Text Book for

INTERMEDIATE

First Year

Zoology

Permission & Support by:

National Council of Educational Research and Training
New Delhi

Board of Intermediate Education, Andhra Pradesh

Telugu and Sanskrit Akademi, Andhra Pradesh

Intermediate

First Year

Zoology

Text Book

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Y.S. JAGAN MOHAN REDDY

CHIEF MINISTER
ANDHRA PRADESH

AMARAVATI

MESSAGE

I congratulate Akademi for starting its activities with printing of textbooks from the academic year 2021 – 22.

Education is a real asset which cannot be stolen by anyone and it is the foundation on which children build their future. As the world has become a global village, children will have to compete with the world as they grow up. For this there is every need for good books and good education.

Our government has brought in many changes in the education system and more are to come. The government has been taking care to provide education to the poor and needy through various measures, like developing infrastructure, upgrading the skills of teachers, providing incentives to the children and parents to pursue education. Nutritious mid-day meal and converting Anganwadis into pre-primary schools with English as medium of instruction are the steps taken to initiate children into education from a young age. Besides introducing CBSE syllabus and Telugu as a compulsory subject, the government has taken up numerous innovative programmes.

The revival of the Akademi also took place during the tenure of our government as it was neglected after the State was bifurcated. The Akademi, which was started on August 6, 1968 in the undivided state of Andhra Pradesh, was printing text books, works of popular writers and books for competitive exams and personality development.

Our government has decided to make available all kinds of books required for students and employees through Akademi, with headquarters at Tirupati.

I extend my best wishes to the Akademi and hope it will regain its past glory.

Y.S. JAGAN MOHAN REDDY

Dr. Nandamuri Lakshmiparvathi
M.A., M.Phil., Ph.D.
Chairperson, (Cabinet Minister Rank)
Telugu and Sanskrit Akademi, A.P.

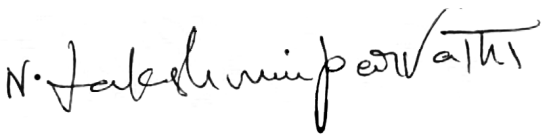
Message of Chairperson, Telugu and Sanskrit Akademi, A.P.

In accordance with the syllabus developed by the Board of Intermediate, State Council for Higher Education, SCERT etc., we design high quality Text books by recruiting efficient Professors, department heads and faculty members from various Universities and Colleges as writers and editors. We are taking steps to print the required number of these books in a timely manner and distribute through the Akademi's Regional Centers present across the Andhra Pradesh.

In addition to text books, we strive to keep monographs, dictionaries, dialect texts, question banks, contact texts, popular texts, essays, linguistics texts, school level dictionaries, glossaries, etc., updated and printed and made available to students from time to time.

For competitive examinations conducted by the Andhra Pradesh Public Service Commission and for Entrance examinations conducted by various Universities, the contents of the Akademi publications are taken as standard. So, I want all the students and Employees to make use of Akademi books of high standards for their golden future.

Congratulations and best wishes to all of you.



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Chairperson, Telugu and Sanskrit Akademi, A.P.

J. SYAMALA RAO, I.A.S.,
Principal Secretary to Government

Higher Education Department
Government of Andhra Pradesh

MESSAGE

I Congratulate Telugu and Sanskrit Akademi for taking up the initiative of printing and distributing textbooks in both Telugu and English media within a short span of establishing Telugu and Sanskrit Akademi.

Number of students of Andhra Pradesh are competing of National Level for admissions into Medicine and Engineering courses. In order to help these students Telugu and Sanskrit Akademi consultation with NCERT redesigned their Textbooks to suit the requirement of National Level Examinations in a lucid language.

As the content in Telugu and Sanskrit Akademi books is highly informative and authentic, printed in multi-color on high quality paper and will be made available to the students in a time bound manner. I hope all the students in Andhra Pradesh will utilize the Akademi textbooks for better understanding of the subjects to compete of state and national levels.

(J. SYAMALA RAO)

THE CONSTITUTION OF INDIA

PREAMBLE

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a [SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC] and to secure to all its citizens:

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all

FRATERNITY assuring the dignity of the individual and the [unity and integrity of the Nation];

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949 do HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.

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Foreword

The Government of India vowed to remove the educational disparities and adopt a common core curriculum across the country especially at the Intermediate level. Ever since the Government of Andhra Pradesh and the Board of Intermediate Education (BIE) swung into action with the task of evolving a revised syllabus in all the Science subjects on par with that of COBSE, approved by NCERT, its chief intention being enabling the students from Andhra Pradesh to prepare for the National Level Common Entrance tests like NEET, ISEET etc for admission into Institutions of professional courses in our Country.

For the first time BIE AP has decided to prepare the Science textbooks. Accordingly an Academic Review Committee was constituted with the Commissioner of Intermediate Education, AP as Chairman and the Secretary, BIE AP; the Director SCERT and the Director Telugu Akademi as members. The National and State Level Educational luminaries were involved in the textbook preparation, who did it with meticulous care. The textbooks are printed on the lines of NCERT maintaining National Level Standards.

The Education Department of Government of Andhra Pradesh has taken a decision to publish and to supply all the text books with free of cost for the students of all Government and Aided Junior Colleges of newly formed state of Andhra Pradesh.

We express our sincere gratitude to the Director, NCERT for according permission to adopt its syllabi and curriculum of Science textbooks. We have been permitted to make use of their textbooks which will be of great advantage to our student community. I also express my gratitude to the Chairman, BIE and the honorable Minister for HRD and Vice Chairman, BIE and Secretary (SE) for their dedicated sincere guidance and help.

I sincerely hope that the assorted methods of innovation that are adopted in the preparation of these textbooks will be of great help and guidance to the students.

I wholeheartedly appreciate the sincere endeavors of the Textbook Development Committee which has accomplished this noble task.

Constructive suggestions are solicited for the improvement of this textbook from the students, teachers and general public in the subjects concerned so that next edition will be revised duly incorporating these suggestions.

It is very much commendable that Intermediate text books are being printed for the first time by the Akademi from the 2021-22 academic year.

Sri. V. Ramakrishna I.R.S.
Director
Telugu and Sanskrit Akademi,
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Preface

This Edition Is the outcome of the indefatigable effort of the BIE, over the last four months, and the deliberations of the committee of Experts set up to frame a new syllabus for Zoology on the lines recommended by the **COBSE**. With the Scope of the text book clearly defined by the authorities concerned, the Editorial Board followed the guidelines set by the NCERT in its text book, with reasonable leverage to add chapters or sub-chapters that do widen the scope of the book. The purpose was to help the students of AP to be better prepared for any challenge, a competitive exam at the national level may offer. It was, however, a tight rope walk indeed-keeping to the frame work of the NCERT, and at the same time, improving the content and quality of the reading material.

Almost every unit is introduced with a tribute to one of the important scientists concerned with the content of the chapter and with a ***special note of introduction*** from the Chief Editor about certain aspects worth knowing about the chapter. We provided the student with an alternate word, where we thought that a student might find a certain word difficult. In some cases, the students are directed to the ***'glossary'*** to know more.

Model long-answer, short-answer and very short-answer questions have been provided at the end of each chapter to help the student get a fairly good idea of what sort of questions can probably find a place in the questionnaires of the public exams. The short *crispy* items included in coloured boxes arc intended to stimulate the thinking of the readers and help them assimilate the subject properly. Some of them pertain to the regular curriculum (course content) and the others are intended to test the skills of the students or to provide additional information. Some items are specifically marked, ***'not for evaluation'*** to warn paper setters against setting questions on such components. We included some model questions which require SKILLS and APPLICATIONS of the knowledge students acquire from a chapter under the caption **'FOR IGNITED MINDS**. It is a *novel component 'tailored'* exclusively for the Text Book of Zoology and we are sure that the teachers and the students will appreciate our efforts to arouse/ignite ***creative thinking*** in them a deviation, though slight, from the routine,

We hied our best to provide error-free information. It is possible that some errors might have crept in, mostly by oversight. We welcome teachers to point them out so that we can correct them in the next edition. We invite their well-intentioned find construction criticism, keeping in mind that this is the First Edition.

ESRK Prasad

Preface to the Reviewed Edition

In view of advancements in Science, periodical review of Text Books at different levels of study has become necessary. Taking into consideration the syllabus for the students of Zoology of Junior Intermediate, Board of Intermediate Education, Andhra Pradesh, the present book is thoroughly reviewed. Lapses in some units are fulfilled and now the present book is as per the prescribed syllabus.

In spite of the best efforts in preparation of this book, some errors may crept in. We welcome the constructive criticism from the academic fraternity. It will be reviewed and incorporated in the coming edition.

We gratefully acknowledge the help received from the Director, Telugu Akademi and the team of dedicated Officials.

Editor
(Reviewed Edition)

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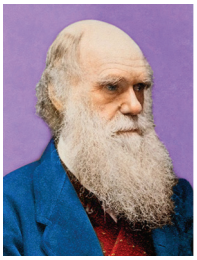


***Charles Darwin**, a British Naturalist, went round the world in the ship called H.M.S. Beagle, for five years. He published his findings in his book - **ORIGIN OF SPECIES**. According to him evolution involves '**descent with modification**'. With no reservations, one can call him - THE BIOLOGIST OF THE NINETEENTH CENTURY.*

Unit

1

Diversity of Living World

Biology is the science of life and living processes. The living world comprises an amazing **diversity** of living organisms. However, living organisms show '***Fundamental Similarity***' in many respects. The study of 'Life' involves a multidisciplinary approach, involving many of the principles of **chemistry**, **physics** and **mathematics** too at some places. Biological systems are the most '***complex chemical systems***' on the Earth. The bodies of early organisms are at the 'cellular' level. However large an organism is, '**cells**' of an organism are the '***Basic Units***' of 'structure' and 'function'. Organisms constantly interact with their surrounding environment '***exchanging energy***' and '***recycling minerals***'. The intricate chemical processes of cells are based on the basic principles of chemistry. Every level of biological organisation involves 'energy transactions' governed by the '***Laws of thermodynamics***'. The fundamental source of energy for all biological systems is the 'Sun'. Green plants, over a period of several millions of years, evolved and have mastered the art of converting ***solar energy*** into ***chemical energy*** involving complex reactions and pass it on to other higher living organisms to keep ***LIFE*** going.

Life defies simple definition although one can easily perceive the difference between ***inanimate matter*** (wind, sea, fire, etc.) and *'living organisms'*. Cellular organisation, ordered complexity, ability to reproduce themselves, showing growth, utilisation and transfer of energy, maintaining constancy in the internal environment (in spite of variations in the surrounding environment), irritability (showing sensitivity to stimuli) and above all, exhibiting the ability to adapt and

evolve (change from simple structure to complex) are some of the '***traits***' of life and living organisms. Diversity in living organisms comes from their ability to 'change'. The process of evolution is continuous and newer forms evolve continuously (***Descent with Modification***), while some perish in the struggle for existence, as envisaged by **Charles Darwin**. Evolution is the 'Fundamental Organising Principle' of life and it answers many questions about life and its complexity - a scientific explanation for 'unity' and 'diversity'. The study and discovery of the molecular structure of DNA by **Watson** and **Crick** (1953) was the major event of the Twentieth Century in the study of biology and it revealed how DNA can ***store information*** and could serve as the '***chemical basis of inheritance***'. Automatic DNA 'sequencing machines' and the enormous computing power of the present day computers, as a part of the Human Genome Project, have laid inroads to understanding ***genetic basis of disease***, ***gene therapy***, ***gene modifications,*** etc., to understand life better and to improve the quality of human life, in particular. Comparative studies of DNA, RNA brought in the necessity of classifying living organisms into three ***Domains*** namely ***Bacteria***, ***Archaea*** and ***Eukarya***. The Five Kingdom classification of **Whittaker** followed until a few decades ago, has given place to Six Kingdoms namely - ***Bacteria, Archaea, Protista, Fungi, Plantae*** (*Metaphyta* or *Viridiplantae*) and ***Animalia*** (*Metazoa*).

The increase in complexity is right from the simple '***cellular level***' to the '***organism level***' followed by '**populations**', '**communities**' and '**ecosystem**' levels in the **Biosphere** (*all the habitable zones of life on the Earth*). Continuity of life is based on 'heritable' ***genetic information*** in the **DNA** and in some cases '**RNA**'. In the following subunits of this Unit, you will get an insight into **life**, description of some of the ***basic traits of life***, its ***complexity of organisation*** including ***nomenclature*** and ***classification*** from a taxonomical angle .

1.1 What is Life ?

'*Life*' is an exclusive property of the various types of living organisms in the world. Recent discovery of fossils of some microscopic organisms extended the known 'history of life' on the Earth to about **3.5** billion years. ***Biology*** is the science dealing with the study of living organisms which are broadly classified into microorganisms, plants and animals.In spite of their wide '***diversity***', they show '***fundamental uniformity***' in possessing *protoplasm* with the genetic substance, the *DNA* which is made up of '***nucleotides***', universally. Living organisms show:

I. **Cellular organization** and **highly ordered structure**: An organism's body is made up of one to many '**cells**', which are the ***structural*** and ***functional units*** of the body. Each cell is isolated from the cells surrounding it by a limiting membrane the plasma membrane. This membrane controls the exchange of various substances across it. Two major kinds of cells occur in the living world – the ***prokaryotic*** cells (without distinct nuclei) and the ***eukaryotic*** cells (with distinct nuclei).

II. **Complexity of organization**: A fundamental feature of life is the presence of a high degree of 'order'. Living organisms show hierarchical organization such as cellular level, tissue level, organ level and organ- system level. Several organ-systems make up an ***organism***. This type of '**ordered complexity**' is not seen in the non-living things. The hierarchy of life can be schematically represented as follows (starting from the inorganic elements that go into the constitution of protoplasm).

ATOMS → MOLECULES → CELL → TISSUE → ORGAN → ORGAN SYSTEM → ORGANISM → POPULATION → COMMUNITY → ECOSYSTEM → BIOSPHERE.

This representation includes both the inorganic and organic components, as living substance is made up of several inorganic constituents and life processes involve continuous exchange and recycling of inorganic elements.

III. Sensitivity/ Response to Environment: It is the property of showing response to external or internal stimuli received through various kinds of 'sense organs'. Living organisms show response to environmental stimuli, which could be physical, chemical or biological. Plants show sensitivity to environmental factors such as light, temperature, water, etc. Ability to show response is called irritability

IV. Growth: Growth is one of the *fundamental characters* of living beings (including the unicellular organisms). Increase in mass and increase in number are twin characteristics of growth. Some non-living things also may show tendency of growth but growth in living beings is '***growth from inside***', whereas growth in the non-living things is by accumulation of material *on the surface.* Higher plants show growth all their life producing new branches, leaves, etc., where as it is

'limited' (up to a certain age only) in animals. *Growth cannot be taken as a defining property of living organisms (Ref: NCERT Text Book) as non-living structures also show growth in some respects*.

V. **Energy utilisation/ Energy processing/ Metabolism**: The sum total of all the chemical reactions occurring in the bodies of organisms constitute metabolism and it is a defining feature of all living organisms without exception. Life activities require 'energy' in different forms. The chief source of energy for living organisms is the *sun light.* Energy is transferred from one trophic level to another level. The life processes which build up or store (*conserve*) energy are called **anabolic** processes and the processes involving expenditure of energy are called **catabolic** processes. Together, they constitute - **metabolism.**

*ATP is the **chief energy carrier** for various reactions in living systems and it is appropriately described as the 'Cellular Energy Currency'.*

VI. **Reproduction**: Living organisms produce young ones of their kind, using molecules of heredity, the DNA molecules (genes), which are passed on to the offspring. It is important to note that '***life comes only from life***' (***biogenesis***) and not from non-living substances. Reproduction,characteristic of all living organisms, occurs by *vegetative, asexual* and *sexual* methods. Sexual method involves fusion of gametes forming a zygote, which through various stages of development becomes a young organism. However, some organisms do not reproduce (mules, sterile worker honey bees, infertile human couples, etc.,). **Protozoans** reproduce by asexual methods such as 'binary fission'. **Sponges, hydra,** etc., reproduce by 'budding'. In **planarians**, fragmented body (by fission) regenerates the lost parts of the body and becomes a new organism.

VII. **Homeostasis**: Maintenance of relatively constant internal conditions (***steady state***) different from the surrounding environment is called '***homeostasis***'. It is the ***dynamic constancy*** of the ***internal environment*** of an organism within a range that the cells can tolerate. Living organisms maintain 'constant internal environment' by various physiological adaptations.

VIII. **Evolution**: Life is not 'static'. It constantly changes(*dynamic*) from simple to more complex forms. Variations in organisms arise through '***mutations***' or '***gene re-combinations***'. Charles Darwin's Natural Selection theory states that living beings accumulate their 'beneficial variations' over a period of time and tend to evolve gradually into new types of organisms (species) after surviving the struggle for existence.

IX. **Senescence** and **Mortality**: Living beings are born, grow into mature forms, undergo ageing process and finally die. The process of ageing is called 'senescence'. It leads to death / mortality. Living beings are thus '***mortal***'.

All the ***life phenomena*** like nutrition, respiration, excretion, irritability, etc., are due to ***interactions*** between the various components of an organism. Properties of tissues are not present in all the constituent cells but arise as a result of interactions among the constituent cells. Similarly properties of cellular organelles are not present in the molecular constituents of the organelle but arise as a result of interactions among the molecular components comprising the organelle. Thus, interactions result in certain properties, at a higher level of organization. This phenomenon is true in the ***hierarchy of organizational complexity*** at all levels. ***Biology is the story of life and evolution of living organisms on the Earth***. All living organisms- the present, past and future are linked to one another by sharing a common ***genetic material***, but to varying degrees.

1.2 Nature, Scope and Meaning of Zoology

Biology is a science devoted to the study of living organisms. Science progressed by breaking down complex subjects into their component parts and so today there are numerous branches of biology of which BOTANY , ZOOLOGY and MICROBIOLOGY are the principal, heterogeneous and divergent groups .

Zoology (zoon-animal; logos-knowledge / study) or '**Animal Science**' is a part of the biological science which deals with the study of various aspects of animals, starting from the sponges (Phylum : Porifera) to mammals (Class : Mammalia). The aim of zoology is to explain the ***animal world*** in terms of ***scientific principles***.

Zoology is studied as a 'pure science' (knowledge gaining) and it has application in other branches such as euphenics, eugenics, biotechnology, bioenergetics, bioinformatics, etc. As applied science, it has tremendous scope in agriculture, aquaculture, animal husbandry, human health, diseases, veterinary science, apiculture,sericulture, pharmacology, animal breeding, etc.

1.3 Branches of Zoology

Lamarck (1809), a French biologist coined the term '**Biology**', which means the 'study of living organisms'. This diverse science which deals with all aspects of animal life has several sub-branches. A few of them are listed below.

Sub branches of Zoology

1. **Taxonomy** (Taxis - arrangement; nomos - rule, custom)

It is the theory and practice of identification, nomenclature and classification of organisms. The term 'Taxonomy' was coined by A.P. de Candolle.

2. **Morphology** (morphos - form; logos - study)

It deals with the study of form, size, shape, colour and structure of various organisms and their tissues, organs, organ- systems, etc. It includes the following

i. **External morphology** It is the study of external characters of an organism.

ii. **Internal morphology** This branch deals with the study of internal structure. It includes the following

a) **Anatomy** (ana - up; tome - cutting): It is the study of the internal arrangement of different organs or organ systems in an organism as observed with the naked eye.

b) **Histology** (histos - tissue; logos - study): It is the study of microscopic structure of different tissues. This branch is also referred to as '**Microanatomy**'.

3. **Cytology** (Kytos - cells; logos - study):

Cytology deals with the study of form and structure of cells and cell organelles. Cell biology is the branch of science that deals with the study of the cell as a structural and functional unit of living organisms.

4. **Physiology** (Physis - nature of functioning; logos - study):

It is the study of different body functions and processes.

5. **Embryology** (Embryon - embryo; logos - study) and **Developmental biology**

Embryology deals with the study of events that lead to fertilization, cleavages, early growth and differentiation of zygote into an embryo. It is also defined as the branch of biology dealing with the formation and development of embryos. **Developmental biology** is the study of embryonic development and the other developmental processes after birth.

6. **Evolution** (e - out; volva - roll):

It is the study of origin of life and continuous genetic adaptations of organisms to the environment. It also deals with the gradual changes that occur in the living organisms through geological time. Evolution means 'unfolding'. **Herbert Spencer** coined the term '**Organic Evolution**'.

7. **Palaeontology** (Paleo - ancient; on - being; logos - study)

Study of fossilized remains of organisms of the past geological ages is called palaeontology. This includes palaeobotany(fossils of plants) and palaeozoology (fossils of animals).

8. **Ecology** (Oikos - house; logos - study)

It is the study of living organisms in relation to the other living organisms (biotic factors) and abiotic environmental factors surrounding them. **Haeckel** coined the term '**Ecology**'.

9. **Genetics** (Gen - to grow into)

Genetics is the study of inheritance of characters from one generation to the next. It deals with **heredity** and **variations**. **Bateson** coined the term 'Genetics'.

10. Ethology (Gk. ethos - character)

The study of the animal behaviour based on the systematic observation, recording, analysis of functions of animals, with special attention to physiological, ecological and evolutionary aspects is called **ethology**.

1.4 Need for Classification

It is impossible to study all living organisms. So, it is necessary to devise some means to make this possible .This process is called '**classification**'. Classification is defined as the process by which anything is grouped into convenient categories based on some easily observable characters. The scientific term used for these categories is 'TAXA' (singular: taxon) .Taxa can indicate categories at different levels e.g. Animalia (which includes multicellular animals), chordata, mammalia, etc., represent taxa at different levels.

Hence, based on certain specific characteristics, all the living organisms can be classified into different taxa. This process of classification is called **taxonomy**. Study of external and internal structures, along with the structure of cell, developmental processes and ecological information of organisms are essential and they form the basis of modern taxonomic studies. Hence, **characterisation**, **identification**, **nomenclature** and **classification** are the processes that are basic to taxonomy.

'Zoos' As Tools For Classification

These are the places where wild animals, taken out of their natural habitat, are placed in protected environment under human care (***Ex-situ* conservation**).This enables us to learn about the animal's external features, food habits, behaviour(ethology) etc. These observations enable us to systematise the organism and position it in the animal world.

Museums

Museums have BIOLOGICAL SPECIMENS preserved in containers or jars in preservative solutions. Animal specimens may also be preserved as dry specimens. Insects are preserved in insect boxes after collecting, killing and pinning on sheets. Larger animals like birds and mammals are usually 'stuffed' and preserved. Museums often have collections of skeletons of animals too.

1.5 Biological Classification

The living organisms exhibit a great deal of diversity due to variations in their structure and function. So far, over 1.25 million animal species have been identified and described. They show diversity in structure, habits, habitats and modes of life. To understand the interrelationships among the diversified animal groups, a systematic classification is necessary.

History of Biological Classification

Carolus Linnaeus (1707-1788), Father of Taxonomy and Founder of Modern Systematics, introduced the system of hierarchical classification. In the 19th and 20th centuries numerical taxonomy and phylogenetic classification emerged.

Classification

Phylogenetic (Cladistic) Classification

It is an evolutionary classification based on how a common ancestry was shared. Cladistic classification summarises the 'genetic distance' between all species in the 'phylogenetic tree'. In cladistic classification characters such as ***analogous characters*** (characters shared by a pair of organisms due to convergent evolution e.g.wings in sparrows and patagia (wing like structures) in flying squirrels) and ***homologous characters*** (characters shared by a pair of organisms, inherited from a common ancestor e.g., wings of sparrows and finches) are followed/taken into consideration. ***Ernst Haeckel*** introduced the method of representing phylogeny by 'trees' or branching diagrams.

1.6 Levels and Hierarchy of Classification

Human beings are not only interested in knowing more about different kinds of organisms and their diversities, but also the relationships among them. This branch of study is referred to as **SYSTEMATICS**. Systematics is the branch of science that deals with the vast diversity of life. It also reveals the trends and evolutionary relationships of different groups of the organisms. These relationships establish the phylogeny of organisms. A key part of systematics is taxonomy. Taxonomic **hierarchy** includes **seven obligate categories** namely **kingdom**, **phylum**, **class**, **order**, **family**, **genus** and **species**, and other intermediate categories such as subkingdom, grade, division, subdivision, subphylum, superclass, subclass, superorder, suborder, super family, subfamily, subspecies, etc. If we consider the three Domain classification, we have eight obligate categories.

Linnaeus was the first taxonomist to establish a definite hierarchy of taxonomic categories called taxa (singular: taxon) like kingdom, class, order, genus and species. Haeckel (1888) introduced the taxon **Phylum**. A species sometimes may have more subspecies, which show some morphological variations (intra-specific variations).

Taxonomic Categories: Nowadays the three ***Domain*** classification is followed. **CARL WOESE** and co-workers observed that many prokaryotes previously classified under 'Prokaryota/ Monera' are more closely related to the 'eukaryotes' and classified them under a separate Domain the ***ARCHAEA***. This type of study is called '**MOLECULAR SYSTEMATICS**'.

Now there is a general agreement on the **THREE DOMAIN CLASSIFICATION** of the living organisms namely **DOMAIN-I** : BACTERIA, **DOMAIN-II** : ARCHAEA and **DOMAIN- III**: EUKARYA. (**NOTE**: *DOMAIN is a taxon higher than 'Kingdom'*).

Bacteria and ***Archaea*** represent two separate, distinct groups(called Domains). Thus, the modern taxonomists replaced the **Kingdom Monera** with two distinct Kingdoms - **BACTERIA** and **ARCHAEBACTERIA**. Studies on RNAs revealed that *Archaea* and *Eukarya* are more closely related to each other than to Bacteria. According to three domain system there are **six kingdoms** namely Eubacteria, Archaebacteria, Protista, Plantae, Fungi and Animalia.

1. **Kingdom**: All multicelluar, non-saprobic, heterotrophs are included in the kingdom **Animalia**/ Metazoa.
2. **Phylum**: It includes one or more classes. E.g. Phylum Chordata includes the classes Cyclostomata, Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammalia, along with the protochordates. All these are based on common features such as presence of notochord, dorsal hollow nerve cord, pharyngeal slits, post-anal tail, etc., in some stage of the life history.
3. **Class**: It includes one or more related orders. E.g. The class Mammalia includes the orders Rodentia (**rats**), Chiroptera (**bats**), Cetacea (**whales**), Carnivora (**dogs**), Primates (**monkeys** and **apes-gorilla**, **gibbon** and **man**), etc.
4. **Order**: It includes an assemblage of one or more related families. E.g. The families Felidae and Canidae are included in the order **Carnivora** along with Hyaenidae (**hyenas**), Ursidae (**bears**), etc.
5. **Family**: It includes one or more related genera and can be distinguished from the other families by important characteristic differences. Family felidae includes the genus of cat (Felis), genus of leopard (Panthera), etc. The members of Felidae can be distinguished from those of Canidae (foxes, dogs, wolves). Adding the suffix-idae to the type generic name forms the name of the family e.g. adding the suffix 'idae' to the type Generic name '***Homo***' gives the name of the Family to which man belongs - **Hominidae**. The name of the subfamily can be coined by adding the suffix-**inae** to the type generic name (e.g. **Homininae**) and the name of the superfamily by adding the suffix**-oidea** (e.g. **Hominoidea**).
6. **Genus**: It is a group of related species, resembling one another in certain characters e.g. *Panthera leo* (lion), *Panthera tigris* (tiger) and *Panthera pardus* (leopard) belong to the genus *Panthera*.
7. **Species** and **Subspecies**: Species is the ***basic unit*** of classification in the hierarchical taxonomic system. Species is a group of similar organisms sharing a '***common gene pool***' and interbreeding freely, producing 'fertile' offspring. A species occurs in the form of many interbreeding groups called 'populations'.

A species may include **subspecies**. Subspecies is/may be a geographically isolated population of a species, which shows some minor **variations** from the parent population, but are capable of interbreeding with the individuals of other subspecies of the same species. *Subspecies are probably new species in the making.*

For example, the scientific name of crow is *Corvus splendens.* Geographically the crows present in India, Pakistan, Myanmar and Sri Lanka are isolated and evolved into different subspecies- *Corvus splendens splendens is the* ***subspecies*** *in* ***India*** *and* ***Pakistan****, Corvus splendens insolens is the subspecies in* ***Myanmar*** *and Corvus splendens protegatus is the* ***subspecies*** *in* ***Sri Lanka****.* In this system of nomenclature the first word refers to the 'genus', the second to the 'species' and the third to the 'subspecies'.

1.7 Nomenclature

It is estimated that the number of species known and described ranges between 1.7 to 1.8 million. They are called by their local names (in regional languages), which vary from place to place and even within the same country. So there is need to standardise the naming pattern of living organisms such that a particular organism is known by the same name all over the world/ universally. This process of naming of animals with a distinctive (scientific) names is called ***nomenclature****. Naming of organisms is done as per the guide lines of the* ***International Code of Zoological Nomenclature (ICZN)****.* ***Binominal nomenclature*** *(originally called Binomial nomenclature) is used in naming organisms all over the world.*

I. Binominal Nomenclature

Carolus Linnaeus*, a Swedish botanist, popularised the '****binomial nomenclature****' by using it in the 10th edition of his book* **Systema Naturae***. It is the type of nomenclature in which each organism is provided with an appropriate scientific name consisting of two components, the "****binomen****". The first word refers to the '****genus****' (pl : genera) and the second word is the 'specific epithet*[1] *(species name) . The word that refers to the 'genus' is a '****noun****', and the specific epithet that refers to the 'species' is mostly an '****adjective****'. The generic name begins with a capital letter and the specific name with a small letter. Names must be in Latin or latinised form and are usually '****printed****' in italic type. When '****written****' the two words are to be underlined separately.* Let us take the example of a 'lion' to understand binominal nomenclature. The scientific name of lion is ***Felis leo***. In this name, the word '***Felis***' represents the genus, while the word '***leo***', is the specific epithet. *The name of the taxonomist follows the scientific name either in full form or in an abbreviated form e.g.* ***Felis leo Linnaeus*** *or* ***Felis leo Linn.***

[1] *Any word or phrase applied to a person or thing to describe an actual or attributed quality(adjective).*

or ***Felis leo L.*** It indicates that this species was first described by Linnaeus. *The year of the discovery is written after the name of the person who discovered it - e.g.* ***Felis leo Linnaeus, 1758****. When the name of the genus is not the one under which the original author placed a species, or if the generic name is changed subsequently, the original author's name and the year are kept in parenthesis e.g.* ***Panthera leo (Linnaeus, 1758)****. It is written so, to understand that Linnaeus originally placed the species name '**leo**' under the genus 'Felis' and it was later shifted to the genus Panthera.*

II. Trinominal Nomenclature

It is the extension of the binominal system of nomenclature. This system permits the designation of subspecies with a three-worded name called '**trinomen**'. This system of nomenclature is used to name the subspecies, which is a category below the level of species. The word denoting the name of sub species also begins with a small letter and it is a latinised word, printed in italics e.g. ***Homo sapiens sapiens; Corvus splendens splendens***.

TAUTONYMY: The practice of naming the animals, in which the generic name and species name are the same, is called tautonymy. So the name is called tautonym e.g. ***Axis axis*** (spotted deer); ***Naja naja*** (the Indian cobra).

1.8 Species Concept

I. Species

*Species is the '**basic unit**' of classification. Species is a Latin word meaning 'kind' or 'appearance'.* ***John Ray*** *in his book '**Historia Generalis Plantarum**', used the term '**species**' and described* it on the basis of common descent (origin from common ancestors) as a group of morphologically *similar organisms. Linnaeus considered species, in his book '**Systema Naturae**', as the basic unit of classification. Buffon, in his book '**Natural History**', proposed the idea of evolution of species which is the foundation for the biological concept of evolution. This biological concept of species (dynamic nature of species) became more popular with the publication of the book "**The Origin of Species**" by Charles Darwin.*

Buffon's biological concept of species explains that species is an interbreeding group of similar individuals sharing the common 'gene pool', and producing fertile offspring. Species is considered a group of individuals which are:

1. Reproductively isolated from the individuals of other species – **a breeding unit**.
2. Sharing the same ecological niche – **an ecological unit**.
3. Showing similarity in the karyotype – **a genetic unit**.
4. Having similar structure and functional characteristics – **an evolutionary unit**.

