A TEXTBOOK OF ZOOLOGY

VOLUME ONE



K. R. SAXENA

A TEXTBOOK
OF
ZOOLOGY

[New Edition For the Students of Intermediate Course]

VOLUME I

By

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PREFACE

The Textbook of Zoology, Volume I is written according to the syllabus prescribed by the Government of Andhra Pradesh for the Two-Year Intermediate Course.

This book includes the types prescribed for the non-chordate and protochordate groups and thus covers the syllabus for the 1st year of the Intermediate Course. The second volume, including chordates and general biology is also intended to be written as per the syllabus.

While writing Vol. I, I have discussed the detailed structure of the 'types' and also the general characters of each phylum to which these types belong. Once the student is well acquainted with the type example of each phylum, I feel, he can understand the classification of the phyla more easily.

The classification as such is discussed at the end in Chapter X, along with a brief account of the Science of Biology and its various branches of study. This will facilitate the student in recalling his knowledge of the types studied and he may be able to follow well the details pertaining to the classification.

The account on 'Parasitic Amoebae' although not included in the syllabus is also given in order to maintain continuity. Further, while dealing with the account of certain types, some additional information is also provided. This is given in small print as it may go high for the first year intermediate student. It may however be useful to the students of the higher classes if they happen to refer to this book.

An attempt has been made to give as many figures as possible to illustrate the description. The life histories of the parasites are particularly illustrated with appropriate diagrams so that a student will be able to understand clearly the intricate life cycles.

At the end of each chapter, a list of probable questions on the 'types' discussed is given. This will be most useful to the students preparing for the examinations.

In writing this book, I have referred to the standard textbooks to keep the information as far as possible up-to-date.

I am highly grateful to Prof. M. R. Suxena, Head, Dept. of Botany and Director, NCERT Study Group in Biology, Osmania University to permit me to undertake this assignment when the offer came to me from the publishers. I also thank the Osmania University authorities for granting me permission to write this textbook.

Dr. Shyam Sunder Simha, Reader in Zoology, University College of Science, Osmania University, extended his whole hearted co-operation to me by providing the standard books on the parasites. I thank him very much for the same.

I was also very much benefitted by the consultations I had now and then with Dr. P. Narayana Rao, Department of Zoology, Osmania University. I extend my hearty thanks to him.

I am thankful to the publishers and their staff for their co-operation in printing this book with devoted interest and utmost care. Every care has been taken to minimise errors of printing, inspite of this, some errors in printing or otherwise might have crept in for which I offer my apologies and further hope to rectify them in future.

I hope the book will be useful to the students. The valuable suggestions and criticisms on this book if any will be most welcome. This will help me in improving the book in its future editions.

K. R. SAXENA,
Reader in Zoology,
University College of Science,
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HYDERABAD
25th Dec., 1969.

PREFACE TO THE SECOND EDITION

The chief feature of this new edition is that the account on **autogamy** in *Paramoecium aurelia*, has been rewritten and the relevant diagram indicating the process of autogamy in *Paramoecium aurelia* is added. A brief account on *cytogamy* in *Paramoecium sp.* is included.

The rest of the book has been thoroughly edited with suitable alterations wherever felt necessary. The basic plan of the book and the format are however kept the same as in the previous edition. Further, Two-Year Intermediate Examination Question Papers are also given for the benefit of the students preparing for the examination.

Hyderabad
July, 1972.

K. R. S.

PREFACE TO THE THIRD EDITION

In the light of the year-wise syllabus prescribed for I year Intermediate Course in Andhra Pradesh, the book has been revised accordingly. Certain portions not included in the syllabus have been deleted. Likewise, based on the revised syllabus, the descriptions of the *cell structure* and *function* as well as *cell division* have been added under *Part II General*. A separate chapter on *Nucleic acids* is however included under Part II General in order to make the students aware of the molecular aspects of cell biology.

Keeping in view the criticisms and suggestions received from the students and teachers both, few of the elaborations in the script made are as follows:

(i) The ultra-structure of a *cilium* has been rewritten with appropriate diagrams (Chapter 1 *p.* 17 and 18).

(ii) Few lines have been added pertaining to the diploid number of chromosomes in the micronucleus and the amount of chromatin found in the meganucleus of paramoecium. (Chapter I *p.* 26 and 32.)

(iii) A separate para in small print on the definitions of the terms *definitive and intermediate hosts* is added (Chapter I *p.* 35) in order to give a clear picture to the students regarding the usages of these terms.

Besides the above mentioned additions, the entire script has been thoroughly revised and edited with suitable alterations wherever felt necessary. The basic plan of the book and the format are however kept the same as in the previous editions.

The Two-Year Intermediate Examination Papers up-to-date are also given for the benefit of the students.

I am highly grateful to Shri Lakshmi Narayana, N.C , partner Messrs Sri Saraswati Book Depot, for all his valuable suggestions and critical editing. I also express my deep sense of gratitude to him and his staff for accepting last minute additions as well as deletions with apparent equanimity.

Hyderabad
31-8-1974.

K. R. S.

PREFACE TO THE FOURTH EDITION

In the light of the feed back received, the book has been revised scrupulously. The basic plan and format of the book are however kept the same as in the previous edition.

Few of the salient and distinctive features of this edition are as follows:

(i) An account on the life history of *Plasmodium* is rearranged in a manner easily comprehensible to the students. The accounts pertaining to the pathogenicity, treatment and control measures were rewritten incorporating thereby all recent information.

(ii) The description of the life cycle of *Ascaris lumbricoides* was totally rewritten so as to present a vivid picture of

the life cycle. Figures 4.3 and 4.5 are the new additions while the description of the reproductive system has been deleted as the life cycle only is included in the syllabus.

(iii) Certain diagrams pertaining to the account on leech as well as the details about the locomotion, copulation and cocoon formation have been deleted as only the external characters of leech are prescribed in the syllabus.

(iv) Under Part II General, an account of the cell structure and function was thoroughly edited and all extra details as and wherever felt unnecessary were ignored.

(v) In Chapter X dealing with the nucleic acids, the matter pertaining to the three possible pathways of DNA replication supported by Fig. 10.9 have been added to give a clear picture of the mechanism of DNA synthesis. Some details as well as certain diagrams included in the previous edition are deleted to make the description concise and compact.

(vi) In an account on cell division, I felt the necessity of adding a note on the '*cell cycle*' in order to make the student aware of the intricate changes that take place during the interphase period in a cell. The scripts on mitosis and meiosis have been rewritten in order to give a student a clear picture of these two types of cell divisions in the light of recent knowledge.

The Two-Year Intermediate Examination Question Papers up-to-date are included for the benefit of the students.

I am thankful to Dr. Shyam Sunder Simha, Professor of Zoology, University College of Science, Osmania University for extending his whole hearted co-operation by providing me suitable source books for the incorporation of the diagrams and relevant up-to-date details on the life cyle of *Ascaris lumbricoides*.

I am highly grateful to Shri Lakshmi Narayana, N.C. Partner Messrs Sri Saraswati Book Depot for all his valuable suggestions and critical editing. His vast experience in the field of publishing

and keen academic interests have always been a source of inspiration in the fulfilment of my task of writing. My thanks are also due to the staff of the press for the whole hearted co-operation in getting this book printed with devotion and utmost care.

The present edition of the book, I hope will cater to the needs of the students and teachers both. The valuable suggestions and criticisms from the students and teachers are most welcome.

Hyderabad. *K. R. S.*
September, 1975.

PREFACE TO THE FIFTH EDITION

In the light of the feed back received, the book has been revised and wherever I, genuinely felt necessary, additions deletions, and changes in the sequence of the subject matter were made. The basic plan and the format of the book are however kept the same.

The salient and distinctive features of this edition are as follows:

1. The account on the "mechanism of pseudopodial formation" has been added to explain to the students the possible explanations of 'amoeboid movements' as visualized under the 'Fountain zone' and 'Protein molecule' contraction theories, (*p.* 4, 5 and 6).

2. A brief note on the immunity measures being investigated, is included, under the heading 'Control measures' in an account of Malarial parasite (*p.* 53, 54) to make the student aware of the ways and means being tried to combat malaria which is now rampant all over Asia and Africa.

3. Some of those terms and phrases earlier used at several places have been precisely defined and explained under the foot-notes which will help the student in a better comprehension of the subject matter discussed.

4. The Two-Year Intermediate Examination Question Papers up-to-date have been included for the benefit of the students preparing for the examination conducted by the Board of Intermediate Education, Andhra Pradesh.

I am thankful to the publishers and their staff for the wholehearted cooperation extended to me in printing this book with utmost care.

I express my deep sense of gratitude to Shri Lakshmi Narayana, N. C., Partner, Sri Saraswati Book Depot, for his constructive comments, criticisms and even the last minute's suggestions. His keen academic interest and vast experience in the field of publishing have always inspired me in the fulfilment of my responsibility.

Every care has been taken to minimise errors. If some errors in printing or otherwise have inadvertently crept in, I offer my apologies for the same and hope to rectify them in future.

The present revised edition of the book I hope will cater to the needs of the students and the teachers both. Valuable suggestions for the improvement of the book are most welcome.

Hyderabad,
30th, October, 1978.

K. R. S.

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CHAPTER I

PROTOZOA—THE FIRST TRUE ANIMALS

The animal organisms consisting of a single cell are included in the phylum *Protozoa*, a name which literally means 'first animals' (Gr. *Protos*, first+*zoon*, animal). Phylum protozoa is the first of the large groups of Phyla into which the animal kingdom is divided.

The protozoans are unicellular organisms. The single cell of a protozoan performs all the essential functions of life e.g., locomotion (movement), feeding, respiration, excretion and reproduction.

The body of higher animals is composed of a number of cells. These cells are differentiated into tissues (cf. chapter IV p. 57 vol. II); the tissues form the organs and the various organs form the body of the higher organisms. Such animals are referred to as **multicellular animals** and are included in a composite group called **Metazoa** (Gr. *Meta*, after+*zoon*, animal).

The single cell of a protozoan may be compared to the cell of a metazoan, but as regards its functions, it differs from the cell of a metazoan. The single cell of a protozoan is the entire organism and performs all the essential activities of life. The unicellular organisms as such are referred to as **acellular organisms** since their body is not divided into many cells as found in the metazoans. We will now study the structure of a protozoan called *Amoeba*.

Amoeba :

The amoeba is found in ponds and ditches, crawling about in the mud at the bottom or over the decaying leaves and twigs.

Size : Amoeba is so minute that it is hardly visible to the naked eye. *Amoeba proteus* (Proteus animalcule) is about $\frac{1}{40}$th of a centimetre across. A giant amoeba recently rediscovered in America is *Chaos chaos*, which, during locomotion attains a maximum length of 2 to 5 mm and is therefore visible to the naked eye.

Form and Structure: When a live *Amoeba proteus* is observed under the microscope it can be seen to consist of a mass of protoplasm

containing many granules and droplets surrounded by a thin plasma membrane. When active, it can be seen to change its shape now and then by sending out blunt processes of protoplasm in various directions. Each such process is called a **pseudopodium** (Gr. *Pseudos*, false+*podos*, foot). *The irregularity of shape in amoeba is as such its striking feature.* In spite of a continuous change in its shape the outline of its body is however distinct due to the presence of a delicate membrane at its surface. This is called the **plasma membrane** or **plasmalemma**. Water passes freely through this membrane. It also permits oxygen to diffuse in and carbon dioxide to pass out; but the proteins, carbohydrates, fats, etc., are not allowed to escape into the surrounding water by this membrane. It has thus a selective action to allow certain substances to get in and disallow others to pass out of the body. Such a membrane is called a **selectively** or **differentially permeable membrane**. It is on account of this ability that the inner contents of the '*body*' of amoeba are kept at constant concentration.

Beneath the plasmalemma lies the cytoplasm. It is distinguished further into a non-granular distinct outer clear transparent peripheral zone called the **ectoplasm** and a central more fluid and granular mass of protoplasm occupying the entire interior portion of the

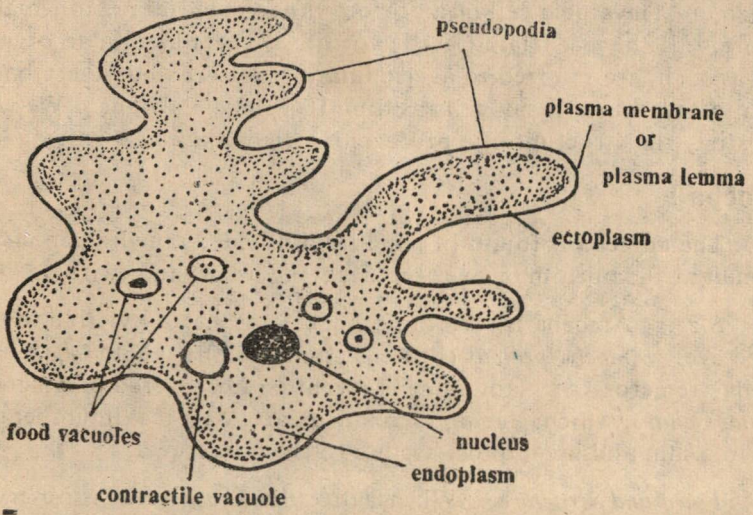


Fig. 1.1 Structure of Amoeba as seen under the high power of a microscope

body called the **endoplasm**. Within the endoplasm lies a distinct body called the **nucleus**. It is usually placed centrally Its position however is not fixed. It can be passively rolled about inside the amoeba when it moves. When the animal is stained with certain dyes, the nucleus can be seen very conspicuously as it takes up a deep stain than the surrounding cytoplasm. Nucleus is important for the survival of amoeba and for performing other vital activities. If the nucleus is removed by micro-dissection from the amoeba, it may survive for some time but will not be able to perform all the other vital activities. Behind the nucleus is a clear spherical space which will be seen to contract and expand regularly in alternate turns. This is called the **contractile vacuole**. Besides these, within the endoplasm may be found vacuoles containing food substances, called the **food vacuoles**.

Locomotion: As already stated, change in shape of *Amoeba* is caused by the apparent flowing of cytoplasm towards certain points of its 'body' as a result of which temporary projections called **pseudopodia** are formed. The pseudopodia can also be withdrawn from somewhere else, consequent to which if the pseudopodia are formed mainly in one direction, the amoeba will not only change its shape but also its position i. e., it performs locomotion as well with the aid of pseudopodia. The pseudopodia are also helpful in the digestion of food as they engulf the food particles.

The movement in Amoeba that occurs due to pseudopodia is called **Amoeboid movement**. Besides amoeba, the amoeboid movement is also observed in a wide variety of metazoan cells ranging from oocytes of sponges to white blood corpuscles of vertebrates.

A number of theories have been proposed to explain the formation of pseudopodia and the mechanism of amoeboid movement in general.

According to one view it is thought that pseudopodia are formed by a change in the colloidal nature of the cytoplasm at the point where the pseudopodium appears. The inner cytoplasm i.e., endoplasm being more fluid is in a **plasma sol** state whereas the outer layer of the cytoplasm i.e., ectoplasm being relatively firm is

in a **plasma gel** state. Amoeboid movement from this point of view can be interpreted as a result of coordinated *gelation* and *solation*.

The formation of pseudopodium may seem to involve the flow of rather fluid inner cytoplasm (plasma sol) at the points where the the relatively firm outer layer of cytoplasm (plasma gel) undergoes temporary liquefaction. The flowing plasma sol thus forms a bulge but on reaching the surface also appears to become transformed into plasma gel as it everts at the surface and passes backwards due to which more plasma sol moves out into the bulge. At the hinder end, the ectoplasm contracting during this process, turns into a sol state and contributes to the continuous streaming of the endoplasm from behind forward. This type of squeezing of endoplasm from behind forward is analogous to the squeezing of a tooth paste out of a collapsible tube by exerting pressure on the surface of the tube at the hinder end.

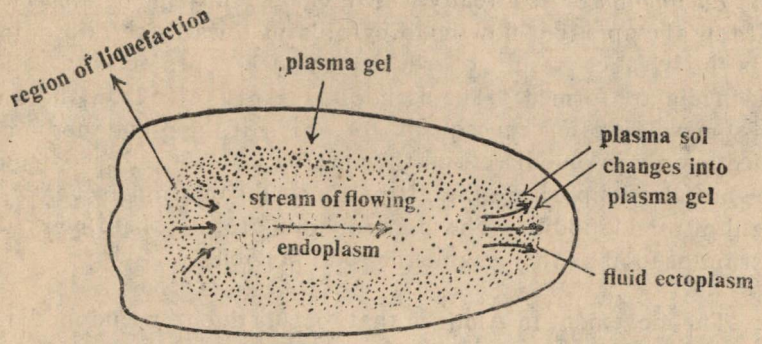


Fig. 1·2 The diagram illustrating mechanism of amoeboid movement

At the end opposite to the pseudopodium can be seen a portion of cytoplasm with wrinkles called the **uroid**—a semi-permanent structure. (See fig. 1·3). When amoebae float in water the pseudopodia radiate more or less in all directions and the animal presents a star-shaped appearance. However, when the animal is crawling on a surface all the pseudopodia tend to point in the direction of movement.

Mechanism of Pseudopodial Formation :

The interpretation given above the formation of pseudopodia remains in principle the most favoured one. According to this,

Amoeba can be thought of as a tube of plasma gel containing the more fluid plasma sol. At the end at any particular moment, the gel undergoes solation and contraction forces the fluid sol forwards. There is a transformation of sol to gel at the anterior end so that solation is balanced by gelation. The above phenomenon of the conversion of gel into sol and sol into gel states may be compared to the flowing stream of liquid cement which while flowing also hardens on the outside and thereby builds ahead of itself a hard tube through which flows more fluid cement from behind forward.

The above mentioned mechanism of pseudopodial formation can be interpreted to some extent on the basis of the structure of cytoplasm. The cytoplasm apart from its membranes and fibrils consists of large protein molecules possibly joined together (with water and metabolites) to form long polypeptide cross linked chains. In the general ectoplasm these polypeptide chains are unravelled (extended) and oriented. At the hinder end the chains become folded and contract so as to force forward the stream of endoplasm. The folding also favours a change to sol state. At the tip of the advancing pseudopodium the protein molecules unravel (extend) and form the ectoplasm. This theory of *Amoeboid movement* is called "*Protein molecule contraction theory*."

In 1961, Robert D. Allen of Princeton University put forward a totally different theory to account for amoeboid movement. Allen argues that the endoplasm is not uniformly solated. He thus supposes that contraction of gel at the posterior end cannot by itself account for the forward flow. Instead, he believes that contraction occurs at the anterior end in a "*fountain zone*" and that this process actively pulls the axial endoplasm forwards. This theory of the mechanism of formation of pseudopodia is referred to as '*fountain zone contraction theory*.' On the basis of careful observation on the behaviour of endoplasm both in intact amoebae and ruptured cells, Allen suggested that the protein molecules are extended (unravelled) in the endoplasm and folded in the ectoplasm, the reverse of the situation claimed by the old theory.

Allen claims that forward movement is not caused by squeezing at the rear end, but by a pulling force at the front end (fountain zone). This, it is thought is attained by the protein molecules of

the endoplasm at the front end before they pass into the endoplasm. Both the theories state that temporary adhesion between the plasmalemma and the substrate should take place. Internal streaming alone cannot cause locomotion. It has been shown that some species of amoebae will continue to move in the same direction for long periods which suggests that such amoebae possess a constant posterior end.

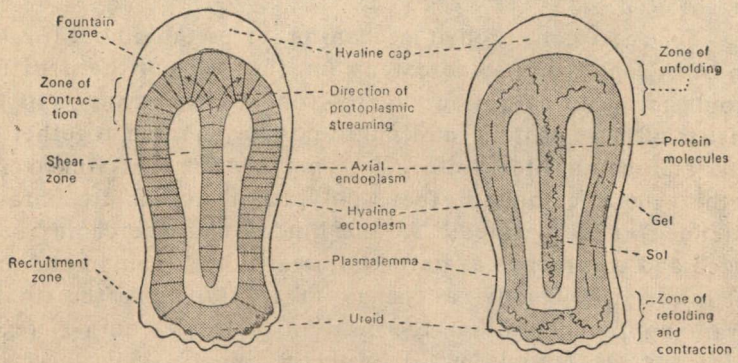


Fig. 1·3 *Mechanism* of *Amoeboid movement* (A) "Fountain zone" contraction theory put forward by Robert Allen et al., 1961; (B) Protein molecule contraction theory by Goldacre and Lorch, 1950.

There is as yet no complete or final explanation of amoeboid movement and some kinds of amoeboid organisms move in quite a different way than amoebae.

It is not known which of the two theories described is correct. The results of studies however on the properties of cytoplasm are more consistent with the *fountain zone theory*.

Sensitivity : There are no special sense organs in amoeba. Inspite of this it is sensitive to a number of stimuli. The entire cytoplasm is capable of responding to the stimuli in such a way as to maintain itself in a suitable environment. If an amoeba is locally

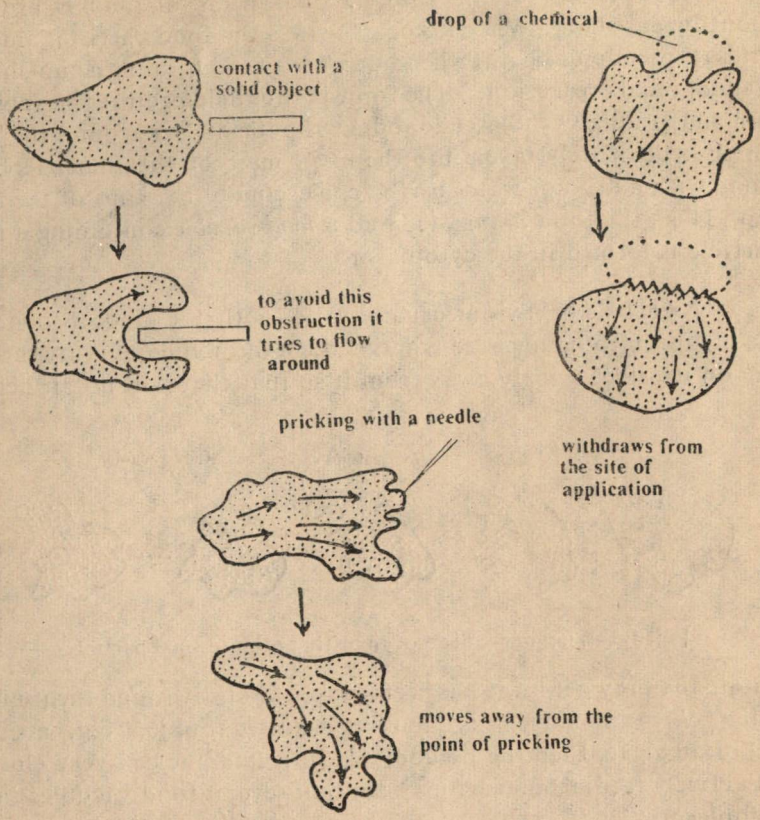


Fig. 1.4 Diagrams illustrating sensitivity in Amoeba

stimulated by applying some chemicals to a part of its body, it withdraws its body from the source of application. It responds to a number of changes, such as contents of the surrounding medium, fluctuation in temperature and also to the intensities of light and heat.

Nutrition: The food of amoeba consists of minute plant organisms like diatoms, some minute flagellates and ciliates (organisms having flagella and cilia which are hair-like protoplasmic processes) and also bits of decaying organic matter. Although they have no special organs of taste and smell; amoebae are yet able to distinguish inert particles from the minute plants and animals upon which they feed.

The process of ingestion i.e., taking in of food is brought about by engulfing. When it comes across the food particle, amoeba sends its pseudopodia on either side of the food forming a cup-shaped pseudopodial projection. The food is thus held against the substratum and gradually the pseudopodia wrap themselves around the food which is ultimately taken into the main mass of the amoeba's body along with a drop of water by the coalescing of the rims of the food cup. Thus, the food is ingested and a *food vacuole* containing a food particle is formed in the cytoplasm.

Amoeba's behaviour usually varies with the kind of food. If the organism to be ingested is active, then the pseudopods are thrown out on its sides widely away from it so that they will not touch or

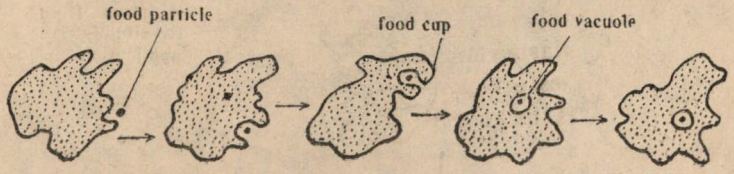


Fig 1.5 The mechanism of ingesting minute food particles

irritate the prey before it has been wrapped totally round the pseudopodia. When the amoeba is engulfing a quiscent object e.g., a single cell of an algae, then the pseudopods surround the cell very closely. An actively feeding amoeba may contain several food vacuoles in its endoplasm.

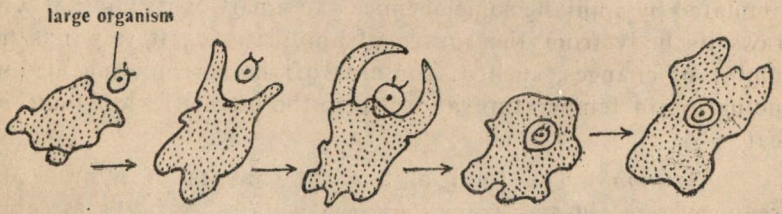


Fig. 1.6 The mechanism of ingesting active and large organisms

After the formation of the food vacuole the digestion of the ingested food takes place. The enzymes are secreted from the surrounding cytoplasm into the food vacuoles along with some fluid.

The nature of this fluid ascertained with the help of some harmless indicator dyes is shown to be acidic in reaction. The acidity perhaps helps to kill the prey. Later, as the digestion proceeds, the contents of the food vacuole give an alkaline reaction. Most of the enzymes of the amoeba act best in an alkaline medium. The enzymatic action in amoeba leads to the digestion of food. The digested food material in solution is absorbed into the surrounding cytoplasm.

The indigestible fragments of the food are eliminated by a simple process of *egestion*. The vacuole containing these undigested particles moves to the outer end of the body where it bursts through the plasma membrane. The particles are ultimately left behind as the animal flows away from them.

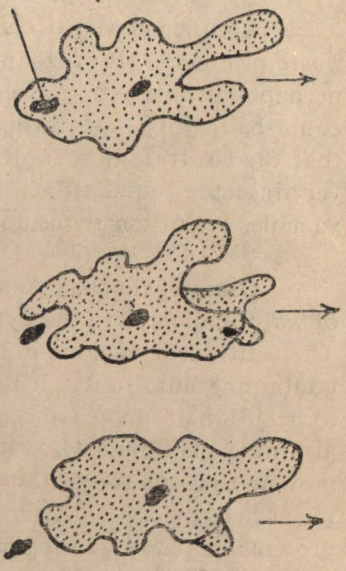


Fig 1·7 The egestion of indigestible food particles by amoeba

It has also been noticed at times that very minute vacuoles are formed at the surface of the body of amoeba. The fluid of these vacuoles is later taken into the endoplasm by a process called **pinocytosis**. Thus, the amoeba like the white blood cells are also capable of taking in food substances in soluble state. In this way, some species of amoeba can sustain themselves well, even when solid food is not available.

Respiration and Excretion: There are no special organs of respiration in the amoeba. The entire surface of the body of amoeba remains in contact with water which contains oxygen. The oxygen simply diffuses into the body through the plasmalemma. Likewise carbon dioxide produced in cellular respiration diffuses out through this membrane into the surrounding water. Diffusion is a pheno-

menon wherein the particles of matter tend to move from regions of higher concentrations to the regions of lower concentrations. In the first instance mentioned above, the concentration of oxygen dissolved in the surrounding water is more than that found in the cytoplasm of the amoeba. The oxygen consequently diffuses into the cytoplasm. Once the oxygen in the cytoplasm is used up in the oxidation of food substances, the carbon dioxide produced will be at a higher concentration in the cytoplasm. The carbon dioxide therefore diffuses out of the cytoplasm into the surrounding water.

Another vital process of life is the elimination of nitrogenous waste products. Protozoans excrete their nitrogen as *ammonia*, and perhaps to some extent as *urea*. It seems likely that these substances could be readily lost through the body surface. The old concept that the contractile vacuole is a specific excretory organ rests on a very insecure foundation. The favoured view is that the contractile vacuoles are primarily osmoregulatory.

Osmoregulation : Amoeba discharges to the exterior the excess of water collected in the cytoplasm through its contractile vacuole. The contractile vecuole is found in the form of a spherical cavity containing fluid in it. It is seen in the endoplasm. It can be found to be gradually increasing in size by the collection of liquid. After attaining maximum size, it may be seen to collapse suddenly by moving towards the surface like a bladder filled with water collapsing when pricked. After its collapse, it soon reappears, gradually growing in size, attaining maximum dimensions and finally collapses. Thus, the contractile vacuole contracts and expands regularly in alternate turns. In other words, it is always in a state of systole and diastole in alternate turns. It is obvious that the contractile vacuole during its periodic appearance and disappearance collects and discharges the fluid to the outside. The fluid accumulated is water which is now and then expelled from the cytoplasm. The contractile vacuole, therefore serves the purpose of controlling the content of water in the cytoplasm. Thus, the process of osmoregulation i.e., the regulation of water content in the cytoplasm is performed by the contractile vacuole. The amoebae living in fresh water have therefore solved the problem of discharging excess water to the exterior through the contractile vacuole.

The excess of water in amoeba occurs in three ways—(i) some is formed during the metabolic activities (ii) some water is taken in during the ingestion of food and (iii) some enters the cytoplasm through the plasma membrane by osmosis.

The water which enters the cytoplasm in the above ways is much more than is needed. If this is allowed to accumulate, the amoeba may swell from internal water pressure and may even burst. The contractile vacuole therefore is indispensible to avoid this danger.

It has further been noticed that amoebae living in salt water do not form contractile vacuoles. This is due to the fact that in such forms the concentration of minerals in surrounding medium is equal to or greater than the concentration of minerals in the cytoplasm of such amoebae. If such amoebae are placed in fresh water, they develop again the contractile vacuoles.

Growth and Reproduction: An amoeba which is feeding actively grows in size on account of the synthesis of new living material. The growth however cannot continue indefinitely. The amoeba after assuming the optimum size resorts to a simple process of division called **binary fission** which means the splitting of a cell body into two parts. It is a type of asexual reproduction as there is no fusion of nuclei obtained from the male and the female sex cells.

In binary fission, the nucleus of a full grown amoeba elongates first and then divides into two parts by a process of mitotic division. The cytoplasm later distinguishes into approximately two equal parts surrounding each nucleus. A central constriction then appears in the cytoplasm which soon narrows to such an extent that it ultimately splits. Thus, two small amoebae with a nucleus and cytoplasm in each are obtained. These are called the *daughter amoebae.* Each one now leads an independent life and grows in size by active feeding. After attaining the maximum size each one again resorts to the process of binary fission. The continuous process of binary fission gives rise to hundreds of amoebae. The organism never faces natural death due to this mode of multiplication. With respect to this phenomenon in amoeba, it has been said that "*Amoeba is potentially immortal*" i.e , the amoebae, which we see are the descendants of parent forms that have lived for millions of years through countless

binary fissions. Death may however come to amoeba by accidents e.g., the adverse conditions of the environment in which they live.

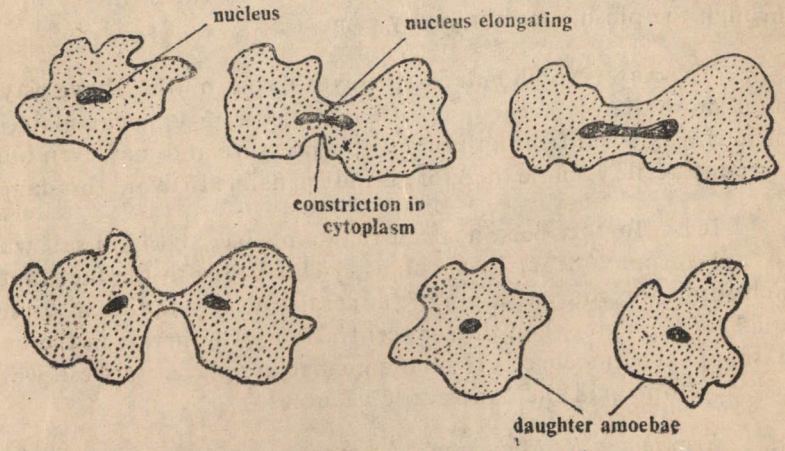


Fig. 1·8 The binary fission in Amoeba

Encystment : The amoebae which exhibit all the activities of life except reproduction are said to be in the vegetative phase. Under certain unfavourable conditions of the environment such as the drying up of a pond, etc., an amoeba is incapable of performing its daily activities and faces a potential danger to its survival. Under these conditions, the amoebae enclose themselves in a protective covering called the cyst. They are said to be *encysted.* The cyst is composed of a substance called chitin. During the encystment, the metabolic activities are reduced to the minimum, necessary to sustain life. These cysts of amoebae may be blown about in the dust by the wind. The encysted amoeba is capable of withstanding unfavourable conditions for a long period. When conditions become favourable the cyst wall ruptures and the amoeba coming out of it resumes its normal vegetative activities.

The formation of cysts in *Amoeba proteus* is doubtful. The possibility of cyst formation in it however cannot totally be denied as it has also to face a condition like drying of ponds occasionally. The amoebae belonging to limax group definitely form cysts to withstand adverse conditions. It has been reported that these soil amoebae are capable of standing a temperature of −270°C during encystment.

During encystment, sometimes the amoeba enclosed in a cyst may undergo multiple fission producing thereby a number of smaller forms called **amoebulae**. When the cyst ruptures, these young amoebulae start feeding actively and after growing to their normal size continue the process of binary fission

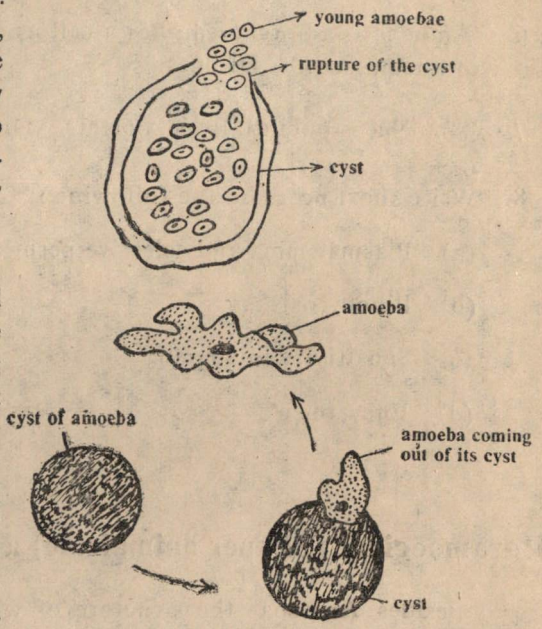


Fig. 1·9 Encystment in Amoeba

It is further claimed that young amoebulae of proteus type coming out of the cysts do not grow directly to their optimum size. They gradually grow and again encyst thereby remaining dormant for sometime. They then hatch i.e., come out of their cysts, then grow and again encyst. This process of growth and encystment goes on alternately a number of times until at last they assume their full size.

Revision questions

1. Describe in detail the microscopic structure of *amoeba* and mention in brief the various life processes performed by this protozoan.
2. What is the mode of locomotion in *amoeba*? Discuss the mechanism of amoeboid movement.
3. How does amoeba obtain its food? Give an account of the process of digestion in amoeba.
4. Describe the process of reproduction in amoeba. What is the significance of encystment?

5. What is meant by osmoregulation ? Describe the role of the contractile vacuole of the amoeba in this process.

6. 'Amoeba is an organism, not a cell as compared with the cell of a metazoan.' Discuss.

7. 'Amoeba is potentially immortal.' Discuss.

8. Write short notes on the following :

   (a) Plasmalemma and selective permeability.

   (b) Pinocytosis.

   (c) Sensitivity in amoeba.

   (d) Encystment.

Paramoecium (Slipper animalcule) a complex protozoan

Besides Amoeba, the structure of which you have already studied, there are other unicellular organisms belonging to phylum protozoa with many more specialisations and complex structures.

One such good example of a complex protozoan is a free living form called *Paramoecium*.

Occurrence : Paramoecia are abundantly found in ponds and streams which are rich in decaying organic matter and abound in bacteria. A number of species are known. The commonest one studied is *Paramoecium caudatum* which attains a length of 0·15 to 0·3 mm. It is just visible to the naked eye and appears as a white speck darting forwards and backwards. *Paramoecium aurelia* is 0·12 to 0·25 mm in length. The body of the paramoecium like that of the amoeba is composed of a single cell but differs from it in having a definite form and shape. Further, paramoecium swims about very rapidly through water as against the slow creeping movements of amoeba.

Form and Structure : The general outline of the body of the paramoecium is quite like that of the sole of a slipper hence its common name, **'the slipper animalcule'**. The anterior end is bluntly round, widest behind the mid-part of the cell body and posteriorly the body is somewhat pointed bluntly. The anterior end appears to be twisted as there extends below this end a shallow groove or depression known as the **oral groove** or the **peristome**. At the hind

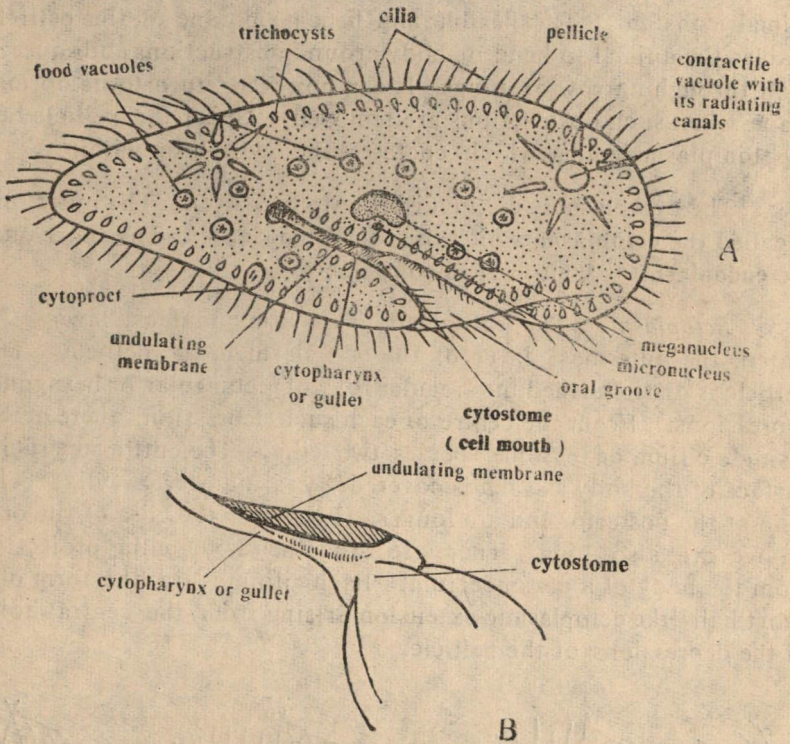


Fig. 1.10 (A) Internal structure of paramoecium (B) Cytostome, cytopharynx and the undulating membrane in Paramoecium

end of the peristome is found the **cell mouth** or the **cytostome**. The cytostome communicates posteriorly with a wide channel running obliquely backward as far back as about one-third of the length of the animal from the posterior end, and then becomes a tube passing obliquely and extends down into the cytoplasm. The tube is referred to as the **gullet** or **cytopharynx**. Through this tube the food

is taken in. During movement the blunt round end is directed forwards, hence it is called the anterior end and the bluntly pointed end is referred to as the posterior end. These terms are however used more for the sake of convenience as the animal can occasionally reverse the direction of its movements.

The entire spherical surface is covered by a distinct elastic and firm membrane called the **pellicle**, which keeps the shape of the animal constant. The flexible and firm membrane of the pellicle enables the animal to bend its body around obstructions and squeeze itself through narrow openings. It can however return to its normal shape when such obstructions are removed. Under the pellicle lies the thin plasmalemma which encloses the cytoplasm within.

The cytoplasm is distinguished into two layers. The outer one is called the **ectoplasm** which is somewhat dense. The inner one, the **endoplasm**, is semi-fluid in consistency.

Ectoplasm: The ectoplasm is a firm and dense layer. As stated, the outermost layer of the ectoplasm is the pellicle. The pellicle is distinguished into regular rows of rectangular or hexagonal depressions. From the centre of each such depression, there arises a single cilium or in some species two cilia. The entire superficial surface of the body as such is covered by a number of cilia. The cilia at the posterior end are longer. Likewise, the cilia of the oral groove are also long. There are altogether 2,500 cilia projecting from the body of a paramoecium. Each cilium is in the form of a short hair-like ectoplasmic extension arising from the central holes of the depressions of the pellicle.



Fig. 1.11 The cilia in a single row, appearing to beat in waves

At the base of each cilium is found a small round granule which takes a dark stain with haemotoxylin. These are called **basal granules** or **kinetosomes**. They are arranged in longitudinal rows. Each such row is called a **kinety**. Running along the sides of each

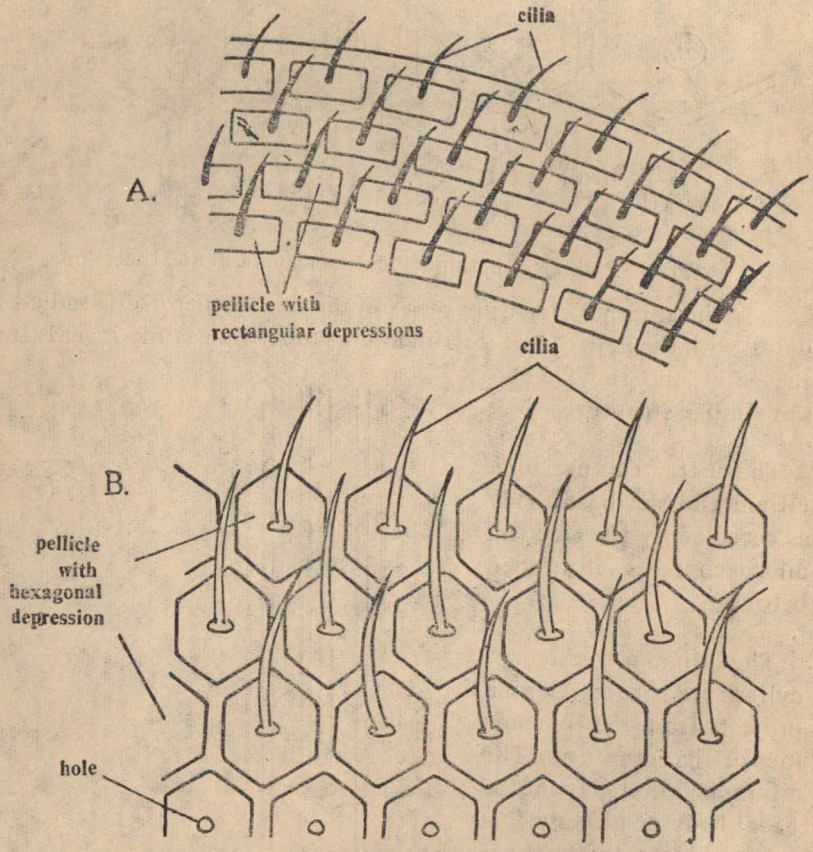


Fig. 1·12 A regular row of (A) Rectangular, (B) Hexagonal depressions in pellicle with cilia emerging from its surface

kinety is found a composite fibre called the **kinetodesma.** Some accessory fibres from each kinetosome or basal granule join with the kinetodesma along its entire length. The functions of kinetodesma are uncertain. They are perhaps contractile structures which bring about distortions in the shape of the animal when it is squeezing through narrow openings. In this respect they resemble the myonemes i. e., the contractile threads found in certain ciliates like **stentor** or in the stalk of **vorticella.**

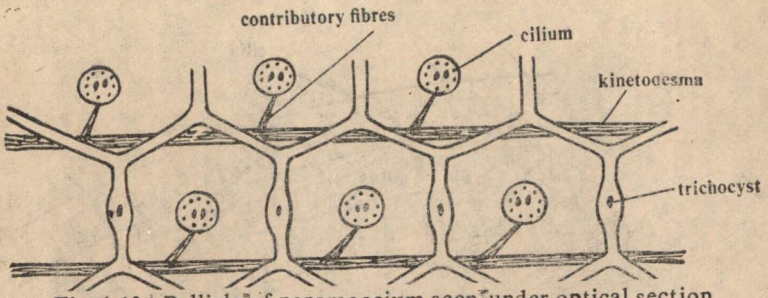


Fig. 1.13 Pellicle of paramoecium seen under optical section

The internal structure of a cilium has further been studied in detail with the help of an electron microscope. This study reveals that the cilia and the flagella are similar structures.

The ultrastructure of a **cilium and the basal body** as revealed by the electron microscope is described below.

The cilium is the slender cylindroid process which projects from the free surface of the ectoplasm. The cilium originates from the **basal body** or **granule**. It is the intracellular organoid similar to the centriole.

The diameter of a cilium in cross-section is about 2000 Å There is an outer ciliary membrane covering the cilium superficially. The ciliary membrane is continuous with the plasma membrane.

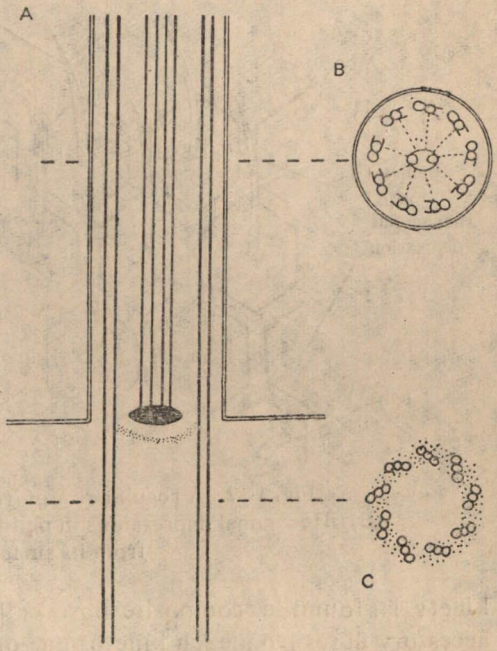


Fig. 1.14 The structure of a cilium. (A) Longitudinal section. (B) Transverse section passing through the ciliary shaft with nine pairs of peripheral and a single pair of central tubules. (C) T. S. basal body showing the arrangement of the fibril triplets

Inside the ciliary membrane is the ciliary matrix. Embedded in the ciliary matrix are found **nine pairs** of fibrils having a tubular substructure. These nine tubules in pairs are circularly disposed. The diameter of each tubule is about 180 to 250 Å. In the centre of the cilium are **two central fibrils** which appear as single tubules. These two central tubules are surrounded by a central sheath. There are also radially oriented links or spokes which extend towards the peripheral tubules. Along the length of the cilium the 9+2 tubular structure is maintained but at the distal end, the peripheral tubules taper while the central ones may extend considerably.

The basal bodies appear as cylinders 1200 to 1500 Å in diameter and 3000 to 20,000 Å (2 μ) in length. As in a cilium, there is an outer wall composed of nine groups of tubules disposed in a circle. Each group however is made of **three tubules** instead of a pair as in cilium. The tubules are disposed in a skewed fashion towards the centre. There are no central tubules. Basal bodies are closed at the outer end by a terminal plate. This plate limits the basal body from the base of the cilium proper.

It is suggested that the basal bodies of cilia and flagella are homologous with the *centrioles*. This homology is now fully confirmed with the introduction of electron microscope.

Trichocysts : Below the pellicle there is a thick clear layer of ectoplasm called the **cortex**. In this are found embedded a regular row of peculiar structures called the **trichocysts**. They are found in the cortex immediately lying under the transverse ridges between the rectangular depressions of the pellicle. They are in the form of spindle shaped sacs with a fine point and consist of some semi-liquid substance. Their pointed ends face towards the outer part of the cortex placed at right angle to the surface.

When a paramoecium is pursued or irritated, a number of trichocysts are suddenly shot out and in so doing they eject long threads. These threads are longer than the cilia. They are probably helpful to the animal in its anchoring or adhesion to the substratum. In other ciliates, they are nodoubt defensive structures and even in paramoecium it is suggested, that the trichocysts are helpful to escape from the attacks of some predaceous ciliates like *Didinium*. In other

ciliates e.g., *Dileptus*, the trichocysts are used to attack and paralyse their prey.

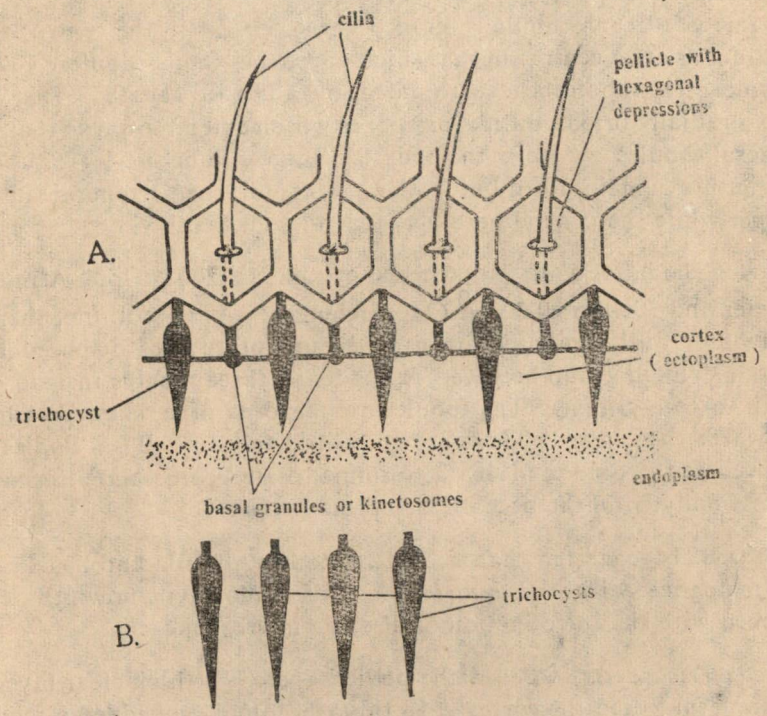


Fig. 1.15 (A) A small portion of the surface of paramoecium showing the cilia and the trichocysts (B) Separate trichocysts

Contractile Vacuoles and Osmoregulation: Within the cortex also lie two contractile vacuoles. They are situated at opposite ends of the body, one at the anterior end and the other at the posterior end. Each vacuole attains its maximum size in the form of a large spherical space surrounded by some six to ten radiating canals arranged like the spokes of a wheel. The wide ends of these canals lie under the central vacuoles and the pointed ends away from it. The central vacuole after complete diastole or expansion, undergoes contraction or systole discharging thereby water to the exterior. When the central vacuole collapses, the radiating canals obviously drain water from the dilated ends towards the inner central point. Thus, a new central

vacuole appears. The canals after conveying water into the central vacuole shrink and appear as mere slits. This process is repeated again and again in alternate turns. Every time the contents of the central vacuole are discharged to the exterior through a minute space in the pellicle.

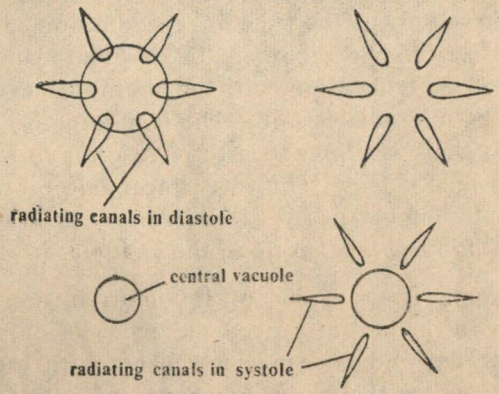


Fig. 1·16 The contractile vacuoles with their radiating canals in a state of diastole and systole

The contractile vacuole fills and empties its contents in about fifteen seconds only. The action of radiating canals along with the central vacuole is similar to what you have learnt about the contractile vacuole of amoeba. They regulate the content of water in the cell and as such perform osmoregulation.

It is observed that the posterior vacuole pulsates more rapidly than the anterior one. This is partly due to its proximity with the cytopharynx which acts as an additional surface for taking in of more water.

It is estimated that the two contractile vacuoles of paramoecium can eliminate within half an hour the volume of water equivalent to its body volume. Amoeba requires nearly four to thirty hours to eliminate water equal to the volume of its body. Man likewise eliminates a volume of urine equal to his body volume in about three weeks. In addition to this, excess of water in man, is also disposed of through his lungs and sweat glands.

Endoplasm : The endoplasm lies below the ectoplasm. In the endoplasm lie embedded two nuclei of different sizes and functions. These nuclei lie above the gullet. The larger one

with a depression at one of its ends is called the **meganucleus**, and the smaller one is called the **micronucleus**. The micronucleus is lodged in the depression of the **meganucleus**. In *Paramoecium aurelia*, there are found two micronuclei. The meganucleus is concerned with the control of the ordinary metabolic activities or the vegetative activities of the organism. The micronucleus becomes functionally active only at the time of reproduction, in which process it plays a very important role. In an allied form of paramoecium, the part of the body along with the micronucleus was removed experimentally by microdissection. The remaining part of the body with the meganucleus was later seen to restore the form of the body and was able to feed. It was however incapable of reproduction. This suggested the important role of micronucleus in reproduction. A number of *food vacuoles* also lie in the endoplasm.

Locomotion: Two modes of locomotion are observed in paramoecium. In the first instance, the paramoecium is able to perform contracting and twisting movements with the help of its cilia. These are called the *creeping movements*. Paramoecium can squeeze through tangled masses of minute water weeds and similar obstacles.

The second type of movement is performed by *swimming*. This is effected by the rapid, concerted and repeated movements of the body forward. It can however move in the reverse direction by the reversal of the ciliary beat.

The cilia do not beat simultaneously but in the form of a wave-like movement which begins at the front end of the animal and then it progresses backwards. This wavy movement may be compared to the waves observed on a paddy field when the wind blows over it. The cilia, besides helping in swimming, can also help in getting the food particles into the mouth. The large cilia of the oral groove produce by their beating, a vortex of water resulting in the ingestion of food particles into the mouth. Thus, the cilia of paramoecium like the pseudopodia of amoeba not only help in locomotion but also in the ingestion of food particles.

During swimming by the beating of the cilia, the paramoecium traces out a spiral path instead of a straight course. Further, the animal while moving forward rotates or revolves on its own axis like

a rifle bullet rotates along its own axis when shot. In addition to this, the anterior end of the body swerves i.e., shifts from the axis of movement so that the oral groove always faces the axis.

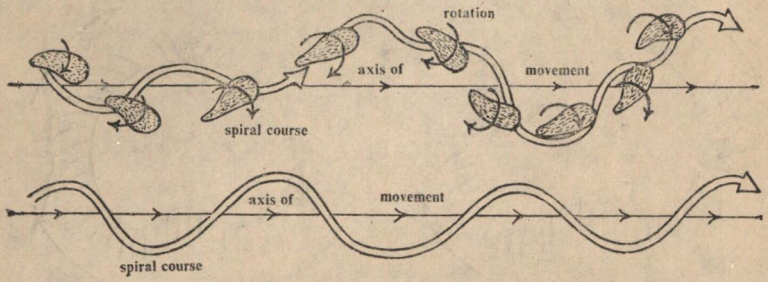


Fig. 1·17 The movements in paramoecium showing the spiral course traced and the rotation of the body.

The sequence of events during swimming are as follows :

1. The cilia first, in the relaxed state of the stroke, reach forward and then give a strong backward lash just as the arms of a swimmer are moved while he takes a crawl stroke.
2. The strong back-stroke of the cilia is not straight but is obliquely to the right. In consequence to this, the animal moves forward. Further, at the same time due to the oblique stroke of the cilia the animal rotates on its own axis on its left side.
3. The beating of the large cilia of the oral groove more strongly than the rest of the body results in the tracing out of a spiral course. If the animal does not rotate on its axis it swims in circles.

The spiral path enables the animal to cover more territory. It further facilitates to test more samples of water. This consequently helps to choose the favourable spots which would not have been possible by moving in a straight line. Paramoecium can swim 180 mm per minute.

If the paramoecium during its usual course of swimming is faced with any obstacle, the ciliary beat is reversed and the animal swims backward for a short distance before resuming its forward

movement in a different direction. The sequence of events during the reversal in the direction of movement are as follows :

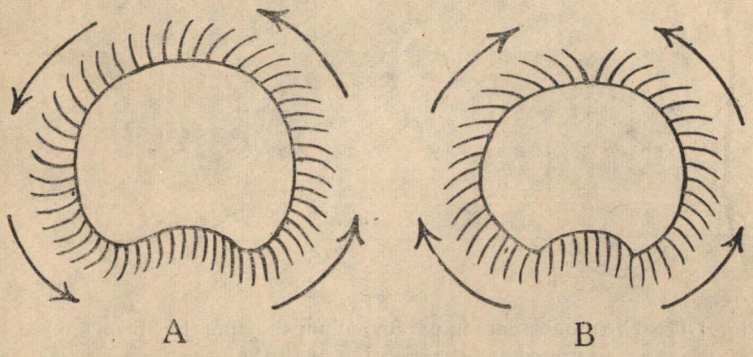


Fig. 1·18 Diagram illustrating the action of cilia as seen from behind (A) Obliquely backward beat during forward movement (B) Opposing action of cilia during the reversal in the direction of movement

When an obstacle is faced, the cilia stop beating momentarily and later they soon beat in the opposite direction. This results in swimming backward for a short distance. When a forward movement is about to be restored, the cilia start beating more directly backward and the animal rotates more slowly. At the same time the cilia on the oral groove beat more strongly increasing thereby the swerve towards the aboral side and the anterior end swings round in a wider arc. The animal ultimately resumes its normal swimming. This type of behaviour shown by paramoecium to resort to reversal in the normal direction of swimming on account of an obstacle is called the **avoiding** or the **shock reaction.**

Nutrition: The food of the paramoecium chiefly consists of bacteria and other small organisms which live with the paramoecium in ponds and puddles. As is already mentioned, the vibrations of the cilia in the oral groove can draw in, a cone-shaped volume of water into the groove from a considerable distance in advance of the anterior end. The particles of food are thus taken into the oral groove along with the current of water and the particles are shifted into the cytopharynx through the *cytostome* or *cell mouth.* The arrangement of the cilia in the cytopharynx is characteristic. They are arranged in

longitudinal rows and are referred to as the **undulating membrane**. This undulating membrane serves to shift the food particles towards the posterior tubular end of the cytopharynx. The food particles after reaching this end of the cytopharynx are taken into the endoplasm along with a minute drop of water to be enclosed in a food vacuole.

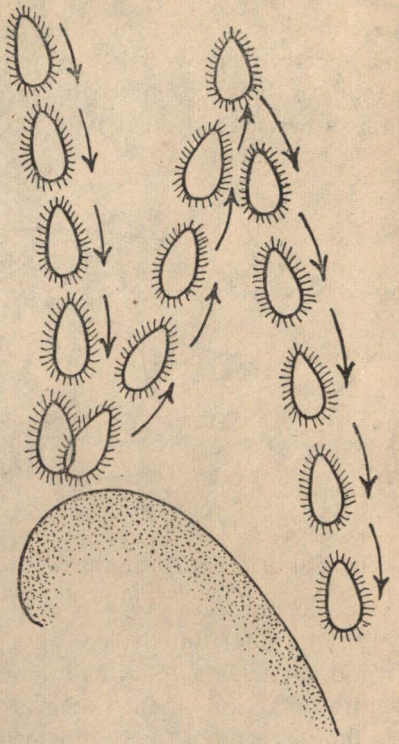


Fig. 1·19 Diagram illustrating shock or avoiding reaction

The food vacuole so formed enters the endoplasm. In the meanwhile, a new food vacuole may be formed and thus this process of the formation of food vacuoles goes on continuously and are shifted into the endoplasm. At a time we may see a number of food vacuoles circulating in the endoplasm in the form of a regular procession. They circulate in the endoplasm along a fairly definite path (the *cyclosis* of the food vacuoles), during which the food is digested. The contents of the food vacuoles during their circulation in endoplasm are subjected first to acid and later to an alkaline phase of digestion as you have learnt to occur in amoeba. The digested food is absorbed and finally assimilated. The indigestible parts of the food are egested at a definite pore called the **cytoproct** or cell anus. The cytoproct is situated in the ectoplasm somewhere between the cytopharynx and the hind end of the body.

It is stated that the paramoecium uses its preferences in selecting particular types of food materials.

Respiration and Excretion : The processes of respiration and the elimination of nitrogenous waste products take place by diffusion through the pellicle.

Sensitivity : Paramoecium responds to several kinds of stimuli. There are however no special organelles for the reception of stimuli. The speed of movement in paramoecium is effected by various chemical substances mixed in water. The anterior end of paramoecium shows special sensitivity.

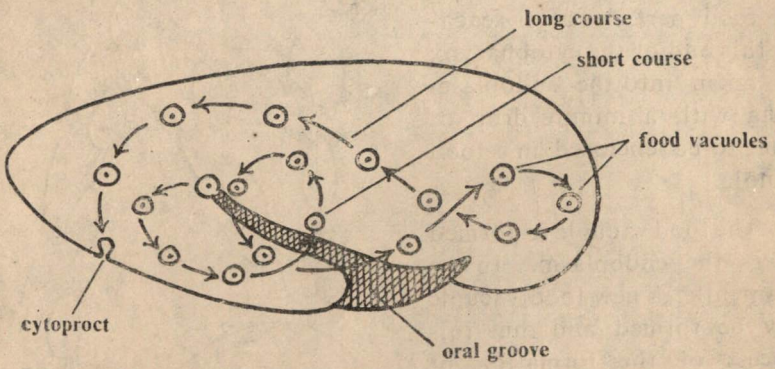


Fig. 1.20 The path of the circulation of food vacuoles (cyclosis of food vacuoles) in paramoecium indicated by arrow.

Paramoecium also shows special preference to certain kinds of food particles. As already mentioned, the paramoecium shows avoiding reaction when it comes into contact with a solid object. The fluctuations in the temperature effects in general the activities of paramoecium.

Reproduction : The common mode of reproduction in paramoecium is the **transverse binary fission.** In this process, the micronucleus divides first into two by mitosis. Later the meganucleus also divides amitotically. Now the cell body constricts in the middle transversely so as to distinguish itself into two parts. Each part of the cytoplasm encloses within it the meganucleus and the micronucleus respectively obtained by the division of the parent nuclei.

Other structures like cytopharynx, contractile vacuole, etc., also duplicate and draw apart so as to occupy their respective positions in each part of the dividing cell body. Ultimately, the mid-transverse constriction of the cytoplasm becomes deep and splits into two halves. Each half, with slight changes, now assumes the form of a normal paramoecium.

Each paramoecium obtained by this method feeds and grows in size. Later they again resort to transverse binary fission once or twice within twenty-four hours. A number of paramoecia so formed are referred to as **clones**. These may continue to divide by binary fission for sometime.

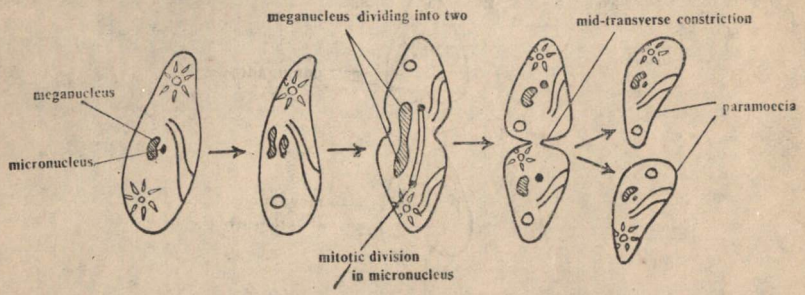


Fig. 1·21 Transverse binary fission in paramoecium

It is noted that after a number of such successive divisions, the progeny become incapable of further division. It appears that some type of '*senescence*' sets in the stock due to cytoplasmic abnormalities. They either die or resort to some other means by which they are '*rejuvenated*'. In this process, certain changes in the nuclei of paramoecia occur. Such changes are brought about either by a process called the **conjugation** or **autogamy.**

Conjugation : In the process of conjugation, two senile paramoecia called the **conjugants** become attached to each other in pairs. They are applied together by their oral surfaces. The conjugating pairs may be seen swimming about in the water. The nuclei of these individuals undergo changes which are as follows.

The micronuclei contain the diploid number of chromosomes. They are thus essentially similar to the nuclei in the cells of higher animals and plants. The micronucleus of each conjugant increases in size and divides successively twice producing thereby four micronuclei. It is certain that during these divisions the number of chromosomes in the nuclei is reduced to half and the resulting nuclei as such contain the haploid number of chromosomes. Out of the four nuclei so obtained, three disintegrate and disappear finally. The remaining, one in each conjugant now divides once into two nuclei

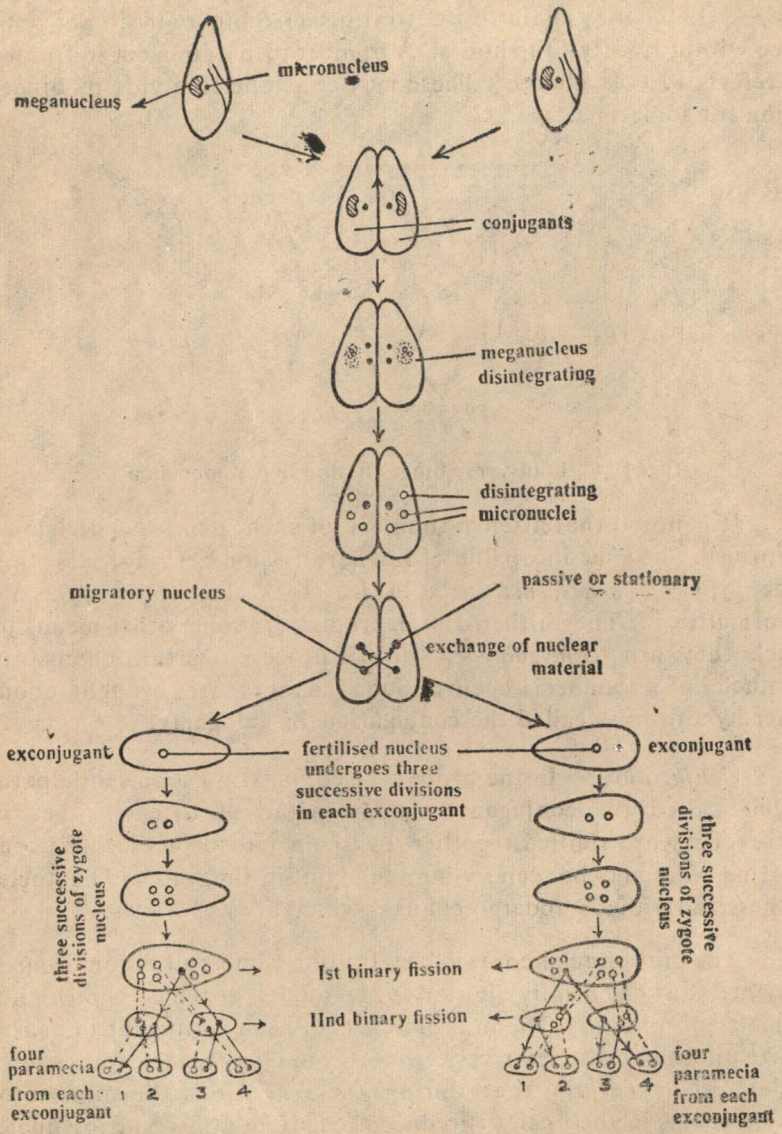


Fig. 1·22 Stages in the process of conjugation in paramoecium

called the *gamete nuclei*. One nucleus is active and capable of migration. It is called the *migratory nucleus*. The other nucleus is passive and stationary.

The migratory nucleus from each conjugant now moves towards the stationary nucleus of the other conjugant and fuses with it to form the **fusion** or **zygote nucleus**. This phenomenon of fusion between the nuclear material obtained from two conjugants is called **amphimixis**. While the above changes are taking place, the meganucleus of each conjugant at first remains unchanged but it gradually disintegrates and later it is absorbed into the cytoplasm.

After the formation of the fusion or zygote nucleus, the conjugants now separate from each other and are therefore referred to as **exconjugants**.

The fusion nucleus of each exconjugant now divides successively thrice by mitosis i.e., first of all into two, then into four and finally into eight nuclei of equal sizes.

Out of a total of eight nuclei, four of them grow in their size to become meganuclei. Three of them disintegrate and disappear. The remaining one becomes the micronucleus. At this stage, we find therefore in each exconjugant four meganuclei and one micronucleus. This micronucleus now divides into two and the exconjugant undergoes the first binary fission to form two cell bodies. Each cell body so obtained secures two meganuclei and one micronucleus. The micronucleus of each cell body divides once again into two nuclei followed by a second binary fission resulting in the production of four paramoecia. Each one receives one meganucleus and one micronucleus i.e., the normal number found in paramoecium. Each exconjugant thus gives rise to four paramoecia i e., altogether eight paramoecia are produced by the two exconjugants. The same process is explained diagrammatically in figure 1.23.

The process of conjugation produces two results — (i) Fusion between the nuclei derived from the different individuals. This may be compared to the sexual process similar to fertilization in higher animals. This fusion also furnishes a mechanism for variation and heredity. (ii) The rebuilding of meganucleus from the micronuclear material. Since the meganucleus and the micronucleus are re-established in the new individuals by successive divisions, it may be

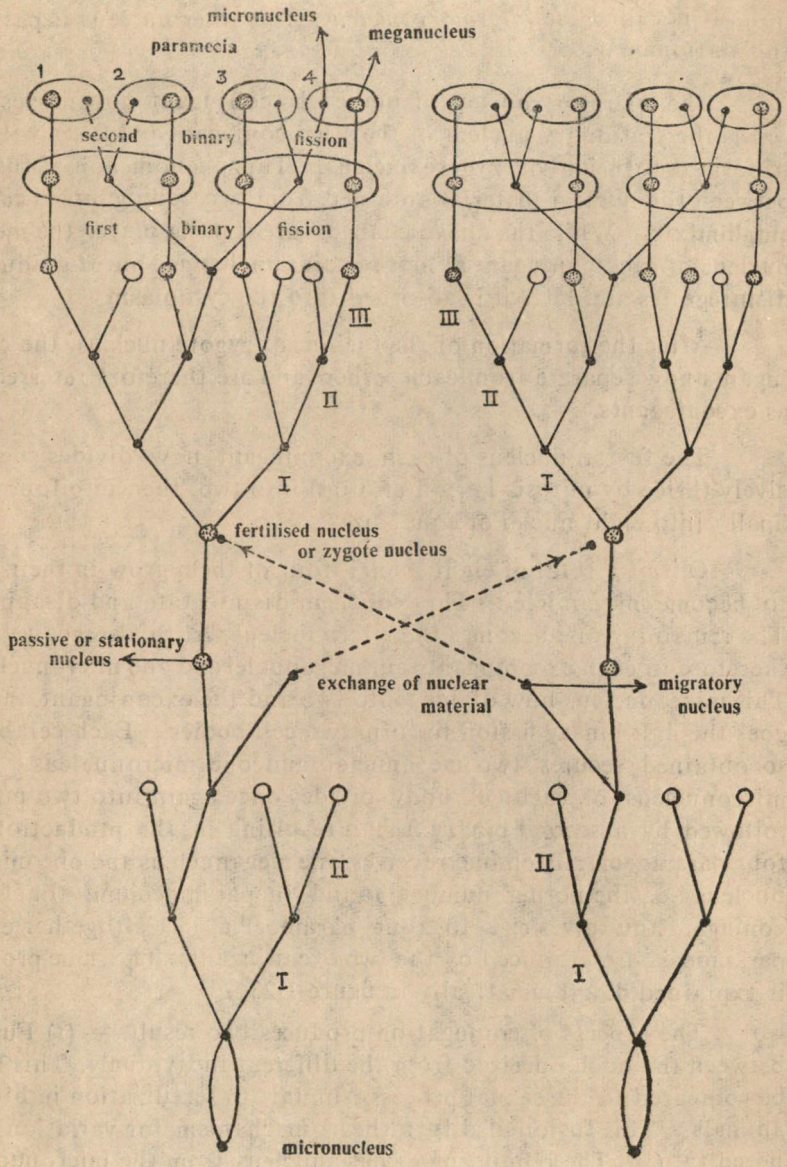


Fig. 1·23 Diagrammatic representation of the process of conjugation in paramoecium

concluded that these new nuclei contain new and different potentialities. The process of conjugation further brings about new vigour and rejuvenation in the race of paramoecia. These paramoecia are now capable of resorting to the common mode of reproduction by transverse binary fission.

The behaviour of the active migratory nucleus and the passive stationary nucleus may be compared to the gametic nuclei of the metazoans. These nuclei as such can rightly be referred to as the gametic nuclei The nucleus obtained by the fusion of these nuclei can be compared to the zygote nucleus of the metazoans. The meganucleus of each conjugant which remains inactive and later disintegrates and disappears may be compared to the *soma* (body) of the metazoa which also meets the same fate.

The process of conjugation which involves the fusion between the two nuclei is the sexual process of reproduction whereas the transverse binary fission where fusion of the nuclei is not at all involved is an asexual mode of reproduction.

Autogamy : Paramoecium is also capable of self-fertilization and the process is designated as **autogamy**. This process involves micronuclear changes in one individual only. The process of autogamy as observed in *Paramoecium aurelia* is summarised below.

Paramoecium aurelia contains one meganucleus and two diploid micronuclei. During autogamy, as well, the meganucleus disintegrates and finally disappears. A new meganucleus is re-established from the products of the division of micronuclei.

The two micronuclei undergo meiosis to produce a total of eight haploid nuclei. Seven of them disappear. The eighth divides mitotically into **two gamete nuclei**. The two gamete nuclei fuse to produce a diploid **zygote nucleus.**

The zygote nucleus divides mitotically to yield four nuclei. Out of these four nuclei, the two enlarge and become meganuclei and the remaining two the micronuclei. The two micronuclei divide mitotically once to produce four micronuclei. The paramoecium in the meanwhile constricts in the middle and eventually divides by the process of transverse binary fission into two paramoecia. Each paramoecium so obtained at the end of autogamy thus receives the

normal number of nuclei present in the parent i.e., one meganucleus and two diploid micronuclei.

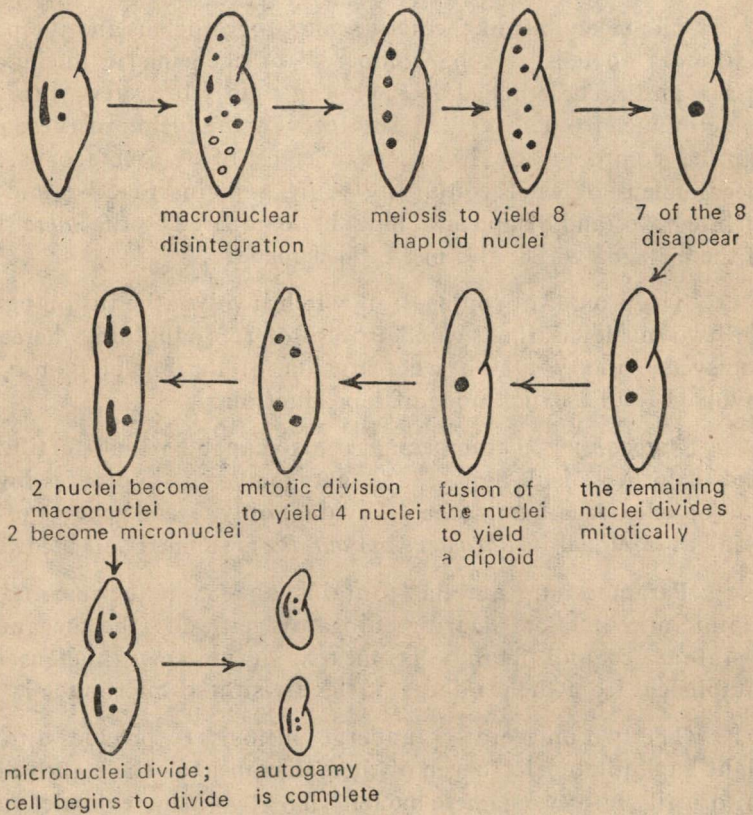


Fig. 1.24 Autogamy in *Paramoecium aurelia*

Cytogamy occurs less frequently in certain paramoecia. **Cytogamy** is a process which involves a pairing of two paramoecia as in conjugation. It, however, differs from conjugation in that no exchange of nuclei takes place between the conjugating individuals. Instead of this, the fusion or zygote nucleus is formed from two nuclei within the same animal, essentially as in autogamy.

In the light of recent investigations, it is known that the meganucleus is large on account of the repeated duplication of chromosome numbers in it during the successive occurrence of the binary fission. The meganucleus thus is a **polyploid nucleus**. (A polyploid nucleus is one in which the chromosome number is in multiples of a basic number or diploid number e.g., if the basic or diploid number of chromosomes in the nucleus of a particular species is 14, then the nuclei of the same species with the multiples of the normal number like 28, 42, 56 and so on are said to be polyploid nuclei). Meganuclei of paramoecia are quite peculiar. They contain many times the diploid amount of chromatin, though usually individual chromosomes are not seen.

In autogamy, like conjugation, the meganucleus is re-established. The question now arises as to why conjugation or autogamy is helpful in fighting senescence and bringing about the rejuvenation of the clones. On the basis of the experimental data available it is now concluded that :

(a) The meganucleus is a polyploid structure due to repeated fissions. This divides amitotically and its chromosomes are distributed at random in the new paramoecia formed. This ultimately results in disharmony and imbalance in the clones. As a result of this, the clones become weak and senile.

(b) The autogamy and conjugation produce a new meganucleus with the correct chromosome number in each of the daughter paramoecia and this results in the renewal of their vigour. This meganucleus is now capable of controlling the activities of paramoecium efficiently.

Certain strains of *Paramoecium aurelia* are reported to cause the clumping and the death of the individuals of the other strains of the same species. Such strains are referred to as **'killers'**. Certain particles called the **kappa particles** found in the cytoplasm of these killers, pass into the other strains of the same species if the killers conjugate with them. Consequently, the individuals of the other strains are destroyed. The individuals of the victim strains are called **'sensitives.'** The kappa particles are self-duplicating structures and are formed of nucleic acid.

As is mentioned, the paramoecia are abundantly found in fresh water ponds which are liable to undergo drying periodically. There should therefore be some provisions in the paramoecia for their protection against the adverse conditions. It is also noted that the culture of paramoecia can easily be obtained from the infusions of dry hay. This suggests that paramoecia do envelope themselves in some type of cysts to protect against the adverse conditions. The cysts of paramoecia however have so far not been seen.

Elaborate structural organisation and specialisation in paramoecium : The paramoecium possesses many specialisations that are not to be seen in amoeba. The cilia found in paramoecium are definite organelles. The pseudopodia of amoeba on the other hand are mere transient structures. The presence of the oral groove with its cytostome and cytopharynx are all specialised areas through which food is obtained in paramoecium. The pellicle gives the paramoecium a definite shape. Further, the definite path of food vacuoles covered in the endoplasm suggests that there is a specialised region of cytoplasm concerned with the process of nutrition. Besides this, the vegetative role of the meganucleus and the reproductive role of the micronucleus are good examples of definite division of functional activity in the two types of nuclei.

Keeping in view these facts, we are justified in regarding the paramoecium as a 'complex protozoan,' in contrast to a simple protozoan like the amoeba.

Revision questions

1. Describe the microscopic structure of paramoecium and mention in brief the functions of these structures.
2. What are the various specialisations met with in paramoecium as compared with amoeba ?
3. Discuss the role of contractile vacuoles in paramoecium.
4. Describe in brief the method of obtaining food and the process of digestion in paramoecium.
5. What is the mode of locomotion in paramoecium ?
6. What are the different modes of reproduction in paramoecium ?
7. Describe the process of conjugation and its significance in paramoecium.

8. Write notes on the following :

(a) Trichocyst. (b) Structure of cilium
(c) Autogamy and cytogamy. (d) Kappa particles.
(e) Avoiding or shock reaction.

Plasmodium—A parasitic protozoan causing malaria in man :

Two examples of free living protozoans i.e., *Amoeba* and *Paramoecium* were discussed earlier.

In the phylum protozoa and in other groups of animals as well, we come across certain organisms which either live on the outer surface or in the internal organs of other animals. They thrive at the expense of another organism in which they live. They lead a dependant mode of life. An organism leading a dependant mode of life in the body of other animals is called a **parasite.** Literally the word **parasite** means, "*eating from the table of another*". The organism which harbours the parasite is called a **host.** The relation which exists between a parasite and its host is called **parasitism.** The parasite which lives outside the body of a host is called an **ectoparasite** e.g. bed bug, headlouse, etc. The parasite which occurs inside the body of the host is called **an endoparasite** e.g., malarial parasite.

The presence of a parasite may be harmful to the host and may cause a disease in the body of the host. Such a parasite is referred to as **pathogenic parasite.** There are, however, certain parasites which do not apparently cause any harm or produce disease in the body of the host. Such parasites are called the **non-pathogenic** ones.

The parasite may further require, one, two or even three hosts to complete its' life cycle. The host in which the adult stages of the parasite are found and where the parasite resorts to the sexual mode of reproduction is called the **definitive host.** The host in whose body the larval stages of the parasite are passed and where the parasite usually resorts to the asexual mode of reproduction is called an **intermediate host.** In some cases the parasites complete their asexual phases of development in two different intermediate hosts which are then called as **first** and **second intermediate hosts** respectively.

When the parasite establishes itself within the body of a host it is called **infection**. The infection of the host by a parasite may take place directly i.e., inhalation, contamination of food, water or dust or by the direct penetration of the parasite into the body of the host. The transmission of the parasites into the body of the hosts usually takes place by the majority of arthropods e.g., insects. They thus act as *intermediary* or *mechanical agents* and are referred to as **vectors**. Inside the body of these vectors the parasite may also undergo multiplication and change of form.

We shall now study in detail a type of Protozoan parasite known by the generic name *Plasmodium*, the organism responsible for the cause of malarial fever in man. It is on account of this that the parasite plasmodium is commonly known as **malaria parasite**. There are also some species of this parasite which infect other vertebrates like birds, monkeys, etc.

Plasmodium passes its' life history in two hosts. A part of it is passed in the female mosquito of the genus *Anopheles*. In female anopheles, the parasite completes its sexual reproduction followed by asexual multiplication giving rise to typical *infective forms* that are found in the salivary glands of the mosquito.

The mosquito is its *definitive host* where the parasite undergoes sexual reproduction, maturation, development and finally the asexual multiplicative phase. Man is its *intermediate host* where the parasite reproduces asexually.

The second phase of life cycle of plasmodium passes in man when the infective forms of the parasite are introduced into the body of a man by the bite of an infected mosquito. In man, the parasite resorts to asexual mode of reproduction and causes malaria.

Irrespective of where the sexual reproduction occurs, some prefer to use the terms **definitive host** for vertebrates and **intermediate host** for arthropods in relation to protozoan parasites which alternate in their life cycles between the two types of hosts i.e., a vertebrate e.g. man and an arthropod e.g., mosquito.

An alternative is also to avoid altogether these terms and to use the terms *vertebrate* and *invertebrate hosts* instead.

Malarial Parasites of Man :

There are four distinct species of plasmodium which infect man and cause the type of malaria known after the name of the species. They are as follows :

1. *Plasmodium vivax* causes **vivax malaria.** The fever tends to reappear every 48 hours or with three days gap. It is a mild type of malaria and rarely becomes fatal, hence called *benign fever.* As it recurs every 48 hours, it is commonly known as **benign tertian fever.**

2. *Plasmodium ovale,* resembles plasmodium vivax and causes **ovale tertian malaria.** *Schizogony** occurs in 48 hours.

3. *Plasmodium malariae* causes **malariae malaria.** Schizogony occurs in 72 hours. As the fever occurs with four day intervals or after 72 hours, it is commonly known as **quartan fever.**

4. *Plasmodium falciparum* (Latin. *falx,* a sickle) causes **falciparum malaria.** The fever is usually of a fatal type hence called malignant. The common name of the fever is **malignant tertian malaria** or *quotidian fever.* The fever is irregularly continuous. Schizogony occurs in 48 hours.

A person may be infected by more than one species of plasmodium at the same time. This condition is referred to as **multiple** or **mixed infection.**

Geographical Distribution :

Malarial parasites occur in all countries extending from 40° S to 60° N. The tropical zone is the endemic home** of all malarial parasites.

Life Cycle of Plasmodium in Man :

The malarial parasites are introduced into the human body when an infected female anopheles bites man. The parasites along with a portion of saliva are introduced into the blood of man. This phase of the parasite is called a **sporozoite.** Each sporozoite is a slender, sickle shaped actively motile organism. It measures 14 μ in length and 1 to 2 μ in breadth. It is pointed at either end with a thick central portion containing a nucleus. It is now known that the sporozoites soon after the bite of an infected mosquito, remain in the peripheral blood of man for half an hour or so after which they completely disappear from the peripheral blood and reach the

* Process of asexual multiplication of the schizont, a stage in the life cycle of malarial parasite.

** A place where the disease is of common recurrence.

parenchymatous cells of the liver. This phase of their cycle in the liver cells and their subsequent multiplication in the liver tissue is called the **pre-erythrocytic cycle** i e., a stage in the life cycle of malarial parasites prior to their attack on the erythrocytes or red blood corpuscles. The details of pre-erythrocytic cycle are as follows :

(A) Pre-erythrocytic Cycle :

After the disappearance of the sporozoites from the peripheral blood, soon after infection, they undergo the first phase of development in the reticulo-endothelial cells* (Kupffer's cells of the liver). These later invade the parenchyma cells of the liver. They now grow in size at the cost of the liver cells and within 6 to 9 days they develop into full grown round bodies called the **pre-erythrocytic schizonts.** The nucleus of the schizont now divides successively into a number of nuclei around which the cytoplasm of the schizont gathers, and form the **merozoites.** By the rupture of the wall of the schizonts, the merozoites are liberated into the liver sinusoids. This process of asexual multiplication by the schizont nucleus resulting in the production of merozoites is called **pre-erythrocytic schizogony** (Gk.*Schizo*, to split,*gene*, generation).

The merozoites so produced may now enter the blood and attack the R.B.Cs. and start the erythrocytic phase of their life history.

(B) Erythrocytic Cycle :

The merozoites liberated during the pre-erythrocytic phase attack the erythrocytes and start the **erythrocytic cycle.** The merozoites soon after their entry into red blood cells become round and enter an active feeding stage called the **trophozoite.**

In the case of **P. vivax, P. malariae** and **P. ovale**, a single sporozoite attacks a single R.B.C. Double or multiple invasion of R.B.Cs. by the merozoites is a common feature in **P. falciparum** infection, where 2 to 6 sporozoites invade a single corpuscle.

The trophozoite at first is in the form of a small rounded mass of protoplasm with a single nucleus. Later there develops a vacuole within its cytoplasm to carry on nutrition. The vacuole soon enlarges

* Cells which possess phagocytic power i.e., the capacity to ingest bacteria, dead cells, tissue debris and foreign substances.

in size and the cytoplasm assumes a ring shape. The nucleus is pushed on the thinner side of the cytoplasm and the trophozoite presents therefore a signet-ring appearance. It is called the **signet ring stage.** The signet-ring form attains an average diameter of 2·5. to 3 μ i. e., about one-third the size of the blood cell which is 7·5 μ in diameter.

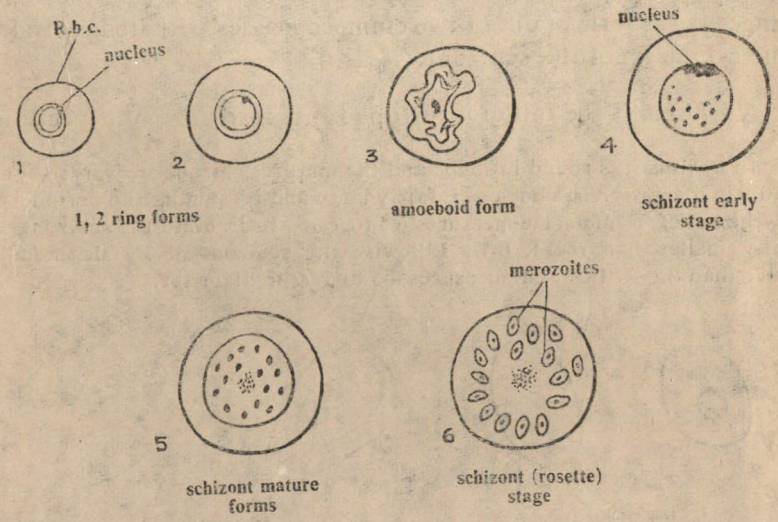


Fig. 1.25 Erythrocytic forms of P. vivax

The significant feature of the signet ring form in P. malariae is, that the parasite usually stretches across the red blood cell presenting a band-like appearance. The nucleus also elongates and is situated at the edge. The ring forms of P. falciparum are smaller than P. vivax i.e., 1·25 to 1·5 μ in diameter. In P. falciparum as many as 8 rings were found in a single corpuscle.



Fig. 1·26 Erythrocytic forms of P. malariae

The ring form however is not maintained for long, as the parasite soon exhibits amoeboid movements. The amoeboid movements also disappear soon and the parasite assumes maximum dimensions and almost fills up the infected red blood cell. It is called

the **schizont.** It has attained its full size due to active feeding, and the haemoglobin of the R.B.Cs. was used as food. In the cytoplasm of this full grown form are to be seen yellowish brown pigment granules called the **haemozoin granules.** These are probably the effete substances produced as a result of the metabolic activity after the use of haemoglobin. The haemozoin granules are at first scattered in the cytoplasm and when the schizont is about to divide they are arranged in the form of one or two clumped masses, situated centrally in the cytoplasm of the schizont.

A *schizont* is the full grown trophozoite ready for multipcation.

In P. **vivax** it is round in shape and the mature schizont measures about 9 to10 μ in diameter. The nucleus is fairly large and is found at the periphery. The schizont of P. malariae measures 6·5 to 7 μ. In P. **ovale** the schizont is slightly smaller than the R.B C. Likewise the schizont of P, **falciparum** is smaller than the R.B.C. and measures 4·5 to 5 μ in diameter.

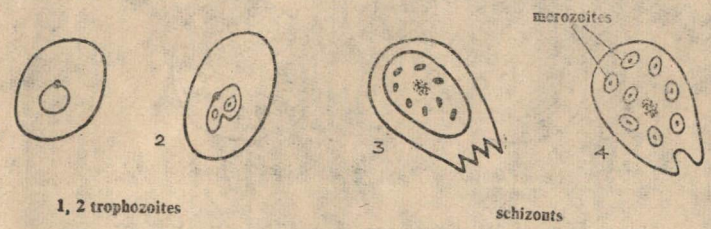


Fig. 1·27 Erythrocytic form of P. ovale

The nucleus of a mature schizont now undergoes repeated division to form a number of nuclei. The cytoplasm of it, later fragments and collects around each nucleus to form individual cell bodies called the merozoites. This process of asexual repeated multiplication of the schizont nucleus to form the merozoites is called **erythrocytic schizogony.** The schizogony leads to the production of 16–24 merozoites, the average number produced being 16. The number of merozoites produced however differs in each species of the malarial parasite.

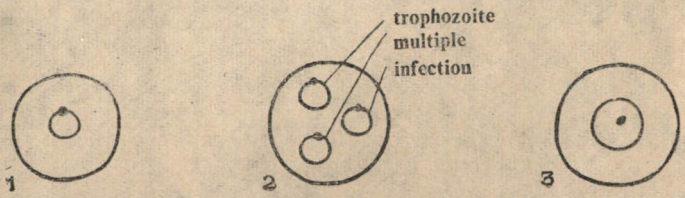
In P. **vivax** for example, some 12-24 merozoites are produced and are arranged in the form of irregular grape-like clusters.

The schizont of P. **malariae** produces 6-12, generally 8 merozoites arranged around a central mass of pigment like a 'daisy' or 'rosette'.

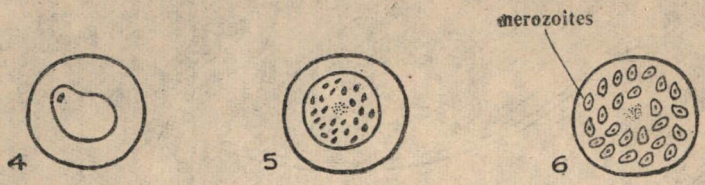
In **P. ovale** 6-12, often 8 merozoites are produced, arranged irregularly.

In the case of **P. falciparum**, 18-24 merozoites are produced or at times even more, arranged in a grape-like cluster.

The schizogony in **P. vivax, P. malariae,** and **P. ovale** takes place in the peripheral circulation. In **P. falciparum** on the other hand, schizogony occurs inside the capillaries of the internal organs like the spleen, liver and the bone marrow.



1, 2, 3 trophozoites



4, 5, 6 schizont (schizogony)

Fig. 1·28 Erythrocytic forms of P. falciparum

A single schizogonous cycle completes in 48 hours or two days in *P. vivax*, *P. ovale* and *P. falciparum*. In *P. malariae* schizogony completes in 72 hours or three days.

Once the nucleus of the schizont completes its repeated division to form merozoites, the wall of the red blood corpuscles ruptures liberating the merozoites, haemozoin pigments and the residual cytoplasm into the blood plasma. Each merozoite is an oval mass of cytoplasm with a central nucleus.

The merozoites so liberated while circulating in the blood stream may attack a fresh R.B.C. and may repeat the erythrocytic cycle mentioned above.

By repeated schizogonous cycles, the parasites are so much in abundance that they bring on a *clinical attack of malaria.* Some of the merozoites are no doubt destroyed by the white blood cells.

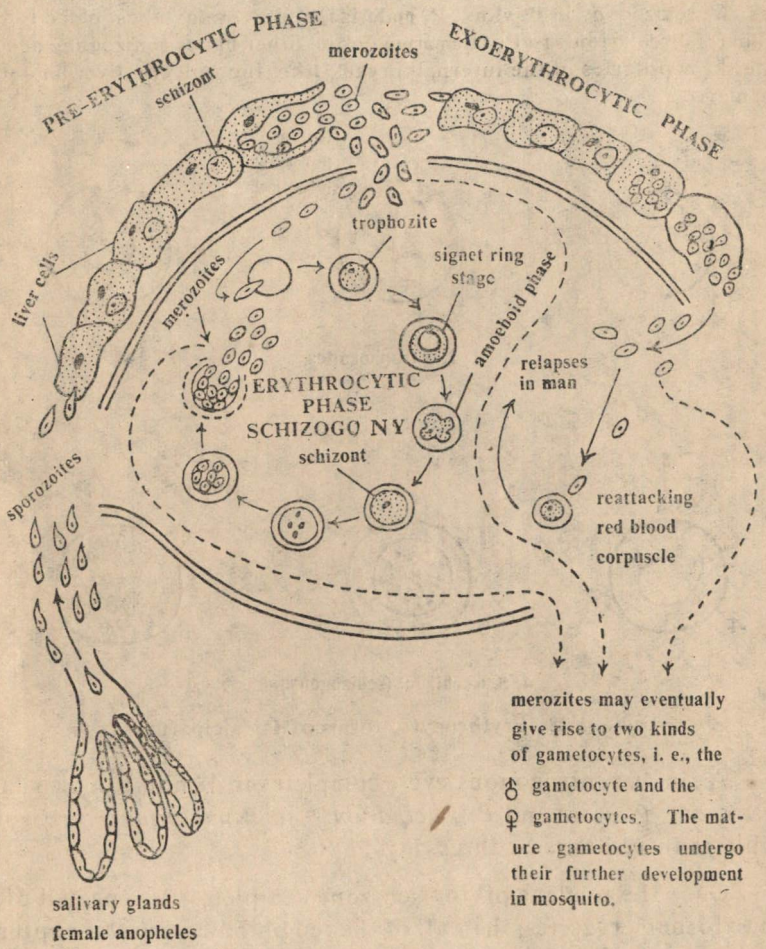


Fig. 1.29 Diagram illustrating the Pre erythrocytic, Exo-erythrocytic and Erythrocytic phases in the life cycle of a malarial parasite in man.

The duration of time between the primary infection (i.e., the first entry of the parasite in the body) till the onset of fever is called the **incubation period**. The incubation period varies with different species of malarial parasites. It is as follows :

P. vivax and *P. malariae*—10 to 17 days (average 15 days)
P. falciparum—8 to 12 days.
P. malariae—21 to 28 days, may even be 30 to 40 days.

(C) Exoerythrocytic Cycle :

As stated earlier, while some of the merozoites of the pre-erythrocytic cycle start their erythrocytic cycle by attacking the R B.Cs., the others enter the parenchyma cells of the liver to continue the late tissue stages referred to as *exo-ertyhrocytic phase.* The merozoites attack the parenchyma cells, grow in their size and become the schizonts. These resort to shizogony producing the merozoites. These merozoites may now attack the R B.Cs By the persistence of the exoerythrocytic phase, the liver cells act like reservoirs of parasites which are responsible for the frequent relapses of fever. The exo-erythrocytic phase continues simultaneously along with the erythrocytic phase.

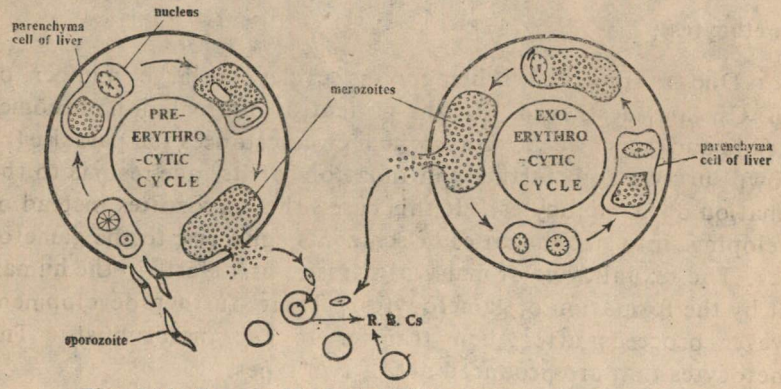


Fig. 1·30 Pre-erythrocytic and Exo-erythrocytic cycle of the malarial parasite in man

The presence of exo-erythrocytic phase in P. vivax is accepted beyond doubt. In the case of **P. falciparum** the presence of exo-erythrocytic phase is disputed. The pre-erythrocytic schizonts of **P. falciparum** produce merozoites within 7 days. These enter the blood without giving rise to late exo-erythrocytic forms.

It has recently been established that in addition to the liver cells, the human bone marrow also is a site for pre and exo-erythrocytic cycles. It is however not yet known whether the bone marrow stages of the parasite have any special biological cycle.

A brief summary of the pre-erythrocytic, exo-erythrocytic and erythrocytic cycles in **P. vivax, P. malariae** and **P. falciparum** is as follows :

Plasmodium vivax and P. malariae

Sporozoites—Pre-erythrocytic schizogony → Erythrocytic schizogony → Primary malaria

Sporozoites—Exo-erythrocytic schizogony → Erythrocytic schizogony → Relapses

P. falciparum

Sporozoites—Pre-erythrocytic schizogony → Erythrocytic schizogony → Primary fever recrudescences*

Sporozoites—No exo-erythrocytic schizogony → No relapses

Gametocytes :

Due to repeated schizogonous cycles, a large number of R. B. Cs. are destroyed. If the patient is untreated, he becomes anaemic and very weak. Under such circumstances the parasite for its own survival and further continuation of its race resorts to the formation of gametocytes. It this case, the merozoites instead of developing into trophozoites or schizonts, give rise to the gametocytes. The sexual cycle of malarial parasite first starts in the human host by the formation of gametocytes. Their further development however proceeds after their transfer to the insect host. The gametocytes that are produced are of two types.

1. The male gametocytes or the **microgametocytes.**

2. The female gametocytes or the **megagametocytes.**

The male or microgametocytes contain large and diffuse nucleus and pigment granules are scattered throughout the cytoplasm. The female or megagametocytes contain small and compact nucleus and the pigment granules immediately surround the nucleus.

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*The term recrudescence is applied to the existence of an erythrocytic phase lying dormant.

The gametocytes of *P. vivax* and *P. malariae* are round in shape whereas the gametocytes of *P. falciparum* are crescentic.

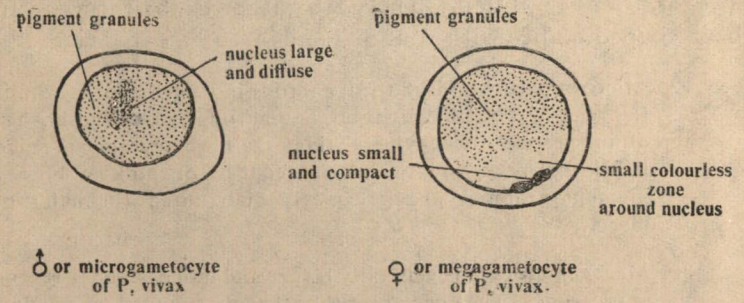


Fig. 1·31 Micro and Megagametocytes of P. vivax

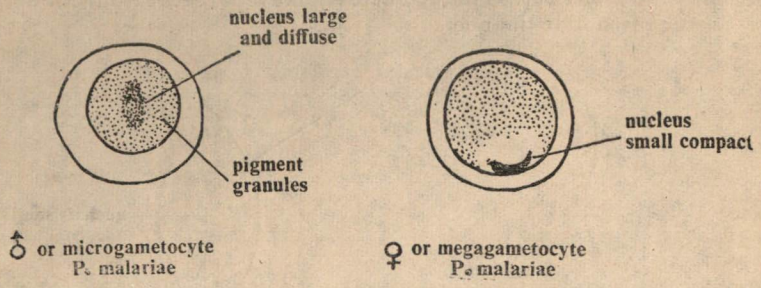


Fig. 1·32 Micro and Megagametocytes of P. malariae

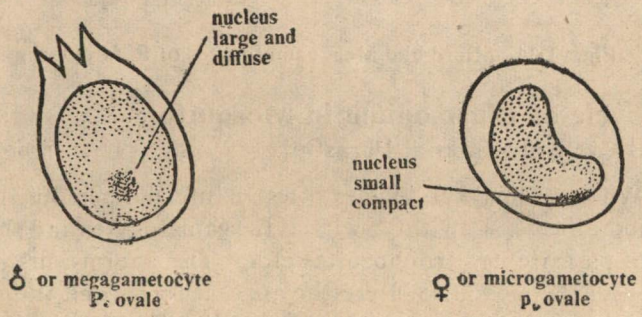


Fig. 1·33 Micro and Megagametocytes of P. ovale

Gametocytes of P. falciparum :

According to the shape, the gametocytes of P. falciparum are generally referred to as **'crescents'** or 'half moon bodies' although their ends are not pointed. They are rather in the form of sausage or bean shaped bodies with rounded ends.

1. Microgametocyte is 8 to 10 microns in length and 2 to 3 microns in breadth. The nucleus is large and found scattered in the form of fine granules occupying a wide area in the cytoplasm and stains lightly. The cytoplasm stains reddish or pinkish blue. The pigment granules are irregularly distributed through the cytoplasm.

2. Megagametocyte is generally larger and more slender resembling a crescent. The ends are either sharply rounded or evenly pointed. It is 10 to 12 microns in length and 2 to 3 μ in breadth. The nucleus is in the form of a small compact mass situated centrally and stains deeply. The cytoplasm stains deep blue. The pigment granules surround the nucleus like a wreath around it and very often hide the nucleus.

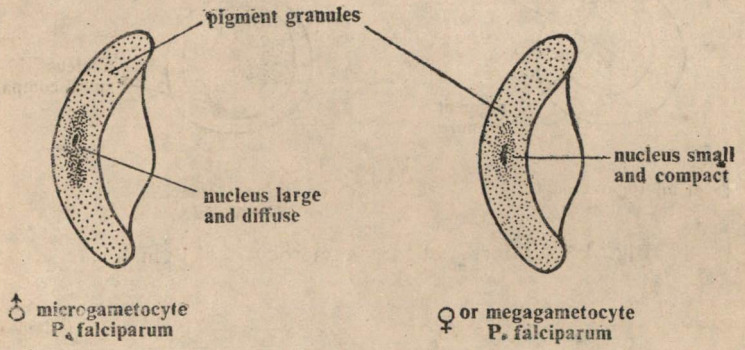


Fig. 1.34 Micro and Megagametocytes of P. falciparum

Life Cycle of Plasmodium in Mosquito :
(Sexual Cycle of Malarial Parasite)

When a female anopheles bites an infected person, it sucks up the blood and takes up along with it the gametocytes and the asexual forms of parasite i.e., trophozoites etc., These forms, first reach the stomach of the mosquito. Here the asexual forms and the immature sexual forms i.e., immature gametocytes die off immediately.

The mature gametocytes only, undergo further development in the stomach of the mosquito.

Gametogony :

The first stage of development is the maturation of gametocytes into the gametes. The gametocytes in the first instance escape from the R.B C. by the rupture of its wall and undergo further development. The gametocytes of *P. falciparum* become rounded after escaping from the R.B.C.

