pushed backwards.

5. **Strobila.** It forms the main bulk of body. It consists of 800 to 1,000 segments or *proglottids* arranged in a linear series in a *chain-like* fashion. (The species *solium*, according to Leuckart, has got its name from *schuschel*, a Syrian word referring to a *chain*). A proglottid is a unit part of the body enclosing a complete set of genitalia. Linear repetition of proglottids, and hence of genital organs, is termed *proglottisation*. Proglottids are budded off in the neck region and pushed backwards due to addition of more proglottids in front. Thus, in a strobila, anterior proglottids are the youngest, while those at the posterior end are the oldest. Adjacent proglottids

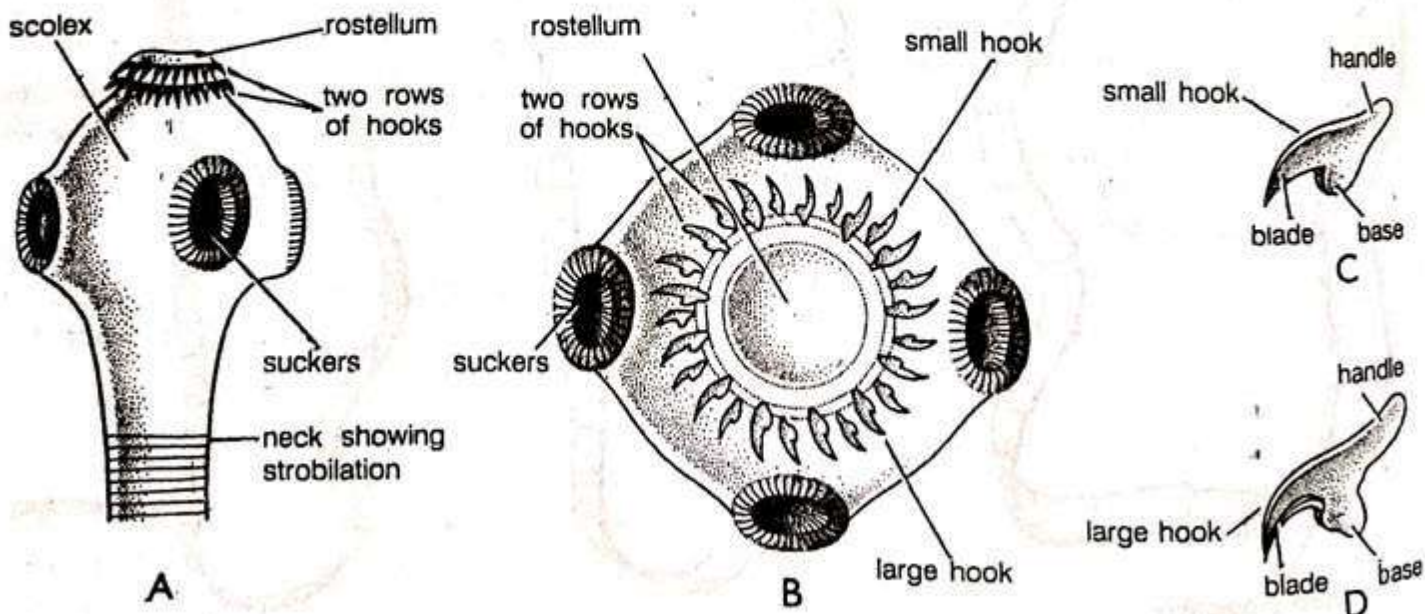


Fig. 3. *Taenia solium*. A - Scolex and neck in side view. B - Scolex in en-face view. C - Small hook. D - Large hook.

remain attached together by longitudinal muscles, excretory ducts and nerve cords, which extend along the entire body length. According to the degree of development, the strobila includes the three kinds of proglottids : *immature*, *mature* and *gravid*.

(a) *Immature proglottids*. These comprise of about 200 anterior proglottids just behind the neck. They are the youngest, sexually immature and devoid of reproductive organs. They are short, broader than long and rectangular in outline.

(b) *Mature proglottids*. There are about 450 mature proglottids forming the middle part of strobila. These are large and squarish in outline. The anterior 100 to 150 proglottids contain only male reproductive organs, while the posterior 250 mature proglottids develop both male and female reproductive organs making them hermaphrodite.

Each mature proglottid, on one side bears a tiny protuberance, the *genital papilla*, at the tip of which is situated the *common genital pore*. These pores, in the successive proglottids, are situated alternately on the right and left sides. A mature proglottid is a complete reproductive unit and produces eggs which are fertilized by its own sperms (*self fertilization*) or by those of other mature proglottids (*cross fertilization*).

(c) *Ripe or gravid proglottids*. The oldest and the last 150 to 350 proglottids, upto the posterior end of body, are termed *gravid* or *ripe*. They are longer than broad in outline. All the male and female reproductive organs have degenerated except the highly branched *uterus* full of fertilized eggs. (Fig. 12).

6. *Apolysis*. Small groups of gravid proglottids regularly detach from the posterior end of strobila and pass out with the host's faeces. Shedding of gravid proglottids is termed *apolysis* and the tapeworm exhibiting this phenomenon is called *apolytic* in contrast to the *anapolytic tapeworms* (most pseudophyllids), which retain all their proglottids throughout life. Apolysis serves a twofold purpose. (i) It serves to transfer the developing embryos to the exterior, where they can be ingested by the secondary host, and (ii) it limits the size of body which may otherwise attain enormous length due to continued proliferation in the neck region.

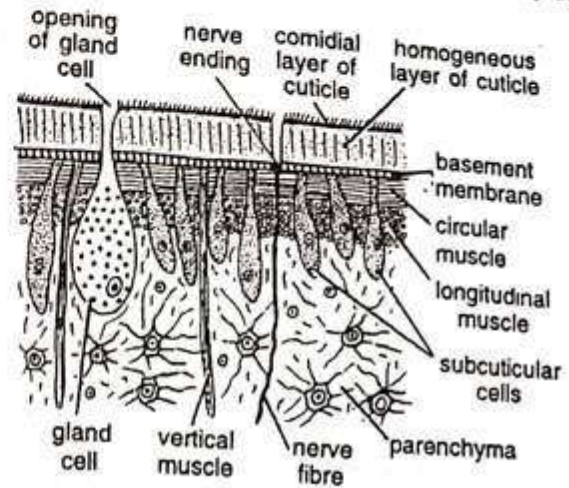


Fig. 4. *T. solium*. V.S. body wall under light microscope.

## Body Wall

Like flukes, tapeworms also lack a cellular or ciliated epidermis. Layers of body wall from surface are : (i) *tegument*, (ii) *basement membrane*, (iii) *integumentary muscles*, and (iv) *parenchyma*.

1. **Tegument.** It is a thick resistant layer clothing the body in the absence of a cellular epidermis. It is composed of protein impregnated with calcium carbonate and is perforated by numerous fine canals. Under light microscope, three layers can be distinguished in this layer : (i) outermost hair-like or fringe-like *comidial layer*, (ii) middle thick *homogeneous layer*, and (iii) innermost *basement membrane*. As no living structures are visible, this layer used to be regarded a non-living *cuticle*. Studies under electron microscope by Threadgold and others have shown that outermost cuticle is in fact a thick, living and syncytial layer called *tegument*, continuous with *tegument secreting cells*, of mesenchyme. Tegument contains mitochondria and lysosomes and gives out *microvilli*-like processes, called *microtriches*, on its outer surface. The Microvilli serve two purposes : (i) they facilitate absorption of host's food by increasing the surface area of body, and (ii) they partially act as holdfast organs (A.H. Rothman 1963) by interlocking with microvilli of cells lining the host's intestine. Tegument is also perforated by numerous fine *pore canals* through which substances (in solution) are absorbed from the host's intestine.

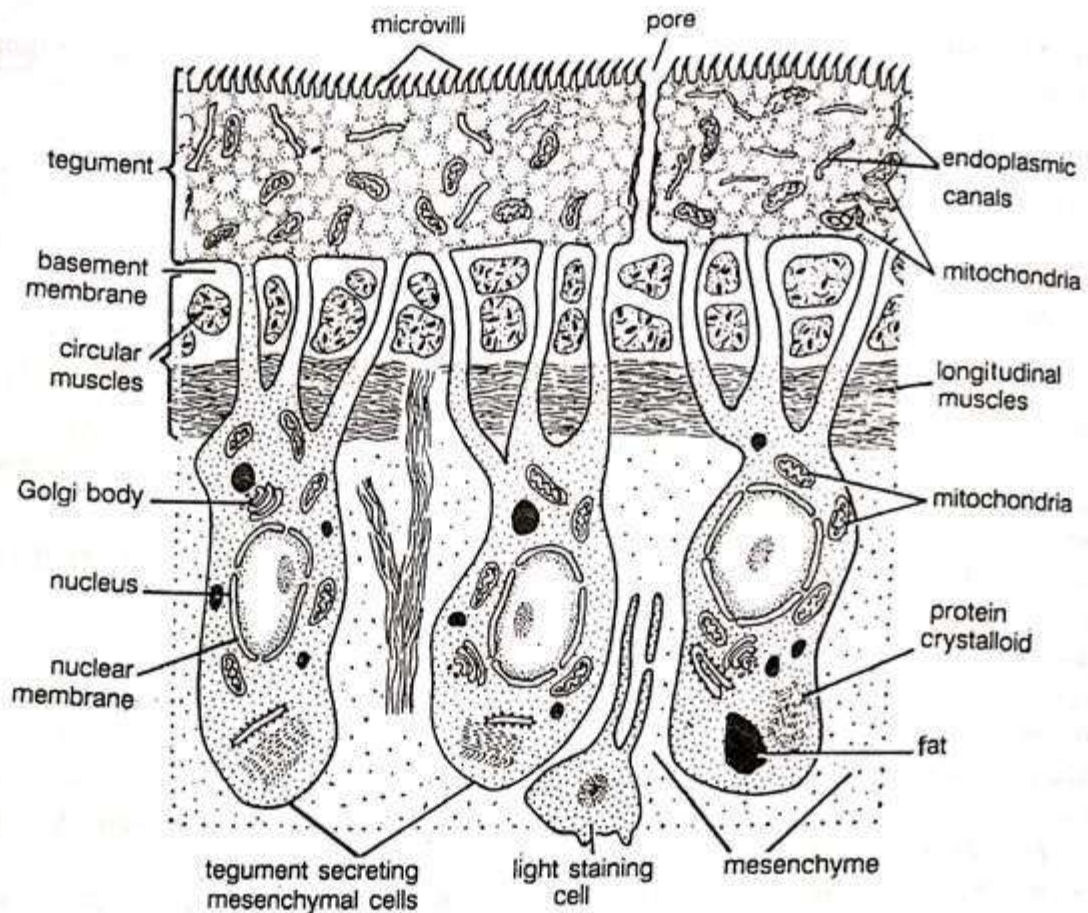


Fig. 5. *T. solium*. V.L.S. body wall based on electron microscope.

Tegument is constantly renewed by the underlying *tegument secreting cells* with which it is continuous.

**2. Basement membrane.** With a light microscope, region beneath tegument (then cuticle) appears as a thin, well-defined acidophilic *basement membrane*. However, with electron microscope, its outer edge is identified, while its inner edge merges imperceptibly with the underlying mesenchyme.

**3. Integumentary musculature.** Beneath the basement membrane musculature consists of well-developed outer *circular* and inner *longitudinal* fibres. Lying in the mesenchyme also is the *mesenchymal musculature* consisting of *longitudinal, transverse or circular, and vertical or dorsoventral muscle fibres*.

**4. Mesenchyme or parenchyma.** It consists of loosely-packed cells with fluid-filled interspaces, forming a *packing* around various internal organs. In young proglottids and in neck region, however, mesenchyme is more compact. Numerous round or oval calcareous bodies, composed of concentric layers of calcium

carbonate, are present in mesenchyme. These are secreted by special mesenchymal *lime cells*, which later atrophy, setting the bodies free in mesenchyme. Besides, it also contains a large number of *tegument secreting cells*. Circular muscle fibres of the mesenchymal musculature, except at the margins, divide the mesenchyme into an outer *cortex or cortical zone* and inner *medulla or medullary zone*.

In addition to its skeletal function mesenchyme acts as an important transport medium in the absence of a blood vascular system.

## Nutrition

As already mentioned, tapeworm completely lacks alimentation in all stages of life-history. The predigested food in host's small intestine (especially ileum) is the chief source of nourishment for tapeworm. Soluble nutrients, like glucose, amino acids, glycerol, etc., diffuse directly through general body surface (tegument). As noted above, the absorptive surface of parasite is greatly increased by the microvilli of

tegument. The swift efficiency with which absorption takes place has been compared with the soaking action of blotting paper. Some tissue fluids from host are probably absorbed by scolex of tapeworm insinuated deeply into intestinal mucosa. Stored food consists mainly of glycogen and of some lipoid substances. Glycogen content of *T. solium*, by net weight, is 2.17% .

For its mode of obtaining nutrients, tapeworm does not require an alimentary canal, which is thus totally absent in all stages of its life history. Moreover, presence of an alimentary canal would not have suited the mode of life of tapeworm as it would have rendered impossible the process of apolysis is indispensable for it. The alternative mode of nutrition described above is thus a parasitic adaptation of tapeworms, unique in the animal kingdom.

### Respiration

Respiration of the tapeworm is mainly *anaerobic* or *anoxybiotic*. Glycogen, the principal reserve food and the chief source of energy, undergoes glycolysis, producing carbon dioxide and fatty acids. Steps involved are same as in liver fluke. In addition to fatty acids, other organic acids, like lactic acid, are also produced.

Free oxygen, whenever available, is also consumed by tapeworms. Rate of consumption is maximum in the anterior proglottids and declines gradually towards the posterior end.

### Excretory and Osmo-regulatory System

It consists of : (i) lateral longitudinal canals, (ii) secondary canals, (iii) capillaries, and (iv) flame cells.

1. **Excretory canals.** There are, on each side, two *lateral longitudinal excretory canals* or the *collecting tubules* of which one is dorsal and the other ventral. In scolex they get connected with one another by a network of tubules or *nephridial plexus*. The canals run through proglottids, just inner to the mesenchymal musculature. *Dorsal canals* are produced and confined to the anterior part of strobila. *Ventral canals* are large and extend along its entire length. Two ventral canals are connected by a *transverse canal* at the posterior part of each proglottid (except the last). In the last proglottid,

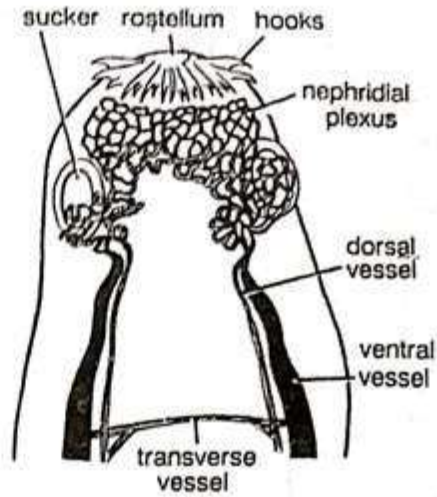


Fig. 6. *Taenia solium*. Excretory system at the anterior end.

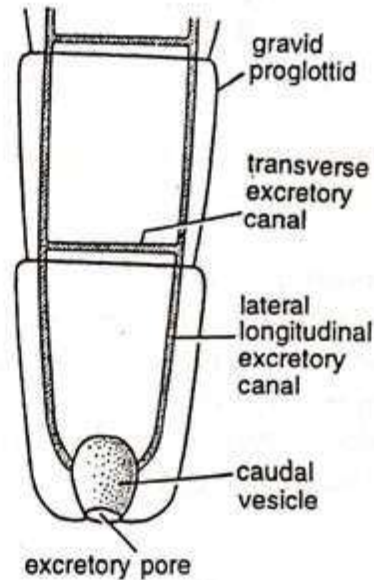


Fig. 7. *Taenia solium*. Caudal vesicle in last proglottid.

they join to form a pulsatile *caudal vesicle*, opening to the exterior by a single *excretory pore*. When the last proglottid is shed off (apolysis), the terminals of the two ventral canals behave as independent excretory pores.

Each longitudinal excretory canal receives numerous *secondary canals* all along its length.

2. **Flame cells.** A secondary canal is formed by the union of several fine *capillaries*, each connected to a *flame cell*. These are scattered throughout parenchyma from which they remove metabolic wastes. A flame cell is of irregular shape, with granular cytoplasm and a nucleus. Bundle of cilia, or flame, arises from basal granules near nucleus. Cilia are enclosed into a funnel-shaped lumen formed by the terminal blind end of a capillary.

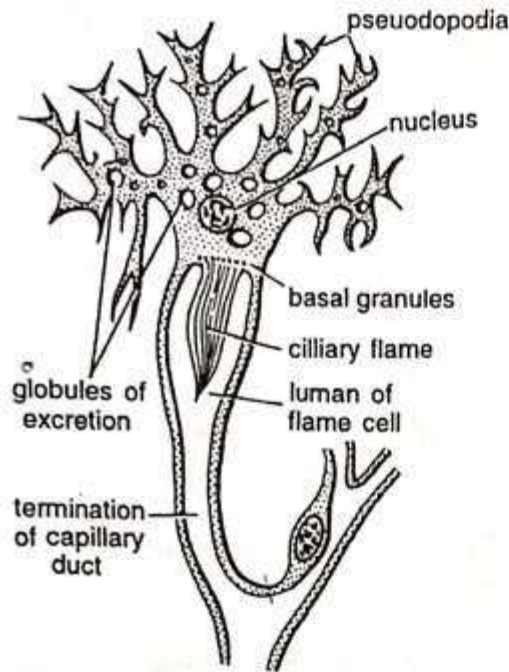


Fig. 8. *Taenia solium*. A flame cell.

**3. Physiology.** Longitudinal canals are lined internally by cuticle, while secondary canals and capillaries have a ciliated lining. Cilia set up a hydrostatic pressure which drives out the excretory products through excretory canals and out of excretory pores. Exact nature of excretory products is, however, not known. Fluid contents of body are also regulated by this system, which is, therefore, also *osmoregulatory*.

## Nervous System

Nervous system of *Taenia solium* has not been thoroughly examined so far. Among the taenoid tapeworms, *Moniezia* (Tower 1900) and *Anoplocephala* (Becker (1921)) have been studied for this system. Their findings in these tapeworms are probably true for other taenoid tapeworms also. Nervous system of *Moniezia* is however, described below.

In the scolex lies a pair of stout cerebral ganglia connected by (i) a ring consisting of a dorsal and a ventral commissure, and (ii) a thick ganglionated cross commissure or the transverse commissure. From the brain complex so formed, 8 nerves are given out anteriorly (4 from ring commissure and 4 from transverse commissure). These terminate into another smaller ganglionated rostellar nerve ring. Fibres from ganglia in scolex supply the suckers and rostellum. From brain complex, 3 pairs of longitudinal nerve cords arise and extend posteriorly into strobila. These are : (i) lateral nerve cords arising from cerebral ganglia and extending through medullary region of mesenchyme, outer to the excretory canals, (ii) dorsal nerve cords arising from dorsal commissure, and (iii) ventral nerve cords arising from ventral commissure. In each proglottid, all

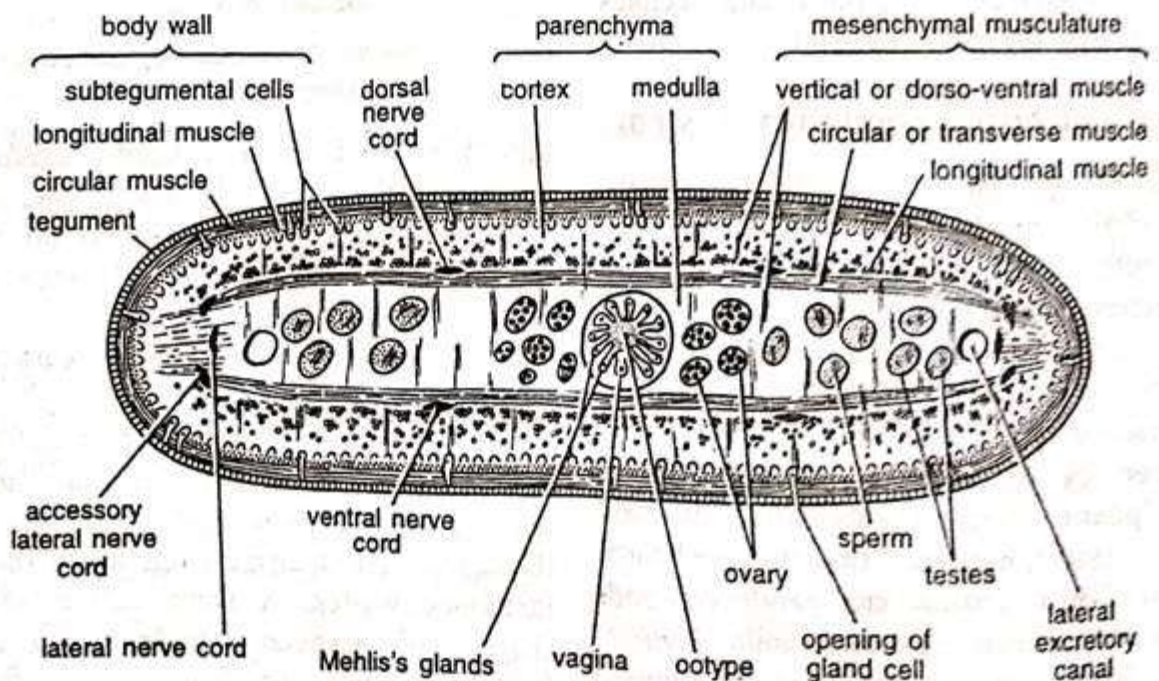


Fig. 9. *Taenia solium*. T.S. mature proglottid through ootype showing positions of 10 longitudinal nerves.



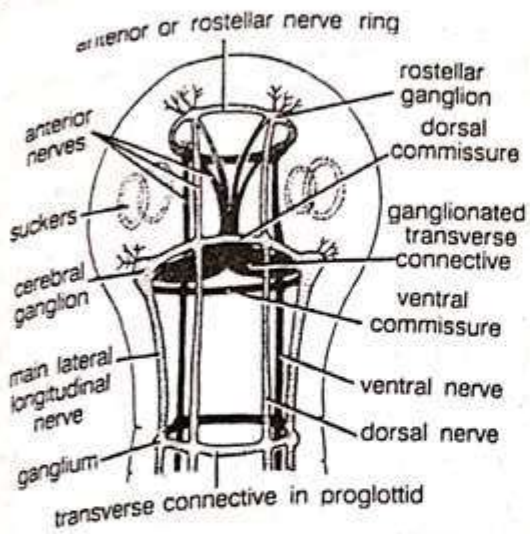


Fig. 10. *Moniezia*. Nervous system in scolex.

the 6 nerve cords are connected by a ring commissure or transverse connective behind the transverse excretory canal.

One feature, in which nervous system of *Taenia solium* and most other tapeworms surely differs from that of *Moniezia*, is that 10 nerve cords instead of 6 (three pairs) arise from brain complex and run through strobila. The 4 additional nerve cords are the accessory lateral

nerve cords, 2 of which accompany each lateral nerve cord.

Special receptors, as found in turbellarians, are lacking in tapeworm. However, numerous free sensory nerve-endings are present throughout the body specially in the scolex. A detached proglottid, passing out with faeces, shows some movement and sensitivity to stimuli.

### Reproductive System

All tapeworms, except *Dioecocestus* (a genus allied to *Taenia*), are *hermaphrodite*. Each proglottid, at maturity, contains a complete set of male and female reproductive organs. These organs develop from mesenchyme and lie embedded in it. Male organs differentiate before the female organs (*protandrous* condition), so that in the mature zone of strobila, consisting of about 450 proglottids, the anterior 100-150 proglottids possess only male system while the remaining posterior ones possess both male and female systems. After a period of intense reproductive activity, mature proglottid loses all its genital organs except the highly-branched uterus filled with fertilized eggs. Segments that

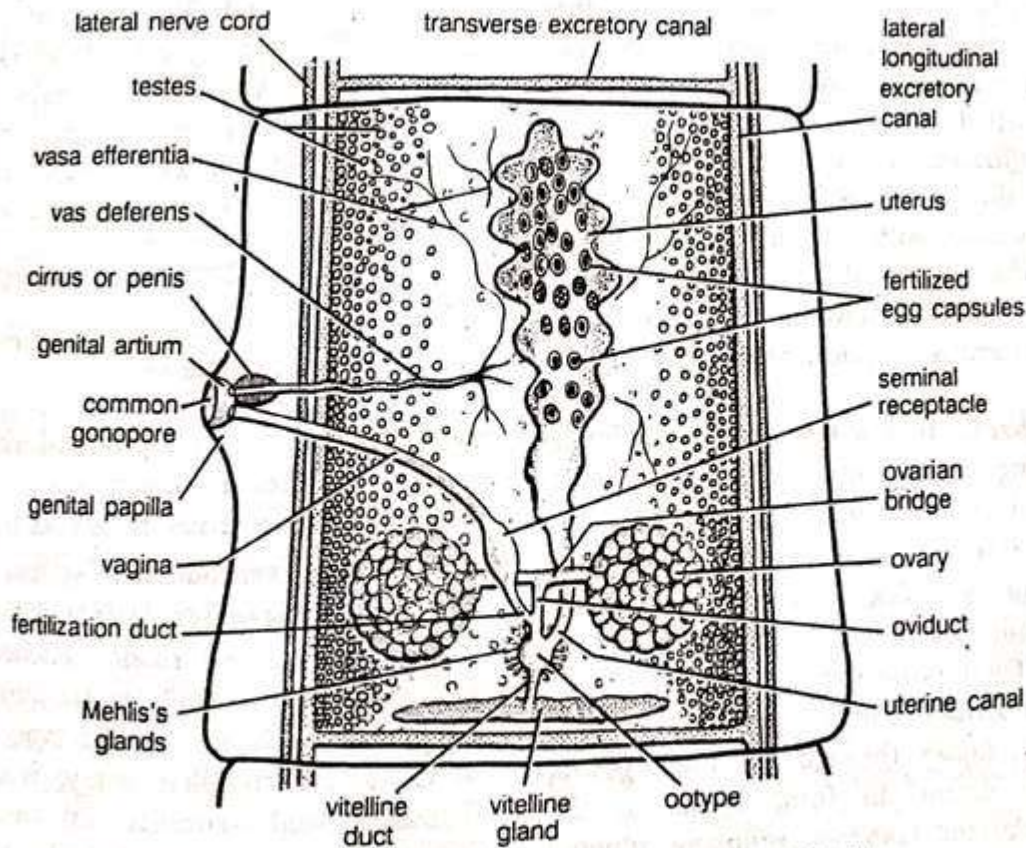


Fig. 11. *Taenia solium*. Reproductive system in a mature proglottid.

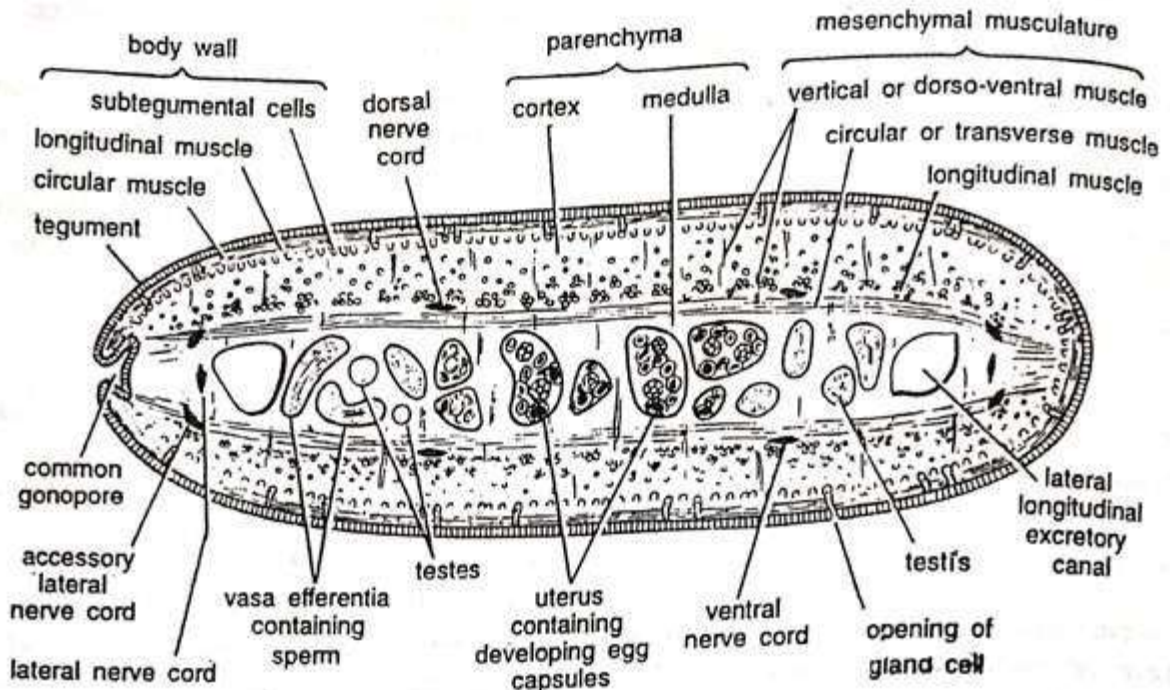


Fig. 12. *Taenia solium*. T.S. mature proglottid through uterus and genital atrium.

have reached this stage, are called *ripe* or *gravid* segments.

**1. Male reproductive system.** (a) *Testes*. Testes are numerous small, spherical bodies scattered throughout the mesenchyme, close to the dorsal surface. (Some workers are of the opinion that the numerous rounded bodies, referred to as testes here, constitute a single and highly subdivided testis).

(b) *Vasa efferentia*. From each testis arises a fine ductule, the *vas efferens*, which frequently gets interconnected with similar ductules from the surrounding testes. All the vasa efferentia finally unite, approximately in the middle of proglottid, to form a common *sperm duct* or *vas deferens*.

(c) *Vas deferens*. It is a thick and convoluted tube, extending upto the lateral margin of proglottid, at right angles to it.

(d) *Cirrus*. Outer end of vas deferens forms the lumen of a thick, muscular, eversible, copulatory organ, the *cirrus*, enclosed in a firm *cirrus sheath*. There is no seminal vesicle.

(e) *Genital atrium*. Cirrus opens into a cup-shaped *genital atrium* through the *male genital pore*. Genital atrium, in turn, opens to the exterior through the *common gonopore* situated at the peak of a tiny protuberance, the *genital papilla*, in the middle of the lateral margin of

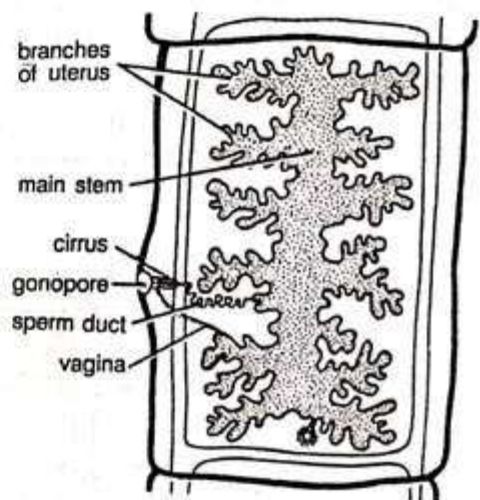


Fig. 13. *Taenia solium*. A gravid proglottid showing branched uterus.

proglottid. Gonopore is provided with a sphincter muscle. Common gonopores of successive proglottids lie alternately on both the sides.

**2. Female reproductive system.** It resembles with the corresponding system of liver flukes.

(a) *Ovary*. A single bilobed *ovary* or *germarium* lies ventrally in the posterior part of proglottid. Each lobe of the ovary (regarded by some as one complete ovary) is dorso-ventrally flattened and consists of a number of radially-arranged *germinal cords* or *follicles*. The right and left lobes are connected medially by a transverse, tubular bridge, the *ovarium isthmus*.

(b) **Oviduct.** A short oviduct arises from about the middle of ovarian isthmus. It runs backwards, joins another slender tube, the *vagina* and then forms a swollen chamber, the *ootype*.

(c) **Ootype.** It is a small rounded chamber formed by the union of oviduct, uterus and vitelline duct. It is surrounded by numerous unicellular *Mehlis's glands*, known after its discoverer.

(d) **Vagina.** Vagina is a bent narrow tube. It originates from the *female genital pore* located behind the male genital pore in genital atrium. It runs obliquely inwards to join the oviduct. Before joining oviduct, vagina swells up to form a sperm-storing sac, the *receptaculum seminis* or *seminal receptacle*. The narrow part of vaginal duct between sac and oviduct is called *fertilization duct*. Vagina of tapeworm probably corresponds to the Laurer's canal of liver fluke.

(e) **Vitelline gland.** A large lobulated gland, the *vitelline gland* or *vitellarium*, forms a compact elliptical mass behind the ovary. It is connected with the ootype by a short median *vitelline duct*. Vitelline gland consists of numerous follicles secreting yolk cells.

(f) **Uterus.** From ootype arises a blind and cylindrical tube, the *uterus*, extending upto the anterior part of proglottid. It consists of a proximal short and narrow tubular portion, the *uterine duct*, and a distal broad part forming the *uterine expansion*. Uterus is the most characteristic feature of reproductive system of tapeworms. It is meant to accommodate thousands of fertilized eggs and in the process of accomplishing this, it forms 7 to 13 lateral branches on each side. The branched uterus is the only genital structure persisting in a gravid proglottid.

## Life History and Development

1. **Copulation and fertilization.** Life cycle of *T. solium* is *digenetic*, involving two hosts as in case of a fluke. But life cycle of tapeworm is much simpler and without a free larval stage. Presence of a single tapeworm in a host diminishes possibility of cross-fertilization. Fertilization is preceded by *copulation* which is accomplished by insertion of cirrus into vagina of

the same or other proglottid to release spermatozoa. It becomes possible when the common gonopores of two mature proglottids come in contact due to folding of strobila. Anterior mature proglottids, having only male genitalia, can enter into copulation only with the posterior mature proglottids with fully developed female genital organs. Fertilization, following copulation between two different proglottids, is sometimes termed *cross-fertilization* to distinguish it from that occurring between gametes of the same proglottid (*self-fertilization*).

*Spermatozoa* injected into vagina, swim down to the seminal receptacle where they are stored till *ova* are released by the ovary. The two finally meet in the *fertilization duct* (part of vagina between seminal receptacle and oviduct) where fertilization takes place and *zygotes* are formed. Thus, fertilization is *internal*.

2. **Capsule formation.** *Zygotes* or *egg cells* pass into the ootype, where each becomes associated with a large *yolk cell* or *vitelline cell* provided by the vitelline gland. The two become enclosed in a thin *shell* or *chorionic membrane*, formed by material exuded by the yolk cell. The *capsule* so formed passes into uterus, where further development takes place. Passage of capsules into uterus is lubricated by the secretion from *Mehlis glands*. As more and more capsules pass into uterus, it develops lateral branches to accommodate them.

3. **Onchosphere formation.** (a) **Cleavage.** *Zygote* or *egg cell* undergoes *cleavage* when the capsule is in uterus. Cleavage is *holoblastic* and *unequal*. First *unequal* division results in a larger *megamere* and a smaller *embryonic cell*.

(b) **Morula.** *Megamere* divides further and forms several similar *megameres*, while *embryonic cell* divides repeatedly producing two types of *embryonic cells*, larger *mesomeres* and smaller *micromeres*. Thus, three types of cells result from the *zygote*; small *micromeres*, medium *mesomeres* and large *megameres*. *Micromeres* form a rounded mass, the *morula*, surrounded by an inner envelope of *mesomeres* and an outer envelope of *megameres*. The yolk or vitelline cell transfers its yolk to the *megameres* and gradually disappears. Large yolky *megameres* fuse to

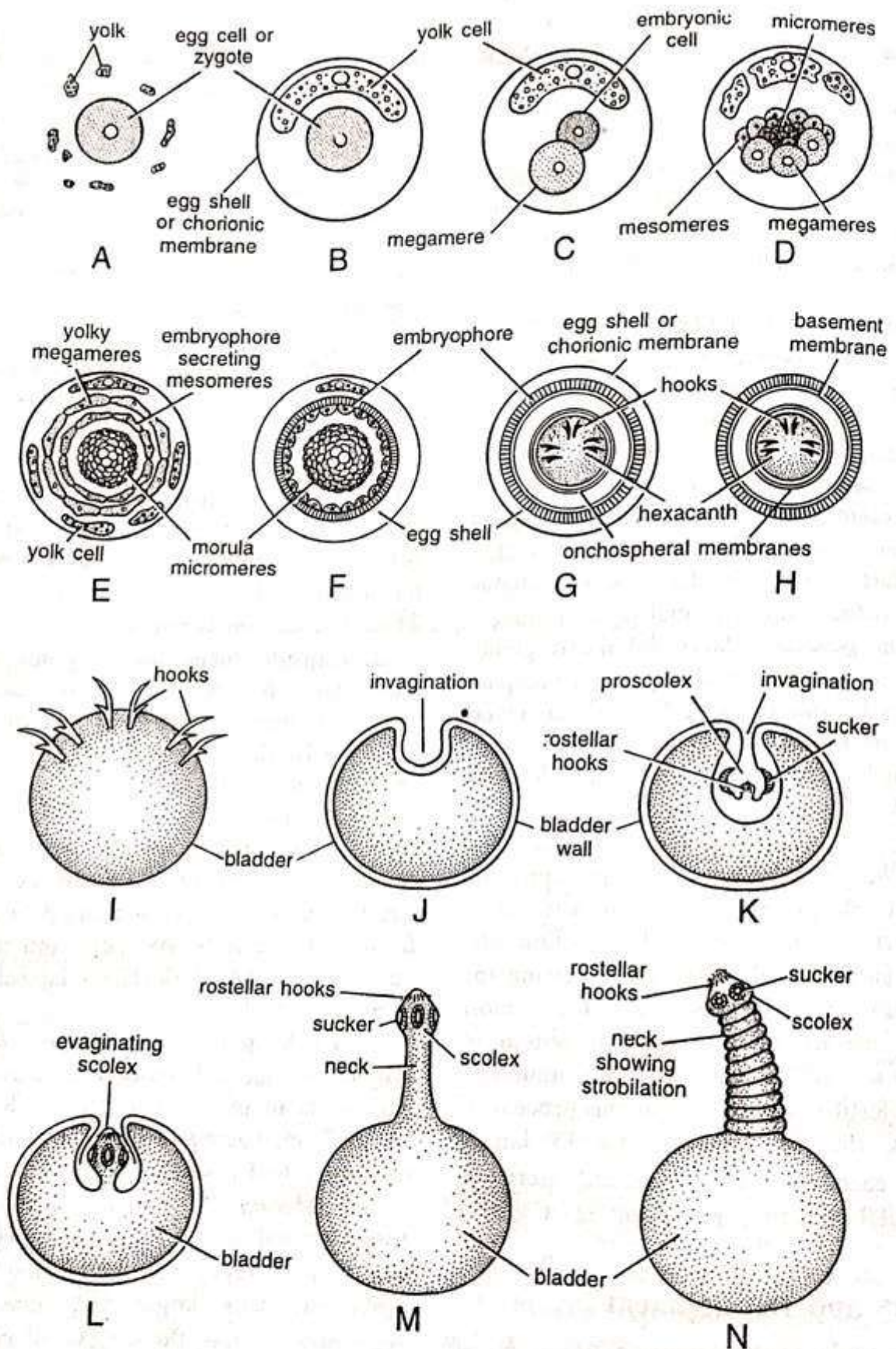


Fig. 14. *Taenia solium*. Stages in development. A—Zygote. B—Zygote in egg shell. C—Two-cell stage. D—Early morula. E—Late morula. F—Formation of embryophore. G—Young onchosphere. H—Onchosphere without egg shell. I—Free hexacanth. J—Bladderworm with invagination of scolex. K—Bladderworm with prosclex. L—Evagination. M—Young cysticercus. N—Neck budding off proglottids.

from an outer syncytial nutritive envelope or *outer embryonic membrane*, which nourishes the embryonic cells and finally disappears. Medium mesomeres form a thick, hard, cuticularized and radially striated shell, known as *embryophore* or *inner embryonic membrane* surrounding morula. Beneath embryophore is a thin *basement membrane*.

(c) *Hexacanth and Onchosphere*. Morula, at its morphologically posterior end, develops three pairs of chitinous *hooks* secreted by pairs of differentiated cells, called *onchoblasts*. This six-hooked embryo, called *hexacanth*, possesses a pair of large penetration glands (Reid, 1947). It is surrounded by two *hexacanth membranes*. The hexacanth, together with all the membranes surrounding it, is known as *onchosphere*. It loses the original thin shell or chorionic membrane so that 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 contains 30,000 to 40,000 onchospheres. In *Taenia saginata*, another intestinal tapeworm of man, uterus of gravid proglottid has 16-20 lateral branches on each side. Leaving the highly-branched uterus, the remaining structures of reproductive system degenerate.