Let us consider the following examples

Example- 1: *Apis indica*, *Apis dorsata*, *Apis mellifera* and ***Apis florea***

In the above example '**indica**', '**dorsata**', '**mellifera**' and '**florea**' are different species belonging to the same genus called **Apis**.

Example- 2: *Pheretima posthuma, Periplaneta americana* and ***Panthera leo***. In the example 2 the words ***'posthuma***', '***americana***' and '***leo***' are names of different species belonging to different genera.

*Sometimes closely related species of a genus can interbreed, but they generally give rise to sterile offspring. A cross between a female donkey and a male horse gives rise to the sterile offspring called '**Hinny**' (a sterile hybrid).*

Dobzhansky introduced the concept of '**Mendelian Population'** while defining a species**.** A Mendelian population is a group of sexually reproducing individuals within which mating takes place. They share a 'common gene pool'. The members of a species show **assortative** (*preferential*) mating. Populations of a species inhabiting different geographical areas are in a continuous process of adapting to the conditions of their surrounding environments. This leads to the evolution of new species, in course of time. Thus, species is **dynamic**.

Find out the scientific names of at least five animals around your home.

1.9 Kingdom: Animalia

Animalia includes eukaryotic, multicellular heterotrophs (generally obtain nourishment by ingestion i.e, holozoic method and digesting the ingested food). They have specific body plans and do not possess cell walls and photosynthetic pigments. Tissue formation is common except in the sponges. Higher forms show elaborate sensory and neuromotor mechanisms. Organ and organ-systems are developed in most of the groups. Nutrition is **holozoic** and a few are parasitic. Reserve food is mostly in the form of ***glycogen***. These are mostly motile and move in search of food (except the sedentary forms). Muscle cells, sensory cells and nerve cells are present. Reproduction is mostly by sexual method; some reproduce by asexual

methods. Animalia includes simple sedentary organisms such as sponges to the highly evolved vertebrates, the mammals.

Classification of Kingdom Animalia

Kingdom Animalia is divided into two subkingdoms based on the organization of cells into tissues or higher levels of organisation.

i) **Parazoa:** These are multicellular animals without the formation of well defined tissues. The only phylum included in this group is Porifera (e.g. *Sponges*).

ii) **Eumetazoa:** These are multicellular animals with well defined tissues and higher levels of organization such as organs and organ- systems in the body. This group includes two taxonomic levels called Grades.

Grade:1. Radiata or Diploblastica

These are the first true metazoans or eumetazoans with radial symmetry and diploblastic body (having two primary germinal layers, the ectoderm and endoderm) Phyla : Cnidaria (e.g. *Hydra, Aurelia,*etc.) and Ctenophora (comb jellies) are included in this Grade.

Grade: 2. Bilateria or Triploblastica

This Grade includes eumetazoans with bilateral symmetry and triploblastic body (having three primary germinal layers, the ectoderm, mesoderm and endoderm). This includes two taxonomic levels called **Divisions**.

Division: I: Protostomia (*Proto* : first ; *Stomium* : mouth)

The eumetazoans in which blastopore develops into mouth are referred to as the protostomians . In the protostomes cleavage pattern is ***spiral*** *and* ***determinate***. This Division includes three Sub-Divisions.

Sub-division: i) Acoelomata: (*a*:without; *coelom*: bodycavity; *ata*:having)

These organisms are the first triploblastic eumetazoans with ***solid body plan*** (without a body cavity/space between the body wall and visceral organs). The perivisceral space is filled with a tissue called parenchyma/ mesenchyme (derived from the germinal layer called mesoderm) e.g. Phylum Platyhelminthes (flat worms).

Sub-division: ii) Pseudocoelomata (*pseudo*:false; *coelom*:bodycavity; *ata*:having):

Animals of this group possess a body cavity between the body wall and the alimentary canal (perivisceral space derived from the embryonic blastocoel).

However it is not a 'true coelom/ secondary body cavity' as it is not lined by mesodermal epithelial layers (parietal and visceral peritoneal layers). Pseudocoel is a remnant of the embryonic blastocoel/ primary body cavity e.g., the phylum Nematoda. (Note: Truecoelom (eucoelom) is called secondary body cavity).

Sub-division: iii) Schizocoelomata: (*schizo*:splitting; *coelom*:body cavity; *ata*:having) They have a 'true coelom', which is a 'schizocoel'. It is formed by ***splitting*** of the mesoderm into outer somatic and inner splanchnic layers e.g. the phyla Annelida, Arthropoda and Mollusca. (Note: In the vertebrates coelom is formed by the splitting of the mesoderm (called secondarily schizocoelic)).

Division: II) Deuterostomia (*deuteron*: secondary; *stomium*: mouth)

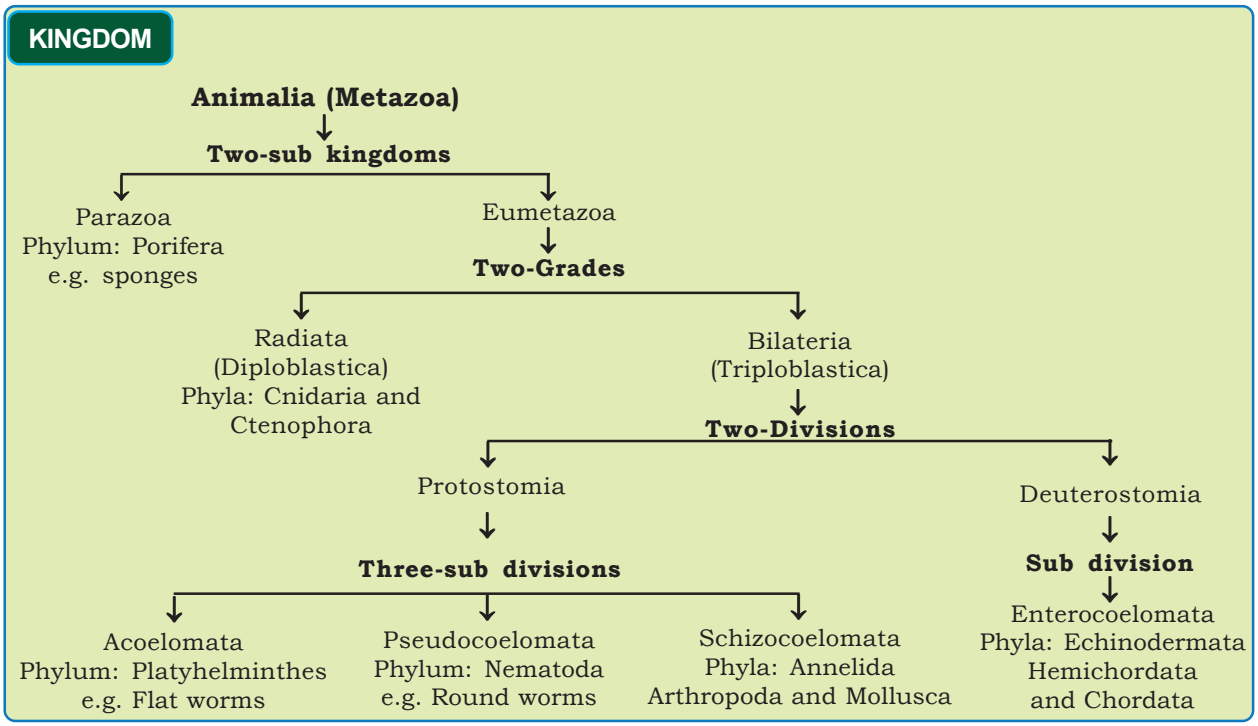
These are eucoelomates in which anus is formed from or near the blastopore. Mouth is formed later (secondarily), away from the blastopore at the opposite end. In deuterostomes cleavage pattern is ***'radial'*** *and* ***'indeterminate'***. It includes only one subdivision, **Enterocoelomata**.

Sub-division: Enterocoelomata

They have a true coelom, which is an 'enterocoel'. It is formed by the out pouching of the archenteron. The phyla Echinodermata, Hemichordata and Chordata are included in this subdivision.

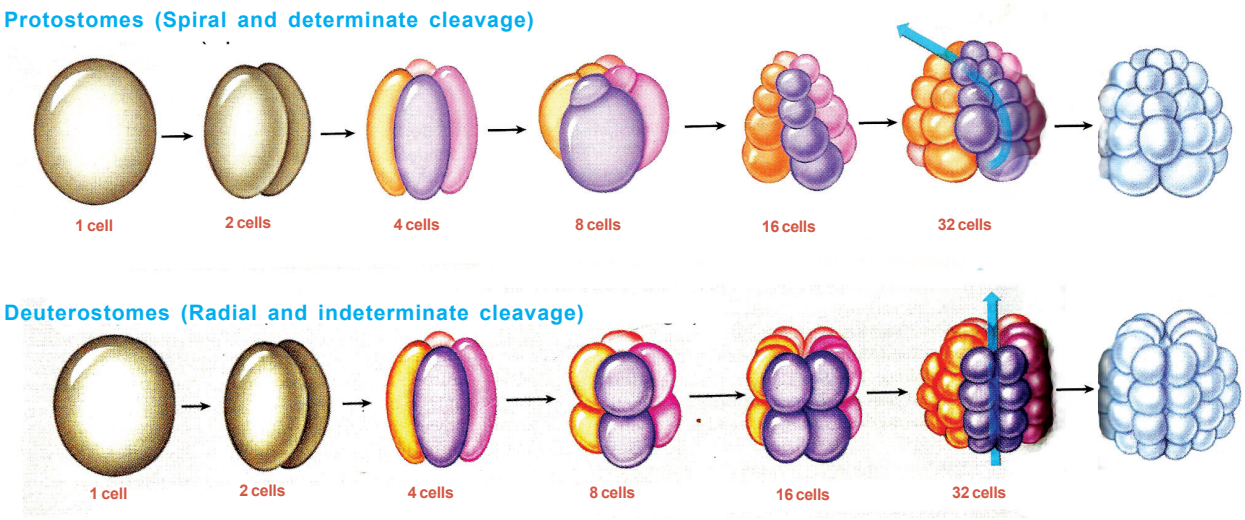
Schizocoelomates and enterocoelomates are together called 'eucoelomates' as they possess a 'true coelom'.

Based on the knowledge gained, can you write the taxonomic position of human being (taxonomic hierarchy) starting from the Kingdom to the species/subspecies? (Take the help of your teacher, if you fail to do).



Note : Embryos of protostomes are called '***mosaic embryos***' and those of deuterostomes are called '***regulative embryos***'

Diagrams showing embryonic development in protostomes and deuterostomes.



1.10 Biodiversity

I. What is Biodiversity?

When we observe our surroundings we find different kinds of organisms which vary in size, form, feeding habits, behaviour, etc. For example there are more than 20,000 species of ants, 3,00,000 species of beetles, 28,000 species of fishes and 20,000 species of orchids. This variation of life at various levels of biological organization is termed as biodiversity.

II. Levels Of Biodiversity

Biodiversity exists not only at the species level but at all levels of biological organization ranging from macromolecules within the cells to ***biomes*** (biotic community in a large area).

The term biodiversity was popularized by the sociobiologist **Edward Wilson** to describe the combined diversity at all levels of biological organization. The three levels of biodiversity are:

1. Genetic diversity
2. Species diversity
3. Ecological diversity.

1. Genetic diversity

It is the diversity of genes within a species. A single species may show high diversity at the genetic level over its distributional

range. For e.g. *Rauwolfia vomitoria*, a medicinal plant growing in the Himalayan ranges shows great genetic variation,which might be in terms of ***potency*** and ***concentration*** of the active chemical (***reserpine*** extracted from it is used in treating high blood pressure) that the plant produces. India has more than 50,000 different strains of rice, and 1,000 varieties of mangoes. ***Genetic diversity*** increases with environmental variability and is advantageous for its survival.

2. Species Diversity

It is the diversity at the species level. e.g: amphibian diversity in the Western Ghats is greater than that of the Eastern Ghats.

3. Ecological diversity

Diversity at a higher level of organization, i.e. at the ecosystem level is called 'Ecological diversity'. e.g: India with its deserts, rain forests, mangroves, coral reefs, wet lands, estuaries and alpine meadows has greater ecosystem diversity than many other countries such as the Scandinavian country Norway.

The three indices of ecological diversity are-***Alpha***, ***Beta*** and ***Gamma*** diversity

i. Alpha diversity: It is measured by counting the number of taxa (usually species) within a particular area, community or ecosystem.

ii. Beta diversity: It is the species diversity between two adjacent ecosystems and is obtained by comparing the number of taxa ***unique to each of the ecosystems***.

iii. Gamma diversity: It is the measure of the ***overall diversity for different ecosystems*** within an ecological region ('***Ecological Region***' *is a large area constituting a natural ecological community with characteristic flora and fauna, bounded by natural boundaries*).

III. Other attributes of biodiversity

A species unique to a given area is called ***endemic species***. Pattern of biodiversity depends on factors such as i)Latitude and ii)Species –area relationship

1. Latitudinal Gradient in Diversity

Biodiversity is not uniform throughout the world but shows rather uneven distribution. The most important pattern of biodiversity is latitudinal gradient in diversity. This means that there is an increasing diversity from the poles to the equator (terrestrial biodiversity increases from the poles to the equator). There is a vast majority of species concentrated in the tropics and sub tropical regions. This means localities at lower latitudes have more species than localities at higher latitudes.

Tropics harbour more species than temperate or polar areas for e.g. The tropical Amazon rain forest in south America has the greatest biodiversity on the Earth. Species diversity is more in the tropics. The following data explains latitudinal gradient :

Place	Number of species of birds	Latitude
Colombia	1400	0^{o}N
New York	105	41^{o}N
Green land	56	71^{o}N

From the above data it is clearly evident that as the latitude increases the species diversity decreases.

Reasons for greater biodiversity in the tropics:

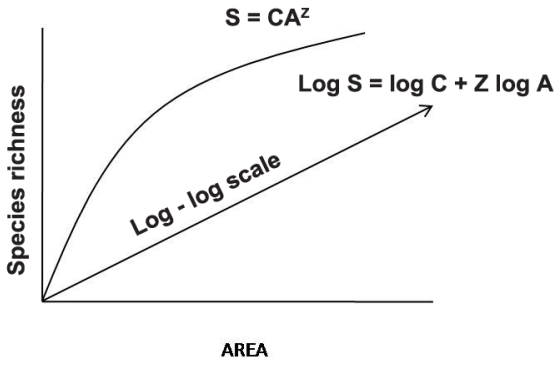
Reason 1: Tropical latitudes have remained relatively undisturbed for millions of years and thus had a long 'evolutionary time'. As long duration was available in this region for speciation, it led to the species diversification. (Note: The temperate regions were subjected to frequent glaciations in the past).

Reason 2: Tropical climates are relatively more constant and predictable than that of the temperate regions. Constant environment promotes **niche specialization** (how an organism responds, behaves with environment and other organisms of its biotic community), and this leads to greater species diversity.

Reason 3: Solar energy, resources like water etc., are available in abundance in this region. This contributed to higher productivity in terms of food production,leading to greater diversity.

2. Species-Area relationships

Before we learn relation between species richness and the area available to them, let us learn the term 'species richness'.



Species Richness is the number of species per unit area. The more the number of species in an area the more is the species richness.

Alexander von Humboldt observed that within a region, species richness increased with increasing explored area, but only up to a limit. In fact, the relation between species richness and area for a wide variety of taxa (angiosperm plants, birds, bats, fresh water fishes) turns out to be a non-linear curve. On a logarithmic scale, the relationship is a straight line described by the equation.

log S= log C+ Z log A

where

S = species richness

A = area

Z = slope of the line (regression coefficient)

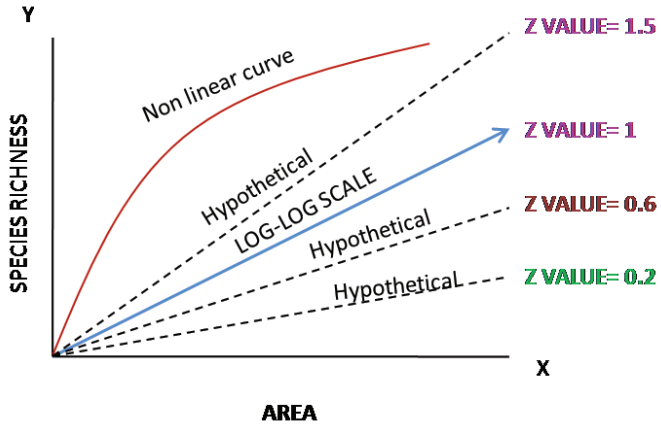
C = Y-intercept

Ecologists have discovered that the value of Z lies in the range of 0.1 to 0.2 regardless of the taxonomic group or the region (whether it is California or New York or Britain).If you analyse species -area relationship among very large areas like entire continents the slope of the line is much steeper(Z values in the range of 0.6 to 1.2) for example for frugivorous (fruit-eating)birds and mammals in the tropical forests of the different continents, the slope is found to be **1.15**.

What do ***steeper slopes*** mean in this context ?

A simplified explanation to help Biology Teachers

Teachers of Biology might find it difficult to understand and explain the mathematical expression represented in this part. The graphic representation is essentially intended to explain the relationship between 'species richness' and 'area'. In a specified area the relation between '**S**' (species richness) and '**A**' (area) is $S=CA^Z$ and it is represented by a **Non-linear curve.**



For easy understanding, to get a ***linear relation*** between S and A, '**log scale**' is taken. Logarithmic relation between A and S is given by **log S = log C+Z log A**. The '***curve***' shows that species richness increases with increase in area to a certain extent and approaches an ***equilibrium state/ stable state***. It does not indicate the '**specific rate**' at which species richness increases with reference to area. The '**SLOPE**' of the graph drawn between log A (taken along **X axis**) and log S (taken along **Y axis)** is **Z**. Increase in the 'slope' indicates ***increase in Z*** indicating 'increase in species richness', as shown in the graph. For example, if the log-log scale makes 45^0 with X axis, Z is **1**. If the slope is less, Z is less than '**1**' and if the slope is more than 45^0 the value of Z is more than **1**. Now it is easy to understand that the value of **Z** in a '***tropical rain forest***' is more than 1, as represented by the 'increased slope'.

Importance of Species Diversity to the Ecosystems

Communities with more types of species (more biodiversity) tend to be more stable than those with less number of types of species .Stable communities generally withstand disturbances (natural or man-made). **Tilman's** experiments with 'outdoor plots' showed that 'plots with more species showed less variations in biomass year-to-year'. He also showed that increased **diversity contributed to higher productivity**.

What if we lose a few species ? Will it affect man's life? **Paul Ehrlich's** experiments 'the **RIVET POPPER**' hypothesis, taking an aeroplane as an ecosystem, explains how removal of one by one 'rivets' (species of an ecosystem) of various parts can slowly damage the plane(ecosystem)-shows how important a 'species' is in the overall functioning of an ecosystem. Removing a rivet from a seat or some other relatively minor important parts may not damage the plane, but removal of a rivet from a part supporting the wing can result in a crash. Likewise, removal of a '**critical species**' may affect the entire community and thus the entire ecosystem.

IV. Role of biodiversity

Biodiversity is beneficial to human beings as it plays an important role at various levels of development and to explain the role played, the different aspects are categorised into three types,

1. Narrowly utilitarian argument
2. Broadly utilitarian argument
3. Ethical argument

1) **Narrowly utilitarian argument:** Human beings derive countless economic benefits from nature as biodiversity is a **reservoir of resources**. Food (cereals, pulses & fruits), Firewood, Fibre, Construction material, Industrial products (tannins, lubricants, dyes, resins, perfumes, rubber, latex, cork, etc.) and products of medicinal importance (for example Anticancer drugs – **Vinblastin** from *Vinca rosea*, **Digitalin** from the 'fox glove' plant (*Digitalis purpurea*) to treat certain cardiac problems, etc.) are obtained from diverse living organisms which are economically important. Bio-prospecting nations endowed with rich biodiversity can expect to reap enormous benefits.

2) **Broadly utilitarian argument:** It explains that biodiversity plays a major role in many ecosystem services that nature provides, for which we cannot put a price tag (*we cannot fix its price*). To exemplify this, consider the following -

e.g.1 : Amazon produces 20 % of the total oxygen in the earth's atmosphere.

e.g.2 : Pollination by pollinating agents(bees, birds, bats, etc.,) without which plants do not produce fruits and seeds. There are other benefits also, the ones which cannot be measured in terms of money , like aesthetic pleasure derived by taking a walk in the woods.

3) **Ethical argument :** It relates to what we owe to plants, animals and microbe species with which we co-exist on this planet. The moral duty to care and pass on biological legacy to future generations is the need of the hour as every species has an *intrinsic value.*

V. Threats to Biodiversity

The following are the '***four major causes***' (***THE EVIL QUARTET***) for accelerated rates of species extinction in the world.

1. **Habitat Loss And Fragmentation :** These are the most important reasons for the loss of biodiversity.
   a) Deforestration-leads to species extinction in forests e.g: tropical rain forests once covering 14% of the earth's land surface is now not more than 4%.
   b) Conversion of forest land to agricultural land e.g: the AMAZON RAIN FOREST, called '**lungs of our planet**', harbouring innumerable species is cut and cleared to cultivate SOYA BEANS or conversion to grass lands for raising beef cattle.
   c) Pollution enhances degradation of habitats and threatens the survival of many species as pollutants change the quality of the environment.
   d) Fragmentation of habitat leads to population decline e.g: mammals and birds requiring large territories and certain animals with migratory habits are badly affected.

Fragmentation
It is the process of formation of discontinuities in the natural habitats due to geological processes or human activities. Geological fragmentation may lead to speciation, but fragmentation caused by man (human activity) mostly leads to extinction of many species.

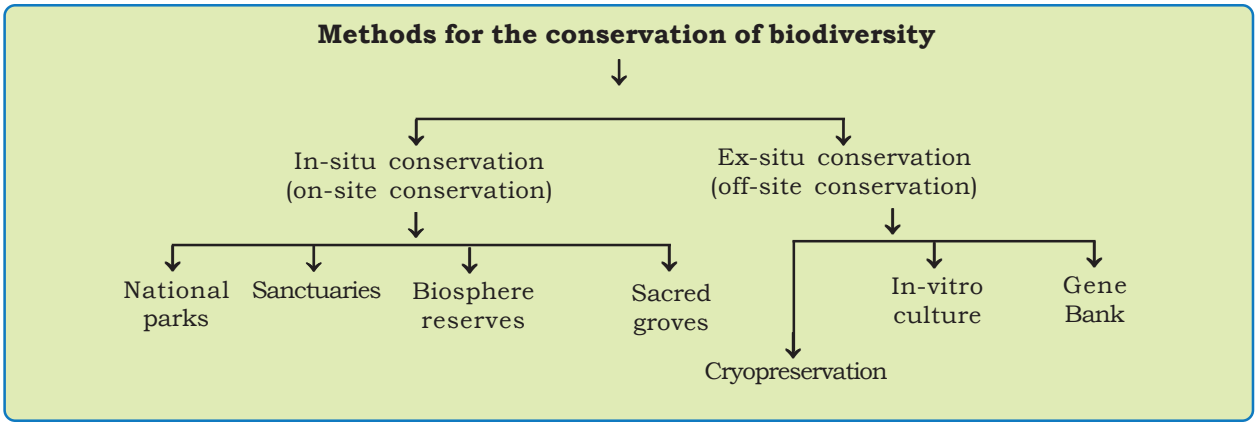
2. **Over-exploitation: When need turns to greed it leads to over exploitation** e.g., Steller's sea cow (sea cow named after Steller, a naturalist),passenger pigeon(which existed in North America)are extinct due to over-exploitation by humans. The existence of many commercially important marine fishes are endangered as they are over harvested.
3. **Invasion Of Alien Species :** When alien species are introduced into a habitat, they turn ***invasive*** and establish themselves at the cost of the indigenous species(organisms which occur naturally in a particular region).
   E.g.1: **Nile perch** introduced into Lake Victoria, in east Africa led to the extinction of 200 species of cichlid fish in the lake.
   E.g.2: Illegal introduction of exotic **African catfish**, *Clarias gariepinus*, for aquaculture purposes is posing a threat to the indigenous cat fishes.

E.g.3: When exotic and invasive weeds like the 'carrot grass' (*Parthenium*), 'spanish flag' (*Lantana*), 'water hyacinth' (*Eichhornia*) are introduced into our ecosystems they not only damaged the environment but also threatened the very existence of native species.

4. **Co-extinctions:** In an obligate association between a plant and an animal, if a plant becomes extinct, the animal also becomes extinct as seen in a parasite and host association. If the host becomes extinct, parasite meets the same fate. Another association which explains co-extinction is **plant-pollinator mutualism** where extinction of one invariably leads to the extinction of the other.

VI. Methods of Conservation of Biodiversity?

The conservation of biological diversity has become a global concern. There are basically two main types of conservation options-**In-situ** conservation and **Ex-situ** conservation. In-situ is usually seen as the 'ideal conservation strategy'. Ex-situ conservation can provide a **backup solution** to in-situ conservation projects.



1. In-situ conservation (On-site conservation)

In-situ conservation is the process of protecting an animal species in its natural habitat. The benefit is that it maintains recovering populations in the surrounding where they have developed their distinctive properties. Conservationists identified certain regions by name '**Biodiversity hot spots**' for maximum protection as they are characterized by very high levels of species richness & high degree of endemism. By definition 'Biodiversity hot spot' is a 'Biogeographic Region' with a significant reservoir of biodiversity that is under threat of extinction from humans. They are Earth's biologically 'richest' and 'most threatened' ***terrestrial*** Ecoregions.

The concept of Biodiversity hot spots swas proposed by **Norman Myers**. There are about 34 biodiversity hot spots in the world. As these regions are threatened by destruction, habitat loss is accelerated e.g. :I) Western Ghats and Srilanka ; II) Indo

Burma; III) Himalayas in India. Ecologically unique and biodiversity rich regions are legally protected as in 1. Biosphere Reserves–**18** (18th is PANNA in Madhya Pradesh), 2. National Parks–**90**, 3. Sanctuaries-**448**.

i. Biosphere Reserves

An area which is set aside, minimally disturbed for the conservation of the resources of the biosphere is '**Biosphere reserve**'. Latest biosphere reserve(17th biosphere reserve in India) is **Seshachalam hills**.

ii. National Parks

A National Park is a natural habitat strictly reserved for protection of natural life. National Parks, across the country, offer a fascinating diversity of terrain, flora and fauna. Some important National Parks in India are - **Jim Corbett National Park** (the first National Park in India located in Uttarakhand), **Kaziranga National Park** (Assam), **Kasu Brahmananda Reddy National Park**, **MahavirHarinaVanasthali National Park** (AP), **Keoladeo Ghana National Park** (Rajasthan), etc.

iii. Sanctuaries

Specific ***endangered faunal species*** are well protected in wildlife sanctuaries which permits eco-tourism (as long as animal life is undisturbed). Some important Sanctuaries in India (AP) include-Koringa Sanctuary, Eturnagaram Sanctuary, Papikondalu Sanctuary.

iv. Sacred Groves

1. A smaller group of trees than a forest is called grove.
2. A grove of trees of special religious importance to a particular culture is called sacred grove.
3. In these regions all the trees of wild life are venerated (respected) and given total protection.

The following is a list of Sacred Groves in INDIA

Name	State
Khasi and Jaintia Hills	Meghalaya
Aravalli Hills	Rajasthan and Gujarat
Western Ghat region	Karnataka and Maharashtra
Sarguja, Bastar	Chhattisgarh
Chanda	Madhya Pradesh

In Meghalaya, Sacred Groves are the last refuges for a large number of rare and threatened species.

2. Ex-situ conservation:

In ex-situ conservation threatened animals are taken out of their natural habitat and placed in special settings where they are protected. This includes Zoological Parks. Advancement in ex-situ preservation techniques such as ***cryopreservation*** are helping us protect endangered species (cryopreservation is the preservation of, for example, gametes, embryos of threatened species, etc., at -196^0 C). Invitro culture, gene banks are mostly used for plants.

VII. IUCN Red data books

International Union for the Conservation of Nature and Natural Resources (IUCN) is the world's main Authority on the issues of conservation status of species.

All the threatened species are listed in the **Red Data Books** published by the IUCN. These species are classified into different categories based on degree of risk and they are chiefly :

a) Critically endangered

b) Endangered

c) Vulnerable

VIII. Conservation of wild life in INDIA

This is through legislation,preservation and organisations

1. Legislation: Under the provision of the **Wildlife Act of 1972**, killing endangered wild animals is strictly prohibited. Trading wildlife products (like tusks, rhino's horns, etc.) is a punishable offence.

2. Preservation: National Parks, Sanctuaries, Biosphere Reserves, Sacred Groves etc. are different regions which are earmarked to protect diverse fauna and flora.

3. Organisational Protection: Organisations which are set up to prevent destruction of India's wild life are

1. Wild life protection society of India (**Dehradun**)
2. Zoological Survey of India (**Kolkata**)

Conservation of biodiversity is a ***global necessity.***It is the collective responsibility of all nations to protect the diverse living forms on the planet. One such step was in the form of **EARTH SUMMIT** (1992-Rio de Janiero)and the other being **WORLD SUMMIT** on sustainable development (Johannesburg-South Africa). They focussed on significant reduction in the current rate of loss of biodiversity at the global, regional and local levels. Efforts must be intensified to pass on our biological legacy to the future generations.

IX. Threatened Species in India

The Asiatic lion	*Panthera leo persica*
The black buck	*Antelope cervicapra*
Red panda	*Ailurus ochraceus*
The lion-tailed macaque	*Macaca silenus*
Tiger	*Panthera tigris*
Kashmiri stag	*Cervus elaphus hanglu*
Elephant	*Elephas maximus indicus*
Pygmy hog	*Sus salvanius*
Siberian crane	*Grus leucogeranus*
Slender loris	*Loris tardigradus*

In conclusion-Nature is a repository of diverse life. Intrusion into nature's domain distorts its equilibrium. Preserving nature is a collective 'Global Responsibility'. Man should conserve and protect nature in his own interest and for the future generations.

GLOSSARY

Nutrition: The process by which an organism assimilates food and uses it for growth and maintenance.

Protein: Building blocks of life which are polymer chains made of amino acids linked together by peptide bonds.

Prokaryotes: Single celled organisms that lack a membrane bound nucleus.

Eukaryotes: Organisms whose cells contain a membrane bound nucleus and other complex membrane bound cell organelles.

Glycogen: It is a polysaccharide that is the principal storage of glucose in animal cells analogous to starch in plants.

Chordata: A phylum which includes animals showing notochord at some stage in life cycle.

Phylogeny: The evolutionary history of an organism.

Analogous Characters: They denote similarity in function without necessary anatomical similarity (wings of birds and butterflies).

Assortative mating: It is a selective mating/ non-random mating within their population.

Tissue: A group of cells of similar origin that perform a similar function.

Holozoic: It is a method of nutrition that involves ingestion of liquid or solid organic material.

Ctenophora: An invertebrate phylum of animals which are commonly called 'comb jellies'.

Spiral cleavage: It is characteristic of the protostomes in which planes of cell division are diagonal to the vertical axis/polar axis of the embryo.

VERY SHORT ANSWER TYPE QUESTIONS

1. Define the term metabolism. Give any one example.
2. How do you differentiate between growth in a living organism and non-living object?
3. What is biogenesis?
4. Define the term histology. What is it otherwise called?
5. Distinguish between embryology and ethology.
6. In a given area, remains of animal that lived in the remote past are excavated for study. Which branch of science is it called?
7. 'Zoos are tools for classification' Explain.
8. Where and how do we preserve skeletons of animals, dry specimens etc?
9. What is trinominal nomenclature? Give an example.
10. What is meant by tautonymy? Give two examples.
11. Differentiate between Protostomia and Deuterostomia.
12. 'Echinoderms are enterocoelomates' Comment.
13. What does ICZN stand for?
14. Give the names of any four protosotomian phyla.
15. What is ecological diversity? Mention the different types of ecological diversities.
16. Define species richness.
17. Mention any two products of medicinal importance obtained from Nature.

18. Invasion of an Alien species leads to extinction of native species. Justify this with two examples.
19. List out any four sacred groves in India.
20. Write the full form of IUCN. In which book threatened species are enlisted.