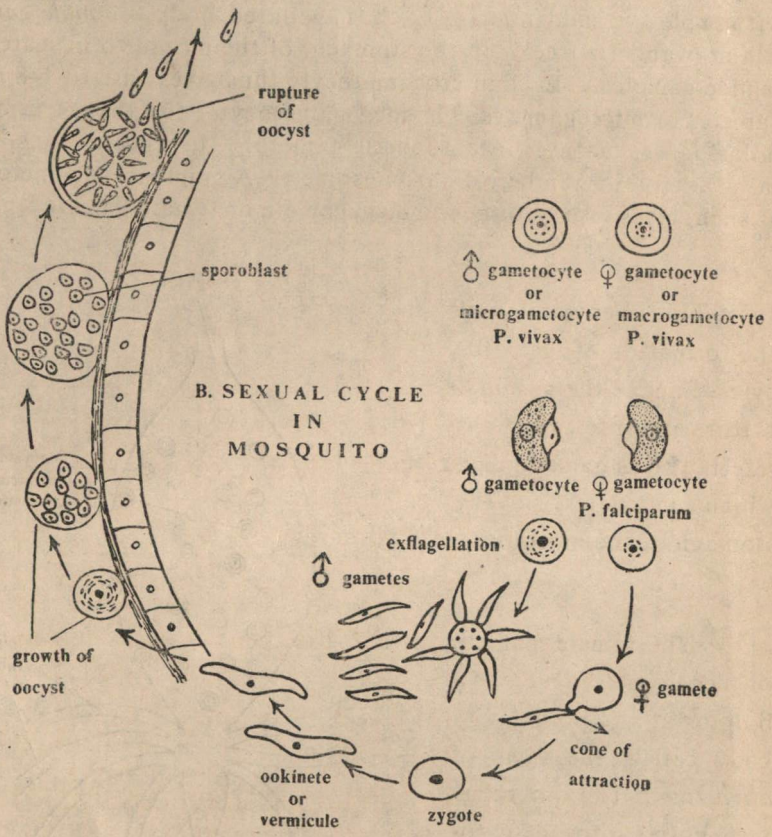


Fig. 1·35 Life cycle of malarial parasite in mosquito

A portion of effete vegetative chromatin from the nucleus of the gametocytes is eliminated in the form of one or two masses of

polar bodies. The nucleus of the gametocyte now contains the haploid number of chromosomes.

The nucleus of the microgametocyte now divides into several daughter nuclei which move towards the periphery of the parent cell. From the periphery of the gametocyte, now project 4–8 actively moving thread-like filaments or *flagellate bodies*. The process of the formation of these flagellate bodies is called **exflagellation**. Later in each flagellate body a nucleus from the periphery passes. The flagellate bodies now with a nucleus within, break off from the cell mass with explosive suddenness. Each flagellated body is a *male gamete* which wanders freely in the stomach of the mosquito in search of female gametes. Each microgametocyte thus gives rise to 4–8 male gametes or **microgametes**. The megagametocyte after the extrusion of polar bodies matures into a female gamete. It's nucleus thus, contains a haploid number of chromosomes. A single megagametocyte as such, gives rise to only one **megagamete** or **female gamete.**

This phenomenon of the formation of gametocytes and their final maturation into gametes is referred to as **gametogony**, which completes in the stomach of the mosquito.

The female gamete or megagamete develops a bulging at one point of its body called the *cone* of *attraction*. The microgamete enters into the cytoplasm of the female gamete through this bulging. The

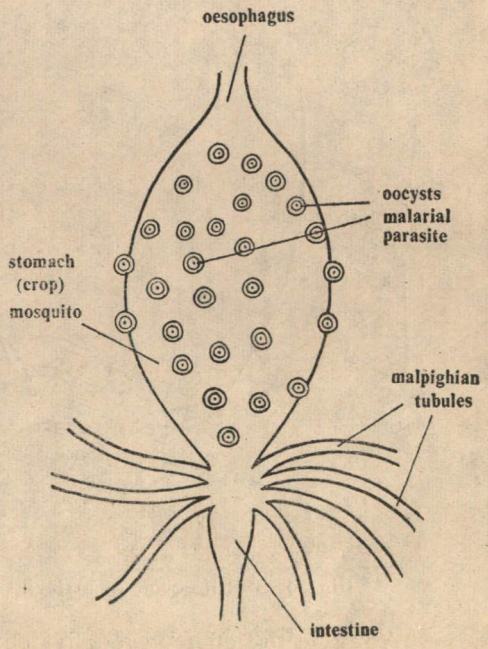


Fig. 1·36 Oocysts on the stomach of mosquito

male and female pronuclei of both the gametes fuse to form a zygote nucleus and the spherical body is called the *zygote*.

The zygote soon loses its spherical shape and becomes elongated or vermiform. It is now designated as a **travelling vermicule** or **ookinete** (18–24 μ in length). It now moves actively over the inner surface of the stomach of the mosquito and gradually bores its way through the epithelium, lining the mucosa of the stomach of mosquito. On reaching the outer surface of the wall of the stomach, the zygote assumes a spherical shape and becomes surrounded by a capsule or cyst and is now called the **oocyst**. These cysts can be seen in the form of small rounded projections on the external surface of the stomach of the infected mosquito.

The oocyst starts growing in its size. It contains a single vesicular nucleus and also the pigment granules. It measures at first 6–12μ is diameter and when full grown may attain ultimately the dimensions of 50 to 60 microns. The number of oocysts varies from 20 to 30 but occasionally large numbers—even as many as 500 have been observed.

Sporogony : The nucleus of the oocyst undergoes repeated divisions to form a number of nuclei. The cytoplasm then gathers around each nucleus to form slender sickle-shaped bodies called the sporozoites. This process of the formation of sporozoites by repeated divisions of the nucleus of oocyst is called **sporogony**. The sporozoites are arranged in a palisade-like manner within the oocyst. As many as 10,000 sporozoites may develop inside an individual oocyst.

The wall of the full grown oocyst ruptures, liberating thereby the sporozoites. These sporozoites now invade all organs and tissues except the ovaries of the mosquito. They finally reach the salivary glands of the mosquito and settle there.

If a man is bitten by such an infected mosquito, the sporozoites along with a portion of the saliva reach the human body and commence their life cycle in man as already mentioned.

A summary of the life history of malarial parasite in man and in mosquito is illustrated diagrammatically in figure 1·37.

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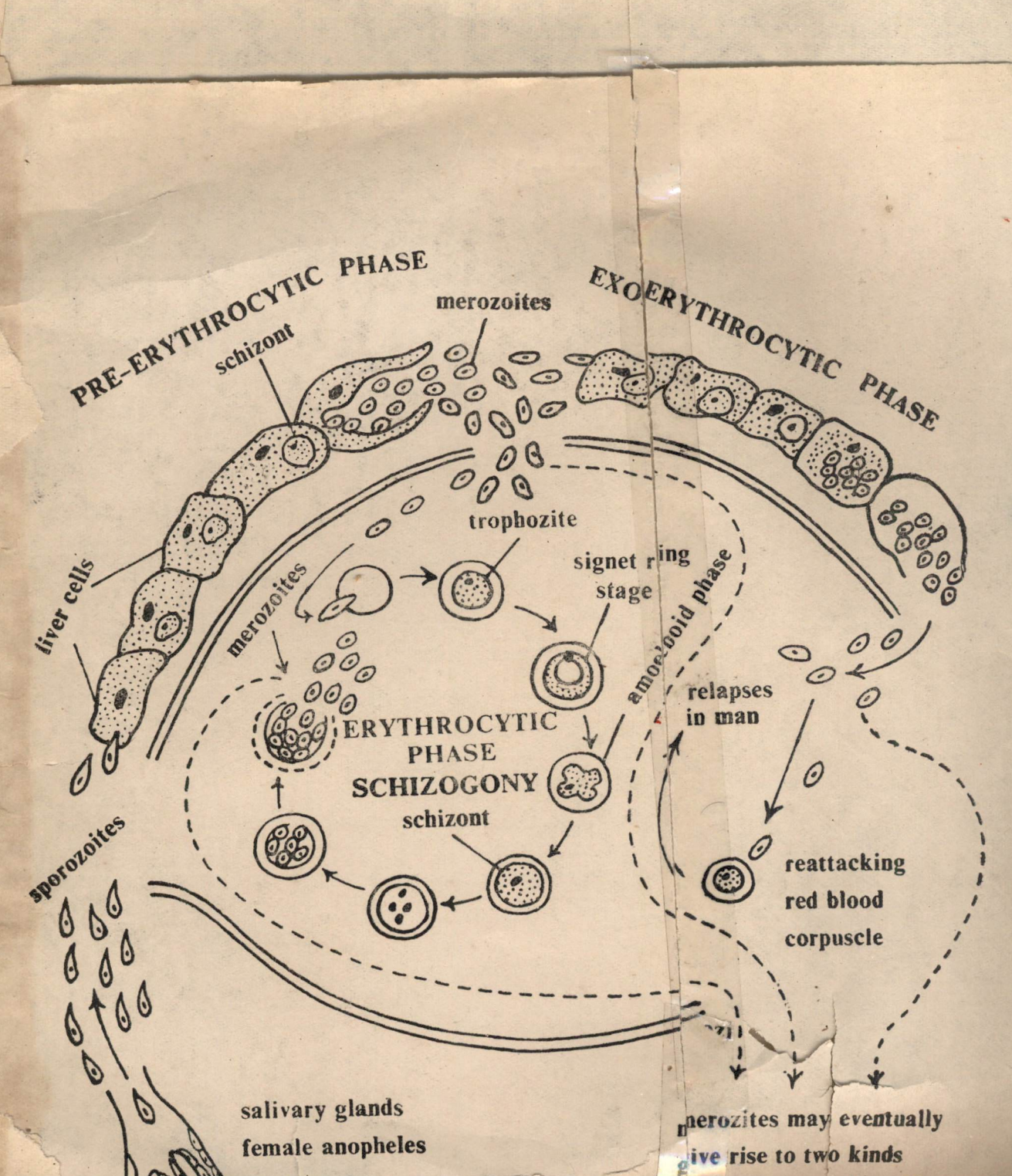
History of the discovery of the malarial parasite : The malarial parasite causes malaria. The term malaria is derived from an Italian word (*malo*; bad, *aria*; air) meaning "bad air". It was so called on the basis of an erroneous belief that the disease is caused due to the inhalation of bad air from the marshy places containing poisonous gases. This belief was however disproved in the light of the investigations made by various scientists. This resulted in the discovery of the life history of the malarial parasite which is the causative organism for malarial fever or ague. A brief history of these investigations is as follows.

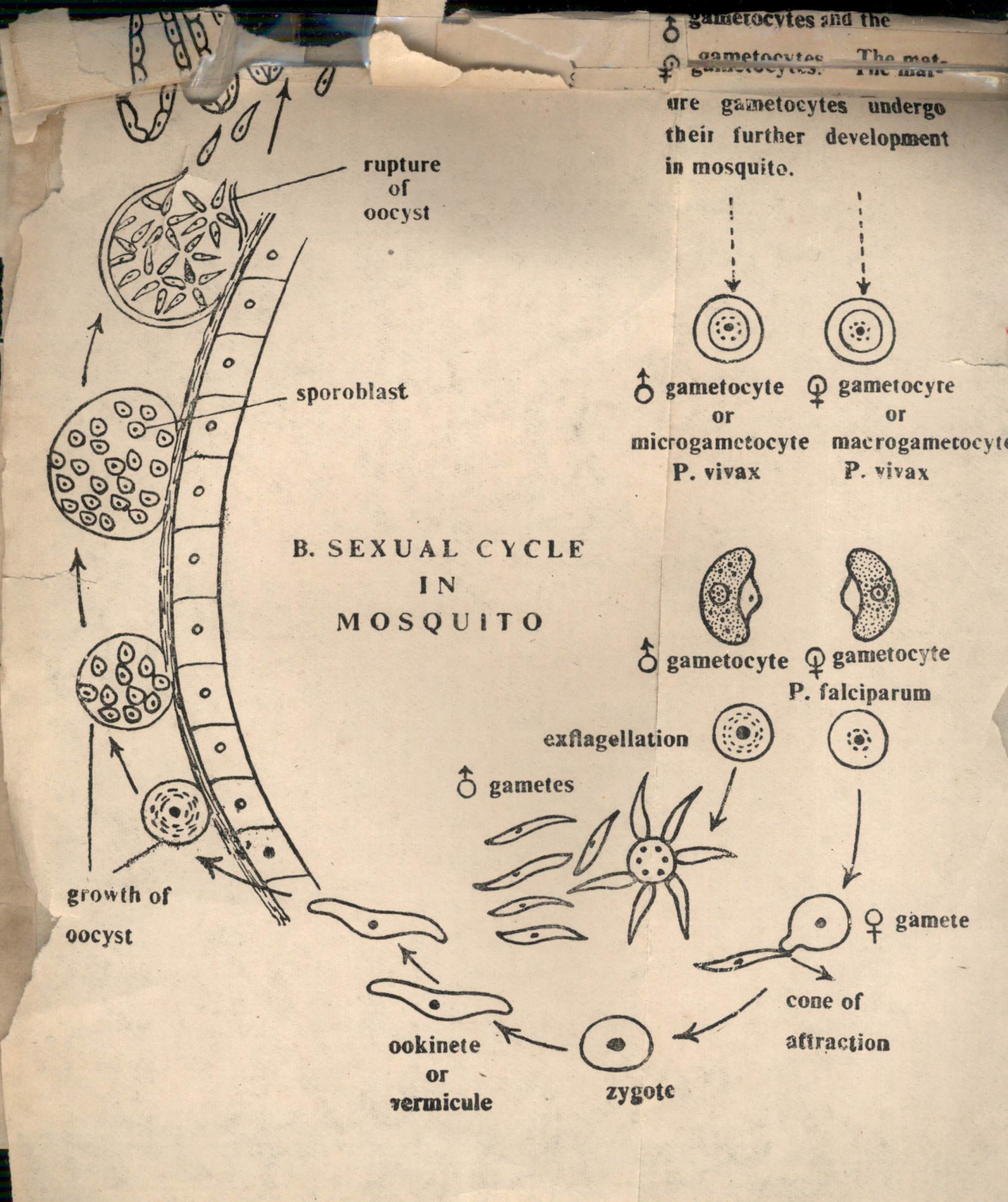
Laveran (1880), a French surgeon discovered first the malarial parasites in the blood of a patient suffering from malaria.

Sir Patrick Manson, in 1894, working on the transmission of filaria suggested that the mosquito may be responsible for the transmission of the malarial parasite. But the mode of transmission he suggested was not by the bite of the mosquito but by the swallowing of the mosquitoes drowned in water.

The epoch-making discovery about the method of transmission of malaria was made by Sir Ronald Ross of the Indian Medical Service. In 1897, he discovered the oocysts in the stomach wall of a dapple-winged mosquito, *Anopheles stephensi* which had been fed on the blood of a malarial patient. A year later i.e., in 1898, he demonstrated the transmission of *Plasmodium praecox* from one sparrow to the other through the agency of the mosquito *Culex pipiens*. He suggested the transmission of human malaria in the same way. In the same year i.e., 1898, Grassi and his co-workers demonstrated the sexual cycle of human malaria in *Anopheles maculipennis*. In 1990, the experiments conducted by Sir Patrick Manson proved the theory of mosquito transmission of malaria beyond doubt.

Tissue phases of the malarial parasite were demonstrated in bird malaria in 1934. After 14 years i.e., in 1948 the tissue phases were discovered in rhesus monkey (macaque monkey) infected by *Plasmodium cynomolgi*. The exo-erythrocytic phase of *Plasmodium kochi* in the liver of a monkey host gave a clue to Col. Short and his associates (1948–49), to locate the pre-erythrocytic phases of


PRE-ERYTHROCYTIC PHASE
EXOERYTHROCYTIC PHASE
merozoites
schizont
trophozite
signet ring stage
liver cells
merozoites
amoeboid phase
relapses in man
ERYTHROCYTIC PHASE
SCHIZOGONY
schizont
sporozoites
reattacking red blood corpuscle
salivary glands
female anopheles
merozites may eventually
give rise to two kinds


gametocytes and the
gametocytes. The mat-
ure gametocytes undergo
their further development
in mosquito.
rupture
of
oocyst
sporoblast
gametocyte
or
microgametocyte
P. vivax
gametocyte
or
macrogametocyte
P. vivax
B. SEXUAL CYCLE
IN
MOSQUITO
gametocyte
gametocyte
P. falciparum
exflagellation
gametes
growth of
oocyst
gamete
cone of
attraction
ookinete
or
vermicule
zygote

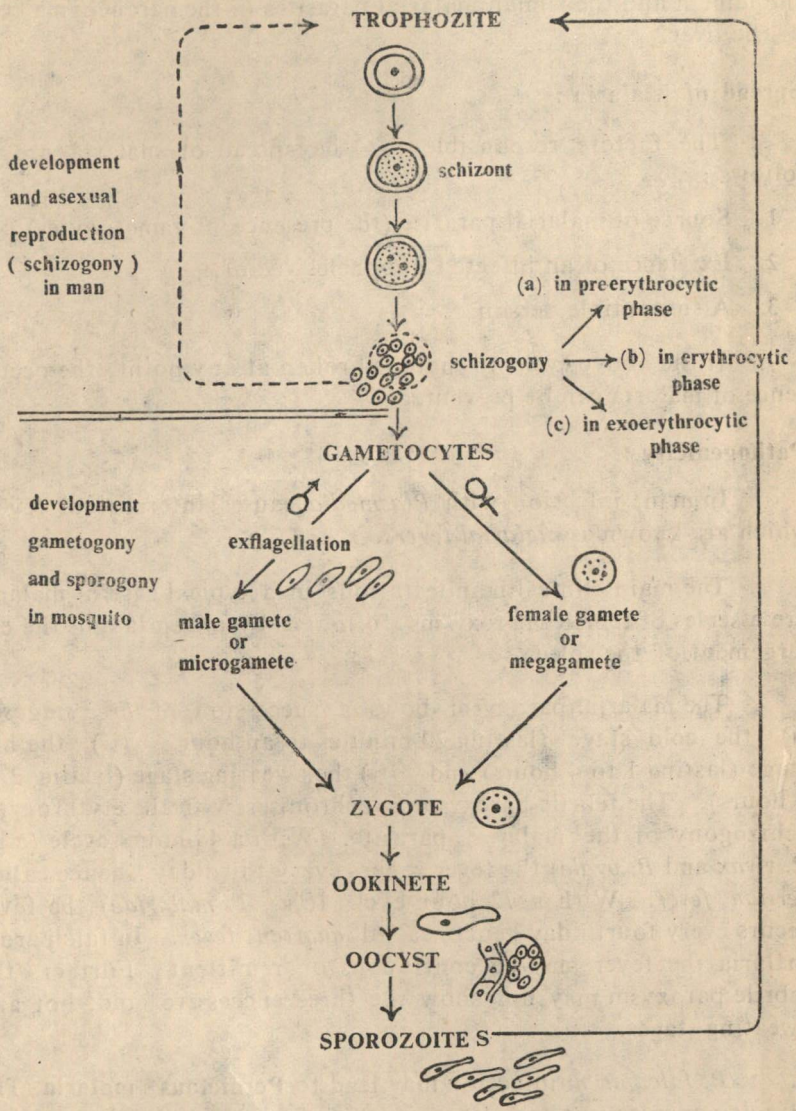


Fig. 1·38 Diagrammatic representation of the life history of the malarial parasite in man and in mosquito

the human and the simian malarial parasites in the parenchyma cells of the liver.

Spread of Malaria :

The factors responsible for the spread of malaria are as follows :

1. Source of malarial parasite (the presence of gametocytes)
2. Existence of an infected anopheles vector.
3. A susceptible person.

If the above cycle or chain is broken at any point, the occurrence of malaria can be prevented.

Pathogenicity :

In man, infection with *Plasmodia* causes intermittent fevers which are known as *malarial fevers.*

The main clinical manifestations in a typical case of malaria are a series of febrile paroxysms followed by anaemia and the enlargement of the spleen.

The malarial paroxysm shows a succession of *three stages*— (i) the cold stage (lasting 20 minutes to an hour), (ii) the hot stage (lasting 1 to 4 hours) and (iii) the sweating stage (lasting 2 to 3 hours). The febrile paroxysm synchronises with the erythrocytic schizogony of the malarial parasite. With a 48 hours cycle (e g , *P. vivax* and *P. ovale*) the fever recurs every third day, hence called *tertian fever.* With a 72 hour cycle (e.g., *P. malariae*) the fever recurs every fourth day hence called *quartan fever.* In falciparum malaria the fever may be continuous or remittent. Further, the febrile paroxysm may not show the three successive cold, hot and sweating stages.

P. falciparum infection may lead to **Pernicious* malaria.** The *P. falciparum* causes agglutination of infected red blood corpuscles leading to the blockade of the capillary vessels of the internal organs. When such a condition occurs in the blood capillaries of the

*Destructive

brain, the blood supply to it is impeded. This may cause *cerebral malaria,* manifested by high fever, coma (unconciousness) and paralysis. One of the complications of pernicious malaria is the *Algid malaria* characterised by cold and clammy skin with vascular collapse leading to peripheral circulatory failure. Along with this there may be either vomiting or watery diarrhoea or passage of blood in faeces. Another complication of pernicious malaria is *septicaemic malaria,* characterised by high continued temperature (resembling typhoid fever). Falciparum malaria may also lead to *'Black water fever'* characterised by sudden intra-vascular haemoglobin followed by fever and passage of haemoglobin in the urine.

In malarial infections the liberation of haemozoin pigment granules in plasma leads to the pigmentation of various organs e g., spleen giving it the characteristic slate-grey or black colour. Chronic malarial infection may cause degenerative changes in the liver, kidneys, heart, adrenal glands, brain and other organs.

Treatment :

Chloroquine and Amodiaquine are potent anti-malarial drugs. Quinine is used for drug resistent P. falciparum. These are schizonticidal drugs. After the clinical cure primaquine is used. It acts on the exo-erythrocytic phases of parasites in the liver and as such prevents relapses. It also acts on the gametocytes. Emergence of drug resistant parasites (P. falciparum) necessitates multiple drug regimen.

An extract from the leaves of *Vitex peduncularis* has been known to prevent the haemolytic crisis of black water fever; Corticosteroids are also administered during haemolytic crisis.

Control Measuers :

One has to employ potent anti-mosquito measures. Destruction of adult mosquitoes can be carried out by spraying with insecticides, such as D.D.T. or Gammexane. Anti-larval measures include the elimination of breeding places of mosquitoes and use of larvicides (oil, parish green, D.D.T. dissolved in oil).

In the early sixties, malaria was brought under control. It has now reappeared all over Asia and Africa. The mosquitoes have

developed immunity to insecticides and the parasites are showing resistance to drugs. This is posing a great threat to humanity.

Prof. Sydney Cohen of the Guy's Hospital Medical School, London and his co-workers are reported to have developed a vaccine prepared from infected red blood corpuscles containing merozoites. Six monkeys were injected with this vaccine and when attempts were made to infect them with the allied forms of malarial parasite, they showed a considerable degree of immunity. This immunisation is yet to be experimented with human parasites.

In India also research on immunisation is underway at different research centres and so far immunisation of rodents has been successful at the Department of Biochemistry and Pathology of the Post Graduate Medical Institute, Chandigarh.

Revision questions

1. Define the terms *parasite* and *parasitism*. Explain this with suitable examples.
2. Give an account of the life cycle of malarial parasite in man.
3. Describe in detail the life cycle of a malarial parasite in mosquito.
4. Describe in brief the various types of malarial fever caused by the different species of Plasmodium.
5. Describe the pathogenecity of malaria and briefly mention the various curative and control measures adopted against this disease.
6. Give a short account of the contributions of various scientists in the establishment of the cause of malarial fever through mosquito transmission and the discovery of the tissue phases of parasite in man.
7. Write notes on the following:
   (a) Pre-erythrocytic and Exo-erythrocytic phases.
   (b) Erythrocytic cycle.
   (c) Vector.
   (d) Gametocytes of P. falciparum.
   (e) Incubation period.
   (f) Definitive and intermediate hosts.

Parasitic Amoebae :

In addition to the free living types of amoeba, an example of which you have already studied in detail, there are certain types of amoebae, which lead a parasitic mode of life. The parasitic amoebae inhabiting the human body are of the following types.

1. *Entamoeba histolytica,* causing amoebic dysentry i.e., intestinal amoebiasis and liver, lung and brain abscesses in man.
2. *Entamoeba coli,* another parasitic form inhabiting human colon but is non-pathogenic.
3. *Entamoeba gingivalis,* a parasite in the mouth of man which is also non-pathogenic.
4. *Endolimax nana,* living in the lumen of the large intestine of man ; is also non-pathogenic.
5. *Iodamoeba butschlii,* living in the colon of man as a harmless commensal.
6. *Dientamoeba fragilis* lives in the intestine of man. It is binucleate and its cytoplasm is fragile. It lives as a harmless commensal in the intestine of man.

The brief accounts of the life history of Entamoeba histolytica and Entamoeba coli are given below.

Entamoeba histolytica : Entamoeba histolytica is the parasitic form of amoeba which causes diarrhoea, dysentry, inflammation of the liver and liver abscess in man. As the parasite dissolves the tissues, it is referred to as E. histolytica (Gr. *histos*; tissues *luein*; to dissolve).

The parasite lives in the mucous and sub-mucous layers of the large intestine of man. It feeds upon the living tissue. Some of the parasites may come out into the lumen of the intestine and undergo encystment. They are passed out along with the faeces. These cysts found in the faeces are responsible for the transmission of the parasite from man to man. The parasite may at times bore through the intestinal wall and may pass through the portal vein into the liver. In certain cases, they may be found in the lung and brain also. These are called *metastatic forms.* Their location in the liver,

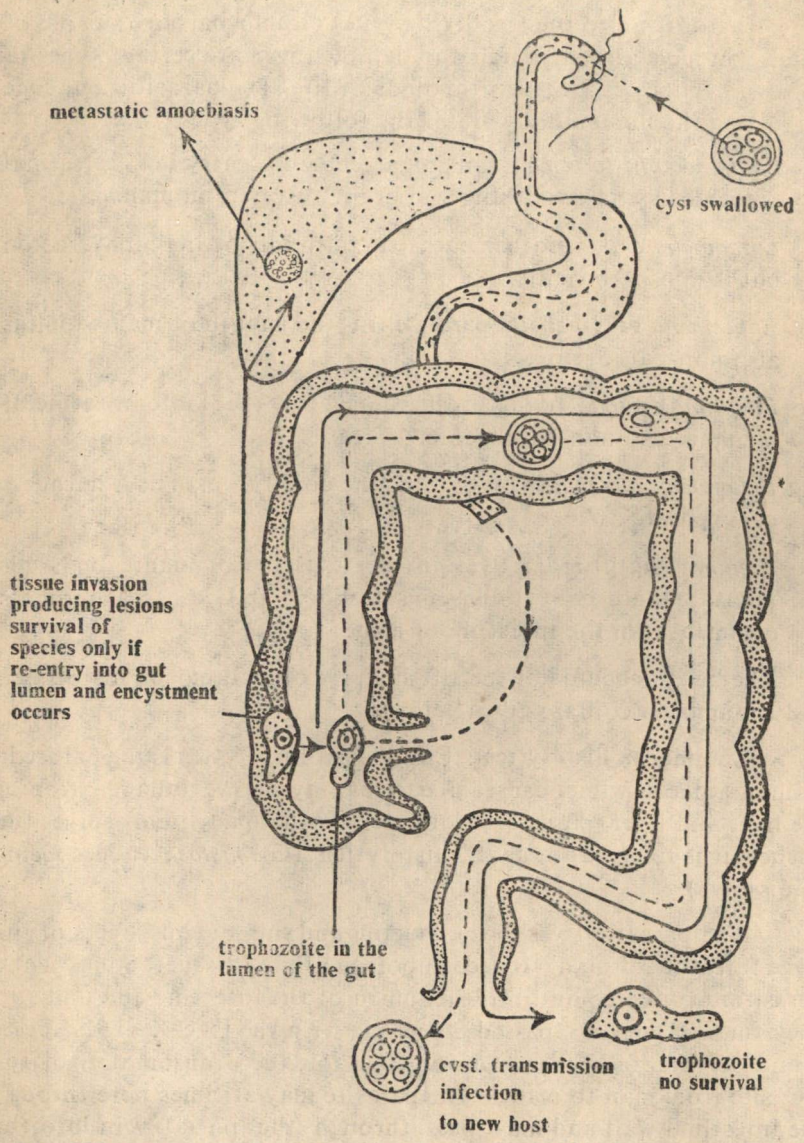


Fig. 1.39 Diagrammatic representation of the life cycle of Entamoeba histolytica

lung and brain may lead to the formation of abscesses at these sites. Pre-cystic and cystic forms are not formed in the liver and brain.

There are three distinct phases in the life cycle of Entamoeba histolytica which are described below.

1. Trophozoite Stage: Trophozoite of E. histolytica is 3 to 5 times the size of a red blood cell and the average size is 20 to 30 μ. The cytoplasm of the trophozoite is distinguished into two portions, a clear translucent thin peripheral ectoplasm, and a granular inner zone of endoplasm. It now and then sends out a blunt pseudopodium. The pseudopodium when formed consists of a clear hyaline ectoplasm into which later, granular endoplasm flows.

Inside the endoplasm lies a spherical nucleus. The chromatin in the form of fine granules is found as a single layer lining the inner side of the nuclear membrane. There lies in the nucleus a centrally placed larger granule called the karyosome surrounded by a clear area or halo. The area between the nuclear membrane and the karyosome is devoid of chromatin granules but is traversed by fine threads of linin net-work, like the spokes of a wheel radiating from

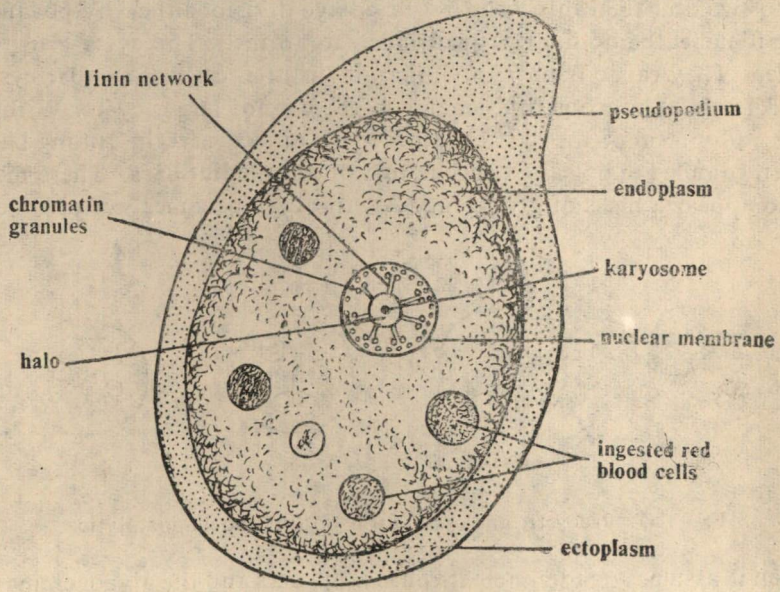


Fig. 1·40 Trophozoite of Entamoeba histolytica

the centrally placed karyosome. Inside the endoplasm are also seen ingested red blood corpuscles, leucocytes and occasionally tissue debris.

2. *Precystic Forms*: The trophozoites may at times assume a round or slightly ovoid shape with a blunt pseudopodium projecting from the periphery. The ectoplasm is hardly distinguished. These forms usually appear when the trophozoite is short of food and faces adverse circumstances. They measure 10 to 20 microns in diameter. On account of their small size they are sometimes referred to as *Entamoeba minuta*. The R.B.Cs. and tissue debris are not found. There appears instead, glycogen in the endoplasm. These forms develop ultimately into cystic forms. In case they are ejected prior to encystment in the stools, no further development takes place.

3. *Cystic Forms*: Precystic forms develop into cystic forms in the lumen of the intestine and are not found in the intestinal wall or in the metastatic stages in liver, lung or brain. When about to encyst, the pre-cystic forms develop around, a highly refractile membrane called the **cyst wall**. Soon after the encystment, the nucleus divides into two and then into four by successive divisions thereby producing **binucleate** and finally **quadrinucleate forms**. The cysts grow in size. They range from 7 to 9 microns in the case of smaller cysts and 15 to 20 microns in diameter in the case of larger cysts. Within the endoplasm of the cystic forms there appear certain oblong bars with rounded ends called **chromatoid** or **chromidial bars**. There may also appear a mass of glycogen. As the cyst becomes mature, i.e.,

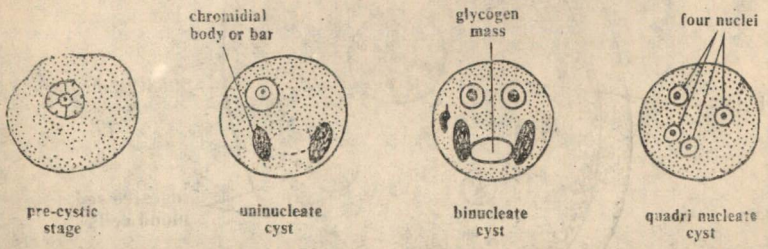


Fig. 1.41 Precystic and cystic forms of Entamoeba histolytica

when it assumes quadrinucleate phase, the bars and the glycogen mass disappear. The chromatoid bars are regarded by some to be nutrient

material while others consider them to be the remains of chromatin net-work thrown during the nuclear division.

The cysts in various stages of their development, are evacuated from the body in the stools. They are highly infective, as when they are swallowed by man, they may undergo their further development.

Life Cycle : When a person swallows mature quadrinucleated cysts along with the contaminated food and drink, they are capable of further development inside the gut of a susceptible person. The cysts pass unaltered through the stomach into the small intestine. In the lower part of the intestine, the cyst may rupture but more often the cyst ruptures when it reaches the caecum. Each cyst here liberates a single amoeba with four nuclei. The nuclei undergo further division successively and the cytoplasm gathers around each to form eight amoebulae. The young amoebae now are actively motile and enter the trophozoite stage. They normally move towards their final resort, the large intestine. Within the caecum, the amoebulae may

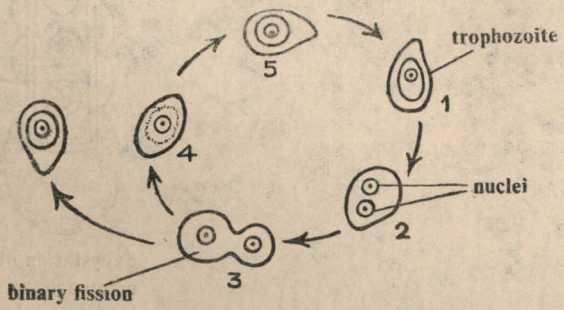


Fig. 1·42 Entamoeba histolytica—tissue invading forms multiplying by binary fission

penetrate its wall and establish themselves in the mucous and submucous layers of the intestine. They start invading the tissue and form flask-shaped ulcers. They often attack fresh tissues. These may multiply within the tissues by binary fission. They actively ingest red blood cells and tissue debris. During their tissue invading phase in the large intestine a certain number of trophozoites are discharged into the lumen of the bowl and are transferred into precystic and finally cystic forms. These cysts may be discharged outside the human body along with faeces and can infect other persons.

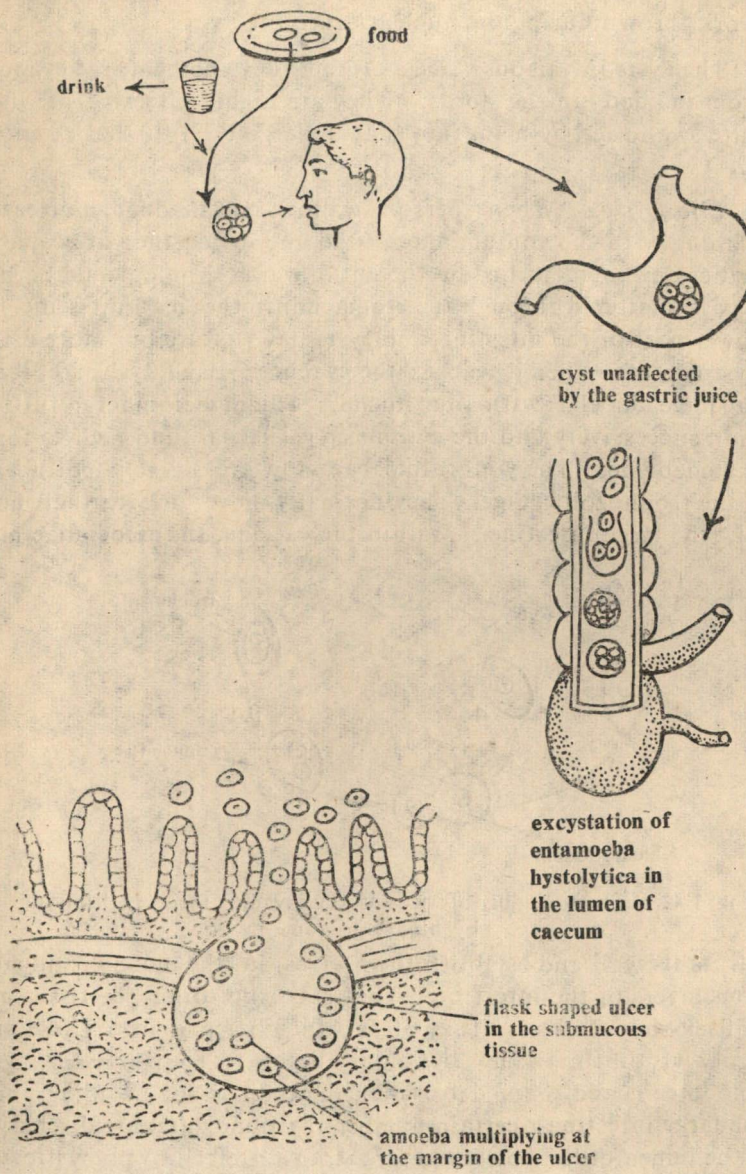


Fig. 1·43 Entamoeba histolytica—the excystation phase and the flask shaped ulcer

These tissue forms at times, may bore through the intestinal wall and enter the portal circulation. They may thus reach in the first instance, the liver which acts like a *first filter*. In the liver they may form liver abscesses. The amoebae may at times travel beyond the liver and may pass into the pulmonary circulation from where they may enter the lung. Within the lungs, they form lung abscesses. In case their further entry is not arrested in the lung, they may enter the systemic circulation, from where they localise themselves in the brain leading to the formation of brain abscesses.

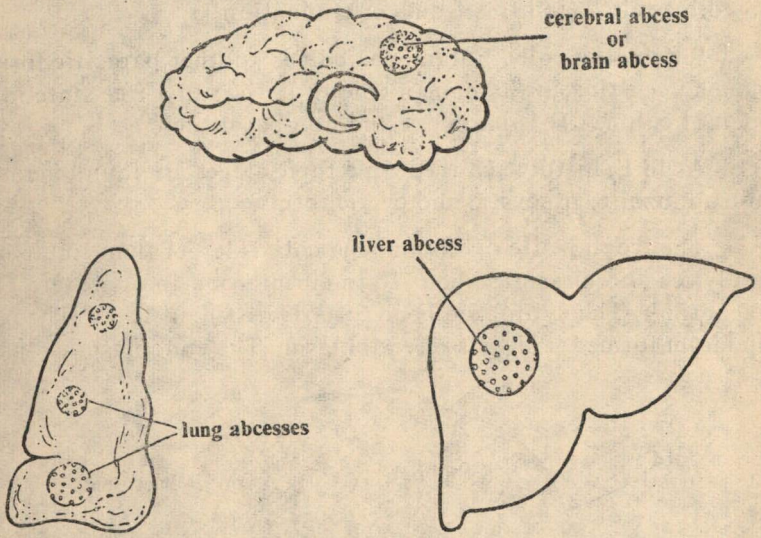


Fig. 1·44 Entamoeba histolytica—Metastatic forms forming liver, lung and brain

E. histolytica causes amoebic dysentry with the frequency of motions with mucus and blood accompanied by generalised abdominal pain and griping. Liver, brain and lung abscesses are highly fatal to the life of a person.

Treatment: The following drugs have specific action on E. histolytica. There are, however, to be used under strict medical advice and supervision.

1. Alkaloids of Ipecacuanha and Kurchi. Emetine is the principal alkaloid isolated from the root of Ipecacuanha.

2. Kurchi is the bark of a small plant *Holarrhena anti-dysenterica* which grows throughout India particularly in tropical Himalayas. In Sanskrit, seeds of this plant are called *Indralaya* or 'Indra's seeds.'
3. *Pentavalent arsenicals*: Stovarsal (acetarsol) and Carbosone.
4. Quinoline derivatives are Chinioform (Yatren), Vioform, Iodochlor hydroxyquinoline and Diodoquin.

Prevention: As the infection results from the swallowing of cysts, good sanitary measures are most essential to keep the water and edibles clean and free from contamination.

Entamoeba coli: Entamoeba coli is another parasitic form of amoeba occurring in the human colon. It lives in a free state in the lumen of colon. It is harmless and non-pathogenic.

As in E. histolytica the same three stages are found here i.e., the trophozoite, precystic and cystic forms.

The trophozoite of Entamoeba coli is larger than Entamoeba histolytica and measures about 20 to 40 microns in diameter. It is less motile. The cytoplasm is not clearly distinguished. The pseudopodium formed, consists of endoplasm. The endoplasm is opaque

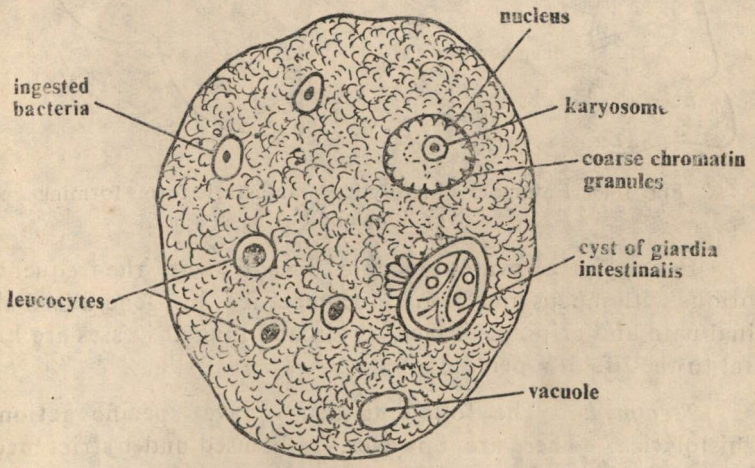


Fig 1.45 Entamoeba coli, Trophozoite

and granular and is filled with food vacuoles. The ingested particles consist of bacteria, yeast and various other substances. They never

contain red blood cells. The nucleus is eccentric in position containing a karyosome surrounded by a broader halo. The nuclear membrane is lined internally with coarse chromatin granules. The region between the karyosome and the nuclear membrane is traversed by fine linin threads.

The precystic stage is round in shape and no ingested material is found in its cytoplasm. The nucleus is clearly visible and has the same structure as is seen in the trophozoite phase.

The precystic form before encystation undergoes reduction in size. The cyst is formed round the cellular mass. The cyst measures about 15 to 20 microns in diameter. In the early stages of the cyst formation, a large glycogen mass is seen which gradually disappears as the cyst matures. The chromatid bodies are either absent or scarcely seen. When present, they are in the form of threads, filaments or with sharp fractured ends, like that of glass splinters. The nucleus of the cyst undergoes successive divisions to form 2, 4 and upto 8 nuclei. Majority of the cysts contain 8 nuclei. No further nuclear division takes place when the amoeba comes out of the cyst. At the time of excystation, it rather loses one to four of the original eight nuclei and as a result, the young amoebae that come out of the cyst will be only 7 to 4 in number.

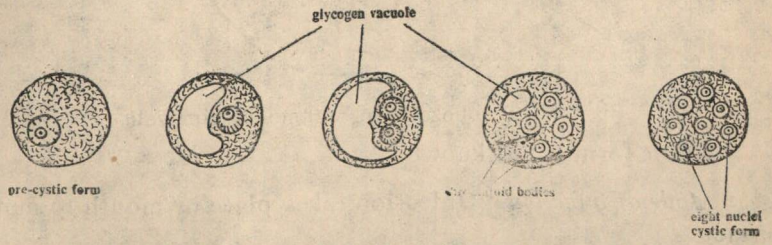


Fig. 1.46 Entamoeba coli—Precystic and cystic forms

Life Cycle: Infection spreads in human beings by swallowing the cysts with contaminated food or drink. They come out of their cysts in the large intestine or the lower part of the ileum. In the large intestine, within its lumen, the trophozoites increase their number by simple binary fission. They never invade the intestinal wall but remain in the lumen of the intestine. They feed on bacteria etc. Under unfavourable circumstances, the trophozoites turn into

precystic forms and then into cystic forms. The cysts so formed are thus discharged to the outside along with the faecal matter and these may reinfect another man. Entamoeba coli is non-pathogenic.

A brief account of the other parasitic forms of amoeba with reference to their habitat, morphology of trophozoite and cystic forms illustrated with suitable diagrams is as follows:

1. Entamoeba gingivalis:

Habitat: Entamoeba gingivalis is found in the human mouth, usually in pyorrhoeal pus pockets. It is non-pathogenic.

Trophozoite is 10 to 20 microns in dimension. No red blood cells are found. Within the endoplasm are seen ingested pus cells. A single nucleus with a karyosome is found.

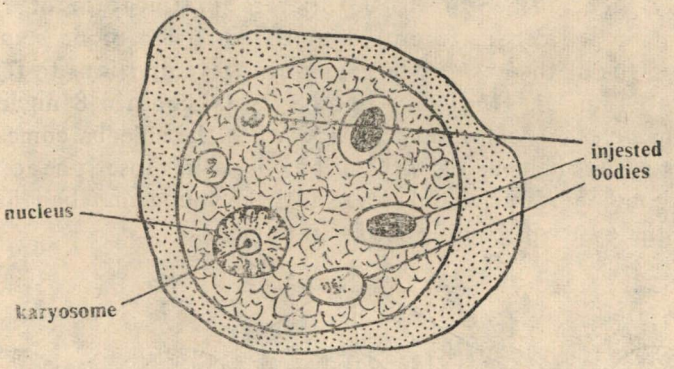


Fig 1.47 Trophozoite of Entamoeba gingivalis

Cystic form is not known.

Mode of infection: Infection takes place by mouth to mouth contact.

2. Endolimax nana:

Habitat: Endolimax nana is found in the lumen of the large intestine of man. It leads the life of a harmless commensal.

Trophozoite is 6–12 microns in diameter. It moves like a slug. It ingests bacteria but never the R.B.Cs. The nucleus with a karyosome is found in the form of a single large irregular mass of chromatin.

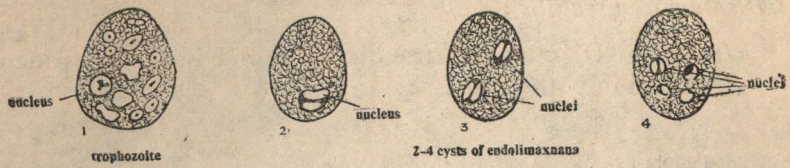


Fig. 1·48 Trophozoite and cystic forms of Endolimax nana

Cystic Forms: Cysts are oval or ellipsoidal in shape. Mature cysts contain 4 nuclei. Glycogen mass and chromatoid bars are not found.

Mode of Infection: Infection occurs through the ingestion of cysts.

3. Iodamoebo butschlii :

Habitat: Iodamoeba butschlii inhabits the colon of man. It never invades the tissues. It is non-pathogenic.

Trophozoite measures 8–12 microns in diameter. Ingested bacteria are found in the cytoplasm. R.B.Cs. are not ingested. The nucleus is fairly big and 2–3·5 microns in diameter. Karyosome is large and circular and in the form of a black mass.

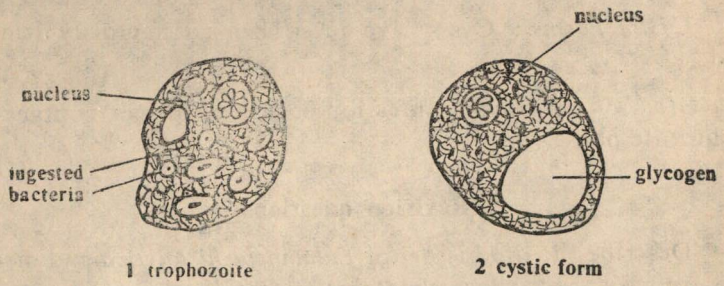


Fig. 1·49 Trophozoite and cystic forms of Iodamoeba butschlii

Cystic Forms: Cysts are spherical or oval in shape, uninucleate and are 8–12 microns in diameter. More than one glycogen mass is present. There are no chromatid bars. Nucleus is eccentric.

Mode of Infection: Infection takes place by the swallowing of cysts.

4. Dientamoeba fragilis :

Habitat : Dientamoeba fragilis is found in the intestine of man and it is non-pathogenic.

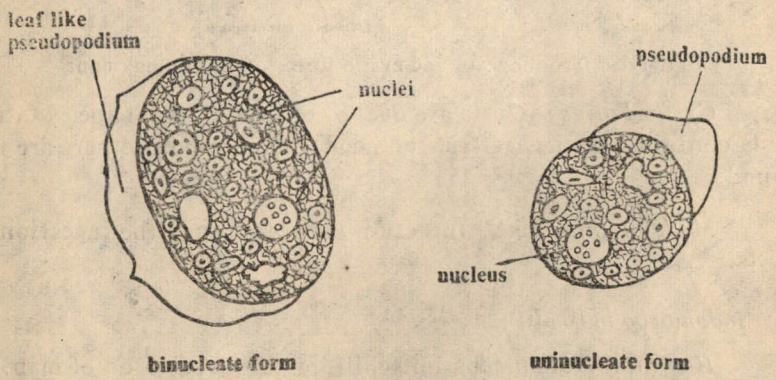


Fig. 1·50 Dientamoeba fragilis—Binucleate and uninucleate forms

Trophozoite is binucleate and 5–12 microns in diameter. Pseudopodium is leaf-like and lobed and consists of ectoplasm only. Ingested bacteria are found. No R. B. Cs are ingested. Cytoplasm of the parasite is very fragile and degenerates soon after leaving it's host.

Cystic Forms : Cysts have never been satisfactorily demonstrated.

Mode of Infection : Infection occurs by direct contact with trophozoite phase.

Revision questions

1. Describe the life history of *Entamoeba histolytica* and mention in brief the various symptoms of amoebiasis.
2. Give an account of the life history of *Entamoeba coli*. What are the various morphological differences in the trophozoites and cystic forms of *Entamoeba histolytica* and *Entamoeba coli*?
3. What are the various types of parasitic amoebae which infect man? Describe in brief the life history of any one pathogenic form of parasitic amoeba infecting man.

CHAPTER II

COELENTERATA—DIPLOBLASTICA

[Animals with two layers of cells]

You have studied in the previous chapter a few examples of unicellular organisms both free living and parasitic. We will now study some examples of multicellular animals which are, as previously mentioned, included in the group metazoa.

There are several examples of metazoans, both simple and complex, which you will be studying. The metazoans are distinguished from the protozoans not only by the larger size but also by the high degree of differentiation and specialisation of their various component parts.

The structure of a simple metazoan belonging to the phylum coelenterata may be studied first. The word **Coelenterata** (Gr. *koilos*, hollow+*enteron*, intestine) literally means hollow intestine. A generalised coelenterate in its simple conceivable form has a simple sac-like body containing a central cavity called the **enteron.** It opens to the exterior by a single aperture, the mouth. The walls of the sac-like body are built up of two layers of cells. The outer layer is the ectoderm and the inner layer is called the endoderm. These two layers are separated from each other by a non-cellular jelly-like substance, the mesogloea.

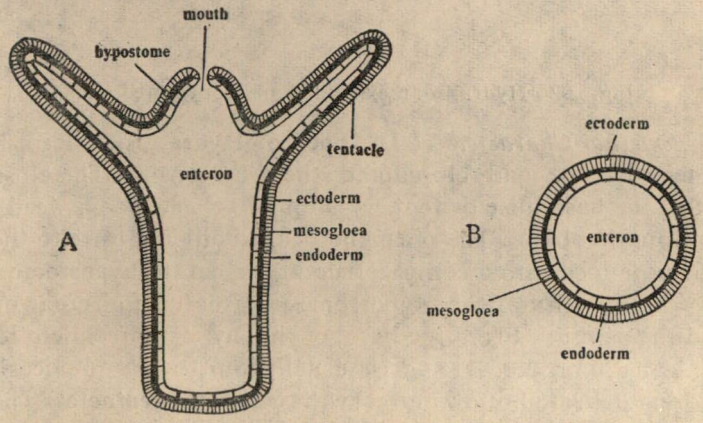


Fig. 2·1 Generalised structure of a Coelenterate

The body of a coelenterate as such is composed of two cellular layers. They are therefore referred to as **two layered animals** and are included in the group **Diploblastica**.

Hydra :

We will now study in detail the structure of a simple metazoan, the Hydra. It is a diploblastic animal belonging to phylum coelenterata. It is found in ponds and ditches, adhering to water weeds in fresh water tanks. Hydras usually attain a length of 5 mm.

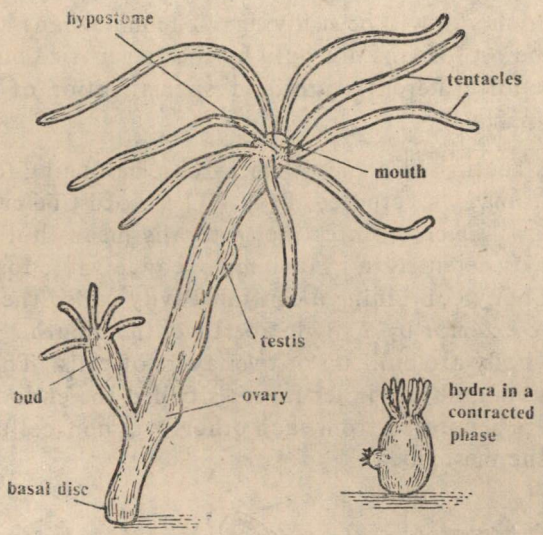


Fig. 2.2 Hydra in an expanded and contracted phase

External Characters : The body of Hydra resembles a hollow cylinder with one end closed and the other open. The closed end is called the **basal disc** or **foot**. It is found attached to a weed of any other aquatic object. The open end of the body opposite to the basal disc is produced into a conical structure called the **hypostome** or **oral cone**. At the apex of the hypostome is situated a circular opening called the **mouth**. From the base of the hypostome where it meets with the body proper, there arise usually four to six and occasionally eight long delicate hollow out-growths called the **tentacles**. These are arranged in the form of a circlet. The mouth leads into a spacious

central cavity, the **enteron** which communicates with the cavities of the tentacles.

On account of the presence of a circlet of tentacles surrounding the mouth, the body of Hydra is **radially symmetrical** i. e., *the body is divisible into similar parts all round radiating* from *a common central axis.* The cylindrical body of Hydra with its circlet of tentacles bears a superficial resemblance to an octopus. Hence hydra is referred to as a **polyp** (L. *polypus*, with many feet)

The following well established species of Hydra are recognised.

(1) *Hydra vulgaris :* It is colourless and is found in all parts of India. (2) *Hydra oligactis* (=H. fusca) is pinkish yellow or brown in colour. It has a stalk and the length of the tentacles is upto 25 cm. It is found in certain parts of India. (3) *Chlorohydra viridissima* (=*H. viridis*). It is bright green in colour and has not been reported so far from any part of India. The tentacles are slender and are not much longer than the body at rest. However, the tentacles can be extended to a very great length. (4) *Hydra attenuata* is also brown in colour without a stalk. The tentacles are twice the length of its body.

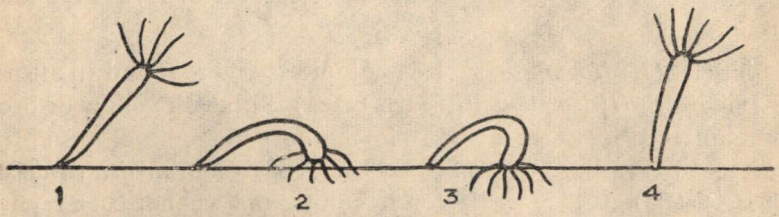
Movement and Locomotion : Hydra continuously changes its form. At one time it elongates its body until its length is fully 15 times its diameter and the tentacles look like long delicate filaments. At another time, the body of hydra is almost contracted into a globular mass and the tentacles look like little blunt knobs. Besides these movements of contraction and expansion the hydra moves from place to place by the following modes of locomotion.

1. After the manner of a looping caterpillar : In this mode of locomotion, while the basal disc remains attached to the surface, the body is bent round so that the distal part of the body i e., the tentacles touch the surface. Now the basal end is detached and it soon fixes itself at a point nearer to the tentacles so that the entire body forms a loop. Now the body expands and the tentacles lose their grip and seek a fresh point of attachment, bit ahead to the former one. The base is then detached and is again fixed at a point nearer to the tentacles. The loop is thus formed again, after which due to the expansion of the body the tentacles seek a new point of

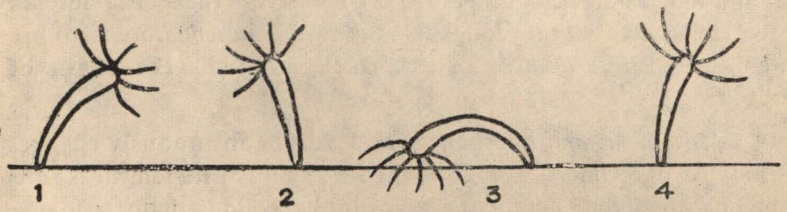
attachment. In this way, this process is repeated in the order mentioned above. These movements resemble in general the looping movements of a caterpillar.



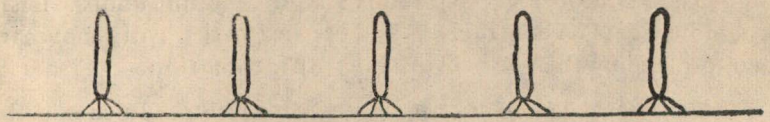
a. floating



b looping like a caterpillar



c. somersaulting



d. crawling on tentacles like cuttle fish

Fig. 2·3 Various modes of locomotion in Hydra

2. *Crawling* : Hydra can also move from place to place by crawling like a cuttle fish by means of its tentacles. The body during crawling on tentacles is kept nearly vertical.

3. *Somersaulting* : A third method of progression is by a series of somersaults, i. e., Hydra stands sometimes on its base and at other times on its tentacles.

4. Floating : Hydra may float very rarely at the surface of the water by means of a bubble of gas secreted by certain cells of the basal disc. It may as such be carried about passively by means of water currents.

The Body Wall :

The cylindrical body of *Hydra* is composed of distinct cellular layers. The outer layer of cells is called the **ectoderm** and an inner layer of cells, the **endoderm.** In between these two cellular layers is found a thin layer of structureless jelly-like substance called the **mesogloea.** The electron microscope shows that mesogloea is granular and sometimes as a fibrous structure and is not limited by a distinct membrane. It penetrates in between the cells of the body-wall like a cementing substance and it appears as if the cellular layers

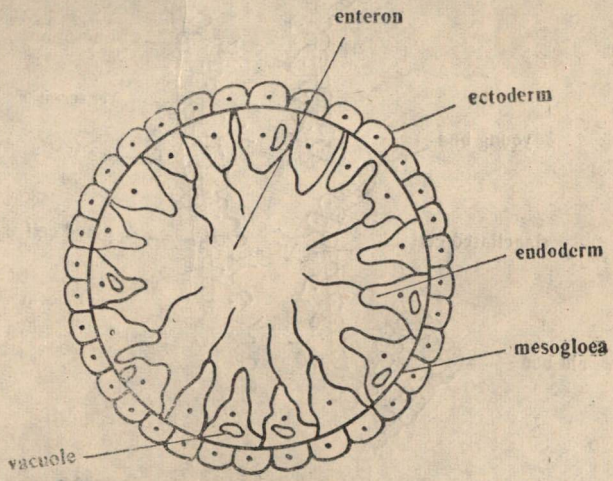


Fig. 2·4 Transverse section passing through the body of Hydra

are found embedded in it. The essential feature, thus in the structure of the body wall is, that it consists of two distinct cellular layers round the central cavity or enteron and the cavities of the tentacles. This structure can very well be understood by observing the transverse and longitudinal sections passing through the body of Hydra.

Hydra is a diploblastic animal with two distinct cellular layers namely the ectoderm and the endoderm radially arranged round the enteron with a space in between these cells filled up with the mesogloea.

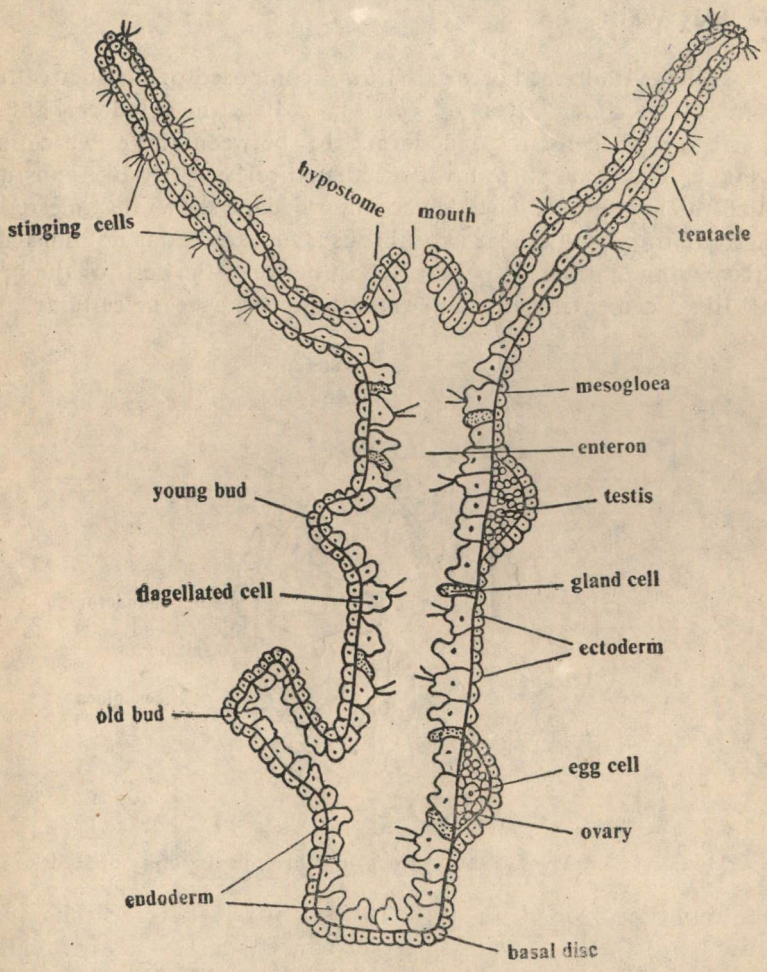


Fig. 2·5 Longitudinal section passing through the body of Hydra

The detailed structure of the two cellular layers i.e., the *ectoderm* and the *endoderm* is discussed below.

4. Floating : Hydra may float very rarely at the surface of the water by means of a bubble of gas secreted by certain cells of the basal disc. It may as such be carried about passively by means of water currents.

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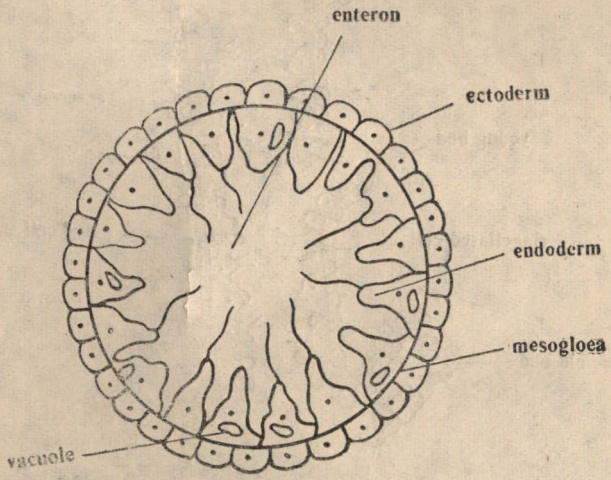


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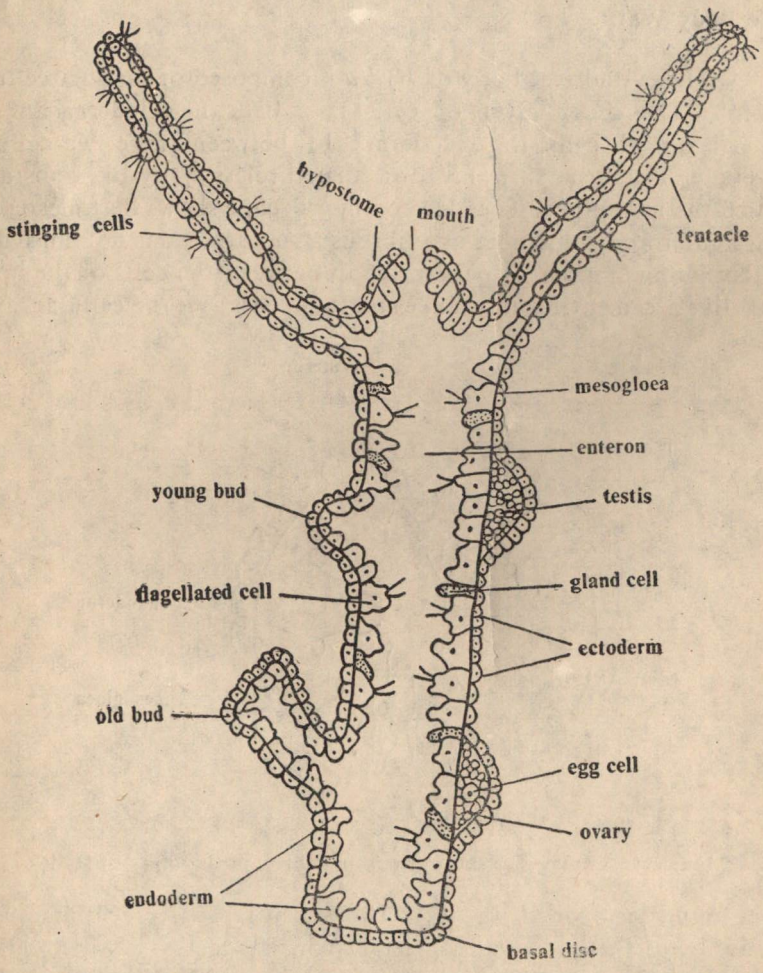


Fig. 2·5 Longitudinal section passing through the body of Hydra

The detailed structure of the two cellular layers i.e., the *ectoderm* and the *endoderm* is discussed below.

The ectoderm is the outer-most layer of the body covering it superficially. The cells of the ectoderm are no doubt simple but they have undergone considerable differentiation into several kinds. The following types of cells are thus recognised.

(a) **Musculo-epithelial cells** *(b)* **The interstitial cells**

(c) **Nematoblasts** *(d)* **Nerve cells**

(e) **Sensory (receptor) cells and** *(f)* **The germ cells.**

(a) The main bulk of the ectoderm is composed of the musculo-epithelial cells. They are conical in shape Their broader bases lie away from the mesogloea. These bases at the superficial surface of the body are linked up with one another forming thereby a continuous superficial covering to the body. The apices of these cells are turned inwards towards the mesogloea due to which spaces are formed in the deeper parts of the ectoderm. The spaces are called the **interstices**. From the apex of each musculo-epithelial cell, a long contractile protoplasmic process arises on each side. These processes lie along the mesogloea parallel to the main axis of the body and are termed as **muscle tails**. They are highly contractile. The muscle tails of the adjacent cells overlap with each other. The contraction of the body is brought about by these muscle tails. The electron microscopic studies have revealed the presence of a thin cuticle on the ectoderm cells except on the cells of the basal disc.

(b) The interstices are filled up with an undifferentiated mass of small cells called the **interstitial cells**. They are small and round and are capable of giving rise to any of the other kinds of ectoderm cells including the reproductive cells or the germ cells. The interstitial cells continuously give rise to the **nematoblasts** which are continually being used up by the animal.

(c) *The nematoblasts* (*cnidoblasts*)are highly specialised cells derived from the interstitial cells. They are found in groups or batteries and lie embedded in the superficial layer of the ectoderm.

Each nematoblast secretes a remarkable structure called the nematocyst. These nematocysts which are abundantly found on the tentacles are the structures used for defence and in paralysing and killing the prey.

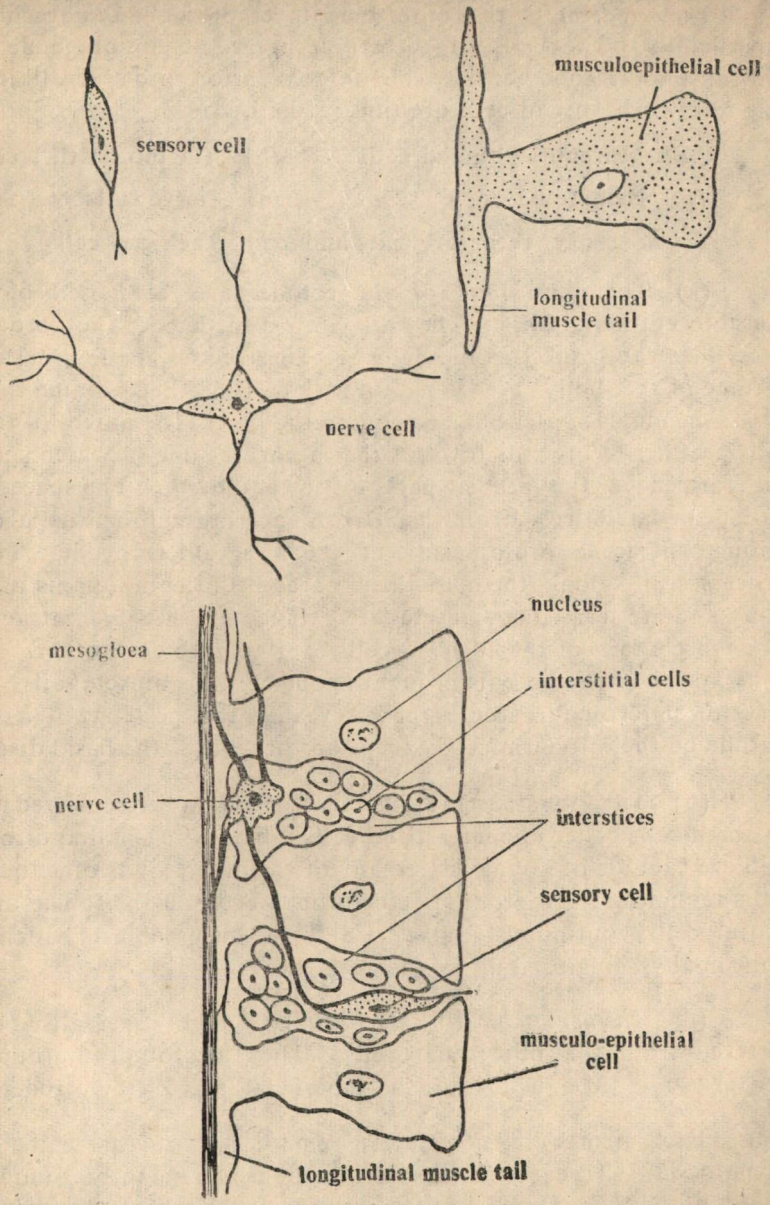


Fig. 2.6 A portion of L. S. of the body wall of Hydra (diagrammatic) to show the structure of ectoderm along with some isolated ectoderm cells

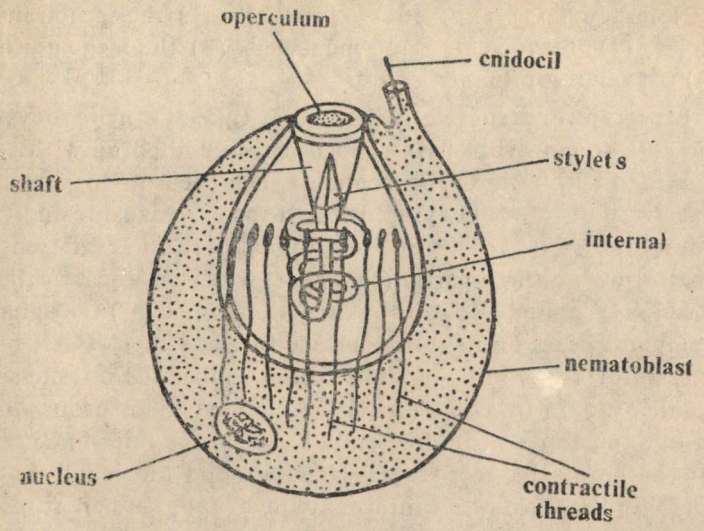
Nematocysts are of four kinds i.e., (1) the **penetrants** or **stenoteles,** (2) the **volvents** or **desmonemes,** (3) the **large glutinants** and (4) the **small glutinants.**

Penetrant or stenotele is the largest type of a nematocyst. It consists of a tough ovoid flask-shaped capsule filled up with a fluid and provided with a lid or **operculum.** The neck of this capsule is produced into a wide tube lying inverted into the capsule and tapers towards its inner end. This entire tubular portion is differentiated into the following three parts. (i) A short wider basal part called the **shaft** which is soon followed by a portion called (ii) the **spinneret.** The spinneret bears on its inner surface three pointed stylets or bars and six spiral ridges in which are found embedded minute spines. The spinneret is followed by (iii) a long coiled filamentous stinging thread-like tube open at its free end. It lies in the fluid-filled capsule and in an undischarged state, winds around the shaft and the spinneret, in the form of an internal coiled tube. When at rest, the points of the stylets converge towards the operculum forming thereby a sort of a nozzle. The wall of the capsule and the stinging thread is formed of a collagen-like material. At one point of the nematoblast nearer to the operculum, there projects from its surface a small sensory bristle the **cnidocil** or the **trigger.** In some coelenterates, it is absent. The nematoblast contains a large nucleus.

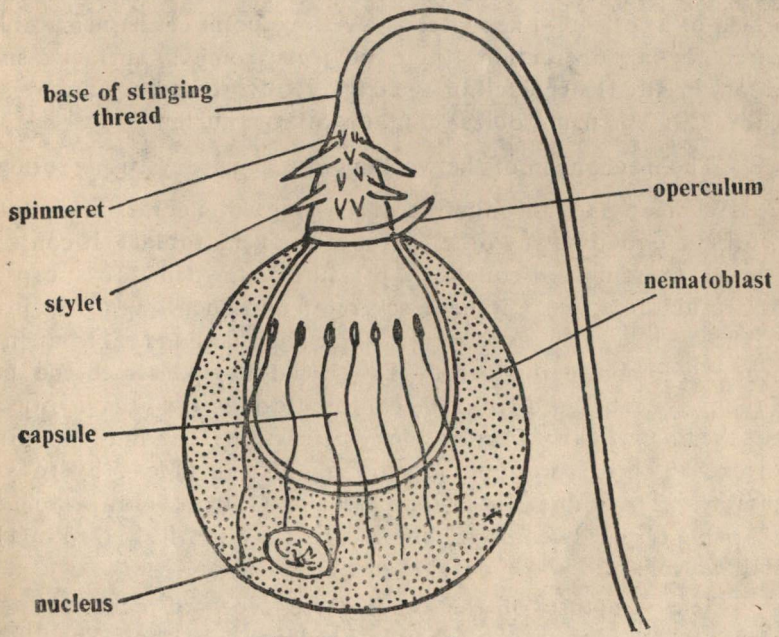
The mechanism of the working of a nematocyst is as follows:

When any animal found in the passing water comes into contact with the cnidocil or any other parts of the nematoblast, it contracts suddenly exerting consequently a pressure on the nematocyst capsule. This results in an instantaneous eversion and uncoiling of the inverted thread-like tube which pushes aside the lid and is shot out in the form of a long stinging thread. The thread may penetrate the body of the prey. The fluid from the capsule through this tube is injected into the body of the prey and may paralyse it. The fluid contains a poison, which is a protein and probably also includes 5 hydroxytryptamine. This substance is about 75% as toxic as cobra venom and is capable of paralysing large animals like a water-flea (Daphnia) or small worms.

The structure of the other three types of nematocysts is essentially the same as described for the large penetrant. The difference however lies in the form and functioning of the everted thread.



A Undischarged state



B. Discharged state

Fig. 2·7 The structure of a nematocyst (Penetrant)

The thread of **volvents** when discharged winds into a tight coil around the animals like small crustacea. This helps in holding the prey for a longer duration. In the case of **glutinants**, the thread after discharge remains straight and possesses adhesive property. It adheres to the prey. The threads of the **large glutinants** can also penetrate the tissues of small animals.

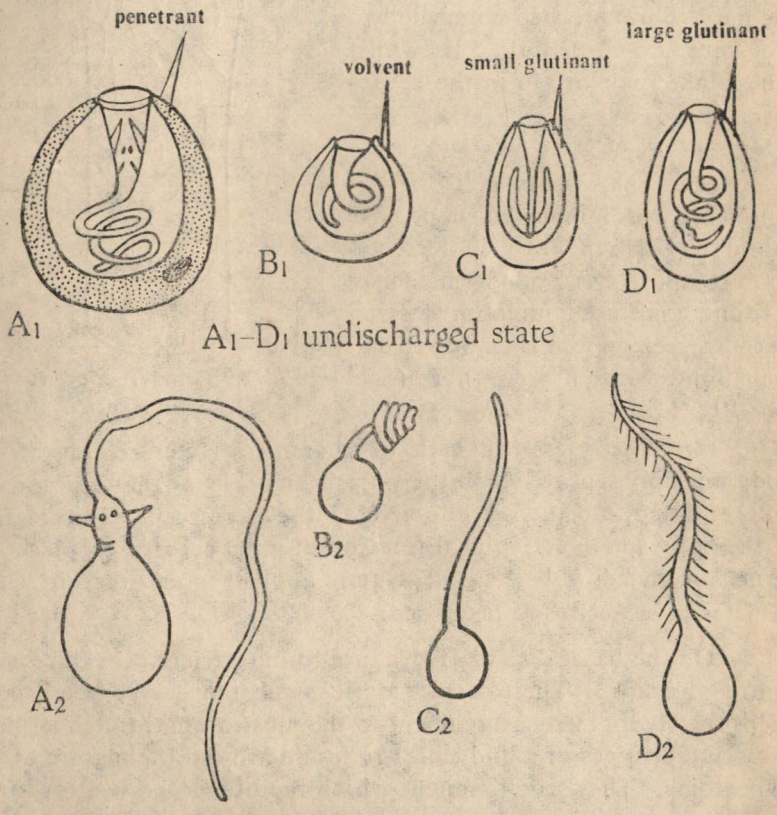


Fig. 2·8 Various types of nematocysts of Hydra

(d) The interstitial cells may give rise to the nerve cells. They lie outside the muscle tails and between the bases of other cells. They form a sort of network on ectodermal as well as on the endodermal surfaces of the mesogloea.

Each nerve cell has a distinct cell body, with a nucleus and a number of branching processes (See fig. 2.6). The fine branches of these processes intermesh with those from the neighbouring cells forming thereby a sort of nerve net. Certain of the nerve fibres are also connected to the musculo-epithelial cells whilst others take their origin in the receptor cells.

(e) The sensory cells or receptor cells, columnar in shape, are found more abundantly in the ectoderm than in the endoderm. There is found a minute conical projection at their free end and their lower end is prolonged into a nerve fibre (See fig.2.6).

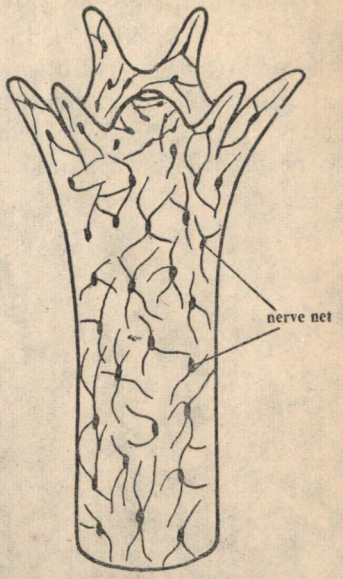


Fig 2.9 Ectodermal nerve net in Hydra

(f) The interstitial cells of certain restricted regions of the body multiply repeatedly in the warmer months of the year and are differentiated into the reproductive or the germ cells. The regions of the body where active proliferation of germ cells takes place are termed as **gonads** It is a general term applied to an organ in which gametes or sex cells are produced.

On the basal disc of Hydra are found strictly speaking musculo gland cells. These secrete a sticky substance This substance helps the Hydra in its attachment to the substratum through its basal disc. Other types of gland cells are found around the margin of the hypostome. They secrete mucus which facilitates the swallowing of large food particles.

The Endoderm : The endoderm lines the enteron. The structure of endoderm cells is much simple as compared with the ectoderm cells. It consists of a single layer of large cells resting on the mesogloea. Two types of endoderm cells are recognised i.e., the **digestive cells and the gland cells.** The bases of the digestive cells are prolonged into muscle tails which run at right angles to the main axis of the

body. Some of these cells are capable of forming pseudopodia. They secrete digestive juices and engulf food particles in the form of food vacuoles within their cytoplasm. As these cells form the lining of the enteron, the cavity of the enteron can be seen now and then obliterated due to the formation of pseudopodia by these cells. Some of these cells instead of forming pseudopodia may also bear two to four flagella towards their free ends.

The gland cells are devoid of muscle tails and do not rest on the mesogloea. They secrete digestive juices.

Between the large endoderm cells are also found a few small interstitial cells. The receptor and the nerve cells have also been reported to be scattered in this layer.

Symbiosis : In the large endoderm cells of green hydra (i.e., Chlorohydra viridissima) are found small spherical green unicellular algae—*Zoochlorellae*. They are so abundant in number that the whole animal appears green in colour. It is also noted that they are even passed on from one generation of hydra to another by entering its developing oocyte. Exact mechanism of this transmission is however not known. Similar but not necessarily identical algae also occur in the cells of certain other coelenterates e.g., corals and sea-anaemones and some flat worms like *Convoluta*.

This type of intimate association between two organisms like green Hydra and Zoochlorella is called **symbiosis**. Both the organisms live together in complete harmony and derive mutual benefits. The algae which lives in the endoderm cells of Hydra is called the **symbiont**.

The symbiotic algae build up carbohydrates from carbondioxide and water by a process of photosynthesis. The proteins are synthesized by a combination of elements of the carbohydrates with nitrogen obtained in the form of solution of nitrates from the surrounding water. It is on account of the presence of the green algae that Chlorohydra viridissima always tends to move towards a source of light which as mentioned above, is necessary for the process of photosynthesis performed by the algae. During photosynthesis the oxygen given off by the algae, is utilised by the animal symbiont for respiration. The CO_2 liberated during respiration is utilised by the algae for the photosynthetic process. The algae also absorb and utilise

much of the phosphates and nitrogenous waste eliminated by the animal. Thus, the algae and hydra are in a state of mutually beneficial association. On one side, the algae gets protection as well as

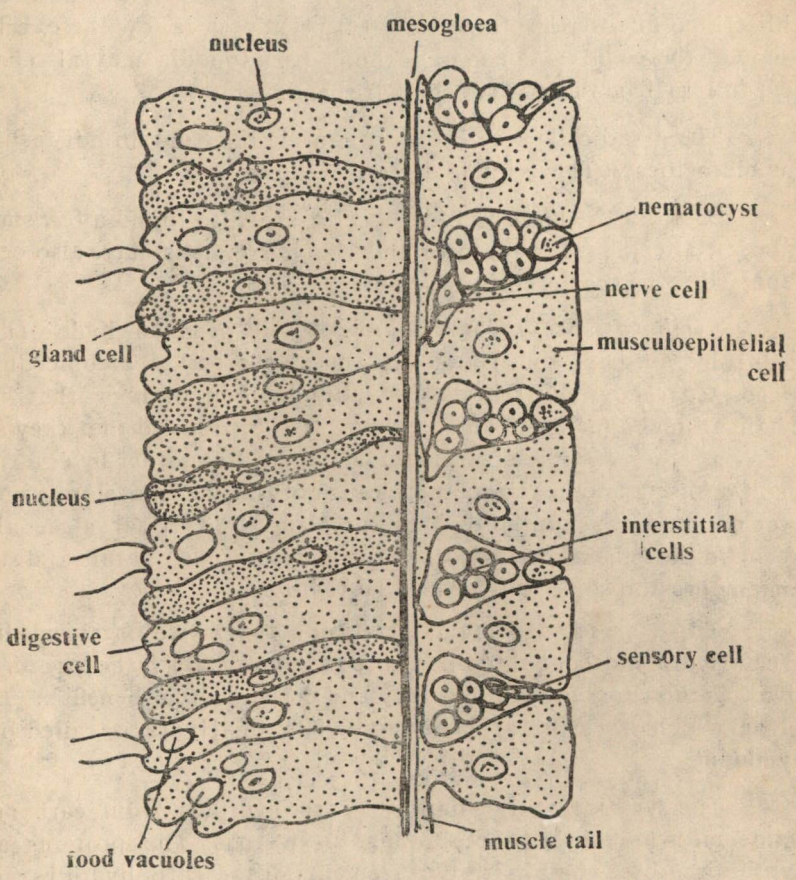


Fig. 2·10 Longitudinal section passing through the body of Hydra showing ectoderm and endoderm

substances from the animal, useful in the synthesis of its food. The algae on its part, supplies the animal with a certain amount of oxygen which it requires.

The brown hydra i.e., *Hydra fusca* (=Hydra oligactis) has in its endoderm cells, a brown algae called *Zooxanthellae*.

Feeding and Digestion : The food of hydra consists of water fleas and other small animals. When a small animal comes in contact with its tentacles, it discharges soon the penetrant and volvent type nematocysts of that region. The threads of the penetrants inject the fluid into the body of the prey, due to which it is soon paralysed. Now the threads of the volvents coil round the body of the prey to hold it firmly, before it is taken into the mouth. Later the tentacle holding the prey contracts and curls over towards the mouth. The other tentacles gradually bend over towards the tentacle holding the prey and finally all the tentacles contract so that the food is brought just above the mouth. The mouth now opens widely and ingests the prey. The animal will not take the prey into the mouth unless it is hungry. In addition to the live prey, hydra ingests dead animals and even bits of gelatine that have been soaked in a crustacean juice.

The food ingested through the mouth is taken into the enteron. If the animal ingested is alive, it will remain so, for sometime but sooner it is killed by the action of the digestive juices secreted by the gland cells of the endoderm. The juice contains a digestive enzyme, the primary function of which is to reduce the food into smaller particles within the enteron. Later on, the fine particles of food are engulfed by the pseudopodia of the endoderm cells and are taken into their cytoplasm along with water as food vacuoles, in the manner, as it occurs in amoeba. The food is finally digested within the food vacuoles of the endoderm cells. The digested portions are later absorbed and assimilated.

The flagella of the endoderm cells by their vibrations maintain a continuous current of water within the enteron. This helps in the distribution of food particles towards the various endoderm cells which engulf them by their pseudopodial activity. The distribution of the smaller food particles is also brought about by some endoderm cells. Such endodermal cells after engulfing the food particles within their cytoplasm lose contact with the neighbouring cells and wander about in an amoeboid fashion through the enteron to various parts where the food is needed.

The indigestible parts of the food are first thrown into the enteron. Later, by the sudden muscular contractions of the body

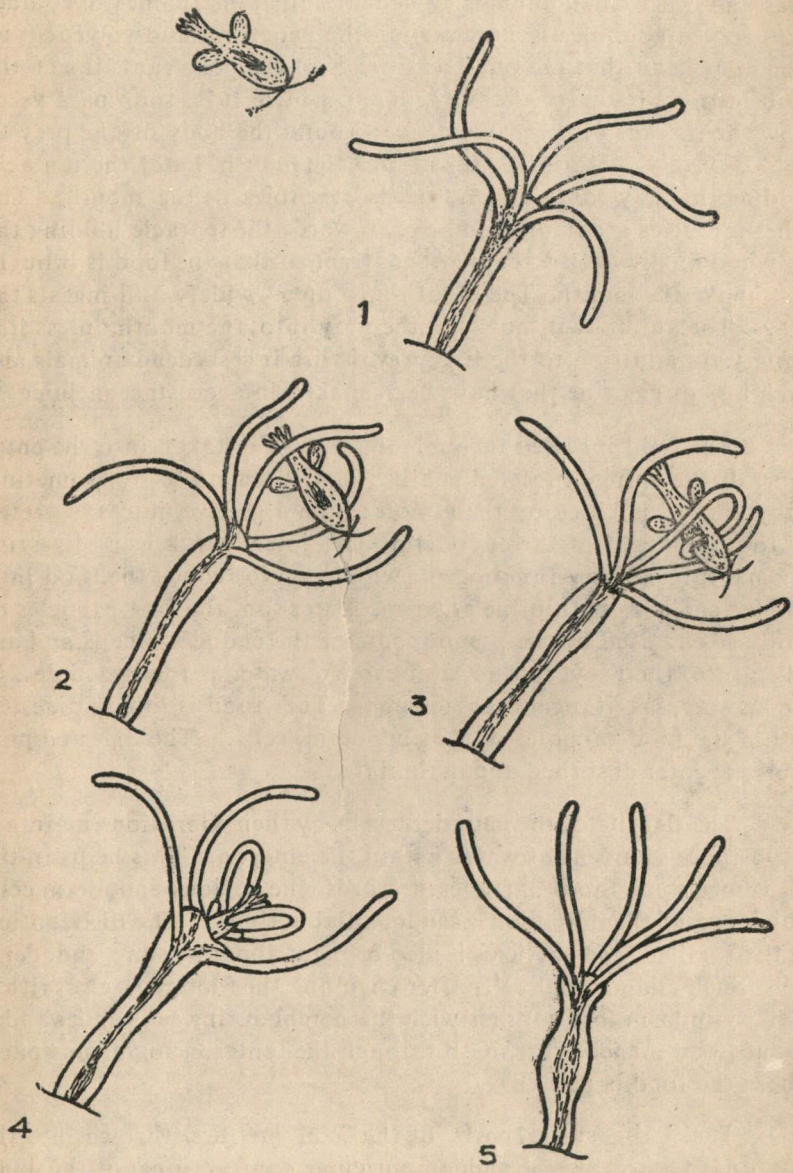


Fig. 2·11 The mechanism of catching the prey in Hydra

these contents are shot out of the enteron through the mouth only. There is no anus. The mouth plays both the roles of ingesting the food particles and egesting the indigestible portions out of the body.

From the above account, it is now evident that the digestion in hydra takes place in two phases.

In the first instance, the digestion starts in the cavity of the enteron where the food is reduced to finer particles by the action of juices. This is just what happens in the higher animals within the lumen of the alimentary canal. This phase of digestion in Hydra is called **intercellular** or **extracellular digestion**

In the next phase, the finer particles are taken into the cytoplasm of the endoderm cells in the form of food vacuoles by the pseudopodial activity. The food is digested completely inside the endoderm cells just as it occurs in amoeba etc. This phase of digestion is referred to as **intracellular digestion**. The products of digestion, by diffusion from the endoderm cells pass to other parts of the body.

Intracellular mode of digestion is probably retained in hydra out of sheer necessity. The contents of the enteron on account of the constant flow of water in it, make the digestive juices secreted, quite dilute. This diluted digestive juice cannot bring about complete digestion and as such by resorting to intracellular digestion, the animal digests its food completely.

Hydra as such is a good example of an animal where two distinct phases of digestion are seen. The extracellular or intercellular digestion in the enteron is comparable with the process of digestion occurring in the alimentary canal of higher animals. Intracellular digestion in the endodermal cells is comparable with the process in a protozoan like amoeba.

Respiration and Excretion : There are no special organs for respiration and nitrogenous excretion in hydra. It can therefore be concluded that the exchange of gases during respiration and the elimination of nitrogenous waste takes place over the whole surface of the body wherever it is in contact with water.

Reproduction : Hydra has two distinct modes of reproduction ; (a) asexual and (b) sexual.

(a) *Asexual Reproduction* : The chief mode of asexual reproduction takes place by a process of **budding**. Budding occurs during summer months when food is abundant. A protuberance at first appears at one point of the body which consists of both ectoderm and endoderm with a continuation of the enteron. The bud so formed soon increases in size and the tentacles develop at its free end. Finally, the aperture of the mouth is formed in the centre of the circlet of tentacles. The bud has assumed all the characters of a young hydra (see figs. 2·2 and 2·5). Now the bud becomes constricted at its base and later detaches itself from the parent individual The young individual so detached migrates upwards towards the surface of water. Sometimes several buds are formed at one time. Each such bud so formed may bud again to form secondary buds before detachment. It this way, a sort of a temporary colony of buds is formed. These buds sooner or later are detached from the parent body into the surrounding water as young hydra.

In the Indian specimens, rarely more than two buds are formed at a time. These buds further do not form secondary buds.

If a hydra is cut into two parts, not below a certain minimal size, and in which ectoderm and endoderm are found, then each cut piece is capable of restoring its lost part and soon assumes the form of a full-fledged individual. This capacity to regenerate the lost part also met with in other animals, is called **regeneration**. The name Hydra is rather given on account of its capacity to regenerate. According to Greek mythology, there was a great sea-serpent Hydra to which Hercules went out to kill. This monster had nine heads and had the capacity to regenerate a new head, if any one of its heads was cut off. The two headed hydra, can like-wise be produced by cutting it from the oral end backwards for some distance. Each bifurcated end later can develop its own head with tentacles. The 'two headed' hydra thus can be obtained by this power of regeneration. These two oral ends are however connected with a single aboral end

(b) *Sexual Reproduction* : Hydra reproduces sexually also. It resorts to sexual reproduction in the autumn. Sexual organs called gonads develop on the body. There are two kinds of gonads—(1) the male gonad i.e., **testis** or **spermary** and (2) the female gonad

or ovary. Both the testis and the ovary may develop on the body of the same individual. Such an individual is called *bisexual or a hermaphrodite.* The symbol ☿ is used for a hermaphrodite animal. In India, hermaphrodite individuals are not reported. Even if hydra is hermaphrodite, it resorts to cross fertilisation only as the testis becomes ripe earlier than the ovary. In some hydras the sexes may be separate. There may thus be male hydra developing testis and female hydra developing ovary. We use the symbol ♂ for the male animal and the symbol ♀ for a female individual.

The gonads develop on the body only temporarily during the breeding season.

The spermary or testis is in the form of a white conical elevation situated on the distal part of the body. Usually one or two testes develop at the same time in a single individual but occasionally there may be as many as twenty spermaries. They are colourless even in green and brown hydra as they are formed exclusively from the ectoderm (See fig. 2·2).

In an immature state, the testis consists of a group of interstitial cells covered by an investment of large flattened ectoderm cells (see fig. 2·5). The multiplication of interstitial cells finally gives rise to the sperm mother cells. These sperm mother cells called **spermatogonia** now undergo reduction division to form a large number of spermatozoa. Each sperm consists of a small ovoid head containing a nucleus and a long vibratile tail. After the formation of sperms, the superficial investing layer of the testis ruptures. Thus, the sperms are liberated which swim freely in water and can fertilize an ovum.

The ovaries are found at the proximal end of the body. These vary in number from one to eight. In a mature state, the ovary is larger than a testis and is hemispherical in shape.

In an immature condition, the ovary like the spermary begins as an aggregation of interstitial cells. Thus, in the earlier stages, the sex of the gonads is indeterminate. In the later development of the ovary, contrary to what happens in testis, one cell begins to grow faster than the rest. It soon assumes amoeboid phase and sends out pseudopodia all round. It ingests the surrounding cells

and grows in size at their expense. This cell in a growing state is called the **oocyte**. Ultimately, this single cell only presists with an investment layer of cells forming a capsule for it. Yolk granules are

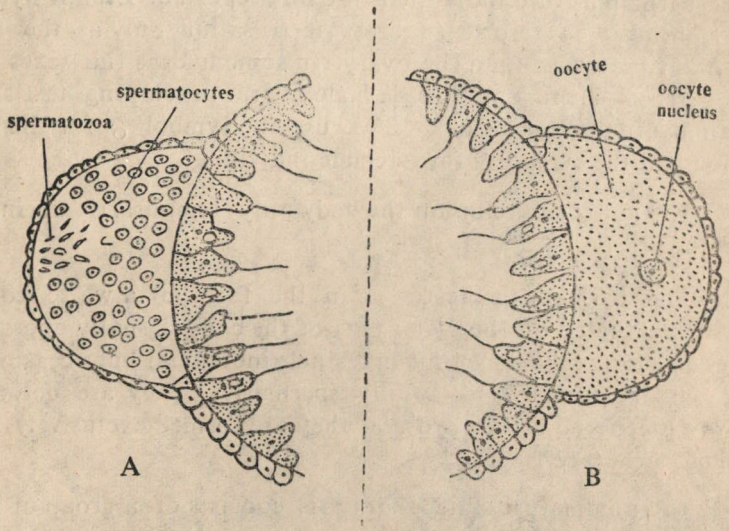


Fig. 2·12 T. S. Body of Hydra—(A) Passing through the testis (B) Passing through the ovary

also deposited in it and in **Chlorohydra viridissima**, it also acquires zoochlorellae. As the ovary becomes ripe, the pseudopodia of the egg cell or oocyte are withdrawn. It assumes a spherical shape and becomes a mature **egg** or **ovum**. Now the investing layer of the ovary ruptures, thereby exposing the ovum so as to allow free access of sperms to it. One of the sperms in the surrounding water conjugates with the ovum and produces the **oosperm** or **zygote**.

The fertilised egg or oosperm soon undergoes cleavage or division as a result of which, a hollow ball of cells—the **blastula** is formed. Its central cavity is the **blastocoel**. It soon becomes **gastrula**. During gastrulation, the cells from the wall of the blastula migrate inwards from all directions. The cavity of the blastocoel becomes much obliterated. In the mass of cells that migrate inward a new cavity, the **enteron** appears. While these changes occur, the outer layer of cells, the ectoderm, secretes a horny envelope or cyst around the developing embryo.

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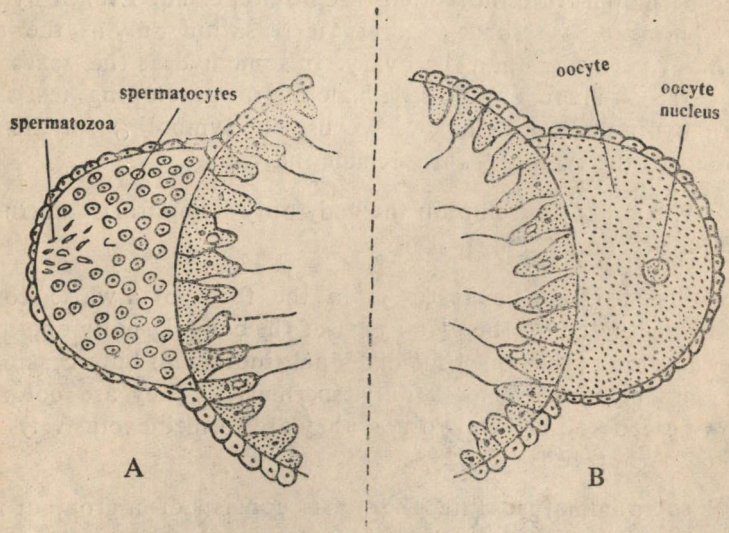


Fig. 2·12 T. S. Body of Hydra—(A) Passing through the testis (B) Passing through the ovary

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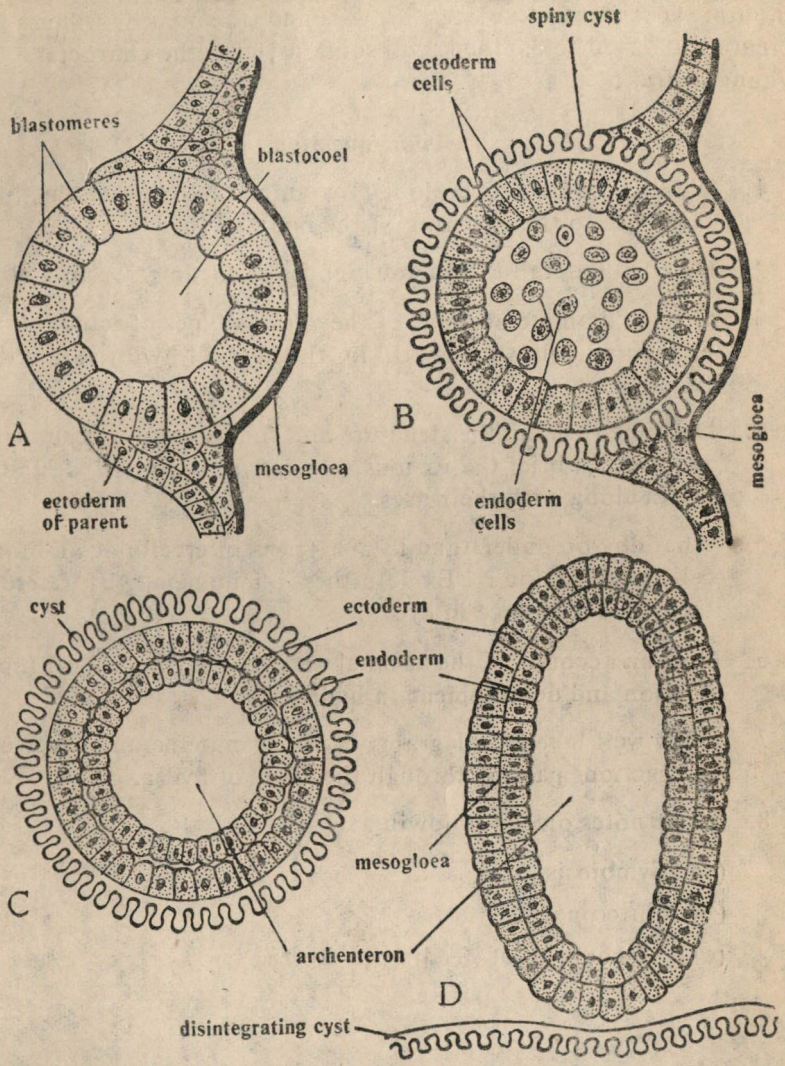


Fig. 2·13 Development of the Oosperm (Zygote)
A. Blastula B. and C. Gastrulae D. Young larva released from the cyst

The embryo now is shed from the ovary and settles at the bottom, where it remains quiscent until next spring. With the approach of warmer weather, a young two-layered embryo comes out of

the cyst. At one place the wall of the embryo perforates to form the mouth. The tentacles later grow round the mouth. Thus, this creature referred to as the larva soon assumes the characters of a young hydra.

Revision questions

1. What is meant by a diploblastic animal ? Explain this with reference to the structure of the body of hydra.
2. Describe in detail the various modes of locomotion in hydra.
3. Give a complete account of the various types of ectoderm and endoderm cells met with in the body of hydra. State their functions.
4. Describe in detail the structure and functions of a nematocyst. Mention in brief the various types of nematocysts found in hydra along with their uses.
5. What do you understand by the terms intercellular and intracellular digestion ? Explain these phenomena with reference to their occurrence in hydra.
6. Give an account of the asexual and sexual modes of reproduction and development in hydra.
7. Draw well labelled diagrams of the transverse and longitudinal sections passing through the body of hydra.
8. Write notes on the following :
   (a) Symbiosis
   (b) Enteron
   (c) Mechanism of feeding in hydra.

CHAPTER III

TRIPLOBLASTICA

[The three layered animals]

In the previous chapter, you have studied in detail the structure of Hydra—an example of a diploblastic animal.

We will now study in the present chapter and also in the following chapters, various other examples of metazoans that have developed further complexities in their structure. The body of these metazoans is composed of three distinct cellular layers, instead of two. Animals built on this three layered plan are included in the group **Triploblastica**. In these animals, in addition to the ectodermal and endodermal layers, there develops a third distinct cellular layer called the **mesoderm** between the ectoderm and the endoderm.

The three layers of cells (germ layers) of these animals are present as such only in the embryo. As the development proceeds the cells soon become specialised and are grouped together to form tissues. These tissues in turn become arranged to form definite organs of the body. Of the three layers of cells the most interesting development occurs in the mesoderm which everywhere separates the ectoderm from the endoderm lining the gut. The mesoderm gives rise to the reproductive and general muscular tissue and also a peculiar sort of loose, cellular tissue called the **mesenchyma** or **parenchyma**. This tissue acts like a packing layer all round the internal organs of the body. The ectoderm and the endoderm retain most of the functions you have studied in Coelentrates. The ectoderm is an outer protective layer of the body, retaining its sensitive nature. It further gives rise to sensory and nervous system. The endoderm lines the gut and performs the function of digestion and absorption.

The three layered animals are further divided into two groups —the **Acoelomata** and the **Coelomata.**

In Acoelomates, the body consists of three layers i.e., ectoderm and endoderm and a loose type of layer in between the above two called the *mesenchyma* or *parenchyma*. There is no body cavity, hence the name Acoelomata.