4. **Infection to secondary host (pig)**. Gravid proglottids at the posterior end of strobila detach (apolysis) in groups of 4 or 5 and pass out with the host's faeces. On ground, proglottids eventually disintegrate, setting free thousands of onchospheres. The secondary or intermediate host acquires infection by ingesting the onchospheres. Pig, which regularly feeds on human excreta is the usual secondary host, but dog, monkey and sheep are also known to get the infection. Man himself may serve as the secondary host by ingesting onchospheres with inadequately cooked or raw vegetables. Auto-infection may take place in a person already serving as a primary host. This happens when due to *reverse peristalsis* the detached proglottids are carried to the stomach, where the onchospheres are liberated.

5. **Migration within secondary host**. In the stomach of secondary host (pig) onchosphere loses its embryophore and basement membrane by the action of acidic juices (acid pepsin). The free hexacanth embryo then passes into the small intestine, where the two persisting hexacanth membranes are also lost by the action of alkaline juices. Hexacanth, now activated by the presence of bile salts, bores its way through the intestinal epithelium to reach a submucosal blood or lymph

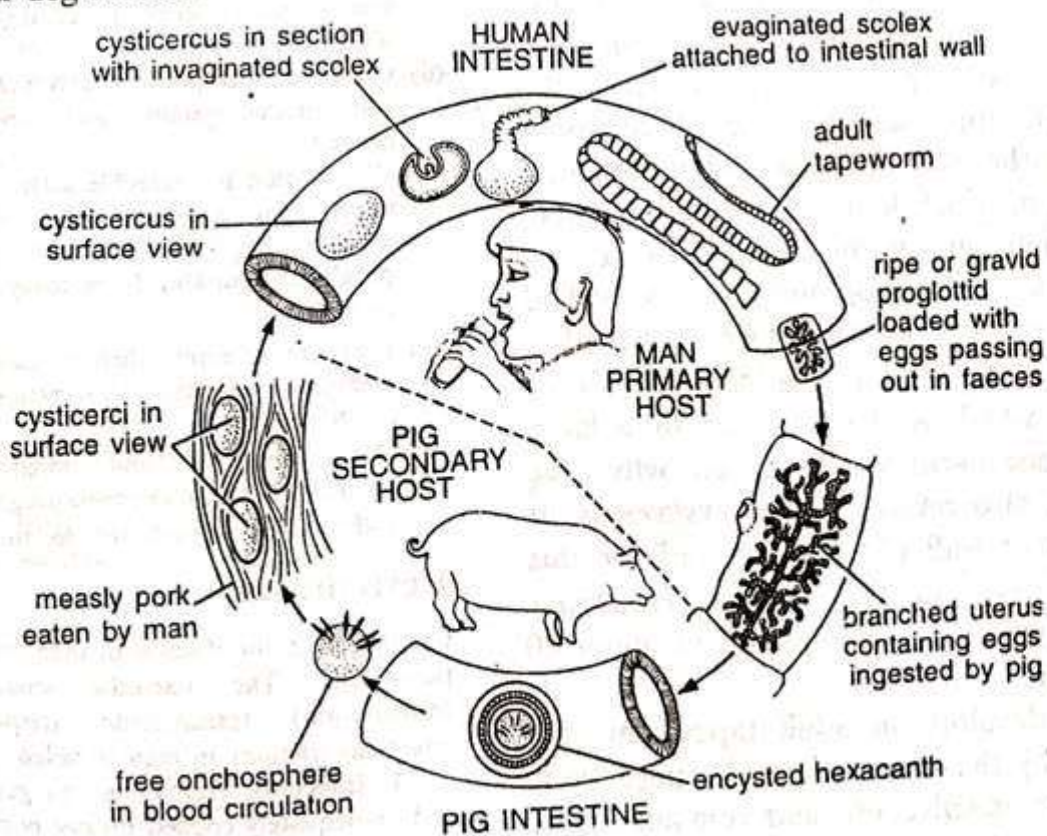


Fig. 15. *Taenia solium*. Life cycle.

vessel. This is accomplished, perhaps jointly by the six hooks and penetration glands. 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 further use, and are shed off. Submucosal blood vessel carries hexacanth to liver via hepatic portal vein. From liver it reaches heart and enters the arterial circulation. It finally reaches the striped (voluntary) muscles usually of the tongue, shoulder, neck, thigh, heart, etc., where it settles to develop into a *bladder-worm* or *cysticercus*. However, these may also develop in other organs such as lungs, liver, kidney or brain. Non-muscular vital organs like eyes, brain or liver may frequently become the sites of cysticercus formation.

#### 6. Cysticercus or bladderworm formation.

Hexacanth, now devoid of hooks, absorbs nourishment from host's tissue and grows in size attaining a diameter of about 18 mm. A central cavity appears as cells in that region break down. It enlarges and becomes filled with a fluid consisting mainly of blood plasma of the host. The fluid-filled vesicle or *bladder*, as it is now called, has a thin wall consisting of an outer layer of thick syncytial protoplasmic mass (the so-called cuticle) and an inner mesenchymal or germinal layer. At a point, morphologically the anterior end (i.e. opposite the side where hooks were present), the wall thickens and invaginates. The invagination, which looks like a hollow knob, differentiates into an *inverted scolex* possessing suckers, hooks and rostellum. It is called *proscolex*, the embryo at this stage is called a *bladderworm*. In *T. solium*, bladderworm is of *cysticercus* type which is characterised by a large vesicle and one scolex. That is why the bladderworm is also referred to as *cysticercus*. It appears to have a wall of cellulose and for this reason, sometimes called *cysticercus cellulosae*. Formation of cysticerci is completed in about 10 weeks in the pig.

Cysticercus develops in adult tapeworm only when ingested by the human host. In pig's body it leads quite an inactive life and remains viable for several years, after which it dies and becomes calcified. Pork (pig's flesh) containing viable

cysticerci is called *measly pork* for its spotted appearance. One kilogram of measly pork may contain 500 or more cysticerci.

7. Infection to primary host (man). Man gets infection by eating undercooked measly pork. Cysticercus becomes active on reaching the small intestine. Proscolex everts or evaginates and anchors to the intestinal wall. Neck begins to proliferate proglottids and the bladder, sooner or later, gets detached and digested. In 10 to 12 weeks the parasite attains adulthood and possesses gravid proglottids ready for apolysis.

### Parasitic Adaptations of *Taenia*

Tapeworm shows several adjustments to its internal parasitic life, in comparison with a free-living animal.

- (1) External body covering or *tegument*, is freely permeable to water and nutrients, but protects against digestion by host's alkaline digestive juices.
- (2) Internal osmotic pressure is higher than that of the surrounding host's fluid or tissue, and pH tolerance is high, 4 to 11.
- (3) Adult as well as larva lack cilia and other organs of locomotion, which are not needed.
- (4) Scolex, with suckers and spines, serves for attachment with the epithelial lining of the host's intestine, so that parasite may not be ejected from intestine due to its peristaltic contractions.
- (5) Alimentary canal is totally absent as the parasite absorbs readily available digested food of the host through its body surface. Microvilli of tegument also increase the absorptive surface.
- (6) Circulatory, respiratory and sensory organs are absent and nervous system poorly developed, as they are not needed.
- (7) Respiration is anaerobic as free O<sub>2</sub> is not available.
- (8) Reproductive system is immensely developed. Production of very large number of eggs (40,000 per gravid proglottid) suitably faces many challenges to survival of species.
- (9) Resistent covering, shell or capsule around zygotes and embryos provides protection from unfavourable conditions.
- (10) Hermaphroditism and proglottization ensures self-fertilization within the same proglottid or cross-fertilization with another proglottid, in the same worm.

### Cestodiasis

Cestodiasis is the disease in man caused by infection due to tapeworms. The scientific study of the occurrence (distribution), transmission, frequency and control of infectious diseases in man is called *epidemiology*.

1. Infection. Human beings get infected by eating raw and inadequately cooked measly pork containing cysticerci of tapeworm.

2. Pathogenesis (symptoms). Man may fall a victim to adult tapeworm as well as its cysticerci; effects of the former

## Taenia solium : The Pork Tapeworm

are referred to as *taeniasis* and those of the latter as *cysticercosis*.

(a) *Taeniasis*. It is indicated by a variety of symptoms including pain in the abdomen, nausea, anaemia, increased appetite, indigestion, increase of eosinophil cells in blood, and above all, nervous disorders of the type occurring in epilepsy. These serious disorders are caused by toxins produced by the parasite and not, as believed earlier, by its continued drain on the host's digested food. Hooks and suckers may cause mechanical irritation in intestine, which may initiate reverse peristalsis leading to auto-infection. Usually a single tapeworm is found to parasitize a host. This is because the presence of one tapeworm provides a kind of immunity or *premunition* to the host against fresh infection.

(b) *Cysticercosis*. It is far more dangerous than *taeniasis*. Encystment of bladder may take place in the host's voluntary muscles, cardiac muscles and even in some more delicate vital organs like liver, eyes and brain. Removal of cysticerci from these delicate tissues is extremely difficult. *Cysticercosis*

of the brain results in several degenerative changes and necrosis in the brain and the patient shows epileptic behaviour.

3. **Therapy (treatment)**. Infection of tapeworm can be tackled by several anti-helminth drugs such as camoquin, carbon tetrachloride, oleoresin of male *Aspidium* (fern), quinacrine, antiphen, dichlorophen, etc. The most satisfactory compound for human infection is *Yomesan* (5-chloro-N; 2 chloro-4- nitrophenyl). Under the action of drugs, strobila is removed but the embedded scolex persists which again buds off a new strobila. Removal of scolex can be brought about by surgery. Removal of cysticerci, especially from delicate organs like brain, eyes and liver is extremely difficult.

4. **Prophylaxis (prevention)**. Consumption of undercooked measy pork should be avoided. Faeces of infected persons should be properly disposed of and destroyed, preventing pigs having access to them and ingesting hexacanth embryos.

Table 1. Comparative study of *Fasciola* and *Taenia*.

Characters	<i>Fasciola hepatica</i> (The Sheep Liver Fluke)	<i>Taenia solium</i> (The Pork Tapeworm)
Habits and habitat	1. Endoparasitic in two hosts ( <i>digenetic</i> ). Several adults live in bile passages of a single sheep or goat (primary host). Larval stages are passed in a freshwater snail (secondary host).	1. Endoparasite in two hosts ( <i>digenetic</i> ). A single adult lives in intestine of a single primary host (man). Larval stages occur in pig (secondary host).
External morphology	2. Body bilaterally symmetrical, dorso-ventrally flattened, oval and leaf-like. Length 1.2 to 5 cm and width about 1.2 cm. Colour pinkish. 3. Body unsegmented. Anterior end produced into a conical projection, the <i>head lobe</i> .	2. Body bilaterally symmetrical (except scolex which is radially symmetrical), dorso-ventrally flattened, tape or ribbon-like, up to several meters in length. Colour opaque white. 3. Body segmented divisible into (i) <i>scolex</i> or holdfast, (ii) <i>neck</i> , and (iii) <i>strobila</i> of about 800 segments or proglottids.
Tegument cuticle	4. <i>Adhesive organs</i> are: (i) an anterior or oral sucker and (ii) a posterior or ventral sucker or acetabulum. 5. <i>Body apertures</i> are a mouth, a common gonopore and an excretory pore. A temporary opening of Laurer's canal appears at the time of copulation.	4. <i>Adhesive organs</i> are : (i) four suckers and (ii) two circular rows of hooks on scolex. 5. <i>Body apertures</i> are a common gonopore on each proglottid and one (two after apolysis starts) excretory pore on the last proglottid.
Musculature	6. With minute spinules and without prominent microvilli. 7. Sub-epidermal musculature of circular, longitudinal and diagonal fibres. Mesenchymal musculature lacking.	6. Without spinules and with prominent microvilli. 7. Sub-epidermal musculature of circular and longitudinal fibres and a mesenchymal musculature of longitudinal, circular (transverse) and dorso-ventral fibres.
Nutrition	8. <i>Holozoic</i> . Alimentary canal comprises a <i>mouth</i> surrounded by oral sucker, suctorial <i>pharynx</i> , <i>short oesophagus</i> and a forked, much-branched <i>intestine</i> .	8. <i>Saprozoic</i> . Gut altogether absent.
Excretory system	9. It consists of flame cells and a system of ramifying excretory ducts. Excretory pore is single, situated at the posterior and <i>Apolysis</i> does not occur.	9. Includes flame cells and four main excretory ducts, only two of which extend up to last proglottid and open through a common excretory pore. When last proglottid is lost by apolysis, two excretory ducts open through separate apertures.

- Nervous system**
10. There is a nerve ring bearing a pair of dorso-lateral ganglia and a ventral ganglion. The ganglia give out numerous fine nerves anteriorly and three pairs (dorsal, ventral and lateral) posteriorly.
- Reproductive system**
11. Hermaphrodite. A single set of reproductive organs persists throughout life.
- Male reproductive organs**
12. Only one pair of large lobed *testes*, lying one behind the other in middle region of body.
13. Two *vasa deferentia* arise from two testes, and unite into a *seminal vesicle*, from which a convoluted *ejaculatory duct* arises and enters a muscular copulatory organ, the *cirrus* or *penis*.
14. *Prostate glands* and *cirrus sheath* present.
- Female reproductive organs**
15. A single, many branched *ovary* is situated before testes on the right side
16. *Oviduct* starts from inner side of ovary and joins the *median vitelline duct*. *Ootype* is absent.
17. A *Laurer's canal* extends from oviduct to the dorsal side of body.
18. *Uterus* is a long, much-convoluted tube. It starts from the point of union of median vitelline duct and oviduct. It opens into genital atrium as the female genital aperture. It enlarges considerably to store the capsules.
19. *Seminal receptacle* is lacking.
20. Numerous rounded *vitelline glands* occupy lateral zones of body. They give two *lateral vitelline ducts* connected by a *transverse vitelline duct*. The latter swells up in the middle to form a yolk reservoir, from which a *median vitelline duct* arises to meet the oviduct.
21. *Mehlis glands* are numerous minute bodies around the junction of oviduct, median vitelline duct and uterus.
- Life history**
22. Capsules are released into host's bile duct, and finally reach the exterior with host's faeces.
23. Capsules with *operculum*.
24. *Development* begins outside parent's body.
25. A conical, ciliated *miracidium* hatches from capsule, swims about for some time and finally penetrates into body of the snail host.
26. In snail, miracidium develops into a sporocyst which produces the first generation of *rediae*. The latter produce a second generation of *rediae* which in turn produce *cercariae*. *Cercariae* leave snail and encyst on some aquatic plant as *metacercariae*.
27. Sheep acquires infection by ingesting *metacercariae* along with aquatic vegetation.
28. Disease caused in sheep is called 'Liver rot' or 'Fascioliasis'.
10. Scolex has a pair of cerebral ganglia connected by a transverse connective and a ganglionated ring commissure. Five pairs of longitudinal nerves are given out into strobila.
11. Hermaphrodite. One complete set of reproductive organs in each mature proglottid. After capsule-formation, only uterus persists, while remaining genitalia degenerate.
12. *Testes* numerous, rounded (follicular), scattered throughout the proglottids.
13. Numerous fine *vasa efferentia*, one from each testis, unite into a single *vas deferens* which enters the *cirrus* or *penis*. *Seminal vesicle* is lacking.
14. Absent.
15. A single *ovary* lies in the posterior part of proglottid. It has two lobes united by a transverse ovarian bridge or isthmus.
16. *Oviduct* starts from the middle of isthmus and opens into the *ootype*, which also receives the *vitelline duct*.
17. Absent.
18. *Uterus* is an unconvoluted, blind tube arising from the ootype and extending towards the anterior side. It not only enlarges, but also becomes much-branched to store the capsules.
19. *Vagina* is a slender tube extending from genital atrium to oviduct. Before opening in oviduct, it dilates to form the *seminal receptacle*.
20. *Vitelline gland* is a single, large, flat mass in the posterior part of proglottid. A single *vitelline duct* arises from it and opens into the ootype.
21. *Mehlis glands* occur around the ootype and open into it.
22. Gravid proglottids reach the exterior with host's faeces and degenerate to liberate capsules.
23. Capsules without operculum
24. Development begins within parent's body.
25. Zygote develops into a six-hooked *hexacanth* which, together with its protective covering, is called *onchosphere*. It is ingested by the pig host.
26. Hexacanth loses its protective envelopes, bores into blood vessels of gut and migrates to voluntary muscles, where it encysts as a *cysticercus*. Thus, a complicated series of larval stages do not occur.
27. Man acquires infection by eating inadequately cooked meaty pork containing *cysticercus*
28. Disease caused in man is called taeniasis.



» **Long Answer Type Questions**

1. Describe the anatomy of *Taenia solium* with special reference to its parasitic mode of life.
2. Give an account of the reproductive organs of *Taenia*. What is meant by a gravid proglottid?
3. Give an account of the life cycle of *Taenia solium* highlighting its characteristic features.
4. What is parasitism? Give an account of the parasitic adaptations of *Taenia*. Also write a paragraph on its economic importance.
5. Compare and contrast the structure and life history of *Fasciola hepatica* and *Taenia solium*.
6. Make full-page, well-labelled diagrams of the following. No description is required.
  - (a) Section of body wall of *Taenia* based on electron microscope.
  - (b) T.S. mature proglottid of *Taenia* through ootype.
  - (c) A mature proglottid of *Taenia* showing reproductive organs.
  - (d) Stages in development of *Taenia*.
7. Write short notes on : (i) Apolysis, (ii) Bladder worm, (iii) Cercaria, (iv) Cysticercus, (v) Gravid proglottid. (vi) Hexacanth. (vii) Measly pork, (viii) Redia, (ix) Scolex of *Taenia solium*, (x) Sporocyst.

» **Short Answer Type Questions**

1. In *Taenia solium*, write the name of the stage which pierce the mucous membrane of the intestine and enters the blood stream ?
2. Where can you locate flame cell ?
3. What are flame cells ?
4. What is the name of the organ of attachment in tape worm ?
5. Describe with diagram the internal organization of a proglottid of *Taenia*.
6. Describe strobilation.
7. Mention five possible methods of eradicating tapeworm at different stages.
8. Write descriptive note on hydatid cyst.
9. Give a description of the head of *Taenia*.
10. Describe briefly the shell gland.
11. Discuss whether *Taenia solium* is metamerically segmented.
12. Give an account of the life cycle of *Taenia*.
13. Describe briefly *Taenia*.
14. Draw a labelled diagram of the mature proglottid of *Taenia solium*.
15. Rewrite the following in order :
 

(a) Cysticercus	(b) Proglottid
(c) Onchosphere	(d) <i>Taenia</i>

» **Multiple Choice Questions**

1. The smallest tapeworm is :
 

(a) <i>Taenia</i>	(b) <i>Moniezia</i>	(c) <i>Echinococcus</i>	(d) <i>Schistosoma</i>
-------------------	---------------------	-------------------------	------------------------
2. In *Taenia*, cross fertilization between different proglottids of the same individual occurs and this is called :
 

(a) self fertilization	(b) cross fertilization
(c) incestuous	(d) apolysis
3. Tapeworms with undivided body, without hooked scolex, and larva are included in subclass :
 

(a) Eucestoda	(b) Monogenea
(c) Digenea	(d) Cestodaria
4. *Taenia* belongs to order :
 

(a) Cyclophyllidea	(b) Pseudophyllidea
(c) Amphilinidea	(d) Echinostomida
5. A proglottid is called gravid proglottid when it has :
 

(a) both male and female reproductive units well developed
(b) only female reproductive unit well developed
(c) only male reproductive unit well developed
(d) branched uterus filled with fertilized eggs
6. In *Taenia*, scolex bears in the middle a prominent :
 

(a) cup shaped sucker	(b) head
(c) rostellum	(d) recurved Hooks
7. In *Taenia solium* the proximal portion of the oviduct that leads into the vagina is called :
 

(a) receptaculum semines	(b) uterus
(c) fertilization canal	(d) vitellarium
8. Who are more likely to get tape-worm ?
 

(a) vegetarians	(b) non-vegetarians
(c) both	(d) none
9. Bladder worm is found in :
 

(a) human muscles	(b) muscles of cow or pig
(c) human faeces	(d) soil
10. Tape worm infesting intestine of animals obtain their nutrition :
 

(a) by ingesting food particles through their suckers
(b) by scraping the intestinal walls with their hooks
(c) by preparing food in their own bodies
(d) by absorption of liquid food through their integument
11. A gravid proglottid of *Taenia* has :
 

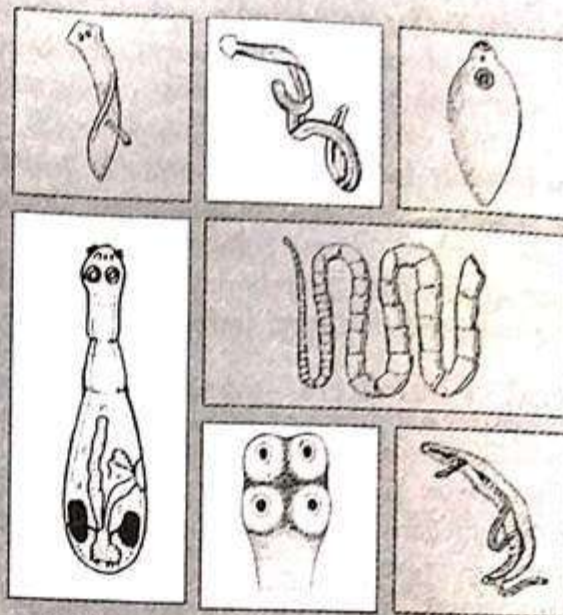
(a) male and female reproductive system
(b) well developed female reproductive system and degenerate male reproductive system
(c) well developed male reproductive system and degenerate female reproductive system
(d) only branched uterus

12. Cysticercosis is a disease caused by accidental infection of :  
 (a) hexacanth of *Taenia*  
 (b) bladder worm of *Taenia*  
 (c) encysted cercaria of *Schistosoma*  
 (d) eggs of *Enterobius*
13. Area for proliferation in body of *Taenia* is :  
 (a) scolex (b) neck  
 (c) strobila (d) gravid proglottid
14. Apolysis is a process in *Taenia* for :  
 (a) regular detachment of proglottid from strobila  
 (b) embryonic development  
 (c) ingestion (d) infection to man
15. Suckers in tape worm are meant for :  
 (a) attachment to intestinal wall  
 (b) ingestion of food  
 (c) attachment during locomotion  
 (d) all these
16. Secondary host of *Taenia* is :  
 (a) pig (b) man (c) snail (d) sheep
17. *Taenia* lack of :  
 (a) digestive system (b) reproductive system  
 (c) excretory system (d) all of these
18. The excretory product of *Taenia* :  
 (a) ammonia (b) fatty acid  
 (c) urea (d) ammonia and fatty acid
19. Larval forms of *Taenia* :  
 (a) oncosphere (b) hexacanth  
 (c) cysticercus (d) all
20. In which forms *Taenia* pass through faecal matter of man :  
 (a) oncosphere (b) hexacanth  
 (c) cysticercus  
 (d) young tape worm
21. Pig acquired infection of *Taenia* by ingestion of :  
 (a) oncosphere (b) hexacanth  
 (c) cysticercus (d) none of above
22. Cysticercus in pig muscle can remain for :  
 (a) two year (b) four year  
 (c) seven year (d) ten year
23. *Taenia saginata* is commonly known as :  
 (a) pork tapeworm (b) beef tapeworm  
 (c) human tapeworm (d) none of them
24. Unarmed tapeworm is :  
 (a) *T. saginata* (b) *T. solium*  
 (c) none
25. The encystment of bladder worm occurs in man is :  
 (a) caretiac muscle (b) liver  
 (c) eye (d) brain  
 (e) all

### Answers

1. (c), 2. (a) 3. (d) 4. (a) 5. (a) 6. (c) 7. (a) 8. (b) 9. (b) 10. (d) 11. (c) 12. (b) 13. (b) 14. (a) 15. (a) 16. (a) 17. (a) 18. (d) 19. (d) 20. (a) 21. (a) 22. (c) 23. (b) 24. (a) 25. (d)

# Platyhelminthes: Characters, Classification and Types



## 33 Chapter

### Definition

The term *Platyhelminthes* (Gr., *platys*, flat + *helmins*, worm) was first proposed by Gegenbaur (1859) for the flatworms. These may be defined as acoelomate, triploblastic, bilaterally symmetrical, vermiform, dorso-ventrally flattened organisms; devoid of a definite anus; without skeletal, respiratory and circulatory systems; with flame cells or protonephridia and with mesenchymal cells representing mesoderm, filling up spaces between various organs.

### Morphological Advances

Platyhelminthes shows an advancement over the previous metazoan phyla (coelenterata and ctenophora) in the following respects :

1. Tissue-organ level of organization.
2. Triploblastic body. Third germ layer mesoderm instead of mesogloea.

3. Symmetry definitely bilateral, at the lowest level.
4. A definite head and tail.
5. Mesodermal muscles in bundles and layers.
6. More complex and efficient gastrovascular cavity.
7. Nervous system with large, anteriorly situated ganglia and nerve cords running along the body.
8. Better developed sensory organs.
9. Internally situated gonads with permanent gonoducts and copulatory structures.
10. Behaviour organization through learning.

### Phylogenetic Significance

Platyhelminthes or flatworms are supposed to have evolved from a coelenterate-like ancestor, which underwent a change from radial to bilateral symmetry. Coelenterate ancestor was like a *planula larva* as primitive acoel worms

share many characteristics with planula, such as : (1) absence of epidermal basement membrane, (2) absence of gut, (3) absence of excretory organs, (4) absence of gonads, (5) a centro-ventrally located mouth, and (6) a nerve plexus under epidermis. Trematodes are thought to have evolved from some commensal or parasitic rhabdocoel turbellarians and cestodes evolved independently from trematodes.

### General Characters

1. Free-living, commensal or parasitic forms.
2. *Tissue-organ grade of organization*, i.e., body cells aggregate into definite tissues and tissues make up organs.
3. *Triploblastic*, i.e., body derived from three embryonic germ layers; ectoderm, mesoderm and endoderm.
4. *Bilaterally symmetrical* with definite polarity of anterior (head) and posterior (tail) ends.
5. *Dorso-ventrally flattened*. Usually with a well-defined ventral surface bearing mouth and gonopore.
6. Body *unsegmented* (except in class Cestoda).
7. *Acoelomate*, i.e., without any body cavity. Spaces between various organs filled with special mesodermal tissue, the *mesenchyme* or *parenchyma*.
8. Adhesive structures like hooks, spines and suckers, and adhesive secretions common in parasitic forms.
9. *Epidermis* cellular or syncytial, frequently ciliated. Absent in some.
10. *Muscular system* of mesodermal origin. Longitudinal, circular and oblique muscle layers beneath epidermis.
11. *Digestive system* branched and incomplete without anus. Altogether absent in Acoela and Cestoda.
12. Skeletal, respiratory and circulatory systems are wanting.
13. *Excretory system* includes lateral canals and protonephridia (flame cells). Absent in some primitive forms.
14. *Nervous system* primitive, ladder-like. Comprises a pair of anterior ganglia with longitudinal nerve cords connected by transverse nerves.
15. *Sense organs* simple. Eye-spots or photo receptors in free living forms.

(Z-1)

16. Mostly *monoecious* (hermaphrodite) with complex reproductive system. Well-developed gonads, gonoducts and accessory organs. Eggs mostly devoid of yolk. Yolk produced separately in *yolk* or *vitelline glands*.
17. *Fertilization* internal, may be cross or self.
18. *Development* direct or indirect. Usually indirect in endoparasites with a complicated life cycle involving many larvae and hosts.

### Classification

#### Class 1. Turbellaria

(L., *turbella*, a stirring)

1. Usually non-parasitic, free-living worms are called *planarians*.
2. Terrestrial marine or freshwater.
3. Body unsegmented, flattened and covered with ciliated cellular or syncytial epidermis, containing mucus secreting cells and rod-shaped bodies called *rhabdites*.
4. Mouth ventral. Intestine preceded by muscular pharynx.
5. Suckers absent. Tango, chemo and photo-receptors common in free-living forms.
6. Mostly hermaphroditic. Some reproduce asexually. Development usually direct.

#### Order 1. Acoela

1. Minute, exclusively marine, less than 2 mm.
2. Ventral mouth; no muscular pharynx and without intestine.
3. Flame cells, definite gonads, gonoducts and yolk glands wanting.
4. Mostly free-living, found under stones, algae or on bottom mud. Some dwell in intestine of sea-urchins and sea-cucumbers.

Examples : *Convoluta*, *Amphiscolops*, *Ectocotyl*, *Afronta*.

#### Order 2. Rhabdocoela

1. Small, usually less than 3 mm.
2. Simple pharynx and sac-like intestine.
3. Protonephridial excretory system.
4. One or two gonads. Yolk glands present or absent.
5. Marine, freshwater or terrestrial. Free-living, commensal or parasitic.

Examples : *Stenostomum*, *Microstomum*, *Actinodactyletta*, *Catenula*, *Macrostomum*, *Mesostoma*.

### Order 3. Allocoela

1. Moderate-sized, between 1 and 10 mm.
  2. Pharynx simple, bulbous or plicate. Intestine straight or branched.
  3. Protonephridia paired, usually branched.
  4. Testes numerous. Penis papilla mostly present.
  5. Mostly marine, common in littoral sand and mud. Some freshwater.
- Examples : *Prorhynchus*, *Plagiostomum*, *Geocentrophora*.

### Order 4. Tricladida

1. Large 2 to 60 cm in length.
  2. Mouth mid-ventral, pharynx plicate and intestine with three branches, each with many diverticula.
  3. Protonephridia as lateral networks with many nephridiopores.
  4. Testes numerous, ovaries two. Yolk glands present.
  5. Marine, freshwater or terrestrial.
- Examples : *Dugesia*, *Gunda*, *Bdelloura*, *Geoplana*, *Bipalium*, *Euplanaria*.

### Order 5. Polycladida

1. Moderate-sized, 2 to 20 mm.
  2. Pharynx plicate. Intestine highly branched.
  3. Gonads many, scattered. Yolk glands absent.
  4. Male and female gonopores separate.
  5. Marine, many bottom dwellers of littoral zone.
- Examples : *Leptoplana*, *Notoplana*, *Cestoplana*, *Planocera*, *Thysanozoon*.

## Class 2. Trematoda

(Gr., *tremta*, hole + *eidos*, form)

1. Ecto- or endoparasitic flatworms, called *flukes*.
2. Body unsegmented, dorso-ventrally flattened, leaf-like. Tegument thick but without cilia and rhabdites.
3. Suckers and sometimes hooks present.
4. Alimentary canal with anterior mouth, simple pharynx and two main branches.
5. Three pairs of longitudinal nerve cords.
6. Mostly monoecious. Development direct (in ectoparasites) or indirect (in endoparasites) with alternation of hosts.

### Order 1. Monogenea

1. Mostly ectoparasites in cold blooded aquatic vertebrates.
2. Posterior adhesive organ or opisthaptor with suckers armed with hooks or spines.

3. Excretory pores two, situated anteriorly on dorsal side.
4. Vagina one or two. Uterus small with a few shelled eggs.
5. Only a single host in life cycle.
6. Free-swimming ciliated larva called *onchomiracidium*.

Examples : *Gyrodactylus*, *Dactylogyrus*, *Polystoma*, *Diplozoon*.

### Order 2. Digenea

1. Mostly endoparasites in vertebrates and invertebrates.
2. Two suckers, oral and acetabulum, both devoid of hooks.
3. Single posterior excretory pore.
4. No vagina. Uterus long with numerous shelled eggs.
5. Life cycle complex with numerous larval stages in two to three intermediate hosts.
6. Larval forms reproduce asexually before metamorphosis.

Examples : *Bucephalus*, *Fasciola*, *Paramphistomum*, *Paragonimus*, *Schistosoma*, *Opisthorchis* (= *Clonorchis*).

### Order 3. Aspidocotylea (= Aspidogastreae)

1. Oral sucker absent.
  2. Large ventral sucker subdivided into several suckers without hooks.
  3. Only one testis in male system.
  4. Endoparasites in gut of fishes and reptiles.
- Example: *Aspidogaster*, *Cotylapsis*, *Stichocotyle*.

## Class 3. Cestoda (= Cestoidea)

(Gr., *kestos*, girdle + *eidos*, form)

1. Endoparasitic flatworms, called *tapeworms*.
2. Body segmented, elongate, flat, ribbon-like. Tegument with microvilli.
3. Scolex (head) with suckers, or hooks, or both.
4. No alimentary canal. No sense organs.
5. Each mature segment or proglottid monoecious, with male and female organs.
6. Life cycle complicated involving one or more intermediate hosts. Embryos with hooks.

### Subclass A. Cestodaria

1. Body unsegmented, leaf-like, without scolex and strobila (*monozoic*).
2. Only one set of monoecious reproductive system.
3. Larva *lycophore*, with 10 hooks.

**Order 1. Amphilinidea**

1. No suckers. Pharynx protrusible.
2. Male genital pore and vagina situated posteriorly. Uterus coiled.
3. Endoparasitic in coelom of primitive fishes.  
Example : *Amphilina*.

**Order 2. Gyrocotylidea**

1. An anterior sucker and a posterior rosette-shaped adhesive organ present.
2. Eversible proboscis at the anterior end.
3. Endoparasites in chimaeroid fishes.  
Example : *Gyrocotyle*.

**Subclass B. Eucestoda**

1. Body long, ribbon-like. Divided into scolex, neck and strobila with many proglottids (*polyzoic*).
2. Mostly with several sets of monoecious reproductive organs.
3. Larvae with six hooks.

**Order 1. Proteocephalidea**

1. Scolex with 4 cup-shaped suckers.
2. Ovary bilobed. Uterus branched. Vitellaria scattered.
3. Parasitic in freshwater fishes, amphibians and reptiles.  
Examples : *Proteocephalus*, *Ophiotaenia*.

**Order 2. Tetrphyllidea**

1. Scolex with 4 leaf-like *bothria*.
2. Testes anterior to ovaries. Vitelline glands scattered.
3. Parasitic in intestine of elasmobranch fishes.  
Example : *Phyllobothrium*.

**Order 3. Disculicepitidea**

1. Scolex with large cushion-like pad at anterior end.
2. Female gonopore, anterior to male gonopore. Testes numerous. Uterus lobed.
3. Endoparasites of Selachii.  
Example : *Disculiceps*.

**Order 4. Lecanicephaloidea**

1. Scolex divided by a transverse groove. Upper disc-like lower with 4 suckers.
2. Vitellaria as two lateral bands.
3. Intestinal parasites in elasmobranch fishes.  
Examples : *Lecanicephalum*, *Tetragonocephalum*.

**Order 5. Pseudophyllidea**

1. Scolex with 2 to 6 *bothria*.

2. Testes numerous. Ovary bilobed. Vitellaria follicular.
3. Parasitic in freshwater fishes (teleosts).  
Examples : *Dibothriocephalus*, *Haplobothrium*.

**Order 6. Trypanorhyncha**

1. Scolex with 2 to 4 *bothria* and 4 spiny tentacles.
2. Vitellaria in continuous layer in cortical parenchyma.
3. Parasitic in elasmobranch fishes.  
Example : *Tetrahyinchus*.

**Order 7. Cyclophyllidea (= Taenioidea)**

1. Scolex with 4 large deep suckers and hooks.
2. Ovary lobed. Uterus blind. Vitellaria follicular.
3. Parasitic in amphibians, reptiles, birds and mammals.  
Examples : *Taenia*, *Moniezia*, *Echinococcus*, *Dipylidium*, *Hymenolepsis*.

**Order 8. Aporidaa**

1. Scolex with 4 suckers. Rostellum armed.
2. No external segmentation.
3. Ootype absent. Vitellaria absent or present. Semiducts and genital apertures absent.
4. Parasites in birds.  
Examples : *Nematoparataenia*, *Gastrotaenia*.

**Order 9. Nippotaeniidea**

1. No scolex but well-developed terminal sucker.
2. Proglottids few. Vitellaria few.
3. Parasites in freshwater fishes of Japan.  
Examples : *Nippotaenia*, *Amurotaenia*.

**Order 10. Caryophyllidea**

1. Scolex without true suckers or *bothria*.
2. Eggs non-embryonated when laid.
3. Parasites in fishes.  
Examples : *Caryophyllaeus*, *Archigetes*, *Glanidan*.

**Order 11. Spathebothridea**

1. Scolex without suckers or *bothria*.
2. Testes are medullary. Ovary median.
3. Parasites in primitive fishes.  
Example : *Spathebothrium*.

**Other Types of Platyhelminthes**

1. *Convoluta*. *Convoluta* is the most common acoel turbellarian. It is a minute and marine creature of gregarious habit, found mostly among sea-weeds between tidemarks. Groups of pigment cells impart characteristic patches to the body.

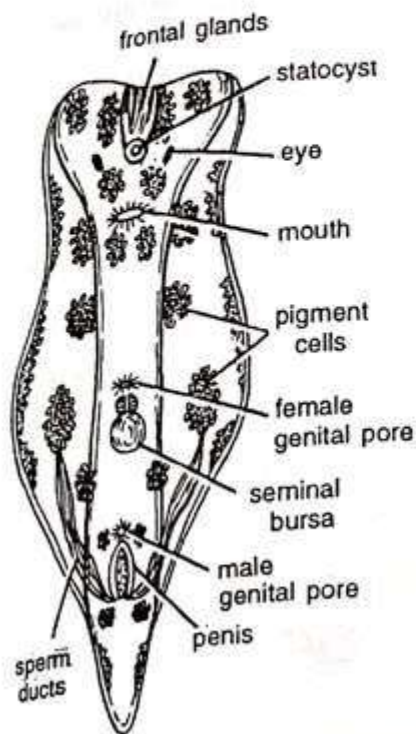


Fig. 1. *Convoluta*.

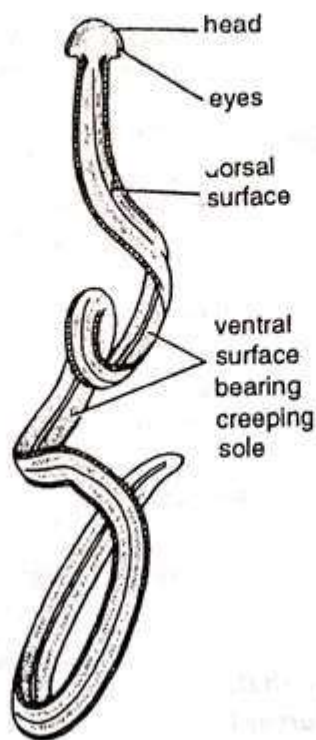


Fig. 2. *Bipalium*.

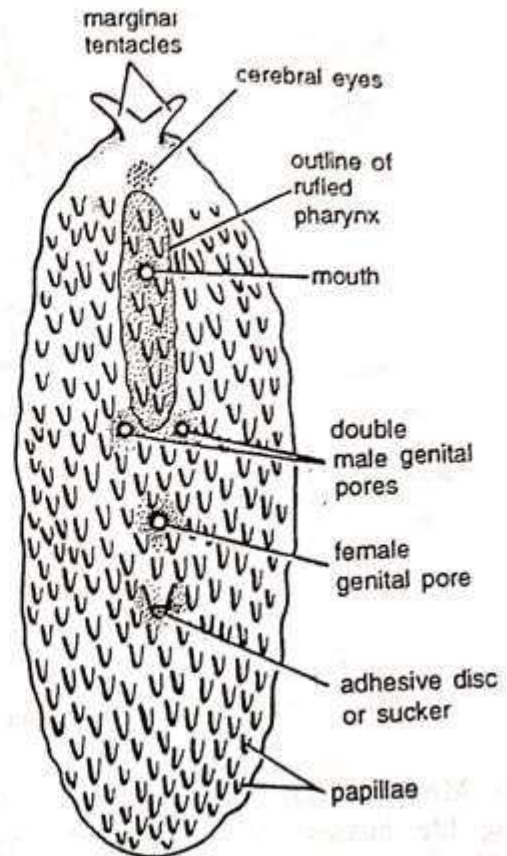


Fig. 3. *Thysanozoon*.