SHORT ANSWER TYPE QUESTIONS

1. Explain the phylogenetic system of biological classification.
2. Explain the hierarchy of classification.
3. What is meant by classification? Explain the need for classification.
4. Define species. Explain the various aspects of 'species'.
5. What is genetic diversity and what are the different types of genetic diversity?
6. What are the reasons for greater biodiversity in the tropics?
7. What is the 'evil quartet'?
8. Explain in brief 'Biodiversity Hot Spots'.
9. Explain '***Rivet Popper***' hypothesis.
10. Write short notes on In-situ conservation.

For ignited minds

- Not For Evaluation

1. If you drink a 'sugar rich' soft drink , the sugar levels in your blood increase quickly. If the sugar levels in blood increase sensitive cells such as' brain cells' are damaged. Your pancreatic islets produce a hormone called 'insulin' which allows uptake of sugars by body cells so that the body cells utilise them and generate ATP for cellular life activities. The sugar levels of your body fluids come down to normal 'tolerable levels'. What do you think is the 'biological phenomenon' that happened in this case?

   Clue: The body always tries to maintain equilibrium state.

2. What, in your expectation, will happen when 'cancer cells' are starved?

   Answer: When cancer cells are starved, they cannot show growth .If there is no growth, cells do not multiply. Anabolism is a necessary part of life.

3. What, in your view are reasons for the occurrence of 'variations' in living organisms and the role played by such variations in nature?

4. Why, in your view, children are not 'exact copies' of their parents, when they do inherit parental DNA, which governs their body features?

5. On a cold winter day when you walk outside , you tend to 'shiver'. Can you explain why such 'shivering' is caused?

6. You have learnt about ageing (senescence) in your lesson. Would you like to know one more interesting concept about ageing - It is also controlled by ***genes*** or to put it in other words ***ageing*** is also '***genetically programmed*** '. Have you heard of '**Dolly**' the lamb produced by '**cloning**' of the 'udder cell' (somatic cell of the mammary glands) of ***Finn Dorset Ewe*** (Finn Dorset is a variety of sheep in England ; Ewe is a 'Female sheep'). The average life span of Finn Dorset sheep is about **12** years by which time it develops 'senescence' and dies. 'Dolly' was developed ***asexually*** by ***cloning***, like how a single zygote cell develops into a young one in the case of sexual reproduction. ***Do you know how long 'Dolly' lived ?*** It is just about ***six years***. Can you guess why it lived for only **six years,** when the average life span of that type of sheep is ***twelve*** years? *The answer is*–'Dolly', when born, was already ***six years old, 'genetically speaking'***, as it developed from the udder cell of a ***six year*** old sheep, the Finn Dorset ewe. When Dolly was 6 years old, its genetic material is 12 years old, hence the death .

7. Do you agree with the statement the log-log scale linear relation in the south American tropical forests will be > 45^0?

8. When the human zygote undergoes the first division into two cells, if the two cells are separated they develop into identical twins. Will the same thing happen in the case of earthworm? Why/ Why not?

9. In your opinion can a population be made up of a group of intra-specific variants'? if your answer is Yes, how do you defend?

10. Which among the following encompasses the others - Genus / Grade / Division / Class / Order?

Marie Francois Xavier Bichat

Bichat *was a French anatomist and physiologist, best rememebered as the '**Father of modern histology**' and **pathology**. He coined the term '**tissue**'. He revealed that diseases attack tissues rather than whole organs.*

Unit

2

Structural Organisation in Animals

TISSUES-THE '*JACKS OF ALL TRADES AND MASTERS OF NONE*'

In the evolution of animals, the major event of significance is the 'development of tissues'. The '**tissue *grade of organisation***' evolved for the first time in the '***cnidarians***'. When the zygote undergoes cleavage, it results in the production of many cells. During the embryogenesis itself, cells differentiate themselves into different kinds of tissues to perform different functions (***division of labour***). When a cell is marked for a specific function, both the cell and its descendants are destined to do that specific function only (except in the ***sponges***). In the parazoans, mature cells can '***dedifferentiate***' or 'redifferentiate' and perform certain functions that are not their usual functions. For example, a choanocyte of a sponge can stop its normal function of collection of food and digestion and can produce gametes.

Production of tissues has an *evolutionary advantage* compared to organisms in which there are no '**true tissues**' (e.g., **sponges**). As somebody rightly observed '**Tissues are jacks of all trades and masters of none**' (they do take part in every biological activity doing their assigned function, contributing their part for the completion of the overall ***integrated biological activity*** of the organism). Tissues are essentially of ***four*** types – epithelial, connective, muscular and nervous.

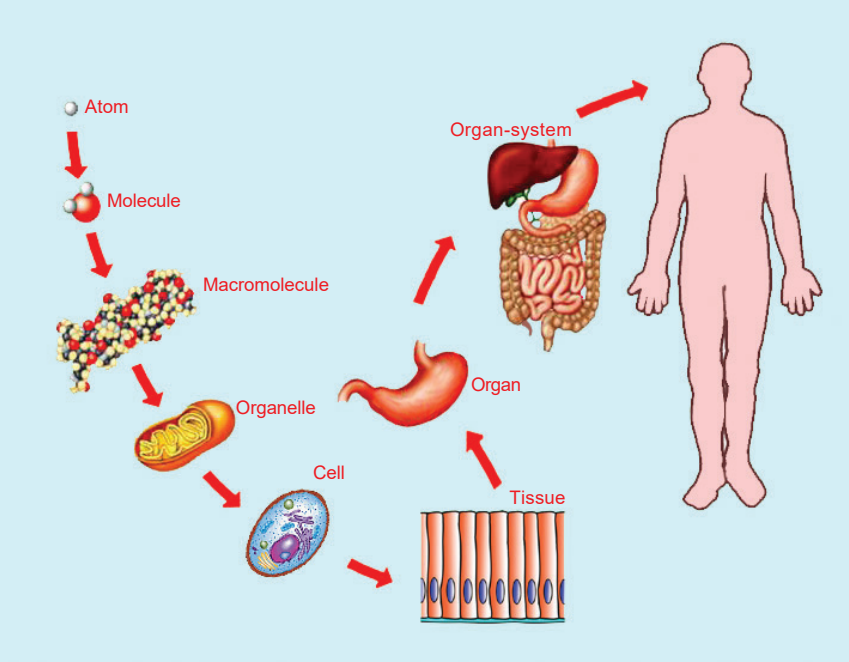
Epithelial tissues cover the outer surfaces/free surfaces of the body organs and act as 'physical barriers' protecting organisms from pathogens. They are also involved in the ***repair of injuries***. Epithelia in 'sense organs' receive ***sensory stimuli***. They form '***glands***', which are ***secretory*** in function, in certain regions of the body.

Tissues show several adaptations to meet the requirements of the body. ***Connective tissues*** help in binding and supporting other tissues. A connective tissue has diffuse cells interspersed by 'extracellular matrix' made up of different types of fibres (collagen, elastic and reticular fibres). Various types of fibres are formed by cells called '***fibroblasts***'. The matrix of connective tissue also contains '***macrophages***' which 'phagocytize' pathogens.

Muscular tissues are concerned with various types of movements in the body. They contain proteins such as '***actin***' and '***myosin***', which together cause contraction in a muscle. Muscles are of three types - skeletal, cardiac and smooth. *Skeletal* and *cardiac* muscles are of the '***striated***' type and smooth *muscles* (also called ***visceral muscles***) are '***unstriated muscles'***.

Nervous tissue senses 'stimuli' and conducts (**transmits**) them in the form of ***nerve impulses*** (*action potentials*) from one part of the body to another. It consists of nerve cells called '**neurons**'. Nervous tissue also contains various types of '***glial cells***', which help in nourishment, insulation of axons, protection etc. Nervous tissue is chiefly involved in bringing about ***coordination*** between the activities of various body parts (***neural integration***).

You probably, understand now why somebody called tissues the '***JACKS OF ALL TRADES BUT MASTERS OF NONE***'.



Levels of organisation

2.1 Levels of Organisation

Living world includes a large number of acellular and multicellular organisms with vast differences in their structure and form. In spite of the differences in the structure and form of different animals, there are fundamental features common to various individuals in relation to the arrangement of cell layers, symmetry and nature of coelom, patterns of digestive, circulatory, reproductive systems,etc.

There are five levels of organisation from the protozoans to the higher metazoans. They are as follows:

Protoplasmic level

Protozoans are the simplest protists. All the basic functions of life such as locomotion, digestion, respiration, excretion, osmoregulation and reproduction are performed by a single cell (The single cell acts as a complete organism) in protozoans. Within the cell, protoplasm is differentiated into cell organelles which carry out different functions. It is called **protoplasmic level of organisation.**

Note: *Mention of the protoplasmic level is only to provide better understanding as only metazoans are dealt with in this chapter.*

2.1.1 Levels of organisation in the metazoans

Though all the members of the kingdom Metazoa are multicellular, all of them do not exhibit the same pattern of organisation of cells. Cells of the metazoans are not capable of independent existence, and exhibit 'division of labour' at various levels of organisation. Among the metazoans of different kinds, cells may be functionally isolated or grouped together to form tissues, organs or organ-systems and as such structural complexity increases from the lower metazoans to the higher metazoans.

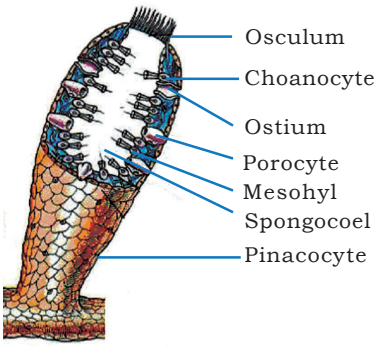


Fig. 2.1 Sponge (body partly cut open) showing cellular level of organisation.

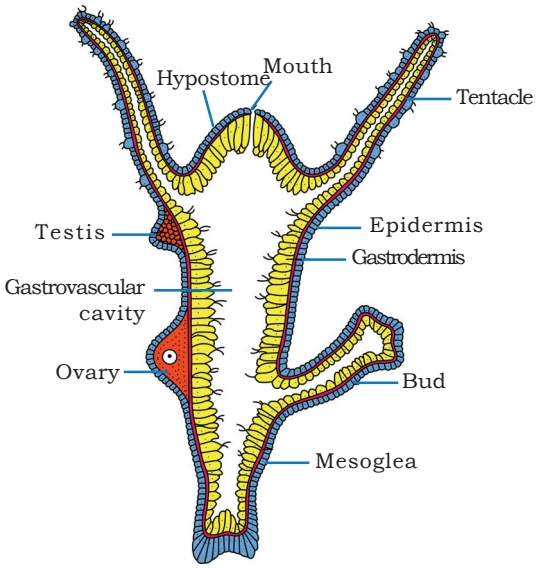


Fig. 2.2 L.S. of Hydra (Showing tissue level of organisation)

The levels of organisation in metazoans are as follows:

I. Cellular level of organisation

It is the lowest level of organisation among the metazoans and is exhibited by the sponges (parazoans). Different types of cells are functionally isolated due to the absence of sensory and nerve cells. The cells are arranged as '**loose cell aggregates**' and do not form tissues. There is division of labour among the cells. The outer layer of body wall is formed by pinacocytes and porocytes (cells that conduct water from the outside into the spongocoel), whereas the inner layer lining the spongocoel is formed by choanocytes. In between the two layers, a non-cellular mesohyl is present.

II. Tissue level of organisation

This is the lowest level of organization among the eumetazoans, exhibited by **diploblastic** animals like the cnidarians. In these animals, the cells which perform the same function are arranged into **tissues**. The cells of a tissue together perform their common function as a highly coordinated unit and this coordination is due to the presence of **nerve cells** and **sensory cells. The formation of tissues is the 'first key transition' in the evolution of the animal body plan.** Development of bilateral symmetry is the 'second key transition' and the origin of perivisceral cavity (body cavity) is the 'third key transition.

III. Organ level of organisation

An aggregation of different kinds of tissues which is specialized for a particular function is called an organ. Organ level of organisation is a further advancement over the tissue level in the evolution of levels of organisation. Organ level of organisation appeared for the first time in the members of the Phylum Platyhelminthes. (Ref: NCERT XI Class biology text book)

IV. Organ-system level of organisation

It is the highest level of organisation among the animals and is exhibited by the triploblastic animals such as the flat worms, nematodes, annelids, arthropods,

molluscs, echinoderms and chordates. In the triploblastic animals, the evolution of '**mesoderm**' resulted in structural complexity. In these animals, the tissues are assembled to form organs and complex organ-systems. Highly specialized sensory and nerve cells bring about a higher level of coordination and integration among the various organ systems to lead an efficient way of life. Organ systems in different groups of animals exhibit various patterns of complexities. For example, the alimentary canal in the members of Platyhelminthes has only a single opening to the exterior, and it serves as both mouth and anus, hence it is called **incomplete gut**. A complete alimentary canal has two openings, the mouth and the anus. Such a gut is seen in the animals ranging from the nematodes to chordates. Similarly, circulatory system may be of two types.

a) **Open type:** In this type, blood pumped out of the heart flows through open spaces bathing the cells and tissues directly. e.g., members of Arthropoda, Mollusca, Echinodermata and Urochordata.

b) **Closed type:** In this type, the blood is circulated through a series of vessels of varying diameter (arteries, veins and capillaries.) e.g., annelids, cephalopods, cephalochordates and vertebrates.

During the evolutionary history of animals, there has been a tendency towards increase in the body size, explain Why?

2.1.2 Diploblastic organisation

Animals, in which the cells are arranged in two embryonic layers, the external **ectoderm** and the internal **endoderm**, are called **diploblastic animals**, e.g., cnidarians and ctenophores. Ectoderm gives rise to the **epidermis**, the outer layer of the body wall. Endoderm gives rise to the **gastrodermis**, the tissue that lines the gut cavity. The cells in each tissue layer are functionally interdependent. An undifferentiated layer, present between the ectoderm and endoderm, is the '**mesoglea**'. In some diploblastic animals, cells occur in the mesoglea, but they are always derived either from the ectoderm or from the endoderm.

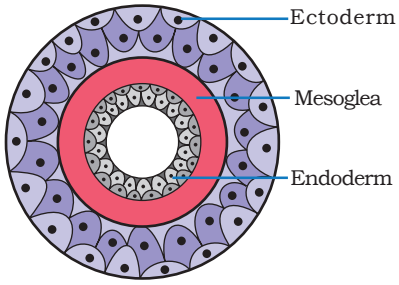


Fig. 2.3 (a) Diploblastic level of organisation

2.1.3 Triploblastic organisation

The animals, in which the developing embryo has a third germinal layer, the **mesoderm**, in between the ectoderm and the endoderm, are called **triploblastic animals**, e.g., flat worms to chordates. Most **triploblastic** animals have an organ-system level of organization. Tissues are organized into organs which form excretory, nervous, digestive, reproductive, circulatory and other systems. Triploblastic animals are usually **bilaterally symmetrical.** (Recall – the taxonomic grade Bilateria is also called Triploblastica).

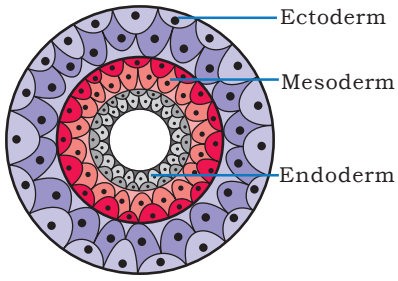
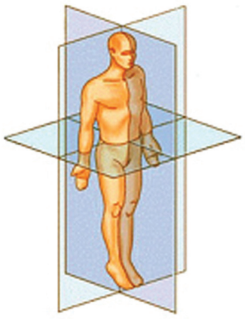


Fig. 2.3 (b) Triploblastic level of organisation



Human body showing symmetry

2.2 Symmetry

The concept of symmetry is fundamental in understanding the organisation of an animal. Symmetry in animals is balanced distribution of paired body parts. The body plan of a vast majority of metazoans exhibits some kind of symmetry. However, most of the sponges and snails show asymmetry (lack of symmetry). The symmetry of an animal and its mode of life are *correlated.*

2.2.1 Asymmetry

Sponge showing asymmetry

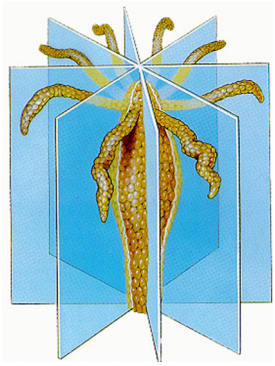
The animals, which cannot be cut into two equal parts (antimeres) in any plane passing through the centre of the body are called asymmetrical, e.g. most sponges and adult gastropods. In the asymmetrical animals, the body lacks a definite form. Asymmetry cannot be said to be an adaptation or advantage to an organism. Primarily asymmetrical organisms do not develop complex sensory and locomotor functions.

2.2.2 Symmetry

The regular arrangement of body parts in a geometrical design relative to the axis of the body is called symmetry. The animals, which can be cut into two equal parts, or antimeres in one or more planes passing through the '**principal axis**' of the body are called symmetrical animals. In a symmetrical animal, paired body parts are arranged on either side of the plane passing through the principal axis, such that they are equidistant from the plane. The unpaired body parts are located mostly on the plane, passing through the principal axis. Basically, the symmetry in animals is of two kinds:

i) **Radial symmetry** and

ii) **Bilateral symmetry**

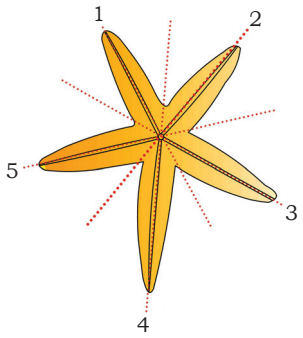


Hydra- showing radial symmetry

i) Radial Symmetry or Monaxial heteropolar (axis is single; poles are different) Symmetry

When any plane passing through the central axis (***oro-aboral axis/ principal axis***) of the body divides an organism into two identical parts, it is called ***radial symmetry***. The animals with radial symmetry are either sessile or planktonic or sluggish forms. It is the principal symmetry of the diploblastic animals such as the cnidarians and ctenophores (considered as biradial animals by some authors). Animals showing radial symmetry live in water and they can respond equally to stimuli that arrive from all directions. Thus, radial symmetry is an advantage to sessile or slow moving animals. However, triploblastic animals such as echinoderms are 'secondarily radially

symmetrical' (as it is five angled, it is also called **pentamerous radial symmetry**). Radially symmetrical animals have **many planes** of symmetry, whereas pentamerous radially symmetrical animals have **five planes** of symmetry.



Sea Star showing pentamerous symmetry

ii) Bilateral symmetry

When **only one plane** (*median sagittal plane*) that passes through the central axis (anterior – posterior axis) divides an organism into two identical parts, it is called **bilateral symmetry**. It is the *'principal type of symmetry'* in the **triploblastic** animals. Among the triploblastic animals, some **gastropods** become secondarily ***asymmetrical***, though they have primarily bilaterally symmetrical larvae.

Symmetry of an organism is determined based on the symmetry of the early developmental stages and not that of the adults.

Bilaterally symmetrical animals are more efficient than the other animals in seeking food, locating mates and in avoiding or escaping from predators, because of **cephalization** (*concentration of nerve and sensory cells at the anterior end*). As a result of cephalization, bilaterally symmetrical animals can sense the new environment into which they enter and respond more efficiently and quickly.

Note: Sea anemones and acnidarians are said to show biradial symmetry.

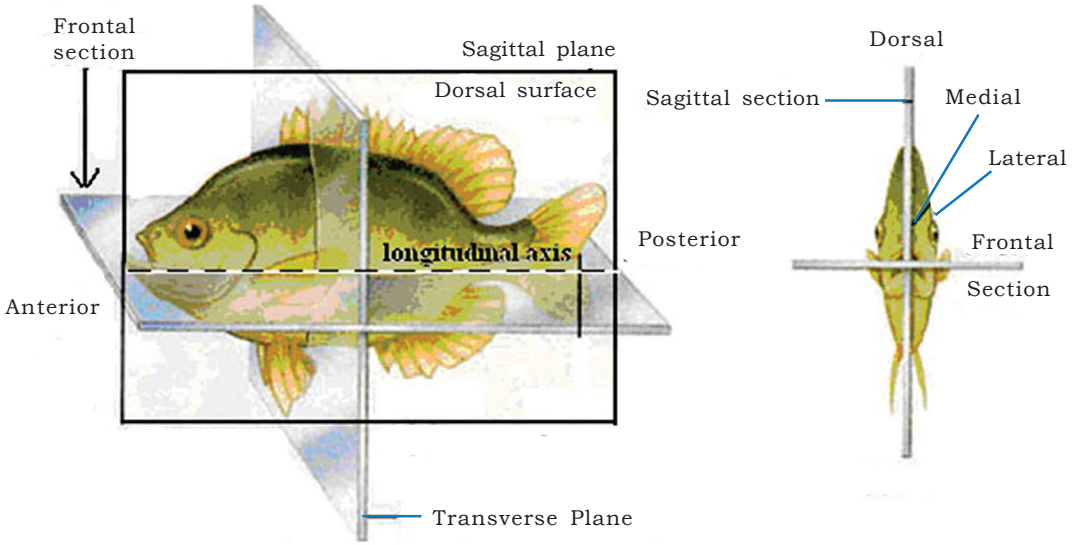


Fig. 2.4 Fish showing bilateral symmetry

2.3 Coelom

The term 'coelom' was coined by **Haeckel**. The body cavity, which is lined by mesoderm, is called coelom. More elaborately, coelom is a fluid-filled space between the body wall and visceral organs and lined by mesodermal epithelium, the peritoneum. Animals possessing coelom are called coelomates/eucoelomates. Evolution of efficient organ systems was not possible until the evolution of coelom for supporting the organs and distributing material.

2.3.1 Acoelomate bilaterians

The bilaterian animals in which the body cavity is absent are called acoelomates, e.g. Platyhelminthes (lowest bilaterians). In these animals, the mesenchyme derived from the third germinal layer, called mesoderm, occupies the entire blastocoel, between the ectoderm and the endoderm, so that the adults have neither the primary cavity (blastocoelom) nor the secondary cavity (coelom). As there is no body cavity, the acoelomates exhibit **solid body plan**. Problems faced by the acoelomates due to absence of perivisceral cavity are - their internal organs cannot move freely, as they are embedded in the mesenchyme, diffusion of material from the gut to the body wall is slow and less efficient.

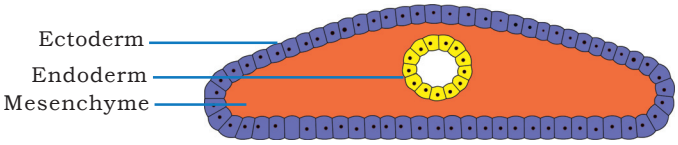


Fig. 2.5 T.S of acoelomate

2.3.2 Pseudocoelomate bilaterians

In some animals, the body cavity is not lined by mesodermal epithelia. Such animals are called Pseudocoelomates. They include the members of phylum Aschelminthes (Nematoda, Rotifera and some minor phyla). During the embryonic development, mesoderm (mesenchyme) occupies only a part of the blastocoel adjoining the ectoderm. The unoccupied portion of the blastocoel persists as **pseudocoelom**, which is filled with **pseudocoelomic fluid**. Pseudocoelomates are the first animals to exhibit a '**tube-within-a-tube**' organisation.

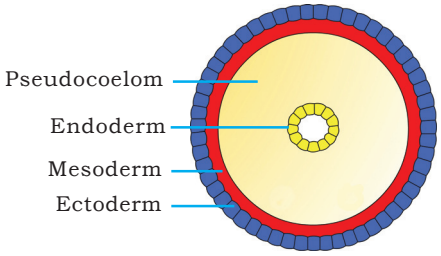


Fig. 2.6 T.S of pseudocoelomate

Cnidarians and some flatworms have an incomplete gut and exhibit 'blind sac plan'. Justify the statement. Animals from nematodes to chordates in general have a complete gut and exhibit 'tube - within-a-tube plan'. Explain.

As the gut wall is made of only endodermal epithelium, diffusion of digested food from the lumen of the gut into the surrounding pseudocoelomic fluid becomes

easier and the absence of circulatory system is thus compensated. Though it is called pseudocoelom (false coelom), it performs almost all the functions of a regular coelom. Pseudocoelomic fluid of pseudocoelomates serves as a 'hydrostatic skeleton' and a 'shock absorber'. It allows the free movements of visceral organs, helps in the circulation of nutrients, and storage of nitrogenous wastes.

"Pseudocoelom is considered a false body cavity." Substantiate the statement?

2.3.3 Eucoelomate bilaterians

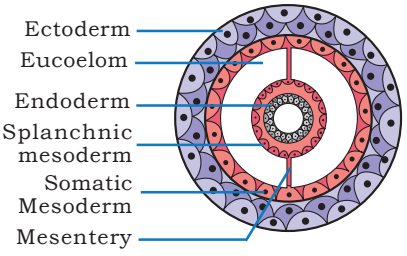


Fig. 2.7 T.S of eucoelomate

Coelom or 'true coelom' is a fluid-filled cavity, that lies between the body wall and the visceral organs and is lined by mesodermal epithelium, the peritoneum. The portion of the peritoneum that underlines the body wall is the ***parietal peritoneum*** or ***somatic peritoneum***. The portion of the peritonieum that covers the visceral organs is the ***splanchnic peritoneum*** or ***visceral peritoneum***. In coelomates, the visceral organs are suspended in the coelom by the peritoneum. A double layered peritoneum that connects some visceral organs to the body wall is called **mesentery**. In some eucoelomates such as the annelids, the dorsal and ventral mesenteries divide the coelom into paired compartments. Certain organs such as the kidneys of the vertebrates are covered by the parietal peritoneum only on their ventral side. Such a peritoneum is called the 'retroperitoneum' and the organs lined by it are called *'**retroperitoneal organs**'*.

During the embryonic development of the eucoelomates, the blastocoel is replaced by true coelom derived from the mesoderm. So, the true coelom is also called '**secondary body cavity**'. In the eucoelomates, mesoderm lines both the body wall and the walls of the visceral organs. So, visceral organs become 'muscular' and exhibit free movements 'independent' of the movement of the body wall in the coelomic fluid. As the wall of the gut becomes thick and muscular, digested food and other nutrients cannot easily diffuse from the lumen of the gut into the coelom i.e. fluid. Circulatory system (blood vascular system) is developed in the eucoelomates to overcome this problem. Based on the mode of formation of coelom, the eucoelomates are classified into two types:

I. Schizocoelomates

Animals in which the body cavity is formed by 'splitting of mesoderm' are called **schizocoelomates**. Annelids, arthropods and molluscs are schizocoelomates in the animal kingdom. All the schizocoelomates are **protostomians** and they show '**holoblastic**', '**spiral**' and '**determinate**' **cleavage**. **The 4d balstomere** or **mesentoblast cell** of the early embryo divides to form mesodermal blocks between the ectoderm and the endoderm and replaces the blastocoel. The split that appears in each

mesodermal block leads to the formation of '**schizocoelom**' **(split coelom)**. In the annelids, the functional body cavity (perivisceral cavity) is schizocoelom. It is in the form of a series of paired coelomic cavities, but in arthropods and molluscs, the functional body cavity that lies around visceral organs is filled with blood (haemolymph) and is called **haemocoel**. It is formed by the fusion of the embryonic blastocoel with some true coelomic spaces and the tissues are directly bathed in the blood (haemolymph).

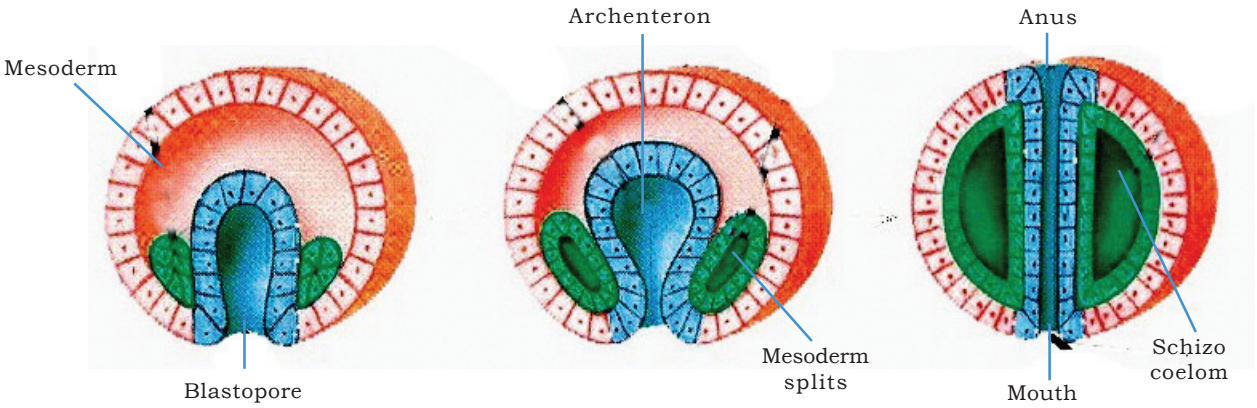


Fig. 2.8 Developement of schizocoelom

II. Enterocoelomates

Animals in which the body cavity is formed from the mesodermal pouches of archenteron are called **enterocoelomates**. Echinoderms, hemichordates and chordates are the enterocoelomates. In these animals, mesodermal pouches that evaginate from the wall of the archenteron into the blastocoel are fused with one another to form the enterocoelom. All the enterocoelomates are **deuterostomes** and they show ***radial*** and ***indeterminate*** cleavage.

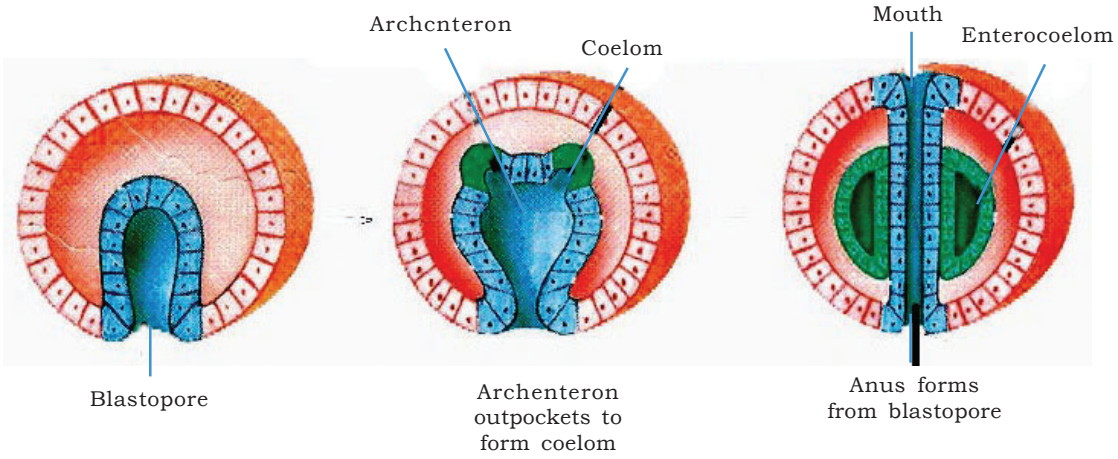
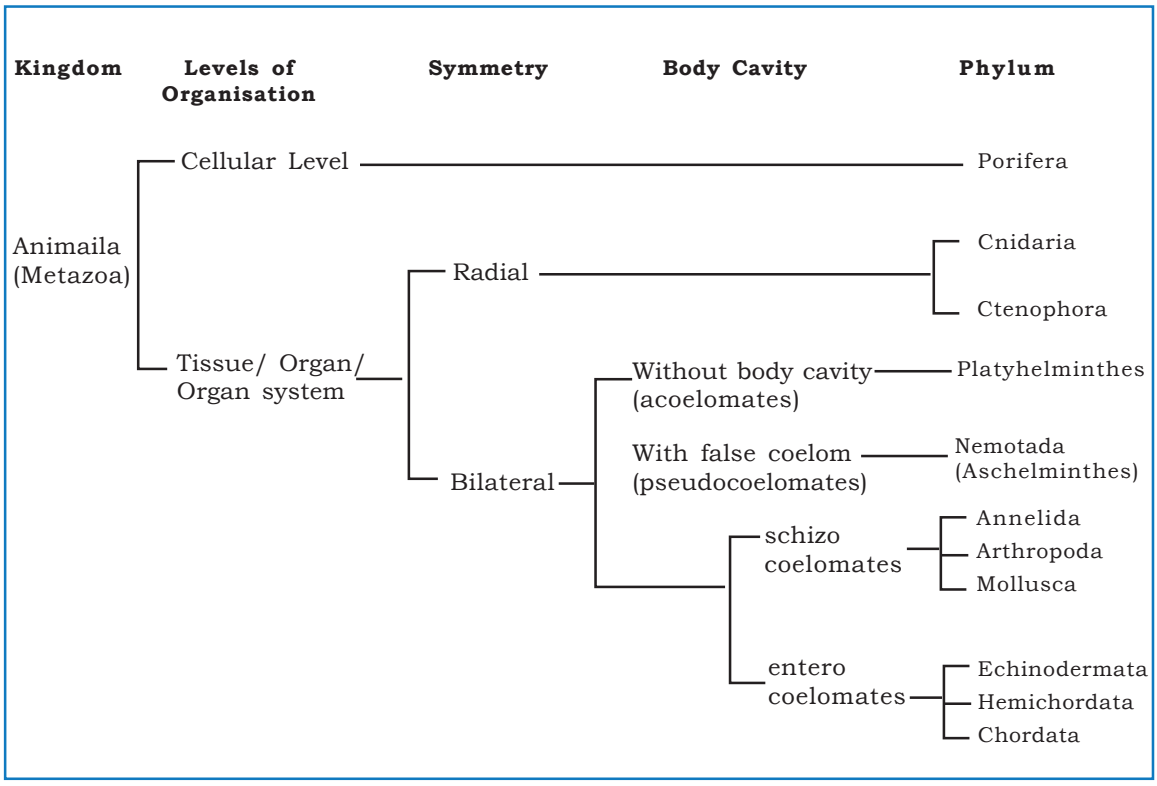


Fig. 2.9 Development of enterocoelom

Advantages of coelom over pseudocoelom

1. Visceral organs of eucoelomates are muscular (because of their association with mesoderm) and so they can contract and relax freely independent of the muscular movements of the body wall in the coelomic space, e.g. peristaltic movements of alimentary canal.
2. Gametes are released into the coelom in some invertebrates (which do not have gonoducts) and in the female vertebrates.
3. In non-chordates, coelomic fluid receives excretory products and stores them temporarily before their elimination.
4. In the eucoelomates, the mesoderm comes into contact with the endoderm of the alimentary canal, and it causes 'regional specialization of the gut, such as the development of gizzard, stomach etc. This is referred to as '**primary induction**'. In the case of the pseudocoelomates, due to the absence of such a contact between the gut and the mesoderm, the wall of the gut does not show complex and highly specialized organs.