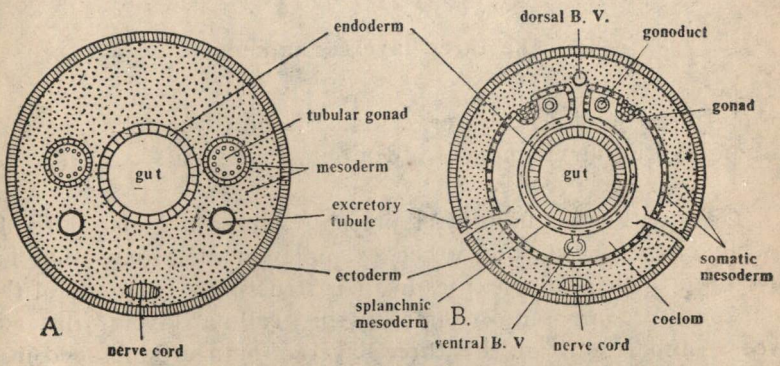


Fig 3·1 Transverse section (Diagrammatic) through
(A) A generalised acoelomates (B) A generalised coelomatie

In the case of coelomates, the middle layer i.e., the mesoderm splits into two layers—a **splanchnic layer** which surrounds the endoderm and a **somatic layer** which lies below the ectoderm. The fluid filled space so formed between the two mesodermal layers is called the **body cavity** or **coelom.** Such animals are called coelomates.

In the first instance we will study the structure of some acoelomate triploblastic animals included in the Phylum platyhelminthes and class Nematoda respectively. This will be followed by the study of the various examples of coelomate triploblastic animals included in the various phyla of the animal kingdom. According to the structure, man is also included in the triploblastic coelomate group.

Platyhelminthes — The flat worms :

The worms included in Pylum platyhelminthes have flat bodies as the name of the phylum suggests (*Platy*, flat; *Helminthes*, worms). They may be leaf-like, ribbon-shaped or tape-like in form. They form a large group of relatively simple acoelomate

tripoblastic animals. There are free living as well as parasitic forms in the group.

We shall here deal in detail, the structure and life history of a parasitic form called *Taenia solium* or tape worm belonging to the class **Cestoda** (Gr. *Cestus*, gridle; *oid*, like).

Taenia solium :

Man is infected with *Taenia solium* by eating the improperly cooked pork. In the body of a pig the developmental stages of *T. solium* occur. As the infection comes from pig it is commonly known as the *pork tape worm.* The word solium according to Leuckart, is derived from a Syrian term 'schusch' meaning a 'chain'. Further in Latin *sol* means the 'sun'. The specific name solium as such may relate to the resemblance of the head of the worm to the figure of sun.

Taenia solium or the tape worm, ribbon or girdle like in shape lives as a parasite in the intestine of man. It lacks the mouth and the alimentary canal. It may attain a length of 3 to 6 metres. At the front end there is a tiny knob-like so called '*head*' or **scolex** by which it remains attached to the wall of the intestine. The rest of the body hangs freely in the lumen of the intestine. The part of the body behind the scolex is called the **strobila**. It consists of a short neck which is a zone of active proliferation. The neck is followed by a region in which the body is divided up into a number of segments called the **proglottides** (singular, proglottis or proglottid). The proglottis can be distinguished into the following types on the basis of the development of reproductive organs.

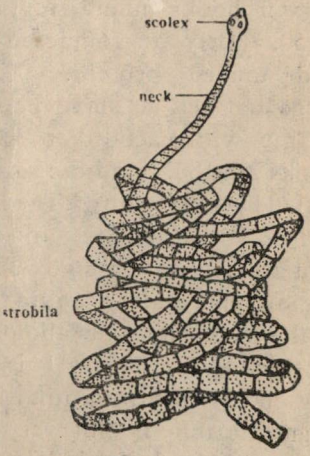


Fig. 3.2 Taenia solium

1. Small *immature proglottides* or segments immediately behind the neck where reproductive organs have not developed.

2. *Mature proglottides* containing a complete hermaphrodite set of genitalia i.e., male and female reproductive organs. Male organs develop before the female organs as such the anterior segments have functional male organs only and those some where near the middle of the body have both male and female organs.
3. The *gravid proglottides* form the hinder part of the strobila where the male organs are degenerated and the whole of the proglottis is practically filled up by the enlarged uterus containing the fertilised eggs.

The details of the morphology of Taenia solium or the tape worm are as follows:

Scolex or head : The scolex is just of the size of a pin's head and measures about 1 mm in diameter. It bears four cup-shaped **suckers** for attachment. The apex of the scolex is produced into a terminal cone or muscular projection called the **rostellum.**

The rostellum is capable of being protruded and retracted to a slight extent. Around the base of the rostellum is found a double row of curved hooks numbering about 25 to 50. They are composed of chitin and tanned protein. There are large as well as small hooks alternating with each other. The large hooks are 180 μ and the small hooks 130 μ in dimensions. The hooks are shaped like daggers or Arabian poniards. As stated earlier, the region immediately behind the scolex is the neck which is about one half as thick as the scolex. It is an active region of proliferation in which segmentation is not very obvious. Immediately behind the neck lie the youngest proglottides and the older ones away from it at the other end. The total number of proglottides in an adult worm is between 800 to 900. The proglottides as mentioned are distinguished

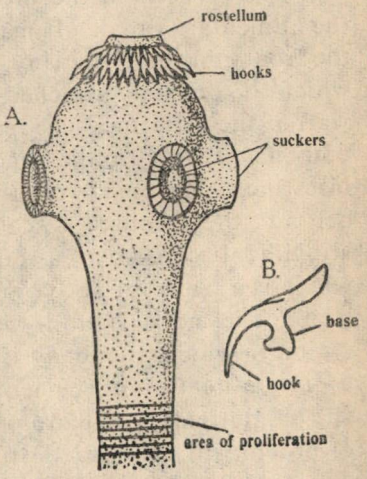


Fig. 3·3 Taenia solium
(A) The scolex; (B) A hook

into *immature, mature* and *gravid* ones. The anterior segments are broader than long, then middle ones are square and the posterior segments are twice as long as they are broad. The two surfaces of the proglottides cannot be distinguished into dorsal and ventral surfaces by the naked eye, but the side where the female reproductive organs are more nearly approximated is the ventral surface and the opposite as the dorsal surface. In the mature segments near the middle of the lateral margins of them and alternating irregularly between the right and the left margins are situated thick prominences called the **genital papillae** containing a common genital pore. The genital pore is the opening of a chamber called the **genital atrium** into which both the male and female reproductive ducts open.

Internal Structure: In order to understand the internal structure of the worm, a cross-section passing through the proglottis from the middle region of the strobila can be studied.

The proglottis is rectangular in outline and is covered by a thick layer of "cuticle". It is in fact a layer of living cytoplasm containing mitochondria and having at its outer surface a brush-like border of projections called the **microvilli**. The cuticle is called the **tegument** which is formed as a superficial extension of certain cells of the mesenchyme. Epidermis loses its distinctness as a distinct layer. Below the cuticle lies a basement membrane followed by a layer of circular muscle fibres. Below these circular muscles lie a much thicker bed of longitudinal muscles.

Just below these longitudinal muscles are embedded the cuticle forming cells in the outer part of the parenchyma (outside a second layer of longitudinal muscle fibres). The tegument is perforated at intervals by fine canals at the bottom of some of which are found either the superficial ends of gland cells or else free nerve endings. Other minute canals perforating the tegument divide into branches and finally open into the parenchyma. These canals along with the numerous vacuoles are helpful in taking substances into the proglottis of the worm. The microvilli greatly increase the absorptive surface. Another layer of muscle fibres running transversely from one side of the proglottis to the other is found below the inner longitudinal muscles. There also extend across the proglottis a

number of vertical muscle fibres. This central part of the proglottis is practically occupied by the reproductive organs. Towards the

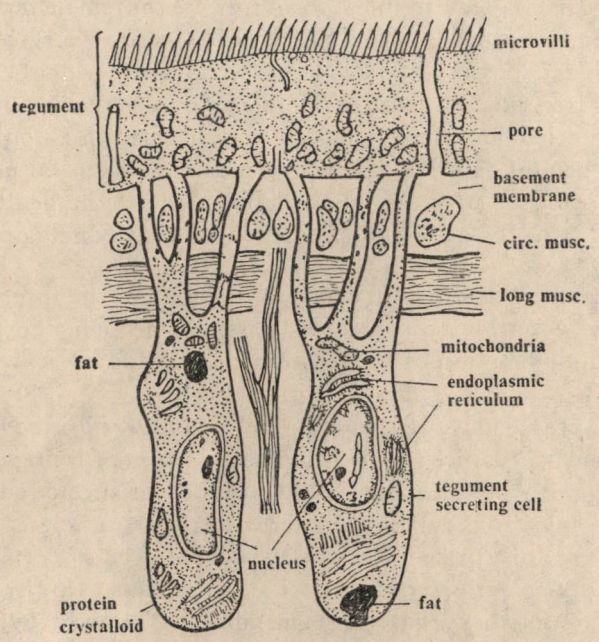


Fig. 3.4 Vertical section of the body wall of a tape worm. (From an electron micrograph)

lateral margins of the proglottis are to be seen the cut ends of the longitudinal nerve and just median to this, the longitudinal excretory canals. There is also sufficient storage of glycogen in the proglottis.

Nervous System : There are found in the scolex two not well defined nerve ganglia in the form of transverse ganglionated bands. From this are given off a number of slender nerves to each of the suckers and also arise two stout nerves which pass backward one on each side near the lateral margins of the proglottides and along the entire length of the strobila.

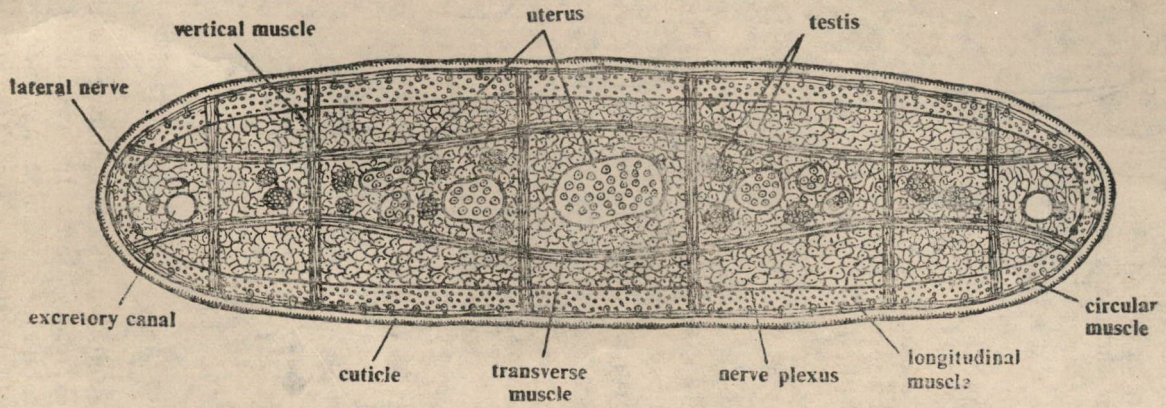


Fig. 3·5 Taenia solium—Transverse section passing through a mature proglottis (Diagrammatic)

The Excretory System : This system consists of much branched tubules. There are to be seen four main longitudinal excretory canals. In the more anterior part of the strobila, there run at the lateral margin of the proglottides two longitudinal canals, an upper and a lower one on each side of the proglottides. In the region of the scolex, the two pairs of longitudinal vessels are connected with a ring vessel. In the more posterior region of the strobila, one of these is lost on each side and only a single longtiudinal excretory duct persists at each side of the proglottis.

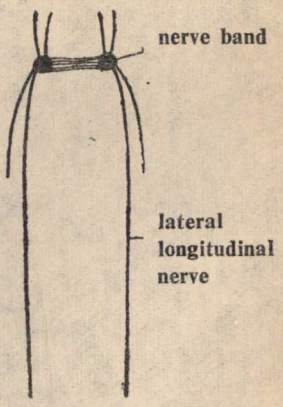


Fig. 3.6 Tape worm Nervous system

Near the posterior margin of each proglottis, the longitudinal vessels are connected by a straight transverse vessel. In the posterior-most proglottis of the strobila, the longitudinal trunks open into

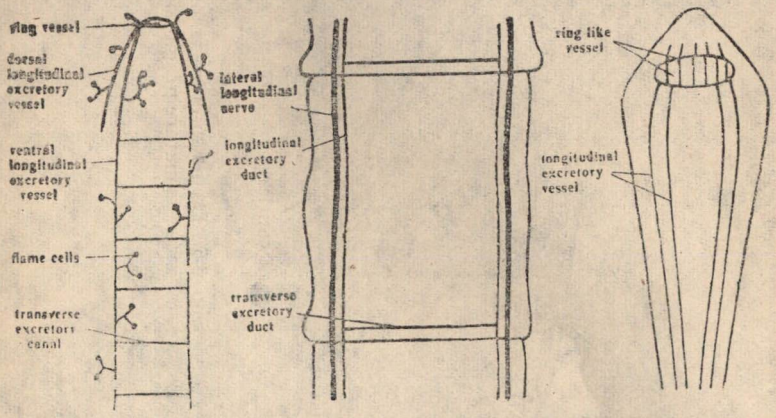


Fig. 3.7 Tape worm—excretory system

a pulsatile **caudal vesicle** which communicates with the exterior through a common excretory pore. In case the last proglottis is detached from the strobila (as it often occurs), then the longitudinal vessels open separately to the exterior through their respective openings.

The main trunks of the excretory system always divide into a number of canalicules and capillaries which ultimately terminate in special types of cells called the *flame cells.*

The flame cells lie fairly superficially in each proglottis. They drain their contents into the system of excretory tubules described above. The excretory products are ultimately discarded outside the body either through the common excretory pore or through the openings of the longitudinal excretory vessels as the case may be.

The structure of a flame cell is as follows. Each flame cell consists of a nucleus found displaced to one side of the cell. The cytoplasm of this cell contains a large central cavity called the *cell lumen,* which is continuous via the intracellular duct with the finer branches of the excretory tubules. Within the central cavity of the flame cell projects a bunch of flagella. The flickering movements of these flagella look like a *flame,* hence the name of the cell.

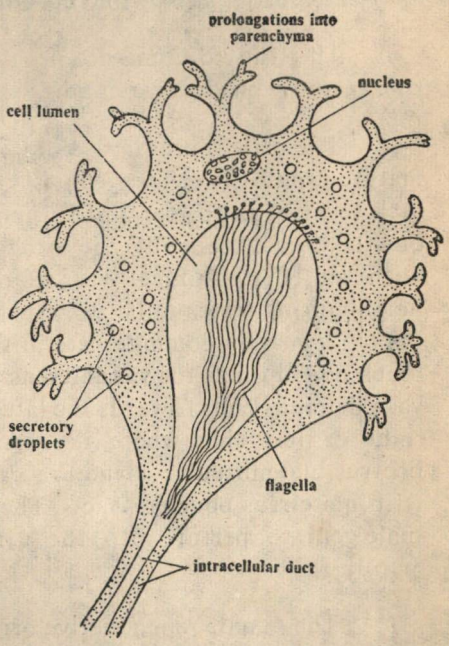


Fig. 3·8 The structure of a flame cell

It is likely that the soluble excretory products diffuse through from the surrounding tissues into the central cavity or lumen of the flame cell. The vibrations of the flagella shift the fluid received by diffusion into the excretory tubules. The role of the flame cell is also osmoregulatory. The flickering movements of the flagellae set up sufficient suction pressure and draw excess fluid accumulated in the surrounding parenchyma.

The fluid so drawn may thus be discharged to the exterior through the excretory pores.

The digestive system is totally absent in tape worms. The scolex is exclusively an organ of attachment. The respiratory and circulatory systems too are likewise absent.

Reproductive organs: In all the mature segments of Taenia solium, a complete set of male and female reproductive organs are found. In an adult worm, thus, each segment with reference to a complete set of male and female reproductive organs may be looked upon as a '*single individual.*'

The reproductive organs first appear at about the 200th proglottis. At first, the male reproductive system is differentiated and later the female part of the reproductive system is also differentiated.

The study of a mature proglottis can show the detailed structure of the reproductive organs.

The male reproductive organs lie at the dorsal surface of each mature proglottis. They consist of a number of testes 150 to 200 in each segment in the form of follicles. They are distributed throughout the dorsal plane of the proglottis. Each testis communicates with an efferent duct (vas efferens). The efferent ducts of the neighbouring testes unite together to form larger ducts and these ducts ultimately communicate in the centre of the proglottis with a much coiled duct, the **vas deferens** or the main duct of the testes. The vasa deferens runs towards the lateral margin of the proglottis on the right or left side where its terminal end communicates with a protrusible muscular structure called the *cirrus* or *penis* enclosed within a **cirrus pouch** or **sac**. The cirrus pouch opens through the male genital aperture into the genital atrium on a swollen genital papilla.

The female reproductive organs lie on the ventral surface of each mature proglottis. They consist of a bi-lobed ovary with approximately equal left and right lobes, the two lobes being joined together by a bridge. The ovary lies towards the posterior border of the segment. The bridge of the ovary leads into a minute oviduct.

The female genital pore situated in the genital atrium, leads into a narrow tube called the *vagina* which runs inwards and backwards towards the middle line of the proglottis and joins a dilated

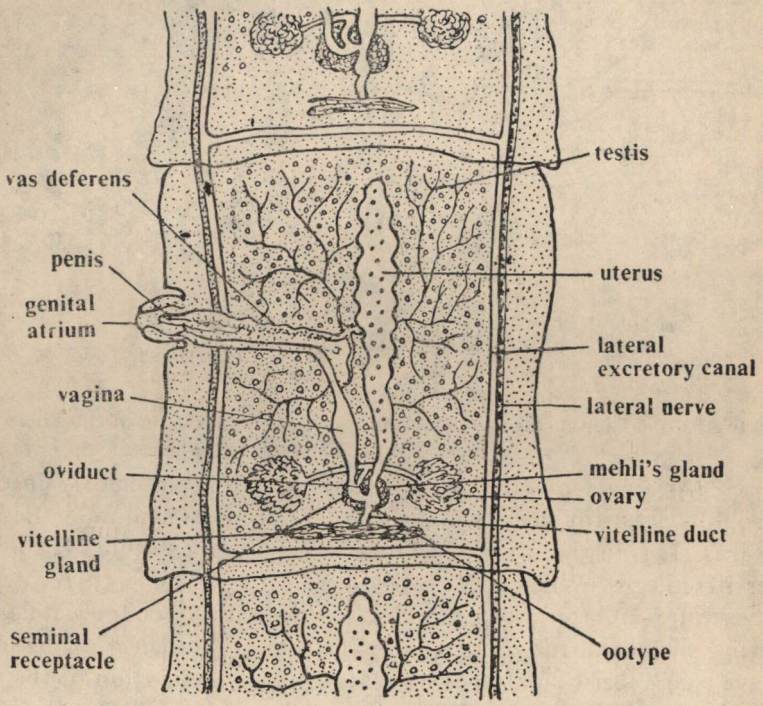


Fig. 3·9 Taenia solium—A mature proglottis showing reproductive organs

tube called the **seminal receptacle** or **receptaculum seminis** for the storage of sperms. From this arises a constricted tubule called the **spermatic duct**, which receives at its terminal end, the oviduct. These two together, later continue into a common tubular chamber called the **ootype** (See Fig. 3·10). Ootype is a chamber where the fertilization of the eggs takes place and all the components of the egg are collected. The ootype is situated posteriorly in the middle line of each segment.

Surrounding the ootype, and situated posterior to the ovary is a very small organ called the **Mehli's gland** (so called shell gland).

It is composed of many unicellular glands which open separately into the ootype. There lies behind the ovary at the posterior margin of the segment, a single diffused mass called the **vitelline gland**. It opens through a short common **vitelline duct** into the ootype.

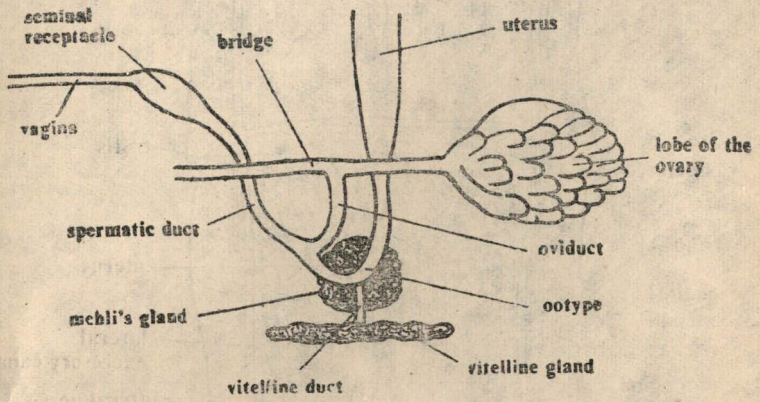


Fig 3·10 Taenia solium—Diagrammatic representation of the ducts of the female reproductive organs

Arising from the ootype and extending anteriorly into the proglottis is found a simple cylindrical diverticulum called the **uterus**. It is in the form of a blind sac in Taenia solium. It contains fertilized eggs. When it is totally filled up with the fertilized eggs, it gives off 5–10 lateral branches and consequently occupies almost the entire surface of the proglottis. The lateral branches of the uterus have characteristic patterns. Because of the occupation of the space by the lateral branches of the uterus, the male and female reproductive organs undergo atrophy. The proglottis has now turned into a gravid one (See Fig. 3·11). These gravid segments are finally detached from the strobila and are expelled in the faeces.

Fertilization: The eggs may be fertilized by sperms from the same proglottis. Cross fertilization between the sperms of one segment and the ova of the other segments of the same worm or occasionally of the other worms may also occur.

The sperms discharged from the male genital opening of the cirrus, pass into the vagina through the female genital aperture. The sperms passed into the vagina may be stored up in the vesicula seminis. These sperms later pass through the spermatic duct into the ootype and fertilize the ovum received in it through the oviduct.

The egg after fertilization is surrounded by a protective covering in the ootype. The egg also receives yolk material from the vitelline gland. The encapsulated fertilized eggs are ultimately deposited in the uterus.

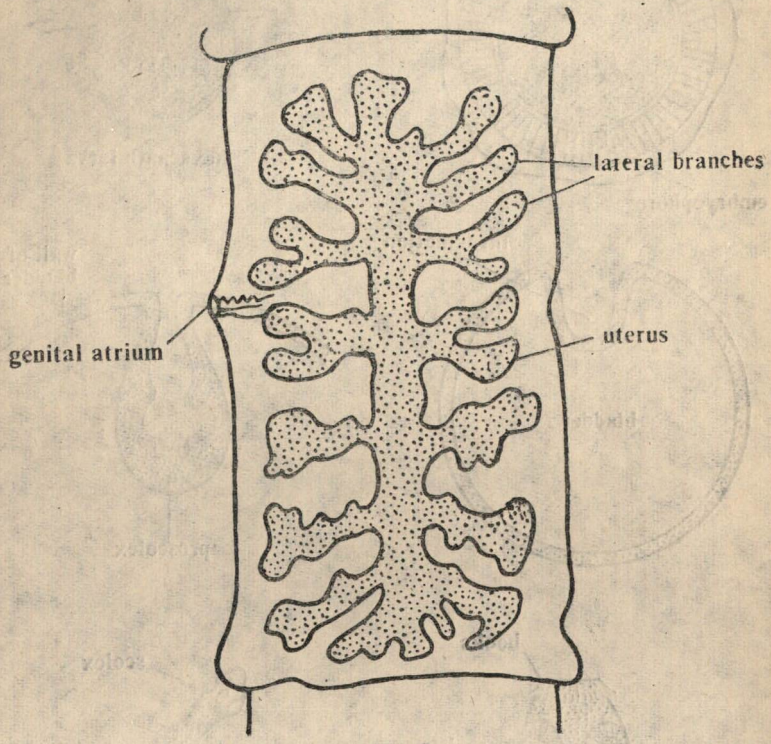


Fig 3.11 Taenia solium—A gravid proglottis from the near end of the strobila

Life History: As the eggs reach the uterus, their development commences straight away. They reach to the exterior by the detachments of the gravid segments. 5 to 6 segments at a time are usually detached and evacuated from the body with the faeces. These segments may remain alive for sometime with limited wriggling movements. Eventually they die and disintegrate. The eggs are thus liberated. The eggs are spherical and brown in colour. They measure 31 to 43 microns in diameter. They are enclosed within a thin shell which is hardly seen and also a thick walled radially striated envelope called the **embryophore.**

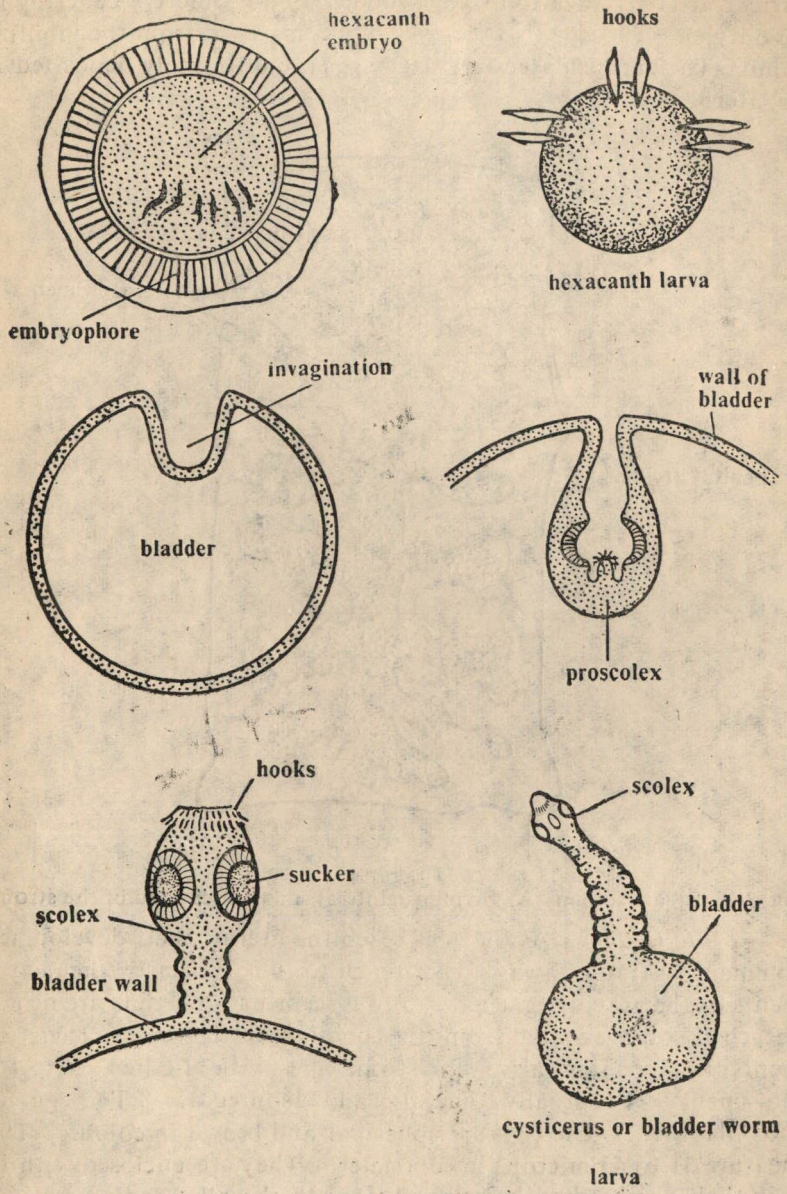


Fig. 3·12 Taenia solium — Stages in life cycle

Inside the embryophore lies a **hexacanth embryo** 14 to 20 μ in diameter with six hooks, hence the name. The further development of the hexacanth embryo takes place only when it is swallowed by a pig which is the secondary host or intermediate host of Taenia solium. The eggs in this stage of embryonic development are viable for many weeks outside the body of man and are infective both to man and pig.

If a pig happens to swallow the eggs, then the egg shell and the embryophore are digested in the stomach of the pig by the action of its gastric juice. The hexacanth embryo is thus released. It possesses six hooks and is spherical in shape. With the aid of the hooks it penetrates through the gut wall of the pig and enters the portal circulation. They, while travelling via the portal vein reach the liver, the right side of the heart, lungs, the left side of the heart and then the systematic circulation. The hexacanth embryos ultimately are filtered out from the systemic circulation into the muscular tissue of the pig. Here they ultimately settle down and undergo further development. These embryos usually select the muscles of the tongue, neck, shoulder, ham (thigh) and also the cardiac muscles. Once within the muscles, the embryo is encysted. It loses its hooks. The cells in the centre are later liquefied and within eight days after infection, it grows to form a fluid-filled bladder. At one point on the surface of the bladder there appears a depression or invagination which soon becomes deep. At the terminal end of this invagination hooks and suckers develop, characteristic of the head or scolex of the adult. This embryonic stage of development is referred to as the **proscolex**. Once the proscolex is formed, the invagination is everted i.e., it turns inside out. It is now referred to as the **cysticercus cellulosae** or **bladder worm.** The cyst of this larva measures 8 to 10 mm in length and 5 mm in width and is ellipsoidal in shape. The muscles of the pig infected with the cysticerci presents a spotted appearance and is called a *measly pork.*

If a man eats the improperly cooked infected pork, the bladder of the larva is digested by the action of gastric juice in the stomach and the young scolex attaches itself to the wall of the intestine. It develops an area of proliferation and begins to bud off a chain of proglottides so as to assume the length of an adult worm.

The worm attains sexual maturity in the course of 2 to 3 months and starts producing eggs which after fertilization may be passed with the faeces along with the gravid proglottides. Usually one worm at a time only harbours the intestine of man. The parasite usually has a long span of life and may survive for a period of 25 years or more.

Pathogenecity :

Adult worm : The symptoms of the presence of the adult worm are trifling. In susceptible persons, it may give rise to vague abdominal discomfort, indigestion, intestinal disorder, anorexia*, vomiting and anaemia. The disease is referred to as *Taeniasis* or *intestinal cestodiasis.*

Larval form (Cysticercus cellulosae) : Man also gets infected from the larvae, by drinking contaminated water or by eating uncooked vegetables infected with the eggs. The cysticerci usually are distributed in the subcutaneous tissues, muscles, occasionally in the brain and very rarely in the eyes. In the brain, they are usually located in the fourth ventricle. The larvae, however, in the course of 3 to 6 years become calcified and obsolete. When the larvae are located in the brain, symptoms like changes in personality, disorder of behaviour and occasionally fits (epileptic type) are noted. The disease caused by the larvae is called *Cysticercosis* or *Somatic cestodiasis.*

Treatment : The following drugs are found to be efficacious in the expulsion of adult worms.

(1) Exact filicis liquidium or Oleoresin of aspidium (filix mas)
(2) Carbon tetrachloride
(3) Tetrachlorethylene
(4) Hexylresorcinol
(5) Atebrin and
(6) Acranil

The choice, administration and dosage of the above drugs should be under strict medical advice.

No specific drugs are known for cysticercosis.

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*Loss of appetite for food

Prevention: Adequate inspection measures to be ensured, to condemn all *measly pork* for eating. Proper disposal of the human faeces is essential to prevent pigs from infection. Eating of raw vegetables and under-cooked pork should be strictly avoided. Care is to be undertaken regarding personal hygiene and there should be a good provision for the treatment of all cases infected with adult worms.

Revision questions

1. Define the term 'Tripoblastic animal'. Mention in brief the main differences in the structure of an acoelomate and a coelomate triploblastic animal with the help of suitable diagrams.

2. Describe in detail the internal structure of a tape worm as revealed by the transverse section passing through its mature segment.

3. Give a detailed account of the reproductive organs of Taenia solium (The pork tape worm).

4. Describe in detail the excretory system of a tape worm and also mention in brief the role and structure of 'flame cells.'

5. Mention in brief the various parasitic adaptations met with in a tape worm.

6. Give a detailed account of the life history of *Taenia solium.*

7. Write notes on the following :

   (a) Flame cells
   (b) Hexacanth embryo
   (c) Proscolex
   (d) Cysticercus cellulosae (Bladder worm)
   (e) Ootype
   (f) Vitelline glands
   (g) Gravid proglottis
   (h) Mehli's gland.

8. What are the various symptoms observed in man due to the infection of the adult and larval forms of *Taenia solium* ? Mention in brief the curative and preventive measures against *Taenia solium* infection.

CHAPTER IV

NEMATODA—ROUND WORMS

The parasitic worms included in the class Nematoda (Gr. *nema*, thread) are thread-like worms commonly known as the *round worms*. The body of a nematode is long, cylindrical and circular in cross-section. They live as parasites in man and also other animals. They also inhabit fresh water or damp soil and are called the *soil nematodes*. Some live as parasites in the roots and stems of plants like tomato, carrot, tobacco, etc. Nematodes living as parasites in plants are referred to as *plant nematodes*. They cause much damage to the crops. A detailed structure of *Ascaris lumbricoides*, the common round worm, inhabiting the intestine of man, specially of children is given below.

Ascaris lumbricoides :

The adult Ascaris lumbricoides (Gr. *askaris*, pin worm) inhabits the small intestine of man. It normally occurs in the upper part of the small intestine. But as the worms wander up and down the intestinal tract, they may even be found in any accessible passage opening into the alimentary tract. In addition to man, the parasite also inhabits the intestine of pigs, larger apes, sheep and cattle. The worm in its size and shape resembles the ordinary earth-worm hence its specific name *A. lumbricoides* (L. *Lambricus*, earthworm, and Gr. *eidos*, resemblance). The Greeks and the Romans designated it as *Lumbricoides teres*.

Distribution : **Ascaris lumbricoides** is cosmopolitan and specially prevalent in the tropics such as China, India and the Pacific Islands.

Morphology : The shape of the worm is cylindrical and round, tapering at the anterior and posterior extremities. The sexes are separate. The body is encased in a tough but smooth semi-transparent cuticle. The anterior end is however thinner than the posterior. There are four longitudinal bands extending along the length of the

body. Two of these run along the dorsal and ventral surfaces of the body and are referred to as **dorsal** and **ventral lines** or **chords.** The remaining two run laterally and are called the **lateral lines** or **chords.** These chords indicate the internal thickenings of the epidermis. There are also found fine transverse striations all over the surface of the body. The colour of the worm when fresh from the intestine, is light brown or pink but it changes gradually to white.

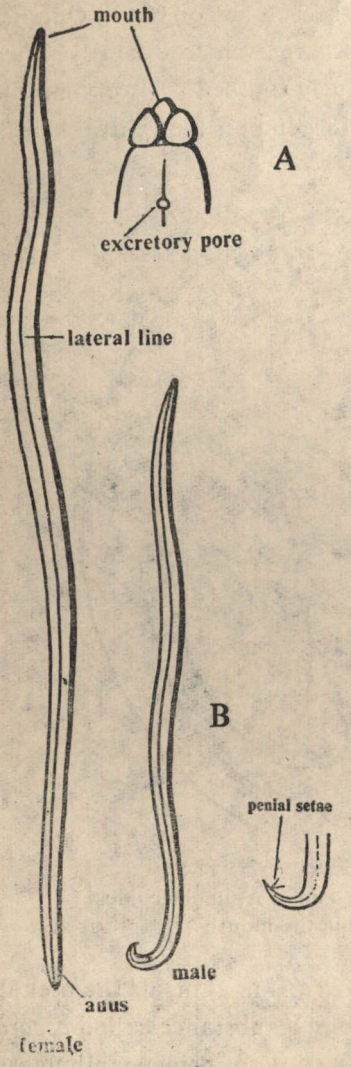


Fig. 4·1 Female and male Ascaris lumbricoides side views,
(A) Anterior end
(B) Posterior end of male worm

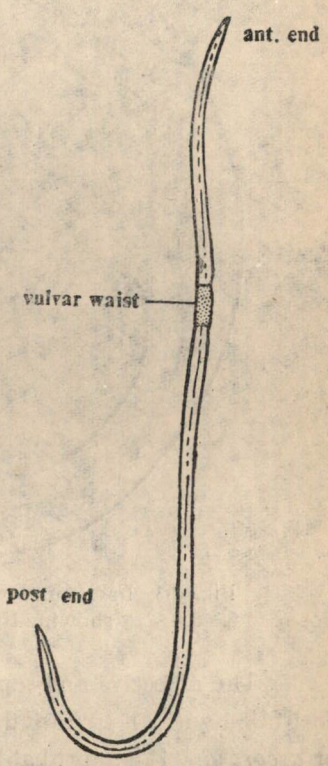


Fig. 4·2 Female Ascaris with a vulvar waist

In Ascaris, the mouth is situated at the anterior end. It is terminal in position and marked off by a sharp constriction from the rest of the body. It is surrounded by three lobes or lips. One lies medio-dorsally and the other two are situated ventro-laterally. They are semi-circular in shape and are finely toothed. A very minute aperture of about 2 mm from the anterior end on the ventral side is the **excretory pore.**

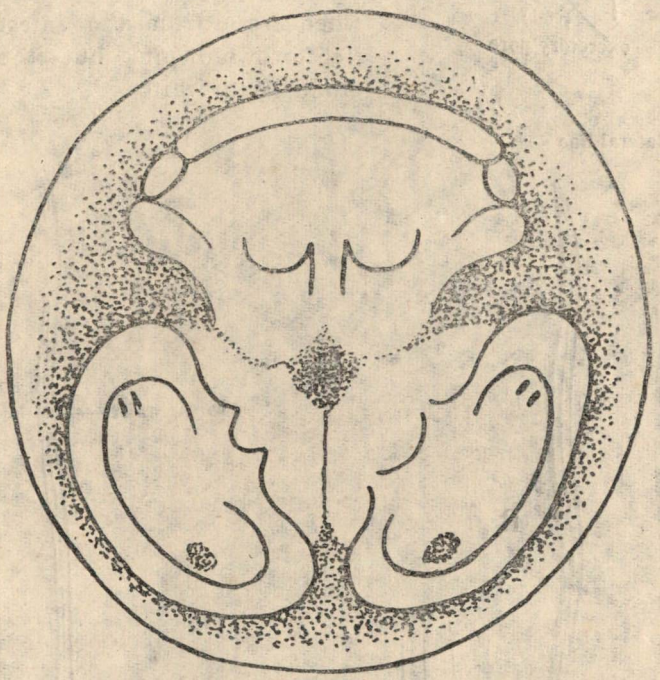


Fig. 4·3 Face on view of anterior end of A. lumbricoides, showing lips surrounding the mouth

The digestive and reproductive organs float inside the pseudocoel filled with an irritant fluid containing a substance called *ascaron* or *ascarase.* It is probably of the nature of primary albumoses (Proteose). Infected individuals and laboratory workers dissecting the worms exhibit allergic manifestations which are due to this **ascaron.**

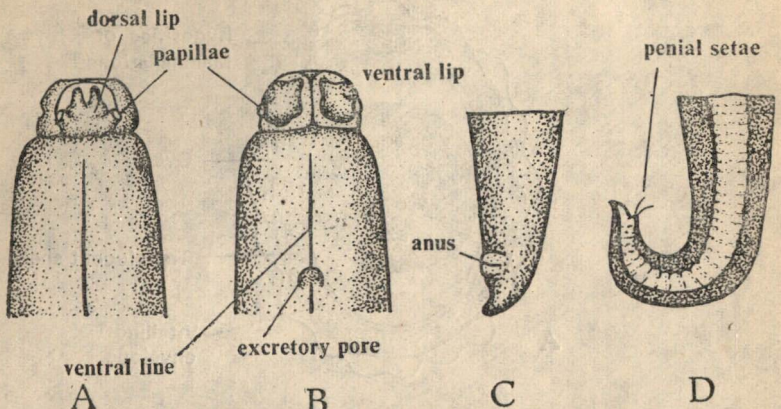


Fig 4.4 Anterior and posterior ends of Ascaris lumbricoides
(A) Ant end dorsal view, (B) Ant. end ventral view,
(C) Post. end female worm, (D) Posterior end male worm

The general characteristics of the male and the female worms are mentioned below.

Male : The male worm measures about 15 to 25 cm. in length with a maximum diameter of 3 to 4 mm. The posterior end is curved ventrally in the form of a hook with a conical tip. The genital pore opens into the cloaca which leads to the exterior a short distance away from the conical tip of the tail. Two curved sclerotized-copulatory spicules, the **penial setae** protrude from the cloaca. The anus opens with the ejaculatory duct (a part of the reproductive system) into the cloaca.

Female : The female worm is longer and stouter than the male. It measures about 25 to 40 cm. in length with a maximum diameter of 5 mm. The posterior extremity is conical and straight. The anus is sub-terminal and opens directly on the ventral aspect in the form of a transverse slit. The female genital aperture **vulva** is situated on the mid-ventral surface about one third the length of the body from the anterior end. This region of the body in female is narrower and is called the *vulvar waist*. The egg-laying capacity of the female is enormous and liberates about 200,000 eggs daily.

Eggs : The fertilized eggs liberated by a female pass out of the human host with the faeces. The characteristics of the fertilized eggs are given below.

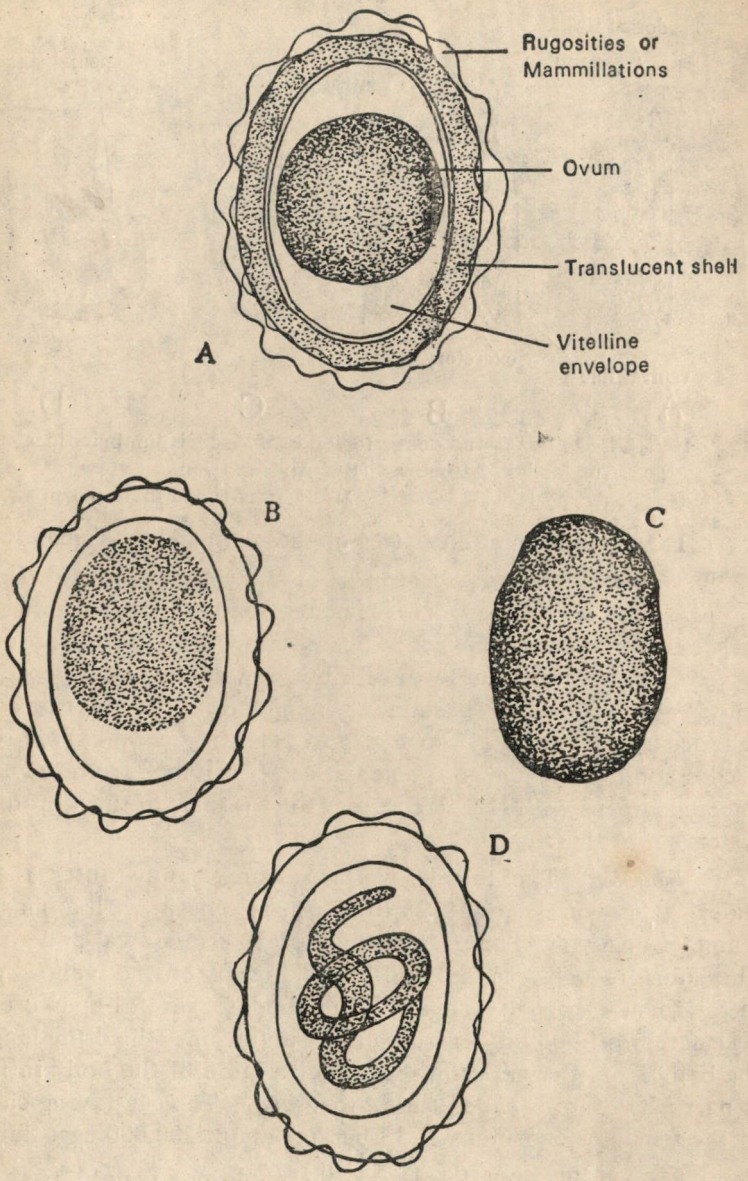


Fig. 4·5 Ascaris lumbricoides (A) Fertilized egg showing important anatomical details, (B) Fertilized egg, (C) Unfertilized egg (D) Egg within which the larva has developed

The fertilized eggs are round or oval in shape. They are 60 to 75 μ in length by 40 to 50 μ in breadth. They are always bile stained and brownish (golden brown) in colour. They are covered by a thick smooth translucent shell with an outer albuminous coat. The surface of the albuminous coat is thrown into *rugosities* or *mammilations*. This albuminous coat is sometimes lost. The fertilized eggs contain a very large conspicuous, unsegmented ovum (the nucleus is hidden by a larger amount of coarse yolk granules). The eggs float in saturated solution of common salt. Unfertilized eggs are also common is human faeces. They are narrower, longer (80 μ in length by 55 μ in breadth) and more elliptical. They have a thinner shell with an irregular coating of albumin. These eggs contain a small atrophied ovum with a mass of disorganised, highly refractile granules of various sizes. They do not float in salt solution, and are the heaviest of all the helminthic eggs.

Both fertilized and unfertilized eggs may be found in a sample of stool. If a stool sample shows only the unfertilized eggs, it signifies that the host is harbouring the female *Ascaris*.

Life Cycle :

The worm passes its life cycle in one host and no intermediate host is required. Man is the only known definitive host of *Ascaris lumbricoides*.

The various stages in the life cycle are as follows :

Stage 1. *Eggs in Faeces* :

The fertilized eggs containing the unsegmented ovum passed with the faeces are not infective to man when freshly passed.

Stage 2. *Development in Soil* :

A Rhabditiform larva is developed from the unsegmented ovum, within the egg shell in 10—40 days, depending on the atmospheric temperature and humidity. The rhabditiform larva is characterised by a short oesophagus with a dilated bulb posteriorly. The development of the larva takes place in the soil i.e., outside the human host. The ripe egg containing the coiled-up embryo is infective to man. Before hatching, the larva undergoes a *moulting* (1 st moulting). Its further development depends on its entry into the human body.

Stage 3 *Infection by Ingestion* :

Man may ingest with food, drink or raw vegetables, the embryonated eggs. These eggs pass down to the duodenum where the digestive juices weaken the egg shell and stimulate the enclosed larvae into activity. By the splitting of the egg shell, the rhabditiform larvae measuring 0·25 mm. in length by 14 μ in breadth are liberated in the upper part of the small intestine.

Stage 4. *Migration of the Larvae* :

The larvae liberated in the small intestine do not directly develop into mature worms. The newly hatched larvae first commence their characteristic '*tour*' or '*migration*'. They burrow their way through the mucous membrane of the small intestine and are carried by the portal circulation to the liver. In the liver, they live for a period of 3 to 4 days. Finally they pass out of the liver and via the right chambers of heart enter the pulmonary circulation. While in the lungs, the larvae grow much bigger and increase in length from 0·2 mm. to 2 mm. They moult twice (i.e., 2nd and 3rd moultings in earlier sequence), first on the fifth or sixth day and the second, after the tenth day. The larvae enter the lung alveoli by breaking through the walls of the lung capillaries. The time taken for such migration is on an average 10 to 15 days.

Stage 5. *Re-entry into the Stomach and the Small Intestine* :

From the alveoli of the lungs, the larvae crawl up the bronchi and trachea. Aided by the current caused by the ciliated epithelium of the respiratory tract, the larvae are propelled into the larynx and pharynx and are thus once more swallowed. The larvae now pass down the oesophagus to the stomach and localise in the upper part of the small intestine, which is their normal abode. Another moulting (4th moulting in sequence) occurs between the twenty-fifth and the twenty-ninth day of infection.

Stage 6 *Sexual Maturity and Liberation of Eggs* :

The larvae on reaching their normal abode (i.e., the upper part of the small intestine) grow into adult worms and become sexually mature in about 6 to 10 week's time. The gravid females begin to discharge eggs in the stool of the host within about two months from the time of infection.

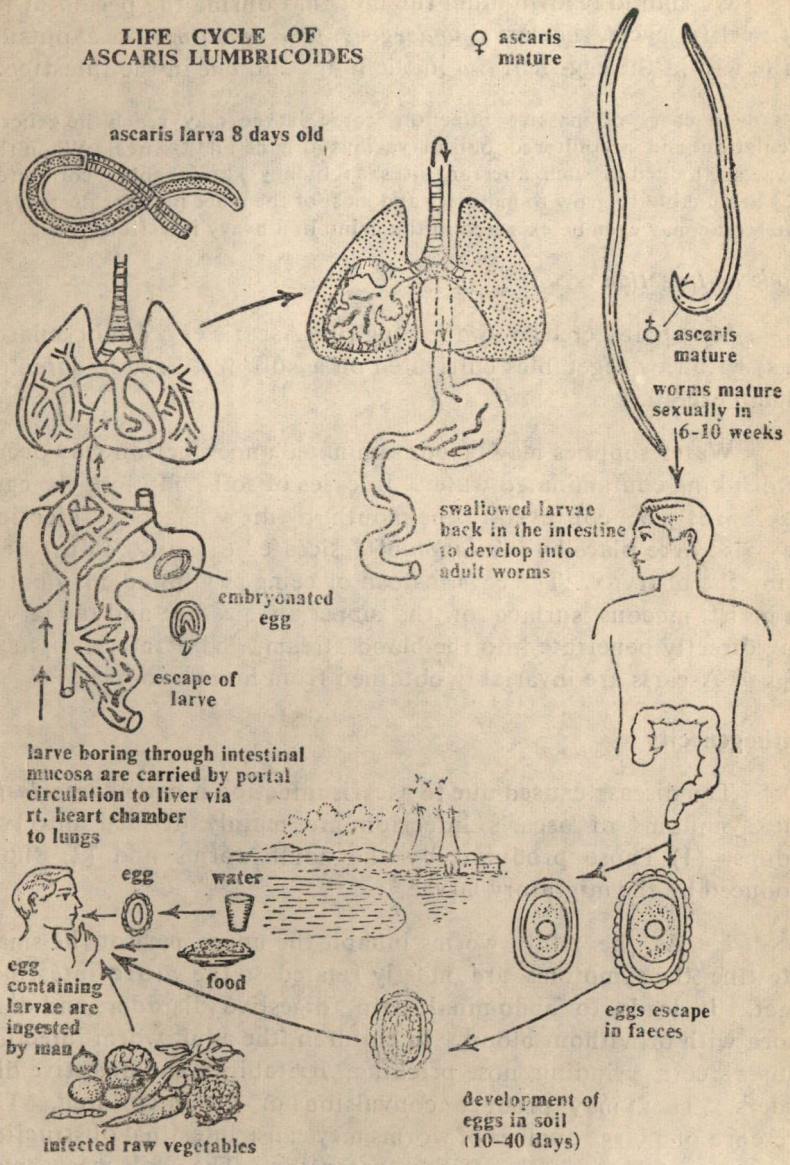


Fig. 4·6 Life history of Ascaris lumbricoides

We should bear in mind the fact that during the period of its entire life cycle the larva *undergoes four moultings—one* outside while within the egg-shell *two* in the lungs and *one* in the intestine.

In cases of massive infection, some larvae may reach the general circulation and are filtered out in various organs and tissues. When the larvae are lodged in such aberrant sites as kidneys, brain, spinal cord, etc., they are unable to grow to maturity and most of them are perhaps destroyed. The larvae may even be excreted in the urine in a heavy infection.

Mode of Infection :

Man is infected by swallowing ripe Ascaris eggs (embryonated eggs) with raw vegetables cultivated on a soil fertilized by infected human excreta.

Water supplies may be contaminated and infection may occur by drinking contaminated water. In cases of soil pollution, the eggs may directly be conveyed to the mouth by dirty fingers. Infection may also take place by *inhalation* of desiccated eggs in the dust reaching the pharynx. The eggs instead of being swallowed, may hatch on moist mucous surface of the upper air passage and the larvae may directly penetrate into the blood stream. The infective stage eggs of Ascaris are invariably obtained from human sources.

Pathogenecity :

The disease caused due to ascaris infection is called *ascariasis*. The symptoms of ascaris infection are mainly divided into two groups—(1) Those produced by the adult worms and (2) those produced by the migratory larvae.

1. As the adult worms inhabit the upper part of the small intestine, the symptoms are mostly related to the gastro-intestinal tract. It leads to abdominal pain, digestive disorders and diarrhoea with or without blood. In children, the adult worm infection causes teeth grinding, nose pricking, irritability and digestive disorders. They may produce convulsions or fits in children. The presence of a large number of worms may cause intestinal obstruction or even in severe infection—intussusception. The adult worms may perforate the intestinal wall, if ulcers are already found in it. The wandering worms may also enter the appendix and give rise to the

symptoms of *appendicitis*. They may also enter the biliary passages and give rise to obstructive jaundice. In the liver they may form abscesses. The migratory worms may enter the stomach and may be vomited out. From the stomach, they pass into the oesophagus and may come out through the mouth or nose. The worms may give rise to toxic symptoms such as typhoid-like fever. The toxicity is probably due to a diffusible proteose of the nature of primary albumoses (ascaron or ascarase) emanated from the worm. It may give rise to anaphylactic action. The presence of worms may produce many allergic symptoms like urticaria*, oedema of face, conjunctivitis and irritation in the upper part of the respiratory passage.

2. In heavy infections, when the larvae traverse the substance of the lung, typical symptoms of '*ascaris pneumonia*' (Loeffler's syndrome) occur. These include, fever, cough and dyspnoea**. Since the diameter of the larvae compared with the diameter of the lung capillaries is considerably large, it results in the rupture of capillaries i.e., haemorrhages. The sputum which is often blood tinged may contain ascaris larvae.

The larvae of ascaris migrating in the general circulation may bring about varied complications. In the brain, they may block cerebral arterioles and may enter the brain substance and form lesions. In the eyes, the larvae may lodge in the smaller branches of the ophthalmic artery and may cause haemorrhages. Disturbances have also been recorded due to their presence in the spinal cord, heart and the kidneys. The larvae have also been reported to pass through placental filter of the pregnant mother and reach the foetus.

The intestinal ascariasis is amenable to treatment. The entrance of parasites in the biliary passages or penetration through intestinal ulcers, appendix, etc., may produce grave symptoms. This often requires surgical intervention.

Treatment: Santonin was regarded as a classical remedy for ascaris infection. Oil of chenopodium and hexylresorcinal are being used as effective drugs against *ascariasis*. A drug Hetrazan is administered orally and is reported to be a good anthelmintic in the removal of worms.

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* An allergic skin eruption.

** Difficulty in or laboured breathing.

Amongst the indigenous anthelmintics, combinations of Santonin, Butea (the seeds of Butea frondosa) and Embella (the dried fruits of Embelia ribes) are also used in the treatment of ascariasis. This has reported to give a cure rate of 64%. The drugs however are to be administered under strict medical advice.

Prevention: The following strict hygienic routine is most essential to escape from infection. Eating of raw vegetables is to be avoided. There should be a good provision for the proper disposal of human faeces. Proper treatment of infected individuals may considerably reduce the source of infection.

Revision questions

1. Describe the external characters of *Ascaris lumbricoides* and mention in brief the main differences in the sexes of the worms.
2. Describe in detail the life history of *Ascaris lumbricoides*.
3. Describe in detail the symptoms of ascaris infection in man caused due to the adult and larval forms. What are the various curative and preventive measures adopted against ascaris infection ?
4. Write a note on Rhabditiform larva.

Wuchereria bancrofti :

Wuchereria bancrofti (Filaria bancrofti) is another example of a parasitic nematode which inhabits the lymphatic vessels and lymph nodes of man. Sexes are separate. The male and female worms live together and are chiefly found in the lymphatic vessels of inguinal and abdominal regions. The larvae are found in the circulating blood.

Human infection is common in the tropical and sub-tropical countries, chiefly Asia, Africa and South America. In India, it is distributed chiefly in the coastal areas and along the banks of big rivers.

Adult worms : The adult Wuchereria bancrofti are long, hair-like, transparent and creamy white in colour. In shape they are filiform, and the body is covered with a smooth cuticle. Both the

ends are tapering. The head end terminates in a slightly round swelling. The alimentary canal consists of oesophagus, intestine followed by a short rectum. The mouth situated anteriorly is unarmed and communicates with the cylindrical oesophagus. The anus is situated close to the posterior extremity of the body.

In Wuchereria bancrofti the male is 2·5 mm to 4 cm in length by 0·1 mm in thickness. The females are larger than the males and measure 8 to 10 cm in length by 0·2 to 0·3 mm in thickness. The male and the female worms usually remain coiled together and can be separated with difficulty. The females are usually more abundant than the males. The tail end of the male is curved ventrally and contains two spicules of uuequal length. The tail end of the female is straight but abruptly pointed. The females lay eggs in which the embryos are in an advanced stage of development. The eggs usually measure 40 to 50 μ in length by 25 to 35 μ in breadth. The parasite may harbour a person for several years—usually 4 to 5 years. They obtain their nourishment from the lymph of the lymphatic system.

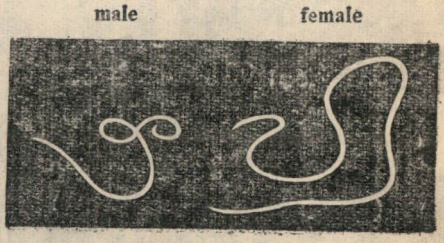


Fig 4·7 Wuchereria bancrofti—Male and female adult worms

Embryos (Microfilariae) : The larvae or the embroys are very active and can move with and against the blood stream. They are referred to as **microfiiariae.** While passing through the lymph nodes, they get into the main lymphatic trunks and again enter the blood. Microfilariae are colourless and transparent organisms measuring 290 μ in length by 6 to 7 μ in breadth. They are enclosed within a closely fit delicate hyaline sheath. It can be best detected at the extremities of the larvae i.e., at its head and tail ends.

At the extremities, the sheath projects beyond them. The sheath is thus much longer (359 μ in length) than the body of the embryo. The embryo can move forwards and backwards within the sheath. The sheath is obtained from the chorionic envelope of the eggs which elongates and forms an investing envelope round the larva.

The central axis of the body of the larva is filled up with granules called the **somatic cells** or **nuclei** which extend from the head to the tail ends of the body. Certain definite spaces can also be seen between these granules. There is a space at the anterior end called the **cephalic space.** In this space there is also found a **stylet.** The larva comes out of the sheath with the help of this stylet. The presence of the stylet is however disputed by some investigators. The other spaces seen, show the position of the rudimentary **excretory organs, nerve ring, anal pore** and the **giant cells.**

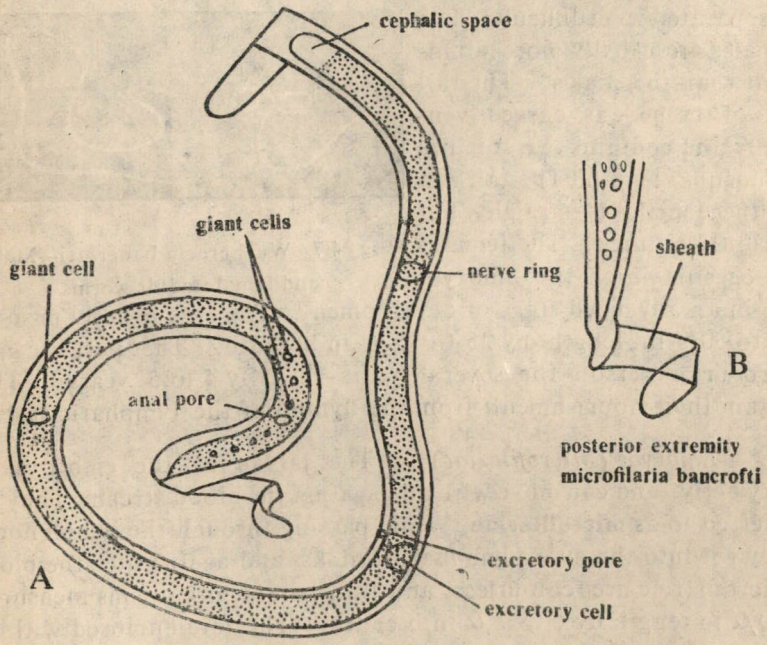


Fig. 4·8 (A) Microfilaria (B) Microfilaria—Posterior end

Biology of the Microfilaria: The larval forms mentioned above do not undergo any further development in the human body. For their further development, they are to be taken up by their appropriate intermediate hosts in which they matamorphose into forms, infective to man. The following species of mosquitoes act as the intermediate hosts to these microfilariae. These are *(i) Culex fatigans, (ii) Stegomyia variegatus and (iii) Anopheles coastalis.*

In the gut of these mosquitoes the microfilariae undergo further development and finally metamorphose into typical infective forms. The usual life span of microfilariae in man is as long as 70 days. Within this period, if they are not sucked up by their insect host e.g., mosquito, they die in the course of time.

Periodicity of Microfilariae bancrofti (Filarial periodicity) :

The microfilariae of *Wuchereria bancrofti* exhibit what is referred to as **nocturnal periodicity.** This is a phenomenon in which the larvae appear in the peripheral blood of man at night periodically. They appear in the peripheral blood gradually, mostly from 10 p.m. to 4 a.m. The maximum number of larvae in the peripheral blood are recorded at mid-night. If blood is examined at this hour, then a large drop of blood (equivalent to 20 cu mm) may contain 300 to 600 microfilariae. After this peak hour they gradually decrease in number and until morning they totally disappear from the peripheral blood. They then pass on to the blood vessels in the deeper parts of the body e.g., capillaries of the heart, lungs, kidneys and big arteries like carotids as well. Manson, referred this phenomenon, as '*Nocturnal periodicity*' as the larvae appear during night in their maximum numbers in the peripheral blood.

The periodicity of the larvae can however be reversed to *diurnal periodicity* if the hour of sleep and work of a patient are reversed. The patient is allowed to work the whole night and sleep during the day time. If this practice is continued for a fortnight or so then it has been noted that the larvae in such a person, appear in their maximum number, at midday in the peripheral blood.

The periodicity however depends on the feeding habits of the intermediate host. In case of *Culex fatigans*, as it has night feeding habits, the nocturnal periodicity of microfilaria bancrofti is observed. From this, it may be inferred that the species of *Wuchereria bancrofti* of different areas, in adaptation to their parasitic mode of life, give rise to diurnal or nocturnal embryos according to the habits of their intermediate host. The interpretation to this phenomenon of periodicity however has not been explained satisfactorily. There are some examples of the larvae reported from countries like Figi and Samoa where no periodicity is noticed.

Microfilaria bancrofti in India and China have however nocturnal periodicity.

Life Cycle : The worm passes its life cycle in two hosts—the man and the mosquito. Man is its definitive host, in the lymphatic system of whom the adult worms are found. The larvae are now and then discharged by the cyclical parturition of the female Wuchereria once in 24 hours. These live embryos (microfilariae) find their way into the blood stream. The larvae can survive in the blood for sometime without undergoing any further development. If at this stage, a female *Culex fatigans* bites the patient, the larvae reach the gut of the mosquito along with the blood sucked.

The larvae are now passed into the stomach of the mosquito, where the sheath of the larva is quickly cast off. The larvae later penetrate the gut wall of the mosquito and migrate to the thoracic muscles. Here the larvae rest and begin to grow. The larvae from the stomach of the mosquito to its thoracic muscles reach within 4 to 17 hours. In the thoracic muscles, the larvae which were at first slender and snake-like, now change to thick, short sausage shaped forms. Within the next two days, they have a short spiky tail, measuring 124 to 250 microns in length by 10 to 17 microns in breadth. They have a rudimentary gut. This is called the **first stage larva.** In the next 3 to 7 days, the larvae grow rapidly and undergo moulting once or twice and attain the length of 225 to 300 microns by 15 to 33 microns in breadth. This is the **second stage larva.** Internal organs at this stage become more definite but the genital organs are still in an undeveloped form. By the end of 10 or 11 days the larvae undergo complete metamorphosis. The tail atrophies and is reduced to a mere stump. The gut, body cavity and genitalia are fully developed. This is now called the **third stage larva** or **the mature infective larva.** It measures 1500 to 2000 microns in length by 18 to 23 microns in breadth. At this stage it can infect a man and on about the 14th day, enters the proboscis sheath (muscular labium) of the mosquito. Unlike the malaria parasites they do not harbour the salivary glands of mosquito. They remain coiled up and are found in pairs. One microfilaria gives rise to one infective larva only in the proboscis. 10 to 20 days are required for the complete development of the larva into an infective phase depending of course on the

almospheric temperature (i.e., 80–90°F) and humidity above 60%. All the microfilaria sucked up along with the blood meal by the

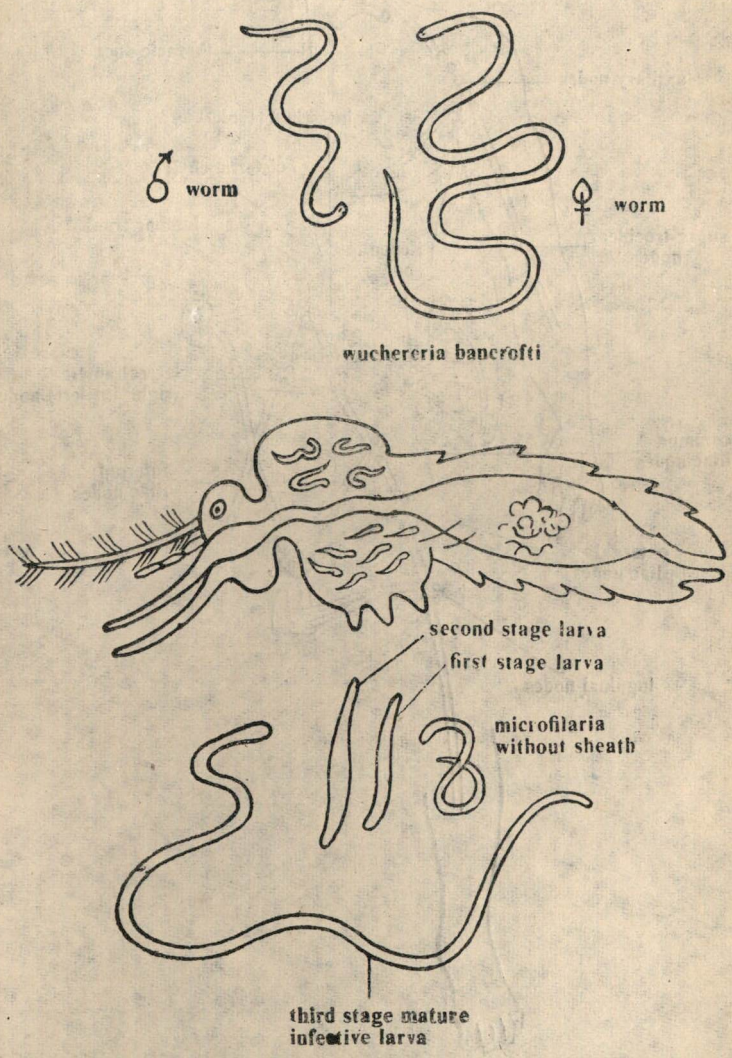


Fig. 4.9 Wuchereria bancrofti--Life cycle in mosquito

mosquito do not develop into infective larvae. Some die in the stomach and some in the thoracic muscles. Only a few develop into the infective phase.

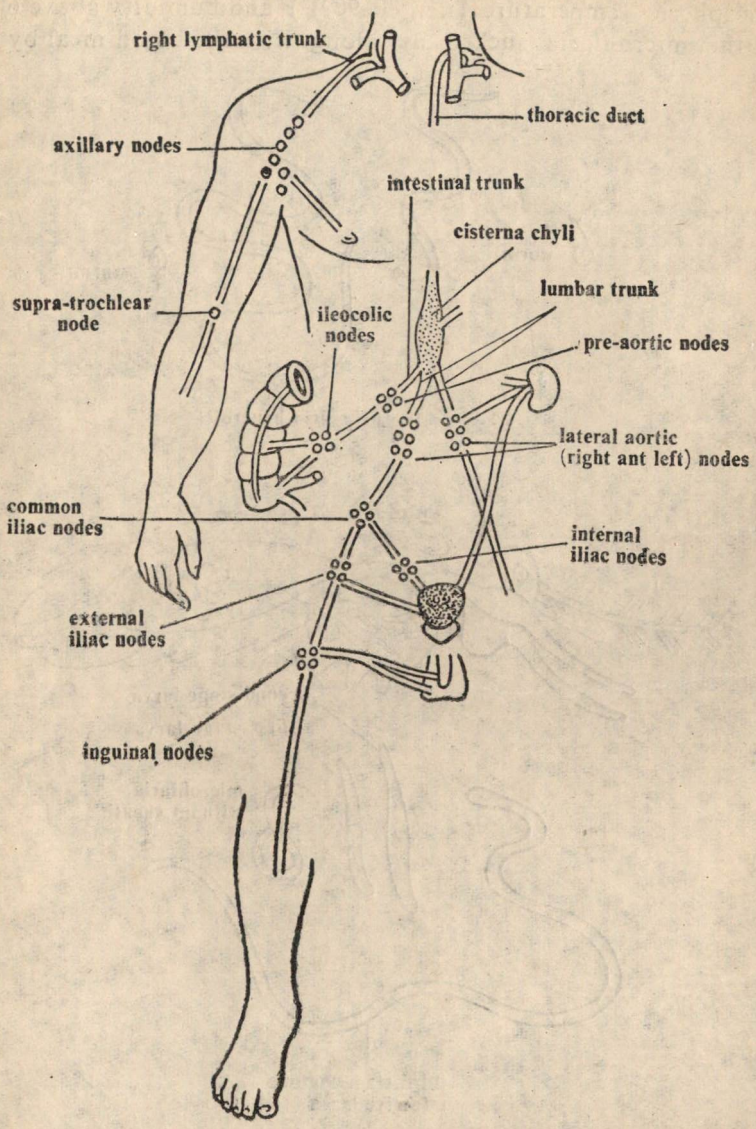


Fig 4.10 The main human lymphatic system involved in Wuchereria bancrofti infection

When the infected mosquito bites a man, the infective larvae are first deposited on the skin near the site of puncture. Later,

under the influence of the warmth of the skin, larvae either enter through the punctured wound or pierce through the skin on their own. After penetrating the skin, the larvae reach the lymphatic channels and settle down at various spots—like the lymphatic vessels of the inguinal, scrotal or abdominal regions. Now they begin to grow in adult forms. After a period of five to eighteen months, the larvae become sexually mature. The male fertilizes the female. The gravid females later parturate and a new generation of microfilariae is emitted. These microfilariae now pass either through the thoracic duct or the right lymphatic duct to the venous system and pulmonary capillaries and finally into the peripheral circulation, (i.e., the capillaries of the systemic circulation) thus completing the cycle. Within the peripheral circulation, the microfilariae await for their chance to be taken up by the intermediate host, the mosquito.

Pathogenecity :

The clinical symptoms produced on account of the presence of the parasite are designated as *Bancroftian wuchereriasis* or *Wuchereriasis bancrofti.* The term filariasis however is also commonly used for the symptoms produced by the infection. Living microfilariae circulating in the blood are not known to produce any pathogenic effect.

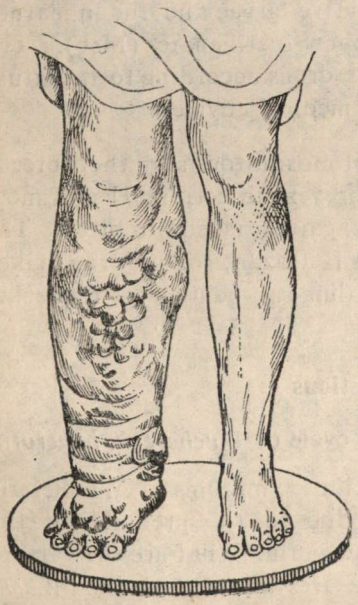


Fig. 4 11 Elephantiasis of right leg

The pathogenic effects are however produced by the adult worms in a living or dead condition. The symptoms are characterised by attacks of irregular fever (Filarial fever), lymphangitis i.e., inflammation of the lymph vessels and enlargement of the lymph nodes and hydrocoel. The blockage of lymphatics by the parasites results in the thickening of the skin and the *elephantiasis* i.e., hypertrophy of the

affected part of the legs, scrotum, vulva very frequently and of the arms and breast less commonly. Lymph vessels become dilated and tortuous. This condition is referred to as *Lymph varix* (varicosity of the lymphatics). Due to the rupture of the varicose lymph vessels through the mucous membrane of the urinary tract (kidneys, ureter or urinary bladder), the chyle (digested fat in the form of an alkaline milky fluid found in lymph vessels) escapes through the urine and a condition called **chyluria** develops.

Treatment : The drugs used against Wuchereria infection are divided into the following groups :

(1) Those, destroying adult worms without any direct action on the microfilaria. In these are included antimonial and arsenical preparations. Neostibosan has been reported to be a most satisfactory antimony preparation. Arsenical preparations include Arsenamide, Mapharson and Melarson oxide.

(2) Those, destroying microfilariae but without any action on the adult worms e.g., Hetrazan—a synthetic piperazine derivative.

(3) Those, destroying the infective larvae and the immature adult worms e.g., para-melaminyl phenyl stibonate (Msb). The dosage and adminstration of the above drugs according to the situation warranted should be under strict medical advice.

Prevention : The destruction of mosquitoes and their breeding places is the best measure to prevent infection. Use of mosquito nets and repellants can protect against mosquito bites. The carriers can be treated effectively with Hetrazan. This drug makes the blood free from microfilariae and thus can be used for rendering transmission impossible.

Revision questions

1. Give an account of the life cycle of *Wuchereria bancrofti.*
2. Describe in detail the various symptoms of Wuchereria bancrofti infection in man due to the presence of the adult and larval forms of the worm. What are the various curative and preventive measures adopted against *Wuchereria bancrofti* infection ?

3. Write notes on the following :

   (a) Periodicity of microfilaria bancrofti.

   (b) The life cycle of Wuchereria bancrofti in the mosquito, *Culex fatigans*.

   (c) The general characters of *microfilaria* found in the peripheral blood of man.

Dracunculus medinensis (Guinea worm) :

Dracunculus medinensis (the generic name Draco means dragon or serpent ; dracunculus is the Latin diminutive of draco.), Guinea worm, serpent or dragon worm ; or Medina worm is a common nematode parasite of man in India, Arabia, Persia, eastern region of U.S.S.R. and Africa. It has also been reported from West Indies and South America.

The guinea worm is known from the days of antiquity and is referred to as 'Fiery serpent' in ancient Hebrew literature. Avicenna, the Arabian physician, named the parasite *'vena medina'* as it was common in Medina.

Habitat : Adult females are usually found in the sub-cutaneous tissues of man, particularly of the legs, cuticle, foot, arms and back. Male worms are rare as after performing its reproductive function, it becomes gradually absorbed in the tissues. The larvae called *microfilariae* are found only on the ulcerated surface, in the centre of which is always visible the prolapsed uterus of the adult female. As the uterus of the female ruptures, the larvae pass out of the ulcerated surface and reach the water when the affected part is being bathed.

The development of the larvae into infective phase takes place in the body of cyclops. In India, six species of cyclops are known to act as intermediate hosts. They are as follows :

(1) Mesocyclops leukarti (2) M. hyalinus (3) M. deciptens (4) M. varicans (5) Paracyclops fimbriatus and *(6) Microcyclops karvei.* The other species of cyclops which feed on Dracunculus larvae and act as intermediate hosts are : *Cyclops quadricornis, C. viridis* ; *C. coronatus* and *C. bicuspidatus.*

Morphology : The adult male worms are rare. Except one case from India, they have not been recovered from man. They have however been recovered from experimental infections in monkeys and dogs. The males are smaller than the females measuring 12 to 29 mm. in length and 0·4 mm in breadth. They possess 4 pre-anal and 6 post anal papillae. The length of the gubernaculum* is 0·2 mm and the unequal copulatory spicules measure 0·49 to 0·73 mm.

The adult female is a slender long worm measuring about 60 cm. to 1 metre in length with a diameter of 1·5 to 1·7 mm similar to a long piece of twine thread. The anterior end of the worm is round. The tail is tapering and bent to form a blunt hook. There is a fluid within the muscular body wall of the worm. This fluid appears to be toxic and forms a blister if it escapes into the tissues of the host. The male worm dies after fertilizing the female. The female worm discharges its embryos by a prolapse of the uterus. The embryos are discharged in successive batches i.e., at each time a limited number of embryos are ejected. This continues for about three weeks until the uterus of the mature female completely empties. The discharge of embryos in batches occurs in succession at each time when the worm comes in contact with water. This is an adaptation to preserve the progeny of the worm as the embryos discharged in water can only get a chance of entering the body of cyclops.

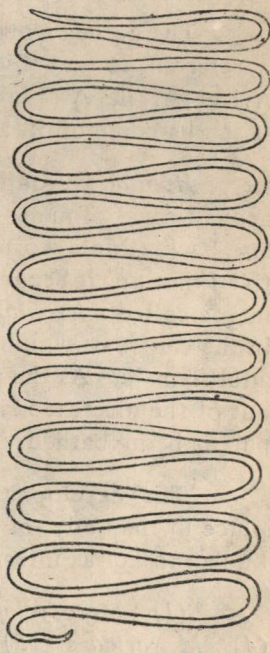


Fig. 4.12 Dracunculus medinensis-adult worm

The life span of a male is hardly 6 months and that of the female worm is about a year.

Embryos : The embryos are flattened, without any sheath, having round heads and coiled bodies with long slender tapering tails. In water, the embryos perform jerky movements due to the coiling and recoiling of their tail. The embryos measure about 650 to 750 μ in

*An elevation on the dorsal wall of the cloaca which guides the spicule during copulation.

length and 17 to 20 microns in breadth. Their oesophagus is provided with a bulb-like dilatation. Their further development depends on their entry into the body of cyclops.

Life Cycle : Each cyclops can ingest 15 to 20 embryos at a time. The infected cyclops die within six weeks after infection. They may die even within 15 days in case they are heavily infected.

The cyclops with its antennae catches the embryos and later swallows them. Within 1 to 6 hours after ingestion, the embryos penetrate the gut wall of cyclops and enter its body cavity. Here they undergo metamorphosis. They grow in size attaining 1 mm length. First moulting occurs between the 7th and the 9th day and the second moulting on 12th and 13th day. It loses its tail at the end of the fifth day and assumes cylindrical shape. Under favourable conditions (in summer) the embryos develop into infective forms in two weeks but the period may extend upto 4 or 6 weeks. An infected cyclops becomes inactive and lies prostrate at the bottom of the wells.

The infected cyclops may be swallowed by man along with drinking water. On reaching the stomach of man, the cyclops are destroyed by the action of gastric juice. The larvae are liberated. These larvae now penetrate through the wall of the intestine and proceed to wander in the subcutaneous tissues where they grow to sexual maturity. They become adult males and females. The males die after fertilizing the females and are not to be found 6 months after infection. The union between the males and the females takes place to the deeper connective tissues of the body. It takes another six months for the gravid female to select site in the body for the discharge of the embryos in water. The female migrates to the parts of the body which are usually liable to come in contact with water. Such areas are the 'backs' of water carriers (*Bhistis*), arms, legs and ankles. When the female reaches such areas of the skin, it secretes some toxins which produce a blister. This blister later ruptures to form an ulcer. In the centre of this ulcerated area, may be seen the prolapsed uterus of the female as a whitish point. From this point, a milky fluid containing a large number of coiled up embryos are ejected now and then in batches whenever the site

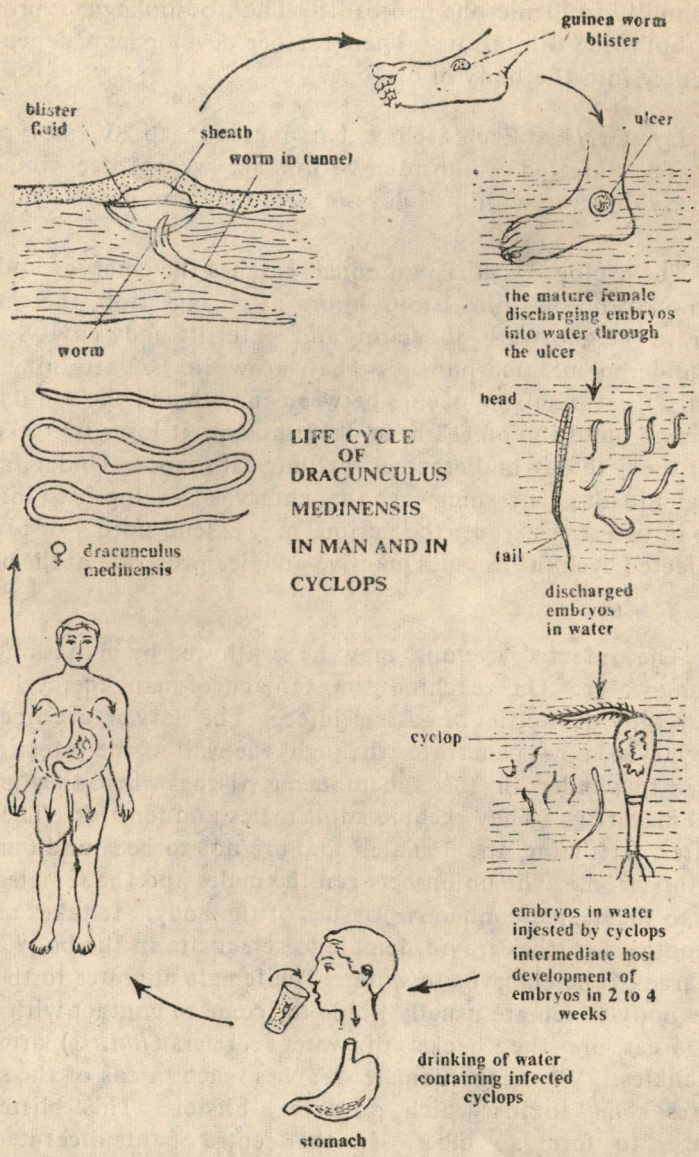


Fig. 4·13 Life cycle of Dracunculus medinensisi n man and in cyclops

comes in contact with water. The embryos in this way are discharged completely in almost 15 to 20 days time after which the adult female is either absorbed or tends to come out spontaneously. A little traction at this juncture may help in the removal of the worm. The traction should not however be applied where the female is in an active phase of discharging the embryos through its prolapsed uterus. The embryos discharged may be swallowed by cyclops where they may undergo development and are transformed into typical infective forms.

The gravid females make their appearance at the surface of the skin through ulcerated area within 9 months or more after the first entry of larvae (contained in cyclops) in the human body.

Pathogenecity :

The disease **dracontiasis** is caused by this worm. The chief signs are the formation of ulcers on the legs, arms, ankles, surfaces of the back or at other points of the body often exposed to a contact with water. In case there is any secondary infection along the track of the worm, it may give rise to severe local and general inflammatory reactions.

Treatment : There is no specific drug for the treatment of *dracontiasis.* The only rational method is to encourage the worm to discharge its embryos by careful douching with cold water at the sites of ulcerations. When all the embryos are discharged from the uterus, the worm dies, loses its grip and it can then be easily extracted manually. Traction to be done only when all the embryos are discharged, otherwise the worm resists extraction. If it is carelessly pulled, the body of the worm tends to break which may give rise to the formation of sepsis in the body.

Prevention : Infected individual should be strictly prohibited from bathing in water used for drinking purposes. The water should be filtered to remove the cyclops from the suspected water. Cyclops can further be destroyed by adding potassium permanganate (0.01 g. of potassium permanganate added in one litre of water is enough to kill the cyclops in a few hours). Addition of bleaching powder every fortnight in wells may destroy the cyclops.

The introduction of certain species of fish e.g., Barbus puckelli which feeds on the guinea worm larvae and other copepods is also a good preventive measure.

Revision questions

1. Describe in detail the life cycle of Dracunculus medinensis (Guinea worm).
2. What are the various remedial and preventive measures against guinea worm infection ?

CHAPTER V

ANNELIDA - SEGMENTED WORMS

Phylum Annelida comprises animals in which the body by the presence of circular rings or grooves is divided externally as well as internally into numerous parts called the **segments** or **metameres**. In phylum Annelida (Annulus=rings i.e., ring bearing animals), this ringed condition is more often known as **segmentation** or **metamerism**. With the exception of a few anterior and some segments at the hind end of the body, all other segments or metameres are more or less alike. The digestive, nervous and circulatory systems run without any interruption from the anterior to the posterior end of the body. The other organs e.g., the excretory organs are arranged on a segmental basis.

Metamerism means more than the mere division of the body into similar segments. It implies not only the serial repetition of homologous parts in each segment but also their working in co-operation with all the others for the maintenance of the activities of the body as a whole. The segmental structures are interdependent and are so integrated that the individuality of the body is retained. The segments of an annelidan body differ in this respect with the segments or proglottides of a tape worm. In tape worm, each mature segment with a complete set of reproductive and other organs may be regarded as an independent entity where no interdependence in the functional activities of these organs with the organs of the other segments is to be noticed. In the case of an annelid, like the earth worm, during its forward movement a functional interdependence and co-ordination between the segmentally arranged structures is evident. The animal moves by rythmical waves of contraction which begin at the posterior end and gradually spread forwards. The muscles, found in each segment of the body contract in such an orderly sequence that the body as a whole moves forward.

In metamerically segmented animals in certain types, the anterior few segments of the body contribute to form a head. This process is referred to as **Cephalisation**. During cephalisation, not

only fusion of the anterior few segments takes place but also the concentration of nervous tissue occurs forming thereby the brain and also other associated sensory organs. Thus, a distinct head is formed with usually associated structures like mouth, sense organs brain, etc.

The annelids, besides being metamerically segmented usually possess an elongated cylindrical body with a bilateral symmetry. They are coelomate triploblastic animals where the coelome or the body cavity is found between the body wall and the wall of the alimentary canal. We can study in detail *Pheretima posthuma*, the common Indian earthworm and *Megascolex* as good examples of the annelid worms.

Pheretima posthuma (The Common Indian Earthworm):

Habitat: Earthworms, as the name itself indicates, spend most of their time in burrows swallowing the earth and depositing it around the mouths of their burrows. The **burrows** are the channels or passages excavated by the earthworm simply by pushing the earth away on all sides. In a compact ground, the soil is actually swallowed by earthworms to make burrows. In moist and rainy weather the worms live near the surface and they can be seen very often to protrude towards the surface of the earth through the mouths of the burrows. During intense cold, they plug the opening of the burrow and move towards the deepest part of the burrow which usually ends in a chamber. Within these chambers, one or several earthworms are rolled up together in the form of a ball and pass the entire winter. During very hot days they also move away from the surface of the earth to avoid dry weather.

Economic Importance of Earthworms: The swallowing of earth besides being a means of digging a burrow also helps in enriching the soil with a good manure. The soil that is swallowed contains organic materials of various kinds e.g., seeds, decaying plants, eggs or larva of animals and other dead bodies of small animals. These pass through the alimentary canal where the swallowed earth containing organic material undergoes a process of digestion. The undigestible portions of the food are passed out of the body in the form of small pellets or **castings** deposited near the mouths of the burrows in heaps.

Such heaps are commonly found in fields and gardens specially during the rainy season. The earth of the castings is thus exposed to the air and the burrows themselves allow the penetration of the air into the soil. This loosening of the soil besides improving drainage also makes easier the downward growth of the roots. The earth swallowed along with the organic matter during the process of digestion undergoes fine grinding and the partially digested remains of the leaves and other organic matter are also added to it and is discharged as castings. This as such is an effective way of *'soil cultivation'* by which the soil is enriched with castings. These castings act like fertile humus that covers the land everywhere except in dry and certain other unfavourable spots. Such an enriched soil with castings facilitates healthy plant growth. The earthworms are thus very helpful to the agriculturists. They constantly plough the soil and enrich it with a useful manure. During this spreading of earth, seeds are covered and are enabled to germinate. Further, the stones and other objects on the surface are covered.

It has been estimated that more than 18 tons of enriched earth per acre per year is brought up from below and deposited on the surface. Darwin calculated that on an average a layer of earth one-fifth of an inch in thickness is thus brought about to the surface in the course of a year.

The earthworm may be regarded as a good friend of the gardener and the agriculturist.

Species of Earthworms: There are several species of earthworms found in India. The common among these are *Pheretima, Eutyphoeus, Helodrilus* and *Megascolex.* Amongst the species common in the British Isles are *Lumbricus, Allolobophora, Eisenia* and *Dendrobaena.* Pheretima posthuma is more or less common all over India hence the same is described here in detail.

External Features : The body of *P. posthuma* is long and narrow, approximately cylindrical in shape having a bilateral symmetry. A full grown earthworm attains a length of about 150 mm and 3 to 5 mm in diameter. They are usually deep brown in colour. The dorsal side being slightly darker than the ventral surface. The dorsal side of the body is further recognised by the presence of a dark median

line running along the entire length of the body. The line is a narrow strip of muscle applied to the inner surface of the skin.

The entire surface of the body is marked by the presence of a series of annular grooves or rings which divide the body superficially and also internally into a number of segments or metameres. The number of these segments in a full grown worm is about 100–120. The external segmentation of the body exactly corresponds with an internal segmentation The internal segments or compartments of the body are separated with one another by transverse partitions called *septa*. Some of the anterior segments show secondary annulation by the presence of additional furrows. This is restricted only to the superficial part of the segment.

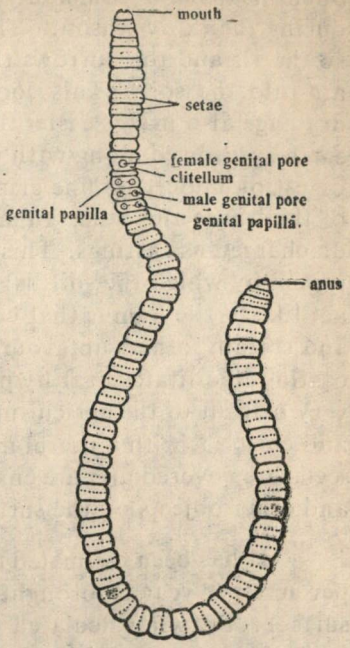


Fig. 5·1 Ventral view of an earthworm

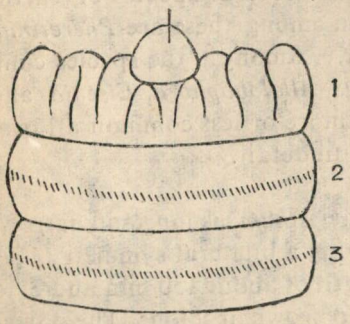


Fig. 5·2 A dorsal view of the prostomium and the first three segments

The anterior extremity of the body is produced into a conical fleshy lobe, the **prostomium**, which over-hangs the mouth. The mouth is situated at the antero-ventral surface of the first segment which is therefore called the **peristomium**. The prostomium is not a distinct segment but is the extension of the peristomium.

The anus in the form of a circular opening at the posterior extremity of the body is located on the last segment. This segment is called the **anal segment**.

The entire superficial surface of the body is invested with a delicate, iridescent membrane called the **cuticle.** It is secreted by the epidermis or the outer epithelial layer of the body.

Setae :

With the exception of the first and the last segment, all other segments of the body are beset with a large number (about 100) of very small cuticular bristles called, **setae** or **chaetae.** The setae are arranged on a distinct ridge which encircles the middle of each segment and form a continuous series round each segment. The tips of these setae face backwards due to which a sensation of a distinct roughness can be felt if a worm is drawn between the fingers from the tail to the

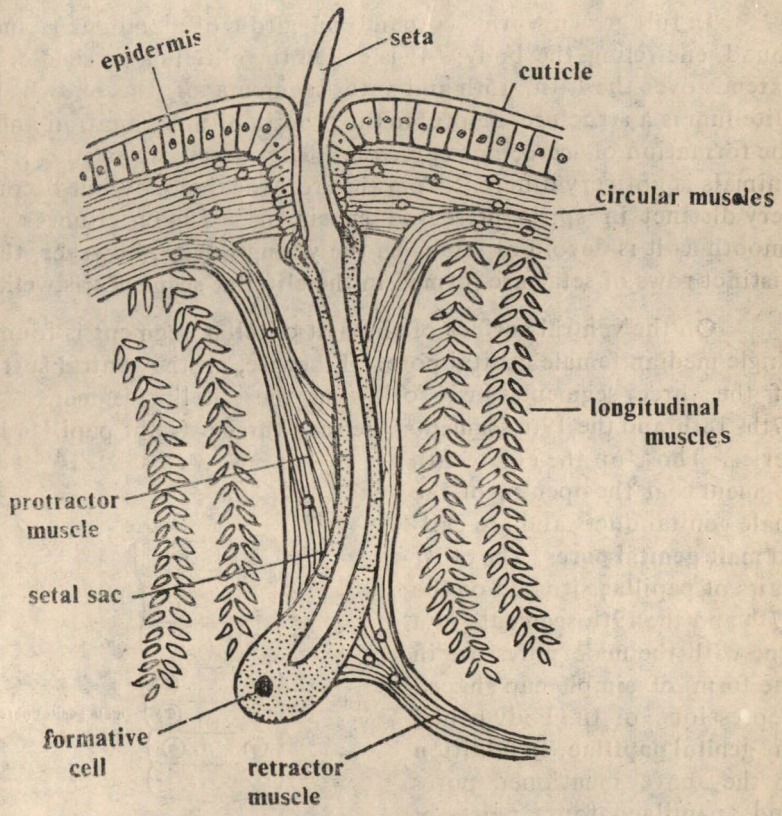


Fig. 5-3 A portion of a section through the body wall of an earthworm to show the position of setae

head end. The setae assist the animal in preventing from slipping backwards as it moves along on the surface of the ground or in its burrow. The setae when worn out may fall out and are replaced repeatedly. Each seta, in the form of a *f*-shaped bristle is a slightly curved body with tapering ends, composed of a horny substance called the *chitin*. The seta is lodged and developed in a small sac, the **setigerous** or **chaetigerous** sac. These setigerous sacs are found as involutions of the epidermis. It is an epidermal sac. Attached to its base are the protractor and retractor muscles. By the action of these muscles the setae can be protruded and retracted respectively. At the bottom of the setigerous sac lies a single large ectodermal cell called the *formative cell* which secretes the seta.

In full grown worms, a band or girdle of glandular tissue is found encircling the body. It is called the **clitellum** or **saddle**. It extends over the 14th, 15th and 16th segments of the body. The clitellum is a structure, helpful in the process of impregnation and in the formation of *cocoon* or *egg case*. The clitellum in the living animals is not very different from the rest of the body but becomes very distinct in spirit preserved specimens. The clitellum is very smooth as it is devoid of setae. In the young worms, however, these distinct rows of setae are formed in the clitellar segments as well.

On the ventral surface of the first clitellar segment is found a single median female genital pore. Likewise, on the ventral surface of the three segments i.e., following the clitellar segments—the 17th, 18th and the 19th segments, are seen three pairs of papillae in a series. Those on the eighteenth segment bear the opening of the male genital ducts and are called **male genital pores**. The other pairs of papillae situated on the 17th and the 19th segments in a line with the male pores are in the form of simple cup shaped depressions of the body called the **genital papillae**. In addition to the above mentioned pores and papillae, four pairs of small openings are also found.

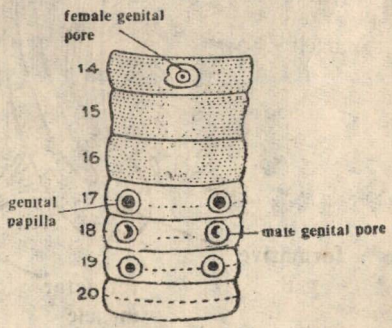


Fig. 5·4 The genital area of Pheretima posthuma

These are called the **spermathecal pores**. They are situated ventro-laterally in the furrows between the fifth and sixth; sixth and seventh; seventh and eighth and eighth and ninth segments of the body. These pores are the openings of the spermathecae (sperm sacs) into which sperms are stored up during copulation.

There are also to be found a series of minute dorsal pores in the middle dorsal line, in the grooves between all the segments of the body except the first twelve. The first dorsal pore thus lies between the intersegmental groove of the 12th and the 13th segments. There is a pore in each succeeding intersegmental groove except the last. The coelom or body cavity communicates with the outside through these dorsal pores. Scattered all over the surface of the body irregularly are found the minute openings of the excretory tubules or nephridia. These pores are called the **nephridiopores**. They are not visible except in thin sections examined under the microscope.

The Internal Structure of an Earthworm: The internal structure of an earthworm can better be followed by observing under the microscope a thin transverse section passing through the body. The transverse section shown in figure 5·5 is taken from the mid-part of the body passing through the region of the intestine.

Body wall: The body wall consists of several distinct cellular layers. The superficial covering consists of a non-cellular cuticle composed of chitin with a characteristic iridescent lustre. It is perforated by numerous minute pores through which open the epidermal glands. It is secreted by the underlying epidermis.

The epidermis lies beneath the cuticle. It consists of a single layer of cells. The epidermis consists of the following types of cells.

(1) The mucus secreting goblet cells which secrete the mucus and keep the skin moist. The mucus prevents desiccation of the animal and also helps in locomotion by lubricating the body. The walls of the burrows are also cemented by the mucus. (2) The albuminous gland cells, contain uniformly distributed fine granules.

The other types of epidermal cells are the supporting cells and the sensory cells which form the epidermal receptors. The epidermis mostly consists of cells having columnar shape.

Beneath the epidermis lies a muscular layer. The greater part of the thickness of the body wall is occupied by muscle fibres which are arranged in two sharply defined layers i.e., (i) An outer layer of circular or transverse muscle fibres in which the muscle fibres extend transversely round the body. (ii) An inner layer of longitudinal muscle fibres arranged longitudinally along the whole length of the body. In section, these are seen as bundles of fibres which have been cut across. The longitudinal layer of muscle fibres are much thicker than the circular muscle fibres. The contraction of the longitudinal muscle fibres causes the body of the worm to get short and thick while the contraction of the circular layer of muscle fibres causes the body to diminish in diameter and consequently the body extends in length.

The innermost layer of the body wall investing the muscular layer and lining the coelom or body cavity is *parietal* or *somatic layer of coelomic epithelium*. It is an extremely thin layer. The body wall is completed by this somatic thin layer or peritonium which thus separates the muscles from the coelom.

Wall of the Intestine : The structure of the wall of the intestine as is seen in the transverse section passing through it reveals that it consists of the following cellular layers. The wall of the intestine is composed of the elements similar to those which constitute the body wall, but arranged in the reverse order.

The lumen of the intestine is lined by a layer of columnar epithelium derived from the endoderm. It is called the **enteric epithelium** and forms the chief absorptive layer of this part of the alimentary canal.

Outside the enteric epithelium is a layer of circular and then a layer of longitudinal muscle fibres both being very thin. The muscular layer is covered by a thin layer of peritonium, the *visceral layer of coelomic epithelium* which forms also a lining of the coelom towards the wall of the alimentary canal. The visceral layer of coelomic epithelium thus completes the wall of the alimentary canal.

The cells of the visceral layer of coelomic epithelium of the intestine, rectum and a considerable part of the oesophagus, get modified into what are known as *yellow* or *chloragogen cells*. These cells contain a yellow pigment excretory in nature. It is probably

lipoidal in nature. The fat from the alimentary canal and also the glycogen is stored up in these cells. These cells are believed to be the sites where, as a result of deamination, ammonia and urea are produced as excretory substances. In this respect they bear a likeness to the liver of the vertebrates. These cells also probably collect silica from the soil passing through the gut as concretions of silica were also detected in them occasionally. The chloragogen cells when

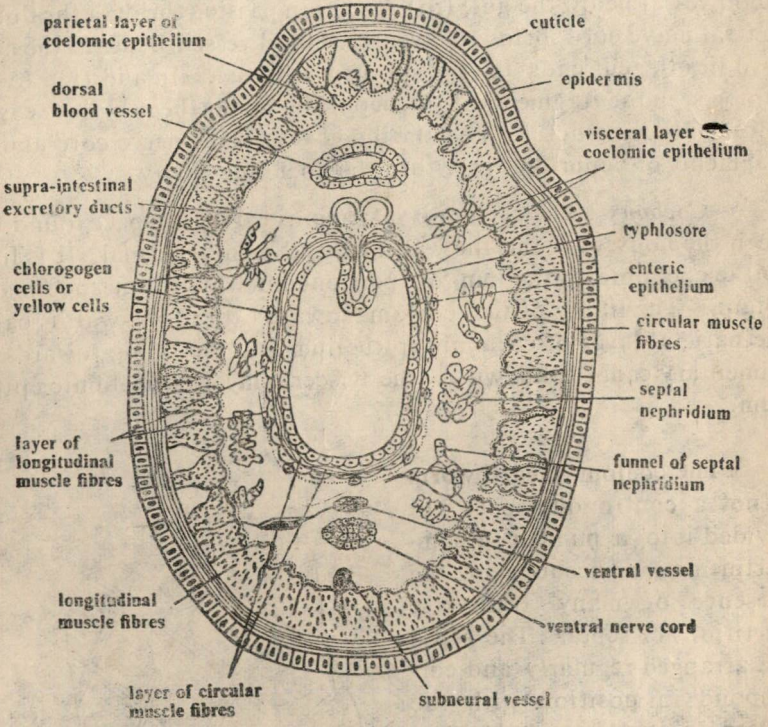


Fig 5·5 A transverse section passing through the region of the intestine of Pheretima posthuma

highly charged with the above substances, fall into the coelomic fluid and there they break and set free their contents in the coelomic fluid. The excretory contents from the coelomic fluid are finally got rid of through the nephridia or the dorsal pores of the coelom. The disintegrating chloragogen cells are finally engulfed by the phagocytic corpuscles of the coelom.

The dorsal wall of the intestine is infolded to form a longitudinal ridge called the *Typhlosole*. The ridge is said to increase the absorptive surface of the intestine. The typlosole is filled up with chloragogen cells.

In the transverse section passing through the body, the other structures to be seen are the following. (i) Cut end of the dorsal-blood vessel lying above the intestine, (ii) Cut end of the ventral-blood vessel below the gut, (iii) A section passing through the double ventral nerve cord, below the ventral blood vessel. Beneath the nerve cord lies the cut ends of the sub-neural vessel. In addition to this can be seen the fragments of the nephridia inside the coelomic cavity. All the above structures i.e , the blood vessel, the nerve cord and the fragments of nephridia lie within the coelomic cavity.

Coelom : The coelom is a spacious cavity or space found between the body wall and the wall of the alimentary canal. It is lined by the coelomic epithelium or peritoneum which is mesodermal in origin. The lining of the coelom towards the body wall is called the parietal layer of coelomic epithelium and the lining towards the alimentary canal is known as the visceral layer of coelomic epithelium.

The coelom in earthworm is not a continuous space but divided into a number of compartments on account of the presence of many transverse partitions or septa. The septa are arranged regularly and correspond in position with the external rings by which the body is divided into segments. The metameric segmentation thus affects the coelom as well. Each septum is in the form of a vertical partition found along the intersegmental groove and connects the wall of the alimentary canal with the body wall. There

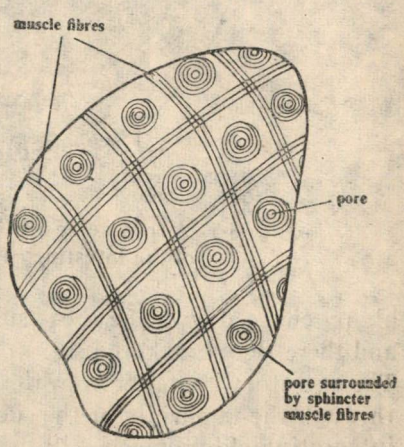


Fig. 5.6 A portion of an intersegmental septum, showing sphinctered apertures

The cavity of the pharynx is compressed dorso-ventrally on account of the presence of dorsal **pharyngeal mass** or **bulb** which depresses the roof so as to bring it near the floor, thereby reducing the cavity within Further, the lateral walls of the pharynx are pushed inwards to form a narrow horizontal shelf on each side. On account of the presence of these lateral shelves the pharyngeal cavity is seen to be completely divided into a dorsal chamber receiving secretions

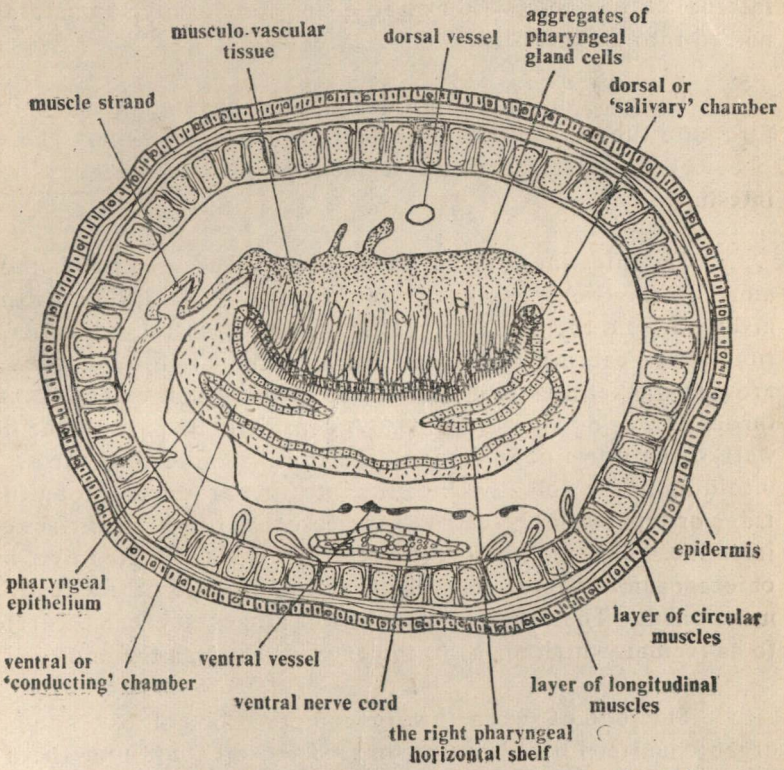


Fig. 5.11 A transverse section of the earthworm through the pharyngeal region (semi-diagrammatic)

of the pharyngeal mass and a ventral conducting chamber. The pharyngeal mass consists of the pharyngeal gland cells. These are irregularly shaped. This glandular mass secretes a salivary secretion into the lumen of the pharynx.