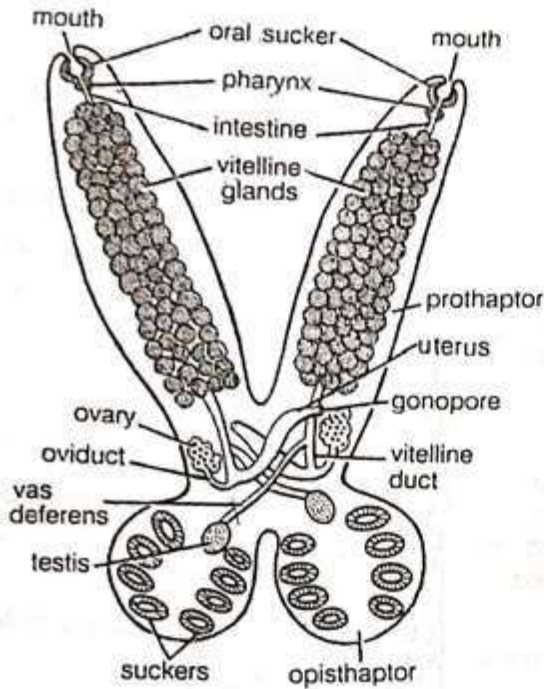
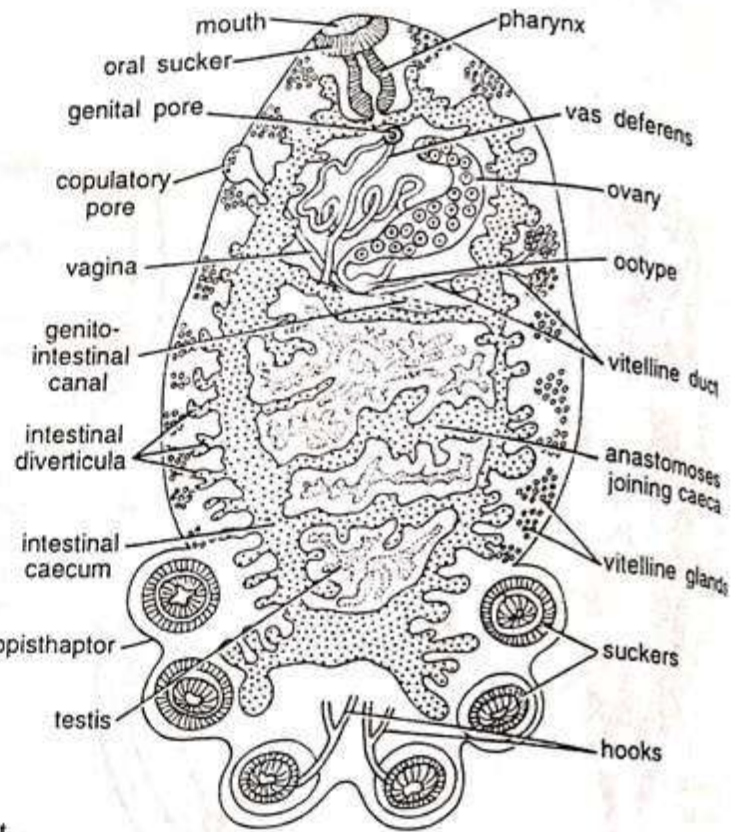
surface. Some species are cylindrical. *Convoluta* is so-called because during locomotion, its anterior end, with out-turned margins, looks more or less like a horn or *cornucopia* after the horn of Amalthea, the goat that suckled Zeus, the supreme God of Greek mythology. For feeding, it protudes its pharynx through *mouth*, situated ventrally near head. Five pairs of nerve cords, interconnected by cross strands, are present. It is protandrously hermaphroditic. Male and female genital apertures are situated close to each other about the middle of body on ventral side. Gonads are not differentiated. Some species are associated symbiotically with green or brown algae dwelling within them.

2. *Bipalium*. This genus is a triclad turbellarian and includes terrestrial species, found commonly in greenhouses. Distribution is cosmopolitan. Body is much elongated attaining a length of up to 50 cm. Head is expanded. There are numerous eyes along head's margin and sides of anterior part of body. Dorsal surface is variously striped and ventral surface bears a

median longitudinal creeping sole. General mode of reproduction is asexual by fragmentation. *B. adventitium* is a North American species living in temperate zone. It breeds sexually. *B. kewense* is cosmopolitan.

3. *Thysanozoon*. It is a polyclad turbellarian found in cool waters. Body is elongate and somewhat oval with a pair of anteriorly-situated marginal tentacles bearing eyes. Behind tentacles are numerous cerebral eyes, behind which is the ventral mouth leading into a ruffled pharynx. Intestine is highly branched, each branch extending into a projection of the body wall, known as papilla or tubercle. This is a characteristic feature of this animal. Two male genital apertures are situated near about the middle of body behind pharynx. A single female pore is situated behind the male pores and in front of an adhesive disc or 'sucker', which is helpful in holding the two individuals together during copulation.

4. *Diplozoon*. It is a trematode flatworm, ectoparasitic on the gills of some freshwater

Fig. 4. *Diplozoon*. Two individuals.Fig. 5. *Polystomum*.

fishes. Most peculiar feature of *Diplozoon* is that, during life history, two larvae (*diporpa larvae*) fuse, both morphologically and physiologically, and remain as such throughout life. Fusion takes place in the region of genital atria of the two, situated a little behind the middle of body. The pair, which appears like an X, thus seems to be engaged in a permanent copulation.

Each individual bears an *oral sucker* at the anterior extremity and a pair of *lateral suckers* just behind. There are 4 pairs of suckers, arranged in two rows, on *opisthaptor* or posterior part of each individual. Mouth is surrounded by the oral sucker. *Pharynx* is muscular. *Intestine* is not forked but has numerous diverticula. *Testis* is single, compact and situated posteriorly. A *vas deferens* arises from testis and crosses over to join the vitelline duct of other individual of the pair. *Ovary* is single, loop-like and situated in front of testis. *Oviduct* joins the vitelline duct of the same individual. *Uterus* is surrounded by Mehlis glands and contains a single egg. Genital ducts of one individual cross with those of the other of the pair. Vitelline glands are in the form of numerous follicles filling up the middle of body in front of the point of fusion.

**5. *Polystomum*.** It is a monogeneantrematode endoparasite in the urinary bladder of frogs,

toads and turtles. Body is flat and leaf like. Posterior end of body or *opisthaptor* contains 3 pairs of suckers, arranged in a circle and 2 to 4 large chitinous hooks. Mouth surrounded by an oral sucker, leads into *pharynx*. *Intestine* is divided into two main limbs with diverticula, and connected by transverse connectives. A nephridiopore opens on either side of mouth. *Polystomum* is bisexual. *Gonopore* opens ventrally a little behind mouth. Several testes are located in the posterior region of body. *Ovary* is single having a short oviduct, which communicates with the right intestinal caecum by a short *genito-intestinal canal* of unknown function. There are two vaginae, which open internally into transverse vitelline duct and externally or laterally funnel-like prominences, one on either side near the anterior end of body.

Life cycle of *Polystomum* shows a remarkable synchronization with that of the amphibian host (frog). Eggs produced in the bladder of frog are passed into water along with the faeces of host. Embryo hatches in the form of a larva called *onchomiracidium*. It has four eyes, cilia in



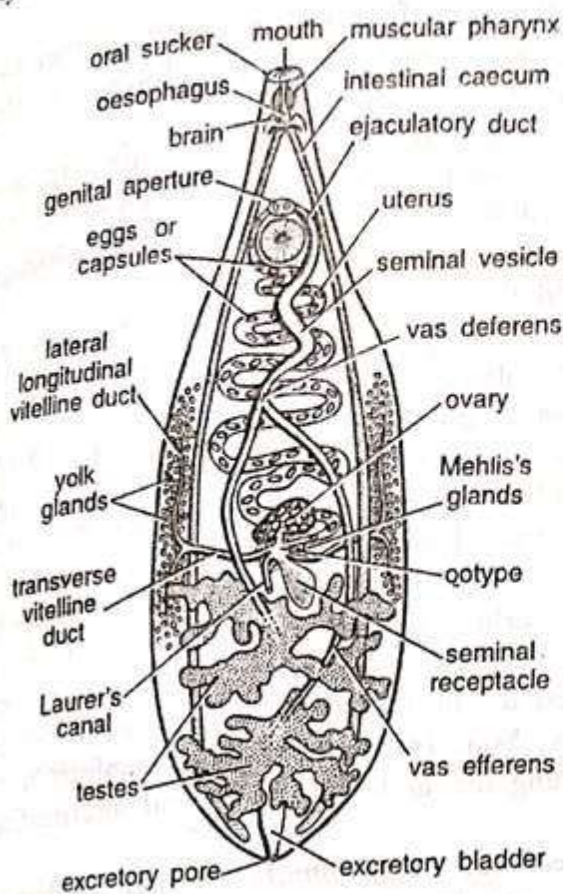


Fig. 6. *Opisthorchis* (= *Clonorchis*) *sinensis*.

transverse bands, two protonephridia and a disc-shaped opisthaptor with 16 hooklets. Larva attaches to the gills of a tadpole. When tadpole metamorphoses, larva leaves the gill chamber and reaches the bladder and develops to adult stage. Eyes and cilia are lost. Neoteny has been reported in some cases of *polystomum* larva. If larva attaches to a young tadpole, then it may become sexually mature and lays eggs. But this ectoparasitic generation dies when metamorphosis occurs.

6. *Opisthorchis* (= *Clonorchis*) *sinensis*. *Opisthorchis* (= *Clonorchis*) *sinensis* is the common liver fluke of man. It is also known as the 'Chinese Liver Fluke' for its common occurrence in China and the neighbouring countries including India. It is smaller and narrower than *Fasciola* which it resembles morphologically. Adults, in thousands, inhabit bile ducts and sometimes pancreatic ducts and duodenum of man. They have been reported from pig and dog also. Life cycle involves two intermediate hosts, a freshwater snail and a freshwater fish.

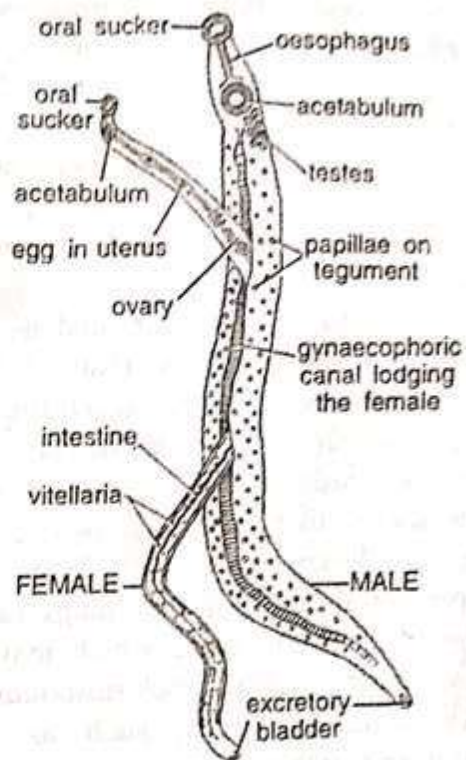


Fig. 7. *Schistosoma*. Male and female.

Eggs hatch when ingested by a snail of the genus *Bythinia*. Earlier larval stages (*miracidia*, *sporocysts* and *Rediae*) are passed in snail. *Cercariae* leave the snail host and bore into a freshwater fish-carp or minnow, in which they encyst as *metacercariae*. Final host (man) acquires infection by consuming infected and uncooked fish.

Mild infections often produce no symptoms but heavy infections may cause diarrhoea, enlarged liver, abdominal discomforts, jaundice and reduced immunity to bacterial infection. The disease is termed *clonorchiasis*. Drugs commonly employed for treatment are coated tablets of gentian violet, chloroquine and antimony compounds.

7. *Schistosoma*. Blood-flukes of man and other animals are placed in the genus *Schistosoma* (Gr., *schistos*, divided + *soma*, body).

*Schistosoma* or *Bilharzia* was discovered by Bilharz in 1851. Three species are known to infect man : (i) *S. haematobium* in blood vessels of bladder and urinary tract, (ii) *S. mansoni* in small branches of mesenteric and portal veins, and (iii) *S. japonicum* in small veins of portal and mesenteric vessels.

Unlike most other flukes, *Schistosoma* is dioecious with well-defined sexual dimorphism and the two intestinal limbs become united into one at the posterior end of body. Female is more slender and cylindrical and lies permanently lodged in the gynaecophoric canal of male formed by the rolling of sides of body behind the ventral sucker.

Life cycle involves a single intermediate snail host and in general resembles that of other flukes, except that the cercariae infect the final host (man) by directly penetrating his skin.

Infection of *Schistosoma* causes various symptoms of allergy like itch, rash, aches, fever, eosinophilia, etc. When infection is heavy, eggs may be deposited in arterioles of lungs causing cardio-pulmonary schistosomiasis which may lead to congestive heart failure. Schistosomiasis is treated with antimony drugs, such as tartar emetic, fuadin and anthiomaline.

8. *Paragonimus*. Flukes of this genus *Paragonimus* parasitize lungs of carnivorous mammals including man, tiger, dog, pig, rat, goat, etc. They are commonly called "lung flukes". They have been reported from India, China, Japan, Philippines, New Guinea, Africa, etc. First species to be described was *P. westermanni* from Bengal tigers. First human species obtained was

named *P. ringeri*. It is still uncertain whether the two species named above are distinct or the same species.

Adult lung-fluke is oval in shape, reddish brown in colour, about 8-12 mm long and 4-6 mm in diameter. General plan organization is more or less the same as that of *Fasciola*.

Adult flukes live in cyst-like pockets near the surface of lung. When these pockets rupture, eggs are liberated which reach the exterior with the host's sputum or excreta. Under suitable conditions, eggs hatch into miracidia into surrounding water. Life cycle involves two intermediate hosts. First intermediate host is a suitable amphibious snail into which miracidia enter. Earlier larval stages are passed in it. Cercariae leaving snail encyst in the second intermediate host, usually a freshwater crab or crayfish. Man (primary host) gets infection by consuming the undercooked second intermediate host.

Effects of *Paragonimus* infection on human host are not very serious but can sometimes lead to tuberculosis. Common symptoms of infection are intermittent cough, streaks of blood in sputum, anemia, slight temperature and fatigue.

9. *Moniezia*. The sheep tapeworm includes about 13 species of intestinal parasites of

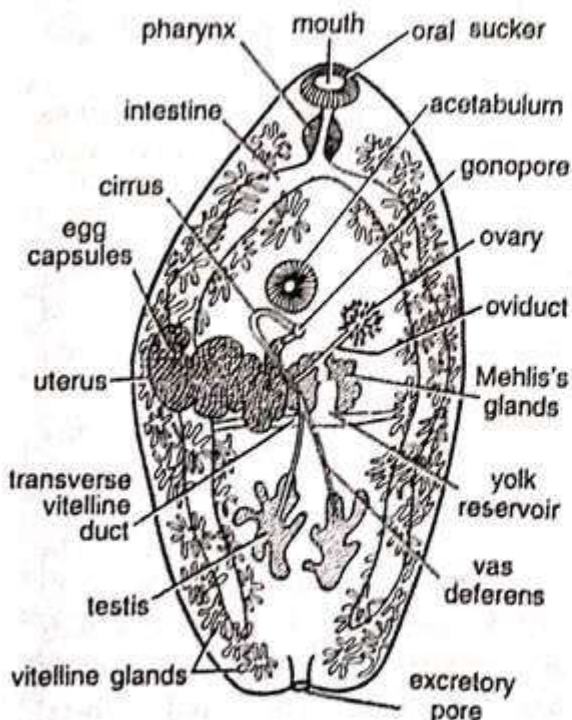


Fig. 8. *Paragonimus*.

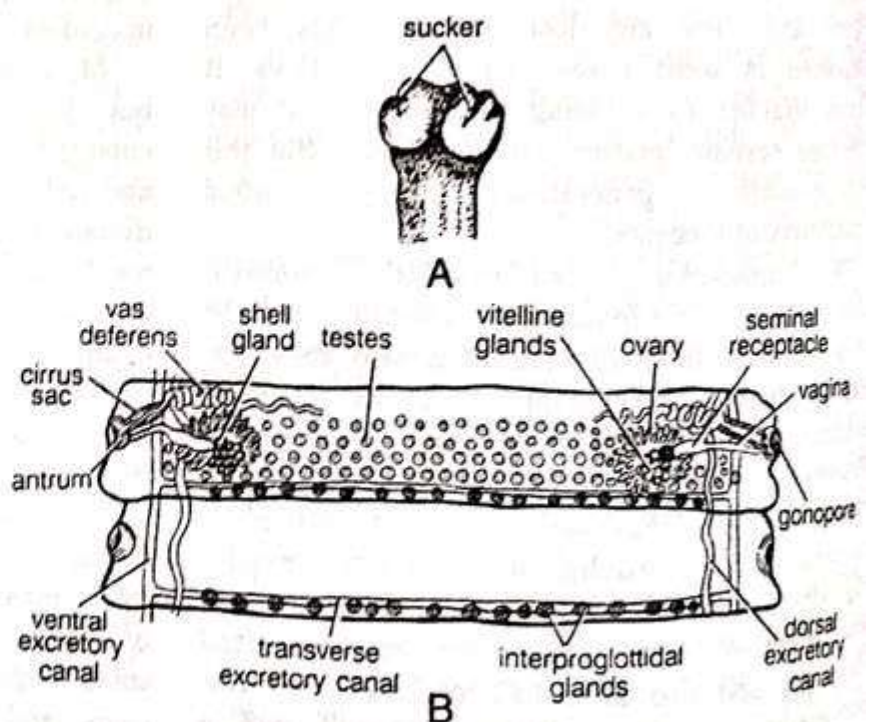


Fig. 9. *Moniezia*. A - Scolex. B - Two proglottids.

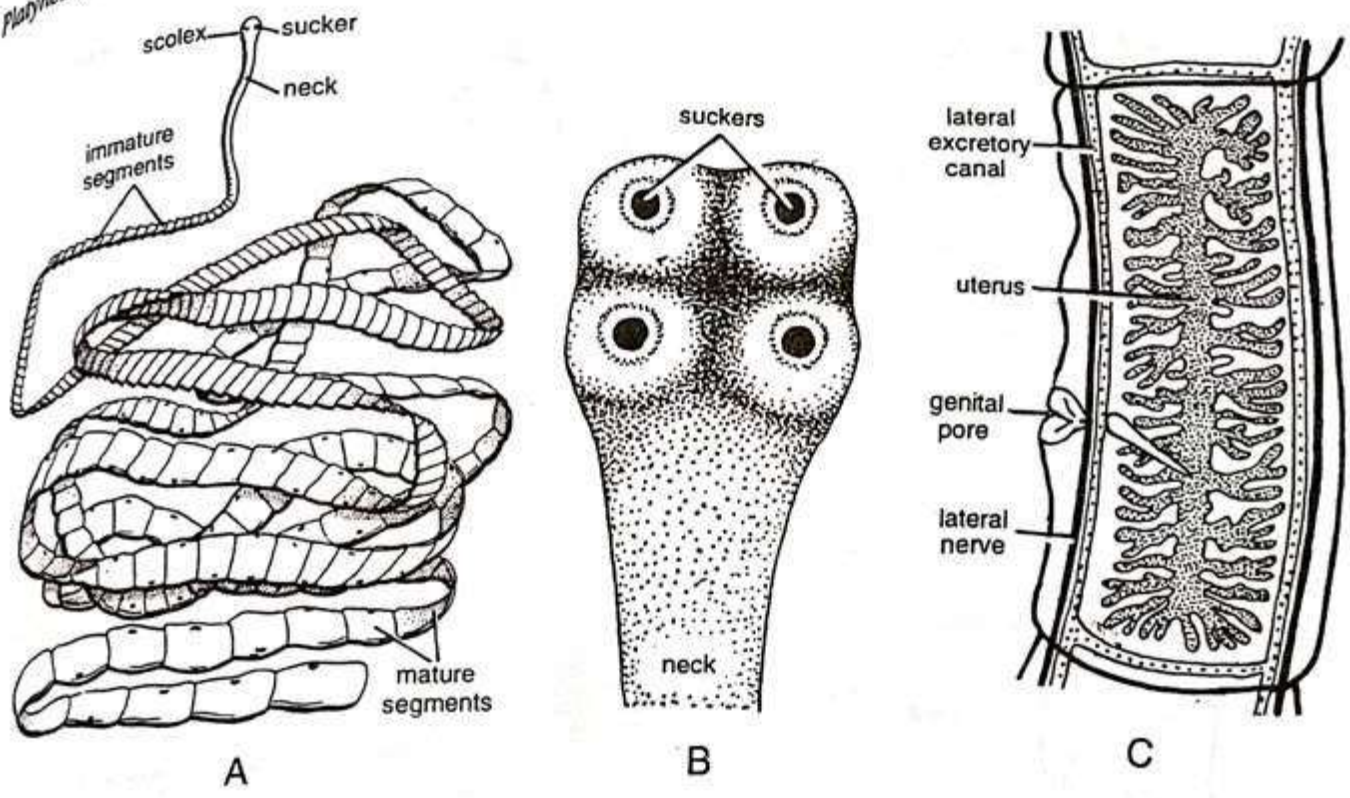


Fig. 10. *Taenia saginata*. A—Entire. B—Scolex. C—Gravid proglottid.

ruminants (sheep, goat, cattle, etc.) and other mammals. *Moniezia expansa*, perhaps the most common species attains a length of 3 to 6 meters. Small scolex has well-developed suckers but is without rostellum and hooks. Proglottids are much wider than their length and each has a double set of reproductive organs. Testes are distributed throughout the central region of proglottid. Ovaries are fan-like. Uteri of two sides form a meshwork. Vagina lies ventral to the cirrus sac on one side and dorsal to it on the other side. Intermediate host is a non-parasitic mite (*Galumina*). Ingested eggs develop into cysticercoids. These mites live about the roots of grass and are often ingested by the final host (sheep or goat) when the latter comes to graze.

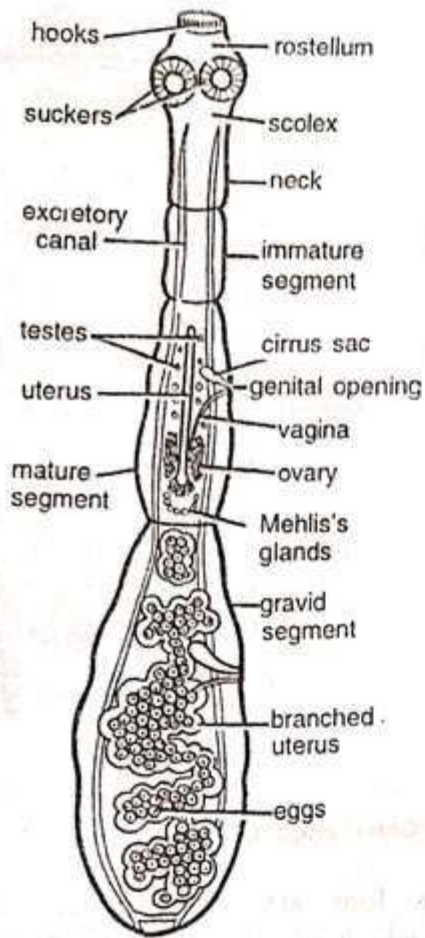
10. *Taenia saginata*. The beef tapeworm *Taenia saginata* is similar to the pork tapeworm *Taenia solium*, in structure and life history. It is the commonest tapeworm of man with a much greater incidence than that of *T. solium*. It enjoys a cosmopolitan distribution infecting the beef-eating population. Its intermediate hosts are cattle and buffaloes. It is longer than *T. solium*, usually attaining a length upto 12 meters or more. Adult lives in human alimentary canal.

Scolex bears four strong, rounded, adhesive suckers but lacks hooks. Strobila comprises up to 2,000 proglottids. A gravid proglottid contains about 100,000 eggs. Uterus of gravid proglottids has 15 to 35 branches on either side. Proglottids are usually shed singly with faeces and disintegrate. Scattered eggs on soil, grass, etc., are swallowed by grazing cattle. Eggs hatch in host's intestine freeing 6-hooked onchospheres which encyst in muscles forming cysticerci or bladder worms. Man is infected by eating such measly meat.

The dog tapeworm *T. pisiformis* is widely used as a type for study in the laboratory.

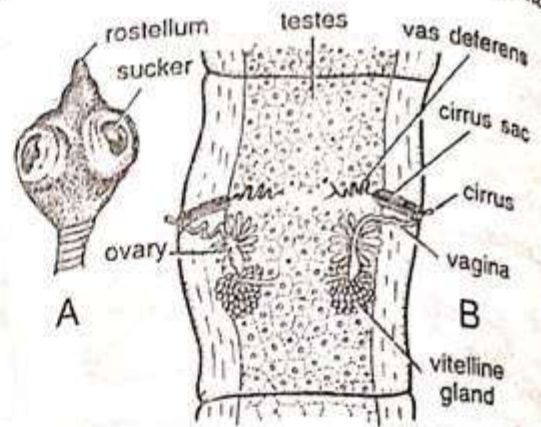
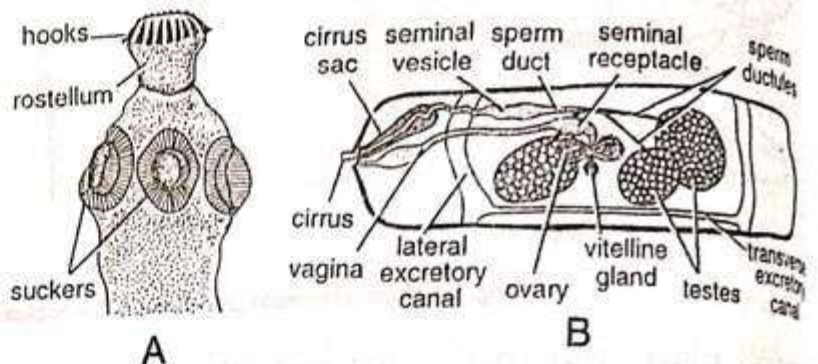
11. *Echinococcus granulosus*. The hydatid worm *Echinococcus granulosus* may be dangerous to man. Adult worms, (*Taenia echinococcus*), in hundreds or even thousands, parasitize the intestine of dog, wolf, fox, cat, etc. Man sometimes serves as an accidental final host. Adult measures 3-6 mm in length. It is made of scolex and 3 to 4 proglottids. Scolex has 4 suckers, rostellum and a double row of hooks.

Life cycle involves a single intermediate host. Eggs escape with the faeces of primary host and develop into *onchospheres*, which infect the

Fig. 11. *Echinococcus granulosus*.

secondary host (man and cattle) through his food or drink or careless association with dogs, sheep, goat, etc. Most harm is done by *cysticercus* larva. In liver or lung and in a few cases in brain, heart, bone, kidney, spleen, muscle, etc., the larva develops into a watery bladder or *hydatid vesicle* or *hydatid cyst*, having a two-layered cyst wall. The cyst produces, by asexual budding, *exogenous* and *endogenous* buds containing brood chambers and many internal scolices. A hydatid cyst may grow upto football size in 12 to 20 years in man, necessitating surgery. Dogs acquire infection when they feed upon slaughtered bodies of infected secondary hosts.

Large hydatid cysts cause inflammation, diarrhoea, abdominal pains, vomiting, eosinophilia, etc. Presence of cysts in brain, eye or kidney may prove fatal. Brood capsules and scolices can be killed by injecting formalin solution into the cysts. Removal of adult from the dog's intestine can be affected by *Areclin hydrobromide*.

Fig. 12. *Dipylidium caninum*. A—Scolex. B—Mature proglottid.Fig. 13. *Hymenolepis*. A—Scolex. B—Mature proglottid.

**12. *Dipylidium*.** The dog tapeworm *Dipylidium caninum* found universally in pet dogs, cats and sometimes children. Adult worm is nearly 25 cm. long with about 200 proglottids, each with 2 sets of reproductive organs. Scolex contains 4 suckers, while rostellum is retractile bearing 4 rows of hooks. Embryonated eggs are passed out and become dried on skin. These are swallowed by the intermediate hosts which are common dog louse *Ctenocephalus canis* and dog-flea *Pulex irritans*, in which larval forms occur. Dog or cat become infected by licking or chewing these intermediate hosts. Human beings, especially children, become infected by accidentally swallowing infected lice or fleas. It takes about 10 weeks for the worms to mature. It is not very pathogenic.

**13. *Hymenolepis*.** The dwarf tapeworm *Hymenolepis nana* is the smallest of human tapeworms, especially among children, throughout the world. Adult is 2 to 4.5 cm. long with 100 to 200 proglottids. Scolex contains 4 suckers. Rostellum is short with a single row of 20 to 30

hooks. There are 3 testes in each proglottid. Life cycle is simple without any intermediate host, but flour beetles and fleas may serve as such. Onchospheres liberated from eggs live in intestinal villi where they transform into cysticercoid larvae. These reenter lumen of

intestine to become attached by evaginated scolices and mature into adults (auto-infection). Unsanitary toilet habits spread infection from person to person. Dwarf tapeworm is pathogenic causing abdominal pain, diarrhoea and eosinophilia.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Give general characters of phylum Platyhelminthes and classify it giving characteristic features and at least two examples of each group.
2. Name and characterize the classes of phylum Platyhelminthes.
3. Write short notes on : (i) *Bipalium*, (ii) *Convoluta*, (iii) *Diplozoon*, (iv) *Dipylidium*, (v) *Echinococcus*, (vi) *Hymenolepis*, (vii) *Moniezia*, (viii) *Opisthorchis* (= *Chlonorchis*), (ix) *Paragonimus*, (x) *Polytoma*, (xi) *Schistosoma*, (xii) *Taenia saginata*, (xiii) *Thysanozoon*.

#### » Short Answer Type Questions

1. Give an example for a polyclad flatworm.
2. What is the name of the cestodarian embryo.
3. How many number of proglottids are present in *Echinococcus* ?
4. Name the intermediate host of *Echinococcus granulosa*.
5. Write the name and the characteristics of excretory organ seen in Platyhelminthes.
6. What is apolysis ?
7. Which subclass among cestodes does not possess a scolex ?
8. What is the characteristic of cestodarian embryos ?
9. Mention ten characteristic features of phylum Platyhelminthes.
10. Classify *Polystomum* upto its order.
11. Mention three main classes of phylum Platyhelminthes and write three features of each class with an example.
12. Comment on the importance of cestodes to man.
13. Mention a parasitic Platyhelminthes in man, where both the male and female live in close association.

#### » True / False

31. *Thysanozoon* is a polyclad turbellarian found in cold water.
32. Coelome present in Platyhelminthes.
33. Fertilization in Platyhelminthes is internal may be cross or self.

#### » Multiple Choice Questions

1. The disease in man caused by infection of bladder-worm is known as :  
 (a) schistosmiasis (b) cysticercosis  
 (c) teaniasis (d) enterobiasis
2. Trematodes are usually described as :  
 (a) blood flukes (b) flukes  
 (c) worms (d) flatworms

14. Give the distinguishing features of the Turbellaria, Trematoda and Cestoda.
15. Differentiate between parthenogenesis and polyembryony.
16. Who proposed the term Platyhelminthes?
17. Which system is absent in the animal of Platyhelminthes?
18. What is the name of the class of Platyhelminthes in which segmented animals are placed?
19. What is rhabdites?
20. How many orders in the class Turbellaria ?
21. Give the name of orders in the class Trematoda.
22. What is the generic name of Chinese liver fluke?
23. Describe the taxonomic condition of *Echinococcus*?
24. In Platyhelminthes the body organisation is .....
25. Skeletal, respiratory and circulatory system are ..... in Platyhelminthes.
26. In Platyhelminthes, the fertilization is .....
27. In order Rhabdocoela the animal are .....
28. Endoparasitic flatworm known as .....
29. The meaning of Cestoidea is .....
30. *Paragonimus* is commonly known as .....

34. The total Platyhelminthes are segmented body's animals.
35. *Schistosoma*, blood fluke of man discovered by Bilharz in 1851.

3. Regeneration can be best described as :  
 (a) removal of unwanted parts  
 (b) replacement of lost parts  
 (c) deformation of lost parts  
 (d) rehealing of a wound
4. Spines are seen in the cuticle of :  
 (a) *Planaria* (b) *Taenia*  
 (c) *Echinococcus* (d) *Fasciola*

5. In platyhelminthes, vitellarium is generally found in association with :  
(a) ovary (b) testis  
(c) both ovary and testis (d) shell glands
6. Flat worms are characterised by presence of :  
(a) protonephridia or flame cells (b) renette cells  
(c) canals (d) nephridia
7. A digestive system is absent in :  
(a) Turbellaria (b) *Ascaris*  
(c) *Taenia* (d) *Schistosoma*
8. Sporocyst is found in :  
(a) sponge (b) *Fasciola*  
(c) *Hydra* (d) all these
9. Anaerobic respiration is likely to occur in :  
(a) earthworm (b) tape worms  
(c) flat worms (d) echinoderms
10. Liver fluke belongs to class :  
(a) Trematoda (b) Nematoda  
(c) Turbellaria (d) Cestoda
11. Cercaria is found in the life cycle of :  
(a) *Taenia* (b) *Fasciola*  
(c) *Ascaris* (d) *Planaria*
12. Parasitic animals have well developed :  
(a) respiratory system (b) reproductive system  
(c) digestive system (d) nervous system
13. Common feature among tapeworm, liver fluke and planarian is that all are :  
(a) segmented (b) found in night  
(c) coelomates (d) flat
14. *Echinococcus* generally known as :  
(a) pig tapeworm (b) sheep tapeworm  
(c) man tapeworm (d) dog tapeworm
15. Intestinal fluke is :  
(a) *Fasciola hepatica* (b) *Fasciola gigantica*  
(c) *Fasciola buski* (d) all
16. Paragium infected to :  
(a) liver (b) heart  
(c) lungs (d) brain
17. Who was suggested the name 'platyhelminthes' :  
(a) Robert Grant (b) Leucart  
(c) Gegenbaur (d) Von Scibold
18. Classification of flatworm is based on :  
(a) mode of life (b) presense of gut  
(c) body coverage (d) all above
19. Psedametamerism is found in :  
(a) *Fasciola* (b) *Taenia*  
(c) *Planaria* (d) *Ascaris*
20. Eye are present in :  
(a) *Dugesia* (b) *Taenia*  
(c) *Fasciola* (d) all above
21. Smallest of human tapeworm :  
(a) *Taenia* (b) *Echinococcus*  
(c) *Hymenolepis* (d) *Polyforma*
22. Sucker absent in :  
(a) Turbellaria (b) Trematoda  
(c) Cestoidia (d) all
23. Lycophore is :  
(a) endoparasite (b) larvae of cestodarian  
(c) parasite of fish (d) parasite of man
24. Opisthapter is a :  
(a) anterior sucker (b) posterior sucker  
(c) hook (d) spine
25. *Polystomum* is endoparasite of :  
(a) frogs (b) fish  
(c) toad (d) all

### Answers

#### » Short Answer Type True / False Questions

24. tissue organs level, 25. absent, 26. internal, 27. free living, 28. tapeworms, 29. girdle worm, 30. lung fluke, 31. true, 32. false, 33. true, 34. false, 35. true.

#### » Multiple Choice Questions

1. (b) 2. (b) 3. (d) 4. (d) 5. (a) 6. (a) 7. (c) 8. (b) 9. (c) 10. (a) 11. (b) 12. (b) 13. (d) 14. (d) 15. (c) 16. (c) 17. (c) 18. (b) 19. (b) 20. (a) 21. (c) 22. (a) 23. (b) 24. (b) 25. (d).

# Superphylum Aschelminthes: The Pseudocoelomate Phyla



## 34 Chapter

There are several groups of animals in which the space inside the body is a *pseudocoel*. It is not a true coelom because it is not lined with mesodermal epithelium, and represents a persistent embryonic blastocoel. These groups of animals are known as *pseudocoelomates*, and they are often placed within a single superphylum *Aschelminthes*.

Very recently they are considered most hardy creatures by NASA, (USA) because a group of small (1 mm adult) *Caenorhabditis elegans* worms, living in petri dishes enclosed in aluminium canisters, survived re-entry in the atmosphere and impact with the ground and were recovered weeks after the space shuttle blew up into small pieces, killing all the seven astronauts. These nematodes were part of a Biological Research in Canisters (BRIC) experiment by NASA Ames Research Center, designed to study the effect of weightlessness on physiology.

### Derivation of Name

The name *Aschelminthes* was proposed by Grobben (1910), in place of the older name Nemathelminthes. It has been derived from two Greek words: *askos*, cavity + *helmins*, worm.

### General Characters

1. Mostly aquatic, free-living or parasitic.
2. Usually small, even microscopic. Some reach a meter or more in length.
3. Body slender, vermiform, unsegmented, flat or cylindrical, bilaterally symmetrical and triploblastic.
4. *Organ system grade* of body organization.
5. Head not distinctly formed with well-defined sense organs.
6. Body wall with a *syncytial* or cellular epidermis, externally covered with thick *cuticle* of scleroprotein.

7. Cilia absent except anterior cilia of rotifers.
8. Musculature includes mostly longitudinal fibres.
9. Body cavity a *pseudocoel* not lined by mesoderm.
10. Digestive canal complete with mouth, specialized pharynx, straight non-muscular intestine and posterior anus.
11. No circulatory and respiratory systems.
12. Excretory system of protonephridia (in some) and canals. Cloaca present in some.
13. Nervous system of cerebral ganglia, or of circumenteric nerve ring with anterior and posterior nerves.
14. Mostly *dioecious*. Male usually smaller than female. Gonads and ducts single or double. Eggs with chitinous shell. Cleavage determinate and spiral.
15. Development usually direct with no larval stages, or indirect with a complicated life history.

### Classification or Major Groups

Aschelminthes includes one very large group (Nematoda) and four smaller groups (Rotifera, Gastrotricha, Kinorhyncha and Nematomorpha). According to some zoologists such as Hyman (1951), Aschelminthes is regarded as a distinct *phylum*, and the various groups included in it as classes. However, others treat different groups as separate phyla and the name of Aschelminthes as a *superphylum* or without any taxonomic rank. Such an approach has been followed in the following scheme of classification.

#### 1. Phylum Rotifera

(G., *rota*, wheel + *ferre*, to bear)

1. Microscopic animals found in ponds, lakes and streams. Rarely in oceans.
2. Body wall thickened into stiff plates or *lorica* into which head may retreat.
3. Anterior end with ciliary disc or *corona* (wheel organ), used for feeding and locomotion.
4. Post-anal tail or with two toes and adhesive glands for attachment.
5. Body musculature includes longitudinal and transverse muscle bands and strands.
6. Digestive system with a grinding organ, *mastax*, lined internally by strong cuticle.

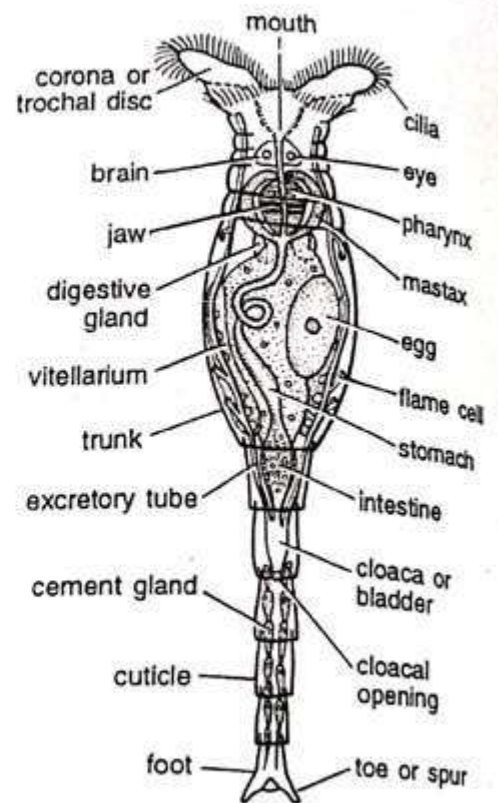


Fig. 1. *Philodina*.

7. Excretory system of protonephridia and protonephridial tubes which empty into bladder.
  8. Nervous system of three major ganglia and nerves.
  9. Sensory organs antennae and eye spots.
  10. Males smaller than females. Parthenogenesis common. No larval stage.
- Examples : *Philodina*, *Asplanchna*, *Rotaria*, *Epiphanes* (= *Hydatina*).

#### 2. Phylum Gastrotricha

(L., *gaster*, stomach + *trichos*, hair)

1. Microscopic, marine or freshwater.
2. Body wall with cuticle bearing short, curved dorsal spines.
3. Corona absent cilia on ventral surface locomotion.
4. Posterior end forked and with adhesive tufts and glands for attachment.
5. Body musculature includes six pairs longitudinal muscles.
6. Mouth surrounded by bristles. Pharynx triradiate and muscular.
7. Excretory system with two protonephridia.



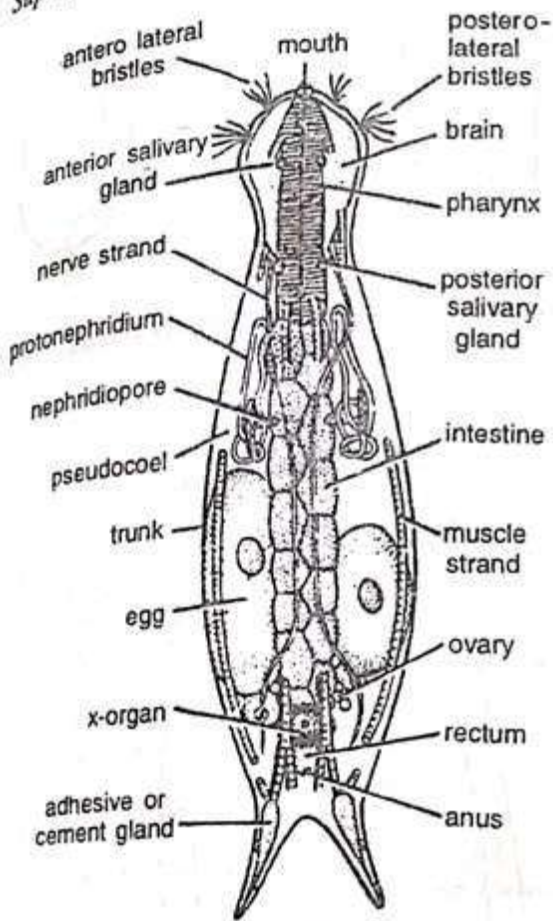


Fig. 2. *Chaetonotus*.