The presence of a simple, thin walled gut in the nematodes allows easy diffusion of the digested foods into the pseudocoelomic fluid, thus compensating for the absence of circulatory system.



Summary of organisational levels, symmetry and body cavity

2.4 Animal Tissues

In acellular animals, all the functions like digestion, respiration, excretion and reproduction are performed by a single cell. In the complex body of multicellular animals, the same basic functions are carried out by different groups of cells in a well-organized manner. In the metazoans, a group of cells and cell products that arise from the same region of the embryo, which also perform a specific function, constitute a ***tissue****. The study of tissues is known as* ***histology*** *or* ***microanatomy****.*

Tissues are made up of cells and extracellular matrix. The extracellular matrix varies in composition and quantity from one type of tissue to the other. Animal tissues are broadly classified into four types: epithelial, connective, muscular and nervous tissues. These tissues differ from each other in types and functions of their cells, composition and relative amounts of the intercellular matrix.

2.4.1 Epithelial Tissues

Epithelium (epi,- upon; thelia: growing) forms the outer covering of the body and the lining of internal organs/cavities. Cells of an epithelium are held together by an intercellular '**cementing substance**'. The specialized 'junctions' provide both structural and functional links between the individual cells of an epithelium. They show different types of junctions so as to serve specific needs of that tissue. They are:

A. ***Tight junctions***: These junctions between epithelial cells prevent 'leakages' of body fluids. For example, they prevent leakage of water into the surrounding cells in our sweat glands (making our skin water-tight). The plasma membranes of adjacent cells are tightly pressed against each other and are bound together by specific proteins.

B. **Desmosomes:** Epithelial and muscle cells are provided with '***desmosomes***' (***anchoring or adhesion junctions***) which act as 'rivets' binding the cells together into strong sheets. Intermediate filaments made of the protein '***keratin***,' *anchor* (support) the desmosomes in the cytoplasm.

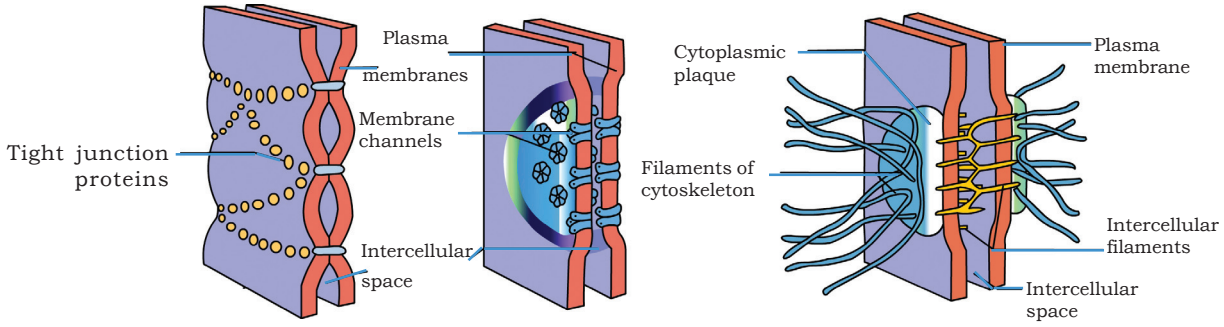


Fig. 2.10 Inter cellular junctions

C. ***Gap junctions*** (***communicating junctions***): They provide continuous '***cytoplasmic channels***' between adjacent cells (comparable to the 'plasmodesmata' between adjacent plant cells).Various types of ions, sugar molecules, amino acids etc., can pass from a cell to an adjacent cell through '***gap junctions***'. They occur in many types of tissues including the '***cardiac muscles***', where they allow rapid conduction of impulses or depolarisation.

An epithelium may be derived from any of the three germinal layers-ectoderm, endoderm or mesoderm. An epithelium rests on basement membrane, which is secreted partly by the epithelial cells and partly by the underlying tissue. Basement membrane consists of **basal lamina** that lies close to the epithelial cells and **reticular lamina** that lies close to the underlying connective tissue. Epithelial tissue is **avascular** and obtains nourishment from the underlying tissue by diffusion. Free surfaces of certain epithelial cells have microvilli or stereo cilia. **Microvilli** increase the surface area of absorptive cells. **Stereocilia** are long and non-motile cilia like processes seen in reproductive ducts (epididymis), internal ear etc. (See Glossary)

Stereocilia are non-motile, whereas cilia are motile. Why?

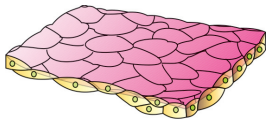
There are **two types of epithelial tissues** namely 'simple epithelia' and 'compound epithelia' based on the number of layers or strata. Various glands in the body involved in secretions are made up of epithelial tissue (glandular epithelium).

1. Simple epithelium

Simple epithelium is composed of a single layer of cells and forms the lining of body cavities, ducts and vessels. It helps in diffusion, absorption, filtration and secretion of substances. On the basis of the shape of the cells, it is further divided into three types:

i) Simple squamous epithelium (Pavement epithelium)

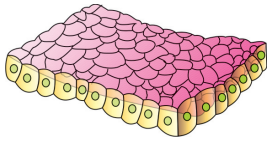
It is composed of a single layer of flat and **tile-like cells**, each with a centrally located 'ovoid nucleus'. It is found in **endothelium** of blood vessels, **mesothelium** of body cavities (pleura, peritoneum, and pericardium), wall of **Bowman's capsule** of nephron, lining of **alveoli** of lungs, etc.



Flattened cell

ii) Simple cuboidal epithelium

It is composed of a single layer of cube-like cells with centrally located spherical nuclei. It is found in the **germinal epithelium**, proximal and distal **convoluted tubules of nephron**. Cuboidal epithelium of proximal convoluted tubule of nephron has '***microvilli***'.



Cube-like cell

iii) Simple columnar epithelium

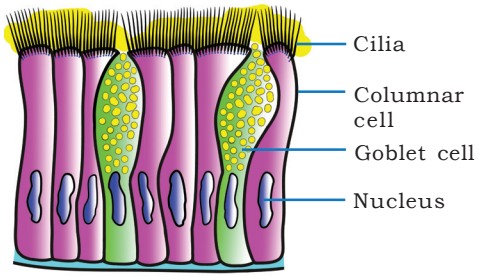


Fig. 2.11 Ciliated epithelium

It is composed of a single layer of tall and slender cells with oval nuclei located near the base. It has mucus-secreting 'goblet cells' in some places. It is of two types:

a) **Ciliated columnar epithelium:** Columnar epithelial cells have cilia on their free surface. It is mainly present in the inner surface of hollow organs like **fallopian tubes**, **ventricles** of brain, **central canal** of spinal cord, **bronchioles**, etc.

Air passages, fluid filled cavities and genital ducts are usually lined with simple columnar ciliated epithelium. Why?

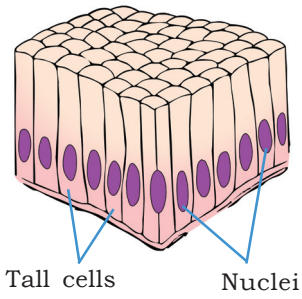
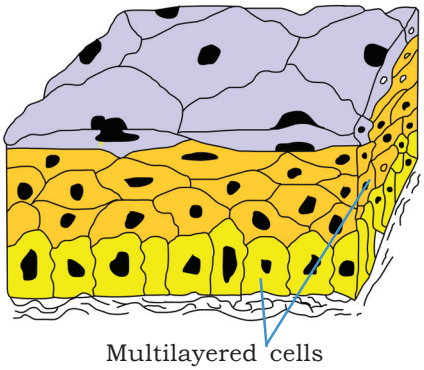


Fig. 2.12 Non - ciliated epithelium

b) **Non-ciliated columnar epithelium:** Columnar cells are without cilia. It is found in the lining of **stomach** and **intestine**. Microvilli are present in the columnar epithelium of intestine to increase the surface area of absorption.

2. Compound epithelium (stratified epithelium)



It is made up of more than one layer of cells. Its main function is to provide protection against chemical and mechanical stress.

i. It covers the dry surfaces of the skin as **stratified, keratinized, squamous epithelium.**

ii. It covers the moist surface of buccal cavity, pharynx, oesophagus and vagina as **stratified non-keratinized squamous epithelium.**

iii. It forms the inner lining of the larger ducts of the salivary glands, ducts of sweat glands and pancreatic ducts as **stratified cuboidal epithelium.**

iv. It forms the wall of the urinary bladder as **transitional epithelium.**

Pseudostratified epithelium. It is a simple epithelium, but gives the false appearance of stratified epithelium. It is due to the presence of nuclei at different levels and all cells are in contact with the basement membrane. It is either ciliated (as in trachea with goblet cells) or non-ciliated (as in epididymis without goblet cells).

Hair of man and horn of a *Rhinoceros* are homologous structures. Elucidate.

3. Glandular epithelium

Some of the columnar or cuboidal cells that get specialised for the production of certain secretions, form glandular epithelium. The glands are of two types -

i) Unicellular glands consisting of isolated glandular cells such as goblet cells of the gut.

ii) Multicellular glands, consisting of clusters of cells such as salivary glands.

On the basis of the mode of pouring (releasing) of their secretions, glands are divided into two types namely ***exocrine*** and ***endocrine*** glands.

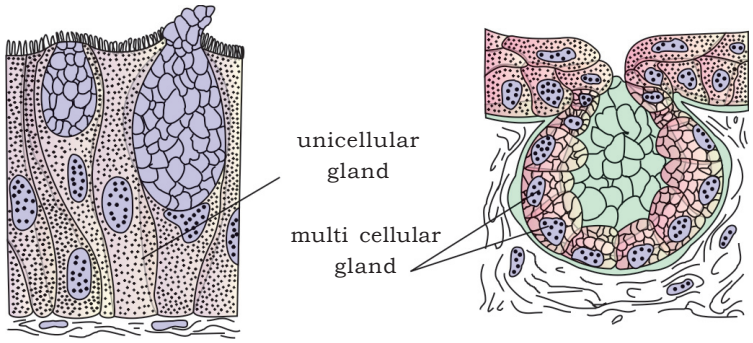


Fig. 2.13 Glandular epithellum

i. Exocrine glands are provided with ducts; secrete mucus, saliva, earwax (cerumen), oil, milk, digestive enzymes and other cell products.

ii. Endocrine glands are ductless and their products are '**hormones**', which are not sent out via ducts, but are carried to the target organs by blood.

Based on the mode of secretion, exocrine glands are further divided into

i. merocrine glands (e.g. pancreas) which release the secretory granules without the loss of other cellular material

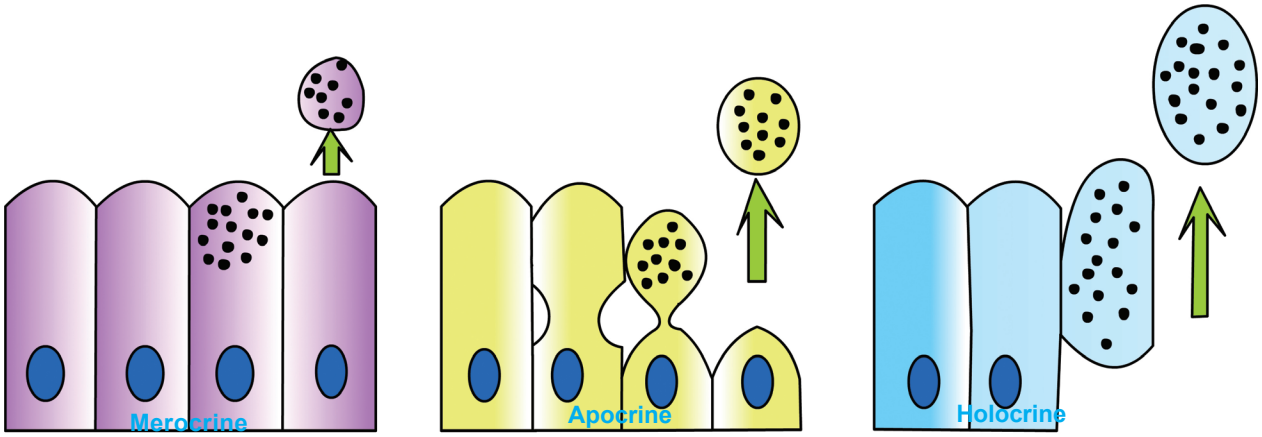


Fig. 2.14 Modes of secretion by exocrine glands

ii. Apocrine glands (e.g. mammary glands) in which the apical part of the cell is pinched off along with the secretory product and

iii. Holocrine glands (e.g. sebaceous glands), in which the entire cell disintegrates to discharge the contents.

2.4.2 Connective tissues

Connective tissues are the most abundant and widely distributed tissues in the body of higher animals. They are named 'connective tissues', because of their special function of binding and supporting other tissues or organs of the body. They are **mesodermal** in origin. Connective tissue consists of cells and large extracellular matrix. It consists of different combinations of fibres (collagen, elastic and reticular) and ground

substance which includes water, polysaccharides and proteins. The fibres provide strength, elasticity and flexibility to the tissue. Connective tissues are classified into three types namely connective tissue proper, skeletal tissue and fluid connective tissue based on the composition of matrix and types of cells.

I. Connective tissue proper

It is of two types,

1. **Loose connective tissue:** Cells and fibres are loosely arranged in a semi fluid ground substance. There are three types of loose connective tissues - areolar tissue, adipose tissue and reticular tissue.

i. Areolar tissue

It is one of the most widely distributed connective tissues in the body. It forms the packing tissue in almost all the organs. Areolar tissue forms subcutaneous layer of the skin. It has cells, fibres and empty spaces called 'areolae'. Cells of the areolar tissue are ***fibroblasts***, ***mast cells***, ***macrophages***, ***adipocytes*** and ***plasma cells***.

1) **Fibroblasts** are the most common cells which secrete fibres. The inactive cells are called **fibrocytes**.
2) **Mast cells** secrete **heparin** (an anticoagulant), **histamine**, **bradykinin** (vasodilators), and **serotonin** (vasoconstrictor). Vasodilators cause inflammation in response to injury and infection.
3) **Macrophages** are amoeboid cells, **phagocytic** in function and act as internal scavengers. They are derived from the monocytes of blood. 'Tissue fixed macrophages' are called ***histiocytes*** and others are 'wandering macrophages'.
4) **Plasma cells** are derived from the B-lymphocytes and produce **antibodies**.
5) **Adipocytes** are specialized cells for the storage of fats.

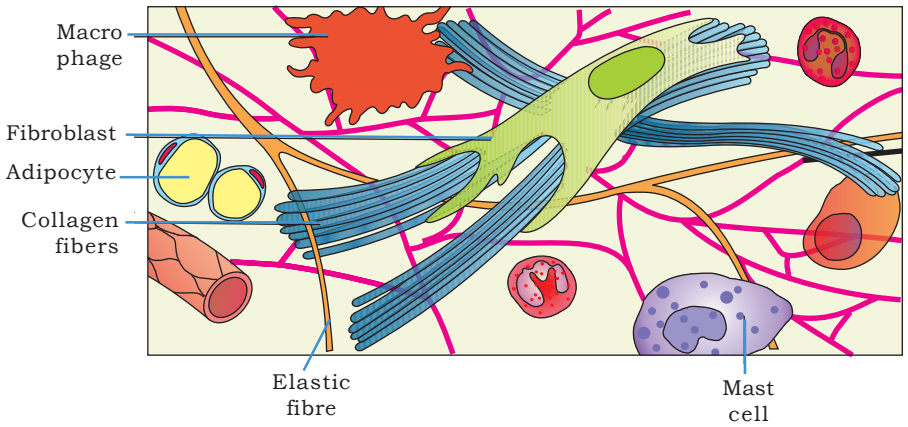


Fig. 2.15 (a) Areolar tissue

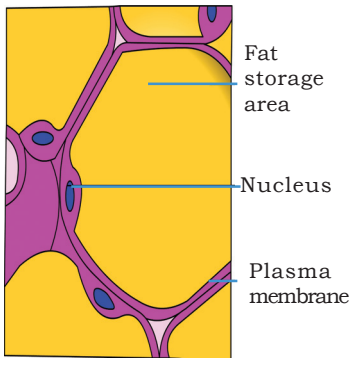


Fig. 2.15 (b) Adipose tissue

Fibres of areolar tissue are of three types. They are collagen, reticular and elastic fibres. Collagen and reticular fibres are composed of the protein ***collagen***, elastic fibres are made of the protein ***elastin***. **Collagen (white) fibres** occur in bundles, and they are **strong** and **stretch resistant**. **Reticular fibres** are thin and form a network and they provide **strength** and **support** to certain tissues such as bone marrow**. Elastic (yellow) fibres** are branched. They are also found in elastic cartilages, elastic ligaments, etc.

ii. Adipose tissue

It is specialized for **fat storage**. It consists of a large number of **adipocytes** (fat storing cells) and few fibres. Adipose tissue which is found beneath the skin provides **thermal insulation** e.g., **blubber** of aquatic mammals such as whales and sea cows. It acts as a storage tissue in the **hump** of camel. It acts as **shock absorber** in palms and soles. Adipose tissue is of two types: white adipose tissue, brown adipose tissue. Excess nutrients which are not used immediately are converted into fats and stored in this tissue.

White adipose tissue (WAT): It is the predominant type in the adults, and the adipocyte has a single large lipid droplet (monolocular). White fat is metabolically less active.

Brown adipose tissue (BAT): It is found in foetuses and infants. Adipocyte of BAT has several small 'lipid droplets' (multilocular) and numerous mitochondria. Brown fat is metabolically active and generates 'heat' to maintain body temperature required by infants. It is comparatively more vascular, hence the brown colour.

iii. Reticular tissue

It has specialized fibroblasts called **reticular cells**. They secrete 'reticular fibers' that form an inter connecting network. It forms the 'supporting frame work' of **lymphoid organs** such as bone marrow, spleen and lymph nodes and forms the **reticular lamina** of the 'basement membrane'.

2. Dense connective tissue

This tissue consists of more fibres, but fewer cells. It has very little ground substance. Based on the arrangement of fibres, dense connective tissue is of three types.

i. Dense regular connective tissue

In this tissue, collagen fibres are arranged parallel to one another in bundles. **Tendons** which attach the skeletal muscles to bones and **ligaments** which attach bones to other bones are examples of this type of connective tissue.

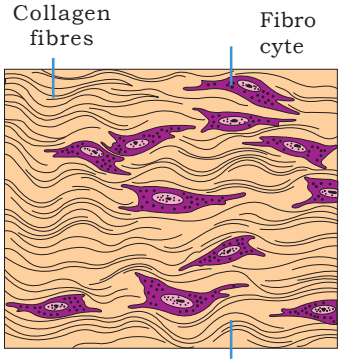


Fig. 2.16 Dense regular fibrous tissue

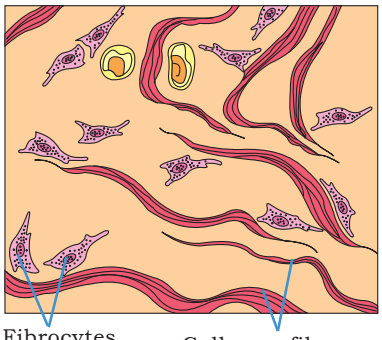


Fig. 2.17 Dense irregular fibrous tissue

ii. **Dense irregular connective tissue :** In this type of connective tissue, bundles of collagen fibres are irregularly arranged. Periosteum, endosteum, pericardium, heart valves, joint capsule and deeper region of dermis of skin contain / are made up of this type of connective tissue.

iii. **Elastic connective tissue:** It is mainly made of yellow elastic fibres, capable of considerable extension and recoil. This tissue can recoil to its original shape, when the forces of stretch are released. It occurs in the walls of arteries, **vocal cords**, **trachea**, **bronchi** and '**elastic ligaments**' present between vertebrae.

In addition to the above mentioned connective tissues, **mucous connective tissue** occurs as foetal or embryonic connective tissue. It is present in the umbilical cord as **Wharton's jelly**.

II. Skeletal tissues / supporting tissues

It forms the endoskeleton of the vertebrates. It supports the body, protects various organs, provides surface for the attachment of muscles and helps in locomotion .It is of two types:

1. Cartilage (Gristle)

Cartilage is a solid, but **semi-rigid (flexible) connective tissue**. It resists compression. Matrix is firm, but somewhat pliable. It has collagen fibres, elastic fibres (only in the elastic cartilage) and matrix-secreting cells called **chondroblasts**. These cells are enclosed in fluid filled spaces called **lacunae**. Chondrocytes are the inactive cells of a cartilage. Cartilage is surrounded by a fibrous connective tissue sheath called **perichondrium**. Cartilage is '**avascular**' and it is nourished by 'diffusion of nutrients' from the blood capillaries of the perichondrium. Growth, regeneration and repair of cartilage take place by the activity of **perichondrial** cells. Cartilage is of three types, which differ from each other chiefly in the composition of the matrix.

i. **Hyaline cartilage :** It is bluish-white, translucent and glass-like cartilage. Matrix is homogeneous and shows delicate **collagen fibres**. It is the **weakest** and the **most common** type of all the cartilages. Perichondrium is present except in **articular cartilages**. It forms the embryonic endoskeleton of bony vertebrates, endoskeleton of cyclostomes (jawless vertebrates) and adult cartilaginous fishes. It forms the **articular cartilages** (free surfaces of long bones that form joints), **costal cartilages** (sternal parts of ribs), and the **epiphyseal plates**. It also forms the **nasal septal cartilage**, **cartilaginous rings** of trachea, bronchi and **cartilages of larynx**.

Degeneration of which part of a long bone results in arthritis (a disease which limits the movements of bones causing severe pain in the joints).

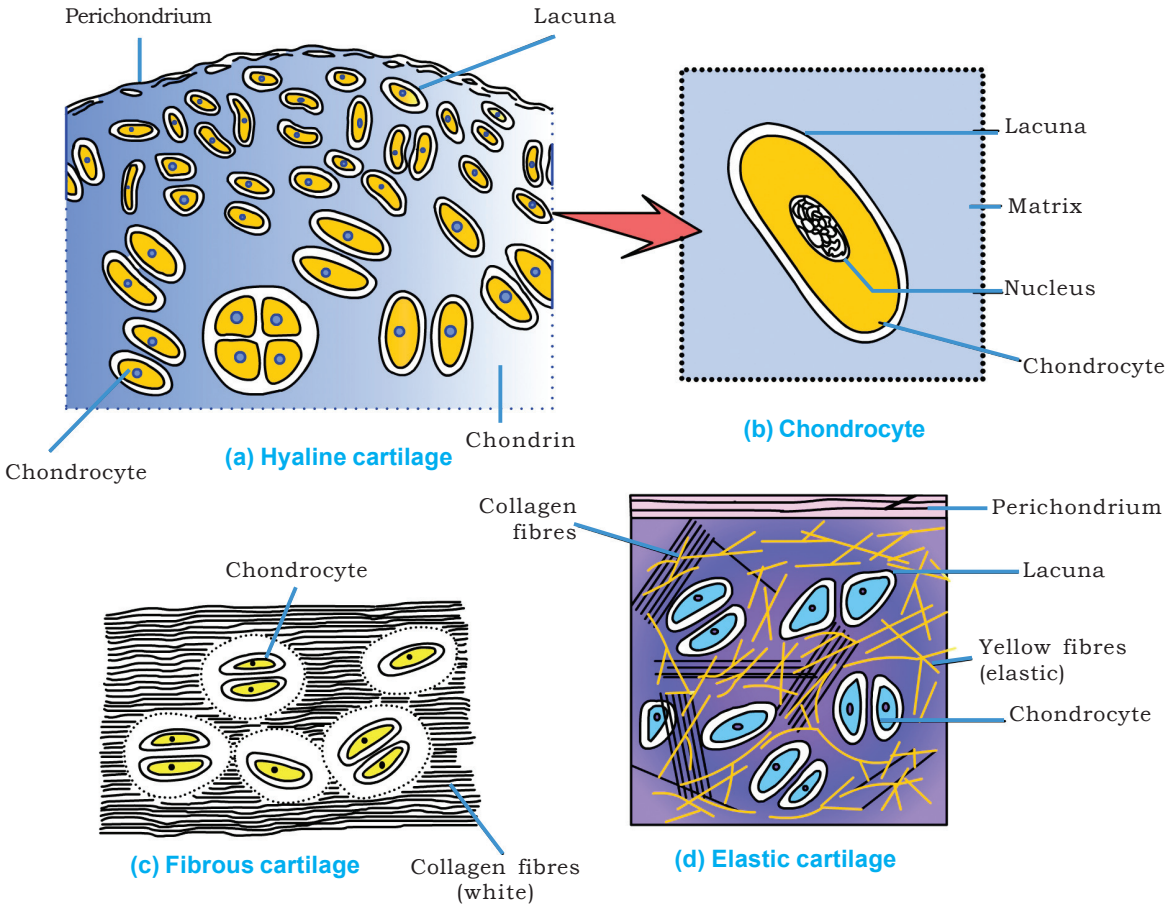


Fig. 2.18 Types of cartilage

ii. **Elastic cartilage:** It is yellowish due to elastic fibres. Matrix has abundance of yellow elastic fibres in addition to collagen fibres. It provides strength and elasticity. Perichondrium is present. It is found in the **pinnae of the external ears**, **Eustachian tubes** and **epiglottis**.

iii. **Fibrous cartilage**: Matrix has bundles of collagen fibres. **Perichondrium** is absent. It is **the strongest** of all the types of **cartilages**. It occurs in the **inter-vertebral discs** and **pubic symphysis** of the pelvis.

2. Bone (osseous) tissue

Bone is highly calcified (mineralized), solid, hard and rigid connective tissue. It is the major component of the endoskeleton of most adult vertebrates. It is the main tissue that provides structural framework to the body. It supports the soft tissues, and protects the delicate organs. Limb bones of animals serve the weight-bearing functions. Bones also interact with muscles attached to them to bring about movements. Bones have a hard and non-pliable matrix, rich in **calcium salts** and **collagen fibres** which give the bone its strength. During ageing, the proportion of inorganic materials increases in a

bone, making it more brittle. Bone forms **homeostatic reservoir** of calcium, magnesium, phosphorus, etc. Bone is **highly vascular**.

Bone has an outer fibrous connective tissue sheath called **periosteum**, the inner connective tissue sheath that lines the marrow cavity called **endosteum**, non- living extra cellular matrix, living cells and bone marrow. Bone cells include **osteoblasts, osteocytes** and **osteoclasts**. **Osteoblasts** (immature bone cells) secrete the organic components (collagen fibres) of matrix and also play an important role in 'mineralization of bone' and become **osteocytes (**mature bone cells**)**. Osteocytes are enclosed in fluid filled lacunae. **Osteoclasts** are phagocytic cells involved in resorption of bone (demineralisation).

A. Types of bones:

a. Types of bones based on the method of formation

i) **Cartilage bones (replacing bones** or **endochondral bones)** are formed by ossification within the cartilage e.g. bones of limbs, girdles and vertebrae.

ii) **Investing bones (membrane bones** or **dermal bones)** are formed by the ossification in the embryonic mesenchyme e.g. most of the bones of **cranium**.

iii) **Sesamoid bones** are formed by ossification in tendons e.g. **patella** (knee cap) and **pisiform** bone of the wrist of a mammal.

iv) **Visceral bones** are formed by ossification in the soft tissues, e.g. **Os cordis** (inside the heart of ruminants), **Os penis** (inside the glans-penis of many mammals such as the rodents, bats and carnivores).

b. Types of bones based on the structure

i. Spongy bone (Cancellous bone or trabecular bone) : It occurs in the epiphyses and metaphyses of long bones. It looks spongy and contains columns of bone called '**trabeculae**' with irregular interspaces filled with red bone marrow.

ii. Compact bone: The diaphysis of a long bone is made up of 'compact bone'. It has dense continuous lamellar matrix between periosteum and endosteum.