The pharynx is followed by a narrow tubular **gullet** or **oesophagus** which extends through the fifth, sixth and seventh segments. In the eighth or even at times in the 9th segment, the oesophagus dilates to form a thick muscular round body called the **gizzard**. The gizzard is a hard muscular chamber with a thick wall of circular muscle fibres and its cavity is lined by a layer of columnar epithelium which secretes an internal horny cuticle. By the contraction of the muscles of the gizzard, the food material is ground up against the internal cuticle and is reduced to a fine state of divison before it is passed into the intestine.

The oesophagus behind the gizzard again continues in the form of a tube extending upto the fourteenth segment. The oesophagus behind the fourteenth segment passes into a wider tube, the **intestine**.

The intestine continues as a thin walled tube right upto the anus. In the twenty-sixth segment, a pair of conical outgrowths are given off from the intestine. These are called **intestinal caeca**. The function of caeca is unknown. Each caecum arising as lateral outgrowths of the intestinal wall in the 26th segment extends forwards through three or four segments. A considerable part of the dorsal wall of the intestine in fornt of the anus, is folded inwards. This infolding in the dorsal wall of the intestine produces a longitudinal ridge **or typhlosole**. It serves to increase the absorptive surface of the intestine. The surface of the intestine is also covered over by the chloragogen or yellow cells, the function of these have already been mentioned. The terminal part of the alimentary canal is referred to as **rectum**, which opens to the exterior through the anus.

The food of the earthworm comprises bits of leaves and other organic matter formed in the soil. The soil containing these food products is swallowed by the worm in large quantities. The buccal cavity is everted and the muscles passing from the pharynx to the body wall, bring about the dilatation of the pharyngeal cavity due to which the food particles are ingested through the mouth by a sucking action. The salivary secretion passed into the pharynx by the pharyngeal mass contains proteolytic enzymes which start the digestion of proteins. The food undergoes grinding in the gizzard. The

sand particles of the soil, and the muscular contraction of the wall of the gizzard helps in the breaking up of food into fine particles. The process of digestion completes in the intestine which secretes digestive juices containing a number of enzymes. The proteins are converted into peptones, starches into sugars and fats undergo splitting into their constituents. The digested food is absorbed by the intestinal wall and passes into the blood. The process of digestion takes place in the lumen of the alimentary canal hence it is *extracellular* or *enteric*. The food is dissolved and rendered diffusible entirely in the cavity of the gut.

The general movements of the body, and the contraction of the muscles of the gut and septa aided by cilia gradually force the food backwards. The indigestible contents of the food in the form of earth and other indigestible matters are ultimately expelled at the anus as *castings*.

Blood Vascular System :

The vascular system of the earthworm consists of blood vessels containg red blood. The colour of blood is red due to the presence of the respiratory pigment haemoglobin. The haemoglobin in earthworm is dissolved in the plasma but not in the corpuscles as is generally seen in the vertebrates. There are, however, a number of colourless nucleated corpuscles found in the plasma. The blood vessels form a single closed vascular system as there is no communication between them and any of the other cavities of the body. The following main longitudinal vessels are very prominent.

1. A large **dorsal vessel** runs along the dorsal surface of the alimentary canal from the anterior to the posterior end of the body.
2. A large **ventral blood vessel** or the sub-intestinal vesse runs along the ventral surface of the alimentary cana along the entire length of the body.
3. A small **sub-neural vessel** runs ventrally to the nerve cor extending from the posterior end of the worm to th fourteenth segment anteriorly.

All these longitudinal trunks supply branches to the variou parts of the body.

The direction of the flow of blood in the dorsal vessel is from the posterior to the anterior end of the body. The blood in the ventral and sub-neural vessels flows backward. The arrangement of the blood vessels behind the thirteenth segment i. e., in the region of the intestine differs from the arrangement in the first thirteen segments of the body. The arrangement of the blood vessels on the whole, may as such be followed, by studying them in the two distinct regions of the body mentioned above.

1. *The typical arrangement of blood vessels behind the thirteenth segment i. e., in the region of the intestine.*

The blood vessels in the region of the intestine consists of :

(a) Three main longitudinal trunks running parallel to one another namely the **dorsal**, the **ventral** and the **sub-neural vessels**.

(b) The intestinal blood plexuses found in the wall of the gut.

(c) The commissural and the integumentary vessels.

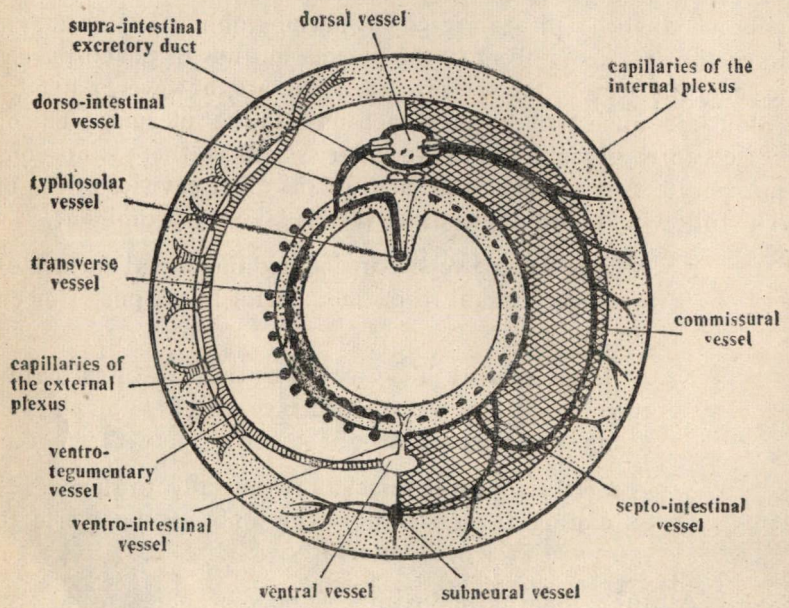


Fig. 5·12 A transverse section (Diagrammatic) showing the disposition of the blood vessels in the intestinal region

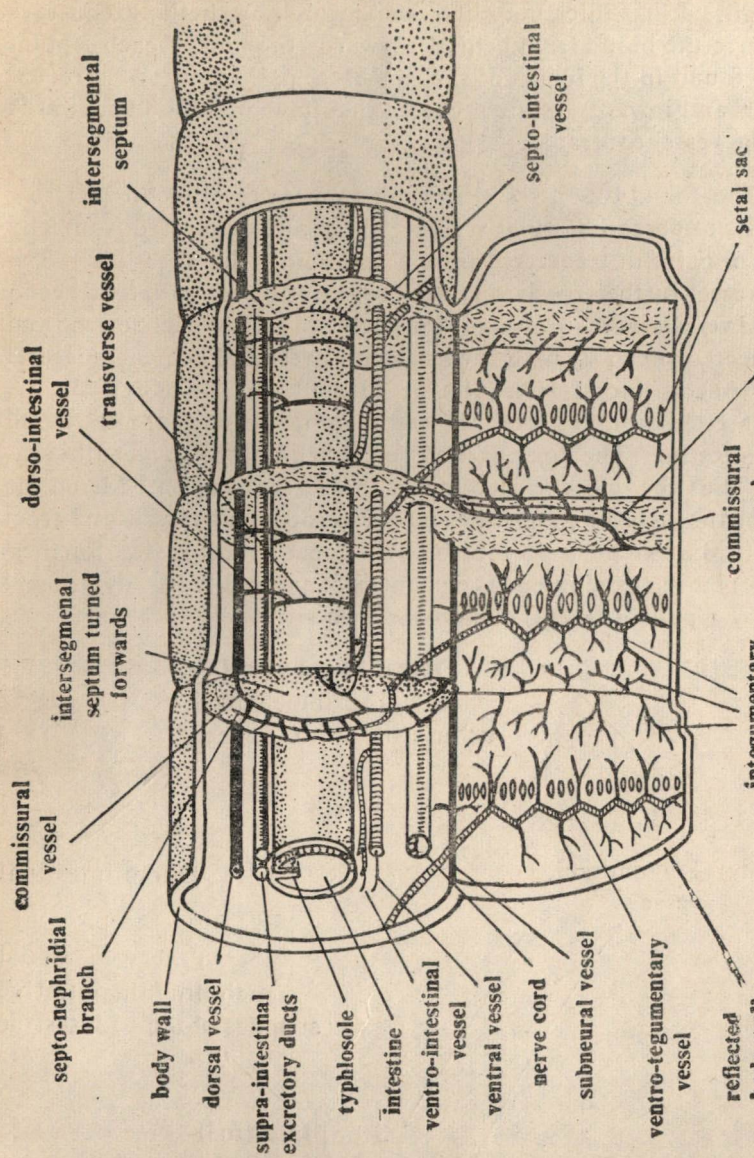


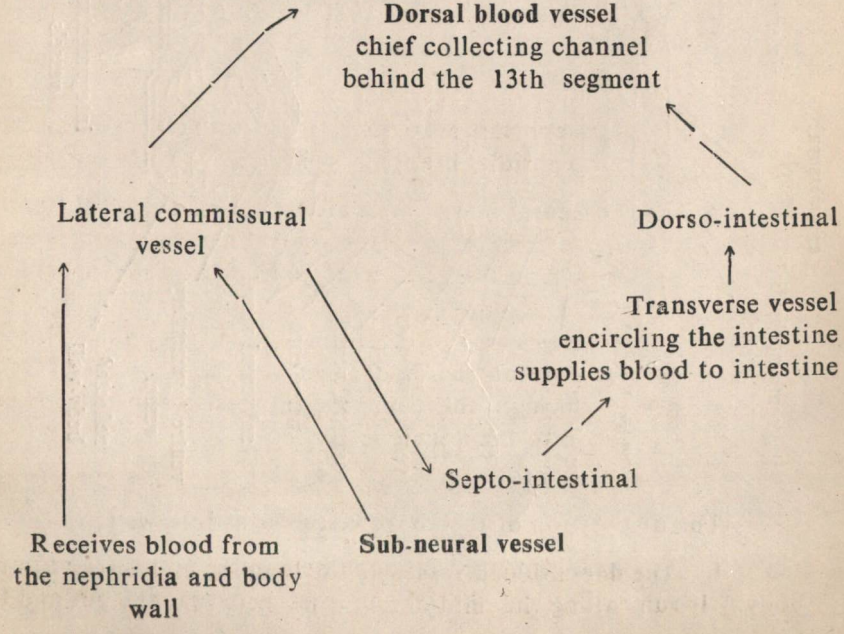
Fig. 5.13 Pheretima posthuma—The typical arrangement of blood vessels behind the thirteenth segment of the body i.e., in the region of the intestine

The disposition of the above vessels is as follows :

1 **The dorsal blood vessel** is the longest blood vessel in the body. It runs along the mid-dorsal line between the gut and the

body wall. It has thick muscular walls which by rhythmic contractions drive the blood from behind forward. In front of each septum there is found in the lumen of the vessel a pair of valves directed forwards and inwards, which check the flow of blood backwards when the vessel contracts.

The dorsal blood vessel in each segment receives on each side two pairs of **dorso-intestinal vessels** which are connected ventrally with two pairs of **transverse vessels** encircling the intestine. The dorsal vessel further receives in each segment a pair of **lateral commissural vessels** which run along the posterior face of each septum and is connected ventrally with the **sub-neural vessel**. Each commissural vessel collects blood from the nephridia, and the body wall. A septo-intestinal branch from the commissural vessels supplies blood to the intestine. The dorsal blood vessel behind the thirteenth segment is thus the chief collecting channel receiving blood from the intestine through the transverse and dorso intestinal vessels and from the nephridia and body wall through the commissural vessel. Further, the sub neural vessel in each segment is connected with the dorsal vessel by a pair of lateral commissural vessels.



The ventral blood vessel runs just below the alimentary canal from the anterior to the posterior end of the body. The flow of blood in this vessel is from the anterior to the posterior end of the body. It is the chief distributing vessel throughout the body, supplying blood to the various organs of the body

The ventral vessel gives off a pair of **ventro-tegumentary vessels** one on each side immediately in front of each septum. The branches of ventro-tegumentaries supply blood to the body wall, integumentary nephridia and the septal nephridia through the **septo-nephridial branch.** The ventral blood vessel besides giving off the paired ventro-tegumentary vessels, also gives off in each segment an unpaired **ventro-intestinal** vessel from its dorsal surface. These vessels supply blood to the ventral wall of the intestine

Ventral Blood Vessel
distributing channel

Ventro-tegumentaries supply blood to

1. Body wall
2. Integumentary nephridia
3. Septal nephridia through septo-nephridial branch.

Unpaired ventro-intestinal
↓
To the ventral wall of the intestine.

The sub-neural vessel runs along the mid-ventral line and as its name indicates, lies beneath the ventral nerve cord. It is a slender vessel extending from the posterior end of the body right upto the 14th segment. The blood in this vessel flows backwards. In each segment it receives a pair of branches which bring back blood from the ventral region of the body wall. It communicates with the dorsal vessel through the commissural vessels and thereby sends a part of its blood to the dorsal vessel.

2. The arrangement of the blood vessels in the first thirteen segments.

The arrangement of blood vessels in the first thirteen segments differs markedly from that of the intestinal region. The dorsal blood

vessel instead of being a collecting channel becomes the main distributing trunk. The function of collecting blood from the anterior region of the gut is taken over by a new vessel, the supra-oesophageal vessel, while the blood from the peripheral regions of the body is collected by the right and left and lateral oesophageals formed by the bifurcation of the sub-neural vessel in the first thirteen segments.

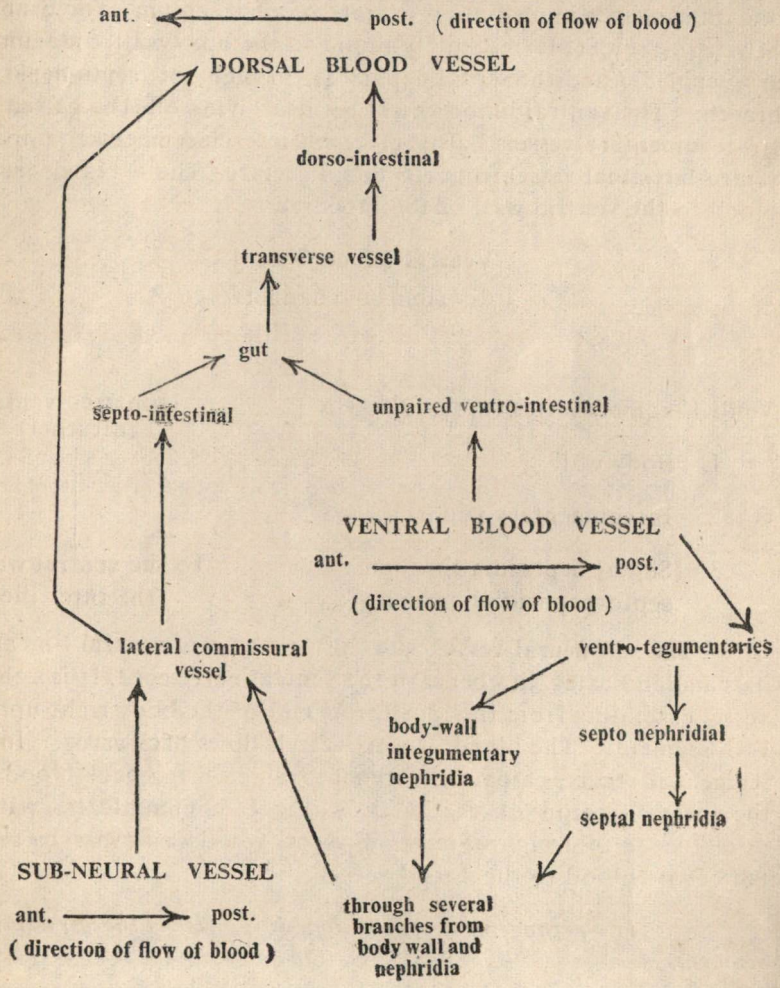


Fig. 5·14 Diagrammatic representation of the circulation of blood behind the thirteenth segment i.e., in the intestinal region

The ventral blood vessel continues to be a distributing channel in the first thirteen segments also. It does not however supply blood to the gut, as the dorsal blood vessel supplies blood to this region of the gut in the first thirteen segments. The details are as follows.

The dorsal blood vessel is the chief distributing channel. It does not receive any commissural or dorso-intestinal vessel in the first thirteen segments. The flow of the blood is from behind forward as is seen behind the thirteenth segment. The blood collected in the intestinal region by the dorsal blood vessel, passes into the ventral blood vessel through four pairs of rhythmically contractile muscular and valvular tubes, the so called **hearts** which are situated in the **seventh, ninth, twelfth** and the **thirteenth** segments. The anterior two pairs of hearts, situated in the **7th** and **9th** segments are called the **lateral hearts**, as they simply connect the dorsal vessel with the ventral blood vessel. The posterior two pairs of hearts situated in the **12th** and **13th** segments are called the **latero-oesophageal hearts** as they carry blood from the dorsal blood vessel and the supra-oesophageal vessel to the ventral blood vessel.

The dorsal blood vessel extends anteriorly upto the cerebral ganglia and gives off paired branches to the pharynx, the pharyngeal nephridia and the gizzard.

The ventral blood vessel in this region also continues to be a distributing channel and the flow of blood is the same i.e., from anterior to the posterior end of the body. It gives off in each segment a pair of ventro-tegumentary vessels which supply blood to the body wall and the nephridia. The other structures found in the body cavity, i e , spermathecae, seminal vesicles, ovaries, etc., also receive their blood supply from the branches of the ventral blood vessels. The ventral blood vessel in the first thirteen segments does not supply blood to the gut as the latter in this region is supplied by the dorsal vessel.

The sub-neural vessel on entering the region of the anterior thirteen segments bifurcates into two **lateral oesophageals** which run on the right and left sides of the alimentary canal. The direction of flow is from anterior to posterior end of the body. In the segments 10th to 13th, the lateral oesophageals are closely attached to the

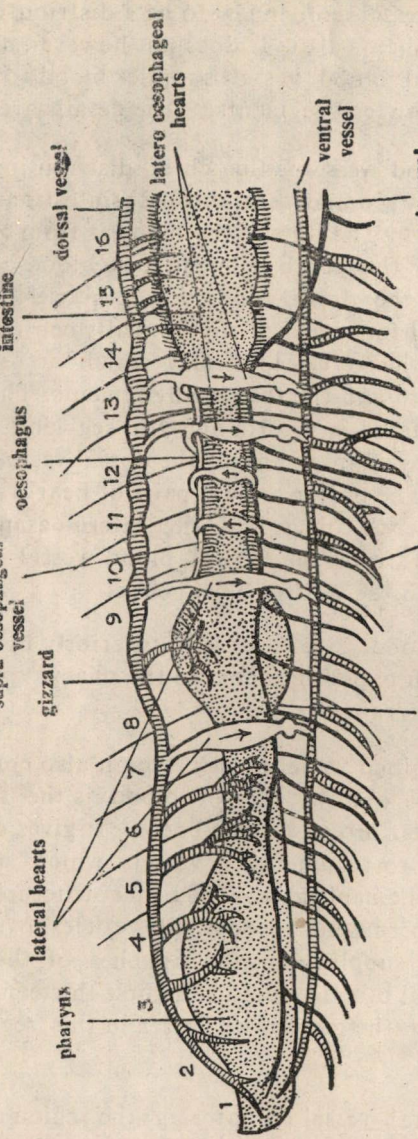


Fig 5.15 Pheretima posthuma—The arrangement of the blood vessels in the first thirteen segments

wall of the oesophagus. The blood from the gut, nephridia, body wall, septa and the reproductive organs is collected by the lateral oesophageals.

The lateral oesophageals are connected with the supra-oesophageal vessel through two pairs of ring vessels or commissural loops surrounding the wall of the oesophagus in the **10th** and the **11th** segments. These ring vessels are called the **anterior loops.** Thus, the blood of the lateral oesophageal in this region passes into the supra-oesophageal through these anterior loops.

The **supra-oesophageal vessel** is confined to the posterior oesophageal region extending from the **9th** to the **13th** segment and

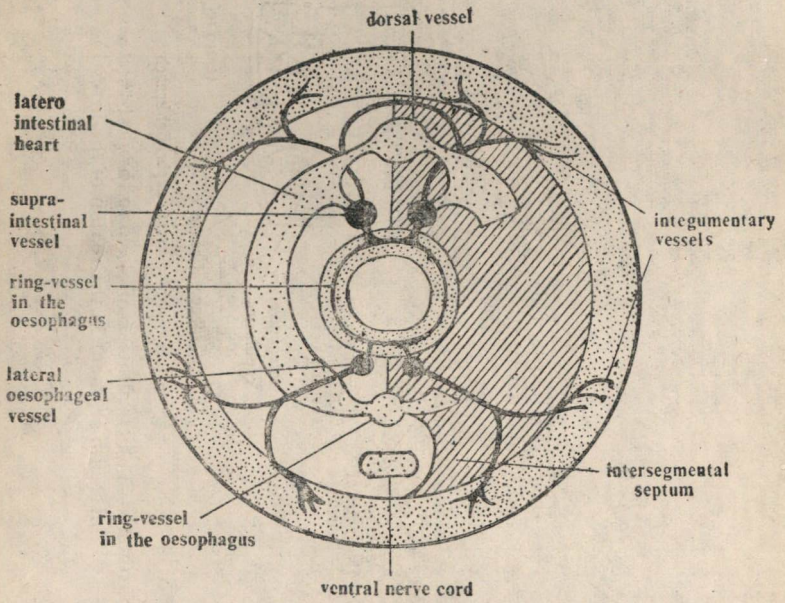


Fig. 5·16 A transverse section (Diagrammatic) through the region of the "Latero-oesophageal" hearts

occupies the same relative position with regard to the gizzard and oesophagus, the dorsal blood vessel occupies in the intestinal region. The supra-oesophageal posteriorly communicates with the two posterior pairs of latero-oesophageal hearts situated in the 12th and the 13th segments. Thus, the blood of supra-oesophageal via the latero-oesophageal hearts may pass into the ventral blood vessel.

The blood that returns to the lateral oesophageal may follow two routes. It may enter the anterior loops from where it goes into

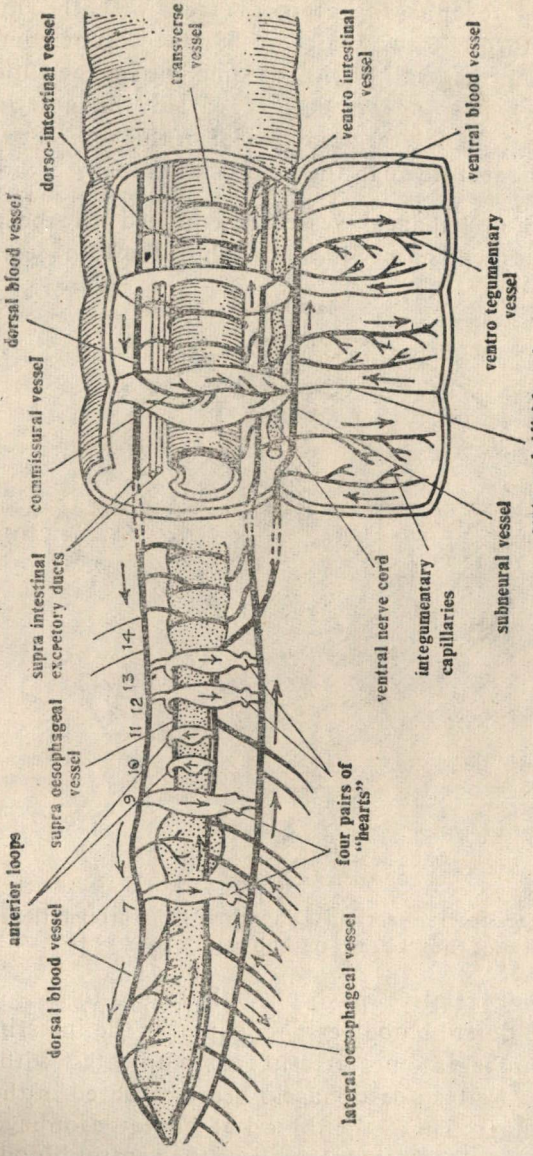


Fig. 5.17 Pheretima posthuma—The circulation of blood in the first thirteen segments and behind the thirteenth segment in the region of the intestine

supra-oesophageal and then through the latero-oesophageal hearts may reach the ventral blood vessel. The blood from the lateral-oesophageals may more directly flow backward into the sub-neural and

the transverse section, it is evident that the nerve cord is composed of two longitudinal cords surrounded by a common sheath. During

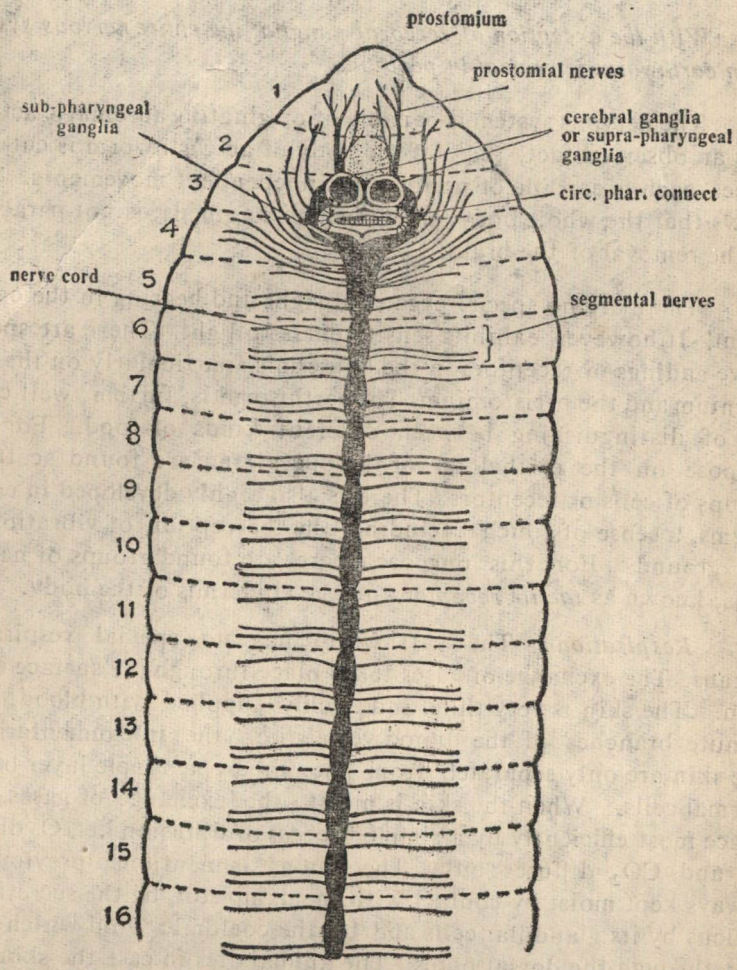


Fig. 5·19 Nervous system—Pheretima posthuma

development, the nerve cord is in the form of two distinct, laterally situated cords which later gradually approach each other and ultimately fuse together in the middle line to form the **double ventral nerve cord** of the adult.

From each ganglionic swelling of the nerve cord arise two pairs of nerves which are distributed to the body wall and the viscera.

With the exception of cerebral ganglia, the entire nervous system of an earthworm is ventral in position.

The nervous system is capable of originating automatic action. It is an observed fact, that, if the body of an earthworm is cut into pieces, each is capable of performing independent movements. This shows that the whole body, as in the higher animals, is not paralysed by the removal of the brain.

There are no special organs of sight and hearing in the earthworm. It however, exhibits sensitiveness to light. There are special nerve endings or receptors in the epidermis, particularly on the prostomium and the peristomium. The earthworm is, further, well capable of distinguishing between different kinds of food. For this purpose on the epithelium of the buccal sac are found scattered groups of cells or receptors. There is also highly developed in earthworms, a sense of touch including the perception of vibrations of the ground. For this purpose there are found groups of narrow cells, known as *tactile receptors*, in the epidermis of the body.

Respiration: The earthworm has no special respiratory organs. The exchange of gases takes place through the surface of the skin. The skin is very thin and richly supplied with blood. The minute branches of the blood vessels i.e., the integumentaries in the skin are only separated from the air by a simple layer of epidermal cells. When the skin is moist, the exchange of gases takes place most efficiently by a simple process of diffusion i.e., O_2 diffuses in and CO_2 diffuses out. The skin as is mentioned previously is always kept moist by contact with the damp soil, by the secretion of mucus by its glandular cells and by the coelomic fluid which oozes out through the dorsal pores. The animal dies in case the skin dries up as it is not able to respire.

Excretory System: The excretory system of the earthworm consists of tubular organs called the **nephridia**. Each nephridium generally consists of a coiled tube, one of it through a wide funnel called the **nephrostome (nephridiostome)** opens into the coelom and

of excretory canals situated on each septum, with a pair of **supra-intestinal excretory ducts.** These ducts run longitudinally near the mid-dorsal line below the dorsal blood vessel. In each segment the supra-intestinal excretory duct communicates with the lumen of the gut.

The excretory products collected by the septal nephridia, via the septal excretory duct, reaches the supra-intestinal excretory duct which in turn pours its contents into the lumen of the gut. The waste products from the gut ultimately reach to the exterior through the anus. Such nephridia, which do not open directly to the outside but open into the gut are referred to as **enteronephric nephridia.**

The structure of a single septal nephridium is as follows :

The septal nephridium consists of a small funnel with a nephrostome. This leads behind into a short narrow tube—first free part of the nephridial tube. This tube bends on itself before joining the body of the nephridium. The main body of the nephridium consists of a short straight tube followed by a long spirally twisted loop. The straight lobe is round at its free end and continues at its other end into one of the limbs of the long twisted loop. The long twisted loop is distinguished into distal and proximal limbs. This twisted loop is more than twice the length of the straight lobe.

The proximal limb of the twisted loop, finally communicates with a terminal nephridial duct. This in turn joins the septal excretory canal. A much coiled nephridial tubule traverses the substance of the septal nephridium and ultimately leads into the terminal excretory duct. The lumen of the tubule is provided at various places with many cilia. The flickering movements of the cilia urge on the excretory products from one end of the nephridium to the other ultimately discharging them into the septal excretory duct. The whole nephridium along with its funnel, hangs freely in the coelomic cavity and is attached to the septum near its outer edge by means of the terminal nephridial duct which runs obliquely along the septum and joins the septal excretory canal.

The nephridia are richly supplied with blood vessels and are lined partly by gland cells and partly by cilia. Water and nitrogenous waste from the different parts of the body pass by diffusion into the blood and are thus conveyed to the nephridia. The gland cells

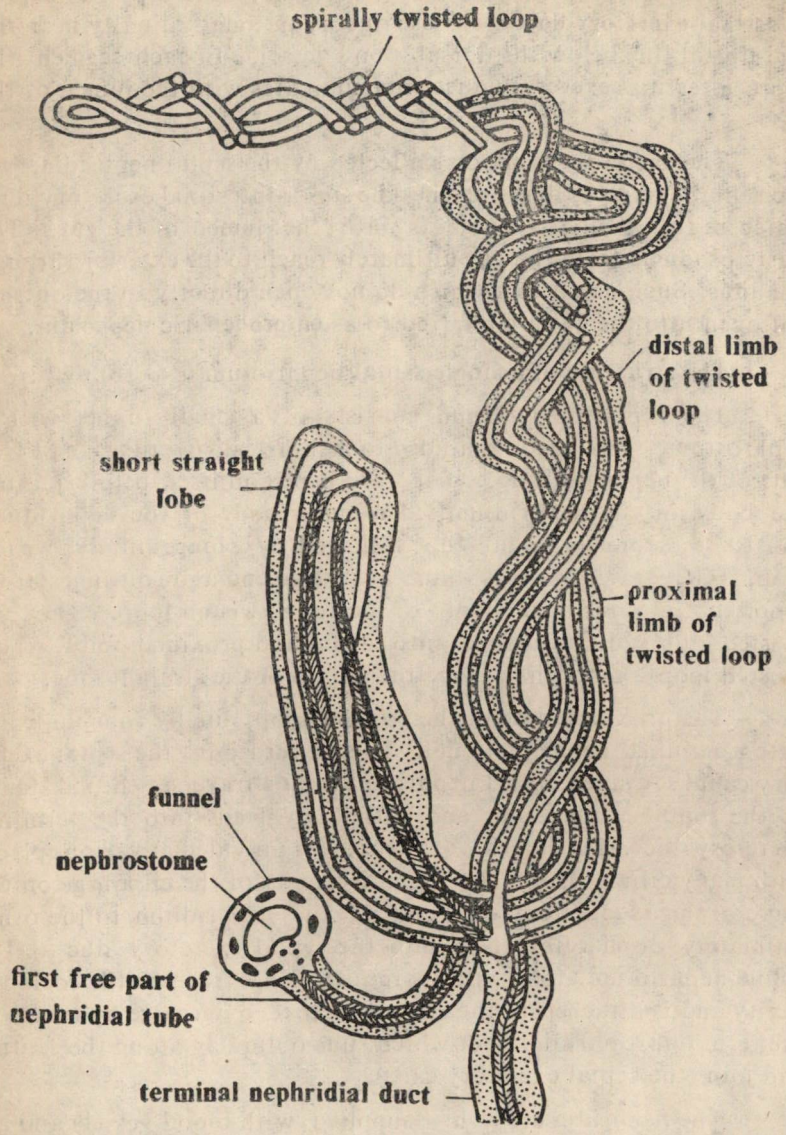


Fig. 5·22 Pheretima posthuma — A single septal nephridium

of the nephridia withdraw the waste products and pass them into the cavities of the tube, and are finally discharged from the body. The

waste matter found in the coelomic fluid also passes through the nephrostomes into the nephridia.

2. **The pharyngeal nephridia** : There are three pairs of **pharyngeal nephridia.** The pharyngeal nephridia are restricted to the **4th, 5th** and **6th** segments of the body on each side of the oesophagus. The pharyngeal nephridia are in the form of tufts or clusters. They are devoid of nephrostomes. The terminal ducts of all the nephridia of a cluster unite together to form ducts which in turn join to form a long muscular duct. There are thus 3 pairs of such long muscular ducts arising from the tufts of the nephridia. The long muscular duct from the nephridia of the 6th segment passes anteriorly and opens into the buccal cavity. Those from the 4th or 5th segments open into the pharynx. Since the pharyngeal nephridia also discharge their contents in the buccal cavity and the pharynx, they are also like the septal nephridia of entero-nephric type. The entero-nephric nephridia, e.g., septal and pharyngeal, help in the conservation of water.

3. **The integumentary nephridia** : They are the smallest of the three kinds. They are less than half the size of the septal, but very much more numerous, attached to the inside of the body wall. They are found in all the segments except the first two. There are 100–250 nephridia in each segment. In the region of the clitellum, they are so numerous as to form **'forests'** and give this region velvetty appearance. They have no nephrostomes and their inner ends are closed. They open to the exterior by the nephridiopores on the surface of the body. Integumentary nephridia are said to be **exonephric** as they discharge their contents directly to the exterior.

Reproductive System : The earthworm is hermaphrodite i. e., both male and female reproductive organs are found in the same individual. Inspite of this, cross fertilization only takes place. Self fertilization, however, is not possible as the testes and the ovaries do not mature at the same time. The testes mature earlier than the ovaries and usually atrophy by the time the ovaries mature.

The gonads develop from certain parts of the coelomic epithelium. In addition to the gonads, there are various accessory organs forming thereby a reproductive apparatus situated in segments 6–21.

The Male Reproductive Organs : The male reproductive organs consist of the following :

(i) Two pairs of **testes sacs** lie ventrally beneath the oesophagus in the tenth and the eleventh segments.

(ii) Two pairs of **seminal vesicles**, extend laterally and are situated on both the sides of the oesophagus in the eleventh and the twelfth segments.

The cavities of the testes sacs of the tenth segment communicate laterally with the seminal vesicles of the eleventh segment and likewise the testes sacs of the eleventh segment communicate, laterally with the seminal vesicles of the twelfth segment. The testes sacs of the same segment also communicate with each other. The cavities of the testes sacs are regarded as the closed off portions of the coelom and the seminal vesicles as the outgrowths of the septa.

In each testis sac lie a pair of **testes** or **spermaries**. They are in the form of minute white bodies found attached to the inner surface of the anterior wall of the testis sac. Each testis is made up of a number of *digitate processes*, five to eight in number, hanging from a narrow base. It contains mulberry-like masses of sperm mother cells or spermatogonia that are now and then shed into the testis sacs and pass into the seminal vesicles where they develop into mature sperms. The mature sperms then pass back to the testis sacs. There is a pair of profusely ciliated **seminal funnels** in each testis sacs behind each testis. The large masses of sperms are usually found attached to the margins of the seminal funnels. Each seminal funnel leads into a **spermiduct** or **vas deferens**, through which sperms are conveyed. The two vasa deferentia of either side, come together in the twelfth segment and run backwards side by side, upto the 17th segment where both the vasa deferentia turn outwards to join the prostatic duct of their own side in the 18th segment.

The **prostate glands** or **spermiducal glands** are a pair of large solid white glands irregular in outline, lying on either side of the intestine in the 16th to the 21st segments. A **prostatic duct** emerges from each gland and is joined by the two vasa deferentia of their own side. These three ducts thus enclosed in a common sheath in the form of a **horse-shoe shaped duct**, open to the exterior at the **male genital pore** on the ventral side of the 18th segment. Since these three ducts, i.e., two vasa deferentia and a prostatic duct although enclosed in a sheath, remain separate, there occur in fact, three independent apertures at the site of the male genital pore on the

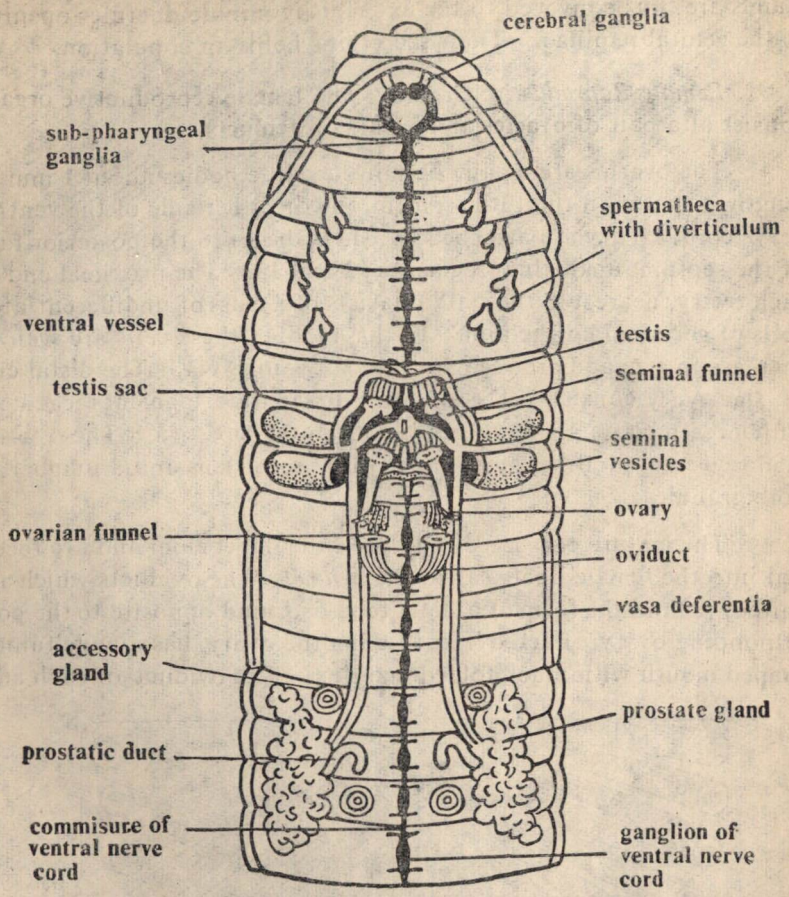


Fig. 5·23 Pheretima posthuma — reproductive system and nervous system

ventral side of the 18th segment. The sperms and the prostatic fluid are thus conveyed to the exterior through their respective openings found on either side of the 18th segment. The prostatic and the seminal secretions are thus carried independently to the exterior.

There are also found two pairs of **accessory glands**, each pair situated in the **17th** and **19th** segments Genital papillae are found in the 17th and 19th segments on the ventral side, corresponding to the position of the accessory glands. The secretions of the accessory

glands are thus conveyed to the exterior by minute ductules opening at the genital papillae. Their secretions helps in copulation.

Female Reproductive Organs: The female reproductive organs consist of a pair of **ovaries** and a pair of **oviducts.**

The ovaries are a pair of minute white bodies about 1 mm in length, situated in the 13th segment one on either side of the ventral nerve cord. They are attached by their bases to the posterior face of the septum separating segments 12 and 13. The proximal end of each ovary, nearest to the stalk consists of a mass of undifferentiated cells of germinal epithelium. In the middle, these cells are seen to increase in size and are recognisable as young ova. The distal end of the ovary consists of a number of separate filaments each of which resembles a string of beads containing ripe ova. The ova are enclosed in a vitelline membrane with a nucleus and a number of yolk granules.

The mature eggs are discharged into the coelom and are received into the female ducts called the *oviducts*. The oviducts which are paired, each in the form of a short tube, is found opposite to the corresponding ovary. Each oviduct facing the ovary, has a wide funnel shaped mouth with much folded margins. The oviduct of each side

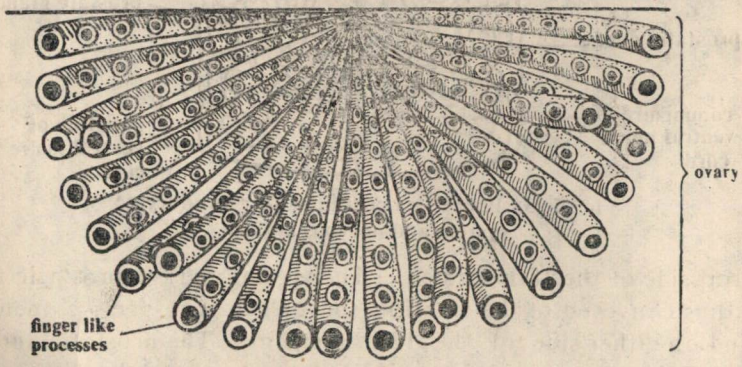


Fig. 5.24 The ovary of the earthworm

perforates the septum found between the 13th and the 14th segments, and later the oviducts converge to meet beneath the nerve cord. After this union, the duct opens to the exterior through a single **female genital aperture** situated in the mid-ventral line of the 14th segment.

There are also found four pairs of **spermathecal sacs (spermathecae)**. Each pair is situated in the sixth, seventh, eighth and ninth segments. They open to the exterior on the ventral side in the grooves between the fifth and sixth, sixth and seventh, seventh and eighth, eighth and ninth segments respectively. Each spermatheca is in the form of a pyriform or flask-shaped sac continued into a duct which opens to the exterior. Just below the duct is found a narrow diverticulum or ampulla. Sperms are stored in the spermathecae received from another worm during copulation.

Copulation: The copulation in *Pheretima posthuma* has not yet been observed. The process of copulation in other earthworms takes place in the following way.

Copulation usually takes place during the rainy season as well as in September and October either at night or early morning. Two

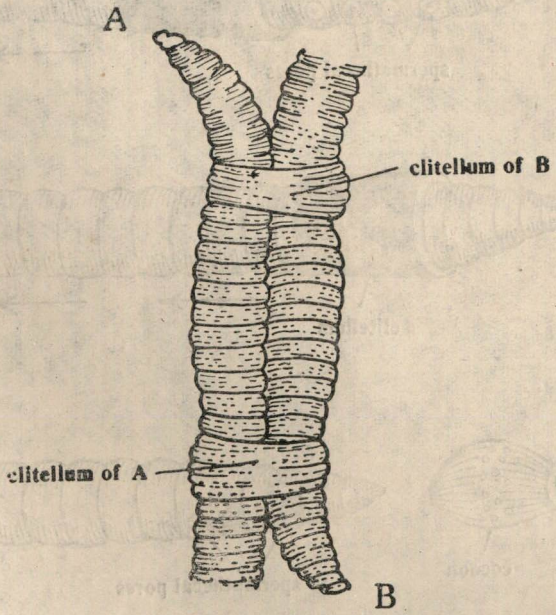


Fig. 5.25 The copulating earthworms

worms from the adjoining burrows are applied together by their ventral surfaces, with their heads in opposite directions. They are thus in a position that the male generative apertures of each worm come to lie opposite to the spermathecal pores of the other.

The worms are firmly applied together in this position with the aid of setae and a viscid glandular secretion from the clitellum. The sperms are passed from the male apertures of one worm into the spermathecae of the other worm. After this mutual transfer of sperms into the spermathecae, the two worms then separate.

Cocoon Formation: The clitellum of each separated worm then secretes a membranous girdle round the body in this region. The girdle hardens when exposed to air. The girdle or tube so formed is gradually slipped forwards by the worm wriggling back out of it. As it passes over the apertures of the oviducts and spermathecae,

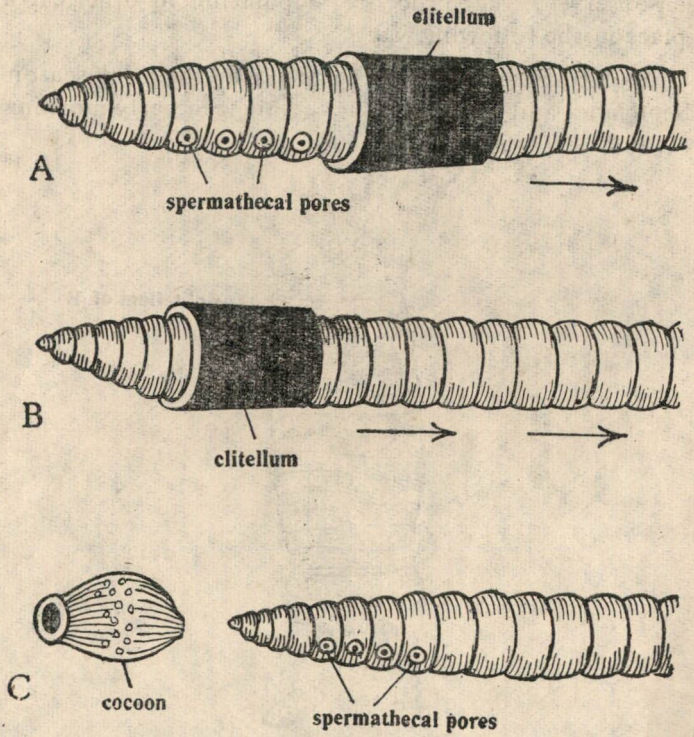


Fig. 5·26 Cocoon formation in earthworm

ova and sperms (the latter derived from the other individual) are passed into it along with some albumen secreted by certain glands present in this region. When the worm completely withdraws itself from this girdle, the openings of this girdle at both the ends close up

by virtue of their elasticity. Thus, a closed case containing eggs and sperms is formed which is known as the **cocoon**. The eggs are fertilized by the sperms within the cocoon and undergo segmentation; usually one fertilized egg undergoes complete development to give rise to a new individual. The albumen in the cocoon serves to provide nourishment to the developing embryo. The young hatches from the cocoon and does not undergo any metamorphosis. In Pheretima, cocoons are formed throughout the summer months particularly during and after the monsoon.

Regeneration : The earthworms do not resort to any asexual reproduction. It, however, frequently happens by accident, that a worm is cut into two or more parts. In this case, each cut end is capable of reforming or regenerating the missing portion. This phenomenon is referred to as *regeneration*.

Revision questions

1. What is meant by the term 'metameric segmentation'? Explain this with the example of an annelid you have studied.
2. Describe in detail the mode of locomotion in an earthworm.
3. What is the economic importance of an earthworm? Why is it called *a friend of the gardener and the agriculturist* ?
4. Describe the internal structure of an earthworm as illustrated by a transverse section passing through the intestinal region of the body.
5. Compare and contrast the structure of a coelomate triploblastic animal like an earthworm with that of a diploblastic animal like the hydra.
6. Describe in detail the flow of blood in *Pheretima posthuma* behind the fourteenth segment of the body i.e, the intestinal region.
7. Describe in detail the circulation of blood in the first fourteen segments of the body of *Pheretima posthuma*.
8. Describe the digestive system of *P. posthuma* and explain how is this adapted to its mode of feeding?

9. What is meant by Enteronephric and Exonephric nephridial systems? Explain this by giving an account of the excretory system of *Pheretima posthuma.*

10. Give an account of the reproductive system of earthworm and mention in brief the process of copulation and cocoon formation.

11. Write notes on the following:
    (a) Chloragogen cells (b) Coelom
    (c) Typhlosole (d) Septal nephridium
    (e) Nervous system of earthworm.

Megascolex mauritii :

Megascolex mauritii is another species of an earthworm commonly found in South India. The details given below about *Megascolex*, particularly refer to the internal structure and characteristics in which it differs from *Pheretima posthuma.*

External Characters : **Megascolex mauritii** is long and cylindrical in shape attaining a length of 80 mm to 210 mm. The dorsal surface of the body is dark purplish brown and the ventral surface is paler in colour. The body is divided up into a number of segments varying from 80 to 100 or more in number. The mouth is situated antero-ventrally. A fleshy lobe called the **prostomium** hangs over the mouth. The segment in which the mouth is situated is called the **peristomium.** At the posterior extremity of the body is the aperture of the anus surrounded by the **anal segment.**

In mature worms, extending over the segments 14 to 17, is found the **clitellum** in the form of a girdle, like the glandular thickening of the skin.

All the segments of the body behind the first have tiny setae. They are composed of a substance called the *chitin.* They are found embedded in the setigerous sacs all round the segment except midventrally. The setae continuously fall out and are always replaced by the new ones during the life of the worm. The region of the clitellum, during the breeding season is devoid of setae as they are shed.

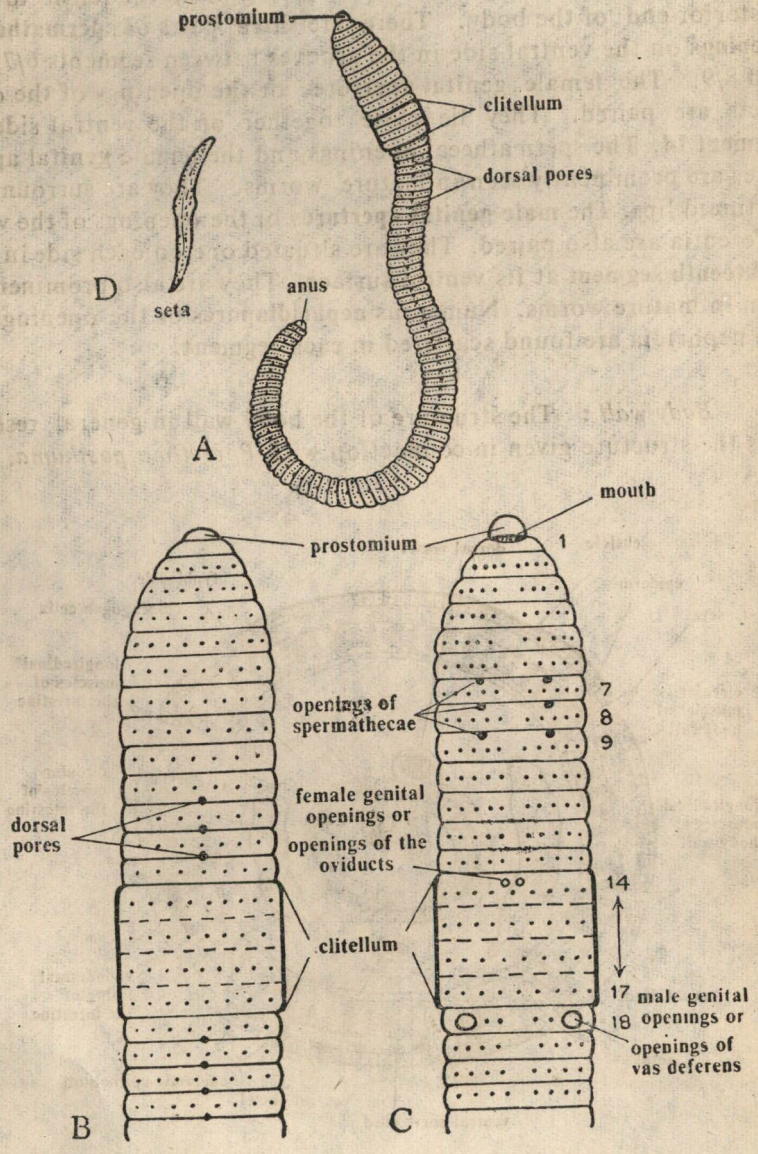


Fig. 5·27 Megascolex — (A) Entire worm (B) Anterior part-dorsal view (C) Anterior part — ventral view (D) A seta

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The dorsal pores are found in the mid-dorsal line one in each groove between the segments commencing from the tenth to the posterior end of the body. There are three pairs of **spermathecal openings** on the ventral side in the grooves between segments 6/7,7/8 and 8/9. The female genital apertures or the openings of the oviducts are paired. They lie close together on the ventral side in **segment 14.** The spermathecal openings and the female genital apertures are prominently seen in mature worms. They are surrounded by tumid lips. The **male genital apertures** or the openings of the vasa deferentia are also paired. They are situated one on each side in the **eighteenth segment** at its ventral surface. They are also prominently seen in mature worms. Numerous **nephridiopores** or the openings of the nephridia are found scattered in each segment.

Body wall : The structure of the body wall in general, resembles the structure given in connection with *Pheretima posthuma.*

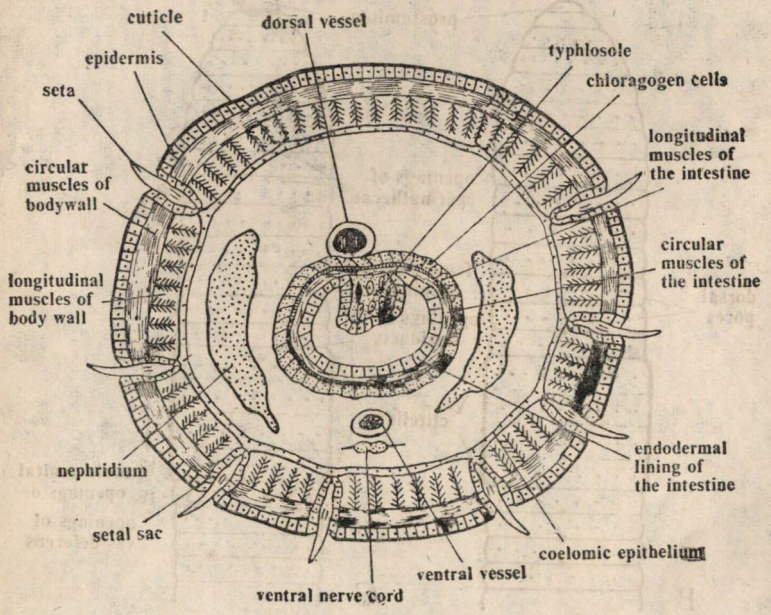


Fig. 5·28 A transverse section passing through the region of the intestine of the earthworm

Body Cavity : The coelom or body cavity is lined by mesoderm and is found between the body wall and the wall of the alimentary canal. It is divided up into compartments due to the presence of septa. The coelom contains the coelomic fluid in which are present the coelomic corpuscles. The coelom communicates to the exterior

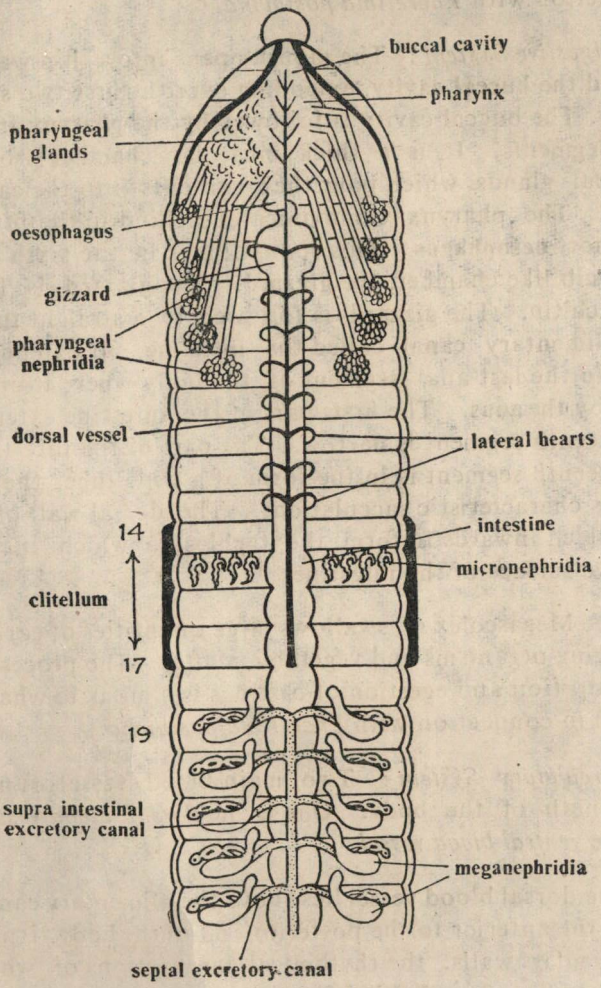


Fig. 5.29 Megascolex mauritii—The alimentary canal, excretory and circulatory systems

through the dorsal pores. In figure 5.28, the various layers of cells forming the body wall and the wall of the alimentary canal are shown.

Locomotion: Locomotion is performed by the contraction and relaxation of the muscles of the body in the same way described in connection with *Pheretima posthuma.*

Digestive System: The mouth opens into a thin walled chamber called the **buccal cavity**, extending over the first two segments of the body. The buccal cavity is followed by the **pharynx** in third and fourth segments. It is a thick muscular chamber provided with pharyngeal glands which pour their contents into the cavity of the pharynx. The pharynx communicates behind in the fifth segment with a short **oesophagus**. This soon dilates in the sixth segment to form a bulb like chamber, the **gizzard**. The gizzard is lined internally by chitin. The gizzard is followed by a straight tubular part of the alimentary canal called the **intestine**. It extends from the seventh to the last anal segment of the body where it opens to the exterior by the **anus**. The first part of the intestine extending upto the fourteenth segment is narrow. The part of the intestine behind the fourteenth segment is in the form of a wide tube, the surface of which has characteristic sacculations. The dorsal wall of the intestine is folded inwards to form the **tophlosole** which increases the absorptive surface of the intestine.

The Megascolex *sp.* swallows large quantities of earth containing decaying organisms and vegetable matter. The process of digestion, absorption and egestion of castings is similar to what has been described in connection with *Pheretima posthuma.*

Circulatory System: Two main blood vessels run along the entire length of the body. One is the *dorsal blood vessel* and the other, the *ventral blood vessel.*

The dorsal blood vessel lies above the alimentary canal extending from the anterior to the posterior end of the body. It is provided with muscular walls, the rhythmical contractions of which, allow the blood to flow from behind forwards The lumen of the vessel is provided with paired valves which allow the blood to flow from the posterior end of the body to the anterior end.

Eight pairs of lateral contractile vessels known as the lateral commissural vessels or the hearts, connect the dorsal blood vessel with the ventral blood vessel. These hearts lie in the 6, 7, 8, 9, 10, 11, 12 and the 13th segments of the body. The last four pairs of hearts situated in segments 10th to 13th are larger than the first four. The hearts pump out the blood from the dorsal to the ventral blood vessel.

The dorsal blood vessel is the chief collecting channel. It receives blood in each segment from the intestine through two pairs of vessels. The blood from the integument is poured into the dorsal vessel through a single pair of vessels.

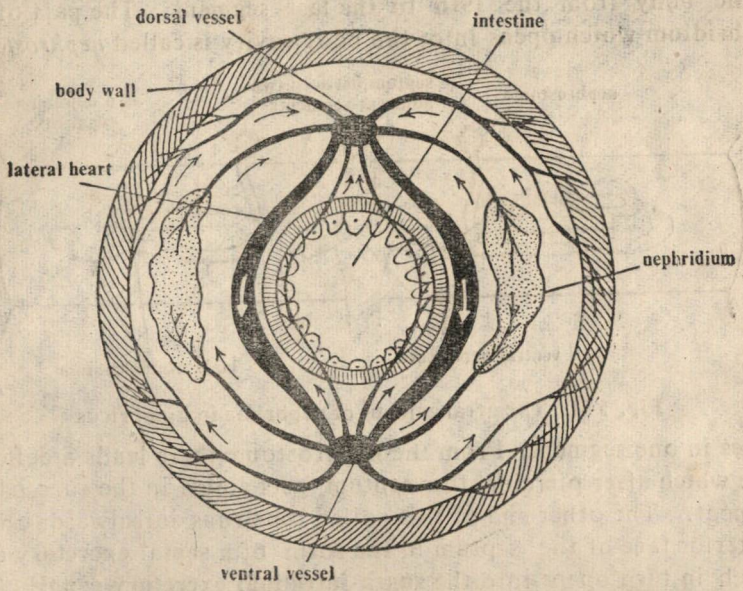


Fig. 5.30 Megascolex—Diagrammatic representation of the course of blood in circulation

The ventral blood vessel like the dorsal, runs along the entire length of the body below the alimentary canal. The ventral blood vessel is non-contractile and the blood in it, flows from the anterior end of the body to the posterior end. It has no valves. It is the chief distributing channel of the body and gives off in each segment branches supplying blood to the intestine, nephridia and body wall.

The summary of the circulation of blood is as follows :

The dorsal blood vessel collects blood from the intestine and the skin. The blood from it, further passes into the ventral blood vessel via the hearts. The ventral blood vessel distributes blood to the various parts of the body. The blood supplied to the skin gets aerated. Likewise, the blood supplied to the nephridia gets rid of its nitrogenous waste. The blood from the skin and nephridia ultimately reaches the dorsal vessel through various branches.

Excretory System : The excretory system in Megascolex like *Pheretima* consists of nephridia. There are three types of nephridia met with in genus *Megascolex.*

1. **Meganephridia** : They are found in pairs in each segment of the body from the 19th to the last segment. The part of the nephridium which opens into the body cavity is called *nephrostome.*

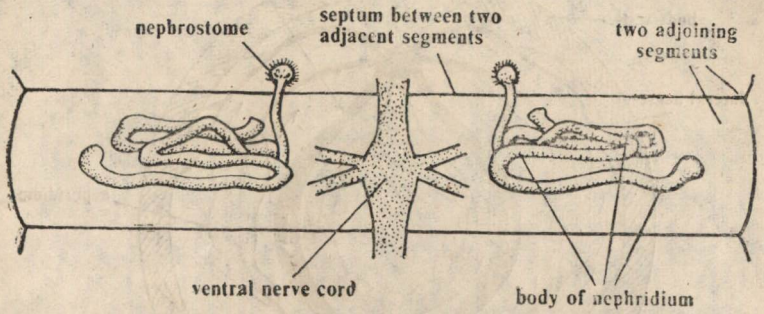


Fig. 5·31 The arrangement of nephridia in Lumbricus

It lies in one segment. From the nephrostome there leads a delicate tube which after piercing the septum, gets coiled in the succeeding segment. The other end of this coiled tube runs dorsalwards on the posterior face of the septum in the form of a **septal excretory duct** which in turn opens into the **supra-intestinal excretory canal.** The supra intestinal canal runs above the intestine and below the dorsal blood vessel. In each segment, the supra intestinal excretory canal communicates with the intestine by paired tubes. Thus, the excretory products separated by meganephridia, via, the septal excretory ducts pass into the supra intestinal excretory canal from where through paired ducts they are ultimately discharged into the intestine. The meganephridia as such do not open directly to the exterior. They are **enteronephric** type of nephridia like the septal and the

pharyngeal nephridia of *Pheretima posthuma* and discharge their contents into the gut.

2. **Micronephridia** (Integumentary nephridia) : They are found behind the fourteenth to the last segment of the body. They are in large numbers; 100–150 in each segment. They are in the form of minute, finger shaped tubes in the form of tufts. They are found attached to the inner surface of the body wall just behind the septa and open to the exterior through the **nephridiopores**. They have no internal openings. Just like the integumentary nephridia of *Pheretima* they are **exonephric.**

3. **Pharyngeal nephridia :** They are found in the form of paired tufts of coiled nephridial tubes situated in segments 5, 6, 7, 8 and 9 on each side of the oesophagus and the gizzard. From each pharyngeal tufts of nephridia, a separate duct arises and ultimately

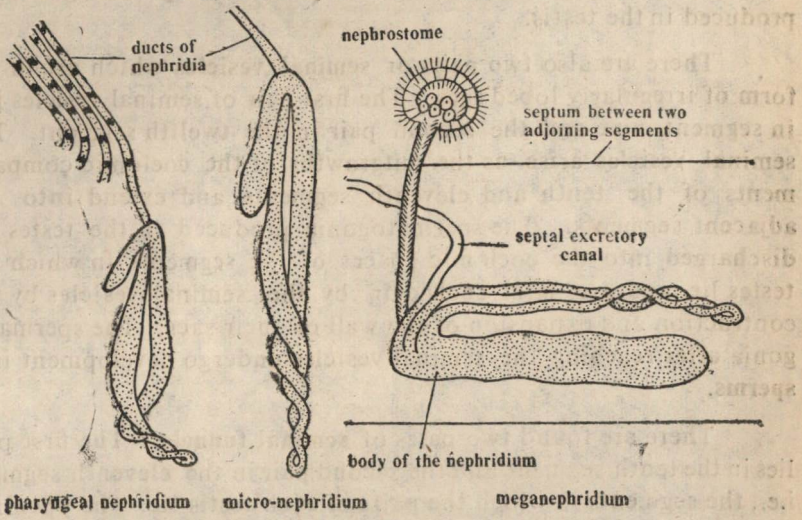


Fig. 5·32 The types of nephridia in Megascolex

opens into the oesophagus. Internal openings are lacking in pharyngeal nephridia like the micronephridia. Chloragogen cells like that of *Pheretima posthuma* are also met with in Megascolex. They are probably excretory in function.

Respiration : The skin is the chief respiratory surface. It is richly supplied with blood capillaries and when it is wet, the

exchange of gases i.e., taking in of oxygen and giving out of carbon-dioxide takes place by the process of diffusion as mentioned in connection with *Pheretima posthuma.*

Nervous System: The nervous system in Megascolex, in general resembles to what has been mentioned in connection with the nervous system of *Pheretima posthuma* (See fig. 5·33).

Reproductive System: Megascolex mauritii like *Pheretima posthuma* is hermaphrodite. Gonads or reproductive organs arise from the proliferation of the coelomic epithelium of the segment in which they lie.

Male Reproductive Organs: Two pairs of testes lie in segments ten and eleven. Each testis is in the form of a tuft of digitate processes. They are found attached to the anterior septa of the 10th and 11th segments. The male sex cells or **spermatogonia** are produced in the testis.

There are also two pairs or **seminal vesicles** which are in the form of irregularly lobed sacs. The first pair of seminal vesicles lies in segment nine and the second pair in the twelfth segment. The seminal vesicles arise as the outgrowths of the coelomic compartments of the tenth and eleventh segments and extend into the adjacent segments. The spermatogonia produced in the testes are discharged into the coelomic spaces of the segments in which the testes lie and are later sucked in by the seminal vesicles by the contraction and expansion of the wall of their sacs. The spermatogonia after reaching the seminal vesicles undergo development into **sperms.**

There are found two pairs of **seminal funnels.** The first pair lies in the tenth segment and the second pair in the eleventh segment i.e., the segments in which the pairs of each testis lie. The openings of the seminal funnels are directed towards the testis. The walls of the funnels are much folded and ciliated. Each seminal funnel continues backwards into a **vas deferens** or the **spermiduct.** There are as such two pairs of vasa deferentia corresponding to the two pairs of seminal funnels. The two pairs of vasa deferentia arising from the hinder ends of the ciliated seminal funnels pierce through the septa on which the funnels lie and later the two vasa deferentia of the same side unite to form a single tube or **common vas deferens.**

Each single tube or common vas deferens on each side of the body later runs backward along the ventral body wall and opens to

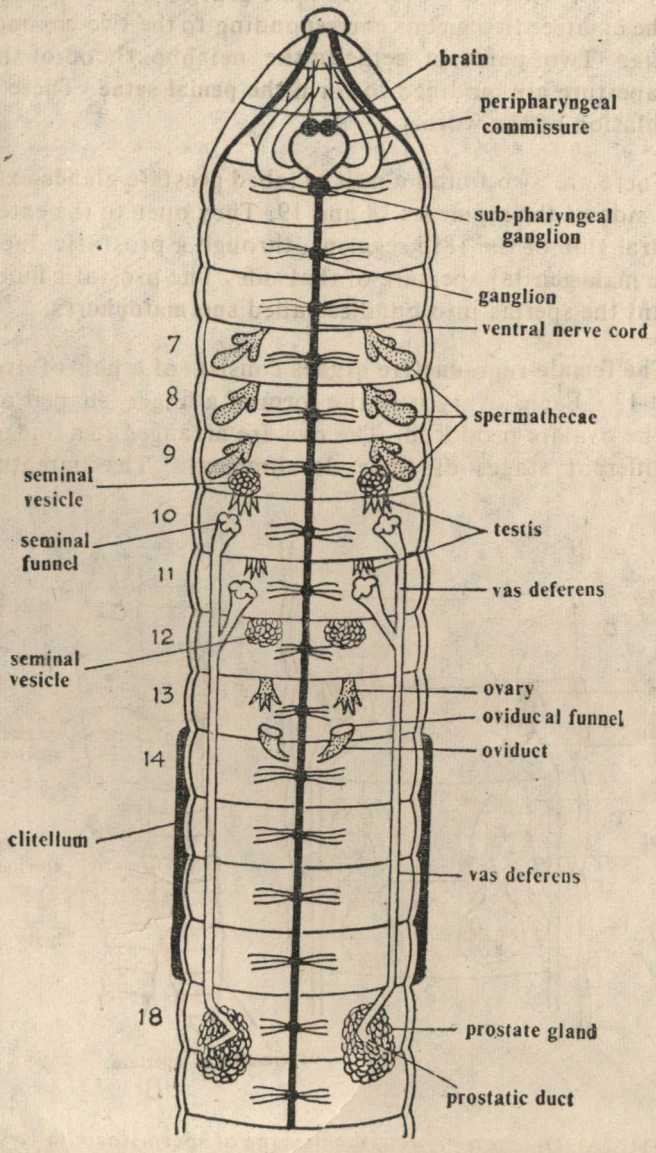


Fig. 5·33 Megascolex—Reproductive and nervous systems.

the exterior through the **male genital aperture** of their own side situated on the ventral side of the eighteenth segment along with the prostatic duct. There are thus two male genital pores on the ventral side of the eighteenth segment corresponding to the two common vasa deferentia. Two pairs of setae in the neighbourhood of the male genital aperture are modified to form the **penial setae**. These help in the copulation of the worms.

There are also found a pair of lobed **prostate glands** extending on each side of the segments 18 and 19. They open to the exterior on the ventral side of the 18th segment through a prostatic duct along with the male genital aperture of that side. The prostatic fluid serves to cement the sperms into bundles called **spermatophores**.

The female reproductive organs consist of a pair of **ovaries** in segment 13. Each ovary is in the form of a finger shaped organ in which the ova are produced. The ova are arranged in a linear series, in the different stages of their development. The immature eggs

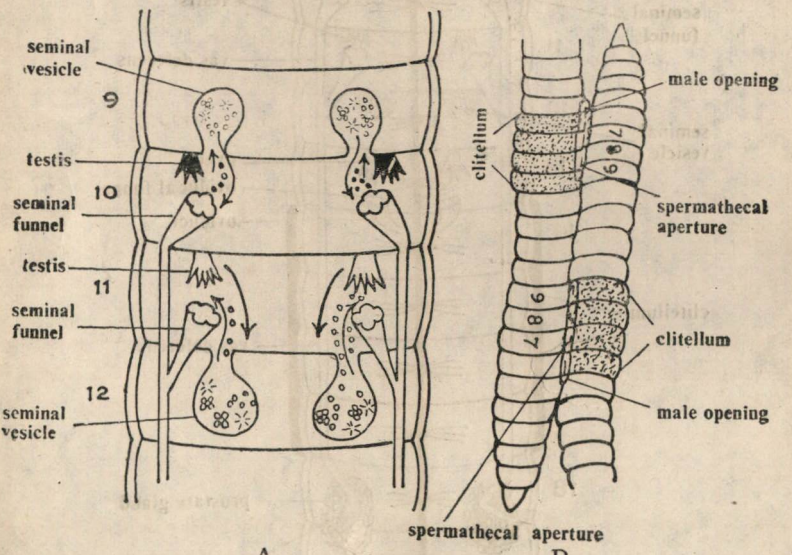


Fig. 5·34 (A) Diagram showing the passage of spermatogonia to seminal vesicle and of sperms to the seminal funnel, (B) Two worms in copulation

being found at the proximal end and the ripe eggs at the distal end of the ovary. Each ovary is found attached to the anterior septum of the 13th segment one on each side of the nerve cord. In front of each overy lies a short **oviduct**. Each oviduct has anteriorly an **oviducal funnel** lying in the 13th segment in front of the ovary. The oviducal funnel continues behind into a short **oviduct** which opens to the exterior through the female genital aperture on the ventral side of the 14th segment. The two **female genital** apertures lie close together on the ventral surface of the 14th segment. Three pairs of **spermathecal sacs** lie in the 7th, 8th and 9th segments of the body and open to the exterior through their respective openings situated on the ventral side between segments 6/7, 7/8 and 8/9. Each spermatheca consists of a sac produced into a neck and opens to the exterior through the spermathecal aperture. Two **small diverticula** are also found one on each side of the base of each spermatheca. The sperms received from another earthworm during copulation are stored in the spermathecae.

Copulation : The copulation between the two worms takes place in the manner described in the account of *Pheretima posthuma*. This results in the mutual transfer of the sperms which are stored in the spermathecae. The worms later separate.

Cocoon Formation : The process of the formation of cocoon is also the same as described in an account on *Pheretima posthuma*.

The fertilized eggs develop within the cocoons. Only a few eggs develop into young worms which crawl out of the cocoon and develop into mature worms.

The chief differences and also resemblances found in *Pheretima posthuma* and *Megascolex mauritii* are summarised below.

Pheretima posthuma

Setae are found alround except mid-ventrally.

Clitellum in segments 14–16.

Blood vascular system : 4 pairs of hearts in segments 7, 9, 12 and 13. First two pairs are called lateral hearts; the last two pairs are known as the latero-oesophageal hearts.

Nephridial system consists of nephridia of three kinds. The septal, integumentary and pharyngeal nephridia. Septal and

pharyngeal nephridia are enteronephric and the ir tegumentary nephridia are exonephric.

Spermathecae : 4 pairs in segments 6, 7, 8 and 9th with a single diverticulum in each spermatheca.

Seminal vesicles : Two pairs in segments 11th and 12th.

Prostate glands : Single pair extending in segments 16 to 21st.

Penial setae absent.

Other Features :

Paired male genital pores are situated on the papillae on the ventral side of the 18th segment. Testes are enclosed in testes sacs. The two vasa deferentia of the same side and the prostatic ducts remain distinct and open by separate apertures on the ventral side of the 18th segment. Female genital aperture is single and is found on the ventral side of the 14th segment. The paired papillae situated on the 17th and the 19th segments bear the opening of the accessory glands.

Distribution : North India, Trivandrum, Ernakulam and Palghat.

Megascolex mauritii

Setae as in Pheretima posthuma.

Clitellum in segments 14–17.

Blood vascular system : 8 pairs of hearts in segments 6th, 7th, 8th, 9th, 10th, 11th, 12th and 13th.

First four pairs small and last four pairs large.

Nephridial system consists of nephridia of three kinds – meganephridia, micronephridia and pharyngeal nephridia.

The meganephridia and the pharyngeal nephridia are enteronephric type. The micronephridia are of exonephric type.

Spermathecae : 3 pairs in segments 7, 8, 9. Each spermatheca with two diverticula.

Seminal vesicles : Two pairs in segments 9 and 12.

Prostate glands : Single pair extending in segments 18 and 19.

Penial setae two pairs. Each pair associated with each male genital aperture.

Other Features :

Male genital apertures paired. Situated on the ventral side of the 18th segment.

Female genital apertures paired lying close together on the ventral side in segment 14.

Distribution : All parts of India with the exception of Uttar Pradesh and Kapurthala in Punjab.

Revision questions

1. Describe the external characters of *Megascolex mauritii.*
2. Describe in detail the circulation of blood in *Megascolex mauritii.*
3. Give an account of the excretory system of *Megascolex mauritii.*
4. Describe in detail the reproductive system of *Megascolex mauritii.*

Leech :

Another good example of an annelid worm is the leech. Leeches are commonly found in fresh water tanks, ponds, slow streams, paddy fields, marshes and swamps. They may occasionally migrate over land to the adjoining ponds or marshes. When they are threatened with drought they usually hide themselves in cool and moist depths of the bed of the pond or swamp in which they live. Some leeches live in the sea as well.

Leeches suck the blood of frogs, fishes, cattle and human beings when they enter the pond. They are thus entirely sanguivorous (blood sucking) animals, hence could be called the **ectoparasites.** The salivary glands of leeches produce a substance called the **hirudin,** which prevents the blood from coagulation while the leech is taking its meal. It is on account of this that the wound made by a leech continues to bleed for a long time even after the leech detaches itself from the site of the wound. The physicians made use of the leeches from ages for their blood sucking habit. The leeches were applied

at the sites of the tumours so as to allow blood letting. With the advancements in the field of medicine, the use of leeches however is now abandoned. Whenever the leeches are in need of a meal, they gorge themselves with blood which may last them from one to six months during which time they live concealed among the weeds and mud. It is also said that leeches can live for more than a year without a second meal.

Leeches belong to the class **Hirudinea**. In the members of this group, the mouth is provided with two or more usually three toothed jaws. Anterior and posterior suckers are found. The body is segmented. The body cavity is much reduced. The setae are absent except in *Acanthobdella*. The nephridia are segmentally arranged. Almost all the leeches are hermaphrodite. The development is direct.

There are several species of leeches. *Hirudo medicinalis* or the medicinal leech is the common British species. *Hirudo (Limnobdella australis)* is an allied Australian form. The giant leech *(Macrobdella valdiviana)* measures 1½ feet when at full length in movement. It is subterranean and carnivorous. *Haemadipsa*, the wiry land leech sucks the blood of man or beast and lives in moist places. The hungry horse leech belongs to the genus *Haemopis*. They are greedily suctorial. *Aulostoma* also is a horse leech, carnivorous in habit.

Herpobdella is a predaceous form with indiscriminating appetite. *Pontobdella muricata* is a marine form of leech preying upon fishes and other animals.

The common leeches found in India belong to the genus *Hirudinaria*. The external characters of *Hirudinaria granulosa* are given below.

Hirudinaria granulosa—The common Indian cattle leech :

External Characters : *Hirudinaria granulosa*, the common Indian cattle leech is found in fresh water ponds, still waters, swamps and slow streams.

A mature fully distended leech is about a foot long. The leech can be contracted into an almost elliptical lump. The body is elongate and dorso-ventrally flattened. The dorsal surface is slightly

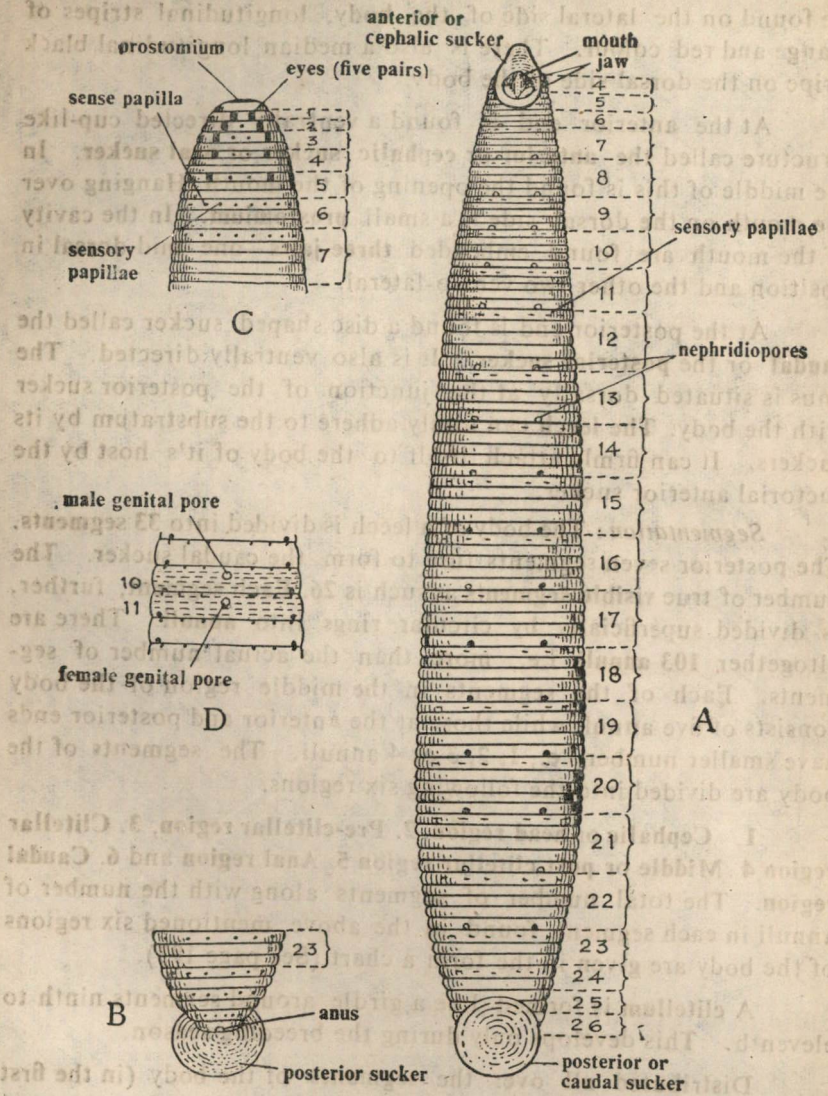


Fig. 5.35 Hirudinaria granulosa— (A) Ventral view, entire worm (B) Hind end, dorsal view (C) Anterior end, dorsal view (D) 10th and 11th segments ventral view with genital apertures

convex and the ventral surface flattened. The dorsal surface presents shades of green colour and the ventral surface is orange red. There

are found on the lateral side of the body, longitudinal stripes of orange and red colour. There is also a median longitudinal black stripe on the dorsal side of the body.

At the anterior end is found a ventrally directed cup-like structure called the **anterior** or **cephalic sucker** or **oral sucker.** In the middle of this is found the opening of the mouth. Hanging over the mouth on the dorsal side is a small **prostomium.** In the cavity of the mouth are found embedded **three jaws**—one mid-dorsal in position and the other two ventro-lateral.

At the posterior end is found a disc shaped sucker called the **caudal** or the **posterior sucker.** It is also ventrally directed. The anus is situated dorsally at the junction of the posterior sucker with the body. The leech can firmly adhere to the substratum by its suckers. It can firmly attach itself to the body of it's host by the suctorial anterior sucker.

Segmentation: The body of a leech is divided into **33 segments.** The posterior seven segments fuse to form the caudal sucker. The number of true **visible segments** as such is **26.** Each segment, further, is divided superficially by circular rings into **annuli.** There are altogether **103 annuli** i.e., more than the actual number of segments. Each of the segments in the middle region of the body consists of five annuli while those at the anterior and posterior ends have smaller number i e., 1, 2, 3 or 4 annuli. The segments of the body are divided into the following six regions.

1. Cephalic or **head region, 2. Pre-clitellar region, 3. Clitellar region, 4. Middle** or **post clitellar region, 5. Anal region** and **6. Caudal region.** The total number of segments along with the number of annuli in each segment found in the above mentioned six regions of the body are given in the form a chart (See page 193).

A **clitellum** is formed like a girdle around segments ninth to eleventh. This develops only during the breeding season.

Distributed all over the segments of the body (in the first annulus of each segment) are found seven pairs of transparent elevations lying around each segment. Four pairs are found on the dorsal side and three pairs on the ventral side of the segment. These are called the **segmental papillae** or **sensory papillae** and have probably a sensory function. At the anterior end of the body on its

Region of the Body	Serial number of segments	Number of annuli in each segment	
	Prostomium	1	
1. Head or cephalic region 1—5=5 segments	1	1	
	2	1	
	3	2	10
	4	2	
	5	3	
2. Pre-clitellar region 6—8=3 segments	6	3	
	7	4	12
	8	5	
3. Clitellar region 9—11=3 segments	9	5	
	10	5	15
	11	5	
4 Post-clitellar or middle region 12—22=11 segments	12	5	
	13	5	
	14	5	
	15	5	
	16	5	
	17	5	55
	18	5	
	19	5	
	20	5	
	21	5	
	22	5	
5. Caudal or anal region 23—26=4 segments	23	4	
	24	3	
	25	2	11
	26	2	
6. Caudal sucker 27—33=7 fused segments	27, 28, 29, 30, 31, 32, 33	...	
Total :	26 segments visible + 7 fused = 33		103

dorsal side are found five pairs of small pigmented spots called the **eyes.** Each pair of the eyes is situated in each of the first five segments of the body.

Leech is a hermaphrodite. Male and female reproductive organs are found in the same individual. On the mid-ventral line in the second annulus of the **tenth segment** is found the **male genital aperture.** Likewise, the **female genital** aperture lies on the second annulus of the **eleventh segment.** Seventeen pairs of **nephridiopores** are situated ventro-laterally in the last annuli of segments **sixth** to **twenty-second.**

Revision questions

1. Describe in detail the external characters of a leech.

CHAPTER VI

ARTHROPODA

[The joint footed animals]

Arthropods are also coelomate triploblastic animals with a bilateral symmetry. Their body also is divided into segments and most of the internal organs of the body are segmentally arranged.

The epidermis secretes a tough cuticle which serves as an *exo-skeleton.* The body is usually distinguished into an anterior **head**, followed by **thorax** and **abdomen.** From the head, thorax and abdomen, a series of segmentally arranged appendages arise. Those arising from the head and surrounding the mouth are helpful in obtaining the food. Other appendages from the thorax, are the limbs which help in locomotion. Likewise, appendages arise from the abdomen also. According to their position, the appendages are referred to as **head, thoracic** and **abdominal appendages.** These appendages are jointed structures, hence the name of the group *Arthropoda* (Gk. *arthron,* joint, *podos,* foot) or *joint footed animals.*

The body cavity in arthropods is very much reduced. The main body cavity is a **haemocoel**—i.e., the blood vascular system is so expanded that the main organs of the body lie in the blood filled cavities or haemocoel.

As an example of an arthropod, the cockroach will be studied in detail.

Cockroach :

The **cockroach** is an anthropod belonging to the group of insects. Insects have their bodies divided into head, thorax and abdomen. They are provided with three pairs of legs and usually a pair of wings. They further possess a pair of **compound** eyes.

It has been estimated that out of roughly one million species of animals so far described, about three quarters are the insects. This figure alone gives us an idea to the success of this group in an evolutionary sense.

The cockroaches are omnivorous. They are the common pests of kitchens, bakeries and store rooms. The cockroaches are nocturnal in habits. Two species of cockroaches are recognised—1. *Periplanata americana* is about 3·2 to 3·8 cm or more in length. Both the sexes have wings. 2. *Blatta orientalis* is smaller in size. The wings in the female are vestigeal. It is often erroneously referred to as the *Black beetle*.

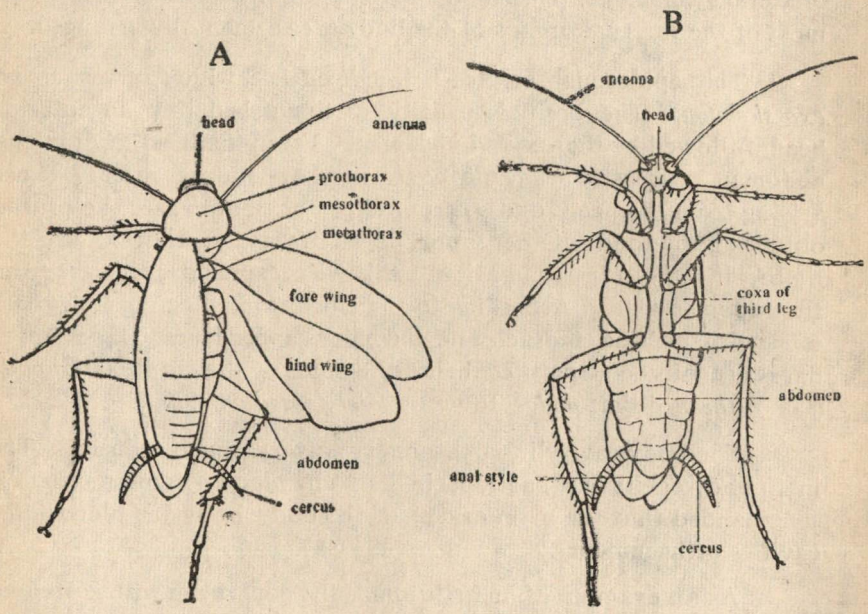


Fig. 6·1 Periplanta americana — (A) Dorsal and (B) Ventral views

External Characters : The body of cockroach is almost ovoid in shaped and dorso-ventrally compressed. The body is covered by a horny exo-skeleton (composed of chitin) in the form of a large number of hard plates or **sclerites.** The sclerites covering the body dorsally are called the **terga** (singular : tergum) and those sclerites covering it ventrally are referred to as **sterna** (singular : sternum). On each side of the body between the tergum and sternum is found the **pleuron.** The pleuron is variable as regards the extent of hardening. Inspite of the hard exo-skeletal plates, the body is well provided with flexibility.

Three distinct regions of the body can be recognised. They are the **head**, the **thorax** and the **abdomen**.

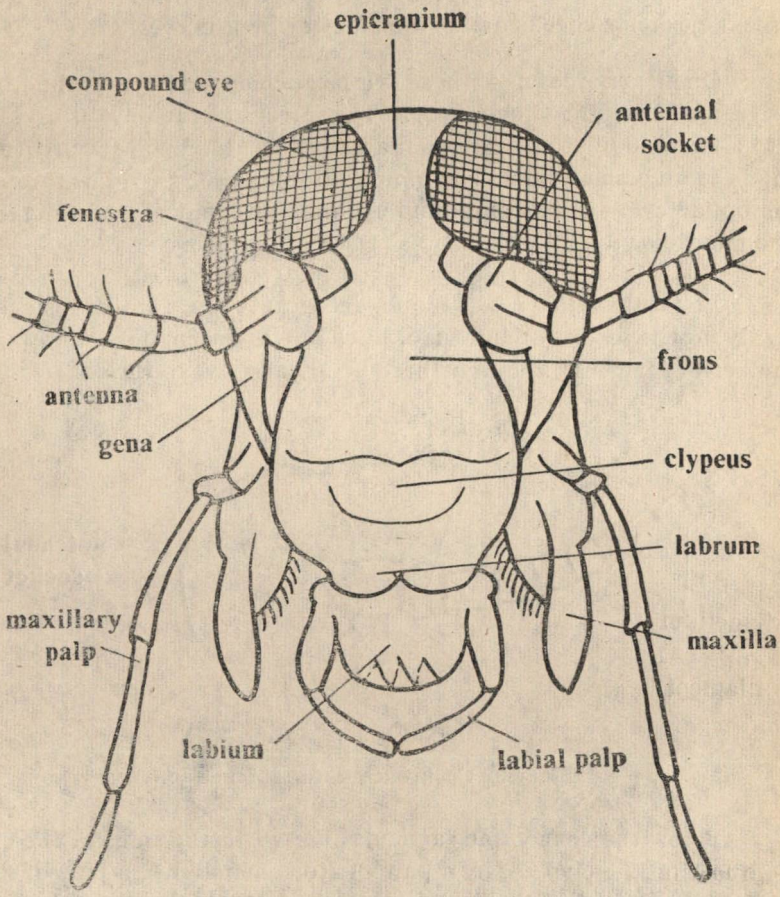


Fig. 6.2 Cockroach — A dorsal view of the head

The head of a cockroach is a flattened pear-shaped structure placed at right angles to the main axis of the body. It is formed of six segments but all external indications of the segmentation have been lost. The sclerites of the head unite to form a compact **head capsule.**

The base of the head capsule consists of a hard plate, the **epicranium** formed by two **epicranial plates**, their position being marked

by the **epicranial suture**. Below the epicranium are the plates, **frons** and **clypeus**. From the lower edge of the clypeus hangs the **labrum** or the anterior wall of the mouth or the upper lip. Two lateral plates—**genae** or **cheeks** are at the sides below the eyes.

On either side of the head is a large **compound eye** in the form of large black kidney-shaped area. The surface of each eye is divided into a large number of hexagonal areas or facets. Each facet corresponds to an **ommatidium**. The ommatidium is a single element of the compound eye. Each compound eye thus is composed of a number of ommatidia.

Just below the eyes, found in sockets are the long slender highly motile feelers or **antennae**. Each antenna is made up of a large number of segments, the first three being larger than the others.

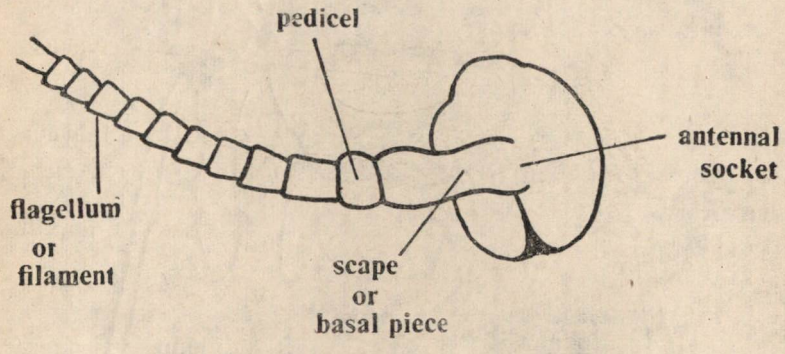


Fig. 6·3 Cockroach — the antenna

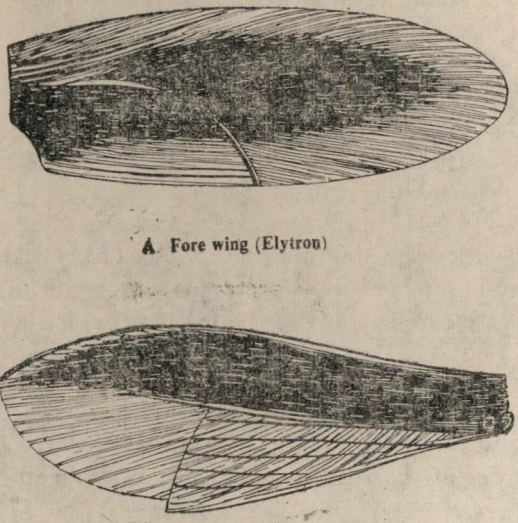
Below the genae and articulating with the sides of the epicranium and the clypeus are a pair of stout **mandibles**, a pair of first **maxillae** with its **maxillary palps** and the **labium**.

On the inner and upper side of each antenna is a small circular area, white in colour and covered by a soft cuticle. These areas are called the **fenestrae**.

The mouth lies at the lower end of the head. It is covered in front by the labrum and below by the labium. The jaws and the first **maxillae** are found at the sides of the mouth.

The Thorax: The head is connected behind with the thorax by a soft slender **neck** or **cervicum.** The cervicum is tucked under the anterior part of the thorax. The thorax consists of three segments called the **prothorax**, the **mesothorax** and the **metathorax** respectively. Each of these segments is covered over dorsally by a chitinous plate, the tergum and ventrally by a sternum. There are two lateral pleura one on each side of the segment. The tergum and the sternum of each thoracic segments are distinct from one another. The tergum of the prothorax is a large triangular plate and overlaps the neck above. It is known as the **pronotum.**

Attached to the anterior border of the tergum of the mesothorax, in both the sexes in **Periplanata americana**, are the anterior pair of **wings** or **elytra.** These are in the form of thick membranous opaque sheaths, and the surface is provided with prominent straight hollow lines called the **veins.** The veins do not form a network but



A. Fore wing (Elytron)

B. The hind wing

Fig. 6.4 Periplaneta — (A) The fore wing (Elytron) (B) The hind wing

are relatively straight. The anterior wings, when folded, extend backwards over the abdomen to some little distance beyond its extremity.

Articulating with the terigum of the metathorax are the posterior pair of wings. These are comparatively thinner membranous expansions, which when at rest, are folded up longitudinally like a fan, under the elytra. The veining is straight.

In the female of **Blatta orientalis**, the wings are only represented by small vestiges.

Attached to the sternum of each segment of the thorax is a pair of legs. There are as such three pairs of legs. Each leg consists of a stout flattened proximal podomere called the **coxa** followed by a small triangular piece called the **trochanter**. From the trochanter there extends an elongated stout **femur**. Femur is well developed in insects which move by leaping. The femur continues into a long **tibia** provided with stiff hairs or setae. The tibia is followed by **tarsus** which is formed by five hairy podomeres. At each joint of the tarsal podomere is found a white adhesive pad called the **plantula**. The last podomere is referred to as **pretarsus** which terminates in a pair of **claws**. The entire surface of the leg is provided with hairs.

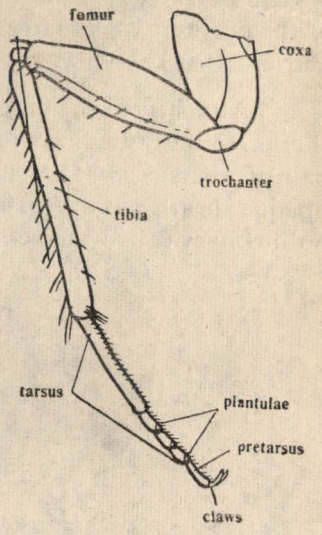


Fig. 6·5 Cockroach—A leg

The Abdomen: The abdomen is dorso-ventrally flattened. There are altogether ten segments of which seven are visible. The 8th and the ninth segments are overlapped by the seventh. The posterior border of the 10th segment presents a deep notch.

The anterior segments of the abdomen bear no appendages. A pair of jointed **cercii** emerge below the edge of the tenth segment *in both the sexes. In the male*, the ninth sternum bears a pair of **anal styles**. The abdominal segments also are covered dorsally by terga, ventrally by sterna and laterally are found the pleura. The tenth segment however has no sternum.

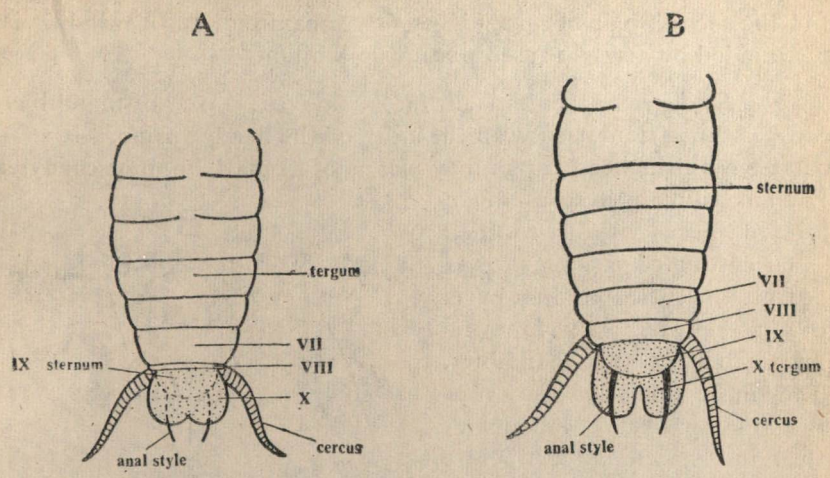


Fig. 6·6 Cockroach — (A) Dorsal view — abdomen (Male)
(B) Ventral view — abdomen (Male)

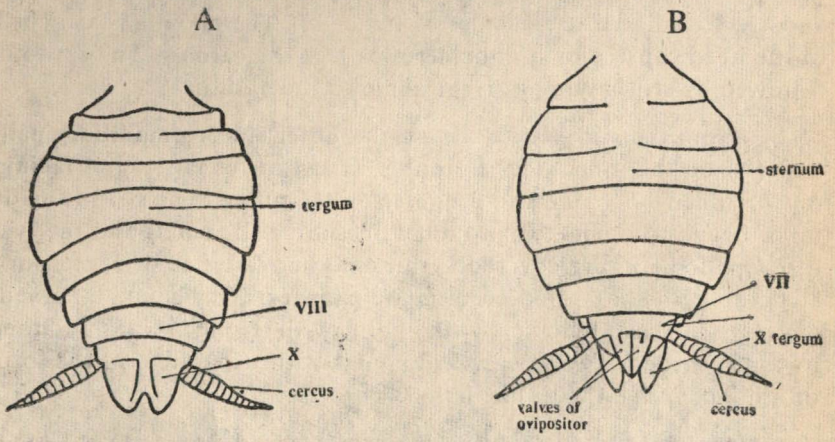


Fig. 6·7 Cockroach — (A) Dorsal view — abdomen (Female)
(B) Ventral view — abdomen (Female)

The mouth parts of cockroach :

The mouth is found on the lower edge of the head. It is covered in front by a small moveable flap, the **labrum** or the upper lip. At the sides it is bordered by the first pair of appendages, the mandibles

and the second pair of appendages, the maxillae and behind, it is surrounded by a single fused plate, the labium.

Mandibles: Once the labrum is removed, a pair of mandibles can be seen articulating with the sides of the head capsule. It articulates with the head capsule by means of a small knob or **condyle**. Each mandible is a stout single jointed piece with a toothed inner **cutting edge**. This bites against the corresponding parts of its fellow. The food is masticated by the mandibles. They move side ways and crush the food particles and render them into smaller pieces before being swallowed in the mouth.

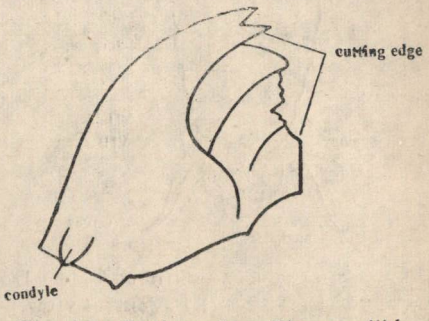


Fig 6·8 Cockroach — The mandible

The Maxillae: The maxillae lie behind the mandibles and are articulated to the sides of the head. The maxilla is attached to the head capsule by a podomere called the **cardo**. The cardo is followed by **stipes** lying at right angle to the cardo.

From the stipes arise (i) on the outer side, a **maxillary palp** and (ii) on the inner side a double structure consisting of **lacinia** on the inner-most side and the **galea** on the outer. The palp is made up of five joints. The two proximal ones are quite small and the two distal podomeres are covered with numerous hairs as it is a sensory structure. The basal podomere is the **palpifer**. The lacinia is curved, ending in a sharp black claw-like point with strong bristles all along its inner border. The galea is triangular at the tip and is in the form of a hood, fringed with fine hairs.

The maxillae function as accessory jaws, assisting in the holding of the food and its mastication.

The Labium: The labium is a median structure. It is in fact formed by the fusion of the two appendages. The fusion is more prominent in its basal region than in the distal parts. It is attached to the head capsule by its base and the remaining part projects downwards and forms thereby the posterior wall of an ill defined cavity.

This cavity is bounded in front by the labrum and on the sides by the mandibles and the maxillae.

The structure of the labium is as follows :

The labium can be divided into two regions – (i) The **post mentum** or **post labium** and (ii) the **prementum** or **prelabium**. The **post mentum** is composed of two median moveable sclerites—the **submentum** and the **mentum**. Beyond the mentum is the region of the labium called the **prementum** or **prelabium**. The evidence of the double composition of the labium here is more prominent.

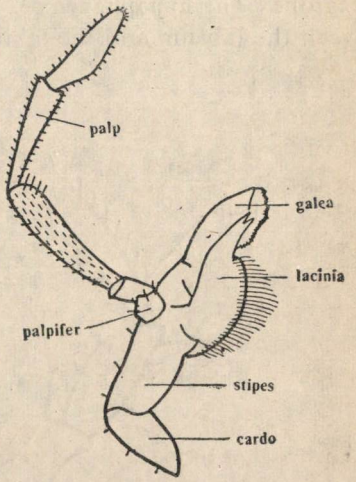


Fig. 6·9 Cockroach—The maxilla

There is a central median sclerotised region of the prementum. From this arises an obviously paired structure, each half of which is composed of an outer **palp** and an inner **bipartite portion**, exactly similar to the distal region of the maxilla.

The outer region, the palp, also called the **labial palp** consists of three joints. Each labial palp arises from a small podomere, the **palpiger**. The bipartite inner portion is made up of outer **paraglossa** and an inner **glossa**. Glossae show partial fusion. They are homologous with the **galae** and **lacinae** of the maxilla, i.e., **paraglossa** is homologous with **galea** and **glossa** is homologous with **lacinia**. In the cockroach, the glossae and the paraglossae are not strongly developed. In honey bee, on the other hand the glossae are much exaggerated.

The structure of the labium thus shows to us it's double nature. An alternative name for the labium is the **second pair of maxillae** and the maxillae are as such referred to as the **first pair of maxillae**.