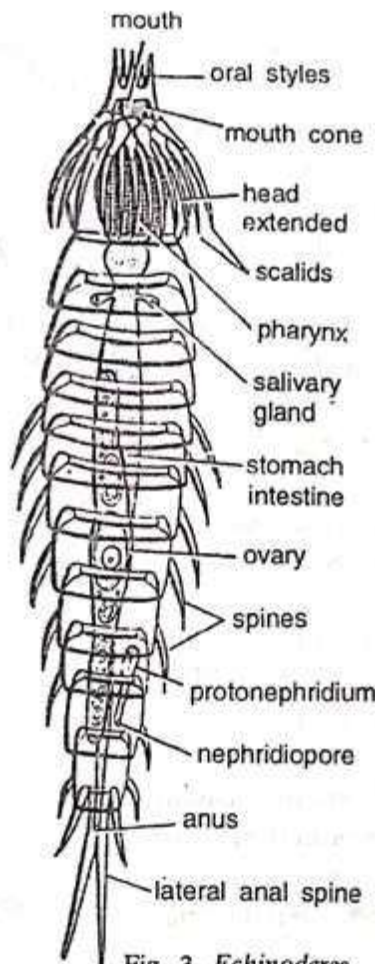


Fig. 3. *Echinoderes*.

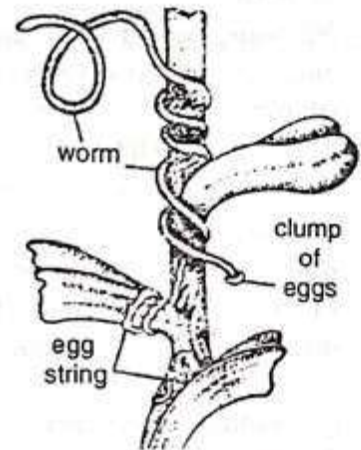


Fig. 4. *Paragordius* (female).

8. Nervous system with a saddle-shaped ganglion and two lateral nerves.
  9. Dioecious or monoecious. Freshwater females parthenogenetic.
  10. Development direct. Young and adult alike.
- Examples : *Chaetonotus*, *Macrodasys*.

**3. Phylum Kinorhyncha (= Echinodera)**  
(Dr., *kineo*, to move + *rhyngchos*, beak)

1. Marine, microscopic animals.
2. Superficial segmentation of body into 13 or 14 overlapping rings (zonites).
3. Body surface with spiny cuticle but no cilia.
4. Mouth cone or head protrusible and covered with scalids.
5. A pair of adhesive tubes in front part of the ventral surface.
6. Pseudocoel with fluid containing amoebocytes.
7. A nerve ring with ventral cord with a ganglion in each zonite. Eyespots in some.
8. Digestive system complete, with salivary glands.
9. Dioecious. Gonads as a pair of tubular sacs. Penial spicules in males.

10. Fertilization internal. Metamorphosis with several larval stages.
- Examples : *Echinoderes*, *Pycnophyes*.

**4. Phylum Nematomorpha (= Gordiacea)**  
(Gr., *nema*, thread + *morphe*, shape)

1. Hair worms, found in fresh water. One genus (*Nectonema*) marine.
2. Body long, slender and cylindrical.
3. Cuticle thick bearing small papillae. Epidermis cellular, single layered.
4. Digestive system complete in larva but degenerates in non-feeding adults. Cloaca present.
5. Pseudocoel mostly filled with parenchyma.
6. No circulatory, respiratory and excretory systems.
7. Nervous system with a circumenteric nerve ring and a mid ventral nerve cord.
8. Dioecious. Gonads and gonoducts paired. Oviducts also open into cloaca.
9. Juveniles parasitic in grasshoppers, crickets and other insects.

Examples : *Gordius*, *Paragordius*, *Nectonema*.

### 5. Phylum Nematoda

(Gr., *nema*, thread + *oidos*, form)

1. Aquatic, terrestrial or parasitic roundworms.
2. Body elongated, cylindrical and unsegmented.
3. Body wall with thick cuticle, cellular or syncytial epidermis and longitudinal muscle cells in four bands.
4. No cilia, circulatory and respiratory systems.
5. Digestive system complete with muscular pharynx and glands.
6. Excretory system of glandular organs, canals or both.
7. Nervous system with circumenteric ring and anterior and posterior nerves. Sense organs simple.
8. Dioecious. Male with penial spicules and smaller than female. Gonads one or two. Male genital ducts lead into cloaca, female genital duct with a separate opening.
9. Fertilization internal. Development usually direct. No asexual reproduction or regeneration.

Examples : *Ascaris*, *Necator*, *Wuchereria*, *Trichinella*, *Enterobius*, etc.

### Inter-relationships

Phylogenetic position of Aschelminthes is obscure. Its relations are not clear with other major phyla with which it has few affinities. Rotifera and Gastrotricha show some resemblances to Turbellaria and may have arisen from a primitive flatworm.

Within Aschelminthes itself, various groups show some relationships. They are usually small to microscopic, worm-like, bilaterally symmetrical, with a thick and tough resistant cuticle, with only longitudinal muscle fibres, and with a pseudocoel not derived from mesoderm. For this reason, various groups are treated by a number of zoologists as classes under a single phylum Aschelminthes.

However, despite these similarities, the pseudocoelomate groups are extremely diverse in other respects, and lack any well-defined distinctive unifying characters to justify their grouping together into one phylum. They are not

(Z-1)

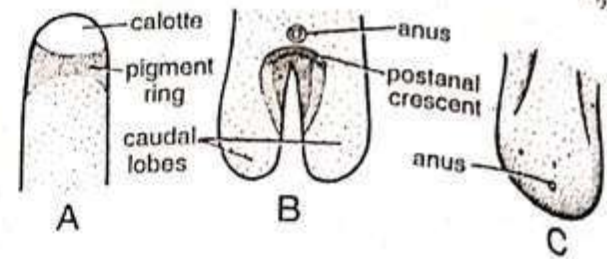


Fig. 5. *Paragordius*. A—Anterior end. B—Posterior end of male. C—Posterior end of female.

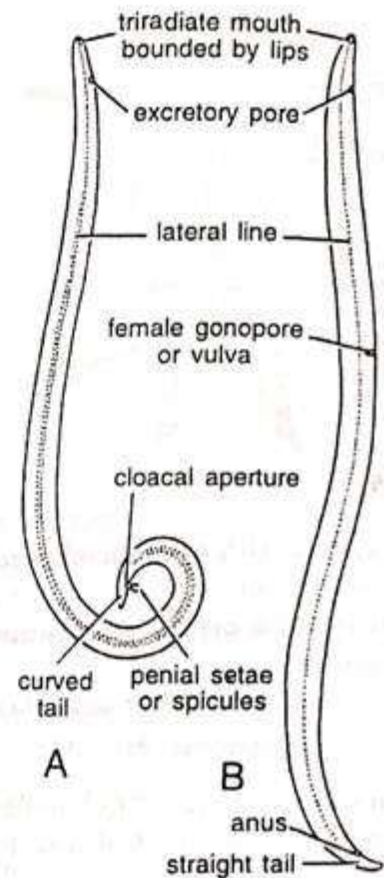


Fig. 6. *Ascaris*. A—Male. B—female.

as clearly related to one another as are the classes in other well-established phyla. For this reason, many zoologists prefer to use the name Aschelminthes as a convenient term without any taxonomic rank. They may call it a superphylum and treat its different groups as independent phyla. In that case, the numerous structural similarities existing between them are supposed to be the result of convergent evolution.

**IMPORTANT QUESTIONS**

» Long Answer Type Questions

1. Describe the general characters of phylum Aschelminthes and discuss its taxonomic status.
2. Give salient characters and examples of major animal groups belonging to Aschelminthes.

» Short Answer Type Questions

1. Define the term pseudocoelome.
2. What is the meaning of Aschelminthes?
3. Which grade of body organisation found in Aschelminthes?
4. Name the groups in which Aschelminthes are classified?
5. Define Rotifera.
6. Give taxonomic condition of Nematoda?
7. Name the larval form in Rotifera? Is this group of animal have any larva?
8. Systematised to Gastrotricha.
9. Define interrelationship among Aschelminthes?
10. No asexual reproduction among Aschelminthes?
11. Describe the systemic position of *Ascaris*.

» True / False

21. *Philodina* belong to the phylum Rotifera.
22. *Chaetonotus* is an animal of phylum Gastrotricha.
23. *Enterobius* belong to Nematoda.

» Multiple Choice Questions

1. Pseudocoelome present in :  
(a) Aschelminthes (b) Platyhelminthes  
(c) Coelenterata (f) Annelida
2. Organ system grade of body organization present in :  
(a) Porifera (b) Platyhelminthes  
(c) Aschelminthes (d) Coelenterata
3. In Rotifera the sense organs are :  
(a) eye spot (b) antennae  
(c) statocyst and eye spot  
(d) eye spot and antennae
4. Development in Gastrotricha is :  
(a) direct (b) indirect  
(c) parthenogenetic (d) regenerative

12. What is syncytial epidermis?
13. Digestive system of Rotifera contain a grinding organ, it is known as .....
14. Parthenogenetic female present in .....
15. In phylum Kinorhyncha head protrusible and covered with .....
16. Pseudocoel mostly filled with ..... in Nematomorpha.
17. No asexual reproduction or regeneration in phylum .....
18. The name aschelminthes was proposed by .....
19. Male is smaller than female and no larval stage in .....
20. *Gordius* belong to ..... phylum.

24. *Wuchereria* is belong to Nematoda.
25. Aschelminthes is a term which proposed by Grobben (1910).

5. One of these known as hair worms :  
(a) Rotifera (b) Kinorhyncha  
(c) Nematomorpha (d) Nematoda
6. Juvenile parasite in grasshopper and other insects :  
(a) Rotifera (b) Kinorhyncha  
(c) Nematoda (d) Nematomorpha
7. Digestive system present complete with muscular pharynx and glands :  
(a) Nematoda (b) Nematomorpha  
(c) Kinorhyncha (d) Gastrotricha
8. Digestive system with a grinding mastax in animal of phylum :  
(a) Rotifera (b) Gastrotricha  
(c) Kinorhyncha (d) Nematomorpha

**Answers**

» Short Answer Type and True / False Questions

13. mastax, 14. gastrotricha, 15. scalids, 16. parenchyma, 17. Nematoda, 18. Grobben, 19. Rotifera, 20. Nematomorpha, 21. true, 22. true, 23. false, 24. false, 25. true.

» Multiple Choice Questions

1. (a) 2. (c) 3. (d) 4. (a) 5. (c) 6. (d) 7. (a) 8. (a).



# 35

Chapter

## *Ascaris lumbricoides* The Common Roundworm

*Nematodes*, commonly called roundworms, constitute the largest phylum *Nematoda* of super phylum *Aschelminthes*. They are distinct from flatworms and tapeworms (platyhelminthes) in having a *cylindrical body*, a *pseudocoel*, and a *complete digestive tract* lined by endodermal epithelium. Majority of them are free-living in soil and water, while a good number of species are parasitic on plants and animals. Species of genus *Ascaris* are large-sized and inhabit the intestines of various mammals (vertebrates). The most common and best known member is *Ascaris lumbricoides*, a gastro-intestinal parasite of man.

### *Ascaris lumbricoides*

Present chapter deals with the morphology, physiology, life history and pathogenicity of *Ascaris lumbricoides*. It is selected for study of nematodes because of its large size, abundance (Z-1)

and wide distribution. It is used in laboratory to illustrate the processes of fertilization, early cleavage and mitosis.

### Systematic Position

Phylum	Nematoda
Class	Phasmidia
Order	Ascaroidea
Suborder	Ascarinae
Family	Ascaridae
Genus	<i>Ascaris</i>
Species	<i>lumbricoides</i>

### Distribution, Habits and Habitat

*Ascaris lumbricoides* is one of the most familiar endoparasites of man. It has also been reported from pigs, cattle, sheep and squirrels (Goody, 1936). It inhabits the small intestine, more frequently of children than of adults. It has a cosmopolitan distribution but chiefly found in India, China, Korea, Philippines and Pacific Islands. Its incidence varies in different parts of

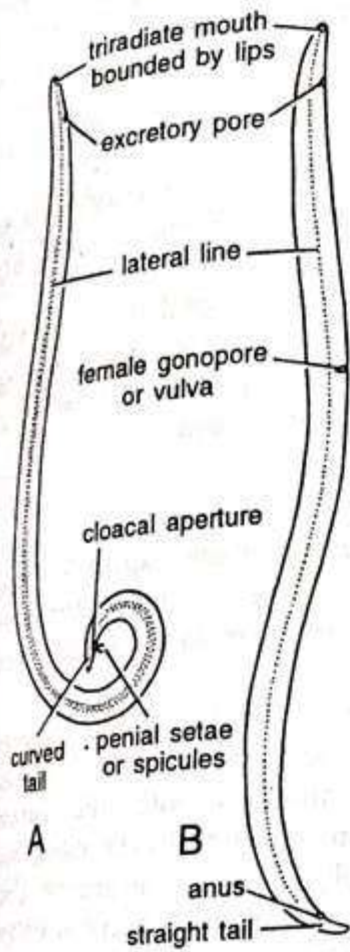


Fig. 1. *Ascaris lumbricoides*. Adult worms in lateral view. A—Male. B—Female.

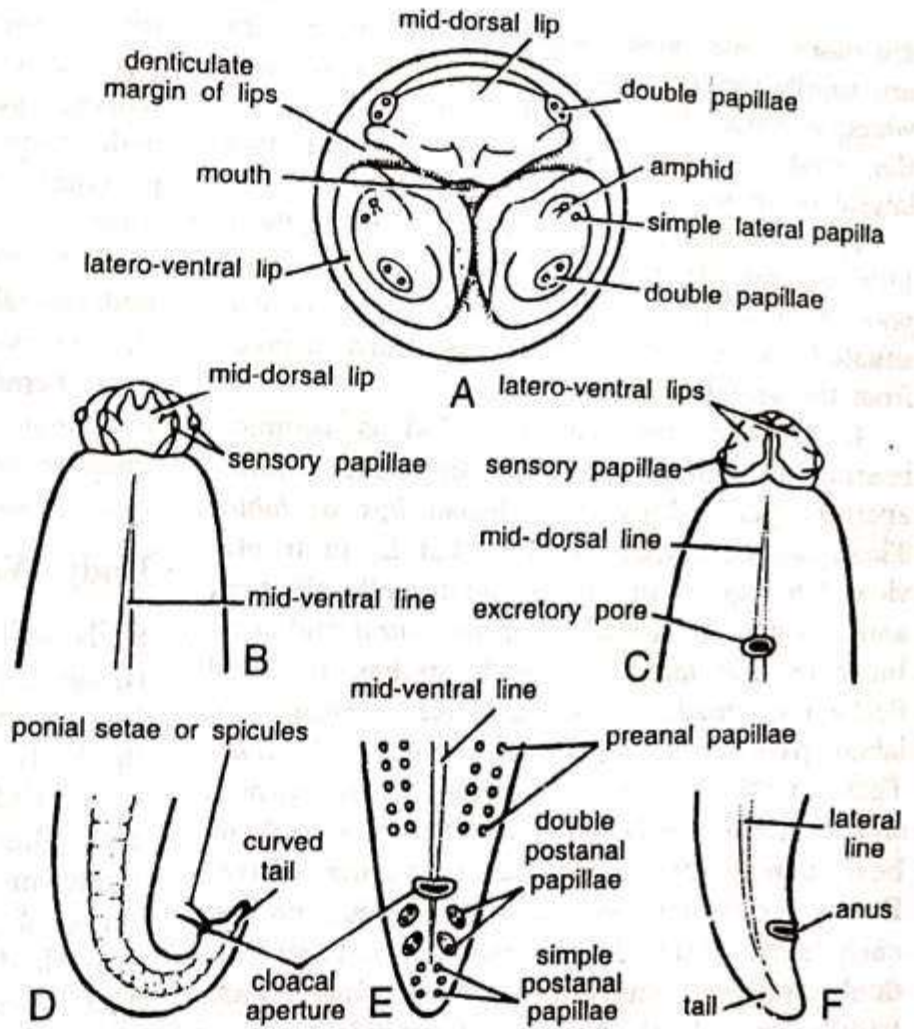


Fig. 2. *Ascaris lumbricoides*. A—En face view of mouth and lips. B—Anterior end in dorsal view. C—Anterior end in ventral view. D—Posterior end of male in side view. E—Posterior end of male in ventral view showing papillae. F—Posterior end of female in side view.

the globe. Stoll (1947) estimated that there are 644 million human infections in the world, of which 3 million are found in North America, 42 million in tropical America, 59 million in Africa, 488 million in Asia, 32 million in Europe, 19.9 million in U.S.S.R. and 500,000 in the Pacific islands.

### External Morphology

**1. Shape and size.** Body is elongate, cylindrical and gradually tapering at both ends, the anterior end being more slender than the posterior. Sexes are separate (*dioecious*) with a distinct sexual dimorphism. Female measures 20 to 40 cm. in length and 4 to 6 mm. in diameter. It has a straight tail. While male is smaller, upto

20 cm in length and 2- to 4 mm in diameter. Its tail is curved ventrally. The cuticle covering the body surface bears minute transverse striations, giving a pseudosegmented appearance to the worm.

**2. Colouration.** Fresh specimens are light yellow to light pink in colour. Semitransparency of body wall enables some of the internal organs to be seen through it.

**3. Longitudinal streaks or lines.** Running along the entire length of body are four longitudinal streaks or lines—one *mid-dorsal*, one *mid-ventral* and two *lateral*. Dorsal and ventral lines appear pure white, while lateral lines, which

are more conspicuous, appear brown. These lines are simply the impressions of syncytial epidermis which is much thickened all along the length at the median dorsal, median ventral and two lateral positions.

The *excretory pore* is situated mid-ventrally, a little behind the mouth. In female, the *genital pore* and *anus* open separately; the *genital pore* is situated mid-ventrally at about one-third distance from the anterior end.

**4. Anterior end.** Anterior end is rounded bearing a small terminal triradiate *mouth* aperture guarded by three broad *lips* or *labia*. These are best seen *en face*, that is, in frontal view. One lip is *mid-dorsal* and broadly elliptical and two are *sub-ventral* or *latero-ventral* and oval. Inner or oral margin of each lip has a forked fleshy core made of two anterior extensions of labial parenchyma, and bears minute *denticles*. These denticulate inner margins of lips form a sort of rasping surface. Outer surface of each lip bears minute *sensory papillae* (L., *papilla*, nipple). Dorsal lip bears two double papillae, one on each side. Each latero-ventral lip bears one double papilla in its ventral portion, and a single papilla in lateral portion, near which is an *amphid*, that is, opening of an amphidial gland. A *cervical papilla* is also present just behind each latero-ventral lip. Papillae are perhaps *chemoreceptors* while amphids are probably *chemoreceptors*.

**5. Posterior end.** As already stated, posterior or tail end of body shows clear sexual dimorphism. It is straight in female, but curved ventrally in male. In female, a little in front of the tail end lies a mid-ventral transverse aperture; or *anus*, guarded by thick lips. Only *digestive tube* opens to outside through anus.

In male, anus is replaced by a *cloaca*. It is the common aperture for digestive and genital tubes. Sometimes, two chitinous spiculate processes of equal size are seen protruding out of the cloacal aperture. These are called *penial setae* or *spicules* which serve to transfer sperms into female vagina during copulation. Part of caudal end behind anus or cloacal aperture may be called the *tail*.

Tail end of male ascaris is characterized by the presence of numerous *genital papillae* on

ventral surface. There are 50 pairs of *preanal papillae* in front of cloaca, and 5 pairs of *postanal papillae* behind it. *Genital papillae* of male help in copulation. Two anterior pairs of *postanal papillae* are double, while the rest are single.

**6. Excretory pore.** A single excretory pore lies mid-ventrally at a distance of about 2 mm. from the anterior end.

**7. Female gonopore.** The genital pore or vulva of female lies mid-ventrally at about one-third distance from the anterior end. But the genital pore of male opens into cloaca.

## Body Wall

Body wall of *Ascaris* is made up of 3 layers: (i) an outer *cuticle*, (ii) a middle *epidermis*, and (iii) an inner layer of *longitudinal muscles* lining the body cavity.

**1. Cuticle.** It is a thick, tough, transparent and glossy layer secreted by the underlying epidermis and continuous with the cuticular lining of pharynx and rectum. In the young worm it is shed off (moulted) to permit growth. Under light microscope, four distinct layers of different chemical composition and different structural arrangements can be identified in the cuticle. A fifth lipid layer has also been revealed under electron microscope.

The five layers of cuticle, along with their sub-divisions as revealed by electron microscope, are as follows —

(a) *Lipoid layer.* It is in the form of a thin osmophilic membrane, about 1000 Å thick.

(b) *Cortical or cortex layer.* It consists of a dense material, or *heratin*, resistant to the digestive juices of host. It includes: (i) an outer *cortical layer* which lies as discontinuous strips or rings around body and (ii) an *inner cortical layer*.

(c) *Matrix layer.* It contains sulphur-rich *matrixin* and consists of (i) an outer *fibrillar layer* traversed by branching canals, (ii) a *homogeneous layer* which shows several radial striations, and (iii) a *boundary layer* resembling the outer cortical layer.

(d) *Fibre layer.* It consists of collagen fibres crossing each other and arranged in three strata.

(e) *Basement membrane.* It is a thin layer forming the inner limit of cuticle.

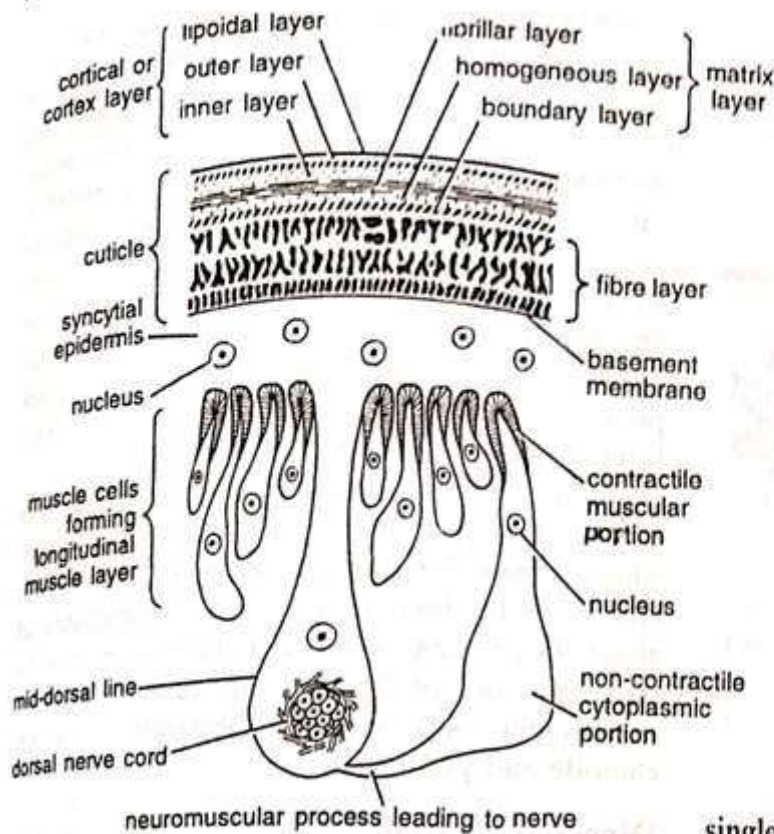


Fig. 3. *Ascaris*. T. S. body wall (a portion).

Cuticle is permeable to salts, water products of metabolism. It is believed that enzymes are present in cuticle of *Ascaris* which control the passage of different metabolites. Some anti-enzymes are also secreted by cuticle of *Ascaris*, which neutralize the effect of digestive juices of host upon the parasite.

**2. Epidermis or hypodermis.** It forms a syncytial layer below cuticle. Along the entire length of body, at median dorsal, median ventral and two lateral positions, it is much thickened to form the *dorsal, ventral and lateral lines or chords*, respectively, bulging into body cavity. Lateral chords are more conspicuous and seen on the surface as yellow lines. Running through each of these is a lateral excretory canal and a lateral nerve. Through less prominent dorsal and ventral chords extend the dorsal and ventral nerve cords, respectively. Epidermis is composed of relatively few cells, the nuclei of which lie in the chords arranged in longitudinal rows, often occurring in groups. Fat and glycogen reserves are abundantly present in epidermis.

**3. Longitudinal muscles.** Circular muscles are altogether absent. Longitudinal muscles form a

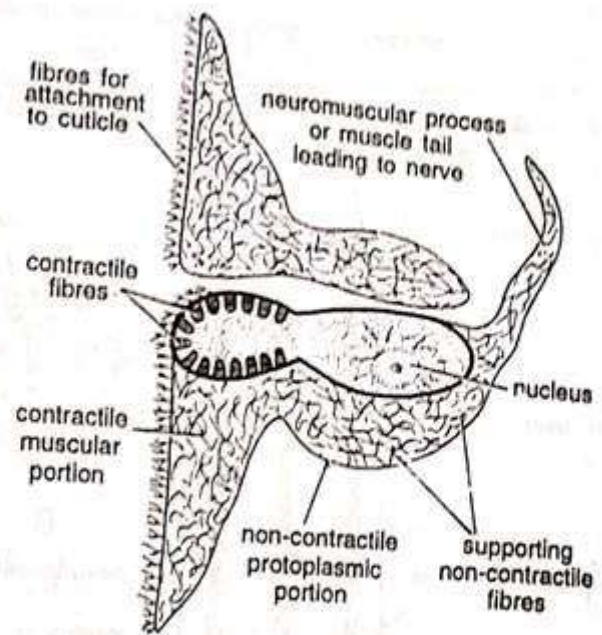


Fig. 4. *Ascaris*. A single muscle cell. The cut part shows structure in T.S.

single layer of spindle-shaped cells beneath epidermis and lining the body cavity. Being interrupted at four places by longitudinal epidermal chords, the muscle layer is divided in four longitudinal columns or strips two dorso-lateral and two ventro-lateral. Each column contains about 150 muscle cells. Number and disposition of muscle cells in nematodes forms a basis for identification of species.

Each muscle cell possesses two distinct portions : (i) a fibrillar, contractile *muscular portion*, lying lengthwise against the epidermis, and (ii) a granular non-contractile *protoplasmic portion* projecting into body cavity. Muscular portion contains longitudinal *contractile fibres* arranged at intervals. It also has fibres for attachment to cuticle. *Non-contractile protoplasmic portion* contains non-contractile supporting fibres and a nucleus and gives out at its free surface one or more neuromuscular processes or *muscle tails*. Muscle tails of all the cells of two dorso-lateral columns are ultimately connected with dorsal nerve cord, while those of two ventro-lateral columns are connected with ventral nerve cord. Electron microscopy has shown that muscle tails are cellular extensions which form synapsis on the motor nerves of dorsal and ventral nerve cords (Debell, 1965).

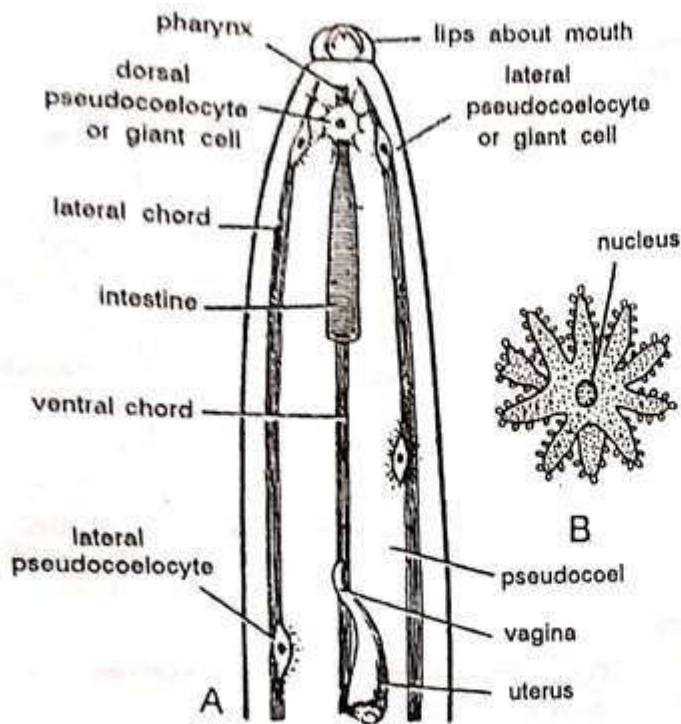


Fig. 5. *Ascaris* A—Position of giant cells in anterior region of pseudocoel. B—Single giant cell or pseudocoelocyte.

## Movements

Change in body length is restricted due to absence of circular muscles in body wall. However, changes in length to about 15% are made possible by the fibres of cuticle. These fibres, though themselves inelastic, are disposed in a spiral and mesh-like arrangement which permits limited change of length.

Undulating movements, in dorso-ventral waves, can be performed by alternate contractions of dorso-lateral and ventro-lateral muscles in the anterior end of body. These movements help the parasite to counteract the peristaltic activity of the host's intestine.

## Body Cavity or Pseudocoel

Between body wall and visceral organs is a spacious fluid-filled cavity. This cavity is not true coelom as (i) it is not lined by coelomic epithelium, (ii) it has no relation with reproductive and excretory organs, and (iii) it develops from blastocoel, i.e., between mesoderm and endoderm of embryo. This body cavity is referred to as *pseudocoel* or false coelom.

Pseudocoel of *Ascaris* contains five giant stellate mesenchymal cells, known as *pseudo-*

*coelomocytes*, occupying fixed positions. Out of these, the largest cell lies on the dorsal side of pharynx, and from it extend numerous thin *cytoplasmic strands* in the form of *fenestrated membranes*. These membranes cross the cavity at various places and form delicate layers over the visceral organs and muscles of body wall. Remaining stellate giant cells occur in the anterior third of the body, two in relation with each lateral epidermal chord. In fact, pseudocoelom is a large intracellular space formed by the union of these coelomocytes.

Pseudocoel is filled with an odorous protein rich fluid, the *perienteric* or *pseudocoelomic fluid*, which serves for transportation of metabolites and keeps the body distended. It is composed of about 93 per cent water and the rest of it is in the form of solids including protein, glucose, chloride and phosphate.

## Digestive System

### [I] Alimentary canal

Alimentary canal is a straight and complete tube extending from mouth at one end to anus on other end of body. It comprises a short *pharynx* or oesophagus representing the *foregut*, a long intestine or *mid-gut*, and a short *rectum* or *hind gut*.

1. **Mouth.** It is a triradiate aperture, situated at the anterior tip guarded by three lips or *labia* (already described).

2. **Pharynx.** Mouth opens into a short, characteristic, cylindrical, thick-walled and muscular *pharynx*. Wall of pharynx, consists of a syncytial epithelium traversed by radial muscle fibres and containing glands. It is bounded externally by a membrane. Internally it is lined by cuticle which, at the margin of mouth, is continuous with the cuticle of body wall. Lumen of pharynx is tri-radiate. Rays are in the form of deep grooves which demarcate the pharyngeal wall into three sectors—one dorsal and two sub-ventral. Dorsal sector contains a pinnately branched *pharyngeal* or *oesophageal gland*, while each sub-ventral sector contains a similar palmately branched gland. Numerous groups of radial muscle fibres extend between inner cuticular lining and outer bounding membrane.



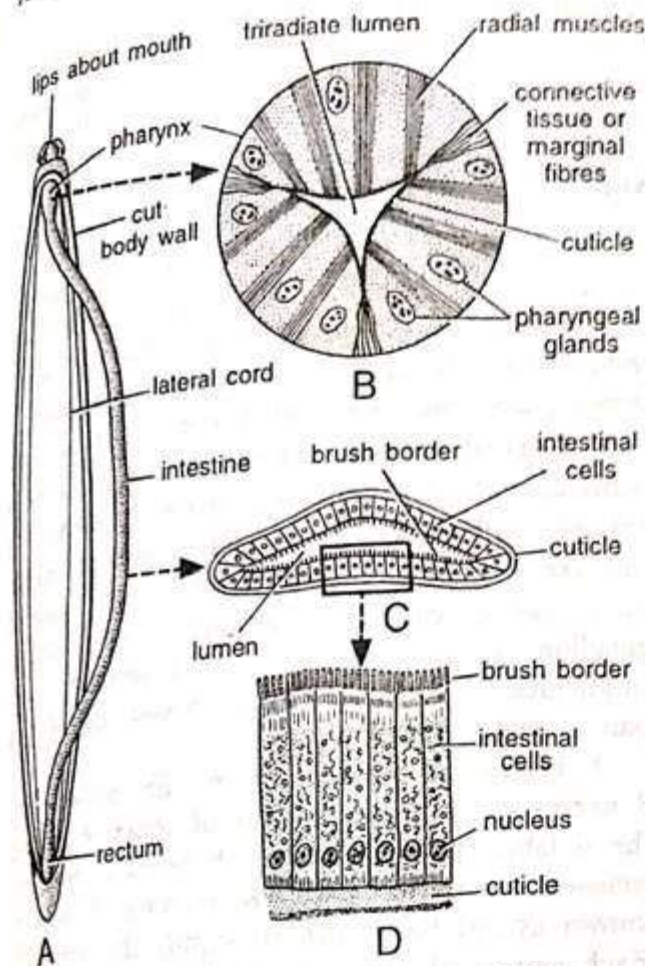


Fig. 6. *Ascaris*. A—Alimentary canal. B—Pharynx in T.S. C—Intestine in T.S. D—A portion of intestinal wall showing brush border.

Contraction of these muscles dilates the lumen. Between outer end of each ray of lumen and outer bounding membrane extend the connective tissue fibres, known as *marginal fibres*, which help in preserving the tri-radiate form of lumen.

**3. Intestine.** Pharynx is followed by *intestine* which extends almost along the entire body length. A small valve is present at the junction of pharynx and intestine which stops the food from going back into pharynx. Intestine is dorsoventrally flattened and its wall consists of a single layer of tall columnar cells, lined externally by a basement membrane and a thin layer of cuticle. Inner free margin of each cell is produced into several hair-like projections, the *microvilli*, forming a sort of *brush border*, to increase the absorptive surface area. The microvilli, in fact, are formed by a bacillary layer. Muscle fibres are wanting in intestine.

**4. Rectum.** Intestine is followed by a short *rectum* which too is dorso-ventrally flattened. Wall of rectum consists of tall columnar cells

and is lined internally by cuticle and externally by muscle tissue. In male, rectum opens into *cloaca* which also receives the ejaculatory duct. While in female, rectum opens out through *anus*. Which is a transverse slit guarded by anterior and posterior lips and is provided with a special muscle, the *depressor ani*. Anus or cloaca lies at a distance of about 2 mm. from tail end.

### [III] Food, feeding and digestion

Food of *Ascaris lumbricoides* consists of blood and fully or partially digested food occurring in fluid form in the host's gut. It is sucked by the rhythmic pumping action of pharynx. Digestion is completely extracellular in intestine and is aided by the enzymes *proteases*, *amylase*, and *lipase*. Digested food is absorbed by the intestinal cells and distributed by the *pseudocoelomic fluid*. Excess of food is stored mainly as *glycogen* and a little fat in *syncytial epidermis*. Some intestinal cells also engulf small solid particles by *phagocytosis*, and digest them *intracellularly*. *Defaecation* of undigested food whenever it occurs, is facilitated by the *depressor ani* muscle which raises the dorsal wall of rectum and posterior lip of anus or cloaca.

### Respiration

*Ascaris lumbricoides*, like most other endoparasites, respire *anaerobically* or *anoxybiotically* because the oxygen content in host's intestine is usually poor. In this process, *glycogen* undergoes *glycolysis* and finally yields carbon dioxide, fatty acids and *energy*. Details of the process are the same as described for *Fasciola hepatica* and *Taenia solium*. Main fatty acids produced are *valerianic butyric* and *caproic acids*. These are excreted through cuticle and impart a characteristic smell like that of canned pineapple.

*Aerobic* respiration probably occurs whenever free oxygen is available in host's intestine. This is indicated by the presence of a small amount of *cytochrome* in parasite. According to some workers (Hyman), haemoglobin present in small amounts in the *pseudocoelomic fluid* and body wall, serves to transport oxygen.

### Excretory System

**1. Excretory organs.** Excretory system is quite simple due to absence of flame cells or

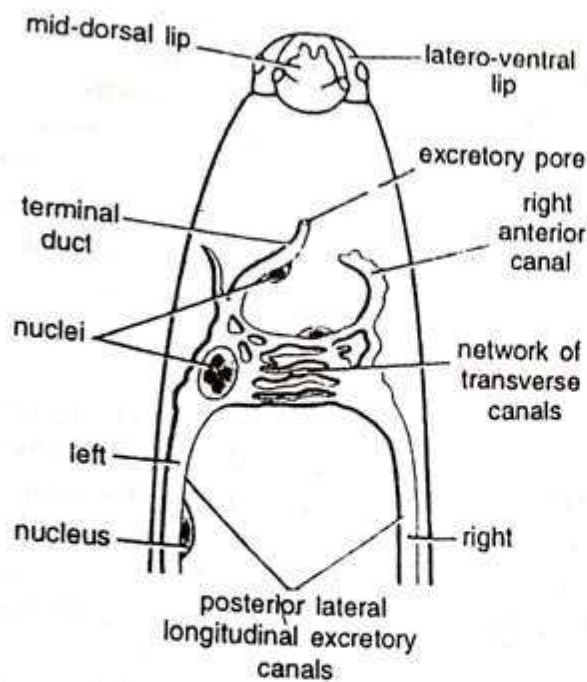


Fig. 7. *Ascaris*. 'H' type excretory system in anterior part of the body (ventral view).

protonephridia. There is a H-shaped tubular excretory system. It is supposed to be formed by a huge excretory *renette cell* at the juvenile stage. Into its cytoplasm tunnel-like structures form canals of the excretory system. It consists of two lateral *longitudinal excretory canals*, right and left, connected anteriorly, below pharynx, by a *transverse canalicular network*. Each longitudinal canal extends posteriorly, along the entire body length through a lateral epidermal chord and is closed at both ends. Externally, their location is marked by the two lateral lines. Left canal is slightly wider than the right. Anterior limbs of H are reduced. Lumen of canals is devoid of cilia. A short *terminal excretory duct* extends from left side of transverse canalicular network to the *excretory pore* situated mid-ventrally, a little behind the anterior tip. The nucleus of the excretory cell lies anteriorly on the left longitudinal canal, two more smaller nuclei have also been located, one on the terminal duct and one on the transverse canalicular network, indicating that the canal system is evolved probably by more than one cell.

**2. Physiology.** Available data suggests that excretory product of *Ascaris* is mainly urea, thus it is a *ureotelic animal*. Excretory canals collect the excretory products from different parts of body. Pressure of pseudocoelomic fluid helps in

ultrafiltration. Excretory products are eliminated through the excretory pore. Some ammonia and uric acid are also passed out with faeces through anus.

## Nervous System

Nervous system of *Ascaris* was exhaustively studied by Goldschmidt (1908-1910). According to his findings, confirmed by other workers, nerve cells forming the system are constant in number, position, form and course of fibres.

**1. Central nervous system.** It comprises of a richly ganglionated *nerve ring* or *circumenteric nerve ring* encircling pharynx. The *ganglia* located on nerve ring are (i) a single *dorsal ganglion*, (ii) a pair of *sub-dorsal ganglia*, one on each side of dorsal ganglion, (iii) a pair of *lateral ganglia*, each subdivided to form six *lateral ganglia*, and (iv) a pair of large *ventral ganglia*.

**2. Peripheral nerves.** From the nerve ring 8 nerves run anteriorly. Out of these, 6 supply the 6 labial papillae and each bears a *papillary ganglion*, near its base. Remaining 2 nerves, known as *amphidial nerves*, supply the *amphidiae*. Each *amphidial nerve* arises from one of the 6 lateral ganglia, called *amphidial ganglion*, of its side.

Posterior part of body is supplied by nerves. A *dorsal nerve cord* (motor) runs through the dorsal epidermal chord. A *ventral ganglionated nerve cord* runs through the ventral epidermal chord. It terminates at the posterior end of body, after forming an *anal ganglion*. There are 2 thin, delicate *lateral nerve chords* (sensory), each extending through a lateral epidermal chord. Besides 2 *dorso-lateral* and 2 *ventro lateral nerve cords* are present, one above and one below the lateral nerve cord, on either side. Several *commissures* or *connectives*, arranged asymmetrically along the entire length connect ventral nerve cord with lateral and dorsal nerve cords.

**3. Rectal nervous system.** In male, at the posterior end of body, (i) lateral nerve cords supply the pre-anal papillae, (ii) ventral nerve cord supplies the post-anal papillae, and (iii) dorsal, ventral and lateral nerve cords become interconnected. No such complications occur at the posterior end of the female.