B. Structure of a compact bone

Diaphysis (shaft) is a part of a long bone that lies in between expanded ends (*epiphyses*). In a growing bone there is a region called metaphysis between the diaphysis and epiphysis. It consists of an epiphyseal plate (formed by hyaline cartilage). It helps in the elongation of the bone. In adults it is represented by a **bony epiphyseal line**. Diaphysis is covered by a dense connective fibrous tissue called **periosteum**. Diaphysis of a long bone has a hollow cavity called **marrow cavity** which is lined or surrounded by the **endosteum**. In between periosteum and endosteum, the matrix of the bone is laid down in the form of 'lamellae'. **Outer circumferential lamellae** are located immediately beneath the periosteum; **inner**

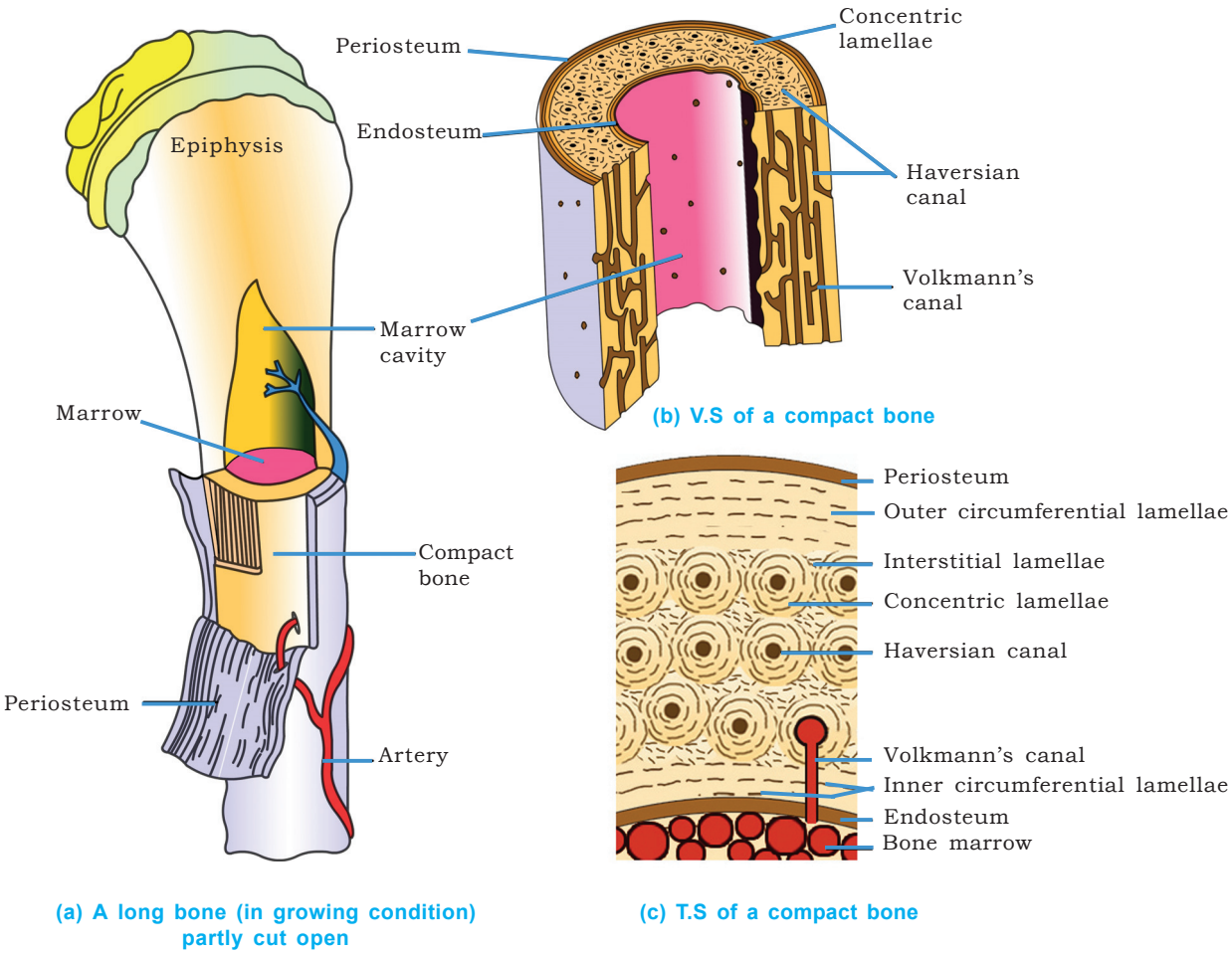


Fig. 2.19 Osseous tissue

circumferential lamellae are located around the endosteum. Between the outer and inner circumferential lamellae, there are many Haversian systems (osteons - units of bone). The spaces between the Haversian systems are filled with **interstitial lamellae**. **Haversian system** consists of a Haversian canal that runs parallel to the marrow cavity. It contains an artery, a vein and a lymphatic vessel. Haversian canal is surrounded by **concentric lamellae**. Small fluid filled spaces called 'lacunae' provided with minute **canaliculi** lie in between the lamellae. Canaliculi connect the lacunae with one another and with Haversian canal. Each lacuna encloses one osteocyte (inactive form of osteoblast). The cytoplasmic processes of osteocytes extend through canaliculi and get inter connected into a network of cells. A Haversian canal and the surrounding lamellae and lacunae are collectively called a **Haversian system** or **osteon**. The Haversian canals communicate with one another, with the periosteum and also with the marrow cavity by transverse or oblique canals called **Volkmann's canals**. Nutrients and gases diffuse from the vascular supply of Haversian canals.

Of the dry weight of a fully grown bone, inorganic matter constitutes about 65% and organic matter constitutes about 35 % . Major part of inorganic matter is calcium phosphate which is present in the form of **crystals** of **hydroxyapatite.** The major organic substance is **collagen**.

Note : *When bones are broken, the osteocytes are reactivated to osteoblasts and start deposition of mineral material, thus joining the fractured bones.*

If, a bone is kept in dilute acid (HCl) it becomes soft. Can you explain why?

III. Fluid connective tissue (Vascular tissue): It is a tissue, which consists of fibre-free 'liquid matrix' called plasma and living cells that do not produce the matrix. It includes blood and lymph.

1. Blood

It is a red coloured, opaque and slightly alkaline fluid. The study of blood is called **haematology.** It is a tissue that circulates to various parts of the body through **cardiovascular system**. It is composed of blood plasma and 'formed elements' or blood cells, the RBC, WBC and platelets. The plasma constitutes about 55% and the cells about 45% of the total volume of blood. The total volume of blood in an adult human being is about 5 to 6 litres. The percentage of total volume occupied by RBCs is called **haematocrit value** or '**packed cell volume**'.

A. Plasma

It is the fluid matrix of blood. It consists of 92% of water and 8% of solutes. Solutes include plasma proteins, mineral salts, nutrients, gases, excretory wastes, enzymes, hormones, etc. Plasma proteins include albumins, globulins and blood clotting proteins such as ***fibrinogen***, ***prothrombin*** and anticoagulant heparin all of which are produced by the liver. Globulins are formed in the liver and lymphoid organs. **Albumin** is the smallest and the most abundant serum protein and it is mainly responsible for '**colloidal osmotic pressure**' of blood. Fall in the levels of albumin in blood plasma, results in **oedema** (accumulation of fluids in tissues). Globulins are of three types, alpha, beta and gamma. Gamma globulins are the antibodies, also called immunoglobulins. Plasma proteins act as '**acid-base buffers**', maintaining the pH of blood at 7.4. Salts of blood plasma are the chlorides, bicarbonates, sulphates, phosphates of Na, K, Ca, and Mg.

B. Formed elements

They include **erythrocytes** (red blood corpuscles), **leucocytes** (white blood corpuscles) and **platelets**. The process of formation of blood cells is called **haemopoiesis** or **haematopoiesis**. In the earliest stages of embryogenesis, blood cells are formed from the **yolk sac mesoderm**. Later on, the **liver** and the **spleen** serve as "temporary haemopoietic tissues". In the final stage of embryonic development and after birth, the **red bone marrow** is the primary site of haemopoiesis.

i. Red blood corpuscles (Erythrocytes)


RBC

Erythrocytes of mammals are circular (elliptical in camels and Llamas), biconcave and enucleate. The biconcave shape provides a large surface area-to-volume ratio, thus providing more area for the exchange of gases. These are 7.8 μm in diameter. The number of RBC per cubic millimeter of blood is about 5 million in a man, and 4.5 million in a woman. Decrease in the number of erythrocytes is called **erythrocytopenia** and it leads to **anaemia**. An abnormal rise in RBC count is called **polycythemia**. Shortage of oxygen stimulates the kidneys to secrete a hormone called **erythropoietin** into the blood. Erythropoietin stimulates the bone marrow to increase the production of RBC. **Vitamin B_{12}** and **folic acid** are required for maturation of RBC. RBCs arranged in the form of rolls of coins called '**rouleaux**'.

Mammalian RBC is surrounded by plasma membrane. Nucleus and other cell organelles are lost in the ***reticulocyte*** stage of its development. Cytoplasm of RBC contains a chromo protein, the 'haemoglobin'. Each Haemoglobin molecule consists of **4 polypeptide (2α & 2β)** chains and **4 haeme** molecules. In the centre of each haeme group is **one Fe^{2+}**, which can combine with one molecule of O_2. Life span of RBC in humans is about **120 days**. The worn out RBC are destroyed in the '**spleen**' and '**liver**'.

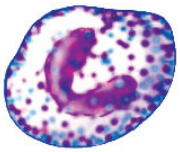
RBC of mammals are biconcave and enucleate. What is the advantage of it?

ii. White blood corpuscles (Leucocytes)

These are nucleate, colourless, complete cells. They are spherical or irregular in shape, and are capable of exhibiting amoeboid movement into the extravascular areas by **diapedesis**. They are larger than RBC in size, and less than RBC in number. The total leucocyte count is 6,000 - 10,000 per cubic millimeter of blood under normal conditions. The process of formation of WBC is called **Leucopoiesis.** Slight increase in the WBC count is called **Leucocytosis** (during infection and allergy).An abnormal increase in the number of WBC is indicated in a type of cancer called **Leukemia**. Fall in WBC count is called **Leucocytopenia. WBC** are of two main types: **Granulocytes** and **Agranulocytes**.

Granulocytes

They possess cytoplasmic granules (specific granules) that may take one of the three different types of stains, neutral or acidic or basic. Nucleus of the granulocytes is divided into lobes and assumes different shapes, hence, these are also called **Polymorph-nuclear leucocytes**. Based on the staining properties these are of three types:



Basophil

Eosinophil

Neutrophil

Basophils

They are the least common type of WBC and constitute about 0.4% of the total leucocytes. Nucleus is partially divided into 2 or 3 lobes. Cytoplasmic granules are 'fewer' and 'irregular' in shape. They take basic stains. They produce **heparin**, **histamine**, etc. They supplement the function of mast cells when needed.

Eosinophils (acidophils)

They constitute about 2.3% of the total leucocytes. Nucleus is distinctly **bilobed**. Cytoplasm has large granules which stain with acidic dyes such as '***eosin***'. They play a role in **allergic reactions**. Their number increases during 'allergic reactions' and 'helminth infections'. They remove '**antigen - antibody complexes**', from the blood. They are capable of phagocytosis and are not as effective as neutrophils in killing bacteria.

Neutrophils

They are the most common type of WBC and constitute about 62% of the total leucocytes. Nucleus is **many lobed** (2-5). Specific cytoplasmic granules are small and abundant. They stain with 'neutral dyes'. These are active **phagocytic cells** commonly described as '***microscopic policemen***'. Certain neutrophils of female mammals have **sex chromatin body** or **Drumstick body** (an extra 'X' chromosome) attached to the nucleus .

Agranulocytes

Cytoplasmic granules are absent in agranulocytes. Nucleus of these cells is not divided into lobes. These are of two types:

Lymphocyte

Lymphocytes: They constitute about 30% of the total leucocytes. They are small, spherical cells with **large spherical nucleus** and scanty peripheral cytoplasm. There are functionally two types of lymphocytes -'B' lymphocytes, which produce 'antibodies' and 'T' lymphocytes which also have an important role in the immunological reactions of the body.

Some lymphocytes live for only a few days while others survive many years.

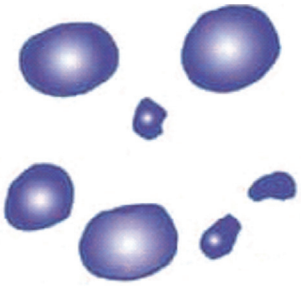
Monocytes

They constitute about 5.3% of the leucocytes . The nucleus is **kidney shaped** (reniform). These are the largest, motile phagocytes. They engulf bacteria and cellular debris (wastes). They differentiate into **macrophages**, when they enter the connective tissues.


Monocyte

iii. Blood platelets (Thrombocytes)

These are colourless non-nucleated, round or oval biconvex discs. Number of platelets per cubic mm of blood is about 2,50,000 - 4,50,000. They are formed from giant **megakaryocytes** produced in the red bone marrow, by **fragmentation**. The average life-span of blood platelets is about 5 to 9 days. They secrete **thromboplastin** and play an important role in blood clotting. They adhere to the damaged endothelial lining of capillaries and 'seal' minor vascular openings.


Blood platelets

2. Lymph

Lymph is a colourless fluid. It lacks RBC, platelets and large plasma proteins, but has more number of leucocytes. It is chiefly composed of plasma and lymphocytes. When compared to the tissue fluid, it contains very small amounts of nutrients (except fats) and oxygen, but has abundant CO_2 and other metabolites. The most important site of formation of lymph is **interstitial space**. As blood passes through the blood capillaries, some portion of blood that includes water, solutes and proteins of low molecular weight passes through the walls of capillaries, into the interstitial spaces due to hydrostatic pressure at the arteriolar ends. This fluid forms the ***interstitial fluid*** (tissue fluid). Most of the interstitial fluid is returned directly to the capillaries due to osmotic pressure at the venular ends. Little amount of this tissue fluid passes through a system of lymphatic capillaries (lymph capillaries of the intestinal villi are called 'lacteals'), vessels, lymph ducts and finally reach the blood through the subclavian veins. The extracellular 'tissue fluid' after passing into the lymph capillaries and lymph vessels is called 'lymph'. Lymphatic system represents an '***accessory route***' by which interstitial fluid flows from tissue spaces into blood.

2.4.3 Muscular Tissue

Muscular tissue is **mesodermal** in origin, except muscles of the ***iris*** and ***ciliary body***, which are ***ectodermal*** in origin. Muscles show three essential properties such as **excitability**, **conductivity** and **contractility**. Muscle fibers contract (shorten) in response to stimulation, then relax (lengthen or return to their un-contracted state), in a coordinated fashion. Muscles play an active role in the movements of the body to adjust to changes in the surrounding environment and to maintain the posture of the body. The study of muscular tissues is known as **myology**. Muscular tissue has

elongated cells called 'muscle fibers' (myocytes) which are surrounded by a connective tissue sheath. Extracellular matrix is absent. The plasma membrane of a muscle fibre is called ***sarcolemma***. The cytoplasm of a muscle fibre is called **sarcoplasm**, the endoplasmic reticulum, the ***sarcoplasmic reticulum***, and the mitochondria, the **sarcosomes**. The cytoplasm of a muscle fibre has several ***myofibrils***. Each myofibril has thick (***myosin***) and thin (***actin***) ***myofilaments***. The regular arrangement of myosin and actin filaments is responsible for the alternate dark and light bands of a 'striated muscle'. Sarcoplasm also contains ATP, phosphocreatine, glycogen and myoglobin. Muscles are of three types - **skeletal**, **smooth** and **cardiac**.

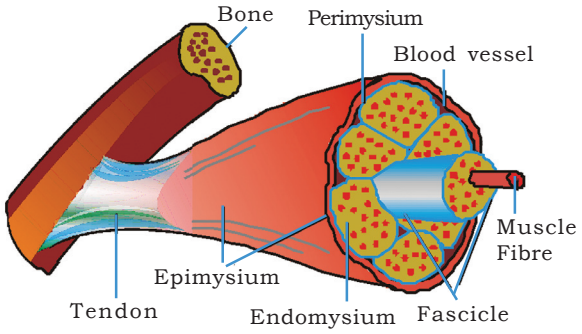


Fig. 2.20 (a) Skeletal muscle

1. Skeletal (striped and voluntary) muscle

It is usually attached to skeletal structures by 'tendons'. In a typical muscle such as the 'biceps' muscle, skeletal muscle fibre is surrounded by a thin connective tissue sheath, the **endomysium.** A bundle of muscle fibres is called a **fascicle**. It is surrounded by a connective tissue sheath called **perimysium**.A group of fascicles form a 'muscle' which is surrounded by an **epimysium** (outer most connective tissue sheath).These connective tissue layers may extend beyond the muscle to form a chord-like **tendon** or sheet-like **aponeurosis**.

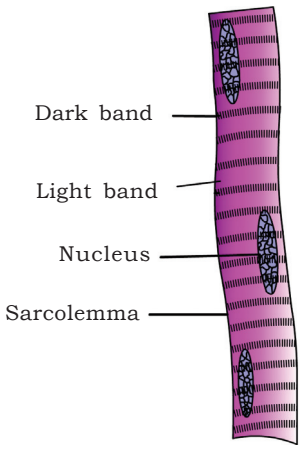


Fig. 2.20 (b) Striped muscle fibre

A skeletal muscle fibre is a **long**, **cylindrical** and **unbranched cell**. It is a **multinucleated** cell with many oval nuclei characteristically in the "peripheral" cytoplasm (a syncytium formed by fusion of cells). Sarcoplasm has many **myofibrils** which show alternate dark and light bands. So it is called **striped** or **striated** muscle. Skeletal muscle usually works under the conscious control of an organism (a **voluntary muscle**). Skeletal muscle **contracts quickly** and undergoes **fatigue quickly**. They are innervated by the 'somatic nervous system'. **Satellite cells** are quiescent (quiet and inactive), mononucleate and myogenic cells (cells that can generate muscle cells) and help in regeneration, which is 'limited'.

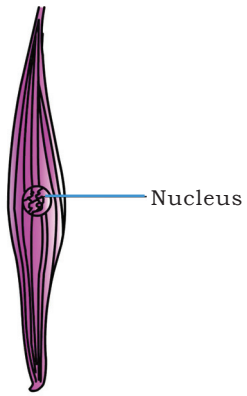


Fig. 2.20 (c) Smooth muscle fibre

2. Smooth (unstriped and involuntary) muscle

It is located in the walls of the **visceral organs** such as blood vessels, trachea, bronchi, stomach, intestine, excretory and genital

ducts, and so this is also called '**visceral muscle**'. As cross striations are absent, it is called '**smooth muscle**'. It is also found in **iris** and **ciliary body** of eye and in the skin as '**arrector pili muscles**' that are attached to hair follicles.

Usually smooth muscles are arranged in 'layers'/'sheets'. A smooth muscle fibre is a spindle shaped (fusiform), **uninucleate** cell. Myofibrils do not show alternate dark and light bands due to irregular arrangement of actin and myosin molecules. They do not work under the conscious control, and so they are called **involuntary muscles**. Smooth muscles exhibit '**slow**' and '**prolonged**' contractions. They may remain contracted for long periods **without fatigue** (show sustained involuntary contractions called '**spasms**'). The contraction of smooth muscles is under the control of the ***autonomous nervous system***.

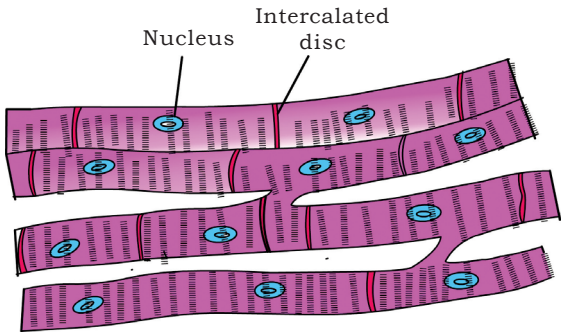


Fig. 2.20 (d) Cardiac muscle

3.Cardiac (striped and involuntary) muscle

The cardiac muscle is striated like the skeletal muscle (shows **sarcomeres**). Cardiac muscle is found in the 'myocardium' of the heart of vertebrates. The cardiac muscle cells or the 'myocardial cells' **are short, cylindrical, mononucleate or binucleate cells** whose ends branch and form junctions with other cardiac muscle cells. Each myocardial cell is joined to adjacent myocardial cells by 'electrical synapses' or '**gap junctions**'. They permit 'electrical impulses' to be conducted along the long axis of the cardiac muscle fibre. The dark lines across cardiac muscle are called **intercalated discs** (**IDs**). These discs are characteristic of the cardiac muscle and are called communication junctions which allow the cells to contract as a unit. Intercalated discs contain three different types of cell junctions and the 'gap junctions' which are responsible for rapid conduction of action potentials.

The cardiac muscle of vertebrates does not require any nerve stimulus to contract because it can produce impulses spontaneously from a specialised auto-rhythmic structure, the '**pace maker**' (myogenic heart). As such, the cardiac muscle is **involuntary** in its function. However, the rate of heart beat is regulated by an autonomic innervation and hormones such as **epinephrine/adrenaline**. The excitation of one myocardial cell results in the excitation of all other myocardial cells quickly to produce a '**whole hearted**' **contraction**', of the entire muscle as a single unit. Thus the cardiac muscle is described as a '**functional syncytium**'. The cardiac muscle is **highly resistant to fatigue**, because it has numerous sarcosomes, many molecules of myoglobin (oxygen storing pigment) and rich supply of blood which facilitate '**continuous aerobic respiration**'.

2.4.4 Nervous Tissue

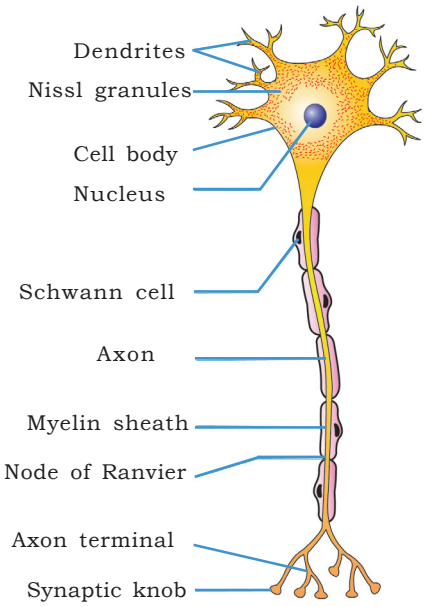


Fig . 2.21 Multipolar Neuron (Structure)

Nervous tissue is derived from the **ectoderm**. It exerts the greatest control over the body's responsiveness to the changing external and internal environment. It consists of two types of cells. The **neurons** (impulse conducting cells) and the **neuroglia** (non-conducting cells or **supporting cells**)

I. Neurons

Neurons are the 'functional units' of nervous tissue. These are electrically excitable cells which receive, initiate, and conduct/transmit impulses. When a neuron is stimulated, an electric disturbance (***action potential***) is generated due to the formation of a series of action potentials, which swiftly travels along its plasma membrane. A neuron usually consists of a "**cell body**" with one to many dendrites and a single axon.

1. Cell body

It is also called **perikaryon**, **cyton** or **soma**. It contains abundant granular cytoplasm and a large spherical nucleus. The cytoplasm has **Nissl bodies** (they represent **RER**, the sites of protein synthesis), neurofibrils and **lipofuscin** granules (the products of cellular wear and tear, accumulating in lysosomes with age). A group of cell bodies in the central nervous system is called a '**nucleus**', and in the peripheral nervous system, it is called a '**ganglion**'.

2. Dendrites

Several short, branched processes which arise from the cyton are called dendrites. They also contain ***Nissl bodies*** and ***neurofibrils***. They conduct nerve impulses towards the cell body (**afferent processes**).

3. Axon

An axon is a single, long, cylindrical process that originates from a region of the cyton called **axon hillock**. Plasmalemma of an axon is called **axolemma**, and the cytoplasm is called **axoplasm**, which contains neurofibrils. However, Nissl bodies are absent. An axon may give rise to **collateral branches**. Distally it branches into many fine filaments called **telodendria** (**axon terminals**), which end in bulb like structures called **synaptic knobs** or **terminal boutons**. Synaptic knobs possess 'synaptic vesicles' containing chemicals called **neurotransmitters**. Axon transmits nerve impulse away from the cyton (**efferent process)** to an interneuronal or neuro-muscular junction called synapse. Groups of axons (nerve fibres) in the central nervous system (CNS) are called **tracts** and in the peripheral nervous system (PNS), they are called **nerves**.

What type of neurons are the most abundant in the human body and how do they differ from the rest of neurons?

II. Types of neurons based on the types of processes

i) **Unipolar neurons:** They are '**sensory neurons**' having a single process arising from the cell body, which divides into two branches, one of which acts as a ***dendrite*** and the other as an **axon**. The 'soma' is found in the **dorsal root ganglion** of spinal nerve. They are also called '**pseudounipolar neurons**'.

ii) **Bipolar neurons** have one axon and one dendrite that directly arise from the cyton. They are found in the **retina** of the eye, **sensory cells** of the internal ear, olfactory sensory epithelium, etc.

iii) **Multipolar neurons** have one axon and two or more dendrites. Most neurons in our body are **multipolar** neurons.

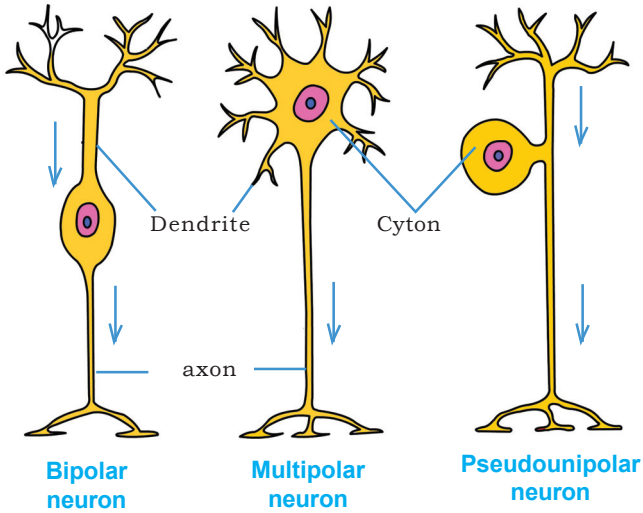


Fig. 2.22 Types of neurons

III. Types of axons based on the presence or absence of myelin sheath

i) **Myelinated axons:** In a myelinated fibre of the PNS, the plasmalemma of a Schwann cell wraps around an 'internode' of an axon. The layers of the Schwann cell contain '**myelin**' (with a high proportion of lipids). The outermost layer that contains cytoplasm and nucleus is called the **neurilemma**. Some Schwann cells do not contain myelin. In the **CNS**, the glial cells, called 'oligodendrocytes' myelinate axons *(a single oligodendrocyte can myelinate many axons)*. The portions of a myelinated nerve fibre (axon) devoid of myelin sheath are called **nodes of Ranvier**. The gap between two adjacent nodes is called an **internode**. Myelinated nerve fibres occur in the white matter of **CNS**, and in most peripheral nerves.

ii) **Non-myelinated axons** are commonly found in the grey matter of the CNS and post-ganglionic neurons of the autonomic nervous system.

IV. Types of neurons based on their function

i) **Sensory neurons (afferent neurons)** carry sensory impulses from the receptors to the CNS.

ii) **Motor neurons (efferent neurons)** carry motor impulses from CNS to the 'effector organs' such as muscles, glands, etc.

iii) **Interneurons** are present in **CNS** and they connect sensory neurons and motor neurons.

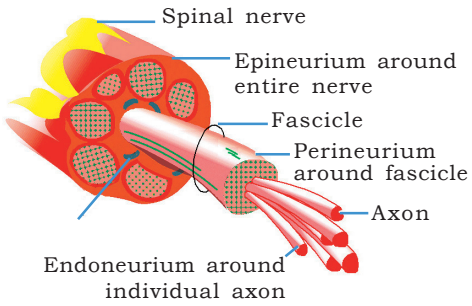


Fig. 2.23 Cross section of a nerve

V. Nerve

A bundle of nerve fibres in the peripheral nervous system form a nerve. Each nerve fibre is covered by a thin connective tissue sheath called **endoneurium**. A group of nerve fibres form a **fascicle** (fasciculus), it is covered by **perineurium**. All the fascicles of a nerve join together to form a bundle, which is surrounded by a connective tissue sheath called **epineurium**, thus forming a '**nerve**'. Nerves are of three types- a) Sensory, b) Motor and c) Mixed.

VI. Neuroglia (supporting cells)

These are the supporting and 'non-conducting' cells that provide a microenvironment suitable for neuronal activity. Unlike neurons, they continue to divide throughout the life. Neuroglial cells of the CNS include

i. Oligodendrocytes (that form myelin sheath as mentioned above);

ii. Astrocytes (star shaped cells) that form interconnected network and bind neurons and capillaries (helping in providing **blood-brain barrier)**;

iii. Ependymal cells, which are **ciliated** cells that line the cavities of brain and spinal cord to bring movements in the cerebrospinal fluid;

iv. Microglial cells, which are **phagocytic cells**, of **mesodermal origin**.

Neuroglial cells of the peripheral nervous system include the **satellite cells** and **Schwann cells**. Satellite cells surround the cell bodies in ganglia, and Schwann cells form neurilemma around axons.

Microglia are the only cells of mesodermal origin in the nervous tissue. They form a part of the 'mononuclear phagocytic system' (MNP system). They become activated into 'phagocytes' when there is infection or injury in the nervous system.

VII. Synapse:

The minute structural gap or functional bridge between the axon terminals of one neuron and the dendrites of another neuron is called synapse.

GLOSSARY

Anticoagulants: These are the substances that prevent the coagulation of blood, when blood flows through blood vessels. e.g. heparin

Articular cartilage: It is the cartilage found at the free surfaces of long bones that forms joints

Blubber: It is the thick, fatty layer that lies underneath the skin of whales and other aquatic mammals. It helps in thermal insulation.

Central axis: An imaginary straight line joining the mid point at one end or surface and the midpoint at the opposite end or surface. It is also called the principal axis.

Diapedesis: The passage of leucocytes of blood into the matrix of connective tissues through the walls of capillaries by an amoeboid movement.

Endothelium: The simple squamous epithelium that lines the inner surface of blood vessels and heart.

Epiphyses: These are the expanded ends of long bones, which are made of spongy bone.

Frontal plane: The plane that runs along the anterior – posterior and transverse axes.

Haemocoel: The functional perivisceral cavity, that lies around the visceral organs of arthropods and molluscs which is filled with the blood (haemolymph).

Haversian canal: These are the elongated canals that run parallel to the marrow cavity of compact bones of mammals. They contain blood vessels, lymphatic vessels and nerves.

Hydrostatic skeleton: In pseudo-coelomates and eucoelomates, the body cavity is filled with a fluid which gives proper shape to the body as an endoskeleton does.

Ligament: A dense fibrous tissue strand, which connects bones to other bones in general. Extensive pulling of ligament causes sprain.

Median sagittal plane: The plane that runs along the anterior, posterior and sagittal axes.

Megakaryocytes: Giant cells of red bone marrow that produce blood platelets by fragmentation.

Muscle fatigue: It is the inability of the muscle to undergo further contraction due to the accumulation of lactic acid formed during anaerobic respiration, because of rapid exercise.

Oedema: It is an abnormal accumulation of interstitial fluid beneath the skin or in one or more cavities. Fall in the levels of plasma proteins mainly serum albumin causes a decrease in the osmotic pressure of blood.

Osteoblasts: These are the immature cells that secrete organic matter of the matrix of a growing bone. Immature osteoblasts become mature cells, the osteocytes, in the adult stage.

Perivisceral cavity: It is the cavity that encloses visceral organs. The perivisceral cavity of nematodes is pseudocoelom, that of annelids is eucoelom.

Plane: The flat area that runs through any axis.

Polycythemia: It is an abnormal rise in the RBC count. The people who live at the higher altitudes generally show polycythemia due to low partial pressure of oxygen at the higher altitudes.

Primary induction: It is a kind of interaction between tissues of different origin involved in the development of specialized tissues.

Reticular cells: These are the specialized fibroblasts that secrete reticular fibres of matrix.

Reticular lamina: It is a part of the basement membrane of the epithelium that lies close to the underlying tissues.

Retroperitoneal organs: Organs that are located in between the dorsal body wall and parietal layer of peritoneum. E.g., kidneys

Sagittal axis: An imaginary straight line that joins mid dorsal and mid ventral ends.

Secondary bodycavity: True coelom of eucoelomates is called secondary body cavity, because it is formed by the replacement of primary body cavity, the blastocoel.

Spasms: These are sudden sustained involuntary contractions of smooth muscles of visceral organs.

Stereocilia: These are non-motile cilia-mechnosensing organelles in internal ear, epididymis etc., respond to fluid motion in numerous types of animals for various functions.

Synaptic knobs: These are bulb-like structures formed distally by the axon terminals and contain synaptic vesicles which have neuro-transmitters.

Transverse plane: The plane that runs through the sagittal axis and transverse axis.

Vasodilators: These are substances like histamine and bradykinin which increase the capillary permeability and cause inflammation in response to infection or injury.

VERY SHORT ANSWER TYPE QUESTIONS

1. The body of sponges does not possess tissue level of organisation, though it is made up of thousands of cells. Comment on it.
2. What is 'tissue' level of organisation among animals? which metazoans do exhibit this organisation?
3. Animals exhibiting which level of organisation lead relatively more efficient way of life when compared to those of the other levels of organisation? Why?
4. What is monaxial heteropolar symmetry? Name the group of animals in which it is the principal symmetry.
5. Radial symmetry is an advantage to the sessile or slow moving organisms. Justify this statement.
6. What is cephalization? How is it useful to its possessors?
7. Mention the animals that exhibited a 'tube-within-a-tube' organisation for the first time? Name their body cavity.
8. Why is the true coelom considered a secondary body cavity?
9. What are retroperitoneal organs?
10. What is enterocoelom? Name the enterocoelomate phyla in the animal kingdom?
11. Distinguish between exocrine and endocrine glands with examples.
12. Distinguish between holocrine and apocrine glands.
13. Mention any two substanses secreted by mast cells and their functions.
14. Distinguish between a tendon and a ligament.
15. Distinguish between brown fat and white fat.
16. What is the strongest cartilage? In which regions of the human body, do you find it?
17. Distinguish between osteoblasts, and osteoclasts?