In addition to the above mentioned true mouth appendages there are other structures which are also to be described along with the mouth parts. Labrum is a structure hinged to the head capsule mentioned earlier in connection with the sclerites of the head. The

inner wall of the labrum is sometimes called the **epipharynx**. The epipharynx forms the roof of the mouth cavity. It is regarded as having a gustatory function. The sense of taste is attributed to this region. The **hypopharynx** is an elongated tongue-like structure between the labrum and the labium. It is in the form of a groove or a

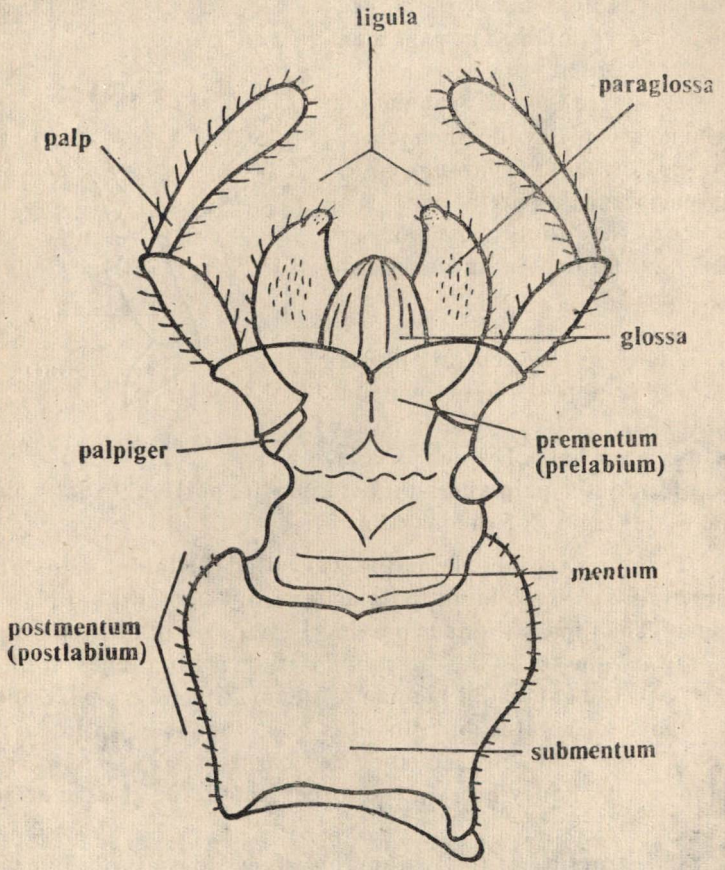


Fig. 6·10 Cockroach — The labium

gutter and is sometimes called **lingua** in the cockroach. The hypopharynx receives the salivary duct and the saliva is discharged and mixes here with the food during external mastication.

The Alimentary Canal : As mentioned above, the ill defined mouth cavity is bounded by the epipharynx and labrum anteriorly,

the hypopharynx and labium posteriorly and at the sides are found the mandibles and the maxillae. At the base of this rather indeterminate cavity lies the aperture of the mouth which leads into the **pharynx**.

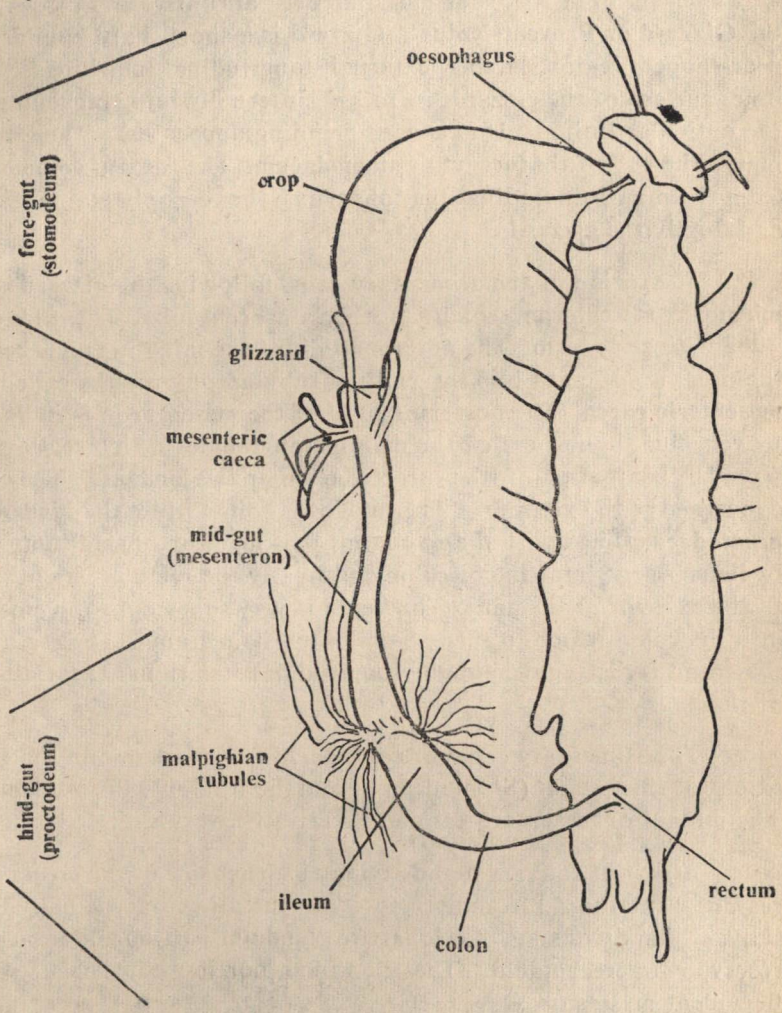


Fig. 6 11 Cockroach — The alimentary canal

The pharynx in cockroach is not very clearly delimited from the succeeding region called the **oesophagus**. The oesophagus traverses

the neck into the thorax and soon dilates to form a **crop**. The crop is in the form of the large pyriform sac which occupies the thorax and extends well into the abdomen.

The crop at its distal end narrows abruptly and passes into the **Gizzard** or **Proventriculus** Gizzard is a short, hard rounded or pear-shaped region having external longitudinal markings. The inner surface of the gizzard is raised internally into thickenings of the cuticular lining. It acts as a grinding apparatus. The gizzard marks the end of the **foregut** or **stomodaeum.** The foregut commences from the mouth including the pharynx, the oesophagus, the crop and finally the gizzard.

The region of the alimentary canal following the gizzard is the **midgut** or **mesenteron**, which is rather a narrow tube. The midgut is lined with endoderm. The anterior limit of the midgut is marked by the presence of eight blindly ending tubular outgrowths called the **mesenteric caeca**. The posterior limit of the mesenteron is indicated by very fine tubules called the **malpighian tubules** which really arise from the beginning of the **proctodaeum** or the **hindgut.** They are concerned with excretion. The midgut is followed by the **hindgut** or **proctodaeum** lined with the ectoderm It is made up of **small intestine** or **ileum, large intestine** or **colon** and finally the rectum which opens to the exterior at the **anus**. The ileum is very short and soon emerges into the colon which in turn passes into the rectum. The rectum is short and is distinguishable by longitudinal striations. It terminates at the anus.

The alimentary canal of cockroach is remarkable in the great extent of the foregut (Stomodaeum) and the hindgut (Proctodaeum). The midgut or mesenteron is comparatively a very short region.

A pair of salivary glands lying on either side of the crop in the region of the thorax form accessories to the alimentary canal. Each salivary gland consists of a **bipartite glandular portion** and a sac-like **reservoir** or **receptacle.** The glandular portion consists of white flocculent masses.

From the glandular portion, a duct arises which soon joins its fellow of the opposite side to form a common duct from the glandular portion. Similarly, the duct from the reservoir or the receptacle also

joins it fellow to form a single duct. The two ducts together, i.e., from the glandular portion and the reservoir finally unite to form a single **efferent salivary duct** which opens into the mouth cavity on the hypopharynx.

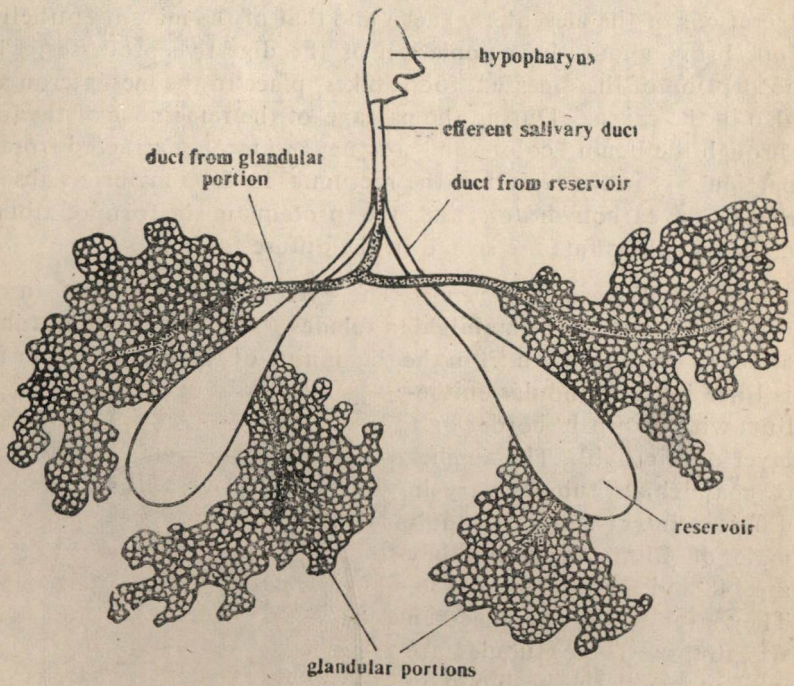


Fig 6·12 Cockroach—The salivary glands and hypopharynx

Nutrition : The cockroach can use any kind of organic material belonging to animals and plants. It can even swallow dead bodies of its fellows and even its own cast cuticle. The food material is held up and is cut into pieces by the mandibles assisted by the maxillae. The food is later pushed into the mouth cavity from where it passes into the pharynx. During mastication the saliva is poured on to the food from the aperture of the salivary duct on the hypopharynx. This moistened food is passed down the oesophagus and later reaches the crop where it is retained for some time. The saliva contains diastatic enzymes; hence the digestion begins at once. Within the crop, the food is acted upon by the proteolytic enzymes which are regurgitated from the midgut. The gizzard by its contraction assists

in breaking up the partially digested food but most probably it acts more like a filter which allows only food particles of the appropriate size to pass into the mesenteron. Within the mesenteron, the food is more completely subjected to the enzymatic secretion. The secretions of the mesenteric caeca and that of the midgut epithelium thus bring about the completion of the digestive processes. The absorption of the digested food takes place in the mesenteron and also in the caeca. During the passage of the remainder of the food through the ileum, colon and rectum, water is extracted from it, particularly in the region of the rectum. The food materials absorbed i.e., the carbohydrates, and the proteins in the form of albuminoids as well as fats are stored in the diffuse fat body.

The Excretory System : The excretory products of insects are carried out by the **malpighian tubules**. Each malpighian tubule arises as an outgrowth from the beginning of the proctodaeum and is lined by a glandular epithelium with a brush border or a layer of microvilli. The number of malpighian tubules vary in different insects. In the adult male of **Blatta orientalis** they are 148 and in the female 186. They are usually arranged in six groups. These tubules are freely exposed to the blood in the haemocoelic body cavity and extract from the blood the nitrogenous waste which is later passed into the proctodaeum.

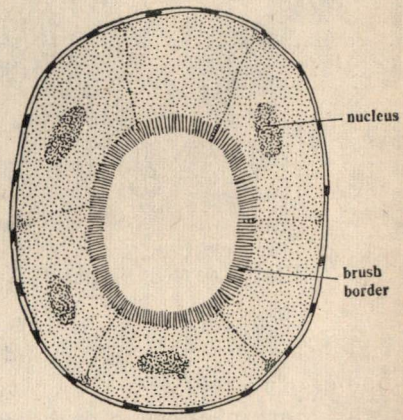


Fig 6.13 Cockroach—A transverse section passing through a Malpighian tubule

The Blood Vascular System : In cockroach, the blood vascular system does not consist of a system of closed blood vessels as was seen in the case of an earthworm. There are no definite blood vessels. The blood is found in large spaces or sinuses which surround the different internal organs. These blood spaces are called the **Haemocoelic spaces**. The blood vascular system mainly contists of a

series of haemocoeles. The circulation of blood through these haemocoeles is maintained by the pulsations of the dorsally situated **'heart'**.

The heart is a long contractile tube enclosed in a **pericardial sinus** or **cavity** lying in the middle line immediately beneath the terga of the thorax and abdomen i.e., close under the skin It is divided into **thirteen chambers**, corresponding to the number of thoracic and abdominal segments. Each chamber of the 'heart' is narrowed in front. This narrowed portion projects into the chamber next in front and is guarded by a valve which permits the blood to flow in a forward direction only. At the broader hinder end of each chamber is a pair of **ostia** or holes through which the blood enters from the pericardial cavity. There are valves which prevent the blood being forced out of the ostia. The heart as mentioned earlier, lies in a pericardial sinus or cavity formed by a horizontal membrane stretched across the body. This pericardial wall or membrane is perforated by a number of small openings through which the blood passes from the haemocoel to the pericardial sinus.

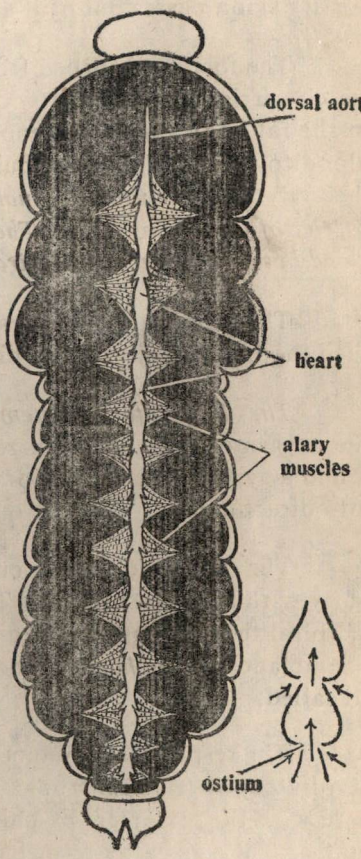


Fig. 6·14 Periplanata—the 'Heart'

A series of 12 paired triangular muscles called the **alary muscles** are found inserted in the ventral pericardial wall. The pointed ends of these alary muscles take their origin from the undersides of the terga of the thorax and the abdomen. When at rest, the pericardial septum is arched upwards. By the contraction of the alary muscles it is pulled outwards and

flattened due to which the cavity of the pericardium enlarges. This facilitates an inflow of blood into the pericardial cavity from the rest of the haemocoel. Later on, the blood from the pericardial sinus enters the 'heart' chambers through the ostia. By the alternate contraction of the alary muscles and the muscular wall of the heart the blood flows into the heart chambers from behind forward. Anteriorly, the heart is continued forwards as the **dorsal aorta** which opens by a trumpet shaped orifice into the haemocoel. Thus, the blood coming from the chambers of the heart after entering the aortic region passes out of it and bathes all the organs of the body.

The food is absorbed from the alimentary canal into the blood which carries it to all parts of the body. Superfluous fat is stored in the fat body and nitrogenous waste materials are carried by the blood to the malpighian tubules from where they are passed out of the body. *Unlike what is usual in other animals the role of blood as a carrier of O_2 is almost nil. The oxygen is carried to all organs not by blood but by a system of respiratory tubes or trachea.*

The blood is a colourless fluid devoid of haemoglobin. Within the blood, numerous large white corpuscles flow.

The Respiratory System : In the terrestrial insects which use the oxygen of the atmosphere for their respiratory needs, there is found a system of air tubes or **tracheae** by which the air is brought into direct contact with the organs and tissues of the body.

The tracheae have a cuticular lining since they are in continuity with the exo-skeleton. The lining of the air tubes has annular or spiral thickenings. This gives the respiratory tubes a superficial resemblance to the *human trachea* and is the reason, for they being so called.

The respiratory system of cockroach consists of a system of respiratory or tracheal trunks. The main tracheal trunks communicate with the exterior by paired apertures termed **spiracles** or **stigmata** The stigmata are segmentally arranged.

On the sides, situated in the soft membranes connecting the terga with the sterna are **ten pairs** of **stigmata** or openings leading to

the respiratory tubes or tracheae. Two of these are larger and situated on the sides of the thorax, one between the prothorax and mesothorax and the other between the meso and meta thorax. The remaining eight pairs of stigmata are situated between the lateral margins of the tergum and sternum at the anterior end of each of the first eight segments of the abdomen. Each spiracular aperture is surrounded by an annular sclerite and leads into a cavity called the **atrium** or tracheal chamber. From the tracheal chamber arise the main tracheal trunks. The main tracheal trunks have a definite and symmetrical arrangement. There are dorsal arches running up towards the heart and ventral arches descending towards the nerve cord. These arches are connected with one another longitudinally by trunks which run on each side of the pericardium and the nerve cord. Large trunks are also given off to the alimentary canal. The main tracheal trunks ultimately terminate in minor branching tubes called the **tracheoles**. The tracheoles in turn divide into capillaries.

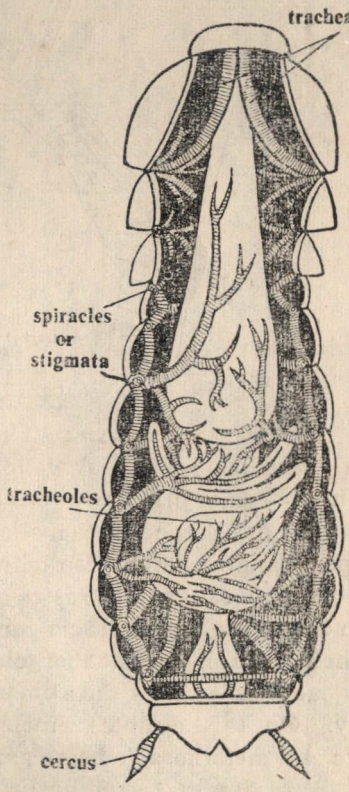


Fig. 6-15 Periplanata—tracheal system

The capillaries are intracellular and have no cuticular lining. They penetrate every organ and tissue of the body. The tracheae being full of air present a glistening white silvery appearance.

Respiration is effected by the alternate arching up and flattening of the abdomen resulting in an alternate increase and decrease of its volume. This secures an alternate inflow and outflow of air from the trachea. Although some CO_2 may pass out into the trachea and leaves the body via the spiracles, it is also

probable that some part of CO_2 dissolves in the blood and then passes outwards through the cuticle. Because of the development of the tracheal system, the respiratory role of the blood is however at a minimum and quite negligible.

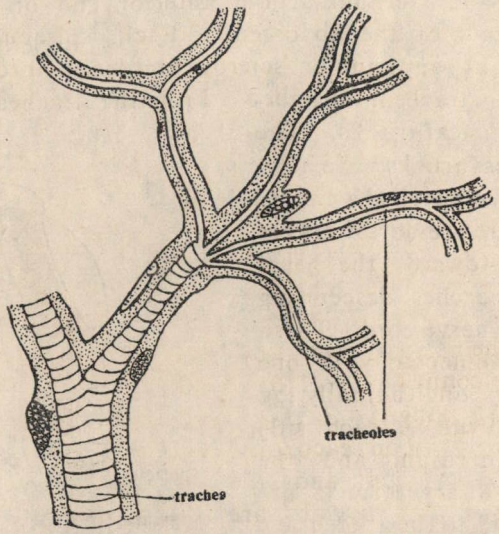


Fig. 6·16 Cockroach—The trachea and the tracheoles

The Nervous System : The nervous system of cockroach consists of a pair of cerebral ganglia lying in the region of the head. From the brain arise two circum-oesophageal connectives, which pass around the oesophagus and meet below with the sub-oesophageal ganglia which also lie within the head capsule. From the sub-oesophageal ganglia passes a pair of stout connectives traversing the neck to the first thoracic ganglion which is quite large and round in shape. From the **1st thoracic ganglion** the two nerve connectives pass backwards below the alimentary canal upto the last end of the body. On this double ventral nerve cord are found the **mesothoracic** and **metathoracic nerve ganglia** and **six abdominal ganglia.** The first five abdominal ganglia lie in the first five abdominal segments and the last, some short distance behind. This last paired abdominal ganglion is larger than the others and represents a number of fused ganglia. From each pair of the ganglia, nerves are issued which pass to the various parts of the segments in which they lie and form the peripheral nervous system. The nerves to the eyes and antennae arise

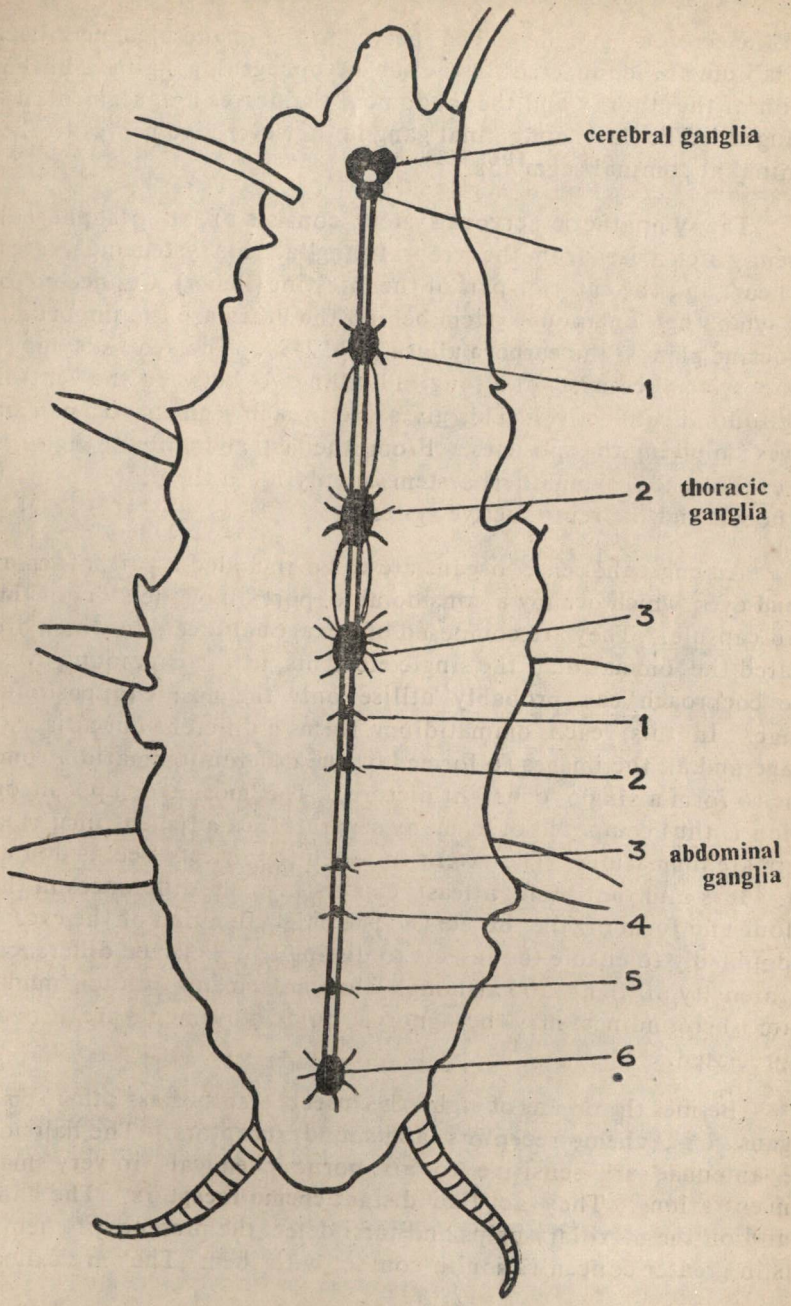


Fig. 6·17 Cockroach—The nervous system

from the cerebral ganglia The nerves to the mandibles, maxillae and labium are connected to the sub-oesophageal ganglia. In the region of the thorax and the abdomen, the nerves are segmentally arranged. The last abdominal ganglia however give nerves to the terminal abdominal segments.

The sympathetic nervous system consists of an oesophageal system which arises from the cerebral ganglia. This system innervates the heart and the anterior part of the intestine (ileum). Connected to this sympathetic nervous system behind the brain are the important endocrine glands, the **corpora allata** (cfp. 219). The ventral sympathetic system consists of a longitudinal nerve between the ventral longitudinal connectives. This gives rise in each segment to a pair of nerves supplying the spiracles. From the last abdominal ganglion, arises the caudal sympatheic system supplying to the posterior part of the gut and the reproductive system.

Amongst the sense organs are to be included a pair of **compound eyes** which occupy a considerable portion of the sides of the head capsule. They are composed of hexagonal facets in which are located the ommatidia, the single elements of the compound eyes. The cockroach can probably utilise only the **mosaic (apposition) image**. In this, each ommatidium forms a different but adjacent image and all the images so formed by the different ommatidia combine to form a single coherent picture. The mosaic or apposition vision is thus composed of as many separate but adjacent images as there are ommatidia. The extent to which the insects 'see' is doubtful. It is said that some atleast can distinguish differences in the colour and form of the objects. The chief function of the eyes is undoubtedly to enable the insects to distinguish between differences in intensity of light and although slow movements in their immediate surroundings may be ignored, quick movements are at once appreciated.

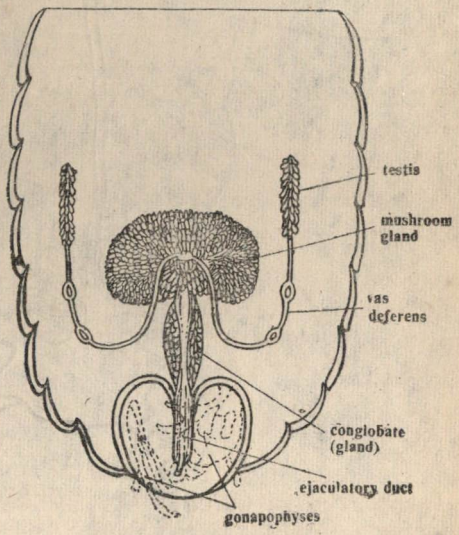
Besides the organs of sight, the insects also possess other sense organs, e.g., chemo-receptors and sound receptors. The hairs on the antennae are sensitive to air borne chemicals in very small concentrations. They act like **distant chemo-receptors**. The hairs found on the maxillary palps and tarsi detect the presence of chemicals in greater concentration in contact with them. They are called

contact chemo-receptors. The hairs on the anal cercii detect air currents or sounds of low frequency. Crickets have better developed hearing organs.

There also occur **sensillae** in the form of a group of sensory cells on the labial palps, antennae, cercii and tarsi. The sensillae detect rise in the temperature. The cold receptors are chiefly located on the tarsi.

The Reproductive System : In cockroach the sexes are separate.

The Male Reproductive Organs : Male reproductive organs consist of a pair of **testes**. They are a pair of small bunches of transparent vesicles one on each side embedded in the fat body below the terga of the fifth and sixth abdominal segments. In the adult, the testes do not function and seem to atrophy. In the young males, they can easily be distinguished. They look somewhat like elongated bunches of cherries which are connected by short ducts. From each testis there arises a short duct, the vas deferens. The vas deferens from each testis opens into a large reservoir, the **vesicula seminalis** or the "**Mushroom shaped gland.**" It consists of a tuft of finger shaped bodies in the form of blindly ending diverticula. Into these mushroom shaped glands, at an early stage, the cells destined to form spermatozoa pass from the testes and undergo their further development.



Fig, 6·18 Cockroach—The male reproductive organs

The mushroom shaped glands open into a median stalk-like muscular tube, the **ejaculatory duct** or the **ductus ejaculatorius**. The ejaculatory duct opens out on a median rod-like structure below the anus through the **male genital pore**. The male genital opening is

placed between the ninth and the tenth abdominal sterna. Upon the ventral surface of the ejaculatory duct lies an accessory gland of unknown function called the **conglobate gland** which opens amongst the **gonapophyses.** The gonapophyses are a series of chitinous hooks and plates around the genital opening and aid in copulation.

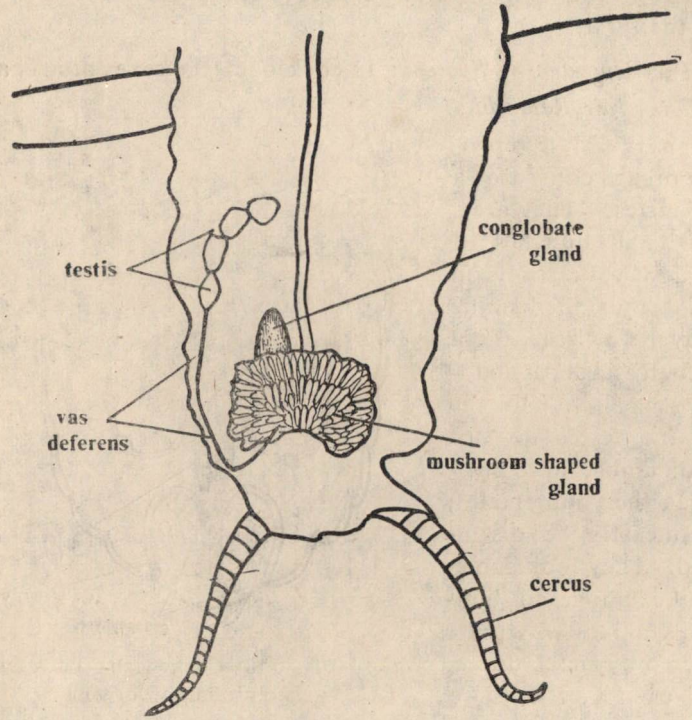


Fig. 6·19 Cockroach—The male reproductive organs the testis and vas deferens are shown on one side only.

The Female Reproductive Organs : The **ovaries** too are paired organs in the posterior abdominal region. Each ovary consists of eight ovarian tubes. They are beaded in appearance as they contain eggs in different stages of development arranged in linear series.

The ovarian tubes of both the ovaries unite at their anterior ends into two cords. Each cord of its own side passes to the dorsal wall of the thorax and becomes attached to the pericardial septum. Each ovary at its posterior end with its ovarian tubules joins to form an **oviduct.** The two oviducts unite to give rise to a median

channel, sometimes called the **vagina** or the **uterus.** The vagina leads into the genital chamber. The genital chamber opens to the exterior through the female genital aperture or **vulva** on the ventral side of the seventh abdominal segment. The seventh abdominal segment is well developed and is modified into the keel-shaped floor of the genital chamber. The genital chamber is provided with a series of chitinous processes forming the gonapophyses. **A spermatheca** also opens into the genital chamber. The spermatozoa from the male are stored in the spermatheca. Into the roof of the genital chamber opens a pair of branched glands called the **colleterial glands**. They produce a substance used to form the **ootheca** or **egg case.**

During copulation, the spermatozoa are introduced into the genital chamber and pass into the spermatheca where they are stored until required. Fertilization takes place evidently after the eggs have been passed from the oviduct. In the genital pouch, the eggs are enclosed within an egg case or ootheca. In a single egg case, sixteen fertilized ova corresponding to the number of ovarian tubules are enclosed. The eggs are arranged in two rows, eight on each side. They are arranged like cigarettes in a cigarette case. The ootheca is a dark brown cylindrical structure about half an inch (1·2 cm) in length and constructed rather like a purse. The upper margin of the ootheca is distinctly crenulated. It is formed by the colleterial glands. The ootheca is formed solely of tanned protein without an admixture of chitin. The ootheca after being formed passes into the genital chamber and protrudes through the terminal abdominal sclerites and is carried by the female in this position for sometime before being deposited.

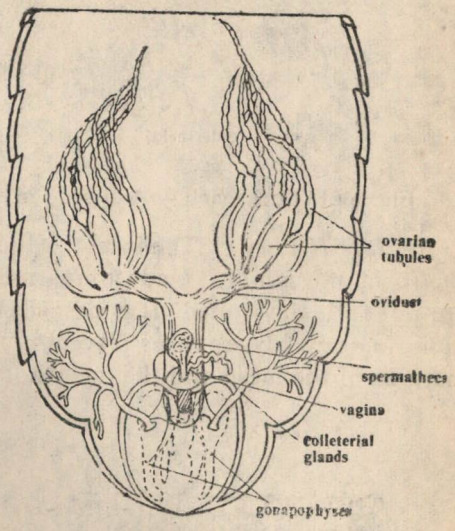


Fig. 6·20 Cockroach
The female reproductive organs

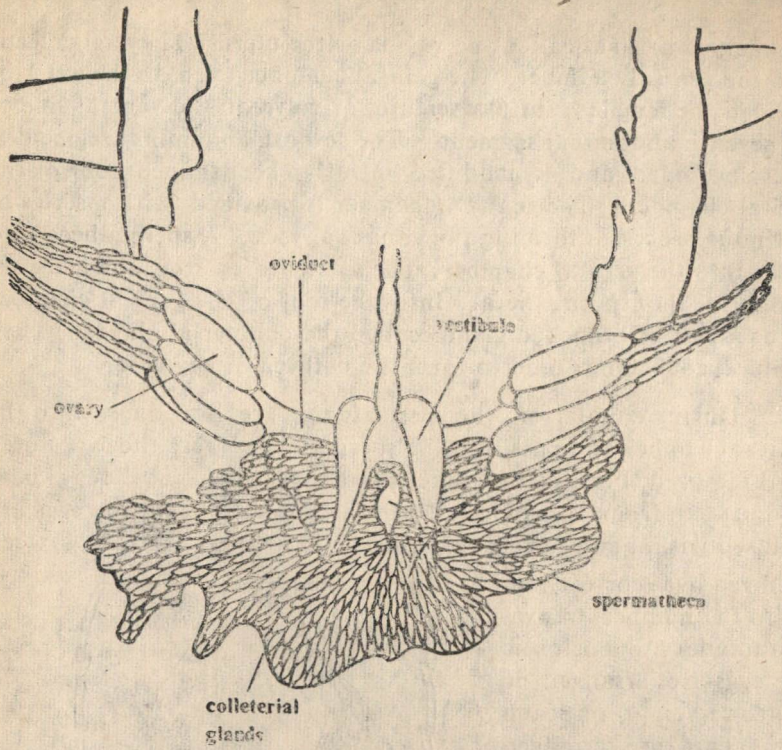


Fig. 6·21 Cockroach — A dissection of female reproductive organs

Life History : The insect which hatches from the egg is in the form of a miniature adult creature. It has no wings. The gonads are not fully developed. It is described as a **nymph.** During growth, moulting or ecdysis takes place a number of times. On the dorsal margins of the meso and the metathorax small projections called the

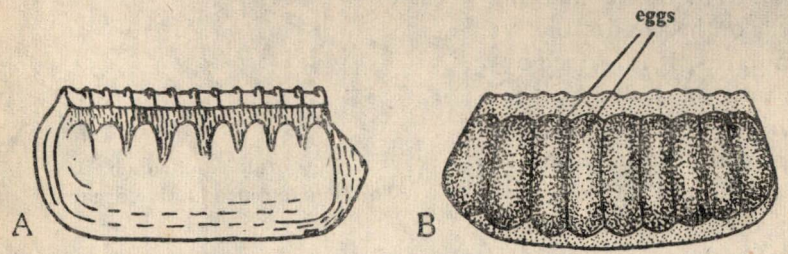


Fig. 6·22 Cockroach — The ootheca

wing pads appear. As growth proceeds, these pads grow progressively larger until at the last ecdysis, the fully developed wings appear.

The moulting or ecdysis in cockroach is under the control of a growth differentiation hormone produced by the **prothoracic glands.** These are in the form of a small pair of glands in the first thoracic segment. The final moult into an adult is suppressed till the secretion of a juvenile hormone by the *corpora allata.* Once the *juvenile hormone* is secreted by the corpora allata, the change from a nymph to an adult takes place.

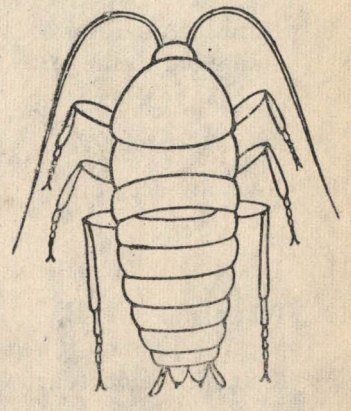


Fig. 6.23 Periplanata—A young nymph

The gradual assumption of the adult characters by the nymph is called **incomplete** or **hemimetabolous metamorphosis.** It differs sharply from **complete** or **holometabolous metamorphosis,** as it occurs in mosquito and house-fly. Here the creature which hatches from the egg is called the **larva** which is totally different from the adult. The larva after a series of ecdyses passes into an apparently quiscent stage—the **pupa** or **chrysalis,** from which the adult insect or the **imago** emerges.

Revision questions

1. Describe in detail the external characters of cockroach.
2. Describe the head sclerites of a cockroach.
3. Give an account of the mouth parts of cockroach and explain how they are adapted to the mode of feeding of the animal.
4. Describe the structure of mandible, maxilla and labium, epipharynx and the hypopharynx of cockroach.
5. Describe in detail the various parts of the alimentary canal of cockroach and also mention the process of nutrition in cockroach.
6. How is excretion performed in cockroach? Describe the structure and function of the malphigian tubules.

7. Give a detailed account of the blood vascular system in cockroach. How does it differ from the closed vascular system of an earthworm ?

8. Describe the respiratory system of cockroach. In what way it is adapted to the terrestrial mode of life of the animal ?

9. Describe in detail the nervous system and sense organs of the cockroach.

10. Give an account of the male reproductive organs of the cockroach.

11. Describe the female reproductive organs of cockroach.

12. What is meant by incomplete or hemimetabolous metamorphosis ? Explain this phenomenon with reference to the development of cockroach.

13. Write notes on the following :

(a) Ommatidium, (b) Salivary glands of cockroach,
(c) Mosaic (apposition) image, (d) Leg of cockroach,
(e) Haemocoel,
(f) Hemimetabolous and holometabolous metamorphosis.

Mosquito and Housefly

1. Mosquito

Mosquitoes abound in India and their study from the health point of view is important as they are the carriers of various diseases. You have already learnt that female anopheles transmits human malaria. The role of mosquitoes in the spread of diseases is discussed at the end of this topic.

Like the cockroach, the mosquitoes are insects belonging to the group Diptera having **two wings**. The body is divided into **head, thorax** and **abdomen**. They undergo complete metamorphosis during the development of eggs. The eggs hatch into **larvae**. The larvae metamorphose into **pupae** or **chrysales**. The pupa after a brief quiscent phase, finally develops into an **adult** or **imago**. In the diagram (Fig. 6·24), the life history of the mosquito (culex and anopheles) is illustrated. There are several species of mosquitoes e.g., *Culex* (Gnat); *Anopheles*, *Stegomya fasciata*, etc.

The head of the mosquito is almost completely occupied by the large **compound eyes**. The head is small and spherical. It is connected with the thorax by a very small neck. In front of the

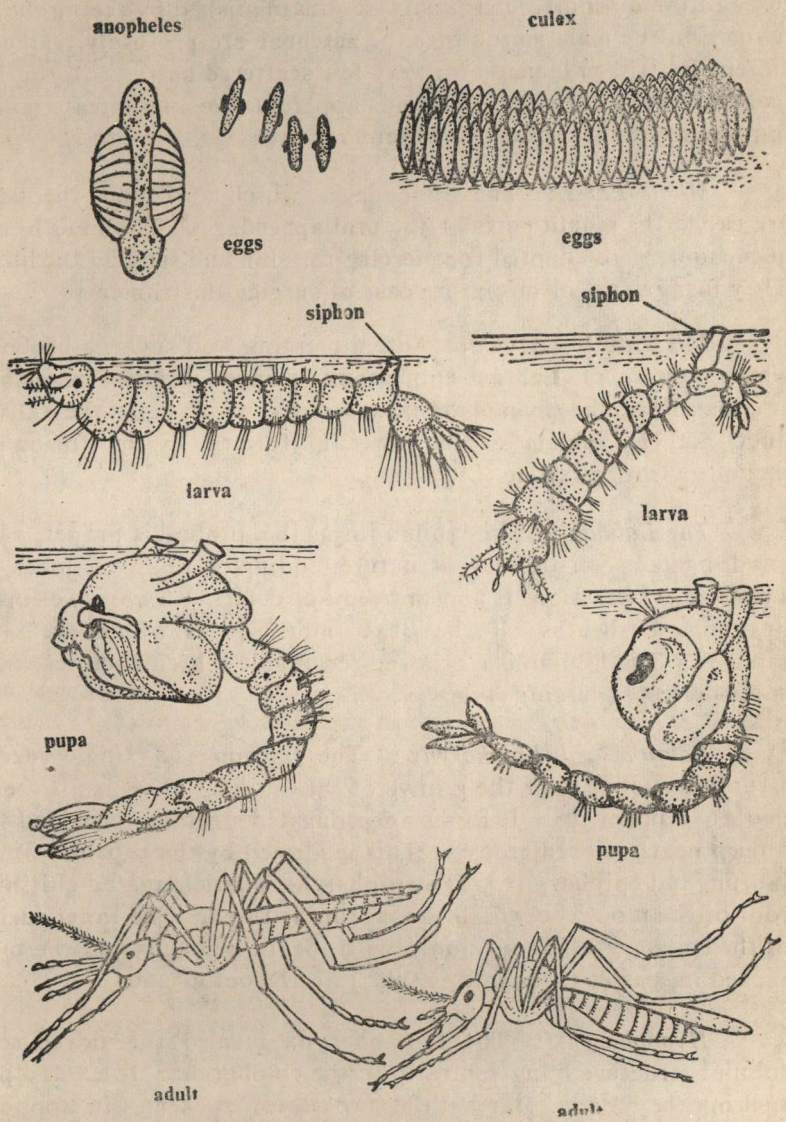


Fig 6·24 The life history of the mosquito (Culex and Anopheles)

compound eye, anteriorly the head is prolonged into the *clypeus* or *frons* over-hanging the base of the mouth parts. On the clypeus are found two long and conspicuous segmented **antennae** or **feelers** The sexes of the mosquito can easily be distinguished by seeing the antennae. In the **male mosquitoes** the **antennae** are **profusely feathered. In females**, the **antennae** bear very **few scattered hairs.** Mosquitoes feel their way, test the food and apparently communicate mutual impressions by means of the antennae.

Mouth Parts : The appendages which surround the mouth are called the **mouth parts** or the **oral appendages**. The mouth parts of mosquito are adapted for **piercing** the skin and **sucking** the blood They form a sort of miniature case of surgical instruments.

The mouth parts constitute a piercing and sucking proboscis which consists of **Labrum-epipharynx** or **upper lip, two mandibles, two maxillae,** the **hypopharynx** (through which runs the salivary duct) and the **labium** or the **lower lip** formed by the fusion of a second pair of maxillae.

The Labium : The labium forms the proboscis proper. It is an elongated semi-tubular structure ending in a pair of lobes, the **Labellae.** In section, it appears semi-circular It's concave surface or groove ensheaths all the other mouth-parts which are six in number. The labium is a grooved receptacle which encloses within it six delicate piercing stylets.

Labrum and Epipharynx : The labrum is a single median structure roofing over the groove of the labium. This is also regarded as an upper lip. It forms an elongated structure provided with a deep nearly closed groove. This is formed by the continuation of labrum and epipharynx. The epipharynx is an elongated chitinized roof of the mouth to which the labrum is fused. The inner surface of the epipharynx is continuous with the oesophagus and the blood sucked in, passes through this tube into the oesophagus.

Hypopharynx : The hypopharynx is also a grooved semi-tubular structure lying ventrally to the epipharynx. It also helps in sucking the blood. During the process of sucking, it applies to the labrum and epipharynx The application of two semi-grooved

structures (i.e., labrum and epipharynx with hypopharynx) forms a temporary tube through which the blood is sucked in. The salivary duct from the salivary glands is carried to the tip of the hypopharynx.

The other structures which are seen within the groove of the labium are a pair of needle-like mandibles and maxillae. **The mandibles** are in the form of stylets placed laterally each bearing a row of saw-like teeth at their extremities. The **maxillae** are also a pair of sword-like elongated piercing organs placed laterally. They inflict the wound in the body of their prey.

The **two maxillae,** the **two mandibles** and the **hypopharynx** lie within the groove of the labium and on the dorsal side of the labium, the wall is roofed over by **labrum** and **epipharynx.** Epipharynx and hypopharynx together applied form a complete tube helpful as a sucking organ. The mandibles and the maxillae are utilised for piercing the skin.

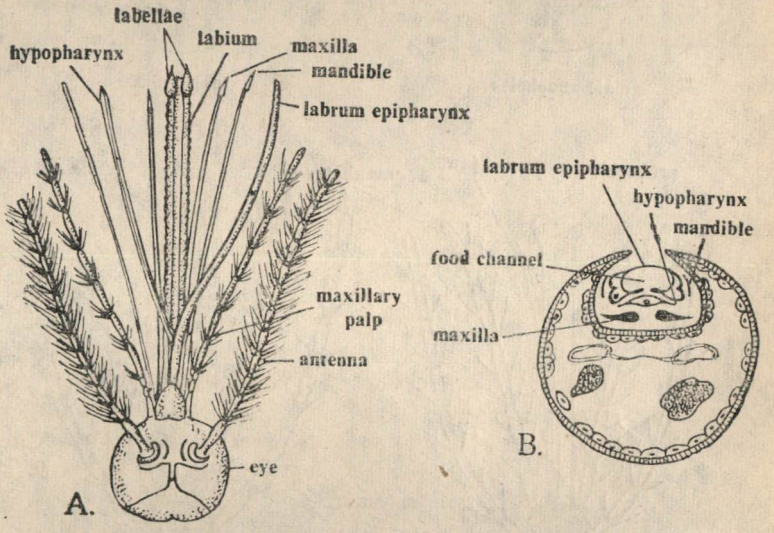


Fig. 6·25 Mosquito—(A) Mouth parts (B) Transverse section passing through the proboscis

In the male mosquito the mandibles have disappeared and the hypopharynx has become fused with the labium.

On the side of the labium is found a **maxillary palp** which is the outer prolongation of the maxilla of its own side. The form and

length of the maxillary palps help in the identification of the species of *culex* and *anopheles*. The function of the maxillary palps is tactile and sensory.

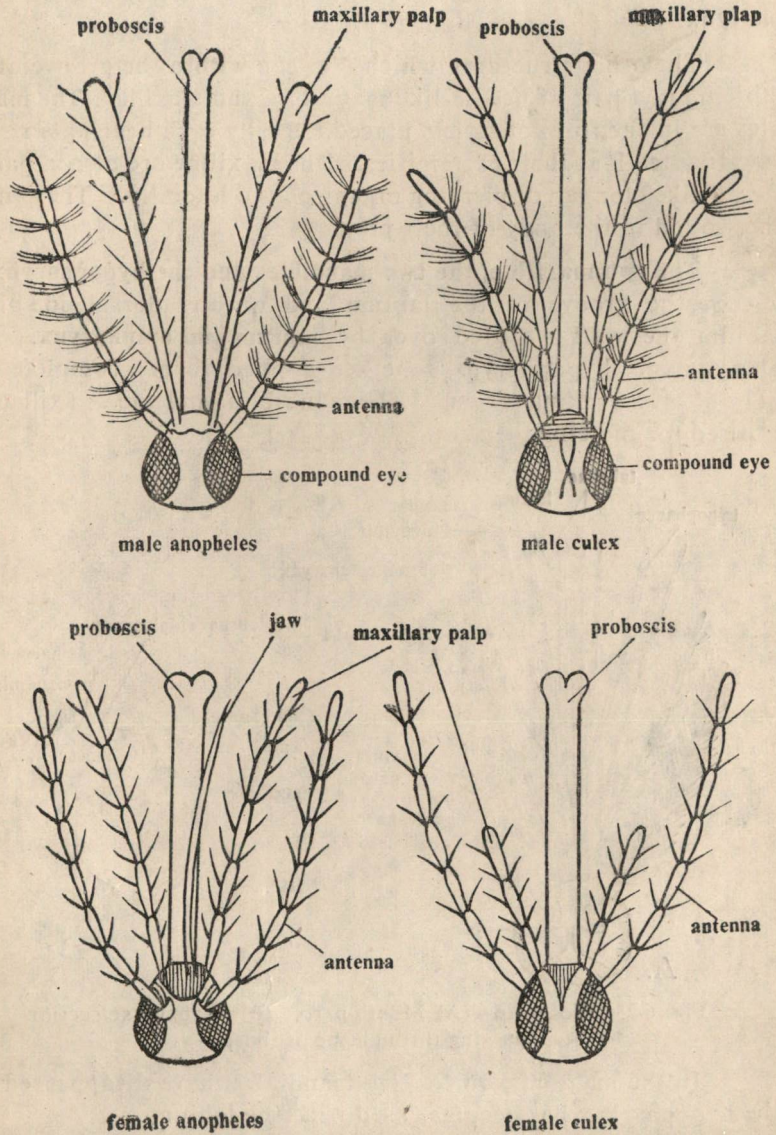
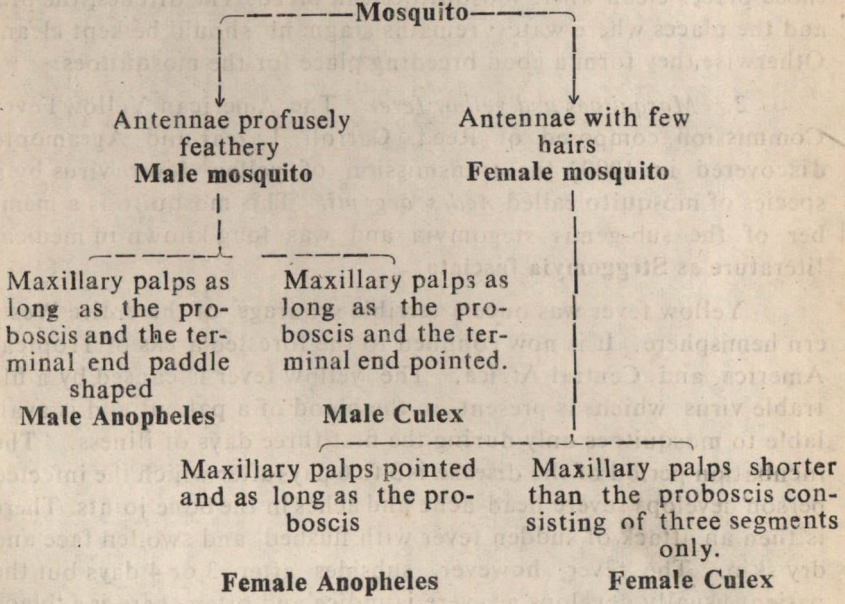


Fig. 6.26 The mouth parts of male and female culex and anopheles

The Mechanism of Piercing and Sucking :

When the female mosquito bites, the end of the labium is pressed against the skin and it becomes bent upon itself. The mandible and maxillae found within the groove of the labium are consequently exposed and inflict a wound in the body through their pointed and serrated tips. Into the wound so formed, is inserted the tube formed by the application of labrum+epipharynx with the hypopharynx. (The saliva may also be injected into the skin through the salivary duct leading into the hypopharynx). The blood from the wound of the prey passes into this tube forcefully by the sucking action of the **pharyngeal pump**. After the wound is inflicted and the blood sucked the mouth parts again retain their normal positions.

The mouth parts of female and male anopheles and culex are shown in figure 6.26. The following points are helpful in the identification of the sex and the species of mosquitoes.



The Role of Mosquitoes in the Spread of Human Diseases :

Mosquitoes amongst the insect pests are regarded as **public enemy No. 1.** The mosquitoes are responsible for the spread of the

diseases like (1) Malaria, (2) Yellow fever, (3) Dengue, (4) Filariasis (5) Encephalitis and (6) Dermatobia.

1. Mosquitoes and malaria : As you have already learnt, **anopheles** mosquitoes are the sole transmitters of **human malaria**. The species of **culex** and **Aedes**, are however less frequently involved. Anopheles are also the **vectors** of malaria of birds and reptiles. There are about 200 species of anopheles out of which only about two dozen species are the important natural vectors of malaria.

Much progress has now been made in the control or even complete eradication of malaria by the residual spraying with DDT and related chemicals. The advantage of residual spraying with DDT lies in the fact that a high percentage of the mosquitoes which bite malarial patients in or around houses, by resting on the sprayed walls after a feed, will die before they can transmit the disease.

In addition to the above measures, it is also essential to keep those places clean where mosquitoes can breed. The ditches, the pits and the places where water remains stagnant should be kept clean. Otherwise they form a good breeding place for the mosquitoes.

2. Mosquitoes and yellow fever : The American Yellow Fever Commission composed of Reed, Carroll, Lazear and Agramonte discovered in 1900, the transmission of **yellow fever** virus by a species of mosquito called *Aedes aegypti*. This mosquito is a member of the sub-genus stegomyia and was long known in medical literature as **Steggomyia fasciata**.

Yellow fever was once a terrible scourage of the entire Western hemisphere. It is now confined to the forested areas of Tropical America and Central Africa. The yellow fever is caused by a filtrable virus which is present in the blood of a patient and is available to mosquitoes only during the first three days of illness. The incubation period of the disease is 3 to 6 days after which the infected person develops severe head-ache and aches in the bone joints. There is then an attack of sudden fever with flushed and swollen face and dry skin. The fever, however, subsides after 3 or 4 days but the patient usually develops a severe jaundice and often there is a 'black vomit' of blood and bile. Adults have a high mortality rate. A highly effective and protective vaccine is available and has been used on a very large scale in rural South America and West Africa.

Aedes aegypti becomes infective within 10 to 12 days of its bite to an infected person. The larvae of this mosquito if exposed to a liquid containing the virus, develop into infective adults. Since the species of **Aedes aegypti** has a wide distribution in the tropics, there is always a danger of the spread of yellow fever disease into India, Malaya or Australia from West Africa or Sudan or into North America from South America. In order to check the spread of yellow fever, strict isolation of individuals coming from the affected areas is observed. Fumigation or spraying of the ships and planes is also done.

3. Mosquitoes and dengue : Dengue or 'Breakbone' fever is a disease caused by a virus. The virus is transmitted principally by mosquitoes of the stegomyia group i.e., Aedes aegypti (Stegomyia fasciata). The virus undergoes some development in the mosquito which becomes infective in 11 days. The patient's blood is infective for mosquito during the first 2 days of the illness. The disease dengue is found in New South Wales, Florida, Brazil, the West Indies, Fiji, Syria, Greece, Turkey and Africa.

The disease starts suddenly with a high fever, flushed face severe pains in the back and extremities. This causes complete *prostration**. The disease is however not fatal.

4. Mosquitoes and filariasis : Manson, in 1879, discovered, that, mosquitoes serve as intermediate hosts for *filariae*. You have already learnt while studying the life history of *Wuchereria bancrofti* that the infection is conveyed to man by mosquito bite, chiefly by the *Culex fatigans*. Besides this species of mosquito, other species of mosquitoes which transmit the disease are the following : *Aedes scutellaris* transmits the disease in Fiji, *Anopheles farauti* in New Guinea, *A. gambiae* in Western Pacific Islands, and *A, funestus* in Africa. In Japan *Aedes togoi* has been reported as a transmitter.

5. Mosquitoes and Encephalitis : In the United States, three strains of viruses (Western equine, Eastern equine and St. Louis strains) causing encephalitis are arthropod borne. Numerous *culcine mosquitoes* have been reported to harbour and transmit these viruses in the United States. *Culex tarsalis* is regarded as the most important vector of Western equine and St. Louis strains of viruses. For Eastern equine, *Culex pipiens* is an important vector. Other species

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* Extreme exhaustion or lack of energy or power

of mosquitoes like *Aedes vexans,* and species of *Psorophora, Mansonia* and *Theobaldia* also act as vectors.

The disease encephalitis, comes on suddenly starting with malaise* and intense head-ache followed by a continuous fever which reaches its peak on the third day. It then gradually subsides. There is marked drowsiness or coma. The patient also suffers usually from nausea, vomiting and convulsions. The fatality of the disease ranges between 3 to 22 percent and is usually higher in adults

6. Mosquitoes and Dermatobia : In tropical America, a larva (maggot) of a botfly *Dermatobia hominis* infests man and also the cattle. The mosquitoes normally serve, in the transportation of Dermatobia eggs to a suitable host. The larvae which hatch from the eggs penetrate the skin of the host and form boil-like cysts on the surface of the skin. These boils cause excruciating pain**. The mosquito involved in this transportation of eggs is *Psorophora luzii* in Central America. *P. ferox* is the most frequent vector in Columbia.

Preventive measures : The extermination, control or protection against mosquitoes and mosquito borne-diseases is most essential. The preventive measures to be undertaken in this regard include (i) personal protection from adult mosquitoes and their destruction (ii) destruction of larvae and (iii) elimination of breeding places.

The use of insecticides has helped a lot in the eradication of mosquito borne diseases. Good sanitary measures have checked to a great extent the breeding of mosquitoes. Certain natural enemies of the mosquitoes are also used in their elimination. A kind of fish *Gambusia affinis* is of great value in the control of mosquito larvae in natural waters, lily ponds, etc. These fishes are stocked in ponds, cisterns, wells, etc.

The fish *Gambusia affinis* is able to live in fresh, brackish or polluted water. It is widely distributed in South Eastern United States and has been extensively introduced elsewhere. These fishes feed on mosquito larvae.

Many types of aquatic plants are also inimical to the larvae of mosquitoes for one reason or the other. Chara produces a high oxygen content of water; the bladderwort, e.g., Utricularia captures the

* A feeling of illness and discomfort

** Unbearable distressing pain

larvae in its trap-like bladders and **Lemnna** (duck weed), the surface covering plants, prevent the larvae from getting access to air.

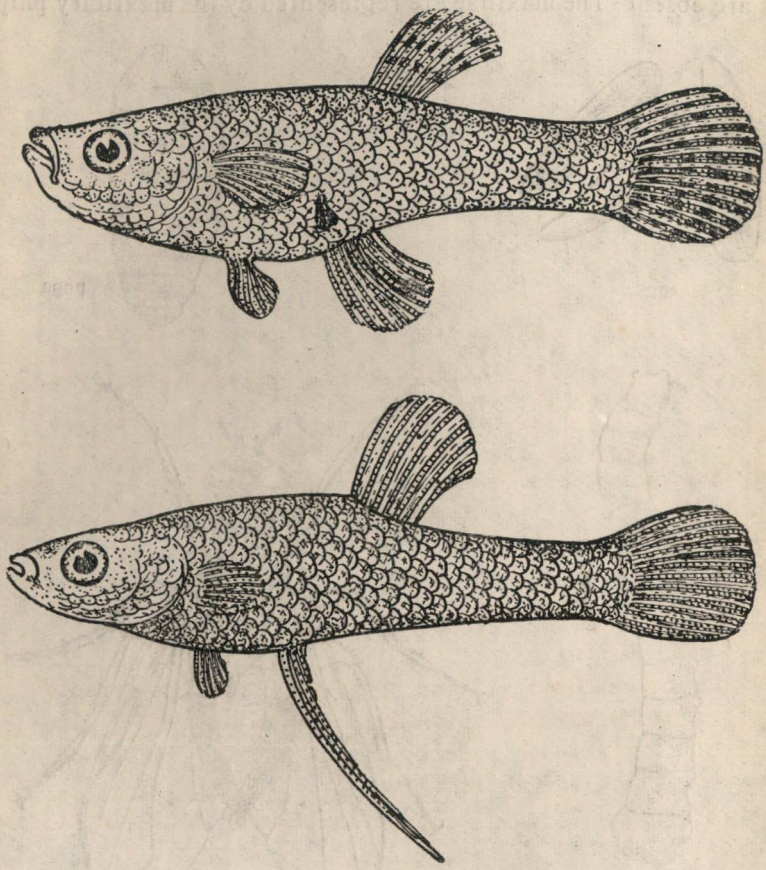


Fig. 6·26 Gambusia affinis—A voracious mosquito eating minnow

2. House Fly (Musca domestica) :

The housefly also is an insect belonging to the family **Muscidae**. It also belongs to the order Diptera having a pair of wings. It is quarter of an inch in length, mouse-grey in colour with four narrow black stripes on the thorax.

The fertilized eggs of a house-fly hatch into larvae called the **maggots**. They undergo metamorphosis. The larvae change into **pupae**. The pupae later develop into **adult flies**.

Mouth Parts : The mouth parts of a house-fly are adapted entirely for sucking. It has lost all piercing mechanism. The mandibles are absent. The maxillae are represented by the **maxillary palps**

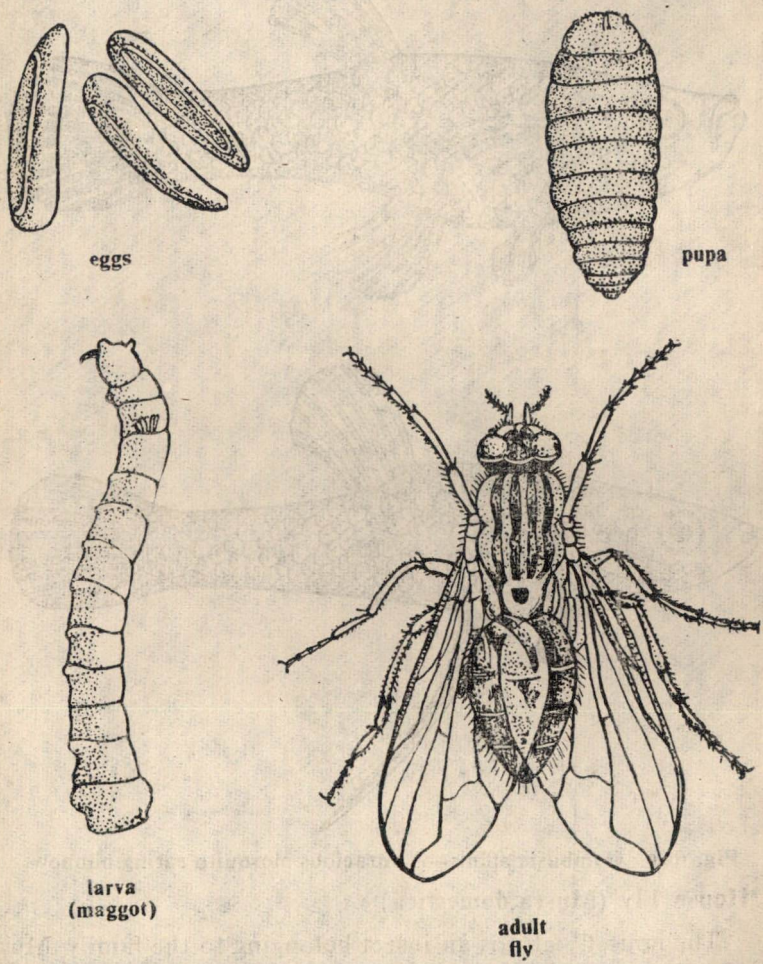
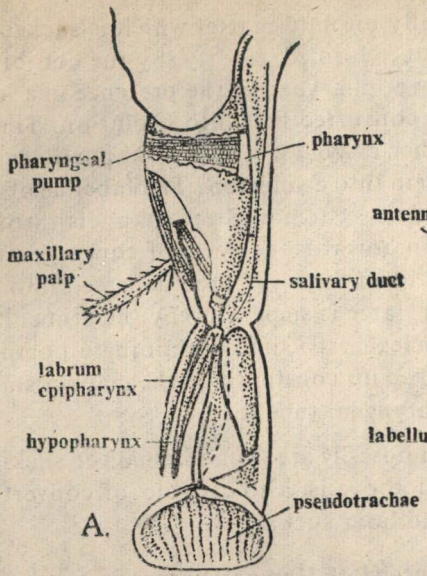
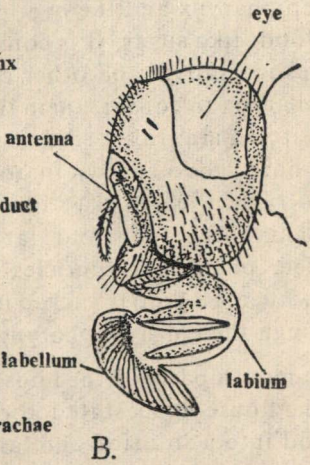


Fig. 6·27 House-fly—Life history

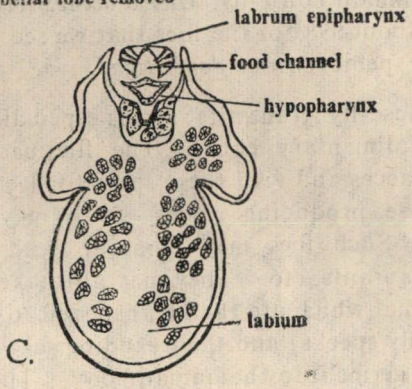
It has a folding **labium** which ends in a pair of fleshy lobes called the **labellae**. On the labella develops a pseudo-tracheal membrane. It is a membrane, the surface of which is produced into small channels which converge towards the narrow end of the labella. The



(A) Proboscis of a housefly extended and with the left labellar lobe removed



(B) Praboscis of a house-fly half folded



(C) Transverse section passing through the proboscis of a house-fly

Fig. 6·28 House-fly—Mouth parts

labium forms a prominent **proboscis.** This, when not in use, is folded away into a cavity under the head.

In addition to the labium, there is also found a prominent **epihypopharyngeal tube** used for sucking.

The house-fly feeds chiefly on fluid matter which is sucked up by the epi-hypopharyngeal tube formed mostly by the conjoined labrum—epipharynx and the hypopharynx. In the presence of a soluble solid food like sugar, it is converted first into a solution. The fly regurgitates its saliva and other enzymes on the solid particles via the hypopharynx to convert them into a solution. The labellae of the labium as stated are traversed by a system of deep channels through which the fluid food is drawn in, towards the point of convergence of the pseudotracheal channels. From here the fluid is passed into the epi-hypopharyngeal tube and later is sucked up by the alimentary canal. The pharyngeal muscles assist in maintaining a pumping action by which the fluid is sucked up constantly in the manner stated above through the epi-hypopharyngeal tube.

The mouth parts of the house-fly are thus adapted for sucking. Further, the house-fly as stated above is also capable of converting soluble food into a solution and later sucking it.

The Role of House-fly in the Spread of Human Diseases :

The common house-fly, *Musca domestica* is world-wide in distribution. About 99% of the flies that we see in our houses usually belong to the species *Musca domestica.*

The house-fly transmits germs especially those affecting the eyes and the alimentary canal. The flies usually feed on garbage, manure and faeces and visit these spots for laying their eggs. They pick up disease producing germs which may be attached to their bristly legs. Such flies may come to feed on our dining tables, kitchens, restaurants, etc. They may also take the germs into their alimentary canal which are then transferred to human food through their faeces (fly specks) and their exuding saliva. In this way, they may transmit germs into the human body. The transmission of the different germs may give rise to diseases like **typhoid**, **paratyphoid**, **cholera, bacillary** and **amoebic dysenteries.** They also play an important part in the transmission of **tuberculosis** and may also cause **food poisoning.** The house-flies also feed on the pus and other discharges from the wounds and the eyes. In Egypt, nearly 90 percent of the village population suffers from **Trachoma** (contagious inflammation affecting conjuctiva, cornea and eye-lids). If untreated, it leads to blindness or other eye diseases on account of the housefly. The

flies thus play the role of transmitting the germs from person to person. The flies can have access to the blood from the infected animals. The poultry that feeds on such infected flies may develop **fowl cholera** (Pasteurella). It has also been reported that the flies can pick up and harbour the virus of poliomyelitis or **infantile paralysis.** The disease is characterised by lesions in the grey matter of the anterior horns of the spinal cord and also in the motor nuclei of the brain stem. The symptoms of the disease include, fever, malaise drowsiness, stiffness in the back and pain in the limbs. Paralysis need not always occur. However, the flies have not been established as an important factor in causing the paralytic form of the disease, poliomyelitis but their possible role is suggested.

Preventive measures : The preventive measures against the flies include the use of insecticides and better sanitary conditions. The advent of DDT sprays played an important role in the elimination of this pest. For fly control, basic sanitary measures are to be followed. These include sanitary disposal of faeces, frequent thin spreading of manure on farms, burial or burning of garbage or other materials (e.g., at slaughter houses) where flies breed. As the house-fly is the most important mechanical carrier of pathogenic organisms we should take all precautions to protect ourselves from it

Revision questions

1. Describe in detail the mouth parts of a mosquito and their mode of action. How are these mouth parts adapted to the mode of feeding in mosquitoes ?
2. Give a detailed account of the role of mosquitoes in the spread of diseases.
3. Describe in detail the mouth parts of a house-fly and their mode of action. How are these mouth parts adapted to the mode of feeding of the house-fly ?
4. Describe in detail the role of a house-fly in the transmission of diseases.

CHAPTER VII

MOLLUSCA

[Soft bodied and shell bearing animals]

The Phylum Mollusca includes soft bodied (L. *mollis*; soft), unsegmented animals. The soft parts of the body are often covered with a hard shell. Next to Arthropods, Phylum Mollusca is the second largest and second most familiar invertebrate group. The fleshy bodies of molluscs, which are of relatively large size are widely used as food by man. The molluscs, live in the sea, in fresh water and on land. The molluscs, living in water respire by means of gills and those living on land respire through lung-like pouches.

The molluscs are fundamentally bilaterally symmetrical, but this symmetry is lost in some e.g., Gastropods.

There protrudes from the ventral surface of the body of a mollusc, a muscular 'Foot' helpful in locomotion. The foot however is much modified according to the habits of various molluscs.

The dorsal or lateral folds of the body wall forms a mantle or pallium, which often secretes a single or bi-lobed shell covering the internal organs of the body, the visceral mass and encloses a space called the mantle cavity. The shell may be absent in some forms. The coelom is reduced and persists as a pericardial cavity.

Sexes are separate. Development is indirect, usually through a larval stage. Some of the better known molluscs are the **clams fresh water mussels, oysters, snails, slugs, octopuses and the cuttle fishes.**

We shall study the external characters and the visceral mass of a fresh water mussel, e.g , *Lamellidens marginalis*, *Unio margaritifera* and *Anodonta cygnea (Clam)*.

Unio—A fresh water mussel :

Unio, the fresh water mussel belongs to the class Bivalvia in which the body is enclosed in a shell with two halves or valves. It

also has a plough shaped foot, hence the name Pelecypoda (Greek. *Pelekys*, hatchet; *Podos*, foot i.e., wedge shaped foot) is also given to the group to which unio belongs.

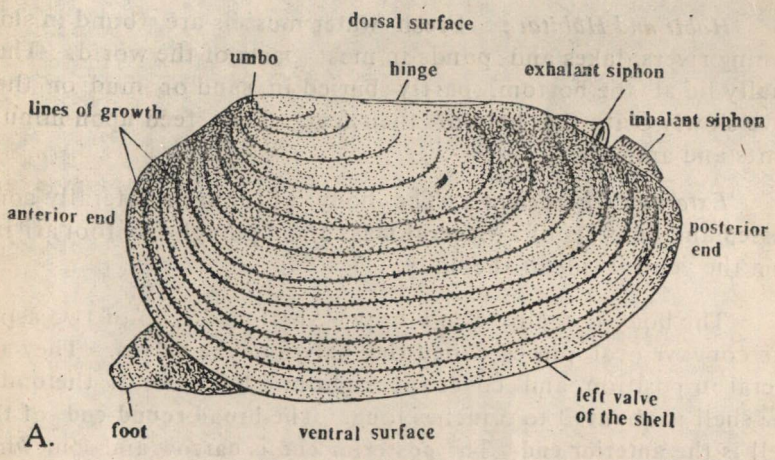
Habit and Habitat : Fresh water mussels are found in slow running rivers, lakes and ponds in most parts of the world. They usually lie at the bottom, partly buried in sand or mud or they move slowly with the help of their feet. They feed upon minute plants and animals.

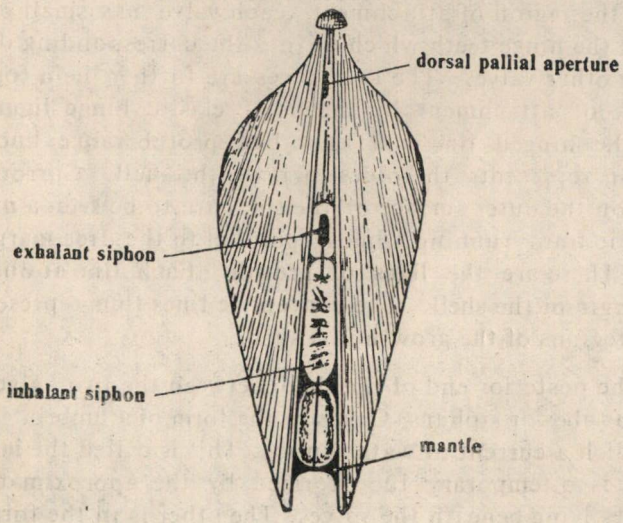
External Characters : The body of unio is laterally compressed and consists of a **visceral mass** and a plough-like foot arising from the ventral side of the body.

The body is enclosed in a brown shell made up of two separate concave oval pieces called the **halves** or the **valves**. They are lateral in position and cover the right and left sides of the body. The shell is about 3 to 5 inches long. The **broad round end** of the shell is the **anterior end** The **posterior end** is **narrow** and somewhat **bluntly pointed**. The two halves of the shell are joined together along one edge by means of ligaments. This end of the shell forms the dorsal side of the animal. The valves are free at their other edges. At the region of attachment, each valve has small projections called the hinge teeth which fit into the corresponding depressions in the other valve. The two valves are further held together at the point of attachment by means of elastic **hinge ligaments.** Close to the hinged line is a knob-like protuberance known as **Umbo**. This represents the oldest part of the shell. Surrounding the umbo, on the outer surface of the shell are to be seen a number of concentric lines running almost parallel to the free margins of the shell. These are the **lines of growth**. Each line at one time was the margin of the shell. The concentric lines thus represent the successive regions of the growth in a shell.

At the posterior end of the shell between the two halves may be seen two tubes or siphons. One is in the form of a fimbriated tube through which a current of water enters. This is called the **inhalant siphon**. It is a temporary tube formed by the approximation of mantle lobes lying beneath the valves. The other is in the form of a simple tube from which the water passes out. This tube is called the **exhalant siphon**. It is an actual tube formed by the union of the two

lobes of the mantle. A wedge shaped muscular foot projects ventrally through the valves at the anterior end, when the animal moves. The two valves of the shell are held together by **an anterior**





Fig, 7.1 The fresh water mussel (Unio)
(A) Seen from left side, (B) Seen from the posterior end

and **posterior adductor muscles**. These muscles extend internally between the two valves. The opening of the valves and their tight closure is brought about by the relaxation and contraction of these muscles.

The inner surface of each valve of the shell is bright and has white pearly appearance. It shows marks of insertion of muscles running transversely between the two valves. At the anterior end of the valve, an oval shaped marking of the **anterior adductor muscle** can be seen. At the posterior end of the valve is found a large impression of the **posterior adductor muscle.** Close to the anterior adductor impression are the two small impressions left by the

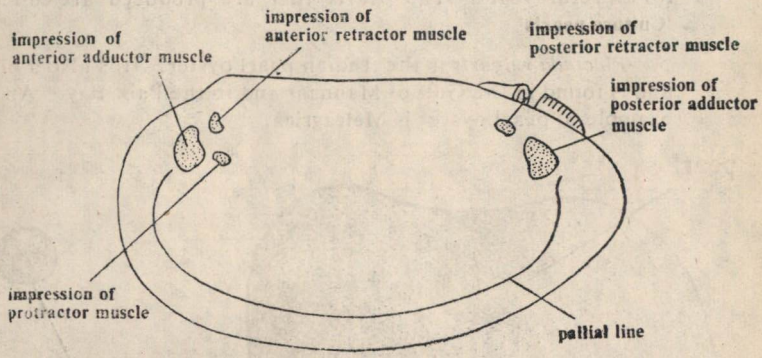


Fig. 7.2 Unio—The inner surface of the valve of the shell

anterior retractor and **protractor muscles.** These help in the withdrawal and the protrusion of the foot during movement. In front of the posterior adductor impression is the marking of the **posterior retractor muscle.** As mentioned earlier, the adductor muscles bring about the tight closure of the valves of the shell The retractors help in the withdrawal of foot and the protractor forces out the foot. All the muscles are of unstriped type. There can also be seen a faint line running parallel to the free edge of the ventral margin of the valve. This is called the **pallial line.** It shows the place of attachment of the internal fold of skin called the mantle or pallium.

Mantle: Lying inside the valves of the shell is a semi-transparent fold of skin called the **mantle** or the **pallium.** The mantle is made up of two lobes corresponding to the two valves of the shell. The two lobes of the mantle are continuous dorsally. The mantle

lobes are however free ventrally and anteriorly. Posteriorly, the mantle lobes fuse to join the exhalant and inhalant siphons already mentioned. The mantle secretes the shell.

Some molluscs like pearl oysters are important as they produce pearls which are of great value. In these oysters, if a small organism like some parasite, gets in between the shell and the mantle, the epithelial cells of the mantle secrete around the organism concentric layers of a pearly substance. This substance soon assumes the shape of a bead called the **pearl**.

Now-a-days pearl formation is also brought about artificially. In Japan, fine particles of clam shell are introduced artificially into the oysters. These oysters are then kept in wire cages in the sea for several years. The pearls that are produced are called the **'Culture pearls'**.

Pinctada vulgaris is the Indian pearl oyster. It is also a bivalve and is found in the Gulf of Mannaar and in the Palk Bay. Another example of pearl oyster is **Meleagrina**.

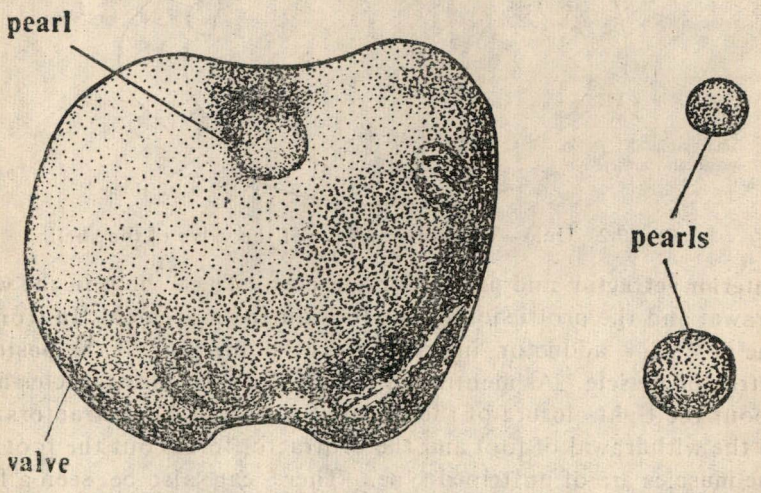


Fig. 7·3 The pearl oyster with pearls

The space found between the mantle lobes is called the mantle cavity. This extends over the entire length of the body on each side.

Visceral mass : The mantle cavity encloses the body of the animal collectively referred to as the **visceral mass.** It is laterally compressed. The head is rudimentary. On the mid-ventral side of the

vesceral mass is found a wedge shaped foot. On each side of the foot lies a **gill** or **Ctenidium**. The visceral mass is composed of digestive, circulatory, excretory and reproductive organs. The structure of a

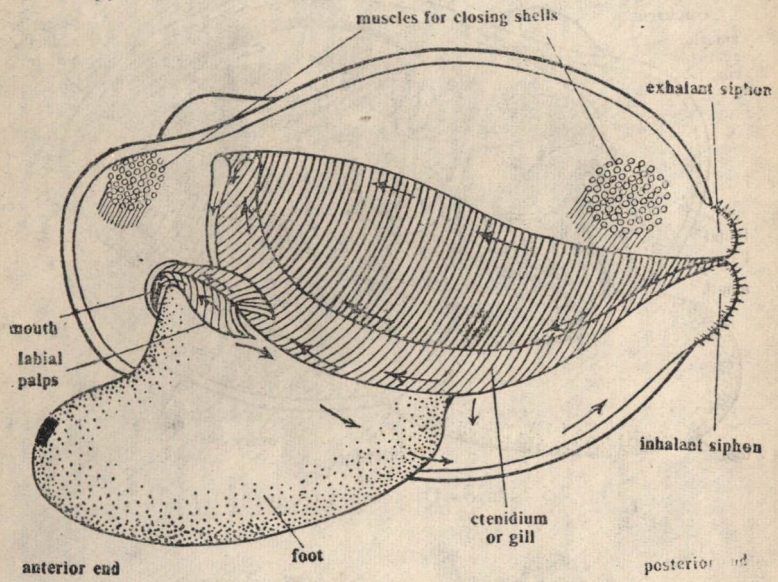


Fig. 7.4 Unio—The foot, the gill, the labial palps and the muscles for closing the shells are shown

fresh water mussel is thus comparable to a book. The two valves of the shell may be compared to the covers of a book. The mantle lobes underlying the valves form the double fly leaves, front and back, attached to the valves. The gills, the visceral mass and the foot are just like the leaves of a book. Some of the organ systems contained in the visceral mass are briefly described below.

Digestive System : The mouth lies in front in the form of a small aperture below the anterior adductor muscle. The mouth is surrounded by a pair of triangular flaps called the **labial palps.**

Behind the mouth, the alimentary canal may be distinguished into oesophagus, stomach, much coiled intestine followed by a straight tubular rectum which terminates in the anus (See fig. 7.6).

Circulatory System : The circulatory system is composed of a heart situated on the dorsal side, surrounded by a pericardium. The

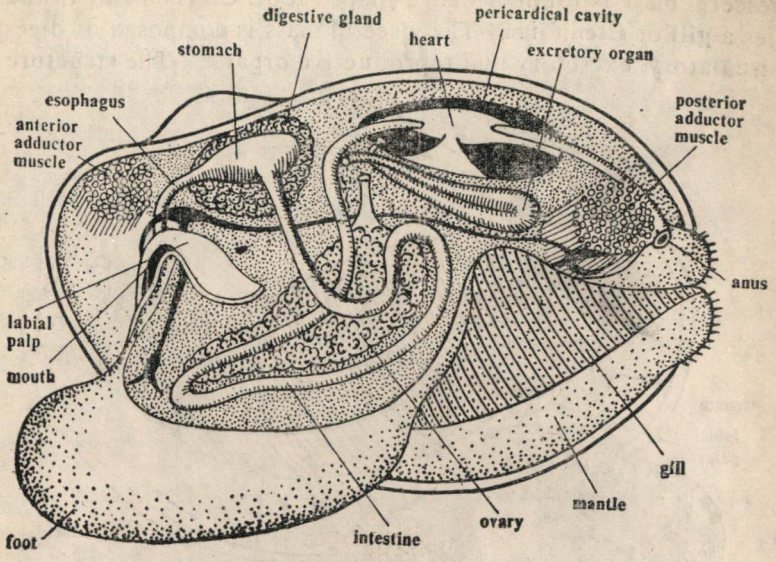


Fig. 7.5 Unio—Dissection from the left side

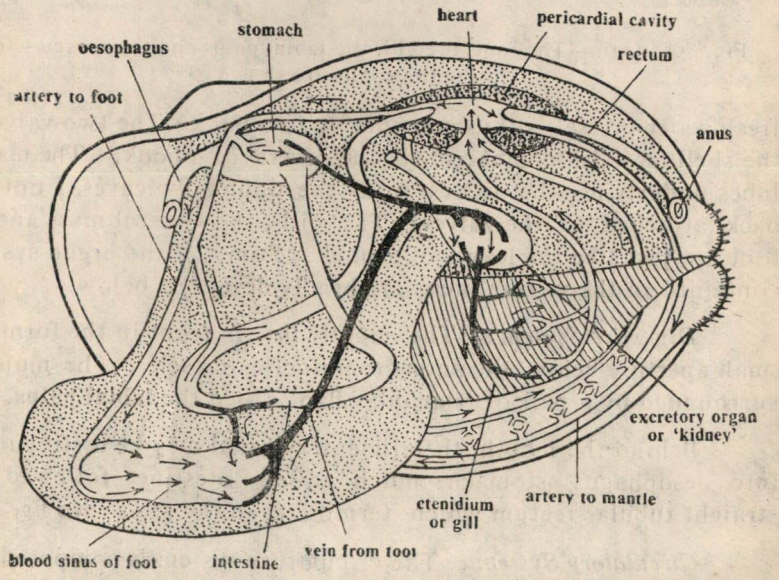


Fig. 7.6 Unio—Some organs of visceral mass are shown

pericardium is a reduced coelomic cavity in the form of an ovoidal chamber surrounding the heart. From the heart a number of arteries arise as shown in figure 7·6. These arteries communicate with an elaborate system of ill-defined blood spaces or sinuses. The blood returns to the heart through the veins.

Excretory System : A pair of kidneys lie below the pericardium. One end of the kidney opens into the pericardium and the other end through an excretory pore leads into the mantle cavity. The kidneys are coelomic in origin and are also referred to as **organs** of **Bojanus** after the discoverer. The kidneys eliminate the nitrogenous waste from the pericardium and blood to the exterior.

Nervous System : The nervous system is composed of nerve ganglia and the nerve connectives as shown in figure 7·7.

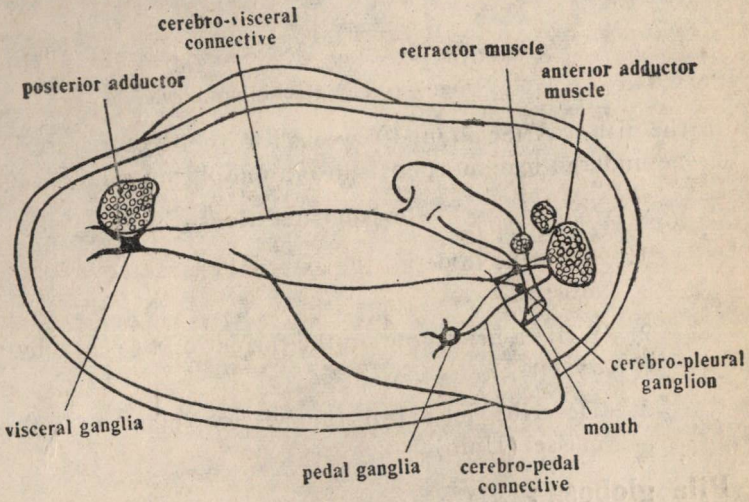


Fig. 7.7 Unio—Nervous system

Reproductive Organs : In unio the sexes are separate. T paired gonads lie on each side surrounding the coils of the intesti in the visceral mass.

Fertilized egg develops into a **glochidium larva.** The larv escape through the exhalant siphon of the mussel. They get attach to the gills or fins of fresh water fishes and feed by absorbing juic

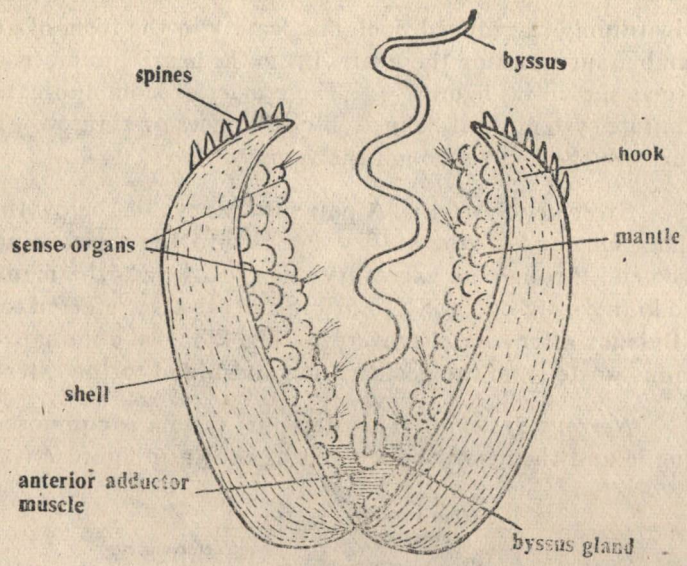


Fig. 7·8 The glochidium larva

of the fish. After about 10 weeks of their ectoparasitic life, the larvae undergo metamorphosis into an adult mussel.

Revision questions

1. Describe in detail the external characters of a fresh water mussel.
2. Write a brief note on the formation of pearls by the pearl oysters.
3. Describe in detail the 'visceral mass' of a fresh water mussel (Unio).

Pila globosa :

Another example of a mollusc is *Pila globosa* or the *apple snail*. These are also fresh water forms inhabiting ponds, tanks, paddy fields, streams and rivers. They usually occur in those areas where aquatic plants like *Vallisneria* or *Pistia* are abundantly found. These plants form chiefly the food of Pila.

Pila, although aquatic in habit, can as well live outside the water since it has a pulmonary sac in addition to a fully developed

ctenidium. It can thus, when on land, breathe air, through its pulmonary sac. In Pila, the sexes are separate. Females are larger than the males.

The Shell: The soft parts of the body of Pila are enclosed in a single piece of shell characteristic of most *Gastropods* to which group, Pila and allied forms belong. The shell is in the form of an elongated cone closely coiled in the form of a spiral, round a central axis.

The extreme top of the shell is called the **apex**. It is comparable to the umbo of a fresh water mussel and represents the oldest part of the shell. It is the first to be secreted by the embryo and is the starting point for the growth of the shell. The **coils** or **whorls** of the shell are in open communication with one another as there exists no partition between them. Commencing from the apex,

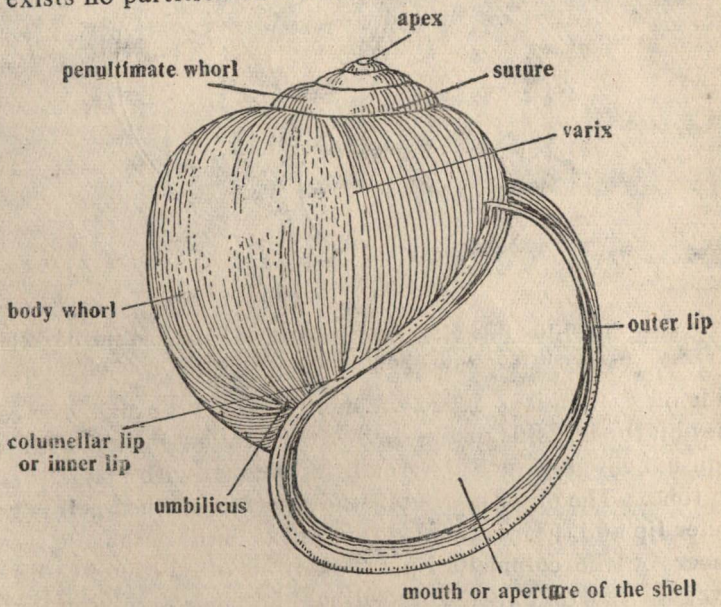


Fig. 7.9 Pila globosa — A shell seen from the ventral surface

the whorls gradually increase in size so that the last two whorls of the shell known respectively as the **penultimate** and the **body whorl** are very large. The greater part of the body of the animal is enclosed in these exceptionally large whorls.

The collective name, the **spire** is applied to the whole series of whorls, exclusive of the body whorl. All the whorls of the shell are coiled round a hollow central axis called the **columella**. The opening of the hollow columella leading to the exterior is called the **umbilicus**. The shells with umbilicus are described as **perforated** or **umbilicated**. The line marking the junction between any two successive whorls is referred to as the **suture**. Towards the posterior end of the shell lying on the right side of it is found the **mouth** or the **aperture of the shell**. If the aperture of the shell lies on the right

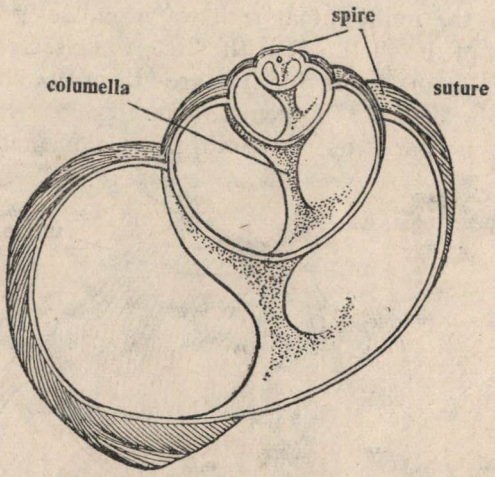


Fig. 7·10 Pila globosa — A shell as seen from the dorsal surface with about half the whorls ground off

side of it, then it is called the **dextral**. This is usually the case. If it lies on the left side of the shell, it is called the **sinistral**. It is an unusual case but such abnormalities are met with in shells from time to time. The outer margin of the aperture of the shell is called the **outer lip** and the margin of it lying next to the columella is called the **inner** or the **columella lip**. This lip is often found to be recurved over the central axis. The shell is thick and often globose in shape. There are usually 6½ whorls in a shell. The lines of growth on the surface of the shell are to be seen in the form of slightly raised lines running parallel to the margin of the aperture.

The shell is usually lemon yellow in colour but much darker shells of brownish or blackish colour are also found. The inner

surface of the shell is white and porcellanous with traces of irregular transverse bands of a brownish or orange colour corresponding to the external transverse bands.

The shells of male animals are comparatively smaller and less dilated than those of the females.

The Operculum : The **operculum** which almost corresponds to the mouth of the shell is a flat calcareous plate. It is formed as a cuticular secretion of a group of cells situated on the dorsal side of the foot. The outer margin is regular and convex and descends gradually to a point at the junction of the anterior and inner margins. The inner margin is slightly concave in its anterior half but becomes

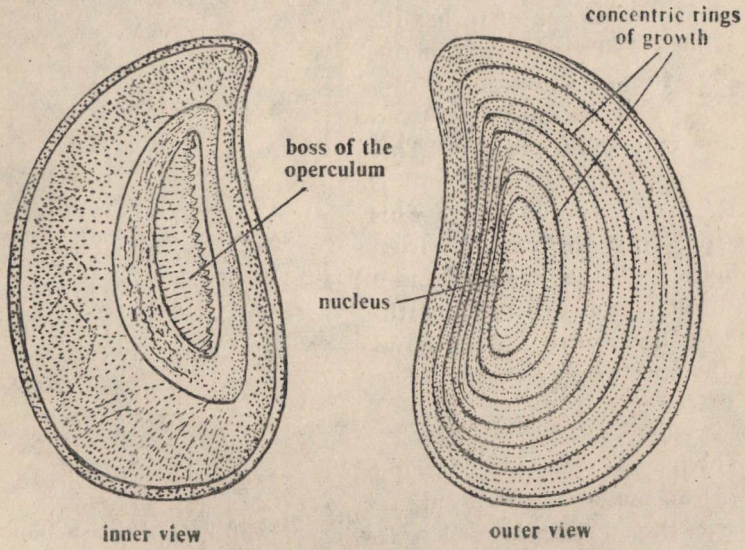


Fig. 7·11 Pila globosa — Operculum, outer and inner view.

rounded further back and makes the posterior margin as such regularly convex in outline. The outer surface of the operculum consists of lemon-yellow chitinous covering. There are also to be seen on the outer surface, a large number of **concentric rings of growth** with a fairly marked **nucleus**. The nucleus is situated sub-centrally at a distance of about one-fourth of its breadth from the inner margin.

The inner surface of the operculum is distinguished into a prominent elliptic area called the **boss.** The operculur muscles are found attached to it. Boss is surrounded by a shallow groove and bears irregular markings to the attachment of the muscle fibres. The boss is of a creamy colour and the rest of the inner surface is usually a shade of shining grey.

External Characters: When the shell is removed, the soft parts of the body of the animal can be seen. The body can be distinguished into three distinct regions—**(1) the head,** (2) **the foot** and (3) **the visceral mass.**

The greater part of the body of the animal in a fully expanded state lies outside the shell. The visceral mass, however, remains enclosed in the upper or rather the inner whorls. The body remains attached to the shell by means of a strongly developed muscular band called the **columellar muscle.** This muscle arises from the foot and is inserted on the columella. This muscle prevents the animal from extending out of the shell beyond a certain limit. It also helps in withdrawing the body into the shell and closing the aperture by means of a tightly fitting operculum.

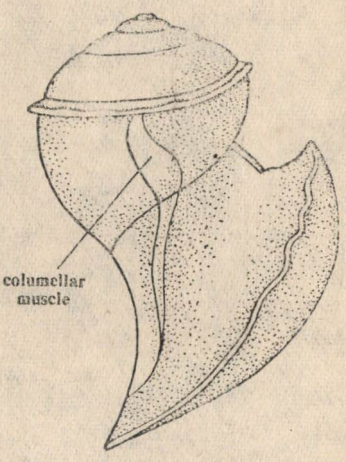


Fig 7.12 A part of the shell of Pila globosa indicating the region of attachment of the columellar muscle.

The part of the skin covering the visceral mass is produced to form the **pallium** or **mantle**, a characteristic molluscan structure. The mantle in an extended animal is seen as a light greenish lining within the aperture of the shell. The mantle encloses anteriorly the head and its' appendages. It also encloses the animal when it retracts. The mantle also serves as an additional organ of respiration. The free edge of the mantle is thick and contains the *shell secreting glands*.

The head is prolonged into a **snout.** It is partly contractile. On either side of the snout is found a **labial palp** or the **first pair** of **tentacles.** The tentacles are mere prolongations of the antero-lateral edge of the snout. These are also highly contractile. Just quarter of an inch behind the snout lie the **true** or **second pair of tentacles.** These are filamentous structures, thicker at the base and gradually taper to a fine thread near the tip. In a fully extended state, these tentacles attain a length of two inches but during contraction they are reduced, and are just one-fourth of their entire length in full extension.

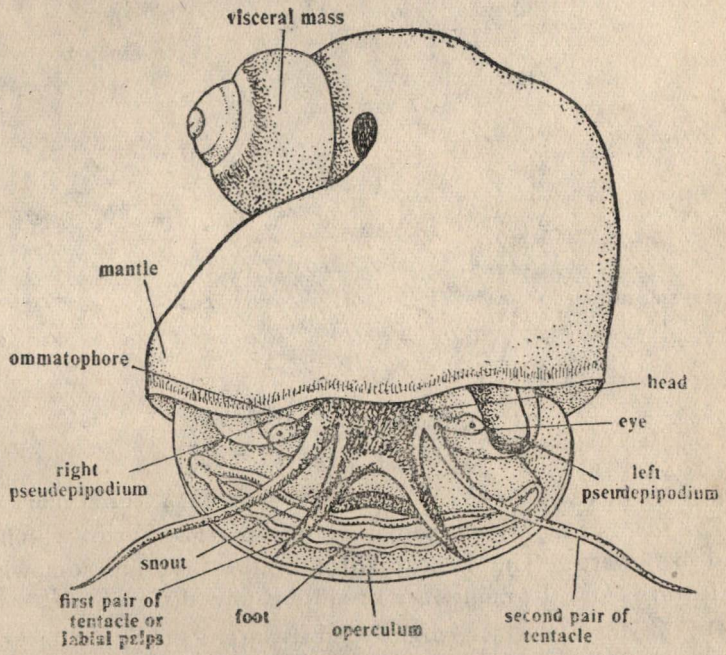


Fig. 7·13 Pila globosa—Front view of the animal after the removal of the shell

In Pila globosa a pair of eyes are also found. They are situated on small stumpy stalks called the **ommatophores,** arising on the outer sides of the bases of the second pair of tentacles.

The two sides of the head are connected to the mantle by two fleshy structures called the **nuchal lobes** or **pseudepipodia.** The **left**

nuchal lobe is better developed and forms a long **respiratory siphon** for aerial breathing. Both the nuchal lobes however play an important part in the respiration of the animal. The nuchal lobes in fact are the prolongations of the mantle.

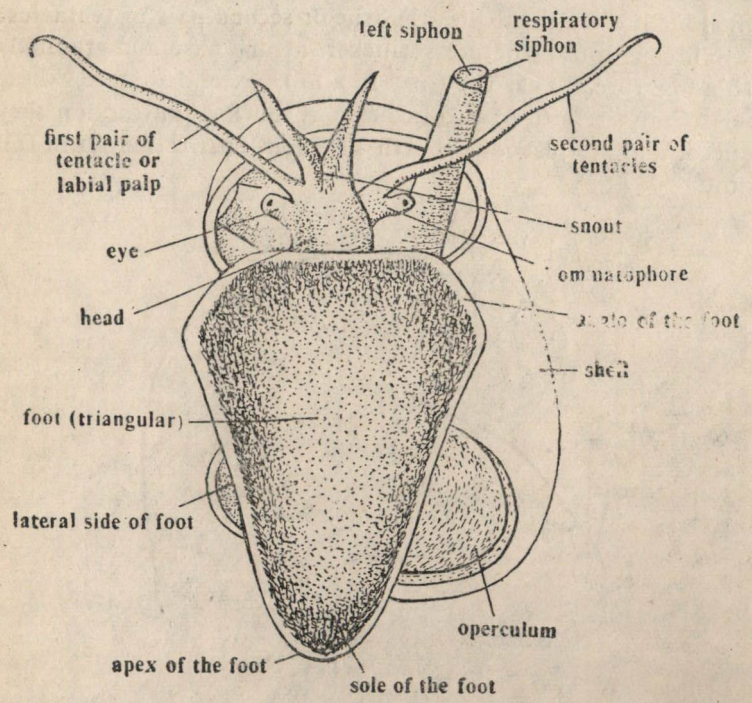


Fig. 7·14 Pila globosa—A living animal seen from the ventral side

The foot is roughly triangular in outline, the apex of which is directed backward. The lateral sides of the foot are somewhat arched inwards and the angles are broadly rounded.

On the dorsal surface, slightly in front of the posterior end, the foot bears the operculum. The smooth ventral surface of the foot is called the **sole.** The foot is a locomotory organ and is highly muscular. The wave-like contractions on the surface of the foot result from the contractions of its vertical muscles. By the contraction of the transverse muscles, the blood is forced forwards extending thereby the foot in front. The longitudinal muscles by their contraction pull the posterior end of the foot forwards in order to keep pace with the extended anterior end.

The visceral mass contains the main organs of the animal. It occupies the greater part of the body whorl and all the inner whorls of the shell. The visceral mass is also spirally coiled like the shell. It varies from greyish to dark brown in colour.

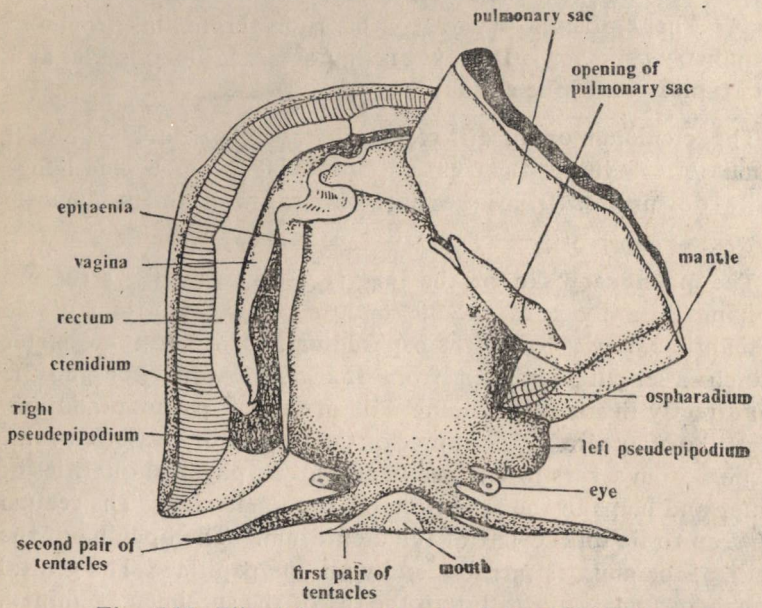


Fig. 7.15 Pila globosa — Organs of the pallial cavity

Mantle cavity and the pallial complex

The mantle or pallium as described earlier, while forming a cloak round the anterior part of the animal, encloses a large space on its dorso-lateral sides. The space is known as the **mantle** or **pallial cavity**. Within this cavity, lie a number of structures collectively referred to as the **organs of the pallial complex**. It consists of the **ctenidium** or **gill**, the **osphradium**, the **hypobranchial gland**, the **rectum**, the **anus**, the **renal** aperture and a part of the renal organ, the genital apertures together with the copulatory organs. When the animal withdraws itself from the shell, the head with associated structures is pulled back into the mantle cavity.

The **pulmonary sac** or **lung** is connected with the dorsal wall of the pallial cavity. It is a specially developed structure in the members of the family Pilidae to which pila belongs.

The organs of the pallial complex found in the mantle cavity are the following.

In the floor of the cavity, runs, a prominent ridge, the **epitaenia**. It arises near the anterior edge of the right pseudepipodial lobe. The epitaenia separates the right branchial from the left pulmonary chamber. It plays an important role in aerial and aquatic respiration of the animal.

The **ctenidium** or the **gill** can be just visible through the wall of the mantle. It lies in the right or branchial chamber and hangs vertically downwards from the dorso-lateral wall of the mantle cavity.

The **pulmonary sac** or the **lung** is a large sac-like structure which hangs from the roof of the mantle cavity. On the left side of the mantle cavity is found the **osphradium.** It is about a quarter of an inch in length and arises from the mantle a little behind the margin directly in line with the middle of the left pseudepipodium. It hangs like a curtain in the course of the respiratory water current. The osphradium serves to test the chemical and physical qualities of the water and helps in the selection of food material. The **rectum** can be seen to lie on the left of the ctenidium. The opening of the rectum i.e , the **anus**, is surrounded by minute papillae. The genital duct, male or female according to the sex of the specimen examined, lies next to the rectum. The genital openings lie at the anterior end of the branchial chamber. The anterior chamber of the renal organ projects into the ctenidial part of the pallial cavity. It is reddish in colour. The greater part of the renal organ, forming the posterior chamber lies within the visceral mass.