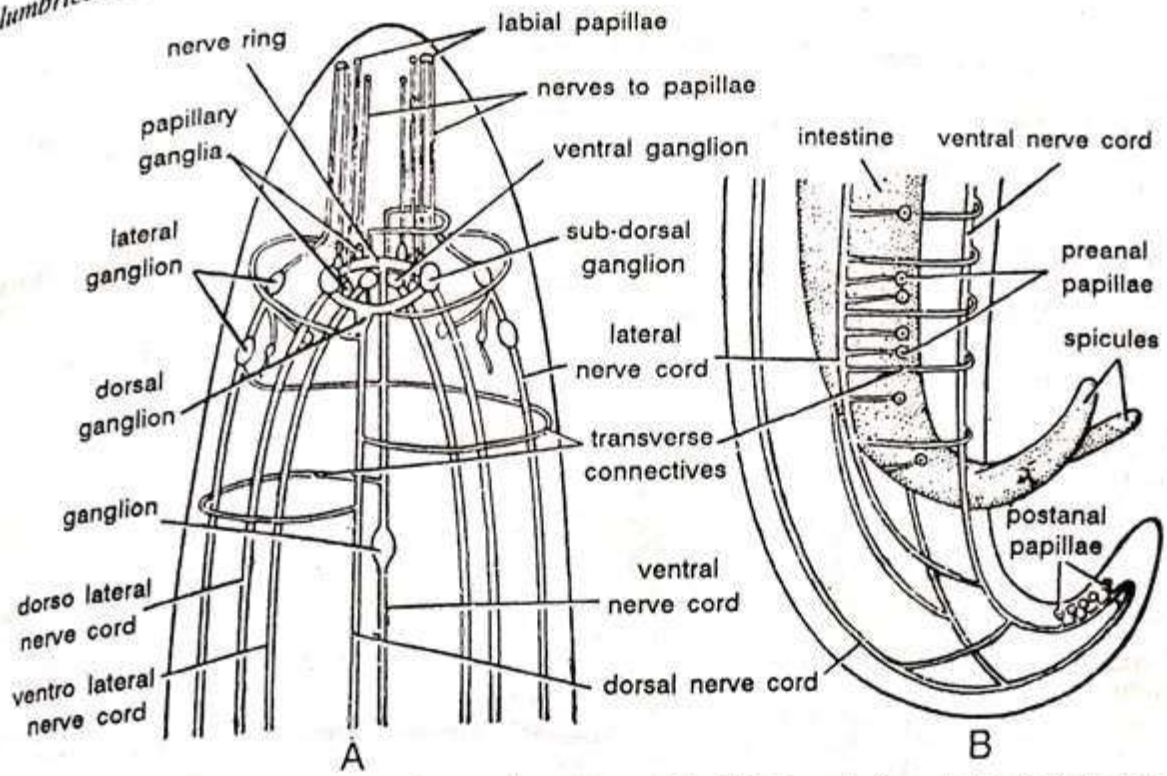


Fig. 8. *Ascaris*. Nervous system. A— In anterior end (dorsal view) B—In posterior end of male (lateral view).

**Sense Organs**

The sense organs of *Ascaris* are simple elevations supplied by nerves. They include various papillae, amphids and phasmids.

1. **Papillae.** Papillae are in the form of small villi situated on different body parts.

(a) **Labial papillae.** These are formed by sensory cells surrounded by many supporting cells. These are gustatoreceptors and present on three lips surrounding mouth.

(b) **Cervical papillae.** Dorsally, about 2 mm behind lips, are present a pair of cervical papillae. These are tactile organs.

(c) **Anal papillae.** Present ventrally below the posterior end of male are 5 pairs of post-anal papillae and 50 pairs of pre-anal papillae. They help in copulation.

2. **Amphids.** On each latero-ventral lip, a single amphid is present near a single papilla. These are gustatory sensory or chemo-receptors.

3. **Phasmids.** These are chemo-receptor unicellular glands, opening one on either side of tail.

**Reproductive System**

Sexes in *Ascaris* are separate and sexual dimorphism is well defined. Males are smaller than females. They possess a recurved tail with

pre- and post anal papillae, a cloaca, and a pair of spicules or penial setae. Gonads are typically long, coiled and tubular. They are attached at the genital pore in female and at cloaca in male.

**[I] Male reproductive organs**

These are confined to the posterior half of pseudocoel.

1. **Testis.** There is a single testis, a condition termed *monorchic* in contrast to the *diorchic* or two testis condition found in some nematodes. It extends to the middle of body and has the form of a long, thread-like, highly twisted tube. Wall of testis is made up of a single layer of cuboidal cells covered by basement membrane. Central axis of testis is in the form of a solid cytoplasmic rachis, around which are clusters of amoeboid sperms in various stages of development. There is no lumen.

2. **Vas deferens.** Distal part of testis continues into a short and thick twisted tube, the *vas deferens*. It is distinguished from testis in having a lumen in place of the central cytoplasmic rachis.

3. **Seminal vesicle.** Vas deferens is followed by a much thicker, wider, somewhat muscular straight tube, the *seminal vesicle*. It lies in the posterior third of pseudocoel below intestine.

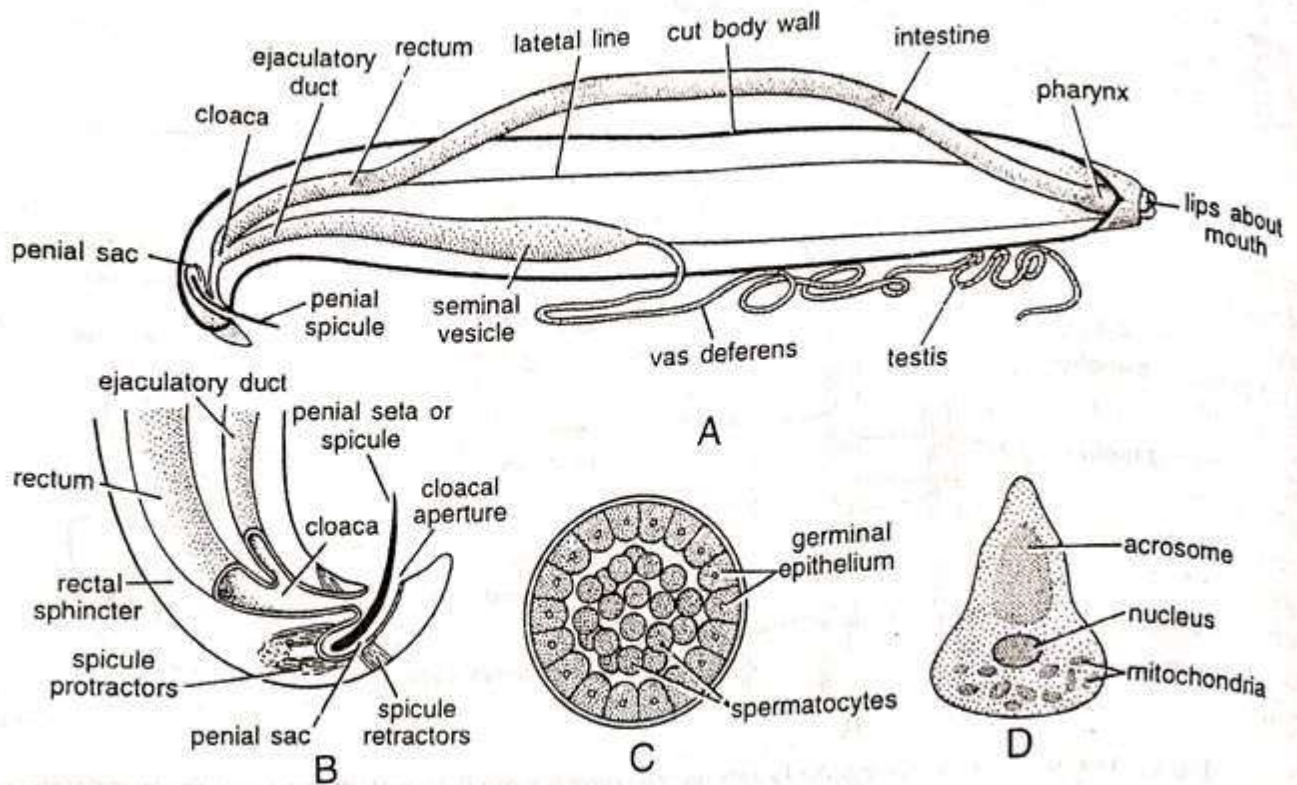


Fig. 9. *Ascaris*. A — Male reproductive system. B— Posterior end of male *Ascaris* in lateral view showing cloaca and spicules. C— T.S. vas deferens. D—A sperm.

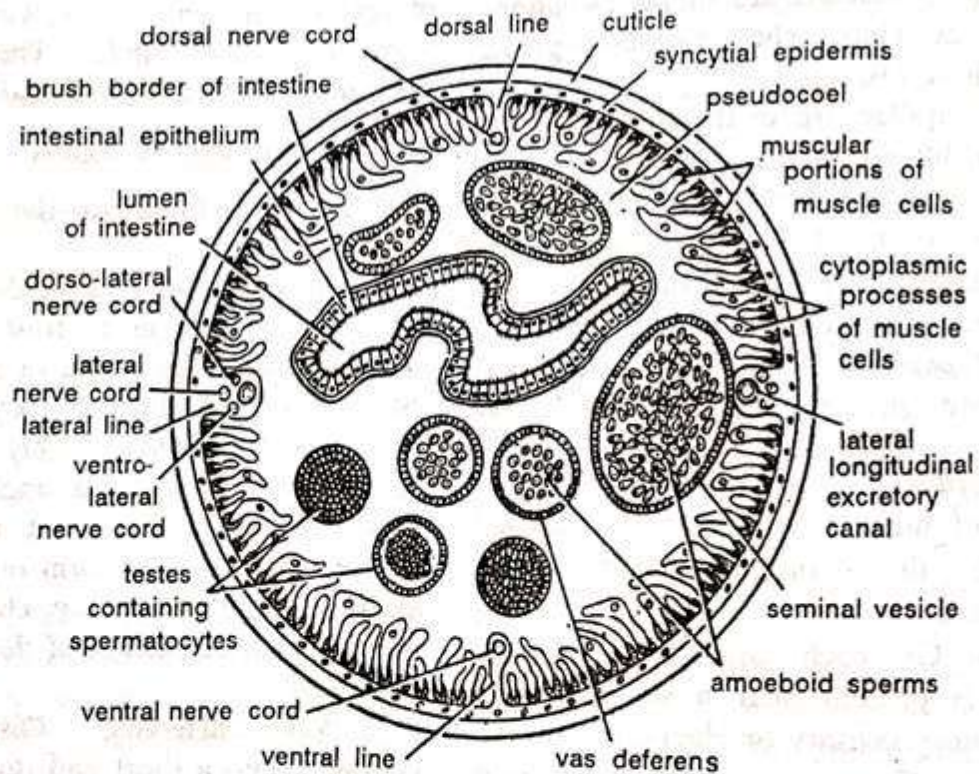


Fig. 10. *Ascaris*. T.S. of mature male.

**4. Ejaculatory duct.** Terminal part of seminal vesicle narrows to form a highly muscular *ejaculatory duct*. It joins rectum to form the cloaca. Ejaculatory duct contains a number of prostatic glands whose secretions help in copulation.

**5. Penial setae.** Situated on the dorsal side of cloaca, and formed by evaginations of the latter, is a pair of small penial sacs or *spicular pouches*. Each spicular pouch secretes and houses a club-shaped *spicule* or *penial seta*, enclosed in a *spicular sheath*, and consists of a cytoplasmic

core surrounded by thick cuticle. The spicules, each 2 to 3.5 mm long, can be protruded and retracted through the cloacal aperture by special protractor and retractor muscles. Spicules help in opening the female gonopore for copulation.

**[II] Female reproductive organs**

These lie in the posterior two third of pseudocoel and comprise two parallel tracts, each consisting of an ovary, an oviduct and a uterus. The didelphic or two tract condition is most common in nematodes, though monodelphic (one tract) and polydelphic (many tracts, upto 10 or 11) conditions are also met with.

1. **Ovaries.** These are two in number. Each ovary of *Ascaris* is a long, thread-like, much twisted and blind tubule. Its wall consists of a single layer of cuboidal epithelial cells lined externally by a basement membrane. Its central axis is in the form of a cytoplasmic rachis, around which are groups of ova. There is no lumen.

2. **Oviducts.** From the distal end of each ovary arises a thicker, wider and twisted oviduct, with a similar wall as that of the former and a lumen instead of solid cytoplasmic rachis.

3. **Uteri.** Each oviduct continues into a much wider, thicker and almost untwisted tube, the uterus. Their wall is composed of tufted cells, surrounded by a muscle layer with inner circular

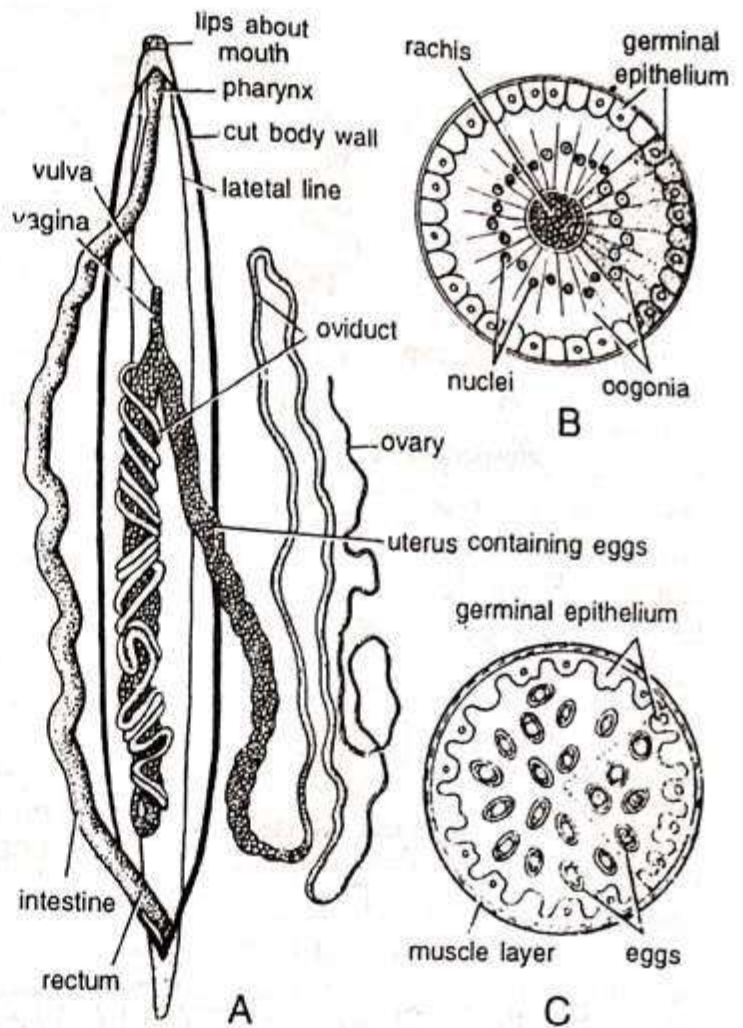


Fig. 11. *Ascaris*. A - Female reproductive system. B - T.S. ovary. C - T.S. uterus.

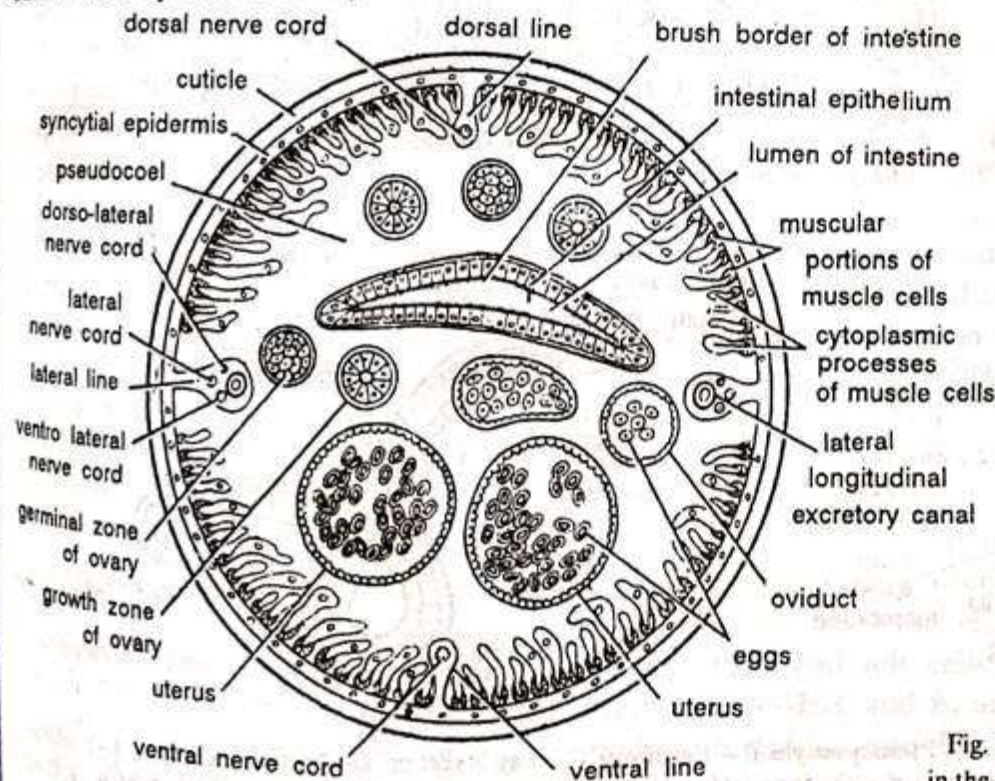


Fig. 12. *Ascaris*. T. S. of a mature female.

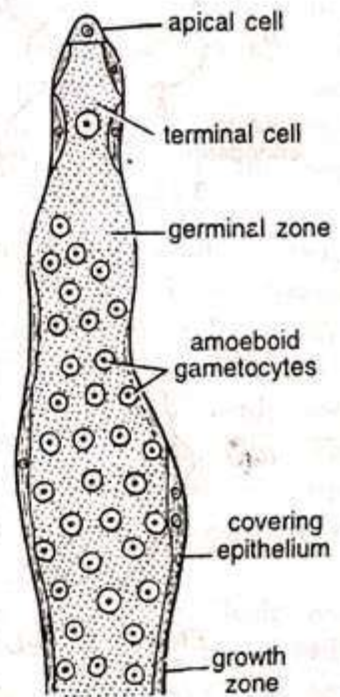


Fig. 13. *Ascaris*. Telogonic origin of sex cells in the proximal end of gonad. Maturation zone of gonad not shown.

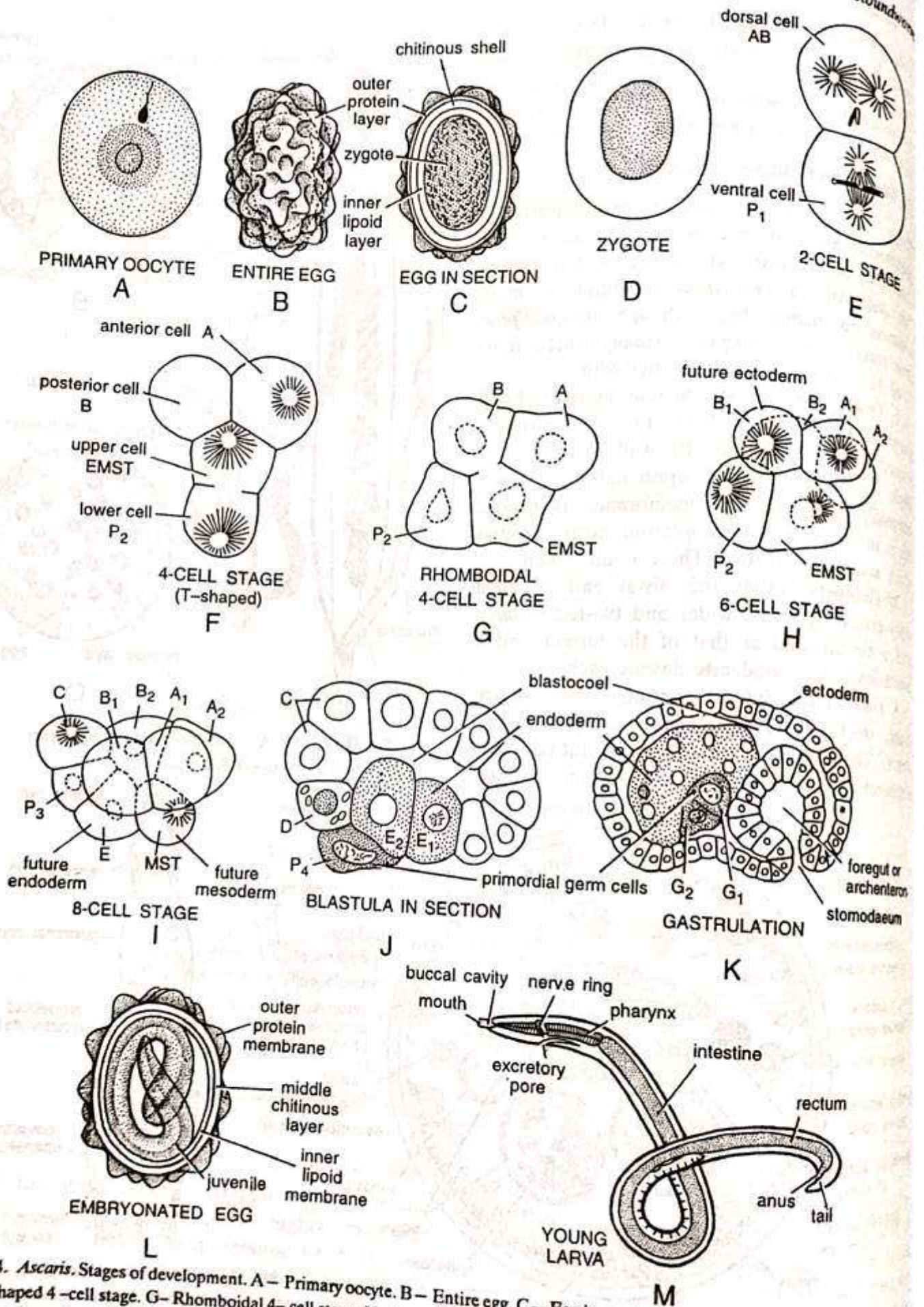


Fig. 14. *Ascaris*. Stages of development. A - Primary oocyte. B - Entire egg. C - Egg in section. D - Zygote without shell. E - 2 cell stage. F - T shaped 4-cell stage. G - Rhomboidal 4-cell stage. H - 6-cell stage. I - 8-cell stage. J - Blastula in median sagittal section. K - Early embryo in median sagittal section. L - Embryonated egg with first stage larva. M - second Free stage larva.

and outer oblique fibres. The uteri serve to store fertilized eggs enclosed in shells.

4. **Vagina.** Near the anterior one third of body, the two uteri unite to form a median, short and highly muscular tube, the *vagina*, having an inner lining of cuticle. It opens to exterior through female gonopore or *vulva*, situated mid-ventrally at about one third distance from the anterior end.

### [III] Gamete formation

In *Ascaris*, *gametogonia* are budded off from the blind proximal end of gonad and undergo gametogenesis as they move towards the distal end. This mode of germ cell formation, termed *telogonic*, occurs in most nematodes. The alternative mode termed *hologonic*, is confined to only two orders, Trichuroidea and Dioctophymoidea. In this latter mode, the germ cells proliferate along the entire length of gonad. In a *telogonic gonad*, three zones can be distinguished:

1. **Germinal zone.** Also known as *proliferation zone*, it lies at the proximal blind end of gonad. Usually a single large *terminal cell* constitutes this zone. A large *apical cell* which is in fact an epithelial cell of the gonad wall, lies in front of the terminal cell, from which *gametogonia* arise by budding.

2. **Growth zone.** It follows the germinal zone. Here *gametogonia*, which lie attached to the cytoplasmic rachis, grow and differentiate into *amoeboid gametocytes*.

3. **Maturation zone.** It is the distal most zone, where *gametocytes* separate from rachis and undergo *maturation* to form *gametes*. It is followed by the *gonoduct*.

*Spermatozoa* (sperms) are amoeboid, while the *ova* are elliptical. Ova at this stage are actually *secondary oocytes*, having resulted from *oogonia* by a single maturation division. Second maturation division occurs after *fertilization*.

### Life History

1. **Copulation and fertilization.** *Copulation* takes place in the small intestine of host (man) where the adult worms live. The male orients its body at right angles to that of female in such a way that its cloacal aperture apposes the vulva of female. Penial setae of male help to open the

vulva and sperms are transferred into vagina, from where they pass on to the proximal ends of uteri. *Fertilization*, which is effected by the entry of a sperm into ova, takes place in the proximal ends of uteri or distal ends of oviducts. After fertilization, ova undergo second maturation division.

2. **Zygote.** Unfertilized egg contains globules of glycogen and fat. Immediately after fertilization, glycogen globules migrate to the surface and form a *fertilization membrane*, which hardens into a thick, clear and *chitinous shell*. Next, the fat globules form a thin *lipoid layer* below shell. As the fertilized egg or *zygote* moves down the uterus, the uterine wall secretes around it a thick hard, yellow or brown *albuminous* (proteinous) *coat* having a typical wavy surface (*rippling*). Fertilized egg at this stage is elliptical, measuring 60-70 $\mu$  by 40-50 $\mu$ .

Uteri of a single mature female may contain as many as 27 million eggs (Cram, 1925) with an average daily production of some 2,00,000 eggs. These leave mother's body through gonopore into host's intestine and finally pass out with the host's faeces. Shelled eggs are remarkably resistant and remain alive in moist soil for several years under adverse conditions.

Under suitable conditions of temperature, moisture and oxygen, eggs undergo cleavage and develop into the infective stage. Optimum temperature for development is 85°F. Below 60°F development stops and above 100°F the eggs gradually degenerate.

3. **Cleavage and early development.** Cleavage is of *spiral* and *determinate* type. First division results in a dorsal (AB) and a ventral cell (P<sub>1</sub>). Dorsal cell divides into an anterior (A) and a posterior cell (B), while ventral cell divides into an upper (EMST) and a lower cell (P<sub>2</sub>). The four-celled embryo, thus formed, is first *T-shaped*, but soon becomes *rhomboidal* as P<sub>2</sub> comes to lie posterior to EMST.

In the next cleavage, A and B divide into right and left cells (A<sub>1</sub>, A<sub>2</sub> and B<sub>1</sub>, B<sub>2</sub>), EMST into MST and E, and P<sub>2</sub> into P<sub>3</sub> and C. Further, E divides into E<sub>1</sub> and E<sub>2</sub> and P<sub>3</sub> divides into P<sub>4</sub> and D. P<sub>4</sub> further divides into G<sub>1</sub> and G<sub>2</sub>. Fate of various cells at this stage is fixed.

(i) Descendants of A and B give rise to the

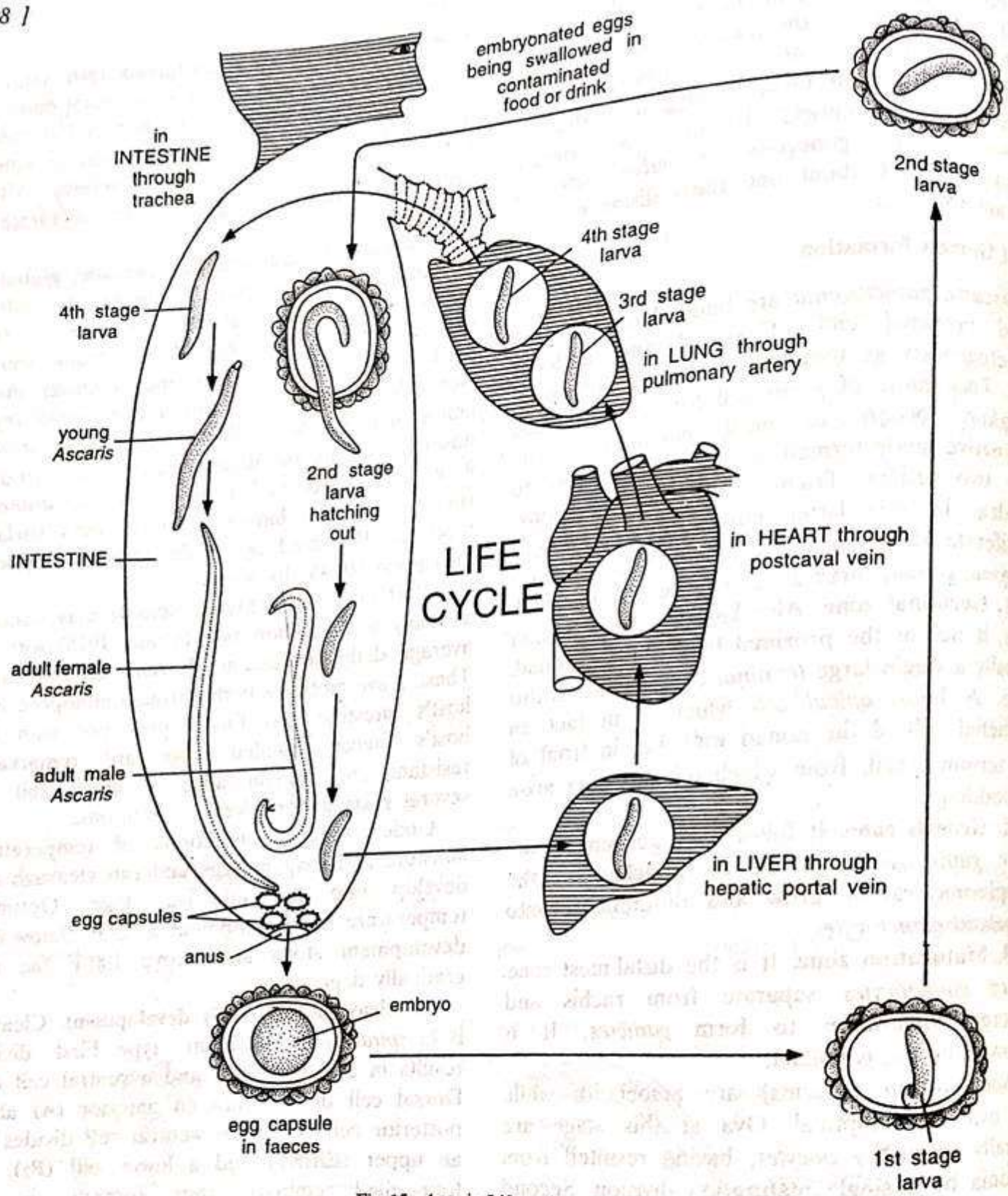


Fig. 15. *Ascaris*. Life cycle.

ectoderm. (ii) MST gives rise to mesoderm and to ectoderm of foregut. (iii) E<sub>1</sub> and E<sub>2</sub> give rise to endoderm. (iv) G<sub>1</sub> and G<sub>2</sub> form the germ cell primordium and (v) C and D together give rise to the ectoderm and mesoderm.

16-celled embryo attains the form of a hollow ball. It is termed *blastula*, and its cavity, the

*blastocoel*. Blastula undergoes a process of invagination and becomes *gastrula*. It grows in length to become an active *juvenile* in 10-14 days from the start of cleavage. Juvenile has an alimentary canal, a nerve ring and a larval excretory system. For its close resemblance with the nematode genus *Rhabditis*, found in soil and



human faeces, the juvenile is also termed *rhabditoid* or *rhabditiform larva* of first stage. It is not infective. In another week's time, it moults within the egg shell and becomes the *second stage rhabditoid*, which is capable of infecting the host. Under suitable conditions of moisture, oxygen and temperature, infective eggs of *Ascaris lumbricoides* are known to remain viable for about six years.

**4. Infection of new host.** There being no intermediate host, man acquires infection by directly ingesting *Ascaris* eggs, containing the infective second stage rhabditoid larva, with contaminated food or water. In the small intestine, by the action of host's digestive juices, the egg shells dissolve and the *juveniles* (second stage larvae) hatch out.

**5. Later development and migration.** At hatching, a juvenile measures 0.25 to 0.3 mm in length and  $13\mu$  to  $15\mu$  in diameter. It performs active thrashing movements and bores through the epithelium of host's intestine and starts its migration in host's body.

(a) **Primary migration.** Larva enters the hepatic portal circulation which carries it to the liver. From liver it finally reaches the heart through post-caval vein. From heart it is transported to the lung via pulmonary artery. Larva generally remains in lung for a few days and increases in size. Then it ruptures out of blood capillary and finally bores its way into *alveoli*. After about 6 day's stay there, the second stage larva moults to become the *third stage larva*. Another moult after 4 days results in the *fourth stage larva*, which has by this time grown to a length of 2 to 3 mm.

(b) **Secondary migration.** Fourth stage larva leaves its temporary home in lung *alveoli* and through trachea reaches the pharynx, from where it is coughed up and then swallowed for the second time into gut. In the intestine, it moults for the fourth and the last time to become an *adult*.

Adult attains sexual maturity within 8-10 weeks. The average life-span of *Ascaris lumbricoides* in the host is 9-12 months.

(c) **Aberrant migration.** Sometimes larva of *Ascaris* does not follow its usual migration path but reaches the brain or spinal cord or any such

organ. Larva is not able to survive in these organs and a calcareous cyst is formed around it.

### Parasitic Adaptations of *Ascaris*

*Ascaris* shows several adaptations to its parasitic mode of life in human intestine.

- (1) Tough, thick and resistant cuticle, covering the body, shields against the action of hosts digestive enzymes and antitoxins. *Ascaris* also secretes anti-enzymes that protect it from hosts digestive enzymes.
- (2) Power of locomotion counteracts peristalsis of host's intestine and compensates for the absence of adhesive suckers and spines. This helps the worm from getting dislodged and remain in host's intestine.
- (3) Muscular pharynx facilitates ingestion of food by sucking action.
- (4) There is a continuous supply of food, as a result the alimentary tract is simple without provision for storage.
- (5) Ingested food is pre-digested, so that there are no elaborate digestive glands.
- (6) Pseudocoelomic fluid serves for absorption, transport and distribution of food, oxygen and wastes, so that there is no circulatory system.
- (7) Extremely low metabolic rate and anaerobic respiration enables the worm to live inside the host's intestine, where free oxygen is negligible.
- (8) Parasite remains well protected inside the host's intestine, from predators, so that there is no need for complicated sensory organs which are quite simple.
- (9) Reproduction is wasteful in the extreme as transfer to a new host is full of many hazards. Firstly, the transfer to a new host is an entirely passive process depending on an accidental ingestion of embryonated eggs by some unsuspecting host. Chances become all the more difficult because the host must be a specific one. Eggs laid by a pig *ascaris* must be ingested by another pig, and similarly, the eggs laid by a human *ascaris* must be picked up by another human. Moreover, the eggs must have undergone some embryological development before ingestion by another host. If an egg is not embryonated and ingested prematurely, it will not develop into a new

worm. Further, only a warm, shady and moist environment is suitable for proper development of the eggs. Dehydration and very high (above 100°F) or low temperatures (below 60°F) are usually fatal to the developing embryos. These and many other hazards are overcome by these parasites by producing enormous quantity of eggs to ensure greater chances for survival. Thus, a single mature female may contain as many as 27 millions of eggs with a daily production of 234,000 eggs or about 162 eggs per minute, which also compensates for the lack of asexual multiplication and hermaphroditism.

- (10) Resistant covering or shell provides safety to the zygotes and embryonated eggs from unfavourable environmental factors. They remain viable for years.
- (11) Minute size, and resistant nature of eggs affords far and wide dispersal of the parasite.
- (12) Infection of a new human is direct, without an intermediate host, which makes transfer from one host to another easier and safer.

### Ascariasis

**1. Infection.** Disease caused by *Ascaris* is commonly called *Ascariasis*. Man gets infection by consuming food and water contaminated with infective eggs. Incidence of *Ascariasis* is greater in children than in adults.

**2. Pathogenesis.** *Larvae* often prove more injurious than adult worms by causing haemorrhages. They sometimes bore through intestinal epithelium and enter general circulation, which may land them in some vital organ structures like kidneys, spinal cord, brain or muscles, where they may cause serious injuries. Severe haemorrhagic conditions develop in lungs where they cause petechial haemorrhages and inflammation of alveolar tissue followed by oedema. In severe infection, they may cause acute pneumonia with fatal consequences. Frequently, infection is immediately followed by temperature, anaemia, leucocytosis and eosinophilia.

Adults usually cause *enteritis* and through their migration into vermiform appendix, gall bladder and common bile duct, may cause inflammation of these structures.

(Z-1)

Adults draw their nourishment from contents of intestine and may suck blood from its walls. Worm produces *toxins* which may cause irritation of mucous membrane, nervous symptoms like convulsions (involuntary contraction of voluntary muscles), delirium (light headedness), coma (deep sleep), and nervousness. A substance produced by parasite combines with trypsin, thus interfering with protein digestion which leads to protein deficiency and hence stunted growth especially among children. Presence of even a few parasites in intestine may result in intense colic pains, abdominal discomforts, diarrhoea, vomiting and mild temperature. Administration of drugs often irritates the parasites, which consequently get entangled in masses to block the lumen. About a hundred to a thousand or even more (up to 5,000 have been recorded) worms may be involved and may prove fatal, if not promptly removed by surgery.

**3. Therapy.** Infection may be diagnosed by examining the stool for *Ascaris* eggs. Infection can be treated with a dose of *hexylresorcinol crystals* in a gelatin capsule after about 12 hours' fasting. The dose, followed by a fast of another four hours, kills the worms, which can be finally expelled by a purgative like sodium sulphate. Some anti-helminth drugs, like oil of chenopodium, are very effective by being highly toxic, while some like tetrachlorethylene simply irritate the worms, which thus entangle and block the lumen. But a mixture of tetrachlorethylene and oil of chenopodium is very effective. Some modern successful antihelminth drugs are hetrazan, piperazine hydrate (or citrate), tetramisole and dithiazanine.

**4. Prophylaxis** (1) Soil pollution, being the chief source of infection, should be prevented. People, specially children, should be made to observe sanitary habits. (2) Vegetables grown in polluted soil should be thoroughly washed and boiled before consumption. (3) Finger nails should be regularly cut to avoid accumulation of egg below them and hands should be properly soap-washed before eating. If reinfection is completely checked, the worms can be got rid of in 9-12 months even if treatment is not taken.

**IMPORTANT QUESTIONS**

» Long Answer Type Questions

1. Give an account of the morphology and physiology of *Ascaris lumbricoides*.
2. Describe the reproductive organs of male and female *Ascaris*. Mention differences between the two.
3. Give an illustrated account of the life history of *Ascaris*.
4. What disease is caused by *Ascaris*? Write an account of its pathogenicity, therapy and prophylaxis.
5. Write a detailed note on parasitic adaptations in *Ascaris*.
6. Make full-page labelled diagrams of T.S. of male and female *Ascaris* passing through the middle of body. No description is needed.

» Short Answer Type Questions

1. What is the shape of sperm of *Ascaris* ?
2. What are the accessory structures that are present in the penial sac of *Ascaris* ?
3. Why is the living *Ascaris* not digested in the human intestine ?
4. Explain ten features of the Rhabditiform larva of *Ascaris*.
5. Trace the journey of *Ascaris* larva through the human host.
6. Define extra-intestinal migration ? Explain with reference to *Ascaris*.
7. With the aid of sketches, mention the sexual dimorphic features of *Ascaris lumbricoides*.
8. Give an illustrated account of male and female reproductive organs of *Ascaris*.
9. Draw labelled sketch of the T.S. through the middle of the body of female *Ascaris*.
10. Draw the T.S. of male *Ascaris* and mark all the parts.
11. Explain the structure of muscle fibre in nematode with a suitable sketch.