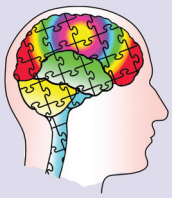
18. Define osteon.
19. What are Volkmann's canals? What is their role?
20. What is a Sesamoid bone? Give an example.
21. What is lymph? How does it differ from plasma?
22. What is the haematocrit value?
23. What are intercalated discs? What is their significance?
24. "Cardiac muscle is highly resistant to fatigue". Justify.
25. Distinguish between '**nucleus**' and '**ganglion**' with respect to the nervous system.
26. Distinguish between **'tracts'** and **'nerves'** with respect to the nervous system.
27. Name the glial cells that form myelin sheath around the axons of central nervous system and peripheral nervous system respectively.
28. Distinguish between white matter and greymatter of 'CNS' .
29. What are microglia and what is their origin and add a note on their function.
30. What are pseudounipolar neurons? Where do you find them?

SHORT ANSWER TYPE QUESTIONS

1. Describe the four different levels of organization in metazoans?
2. In which group of bilaterians do you find solid bauplan? Why is it called so?
3. Mention the advantages of coelom over pseudocoelom?
4. Describe the formation of schizocoelom and enterocoelom.
5. Describe briefly about the three types of intercellular junctions of epithelial tissues.
6. Give an account of glandular epithelium.
7. Give a brief account of the cells of areolar tissue.
8. Describe the three types of cartilage.
9. Explain Haversian system.
10. Write short notes on lymph.
11. Describe the structure of a skeletal muscle.
12. Describe the structure of a cardiac muscle.
13. Given an account of the supporting cells of nervous tissue.
14. Describe the structure of a multipolar neuron.
15. Write short notes on (A) Platelets and (B) Synapse.

LONG ANSWER TYPE QUESTIONS

1. What is coelom? Explain the different types of coelom with suitable examples and neat labelled diagrams?
2. What is symmetry? Describe the different types of symmetry in the animal kingdom with suitable examples.
3. Classify and describe the epithelial tissues on the basis of structural modification of cells with examples.
4. Describe the various types of connective tissue proper with suitable examples.
5. What is a skeletal tissue? Describe structure of a compact bone.
6. Give an account of the "formed elements" of Blood?
7. Write notes on striated muscles.



For ignited minds

- Not For Evaluation

1. **Microtome** invented by **His** is used for taking fine sections of tissues for their observation under a microscope.
2. **Canada balsam** is used in the preparation of permanent slides to mount sections of tissues and micro-organisms as its refractive index is same as that of glass.
3. **Collagen** is the most abundant protein in the human body.
4. The **first key transition** in the eumetazoan body plan is the evolution of **tissues**.
5. The **second key transition** in the eumetazoan body plan is the evolution of **Bilateral symmetry**.
6. The **third key transition** in the eumetazoan body plan is the **evolution of coelom**.
7. Structural **complexity** of body organisation is attained due to the evolution of **mesoderm**.
8. The skin and its derivatives constitute the **integumentary system**.
9. The branch of medicine that deals with the study of skin and its diseases is known as **dermatology**.
10. In flatworms the segmentation cavity is completely filled with mesenchyme (**parenchyma** of **mesodermal** origin) whereas in round worms, it is partly filled with it.
11. Dermis of the skin of the large mammals yields leather produced by a chemical treatment called '**tanning**'.
12. Excluding the **haemopoietic tissue**, the most rapidly multiplying tissue is the epithelial tissue. Thats why cancers of epithelia(carcinomas) are the most common type of cancers. The more the cells divide, the more is the chance of mutation occurring in the DNA leading to uncontrolled cell cycles.
13. In young people, bones do not break easily and fractures are joined (healed) quickly, where as the reverse is the case in the grownups. Can you make an educated guess on it?
14. When a bone is fully grown, it stops growth as osteoblasts become inactive osteocytes. But, when a bone is fractured how is it healed when there are no osteoblasts?
15. Impulse conduction is relatively faster in the cardiac muscle. Elucidate.
16. When a person slips ascending a stair case, he is likely to develop a sprain. **Can you guess what happened in the tissue concerned**.
17. '**Water, 'water everywhere but not a drop to drink**' is an old saying. '**Oxygen, oxygen everywhere, but not a pinch to be used for the cell's own respiration**'. What in your opinion are we talking about?

    (**CLUE:** It is a type of cell involved in oxygen transport).
18. Passing of certain blood cells through the walls of capillaries into the connective tissue is referred to as **diapedesis**. However, there are some cells which undertake what might be called '**reverse diapedesis**'. Can you guess which cells do that?

    (**CLUE:** These cells have a major role to play in the immune system).
19. Can you identify the largest WBC just by looking at the nucleus. If so, what are they and how could you identify?
20. What are the smallest of the 'formed elements' in the human blood? What is their chief role?

    (**CLUE:** When you get an intravenous injection, they initiate their role, a few seconds after the syringe is withdrawn).

Libbie Henrietta Hyman

***L.H. Hyman** is a very big name in '**Invertebrate Zoology**'. Her six volumes on the systematics of the invertebrates are monumental editions - a work which goes in **gilt letters** in the annals of the History of Zoology.*

Unit

3

Animal Diversity - I

Non - Chordate Phyla

LIFE - LOOKS SO SIMPLE - YET IT IS SO COMPLEX

ANIMAL DIVERSITY, THE LANGUAGE OF COMPLEXITY

Animalia (**Metazoa**) includes **multi-cellular**, **heterotrophic** (obtain nourishment by mostly ingesting and digesting the ingested food), **eukaryotes** with specific body plans (**bauplans**). Animal cells do not have cellulose cell walls, but they are held together by certain structural proteins. **Collagen** is the most abundant protein and unique to the Kingdom Animalia.

Animals reproduce mostly sexually, by the fusion of 'gametes' resulting in the production of '**zygotes**'. Zygotes undergo different types of cleavages and pass through simple stages such as '**blastula**', '**gastrula**' etc. and further differentiate into an adult, either '**directly**' (without a larval stage), or **'indirectly'** (with a larval stage).

The most simple multi-cellular organisms are the 'sponges' which show '**cellular level of organisation**'. The 'choano-flagellates' (mastigophores) of the kingdom '**Protista**'/ '**Protoctista**', are the closest **living relatives** of the metazoans. While sponges have 'unorganised' cells, the 'diploblastic organisms' (cnidarians and ctenophores), are the 'first true metazoans' with two germinal layers, namely 'ectoderm' and 'endoderm'. They show '**tissue level of organisation'**. The diploblastic organisms show 'co-ordination' between body parts, due to the presence of '**sensory cells'** and '**nerve cells'**.

The next higher level of organisation is reached with the development of the 'triploblastic level of organisation' (three germinal layers namely – **ectoderm**, **endoderm** and the third germinal layer, the **mesoderm**) – a promotion from '**tissue**' to

'**organ**' and '**organ-system'** level of organisation. The first 'triploblasts' have a '**solid bauplan**' (the space between the ectoderm and endoderm/ the perivisceral space, is filled with a tissue called 'parenchyma/mesenchyma' derived from the '**mesoderm**' - the '**Acoelomates**').

The first '**tube - within - a tube'** body organisation (outer tube-the **body wall** and the inner tube - the **alimentary canal**) arose with the evolution of the nematodes. The space between the body wall and the alimentary canal, in the body of a nematode is the remnant of the 'primary body cavity' (**blastocoel**) and is called '**pseudocoel**' (false coelom). Coelom (perivisceral space lined by mesodermal coelomic epithelia/ peritoneal layers) arose by the splitting of the mesoderm. It is called '**schizocoelom**' (schizo- splitting). It is typically seen in the 'annelids', 'arthropods' and 'molluscs'. The echinoderms, hemichordates and chordates also have a true coelome (**eucoelom**). It arises by the confluence of the 'out-pouchings' of the archenteron (primitive gut). As such the coelom in them is described as '**enterocoelom**'.

In the development of animals, the blastula stage develops into gastrula stage. Gastrula is a 'double layered stage' with a new cavity called '**archenteron**', which opens to the exterior by a '**blastopore**'. It is a very crucial in the developmental processes. Gastrulation finally leads to the differentiation of the three embryonic cell layers (**germinal layers**). The organisms in which the blastopore develops into the **mouth** are called '**protostomes**' (**platyhelminths** to the **molluscs**) and the organisms in which the blastopore usually develops into the '**anus**' and the 'mouth' is formed secondarily are called '**deuterostomes**' e.g., **echinoderms**, **hemichordates** and **chordates**. In the prtostomes cleavage is '**spiral**' and '**determinate**'. The embryos of protostomes are described as '**mosaic embryos**'. The cleavage in the deuterostomes is '**radial**' and '**indeterminate**' and their embryos are called '**regulative embryos**'. The fate of each blastomere is '**predetermined**' in the case of determinate development and in the case of regulative embryos, their fate is decided late in the development.

Evolution of tissues**, development of **bilateral symmetry** and origin of the **body cavity** are successively considered the **first**, **second** and the **third** **'key transitions'** in the animal organisation. This **Unit** traces the entire history of evolution of organisation in the animal kingdom from simple to more complex levels. You will be learning more **salient features** of different major groups (**phyla**) of the Kingdom **Animalia** as you are taken from the study of the **sponges** to that of the **chordates.

*Animals are broadly classified into **invertebrates** and **vertebrates**. The animals which lack a **notochord** are called **invertebrates.** **Libbie Henrietta Hyman** (1888-1969) was the 'pioneer' in the field of systematics of the invertebrates. Her legendary volumes (6 volumes, 1940-68) on the **Invertebrates** are popular and considered authoritative, even in recent times. The invertebrates are characterized by the absence of vertebral column (back bone) and presence of solid, ventral ganglionated nerve cord. Alimentary canal is dorsal to the nerve cord. They exhibit many types of reproduction.*

Invertebrate Phyla

3.1 Phylum-Porifera

(Subkingdom-Parazoa)

- An Evolutionary Blind Offshoot

3.1.1 General Characters

The term *Porifera* (***pore bearing***) was coined and their true '*animal nature*' was established by **Robert Grant**. Members of this phylum are commonly called sponges. They are generally marine (with the exception of families Potamolepidae and Spongillidae, which include freshwater **sponges** e.g. *Spongilla*). They are either **radially symmetrical** or **asymmetrical** animals (Figure 3.1). These are primitive, **multicellular** and sessile animals and have **cellular level of organisation**. The body wall is composed of two layers (outer epidermis/ pinacoderm and inner choanoderm) separated by a gelatinous matrix called **mesohyl**. Sponges have a **canal system** that constantly conducts water. Water enters through minute pores called **ostia** (inhalent apertures) in the body wall into a central cavity, the **spongocoel** (paragastric cavity), from where it goes out through the **osculum** (exhalent aperture). This transport of water is helpful in gathering food (nutrition-**filter feeders**), respiratory exchange of gases (respiration) and removal of wastes (excretion). **Choanocytes** or **collar cells** line the spongocoel and the canals. Nutrition is holozoic and digestion is **'intracellular'**. Reserve food is stored in cells called 'thesocytes'. Nerve cells and sensory cells are absent and so they do not show much co-ordination between the functioning of various parts of the body. The body is supported by a skeleton made up of **calcareous or siliceous spicules or spongin fibres** or both. Sexes are not separate (hermaphroditic or monoecious), i.e., egg cells and sperms are produced by the same individual. Sponges reproduce asexually by fragmentation, budding etc., and sexually by formation of gametes.

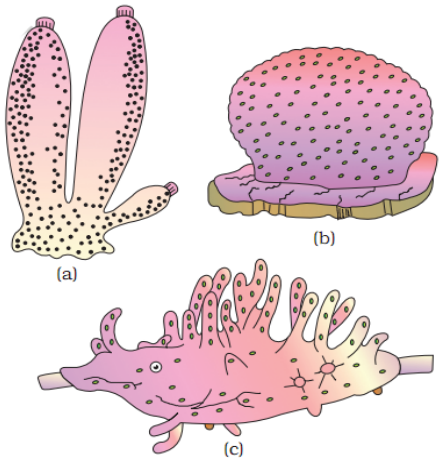


Fig 3.1 Examples for Porifera :
(a) Sycon (b) Euspongia (c) Spongilla

Fertilisation is internal. Cleavage is holoblastic and development is indirect involving different types of larval stages such as **parenchymula**, **trichimella** and **amphiblastula** which are morphologically different from the adult. Power of regeneration is well developed. They are considered an evolutionary blind offshoot.

Examples: *Sycon*, *Euplectella, Spongilla* and *Euspongia*.

3.1.2 Classification of the phylum Porifera

Phylum Porifera is classified into three classes, **1. Calcarea 2. Hexactinellida** and **3. Demospongiae**

Class-1: Calcarea

They live in shallow marine waters. They are solitary or colonial. Body structure is simple. Spicules are calcareous (made up of Ca CO_3).

Examples: *Sycon* (*Scypha*), *Leucosolenia*, *Grantia*.

Class-2: Hexactinellida

They live in deeper parts of the sea. They are solitary. Spicules are six rayed (hexactinal) and siliceous (made of silicon dioxide – *glass*).

Examples: *Euplectella* (Venus' flower basket), *Hyalonema* (Glass - rope sponge).

Class-3: Demospongiae

There are both marine and freshwater sponges in this class. They are colonial. Skeleton consists of siliceous spicules (other than six rayed) or spongin fibres or both or skeletal structures may be absent.

Examples: *Spongilla* (freshwater sponge), *Euspongia* (bath sponge), *Chalina* (dead man's fingers).

3.2 Phylum-Cnidaria (Coelenterata)

- Tissues and the radial body plan

3.2.1 General Characters

Cnidarians (previously called coelenterates) are aquatic, mostly marine, solitary or colonial, sessile or free-swimming, **radially symmetrical** animals (sea anemones are biradially symmetrical) (Figure 3.2). The recent name Cnidaria is derived from the '***stinging cells***' called **cnidoblasts** or **cnidocytes** present mostly on the tentacles and the body. Cnidoblasts are used for anchorage, defence and capture of prey (Figure 3.3). Cnidarians are the first metazoans to exhibit '**tissue level of organisation**' and are '**diploblastic**'. They have a central

gastro-vascular cavity or **coelenteron** (serves both digestive and circulatory functions), hence the earlier name coelenterata , with a single opening, the mouth serving the purpose of ingestion and egestion, there being no anus. Digestion is both **extracellular** (in the coelenteron) and **intracellular** (in the nutritive muscular cells of the endoderm). Nervous system is of primitive type formed of diffuse '*nerve net*' (formed by non-polarised nerve cells). Sensory structures such as **statocysts** occur in the medusoid forms. Some of the cnidarians, e.g., coral forming cnidarians have an exoskeleton composed of calcium carbonate. Cnidarians show two basic body forms called **polyp** and **medusa** (Figure 3.2). The former is a sessile and cylindrical form (e.g. *Hydra*, *Adamsia* etc.), whereas, the latter is '*umbrella-shaped*' and free-swimming form (e.g. *Aurelia* – commonly called jelly fish). Those cnidarians which exist in both forms exhibit alternation of generations (**metagenesis**), i.e., polypoid forms produce medusae asexually and medusae form the polypoid forms sexually (e.g. *Obelia*). Asexual reproduction is by budding and sexual reproduction is by syngamy. Development is indirect and includes a free swimming ciliated larva, the **planula**.

Examples: *Physalia*, *Adamsia*, *Pennatula*, *Rhizostoma* and *Meandrina*.

3.2.2 Classification of the phylum Cnidaria (Coelenterata)

Phylum Cnidaria is classified into three classes, namely **1. Hydrozoa 2. Scyphozoa** and **3. Anthozoa**.

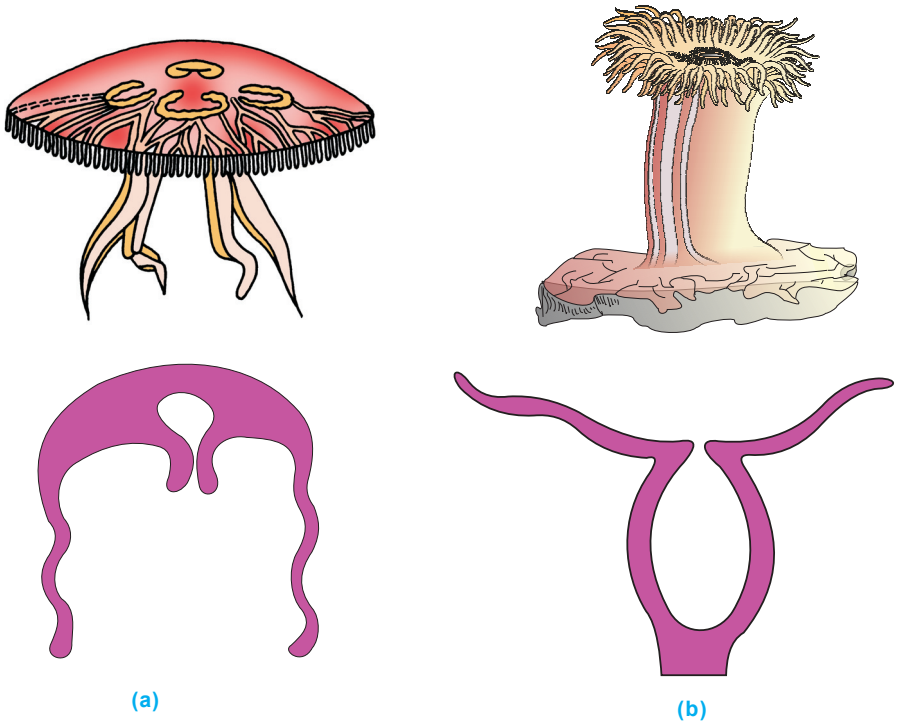


Fig. 3.2 Examples of coelenterata indicating outline of their body form: (a) Aurelia (medusa) (b) Adamsia (polyp)

Class-1: Hydrozoa

They may be solitary (e.g.Hydra) or colonial. Life history includes sedentary, asexual, polypoid form and free swimming, sexual, medusoid form alternating with each other (e.g. *Obelia*). Mesoglea is non-cellular. Coelenteron is undivided (simple). Cnidocytes (cnidoblasts) occur only in the ectoderm. Germ cells are derived from the ectoderm. Some exhibit *polymorphism* with different types of **zooids** e.g.*Physalia*.

Examples: *Hydra* (freshwater polyp), *Obelia (*sea fur*)*, *Physalia* (Portuguese man-of-war). Note: Zooid is a single individual in a colony.

Do you know why Physalia is commonly called 'Portuguese man-of-war' or 'man o' war'? The word 'Man of War' means a 'battle ship with cannons and other powerful weapons' Portugal once had. *Physalia* has many tentacles provided with venomous 'stinging cells', that are harmful to other organisms, hence the name 'Portuguese man-of-war'.

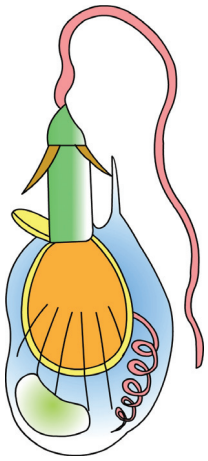


Fig. 3.3 Diagrammatic view of cnidoblast

Class-2: Scyphozoa

They are commonly referred to as jelly fishes as they possess a large quantity of jelly like mesoglea. They are solitary and medusoid in form. Mouth is surrounded by four oral arms. Coelenteron is divided into four chambers and some canals. Mesoglea contains amoebocytes. Cnidocytes occur in ectoderm and endoderm. Germ cells are derived from the endoderm.

Examples: *Aurelia* (jelly fish or moon jelly), *Rhizostoma*.

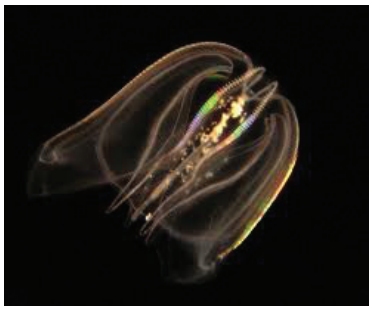
Class-3: Anthozoa or Actinozoa

They are commonly referred to as *sea anemones*. They are sedentary and *only* polypoid in form. Coelenteron is divided into several compartments by vertical septa called mesenteries. Mesoglea contains connective tissue. Cnidocytes occur both in the ectoderm and endoderm. Germ cells are derived from the endoderm.

Examples: *Adamsia* (sea anemone), *Corallium rubrum* (precious red stone coral), *Gorgonia* (sea fan), *Pennatula* (sea pen).

3.3 Phylum-Ctenophora

- Close relatives of cnidarians



3.3.1 General Characters

Ctenophores, commonly known as '**sea walnuts**' or '**comb jellies**' or '*sea gooseberries'*, are exclusively marine, **radially symmetrical**, diploblastic organisms with tissue level of organisation. The body bears *eight* external rows of ciliated **comb plates**, which help in locomotion, hence the name 'ctenophora'. Cnidocytes are absent. However, they possess '**glue cells**' called

lasso cells or **colloblasts** which help in food capture. Digestion is both extracellular and intracellular. **Bioluminescence** (the property of emitting light by living organism) is well-marked in the ctenophores. Sexes are not separate (monoecious). Reproduction takes place only by sexual method. Fertilisation is external. Development is indirect and includes a larval stage called **cydippid larva**.

Examples: *Pleurobrachia, Hormiphora.*

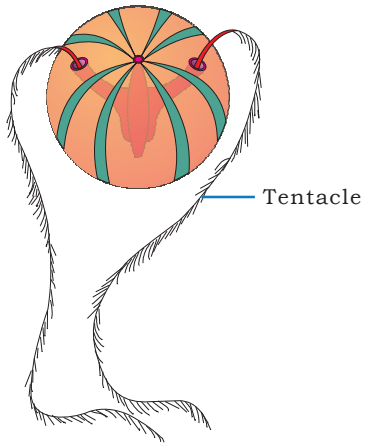


Fig. 3.4 Example of ctenophora (*Pleurobrachia*)

3.3.2 Classification of the phylum Ctenophora

Phylum Ctenophora is classified into two classes, 1. Tentaculata and 2. Nuda.

Class-1: Tentaculata

The adults possess two aboral tentacles.

Examples: *Pleurobrachia, Ctenoplana.*

Class-2: Nuda

Tentacles are absent even in the larval stages.

Examples: *Beroe.*

Note: ***Sea anemones and sea walnuts are said to be 'Biradially Symmetrical'.***

3.4 Phylum-Platyhelminthes

- Mesoderm and the bilateral plan

3.4.1 General Characters

They have **dorso-ventrally flattened body**, hence are called **flatworms**. These are mostly endoparasites found in animals, including human beings. Flatworms are the first **bilaterally symmetrical**, **triploblastic** and **acoelomate** animals with **organ-system level of organisation** (Fig. 3.6-3.8). Body is not segmented, but some exhibit pseudometamerism. They show moderate cephalization and unidirectional movement (locomotion). **Hooks** and **suckers** are present in the parasitic forms (Fig. 3.5). Digestive system, if present, has mouth only; anus is absent. Nervous system is moderately developed with brain (cephalic ganglia) and nerve cords forming 'ladder like' system. Specialised excretory cells called **flame cells** (**protonephridia**) help in osmoregulation and excretion. Sexes are not separate (monoecious). Fertilisation is internal and development is indirect with many stages (**miracidium, sporocyst, redia, cercaria** etc.). **Polyembryony** is common in some (Liver

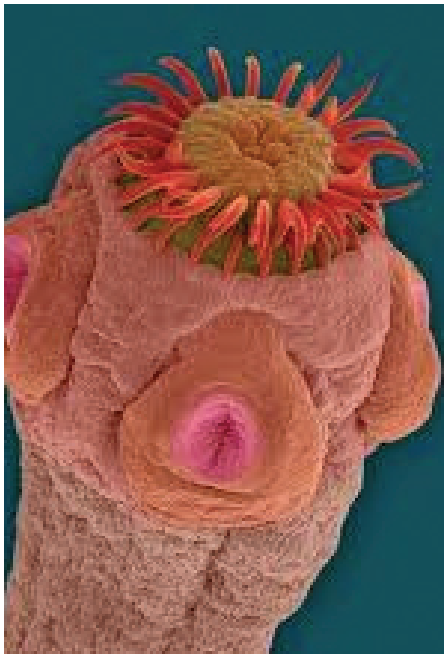


Fig. 3.5 Scolex of tape worm

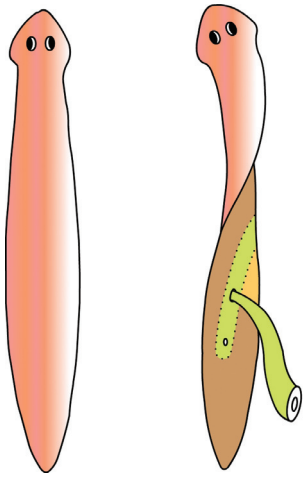


Fig. 3.6 Dugesia

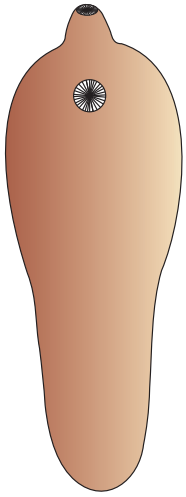


Fig. 3.7 Fasciola

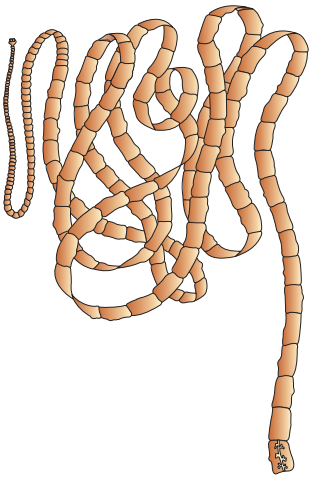


Fig. 3.8 Taenia

fluke). Some members like *Planaria* possess high degree of **regeneration** capacity.

Examples: *Taenia*, *Fasciola*, *Schistosoma*, *Dugesia.*

3.4.2 Classification of the phylum Platyhelminthes

Phylum Platyhelminthes is classified into three classes, namely **1. Turbellaria 2. Trematoda** and **3. Cestoda.**

Class-1: Turbellaria

They are mostly free living, unsegmented flat worms. Body wall bears cilia and mucus forming structures called **rhabdites** in the epidermal cells. Reproduction is by asexual and sexual methods. Development is indirect and includes free swimming, ciliated **Muller's larva**.

Examples: *Dugesia*, *Convoluta.*

Class-2: Trematoda

They are commonly called *flukes*. They are parasitic on other animals. Body is covered by a thick cuticle (tegument); bears two suckers, an oral and a ventral (acetabulum). Mouth is anterior and the intestine is bifurcated. They are bisexual (monoecious). Life history is complex with many hosts and different types of stages (*miracidium, sporocyst, redia, cercaria* etc.).

Examples: *Fasciola* (liver fluke), *Schistosoma* or *Bilharzia* (blood fluke).

Class-3: Cestoda

They are commonly called *tapeworms*. All are endoparasites. Body is covered by protective ***syncytial tegument***. They show ***pseudometamerism*** (body is divided into segment like units called proglottids which are not 'true segments'). Scolex bears hooks, suckers and **bothridia** (leaf like outgrowths) for anchoring. Mouth and gastrovascular cavity are absent. They are bisexual (monoecious). Life history is complex with many hosts and development is indirect with cysticercus larva (bladder worm).

Examples: *Taenia solium* (pork tapeworm), *Echinococcus granulosus* (dog tapeworm).

3.5 Phylum-Nematoda

(Aschelminthes , as used in NCERT book)

- Body cavity, a 'one way gut' and 'tube with-in-a tube'

3.5.1 General Characters

The body of a nematode is circular in cross-section, hence the name **s** (Figure 3.9). They may be free living or parasitic on plants and animals, aquatic or terrestrial. Roundworms have organ-system level of organisation. They are bilaterally symmetrical, triploblastic and **pseudocoelomate** animals. Body is unsegmented and covered by a transparent, tough and protective **collagenous cuticle** (a *unique character*). In some, the epidermis is **syncytial**. Alimentary canal is complete with a mouth, well developed muscular pharynx and anus. Excretory system consists of **renette gland** (excretory gland) and ducts. Nervous system consists of a circum enteric nerve ring with ganglia and nerves. Sense organs like **amphids** and **phasmids** occur. Sexes are separate (dioecious). They exhibit sexual dimorphism, often females are longer and larger than males. Males have curved posterior end with a cloacal aperture and one or two copulatory (penial) spicules. Fertilisation is internal, majority are oviparous (e.g. *Ascaris*), a few are ovo-viviparous (e.g. *Wuchereria*) and development may be direct (the young ones resemble the adult- called **juveniles**) or indirect. Growth into adult forms involves typically four **moultings** in the larval or juvenile stages.

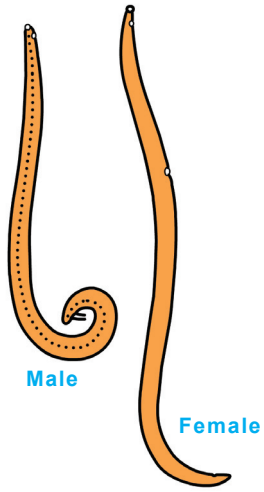


Fig. 3.9 Ascaris lumbricoides

Examples: *Ascaris*, *Wuchereria*, *Ancylostoma*.

In nematodes, the number of body cells (except the cells in gonads) remains constant, once the animal reaches the adulthood. It means the number of nuclei too is constant. This phenomenon is called 'eutely'. If there is growth in the size of the body, it is due to the growth in the size of the cells (hypertrophy).

3.5.2 Classification of the phylum Nematoda

Phylum Nematoda is classified into two classes, namely **1. Aphasmidia** and **2. Phasmidia**.

Class-1: Aphasmidia

In the members of this class **amphids** (cuticular depressions around oral region performing chemoreceptor function) are highly modified, but phasmids (posterior glandulo-sensory structures) are absent.

Examples: *Trichinella* (trichinaworm), *Trichuris* (whipworm).

Class-2: Phasmidia

In the members of this class amphids are simple and **phasmids** are present. Excretory system is well developed.

Example: *Ascaris* (roundworm), *Ancylostoma* (hookworm), *Enterobius* (pinworm), *Wuchereria* (filarial worm).

3.6 Phylum-Annelida

-Segmented body plan

3.6.1 General Characters

The term annelida (L. *annulus* : little ring and Gr. *edios* : form) was coined by **Lamarck**. They may be aquatic (marine and freshwater) or terrestrial; free-living, and sometimes parasitic. They exhibit organ-system level of body organisation and bilateral symmetry. They are triploblastic, **metamerically segmented (metamerism)** and **coelomate (schizocoelic coelom)** animals (Fig. 3.10-3.12). Their body and the coelom are divided by transverse septa into segments or **metameres**. They possess longitudinal and circular muscles in the body wall, which help in locomotion. Coelom with coelomic fluid provides a **hydrostatic skeleton** giving stiffness to the body parts thus aiding in locomotion. Aquatic annelids such as *Nereis* possess lateral appendages, the **parapodia**, which help in swimming; chitinous *setae* and *suckers* also help in locomotion in some. Cephalization is more pronounced with distinct head and sense organs in some polychaetes. Respiration is by simple diffusion through the body wall and in *Nereis* highly vascularised parapodia help in respiration. A *closed* circulatory system is present. Respiratory pigments such as **haemoglobin**, **chlorocruorin** are found dissolved in the plasma (a feature unique to the invertebrates). Nephridia (metanephridia- nephridia with nephrostomes), which are 'ectodermal' in origin, help in osmoregulation and excretion. Nervous system consists of paired (cerebral and sub-pharyngeal) ganglia connected by lateral nerves around the pharynx forming a **nerve ring** and to a ganglionated 'double ventral nerve cord' (annelidan type of nervous system). Sense organs like eyes, palps and tentacles occur in some. They may be dioecious (sexes are separate-e.g. *Nereis*) or monoecious (hermaphrodites – e.g. earthworms and leeches). Reproduction is usually sexual. Cleavage is holoblastic (complete) and spiral. Development is direct in the monoecious (bisexual) annelids and indirect in the dioecious (unisexual) annelids. Characteristic larval form, the **trochophore** occurs in the life history.

Examples: ***Nereis***, ***Pheretima***, ***Megascolex*** and ***Hirudinaria***.