Revision questions

1. Describe in detail the shell and the operculum of *Pila globosa.*
2. Describe in detail the mantle cavity and the various structures found in the pallial complex of *Pila globosa.*

CHAPTER VIII

THE SCIENCE OF BIOLOGY

Biology (Gk. *Bios*; life, *logos*; a discourse) is the science which deals with the study of all living creatures, animals, plants and human beings. Under the science of biology, we include **Zoology** the science of animals and **Botany** (Gk. *Botane*; a herb), the science of plants. In addition to these, we also include **Microbiology** under the science of Biology. **Microbiology** deals with the study of such plants and animals which can be seen only with the aid of a microscope. It deals as such chiefly with the organisms which cause diseases or are otherwise important.

The science of **Zoology** (Gk. *Zoon*; animal + *logos*; discourse), deals with the structure and functions of animals, their habits, where and how they live, their relations to one another and to their environments, their classification and many other features.

Animals and plants are studied in different ways. Some of these ways form a distinct branch of biology. The study of individual animals and plants is based upon the following sub-divisions of biology.

Morphology (Gk. *Morphe*; form) is the study of the external and internal forms of the organisms. It is further sub-divided into (a) **Anatomy** and (b) **Histology**.

(a) *Anatomy* (Gk. *Ana*; up + *temno*; cut) deals with the study of the gross internal structure of the organisms or of its separate parts. It deals with the structures as revealed by dissection. (b) *Histology* (Gk. *Histos*; tissues) deals with the study of the microscopic structure of the tissues

Cytology (Gk. *Kytos*; hollow) is the study of cells – the small units of which plants and animals are composed. This branch of study is also referred to as **cell biology**.

Physiology (Gk. *Physis*; nature) deals with the living processes or functions within the animals and the plants. **Embryology**

(Gk. *En*; in+*bryo*; swell) is that branch of study which deals with the growth and development of the new individual within the egg.

Palaeontology (Gk. *Palaios*; ancient+*ont*; being) is the study of the remains of the plants and animals which lived millions of years ago and which are now extinct. Their remains are now preserved in rocks etc., as **fossils**. This branch of biology thus helps us to understand how plants and animals are evolved.

Genetics (Gk. *genesis*; origin) is the study of the inheritance of characters or the study of heredity and variations amongst the animals and plants. It deals with the study of the similarities and differences existing between parents and offsprings, and the factors which control the same.

Pathology (*Pathos*; suffering) is the branch of study which deals with the nature, symptom and cause of diseases.

Ecology (Gk. *Oikos*; house) is that branch of study which is concerned with the relations of animals and plants to their environments i.e., to their living and non-living surroundings. The non-living factors which affect life are light, water, soil, temperature and so on. The living factors are the other organisms including the man.

Zoo-geography or animal geography is the science which deals with the distribution of animals in the larger geographical divisions of the earth.

Taxonomy (Gk. *Taxis*; arrangement + *nomos*; laws) is the science of animal and plant classification. For the study of different kinds of animals and plants the biologists for the sake of convenience, classify them in different groups. This classification indicates different degrees and kinds of similarities or relationships amongst the animal and plant groups.

We shall now discuss below, the principles of animal classification in detail.

Principles of Animal Classification and Binomial Nomenclature :

You have learnt in the previous chapters the examples of various animal types with particular reference to their habitat,

structure, function and life history. This study reveals the presence of a diversity amongst the various types so far studied. Besides these types, there are a number of other animals which inhabit the earth. Many others have lived here during past geological times. Upto the present day, about a million different types of animals have been described and their number is being continuously added to as a result of new work. Some of these animals are in abundance, others are exceedingly rare and there is also seen a considerable diversity of form in them.

A Swedish Naturalist **Linnaeus**, enumerated all the known animals and published them in his book '*Systema Naturae*'. The tenth edition of this book was published in 1758.

Methods of Classification : If one examines a mixed assemblage of animals, one may notice various degrees of resemblances and differences. The domestic animals on a farm, the cow and sheep can differ in size and colour and also the texture of their body. They are, however, alike in having horns and cloven hooves. A horse may differ from them in lacking horns and having solid hooves. It however agrees with the cow and the sheep in having long legs and the teeth of the grinding type. A dog differs from all the three types in having nails and soft pads on its toes instead of hooves. The teeth of dog are of stabbing and shearing type. It however agrees with the above mentioned types in being covered with hair.

We thus try to classify animals into major and minor groups on the basis of certain characters found in them. The purpose of classification is therefore to arrange animals into groups so as to show their presumed relationship. The most useful scheme of classification is one which is based on the maximum number of important characters found amongst the animals. Such a type of classification which indicates inter-relationship amongst the animal groups is referred to as '**Natural classification**'.

In this method of natural classification, it is necessary to distinguish characters and structures that show similarity of origin. The arms of man, the fore-legs of mammals, the wings of birds are essentially similar structures having the same basic plan and common origin. These structures have similar bones, muscles, etc.

Their function however in each case differs. Such organs having the same basic plan of structure are referred to as **Homologous organs.** This phenomenon of similarity in origin is referred to as **Homology.**

In an **artificial classification** one may classify animals on the basis of apparent similarity in their functions. The structures having similar functions but different origin are referred to as **Analogous** and thus the phenomenon of similarity of function but not necessarily of origin or relationship is called **Analogy.** We can as such make an artificial grouping of animals on the basis of analogy. The butterflies and birds can be grouped together as *flying animals.* The whales and fishes can be classified as *aquatic animals.* In this type of classification, we see that the birds and insects are nodoubt grouped together as aerial animals but the origin of the wing of a bird and the wing of an insect are totally different. Likewise the *flippers* of a whale and *fins* of a fish are of different origins.

In the classification of animals, the **natural classification** only provides a basis whereby the true **phylogenetic relationships** of the groups are expressed.

Species: The basic group or unit of biological classification is the *species.* A species is a group of individuals exhibiting the following characteristics.

1. They have many characters in common.
2. They differ from and do not integrate with other groups.
3. The have a geographic range separate from related groups.
4. They are infertile with related groups.
5. Members of a species are all derived from a common ancestry and can breed with one another to yield fertile offspring.

Higher Groups: Two or more species which have certain characters in common constitute a **genus.** The closely related genera with some common characters are grouped as a **family.** The families with certain common characters constitute an **order.** The

closely related orders are grouped into **classes** and finally the closely related classes form a **phylum**. All the phyla of animals thus form an **animal kingdom** or **kingdom animalia.**

Binomial Nomenclature : **Linnaeus** was the first Swedish naturalist who introduced the binomial system of nomenclature. According to this system, every species of animals (or plants) is given two names. One of these is the specific name which particularises the species from all others, whilst the other, the generic name (which is written before the specific name) is shared by other related species which are considered to be sufficiently similar to be grouped in the same genus. The specific and generic names have their Latin origin and are usually printed in *italics*. The initial letter of the generic name is capital and that of the specific name is small. For example the name of one of the species of cockroach is *Periplaneta americana*. The systematic position of the species e.g., *Periplanata americana* in animal classification is as follows :

Kingdom	—Animalia
Phylum	—Arthropoda
Class	—Insecta
Order	—Orthoptera (Dictyoptera)
Family	—Blattidae
Genus	—Periplaneta
Species	—*Periplaneta americana*

A brief account of the classification of the phyla discussed in the book is given below. The extinct groups of animals and some other phyla are however not included. Some of the details about phyla and classes may also be obtained in the account of the types discussed in the previous chapters.

Kingdom Animalia :

Phylum Protozoa : The protozoans are unicellular or *acellular* organisms sometimes in colonies of similar cells.

Class I *Mastigophora :* One to many flagella for locomotion e.g., *Euglena.*

Class II *Sarcodina* (Rhizopoda) : Pseudopodia for locomotion e. g., *Amoeba.*

Class III *Ciliophora* : Cilia at all or some stages in life history e. g., *Paramoecium, Vorticella.*

Class IV *Sporozoa* : No locomotor organelles. All are parasitic e. g., *Plasmodium.*

Class V *Suctoria* : Ciliated young stages, adults with sucker-like tentacles e.g., *Acineta.*

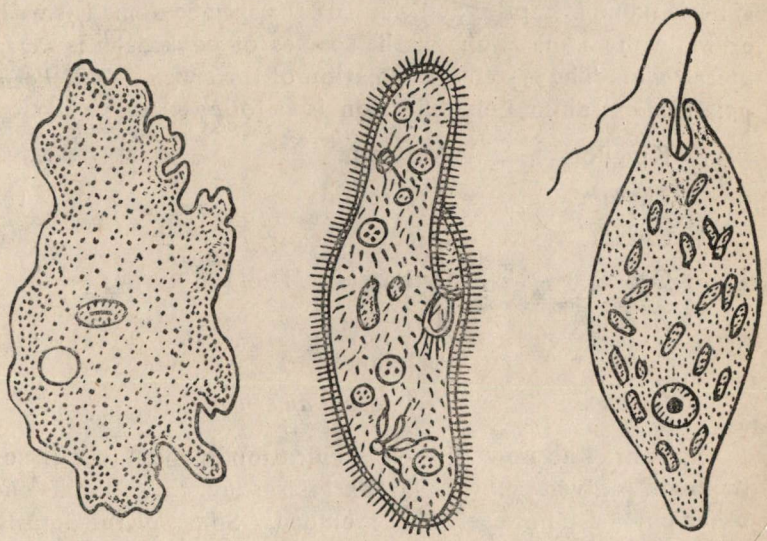


Fig 8·1 Single celled animals — The protozoa.

Phylum Porifera or sponges are all aquatic and mostly marine animals with a multicellular body. The cells are arranged in two layers around a central cavity, the **gastric cavity.** The body surface is provided with a number of pores. They are attached to rocks, weeds and other submerged objects and grow by branching in a plant

like manner. They are provided with a canal system and a skeleton composed of spicules and spongin fibres. The natural bath sponge sold in the market is really the skeleton of a sponge animal.

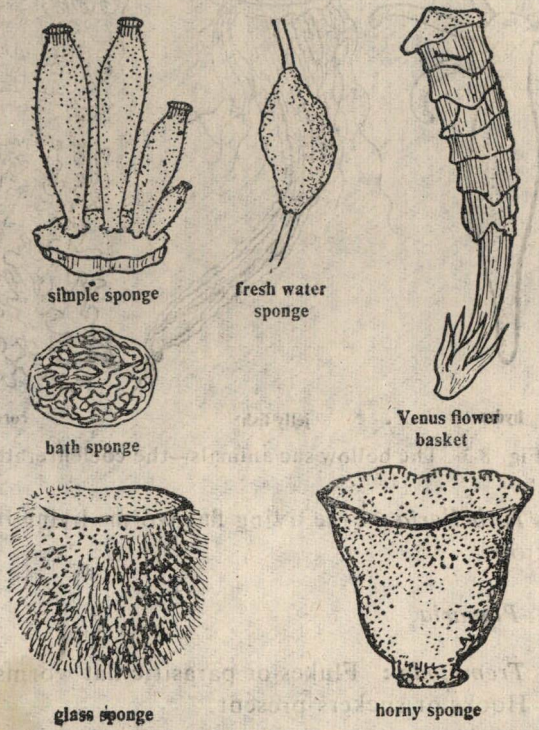


Fig. 8·2 Pore-bearing animals – the porifera (sponges)

Phylum Coelenterata consists of animals with radial symmetry, in the form of a sessile cylindrical polyp often in colonies. Some are bell-like free floating medusae with much gelatinous mesogloea. Some form corals.

e.g., *Hydra, Aurelia, Sea anaemone, Stylaster, Pleurobrachia, Hormiphora.*

Phylum Platyhelminthes consists of flat worms. Body depressed, thin and soft. Leaf or ribbon-like. Digestive tract branched or without anus. In some it is absent.

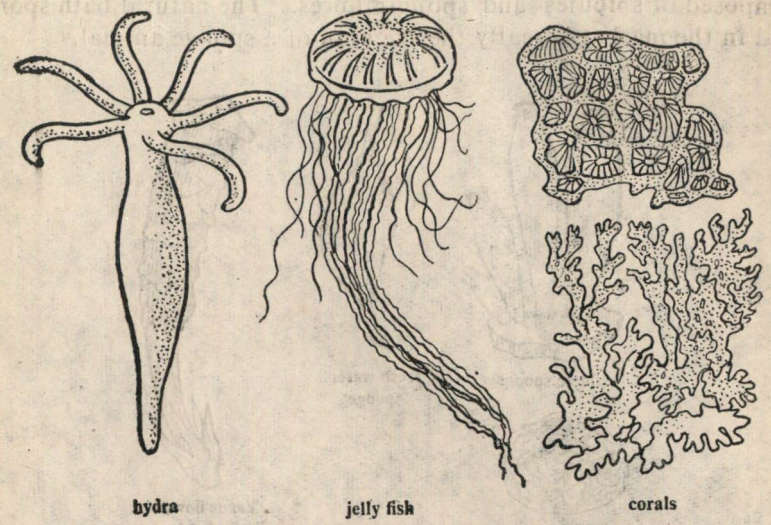


Fig. 8·3 The hollow sac animals—the coelenterates

Class *Turbellaria* : Free living flat worms living in water or in damp situations.

e.g., *Planaria.*

Class *Trematoda* : Flukes or parasitic flat worms with a leaf-like body. Hooks or suckers present.

e.g., *Fasciola* ; *Schistosoma.*

Class *Cestoda* : The Tape worms. Internal parasites. Alimentary canal is lacking. e.g., *Taenia, Echinococcus.*

Phylum Nematoda consists of round worms. Body covered with a tough cuticle. Sexes are separate. Both free living and parasitic nematodes are known.

e.g., *Ascaris, Ancylostoma, Dracunculus, Filaria* (Wuchereria).

Phylum Annelida consists of segmented worms. Triploblastic and coelomate with metameric segmentation.

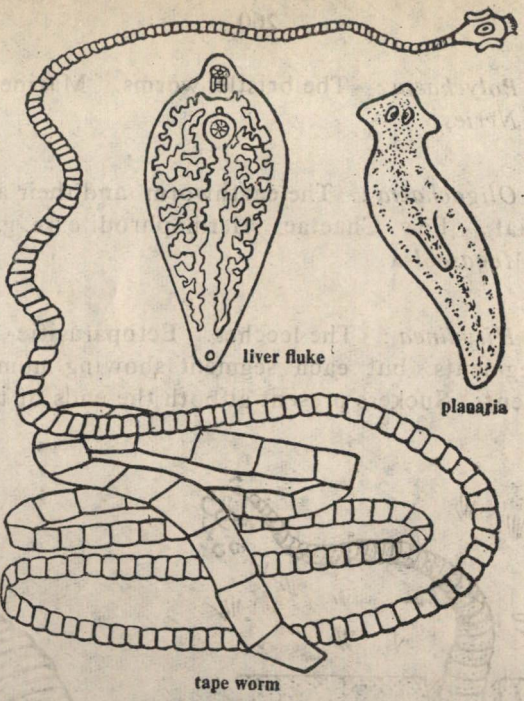


Fig. 8·4 The flat worms—The platyhelminthes

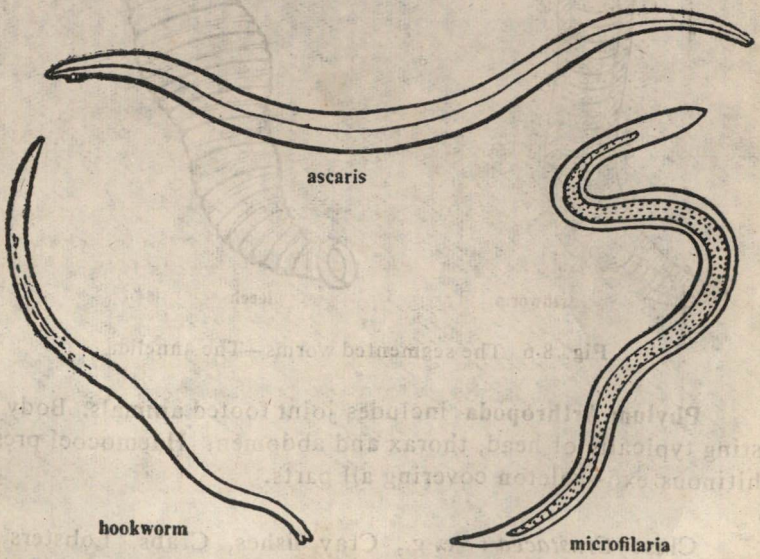


Fig. 8·5 The round worms—The nematoda

Class *Polychaeta* : The bristle worms. Marine. Parapodia present e.g., *Neries*.

Class *Oligochaeta* : The earthworm and their allies. Many are terrestrial. Few Chaetae, Hermaphrodite. e. g., *Pheretima*, *Lumbricus*, *Megascolex*.

Class *Hirudinea* : The leeches. Ectoparasitic annelids with few true segments, but each segment showing numerous annuli. Chaetae absent. Suckers present at both the ends of the body e. g., *Hirudo*.

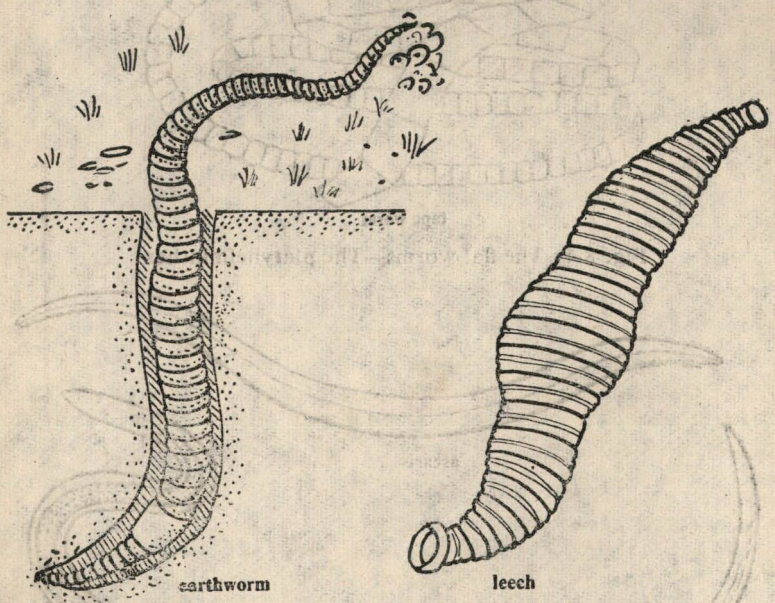


Fig. 8·6 The segmented worms—The annelida

Phylum Arthropoda includes joint footed animals. Body consisting typically of head, thorax and abdomen. Haemocoel present. Chitinous exo-skeleton covering all parts.

Class *Crustacea* : e. g., Cray fishes, Crabs, Lobsters and Shrimps.

Class *Onychophora* : Tracheate arthropods with thin cuticle. Terrestrial. Head composed of three segments with one pair of jaws. Body segments similar and bear appendages.

e.g., *Peripatus*.

Class *Myriapoda* includes centipedes and millipedes. Leg bearing. Body segments are smaller. Tracheate arthropods. There is one pair of antennae.

e.g., *Scolopendra* (Centipede), *Julus* (Millipede).

Class *Insecta* : Tracheate arthropods with body divided into head, thorax and abdomen. Wings, when present arise from the second and third thoracic segments. Life history usually shows metamorphosis.

e.g., Cockroach, House-fly, Mosquito.

Class *Arachnida* : Scorpions, Spiders, King Crabs, Mites. The body is divided into *prosoma*, *mesosoma* and *metasoma*. Head appendages are peculiar i.e., prehensile chelicerae, sensory or prehensile pedipalpi. There are four pairs of walking legs on the mesosoma. The respiratory organs are gill books, lung books or tracheae.

Phylum Mollusca includes the Snails, Slugs, Bivalves and Octopuses. Coelomate animals which do not show segmentation. The body is divided into head, foot and visceral mass. The pericardial cavity is coelomic in origin.

e.g., *Mytilus*, *Anodonta*, *Sepia*, *Octopus*.

Phylum Echinodermata includes triploblastic coelomate animals. The larvae are bilaterally symmetrical. Adults have acquired a large measure of radial symmetry. A calcareous skeleton is developed in the mesoderm. Larvae are pleagic and swim by means of ciliated bands.

Class *Asteroidea* : Sea Stars or Star fishes, star shaped body.

e.g., *Asterias*.

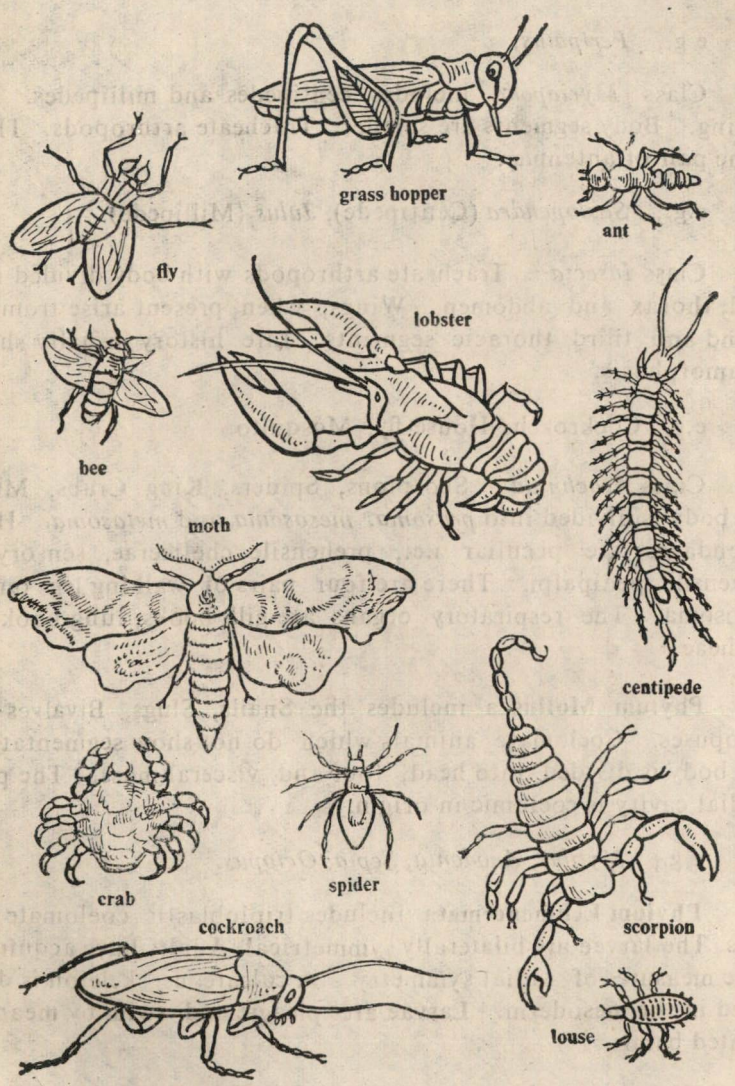


Fig. 8·7 Animals with jointed limbs—The arthropoda

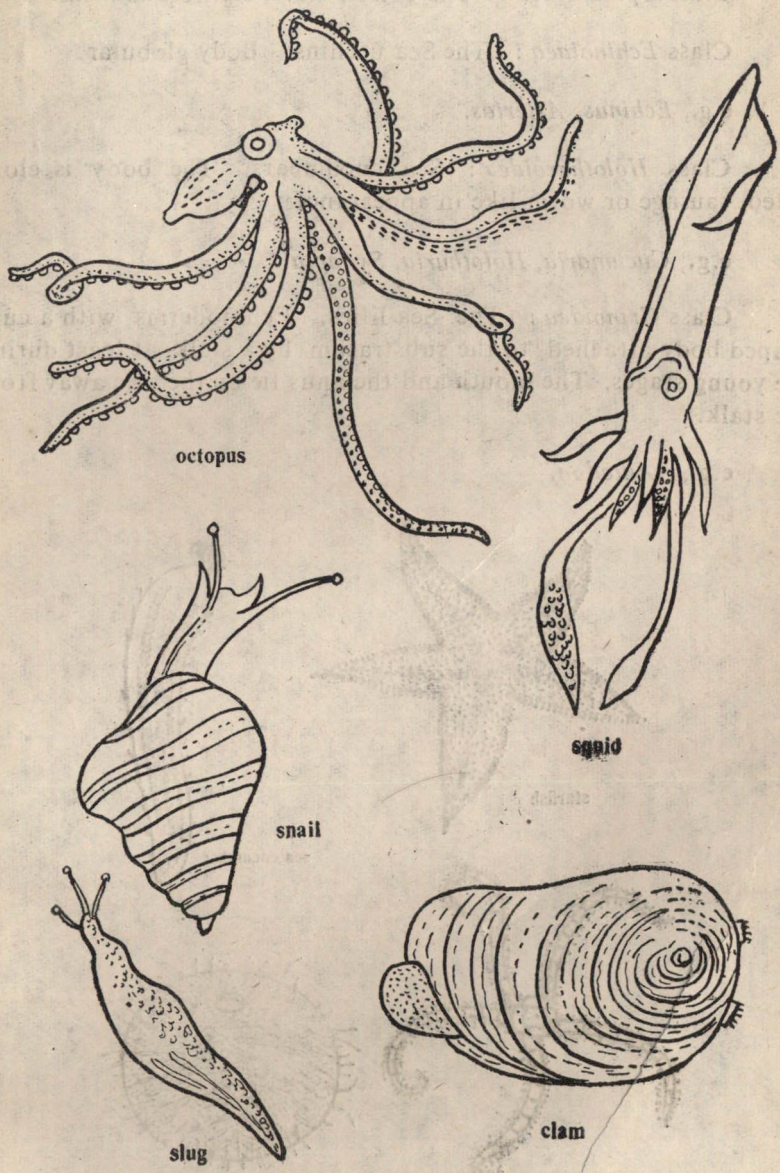


Fig 8·8 Soft bodied and shell bearing animals—The mollusca

Class *Ophiuroidea* : The Bristle stars. e.g., *Ophiothrix.*

Class *Echinoidea* : The Sea urchins. Body globular.

e.g., *Echinus, Asterias.*

Class *Holothuroidea* : Sea cucumbers. The body is elongated, sausage or worm-like in appearance.

e.g., *Cucumaria, Holothuria, Synapta.*

Class *Crinoidea* : The Sea lilies. Echinoderms with a cup-shaped body attached to the substratum by a stalk, at least during the young stages. The mouth and the anus lie on the side away from the stalk.

e.g., *Antedon.*

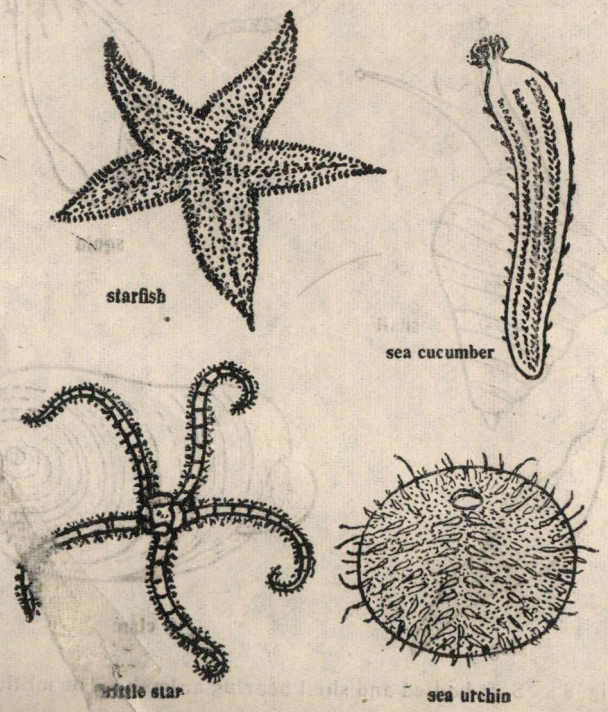


Fig. 8·9 The spiny skinned animals—The echinodermata.

Phylum Hemichordata includes peculiar marine, worm-like creatures having only doubtful affinities with other chordates. The *so called notochord* in fact is a **buccal diverticulum** or **pre-oral gut diverticulum.**

e g., *Balanoglossus, Cephalodiscus, Rhabdopleura.*

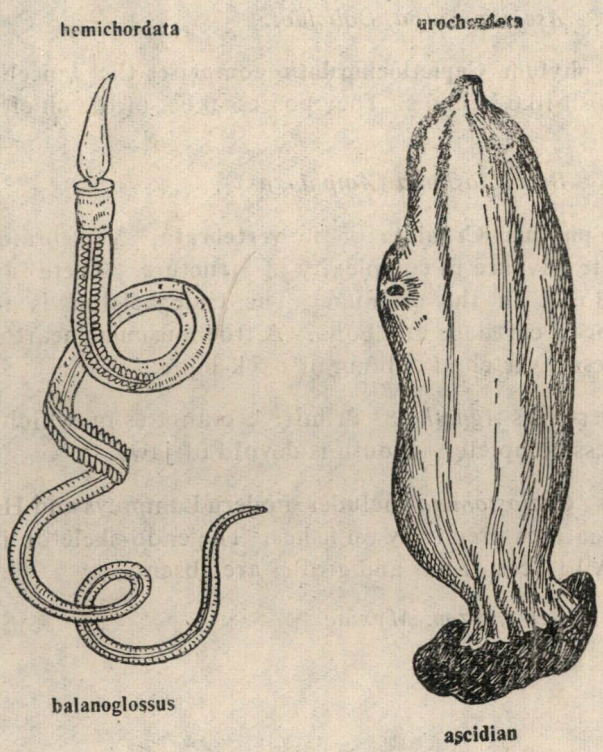


Fig. 8·10 The Protochordates

Phylum Chordata :

Sub-phylum Urochordata (Tunicata) consists of ciliary feeders, Sea squirts and their allies. Most of them are sedentary. Chordate characters are lost in the adult. The larva possesses chordate features which are lost in the process of *retrogressive metamorphosis.*

e.g , *Ascidia, Salpa, Doliolum.*

Sub-phylum Cephalochordata comprises the lancelets which are small fish-like animals. They possess most of the chief chordate characters.

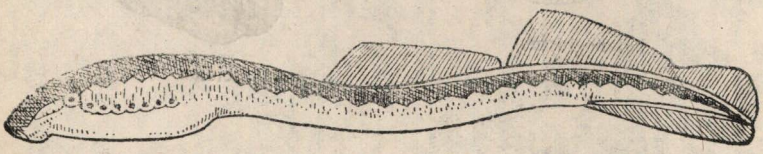
e g., *Branchiostoma* (*Amphioxus*).

Sub-phylum Craniata or the **vertebrata.** Vertebrates show a very definite advance in complexity of structure. There is a definite brain enclosed in the cranium. The endoskeleton is formed of cartilage or of cartilage and bone. A true muscular heart develops. They possess a vertebral column or back-bone.

Super-class *Agnatha :* Primitive craniates in which cephalisation is less complete. Mouth is devoid of jaws.

Class *Cyclostomata* includes modern Lampreys and Hag fishes. Eel like creatures predatory on fishes. The endo-skeleton is cartilaginous. All traces of fins and girdles are absent.

e g., *Petromyzon, Myxine.*



lamprey

Fig. 8·11 The Cyclostomes

Super-class *Gnathostomata* includes craniates in which the mouth is bounded by jaws.

Class *Chondrichthyes* : The Sharks, Dog-fishes, Skates, Rays etc. The skeleton is cartilaginous.

Class *Osteichthyes*: The bony fishes. The exoskeleton consists of scales. Fins present. e.g., *Channa striatus*, Kali Murrel.

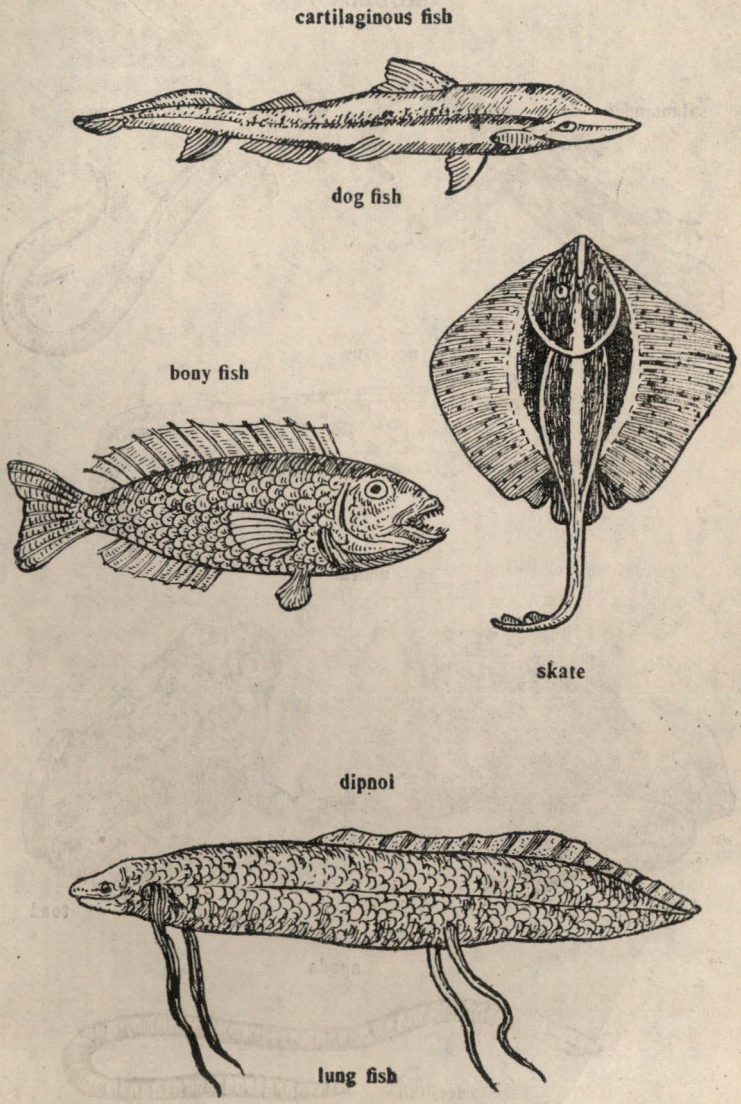


Fig. 8·12 The fishes

Class *Amphibia*: Animals which lead partly aquatic and partly terrestrial mode of life. e.g., Frogs, Toads, Salamanders, Proteus, Necturus and Coecilians (Ichthyophis).

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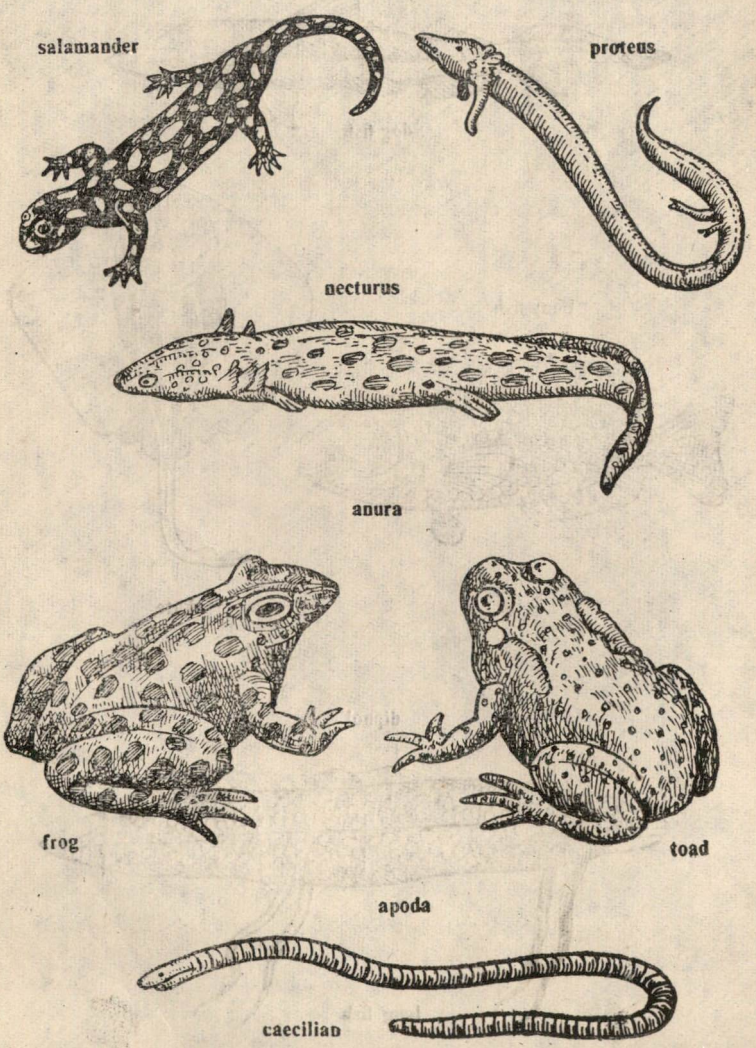


Fig. 8.13 The amphibians

Class *Reptilia* includes Lizards, Crocodiles, Snakes and Turtles. They are adapted to life on dry land. Skin dry and bears horny epidermal scales.

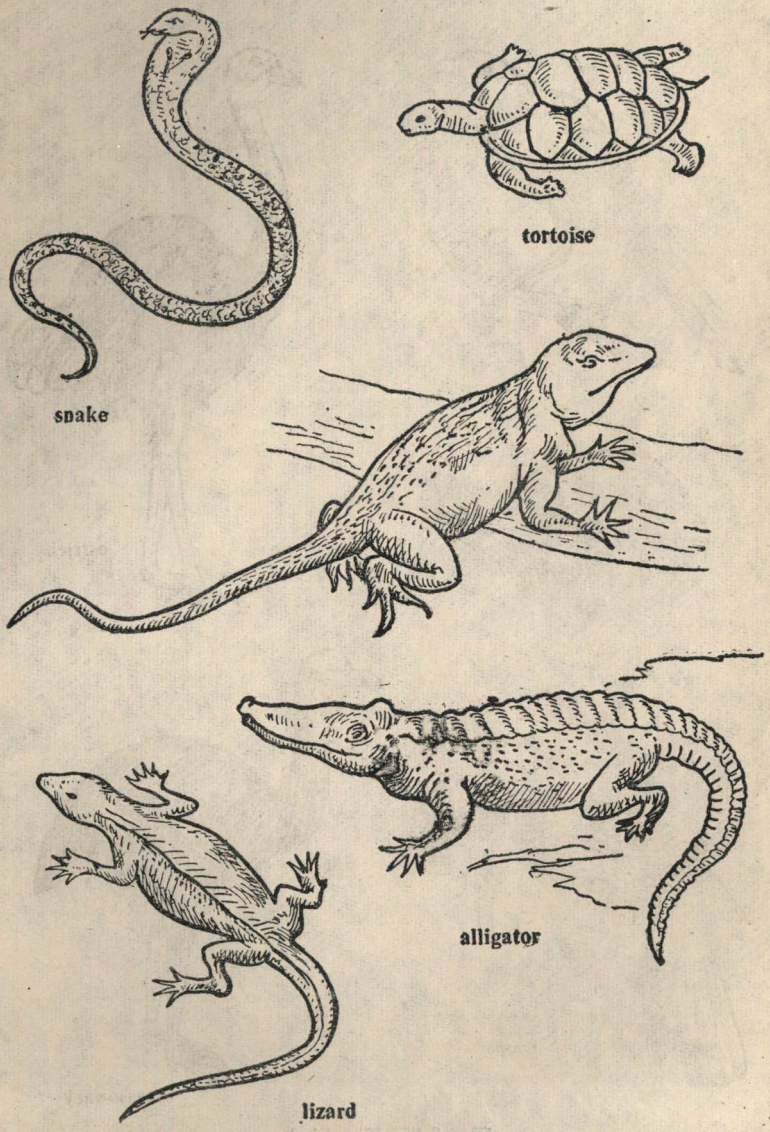


Fig. 8·14 The reptiles

Class *Aves* : Aerial mode of life Body covered with feathers. Heart completely four chambered. Warm blooded animals.

e.g., Ostrich, Gull, Duck, Crow, Sparrow.

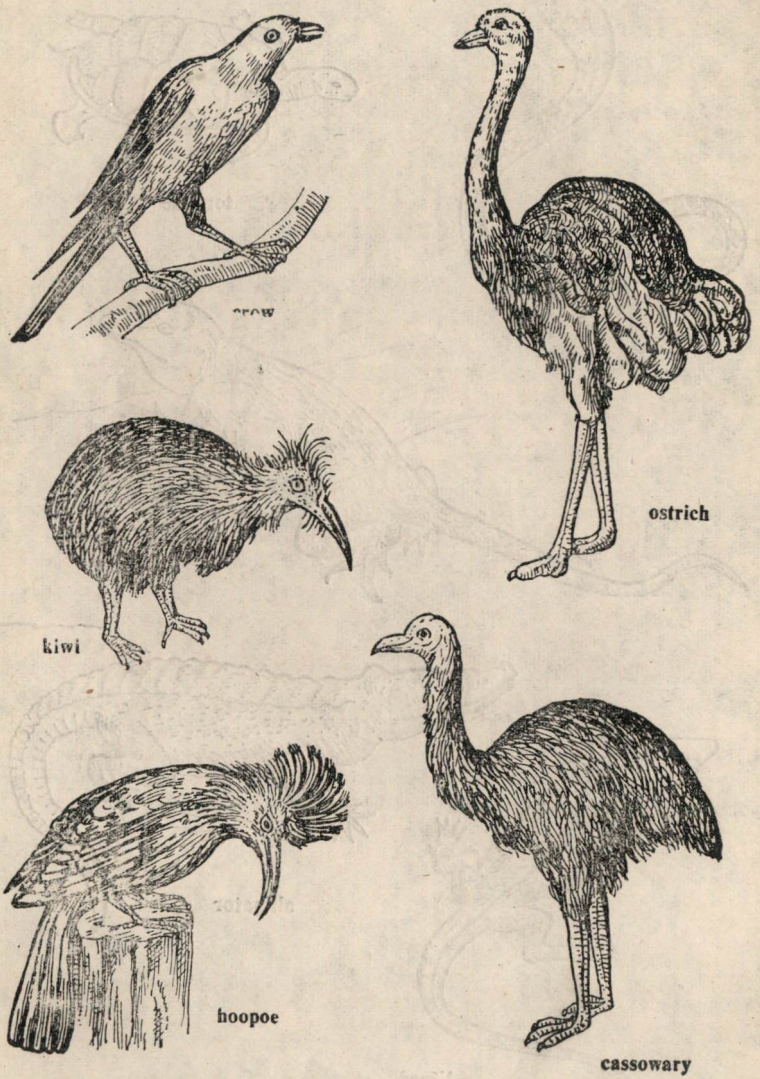


Fig. 8·15 The birds

Class *Mammalia* : Body usually covered with hair. Heart four chambered. Warm blooded. Females with mammary glands providing milk for the nourishment of the young.

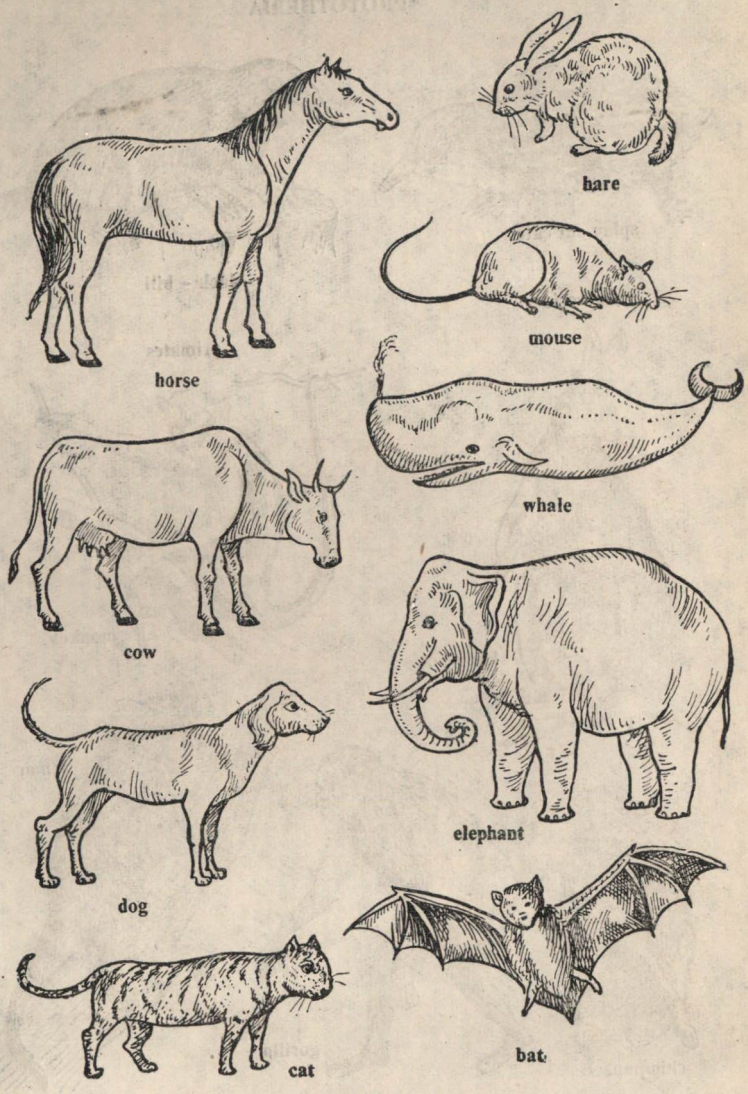


Fig. 8.16 The mammals

e.g., Duckbill, Kangaroo, Opossum, Horse, Monkey and *Homo sapiens* (Man).

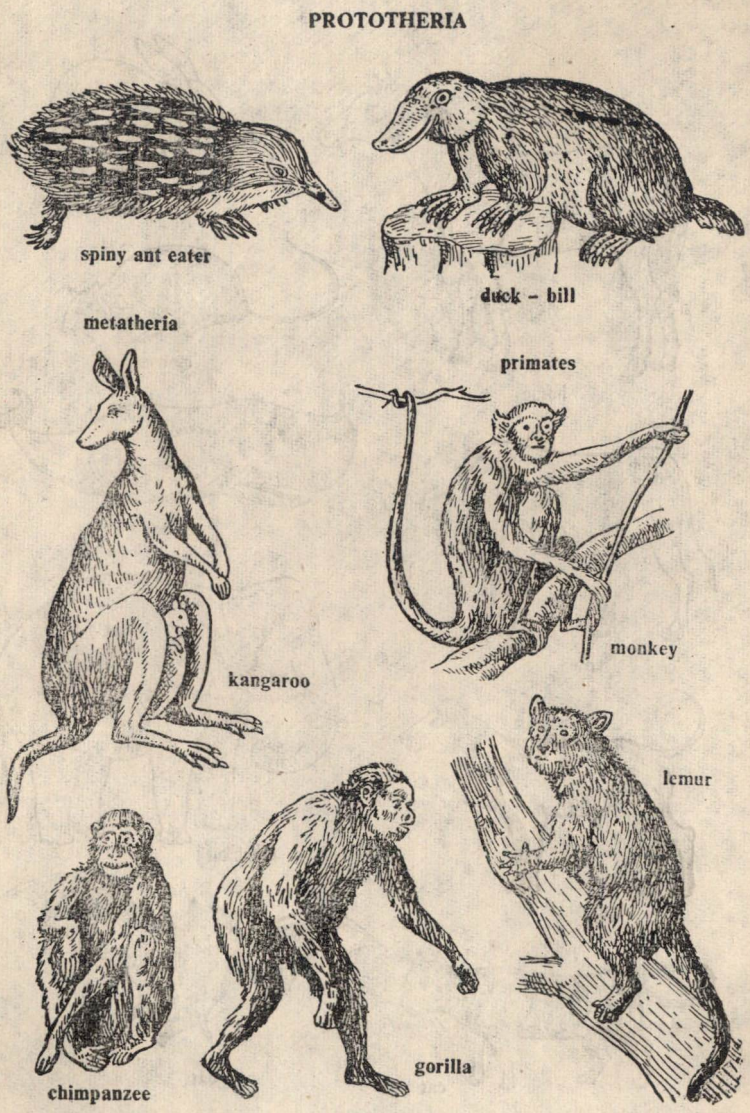


Fig. 8·17 The mammals

Revision questions

1. What are the various branches of study of the science of Biology ?
2. Define the term 'binominal nomenclature' and describe in brief the outline classification of animal kingdom.
3. What is a species ?
4. Write notes on the following :
   (a) Genus.
   (b) Microbiology.
   (c) Ecology.
   (d) Homology.
   (e) Analogy.

PART II

GENERAL

CHAPTER XI

CELL STRUCTURE AND FUNCTION

The bodies of all living organisms are composed of cells. The cell is the basic structural and functional unit of the body of living organisms.

The branch of study which deals with the structure and functions of the cells is called **Cytology** or **Cell biology.**

The knowledge about cells came to us by the application of lenses to magnify the parts of living things. An English Scientist **Robert Hooke** in 1665, took thin slices of cork and observed their structure by means of magnifying lenses. The tiny compartments or box-like structures much like a honey comb were observed. These were named as **cells** (Gk. *Kytos*; cell. L. *Cella*; hollow space). French Botanist, **Dutrochet** (1824), saw under the microscope box-like units in the plant material after being boiled up in nitric acid. The emphasis however so far was laid on the walls of the box-like compartments. These thick walls were the cellulose walls of plant cells laid down by living material. The term cell to such chambers was however quite appropriate. This term is retained even to this day, although by *cell we mean now not only it's wall but also it's inner living contents*.

Leeuwenhoek (1674), discovered free cells as opposed to the '*walled in*' cells of **Hooke** and observed some organization within the cells.

By 1800, there was rather a general acceptance of the idea that all organisms are cellular and a definite **cell concept** was thus developed. The names of **M. J. Schleiden** a German Botanist (1838), and that of **Theodre Schwann**, a German Zoologist (1839), are

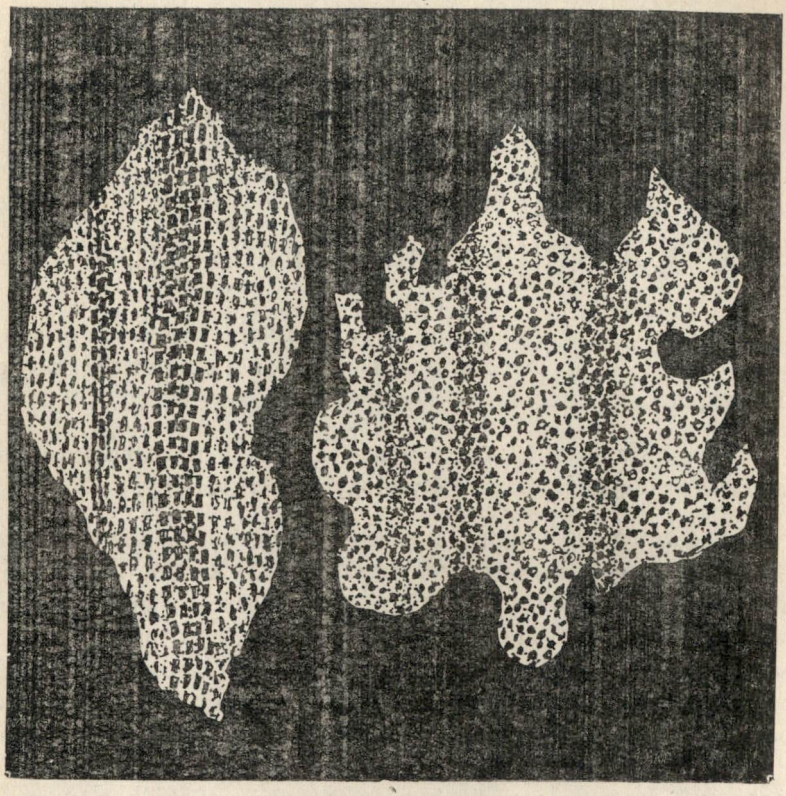


Fig. 9·1 Robert Hooke's drawings of the cellular structure of cork as published in 1665

usually associated with the development of the **cell concept**. It should however be remembered that many investigators prior to **Schleiden** and **Schwann** have equally contributed to our knowledge of cells, their structure and functions.

By the middle of the nineteenth century, the occurrence of *cell division* as the central phenomenon in the reproduction of organisms was established. **Rudolph Virchow,** a German biologist (1854), expressed this phenomenon of cell division in the famous aphorism "*Omnis cellula e cellula*" (Every cell comes from a cell) or *the cells arise from the pre-existng cells by a process of 'cell divtston'*.

The Living Matter of a Cell (Protoplasm):

The cells of animals and plants irrespective of their structure and function consist entirely of chemical compounds forming the **living substance** or **living matter** of the cells. The term *protoplasm* was applied to the living matter of cells. This term, protoplasm, is however falling into disuse on the basis of the fact that *the living matter of cells does not consist of any single material.* The living matter of cells is composed of a large variety of different chemical molecules which have their specific organization. The molecules of the component substance of the living matter are arranged in ways that are extremely unlikely to occur by chance. Protoplasm is a misleading term for living matter (if it is interpreted to mean a homogeneous substance), because the living matter as stated above is a complexly organized system of heterogeneous parts, the smallest representative piece of which is the cell. It is, therefore, no more accurate or meaningful to state that a cell is composed of protoplasm than it is to say that a radio set is composed of '*radioplasm*'. How can there be a representative particle of '*radioplasm*' when the whole radio set is a complex and heterogeneous unit of tubes, condensers, wires and the like ?

Four of the most widely distributed elements on earth i. e., oxygen, carbon, hydrogen and nitrogen form a major component of living matter. 95% of the approximate weight of living substance is composed of these four elements. The remaining 5% of the weight is contributed by other elements. Certain elements are found in very small quantities or in traces, while others may be incorporated in the living substance along with the nutrient materials.

All the elements are found in the form of both organic and inorganic compounds.

The most important inorganic constituent of a cell is water. The percentage of water in living matter is about 65 to 72% or can be as high as 95%.

The other inorganic constituents or cellular minerals occur either free or combined with organic compounds. When in solution most of these exist as *ions*. The most abundant positively charged ions in the living matter are H^+ (hydrogen ions), Ca^{++} (Calcium

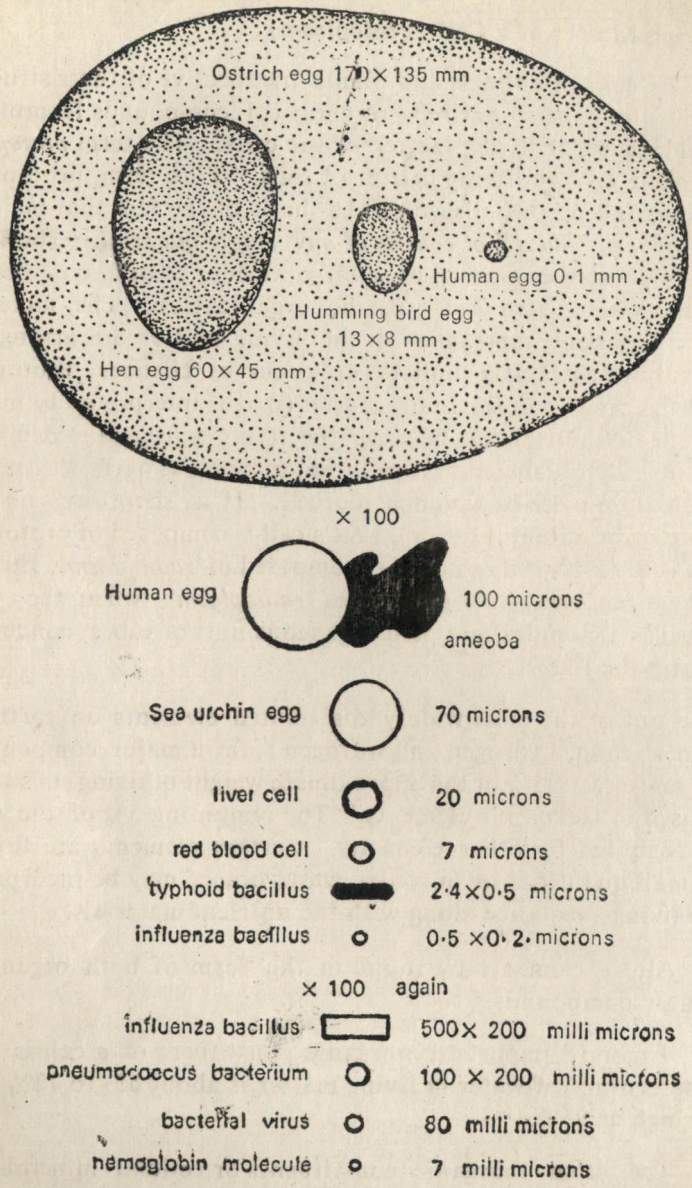


Fig 9.2 A scale of sizes of different types of cells with the bacterial virus and haemoglobin molecule for purposes of comparison

ions), Na^+ (Sodium ions), K^+ (Potassium ions) and Mg^+ (Magnesium ions). The negatively charged ions are OH^- (Hydroxyl ions), CO_3^{--} (Carbonate ions), HCO_3^- (Bicarbonate ions), PO_4^{---} (Phosphate ions), Cl^- (Chloride ions) and SO_4^{---} (Sulphate ions).

The chief organic constituents of cells are the proteins, carbohydrates, lipids (fatty substances) and the nitrogen base derivatives which include adenosine phosphates and nucleic acids.

The living substance thus has a complex structure. In physical appearance it is generally a translucent, essentially colourless, slimy and cohesive substance. It has sometimes the viscosity of stiff gel or it may flow almost like water (sol). The living substance thus is of varying consistency so to say occuring in the *gel* or *sol* states.

Sizes and Shapes of Cells :

(a) **Cell size** : The cells occur in a variety of sizes. The **eggs** are single cells and most of them can be seen easily with the naked eye. This is because of the abundant quantity of food reserves they contain. The **hen's egg** is a single cell 60×45 mm. in dimensions. The **egg of an Ostrich** may attain the dimensions of 170×135 mm. The **nerve cells** in the human body have long processes, over 1 metre in length but their diameter is very small. The cells composing the **jute** or **hemp** fibres may range from 30 to 40 cm. in length. Most of the cells of living organisms are very small and can only be seen with the aid of a microscope.

To measure the dimensions of cells of microscopic sizes we use the unit of measurement termed as **micron**, represented by the symbol μ. A micron is 1/1000th of a millimetre i.e., $1\mu = 0{\cdot}001$ mm. Bacteria are as small as 0·001 mm. The diameter of the human red blood corpuscle is 7·5 μ. To determine the dimensions of most cell structures (i. e., the cell components) we use the finer units of measurements such as the millimicron (m μ). One millimicron corresponds to $\frac{1}{1000}$th of a micron i.e., 0·001 μ. Further sub-division of the millimicron into units of ten gives the Angstrom unit (Å). One Angstrom unit corresponds to one-tenth of a millimicron (0·1mμ). The millimicron unit is used to measure sub-microscopic structures of cells revealed by the electron microscope and to determine the wave-length of radiations.

(b) Cell shapes : The cells vary markedly in shape as well. Some cells, such as *amobae* and *leucocytes* change their shape frequently. Other cells always have a typical shape, more or less fixed and is specific for each cell type. The spermatozoids, the erythrocytes, the epithelial cells, the nerve cells and most plant cells, etc., have a definite shape.

The shape of a cell is usually a clear reflection of the function it carries out. Nerve cells which transmit electrical impulses over long distances, have long extensions in some cases several feet in length. Muscle cells are elongated so that the force of contraction can be exerted efficiently in one direction. The supporting cells of plants have thick walls. Where masses of cells are simply packed together, they assume the shape of a polyhedron, a solid with many faces. This shape allows close packing of the cells without a large amount of space in between them.

The shape of cells thus depend chiefly on functional adaptations, partly on the surface tension and viscosity of the living substance, and the mechanical action by the adjoining cells as well as the rigidity of the cell membrane.

Cell volume : The volume of cells varies between 200 μ^3 to 1500 μ^3. The volume of a cell in general is fairly constant for a particular cell type and is independent of the size of the organism. For example, the kidney or the hepatic cells have about the same size in the bull, horse and mouse and the difference in the total mass of the organ is due to the number and not the volume of the cells. This is sometimes called the *law of constant volume.*

Basic cell types : Two basic cell types are recognised i.e., the **Prokaryotic cells** and the **Eukaryotic cells.**

In the **Prokaryotic cells**, there is no *true nucleus.* The nuclear material is not separated from the cytoplasm. The cells of *blue-green algae and bacteria* are of Prokaryotic type. Beyond this level the organisms have Eukaryotic cells.

Eukaryotic cells have *true nucleus* separated from the cytoplasm by the nuclear membrane. The cytoplasm contains within it various components concerned with the performance of different cellular activities.

The Structure of the Animal Cell :

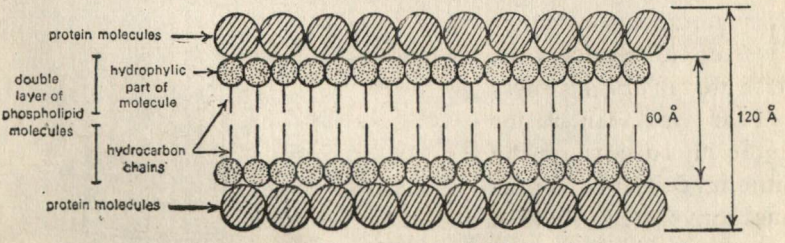
The cell is a dynamic unit of the body of all organisms. There is no such cell which could be referred to as a *'typical cell'*. The structure of a cell has been studied under the light microscope. The advent of electron microscope has further revealed finer details of cell structure. The details of the ultra structure of a cell are as follows :

The cell is bounded by a **cell membrane** or **plasma membrane** which separates it from the environment and through which materials entering or leaving the cell must pass.

Within the plasma membrane two distinct parts can be recognised of all Eukaryotic cells. (i) A conspicuous structure called the **nucleus**, enclosed by the **nuclear membrane**. (ii) The portion of the cell substance around the nucleus called the **cytoplasm.**

The Cell Membrane or Plasma Membrane :

The **plasma membrane** invests the outer surface of all cells. The plasma membrane provides an important barrier between the interior of the cell and the exterior. Water and many other small molecules pass through it quite easily. On the other hand, many ions such as the sodium (Na^+) and large molecules such as protein molecules pass through with great difficulty. A membrane that permits the free passage of some materials and not others is called a **semi** or **differentially permeable membrane.** The permeability of the cell membrane changes with changing conditions which suggests that it is not a passive barrier but is selectively permeable.



Fig, 9·3 Molecular structure of biological membranes such as the plasma membrane or the cell membrane

The plasma membrane is very thin i.e., 75–100Å. The chemical and physical studies of the cell membrane suggest that it is made up

of three layers of roughly equal thickness. The outer layer seems to be composed chiefly of *protein molecules*. The middle layer is actually a double layer of *phospholipid molecules*. The inner layer is another *protein layer*. The plasma membrane of animal cells thus has a *trilaminar structure*. *The protein—lipid—protein membrane* seems *to be such a fundamental structural unit throughout the cell* that the plasma membrane has been given a special name, the **unit membrane.**

Functions of the Plasma Membrane :

The variety of enzyme systems associated with the plasma membrane or forming an integral part of it, together with the nature of membrane, govern the rate of entry of molecules as well as the kinds of molecules which can enter or leave a cell.

Parts of the cell surface of certain cells are concerned with *absorption, secretion, fluid transport* and other physiological processes.

At the surface of certain cell membranes are slender processes called **microvilli.** These are the *brush borders* such as are seen under a light microscope on the epithelial cells of the proximal convoluted tubule in the kidney. The so called *striated border* of the intestine also consists of microvilli 0·6 to 0·8 μ long and

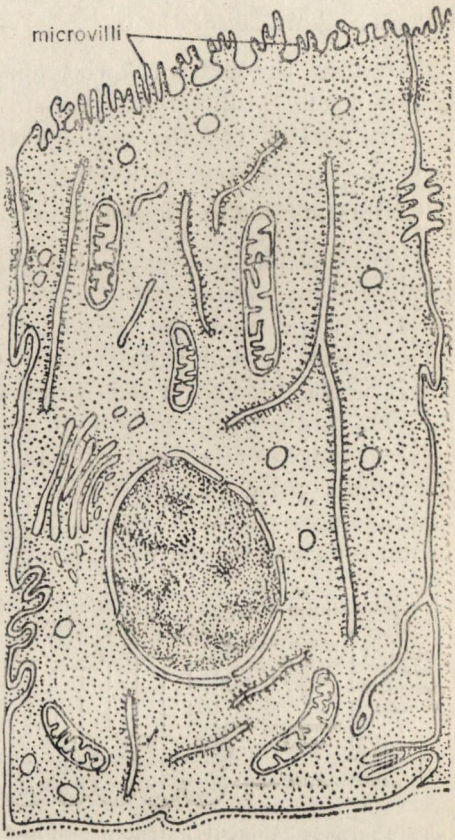


Fig. 9·4 Electron microscope structure of a cell showing the microvilli that are active in absorption

only 1000 Å in diameter. The microvilli are dense cytoplasmic processes covered by the plasma membrane. They increase the effective surface of absorption. A single cell may have as many as 3,000 microvilli, and in a square millimetre of the intestine, there may be 200,000,000. The narrow spaces between the microvilli form a sort of sieve through which substances must pass during absorption. The microvilli have also been found in the mesothelial cells, in the epithelial cells of the gall bladder, uterus and yolk sac as well as in the hepatic cells.

Intimately related to the activities of the plasma membrane are the phenomena of **phagocytosis** and **pinocytosis**. These are the processes by which solid or fluid materials are ingested in bulk by the cell.

In **phagocytosis** (Gk. *Phagein*; to eat) arms of cytoplasm engulf droplets of liquids containing solid material, such as bacteria, and draw these materials into the cytoplasm, where the digestive enzymes break-up the engulfed material down into usable fragments. Among protozoa, phagocytosis is intimately linked to amoeboid motion. An amoeba ingests large particles, including microorganisms by surrounding them

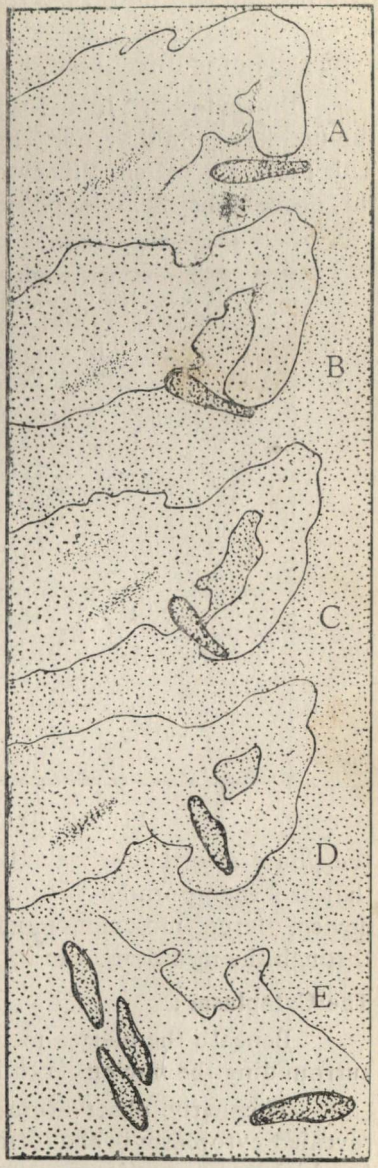


Fig. 9·5 The process of phagocytosis

with pseudopodia to form a food vacuole. Within this food vacuole the digestion of food takes place. The leucocytes and other phagocytic cells of multicellular animals also perform *phagocytosis.*

Pinocytosis : In addition to the ingestion of solid particles, the uptake of fluid vesicles by the living cell has been observed. This process is called **Pinocytosis** (Gk. *Pinein;* to drink). During this process the flexible plasma membrane forms a channel to get

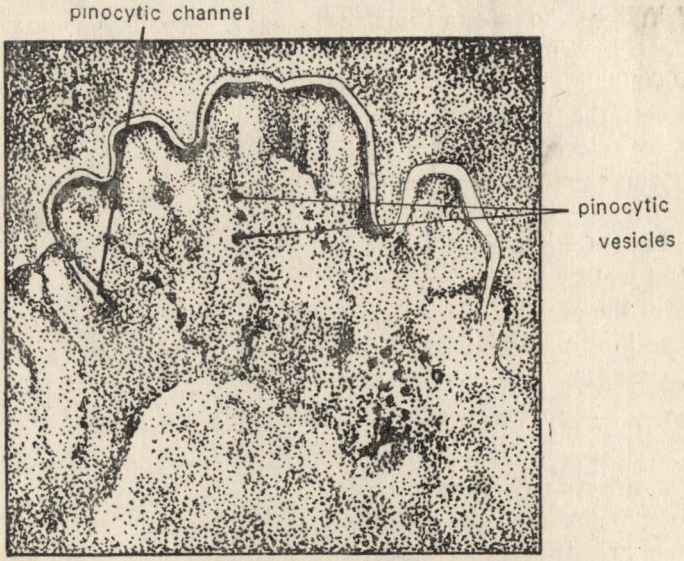


Fig. 9·6 The process of pinocytosis

the liquid into the cell and then pinches off the liquid filled pockets that are incorporated into the cytoplasm to be digested. By this device, large molecules and various ions incapable of passing through the membrane can be taken up by the cells.

The Cytoplasm :

Beneath the plasma membrane, the part of the cell substance surrounding the nucleus is called the **cytoplasm.**

The early observations under an electron microscope have revealed cytoplasm in the form of a homogeneous amorphous region in which some particulate structures such as mitochondria, etc., were found embedded. This was called the *ground* or *fundamental cytoplasm* or the *hyaloplasm.* Frequently, the peripheral layer of the

cytoplasm is called the **ectoplasm.** It is relatively more rigid and devoid of granules. The ectoplasm often behaves as a colloid and undergoes reversible *gelation* and *solation.* The internal cytoplasm, called the **endoplasm**, contains different granules, and is less viscous than the ectoplasm.

Under the electron microscope, it is now revealed that a complex system of membranes consisting of tubes or vesicles or flattened cisternae pervade the ground cytoplasm. This is called the **endoplasmic reticulum** or **ergastoplasm.**

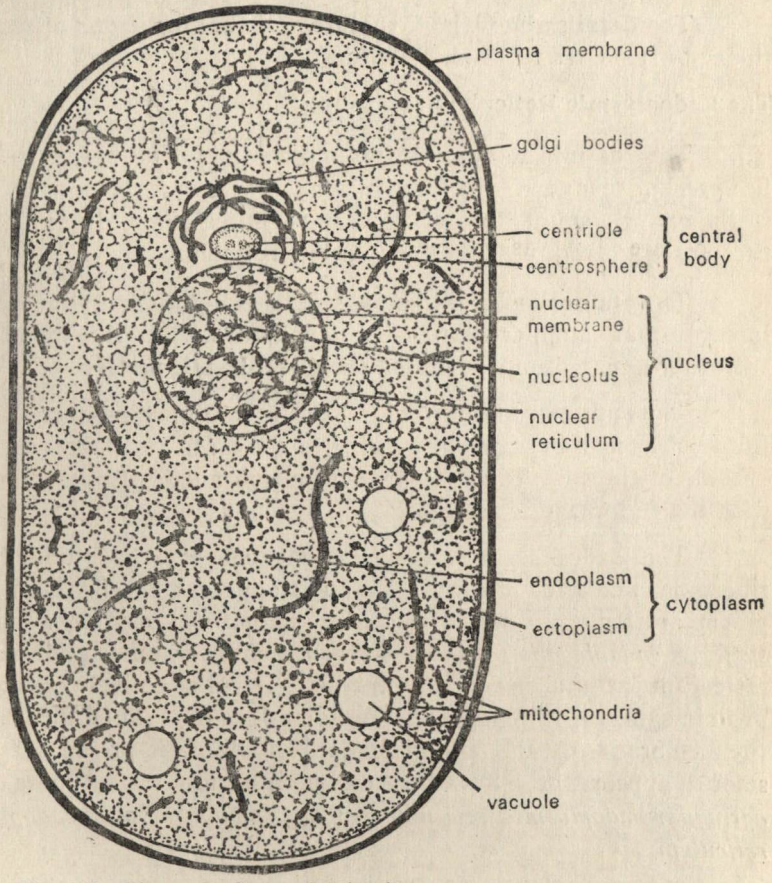


Fig. 9·7 Diagram of an animal cell as seen under a light microscope

Besides the endoplasmic reticulum, within the cytoplasmic matrix are found embedded many important components of a cell,

involved in various metabolic activities. Those important cell components concerned in the metabolic activities are referred to as the **cell orgnaelles.**

Besides the **nucleus**, the other cell organelles are the *endoplasmic reticulum*, *ribosomes*, *golgi complex*, *mitochondria*, *centrioles*, *lysosomes*, *microbodies*, *microtubules* and *vacuoles*. The plant cells, in addition, contain *chloroplasts* which are important cell organelles actively concerned with the process of photosynthesis.

The details about the structure and the functions of some of the cell organelles will now be discussed.

The Endoplasmic Reticulum :

The endoplasmic reticulum consisting of tubes, vesicles or flattened cisternae in the form of a net-work is more concentrated in the endoplasm of the cell than in the so called ectoplasm. It is therefore referred to as the **endoplasmic reticulum.**

The endoplasmic reticular system sub-divides the cytoplasm into two main compartments—one enclosed within the membrane; the other situated outside called the **Cytoplasmic matrix.**

The endoplasmic reticulum extends to varying degrees from the nuclear membrane on the inside to the plasma membrane on the outside of the cell. The outer nuclear membrane is often continuous with the endoplasmic reticulum.

The endoplasmic reticulum of a cell may be studded with ribosomes and thus presents a granular appearance. Such an endoplasmic reticulum is called *granular endoplasmic reticulum* or *rough surfaced endoplasmic reticulum.* The rough or granular endoplasmic reticulum is found in great abundance in cells actively engaged in protein synthesis. When the ribosomes are not found attached to the membranes of the endoplasmic reticulum, it presents then, a smooth appearance. Such type of endoplasmic reticulum is called *agranular endoplasmic reticulum* or *the smooth surfaced endoplasmic reticulum.*

The membrane of the endoplasmic reticulum is about 50 to 60 Å thick. Although it is thinner than the cell membrane, it does exhibit *unit membrane* structure or the *trilaminar* structure. The cavity

of the endoplasmic reticulum is sometimes very thin with the two membranes closely apposed; but more frequently there is a true space between the membranes which may be filled with a material of varying opacity.

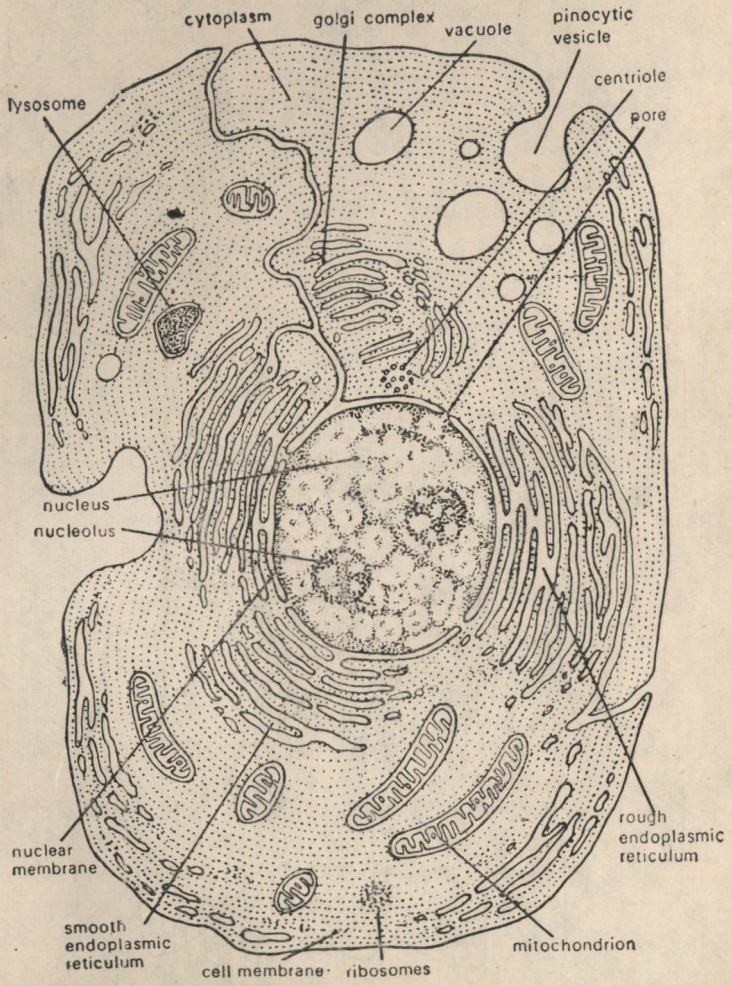
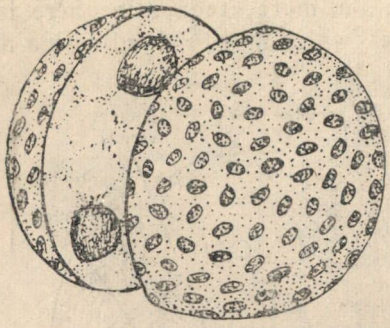
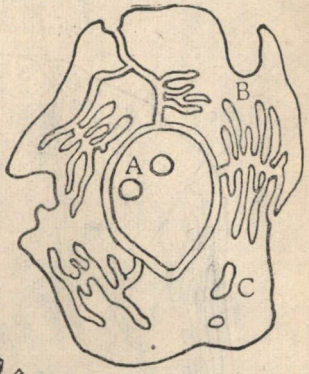


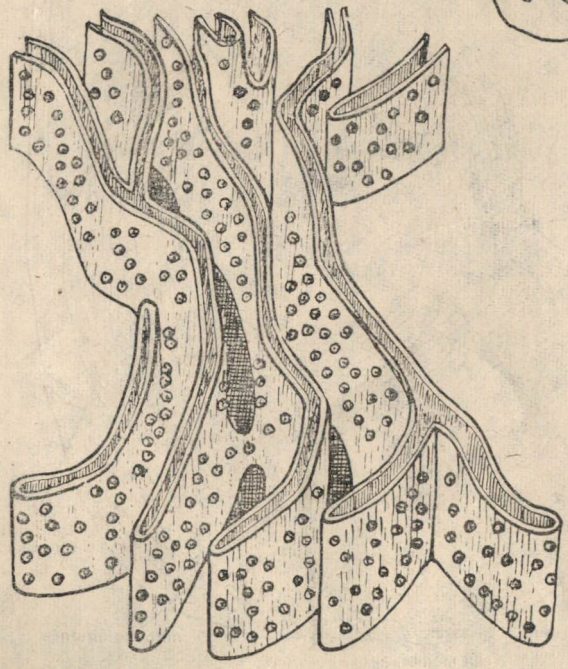
Fig. 9·8 A diagram of a generalised cell as seen under an electron microscope

Functions: The endoplasmic reticulum together with the plasmic matrix divides the fluid content of the cell into compart



nucleus





endoplasmic reticulum

g 99 Above—Left : The nucleus with nuclear pores and nucleoli in three nensional view, Right : A diagrammatic drawing of a cell with endoplas- reticulum. Below : The endoplasmic reticulum in three dimensional view with ribosomes attached to its membranes

The endoplasmic reticulum thus provides supplementary mechanical support for the colloidal structure of the cytoplasm.

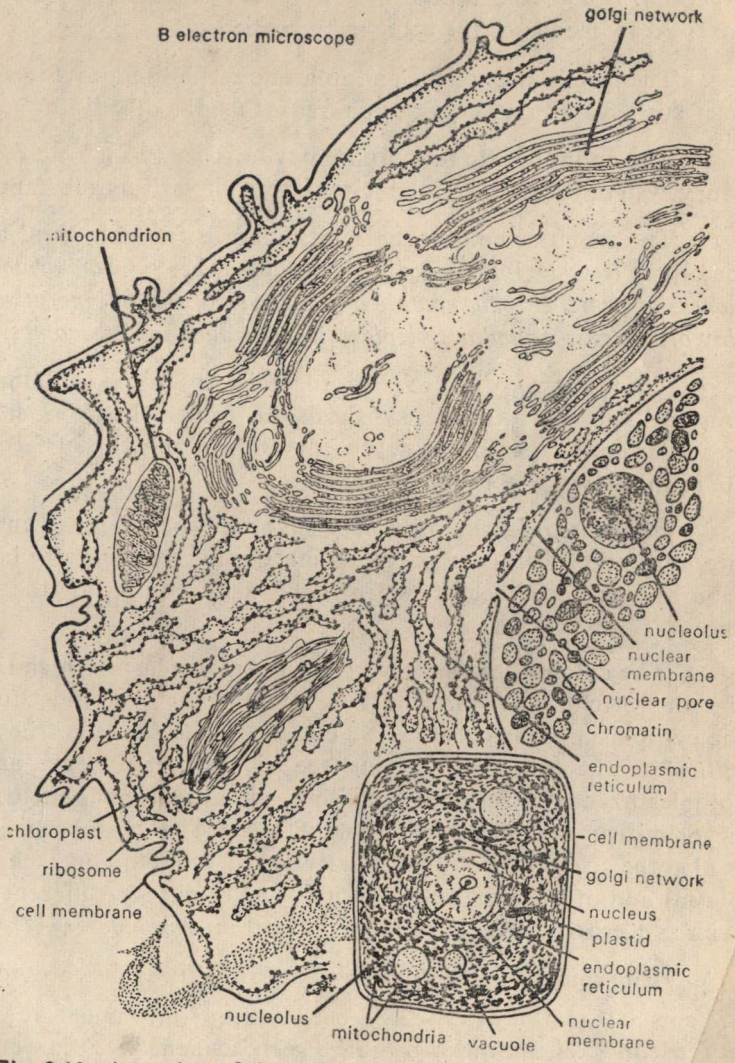


Fig. 9.10 A portion of the cell as seen under an electron microscope. Inset—A cell as seen under a light microscope.

The membranes of the endoplasmic reticulum may regulate the exchange between the inner compartment or the outer compartment,

or between the compartments and the cytoplasmic matrix. Numerous enzymes are associated with the membranes of the endoplasmic reticulum. The membranes participate in different metabolic reactions by means of the attached enzymes.

The membranes of the endoplasmic reticulum provide a larger inner surface and consequently increase the area of cellular activity.

The endoplasmic reticulum may also act as a kind of circulatory system for intracellular circulation of various substances.

The granular endoplasmic reticulum is found in great abundance in cells actively engaged in protein synthesis. *This synthesizing process of proteins is a complex process involving co-operative interplay of nucleus, granular endoplasmic reticulum and ribosomes.*

The agranular type of endoplasmic reticulum is abundant in those cells involved in the synthesis of lipids. In plant cells, the agranular endoplasmic reticulum develops along the surface where the cellulose walls are being formed.

The *sarcoplasmic reticulum*, a specialised form of endoplasmic reticulum found in striated muscle fibres transmits impulses from the surface membrane into the deep regions of the muscle fibre.

The **cytoplasmic matrix** or ground cytoplasm which lies outside the reticular system contains most important constituents of the cytoplasm. The cytoplasmic matrix constitutes the true *internal milieu** of the cell. It contains free ribosomes, glycogen particles, soluble enzymes, structural proteins and all the components found in primitive organisms excluding DNA. The cytoplasmic matrix is also the site of the colloidal activity of the living matter (protoplasm) and of the production of many cytoplasmic differentiations, such as Keratin fibres, myofilaments and *microtubules*.

Ribosomes: The **ribosomes** are roughly spherical bodies and are so small (150 Å) that they can be seen only under an electron microscope. The minute granules seen attached to the rough surfaced endoplasmic reticulum are the ribosomes. They are also found dispersed in the cytoplasm either singly or in groups. Ribosomes are

* Internal environment.

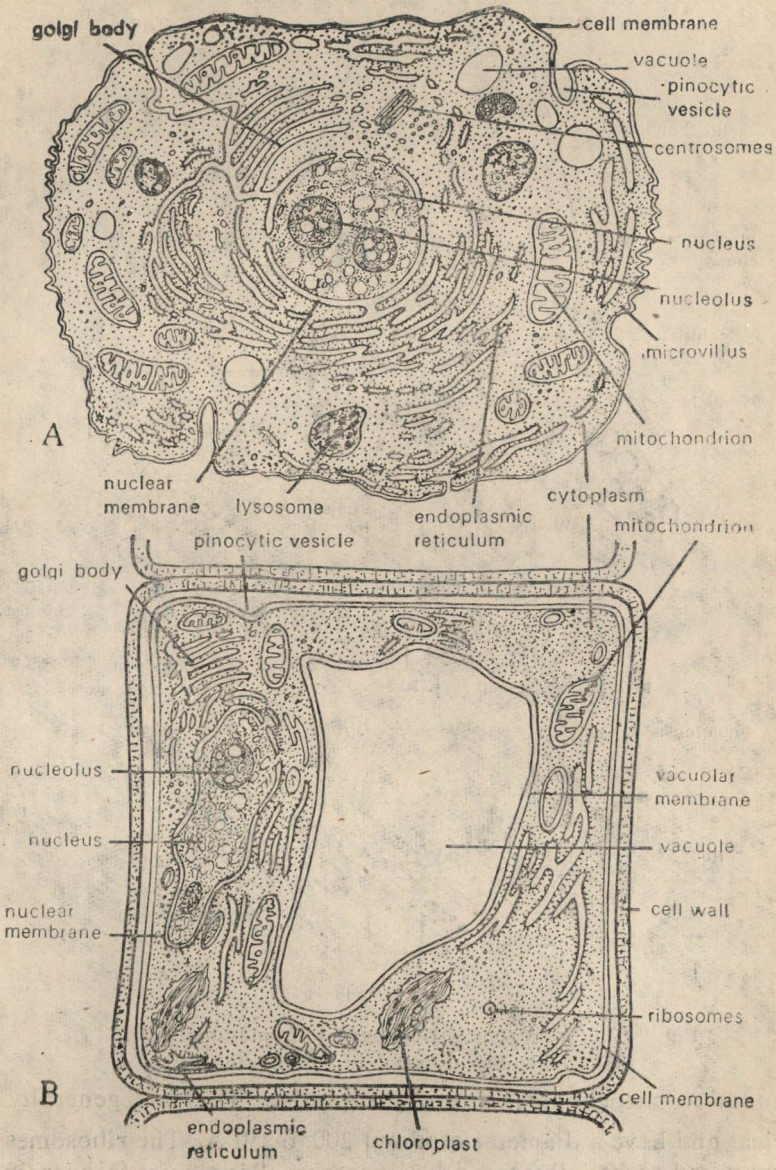


Fig. 9·11 (A) An animal cell and (B) A plant cell as seen under an electron microscope.

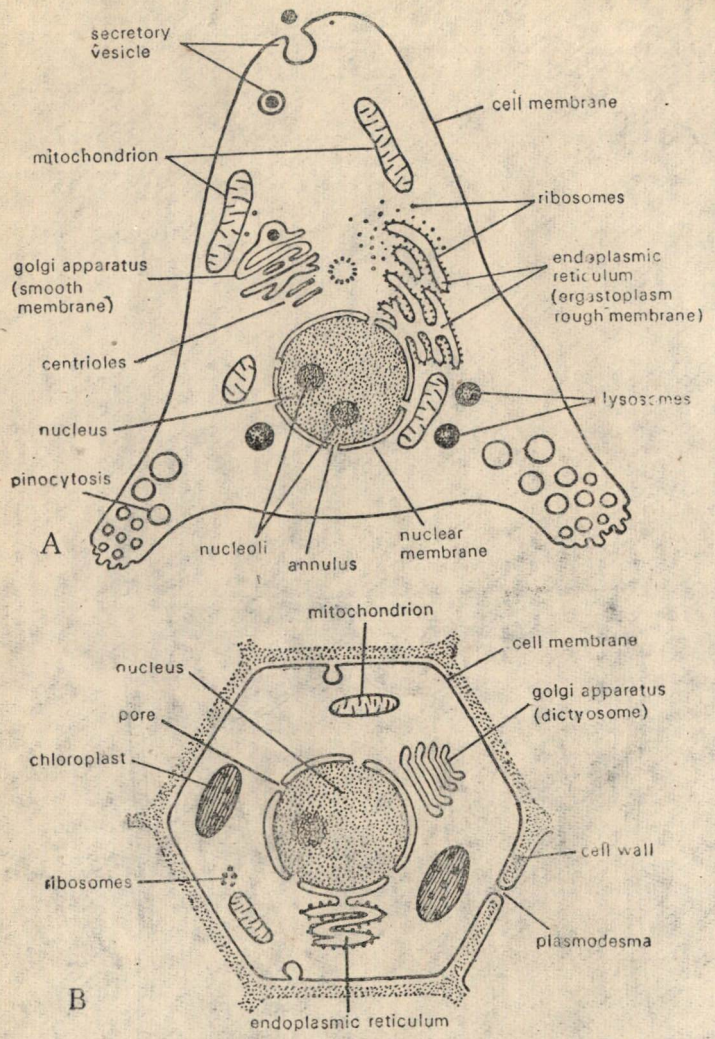


Fig. 9·12 (A) A schematic diagram of an animal cell.
(B) Schematic diagram of a plant cell.

also found in mitochondria and chloroplasts. They are generally spherical and have a diameter of about 200 to 250 Å. The ribosomes are composed of 60% RNA and 40% proteins. Ribosomes frequently aggregate to form the *polysomes* consisting of a definite number of

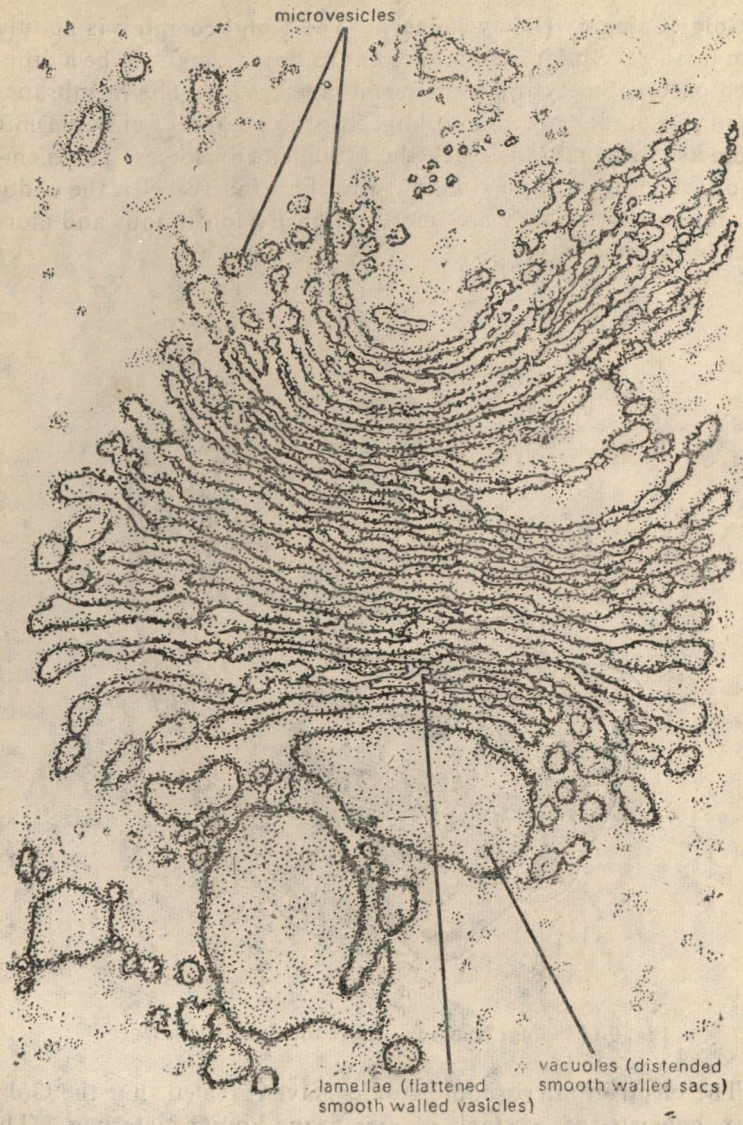


Fig. 9·13 The structure of Golgi complex as revealed by an electron microscope.

ribosomes. Ribosomes are the sites where synthesis of proteins takes place. It is now demonstrated *that the nucleolus plays a key role in the biogenesis of ribosomes.*

Golgi Complex (Dictyosomes) : The Golgi complex is mainly a system of intracellular membranes and is now thought to be a differentiated part of the cytoplasmic membrane system. The membranes of the Golgi complex are comparable to the agranular endoplasmic reticulum as it's membranes lack the attached ribosomes. The membranes of the Golgi complex may show continuity with the endoplasmic reticulum but they are more often discontinuous and more compact in morphology.

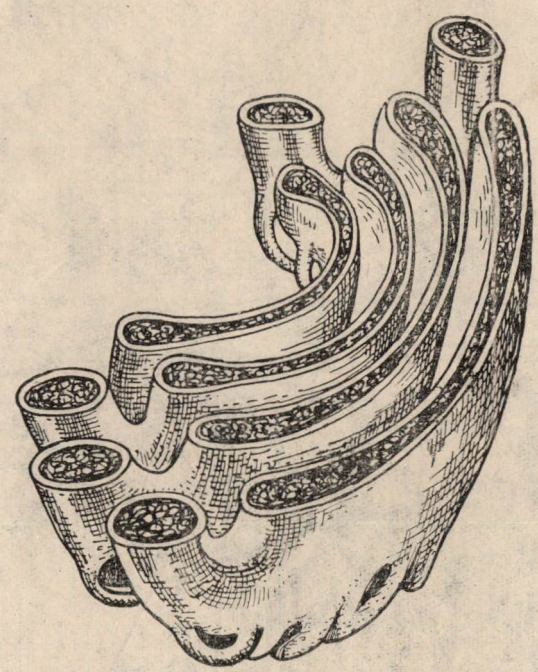


Fig. 9·14 Golgi complex—three dimensional view

The electron microscopic studies have revealed that the Golgi complex consists of a stack of membrane-bound cisternae. The cisternae are arranged in straight or curved bundles and give rise to various small vesicles at their edges. The vesicles originate from the cisternae by being pinched off, and frequently contain secretion products of both soluble and particulate nature.

In plant cells and in invertebrate tissues the Golgi complex is scattered throughout the cytoplasm into bodies called the **dictyosomes.** The dictyosomes are almost exclusively formed by the flattened sacs with clusters of small vesicles at the edge.

Functions: The functions attributed to the Golgi complex are as follows :

In the cells that are known to produce and secrete carbohydrates it is quite likely that atleast a part of the synthesis of carbohydrates is carried on by enzymes of the Golgi complex.

In cells actively involved in protein synthesis, the proteins produced on the ribosomes are channeled by the granular endoplasmic reticulum to the Golgi complex. In Golgi complex these proteins are concentrated and packaged for distribution outside the cell. It is also evident that the Golgi complex plays a role in the metabolism of lipids.

The Golgi complex has its important role in the transformation of the spermatid into a mature spermatozoan. The **acrosome** which caps the compact nucleus of the mature sperm is derived from the **Golgi materials of the spermatid.**

In the earlier stages of oogenesis, the Golgi substances in the oocyte are usually concentrated around the centrosome to form a structure known as the **yolk nucleus.** The yolk nucleus lies from the start eccentrically on one side of the nucleus of the oocyte. The yolk nucleus, soon enlarges and breaks up into pieces which disperse in the cytoplasm of the egg and lay down the spherules of the yolk.

The Mitochondria : The mitochondria (Gk. *mito*; thread + *chondrion*; granule) in the form of rod like, granular or filamentous organelles are present in the cytoplasm of the animal and plant cells.

The size of the mitochondria ranges from 0·2 to 7 μ in diameter. In the unicellular green alga, *Microsterias*, there is a single mitochondrion per cell. There may be upto 500,000 mitochondria in the **giant amoeba**, *Chaos chaos*. A mammalian liver cell, 25 μ in diameter, may have as many as 1,000 mitochondria. In a kidney cell there may be 300 and in a sperm-cell some 25 mitochondria are present

The large mitochondria can be seen under the light microscope but their basic structure has been very well revealed by the electron microscope. Each mitochondrion has a double membrane. The outer membrane, is a smooth unit membrane about 60 to 70 Å in thickness. The inner membrane separated from the outer by a clear space of about 60 to 80 Å is also of unit construction. The inner membrane however is repeatedly extended into folds which project into the **interior space** or **matrix** of the mitochondrion. These shelf-like inner folds of the inner membrane are called **Cristae** or **Crests**. The inner membrane produced into the cristae is also about 60 Å thick.

Mitochondria do not have a constant shape. They can swell and contract in a manner which shows that these movements are correlated with their chemical activity. There appears to be present in the outer membrane a protein similar to actomysin (a contractile protein of muscles) and which may be responsible for the changes in the volume of mitochondria.

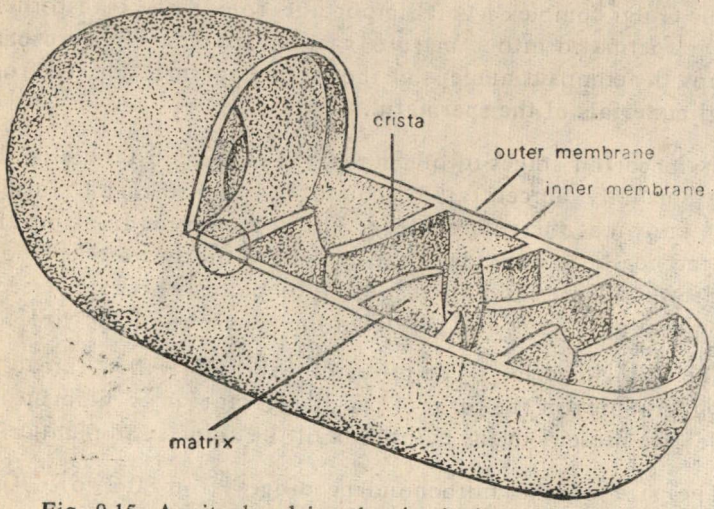


Fig. 9·15 A mitochondrion showing its internal structure

It has recently been demonstrated that mitochondria contain a specific type of DNA which however differs in molecular nature from nuclear DNA. They have their own machinery for protein synthesis and that they may participate in inheritance and differentiation.

Functions : The mitochondria are the *aerobic respiratory centres* of the cell. They contain the enzymes which carry out oxidation of food substances by their stepwise degradation in the presence of oxygen.

The three major food stuffs of the cell i.e., carbohydrates, lipids and proteins are ultimately degraded in the cytoplasm to two carbon unit that is bound to coenzyme *A* to form **acetyl coenzyme** *A*.

When acetyle coenzyme *A* penetrates the mitochondrion, the acetate group enters the **krebs tricarboxylic acid cycle** or **citric acid cycle**

After complex series of steps involving several enzymes, the acetate group is decarboxylated losing thereby CO_2.

At several points in the Krebs cycle, pairs of **electrons** or their equivalent **hydrogen atoms** are removed by dehydrogenases. These hydrogen atoms enter into the **respiratory chain** called the **electron transport system**. At the end of this chain, the **hydrogen atoms** ultimately combine with **molecular oxygen** (brought to the cell during the aerobic respiration) to form **water.**

The main components of the electron transport chain or respiratory chain are the two flavo-protein enzymes, succinic and nicotine amide dinucleotide (NAD) dehydrogenases, four cytochromes and also nonheme iron, copper and coenzyme *Q*

At three points along this electron transport chain the energy lost by a pair of electrons is utilized to form a high energy bond chemical called the ATP, Adenosite triphosphate from ADP and inorganic phosphate. Because of this, the respiratory chain is said to be normally coupled to **phosphorylation**. The final products of all these changes is ATP plus CO_2 and H_2O. The **ATP** supplies the cell, the required energy. The ATP is the energy currency of the body of organisms.

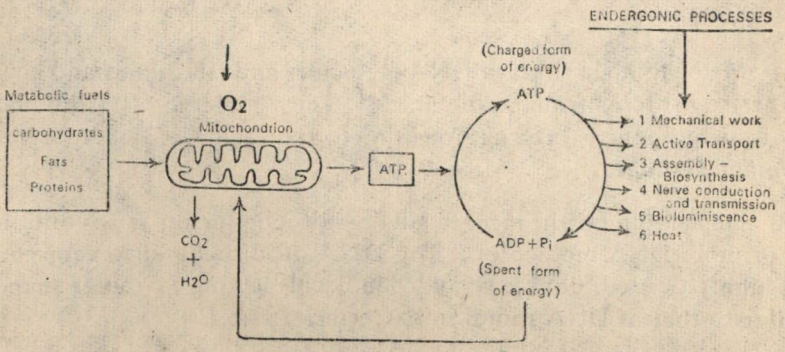


Fig. 9.16 A diagrammatic representation of the flow of energy in a cell from the metabolic fuels. The production of ATP in the mitochondria. The ATP and the ADP+(Pi) are respectively, the charged and spent forms of energy.

More than 70 enzymes and co-enzymes in addition to numerous co-factors and metals are found in a mitochondrion. Some of the enzymes present in a mitochondrion are organized in compact *'assemblies'* that are regularly spaced on the mitochondrial cristae or crests. The enzymes in an *assembly line* are so arranged that the breakdown or synthetic product of one enzyme becomes the substrate upon which the next enzyme in the assembly line acts. A possible arrangements of the 'assembly lines' of enzymes arranged on the mitochondrial crests is shown in figure 9·17.

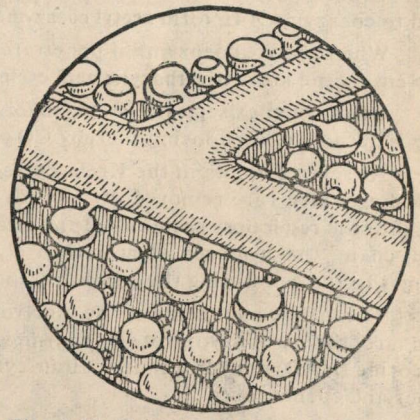


Fig. 9·17 Assembly lines of enzymes arranged on mitochondrial crests

The matrix of mitochondria contains soluble proteins. The soluble proteins comprise most of the enzymes involved in the Krebs cycle and fatty acid cycles. The matrix also contains different nucleotides as well as nucleotide coenzymes and inorganic electrolytes such as K^+, HPO_4^{--}, Mg^{++}, Cl^- and SO_4^{--}.

The recent investigation discloses that mitochondria are the cell organelles which behave with a certain degree of autonomy within the cells.

Mitochondria contain DNA molecules and ribosomes and may synthesise proteins from amino acids. They undergo division and may bear biological information which represents a type of *cytoplasmic inheritance*.

Depending on the size, a single mitochondrion may contain one or more DNA molecules. The DNA of mitochondrion appears as a highly twisted, double stranded molecule having a circular shape similar to that of DNA found in bacteria.

Mitochondria can be regarded as remarkably complex organelles concerned with the capture, conversion and transfer of cellular energy. Their principal function is to form and release ATP. The

nitials stand for adenosine triphosphate, the substance that provides energy for muscle contraction and for a host of other biological processes such as active transport, biosynthesis nerve conduction and transmission, etc. The mitochondria thus have aptly been referred to as the '**Power Houses**" of the cell.

Lysosomes : Lysosomes are sub-cellular structures found in the cytoplasm of both the animal and plant cells. They are in the form of dense bodies about 0.4 μ in diameter. They have a single outer membrane and small granules of high electron opacity similar to the ferritin molecules. They contain more than a dozen hydrolytic enzymes. These enzymes can breakdown and destroy cellular fragments etc. On the rupture of the external membranes of the lysosomes, the enzymes released may digest the cell components and the cell itself. This results in the autolysis or death of the cell. It is suggested that lysosomes originate from vesicles derived from the Golgi complex.

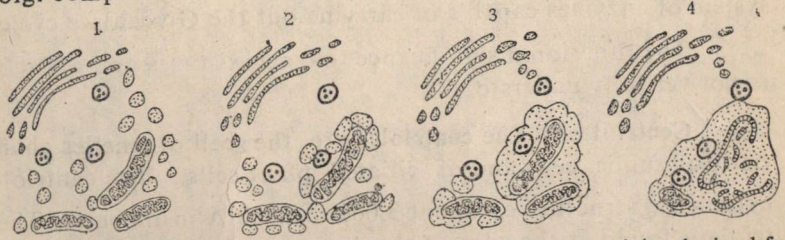


Fig. 9.18 The lysosomes are suggested to originate from vesicles derived from the Golgi complex The vesicles (1) surround cellular materials, (2,3) coalesce and (4) digest the enclosed materials by means of hydrolytic enzymes.

The lysosomes play an important role in the elimination of cell organelles. They also perform '*digestion*' of materials penetrating from outside the cell. In other instances lysosomes are secreted to the cell exterior as *residual bodies*. The remodelling of tissues with the destruction of numerous cells is accomplished by lysosomal enzymes *during the metamorphosis of amphibians*. The lysosomal enzymes may be discharged outside the cell to produce lytic effects. In cultured bone tissue with excess of vitamin *A* dose, the bone absorption increases which is apparently due to the 'activation' of lysosomes. This may probably be the cause of *spontaneous fractures* in animals which have *vitamin A intoxication*. The opposite effect is observed with cortisone and hydrocortisone. These steroids which

possesses anti-inflammatory action, have a *stabilising effect* on the membrane of the lysosomes.

Lysosomes are usually found in animal cells. Lysosome-like organelle in plant tissues however has also been reported.

Microbodies :

The microbodies are the sacs enclosed by a single membrane. These are packed with material. Two types of microbodies—**Peroxisomes** and **Glyoxisomes** are recognised. They are said to be involved in oxidative metabolism in the cytoplasm.