» Multiple Choice Questions

1. An *Ascaris*, the reserve food is stored as glycogen and fats in :  
(a) intestine (b) muscles  
(c) hypodermis or epidermis (d) all of these
2. The mammilated eggs of *Ascaris* are enclosed in :  
(a) one layered membrane  
(b) two layered membrane  
(c) three layered membrane  
(d) none of the above
3. Sheathed microfilaria normally circulate at night :  
(a) in the arteries (b) in the caval veins  
(c) in the peripheral blood vessels  
(d) deep in the lymph vessels
4. The mouth of *Ascaris* is guarded by :  
(a) two lateral lips  
(b) one dorsal and two ventro-lateral lips  
(c) one ventral and two dorso-lateral lips  
(d) one ventral, one dorsal and two lateral lips
5. When egg of *Ascaris* is swallowed by man it settles in intestine after :

12. Draw T.S. of female *Ascaris*, label it and mention five points in which it differs from that of *Fasciola hepatica*.
13. The innermost layer of mammilated eggs of *Ascaris* is formed of ....
14. Gonads of *Ascaris* are ....
15. Body cavity in *Ascaris* is ....
16. The sperm of *Ascaris* is .... in shape. The lumen of *Ascaris* pharynx is .... The hydrostatic skeleton of *Ascaris* consists of ....
17. Female *Ascaris* is didelphic.  
True / False / Do not know
18. Sperm of *Ascaris* is amoeboid in shape.  
True / False / Do not know
19. Male *Ascaris* is longer than the female and has anus as in female.  
True / False / Do not know
20. Caudal end of all male round worms is curved.  
True / False / Do not know
21. Rhabditiform larva performs extraintestinal migration.  
True / False / Do not know

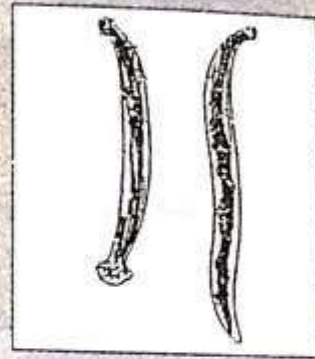
- (a) 3 days (b) one week  
(c) two weeks (d) three weeks
6. While migrating the larva of *Ascaris* takes its 4th moult in :  
(a) intestine (b) liver (c) lungs (d) heart
7. In which of these animals, the syncytial epidermis follows the cuticle :  
(a) *Fasciola* (b) *Ascaris* (c) *Taenia* (d) Earthworm
8. Pineal satae are present in :  
(a) earthworm (b) *Ascaris* (c) cockroach (d) none of these
9. The pseudocoelom of *Ascaris* is :  
(a) an intracellular space in mesodermal cells  
(b) a space between few mesodermal and endodermal cells  
(c) a space in between botryoidal tissue  
(d) intercellular space between false mesodermal cells
10. *Ascaris* has a body cavity which is :  
(a) intracellular (b) pseudocoel  
(c) intercellular & pseudocoel  
(d) highly obliterated by cells

11. *Ascaris* has no :  
 (a) cephalisation (b) alimentary canal  
 (c) receptors (d) larva
12. Maximum number of eggs released by single female *Ascaris* in any day is :  
 (a) 2,000 (b) 20,000 (c) 5,000 (d) 2,00,000
13. Final moult in life cycle of *Ascaris* takes place in :  
 (a) soil (b) lung  
 (c) intestine (d) intestine before migration
14. *Ascaris* is :  
 (a) host (b) bisexual (c) dioecious (d) digenetic
15. Infective stage of *Ascaris* for new host :  
 (a) I stage juvenile (b) embryonated egg  
 (c) II stage juvenile (d) larva after I moult
16. Embryonated egg is :  
 (a) shelled egg (b) shelled zygote  
 (c) shelled II stage juvenile (d) II stage juvenile
17. The stage hatched from the ingested egg of *Ascaris* is called :  
 (a) bladder worm (b) hexacanth  
 (c) maggot (d) rhabditiform larva
18. Ovaries of *Ascaris* are :  
 (a) monodelphic (b) diadelphic  
 (c) opisthodelphic (d) none of these
19. The lips of *Ascaris* are :  
 (a) denticulate (b) smooth  
 (c) cartilaginous (d) bony
20. Muscle cells are found in :  
 (a) body wall of *Ascaris*  
 (b) circular muscle layer of *Taenia*  
 (c) medullary parenchyma of *Fasciola*  
 (d) mesogloea of *Hydra*
21. The correct statement for *Ascaris* is that it has :  
 (a) diploblastic body (b) segmented body  
 (c) radial symmetry (d) denticulate lips
22. Epidermis in body wall of *Ascaris* is :  
 (a) cellular (b) syncytial  
 (c) with antienzymes (d) none of these
23. Excretory organs in *Ascaris* are :  
 (a) nephridia (b) kidneys  
 (c) flame cells (d) none of these
24. Two sexes of *Ascaris* can be identified as :  
 (a) post. end of female is straight  
 (b) anal papillae are found in male  
 (c) female has vulva  
 (d) all of these
25. Penial setae arise from :  
 (a) cloaca of male (b) anus of female  
 (c) vulva of female (d) none of these
26. In *Ascaris* eggs are fertilized in :  
 (a) oviduct (b) uterus  
 (c) vagina (d) outside human body
27. Eggs of *Ascaris* passed out of hosts body are :  
 (a) unfertilized (b) fertilized  
 (c) fertilized and shelled (d) with a larva
28. During development *Ascaris* needs :  
 (a) one intermediate host (b) two definitive hosts  
 (c) no intermediate host (d) no definitive host
29. In Life cycle of *Ascaris* the juvenile hatches out of egg in :  
 (a) lung (b) liver  
 (c) intestine (d) none of these
30. The final moult in Juvenile of *Ascaris* occurs in :  
 (a) lung (b) intestine (c) liver (d) none of these
31. *Ascaris* is not :  
 (a) endoparasite (b) monogenetic  
 (c) free living (d) dioecious
32. *Ascaris* has well developed :  
 (a) nervous system (b) reproductive system  
 (c) receptors (d) digestive system
33. In the development of *Ascaris*, the second stage juvenile is formed :  
 (a) within the eggs itself (b) in the intestine of man  
 (c) in the lung of man (d) in the liver of man
34. The musculature in the body wall of *Ascaris* comprises :  
 (a) outer longitudinal and inner circular muscles  
 (b) outer circular and inner longitudinal muscles  
 (c) longitudinal muscles only  
 (d) circular muscles only
35. The reproductive organs of *Ascaris* comprise :  
 (a) one pair of testes in male and one pair of ovaries in female  
 (b) a single testis in male and one pair ovaries in female  
 (c) one pair of testes in male and a single ovary in female  
 (d) a single testis in male and a single ovary in female
36. The kind of body cavity found in *Ascaris* is known as :  
 (a) haemocoel (b) enterocoel  
 (c) coelenteron (d) pseudocoel
37. Syncytial epidermis is found in :  
 (a) *Hydra* (b) *Ascaris*  
 (c) earthworm (d) star fish
38. The adult male of *Ascaris* can be identified externally by the presence of :  
 (a) pineal setae  
 (b) fifty pairs of pre-anal papillae  
 (c) five pairs of post anal papillae  
 (d) all of the above

## Answers

1. (c) 2. (c) 3. (b) 4. (b) 5. (c) 6. (a) 7. (h) 8. (b) 9. (b) 10. (b) 11. (a) 12. (d) 13. (c) 14. (c) 15. (b) 16. (c) 17. (d) 18. (b) 19. (a) 20. (a) 21. (d) 22. (b) 23. (d) 24. (d) 25. (a) 26. (a) 27. (d) 28. (c) 29. (c) 30. (b) 31. (c) 32. (b) 33. (a) 34. (c) 35. (a) 36. (d) 37. (b) 38. (d)

# *Ancylostoma duodenale*: The Common Hookworm



# 36

Chapter

Hookworms are the most dangerous parasitic roundworms, causing serious infections in humans. They belong to the order Strongyloidea of phylum Nematoda. They differ from ascaroid nematodes in the absence of *lips* but in the presence of a cuticulate buccal capsule of taxonomic importance. An outstanding morphological feature is a *copulatory bursa* in male, supported by rays, disposition of which is also of taxonomic significance. Following description applies mainly to *Ancylostoma duodenale*, the common hookworm. It was discovered in 1838 in an autopsy of an Italian peasant woman by Dubini.

## *Ancylostoma duodenale*

### Systematic Position

Phylum	Nematoda
Class	Phasmidia
Order	Strongyloidea
Family	Ancylostomidae
Genus	<i>Ancylostoma</i>
Species	<i>duodenale</i>

### Geographical Distribution

About one-half billion people, or nearly 25% of world population, are infected by hookworms.

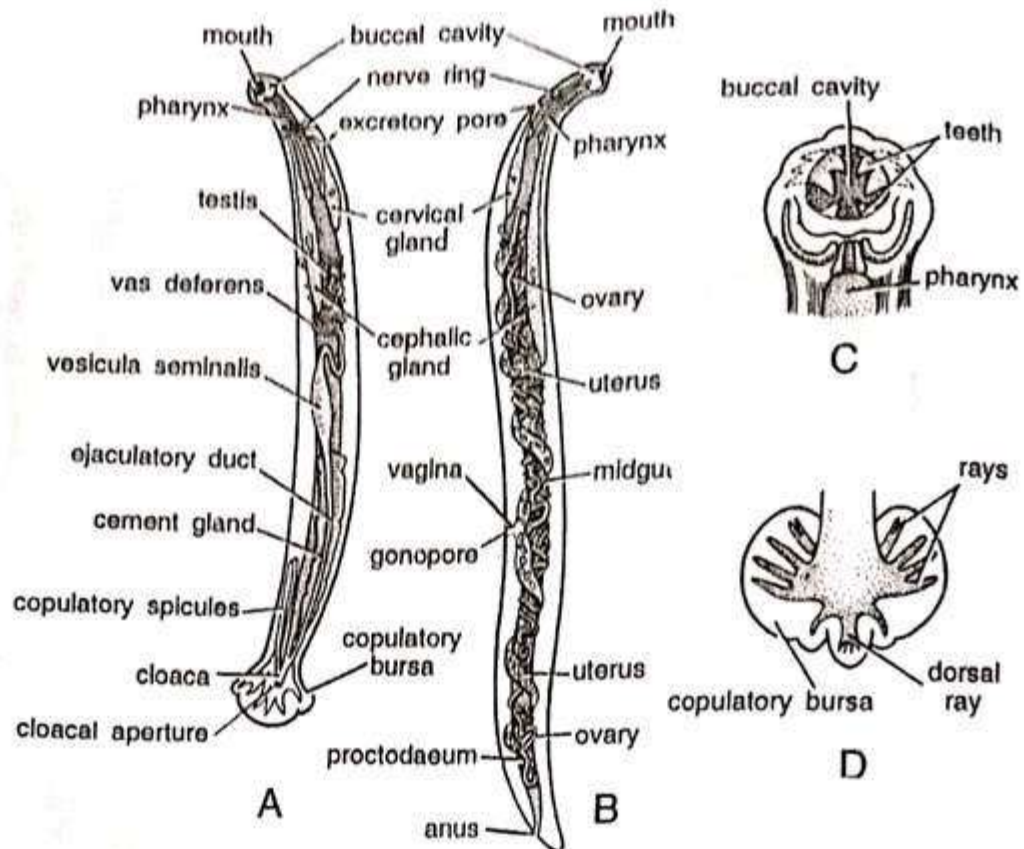


Fig. 1. *Ancylostoma duodenale*- A- Adult male. B-Adult female. C-Anterior end. D-Posterior end of male.

*Ancylostoma duodenale*, is commonly known as the "Old World Hookworm". It is common in tropical, subtropical and temperate regions of Asia, Africa, Europe, Pacific Islands and two Americas. However, the incidence is greater in Europe and Asia. Some other species, namely, *A. caninum* and *A. braziliense*, both in dogs and cats, and *A. malayanum* in bears, are also common.

### Habits and Habitat

Hookworms flourish under primitive conditions where people go barefoot, modern sanitary conditions do not exist and human faeces are deposited on ground. The adult worms live parasitically in the intestine of man where they suck blood, lymph, bits of mucous membrane and tissue fluids from the lining of the intestinal wall. The infective juveniles enter the human host percutaneously from the soil contaminated by faeces in which they abound.

### Morphology

1. **External features.** They are called 'hookworms' because the male has a hook-shaped body. Besides, prominent hooks are present in the genital bursa of male, while smaller hooks occur within the mouth of both sexes.

(a) **Shape and size.** Sexes are separate. Mature worms are cylindrical in shape and white or grey in colour. Adult male is 8 to 11 mm long and 0.4 to 0.5 mm in diameter; while adult female is generally larger, 10 to 13 mm long and 0.6 mm in diameter.

(b) **Buccal capsule.** Anterior end of male and female is similar, somewhat narrower and curved dorsally, probably the reason for their being called the hookworms. Mouth leads into a large cup-shaped cavity or buccal region or capsule, lined internally by cuticle. Entrance to mouth is armed with a pair of chitinous ventro-lateral cutting plates bearing teeth. Two sharp teeth or lancets are also present at the base of buccal

capsule which serves for attachment with the intestinal wall of host. Dorsal curving of anterior end of body presumably permits a better grip of chitinous plates and lancets on the hosts intestinal epithelium.

(c) **Copulatory bursa.** Posterior end of female tapers, while that of male is in the form of a broad, umbrella-like structure, the *copulatory bursa*, surrounding the cloaca. Bursa is supported by fleshy bursal rays having a definite arrangement. Bursal rays and teeth in buccal capsule are of taxonomic value.

2. **Body wall.** In cross section, bodywall includes from outside a cuticle, an epidermis and a longitudinally directed musculature. Body cavity is a pseudocoel surrounding the following organ systems.

3. **Digestive system.** Digestive system comprises a mouth, a buccal capsule, a muscular pharynx with a tri-radiate lumen lined with cuticle, an oesophageal bulb, an intestine, a rectum and an anus in female but a cloaca in male. Food consists of mucous membrane of host's intestine, blood cells and serum. Blood and other fluids are sucked by the sucking action of pharynx from holes cut by tiny teeth or lancets, in the intestinal wall of host, that has been pinched into buccal capsule by the cutting plates. Worms secrete an anti-coagulant in wound that prevents blood from clotting. Wounds keep oozing blood for some time even though the worms have moved to another location. Each adult worm sucks about 0.8 cc. of blood per day from the host, resulting in severe anaemia. Digestion occurs in the intestine.

4. **Excretory system.** Excretory system is similar to that of *Ascaris*. It includes two longitudinal canals in the lateral cords and short anterior excretory canal which opens to the exterior through the excretory pore.

5. **Reproductive system.** Male has a single tubular thread-like testis twisted around the intestine in the middle of body. It leads posteriorly into a vas deferens, followed by a seminal vesicle. Posterior end of seminal vesicle tapers into an ejaculatory duct which enters the cloaca.

Female has two much convoluted ovarian tubules, one anterior and the other posterior, to the

level of gonopore. Each ovary leads into a short oviduct that opens into a dilated seminal receptacle. From the latter arises a muscular uterus that terminates into a vagina. Two vaginae become confluent and open through the common gonopore or vulva.

## Life Cycle

1. **Copulation and fertilization.** Hookworms mate in the host's intestine. During copulation, bursa of male is applied on the vulva of female and sperms transferred. Fertilization occurs in the seminal receptacles.

2. **Eggs.** Fertilized eggs pass out with the host's faeces. Each female produces about 9,000 fertile eggs per day. Eggs are oval in shape and protected by hyaline chitinous shells. Zygote within has already cleaved into a four or eight-celled embryo.

3. **Larvae.** Under favourable environmental conditions of moisture, oxygen supply and temperature (68-85°F), embryo develops into the *first-stage juvenile* or *rhabditiform larva* which hatches out within 24 to 48 hours. Newly hatched larva has a mouth, a buccal capsule, an elongated pharynx with an oesophageal bulb, and an intestine. It feeds on bacteria of faeces or other organic debris of soil for 4 to 5 days and moults twice to form a *third-stage juvenile* or *filariform larva*. This juvenile is about 0.5 mm long and infective for man. It has a nonpatent mouth and therefore does not feed. But, it remains alive and infective for several weeks under favourable conditions.

4. **Infection of a new host.** Filariform larva infects a new host (man) by chance contact with his skin. Its anterior end is equipped with oral spears which enables larva to penetrate skin of a potential human host. Larvae may bore through skin in any part of body. Generally they penetrate the soft skin on the sides of feet and hands, through hair follicles. Their penetration is generally accompanied by a severe dermatitis called "ground itch", characterized by ulceration of skin about wounds. Besides percutaneous entrance, infection is also possible through ingestion of contaminated food and water.

5. **Larval migration.** Within 24 hours of infection, larvae reach blood vessels and follow

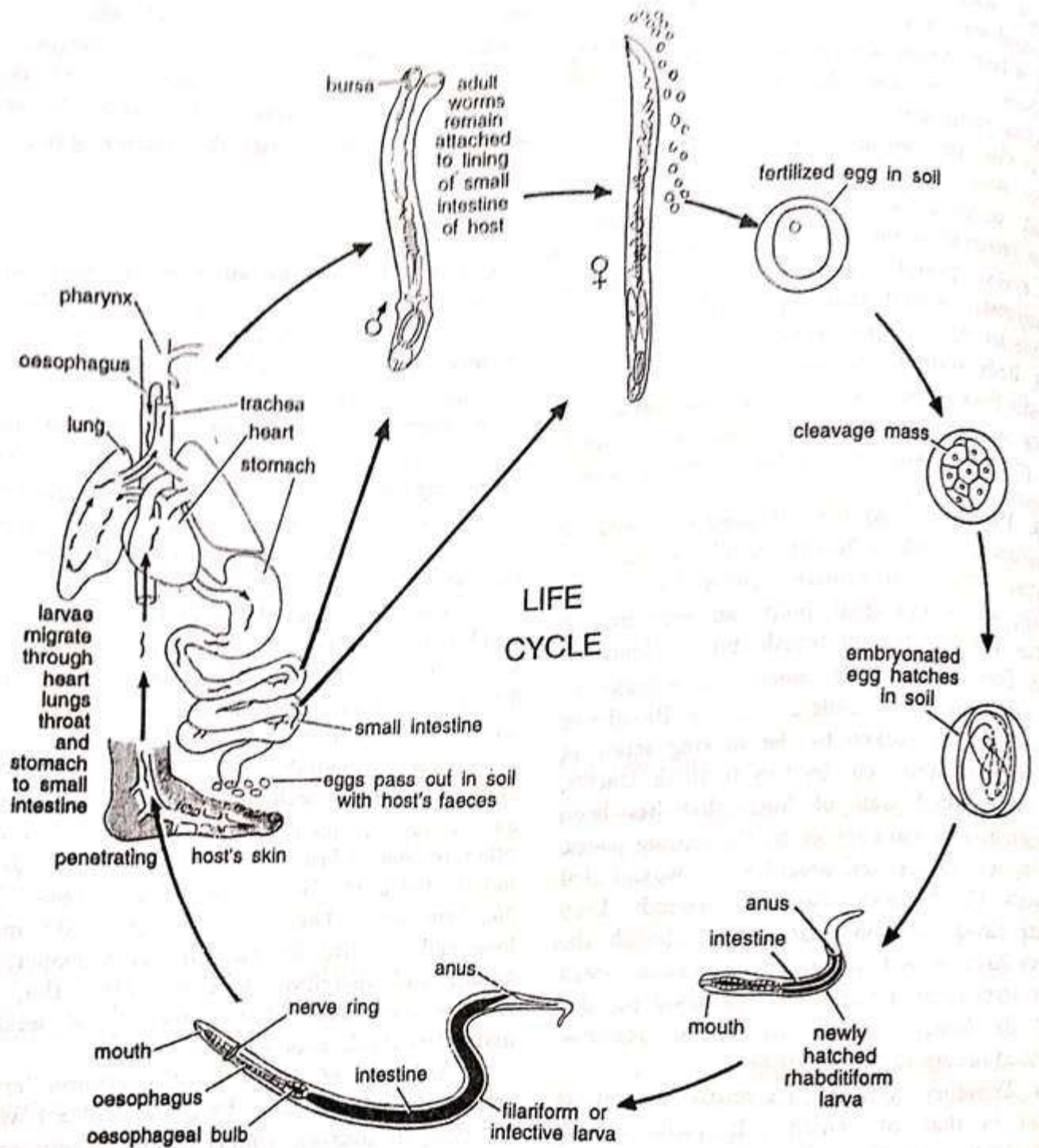


Fig. 2. *Ancylostoma duodenale*. Life cycle.

the same migratory course described for the larvae of *Ascaris*. In blood stream they are carried first to the right ventricle of heart and then to lungs by way of pulmonary arteries. In lungs they break out of pulmonary capillaries into alveolar spaces. From lungs larvae ascend trachea to reach pharynx, become swallowed through oesophagus and finally reach the small intestine (ileum), where they become attached to

the mucous lining and feed on blood of host. In 5 to 6 weeks, they moult twice to become adult. Male and female copulate and female starts laying eggs which pass out in the faecal material of human host.

Normal life-span of hookworms is 5 to 7 years that can extend to a maximum of 16 years (Taylor, 1933).



## Ancylostomiasis

*Ancylostomiasis* is the name given to infection caused by the Old World hookworm *Ancylostoma duodenale*. Larvae which occur in contaminated soil, invade the host (man) and burrow through skin of feet into blood.

1. **Diagnosis.** Hookworm infection is diagnosed by the observation of hyaline "eggs" in a faecal smear from infected person.

2. **Pathogenesis (symptoms).** Pathogenicity is fairly extensive involving skin, lungs and small intestine. Penetrating larvae cause characteristic tiny and irritating sores, called *dew sores* or *ground itching*, and inflammation of skin. In lungs, migratory larvae cause petechial haemorrhages and bronchial pneumonitis. But greatest damage occurs in small intestine by the adult worms. Here, the punctured wounds continue to bleed for some time so that more blood is lost than worms can consume. This results in severe anaemia, decrease in general immunity and bloody stools. Intestinal wounds may lead to various forms of detrimental infections. Deleterious toxins secreted by glands in head region of worms cause stomach pain, food fermentation, diarrhoea, constipation, dyspnea, palpitation of heart, eosinophilia, loss of health and collapse. Mental and physical growth is retarded in children and growing youth. Patient tries to ease the epigastric pain by eating, even dirt, hence the term "dirt eaters". Unchecked infection may lead to fatty degeneration of heart, liver and kidneys, ending in death.

3. **Therapy (treatment).** Treatment involves administration of drugs, such as carbon tetrachloride, thymol, oil of chenopodium, hexylresorcinol, etc. — Most commonly recommended drug is tetrachloroethylene or

blephenium because of its high efficiency and low toxicity. Treatment is followed by a purge to flush out the dead worms. Iron is usually prescribed to overcome the haemoglobin deficiency due to anaemia.

4. **Prophylaxis (control).** The Hookworm disease is responsible for considerable economic loss as well as poor health. Important prophylactic or preventive measures include wearing shoes and sanitary disposal of human faeces in affected areas so that soil may not be polluted.

## *Necator americanus*

Another important human hookworm is the "New World hookworm" or *Necator americanus*, which literally means the "American killer." It is the causative agent of the hookworm disease or *Necatoriasis* in man in Africa, Asia, Sri Lanka and tropical America. It is believed to be introduced into America, before their civil war, with the infected slaves from central and southern Africa. It was first discovered in 1902 by Stiles.

*Necator americanus* is smaller than *Ancylostoma duodenale*. Adult female attains a length of 10 mm, whereas male is still shorter. Buccal capsule has a pair of ventral plates and a pair of relatively smaller dorsal plates which lack teeth, unlike *Ancylostoma*. Each pair of plates presents a halfmoon appearance, hence the name *semilunar plates*. Besides plates, there is a dorsal cone and two pairs of lancets in the base of buccal capsule. Bursa of *Necator* is longer and narrower than that of *Ancylostoma*. Female *Necator* is capable of delivering about 15,000 eggs per day. Rest of Morphology, life cycle, diagnosis, pathogenicity, therapy and prophylaxis are similar to those of *Ancylostoma*.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. Describe the structure and life-history of *Ancylostoma duodenale*.
2. What disease is caused by *Ancylostoma*? Describe its pathogenesis, therapy and prophylaxis.
3. Enumerate the main differences between *Ancylostoma* and *Necator*.

#### » Short Answer Type Questions

1. Why *Ancylostoma* is known as hookworm?
2. Where adult *Ancylostoma duodenale* lives?
3. Describe the structure of copulatory bursa of male *Ancylostoma*.
4. Draw a well labelled diagram of male *Ancylostoma*.
5. Infective juveniles enter the human host .... from the contaminated soil.
6. At the posterior end copulatory bursa is found in ... worm.
7. Male hook worm is larger than that of female. True / False / Do not know

#### » Multiple Choice Questions

1. Rhabditiform larvae of *Ancylostoma duodenale* grows by feeding is parasite of :
 

(a) man	(b) horse
(c) cow	(d) pig
2. Infective stage of larva is :
 

(a) filariform larva (3rd stage juvenile)	(b) rhabditiform larva (1st stage juvenile)
(c) 4th stage juvenile	(d) zygote
3. Rhabditiform larva hatches out in :
 

(a) 24 to 28 hrs.	(b) 36 to 48 hrs.
(c) 48 to 60 hrs.	(d) 3rd day
4. *Ancylostoma* live in intestine of man and feed upon :
 

(a) digestive juice	(b) blood
(c) food	(d) all of these
5. No secondary host in life history of :
 

(a) <i>Fasciola</i>	(b) <i>Taenia</i>
(c) <i>Ancylostoma</i>	(d) <i>Plasmodium</i>
6. Who discovered *Ancylostoma* :
 

(a) Dubini	(b) Manson
(c) Ross	(d) Huxley
7. The cause of Ancylostomiasis :
 

(a) <i>Wuchereria</i>	(b) <i>Trichuris</i>
(c) <i>Ancylostoma</i>	(d) <i>Enterobius</i>
8. The 'Old World Hookworm' :
 

(a) <i>Ancylostoma</i>	(b) <i>Wuchereria</i>
(c) <i>Enterobius</i>	(d) none
9. *Ancylostoma* generally known as :
 

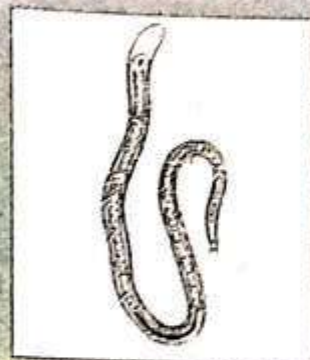
(a) pinworm	(b) whip worm
(c) eye worm	(d) hook worm
10. Maximum puple infected by :
 

(a) <i>Taenia</i>	(b) <i>Ascaris</i>
(c) <i>Ancylostoma</i>	(d) <i>Trypanosoma</i>

### Answers

1. (a) 2. (a) 3. (a) 4. (b) 5. (c) 6. (a) 7. (c) 8. (a) 9. (d) 10. (c)

# *Wuchereria bancrofti*: The Filarial Worm



## 37 Chapter

The filarial nematodes belong to the order Filarioidea. They are lipless and filiform worms in which pharynx is not bulbous, but muscular anteriorly and glandular posteriorly. Genital aperture in female is present in the pharyngeal region, and males are non-bursate. Following description belongs to *Wuchereria* (= *Filaria*) *bancrofti*, the human filarial worm causing filariasis or elephantiasis.

### *Wuchereria bancrofti*

#### Systematic Position

Phylum	Nematoda
Class	Phasmodia
Order	Filarioidea
Family	Filariidae
Genus	<i>Wuchereria</i>
Species	<i>bancrofti</i>

#### Geographical Distribution

*Wuchereria bancrofti* has a widespread distribution throughout world except Polar regions. It is found in Arabia, India, Malaya, China, Korea, Japan, East Indies, Brazil and South Pacific Islands. It is relatively absent from Europe, North America and Africa.

#### Habits and Habitat

Filarial worm is a dreaded human parasite of human blood and lymph. It is a digenetic parasite completing its life cycle in two hosts. Final host is man harbouring the adult worms, while intermediate host is a blood-sucking insect, usually a mosquito. Adult worms live coiled up in the lymph glands and lymph passages of man, where they often obstruct the flow of lymph.

### Morphology

Adult worms are filiform and cylindrical in shape and both body ends terminate bluntly. They are coloured creamy white. Sexes are separate and there is a distinct *sexual dimorphism*. Female measures 65 to 100 mm in length and 0.25 mm in diameter, while male 40 mm and 0.1 mm, respectively. Mouth aperture is simple, without lips. Pharynx or oesophagus is divisible into an anterior muscular portion and a posterior glandular portion. An oesophageal bulb is lacking. Intestine is simple, as in other nematodes. Posterior end of male is sharply curved ventrally, containing a number of genital papillae, caudal alae and two unequal copulatory spicules. Vulva or genital pore of female is located ventrally in the pharyngeal region, and provided with pyriform ejector mechanism or ovjector.

### Life Cycle

**1. Copulation.** *Copulation* takes place when individuals of both sexes are present in the same lymph gland.

**2. Larval development in man.** Female is viviparous (probably ovoviviparous) releasing numerous Juveniles called *microfilariae*. They are born in a very immature state, being in fact embryos rather than juveniles. They are microscopic, about 0.2 to 0.3 mm long, surrounded by a delicate cuticular sheath and containing rudiments of various adult structures. 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 backwards are: future mouth or oral stylet, nerve ring band, nephridiopore, renette cell, darkly staining inner mass, 4 large cells and future anus. *Microfilariae*, discharged into lymph vessels, soon enter blood vessels and circulate with blood showing active movements. They migrate to reside ultimately in deeper blood vessels of thorax. But they do not undergo

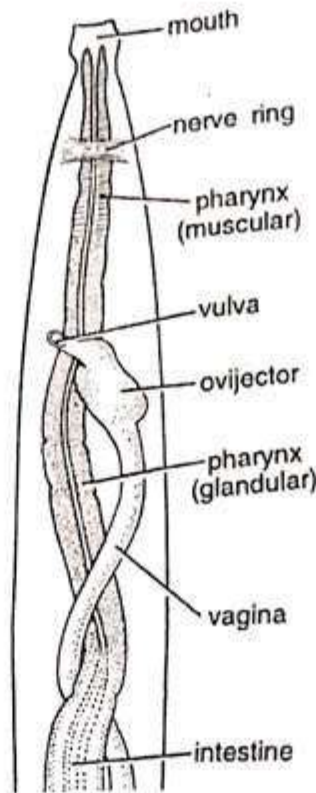


Fig. 1. *Wuchereria bancrofti*. Anterior part of female.

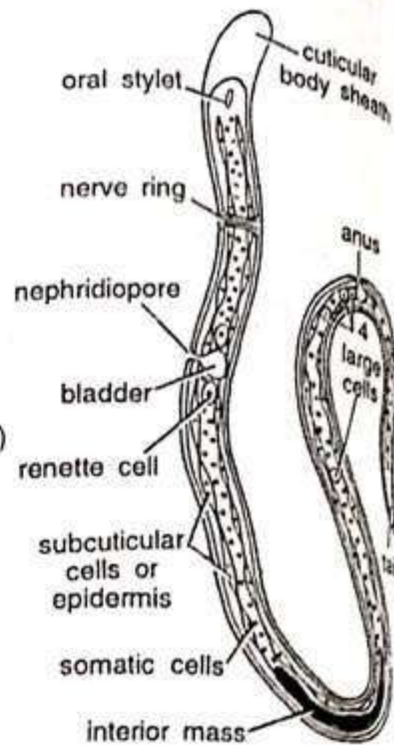


Fig. 2. *Wuchereria bancrofti*. Juvenile or microfilaria.

further development until sucked by the intermediate host, i.e., mosquito\*.

In blood of man, microfilariae show day and night periodicity, called diurnal rhythm. By day they live in large deep-seated blood vessels, but at night or during sleep they come into superficial or peripheral vessels in skin, to be sucked by nocturnal mosquitoes (*Culex* or *Aedes*) which serve as intermediate host. In places where there are diurnal mosquitoes, they reverse this periodicity. Microfilariae in human blood eventually die unless ingested by the intermediate host sucking blood from infected humans.

**3. Development in mosquito.** In the stomach of mosquito microfilariae lose their sheath, penetrate the stomach wall and migrate to thoracic muscles or wing musculature where they undergo metamorphosis and grow. They change first to a plump sausage-shaped organism, later to a more elongated form, and finally to a long slender juvenile of the third infective stage.

\* Filarioidea differ from all other nematodes in that they require transmission through skin by a blood sucking intermediate host. This was discovered by Manson, in 1878, for *Wuchereria bancrofti*. Incidentally, this discovery was the first proof of transmission of a human blood parasite by an insect.

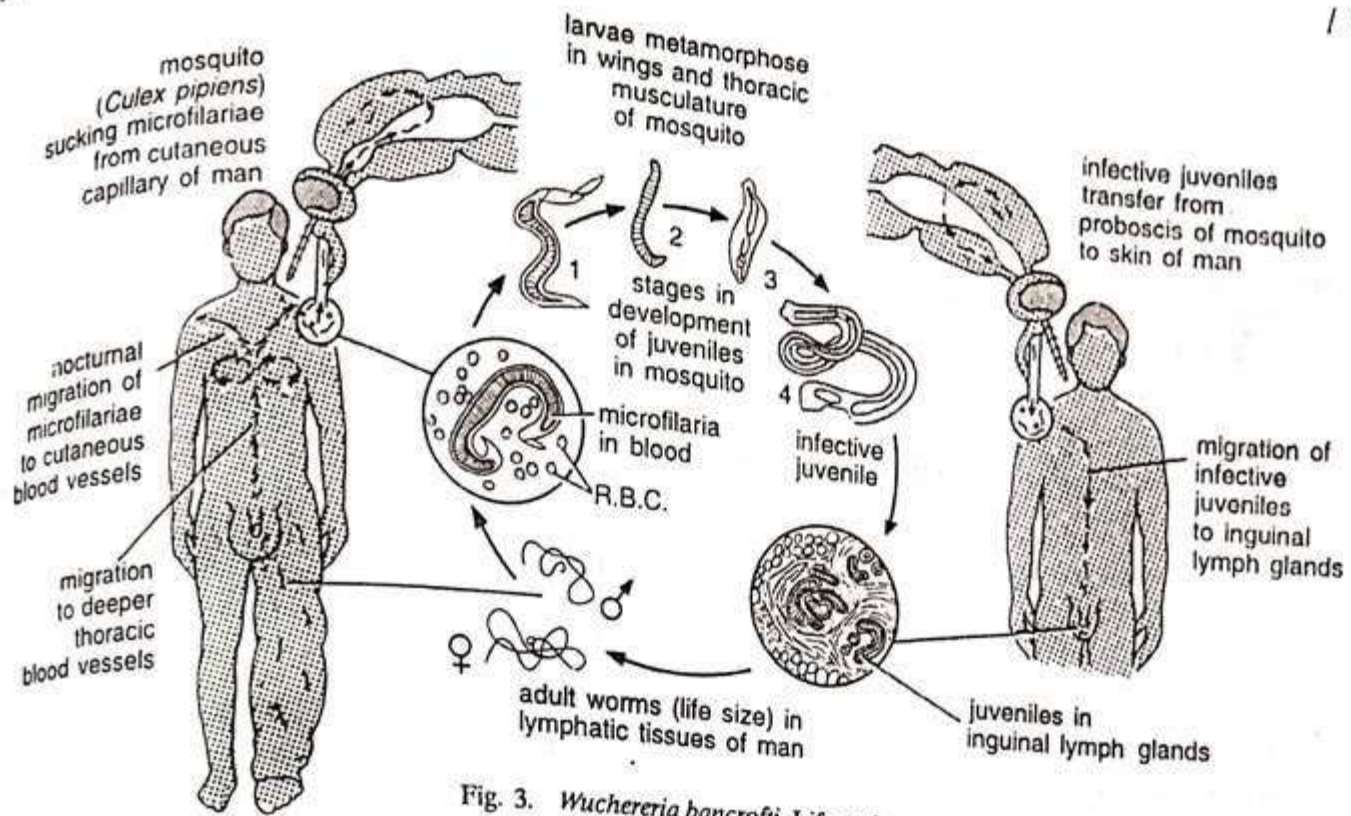


Fig. 3. *Wuchereria bancrofti*. Life cycle.

Microfilariae undergo two moults in about 10 days to reach the third stage larvae which are about 1.5 mm long. Infective juveniles now migrate into mosquito's labium (proboscis).

4. **Infection of new human host.** When this mosquito pierces its proboscis into another potential human host, the infective juveniles come out of labium on the skin of victim and enter it. They probably penetrate through the wound made by mosquito and enter blood of human host. In new human host, juveniles pass into lymph glands and lymph passages, where they coil up and develop into adult forms. Adults copulate and the females deliver microfilariae.

### Filariasis or Elephantiasis

Filarial worms (*Wuchereria bancrofti*) live in the lymphatic system of man, where they obstruct the flow of lymph, causing a severe condition known as *elephantiasis*, in which the limbs or other body parts grow to enormous size.

1. **Diagnosis.** Diagnosis of filarioids involves the study of microfilariae after staining. Microfilariae of different species are identified after their specific shape and morphological characters.

2. **Pathogenesis.** Light infection produces no serious symptoms. It causes filarial fever, mental depression, headache, etc., In heavy infection, accumulation of living or dead worms eventually blocks the lymphatic vessels and glands, resulting in various pathological conditions. Most spectacular is the immense swelling of the affected body parts, termed *elephantiasis* or *filariasis*. Due to lymphatic obstruction lymph cannot get back into circulatory system, accumulates into organs and causes them to swell or enlarge to fantastic proportions (lymphedema). Generally lower limbs, scrotum in male, legs and mammary glands are affected. Concurrently there occurs inflammations of lymphatic vessels (lymphangitis) and lymphatic glands (lymphadenitis). In severe cases, abnormal connective tissue form in the affected areas to further complicate the condition.

3. **Therapy and control.** No proper or satisfactory treatment is yet known. Infection may be reduced or eliminated by eradication of microfilariae from circulation by administering heterazan and compounds of antimony and arsenic. An important preventive measure is protection from mosquito bites.

**IMPORTANT QUESTIONS**

» Long Answer Type Questions

1. Describe the habitat, structure and life history of any nematode studied by you.
2. Describe the habit, mode of infection, effect on the human host and other important features in the life history of *Wuchereria bancrofti*. How would you account for its periodicity?

» Short Answer Type Questions

1. Name the intermediate host of *Wuchereria bancrofti*.
2. Write the name of the insect vector that is involved in the transmission of elephantiasis.
3. Explain the externals of *Wuchereria bancrofti* and write the points of differentiation between male and female.
4. Describe the life history of *Wuchereria bancrofti*.
5. Mode of transmission in filaria is inoculative.  
True / False / Do not know
6. Eradication of mosquitoes will eradicate spreading of parasitic disease elephantiasis.  
True / False / Do not know
7. Microfilariae occur in peripheral blood vessels of the man throughout the day.  
True / False / Do not know
8. Females of *Wuchereria bancrofti* give rise to microfilaria by parthenogenesis.  
True / False / Do not know

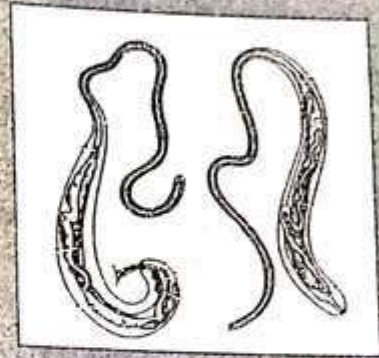
» Multiple Choice Questions

1. Elephantiasis is a common disease in :  
(a) sub tropical countries  
(b) sub tropical and tropical countries  
(c) tropical countries  
(d) polar regions only
2. The vector of elephantiasis is :  
(a) *Culex* mosquito (b) female mosquito  
(c) female *Anopheles* mosquito  
(d) infected *Culex* mosquito
3. *Wuchereria bancrofti* is transmitted by :  
(a) Tse tse fly (b) *Anopheles*  
(c) *Culex* (d) Sandfly
4. Microfilariae during night resides in :  
(a) deep seated blood vessels  
(b) peripheral vessels  
(c) caval veins (d) mesenteric veins
5. Viviparity generally occurs in :  
(a) *Wuchereria* (b) *Ancylostoma*  
(c) *Enterobius* (d) *Trichuris*
6. Microfilaria is larva of :  
(a) tape worm (b) pin worm  
(c) round worm (d) filarial worm
7. Filariasis result as the *Wuchereria* due to :  
(a) block lymph gland  
(b) block blood capillary  
(c) block the veins  
(d) block the artery
8. The place where adult *Wuchereria bancrofti* :  
(a) human blood vessels (b) human lymph gland  
(c) muscles of *Culex*  
(d) salivary gland of *Culex*
9. *Wuchereria* was discovered by :  
(a) Huxley (b) Manson  
(c) Ross (d) Leibe
10. Transmission of *Wuchereria* to new host :  
(a) larval stage (b) encyst stage  
(c) juveniles stage (d) none of the above

**Answers**

1. (b) 2. (d) 3. (c) 4. (b) 5. (a) 6. (d) 7. (a) 8. (b) 9. (b) 10. (c)

# Phylum Nematoda: Characters, Classification and Types



## 38

### Chapter

Nematodes (Gr., *nema* thread + *eidos*, form) are commonly referred to as nonsegmented roundworms, threadworms or pinworms, as distinct from lower flatworms and higher segmented annelids. They constitute the largest phylum of pseudocoelomate groups combined under the super phylum Aschelminthes.

### General Characters

Main distinguishing features of phylum Nematoda are as follows:

1. Widely distributed, aquatic or terrestrial, and parasitic or free living.
2. Body elongated, cylindrical, unsegmented, worm-like, bilaterally symmetrical, and tapering towards both ends.
3. Body triploblastic with organ-system grade of organization.
4. Body wall with thick resistant cuticle, cellular or syncytial epidermis, and only longitudinal muscle fibres in four bands.

5. True coelom absent. Persistent blastocoel or pseudocoel present not lined by mesoderm.
6. No cilia, no circulatory and no respiratory system.
7. Digestive system complete with anus, with muscular pharynx and non muscular intestine.
8. Excretory system of glandular organs or canals or both. Flame cells absent.
9. Nervous system with circumenteric ring and anterior and posterior nerves.
10. Sense organs poorly developed, in the form of small papillae and amphids near on two body ends.
11. Dioecious with sexual dimorphism. Male smaller than female. Gonads simple and coiled. Male genital ducts lead into cloaca. Female genital ducts with a separate opening. No asexual reproduction.
12. Fertilization internal. Development usually direct, with or without an intermediate host.

## Classification

Nematodes are among the most numerous of any phylum. Every fistful of soil may contain thousands of them. About 15,000 species of nematodes are known at present. Their classification is difficult due to much diversity in form and structure. Chitwood (1933) divided them into two classes, *Phasmidia* and *Aphasmidia*, on the basis of presence or absence of phasmids. These are grouped into 17 orders, but only some important orders have been included below.