3.6.2 Classification of the phylum Annelida

Phylum Annelida is classified into three classes, namely

1. Polychaeta 2. Oligochaeta 3. Hirudinea

Class-1: Polychaeta

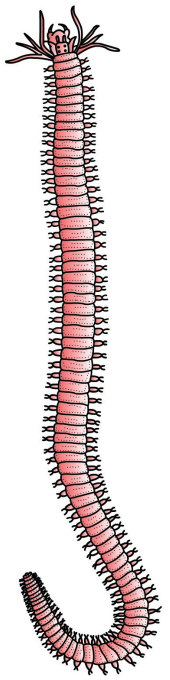


Fig. 3.10 Nereis

Polychaeta (*poly* : many; *chaetae* : setae) includes marine annelids commonly called bristle worms. Some are free-moving and others burrowing or tubicolous (tube dwelling). Head is distinct with sense organs such as eyes, tentacles and palps. **Parapodia** which bear many setae (hence the name polychaeta) help in locomotion and respiration. Clitellum is absent. They are dioecious (unisexual); gonoducts are absent; gametes are shed into the coelom and passed out through the nephridiopores. Fertilization is external; development includes a trochophore larva.

Examples: *Nereis* (sandworm or ragworm or clam worm), *Aphrodite* (sea mouse), *Arenicola* (lugworm).

Class-2: Oligochaeta

Oligochaeta (*oligos :* few; *chaetae :* setae) includes earthworms which live in moist soil and some live in freshwater (e.g. *Tubifex*). They lack distinct head. Chitinous setae help in locomotion. Clitellum forms a cocoon during the breeding season. They are monoecious (bisexual); development is direct without larval stage.

Examples: *Pheretima*, *Megascolex* and *Tubifex.*

Class-3: Hirudinea

Fig. 3.11 Leech

Hirudinea (*hirudo* : leech) includes *leeches*; all are ectoparasites; majority live in fresh water; some are marine and others live on moist land (terrestrial). They have dorso-ventrally flattened body with a **definite number** of segments ; the segments are externally sub divided into **annuli**; internal segmentation is absent ; suckers help in locomotion. Clitellum is conspicuous during the breeding season only. Coelom is filled with a characteristic tissue called **botryoidal tissue** (*botryoidal*: resembling a bunch of grapes; opinions differ on the function of botryoidal tissue - they range from excretion to storage of iron, calcium, revascularization in areas of injury etc.). They are monoecious (hermaphroditic); male reproductive system possesses a copulatory organ, the *cirrus*. Fertilization is internal and development is direct .

Examples: *Hirudinaria* (freshwater leech), *Pontobdella* (marine leech), *Haemadipsa* (land leech).

3.6.3 Earthworm

Fig. 3.12 Earthworm

Earthworm is a reddish brown terrestrial invertebrate that inhabits the upper layers of the moist soil rich in decaying organic matter. It is nocturnal and during the day time, it lives in burrows made by boring and swallowing the soil. In gardens, they can be traced by their faecal deposits known as **worm castings**. They are considered, the ***Friends of farmers***. The common Indian earthworms are *Pheretima, Lumbricus and Megascolex.* ***Drawida grandis*** of south India is the longest earthworm in India. *Chaetogaster annandalei* is the smallest earthworm, while *Megascolides australis* is the longest earthworm.

I. Morphology

Pheretima posthuma has a long cylindrical body which is divided into 100 to 120 segments (metameres). The dorsal surface of the body is marked by a dark mid-dorsal line (representing the dorsal blood vessel) along the longitudinal axis of the body. The ventral surface of the body shows genital apertures (pores). The anterior end bears a

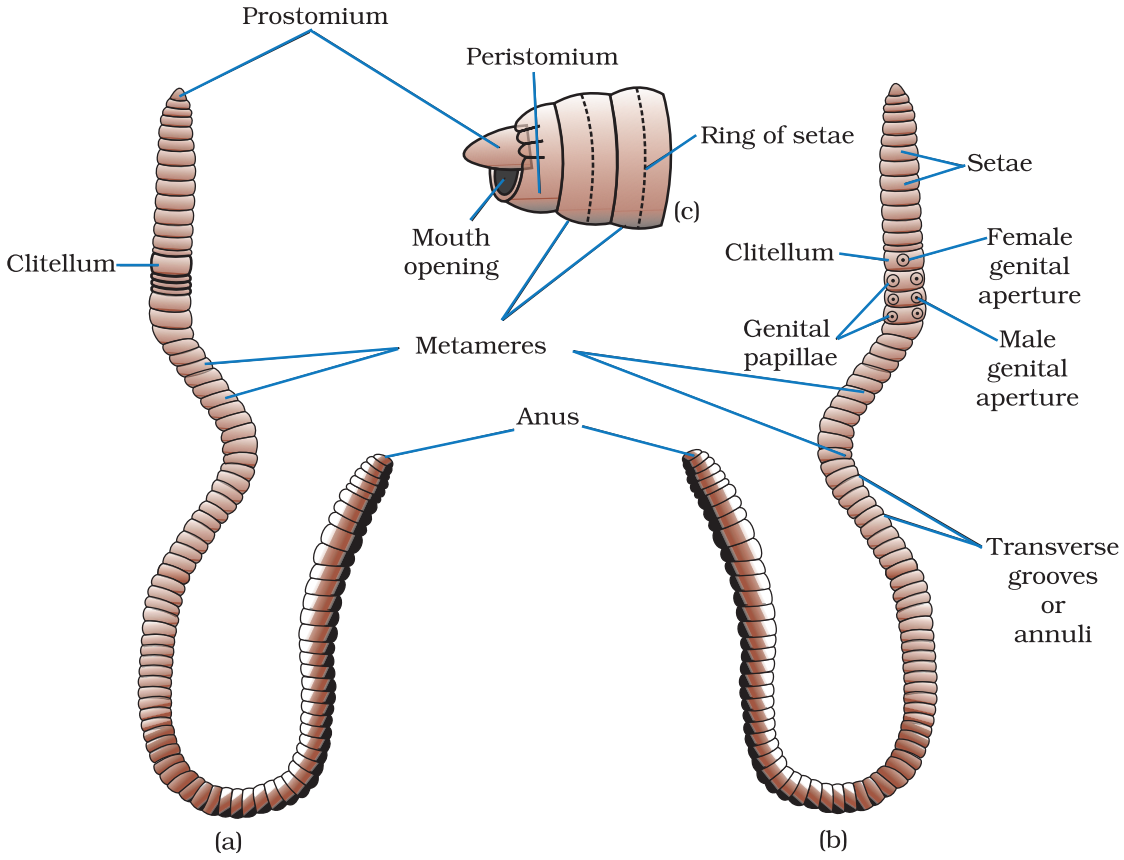


Fig. 3.13 Body of earthworm: (a) dorsal view (b) ventral view (c) lateral view showing mouth opening

lobe which serves as a covering for the mouth, the **prostomium**, which is not a true segment and over hangs the oral aperture. The prostomium bears some sense receptors. The first body segment is the **peristomium** (*buccal segment*) which surrounds the mouth and the prostomium. In a mature worm, the segments 14-16 are covered by a prominent dark band of glandular tissue called **clitellum** or **cingulum** (**L.** *clitellum*: a pack saddle; *cingulum*: a belt). The body is divisible into three prominent regions –the **pre-clitellar**, **clitellar** and **post-clitellar** regions (Figure 3.13). Four pairs of spermathecal apertures are situated on the ventro-lateral sides of the inter-segmental grooves, from 5th to 9th segments (5/6, 6/7. 7/8 and 8/9). A single female genital pore is present in the mid-ventral line of the 14th segment. A pair of male genital pores is present on the ventro-lateral sides of the 18th segment. Numerous minute pores called nephridiopores open on the surface of the body from the 3rd segment to the last . In each body segment, except the first, last (pygidium) and clitellum (in mature worms) there are rows of s-shaped chitinous **setae** or **chaetae** embedded in the epidermal pits (setal or setigerous sacs) in the middle of each segment. Setae can be protruded or retracted. They play an important role in locomotion.

II. Anatomy

The body wall of earthworm is covered externally by a thin non-cellular cuticle below which is the epidermis, two muscle layers (outer circular and inner longitudinal) and the innermost layer, the outer coelomic epithelium (parietal peritoneum). The epidermis is made up of a single layer of columnar epithelial cells which contain secretory gland cells. The coelomic epithelium is derived from the mesoderm and consists of the outer parietal (somatic) layer and inner splanchnic (visceral) layer. The space between the body wall and alimentary canal is called coelom (perivisceral cavity). It is a *schizocoelom* and is divided into compartments by septa filled with coelomic fluid. The coelomic fluid provides a '**hydrostatic skeleton**' for the earthworm during locomotion.

III. Digestive system

The alimentary canal is a straight tube and runs from the first to the last segment of the body (Figure 3.14). The mouth opens into the **buccal cavity** (1-3 segments) which leads into the muscular **pharynx** (4th segment). A small narrow tube, **oesophagus** (5-7 segments), continues into a muscular **gizzard** (8th segment). It helps in grinding the small particles of food the decaying leaves (**grinding mill**).

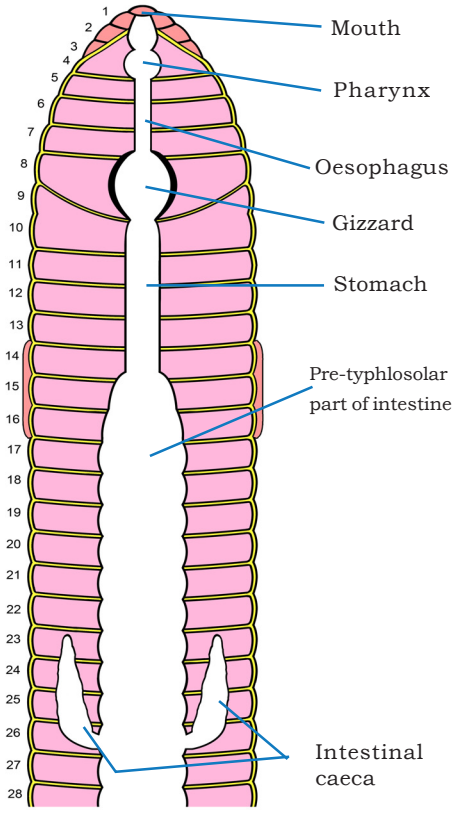


Fig. 3.14 Alimentary canal of earthworm

The stomach extends from the segments 9 to 14. The food of earthworm is decaying leaves and other organic matter mixed with the soil. Calciferous glands, present in the **stomach**, neutralise the humic acid present in the humus of the soil. The intestine starts from the 15th segment and continues till the last segment. A pair of short and conical intestinal caecae project from the intestine in the 26th segment. An internal median fold of the dorsal wall of the intestine called **typhlosole**, helping in increasing the area of absorption, is poorly developed in *Pheretima* (between the 26th and the **rectum**, which occupies the last 23 to 28 segments). The alimentary canal opens to the exterior by a small rounded aperture called anus. The ingested soil rich in organic matter passes through the digestive tract where digestive enzymes breakdown complex food into smaller absorbable units. These simpler molecules are absorbed through intestinal membranes and are utilised for various metabolic activities.

IV. Blood vascular system

Pheretima exhibits a **closed type** of blood vascular system, consisting of blood vessels, capillaries and 4 pairs of hearts. (Figure 3.15). Hearts connect the dorsal and ventral blood vessels. Due to closed circulatory system, blood is confined to the blood vessels. Contractions of the DBV keep blood circulating in the body. Smaller blood vessels supply blood to the gut, nerve cord and the body wall. **Blood glands** are present in the 4th, 5th and 6th segments. They produce blood cells and 'haemoglobin' which is 'dissolved in the plasma'. Blood cells are phagocytic in nature.

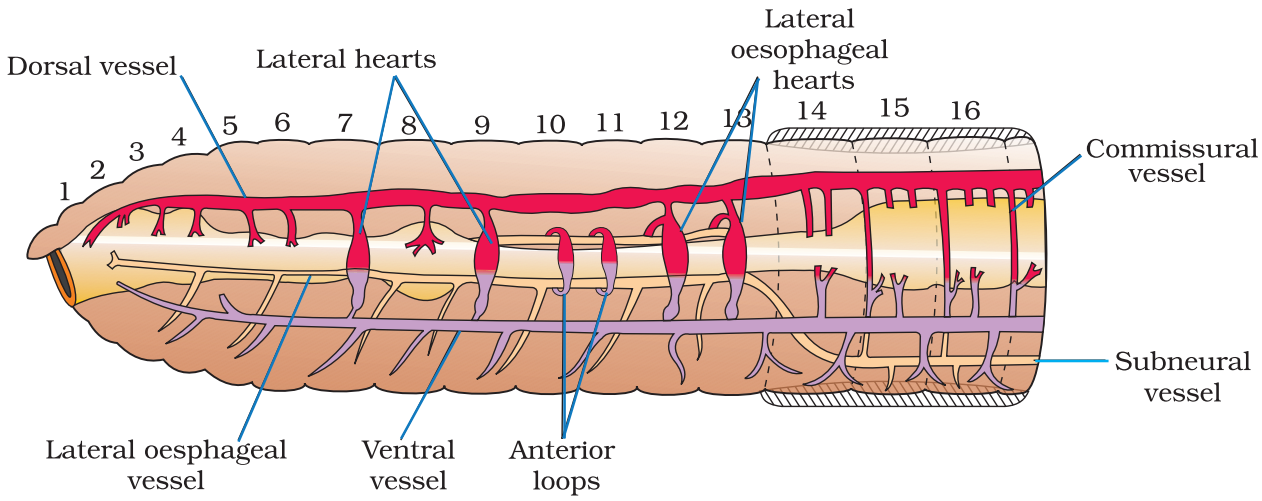


Fig. 3.15 Earthworm circulatory system

V. Respiratory system

Earthworms lack specialised respiratory structures. Respiratory exchange of gases occurs through the moist body surface by diffusion.

VI. Excretory system

The excretory organs occur as segmentally arranged coiled tubules called **nephridia** (sing: *nephridium*). They are of three types:

i) septal nephridia, present on both the sides of the inter-segmental septa of segments 15th/ 16th to the last. They open into the intestine

ii) integumentary nephridia, attached to the inner body wall from the 3rd segment to the last. They open to the exterior on the body surface by nephridiopores and

iii) pharyngeal nephridia, present as three paired tufts in the segments 4th , 5th and 6th (Figure 3.16). They open into the buccal cavity and pharynx. The different types of nephridia of *Pheretima* are fundamentally similar in structure. Nephridia with nephrostomes are called **open** nephridia (e.g. septal nephridia) and the nephridia which do not have nephrostomes are called **closed** nephridia (e.g. pharyngeal nephridia and integumentary nephridia). The nephridia that open to the exterior through nephridipores are called '**exonephric nephridia**' and those opening into the gut are called '**enteronephric nephridia**'. Enteronephric nephridia have a role in **osmoregulation**/conservation/ **homeostasis** of water. Earthworms are mostly *ureotelic* animals. The chief nitrogenous excretory waste is urea.

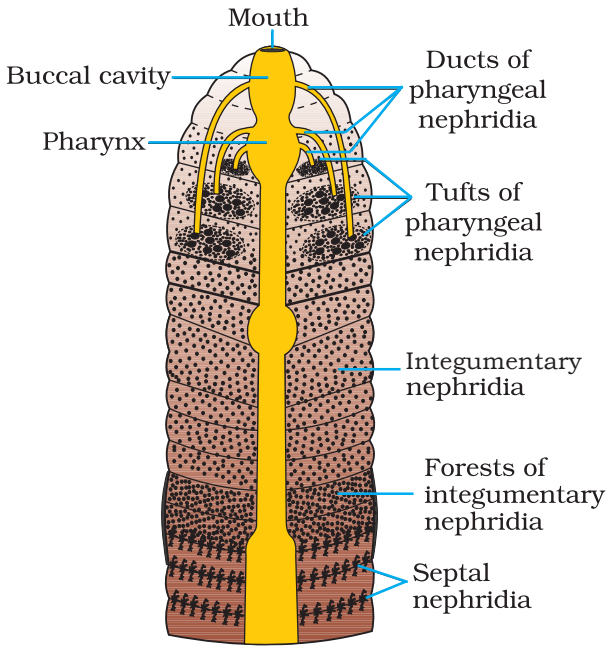


Fig. 3.16 Nephridial system in earthworm

VII. Nervous system

Nervous system consists of a **nerve ring** around the pharynx (in the 3rd and 4th segments) and a double ventral nerve cord. The cerebral ganglia (brain) along with other nerves in the ring integrate sensory input as well as command muscular responses of the body. Sensory system consists of receptor cells that receive light, touch and chemical stimuli. These sense organs are located mostly in the anterior part of the body.

VIII. Reproductive system

Earthworm is a hermaphrodite (bisexual) (Figure 3.17). There are two pairs of **testes** one pair each present in the 10th and 11th segments. Their **vasa deferentia** run up to

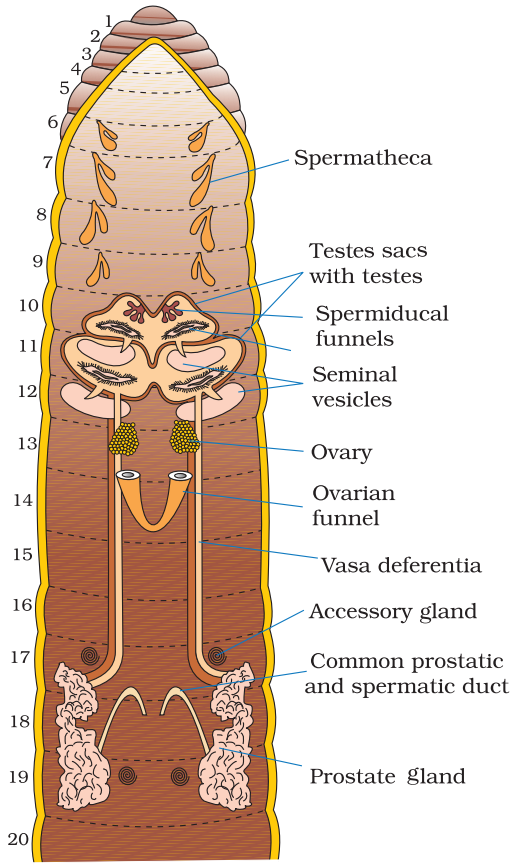


Fig: 3.17 Reproductive system of Pheretima

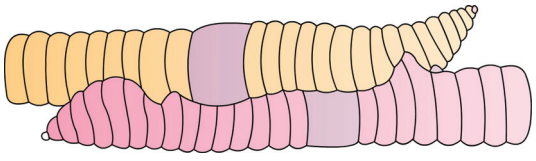


Fig. 3.18 Copulation

the 18th segment where they join the prostatic ducts. Two pairs of seminal vesicles present in the 11th and 12th segments are sacs in which spermatogonia mature into spermatozoa. The common prostatic and spermatic ducts open to the exterior by a pair of male genital pores on the ventro-lateral sides of the 18th segment. Two pairs of accessory glands are present one pair each in the 17th and 19th segments. Four pairs of **spermathecae** are located in the segments 6th to 9th (one pair in each segment). They receive and store spermatozoa (**spermatophore**) during copulation.

One pair of ovaries is attached to the posterior face of the inter-segmental septum of the 12th and 13th segments. *Oviducal funnels* are present beneath the ovaries and they continue into oviducts (14th segment). They join together and open to the exterior on the ventral side of the 14th segment by a single median female genital pore.

IX. Fertilization, cocoon formation and Copulation

Earthworm is protandrous. Mutual exchange of spermatozoa occurs between two mature worms during mating. They mate juxtaposing opposite gonadal openings, exchanging packets of sperms called **spermatophores** (Ref. NCERT book). Mature sperms and egg cells and nutritive fluid produced by the gland cells of the clitellum are deposited in **cocoons**. Fertilisation and development occur within the cocoons which are deposited in the moist soil. The cocoon contains the developing embryos. After about 3 weeks, each cocoon produces on average four earthworms (Ref: NCERT text book). Development is direct i.e., there is no larval stage.

X. Economic importance

Earthworms are known as **Friends of farmers** because they make burrows in the soil and make it porous, which helps in aeration of the soil. The process of enriching the fertility of soil by earthworms involves the process called **vermi-composting**. Earthworms are also used as bait in fishing.

3.7 PHYLUM-ARTHROPODA

- Tagmatization of the body; jointed legs.

3.7.1 General Characters

This is the **largest phylum** of the Kingdom: Animalia, and it includes the **largest Class** called **Insecta**. Over two-thirds of all named species on earth are arthropods accounting for 80% of the animal species (Figure 3.19 to 3.25). They are bilaterally symmetrical, triploblastic, metamerically segmented and coelomate (**schizocoelomate**) animals. The body of arthropods is covered by a chitinous exoskeleton as a protection and to prevent loss of water and it is periodically shed off by a process called **moulting** or **ecdysis** to allow growth of the body. The body is segmented and consists of *head, thorax* and *abdomen*. They have jointed appendages (arthros : joint; podium : foot). Muscles are striated and aid in rapid locomotion. ***(Note: striated muscles appeared for the first time in evolution, in the arthropods)***. Body cavity is a **haemocoel**. It is a cavity filled with haemolymph. It is formed by the fusion of embryonic blastocoel with some coelomic spaces. The coelom is reduced to the spaces around excretory organs and gonads. Respiratory organs are *gills, book gills, book lungs* or *tracheae*. Circulatory system is of **open type**. Heart is dorsal in position. In some (crustaceans and chelecerates) the haemolymph contains a '*copper*' containing respiratory pigment called '**haemocyanin**' dissolved in the haemolymph. Nervous system is of annelidan type consisting of a *nerve ring* (around oesophagus) and a double ventral nerve cord. Sensory organs like antennae, eyes (compound and simple), statocysts (organs of balance/ equilibrium) are present. Excretion takes place through **malpighian tubules**, **green glands**, **coxal glands**, etc. They are mostly dioecious (unisexual / gonochoric). Fertilisation is usually internal. They are mostly oviparous. Development may be direct or indirect. Life history includes one to many larval stages followed by metamorphosis.

Examples: *Periplaneta*, *Palaemon*, *Cancer*, *Palamnaeus*, *Aranea*; ***Economically important insects*** – *Apis*, *Bombyx*, *Kerria* (*Laccifer*); ***Vectors of common pathogens*** – *Anopheles, Culex* and *Aedes*; ***Gregarious pest*** – *Locusta*; ***Living fossil*** – *Limulus.*

3.7.2 Classification of the phylum Arthropoda

Phylum **Arthropoda** is classified into **three sub-phyla, 1. Trilobita 2. Chelicerata** and **3. Mandibulata.**

Sub-phylum-1: Trilobita

They are extinct marine arthropods. Appendages are numerous, similar and *biramous*. Body is divided into a median and two lateral lobes by two prominent *longitudinal furrows*, hence the name trilobite.

Examples: *Triarthrus, Dalmanites.*

Fig. 3.19 Trilobite (fossil)

Sub-phylum-2: Chelicerata

Body consists of an anterior six segmented **cephalothorax** or **prosoma**, a posterior thirteen segmented **abdomen** or **opisthosoma** which is further divided into **mesosoma** and **metasoma**. Prosoma bears six pairs of appendages; the first pair is modified for feeding (**chelicerae**). Antennae and jaws (mandibles) are absent. Respiratory organs are **book-gills**, **book-lungs** and **tracheae**.

The sub-phylum **Chelicerata** is classified into **two classes,** namely **1. Xiphosura** and **2. Arachnida**.

Class-i: Xiphosura

They are marine organisms with branchial respiration; includes both **extinct** and **only three genera of extant** (living) animals. Prosoma is covered by broad horse-shoe shaped *carapace*; bears a pair of chelicerae and four pairs of walking legs and one pair of '**pusher legs**'. Mesosoma bears six pairs of appendages, the first pair is fused to form **genital operculum** and the other five pairs are modified into **book-gills**. Metasoma ends in **telson**. Development includes **trilobite larva** in *Limulus*.

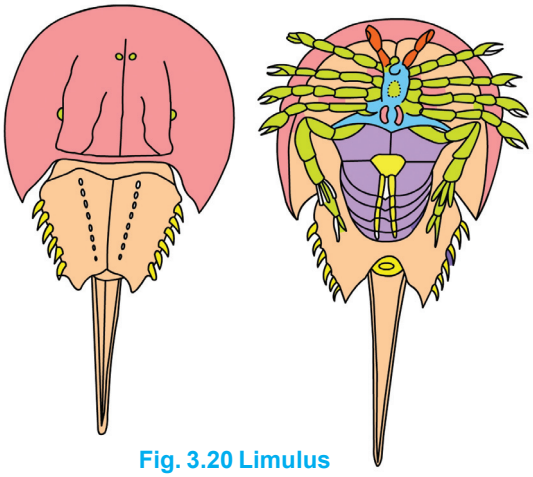


Fig. 3.20 Limulus

Examples: *Limulus* (king crab, a living fossil).

Class-ii: Arachnida

They are terrestrial; prosoma bears a pair of chelicerae, a pair of pedipalpi and four pairs of walking legs. Mesosomal appendages are modified into *book-lungs*. Four pairs of posterior abdominal appendages are modified into **spinnerets** in spiders. Respiratory organs are **book-lungs** (scorpions and some spiders), **tracheae** (some spiders) or **both** (some spiders). Respiratory pigment is '*copper*' containing **haemocyanin**. Excretory organs are **Malpighian tubules** and **coxal glands**. Development is **direct**; scorpions are **viviparous**.

Fig. 3.21 Scorpion

Example: *Palamnaeus* (scorpion), *Aranea* (spider), *Sarcoptes* (itch mite).

Sub-phylum-3: Mandibulata

They are aquatic (freshwater or marine) or terrestrial. Body is divided into two (cephalothorax and abdomen) or three (head, thorax and abdomen) parts. Head bears antennae, mandibles and maxillae. Respiratory organs are gills or tracheae.

The sub-phylum Mandibulata is classified into four classes **1. Crustacea 2. Chilopoda 3. Diplopoda** and **4. Insecta**.

Class-i: Crustacea

They are aquatic. Head and thorax fuse forming the **cephalothorax** (covered by chitinous **carapace**). In some the exoskeleton is hardened by calcium carbonate (crabs and lobsters). Cephalic region bears two pairs of antennae (***antennules*** and **antennae** – ***a unique feature***), one pair of mandibles and two pairs of maxillae. Thoracic and abdominal appendages are '**biramous**'. Respiratory organs are gills (branchiae). Excretory organs are **green glands** or **antennary glands**. Sense organs include **antennae**, **compound eyes**, **statocysts**, etc. Development is **indirect** and includes different larval forms.

Examples: *Palaemon* (freshwater prawn), *Cancer* (crab), *Balanus* (rock barnacle), *Sacculina* (root-headed barnacle), *Astacus* (cray fish), *Daphnia* (water flea).

Fig. 3.22 Prawn

Class-ii: Chilopoda

Chilopoda includes **centipedes** (*hundred leggers*).They are terrestrial, air-breathing, carnivorous animals. Body consists of head and trunk. Each segment of the trunk bears a pair of clawed appendages; first pair of trunk appendages bears ***poison claws***. Respiratory structures are *tracheae*. Excretory organs are **Malpighian tubules.**

Examples: *Scolopendra, Scutigera.*

Fig. 3.23 Scolopendra

Class-iii: Diplopoda

Diplopoda includes **millipedes** (*thousand leggers*). They are terrestrial, air-breathing animals, feeding on decaying plant material. Body consists of head and trunk. Head bears paired antennae, mandibles and maxillae (maxillae are modified into **gnathochilarium**). Each trunk segment bears two pairs of legs. Respiratory organs are *tracheae*. Excretory organs are **Malpighian tubules**.

Examples: *Spirostreptus, Julus.*

Fig. 3.24 Spirostreptus

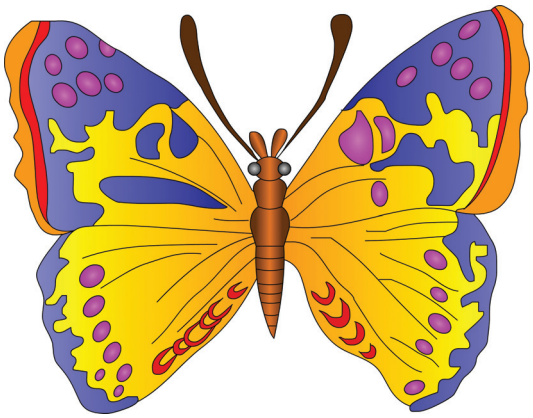


Fig. 3.25 Butterfly

Class-iv: Insecta

Insecta includes the most successful and the largest group of animals on the Earth. They are cosmopolitan, but absent from the marine habitat. Body consists of head, thorax and abdomen. Head bears paired compound eyes, antennae, mandibles, maxillae and an unpaired labium. Thorax consists of three segments and each segment bears a pair of *jointed walking legs*, hence this class is also referred to as **hexapoda**; thorax also bears one to two pairs of wings or wings may be absent (*Lepisma*). Respiratory organs are tracheae. Excretory organs are **Malpighian tubules**; they are **uricotelic** (excrete uric acid crystals as a ***water conservation adaptation***). Development is mostly **indirect** with larval stages and **metamorphosis**.

Examples: *Periplaneta* (cockroach), *Musca* (house fly), *Lepisma* (silver fish).

3.8 Phylum-Mollusca

- Unsegmented schizocoelomates

3.8.1 General Characters

Mollusca is the **second largest** phylum (Figures 3.26-3.28) in the Kingdom Animalia. Molluscs are terrestrial or aquatic (marine or fresh water). They are **bilaterally symmetrical** (some are asymmetrical, e.g. snail) and **coelomate** animals. Body is covered by a **calcareous shell** (mostly external, in some internal or reduced or absent) and is **un-segmented** with a distinct **head**, **muscular foot** and **visceral mass / visceral hump**. A soft and spongy layer of skin forms the **mantle** (*pallium*) over the visceral mass and secretes the shell. The space between the visceral mass and the mantle is called the '*mantle cavity*' in which comb like gills (*ctenidia*) are present. They have respiratory and excretory functions (Ref: NCERT text book). The anterior head region has sensory tentacles. The body cavity is a **haemocoel**, and the true coelom is confined to the kidneys, gonads and pericardial space. The buccal cavity contains a file-like rasping organ called **radula** for feeding except in the bivalves. Except for cephalopods circulatory system is of *open type*; haemolymph contains a copper containing respiratory pigment, the **haemocyanin.** Nervous system consists of ganglia, commissures and connectives; sense organs are tentacles, eyes and **osphradium** (tests the purity of water – present in the bivalves and gastropods). Excretory organs are

Fig. 3.26 Pila globosa

metanephridia (commonly called *kidneys* or renal organs). They are usually dioecious (unisexual /gonochoric) and oviparous with indirect development which includes a characteristic ciliated **veliger larva** (*a modified trochophore*).

Examples: *Pila*, *Pinctada*, *Sepia*, *Loligo*, *Octopus*, *Aplysia* , *Dentalium*.

3.8.2 Classification of the phylum Mollusca

Phylum Mollusca is classified into seven classes, namely **1. Aplacophora 2. Polyplacophora 3. Monoplacophora 4. Gastropoda 5. Scaphopoda 6. Pelecypoda** and **7. Cephalopoda.**

Class-1: Aplacophora (Gr. *a* : without; *placos* : plate; *pherein* : bearing)

They are primitive '*worm like*' marine molluscs without mantle, shell, foot and nephridia. Head is poorly developed; a **radula** is present. Cuticle contains **calcareous spicules.** In some there is a *mid-ventral groove* which is homologous to the foot of the other molluscs.

Examples: *Neomenia, Chaetoderma.*

Class-2: Polyplacophora (Gr. *poly* : many; *placos* : plate; *pherein* : bearing)

This class includes **chitons**. They are bilaterally symmetrical and dorsoventrally flattened. Shell is dorsal and consists of **eight** transverse plates (*valves*). Foot is ventral, elongated and flat. Gills are 6 to 88 pairs. Development includes a trochophore larva.

Examples: *Chiton, Lepidopleurus.*

Class-3: Monoplacophora (Gr. *Mono* : single; *placos* : plate; *pherein* : bearing)

The members of this class were believed to have become extinct millions of years ago; *Neopilina* was collected from the deep sea off the Pacific coast of Costa Rica in 1952 by the oceanographic research vessel called **Galathea**. They are bilaterally symmetrical. Nephridia and gills show '**serial repetition**' (some call it ***internal segmention***). Shell is single and plate like. Heart is unique with two pairs of atria opening into two ventricles.