Peroxisomes carryout the transport of hydrogen from a number of substrates to oxygen. Peroxisomes have been identified in several organisms e.g., the liver and kidney cells of rats and in yeasts and protozoa.

Glyoxisomes found in germinating bean seedlings contain a system of enzymes capable of carrying out the Glyoxalate cycle.

The functional significance of peroxisomes and glyoxisomes is not yet fully understood.

Centrioles : **The centrioles are** the cell organelles characteristic of animal cells and of ciliated plant cells. The centriole is a cylindrical structure of about 3,000 to 5,000 Å in diameter. The centriole is found at the edge of the nucleus and often in an indentation of the nuclear membrane. It is also often associated with, and partially surrounded by the Golgi complex. When two centrioles are found together, one is generally oriented perpendicular to the other. They determine the axes of division when a cell divides.

In a cross-section, the centriole shows nine sets of triplet microtubules arranged in a circle and running the length of the hollow cylinder.

The centrioles have been said to contain DNA. In a majority of animals, the centrioles arise only from the pre-existing centrioles. There are, however, certain plants and animals where the centrioles appear to arise *de novo*.

Microtubules : In recent years the widespread occurrence of **microtubules** in the cytoplasm of numerous cells has been recognised.

The microtubules appear to be important in certain cell functions such as cell division, cytoplasmic streaming, intracellular transport and possibly the general contractility of the cytoplasm.

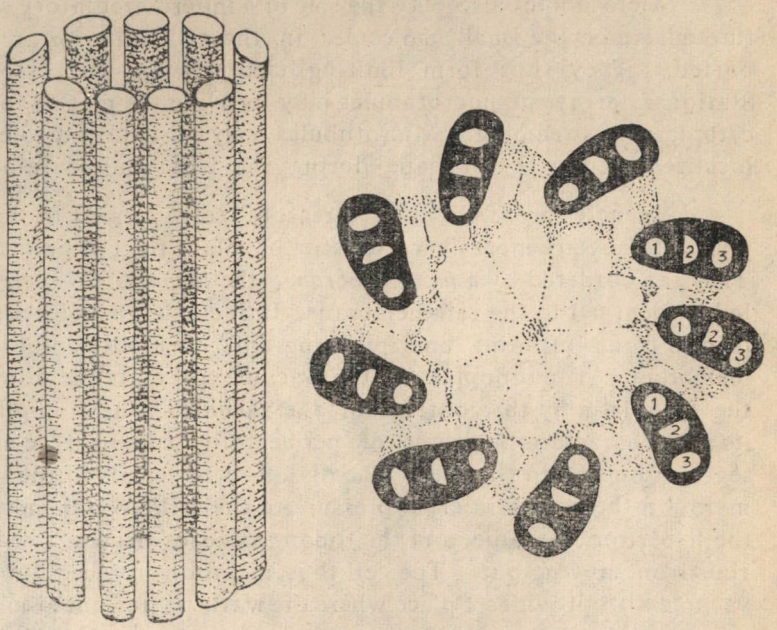


Fig. 9.19 Left : Diagrammatic ultra-structure of a centriole showing nine tubules Right : Diagrammatic cross section of a centriole showing nine sets of triplet tubules arranged in a circle

Cytoplasmic microtubules are uniform in size and remarkably straight. They are straight cylinders of protein. They are about 240 Å in diameter and several microns in length and 60 Å in thickness. They are similar to the tubules of cilia and flagella Microtubules of cilia and flagella are much more resistant to treatments. The microtubules forming the *spindle fibres* and the others present in the cytoplasm are, in general, labile and transitory structures.

Functions: In the mitotic spindle and the cytoplasm of the contractile protozoans, as well as in the cilia and flagella, the microtubules are related to contraction.

The shape of some cell processes or protuberances are determined by the orientation of the microtubules. They are thus considered as a frame work or cyto-skeleton which operates to process the shaping of the cell and to redistribute its contents.

Microtubules also play the role of a 'microcirculatory system' through which the small molecules in the cell's interior are transported. They thus form limiting channels in the cytoplasm. Stationary arrays of microtubules may provide the motive force for cytoplasmic streaming. Microtubules may also play a role in the localized changes in cell shape during the embryonic development.

Vacuoles are 'fluid filled' areas of cells present in the cytoplasm. They are more characteristic of plant than of animal cells. They are bordered by a *unit membrane*, the *tonoplast*, which is probably identical to the cell membrane. In fact, the vacuoles are often formed by an infolding and pinching off, of a portion of the cell membrane. The tonoplast of the vacuole prevents the dilution of the cytoplasm by the contents of the vacuole. The tonoplasts by its own characteristic degree of permeability can preserve areas of segregation within the cell. The dissolved materials in the vacuole maintain the proper internal pressure in the cell. Water moves into the hypertonic vacuole, and the tonoplast keeps the dissolved materials from moving out. The cell thus maintains its turgidity. The vacuole also provides a place where the waste or unwanted materials are dumped.

In young, actively growing cells of plants, the vacuoles are small, but eventually they coalesce to form one large vacuole which forces the cytoplasm to the outside of the cell. There is an advantage to a plant cell by this shifting of the nucleus and the cytoplasm to the periphery of the cell. In a thin layer of the cytoplasm, the exchange of gases can readily take place. This is all the more essential for a cell engaged in photosynthesis; the molecules of O_2 and CO_2 do not have to pass through a mass of cytoplasm as the thin layer of cytoplasm forces the chloroplasts towards the surface of the cell, where light can readily reach them.

Nucleus : All the Eukaryotic cells are characterised by a **true nucleus** surrounded by a *nuclear membrane* or a *nuclear envelope*. It is an important cell organelle. The nuclear envelope divides the

cell into two main compartments, i.e., *nucleus and cytoplasm.* The red blood cells of mammals may lose their nuclei by the time they are fully differentiated. That is why the mature red blood cells have a short span of life of about 120 days. They are incapable of further division.

The nucleus in animal cells is usually placed centrally in the form of a spherical body. The shape of the nucleus varies in different kinds of cells. It may be fusiform, ellipsoidal or variously lobed.

The vast majority of the cells possess a single nucleus. Striated muscle cells of mammals are generally *multinucleate. Paramoecium* has two nuclei, the *micronucleus* and the *macronucleus.*

The nucleus is surrounded by a double layered **nuclear membrane.** The two membranes are separated by *Perinuclear space* of varying width. The outer nuclear membrane is often continuous with the elements of the endoplasmic reticulum. The nuclear membranes have the same trilaminar structure like the plasma membrane. It is quite likely that the outer nuclear membrane and possibly the inner one also is derived from the endoplasmic reticulum. During the cell division, it was noted that the nuclear membranes of the newly formed nuclei are partially formed from the coalescing fragments of the endoplasmic reticulum.

The nuclear membranes are interrupted at regular intervals by **pores.** The pores are *octagonal in shape* and at the edges of the pores the inner and outer nuclear membranes are continuous. The presence of nuclear pores suggests that the exchange of substances between the nucleus and the cytoplasm may occur.

Inside the nuclear membranes there is a homogeneous material of matrix called the **nuclear sap** or **karyolymph.** The nuclear sap completely fills the nuclear space between the other nuclear components. The nuclear sap contains proteins (glycoproteins) RNA and a number of hydrolytic enzymes.

Throughout the nuclear sap are seen distributed twisted filaments containing a substance called *chromatin.* In the interphase nucleus (a nucleus not in the process of active division) the chromatin

filaments are entangled among themselves presenting thereby the appearance of a network often referred to as *chromatin reticulum* or *network*. At the time of cell division, the chromatin filaments are

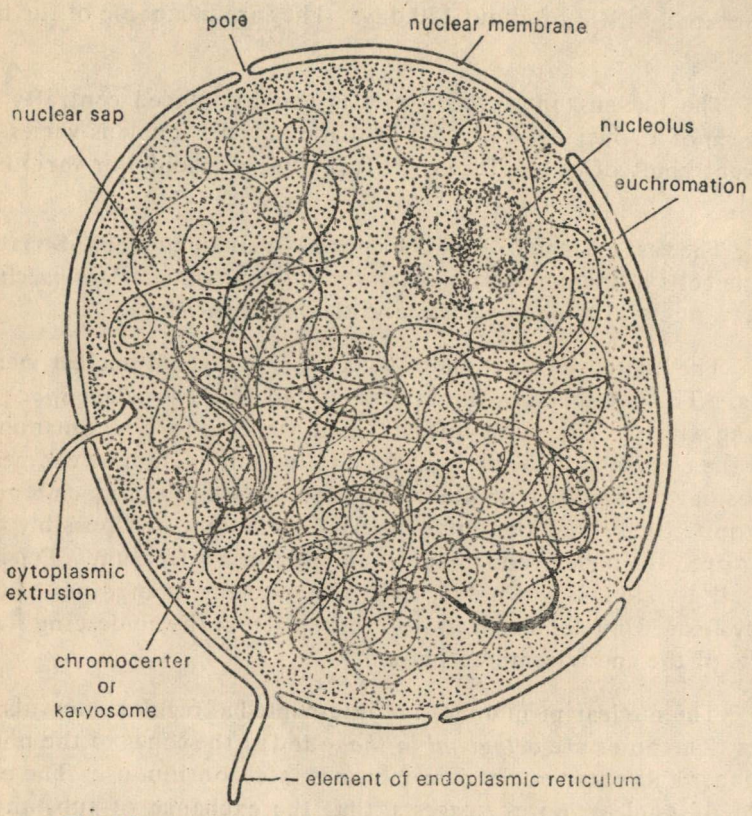


Fig. 9.20 A generalised structure of an interphase nucleus

distinguished as discrete units known as **chromosomes**. The *chromatin filaments* as such should be considered *interphase chromosomes* before they organize into discrete units during the cell division.

In the interphase nucleus, amongst the chromatin filaments can be seen certain flakes of chromatin called the *chromocentres* or *Karyosomes* (also called *false nucleoli*). These are more condensed regions of chromatin *(heterochromatin) in which, parts of the chromosomes remain condensed (spiralized)*. Some such chromocentres

may adhere to the nucleolus forming the chromatin associated with the nucleolus. The name *heterochromatin* was formerly applied by Heitz (1928), to chromocentres of the interphase nucleus. The rest of the chromosomal substance which uncoils and swells during the same period is called *euchromatin*. The heterochromatin regions are darkly stained by basic dyes while the euchromatin receives light stain. The heterochromatin region should be considered a state of the chromosomes and not as a special substance.

Within the nuclear sap is a refractile spherical body, the **nucleolus**. In some cells the number of nucleoli may be more than one. A large amount of nuclear RNA is located in the nucleolus. Phosphoproteins are the main protein components of the nucleolus. The nucleoli are formed by particular chromosomes which possess a structure known as the *nucleolar organizer*. This manufactures nucleolar material and organizes it into *nucleolus* in the form of a dense body. *The nucleolus plays an important part in the biogenesis of the cystoplasmic ribosomes.*

The nucleus thus is an important cell organelle which goes through a series of changes at cell division during which the exact partitioning of the chromatin content takes place. The nucleus is the chief control center which regulates all the vital activities of the cell.

Chromosomes : As described above, within the nuclear membrane, the main component of the cell sap, in an interphase nucleus is the *chromatin* network of reticulum. This network, as stated (during the cell division) organizes into discrete units called the **chromosomes**. *The chromosomes in the nucleus, thus, exist throughout the life of the cell and never lose their entity or individuality. They are however discernible as discrete units only during the cell division. A chromosome thus is a nuclear component with a special organization, individuality and function It is capable of self-replication and maintains the morphologic and physiologic properties through successive cell divisions.*

Chromosome Chemistry : The basic chemical constituent of chromosomes is, DNA, the molecule which is the genetic material. The total quantity of DNA per chromosome is generally constant for

a particular species. In addition to the DNA, chromosomes contain an equal mass of proteins, the *histones*. There are indications that histones are somehow involved in the regulation of gene function and thereby, the differentiation of cells. In addition to the invariable components, the DNA and histones, the chromosomes contain various amounts of RNA and complex of non-histone type proteins. Microbial geneticists have applied the term 'chromosome' to the DNA of viruses and bacteria.

The genetic material of chromosome, the DNA is organized into units called the *genes*. The genes possess the genetic information necessary for the formation or control of a specific genetic trait. Genes occupy a definite location on the chromosomes. It should however be noted that no one has ever isolated a gene from any animal or higher plant. We have no way so far of recognizing a gene after it has been removed from the cell.

Chromosome Number:

The chromosome number is characteristic for a species. In sexually reproducing organisms the fertilized eggs and somatic or body cells derived from it have two sets of chromosomes, one from the egg and the other from the sperm. Cells with two chromosome sets are called the *Diploid* (i e. 2*n*), *Haploid cells*, like the egg and sperm (gametes) contain only one set of chromosomes (i.e., *n*).

The number of chromosomes in the body cells of man is 46 i.e., 23 pairs. The fruity fly, *Drosophila melanogaster* has 8 chromosomes in body cells i.e., 4 pairs. Indian muntjae or barking deer *Muntiacus munijae*, has an anusually low diploid number of exceptionally large sized chromosomes–six in females and seven in males.

Morphology of Chromosomes:

The morphology of chromosomes can be studied during the metaphase and anaphase stages of cell division.

Four distinct types of chromosomes on the basis of their shape can be recognized in metaphase or in anaphase.

1. *Telocentric chromosomes:* These are rod-like chromosomes with a centromere situated on the proximal end.

2. *Acrocentric chromosomes* are also rod-like but with a small or even imperceptible arm.

3. *Sub-metacentric chromosomes* have unequal arms and are therefore L-shaped.

4. *Metacentric chromosomes* possess equal or almost equal arms and are as such V-shaped.

The various chromosomal types are constant for each homologous chromosome. The chromosomal type may also be constant throughout a species or even a genus.

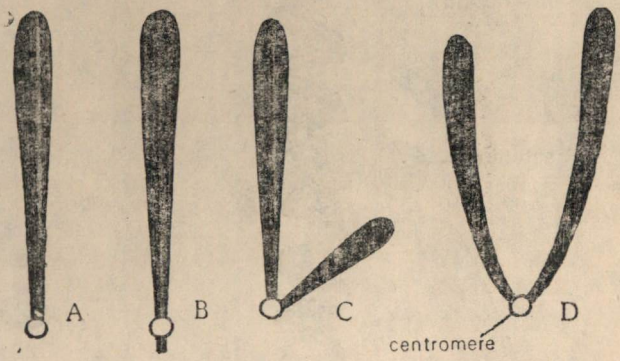


Fig. 9.21 Four morphological types of chromosomes according to the position of the centromeres.
(A) telocentric (B) acrocentric (C) sub-metacentric (D) metacentric

The point where the two arms of a chromosome meet is called the *primary constriction* which determines the shape of the chromosome. Within the primary constriction is a clear zone which contains a small granule or spherule. This clear region is called the so called *centromere* or *kinetochore*. The centromere is functionally related to the chromosomal movements which occur during mitosis. It has been demonstrated cytochemically that the centromere contains DNA. The middle zone of the centromere maintains the relationship of the chromosome to the spindle.

The other important characteristics of the chromosomes is the presence of *secondary constrictions*. The secondary constrictions are constant in their position and extent. One can identify particular

chromosomes in a set by seeing these secondary constrictions. The secondary constrictions may be either short or long. They are distributed along the chromosome. They can be distinguished from the primary constriction by the absence of marked angular deviations of the chromosomal segments.

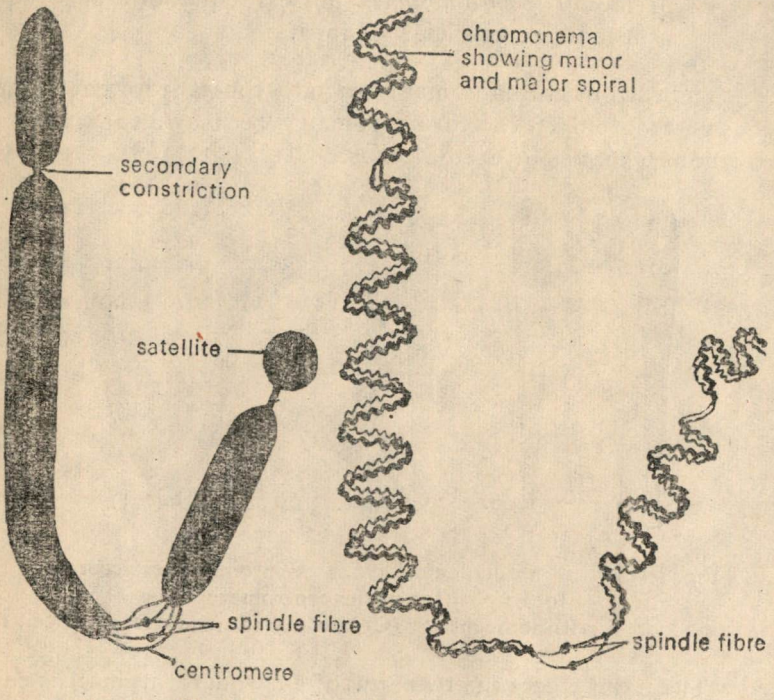


Fig. 9·22 A metacentric chromosome
Left : External view showing the centromere; the satellite; secondary constriction and the spindle fibre
Right : Same chromosome showing the inner structure with two chromonemata and the major and the minor coils

In certain chromosomes, a **satellite** is present. A **satellite** is a round elongate body separated from the rest of the chromosome by a delicate chromatin filament. The chromosomes having a satellite are designated as **SAT chromosomes**. The shape and size of the satellite and its filaments are also constant.

Certain secondary constrictions are intimately associated with the formation of the *nucleoli*. These specialized regions are called the

nucleolar zones (nucleolar organizers). There are generally two chromosomes in each nucleus, called the nucleolar chromosomes which have the nucleolar zone. The extermities of the chromosomes are referred to as *telomeres.*

The length of a chromosome may vary from 0·2 to 2 μ. In man, the most common length of a chromosome is 4 to 6 μ.

Karyotype is the name given to the group of characteristics which identifies a particular chromosomal set. The Karyotype may be represented by a diagram called an *idiogram.* In an *idiogram,* the pairs of homologous chromosomes are ordered in a series of decreasing sizes.

In the compact stages of a metaphase and anaphase, the chromosomes do not show any special structure under the light microscope. In the less compact stages, however, a coiled filament is visible within the chromosome. The coiled filament is called **chromonema.** The number of threads within the chromonema may be two, four or more depending on the species. The chromonema may be single during one stage of development and two or four stranded during another. Between two or more chromonemal threads certain types of coils are formed. The *coiling cycle* of the chromonema is characteristic of mitosis and meiosis as well.

Revision questions

1. Describe in detail the ultra-structure of an animal cell.
2. What is a cell organelle ? Describe the structure and functions of a mitochondrion and state why it is called the '*power house*' of the cell ?
3. Describe the structure of 'Golgi complex' and its functions. Mention in brief the role of Golgi complex in the process of maturation of sperms and ova.
4. What is meant by a 'Unit membrane' ?
5. Describe the structure and functions of the cell membrane.

6. Write notes on the following :
   (a) Lysosomes
   (b) Centrioles
   (c) Vacuole
   (d) Endoplasmic reticulum
   (e) Nucleolus
   (f) Microtubules
   (g) Gene
   (h) Peroxisome and Glyoxisome

7. Describe the structure and kinds of chromosomes.

8. Draw a labelled diagram of the structure of a generalised animal cell as revealed by an electron microscope.

CHAPTER X

NUCLEIC ACIDS

Nucleic acids are chemical compounds of utmost biological importance. They are the largest and the most fascinating molecules found in the living organisms.

In the latter part of the 19th century, a Swiss biochemist, **Friedrich Miescher** (Mee-sher), was the first to isolate substances associated with the proteins of the cell nucleus. He discovered these substances from the nuclei of the white blood cells and sperm cells in **1872.** As they were found in cell nuclei, the term **nucleic acid** was applied to them.

Nucleic acids are the complex derivatives of **nucleosides.** A **nucleoside** consists of a *nitrogen base (Purine* or *pyrimidine)* and a *Pentose* or *5-carbon sugar (Ribose* or *deoxyribose).* When a single phosphate group is added to the pentose portion of a nucleoside, then a *nucleotide* of a nucleic acid is formed.

$$\text{Nitrogen base} + \text{Pentose} + \text{Phosphate} \longrightarrow \text{Nucleotide of nucleic acid}$$

$$\text{Nucleotide} + \text{Nucleotide} \xrightarrow{\text{Polymerisation}} \text{Nucleic acid}$$

The *nucleic acid* is a *high polymer of nucleotides.* A nucleic acid is formed when upto hundreds or thousands of nucleotide units undergo polymerisation to form a chain of polynucleotides. **Polymerisation** is a general chemical process in which molecular units of similar or identical types are synthesized into a single larger molecular unit known as a **Polymer** (Gk. *Poly;* many; *meros;* part).

One kind of nucleic acid along with the nitrogen bases and phosphate, contains the five carbon sugar *ribose,* hence called the **Ribonucleic acid** or **RNA**.

The other kind of nucleic acid, besides the nitrogen bases and phosphates, contains 5 carbon sugar called *deoxyribose*. The deoxyribose differs from ribose in having a hydrogen (–H) atom instead of the hydroxyl group (–OH) at that same carbon atom. One oxygen atom is therefore 'missing' compared to ribose, hence called '*deoxyribose*' i.e., the *ribose deprived of oxygen*. The nucleic acid with deoxyribose sugar is therefore called **deoxyribonucleic acid** or **DNA**.

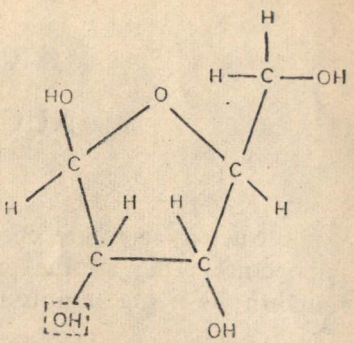


Fig. 10·1 Ribose

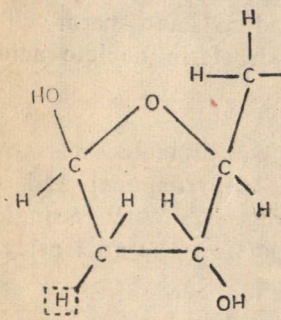


Fig. 10·2 Deoxyribose

When nucleic acids are split apart by hydrolysis, we find in them in addition to the sugar molecules (ribose or deoxyribose) two other kinds of molecules which are as follows :

The first is a compound of phosphorus called phosphoric acid.

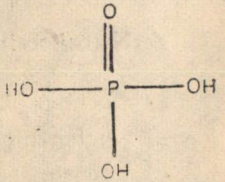


Fig. 10·3
Phosphoric acid

The second kind of molecules are ring like structures of carbon and nitrogen known as **nitrogen bases**. Two types of nitrogen bases are found in the nucleic acids.

1. **Pyrimidines** such as the **cytosine** and the **thymine** are found in **DNA**; **cytosine** and **uracil** instead of thymine in **RNA** molecules. Pyrimidine has a basic structure of four carbon and two nitrogen atoms in a ring.

2. **Purines** such as **guanine** and **adenine** are present both in DNA and RNA. Purines have a basic skeleton that is a double ring of carbon and nitrogen atoms.

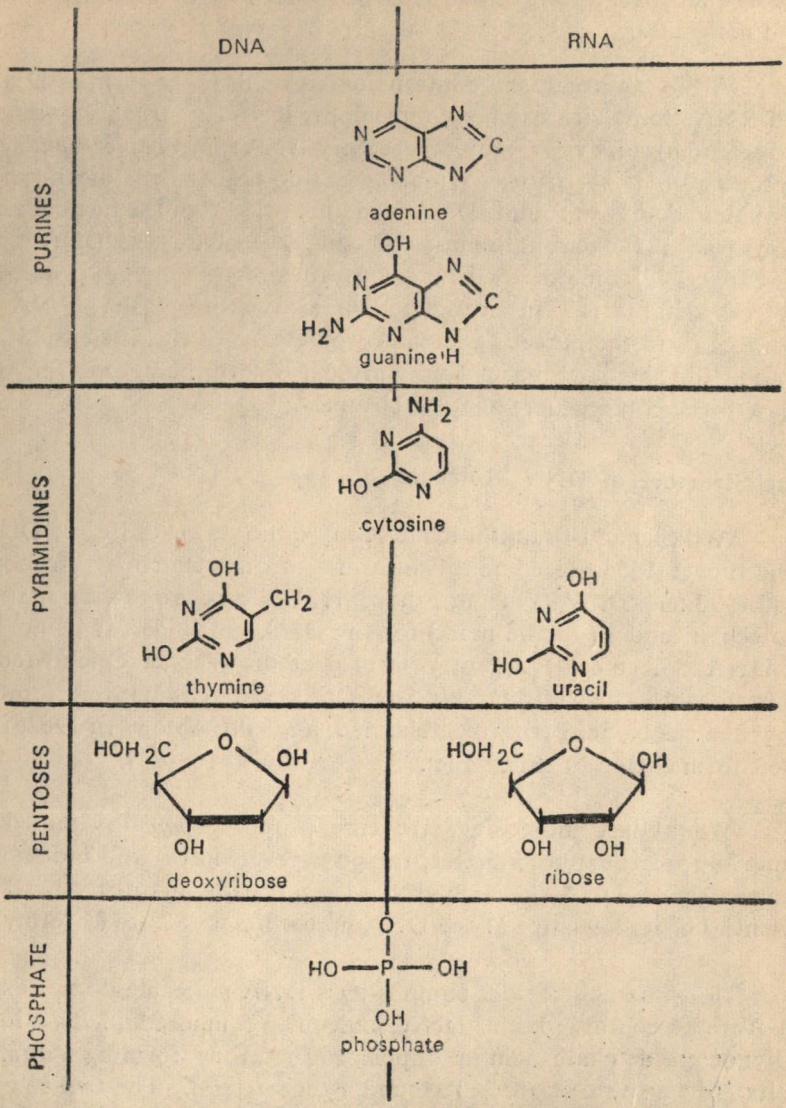


Fig. 10.4 The structure of DNA and RNA

One molecule of 5-carbon sugar (Ribose or deoxyribose) with a nitrogen base (purine and pyrimidine) and phosphoric acid forms a single nucleotide of a nucleic acid. Hundreds and thousands of

nucleotides form a long polynucleotide chain resulting in a nucleic acid molecule.

All living organisms contain nucleic acids in the form of DNA and RNA. Some viruses may contain only RNA e.g., *Tobacco mosaic* and *Poliomyelitis virus* and others only DNA e.g., *bacteriophages*, *vaccinia* and *adeno-viruses*. In bacteria and higher cells, both types of nucleic acids are found. DNA is mainly present in the nucleus and forms part of the chromosomes. During interphase, the DNA is in the chromatin combined with proteins forming the nucleo-proteins. DNA is also present in mitochondria and chloroplasts. RNA is found both in the nucleus and the cytoplasm. In the nucleus, it is present in the nucleoplasm and chromatin. In the cytoplasm, the RNA forms a large part of the ribosomes.

The Structure of DNA Molecule :

Wilkins and **Franklin** made X-ray diffraction studies of DNA structure in 1953. Based on this information and electron microscope studies, **James D. Watson** and **Francis H. C. Crick** proposed a spatial molecular model (double helix) for the DNA molecule. This model of DNA molecule is frequently termed as the **Watson-Crick Model** as indicated in figure 10·6. Watson, Crick and Wilkins were jointly awarded the Nobel Prize in Medicine and Physiology in 1962, for their formulation of this model.

The DNA molecular structure proposed by this model is important as it explains better, the physico-chemical and biological properties of DNA, particularly its replication in the cell. The essential characteristics of the DNA molecule model are as follows :

1. The nucleotides composing a DNA molecule do not exist as straight chains. Each DNA molecule composed of two long polynucleotide chains run in opposite directions forming a double helix (like a spiral staircase) around a central axis. The two chains of the double helix are coiled together like the coils in a rope. Each nucleotide of a DNA molecule has about a 36 degree turn, causing the chain to coil into an alpha helix. A length of ten nucleotides make a complete 36 × 10 i.e., 360° turn. The diameter across the

two helices is consistently about 20 Å. In a long polynucleotide chain of a DNA molecule at every 10th nucleotide, a 360 degrees turn is exhibited. The outer edges of each chain forming the back-bone have alternating molecules of phosphoric acid and deoxyribose sugar.

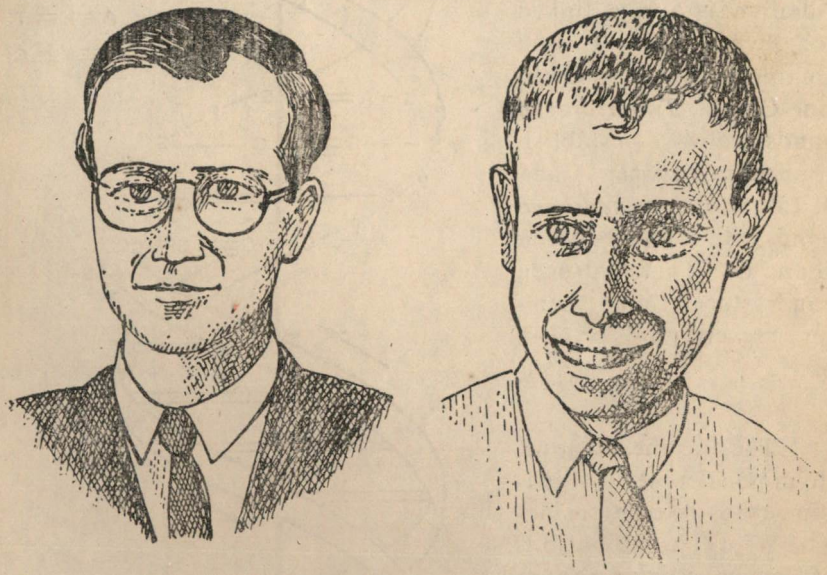


Fig. 10·5 **James D. Watson** (Right) and **Francis H C Crick** proposed a model for the structure of DNA molecule (1953), based upon the X-ray diffraction studies of **M. F. Wilkins** (Left). These three scientists shared the Nobel Prize in 1962

2. The two coiling strands or chains of DNA molecule are held together by *hydrogen bonds* established between the nitrogen bases, purines and pyrimidines. The nitrogen bases, purines and pyrimidines lie across the two strands or on the rungs of the ladder if we compare the DNA molecule as a twisted ladder. While the nitrogen bases are held together by hydrogen bonds, each base is also linked to the sugar molecule at its own side of the strand.

3 The pairing of nitrogen bases is highly specific. As there is a fixed distance between the two twisted strands of the DNA molecule, one purine base can pair only with one pyrimidine base. Adenine is always linked to thymine A = T and Guanine is linked to Cytosine G≡C. *Two hydrogen* bonds always establish connection between A and T. Likewise *three hydrogen* bonds are found between G and C. This hydrogen bond formation therefore prevents A–C or G–T pairs.

The adenine thymine, thymine-adenine, guanine-cytosine or cytosine-guanine combinations can occur any number of times and in any sequence forming thereby the complex DNA molecule.

If the sequence of bases in one chain is T, G, C, T, G, A, then on the other chain the sequence of bases must be complementary to the first as shown on the following page.

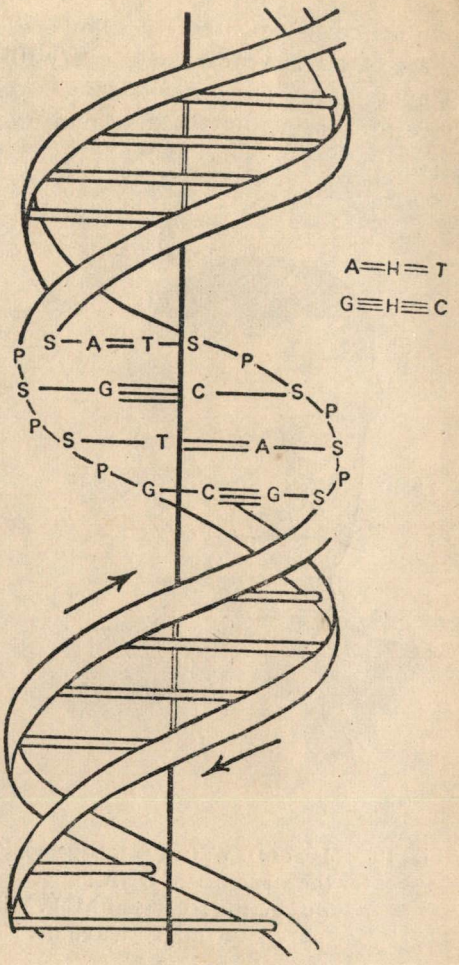


Fig. 10·6 **The Watson Crick model of DNA** The DNA molecule is composed of two polynucleotide chains held together by hydrogen bonds between their adjacent nitrogen bases. The double chained structure (shown to be twisted around a hypothetical central axis) is coiled in a helix. The width of the molecule is 20 Angstroms. S=Sugar, P=Phosphate, A=Adenine, T=Thymine, G=Guanine and C=Cytosine.

I Chain → T, G, C, T, G, A, G.

II Chain → T, C, G, A, C, T, C and so on.

As the pairing of nitrogen bases occurs in the above manner the amounts of adenine and thymine should be equal and quantities of cytosine and guanine should likewise be equal to each other.

The DNA of different species is distinguished by the relative numbers of AT and CG pairs, their sequence, whether these occur as AT or TA and as CG or GC and the number of such base pairs.

DNA Replication or Synthesis :

When DNA is synthesised biologically, it is said to replicate i.e , produces copies of itself. This is accomplished by a process called **template synthesis**. The knowledge about DNA replication comes from the work of **Kornberg** and his colleagues. Kornberg has suggested a model procedure for DNA replication. This has been further confirmed by a series of ingenious experiments performed by **Meselsan** and **Stahl**.

Under this *DNA strand separation theory*, the two complementary polynucleotide chains of a helix separate or dissociate at the hydrogen bonds which link purine pyrimidine pairs. The weak hydrogen bonds between the purine pyrimidine pairs holding together the double helical strands of the DNA molecule work somewhat like a '*Zipper*.' At the time of replication, the process of '*unzipping*' starts at one end of the DNA molecule at the sites of hydrogen bonds. This process of unzipping proceeds gradually at the other end of the DNA molecule consequent to which the two DNA strands get apart. As the strands of the DNA molecule separate, the purines and pyrimidines are therefore separated. Each separated strand of DNA molecule now acts like a **template*** and attracts and binds the appropriate complementary bases which must be available in the nucleus and thus form two new double helices of DNA. Under the strand separation hypothesis each newly replicated double helix,

*A pattern or mould, shaped to the required outline from which, workmen execute moulding. The use of templates in industry for the easy mass production of all kinds of items is well known.

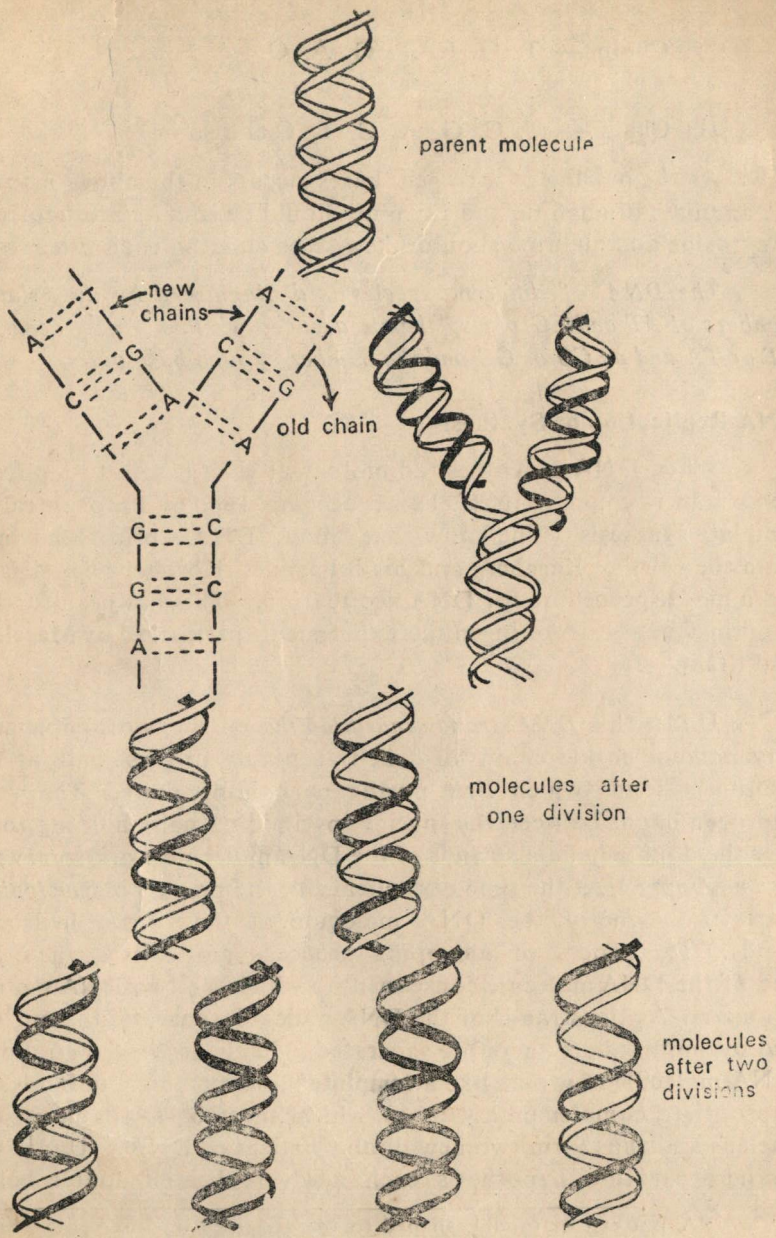


Fig. 10·7 DNA Replication : As the two polynucleotide chains of the parent molecule (white) uncoil, new polynucleotide chains (black) are synthesised on their surfaces. The process produces two complete double chained molecules each of which is identical in base sequence to the original parent molecule. Two successive replications or divisions of DNA molecule are shown in the diagram.

consists of one old or original strand and one new one i.e., a strand with a base complement of the original or parent strand. The same is shown diagrammatically in figure 10·8.

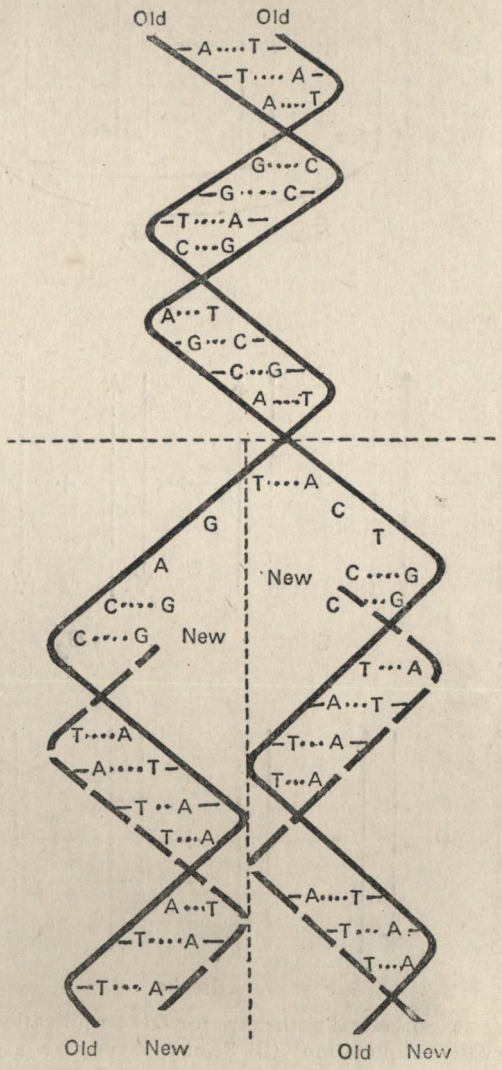
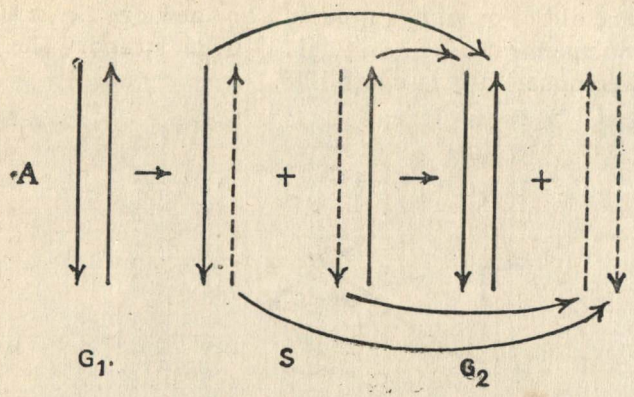
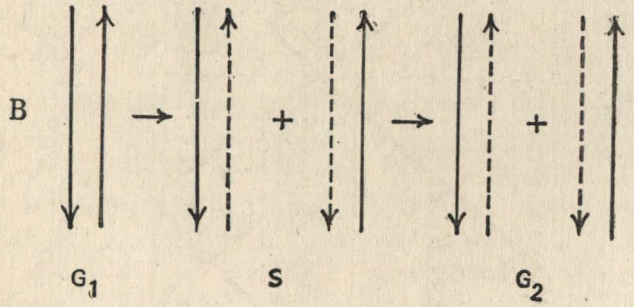


Fig. 10·8 DNA replication takes place during interphase. The old helix (centre) uncoils and the two new helices are formed.





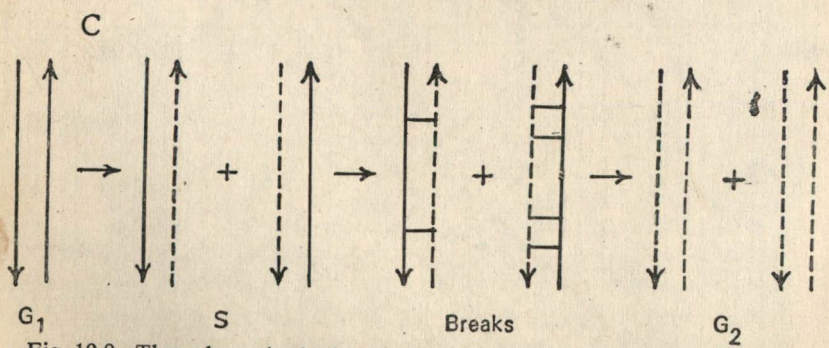


Fig. 10·9 Three hypothetical path-ways for DNA replication (see text), (A) Conservative replication (B) Semi-conservative replication (C) Dispersive replication. G_1=Gap period I; S=Synthetic period; G_2=Gap period II. (cf. Cell cycle under the chapter 'cell division')

Max Delbruck and **Gunter S. Stent** suggested that the distribution of the newly synthesized strands of DNA can follow one of the three pathways after replication. These are as follows:

(i) Conservative replication: In conservative replication, the two strands of the original DNA molecule, after separating and serving as templates, pair again. The newly synthesized strands likewise pair together. This produces two molecules, one composed entirely of 'old' strands and one of 'new.'

(ii) Semi-conservative replication: In the semi-conservative replication, the two original strands, after separating and serving as templates remain paired with their newly synthesized complementary strands. As a result of semi-conservative replication, each of the molecules formed contains an 'old' and a 'new' half.

The terms 'conservative' and 'semi-conservative' used in these models imply that in both the pathways the original strands although separating and acting as templates, remain intact.

(iii) Dispersive replication: In dispersive replication, the linear continuity of the parent or 'original' DNA strands is broken and the parts are distributed randomly between the daughter molecules as shown in figure 10.9. In this case, numerous breaks appear in the 'parent' strands before unwinding and separation. Distribution of broken sub-strands between the replicated molecules is random.

A decisive bit of evidence on the actual mechanism of DNA replication is now available in the light of enzymatic studies of **Arthur Kornberg**. He successfully synthesized DNA, in a test tube. Soon after the discovery of double strandedness of DNA, Kornberg discovered *DNA polymerase*, the enzyme which catalyzes the formation of the DNA chain from its four component deoxyribonucleotides in the form of their triphosphate derivatives. The synthesis of new DNA complementary strands require not only the four nucleotides, —magnesium ions and DNA polymerase but also small amount of *single stranded fully formed DNA which acts as an information containing and sequence ordering* **primer** or **template** for the reaction. It is significant to note that polymerization does not occur unless the single stranded DNA is present. The reaction can be expressed as shown on the following page.

$$\left.\begin{matrix} x \text{ molecules of A·dR·PPP} \\ x \text{ molecules of T·dR·PPP} \\ y \text{ molecules of G·dR·PPP} \\ y \text{ molecules of C·dR·PPP} \end{matrix}\right\} + \text{DNA (Primer)} \rightleftharpoons$$

$$\left.\begin{matrix} x \text{ A·dR·P} \\ x \text{ T·dR·P} \\ y \text{ G·dR·P} \\ y \text{ C·dR·P} \end{matrix}\right\} \cdot \text{DNA} + (2x+2y)\ \text{PP}.$$

Key: dR = deoxyribose
A = Adenine; T = Thymine
G = Guanine; C = Cytosine
x represents the number of A or T nucleotides.
y represents the number of G or C nucleotides.

The DNA is the **master molecule of life** which plays a significant role in *the transmission of hereditary characteristics from generations to generations. The DNA also passively controls protein synthesis by a process referred to as transcription (cf. P. 325).*

The Structure of Ribonucleic Acid, RNA:

The structure of RNA is similar to that of DNA except that RNA contains ribose instead of deoxyribose and uracil nitrogen base instead of thymine. The RNA molecules may be single or two stranded as in DNA. On the basis of molecular weight and other properties, three clearly recognised types of RNA are, messenger ribonucleic acid (mRNA), soluble (or transfer) ribonucleic acid (sRNA or tRNA) and ribosomal ribonucleic acid (rRNA). The individual functions of these ribonucleic acids are well established. They are used in the synthesis of proteins and enzymes. The principal kinds of RNA are very different. Their base ratios may differ widely. They vary greatly in molecular size and they perform different, though related functions. *This should however be remembered that all cellular RNA's including messenger, ribosomal and transfer RNA are transcripts of the DNA.* In any given segment of DNA only one of the two complementary strands is used as a template to generate the RNA.

Messenger RNA (mRNA) carries the information for protein synthesis from the DNA to the sites of protein formation i.e., the ribosomes. The mRNA is heterogenous. It has a rapid turnover

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Messenger RNA (mRNA) carries the information for protein synthesis from the DNA to the sites of protein formation i.e., the ribosomes. The mRNA is heterogenous. It has a rapid turnover

and a complementary base composition with DNA and aligns with the ribosomes. The most important property is that it functions as a template in protein synthesis. The messenger RNA is formed on a template of DNA by a process referred to as **transcription.** The transcription is similar to the duplication process of DNA. *In this process of transcription, the two strands of DNA are separated. One of the DNA strands then serves as the template for the formation of an RNA chain according to complementary base pairing rule as described under DNA replication.* The base pairing in the growing RNA chain will be as follows :

Where DNA contains Adenine (A) the growing RNA chain will receive Uracil (the RNA equivalent of T) and where C is in the

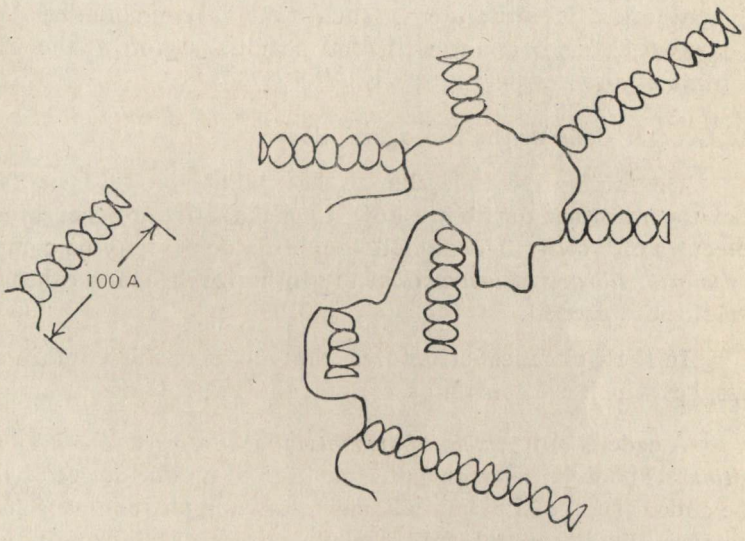


Fig. 10·10 Left : Model of transfer RNA Right : Hypothetical structure for ribosomal RNA showing helical and non-helical regions.

DNA, the RNA will contain G. When the entire gene (DNA segment) has been transcribed, the base sequence in the RNA is complementary to one strand in the DNA and therefore identical with the other, except for the substitution of U for T. This messenger RNA serves as an immediate template for protein synthesis at the ribosomes. This shows that DNA does not itself direct the assembly of

proteins but its information is transcribed to the mRNA. Transcription is catalyzed by an enzyme (The DNA-dependent RNA polymerase) using activated precursors – ribonucleoside triphosphates of each of the RNA base.

Ribosomal RNA or **rRNA** as the name itself suggests, is found in the ribosomes. About 60% of the RNA is helical i.e., double stranded and contains paired bases. The most abundant bases are guanine and adenine.

The Transfer RNA or tRNA :

The transfer RNA or tRNA is the most precisely characterised RNA. It has the special function of acting as an adaptor for attaching amino acids to the mRNA template in the course of protein synthesis. Its structure is such that it can combine with an amino acid at one part and with the specific region of the mRNA template at another part.

The Genetic Code or the Biological Code :

The biologists today know that the nucleic acids contain in them the information about how to make all the other kinds of molecules of a cell. The nucleic acid molecules may be compared to a *master library of instructions* to synthesize the many other kinds of molecules needed.

In their chemical structures the nucleic acids contain **coded messages** which are specific to cells for the control of their activities.

A code *is any system of symbols that are used to convey information.* The written language is one kind of a code devised by man. The code system of English language, for example, contains 26 symbols i.e., the letters of four alphabet – plus various punctuation marks. With these 26 letters an unlimited number of books can be written. The Hawaiian alphabet uses only 12 letters. The ten symbols used in constructing numbers i.e., 1–9 digits and zero are enough to encode an infinite set of numbers.

As regards the DNA code, the question arose as to how many symbols might there be in a DNA code. The DNA molecule as we know although consists of a long polynucleotide chain, yet is basically

made of only *four kinds of nucleotides* i.e., in DNA, *Adenine nucleotide, Cytosine nucleotide, Guanine nucleotide* and *Thymine nucleotide* and in RNA are found first three nucleotides as in DNA and the *Uracil nucleotide* in place of Thymine nucleotide.

The DNA alphabet	The RNA alphabet
A (Adenine nucleotide)	A (Adenine nucleotide)
C (Cytosine nucleotide)	C (Cytosine nucleotide)
G (Guanine nucleotide)	G (Guanine nucleotide)
T (Thymine nucleotide)	U (Uracil nucleotide)

Since DNA controls the kind of protein made, the rules governing the translation of four letters into twenty (amino acids) letters language constitutes a code. *In this alphabet of 'four letters' thus is written the language of life.*

You know that the only links between the generations of higher forms of life are the reproductive cells i.e., gametes, sperms or eggs. The information to *'build'* the entire chick or an entire man may therefore be coded in DNA molecules carried in the tiny nuclei of the sperm and egg cells.

We know that there are different numbers of the four nucleotide molecules in various kinds of DNA. There are about 20 amino acids which form the building blocks of different proteins. Now the question arises as to how many DNA nucleotides would be required to code a message giving directions, about a single amino acid. Each message must be distinct so that the cell would not confuse one amino acid with the other. Since there are about 20 amino acids, at least 20 different messages are needed—i.e , one for each amino acid.

If a single kind of nucleotide were to code a single amino acid, then only four amino acids in all would be coded with the corresponding four nucleotides present in DNA or RNA molecules.

A
G
C
U

4 single nucleotides in RNA

It is evident that four single letters of nucleotides are not sufficient to code 20 amino acids and therefore more complicated words or nucleotide combinations are required. For example, if two nucleotides in sequence in an RNA could mean to add one amino acid, then $(4 \times 4) = 16$ amino acids could be coded by dinucleotide combinations as per the details given below.

AA	AG	AC	AU
GA	GG	GC	GU
CA	CG	CC	CU
UA	UG	UC	UU

16 dinucleotides ('twins')

The dinucleotide combination is also not enough to code for all the 20 am no acids. It was therefore concluded that groups of at least three nucleotides *(Trinucleotides* or *triplets)* are needed to code enough information to specify each of the 20 amino acids. If the trinucleotide combination forms a code to specify an amino acid, there will therefore be $4 \times 4 \times 4$ or 64 different trinucleotide combinations ('triplets') as per the combinations given below.

AAA	AAG	AAC	AAU
AGA	AGG	AGC	AGU
ACA	ACG	ACC	ACU
AUA	AUG	AUC	AUU
GAA	GAG	GAC	GAU
GGA	GGG	GGC	GGU
GCA	GCG	GCC	GCU
GUA	GUG	GUC	GUU
CAA	CAG	CAC	CAU
CGA	CGG	CGC	CGU
CCA	CCG	CCC	CCU
CUA	CUG	CUC	CUU
UAA	UAG	UAC	UAU
UGA	UGG	UGC	UGU
UCA	UCG	UCC	UCU
UUA	UUG	UUC	UUU

64 trinucleotides ('triplets')

There are 64 possible sets of triplets and there are about 20 amino acids to choose from. Hence one should find that many amino acids have several synonymous triplets i.e., several different triplets that code for one amino acid. In fact this situation is found. There is also an evidence that some amino acids are determined by more than one base triplet.

In order to find out a triplet code specifying a particular amino acid, biochemists made an RNA chain of just one kind of nucleotide, say trinucleotide of uracil UUU. The nucleotide chain was then introduced into a mixture of all 20 amino acids. After the chemical reaction took place, the protein that was formed, was analysed to see what amino acid the RNA trinucleotide or triplet (UUU) had selected. It was found to be the protein with one kind of amino acid in it—the *phenylalanine*. It was therefore assumed that the sequence of three uracil nucleotides UUU may mean *attach one molecule of phenylalanine to one protein molecule*. Thus, the first trinucleotide letters UUU of the genetic code were discovered in 1961.

-U-U-U-	*-U-U-U-*	*-U-U-U-*
add	add	add
phenylalanine to	phenylalanine to	phenylalanine to
protein	protein	protein

The trinucleotide or triplet specifying a particular amino acid is called a **codon.** Each codon (comprising three nucleotides) thus is a fundamental unit which contains the information to code for a single specific amino acid.

Protein Synthesis and Nucleic Acids :

There exists an intimate relationship between the proteins and the nucleic acids. DNA is considered to be the '*genetic material*' which, by means of a code formed by the orderly sequence of its constituent nucleotides, determines the order of amino acids in proteins.

The RNA appears to operate as an intermediary between DNA and proteins. All cellular RNA including mRNA, rRNA and transfer RNA are transcripts of the DNA. In any given segment of DNA as stated, only one of the two complementary strands is used as a template to generate RNA copies.

The mRNA could transcribe and carry information from DNA to the *ribosomes, the site of protein synthesis.* The mRNA thus is an intermediary between the information carrying DNA and the ribosomes (rRNA) where proteins are assembled. The DNA message is transcribed as a complementary base sequence with reference to the polynucleotides in a DNA strand. When the mRNA bases in close association with a DNA strand have been joined together in a tandem in an enzymatic reaction, the mRNA leaves the DNA template or is pulled from it by the ribosomes. The messenger RNA now becomes associated with the ribosomes and specifies the amino acid sequence in the protein strand to be formed. The mRNA strand ties temporarily a series of ribosomes called *polyribosomes* or *ergosomes* during protein synthesis. Polysomes may be found free in the cytoplasm. They are also typically found associated with endoplasmic reticulum as already mentioned.

Amino acids to be incorporated into a polypeptide protein chain are brought to the ribosomes by tRNA units. The amino acids are found dispersed in the cell. In man, some amino acids are synthesised in the cell but others (the essential amino acids) must be supplied in the diet.

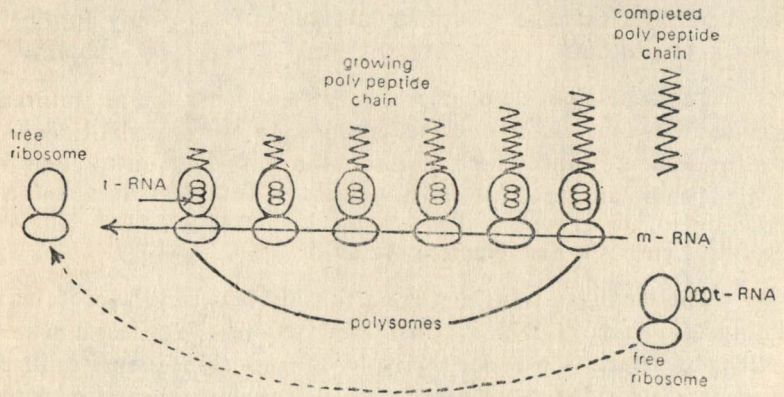


Fig. 10·11 Diagrammatic representation of the mechanism of protein synthesis

For each amino acid to be accepted by the specific tRNA, there is a specific *activating enzyme.* This activating enzyme first activates the carboxyl group of that amino acid for covalent bonding with the adenilic acid residue of the tRNA.

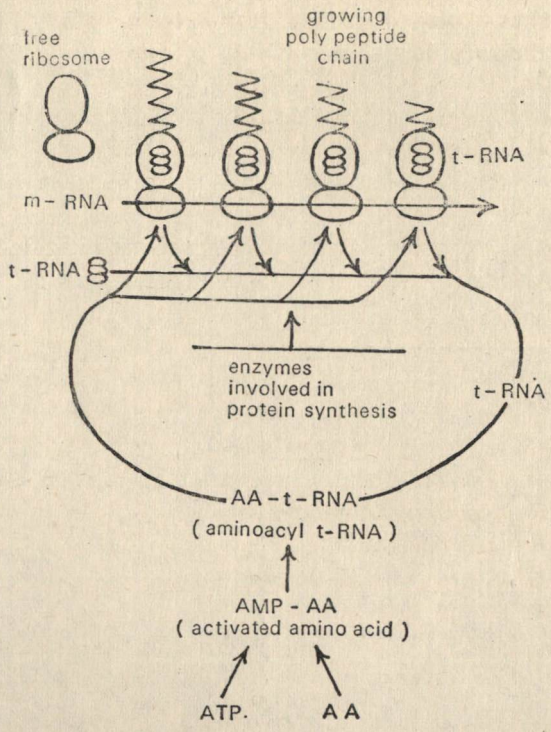


Fig. 10·12 Activated amino acid complex and mechanism of protein synthesis

The first step of the activating enzyme in activating the carboxyl group of amino acid involves the use of ATP. The first reaction thus can be represented in the following way.

$$\underset{\text{(amino acid)}}{AA}+ATP \xrightarrow[\text{Synthetase (activating enzyme)}]{\text{Aminocyl}} AA\sim AMP+P\sim P \quad ...(1)$$

The AA∼AMP (or amino acyladenylate) formed in this way is extremely reactive and remains bound to the activating enzyme.

The activating enzyme then performs a second role by bringing a molecule of tRNA into contact with AA∼AMP on its surface.

$$AA\sim AMP+tRNA \underset{\text{synthetase}}{\overset{\text{aminoacyl}}{\rightleftharpoons}} AA\sim tRNA+AMP \quad ...(2)$$

In order to perform these two functions, the *activating enzyme* has two sites—one to recognize the amino acid and another to recognize the specific tRNA.

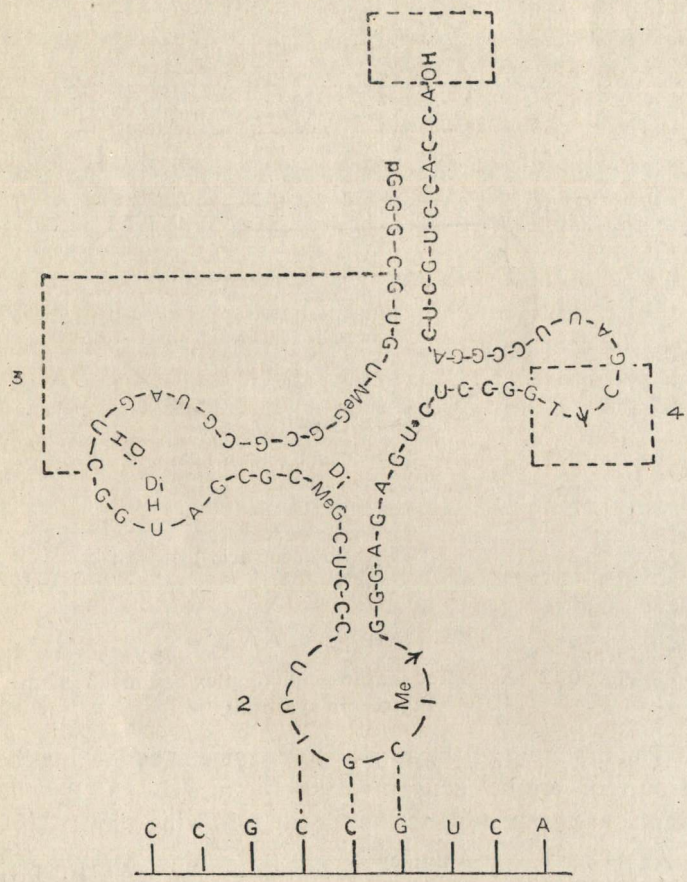


Fig. 10·3 Alanine transfer RNA with short double stranded regions

The activating enzyme is thus responsible for recognizing the amino acid and the tRNA molecule and bringing them together. Each of the twenty amino acids has specific activating enzymes and specific tRNA.

A complete series of tRNA with attached amino acids is formed. The next step in protein synthesis is the alignment of these on a template to form a protein molecule.

The activated amino acid attached to tRNA can be bound by the ribosomes which also have the capacity to bind the mRNA. It is well established that ribosomes play a key role in aligning aminoacyl tRNA molecules on an mRNA template and in the formation of polypeptide chains. The mechanism is illustrated in figure 10·12. The amino acids brought to the ribosomes by tRNA are joined in a proper order. The information, determining the sequence in which the amino acids must be assembled to form a particular polypeptide chain of protein, comes from the mRNA. The process of polypeptide synthesis on mRNA is referred to as *translation.*

The immediate function of tRNA unit completes, the moment it delivers an amino acid. Later the tRNA is released to move in the cytoplasm and pick up another amino acid which it transports to an *mRNA ribosome system* for incorporation into protein. This process goes on rapidly in a living cell engaged in protein synthesis. It has been estimated that bone marrow cells can combine some 150 amino acids into a molecule of haemoglobin in just 80 seconds.

Revision questions

1. What are nucleic acids? What are the main differences between DNA and RNA?
2. Describe the process of DNA replication and DNA transcription.
3. Describe the Watson and Crick model of DNA.
4. Describe the structure and kinds of RNA
5. What is a genetic code? Explain this with examples.
6. Describe the role of DNA, RNA and ribosomes in the synthesis of proteins.

CHAPTER XI

THE CELL DIVISION

The fundamental characteristic of living matter is the ability to reproduce. In all living organisms, the ability to reproduce ultimately depends on processes taking place at the cellular level.

In the single cellular organisms, the divisions of the parent cell into daughter cell is the means of reproduction. By this process, two or more new individuals arise from the mother cell.

In the case of higher organisms, where sexual reproduction occurs, the life of an organism starts when an egg is fertilized to form the zygote. The zygote during the course of its development is transformed into an embryo and then into a recognizable individual by the *process of cell division* and *cell differentiation.*

The growth and development of every living organism thus directly depends on the growth and division of its cells. The human body of average height and weight consists of approximately 10^{14} cells.

Cell division in the organisms is a complex phenomenon by which the cellular material is divided equally between the daughter cells. *The process of cell division is only the final and microscopically visible phase of an underlying change that has occured in the cell at molecular and biochemical levels.*

The end result of cell division is the same in both plant and animal cells; the formation of daughter cells of the like genetic constitution. In certain abnormal cases, the uncontrolled cell division and growth may produce **cancer.**

There are two distinct types of cell divisions i.e . *Mitosis* and *Meiosis.*

Mitosis is the commonest method of cell division occuring in the body cells or somatic cells of the organisms. Mitosis is accompanied by complex nuclear changes. Before the cell divides by mitosis, its fundamental components are duplicated and divided, particularly those involved in hereditary transmission. Organisms increase their cell numbers by mitosis. The zygote also undergoes repeated cell

divisions by mitosis and later differentiations of various organs of the individual occur. During mitosis, the number of chromosomes found in a somatic cell to divide, is kept constant in its descendent cells also. The daughter cells retain precisely the same chromosomal complement as that of the parent cell.

Meiosis is the special type of cell division resulting in the production of gametes. Each gamete formed has only half (haploid) the number of chromosomes present in the parent cell. Under pathological conditions, in some cell types such as tumours, an alternate mechanism to mitosis, termed *amitosis* may be found. In this form of cell division, the nucleus simply divides by means of a gradually deepening central furrow which eventually divides the nucleus into two parts followed by the division of the cytoplasm. The process of **mitosis** in detail will first be described.

Mitosis :

Walter Flemming (1882), described the process of **mitosis** (Gk *Mitos;* a thread). In mitosis, nuclear division i.e., *Karyokinesis* (Gk. *Karion;* nucleus, *Kineses* =movement) is followed by the division of the cell body i.e., *Cytokinesis* (Gk. *Kytos;* cell). Since the cells constituting the *body* or *soma* multiply by mitosis, the process is also designated as the *somatic cell division.*

The somatic division cycle of *eukaryotes* can be divided into two phases—*Interphase* when the nucleus is mechanically inactive and the division phase (*mitosis*).

The interphase of a cell is thus an *inter mitotic* period. The interphase is the principal metabolic period of a cell. The metabolic processes during interphase of a cell occur in a definite sequence or cycle termed as the *cell cycle.*

The Cell Cycle : The sequence of events during a cell cycle are summarised below :

Soon after *Cytokinesis,* the cell enters a period of varying length called the G_1 (G=gap) or Gap I. It is also called the *Pre-synthetic period.* It is a period of varying length in which no DNA synthesis can be detected. The nucleus therefore contains the usual somatic amount of DNA[1]. At sometime late in the G_1 an unknown event starts the period of DNA replication termed the 'S' or *synthetic period.*

After replication is complete, another interval, G_2, Gap II or *post-synthetic period passes* before mitosis commences. During G_2, the cell contains four times 4C the amount of DNA[2] in a gamete.

1, 2, the amount of DNA at various stages of the *cell cycle* is designated by the 'C-value.' "C" is the letter arbitrarily chosen to indicate the relative amount of DNA per nucleus at different stages. The relative amount of DNA in the gametes of an organism is used as the *base level*. Gametes are therefore 1 C Somatic cells before replication are 2 C i.e., the usual somatic amount of DNA. After replication during G_2 the somatic cells contain the 4C amount of DNA i.e., four times the amount of DNA in a gamete.

At the end of G_2, the cell undergoes mitosis and cytokinesis. The daughter cells obtained may repeat the same cycle of G_1, S, G_2 during interphase in the order mentioned above prior to mitosis and cytokinesis. The sequence of events in the *cell cycle* during the interphase are diagrammatically represented in figure 11·1.

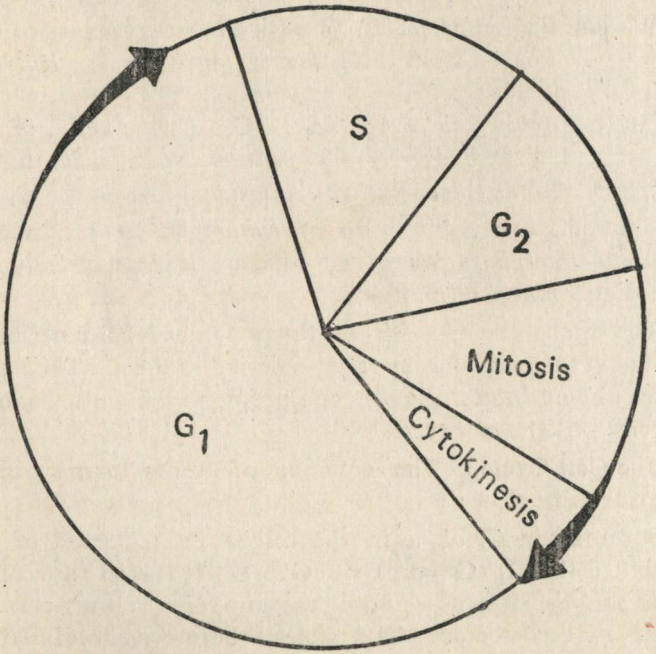


Fig. 11·1 The cell cycle. During the interphase G_1, S and G_2 occur in sequence. G_1 may be of a varying length, but for a given cell type S and G_2 are usually of uniform duration.

During interphase i.e., G_1 to G_2, precursors of mitotic spindle are continuously synthesized. Replication of centrioles, if present also usually takes place during interphase. At the end of interphase, synthesis of almost all constituents essential for the division of cell is complete. Synthesis of RNA, including both messenger and ribosomal RNA, however, continues until late in mitotic phase.

The lengths of S and G_2 are fairly constant in a given cell type. In most cells DNA synthesis (during S period) takes between 7 and 8 hours of the cell cycle. The subsequent G_2 period may last from 2–5 hours.

Since S and G_2 lengths are usually more or less fixed, the *triggering event* for all the stages of cell division, including S, G_2, mitosis and cytokinesis must occur during the G_1 period. The identity of the initiating event for cell division has occupied the attention of scientists for many decades. It was once thought that the initiation of mitosis followed an increase in mass of the cell to a prescribed level. There are however many exceptions to this hypothesis. It is now generally accepted that although the division of cells, parallels an increase in mass of the cell, this increase alone is not enough to initiate division. *The triggering event for a cell division is still unknown.* It probably involves a sequence of inter-actions between the nucleus and its cytoplasmic and extracellular environment with the activation of genes that code for an *initiation substance.* This *initiator substance* may be a protein as the studies show, that a brief period of protein synthesis is necessary for the initiation of S phase. Other investigations have revealed that additional synthesis of RNA template and protein is required during S and G_2 for the cell to enter into mitosis.

As described, the end of G_2 period of the interphase, marks the commencement of mitosis or somatic cell divisions the details of which are given below.

Stages of Mitosis :

Mitosis or somatic cell division is a continuous process. It is however convenient to divide mitosis into four arbitrary stages :

(i) Prophase (*pro*=before).

(ii) Metaphase (*meta*=between).

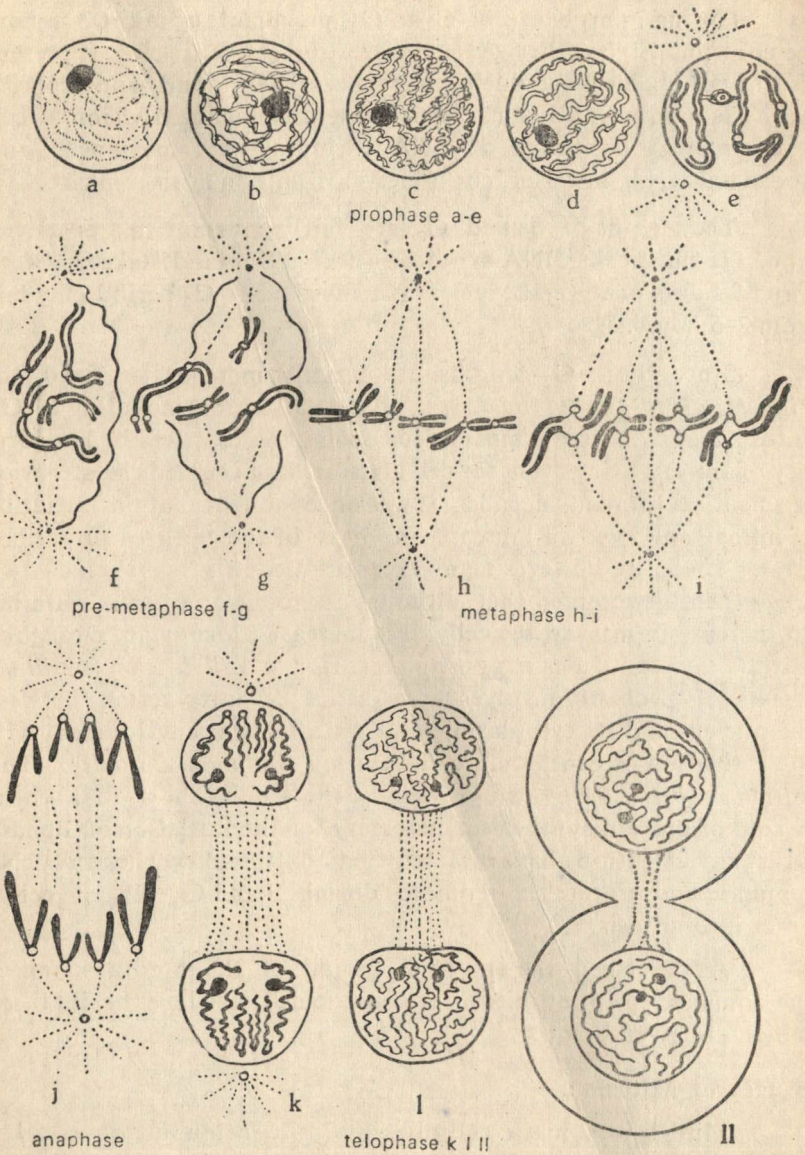


Fig. 11·2 Diagram representing different stages of mitosis

(iii) Anaphase (*ana*=back).
(iv) Telophase (*telo*=end).

The above stages in the process of mitosis are shown in figure 11·2. The details of each stage are described below:

Prophase:

The nucleus shows little differentiation in its internal structure during interphase. The beginning of the prophase however is marked by the first appearance of chromosomes as faint threads in the nucleus. The word *mitosis* (mitos=thread) is used to indicate the thread-like aspect of the chromosomes. The chromosomes are often seen to be double as soon as they become visible in the prophase nucleus. Each prophase chromosome thus consists of two sub-units called the *chromatids*, which are the products of the replication of the chromosome. The replication of chromosomes as already stated under cell cycle, occurs during the S-period of interphase. During the progress of prophase, coiling and condensation in the chromosomes continue on account of which, the chromosomes become comparatively shorter and rod-like. As the condensation completes, the two chromatids of each chromosome, lie more or less parallel to each other. The two chromatids of a chromosome are held together by the centromere.

As prophase progresses, the *nucleolus* in most species becomes smaller and by late prophase or metaphase, the nucleolus eventually breaks down and disappears. The nucleolar components of the disintegrating nucleolus become distributed in the nucleoplasm.

The end of prophase is marked by the fragmentation of the nuclear envelope. With the disintegration of the nuclear membrane, the nucleolar material becomes indistinguishable from cytoplasmic ribonucleo-protein that invades the nuclear area. Except for some proteins, the nucleolar substance released during prophase is incorporated into the cytoplasm and does not enter into the reorganizing nucleolus at the completion of mitosis.

In almost all animal cells, and in cells in plants giving rise to motile gametes, the cytoplasm just outside the nucleolus contains a pair of small barrel shaped bodies called *centrioles*. (cf. p. 302). A radiating system of microtubules is formed in relation to each centriole. This alignment of the microtubules around the centrioles, shapes adjacent cytoplasmic particles into a star-like array called the **aster.**

Centrioles are replicated during the interphase, usually during the S-period. One pair of centrioles and the associated microtubules remain in position just outside the nuclear envelope. The other pair migrates approximately 180° around the periphery of the nucleus, coming to lie at the opposite end of the cell just outside the nuclear envelope. As the pairs of centrioles separate, the microtubules between them frequently lengthen accordingly, so that the two asters remain interconnected by a system of tubules at one side of the nucleus. The continuous microtubules are formed between the separating centrioles but are not connected to the centrioles. The continuous microtubules, it is suggested are the means of segregating the centriolar pairs.

The position attained by the centrioles and *asters* at the completion of their migration locate the future division poles for the subsequent metaphase and anaphase.

Metaphase :

In most organisms the fragmentation and disappearance of nuclear envelope marks the end of prophase and the transition into metaphase. After the break-down of the nuclear envelope three major rearrangements occur which are as follows :

(i) The area formerly occupied by the nucleus becomes filled with the spindle, a system of microtubules extending between the poles of the cell.

(ii) The chromosomes which are randomly scattered throughout the nucleus at the time of fragmentation of the nuclear envelope, move to the mid-point of the spindle. At the mid-point of the spindle, each chromosome becomes attached at the centromere to a bundle of spindle microtubules. This condition establishes metaphase. The spindle thus is completely formed, and the chromosomes each attached at the centromere to spindle microtubules are aligned at the mid-point of the spindle. The movement of the chromosomes and their alignment at the mid-point of the spindle is called *congression* or *metakinesis*.

The centromeres, already double as a result of replication of chromosomes during interphase, attach to the spindle in such a way that the two centromeres of each chromosome (chromatid) face and are connected to the opposite poles (See fig. 11·3).

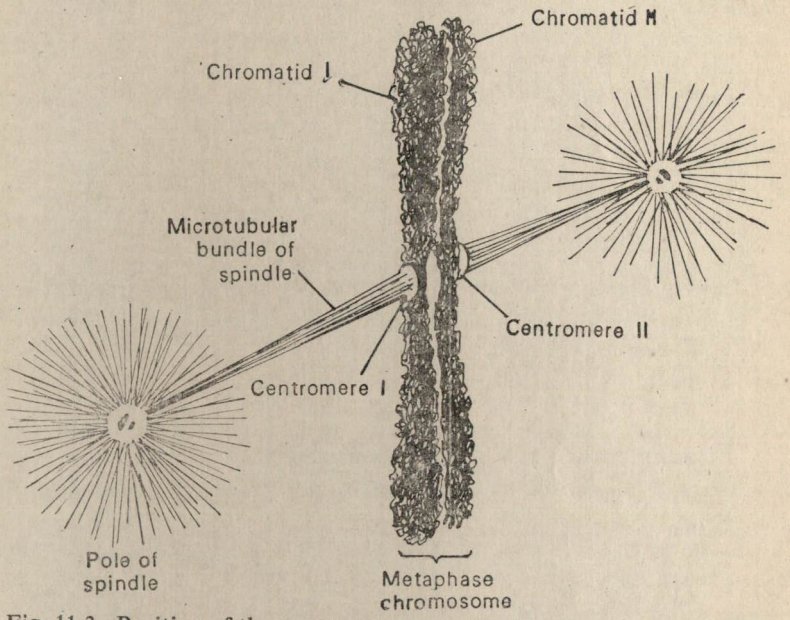


Fig. 11·3 Position of the centromeres at metaphase. Two centromeres are present. They are directed towards and make fibre connections to the opposite poles of the spindle

Each chromosome via the centromeres connects to a bundle of 4 to 8 or more microtubules. Such a composite spindle fibre is called a *chromosome fibre*. However large numbers of spindle microtubules remain extented from pole to pole without making connections to the chromosomes. These are called the *continuous fibres* to distinguish them from chromosome fibres of the spindle. Both the types of the microtubules persist in the spindle throughout the metaphase and anaphase.

Structure of the Spindle :

The spindle is broadest at the mid-point and is roughly circular in cross-section at all levels. At either pole the spindle narrows, and the component microtubules converge towards these points. This

narrowing is most pronounced in organisms in which the spindle fibres converge to centers formed by the asters. Such spindles are called *astral spindles*. In the plant and animal cells containing no asters or centrioles, the spindle is broader at the ends, assuming a barrel rather than a spindle shape. Such a spindle is called *anastral spindle.*

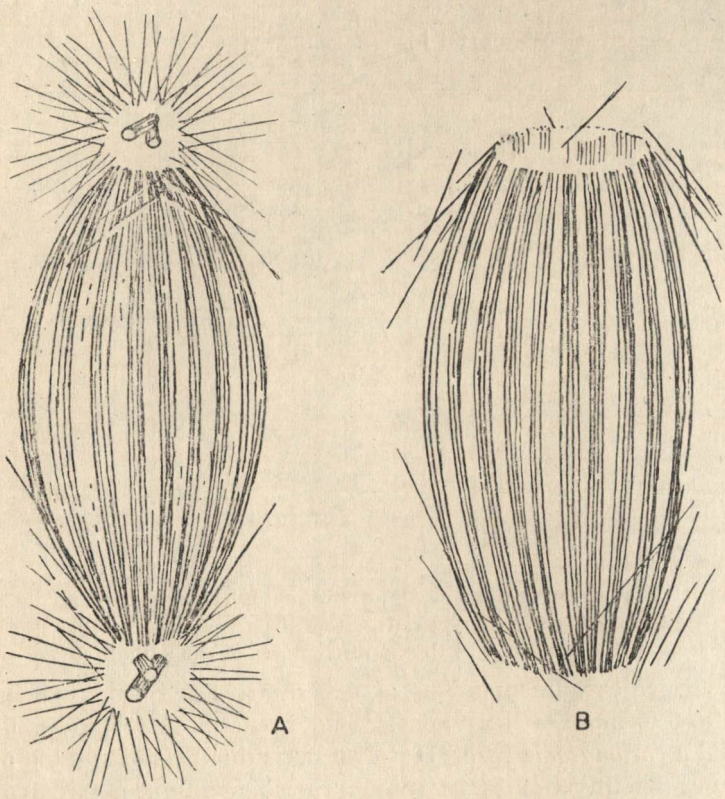


Fig. 11·4 (A) Astral spindle (B) Anastral spindle

The spindle consists of 500–1000 or more microtubules. In addition to tubules, the various regions of the spindle may contain scattered vesicles, ribosomes, fragments of smooth and rough endoplasmic reticulum and concentrations of amorphous, electron dense material of unknown identity. These structures are found dispersed throughout the spindle between the bundles of parallel microtubules. The vesicular components are usually concentrated at the poles of the spindle.

The microtubules of the spindle are unbranched hollow cylinders which may reach many microns in length. The microtubules are variously reported to be 150–220 Å in diameter, slightly smaller than the tubules seen in the shafts of cilia and flagella. The walls of the microtubules are electron dense and in cross-section can be seen to be 40–60 Å thick. As already mentioned the tubules are inter-mixed with other substances due to which the analysis of the substances going into the composition of microtubules is very difficult. The analysis however reveals that some proteins are found in abundance. These proteins thus are believed to represent the structural sub-units of spindle microtubules. This idea has been supported by the binding capacities of a chemical called colchicine which is a spindle inhibitor. Colchicine causes rapid disruption of the spindle apparatus, but when it is removed, the spindle is *quicky restored. Colchicine* binding appears to be specific to 6 S protein units. It has therefore been suggested that the *microtubules of the spindle consist of protein sub-units which may exist in an assembled (polymerized) or disassembled (monomerpool) state.*

The final position of the chromosomes at the mid-point of the spindle aligning through their centromeres to the microtubules is referred to as the *metaphase plate.* The appearance of the metaphase plate completes the establishment of the metaphase.

Anaphase :

Anaphase commences, the moment the two halves i.e., chromatids of each metaphase chromosome begin to separate and move to opposite poles of the spindle. A number of models of chromosome movement have been formulated. According to these models formulated, the microtubules are regarded as the basic motile units, the chromosome being passive.

The distinctive features of the model formulated by **McIntosh** and his colleagues are as follows :

(i) The spindle microtubules have lateral arms which confer polarity.

(ii) The lateral arms serve both structural and mechanochemical roles and form across bridges between the spindle microtubules.

It is also assumed that the intertubular links serve to bend the normally straight microtubules into the curved paths of the spindle. Anti-parallel tubules can interact so that they slide over one another. This means that the lateral arms contain enzymes which are capable of releasing chemical energy from ATP and converting part of it into mechanical work.

The process of chromosomal movements is explained with the help of a diagram (See fig. 11·5).

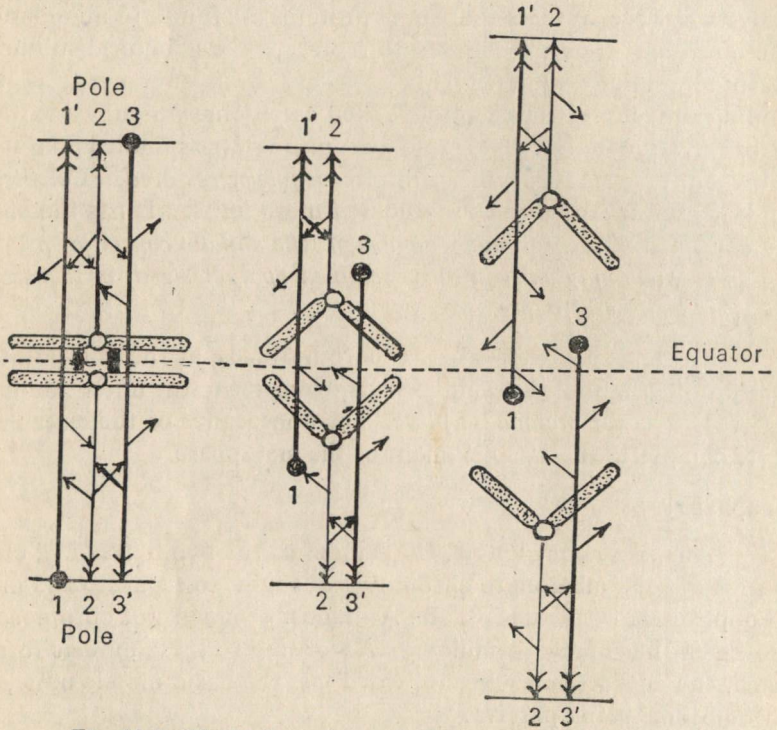


Fig. 11·5 The McIntosh model of mitosis pertaining to the nature of chromosome movement during anaphase.

In order to explain the nature of chromosome movement, a minimum number of three microtubules are shown in the diagram. 1–1′ and 3–3′ are *polarized continuous interpolar tubules*, while 2 represents the *half spindle microtubule* extending from one pole to the centromere of chromatid. During anaphase, microtubules that lie anti-parallel slide on one another i.e., 1–1′ slides on 3–3′ in opposite

directions. In addition to this, the length of both the half spindle fibres (2) and continuous fibres 1–'1 and 3–'3 decreases by the disassembly of microtubular sub-units. The half spindle fibres along with their chromatids attached to them by centromeres, are moved towards the poles while the continuous fibres slide in the direction of opposite pole. Relative sliding of anti-parallel tubules then continues until a point of self-termination is reached when there are too few bridges left to move the tubules any further.

Anti-parallel sliding of the continuous fibres, the movement of the half spindle fibres towards the poles coupled with the shortening of the tubules by the disassembly of their sub-units, are the events responsible for the movements of the chromosomes towards the opposite poles.

In the final phase of anaphase the chromosomes approach their respective poles *but do not quite reach the poles of the spindle.*

It should however be remembered that the McIntosh model does not offer a really satisfactory explanation regarding the movements of the chromosomes. Whether the spindle fibres pull the chromosomes to the poles or the chromosomes are put in motion by some other agency are the questions which are not yet properly answered.

Telophase:

There is no clear cut stage of demarcation from anaphase to telophase. Telophase, the final stage in mitosis is marked by the aggregation of the two groups of chromosomes into masses of chromatin in the neighbourhood of the poles. These chromatin masses which subsequently form the two daughter nuclei, become surrounded by discontinuous segments of the nuclear envelope. The segments of the nuclear envelope progressively fuse until the chromatin mass is completely separated from the cytoplasm.

With the reconstruction of the nuclear envelope, the chromatin mass becomes diffuse and the nucleus takes on the typical interphase aspect. As the nucleus takes shape, the nucleolus is reorganized on sites of the chromosomes known as the *nucleolar organizer* (cf. p. 311).

Most of the microtubules of the spindle disappear from the cytoplasm during telophase. In cells containing centrioles, the aster remains after the completion of telophase. In addition to this some short lengths of microtubules also persist at the former mid-point of the spindle. These persistent microtubules contribute to the division of the cytoplasm in the subsequent cytokinesis.

Cytokinesis :

Nuclear division (Karyokinesis) need not be followed immediately by cytoplasmic cleavage. It may not follow at all when a multinucleate condition results. This occurs as a regular feature in the development of vertebrate skeletal muscle and in the formation of the liver in some mammals.

In most cells, however, mitosis and cytokinesis take place in close sequence. The division of the cytoplasm is usually initiated during mitotic anaphase after the movement of the chromosomes to the poles. In animal cells, a furrow appears in the plasma membrane and gradually deepens by contractile mechanism, until the daughter cells are completely separated. The furrow follows a plane through the former mid-point of the spindle, which is distinguished by short lengths of the microtubules which persist in this region. The microtubules are intimately involved in the division of cytoplasm or cytokinesis.

The Duration of Mitosis :

The time required for the completion of mitosis may vary from as little as 5–10 minutes (in the early development of the Drosophila embryo) to several hours. Average values range between 30 minutes and 2–3 hours. The prophase is the longest stage in mitosis. Telophase is next longest. Metaphase and anaphase usually require the least time for completion.

The Significance of Mitosis :

The functional significance of replication and mitosis is the production of two daughter nuclei, each with genetic capacity equivalent to the original parent nucleus. Mitosis is a distributive mechanism basic to all higher organisms. The cell division also involves the assimilation of materials from the outside, their transformation

through break-down, and synthesis into new cellular parts. Cell division guarantees a continuous succession of similarly endowed cells, the absence of which may lead to chaos. The division of cells however accompanied by the usual growth, brings fresh substance into the cell, which prevents effectively, *aging* and gives to the cell a potential immortality. In multicellular organisms, cell division provides added cells, among which division of labour can take place. Viewed from this angle, the cell division therefore is also a first step towards *cell differentiation.*

Meiosis :

J. B. Farmer and J. E. Moore termed this special form of nuclear division *Maiosis* (Gk. *Meioun*; to diminish). This term was later changed to **Meiosis.** It essentially comprises two cell divisions and results in four nuclei, each of which has a single set (Haploid number) of chromosomes. The two divisions in meiosis are referred to as *first* and *second meiotic divisions* or simply *divisions I and II.* Meiosis occurs only in germ cells of sexually reproducing animals and plants. In male animals it occurs during the *spermatogenesis* to form *spermatozoa* and in females during oogenesis to produce *ova* or *eggs.* These *sperms* and *ova,* due to meiotic division receive a *haploid number of chromosomes.* The haploid number of chromosomes in gametes is essential, as, when the sperm nucleus fuses with the nucleus of the ovum in fertilization, the zygote receives a diploid number of chromosomes. The diploid number of chromosomes or the zygotic number of chromosomes is constantly maintained in the somatic cells during mitosis.

The details of meiotic division are now given. The successive stages in meiosis are as follows :

Premeiotic Interphase :

The cells destined to undergo meiosis are the product of ordinary mitotic divisions. At some point following a DNA replication, the gametic cells enter a meiotic rather than mitotic sequence. Replication of chromosomes takes place during premeiotic interphase In contrast to mitosis, this replication is extended over longer periods of time. The first irreversible changes directing cells towards meiosis may take place early in G_2. The nature of this change is unknown, but the shifting mechanism probably represents

the activity of one or more genes controlling the division cycle. Cells in premeiotic interphase are similar in morphology to premitotic cells except that late in interphase the nuclei of premeiotic cells enlarge. The details of meiotic division I are given below.

Meiotic Division I:

The first meiotic division is marked by a *prolonged* **prophase I** during which *homologous chromosomes pair* (i. e., the maternal and paternal sets of chromosomes or partner chromosomes) *closely, and interchange hereditary material.* The following phases may be observed during **prolonged prophase I** of the *first meiotic division.*

Prophase I

Meiotic prophase for the sake of convenience is divided into five stages i. e. (i) Leptotene (or leptonema), (ii) Zygotene (or zygonema), (iii) Pachytene (or pachynema), (iv) Diplotene (or diplonema) and (v) Diakinesis.

(i) Leptotene (leptos=fine or thin) is marked by the first appearance of chromosomes as extended faint threads in the nucleus. The chromatids have bead-like swellings, called *chromomeres* which are probably formed by localized differences in the degree of coiling of the chromatin fibres. Chromomeres were once thought to represent the genes.

As leptotene progresses, there occurs the condensation of chromosomes with further shortening and thickening of the chromosome arms. Each chromosome consists of two chromatids as the replication has already taken place. This division into chromatids is not visible and each leptotene chromosome appears to be a single unit under a light microscope. In many animals, at this stage, a peculiar arrangement of the chromosomes is noted in which the ends of the chromosomes are attached to the nuclear envelope at points near the centrioles which at this stage are still contained in a single aster. The remainder of the chromosome extends as a loop into the nucleoplasm.

(ii) Zygotene (Zygon, yolk, adjoining). The zygotene phase is marked by the pairing between the homologous chromosomes. The two chromosomes of a pair, called *homologues* (partner chromosomes) have the same genes in the same order along the chromosomes

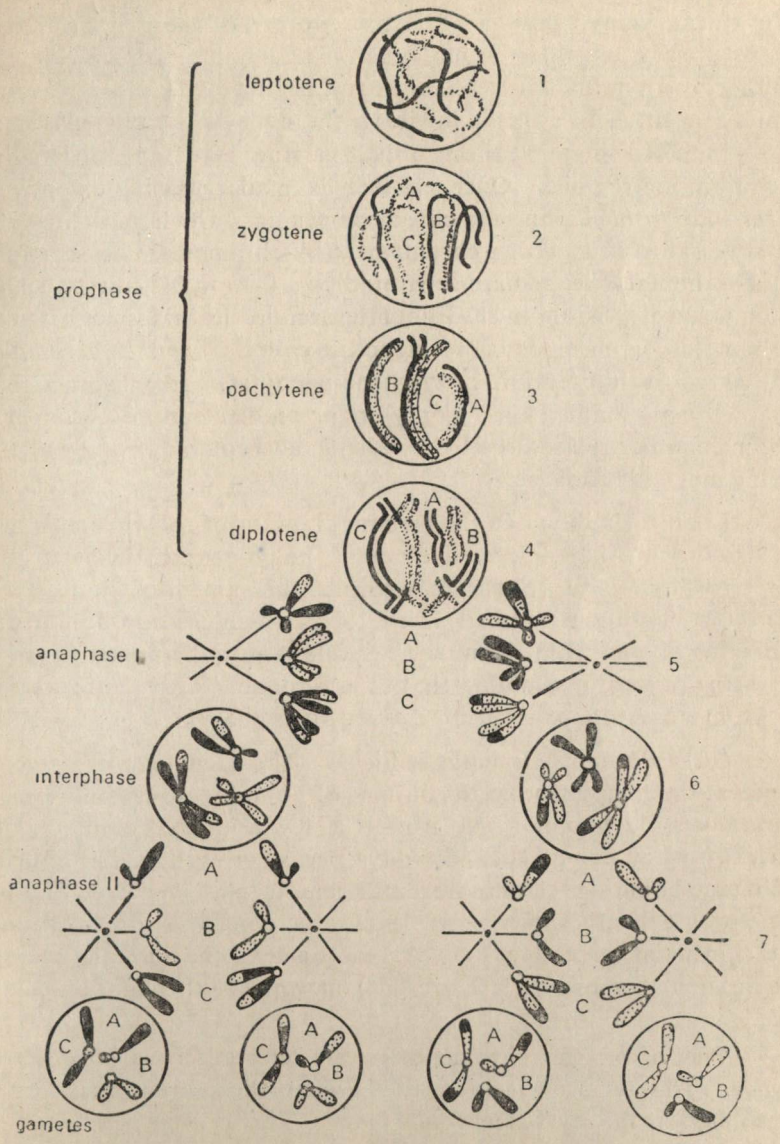


Fig. 11.6 A diagram representing stages in meiosis illustrating union, separation and distribution of the chromosomes

in a linear array, but the alternate forms of the genes (alleles) may be present in either homologue. The homologues are brought together by an unknown mechanism and begin to pair closely at one or more points. In animals in which the ends of the chromosomes are attached to the nuclear envelope, pairing is often initiated at these terminal regions. Once contact is made, pairing extends in *zipper-like fashion* along the chromosomes until the homologues are closely aligned in a precise chromomere-by-chromomere association. The two homologues remain separated by a 0·15 to 0·2 micron space which is hardly visible in the light microscope. In this space between the homologous chromosomes a structure called *synaptinemal complex* is observed in thin sections of zygotene-pachytene chromosomes. The synaptinemal complex visible only under an electron microscope, is in some manner related to close pairing and combination of alleles during meiotic prophase.

In animals in which the terminal regions of the chromosomes are attached to the nuclear envelope at the point near the aster, the pairing of homologues apparently reduces the number of loops to one half of the leptotene number. These loops which are now double due to pairing extend from the nuclear envelope into the nucleoplasm in a striking pattern resembling that of a 'bouquet.' This configuration of chromosomal loops is often referred to as the '*Bouquet stage.*'

(iii) Pachytene (pachus=thick). The pachytene phase commence at the completion of the pairing of homologous chromosomes. Leptotene and zygotene take usually a few hours to complete. In contrast, pachytene may last for days, weeks or even years. During pachytene homologous chromosomes remain closely paired and become progressively shorter and thicker as condensation continues. Attachment of the ends of the chromosomes to the nuclear envelope (where such attachments are present), may persist throughout pachytene.

The pachytene chromosomes are referred to as *bivalents* or *tetrads.* The term *bivalent* is used when the paired structure is considered at the level of chromosomes. This reflects the fact that the homologues are paired by twos to form the pachytene configuration. When the paired structures are considered at the level of chromatids we use the term *tetrads.* As mentioned, each homologue consists of two chromatids which are products of the premeiotic

replication. The two paired homologues thus with their corresponding double chromatids will give a total of four chromatids, hence referred to as the *tetrads*. This is shown diagrammatically in fig. 11·7. It should however be remembered that the sub-division of the homologous chromosomes is not visible under the light microscope at pachynema.

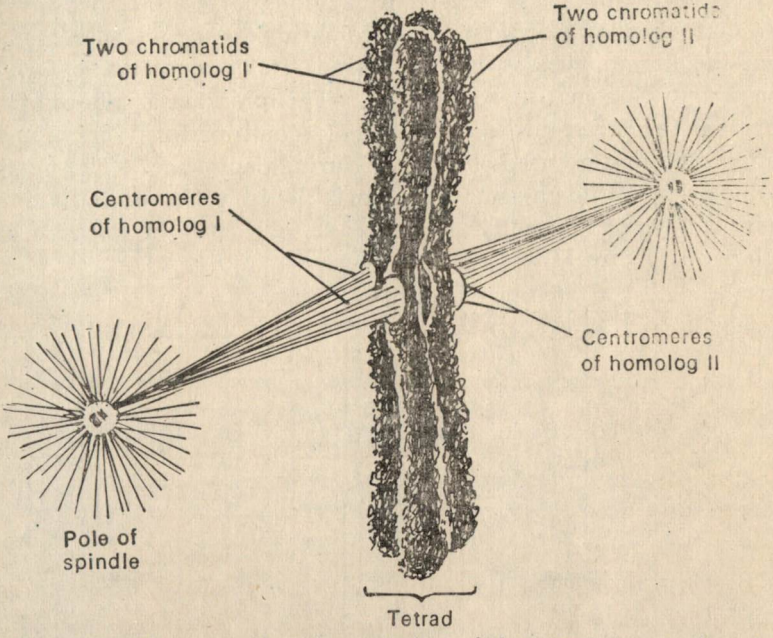


Fig. 11·7 Diagrammatic representation of the tetrad at metaphase I of first meiotic division showing the orientation and spindle fibre connections of the centromeres

It has been shown by various methods that the chromatids of homologous chromosome pairs *exchange segments* or *recombine* during pachytene. However, no evidence of cross overs or exchanges between the homologues can be seen at this stage in either the light or electron microscopes. This suggests that the exchange of segments or recombinations are at the molecular level hence at the pachytene stage no alterations are visible in the arrangement of chromosomes.

(iv) Diplotene : The end of pachytene and the beginning of diplotene stage is marked by a widening of the separation between the paired chromosomes. Sometimes the separation is to the extent

that the homologues seem to repel each other. The sub-division between the chromatids becomes visible for the first time. At diplotene, all the four chromatids of the tetrad become clearly visible.

The homologues instead of separating completely are held together at one or more points spaced along the chromosomes. On close examination, these persistent regions of contact prove to be points at which two of the four chromatids of the tetrad cross between the homologues. These crossing sites are called *chiasmata* (Singular : chiasma = cross piece). The chiasmata undoubtedly represent the end result of exchanges (recombinations) between the homologues that occured previously during pachytene. The number and position of the chiasmata is variable in different individuals. There is however normally at least one chiasma per tetrad, which is shown in figure 11.8.

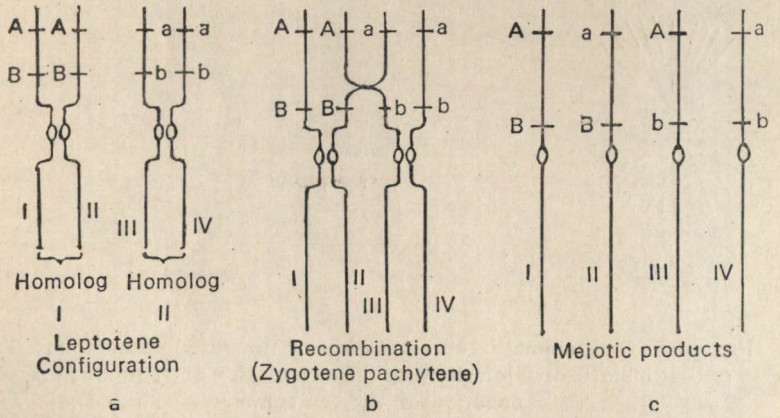


Fig. 11.8 The diagrams representing the presumed mechanism accounting for recombination during meiotic prophase I

Meiotic cells can remain in diplotene for long periods of time. For example, in the human female the oocytes in the ovary of the foetus, reach diplotene stage by fifth month of pre-natal life and remain arrested in this stage until shortly before ovulation, which may not take place until 12 to 50 years later. During diplotene the chromosomes in most species uncoil atleast to some extent. The uncoiling is correlated with intensive RNA synthesis and growth of the cell.

(v) Diakinesis: At the end of diplotene phase, the chromosomes, if uncoiled, return to the tightly coiled state. It is not easy to determine the transition from diplotene to diakinesis (dia= across). The chromosomes reach their greatest prophase contraction in diakinesis. In some cases they become spherical. In many species at this stage the nucleolus disappears, and the tetrads become more or less evenly distributed throughout the nucleus. With the progress of diakinesis, the chiasmata may move toward the ends of the chromosome arms. This process, referred to as *terminalization*, continues until many of the tetrads are held together only at the tips of the chromosomes.

Metaphase I:

Just as in mitosis, the beginning of metaphase I is marked by the breakdown of the nuclear envelope. Prior to this, the centrioles and asters, if present, divide and migrate to points at opposite sides of the nucleus. The process of the formation of the spindle whether centrioles are present or not, is the same as in mitosis. With the formation of the spindle, the tetrads left scattered in the region of the cell formerly occupied by the nucleus, move to the equator or the mid-point of the spindle. This movement of tetrads to the equator is called *congression*, the basis of which is unknown.

At the equatorial region of the spindle the centromeres of each tetrad, get attached to the microtubules of the spindle. The attachment of the centromeres to the microtubules of the spindle is made in a fundamentally different way from the metaphase of mitosis. As already mentioned, four centromeres are present in the tetrad i.e., two centromeres are present in each homologue. Eventhough two centromeres are present in each homologue, the electron micrographs show, that the two centromeres of one homologue make connections to only one pole of the spindle and the two centromeres of the other homologue make attachments to the spindle microtubules leading to the opposite pole. This mode of attachment of the centromeres provides the basis for the segregation of homologues into different daughter cells after the first meiotic division. The two centromeres of each homologue thus act as a functional unit at metaphase I of meiosis.

Anaphase and Telophase I :

As a result of the connections established at metaphase I, the homologues are separated at anaphase I and move to opposite poles of the spindle. As the homologues separate, any remaining chiasmata are pulled apart. At the end of anaphase I, each pole contains only one of the two chromosomes of each homologous pair. In terms of chromosomes, the poles now contain the *haploid number.* Each chromosome it should be recalled consists of two chromatids. It should also be remembered that by way of the chiasmata, the segments were transposed between two of the chromatids of each homologue. As such, when the homologous paternal and maternal chromosomes separate in anaphase, their composition is different from that of the originals.

At telophase I of meiosis, the chromosomes may either partially revert to an interphase condition or may continue directly into the second division of meiosis without uncoiling. In most organisms a transitory nuclear envelope is formed around polar masses of chromosomes during telophase I for atleast a brief period.

Meiotic Division II :

The mechanism of second meiotic division is essentially the same as in ordinary mitosis with of course two significant differences i. e., (i) There is no replication of chromosomes between the first and second meiotic division and (ii) The chromosomes are present in the haploid number.

The interphase between meiotic divisions I and II may be very short or even non-existent. This depends upon the degree of uncoiling of the chromosomes at telophase I. Likewise, the duration and extent of prophase II depends on whether significant uncoiling occurs in telophase I. In these organisms where little or no reversion to interphase state occurs during telophase I, the chromosomes may pass almost directly from telophase I to metaphase II.