### Class 1. Aphasmidia (Adenophorea)

1. Phasmids (caudal sensory organs) absent.
2. Amphids (anterior sense organs) of various types, rarely pore-like.
3. No excretory system. If present, poorly developed.
4. Mesenterial tissue well developed.
5. Caudal adhesive glands present.

#### Order 1. Enoploidea

1. Anterior end with six labial papillae and 10-12 sensory bristles.
2. Cuticle usually with bristles.
3. Amphids cyanthiform.
4. Chiefly marine, free-living.  
Examples : *Enoplus*, *Metonchdiamus*.

#### Order 2. Dorylaimoidea

1. Anterior end with 6-10 papillae.
2. Cuticle smooth, no bristles.
3. Amphids cyanthiform.
4. Buccal cavity with protrusible spear.
5. Free-living in soil and fresh-water.  
Example : *Dorylaimus*, *Tylencholaimus*.

#### Order 3. Mermithoidea

1. Large-sized.
2. Anterior end with 16 labial papillae and no sensory bristles.
3. Cuticle smooth, no bristles.
4. Amphids cyanthiform or reduced.
5. Oesophagus long leading into blind intestine.
6. Larvae parasitic in invertebrates, adults free-living.  
Examples : *Mermis*, *Agamermis*, *Paramermis*.

#### Order 4. Chromadoroidea

1. Small-sized.
2. Cuticle smooth or ringed; with heavy bristles.

3. Amphids spiral.
4. Buccal cavity with teeth.
5. Pharynx with posterior bulb.
6. Mostly marine; free-living.  
Example : *Halichoanolaimus*.

### Order 5. Monohysteroidea

1. Small-sized.
2. Amphids circular.
3. Cuticle smooth or slightly ringed, often with bristles.
4. Anterior end with 4, 6, 8, or many sensory bristles.
5. Free-living; mostly marine, some fresh-water, some terrestrial.  
Examples : *Monohystera*, *Plectus*.

### Order 6. Desmoscolecoida

1. Small-sized.
2. Amphids crescent-shaped or pump-shaped.
3. Cuticle heavily ringed.
4. Anterior end with four sensory bristles, head armoured.
5. Marine; free-living.  
Example : *Desmoscolex*, *Epsilonema*.

### Class 2. Phasmidia (Secernentea)

1. Phasmids present.
2. Amphids pore-like.
3. Excretory system developed.
4. Mesenterial tissue weakly developed.
5. No caudal adhesive glands.

#### Order 1. Trichuroidea (Trichinelloidea)

1. Body filiform anteriorly.
2. Mouth without lips; pharynx slender.
3. Female with one ovary and male with one or none spicule.
4. Parasites of vertebrates.  
Examples : *Trichuris*, *Trichinella*.

#### Order 2. Dioctophymoidea

1. large worms.
2. Mouth without lips; with 6, 12 or 18 papillae.
3. Pharynx elongated and with no bulb.
4. Female with one ovary and male with one or more spicule and muscular bursa.
5. Parasites of mammals and birds.  
Examples : *Dioctophyma*, *Hystrichis*.

#### Order 3. Rhabditoidea

1. Small to moderate sized.
2. Cuticle smooth or ringed.



3. Sensory bristles as papillae in two rings an inner ring of 6 and outer ring of 4, 6 or 10.
4. Copulatory spicules in male accompanied by gubernaculum.
5. Free-living or parasitic in animals and plants. Examples : *Rhabditis*, *Heterodera*.

#### Order 4. Rhabdiasoidea

1. Medium-sized.
2. Cuticle smooth.
3. No pharyngeal bulb.
4. Parasite stage in vertebrates is either hermaphroditic or parthenogenetic. Examples : *Rhabdias*, *Strongyloides*.

#### Order 5. Oxyuroidea

1. Pin-shaped small worms.
2. Mouth surrounded by 3-6 simple lips.
3. Pharynx with valvular posterior bulbs.
4. Female with long pointed tail.
5. Parasitic in invertebrates and vertebrates. Examples : *Oxyuris*, *Enterobius*.

#### Order 6. Ascaroidea

1. Large-sized worms.
2. Mouth surrounded by 3 lips.
3. Pharynx without bulb.
4. Male with ventrally coiled tail.
5. Parasitic in vertebrates. Examples : *Ascaris*, *Ascaridia*.

#### Order 7. Strongyloidea

1. Mouth without lips but with leaf crowns.
2. Buccal capsule well developed.
3. No pharyngeal bulb.
4. Male with expanded copulatory bursa; female usually with ovjector.
5. Parasites of vertebrates. Examples : *Necator*, *Ancylostoma*, *Strongylus*.

#### Order 8. Spiruroidea

1. Mouth with two lateral lips.
2. Pharynx with bulb, muscular anteriorly and glandular posteriorly.
3. No copulatory bursa in male but with spirally coiled tail.
4. Parasites in animals. Examples : *Thelazia*, *Gnathostoma*, *Spiroxyx*.

#### Order 9. Dracunculoidea

1. No lips or buccal capsule.
2. Mouth surrounded by ring of papillae.

3. No pharyngeal bulb; pharynx muscular anteriorly and glandular posteriorly.
4. Male without copulatory bursa.
5. Parasites of vertebrates. Examples : *Dracunculus*, *Philometra*.

#### Order 10. Filarioidea

1. Filiform slender worms.
2. No lips and buccal capsule.
3. Six labial papillae present.
4. No pharyngeal bulb.
5. Male small with coiled tail.
6. Microfilariae in blood or skin and develop in blood-sucking insects.
7. Parasites of vertebrates. Examples : *Wuchereria*, *Microfilaria*, *Loa*.

### Common Nematode Parasites

1. *Trichuris trichiura* (The Whip Worm). This parasitic nematode dwells in the caecum and large intestine of man, especially children, in tropical regions. Adult female measures 30 to 50 mm in length, male being slightly shorter. Anterior two-third of body is narrow and presents a thread-like or whip-like appearance, hence the name 'whip worm'. This whip-like portion contains the long oesophagus and anchors worm to wall of host's intestine. Life cycle is direct. Eggs pass out with faeces and embryonate in about three weeks' time in moist soil. Host acquires infection by ingesting embryonated eggs with contaminated food or drink. Larvae hatch out near caecum and develop into adults in about two months. Infection usually causes gastro-intestinal troubles. Heavy infections cause severe diarrhoea and even anaemia due to blood sucking habit of adults.

2. *Trichinella spiralis* (The Trichina Worm). *Trichinella spiralis* or 'Trichina worm' is an important parasitic nematode of man, and other mammals like pig, dog, cat, rat, black bear and polar bear. It causes a disease known as trichinosis, common in U.S.A., Europe and the Arctic regions. Parasite occurs as a coiled, encysted larva in voluntary muscles of host, usually in limbs, chest, diaphragm, tongue, eye and neck. Larva measures about 1.0 mm in length, while the cyst has a diameter of 0.25 to 0.5 mm. One ounce of flesh may contain (Z-1)

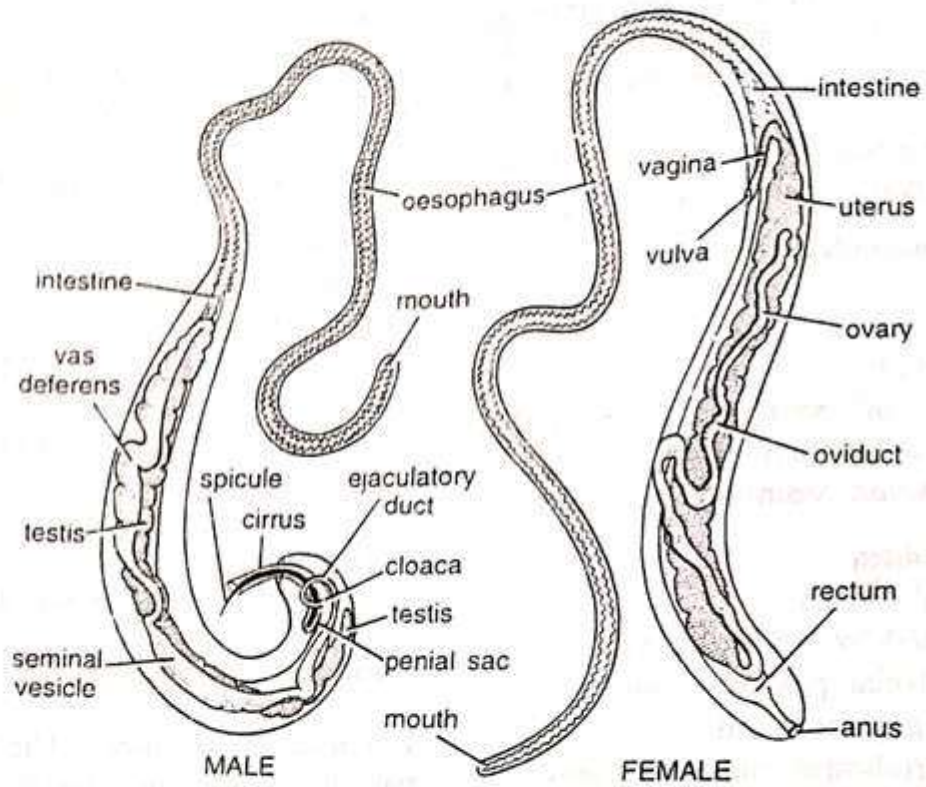


Fig. 1. *Trichuris trichiura*. Male and female individuals.

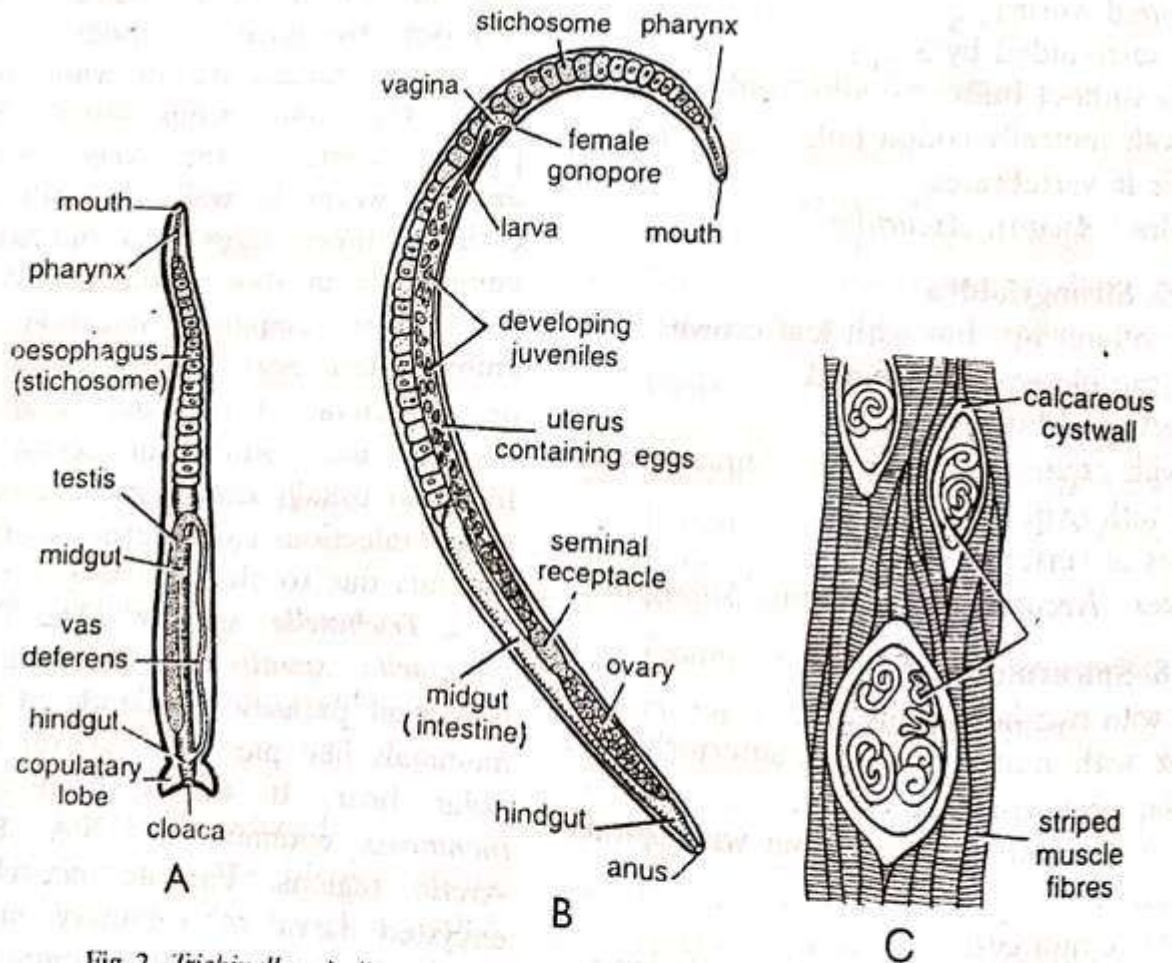


Fig. 2. *Trichinella spiralis*. A—Adult male. B—Adult female. C— Encysted larvae in striped (voluntary) muscle of pig.

thousands of such larvae. A new host acquires infection by eating raw or improperly cooked flesh containing encysted larvae. Cysts dissolve by the action of digestive juices and larvae are liberated in the intestine of new host. They soon move to safer places between villi of intestine. Within about two day's time they attain sexual maturity and become adults. Adults are short-lived, surviving only for a week or two but encysted larvae retain viability for several years.

Males are smaller than females. Male is 1.4-1.6 mm long and female 3-6 mm. In both sexes, anterior end is pointed and posterior end fleshy. Cuticle is transversely striated. Mouth leads into pharynx followed by the capillary oesophagus embedded in large granular cells, called *stichosomes*. Male has a pair of conical appendages or *copulatory lobes* at the posterior end.

Copulation takes place in intestine, after which males usually die and pass out. Females burrow into intestinal wall and live there for some time, each producing about 1,500 young larvae, about 0.1 mm long. These enter lymphatics or blood circulation and reach voluntary muscles, where they grow to a length of about 1.0 mm, coil up and encyst. Formation of cyst is completed in about 9 weeks. Larvae, within cysts, may remain viable for 10 to 20 years or even more, but finally undergo calcification and die. Calcified cysts persist in host's muscles throughout life. Viable encysted larvae attain sexual maturity only when ingested by a new host. Human infection is practically a "dead end" for the worm, because consumption of human flesh is rare.

Mild infection usually produces no symptoms. Heavy infection causes the disease *trichinosis*, producing a variety of symptoms like diarrhoea, nausea, abdominal pain, hyper eosinophilia, thrombosis, muscular pains etc. As the larvae spread, there is fever and muscles swell and harden. Difficulty in breathing and swallowing may also be felt. Heavy infections may be fatal. There is no sure treatment for the disease. However, piperazine citrate has been found effective in the removal of adult worms from intestine.

3. *Rhabditis*. This genus includes several free-living and semi parasitic forms. *R. hominis* is

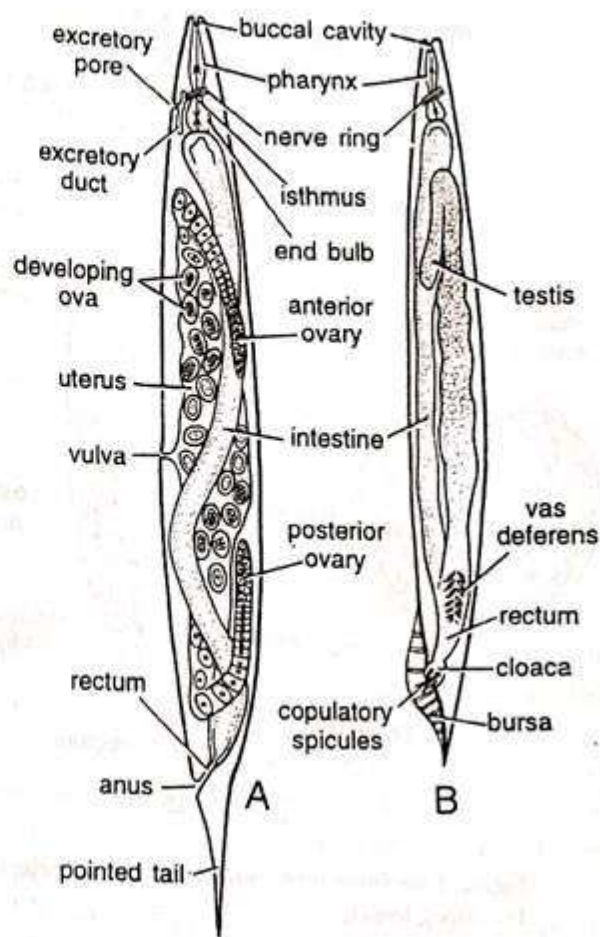


Fig. 3. *Rhabditis*. A—Adult female. B—Adult male.

found in human stool. *R. peltio* lives in human vagina and its larvae escape in urine. *R. maupasi* lives in soil and its juveniles are found in earthworms. Adult male and female of this species measure 1.7 and 2.0 mm in length, respectively. Male has a single tubular testis and the female has two ovaries. Life cycle is simple and direct. Eggs pass into earthworms in which they become juveniles. These attain maturity in decaying flesh after death of earthworm.

4. *Enterobius vermicularis* (The Pin Worm of Man). *Enterobius vermicularis* is the human "pin worm" or "seat worm" and is perhaps the most common parasitic nematode of man throughout world. It has been reported to occur in chimpanzee also. Its incidence, however, is greater in women and children. Adult worms live in caecum, appendix and at the junction of small and large intestines. Sexes are separate and there is distinct sexual dimorphism. Worms are slender and cream-colored. Male is 2 to 5 mm long, with a diameter of 0.1 to 0.2 mm. Female is 8 to 13 mm long with a diameter of 0.3 to 0.5 mm. At

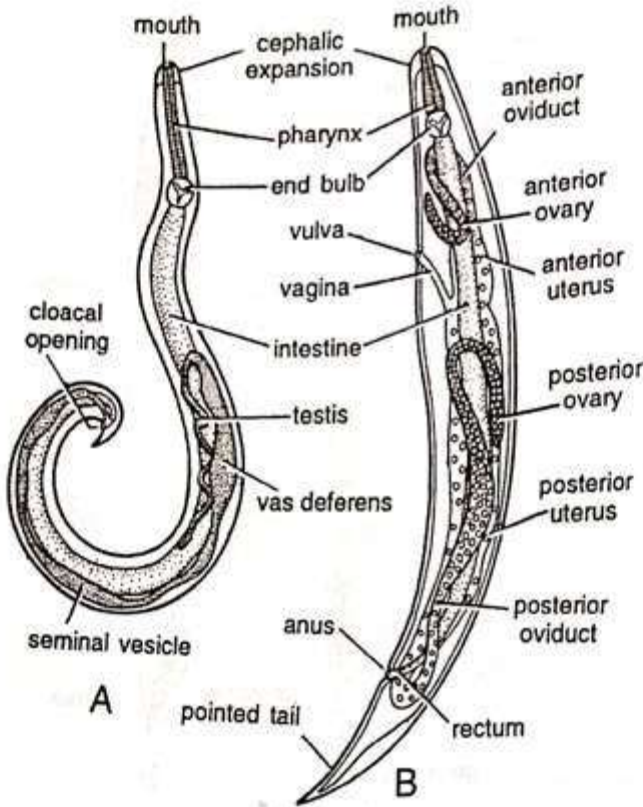


Fig. 4. *Enterobius vermicularis*. A—Adult male. B—Adult female.

Life cycle is simple and direct. No intermediate host is involved. At night, females with eggs migrate to anus and deposit eggs. This causes severe itching at the anal and perineal regions and the host is tempted to scratch. Tiny eggs, about  $55\mu$  by  $30\mu$  and each containing a much developed larva, thus associate with fingers and finger nails and finally enter its gut with food to cause a reinfection. Eggs hatch in duodenum. Larvae reach small intestine, where they moult twice and become adults.

Adults live in host for 20 to 30 days. Infection thus automatically dies out within a month provided there is no reinfection. Good sanitary habits are the best weapon against infection. Symptoms of infection are loss of appetite, insomnia, hysteria, restlessness and inflammation of mucous membrane of infected regions.

5. *Dracunculus medinensis* (The Guinea Worm). It is a common human parasite, known to man since Biblical times, when it was known as the "Fiery Serpent". It is of common occurrence in dry regions of Africa, India, Arabia, China, etc. It also occurs in some other mammals. In United States, it has been found in dogs, raccoons, foxes and minks. Adult worms occur in subcutaneous tissue, especially of arms, shoulders and legs. Females attain a length of 100 to 400 cm. Males, are rare and 12 to 29 mm in length. At the anterior end is a cuticular ring bearing a mouth, an inner circlet of six labial papillae and an external circlet of four double

the anterior end, in both sexes, are 3 lips and a pair of cephalic expansions. Posterior or tail end of female is long and pointed, while that of male is curved, blunt, and with a bursa-like expansion and a single spicule. There is no gubernaculum. Papillae support caudal algae. Male is monorchic and female didelphic.

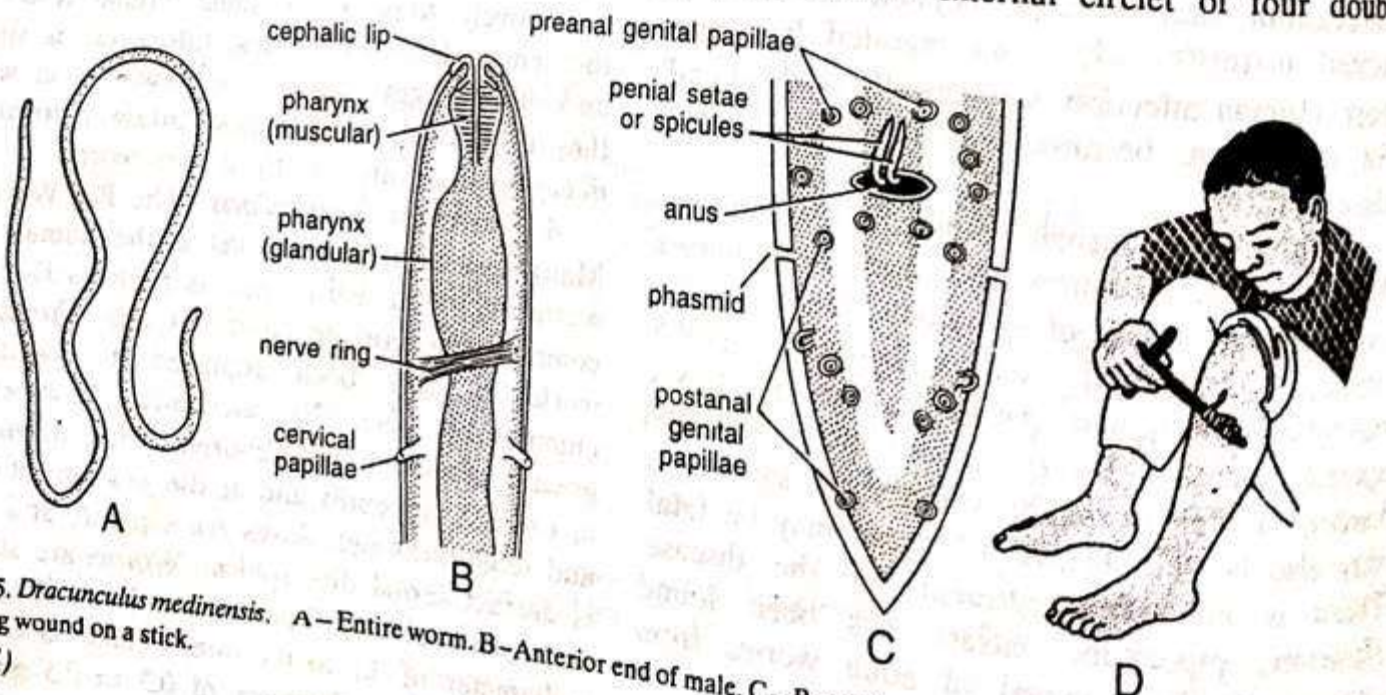


Fig. 5. *Dracunculus medinensis*. A—Entire worm. B—Anterior end of male. C—Posterior end of male in ventral view. D—Guinea worm being wound on a stick. (Z-1)

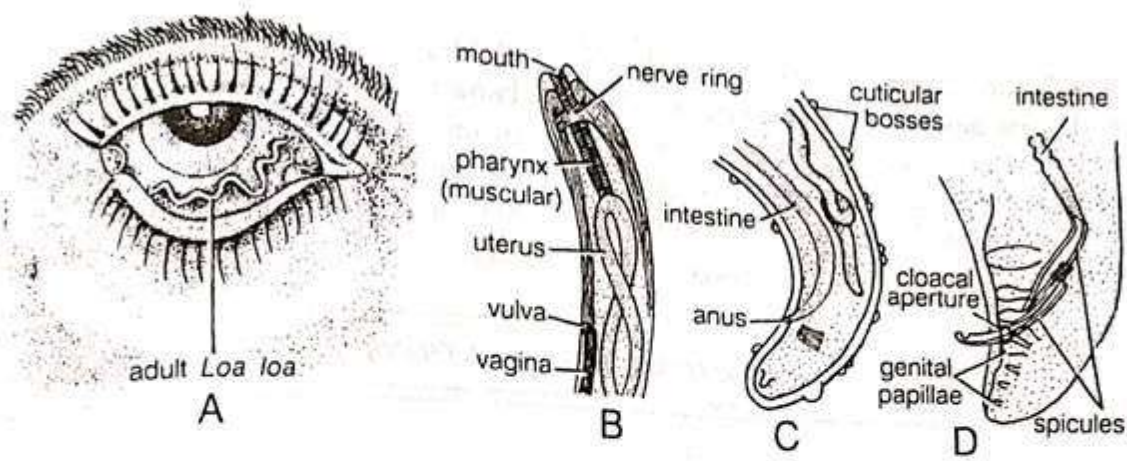


Fig. 6. *Loa loa*. A—Adult across the bulbar conjunctiva of human eye. B—Anterior end of female. C—Posterior end of female. D—Posterior end of male.

papillae. Posterior end of male bears 10 pairs of papillae (4 pairs pre-anal and 6 pairs post anal). Oesophagus has two regions, an anterior narrow muscular region and a posterior broad glandular region. Female is didelphic with apposed uteri and vulva near the middle of body. Male has equal-sized filiform spicules and gubernaculum.

Mature female contains numerous embryos in its much enlarged uterus which fills up the body cavity. Egg-laying female worm takes up its position just below skin in such a part of body which regularly comes in contact with cold water, like hands, feet, legs, etc. Here the parasite produces toxic secretions which produce a blister on skin. Soon an ulcer is formed. On coming in contact with water, the ulcer breaks and worm freely projects its uterus and releases tiny coiled embryos in water. Larvae, after swimming freely for a short time, penetrate the body of intermediate host *cyclops*, a copepod crustacean. In *cyclops*, larva moults twice and becomes infective in three weeks' time. When infected *cyclops* is taken in by man with water, the larvae escape and bore their way into subcutaneous tissue where they attain adulthood.

Primitive method of removing the worm from body is by winding it on a thin stick, a few turns a day. An attempt to remove the worm more rapidly results in its rupture leading to serious bacterial infection. Guinea-worm infection causes itchiness, nausea, diarrhoea, vomiting, asthma, eosinophilia, etc. These effects are due to toxic substance produced by the parasite. Infection can be treated with injections of phenothiazine emulsified in olive green.

6. *Loa loa* (The Eyeworm). The other important human filaria is the African eye-worm *Loa loa*, chiefly found in Africa. They commonly invade subcutaneous tissue and during their migration may pass across the eye-ball, hence the name eye-worm. Male and female measures 20 to 35 mm and 20 to 70 mm in length, respectively. Body is covered by numerous warts. Gravid females produce ensheathed juveniles or microfilariae. They show diurnal periodicity, the microfilariae appearing only in day times in peripheral circulation but disappearing at night. Intermediate hosts are mango flies, *Chrysops dimidia* or *C. silacea*. Larvae moult and develop up to infective stage in fly and are again infected in the blood stream of man through proboscis.

*Loa* microfilariae cause very injurious and fatal cases when they penetrate brain and spinal cord and perhaps carry neurotropic viruses. During their migration they cause intense itching and swelling. They also cause swelling and pain in eyes, known as "calabar swellings".

7. *Tococara canis* (The Dog Ascarid). The dog ascarid, *Toxocara canis*, is quite interesting. Larvae hatching from eggs ingested by a pregnant female dog, migrate through placenta to enter the developing embryos or foeti. Puppies born may show a heavy infection of these worms. Adult individuals generally have fewer worms. Adult male and female worms reach up to 10 and 20 cm respectively. Eggs start development in host's faeces and become infective in 4 or 5 days. When ingested, they hatch in the new host's intestine to liberate juveniles. They penetrate the intestinal wall, reach lung through

hepatic portal circulation, break into alveoli, migrate up the air passage, become swallowed in pharynx and re-enter intestine. Dog ascarid is also important medically. Embryonated eggs in contaminated soil may be ingested by children, especially during the dirt eating stage, when

*Nematoda : Characters, Classification and Types*  
 children are one to three year old. Larvae, known as *larva migrans*, continue to live in liver of infected children indefinitely. Damage depends on the number of larvae present. Usually, they are not enough to produce symptoms, but may prove fatal when present in larger numbers.

### IMPORTANT QUESTIONS

#### » Long Answer Type Questions

1. What are the general characteristics that describe the roundworms as a group?
2. Classify Nematoda giving diagnostic characters and examples of each group.
3. Name common human nematode parasites. Give a brief account of any one of them.
4. In what ways are the Nematoda more advanced than the Platyhelminthes?
5. Write an essay on medical importance of nematodes.
6. Write notes on : (i) *Ancylostoma duodenale*, (ii) *Enterobius vermicularis*, (iii) *Trichinella spiralis*, (iv) *Wuchereria bancrofti*.

#### » Short Answer Type Questions

1. Name the nematode parasite whose juvenile enters the human host by active penetration.
2. Name a helminth parasite which is unisexual.
3. What is aberrant visceral migration?
4. Name a helminth parasite whose primary host is man and the intermediate host is cyclops.
5. Name five human nematode parasites causing diseases.
6. Classify the animal upto order *Trichinella spiralis*.
7. Classify the following, giving two peculiar features in their structure.  
*Dracunculus*, *Trichinella spiralis*.
8. Write the common name of *Dracunculus medinensis*? Mention its mode of infection, and explain its development.
9. Give an account of nematode parasites in man, and discuss the parasitic adaptations of any one of them.
10. Describe the structure, habit, and disease caused by any four important nematode parasites in man.
11. *Schistosoma haematobium*, causes ....
12. *Schistosoma haematobium* is parasitic in ....

#### » Multiple Choice Questions

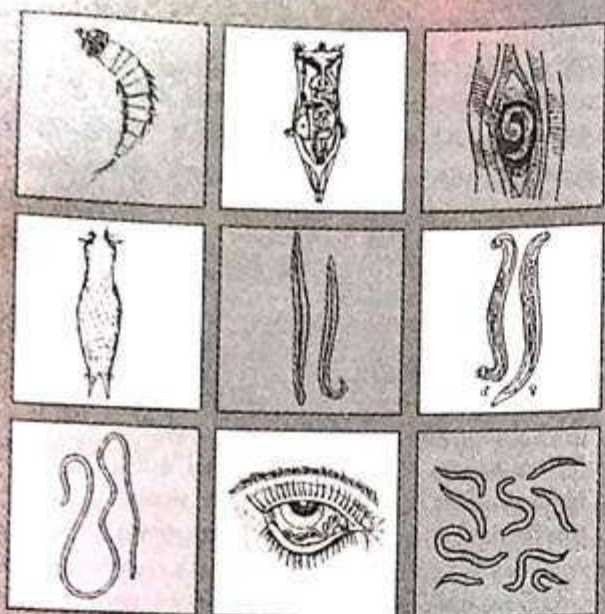
1. Which larval stage is not found in *Schistosoma* ?  
(a) Miracidium (b) Sporocyst  
(c) Redia (d) Cercaria
2. In the development of *Schistosoma* (blood flukes) one of the following stage is skipped :  
(a) Cercaria (b) Sporocyst  
(c) Miracidium (d) Redia
3. *Dracunculus medinensis* (Guinea worm of man) is a parasitic worm which invades :  
(a) subcutaneous connective tissue  
(b) lymphatic vessel  
(c) small intestine (d) colon and rectum
4. Microfilariae refers to :  
(a) female *Wuchereria bancrofti*  
(b) male *Wuchereria bancrofti*  
(c) living embryo of *Wuchereria bancrofti*  
(d) embryo set free in water by female mosquito
5. All roundworms differ from all flatworms in having :  
(a) longitudinal nerve cord (b) segmented body  
(c) pseudocoel  
(d) metamorphosis in their life history  
(e) blood circulatory system
6. There is only single host in the life history of :  
(a) roundworm (b) tapeworm  
(c) *Schistosoma* (d) *Fasciola*
7. One of these is different from others :  
(a) *Ancylostoma* (b) *Trichinella*  
(c) *Enterobius* (d) *Ascaris*
8. One of these is different from others :  
(a) *Ascaris* (b) *Ancylostoma*  
(c) *Enoplus* (d) *Enterobius*
9. *Dracunculus medinensis* is transmitted to man by :  
(a) mosquito (b) fly  
(c) crustacea (d) infected cyclops
10. Which of the following parasites have no intermediate host ?  
(a) tape-worm  
(b) *Ascaris* (round worm)  
(c) liver-fluke  
(d) malarial parasite
11. Oral infection occurs in :  
(a) malaria (b) filaria  
(c) ascariasis (d) none of these

*Nematoda : Characters, Classification and Types*

- 12. The animal that never performs locomotion :  
 (a) *Ascaris* (b) *Leucosolenia*  
 (c) both (d) *Hydra*
- 13. The term Nematoda was coined by :  
 (a) Gegenbaur (b) Grobben  
 (c) Rudolphi (d) Lamarck
- 14. Which is parasite of man :  
 (a) hook worm (b) pin worm  
 (c) whip worm (d) eye worm  
 (e) all
- 15. The word 'Aschelminthes' was proposed by :  
 (a) Gegenbaur (b) Grobben  
 (c) Rudalphi (d) Lamark
- 16. Sexual dimorphism in :  
 (a) Porifera (b) Coelenterata  
 (c) Platyhelminthes (d) Aschelminth
- 17. Free living nematodes :  
 (a) *Trichuris* (b) *Trichinella*  
 (c) *Rhabdite* (d) *Wuchereria*
- 18. The eye worm of man is :  
 (a) *Wuchereria* (b) *Trichuria*  
 (c) *Loa loa* (d) none
- 19. Commonly known as hook worm :  
 (a) *Ancylostoma* (b) *Necator*  
 (c) both (d) none
- 20. Match the following :  
 (a) *Ascaris* (a) Whip worm  
 (b) *Ancylostoma* (b) Pin worm  
 (c) *Wuchereria* (c) Filarial worm  
 (d) *Enterobius* (d) Hook worm  
 (e) *Trichuris* (e) Round worm

**Answers**

1. (c) 2. (d) 3. (a) 4. (c) 5. (c) 6. (a) 7. (d) 8. (c) 9. (d) 10. (b) 11. (c) 12. (a) 13. (a) 14. (e) 15. (b) 16. (d) 17. (c) 18. (c) 19. (c) 20. [(a-e), (b-d), (c-c), (d-a), (e-a)].



# Helminthes: General Account

## 39 Chapter

### Evolution of Parasitism in Platyhelminthes

There are several conflicting views about the origin of Platyhelminthes. According to *Ciliate theory*, ciliate-like multinucleate ancestors became bilaterally symmetrical syncytial metazoans and led to the modern Acoela. According to *Planula theory*, a planuloid ancestor became flattened and acquired a ventral mouth leading either into a semisolid interior (Acoela) or into a central cavity (Polyclada). Acoela are regarded by some as primitive platyhelminths most nearly related to the ancestral platyhelminth. Others think Acoela to have been secondarily simplified polyclad ancestors.

Parasitic platyhelminths (trematodes and cestodes) have clearly been derived from free-living turbellarian progenitors which were ectoparasites on molluscan, crustacean and echinoderm hosts. It is quite possible that monogenetic and digenetic trematode parasites had separate origins.

According to Hyman, molluscs could have been the original hosts of digenetic trematodes. Some ancestral rhabdocpels with a suctorial pharynx to feed on soft tissues of relatively large molluscs could have entered the mollusc body through feeding wound and became endoparasites. Thus, endoparasitic forms resulted from those free-living

forms that were accidentally introduced into the invertebrate host with the evolution of vertebrates, they invaded the new hosts but connection with the original hosts were retained which became intermediate hosts. During the course of evolution the endoparasites acquired certain adaptations to endoparasitism for survival in the intestine of a predator vertebrate host. These included changes in structure and physiology as a result of continuous mutations. The well-marked changes include: (i) degeneration of alimentary canal in flukes and absent in tapeworms. (ii) nervous degeneration, (iii) development of suckers and hooks for attachment, (iv) greatly developed reproductive system, and (v) complex life-cycles. Thus, a second or vertebrate host added to life-cycle became obligatory. Second and even third intermediate invertebrate hosts, which formed organisms in the food chain of vertebrate host, were eventually incorporated in life cycle of parasite. Hazards of a two or multiple host cycle may have been compensated for by the development of polyembryony and larval multiplication in molluscan host. In this manner, modern digenetic endoparasites, with their complicated life-cycles, may have emerged.

Flukes and tapeworms which involve many intermediate hosts, are more advanced, since the parasites become



adapted, in time, to several species of hosts. With the elimination of some intermediate hosts, still more advanced parasitic forms now restrict to one or two intermediate hosts. It seems likely that monogenean parasites of vertebrates arose from free-living rhabdocoels long after the digenean parasites.

## Parasitic Adaptation of Flatworms

**Adaptation.** Adaptation is the fitness of an organism to its environment. It is the characteristic which results in suitable and convenient morphological and functional correlation between an organism and its environment.

**Parasitic adaptations.** Parasitic flatworms (trematodes and cestodes) have undergone profound adaptations to suit their parasitic mode of life. These adaptations termed parasitic adaptations in such cases, are of morphological as well as physiological nature.

### [I] Morphological adaptations

1. **Body covering.** Thick *tegument*, frequently provided with scales, affords suitable protection to the parasite. It is probable that this thick protoplasmic layer is continually renewed by the mesenchymal cells forming it.

2. **Organs of adhesion.** For a firm grip on or in the host's body, some special organs of adhesion are necessary. Flatworms, for this purpose, are variously 'armed' with suckers, hooks and spines. Suckers themselves may be with or without hooks and spines.

3. **Organs of locomotion.** Locomotion is actually an effort for procuring food. But parasites habitually inhabit such places in host's body, where sufficient food is available without effort. Thus, organs of locomotion, such as cilia of free-living turbellarians, are absent in parasitic forms. It is interesting to note that locomotory organs are duly present in free-living larvae of parasitic forms. Miracidium possesses cilia and cercaria possesses a tail for locomotion.

4. **Organs of nutrition (trophic organs).** Food of parasite comprises readily available digested and semi-digested food of the host. Elaborate organs for nutrition are thus not needed. Trematodes have an incomplete gut and, in most cases, a suckorial pharynx for sucking food. An eversible pharynx present in free-living turbellarians is absent in this case, as the parasite has not to capture a large prey. In cestodes, parasite freely bathes in digested food of host which is absorbed directly. There is thus total absence of alimentation in tapeworms.

5. **Neuro-sensory system.** Need for quick and efficient "response to stimuli" is associated with free active life and not with a quiet parasitic life in a safe environment. In parasites, therefore there is profound reduction of nervous system and total absence of sense organs. But, the free-living miracidium possesses eye spots.

6. **Reproductive system.** It is the best developed system in helminth parasites, designed and perfected to meet the need for tremendous egg production. Parasitic flatworms, with a few exceptions like *Schistosoma*, are monoecious (hermaphrodite). Hermaphroditism is of distinct advantage to the parasite, because (i) it ensures copulation even when a

few individuals are present, (ii) after copulation both individuals lay eggs, thus doubling the rate of reproduction and (iii) in the absence of a companion parasite can reproduce offspring. In cestodes reproductive system is much more elaborate and each mature proglottid possesses one (e.g. *Taenia solium*) or two (e.g., *Conugnia*, *Moniezia*, *Dipylidium*) complete sets of male and female genitalia. In a gravid proglottid all other organs of the system degenerate to make room for the uterus which becomes highly enlarged and branched to accommodate large number of eggs.

### [II] Physiological adaptations

1. **Protective mechanism.** Alimentary canal parasites have to protect themselves from the action of digestive juices of host. Tapeworms accomplish this: (i) by stimulating walls of gut to secrete mucus, which then forms a protective clothing around the parasite (ii) by secreting antienzymes to neutralize the digestive enzymes of host, and (iii) by probably continually renewing their protective body covering i.e., tegument.

2. **Anaerobic respiration.** Environment in gut and bile ducts is devoid of free oxygen. Flatworms inhabiting these places, therefore, respire anaerobically by breaking down glycogen.

3. **Osmoregulation.** Osmotic pressure of endoparasite's body fluids, especially in case of trematodes is almost the same as that of host. This renders osmoregulation unnecessary. But in intestinal tapeworms, osmotic pressure is a little higher. This permits ready absorption of host's digested food by tapeworms.

4. **High fertility.** Eggs produced by a parasitic flatworm face a very uncertain future. While passing through the complex life cycle, these potential offsprings face several hazards as a result of which a very small percentage of total eggs produced reaches adulthood. This threat to the very existence of species is suitably met by the parasite which in its life time may produce eggs in millions. Reproductive organs of flatworms, as already noted, are accordingly developed.

Additional multiplicative phases in life-cycle of some flatworms further increase the output of potential offspring. Several cercariae develop from a single miracidium of liver fluke and a single hexacanth of *Echinococcus* produces several scolices, each of which is a potential tapeworm.

## Helminths and Human Diseases

Helminths are animals that belong to the phyla Platyhelminthes and Nematoda (Nematelminthes.) Many parasitic forms of this group, popularly known as parasitic worms, are endoparasites of gut and blood in human body which cause diseases, collectively called *helminthiasis*. Following three forms of helminthiasis are the most widespread : (i) nematodiasis, (ii) trematodiasis and (iii) cestodiasis.

## A. Nematodiasis

Diseases caused by nematode helminths constitute *nematodiasis*. Most widespread human diseases due to infestation with nematodes are as follows :

**1. Ascariasis.** *Ascariasis* is a highly prevalent disease caused by the giant intestinal roundworms, *Ascaris lumbricoides*. It is off white in colour, resembles an earthworm and is most frequently seen in children. Female is longer than male and lays about 200,000 eggs daily that pass out with human faeces and may remain alive in the soil for several days. In man infection follows the ingestion of embryonated eggs with contaminated food (raw vegetables, fruits) and drinking water. Among children playing in contaminated soil, there is also hand to mouth transfer of eggs. In intestine, juveniles hatch out of eggs and cycle of larval development begins. Juveniles penetrate the intestinal wall and migrate to liver and from there to heart and lungs. Finally they return back into intestine and develop into adult parasites.

With adult *Ascaris* residing in intestine, the patient complains of abdominal pains, vomiting, headache, irritability, dizziness and night terrors. Sometimes there is diarrhoea and salivation. Often the patient grinds his teeth in sleep. When adult worms migrate through intestinal wall, they cause severe *peritonitis*. They may find their way into other areas causing appendicitis, gall bladder trouble and liver disease. In lungs, juveniles may cause bronchitis.

Treatment of human ascariasis has been fairly successful through oral administration of *Piperazine citrate syrup* (two teaspoonful twice a day for one week followed by another course after a gap of one week) and *Hexylresorcinol tablets* (100 mg. taken at one time with water). *Santonin* and *Oil of Chenopodium* are also useful.

**2. Ancylostomiasis.** *Ancylostomiasis* is caused by two hook worms *Ancylostoma duodenale* and *Necator americanus*. Both nematodes are parasites within the intestine. They are most frequent in rural areas. Female hookworms produce 5000 to 10,000 eggs per day which pass out in stools. Man acquires infection when eggs hatch and juveniles penetrate through soft skin of

hands and feet. They enter the blood vessels and are carried to heart and lungs. Now they make their way to one of the bronchial tubes, pass into small intestine and finally develop into adult worms.

Characteristic symptoms of *ancylostomiasis* are gastro-intestinal disturbances, anaemia and nervous disorders. Patients appear pale and are often weak. They complain of dizziness, ringing in ears and headache. Nausea and vomiting are frequent. In more severe cases, men may become impotent and women may cease to menstruate.

In the treatment of hook-worm, safe and effective drugs are *tetrachloroethane* and *carbon tetrachloride*.

**3. Enterobiasis.** This disease is caused by *Enterobius vermicularis*, commonly called pin-worms or seatworms. These are small white worms about 6 or 7 mm long and inhabit the upper part of colon. Females migrate out through colon and rectum and deposit enormous number of eggs in the skin folds about anus, where they cause intense itching. When skin about the anus is scratched, eggs are easily picked upon fingers and under nails from where they find their way to food and are swallowed. They hatch in stomach and the juveniles migrate to colon and develop into adult worms.

Pin-worm infection is more frequent in children, than adults. Symptoms of disease include severe itching around anus, loss of appetite, sleeplessness, bed-wetting, grinding of teeth, nausea and vomiting. In girls irritation of genitalia by pin-worms leads to an early sexual desire.

*Piperazine* is the most effective drug in treatment of pin-worms. The patient must wash his perianal region with warm water and soap before going to and on rising from bed.

**4. Trichuriasis.** This disease is caused by *Trichuris trichiura*, commonly called whip-worms. These worms inhabit the large intestine, mainly caecum or vermiform appendix. Females lay enormous number of eggs daily that pass in stools. Eggs gain entry to human body with contaminated drinking water and raw fruits and vegetables. They may also be spread by flies. In the intestine eggs hatch and larvae develop into adult whip-worms.

Patient suffering from whip-worm disease complains of nausea, vomiting, constipation, headache, slight fever, and even paroxysmal pains resembling appendicitis. In more severe cases, anaemia and eosinophilia develop.

Drugs most commonly used for expulsion of whip-worms are *osarsol* (acetarsone) and *dithiazanine*.

**5. Trichinosis.** This disease is caused by *Trichinella spiralis*. The trichina worms, and is widespread in America. It is transmitted by raw meat, especially pork. Man becomes infected following ingestion of encysted larvae with raw or under-cooked pork. In the intestine, larvae hatch out of cysts and develop into sexually mature adult worms. Female lays eggs that hatch and the resulting young larvae enter blood stream and carried to muscles of chest and legs. Here they form cysts.

Early symptoms of trichinosis are nausea, vomiting, oedema of face and eyelids and fever. After this, muscular pains are felt. Patient complains of pains in chewing, swallowing, breathing and in moving his arms and legs. There is no specific treatment for this disease.

**6. Strongyloidosis.** This disease is caused by *Strongyloides stercoralis*, commonly called thread-worms. These invade the lining of alimentary canal. Female lays large number of eggs that pass out in faeces and develop into *rhabditiform larvae*. These transform into *filariform larvae* that penetrate the skin of bare feet, and thus enter human body.

Patient with thread-worm disease complains of nausea, dizziness and bloody diarrhoea resulting from ulcerations due to parasites lodged within the intestinal mucosa and glands. There may also be vomiting, cough and fever.

Most effective drug for treatment of thread worms is *gentian violet*. *Dithiazanine* also works well.

**7. Filariasis or Elephantiasis.** Causative organism for this disease is a nematode, *Wuchereria bancrofti*, commonly called the filaria worm. These tiny worms live in lymphatic system and connective tissues of body and are also found in circulating blood at night. Infection is spread through *Culex* mosquito. Following copulation, female worm delivers juveniles called

*microfilariae*. These, at night, get into blood capillaries of skin to be sucked up by mosquito with blood meal. Mosquito transmits them into another human body where they enter the lymph nodes and develop into adult parasites.

Infection of filaria worms causes enlargement of limbs, scrotum and mammae. Swelling takes place due to blockage of lymph circulation by parasitic worms, resulting into inflammation of lymph vessels and lymph glands.

There is no effective drug for eradication of filaria worms. *Cyanine dyes* and *Diethylcarbamazine* may be used for some success. Very large swellings can sometimes be removed by surgery.

## B. Trematodiasis

The diseases caused by trematode helminths constitute *trematodiasis*. Some common such human diseases are as follows :

**1. Opisthorchiasis (= Clonorchiasis).** This disease is caused by *Opisthorchis (= Clonorchis) sinensis* which inhabits the bile ducts. Disease is widespread in China, Japan, Korea, Vietnam and India. Human infections are acquired through eating raw or under-cooked fish which harbour *metacercariae*. Thousands of adult flukes are found in biliary ducts, causing the thickening of duct walls. Severe cases usually lead to cirrhosis and ultimate death.

*Gentian violet* and *chloroquine* proves helpful in curing infections. Most important is prevention. All freshwater fish should be thoroughly cooked before eating.

**2. Fasciolopsiasis.** This disease is caused by the intestinal fluke *Fasciolopsis fuelleborni* in India. It utilizes snail as intermediate host in which it passes through an elaborate developmental cycle, producing *metacercariae* that leave the snail to be located on water plants. Infections are acquired by eating these water plants, particularly the water nuts. In intestine these *metacercariae* develop into adult worms within three months.

Worms cause erosion of intestine lining, resulting in bleeding and pain. This is followed by diarrhoea, nausea, and vomiting. *Hexylresorcinol* and 'Crystaloids' anthelmintic are helpful in the eradication of the intestinal flukes.

3. **Schistosomiasis.** This type of disease is caused by three species of blood flukes—*Schistosoma mansoni*, *S. japonicum* and *S. haematobium*. These live in the blood stream. Disease is widespread throughout the world. Females lay enormous number of eggs in blood stream from where they find their way either into intestine (*S. mansoni*, *S. japonicum*) or urinary bladder (*S. haematobium*) and are ejected in faeces or urine. When eggs come in contact with water, miracidia hatch out and get into snail. Here these develop into cercariae which leave the snail, swim freely in water and penetrate the skin of man. Through blood circulation cercariae reach lungs to become adult worms. Adults then get into blood stream.

Blood flukes cause asthmatic attacks and hepatitis. This may be followed by fever, sweating, diarrhoea, weight loss and lack of appetite.

For treatment of disease, *antimony compounds* are recommended. Sanitary disposal of all human faeces and urine is essential for the control of Schistosomiasis.

4. **Paragonimiasis.** This disease is caused by the lung fluke, *Paragonimus westermani*. Infection is wide-spread in Asia, Africa and South and Central America. Flukes are found in lungs in encapsulated form. Eggs are expelled out in sputum and when they come in contact with water these develop into miracidia. Miracidia find their way into snail host where they develop into cercaria. Cercariae emerge and get into crabs and crayfish and encyst into metacercarial cysts. Man acquires infection from eating raw or under-cooked crabs and crayfish. Excystment occurs in the man's intestine and juveniles migrate into lungs where they attain maturity and become encapsulated.

Lung flukes cause chronic cough with emission of bloody sputum. Heavy infections cause chest pain with pleurisy, shortness of breath, fever and anaemia. *Emetine hydrochloride* and *sulpha drugs* are recommended for the treatment of lung flukes.

### C. Cestodiasis

*Cestodiasis* is caused by tapeworms. The two common forms of this disease are as under.

1. **Taeniasis.** This disease is caused by the species belonging to the genus *Taenia*, which include mainly *Taenia solium* (pork tapeworm) and *Taenia saginata* (beef tapeworm). Man acquires infection by eating raw or under cooked pork or beef that contains the cysticerci. In intestine cysticerci develop into adult tapeworms. Presence of tapeworms in intestine causes gastro-intestinal disorders. Some patients complain of hunger pain. Anaemic conditions may also develop. *Atabrin* or *quinacrine hydrochloride* is the drug of choice. Prevention requires the eating of thoroughly cooked pork or beef.

2. **Hydatid disease.** The disease is caused by the hydatid worm, *Echinococcus granulosus*. Primary host of this worm is dog in whose intestine the eggs are set free. These pass out in faeces and develop into *onchospheres*. Man acquires infection on eating food or drinking water contaminated with onchosphere-containing eggs. In man, hydatid cysts develop in liver, lungs and other tissues and represent the end of parasitic life-line. Cysts cause inflammation of tissues. Presence of cysts in brain and kidney may prove fatal. Recommended drug is the same as for Taeniasis.

### Nematode Parasites of Man and Animals

Nematodes are elongated, unsegmented, triploblastic, pseudocoelomate animals, commonly known as "roundworms." They are widely distributed free-living as well as parasitic animals. Free-living nematodes are found in all sorts of environments in sea, in fresh water and in soil on land. Parasitic nematodes parasitize all kinds of plants and animals and display all degrees of parasitism. About 50 species of nematodes are known to occur in man, but only a dozen of these are of pathogenic importance. They are of utmost economic and medical importance to man. Some of these nematode parasites of man and animals have already been described in the previous chapter. These are *Trichuris trichiura*, *Trichinella spiralis*, *Rhabditis*, *Enterobius vermicularis*, *Dracunculus medinensis*, *Loa loa*, *Toxocara canis*, *Ancylostoma duodenale*, *Necator*

*americanus*, *Wuchereria bancrofti* and *Ascaris lumbricoides*. Readers may refer to previous pages for their ecology, morphology, pathology

and prophylaxis, etc. To describe them here again will be merely repetition of what has already been written.

### IMPORTANT QUESTIONS

#### Long Answer Type Questions

1. Write an essay on "Helminths and Human Diseases".
2. Give an account of some of the human diseases caused by nematodes.
3. Describe some nematode parasites of man and domestic animals.
4. Name common human nematode parasites. Give a brief account of any one of them.

#### Short Answer Type Questions

1. What is nematodiasis?
2. Clarify the trematodiasis.
3. What are the flukes and how they infect the human ?
4. How you understand the term cestodiasis?
5. How you define the parasite?
6. Distinguish between exo and endo-parasite.
7. Give a definition of adaptation?
8. What is helminthiasis?
9. What is the treatment of ascariasis?
10. What is the way of infection of pin worms?

#### True / False

21. Hydatid disease is caused by *Echinococcus*.
22. *Peragonimus* is known as lung fluke.
23. Fasciolopsiasis is caused by *Fasciola hepatica*.

#### Multiple Choice Questions

1. Treatment of human ascariasis fairly successful through :  
(a) oral administration of drugs  
(b) vaccine  
(c) inject the medicine into muscles  
(d) none the above
2. Characteristics symptoms of ancylostomiasis :  
(a) gastro-intestinal disturbance  
(b) anaemia  
(c) nervous disorders (d) all the above
3. Pinworm is a common name of :  
(a) *Ancylostoma* (b) *Enterobias*  
(c) *Trichuris*  
(d) *Trichinella*

11. What is the cause for the disease enterobiasis?
12. Give any five point of parasitic adaptation of helminthes
13. Explain the causes of hydatid disease?
14. What are round worms?
15. Describe polyclada.
16. Parasitic platyhelminthes are trematodes and .....
17. Molluscs could have been the original hosts of ... trematodes.
18. The oil of chenopodium is useful in treatment of .....
19. Female larva worm produce 5000 to .....eggs per da
20. Blood fluke cause asthmatic attack and .....

24. Elephantiasis is caused by *Trichenilla*.
25. Enterobiasis is commonly known as pin worms.

4. *Trichuris trichiura* is commonly known as :  
(a) *Ascaris* (b) pin worm  
(c) whip worm (d) round worm
5. Elephantiasis spread through the vector :  
(a) *Anophelese* (b) *Culex*  
(c) *Musca-domestica* (d) contaminated water
6. *Opisthorchis* inhabit into :  
(a) blood (b) liver  
(c) bile duct (d) intestine
7. Antimony compounds recommended to the treatment  
(a) elephantiasis (b) fasciolopsiasis  
(c) schistosomiasis (d) none to any
8. Beef tapeworm is :  
(a) *T. solium* (b) *T. saginata*  
(c) both of them (d) none of them

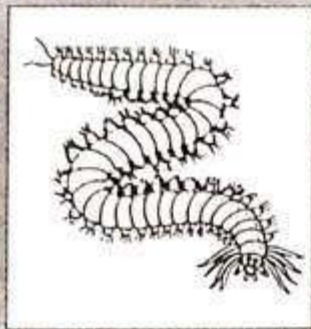
### Answers

#### » Short Answer Type and True / False Questions

16. Cestodes 17. digenetic 18. ascariasis 19. 10000 20. hepatitis 21. true 22. true 23. false 24. false 25. true.

#### » Multiple Choice Questions

1. (a) 2. (d) 3. (b) 4. (c) 5. (b) 6. (c) 7. (c) 8. (b)



## *Neanthes* or *Nereis*: A Clamworm

# 40

## Chapter

Phylum Annelida (L., *annulus*, a little ring), sometimes called Annulata, comprises 3 main classes of segmented worm - like invertebrate animals. All are characterized by *metameric segmentation*, which means their body is typically divided into a linear series of similar segments, called *somites* or *metameres*. Previously described flatworms and roundworms do not have this type of body segmentation. Classes Oligochaeta and Hirudinea include the familiar earthworms and leeches, respectively. Third and the largest Class *Polychaeta* includes marine worms of which most persons are not aware. As their name implies, each body segment bears numerous setae on a pair of lateral appendages the *parapodia*. *Nereis* is a typical polychaete genus, living in burrows in sand or mud, often with clams, a reason for which its species are commonly known as *clamworms* or *sandworms*. Several authors have placed these worms under the genus *Neanthes* but both

(*Nereis* and *Neanthes*) are distinct and well established genera with many species belonging to each one.

*Nereis* includes several species, of which more common are *N. virens*, *N. cultrifera*, *N. dumerilii*, *N. diversicolor*, *N. pelagica* and *N. succinea*. The following account largely pertains to *Nereis virens*.

### *Neanthes (Nereis) virens*

#### Systematic Position

Phylum	Annelida
Class	Polychaeta
Subclass	Errantea
Family	Nereidae
Genus	<i>Neanthes</i> or <i>Nereis</i>
Species	<i>virens</i>

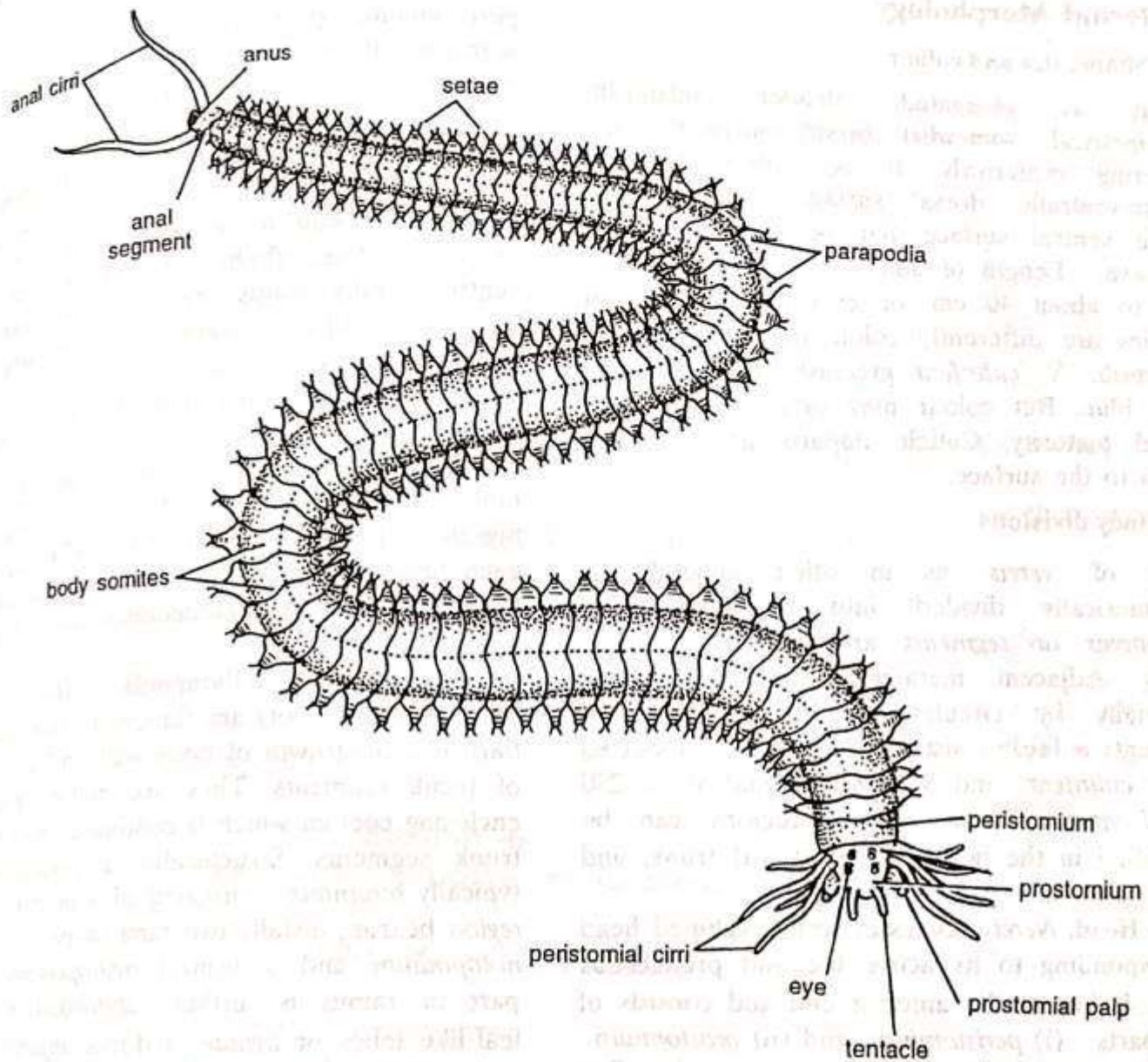


Fig. 1. *Nereis*. External features in dorsal view.

### Habits and Habitat (Ecology)

*Nereis* is a cosmopolitan marine polychaete, usually found on sandy shores between tidemarks. It remains overlooked by casual observers because of its secretive habits. Most of the time it lives in burrows, which it forms with the help of its jaws. Burrow is U-shaped, up to 60 cm. deep and coated with mucus, secreted from body, which binds together fine particles of sand. Worm maintains a constant current of water through the burrow by dorso-ventral undulations of its body. Water current brings oxygen for respiration. Worm is nocturnal and carnivorous. At night it keeps its head protruded

out of the burrow in search of prey, which is usually a small crustacean, mollusc or annelid. Prey is captured by protruding the pharynx provided with chitinous teeth and jaws, dragged into burrow and then devoured. Occasionally, the worm leaves its burrow and creeps about beneath stones and rocks or among seaweeds, in search of food. During breeding season, the worm leaves its burrow permanently and swims about actively in surface layers of water. At this stage, it is known as *heteronereis*.

Clamworms are frequently used for fish bait. In Greek mythology, nereids were sea-nymphs or beautiful human figures who sometimes lured sailors into captivity.

## External Morphology

### [I] Shape, size and colour

Body is elongated, slender, bilaterally symmetrical, somewhat broad anteriorly and tapering posteriorly. It is slightly flattened dorso-ventrally, dorsal surface being convex, while ventral surface flat or even somewhat concave. Length of adult worm varies from a few to about 40 cm. or even more. Different species are differently coloured. *N. pelagica* is brownish, *N. cultrifera* greenish and *N. virens* steel blue. But colour may vary with age and sexual maturity. Cuticle imparts an iridescent sheen to the surface.

### [II] Body divisions

Body of *Nereis*, as in other annelids, is metamERICALLY divided into a number of *metameres* or *segments* arranged in a linear series. Adjacent metameres are demarcated externally by circular grooves. Number of segments is fairly constant for a species; about 80 in *N. cultrifera* and *N. dumerilli* and about 200 in *N. virens*. Three distinct regions can be identified in the body: (i) head, (ii) trunk, and (iii) pygidium.

**1. Head.** *Nereis* possesses well-developed head corresponding to its active life and predaceous habit. It lies at the anterior end and consists of two parts: (i) *peristomium*, and (ii) *prostomium*.

**(a) Peristomium.** Peristomium is the first segment of body, distinct from others. It is large, ring-like and surrounds the ventral, transversely elongated slit-like *mouth*, hence its name (Gr., *peri*, around + *stoma*, mouth). It is formed by the fusion of first two embryonic segments during cephalization. It differs from a trunk segment in being longer, in lacking *parapodia* and in the presence of two pairs of thread-like *peristomial cirri* on each side. The dorso-lateral pair of cirri is longer than the ventro-lateral pair. Peristomial cirri are homologous with the notopodial and neuropodial cirri of parapodia of trunk segments. Each cirrus is a long, slender, tactile structure, having a short proximal joint and a long distal joint.

**(b) Prostomium.** It is not a true segment of body but rather dorsal, anterior projection of

*peristomium*, presumably of its first fused segment. It is a roughly triangular, dorso-ventrally flattened, fleshy lobe lying above and in front of *mouth* (Gr., *pro*, anterior + *stoma*, mouth). It bears two pairs of simple pigmented *eyes* on dorsal surface, a pair of short cylindrical, sensory *peristomial tentacles* anteriorly, and a pair of short, stout, fleshy, and two-jointed *palps* ventro-laterally. Palps are somewhat contractile and their small distal joints can be retracted into their large proximal joints.

Tentacles, palps and cirri, all serve as sensory organs.

**2. Trunk.** It comprises practically the entire body excluding head and last body segment or *pygidium*. It consists of 80-200 similar segments, each broader than being long and characterized by the presence of a *parapodium* on each lateral side.

**(a) Parapodia.** Parapodia (Gr., *para*, beside + *podos*, foot) are flattened, fleshy, vertical flap-like outgrowth of body wall on lateral sides of trunk segments. They are hollow structures enclosing coelom which is continuous with that of trunk segments. Structurally, a parapodium is typically *biramous*, consisting of a proximal *basal region* bearing distally two rami or parts, a dorsal *notopodium* and a ventral *neuropodium*. Each part or ramus is further subdivided into two leaf-like lobes or *ligulae*, a dorsal *superior ligula* and a ventral *inferior ligula*.

Each part bears at its base a slender, tentacular process known as *cirrus*. Notopodial or *dorsal cirrus* is slightly larger than neuropodial or *ventral cirrus*. Each part is supported internally by a deeply-embedded, long, stout and black chitinous rod, known as *aciculum*. It also serves for attachment of *setal muscles*, thus serving as a sort of endoskeleton. Each part also bears a bundle of long, fine, stiff, chitinous bristles, the *setae* or *chaetae*, which project beyond its margin. Each seta is lodged in a *setal* or *setigerous sac*, formed by an inpushing of epidermis and arises from a single *formative cell*, lying at the base of sac. New setae are continuously produced by setal sac as older ones are lost. Setae can be protruded, retracted or turned in various directions with the help of *setal muscles*. Each



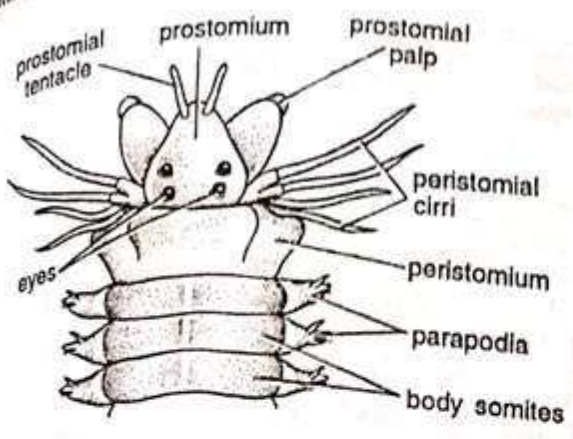


Fig. 2. *Nereis*. Head in dorsal view.

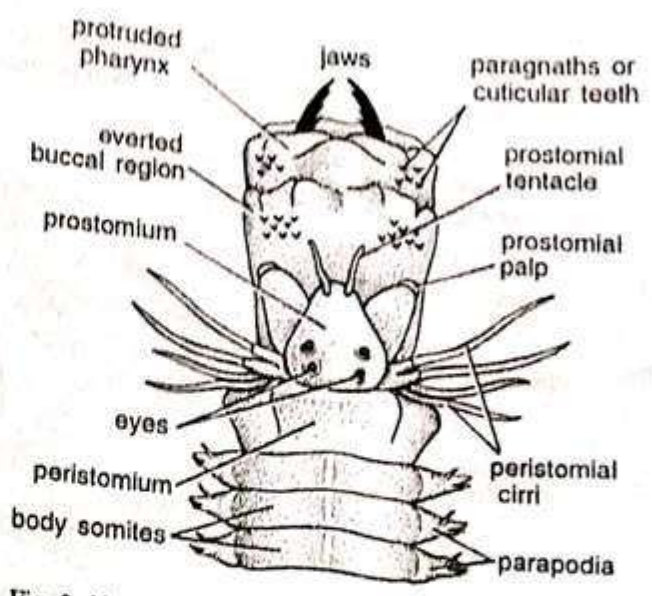


Fig. 3. *Nereis*. Head in dorsal view with everted proboscis.

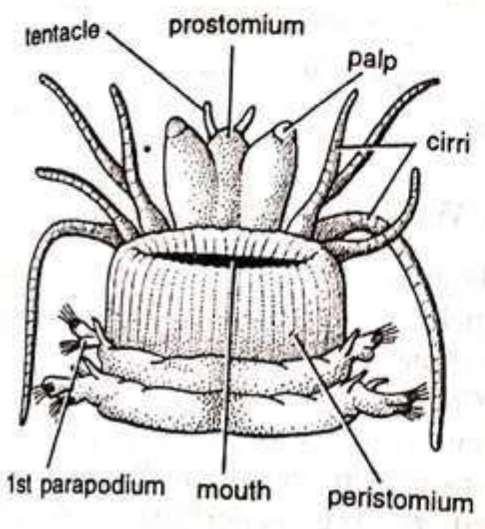


Fig. 4. *Nereis*. Head in ventral view

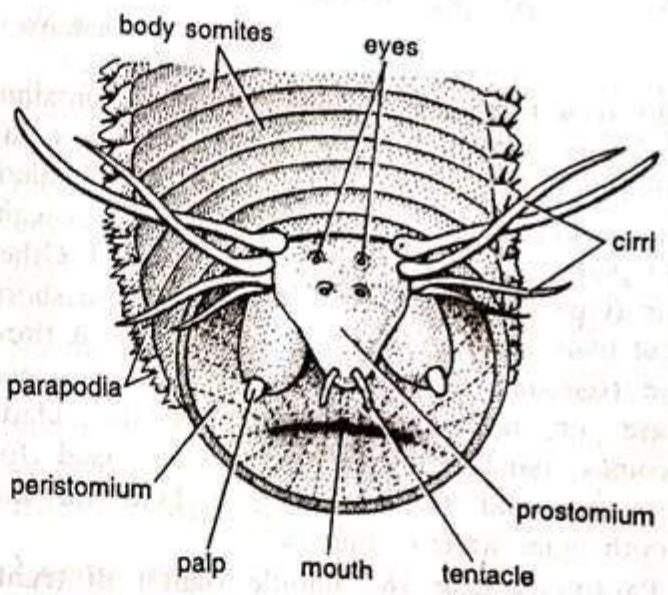


Fig. 5. *Nereis*. Head in frontal view.

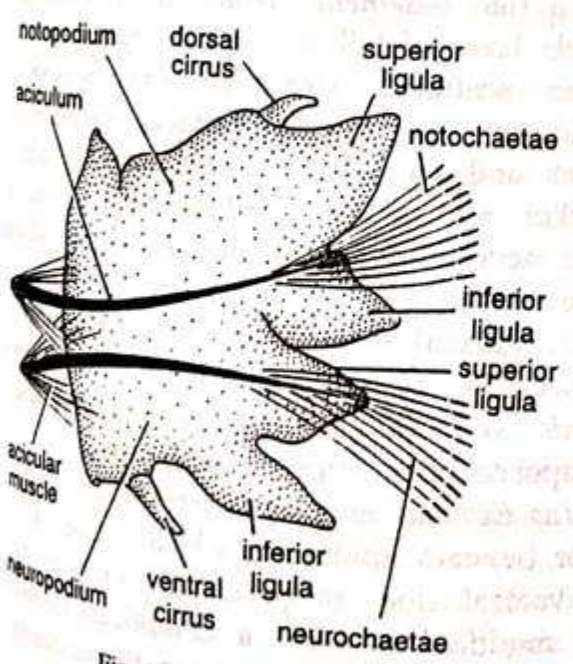


Fig. 6. *Nereis*. Parapodium.

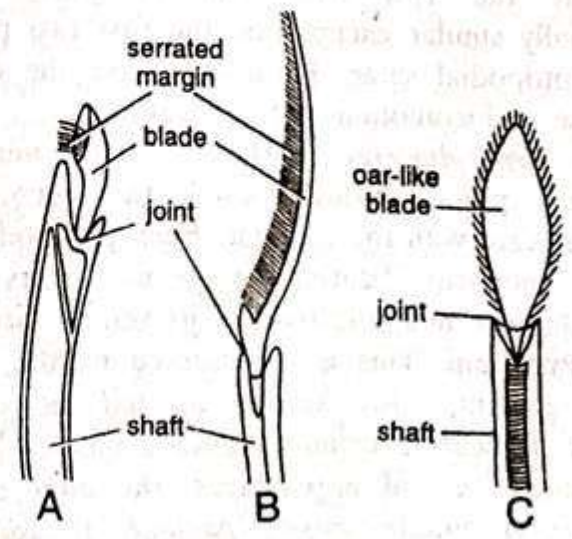


Fig. 7. *Nereis*. Kinds of setae. A—Typical. B—Long-bladed. C—Oar-shaped of *Heteronereis*.

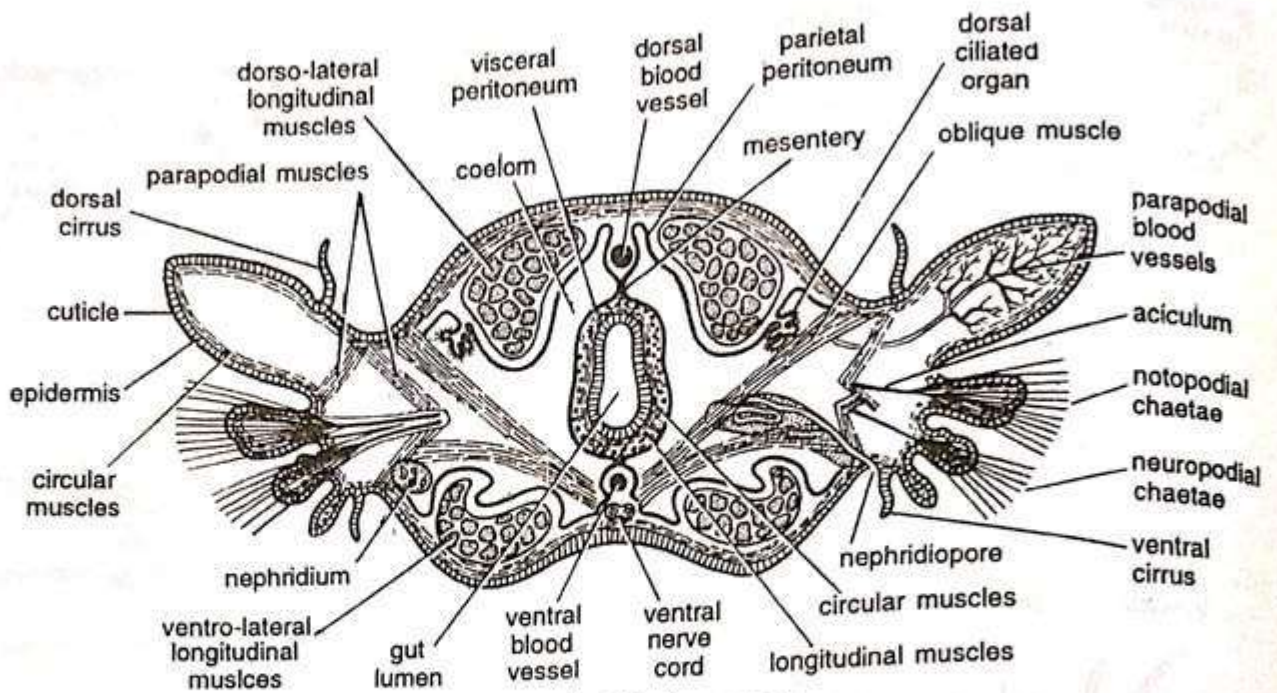


Fig. 8. *Nereis*. T.S. of a segment.

seta is a two-jointed structure with a proximal *shaft* and a distal *blade*. Setae of *Nereis* are generally of two types. One type (long-bladed) has a small shaft and a long, slender, straight and pointed blade with one edge serrated. Other type (typical) has a large stout shaft and a short, stout blade with an incurved notched tip. A third type (oar-shaped) of seta occurs in the sexual phase or heteronereis in which the blade becomes oar-like. Sharp setae are used for protection and for obtaining a hold on the smooth inner walls of burrow.

Parapodia near the middle region of trunk are the largest and gradually decreases in size towards the two ends. All parapodia are essentially similar except that the first two pairs lack notopodial setae. Parapodia serve the dual purpose of locomotion and respiration.

(b) **Nephridiopores.** These are minute excretory pores through which the nephridia communicate with the exterior. Each parapodium of a nephridia-bearing segment bears a nephridiopore near the base of its ventral cirrus.

3. **Pygidium.** This is represented by the last body segment, also known as *tail* or *anal segment*. It bears a terminal *anus*, a pair of long filamentous, ventral appendages, the *anal cirri*, and several minute *sensory papillae*. Parapodia are absent.

(Z-1)

## Body Wall and Musculature

The body wall of *Nereis* consists of four layers - (i) cuticle, (ii) epidermis, (iii) musculature, and (iv) peritoneum.

1. **Cuticle.** It is the outermost, thin, tough and chitinous layer, with a system of intersecting striations which impart iridescence to it. It is secreted by the underlying epidermis and is perforated by numerous minute openings of epidermal gland cells.

2. **Epidermis.** It lies beneath cuticle and rests on a thin *basement membrane*. It consists of a single layer of tall columnar *supporting cells* and some scattered *glandular* and *sensory cells*. Epidermis on ventral surface, especially near bases and on lobes of parapodia, is somewhat thicker and more glandular. Epidermal gland cells secrete *mucus*, which lines the U-shaped tube in which the worm lives.

3. **Musculature.** *Nereis* has a well-developed musculature consisting of (i) *circular*, (ii) *longitudinal*, and (iii) *oblique* muscles. These are composed of unstriated muscle fibres.

(a) **Circular muscles.** These form a continuous layer beneath epidermis, which is slightly thicker on ventral side. In parapodia, circular muscles are modified to form a complicated system of parapodial muscles comprising the *protractor* and *retractor* muscles.

retractor muscles. Protractors radiate from bases of setigerous sacs to the layer of circular muscles on all sides. Retractors extend from outer part of setigerous sacs to the dorso-lateral body wall.

Contraction of circular muscles make the body longer and thinner, while that of protractors and retractors causes respectively the protrusion and retraction of parapodial acicula and lobes.

(b) *Longitudinal muscles*. These do not form a continuous layer beneath circular muscles, but occur in four powerful longitudinal bundles, two dorso-lateral, one on either side of dorsal blood vessel, and two ventrolateral, one on either side of ventral nerve cord. Contraction of longitudinal muscles causes shortening and thickening of body.

(c) *Oblique muscles*. These lie in each segment in two pairs. First pair is situated at the level of anterior limit, and second at the level of posterior limit of parapodia. Each oblique muscle arises between ventral nerve cord and a bundle of ventro-lateral longitudinal muscles. It soon bifurcates into a dorsal and a ventral branch, each extending to the base of corresponding parapodium.

Oblique muscles are responsible for bending movements of parapodia and their complete retraction.

4. *Peritoneum*. Muscles are lined internally by a thin, delicate layer of *coelomic epithelium* or peritoneum. This layer also lines the coelom externally and is thus also described as the somatic or parietal layer of coelomic epithelium. It secretes the coelomic fluid.

5. *Functions of body wall*. Body wall of *Nereis* performs a variety of functions. (i) Cuticle protects the body against desiccation and mechanical injuries. (ii) Epidermis, being highly vascular, serves for respiration. (iii) Epidermal glands secrete mucus for lining the burrow so as to prevent it from collapsing. (iv) Epidermal sensory cells are responsible for perceiving external stimuli. (v) Musculature helps in various types of movements. (vi) Setae serve for locomotion. (vii) Peritoneal cells lining coelom secrete the coelomic fluid and give rise to gonads during breeding season.

## Coelom

Body cavity of *Nereis* is a true coelom of schizocoelic origin, i.e., it is formed by the splitting of embryonic mesoderm. It forms a spacious perivisceral cavity between the body wall and alimentary canal. Numerous membranous transverse *septa* or *coelosepta* divide the entire coelom into a linear series of compartments, each corresponding to a segment of body. Septa correspond in position to the external intersegmental grooves. They are perforated and each is composed of connective tissue and muscles sandwiched between two layers of coelomic epithelium. Coelom of each segment is further divided into right and left compartments by dorsal and ventral mesenteries. The latter, however, disappears in older segments.

Coelom is filled with a colourless coelomic fluid containing amoeboid corpuscles (*leucocytes*) and, during breeding season, numerous reproductive cells in various stages of development. It is internally lined by thin, delicate *coelomic epithelium* divided into two layers: a *parietal layer* beneath body wall and a *visceral layer* covering the alimentary canal. Coelom communicates with the exterior through nephridia. Coelomic fluid acts as an *hydrostatic skeleton* and for transportation of digested food, gases and waste materials.

## Locomotion

*Nereis* can crawl on substratum as well as swim actively. *Crawling* is affected by the activity of parapodia alone, while *swimming* involves parapodial activity as well as snake-like lateral undulations of body which are brought about by the wave-like contractions of longitudinal muscles.

Gray (1939) has described the pattern of parapodial activity during locomotion in *Nereis*. According to his observations, each parapodium behaves like a miniature paddle, alternately beating backwards (*effective stroke*) and forwards (*recovery stroke*). Opposite parapodia of adjacent segments always perform the same stroke at a time, while opposite parapodia of the same segment perform reverse strokes at the same