At the end of prophase II, the nuclear envelopes surrounding the two groups of chromosomes separated by the first meiotic division breakdown (if nuclear envelopes have indeed formed). Ordinarily no nucleolus appears during interphase or prophase of the second meiotic division. At metaphase II, two spindles are formed anew in the

areas corresponding to the two poles of telophase I. The alignment of chromosomes on these spindles is exactly the same as in metaphase of mitosis. Each chromosome, consisting of two chromatids, attaches to both the poles of the spindle. As these attachments are made, the two centromeres of each chromosome, previously side-by-side at telophase I, separate and rotate to face the opposite poles of the spindle.

At anaphase II, the two chromatids of each chromosome are separated and move to opposite poles of the spindle. At the end of anaphase II, each pole contains the haploid number of chromosomes. At telophase II, nuclear envelopes form around the four division products and the distinct outline of the chromosomes is lost. In animals, the four products are segregated into separate cells by the process of furrowing. The development of these haploid cells into functional gametes is termed as *gametogenesis* which is complex. The process of gametogenesis varies not only between species but also between males and females of the same species.

Meiosis thus is a mechanism for distributing the hereditary units (genes) and permitting their random independent recombination. Crossing over during meiosis provides a means whereby the genes of different chromosomes can be brought together and recombined. If the process of crossing over did not take place, the evolution of the species would be suspended by unalterable chromosomes and organisms would not exhibit characteristic diversity.

The knowledge of the process of meiosis is a pre-requisite for the understanding of the *chromosomal basis of heredity.*

The stages in **meiosis** described, are listed below in their successive order.

Meiotic Division I

Prophase I	*(a) Proleptotene*
(Prolonged)	*(b) Leptotene*
	(c) Zygotene
	(d) Pachytene
	(e) Diplotene
	(f) Diakinesis.

Prometaphase I
Metaphase I
Anaphase I
Telophase I

Cytokinesis.
Interphase (Interkinesis).

Meiotic Division II

Prophase II
Metaphase II
Anaphase II
Telophase II

Cytokinesis

Revision questions

1. Describe in detail the process of mitosis and the significance of cell division.
2. Give an account of meiosis and discuss its significance.
3. Write notes on the following:
   (a) Cell cycle.
   (b) Tetrads.
   (c) Synaptinemal complex.
   (d) Structure of the spindle.

TWO-YEAR INTERMEDIATE EXAMINATION

JUNE, 1971

Part III—Sciences

Biological Sciences—Paper II

(Zoology)

Time : **3** hours. Max. Marks : **100**

Instructions: 1. Answer any *Six* questions.
2. Illustrate your answers with well-labelled diagrams wherever necessary.
3. All questions carry equal marks.

I. (a) Give an account of the structure and reproduction in *Amoeba.* OR

Give the general characters of the Phylum protozoa. Classify with examples.

(b) Write notes on any *Two* of the following :
1. Autogamy. 2. Osmoregulation.
3. Erythrocytic cycle of *Plasmodium.*

II. (a) Describe the life history of Liver fluke.

(b) Describe any two of the following :
1. Gravid Proglottid. 2. Rhabditiform Larva.
3. Parasitic Protozoa.

III. (a) Describe the alimentary canal of Cockroach with its associated structures. Add a note on the physiology of digestion. OR

Describe the organs of excretion.

(b) Explain briefly any *Two* of the following :
1. How a male Roundworm differs from a female Roundworm.
2. How a Coelom differs from a Haemocoel.
3. How asexual reproduction differs from sexual reproduction.

IV. (a) Describe the mouth parts of Cockroach. How they differ from Mosquito. OR

Describe with a suitable diagram, the external features and mantle cavity of fresh water mussel.

(b) What are the functions of:

1. Water vascular system. 2. Spermatheca.
2. Clitellum. 4. Gill.

V. (a) Describe how Respiration takes place in frog. OR Describe the Brain of Frog and functions of various parts.

(b) Explain any *One* of the following:

1. Why Frog is considered to be an Amphibian.
2. Why Pigeon is included under class Aves.
3. How a Quill feather differs from a filoplume.

VI. (a) Describe the process of cell division (Mitosis). OR Give an account of Spermatogenesis.

(b) Comment upon any *Two* of the following:

1. Cartilage. 2. Striated muscle. 3. Nerve cell.

VII. (a) What is Evolution? Describe the Fossil evidence. OR Classify Mammalia, giving characters and examples.

(b) Comment upon any *Two* of the following:

1. Vestigeal organs. 2. Structure of a spermatozoan.
3. Centrosome.

TWO-YEAR INTERMEDIATE EXAMINATION

DECEMBER, 1971

Part III—Sciences

Biological Sciences–Paper II

(Zoology)

Time: 3 hours Max. Marks: 100

Instructions: 1. Answer any *Six* questions.

2 Illustrate your answers with well-labelled diagrams wherever necessary.

3. For general neatness like clarity of answers, well labelled diagrams, 4 marks will be given.

I. (a) Describe the life history of Amoeba proteus. 6

(b) Write notes on any *Two* of the following : 5

1. Endomixis.
2. Characters of living organisms.
3. Contractile vacuole in Paramoecium.

II. (a) Describe the various kinds of cells found in the body-wall of Hydra.

(b) Describe any *Two* of the following : 5

1. Budding in Hydra. 2. Scolex of tape worm.
3. External characters of Leech.

III. (a) Give an account of reproductive organs of Cockroach.

OR

Describe the life history of Round worm. 6

(b) Explain any *Two* of the following : 5

1. Lateral hearts of earthworm.
2. Integumentary nephridia.
3. Blood of Cockroach has no respiratory value.

IV. (a) Giving the General characters of the Phylum arthropoda, classify giving examples. OR 6

With a neat labelled diagram describe the mantle cavity of fresh water mussel.

(b) Describe the functions of : 5

1. Spermathecae. 3. Alary muscles. 3. Tube feet.
4. Epithelia. 5. Sebaceous glands.

V. (a) Describe the circulatory system in Amphioxus. 6

(b) Describe any *Two* of the following : 5

1. Portal circulation. 2. A wing feather.
3. Wheel organ. 4. Skin of Frog.

VI. (a) Enumerate the general characters of birds (Aves). 6

(b) Explain the zoological importance of any *Two* of the following. 5

1. Sphenodon. 2. Tadpole larva of Frog.
3. Archaeopteryx.

VII. (a) Describe Charles Darwin's Natural Selection OR Describe the process of Mitosis.

(b) Answer any *Two* of the following :

1. DeVries Mutation Theory.
2. Mitochondria. 3. Oogenesis.

TWO-YEAR INTERMEDIATE EXAMINATION

APRIL, 1972

Biological Sciences—Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions : 1. Answer any *Six* questions.

2. Illustrate your answers with well labelled diagrams wherever necessary.

3. For clarity of answers and general neatness 4 marks are allotted.

I. (a) Describe the structure of Paramoecium. OR 6

What are stinging cells ? Describe the different kinds of stinging cells and their functions.

(b) Describe any *Two* of the following : 5

1. *Dracunculus medinensis.*
2. Body wall of Earthworm.
3. Heart of Cockroach.

II. (a) Give an account of the Excretory System in Earthworm. 6

(b) Explain the following (any *Two*) : 5

1. Compound eye of Cockroach.
2. Ciliary mode of feeding in Amphioxus.
3. Oral view of star-fish.

III. (a) Describe the digestive system of frog. Add a note on physiology of digestion. OR 6

Give an account of the vertebral column of Frog. What are its uses ?

(b) Write what you know about the following (any *Two*): 5

1. Poison apparatus of a snake.
2. Larynx of frog. 3. Pituitary.

IV. (a) Give an account of different kinds of feathers of a bird and their uses.

(b) Write notes on any *Two* :

1. Metatheria. 2. Internal ear of frog
3. Air sacs in a bird.

V. (a) Draw a neat labelled diagram of an animal cell as seen under an electron microscope. 6

(b) Explain any *Two* of the following : 5

1. Prophase of meiosis. 2. Columnar epithelium.
3. A neurone (Nerve cell).

VI. (a) Explain in detail the theory of Lamarckism in support of organic evolution. OR 6

Explain the monohybrid cross in Drosophila with reference to body colour and state how it supports Mendel's laws of inheritance.

(b) Write notes on any *Two* : 5

1. Law of independent assortment. 2. Homozygotes.
3. Compatibility of blood groups.

VII. (a) Give the composition of human blood and explain the mechanism of blood clotting. OR 6

Define an ecosystem. What is the role played by different factors in an ecosystem. Describe the different regions of a land locked lake.

(b) Write notes on any *Two* of the following : 5

1. Diaphragm. 2. Heterodont dentition.
3. Mongoloid race.

TWO-YEAR INTERMEDIATE EXAMINATION

OCTOBER, 1972

Part III--Sciences

Biological Sciences—Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions: 1. Answer any *Six* questions.
2. Illustrate your answer with well labelled diagrams wherever necessary.
3. For clarity of answers and general neatness 4 marks are allotted.

I. Explain with a diagram the structure of an animal cell. Mention the function of each part. OR 11
In what respect animals and plants resemble and differ ?

II. Give an account of reproduction in Hydra. 11

III. (a) Describe the process of conjugation in paramoecium. 6

(b) Describe the following (Any *two*) :
1. Respiration in cockroach.
2. Hyoid apparatus of frog.
3. Wuchereria bancrofti.

IV. Describe the internal structure of frog's heart and explain the course of blood in the chambers of the heart. OR
With an aid of diagram describe the alimentary canal of cockroach with its associated structures. Mention the function of each part. 11

V. (a) Describe the brain of frog.

(b) Explain any *two* of the following :
1. Mantle cavity of pila.
2. Renal portal system in frog.
3. Kinds of feathers in birds.
4. Prototheria.

VI. Give an account of poisonous snakes you have studied.

OR 11

Give an account of Meiosis.

VII. (a) Write what you know about Darwin's Natural Selection.

(b) Write notes on any *four* :

1. Ostrich.
2. Mouth parts of Housefly.
3. Sweat glands.
4. Procoelous vertebra.
5. Sphenodon.

TWO-YEAR INTERMEDIATE EXAMINATION

MAY, 1973

Part III—Sciences

Biological Sciences—Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions : 1. Answer any *Five* questions.

2. Illustrate your answers with well labelled diagrams wherever necessary.
3. All questions carry equal marks.

I. Describe the structure and life-history of Amoeba proteus.

OR

Give an account of the different kinds of cells present in the body wall of Hydra.

II. (a) Describe the following :

1. Scolex of Tape worm.
2. Nervous system in Cockroach.
3. External features of Star-fish.

(b) Describe the alimentary canal in Earthworm and add a note on the physiology of digestion.

III. With the aid of diagrams, describe the reproductive organs of Cockroach. OR

Describe the following :

(a) Ciliary mode of feeding in Amphioxus.

(b) Structure, composition and functions of Frog's blood.

IV. With a labelled diagram describe the structure and function of heart of Frog. OR

Enumerate the general characters of the phylum Arthropoda.

V. (a) Describe any *Two* of the following :

1. Endomixis. 2. Mantle cavity of pila.
3. Leech (Ext. characters). 4. Tadpole larva of Frog.

(b) Listing out the evidences in favour of the theory of organic evolution, briefly explain the palaeontological evidence.

VI. Give an account of the Nephridial system in Earthworm.

OR

Describe the external characters and life history of Dracunculus.

VII. (a) Write short notes on any *Three* :

1. Germplasm theory 2. Retina of the Eye.
3. Pancreas. 4. Clitellum.

(b) Describe the Mouth-part of a Mosquito you have studied.

TWO-YEAR INTERMEDIATE EXAMINATION

DECEMBER, 1973

Part III - Sciences

Biological Sciences—Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions : 1. Answer any *Five* questions.

2. Illustrate your answers with well labelled diagrams wherever necessary.

3. All questions carry equal marks.

I. Describe the methods of reproduction in Hydra. OR
Describe the excretory system in Earthworm.

II. (a) Describe the following :
1. Multiple Fission. 2. Compound eye of Cockroach.
3. Mantle cavity of Pila.

(b) Describe the mouth parts of House-fly.

III. With the aid of a diagram describe the circulatory system in Earthworm. OR

Describe the following :
1. Buccal cavity of Frog.
2. Excretory organs of Amphioxus.

IV. With labelled diagrams describe Metamorphosis in Frog's life history. OR

Describe the structure and life history of Wuchereria bancrofti.

V. (a) Describe any *Two* of the following :
1. Male reproductive organs of Cockroach.
2. General characters of Echinodermata.
3. Shell of Fresh Water Mussel.
4. Renal portal system.

(b) Explain the theory of Natual Selection by Darwin.

VI. Describe the alimentary canal of Cockroach and add a note on digestion. OR

Describe the general characters of the Phylum mollusca.

VII. (a) Write short notes on any *Three* :
1. Lamarck 2. Mendelism.
3. Quill feathers. 4. Metatheria.

(b) List out the general characters of Amphibia.

TWO-YEAR INTERMEDIATE EXAMINATION

MAY, 1974

Part III—Sciences

Biological Sciences—Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions : 1. Answer any *Six* questions.
2. Illustrate your answer with well labelled diagrams wherever necessary.

3. For clarity of answers and general neatness 4 marks are allotted.

I. (a) Define 'Conjugation'. Describe the process and significance of conjugation in Paramoecium. OR 5
Discuss the general characters of Mollusca.

(b) Write short notes on any *Two* of the following : 6
1. Compound eye of Cockroach.
2. Renal portal system. 3. Columnar epithelium.

II. (a) What do you understand by the term 'Mitosis' ?
Describe the various stages in it. OR 6
Describe in detail the life cycle of Ascaris.

(b) Write notes on any *Two* of the following : 5
1. Pseudopodia 2. Metamerism. 3. Autogamy.

III. (a) Explain in detail the theory of Lamarck in support of Organic Evolution. OR 5
Describe the various types of cells found in the body-wall of Hydra.

(b) Write notes on any *Two* of the following : 6
1. Chloragogen cells. 2. Internal ear of Frog.
3. Monohybrid Cross.

IV. (a) Describe in detail, the reproductive system of Earthworm. OR 5
Describe the vertebral column of Frog.

(b) Write notes on any *Two* of the following : 6
1. Dracunculus 2. Cartilage 3. Endomixis.
4. Mouth parts of Mosquito.

V. (a) Describe in detail the clotting of blood. OR 5
Give an account of anatomical evidence in favour of Organic Evolution.

(b) Write short notes on any *Three* of the following :
1. Scolex. 2. T. S. Artery.
3. Metatheria. 4. Spermatozoan.

VI. (a) What is an Ecosystem ? Describe a land locked lake.

OR

Describe in detail the Brain of Frog. 6

(b) Explain any *Two* of the following: 5

1. Nerve cell. 2. Fossil.
3. DNA (Deoxyribonucleic acid).

VII. (a) Describe in detail the digestive system of Cockroach.

OR

Write an account of the structure of Paramoecium. 5

(b) Write short notes on any *Two* of the following: 6

1. Cyclosis. 2. Prostate glands.
3. Homology of organs.

TWO-YEAR INTERMEDIATE EXAMINATION
NOVEMBER, 1974
Part III—Sciences
Biological Sciences—Paper II
(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions : 1. Answer any *Five* questions.

2. Illustrate your answers with well labelled diagrams wherever necessary.
3. All questions carry equal marks

I. (a) Describe in detail the modes of reproduction in Amoeba. OR 5

Describe the life cycle of Taenia Solium.

(b) Write short notes on any *Three* of the following: 6

1. Flame cell. 2. Binary fission.
3. Atlas vertebra 4. Vestigeal organs.

II. (a) What do you understand by the term "Binomial nomenclature". Illustrate with examples. OR 6
Describe in detail the structure and working of the heart of frog.

(b) Explain any *Two* of the following : 5

1. T. S. Ascaris. 2. Ovum.
3. Mouth parts of cockroach. 4. Prototheria.

III. (a) Define "Organic Evolution". Give embryological evidences in favour of organic evolution. OR 5
Describe in detail the excretory system of frog.

(b) Describe any *Two* of the following. 6

1. Body wall of Earthworm. 2. Heart of cockroach.
3. Wuchereria.

IV. (a) What is a tissue? What are the primary divisions in the tissues? Illustrate each type with an example. 6

OR

Describe in detail the locomotion in Hydra.

(b) Write short notes on any *Two* of the following: 5

1. Nematocyst. 2. Ookinete.
3. T. S. Bone.

V. (a) Give an account of general characters of birds. OR 5
What are Mendel's laws of heredity?

(b) Write notes on any *Two* of the following: 6

1. Poisonous snakes. 2. Tadpole of Frog
3. Mitochondria.

VI. (a) Describe the life cycle of Plasmodium in man. OR 6
Describe the reproduction in Hydra.

(b) Write short notes on any *Two* of the following: 5

1. Animal cell.
2. Mantle cavity of fresh water mussel.
3. Typical Nephridium.

VII. (a) Mention the diseases spread in human beings by mosquito and fly. OR 6
Describe the external characters of leech.

(b) Write short notes on *Two* of the following : 5
1. Liver of Frog. 2. Eye of Frog.
3. Squamous epithelium.

TWO-YEAR INTERMEDIATE EXAMINATION

APRIL, 1975

Part III – Sciences

Biological Sciences – Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions : 1. Answer any *Six* questions.
2. Illustrate your answers with well-labelled diagrams wherever necessary.
3. For clarity of answers and general neatness 4 marks are allotted.

I. (a) Give an account of the structure of Paramoecium. OR
Write an account of the role of mosquitoes and flies in the spread of human diseases. 5

(b) Write short notes on any *Two* of the following : 6
1. Hermaphrodite. 2. Frog tadpole.
3. Smooth muscle.

II. (a) Write a brief account of the life-history of Ascaris. OR
Describe in detail the structure of the eye in frog. 6

(b) Write short notes on any *Two* of the following : 5
1. Trichocyst. 2. Chromosome.
3. Laryngo-tracheal chamber.

III. (a) State and explain Mendel's Laws. 5

OR

Give an account of the general characters of Coelenterata.

(b) Write short notes on any *Two* of the following : 6

1. Salivary glands. 2. Marsupium.
3. Mitonchodria.

IV. (a) Classify Platyhelminthes giving suitable examples. OR Describe in detail the pectoral girdle of frog. 6

(b) Write short notes on any *Two* of the following : 5

1. Mouth parts of house fly. 2. T.S. of Frog spinal cord.
3. Histology of pancreas.

V. (a) Mention the distinguishing features of poisonous and non-poisonous snakes. 5

OR

Briefly describe the various tissues in animals.

(b) Write short notes on any *Three* of the following : 6

1. Contractile vacuole. 2. T. S. of vein.
3. Ornithorhynchus. 4. Centriole.

VI. (a) What is nephridium? Describe various types of nephridia in Earthworm. OR 6

Describe in detail the buccal cavity of Frog.

(b) Explain any *Two* of the following :

1. Binomial nomenclature. 2. Spermathecae.
3. RNA.

VII. (a) Describe in detail the respiratory system in Cockroach.

OR 6

Give an account of the male and female reproductive systems in Frog.

(b) Write short notes on any *Two* of the following : 5

1. Hepatic portal system. 2. Clitellum.
3. Cutaneous respiration.

TWO-YEAR INTERMEDIATE EXAMINATION

OCTOBER, 1975

Part III—Sciences

Biological Sciences—Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions: 1. Answer any *Six* questions.
2. Illustrate your answers with well labelled diagrams wherever necessary.
3. For clarity of answers and general neatness 4 marks are allotted.

I. (a) Give an account of the process of locomotion and feeding in Amoeba. OR

Describe the general characters of Annelida.

(b) Write short notes on any *Two* of the following :

1. Mantle cavity of Pila. 2. Urostyle.
3. Striated muscle.

II. (a) Write an account of the structure of the animal cell.

OR

Give a detailed account of the structure of Taenia solium.

(b) Write short notes on any *Two* of the following :

1. Cocoon. 2. T. S. of Hydra.
3. Cloaca of Frog.

III. (a) Briefly indicate the evidences for organic evolution.

OR

Give a detailed account of locomotion in Hydra.

(b) Write short notes on any *Two* of the following :

1. Malpighian tubules. 2. Septal nephridium.
3. Eustachian tube.

IV. (a) Give an account of the general characters of Pisces.

OR

Briefly describe the circulatory system of Earthworm.

(b) Write short notes on any *Two* of the following :

1. Mouth parts of Cockroach.
2. Hyoid apparatus.
3. Cytopharynx.

V. (a) Give a brief account of the principles of classification.

OR

What is metamorphosis? Give an account of metamorphosis in Frog.

(b) Write short notes on any *Three* of the following :

1. Metatheria.
2. Histology of intestine.
3. Cytoplasm
4. Cartilage.

VI. (a) Enumerate the general characters of Arthropoda.

OR

Give an account of the main poisonous snakes of India.

(b) Explain any *Two* of the following :

1. Ring Stage.
2. Mitotic spindle.
3. Ecosystem.

VII. (a) Describe in detail the female reproductive system of cockroach. OR

Give an account of the structure of heart in Frog.

(b) Write short notes on any *Two* of the following :

1. T. S. of Earthworm.
2. Multiple fission in Amoeba.
3. Analogous organs.

TWO-YEAR INTERMEDIATE EXAMINATION

MARCH, 1976

Part III—Sciences

Biological Sciences–Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions : 1. Answer any *Six* questions.

2. Illustrate your answers with well-labelled diagrams wherever necessary.

3. For clarity of answers and general neatness 4 marks and allotted.

I. (a) Describe in detail the life-cycle of plasmodium in mosquito.

OR

Give a detailed account of reproductive system of Taenia solium. 5

(b) Write short notes on any *Three* of the following : 6

1. Flame cell. 2. Multiple fission.
3. Ornithorhynchus. 4. T. S. of vein.

II. (a) What do you understand by the term "Binomial nomenclature" ? Expain the same by suitable examples.

OR

Describe in detail the respiratory system in frog. 6

(b) Explain any *Two* of the following : 5

1. T. S. of Earthworm. 2. Mitosis.
3. Metatheria.

III. (a) Describe in detail the internal structure of the heart of frog and circulation of blood in it. OR

Give a detailed account of digestive system of cockroach. 6

(b) Describe any *Two* of the following: 5

1. Urostyle.
2. Mouth parts of Housefly.
3. T. S. of spinal cord.

IV. (a) What is nephridium? Describe various types of nephridia found in Earthworm. OR

Give a detailed account of a structure of any diploblastic animal you have studied. 6

(b) Write short notes on any *Two* of the following: 5

1. Kidney of frog.
2. Bladderworm.
3. T. S. of Bone.

V. (a) Give an account of general characters of fishes. OR

What are Mendal's laws of Heredity? 5

(b) Write short notes on any *Two* of the following: 6

1. Non-poisonous snakes.
2. Locomotion in Amoeba.
3. Buccal cavity of frog.

VI. (a) Write a brief account of the life history of Ascaris.
OR

What is metamorphosis? How metamorphosis occurs in frog? 6

(b) Write short notes on any *Two* of the following: 5

1. Animal cell.
2. Dorsal view of frog's brain.
3. Endomixis.

VII. (a) Write an account of the role of mosquitoes and flies in spreading of human diseases. OR

Describe external characters of leech. 6

(b) Write short notes on any *Two* of the following: 5

1. Blood of frog.
2. Castings of Earthworm.
3. Squamous epithelium.

INTERMEDIATE PUBLIC EXAMINATION
MARCH/APRIL, 1977

Part III—Sciences

Biological Sciences—Paper II

(Zoology)

Time : **3** hours. Max. Marks : 70

Instructions : 1. Answer any *Six* questions.
2. Illustrate your answers with well labelled diagrams wherever necessary.
3. For clarity of answers and general neatness 4 marks are allotted.

I. (a) Describe in detail the life cycle of Plasmodium in Man.

OR

Give an account of different types of Epithelial tissues. 6

(b) Explain any *Two* of the following : 5

1. Metamorphosis. 2. Binomial nomenclature.
3. Homologous organs.

II. (a) Give an account of conjugation in paramoecium.

OR

Describe the external characters of Leech. 6

(b) Write short notes on any *Two* of the following : 5

1. Meganephridium 2. Cartilage
3. Budding in Hydra.

III. (a) Describe the reproductive organs in Earthworm.

OR

Give an account of the blood vascular system in cockroach. 5

(b) Write short notes on any *Three* of the following : 6

1. Structure of kidney. 2. Mitochondria.
3. Osphradium. 4. Elephantiasis.

IV. (a) Describe the arterial system in Frog.

OR

Give an account of general characters of Birds. 6

(b) Write short notes on any *Two* of the following : 5

1. Echidna. 2. Endoplasmic reticulum.
3. Chloragogen cells.

V. (a) Describe mitosis in animals.

OR

What are mutations ? Give an account of Mutation Theory. 6

(b) Describe any *Two* of the following : 5

1. Mantle cavity of Fresh Water Mussel.
2. Dihybird. cross. 3. Compound eye.

VI. (a) What are the distinguishing characters of the poisonous snakes ?

OR

Describe the life history of Taenia Solium. 5

(b) Write short notes on any *Three* of the following : 6

1. Pituitary gland 2. Nematocyst.
3. Ecosystem. 4. Contractile vacuole.

VII. (a) Give an account of locomotion and reproduction in Amoeba.

OR

What is portal circulation ? Give an account of Hepatic Portal circulation in Frog. 6

(b) Draw and label parts of any *Two* of the following : 5

1. Mouth parts of Mosquito.
2. Frog brain—Ventral view.
3. Sex organs of Taenia.

INTERMEDIATE PUBLIC EXAMINATION

SEPT./OCT., 1977

Part III—Sciences

Biological Sciences—Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions: 1. Answer any *Six* questions.
2. Illustrate your answers with well labelled diagrams wherever necessary.
3. For clarity of answers and general neatness 4 marks are allotted.

I. (a) Describe nutrition, locomotion and osmoregulation in Paramoecium.

OR

Give an account of the muscular tissues. 6

(b) Write short notes on any *Two* of the following: 5
1. Endomixis. 2. Ookinete.
3. Salivary glands.

II. (a) Describe sexual reproduction in Hydra.

OR

Give an account of excretory system in Earthworm. 6

(b) Write short notes on any *Two* of the following: 5
1. T. S. of Hydra. 2. Scolex.
3. Locomotion in Amoeba.

III. (a) Describe the structure of a generalised animal cell.

OR

Give an account of general characters of Mammalia. 6

(b) Draw and label the parts of any *Two* of the following:
1. Mouth parts of Housefly. 2. T.S. of Taenia.
3. Pectoral girdle of Frog. 5

IV. (a) What is Metamorphosis ? Describe metamorphosis in Frog.

OR

Give an account of the principles of classification. 6

(b) Write short notes on any *Two* of the following : 5

1. Mutation Theory. 2. Ring stage.
3. Holozoic nutrition.

V. (a) Describe the mechanism of respiration in Frog.

OR

Give an account of male and female reproductive organs in Cockroach. 6

(b) Write short notes on any *Two* of the following: 5

1. T. S. of bone. 2. Cobra.
3. Sinus Venosus.

VI. (a) Give an account of Mendel's laws of heredity.

OR

Describe external characters of leech. 5

(b) Write short notes on any *Three* of the following: 6

1. Telophase. 2. Parasites.
3. Pituitary gland. 4. Blood of Frog.

VII. (a) Give an account of embryological and physiological evidences in support of organic evolution.

OR

Give an account of general characters of Mollusca. 5

(b) Write short notes on any *Three* of the following: 6

1. Multiple fission. 2. Sea snakes.
3. Columnar epithelium. 4. Cloaca.

INTERMEDIATE PUBLIC EXAMINATION

MARCH/APRIL, 1978

Part III—Sciences

Biological Sciences—Paper II

(Zoology)

Time : 3 hours. Max. Marks : 70

Instructions : 1. Answer any *Six* questions.

2. Illustrate your answers with well labelled diagrams wherever necessary.

3. For clarity of answers and general neatness 4 marks are allotted.

I. (a) Describe in detail the life cycle of Plasmodium in Mosquito.

OR

Give an account of binary fission and endomyxis in Paramoecium. 6

(b) Write short notes on any *Two* of the following : 5

1. Nematocyst. 2. Analogous organs.
3. Coelenteron.

II. (a) Describe the reproductive system of Taenia Solium.

OR

Give an account of general characters of Pisces. 6

(b) Draw and label the parts of any *Two* of the following : 5

1. Mouth parts of house-fly.
2. Pectoral girdle of frog.
3. Mantle cavity of Pila.

III. (a) Describe the different methods of locomotion in Hydra.

OR

Give a brief account of the circulatory system of earthworm. 5

(b) Write short notes on any *Three* of the following : 6

1. Holozoic nutrition. 2. Liver.
3. Medulla Oblongata. 4. Binomial nomenclature.

IV. (a) Describe the structure and working of the heart of frog

OR

Give an account of general characters of Reptilia. 6

(b) Write short notes on any *Two* of the following : 5

1. Copulation in earthworm. 2. Microfilaria.
3. Buccal cavity of Frog.

V. (a) Give an account of Mendel's laws of heredity.

OR

Describe the ultra-structure of an animal cell. 6

(b) Write short notes on any *Two* of the following : 5

1. Schizogony. 2. Chromosomes.
3. Vestigeal organs.

VI. (a) Describe the structure, locomotion and osmoregulation in Amoeba.

OR

Give an account of the muscular tissue. 5

(b) Write short notes on any *Three* of the following : 6

1. Anaphase. 2. Nucleic acids.
3. Laryngotrachea 4. Cartilage.

VII. (a) Describe the digestive system and process of digestion in Cockroach.

OR

Give an account of Darwinism. 6

(b) Write short notes on any *Two* of the following : 5

1. Metatheria. 2. Sea snakes
3. Mutations.

INTERMEDIATE PUBLIC EXAMINATION

SEPT./OCT., 1978

Part III — Sciences

Biological Sciences—Paper II

(Zoology)

Time: 3 hours. Max. Marks: 70

Instructions: 1. Answer any *Six* questions.
2. Illustrate your answers with well labelled diagrams wherever necessary.
3. For clarity of answers and general neatness 4 marks are allotted.

I. (a) Describe locomotion and nutrition in Amoeba.

OR

Give an account of general characters of Echinodermata. 5

(b) Write short notes on any *Three* of the following: 6

1. Malpighian tubules.
2. Wucheraria bancrofti.
3. Penial Setae.
4. Telophase.

II. (a) Describe the structure and osmoregulation in Paramoecium.

OR

Give an account of the general characters of Metatheria. 6

(b) Draw and label any *Two* of the following: 5

1. T. S. of Proglottid.
2. Salivary apparatus of cockroach.
3. Mouth parts of Mosquito.

III. (a) Give an account of the various diseases spread by Mosquito and housefly.

OR

Describe the male and female reproductive system in cockroach. 6

(b) Write short notes on any *Two* of the following : 5

1. Endomyxis 2. T. S. of ileum
3. Multiple fission.

IV. (a) Describe the excretory system in earthworm.

OR

Give an account of the pulmonary respiration in frog. 5

(b) Write short notes on any *Two* of the following : 6

1. Pelvic girdle of frog. 2. Ookinete.
3. Endoplasmic reticulum.

V. (a) Give an account of the sexual reproduction in Hydra.

OR

Describe the external characters of leech. 5

(b) Write short notes on any *Three* of the following : 6

1. Ospharadium. 2. Ring stage.
3. Golgi apparatus. 4. Pancreas.

VI. (a) Give a brief account of evidences in support of organic evolution.

OR

Describe the female urinogenital system in Frog. 6

(b) Write short notes on any *Two* of the following : 5

1. Mutation theory. 2. Cartilage.
3. Binomial nomenclature.

VII. (a) Give an account of the ultra-structure of an animal cell.

OR

Describe the external characters of fresh water mussel. 6

(b) Write short notes on any *Two* of the following : 5

1. Sinus Venosus. 2. Interstitial cells.
4. Russell's Viper.

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A SUPPLEMENT TO

A Textbook of Zoology

Volume I

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Preface to the Supplement

Keeping in view the revision of the syllabus in Zoology (Intermediate I Year) by The Board of Intermediate Education, Andhra Pradesh, Hyderabad, certain types e.g., *Euglena*, *Obelia* and the general characters of starfish introduced, have been incorporated in the form of Supplements I, II and III.

While describing these type examples, the same pattern and sequence of presentation have been retained that are adopted for the other types included in the main book, Volume I This will go as a regular part of Volume I in future editions.

Constructive comments and criticisms on the types described are most welcome from the teaching profession.

I acknowledge my deep sense of gratitude to the publishers M/s. Sri Saraswati Book Depot, Hyderabad and particularly to Sri Lakshmi Narayana, N. C. for his critical editing and also to the members of the staff, who extended their whole, hearted co-operation in bringing out this supplement for the benefit of the students taking up their examinations in March/April, 1980

Hyderabad
Sankranti, 1980.

K R. Saxena

SUPPLEMENT I

EUGLENA Sp.

(A Flagellate Protozoan)

The unicellular organisms included in the class mastigophora (Gr. mastix = whip + phoros = bearing) are characterised by the presence of one or more long slender flagella (Sing. flagellum) at some or all the stages of their life cycle. The flagella commonly serve for locomotion.

Flagellates are usually grouped into two main sub-divisions often called sub-classes, the Phytomastigia which are plant-like in their nutrition and the zoomastigia, which are heterotrophic[1].

Euglena Sp. is a good example of a plant-like flagellate. The taxonomic position, habitat and the details of its structure are described below :

Euglena Viridis :

Phylum Protozoa

Class	:	Mastigophora
Sub-class	:	Phytomastigia
Order	:	Euglenoidida.
Family	:	Euglenidae
Genus	:	*Euglena*
Species	:	*Euglena viridis*

Habitat :

Most euglenoids including *Euglena viridis* live in fresh water habitats, occuring throughout the world in puddles, ditches, ponds, lakes, streams and rivers. Large populations of euglenoids occur in waters contaminated by animals or decaying vegetable matter, often producing green pools in water butts, farm yards, green house tanks, agricultural drainage channels, dew ponds, visited by cattle. Marine englenoids are less common, however some species are known from the open sea, from tidal zones amongst sea weeds and from sandy beaches.

1. Organisms unable to synthesise their food from purely inorganic substances.

Form and Structure :

Euglena viridis ranges in size from 35 to 90 μ by 10 to 22 μ. It is a fat spindle shaped organism but sometimes cylindrical. The anterior end is round and the tail tapers to a point. The superficial surface of the body is surrounded by a distinct pellicle. Within the cytoplasm lie the *chromatophores* or *chloroplasts* 7 to 12 in number. They are long, spear-shaped bodies, star shaped in arrangement with the centre of the star lying anterior to the *nucleus*. The nucleus is post median and is partly obscured by the chromatophore bands. The **Paramylum (Paramylon)** bodies in

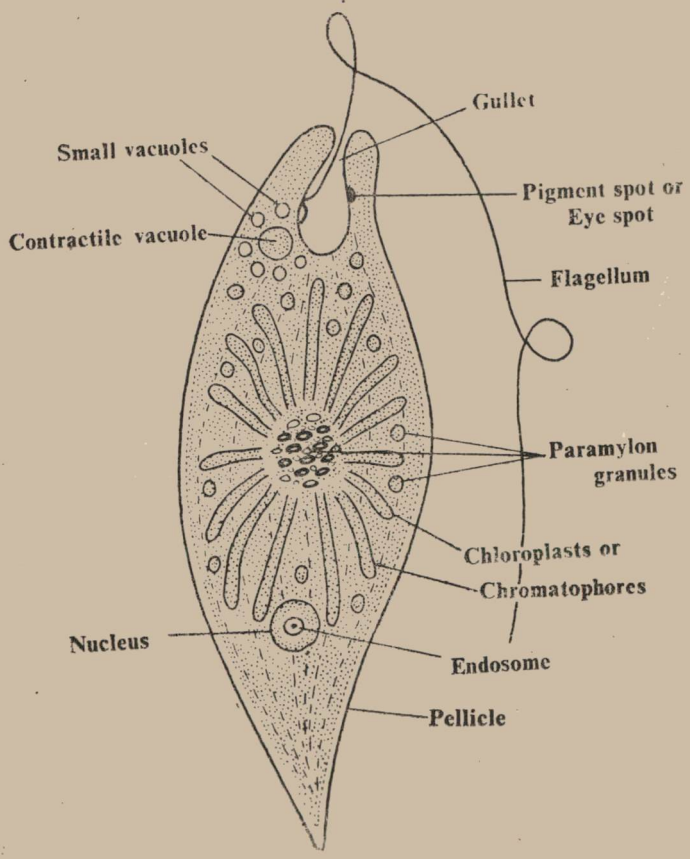


Fig. 1 Structure of *Euglena viridis*, a free living flagellate (Class Mastigophora)

the shape of small ovals and bricks, are clustered around the chromatophoral star centre. They are however also found in other parts of the cytoplasm. The active *flagellum* is longer than the body and is easily discarded or lost. The *eye-spot* or *stigma* is crimson. The organism is metabolic (plastic), but not strongly so, and swims quite rapidly. At the anterior end can be seen a channel called the **gullet** continuing into a dilated *reservoir*, the two together being flask shaped and are often referred to as *gullet reservoir*. Adjacent to the reservoir is found the *contractile vacuole*. Near the base of the long flagellum within the reservoir and exactly opposite to the eye-spot lies a swollen structure called the *photo-receptor*.

Pellicle and the Euglenoid Movement :

Pellicle as stated, surrounds the entire surface of the body. It is an organized structure of the cell surface. On account of the structure of the pellicle, the euglenoid cell presents a helical (screw) symmetry which is its diagnostic character.

The electron microscope shows that the pellicle consists of helically disposed strips which overlap and articulate along their edges and fuse at both ends of the cell. Running parallel with each strip of the pellicle is a row of *muciferous bodies* [1] and a bundle of *microtubules*[2]. The pellicle, the muciferous bodies and a bundle of microtubules form therefore a *complex* which lies internal to the plasma membrane and thus is a part of the living cell and is in *no way homologous with a plant cell wall*. Pellicle may consist of a material which may be a protein of the fibrous elastic group. In *Euglena viridis* which is highly mobile the pellicle in very thin but it is thicker in less plastic forms.

The pellicle is firm and strong, as well as sufficiently flexible and elastic, due to which the body exhibits occasionally considerable and characteristic changes of form. These changes in form consists of the contraction of one part of the body and the dilatation of another and are referred to as *euglenoid movements*. Such type of

1. Mucilage producing bodies; peripheral vesicles of Endoplasmic reticulum (See Vol. I page 288; Vth Edition, 1978)
2. Ultra microscopic components of eukaryotic cells apparently concerned with cell movement within cells, and for cell support. (See Vol. I, page 302, 304, Vth Edition, 1978.)

movement encountered by other protozoan organisms are also referred to as *euglenoid movements.*

As regards the exact mechanism of euglenoid movement it can be said that there is a certain amount of relative movement between adjacent strips of pellicle, presumably by the ridge of one strip sliding in the groove of the next. A possible function of the muciferous bodies is the supply of mucilage to the grooves as lubricant. How actually the euglenoid movement occurs is still an *enigma.* The molecular organization of the pellicular strip is such that it makes it flexible and plastic but not contractile. There is also no evidence that microtubules are contractile. The old microscopist's references to the presence of myonemes and 'muscle fibres' in euglenoids is erroneous. The helical structures alleged to be found in myonemes and muscle fibres are nothing but the lines of overlap of the pellicular strips. *Under these findings one can say that euglenoid movement is merely an expression of cytoplasmic flow (itself an unexplained phenomenon) within the confines of an elastic pellicle which continually recovers to a definite shape.*

Gullet–Reservoir :

At the anterior end of the cell the pellicular strips curve and fuse to form a canal called the *gullet.* The pellicular material terminates at the base of the gullet. The gullet in certain near

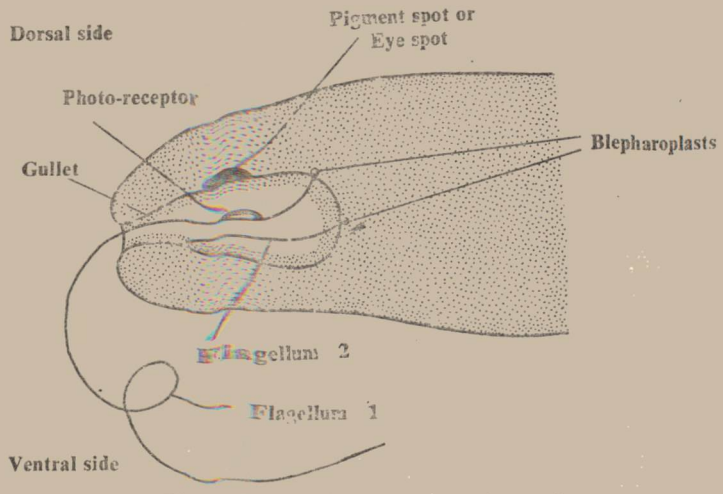


Fig. 2 *Euglena sp.*—Anterior end

relatives of Euglena serves for intake of food particles and is then referred to as *cytopharynx*. In Euglena, however, the gullet is in name only as no intake of food particles occurs through the gullet.

The gullet continues, behind in the form of a dilated structure the pyriform chamber, the so called *reservoir*. The reservoir is lined by cell membranes and microtubules only. This is a feature significant for osmo-regulation and pinocytosis[1]. This process of pinocytosis could serve in both nutrition and chemoreception i. e, a sounding out of environment by 'tasting it'. It should however be noted that green euglenoids do not digest particulate food and the phagotrophic[2] colourless species have a cytostome independent of the reservoir.

The gullet and the reservoir are collectively referred to as gullet reservoir.

Eye-spot, Pigment-spot or Stigma :

At one side of the reservoir, termed for the sake of convenience the dorsal side is a prominent crimson *eye-spot*, *pigment-spot* or *stigma* ensheathing the neck of the reservoir. Green euglenoids and a few colourless ones have an orange red eye spot. The spot contains B-carotene derivatives and other carotenoid pigments. Unlike all other plant cells the eye-spot in euglenoids is not a specialised region of chloroplast.

Photoreceptor :

As stated, photoreceptor is a lateral swelling near the base of the main flagellum within the reservoir lying exactly opposite to the eye-spot. All euglenoid species with an eye-spot possess this *photoreceptor*. The photoreceptor possibly contains lactoflavin as a sensitizer. The eye-spot acts as a screen and shades the sensitizer intermittently as the swimming cell rotates. On account of this, the organism is thus able to judge both the intensity and direction of the source of illumination and will swim away from bright light

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1. 'Micro-drinking' ; uptake of large molecules by membrane invagination at the cell surface. (See also Vol. I, page-286 Vth Edition, 1978).

2. Phagotrophic organism or phagotroph is one that ingests solid food.

(negative phototaxis) and from darkness towards dim light (positive phototaxis).

Flagella :

From the inner side of the ventral wall of the gullet, arises a long flagellum on the root of which lies the photoreceptor already described. A second short flagellum is also present close to it. The flagella originate from the *basal bodies* also termed as *basal granules*, *kinetosomes* and *blepharoplasts* at the bottom of the reservoir. (Cf. page 18, 19–Vol. I. Vth edition, 1978). The diameter of the locomotory flagella is increased by a rod of material which runs along the axis to one side of the '9+2' configuration of microtubules characteristic of flagella and cilia in all eukaryotic organisms (Cf. page–18 & 19, Vol. I. Vth edition, 1978.)

In all euglenoids, a unilateral row of fine hairs (2–3 μm long) are found on the emergent flagella along with extensive accessory material in the form of helically disposed shorter hairs and fibrous bands. The long flagellar hairs trail passively during swimming but will increase the viscous drag of the flagellum and hence its efficiency of propulsion.

Contractile Vacuole and Osmo-regulation :

In common with any naked cell in fresh water, the euglenoid flagellates continually take in water by *osmosis*. To counteract this, the contractile vacuole actively pumps water out of the cell against the osmotic gradient. A large contractile vacuole lies near the ventral wall of the reservoir into which it discharges the excess water, when it collapses. Before the large vacuole collapses, smaller vacuoles can be seen near to it and these run together to form the next functional contractile vacuole after the collapse of the earlier one. This processes is repeated again and again thereby excess water is discharged into the reservoir via its cell membrane and the solutes are retained in the cytoplasm. The contractile vacuole thus is an *osmoregulatory device* as is seen in other fresh water protozoa like *Amoeba* and *Paramoecium*.

The Nucleus :

The interphase nucleus in euglenoids lies in the centre or posterior half of the cell. It contains one or more *endosomes*

(nucleoli that persist during mitosis.). The chromosomes are permanently condensed and the nucleus is enveloped by a double nuclear membrane.

A rather different investigation of the nuclei of euglenoids is the presence of the living populations of bacteria. Some strains of *Euglena*, *Strombonas*, *Trachelomonas* have 20-200 bacteria per nucleus. The bacteria multiply to keep pace with cell division. There is no evidence that the euglenoids benefit from or are harmed by the association. The bacteria obviously derive their food from the euglenoid host and thus have found safe ecological niche for themselves. The bacterial population is shared out between daughter nuclei at mitosis (during which the nuclear envelope remains intact). The attempts to transfer the endonuclear bacteria to 'un-infected' euglenoids have been unsuccessful.

Chromatophores or Chloroplasts :

The disposition and the number of chloroplasts are described earlier. Euglenoid chloroplasts show considerable morphological diversity which is an important feature in the determination of species in several genera.

The internal structure of chloroplasts is similar to the chloroplasts of most algal cells. A membranous envelope encloses a lamellar system, a granular matrix and fat globules. Chlorophyll is situated on the lamellar membranes and the enzymes of photosynthesis are shared between the lamellae and the matrix.

Plastids of *Euglena gracilis* (and presumably other euglenoids) contain chlorophyll *a* and *b*, *B* carotene, antheroxanthin, neoxanthin and small amounts of other carotenoids and quinones. These pigments are similar to those in higher plants whereas most other algae lack chlorophyll *b*. About 14 lamellae are found in a chloroplast.

Studies reveal that within the chloroplasts a minor component of D N A is localized. This *plastidial D N A* differs in base composition from nuclear D N A and may be involved in the synthesis of chloroplast materials. There is also a specific R N A in Euglena plastids and it is possible that this contains specific information for synthesis of plastidial protein.

Paramylon or Paramylum Bodies :

Paramylum bodies are the carbohydrate storage products of euglenoids, the disposition of which in the cell is already described.

Unlike starch grains in higher plants, paramylon is formed outside the chloroplast. Paramylon is the carbohydrate reserve of both the colourless and green euglenoids. The material of the paramylon is significantly different chemically from the various starches formed as reserve polysaccharides in green algae and higher plants (and also in red and blue green algae). This material can be differentiated from starch on the basis that it is not stained by iodine. The starches are all α-1 : 4- linked glucans.

Paramylon is a utilizable reserve. An enzyme paramylase exists in euglenoid cells to hydrolyse paramylon. This has, however not been isolated but enzyme preparations from the stomach glands of various mollusc predators of euglenoid flagellates digest paramylon completely.

Pyrenoids :

Paramylon-sheathed pyrenoids are characteristic of certain species of *Euglena, Trachelomonas* and *Colacium*. They are very small, dense, colourless bodies associated with chloroplasts. They are not easily distinguishable and are difficult to observe. They may be located deeply within or partly exposed at the surface of the chloroplasts. They are frequently covered with a sheath of carbohydrate—usually a starch. These bodies are believed to be the centres of carbohydrate production but some organisms which produce starch have no discernible pyrenoids. The occurrence of pyrenoid in *Euglena viridis* is questionable.

Locomotion :

Euglena can crawl by spiral movements of the cell body.

At times it performs worm-like 'Euglenoid movements' by local expansions and contractions that suggests peristalsis in a vertebrate's intestine. The details of euglenoid movements have already been discussed. Euglenoids move by means of swimming.

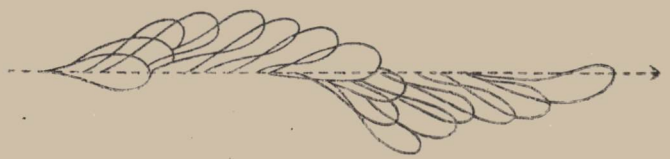


Fig. 3 *Euglena*—Successive positions of the organisms taken up during the forward locomotion through one complete gyration and rotation

Euglena can swim fairly rapidly 3-6 mm per minute. The swimming is brought by the lashing of the flagellum. In most of the genera with only one emergent flagellum, such as *Euglena*, *Astasia*, *Trachelomonas*, *Phacus*, *Rhabdomonas* and *Menoidium*, the flagellum is continually mobile from base to tip and is held either infront of the swimming cell like a spinning lasso or laterally. Similarly, mobile flagella are found in forms with two emergent flagella such as *Eutreptia* and *Distigma*. In all these examples, swimming is rapid and rather jerky, with cell gyrating about its long axis. The anterior end of the cell traces a wider circle than the posterior. It has therefore been thought that the cell acts as a rotating inclined plane or propeller, screwing itself forwards through the water.

Unfortunately the above neat hypothesis is disproved by modern hydrodynamic studies which demonstrate that cell rotation in *Euglena* is so slow that it cannot cause the observed swimming rate. On the contrary, it is thought that the forward component of the flagellar thrust is sufficient on its own to push or pull the cell through the water.

Nutrition :

Nutrition is varied in euglenoids. It is their distinctive feature. There are certain forms which are *photosynthetic*, *saprophytic*[1] and *phagotrophic*[2]. There are some species with an ability to switch from one mode of nutrition to another. All green euglenoids studied so far are *Auxotrophic*[3], needing the supply of at least one vitamin for *phototrophic*[4] existence and some can grow *heterotrophically*[5] in the dark if supplied with suitable organic carbon sources. Colourless euglenoids are obligate heterotrophs, either obtaining their nutrients in soluble form (*osmotrophs*[6]) or ingesting particulate food (*phagotrophs*).

---

1. Obtaining nourishment by absorption of preformed organic matter.
2. Organism that ingests solid food.
3. Organism capable of growth in a medium devoid of complex organic nutrient, but needing at least one vitamin or other specific substance.
4. Organism capable of growth by photosynthesis.
5. Growth only in a medium containing a complex organic carbon source.
6. Organism that absorbs nutrients in soluble form only.

Euglena viridis contains chloroplasts. It can thus synthesise carbohydrates from carbon dioxide and water like any ordinary green plant. It's nutrition may be referred to as holophytic.

In nature many green euglenoid flagellates probably combine *phototrophy*[1] with osmotrophic heterotrophy as is indicated by the preference of some species for water's rich in decaying organic matter. This should however be noted that no green species is phagotrophic. The experiments on some green euglenoids which are facultative heterotrophs indicate that they thrive on acetates, simple organic acids and alcohols. Sugars are apparently less used. Under suitable conditions, however, *Astasia longa* and *Euglena gracilis* can efficiently metabolize glucose. *Euglena gracilis* is auxotrophic. This is demonstrated by the fact that these organisms show an absolute requirement of cobalamin (Vitamin B_{12}) and many also need thiamin (Vitamin B_1). It is on account of this ability, *Euglena gracilis* is used in hospital laboratories as an organism to assess the presence of cobalamin, lack of which causes *pernicious anaemia*[2] in man.

The nutritional requirements of normally phagotrophic species are more complex. A culture medium developed for *Peranema trichophorum* contains plant and animal sterols, thiamin, cobalamin and riboflavin, nucleic acid constituents, linoleic, oleic and stearic acids, lysine, glycine, asparagine and glutamic acid and methyl cellulose as a particulate component. A number of phagotrophic genera such as *Peranema*, *Heteronema* and *Entosiphon* ingest through a permanent cytosome, with skeletal rods or tubes, actively participating in the capture and intake of food particles and living prey. Other phagotrophs such as *Notosolenus*, do not possess a special ingestion organelle.

Respiration and Excretion :

During respiration oxygen diffuses into the cytoplasm through the pellicle and carbon dioxide outwards. However, when the organism is actively performing photosynthesis, intake of oxygen

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1. Organisms capable of growth by photosynthesis.
2. Pernicious anaemia results from the inability of the bone marrow to produce normal red cells because of the deprivation of an intrinsic factor called *Cyanocobalamin* (Vitamin B_{12}).

is masked by the intake of carbon dioxide and the out put of oxygen is to be observed.

The excretory products that are produced also diffuse out of the cell surface.

Behaviour of Euglenoids :

Euglena, like other protozoans gives an '*avoiding reaction*' to unpleasant stimuli. The most noticeable thing in the behaviour of euglenoids is their reaction to light. When a large container of euglenas is placed so that a part of it is shaded, a part subjected to intense sunlight, and a part subjected to moderate light, the organisms will collect in the latter region. As stated the eye-spot is known to play an important part in this reaction. In general the reactions of euglenas are adaptive, that is, they move away from harmful stimuli and concentrate towards benefical stimuli.

When Euglena is treated with streptomycin or certain other antibiotics, antihistamines or ultra-violet irradiation, the chloroplasts disappear. Cultures of such colourless forms have been obtained.

A major area of research involves the experimental "bleaching" of Euglena gracilis. If cultures are grown at 32°C.–35°C; cell division continues but chloroplast division is inhibited and cells with no chloroplasts are soon produced. These cells can be isolated and grown into permanently colourless races which never regain or reform chloroplasts. They resemble the naturally occuring *Astasia longa*, besides providing a support to the suggestion that colourless euglenoid genera are derived from green ones.

Reproduction :

Sexual reproduction appears to be lacking in all euglenoids.

The only mode of asexual reproduction is by *longitudinal binary fission*. Prior to fission the organism ceases to swim about and encloses itself in an envelope of mucilage. The flagellum is withdrawn. The nucleus divides by mitosis and then the cytoplasm divides lengthwise. The cleavage begins at the anterior end of the cell. The cleavage line progresses helically backwards between daughter reservoirs and nuclei until two daughter cells are formed.

Partition of organelles is usually equal but on occasion one cell may receive all or most of the chloroplasts, or both daughter nuclei. The anucleate cell swims and behaves normally but cannot divide and eventually dies.

Euglenoid mitosis differs from classical mitosis in persistence and division of the endosome and the retention of the nuclear envelope as well as the absence of centromeres. Several of the structural features indicate the absence of mitotic spindle of a type found in most plant and animal mitoses and this corroborated by the lack of effection euglenoid mitosis of colchicine and other spindle inhibitors.

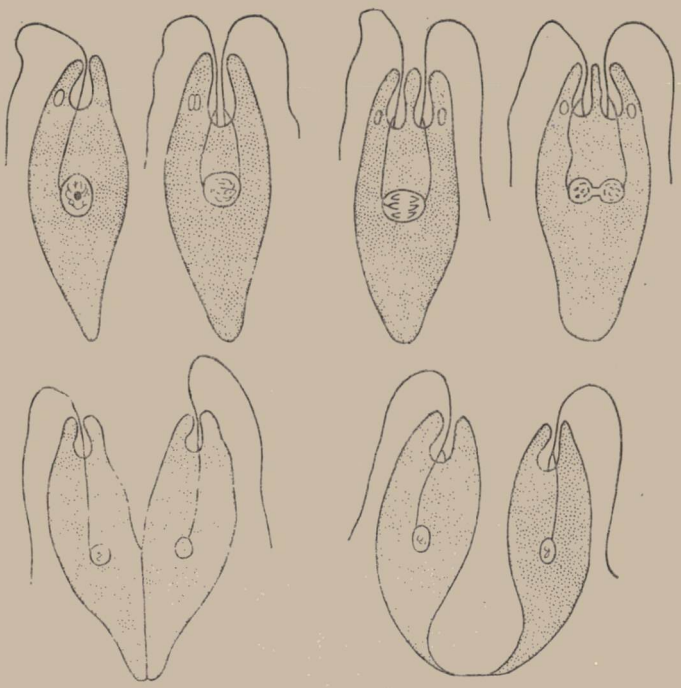


Fig. 4 Longitudinal binary fission–Various stages

It is postulated that euglenoid mitosis represents a stage in the evolution of classical mitosis, a stage in which centromeric attachment of chromosomes to the spindle has not yet developed and the dividing chromosomes are not exposed to the cytoplasm by break-down of the nuclear envelope.

The life cycle of euglenoids involves both an active or *trophic phase* during which the organism moves about and an encysted phase in which the organism is rounded up with a protective cyst membrane surrounding it. The cyst is composed of a special carbohydrate, yellowish-brown in colour. Asexual reproduction by cell division occurs in both the active and encysted stages. It is generally considered that some unfavourable condition or conditions in the environment induce encystment. With the return of favourable conditions the encysted organisms come out of their cysts and become active again.

The Position of the Euglenoids :

Euglenoid flagellates especially *Euglena* (probably first seen by the first microscopist, Leeuwenhoek in about 1675) its colourless equivalent, *Astasia*, and the voracious phagotroph, *Peranema* have been studied intensively for many years. The green genus *Euglena* is important both as the classic '*plant animal*' of biological teaching and as a key organism in research on photosynthesis, chloroplast structure and physiology of nucleic acids, nutrition, respiration, lipid metabolism, photoreception and flagellar activity. *Euglena* is definitely an "in between" type of organism. It has green chloroplasts but no cellulose cell wall; *astaxanthin*, a pigment found in the eye-spot is definitely an animal carotenoid.

The pigmented forms of euglenoids which swim by lashing flagella are kept at the base of the plant and animal kingdom. These are the phytoflagellates i.e., the only organisms that photosynthesise like plants but are classified by zoologists among the animals.

Recent protozoological classification divide the phytoflagellates into many orders and some of these including the euglenoids (order Euglenoidida) contain colourless forms that are clearly related to the pigmented ones and are supposed to have lost their chloroplasts secondarily.

In botanical classification the euglenoids appear within the algae as the class Euglenophyceae (or Phylum Euglenophyta) and separated from the other algal classes on some criteria.

Most workers are agreed that primitive green flagellates gave rise in evolution to the green algae and through them to the other higher plants. They also gave rise to the animal like flagellates and through them to the rest of the animal kingdom. Based on this assumption, the Flagellates or Mastigophores are divided into two major divisions comprising plant flagellates or Phytomastigia (to which englenoids belong) and animal flagellates or (Zoomastigia).

Revision questions

1. Describe the structure and habitats of *Euglena Sp.*
2. Give a general account of the various modes of nutrition in euglenoids with suitable examples.
3. Describe the mode of locomotion in *Euglena Sp.*
4. Describe the process of longitudinal binary fission in *Euglena Sp.* Mention in brief the salient features of euglenoid mitosis.
5. Discuss the position of euglenoids in animal kingdom with appropriate examples.
6. Write notes on the following.
   (a) Contractile vacuole and Osmo-regulation in Euglena.
   (b) Chromatophores
   (c) Photoreceptor.
   (d) Paramylon granules
   (e) Pyrenoids
   (f) Euglenoid movement.

SUPPLEMENT II

OBELIA Sp.

(A Colonial Hydrozoan)

Obelia is a marine colonial hydrozoan, commonly called a *Zoophyte* (Gr animal plant) on account of the plant-like appearance of its colony.

The taxonomic position of Obelia sp. is as follows :

Phylum	:	Cnidaria (Coelenterata)
Class	:	Hydrozoa
Order	:	Hydroida
Sub-order	:	Leptomedusae (Thecata)
Genus	:	Obelia
Species	:	Obelia geniculata.

The phylum cnidaria includes those forms which possess cnidoblast (nematocysts). The class Hydrozoa comprises the fresh water polyps, zoophytes and a few coral-like hydrozoans. The order hydroida includes those hydrozoans in which there is a fixed zoophyte stage and in which the sense organs are exclusively ectodermal. The sub-order Leptomedusae (Thecata) includes those hydroida in which hydro and gonothecae are present. The medusa bear the gonads in connection with the radial canals and usually have either lithocysts or eye spots.

Habitat :

Obelia is a common zoophyte, marine in habitat. The colony of *Obelia sp.* occurs as a delicate whitish or light brown, almost fur-like growth on sea weeds attached usually to the fronds of *laminaria* or the wooden piers.

General Structure :

The general structure of the colony is better seen under a low power microscope. The colony consists of a common stem on which are found numerous *zooids* i.e., the members or the individuals of the colony that are interconnected and perform specific functions for the entire colony. The stem is divided into two

parts—(i) the horizontal portion or creeping stem called the *hydrorhiza* by means of which the colony is anchored to the substrate

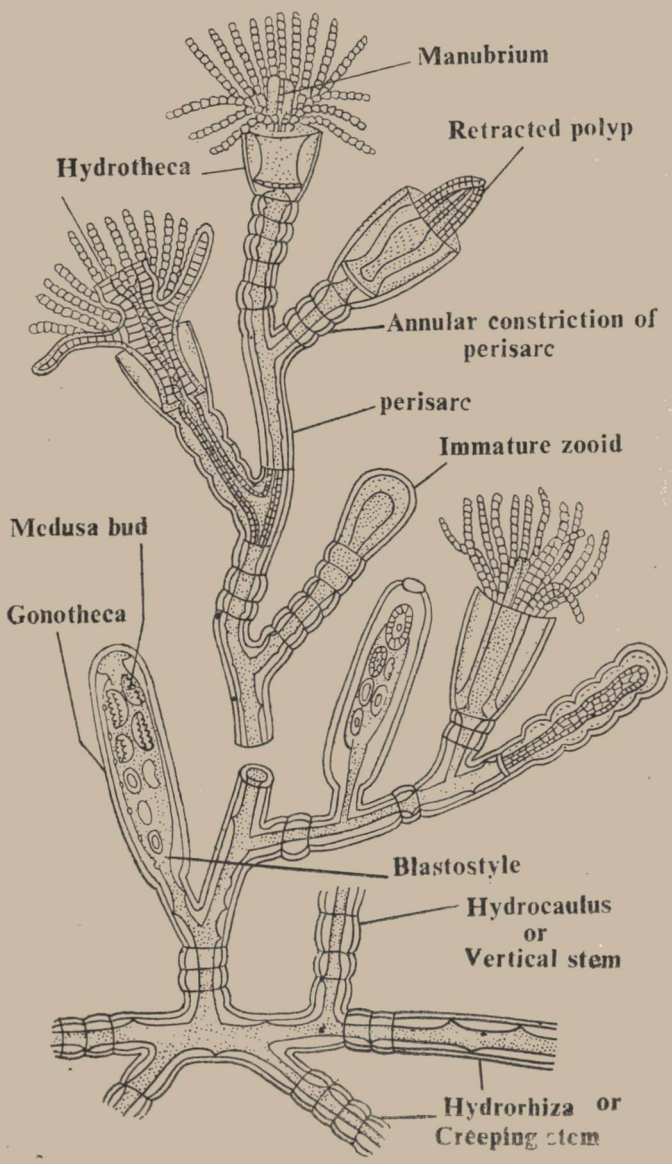


Fig. 1 Obelia colony

(ii) The vertical or upright portion of the stem called the *hydrocaulus*. From the hydrocauli arise short lateral branches in an alternate manner. These lateral branches bear at their terminal ends, the *zooids*. In many cases, the branches end in simple club-like dilations representing *immature zooids*.

Three types of zooids are found in the colony. (i) Hydranths or polyps, (ii) Blastostyles and (iii) the medusae (singular : Medusa) which are budded off from the blastostyles and are set free in the surrounding water as *free swimming reproductive zooids* of the colony.

The structures of the three types of zooids are discussed below.

Hydranth or Polyps :

Each hydranth or polyp consists of a cylindrical, hollow body joined to the common stem by its proximal end. It is produced at its distal end into a conical elevation, the *manubrium*. At the free end of the manubrium is the aperture of the mouth, and the conical part of the manubrium below the mouth is called the *hypostome* which is about one-third the total length of the zooid. From about the base of the hypostome where it joins the rest of the body twenty four *tentacles* arise in the form of a circlet. Both the body and the manubrium contain a spacious cavity called the *enteron* or *coelenteron* which commuunicates to the outside by the mouth and towards the inner side with the main coelenteric cavity of the stem. The mouth is capable of dilation and contraction and the manubrium accordingly appears either conical or trumpet shaped. Under favourable conditons, small organisms may be seen to be caught by tentacles and carried towards the mouth to be swallowed. Since the polyp or hydranth is concerned with the process of obtaining food, it is also referred to as *feeding* or *nutritive* or *gastric zooid* of the colony.

The body wall of each hydranth is built up of ectoderm, mesogloea and endoderm which lines the coelenteron. The tentacles are solid since the endoderm in them does not enclose an extension of the enteron, but forms a solid core of vacuolated cells. The hydroliza, and hydrocaulus i.e., the creeping and vertical parts of the stem also consist of ectoderm, mesogloea and endoderm enclosing the coelenteron. The wall of the stem with the above cellular layers

is called the *coenosarc*. The coenosarc thus is hollow, its tubular cavity being continuous with cavities of the polyps and contains a fluid in which flickering movements of the cilia may be observed.

The entire colony is ensheathed in a cuticular secretion (stated to be a form of chitin) of the ectodermal cells called the *perisarc*. The perisasc is not in contact with the ectoderm but is separated from it by a space, except at occasional places where the ectodermal cells extend to meet it. The tubular perisarc dilates at the end of each branch bearing a hydranth and forms an investment called the *hydrotheca*. It is shaped like a vase or wine glass and is perfectly transparent and colourless. The distal end of each hydrotheca is open; hence the hydranth can be protruded or retracted into the hydrotheca. Between each hydrotheca and stem, the perisarc has

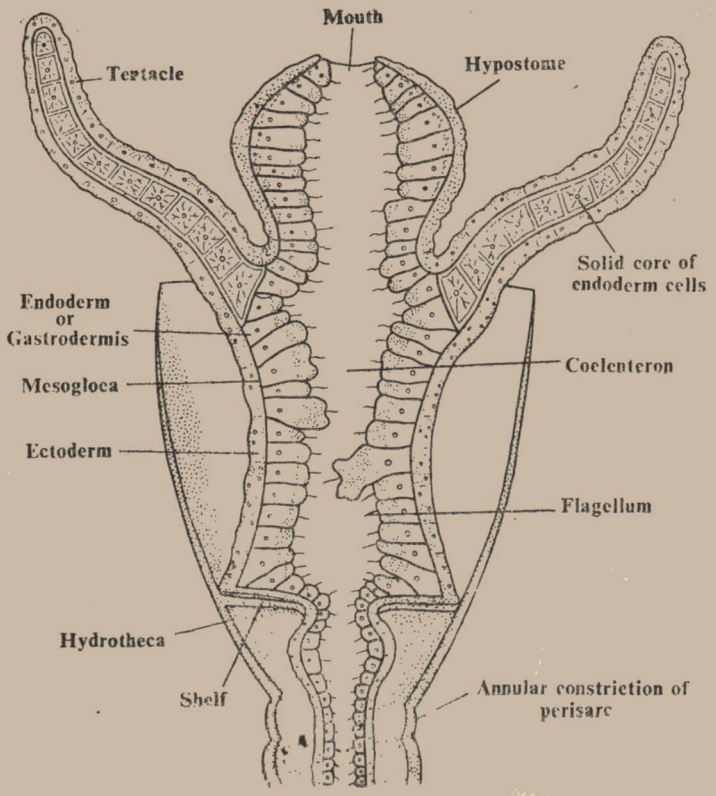


Fig. 2 L. S. Hydranth—*Obelia* colony

annular constrictions and also there is usally one in the main stem itself just below the base of each zooid. At interior side of each hydrotheca near its base is present a ring-like shelf on which rests the base of the hydranth.

If the polyp is irritated by a touch or by an application of an irritating chemical substance, it undergoes a marked contraction. It suddenly withdraws more or less completely into hydrotheca and the tentacles become greatly shortened and curve over the manubrium.

Perisarc :

The transparent outer layer of the stem or *perisarc* has only a delicate lamination without a cell structure. It is a cuticular structure formed layer by layer as secretion of the ectodermal cells. It is composed of a substance of chitinoid or horn-like consistency and acts as a protective external skeleton. When first formed, it is of course in contact with the ectoderm but when the full thickness is attained, the ectoderm retreats from it, and the connection is maintained only at irregular intervals by ectodermal cells. The hydrothecae and gonothecae (ensheathing the blastostyles) are the cuticular products of the ectoderm of polyp and blastostyles respectively.

Ectoderm or Epidermis :

The ectoderm or epidermis is in the form of a columnar epithelium. It is mainly composed of epithelio-muscular cells. They are basically columnar with elongated tails which extend out parallel to one another and are attached to the mesogloea. The tails contain myonemes and are thus the *functional muscles* of the polyps. Between the bodies of epidermal cells there occur clumps of small rounded *interstitial cells* and occasional large branched nerve cells. The nerve cells are arranged in a non-polarised synaptic net-work throughout the interstitial spaces of the epidermis. Nerve cell processes have not been noted to cross through the mesogloea to the gastrodermis (endoderm cells lining the enteron). Other cell types in the epidermal cells are the *sensory cells* which are in synaptic contact with the nerve cells. There are goblet shaped gland cells also which are generally full of granular secretion products. The muscular tails of the epithelio-muscular cells of the walls

of tentacles, manubrium and polyps are arranged longitudinally. By their contraction, shortenings of the tentacles, manubrium and

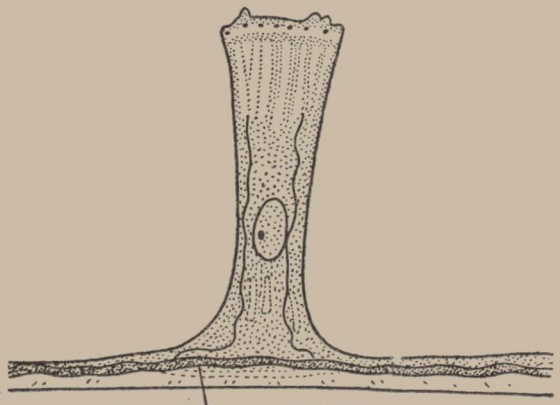


Fig. 3 Epithelio-muscular epidermal cells

polyp occur. Found embedded in certain of the epidermal cells are numerous ovoid bodies called the *stinging capsules* or *nematocyts*. The nematocysts are developed from an interstitial cell which forms a *cnidoblast* which when approaches maturity migrates to the surface where it becomes part of the ectodermal epithelium. (Cf.p. 75 vol. I. V edition). The secretion of nematocysts exert a numbing effect on the animals upon which Obelia preys.

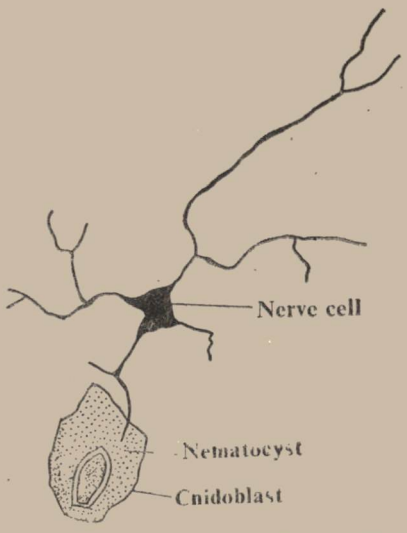


Fig. 4 Nematocysts & Nerve cell

Endoderm :

Endoderm is also found in the form of a columnar epithelium within the body of the polyp. The endoderm cells are large and are capable of sending out *pseudopadia* at their ends. These pseudopodia apparently

seize and ingest minute particles of the partly digested food. As in many protozoa, the pseudopodia may be drawn in and long flagella may be protruded. The lashing of flagella causes a constant movement of the food particles in the enteron. Among the large endoderm cells are found narrow cells within highly granular protoplasm. There are gland cells which secrete a digestive juice. In the manubrium and body of the polyp a layer of gastrodermal epithelio-muscular cells is found which is oriented transversely and thus antagonises the longitudinal muscles. These epithelio-muscular cells by their transverse direction are responsible for the contraction of enteric cavity. In the tentacles, the endoderm consists of a single row of short cylindrical cells almost cubical in longitudinal section. Their protoplasm is highly vacuolated and the cell walls are so thick that these cells may by considered as forming a sort of internal skeleton to the tentacles.

Blastostyles :

Blastosyles are special elongated zooids without mouth and tentacles. They arise as buds in the axils of soms of the lower hydranths and have the form of a narrow tube closed at the distal end. The blastostyle, like hydranth is also enclosed in a special vase-like portion of the perisarc called the *gonotheca*. Each blastostyle gives rise to numerous lateral buds.

The medusae when fully developed are set free and escape to the surrounding water by the rupture of the gonotheca at its distal end.

Medusae : .

The medusaein the young condition are mere hollow offshoots of the

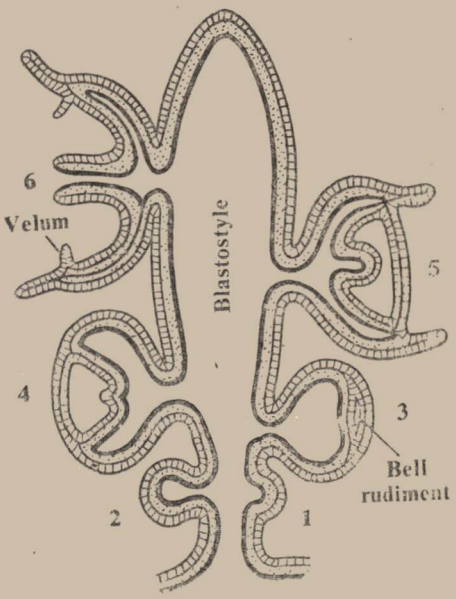


Fig. 5 Diagram showing the development of medusa from a blastostyle

blastostyles. When fully developed, they look like saucers attached by the middle of convex surface to the blastostyle (See Fig 5).

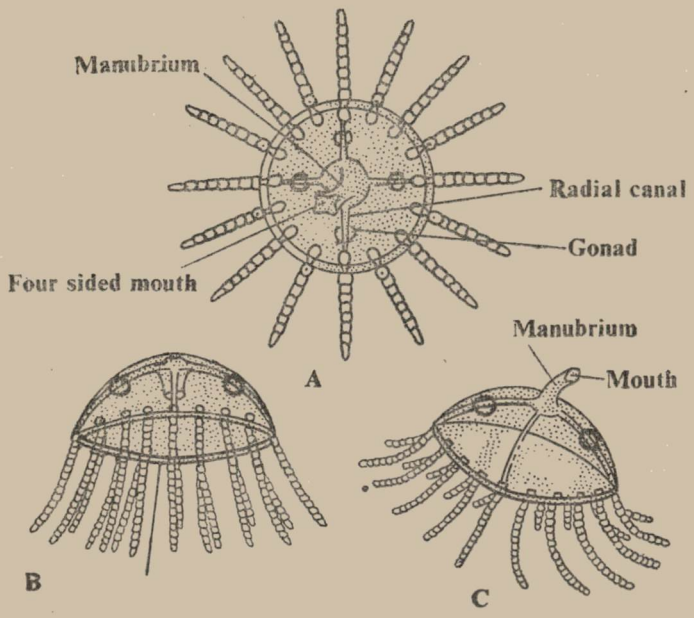


Fig 6 (A) Medusa oral aspect (B) A fully developed medusa (C) The same with reverse umbrella

The structure of a fully developed medusa which escapes from the blastostyles is as follows.

A fully developed free swimming medusa is bell-shaped or saucer-shaped or umbrella-like, concave on one side and convex on the other side. The convex outer surface of the bell or umbrella by which the zooid was originally attached to the blastostyle is distinguished as the *ex-umbrella*, and the concave inner surface as the *sub-umbrella*. From the centre of the sub-umbrella a short projection called the *manubrium* hangs. The manubrium of the medusa corresponds to the handle of the umbrella. At the apex of the manubrium is the opening of the mouth which is *four sided.* The mouth leads into an enteric cavity which occupies the whole interior of the manubrium with a dilated base. The dilated base of the enteric cavity sends off four delicate tubes—the *radial canals*, which

pass at equal distances from each other through the substance of the umbrella to its margin. At the margin of the bell the four radial canals open into a *circular canal*, running parallel with and close to the margin. By means of this system of radial and circular canals, the food, taken in at the mouth and digested in the manubrium is distributed to the entire medusa.

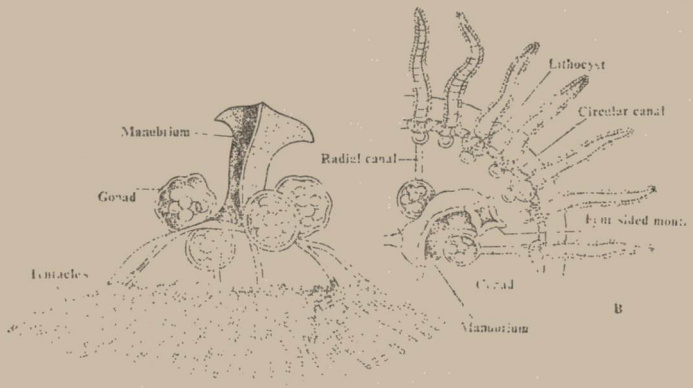


Fig. 7 Left : Matured medusa swimming with averted umbrella
Right : One-quarter of the same with oral aspect

The edge of the umbrella is produced into a very narrow fold or shelf called the *velum*. From the margin of the bell are also given off the tentacles which are sixteen in number in the newly formed medusa but are numerous in the mature medusa. At the bases of eight of the tentacles two in each quadrant are minute globular sacs called the marginal *sense organs* or *lithocysts*.

Internal Structure of Medusa :

The manubrium of the medusa consists of exactly the same layers as are found in the hydranth——ectoderm, mesogloea and endoderm. The ectoderm is continued on to the sub-umbrella, and then round the margin of the bell on to the ex-umbrella so that both surfaces of the bell are covered with the ectodermal layer referred to conveniently as sub-umbrellar and ex-umbrellar ectoderms. The base of the enteric cavity along with the radial and circular canals is lined by the endoderm. In the portions of the bell between the radial canals there is found between the outer and inner layers of epidermis; a thin continuous sheet of endoderm called the ***endoderm***

lamella. The endoderm lamella thus stretches between the adjacent radial canals, the circular canal and the enteric cavity.

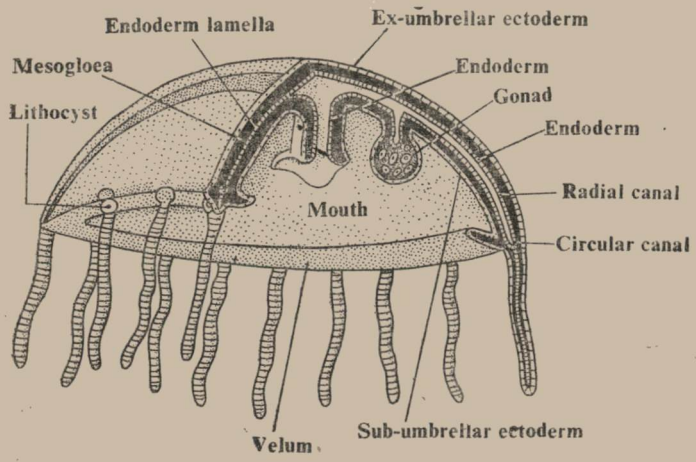


Fig. 8 Dissection of a medusa with more than one-quarter of the umbrella and the manubrium cutaway (Diagrammatic) to show the internal structure.

The velum consists of a double layer of ectoderm and a middle one of mesogloea without extension of endoderm. The tentacles like those of the hydranth, are formed of a core of endoderm covered by ectoderm. The ectodermal cells of the tentacles are abundantly supplied with stinging capsules. Each tentacle of the bell has somewhat swollen base These swellings are due to the accumulation of interstitial cells which are however absent from the other regions of the ectoderm. These accumulations of the interstitial cells which are the reservior cells from which the cnidoblasts are produced as they are constantly used up by the tentacles. Sometimes at the bases of the tentacles are found pigment granules. They have however no visual function. They are in all probability the accumulation of excretory matter. The medusa is well equipped with contractile elements which are almost entirely confined to the lower surface of the bell.

Nervous System :

The nerve cells and their fibres in the medusa are especially concentrated around the margin of the bell to form double nerve ring. The presence of this double nerve ring is associated with the development of receptor organs at the bases of tentacles called the *lithocysts*.

Sense Organs (Receptors) :

As described earlier, at the base of eight of the tentacles two in each quadrant are found the lithocysts on the sub-umbrellar surface, just inside the margin of the bell. Each lithocyst is a small fluid filled ectodermal sac containing a particle of calcium carbonate secreted by a single large cell. The wall of the sac is composed of an epithetial layer which in one region on the side nearest to the

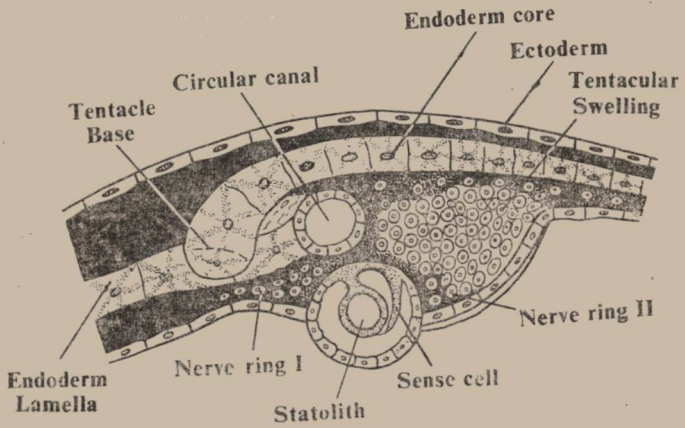


Fig. 9 L. S. passing through the base of an ad-radial tentacle with sense organ

margin of the bell, is sensory and its cells bear fine photoplasmic processes which arch over the particle of calcium carbonate. The sac is called *lithocyst*, *statocyst* or *marginal vesicle* whilst the particle is a statolith. The lithocysts are the receptor organs concerned with the detection of the changes in the orientation of the medusa and keep the bell in horinzontal position in water. The statocysts are also helpful in encouraging the swimming movements of the medusa. The statocysts thus play a part in reinforcing the rhythemical impulses originating in the nervous system and controlling the swimming movements of the bell.

Swimming Movements of Medusa :

The medusa swims through the water by alternately opening and closing the bell in much the same way that the umbrella is opened and shut. Shutting is caused by contraction of the ectodermal muscle tails, the wave of contraction spreading from the

sub-umbrellar surface, where the contractile elements are best developed and not occuring at all on the upper surface except at its sides. Opening of the bell is brought about chiefly by the elastic mesogloea regaining its shape and partly by contraction of the muscle tails in the middle of the upper surface.

Very commonly as the medusa is swimming, the umbrella becomes turned inside out, the sub-umbrella then forming the convex surface and the manubrium springing from its apex. This phenomenon however is unusual.

Polyp and Medusa—A Comparison :

There appears to be an apparent striking difference between a polyp and a medusa. It should however be noted that inspite of apparent differences the polyps and medusae are strictly homologous structures. The medusa can readily be derived from a simple polyp form. It is clear that the apex of the umbrella corresponds with the base of a hydranth, being the part by which the zooid in each case is attached to the parent stem (See Fig. 10).

The mouth and the manubrium are also homologous structures. In order to illustrate the homologies between the structure of a polyp and medusa, let us suppose that the tentacular region of the polyp is pulled out as it were into a disc-like form and later to be bent into the form of a saucer with the concavity distal, that is towards the manubrium. The result of this would be a medusa-like body with a double wall to the entire bell, the narrow space between the two layers with a prolongation of coelenteron lined with endoderm. From such a form the actual conditions of things present in the medusa would be produced by a continuous cavity in the bell being for the most part obliterated by the growing together of its walls so as to form the endoderm lamella. The coelenteric cavity thus would remain only along four meridional areas, the radial canals, and as a circular area, the circular canal close to the edge of the bell.

The polyp and medusa are both radially symmetrical. It can however be noted that the increase in complexity of medusa is accompanied by a differentiation of the structures lying along certain radii.

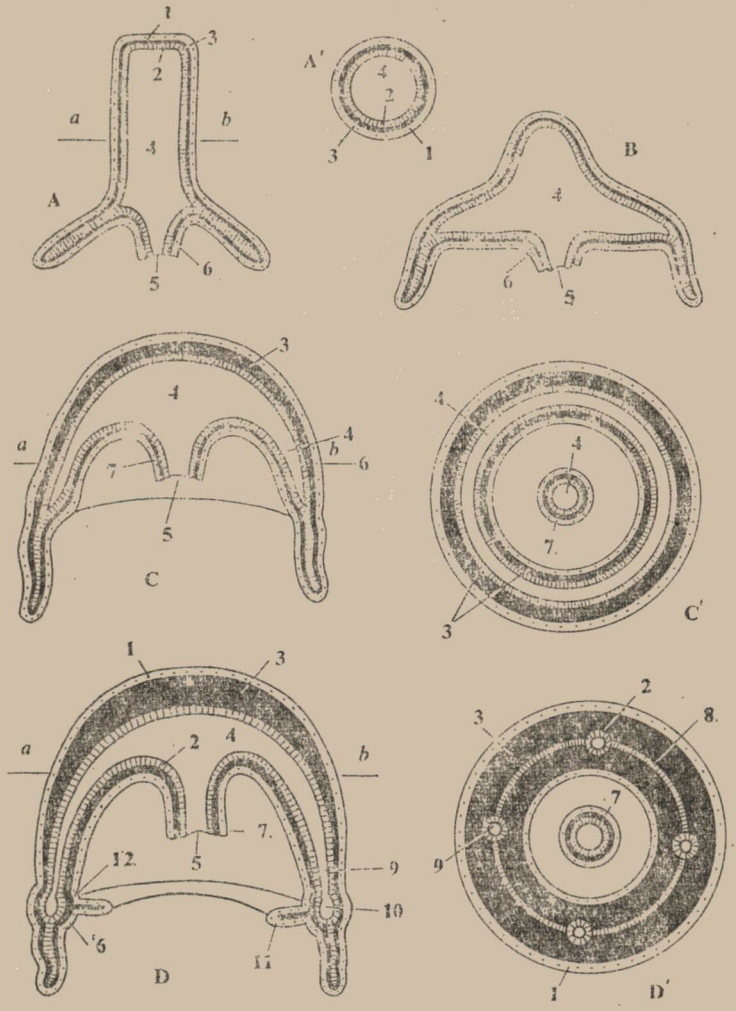


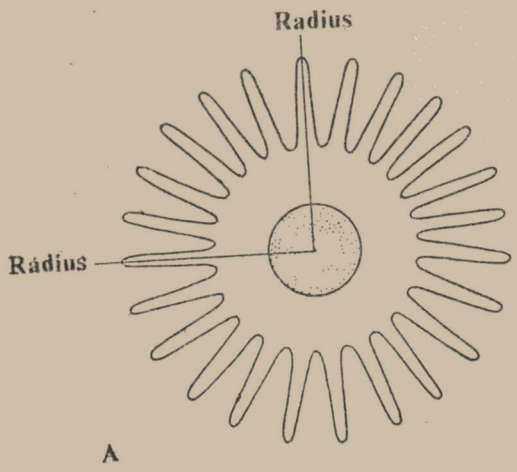
Fig. 10 The derivation of the medusa from the polyp—Illustrated diagrammatically

1. Ectoderm 2. Endoderm 3. Mesagloea 4. Enteric cavity 5. Mouth 6. Hypostome 7. Manubrium 8. Endoderm lamella 9. Radial canal 10. Circular canal 11. Velum 12. Nerve ring (A) Longitudinal section (A') Transverse section (along the line *ab*) (B) Polyp form with extended tentacular region (C) Vertical section (C') Transverse section (along the line *ab*) of form with tentacular region extended in the form of a bell (D) Vertical section (D') Transverse section (along the line *ab*) of medusa. **The ectoderm is dotted, the endoderm striated and the mesagloea black.**

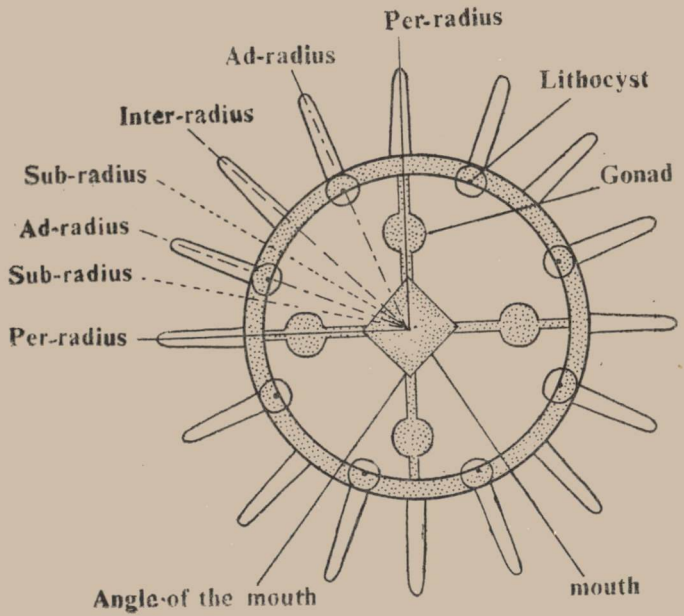
If a polyp is projected on a plane surface taken at right angles to the long axis, a large number of radii (about 24) can be drawn from the centre outwards, all passing through similar parts i. e., along the axis of a tentacle and through similar portions of the body and manubrium In the case of medusa however the situation is different. The presence of four radial canals distinguishes the four principal radii called the *Per radii*. Half way between every two per-radii, a radius of the second order or *inter radius* may be visualised. Halfway between any per radius and the inter radius on either side, a radius of the third order or *ad radius* may be obtained. Likewise halfway between any ad radius and the adjacent per radius or inter radius, a radius of the fourth order called the *sub-radius* occurs Thus, according to this there are four per radii, four inter radii, eight ad radii and sixteen sub radii are found. In the case of *obelia* medusa, the radial canals, the angles of the mouth and the four of the tentacles lie in perradial plane, four more tentacles are inter radial and the remaining eight tentacles bearing the lithocysts, are adradial. The subradii in the case of the medusa of obelia are of no importance as no particular structures are found in this plane.

Reproduction :

The gametes are found in the regions of the medusa called the *gonads* which are four in number in the form of ovoid bodies. Each gonad hangs at equal distances from the sub-umbrella in immediate relation with the radial canal and therefore perradial in position. Each gonad consists of an outer layer of epidermis continous with that of sub-umbrella and an inner layer of endoderm, continuous with that of the radial canals with a prolongation of the radial canal. There is also lying between the epidermis and the endoderm an intermediate mass of cells which have become differentiated into ova or sperms. As each medusa bears organs of one sex only (testes or ovaries as the case may be), the individual medusa as such are dioecious. The germ cells in the early development of the medusa have been traced in the blastostyles. They originate in the ectoderm of the manubrium and later migrate to the endoderm and then to the gonad where before maturity they leave the endoderm and lie between the ectoderm of the sub-umbrellar surface and the mesogloea. When ripe, they burst through the ectoderm into the



A



B

Fig. 11 Polyps—(A) Medusa (B) Projected to show the various orders of radii

sea where fertilization and development takes place after which the medusae die.

Development :

When the gonads are ripe, the sperms of the male medusae are discharged into the water and carried by currents to the females where they fertilise the ova. The fertilised egg—the *zygote* undergoes complete clevage and is converted into an ovoidal body called the *Planula* (GH). The planula consists of an outer layer of ciliated ectoderm cells and an inner mass of endoderm cells in which a space

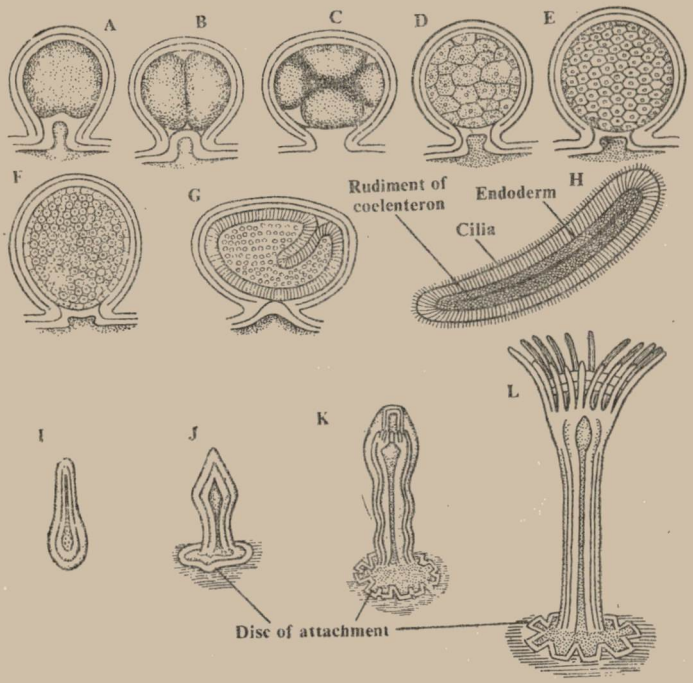


Fig. 12 Stages in the development of two zoophytes (A-H) Laomedea; (I-L) Eduendrium allied to *Obelia*

arises as a rudiment of the coelenteron. The planula swims freely for a time (H) then settles down on a piece of timber or sea-weed, fixes itself by one (J) end, and becomes converted into a *hydrula* (KL) or *Polyp* with a disc of attachment at its proximal end, and at its dilated end a manubrium with a circlet of tentacles. Very soon

the hydrula sends out lateral buds and by the repeated process of budding becomes ultimately converted into the colony of obelia. It should be noted that the plenula is polarised with one end usually forward in locomotion. It is this end, the anterior, which attaches to the substrate.

Life History :

The life history of Obelia, can be considered as an example of *alternation of generations or Metagenesis.* The colony of obelia is sexless, having no gonads, and developing only by the asexual process of budding. Certain buds of obelia colony e. g., medusae develop gonads and from their fertilised eggs new obleia colonies arise. This gives an alternation of asexual generation in the obelia colony, with a sexual generation in medusa. The word generation as used here may be disturbing to the student since the life cycle of obelia with egg, sperm, zygote, planula, hydroid, sexually matuie medusa represents one generation in the ordinary sense. Some hydrozoans have perennial hydroids which sexually release the sexual phase, the medusa. Commonly the hydroid stage lives longer and is more persistent than the rather evanescent sexual adult. In obelia there is in fact no true alternation between the sexual and asexual generations. The sex cells carried in the gonads of medusa do not actually arise there but may be observed in various stages of maturity in the ectoderm of the blastostyles and it is only at a later stage the gametes migrate into the medusa and take up their positions on the gonads situated on the radial canals. One cannot as such differentiate very clearly between sexual and asexual generations in the life cycle of obelia. The life cycle of Obelia is rather a particular example of *polymorphism* which, as has been stated, above involves the setting aside of some zooids (hydranths) for feeding the colony, some blastostyles for budding off a third motile type of zooids, the medusae. The obelia thus is a good example of a *trimorphic colony* with hydranths, blastostyles and medusae as three forms of zooids.

The function of the free swimming medusae is to carry away the gametes from the parent colony and may as such effect dispersal and prevent overcrowding of the species. It should however be remembered that there is always an enormous wastage of medusae

and gametes for the chances of the eggs being fertilised are slight. Most planulae also perish before reaching the stages at which they can settle and metamorphose and those that do so may not find themselves in a condition in which the hydroids can survive. So the role of free swimming zooid—the medusa is difficult to assess. The generally accepted idea that a free swimming phase in the life history of marine animals to ensure dispersal is also doubtful in most instances.

Revision questions

1. Describe the structure and functions of the polyp of Obelia colony.
2. Give an account of the mesuda of Obelia colony and discuss its role in the life history of Obelia
3. Define the terms "Trimorfic colony" and "Metagenesis". Explain the same with reference to the life history of Obelia.
4. Compare and contrast the structure of polyp and mesuda. Are they homologous? If so, how can a mesuda be derived from a polyp.
5. Write short notes on the following :
   (a) Blastostyle (b) Lithocysts
   (c) Endoderm lamella and velum (d) Nemotocyst.

SUPPLEMENT III

ECHINODERMATA

(The spiny skinned animals)

The animals included in Phylum **Echinodermata** have a rough outer covering with projections or spines, hence the name of the group *Echinodermata* (Gk. Echinos=spine; derma=covering). All echinoderms are marine and their body is radially symmetrical. The larvae of echinoderms are however bilaterally symmetrical. The body of echinoderms is not segmented. There is no head. The phylum includes five distinct groups of animals commonly referred to as **Star fishes, Brittle stars, Sea-urchins, Sea-cucumbers and Feather stars.** Sea-urchins have a globular body. Sea-cucumbers are elongated ; the rest as the name suggests have star-shaped bodies.

The most familiar example of Echinoderms is the starfish, as such the external characters of it are described below.

Starfish — Asterias rubens

There is no resemblance of a starfish to a fish. It should rather be referred to as a "Sea Star" from its shape but the name starfish has gained wide usage.

Habitat : The starfishes are mostly found around sea coasts especially on rocky shores. They live from the tide lines to considerable depths on sand and mud. They are highly predacious, feed upon molluscs, crustaceans, worms and other invertebrates. Starfishes are very harmful to the pearl industry as they feed on oysters.

Structure : There are a little over 1000 species of starfishes which differ in certain details. There are found, however, many similarities in the structure of the various types of starfishes.

Asterias rubens is a common starfish often seen in shore pools. *Pentaceros* (which is now included in the genus *Oreaster*) is found commonly in the Indo-Pacific ocean and around the West Indies. It is also found in the Bay of Bengal and the Arabian Sea.

The body of a starfish consists of a **central disc** from which radiate usually five arms or rays. Some species have a larger number of arms. The axes of the arms are termed *radii* and the spaces between them on the disc as *inter-radii*. The **mouth** lies in the centre of the flat surface of the central disc. This forms the

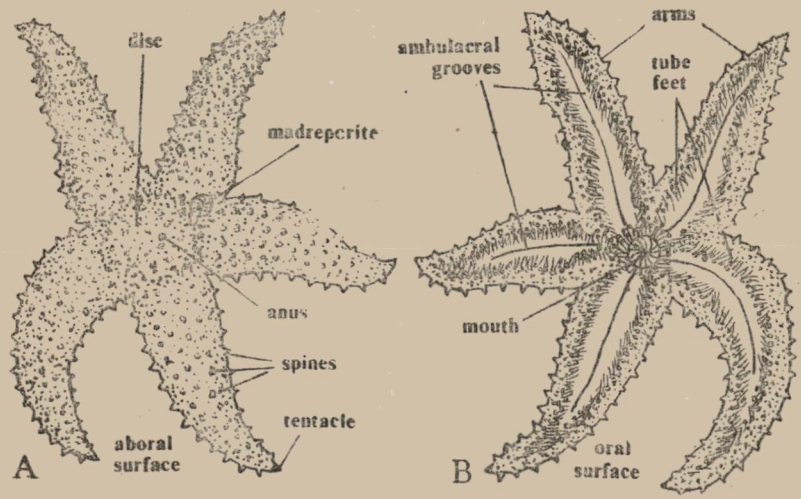


Fig 1 Starfish (Asterias rubens) (A) Aboral surface (B) Oral surface

under surface or the **oral surface** of the body on account of the presence of the mouth. In the natural position of the living animal the oral end is always directed downwards. The **anus** lies on the upper convex surface of the central disc. It is called the **aboral surface** and is always directed upwards in the natural position of the animal.

Oral surface : There is a five rayed aperture called the **actinostome** in the centre of the oral surface. This encloses the mouth. From the actinostome arises an **ambulacral groove**, which extends along the entire length of each arm in the middle of it. There are thus five ambulacral grooves corresponding to the number of arms. The ambulacral grooves on each side are bordered by two or three rows of movable calcareous **ambulacral spines**. On each side of the ambulacral groove is also found a row of slender **tube feet** or **podia**. The term ambulacral groove is derived from a Latin

word meaning a "walk." The double row of the tube feet lining the groove reminded someone probably of a *'flower lined garden walk'*, hence the name ambulacral groove. Tube feet are in the form of hollow finger shaped processes provided with suckers at their end. The tube feet can be distended and are attached to the substratum. They are locomotory organs. The movable row of calcareous spines can be brought together to close the ambulacral groove, protecting thereby the tube feet when the animal is attacked.

The tip of each arm bears a small soft **tactile tentacle** and a red light sensitive **eye-spot.** The tactile tentacle is olfactory in function.

Aboral surface : The convex aboral surface is studded with numerous irregularly arranged short stout spines. Large spines are found on the margins of the arms. The spines are supported by

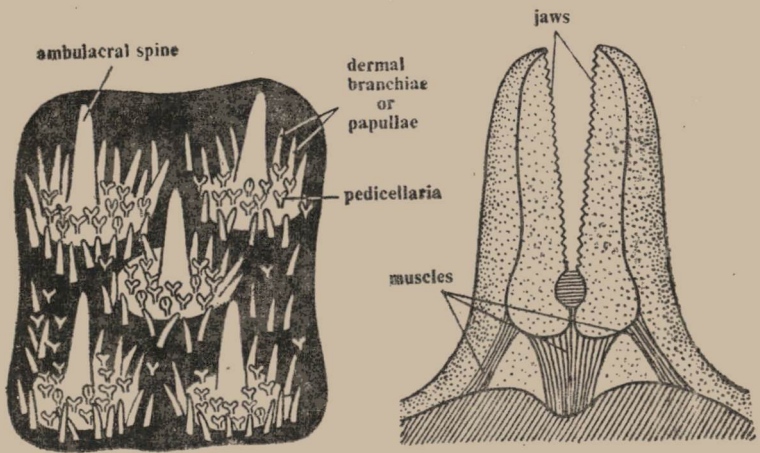


Fig. 2 Starfish—(A) Small portion of the surface of a starfish showing ambulacral spines, papulae (Skin gills) and pedicellariae (B) A single pedicellaria

irregularly arranged ossicles embedded in the integument. Between the spines are found a number of filiform processes called the **dermal branchiae** or **papulae**. Their cavities are continuous with the coelom. They are retractile and are helpful in respiration and excretion. The papulae are restricted to the aboral surface only.

On the aboral surface, besides the anus, there is also found a flat, circular plate situated between the bases of the two of the rays. This is called the **madreporite** or **sieve plate.** The surface of the madreporite is marked by a number of radiating, narrow, straight or slightly wavy grooves. The madreporite communicates internally with a S-shaped canal surrounded by hard calcareous rings. It is therefore, called the **stone canal.** The two rays between which the madreporite lies are termed the **bivium**, and the three remaining rays are referred to as the **trivium.**

On both the oral and aboral surfaces of the body are also situated the **pedicellariae.** They are found near the papulae and around the spines. Each pedicellaria is provided with two jaws and works like a forcep. The pedicellariae keep the surface of the animal free of organisms, debris, etc , and are helpful in catching the food. The entire body is covered by ciliated epidermis. Beneath the epidermis lies the mesoderm. It produces a framework of various hard plates called the **ossicles.** The ossicles have definite shapes and are arranged in regular pattern. The different ossicles are cemented together by connective tissue and are joined by muscle fibres. These ossicles in starfish, as they lie embedded in the skin form a sort of **endoskeleton.** It differs from the exo-skeleton of Arthropods which lies outside the body. You have studied in cockroach that the tergal and the sternal plates are found at the external surface of the body.

Locomotion : In starfish, locomotion takes place by means of a kind of hydraulic-pressure mechanism, known as **water vascular system.** This system is a unique feature to Echinoderms. Water enters this system through madreporite, from where it is drawn under a ciliary action into the stone canal. The water from the stone canal passes into a ring canal which encircles the central disc. From the ring canal originate five radial canals, one for each arm. The radial canals, by numerous short branches are connected with many pairs of tube feet. The tube feet as described are hollow, thin walled cylinders ending in suckers. Each tube foot is further connected with an **ampulla.** As mentioned above, the water, via madreporite, stone canal, ring canal and the radial canal and its branches reaches finally into the ampullae.

When the ampulla contracts, the water is forced under pressure into the tube foot. This causes the tube foot to extend and as such it attaches to the substratum by its sucker. In the next step,

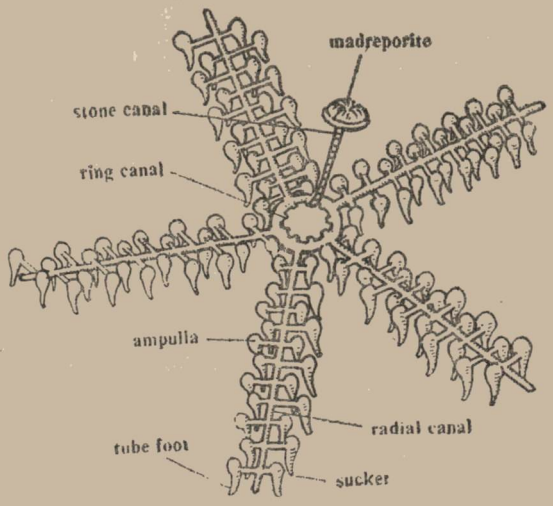


Fig. 3 Starfish—Water vascular system

as the muscles of the tube foot contract, it becomes short and forces the water back into the ampulla. This results in drawing the animal forward. Since there are hundreds of tube feet in a starfish, the combined simultaneous action of all the tube feet, enables a starfish to move slowly over the ocean floor. The tube feet can only work in the manner described above when the animal is moving over a rock or some kind of hard substratum. Starfishes move rather slowly. On the soft sand or mud the suckers are however of little use and tube feet act as little legs. In some starfishes the ends of the tube feet have no suckers.

Revision questions

1. Describe in detail the external characters of a starfish.
2. What is the significance of the water vascular system in starfish in the process of locomotion ?
3. Write short notes on the following :
   (a) Pedicellaria (b) Madreporite
   (c) Dermal branchiae or papulae