Example: *Neopilina galathea.*

Class-4: Gastropoda (Gr. *Gaster* : belly; *podos* : foot)

Gatropoda is the largest and most diverse class of the phylum Mollusca; includes snails, slugs, limpets, etc.; mostly marine; some are freshwater or terrestrial. Shell is external, univalve and spirally coiled or internal (*Aplysia*) or absent (*Doris*). Head is distinct with eyes and tentacles. **Radula** occurs in the buccal cavity. Foot is ventral, flattened, muscular and helps in creeping. Respiratory organs are gills or lungs (pulmonary sacs) or both. During embryonic development, one side of the visceral mass grows faster than the other side; this uneven growth rotates the visceral mass up to 180°. This process is called '**torsion**'. They are mostly dioecious; development is indirect and includes **veliger larva**.

Fig. 3.27 Pila globosa (shell)

Examples: *Pila* (apple snail), *Aplysia* (sea hare), *Doris* (sea lemon).

Class-5: Scaphopoda (Gr. *Scapho* : boat, hollow shell; *podos* : foot)

They are marine and are commonly called '**tusk shells**' or '**tooth shells**' as the shell is tubular and '*tusk*' like, opening at both the ends. Foot is *cone* like and useful for digging. Eyes, tentacles, *ctenidia* (gills) and atria are absent. A large number of thread like structures called **captacula** help in the capture of food.

Examples: *Dentalium, Pulsellum.*

Class-6: Pelecypoda or Bivalvia or Lamellibranchiata (Gr. *pelekys* : axe, hatchet; *podos* : foot)

This class includes *mussels, oysters, clams,* etc. Body is laterally compressed and covered by a shell made up of two valves (Bivalvia). Head and sensory appendages are greatly reduced. Foot is '*wedge shaped*' (hence the name pelecypoda) and adapted for digging. Byssus threads occur in some (e.g. *Mytilus)* and help in attaching to the substratum. Radula is absent. They are '*suspension feeders'* or '*filter feeders*'. In some a '**crystalline style**'occurs in the stomach and helps in the digestion of starches. Respiratory organs are '*plate like*' gills (hence the name lamellibranchiata). They are dioecious (sexes are separate); development is indirect including larval forms such as **trochophore** and **veliger**; a **glochidium larva** occurs in freshwater mussels such as *Unio* (adapted for parasitic life on the gills of fish).

Examples: *Unio* (freshwater mussel), *Mytilus* (marine mussel), *Pinctada* (pearl oyster).

Class-7: Cephalopoda or Siphonopoda (Gr. *cephalo* : head; *podos* : foot)

This class includes *cuttle fishes, squids, octopuses, nautili* etc. Head is distinct with conspicuous eyes similar to those of vertebrates, a pair of horny beak like jaws and a radula occur in the buccal cavity. Shell may be external and multi-chambered (*Nautilus*) or internal (*Sepia, Loligo*) or absent (*Octopus*). The shell of *Sepia* is commonly called '**cuttle bone**' and that of *Loligo* is commonly called '**pen**'. Foot is modified into eight (*octopus)* or ten arms (*Sepia, Loligo*) provided with suckers present around the mouth and a part of the foot is modified into a '**siphon**' (useful in swift darting movements). Some possess **ink gland** and eject a cloud of ink to escape from the predators (*defensive adaptation*). Ctenidia, atria and nephridia are *two* in **dibranchiates** (*Sepia*) and *four* in **tetrabranchiates** (*Nautilus*). Circulatory system is a **closed type** (*unique feature of cephalopoda*); heart has two to four atria and a ventricle. Nervous system is well developed with a well developed brain enclosed in a **cartilaginous cranium** (*brain case*). They are dioecious (sexes are separate); development is direct.

Fig. 3.28 Octopus

Examples: *Sepia* (cuttle fish), *Architeuthis* (giant squid - the largest living invertebrate), *Nautilus*, *Octopus* (devil fish).

3.9 PHYLUM-ECHINODERMATA

- Deuterostomes with radial bodies

3.9.1 General Characters

The **echinoderms** (**Gr.** *echinos* : spiny; *dermos* : skin) are non-chordate deuterostomes and enterocoelomates. All are marine. The adult echinoderms are **radially symmetrical** (**pentamerous radial symmetry**), but the larvae are **bilaterally symmetrical**. Body wall is thick and body surface spiny; echinoderms possess a mesodermal endoskeleton of calcareous *ossicles*, which support the spines, hence the name 'Echinodermata' (*spiny bodied animals*). In some, the spines are modified into '**pedicellariae**'. The most distinctive feature of echinoderms is the presence of **water vascular system** or **ambulacral system** derived from the coelom which helps in locomotion, capture and transport of food and respiration. Water enters the ambulacral system through the *madreporite*. Circulatory system is of **open type**, without heart and blood vessels. Respiratory organs are '**papulae**' or '**dermal branchiae**' (thin outgrowths of the body wall between the spines), ***cloacal respiratory trees*** (*sea cucumbers*),etc. Special excretory organs are absent (excretion is by simple diffusion). Nervous system is poorly developed and brain is absent; sense organs are poorly developed. Sexes are separate (dioecious) but do not exhibit sexual dimorphism. Reproduction is sexual. Fertilisation is usually external. Development is indirect with a free-swimming **bilaterally symmetrical larva**. Power of regeneration is remarkable. Some exhibit **autotomy** (*auto* : self; *tome* : cut; self mutilation or self amputation) when captured by a predator, and the lost body parts are regenerated. A hypothetical larva, **dipleurula** is considered the ancestor of all echinoderms.

Examples: *Asterias*, *Echinus*, *Antedon*, *Cucumaria* and *Ophiura* .

3.9.2 Classification of the phylum Echinodermata

Phylum Echinodermata is classified into **two sub-phyla** namely **1. Pelmatozoa** and **2. Eleutherozoa**.

Sub-phylum-1: Pelmatozoa

They are sessile, attached to the substratum by long stalk (*sea lilies*) and some are free swimming (*feather stars*). Mouth and anus are present on the upper surface (oral surface). Madreporite is absent. Ambulacral grooves are open.

The sub-phylum **Pelmatozoa** includes **one class only 1. Crinoidea**

Class-1: Crinoidea (Gr. *crinon* : lily; *eidos* : form)

This class includes the oldest and most *primitive* forms. Some are stalk-less and free moving and others are stalked. Viscera is enclosed in a calcareous *test* called **theca.** Arms are ***biramous*** and bear **pinnules** and help in food capture. Mouth and anus are

present on the upper surface (oral surface). Ambulacral grooves are ***open***. Tube feet do not bear suckers. Madreporite, spines and pedicellariae are absent. Some attach to the substratum by '**cirri**'. Development includes **doliolaria larava**; it develops into a stalked, sessile **pentacrinoid larva** in feather stars.

Examples: *Ptilocrinus* (Sea lily with cirri), *Bathycrinus* (sea lily without cirri) and *Neometra* (feather star).

Sub-phylum-1: Eleutherozoa (Gr. *eleuthros* : free; *zoon* : animal)

They are free moving and do not have a stalk. Mouth (oral surface) is directed downwards. Madreporite is present. Ambulacral grooves are closed (except in *Asteroidea*).

The Sub-phylum **Eleutherozoa** is classified into **four classes 1. Asteroidea 2. Ophiuroidea 3. Echinoidea** and **4. Holothuroidea**.

Class-1: Asteroidea (Gr. *aster* : star; *eidos* : form)

Fig. 3.29 Starfish

This class includes sea stars (*star fishes*). The arms are not clearly demarcated from the central '*disc*' of the body. **Ambulacral grooves** are open; tube feet bear suckers. Pedicellariae are two jawed and are useful in food capture, protection and cleaning the surface of the body. Madreporite is aboral (dorsal side) in position. Respiratory organs are **papulae** or **dermal branchiae**. Development includes **bipinnaria** and **brachiolaria larvae.**

Examples: *Asterias, Astropecten, Pentaceros.*

Class-2: Ophiuroidea (Gr. *ophiuros* : serpent tail; *eidos* : form)

This class includes *brittle stars, serpent stars, basket stars,* etc. Arms are long and clearly demarcated from the central disc of the body; arms are flexible, fragile and '***branched***' in some (*Gorgonocephalus*). They move by serpentine lashing of the arms.

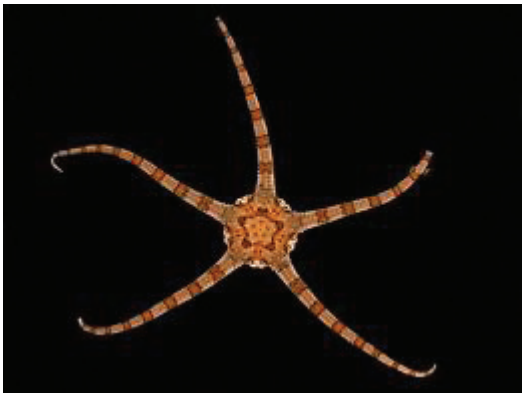


Fig. 3.30 Brittle star

Ambulacral grooves are closed; tube feet lack suckers. Madreporite is on the oral surface. Pedicellariae are absent. Anus is absent. Development includes **ophiopluteus larava**.

Examples: *Ophiothrix* (spiny brittle star), *Gorgonocephalus* (basket star).

Class-3: Echinoidea (Gr. *echinos* : hedgehog; *eidos* : form)

This class includes '*sea urchins*' such as, *heart urchins, sand dollars, sea biscuits,* cake urchins etc. The body is ovoid (*sea urchin*) or discoid (*sand dollars*) and covered with movable spines. Arms are absent;

tube feet bear suckers. Calcarious ossicles of the body unite to form a rigid **test** or **corona** or **case**. Madreporite and anus are aboral in position. Ambulacral grooves are closed. Pedicellariae are three jawed. In the mouth of sea urchin a complex five jawed masticatory apparatus called **Aristotle's lantern** is present (absent in the heart urchins). Development includes **echinopluteus larava**.

Examples: *Echinus* (sea urchin), *Echinocardium* (heart urchin), *Echinodiscus* (sand dollar), *Clypeaster* (cake urchin).

Class-4: Holothuroidea (Gr. *holothurian* : water polyp or sea cucumber; *eidos*:form)

This class includes sea cucumbers. Body is elongated in the oro-aboral axis; body wall is leathery (coriaceous) and dermis contains loose spicules. Arms, spines and pedicellariae are absent. Mouth is surrounded by retractile tentacles (modified tube feet useful for feeding). Ambulacral grooves are 'closed'; tube feet bear suckers. Madreporite is *internal* (occurs in coelom). Respiratory organs are a pair of cloacal '**respiratory trees**'. Development is indirect and includes **auricularia larva**.

Examples: *Holothuria, Synapta, Thyone.*

3.10 Phylum - Hemichordata

- Half chordates

3.10.1 General Characters

Hemichordata was earlier considered a sub-phylum under phylum Chordata. But now it is placed as a separate phylum under the non-chordates. This phylum consists of a small group of **worm-like** marine animals. They are **bilaterally symmetrical**, **triploblastic** and **coelomate (enterocoelous) animals**. The body is cylindrical and is composed of an anterior **proboscis**, a **collar** and a long **trunk** (Figure 3.31). A median **buccal diverticulum**, the **stomochord** (once believed to be the notochord) extends into the proboscis. Circulatory system is of open type with a dorsal heart. Respiration takes place through paired gill slits opening into the pharynx. Proboscis gland acts as the excretory organ. Development is indirect and includes a **tornaria larva**.

Examples: *Balanoglossus* (acorn worm), *Saccoglossus.*

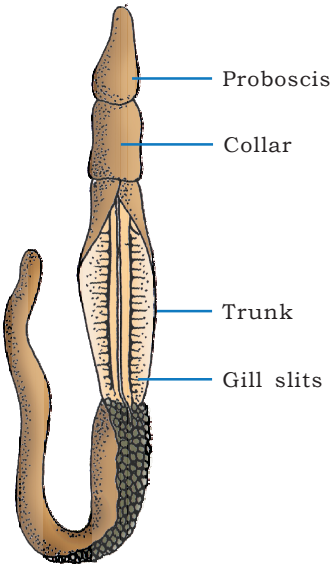


Fig. 3.31 Balanoglossus

3.10.2 Classification of the phylum Hemichordata

Phylum : Hemichordata is classified into **two classes**, **1. Enteropneusta** and **2. Pterobranchia**.

Class-1: Enteropneusta (Gr. *enteron* : gut; *pneustos* : breathed)

They are commonly called *acorn worms*. They are free, solitary and burrowing animals. Development includes a free swimming **tornaria larva.**

Examples: *Balanoglossus* (acorn worm), *Ptychodera.*

Class-2: Pterobranchia (Gr. *pteron*: feather or wing; *branchion* : gill)

They are sedentary, colonial (*Rhabdopleura*), and tube dwelling animals.

Examples: *Rhabdopleura, Cephalodiscus.*

GLOSSARY

Amphids: They are the cuticular depressions present on the lips surrounding the mouth in the nematodes. They are well developed in free living nematodes and serve as chemoreceptors.

Autotomy: It is the process of voluntary breaking of the injured part of the body (self mutilation or amputation). It is a device developed to protect the body from the enemies and parasites as seen in the echinoderms .

Bothridia: The leaf like organs present on the scolex of certain cestodes. They act as the organs of attachment to the body parts of the host.

Cercaria: It is a free swimming larva consisting of an ovoid body and a tail. It occurs in the life history of liver flukes.

Choanocyte: It is a specialized flagellated cell with a cup shaped collar around the base of the flagellum. It maintains the current of water through the body.

Clitellum: It is a belt or *girdle* shaped thickening of the skin, in a specific region of the body (14 to 16 segments in *Pheretima*). It secretes the cocoon and albumen (food for the developing young one), during the breeding season.

Cocoon: It is a bag like structure secreted by the clitellum. Eggs and sperms are deposited into it. Fertilization and development occurs within the cocoon.

Comb plates: They are ciliated plates helping in locomotion in the ctenophores.

Ctenidia: They are the respiratory organs of molluscs. Each ctenidium (gill) consists of a central axis and one or two rows of filaments.

Flame cell: It is a hollow cell containing a tuft of cilia in the inner space. It is excretory and osmoregulatory in function. Flame cell is a primitive type of excretory organ (protonephridium).

Gemmules: They are the '*internal buds*' of some sponges aiding in asexual reproduction. They also help tide over unfavourable conditions.

Juvenile: It is an immature young form resembling the adult in all aspects.

Madreporite: It is a circular porous plate present in the body of most echinoderms. Through its pores sea water enters the water vascular system.

Mesenteries: They are vertical partitions dividing the coelenteron of sea anemones. They are developed as inward folds of the endoderm. They bear cnidoblasts.

Miracidium: It is a free swimming larva of liver fluke. It contains ciliated epidermis, penetration glands, etc. It transforms into the sporocyst stage in the body of freshwater snail , which is the invertebrate host of liver fluke.

Moulting or **Ecdysis:** It is the process of casting off the outer body wall. During development of nematode larvae, the cuticle is cast off 4 times.

Muller's larva: It is the characteristic larva of turbellarians. It bears an apical tuft of cilia.

Nephridia: They are highly coiled excretory organs derived from the ectoderm.

Osculum: It is a large opening present at the free end of a sponge body. Water from the spongocoel flows out through the osculum.

Ostia: They are numerous openings present on the body of a sponge. Water is drawn in through the ostia and sent out through the osculum (choanocytes play an important role in drawing in water).

Parapodia: They are hollow biramous appendages of polychaetes. They bear tufts of many setae and help in locomotion.

Parenchymula: It is the larva of sponges such as *Clathrina*. It is similar to the planula of cnidarians. It is covered with cilia all over.

Pedicellariae: They are '*forceps like structures*' (modified spines) in the body of sea stars and sea urchins . They remove foreign particles that may settle on the body surface and thus help in keeping the body surface clean.

Phasmids: They occur in some nematodes. They are well developed in parasitic nematodes and are glandulo-sensory in function.

Planula: It is a ciliated, double walled, free swimming larva characteristic of a cnidarian.

Polyembryony: Formation of several young ones from a single zygote. It occurs during the formation of redia and cercaria larvae in the life history of a liver fluke.

Polyp or **Hydranth:** It is a flower shaped or hydra shaped zooid of the colonial cnidarians such as *Obelia*. It bears several tentacles around the mouth. It is a nutritive zooid.

Radula: It is a thin ribbon shaped body lying in the buccal cavity of molluscs. It consists of a median stalk and two lateral lobes. Each lobe bears many rows of chitinous teeth. Radula works like a '*file*' and rasps the vegetable food.

Redia: It is an elongated larva of liver fluke produced by the sporocyst asexually/ parthenogenetically. It gives rise to the second generation of rediae or the cercaria larvae.

Rhabdites: They are rod shaped bodies present in the epidermal cells of turbellarians. On discharge they form a slimy (mucus) substance helping in locomotion by smoothening the path of gliding movement and also in defence.

Setae: They are small, *f*-shaped, chitinous structures present in the pits (*setal sacs*) of the body wall of earthworms. They aid in locomotion. In some setae are modified into '*penial setae*' and help in copulation.

Spicules of a sponge: They are the supporting structures of the body secreted by *scleroblasts*. They are of different shapes and sizes. They are made up of calcium carbonate or silica.

Spongocoel: It is the large central cavity of a sponge body.

Statocyst: Statocyst is a sense organ concerned with the maintenance of equilibrium of the body.

Syncytium: It is a multinucleate mass of protoplasm without any division into cells. The tegument of flatworms is syncytial.

Trichemella: It is a larval form characteristic of the hexactinellid sponges.

Trochophore: It is the characteristic larva of annelids. It is 'top' shaped and bears one or more bands of cilia, an epical tuft, an eye etc. It contains coelom and nephridia. It is believed to be the forerunner of higher invertebrates.

Zooid: It is an individual member of a 'coelenterate' colony. Different types of zooids serve different functions (division of labour).

VERY SHORT ANSWER TYPE QUESTIONS

1. Name the cells and sytem peculiar to porifera.
2. Which structures form the skeleton of a sponge? What are the chemicals involved in the formation of these structures?
3. What are the functions of canal system of sponges?
4. What are the two chief morphological 'bodyforms' of cnidarians? What are their chief functions?
5. What is metagenesis? Animals belonging to which phylum exhibit metagenesis?
6. What is the cnidarian group with quantitatively/relatively large mesoglea? What is the significance of such a well developed mesoglea pertaining to the aquatic life of that group?
7. What is the chief difference between the hydrozoans and the rest of the cnidarians regarding the germinal layer(s) in which its 'defencive structures or cells of defence' occur?
8. What are the excretory cells of flatworms called? What is the other important function of these specialized cells?
9. Distinguish between amphids and phasmids.
10. What is the essential difference between a 'flat worm' and a 'round worm' with reference to the perivisceral area of their bodies ?
11. How do you account for the the origin of the perivisceral space in the body of a nematode and an annelid?
12. What is metamerism? What is the essential difference between the mode of formation of individual morphological body units of a tapeworm and those of an earthworm?
13. How do you distinguish a 'hirudinean' from the rest of the annelids , based on the morphological features pertaining to metamerism? How does the coelom of a leech differ from the coelom of an earthworm with reference to its contents?
14. What do you call the locomotor structures of *Nereis*? Why is *Nereis* called a polychaete?
15. What is botryoidal tissue?
16. What is the difference between the epidermis of a nematode and that of an annelid? How does a nematode differ from an annelid with reference to the musculature of the body wall?
17. What do you call the first and second pairs of cephalic appendages of a scorpion ?
18. What is the uniqueness about the first two pairs of cephalic appendages of a crustacean compared to those of the other extant arthropods?
19. What is the sub-phylum to which 'ticks' and 'mites' belong? How do you distinguish them from the insects with reference to their walking legs?
20. What are the respiratory structures of *Limulus* and *Palamnaeus* respectively?
21. What are antennae? What is the arthropod group without antennae?
22. What do you call the perivisceral cavity of an arthropod? Where from is it derived during development?
23. Which arthropod, you have studied, is called a 'living fossil'? Name its respiratory organs?
24. How do you identify a *Chiton* from its external appearance? How many pairs of gills help in the respiration of *Chiton*?

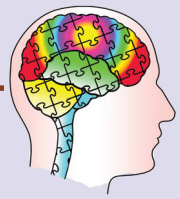
25. What is the function of radula? Give the name of the group of molluscs which do not possess a radula?
26. What is the other name for the gill of a mollusc? What is the function of osphradium?
27. What is Aristotle's lantern? Give one example of an animal possessing it?
28. What is the essential difference between the larvae and adults of echinoderms, symmetry wise?
29. What are blood glands in *Pheretima*?
30. What are spermathecae on the body of pheretima?

SHORT ANSWER TYPE QUESTIONS

1. Write short notes on the salient features of the anthozoans.
2. What is the class to which the flukes belong? Write short notes on the chief characters of that group?
3. What are the salient features exhibited by polychaetes?
4. How do the hirudineans differ from the polychaetes and oligochaetes?
5. What are the chief characters of the crustaceans?
6. Mention the general characters of Arachnida.
7. Compare briefly a centipede and a millipede.
8. Cephalopods show several unique or advanced features when compared to the other molluscs. Discuss briefly.
9. What are the salient features of pelecypoda.
10. What are the salient features of the echinoids?
11. Mention the salient features of Holothuroidea.
12. What is the function of nephridia?
13. Give an account of the hearts in the circulatory system of *Pheretima*.
14. Name the phylum to which comb jellies belong to and mention its important features.
15. Give a brief account of hemichordates.

LONG ANSWER TYPE QUESTIONS

1. Draw a labelled diagram of the reproductive organs of *Pheretima*.
2. Describe the digestive system and process of digestion in *Pheretima*.



For ignited minds

- Not For Evaluation

1. Why do we call *Limulus*, a 'Living fossil'?
2. How do you distinguish a '**King crab**' from a '**scorpion**' based on a morphologically distinctive character, on the ventral aspect of the prosomas of the two animals.
3. When there is no respiratory pigment in the blood of an insect or a centipede or a millipede, why should there be a pigment in the blood of a scorpion?
4. Blood flows in our body. Similarly blood flows in the body of cockroach also (in spite of the open circulatory system , it has). How come that the blood of cockroach is mostly referred to as 'haemolymph'?
5. There is a perivisceral cavity in the body of a nematode almost similar to that seen in the body of an earthworm. In such a case, why do you call it a 'pseudocoel' instead of 'coelom'.
6. "All non chordates are 'schizocoelomates' and chordates are 'enterocoelomates". Do you agree with the above statement? Give reasons for your positive or negative answer.
7. "All schizocoelomates are protostomeates, while all protostomeates are not schizocoelomates". Do you think the statement is correct? If so give reasons. If not, how do you defend.
8. Echinoderms show 'pentamerous radial symmetry'. Yet, they are classified under the Grade Bilateria. Does it not look anomalous to you? What is your suggestion to taxonomists? Do you want them to reclassify the animal world?
9. In almost all animals of the animal kingdom, gonads arise from the germinal layer called mesoderm. However, some animals /animal groups differ. Can you name them and explain the origin of germ cells in them.
10. There is a maximum number of four chambers in the heart of a vertebrate. There are invertebrates with more number of atria and ventricles. Can you give examples for such organisms.

Alfred Sherwood Romer
A ***palaeontologist*** *par excellence, comparative anatomist and a specialist in the study of* ***vertebrate evolution****.*

Unit

4

Animal Diversity - II

The 'Bioarchitecture' of the 'Chordates' and the 'Emerging Bioarchitect'

- A Brief History of 'Chordates'

About 60,000 known species of highly evolved, heterogeneous group of organisms constitute the phylum **Chordata**. The evolution of the chordates dates back to more than half a billion years. The development of a flexible rod like '***notochord***' along the dorsal aspect of the embryo and the ***attachment of various muscles to that 'endo-skeletal structure'*** helping side to side 'swinging movements' can be considered a major factor in the evolution of chordates. Chordates are '***enterocoelous***' ***deuterostomes***, with their closest invertebrate relatives in the group ***Echinodermata***.

A mid dorsal, ectodermal, hollow, non-ganglionated 'nerve cord' (above the notochord), which differentiates into the '***brain***' and '***spinal cord***'- is another contrasting feature, when compared to an invertebrate (non-chordate).The notochord is replaced by a '**vertebral column**', which encloses and protects the nerve cord, in the higher chordates (vertebrates/craniates).There are two more distinguishing features-the ***pharyngeal slits*** and *muscular* **post–*anal tail***. The urochordates and the cephalochordates are the ***non-vertebrate chordates***. The appearance of 'jaws' is perhaps the ***major evolutionary step*** that led to the domination of the 'jawed fishes' during the **Devonian Period.** The amphibians ***invaded land***, but they remained an '*imperfect group*' as they could not adapt completely to terrestrial life. They have to return to water to lay eggs. The next group to have evolved were the reptiles and they (the giant bodied dinosaurs) dominated the Earth, during the **Mesozoic Era**. They developed a ***dry scaly skin*** and '***cleidoic eggs***' (also called '***amniotic eggs***'). The reptiles gave rise to two major groups – the **AVES** and the **MAMMALIA.** Kidneys

evolved from the primitive '***pronephros***' to '***mesonephros***' and finally the '***metanephros***'. There was a continuous complexity in the development of the '***brain***'. Fossil records of ***connecting links*** such as the '***osteolepid fishes***', '***labyrinthodont amphibians'***, '***therapsid reptiles***' and '***theropod dinosaurs***' are available to ***endorse*** the presumed course of chordate evolution. The origin of ***amnion*** and other foetal membranes in the reptiles, ***air sacs, feathers*** of *birds*, the ***hair***, ***mammary glands*** and ***chorio-allantoic placenta*** of mammals are the major '***Bioarchitectural wonders***', the chordate world witnessed through the course of evolution. The current ERA is definitely the '***AGE OF THE MAMMALS***'. *Homo sapiens sapiens* the 'modern man' is sitting on the top, 'visualising' the ENTIRE HISTORY OF EVOLUTION on his '**mind's screen**'. There was a tremendous '***genetic transformation***' making man ***unique***. For example, the gene ***FOX P2*** is believed to play a key role in **human language expression** (along with some other essential genes) that kept man-***apart from the other organisims***. They enabled him develop ***cognitive skills***, richly deserving his specific epithet '***sapiens***' (meaning '***wise***'/'***intelligent***')- a name which was so optimistically given by **Linnaeus**. Well, we had a look into the ***bioarchitecture*** of ***chordate body*** and ***who is this emerging architect***? Ofcourse **MAN** himself, because he is guiding the process of evolution – ***making himself the 'EMERGING BIOARCHITECT'***.

4.0 Phylum – Chordata
4.1. Subphylum – Urochordata
4.2. Subphylum – Cephalochordata
4.3. Subphylum – Vertebrata
4.4. Super class – Agnatha
4.4.1. Class – Cyclostomata
4.5. Super class – Gnathostomata
4.5.1 – Pisces
4.5.2. Class – Chondrichthyes
4.5.3. Class – Osteichthyes
4.6. Tetrapoda
4.6.1. Class – Amphibia
4.6.2. Class – Reptilia
4.6.3. Class – Aves
4.6.4. Class – Mammalia

4.0 PHYLUM: CHORDATA

Chordates are one of the most familiar groups of animals to mankind. Phylum ***Chordata*** *includes all those animals that possess the notochord (a primary endoskeletal element, their* ***chief distinctive*** *character) at some stage in their life time. It is one of the major animal phyla in terms of the number of species. Chordates are believed to have descended from* ***echinoderm larvae-like ancestors*** *during the* ***Precambrian*** *period. Chordates include* ***protochordates*** *(tunicates, lancelets) and* ***vertebrates*** *(cyclostomes, fishes, amphibians, reptiles, aves and mammals). Most of them are aquatic and some are amphibious or terrestrial animals. Though they exhibit variation in the size and shape of their bodies, they display similarity in their basic body plan. The first and the second largest of the living animals, namely blue whale (****Balaenoptera musculus*** - a marine mammal*) and whale shark (****Rhinodon typus****) are members of the phylum Chordata.*

I. The four principal chordate characters

1. Notochord

It is a flexible rod like structure situated along the mid dorsal line between the gut and the nerve cord. It is the first part of the endoskeleton to appear in the embryo. It is derived from the embryonic **chorda mesoderm**. It is made up of a core

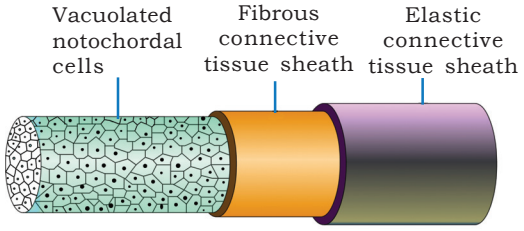


Fig. 4.1 Longitudinal view of notochord

of 'vacuolated cells' surrounded by an inner thick **fibrous** and an outer thin **elastic** connective tissue sheaths. It is persistent throughout their life in the **lancelets, cyclostomes** and fishes of the group chondrichthyes (NCERT). It is present in the tail of the tadpole larva of an **ascidian** which is lost in its adult stage due to **retrogressive metamorphosis** (see Glossary). It is present in the embryonic stages, but is replaced partly or wholly by the vertebral column in the adults of higher chordates. Remnants of notochord occur as **nuclei pulposi** in the **intervertebral discs** of mammals.

2. Dorsal tubular nerve cord

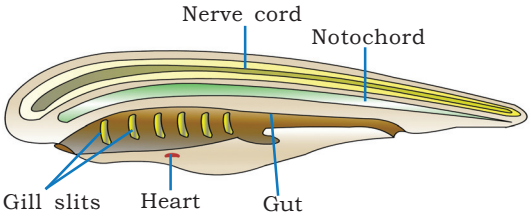


Fig. 4.3 Typical chordate

A single, hollow tubular and fluid filled nerve cord is situated above the notochord and below the dorsal body wall. It is **non-ganglionated**, unlike that of the non-chordates. It is produced in the embryonic stage by the 'sinking in' of the median dorsal strip of **ectoderm** above the **notochord**. In the higher chordates, it gets enlarged to form a distinct **brain** at the anterior end and the rest of it becomes the **spinal cord**.

3. Pharyngeal slits or clefts

Pharyngeal slits are a series of lateral perforations in the wall of the pharynx through which water flows out from the pharyngeal cavity. They are **ecto-endodermal** in origin. They are persistent throughout the life in the protochordates, fishes and some amphibians. The walls of the pharyngeal slits develop vascular lamellae to become 'gills' (branchiae) and are helpful in the exchange of respiratory gases. They are present in the larval stages, but are absent in the adults of many amphibians. Among the amniotes, non-functional pharyngeal pouches appear in the early embryonic life and disappear later. The occurrence of such structures in the early embryos of amniotes provides a clue to their 'aquatic ancestry'.

4. Post-anal tail

Chordates have a tail extending posterior to the anus. It is lost in many species during the late embryonic development. It contains skeletal elements and muscles. However, coelom and visceral organs are absent in it. It provides the propelling force in the locomotion of many aquatic species and acts as a 'balancing organ' in some terrestrial forms such as Kangaroos.

Chordates share **deuterostomeate condition**, **radial** and **indeterminate** cleavage and **enterocoelom** with the echinoderms.

II. Other chordate characters

Bilateral symmetry, triploblastic condition, organ-system level of organisation, metamerism, cephalisation, 'enterocoelic' coelom (except in the higher chordates in which it is secondarily schizocoelic), 'complete' digestive tract, closed circulatory system, ventral 'myogenic' heart (except in the lancelets), phosphocreatine (muscle phosphagen), etc., constitute the other important features of the chordates.

Phylum Chordata is divided into three subphyla: **Urochordata** or **Tunicata**, **Cephalochordata** and **Vertebrata**. Urochordates and Cephalochordates are together referred to as '**protochordates**'.

III. Comparison of Chordates and Non-chordates

S.No.	Chordates	Non-chordates
1.	Notochord is present.	Notochord is absent.
2.	Central nervous system is dorsal, hollow, single and non-ganglionated.	Nerve cord is ventral, solid, double and ganglionated.
3.	Pharynx is perforated by gill slits.	Pharyngeal gill slits are absent.
4.	Heart is ventral.	Heart is dorsal (if present).
5.	A post-anal tail is present.	Post-anal tail is absent.

4.1 Subphylum-Urochordata or Tunicata

(Gr.*oura*- a tail; L. *chorda*- cord)

All urochordates are marine and occur from the surface water to greater depths. They are either sessile (ascidians) or pelagic (*Salpa, Doliolum*) and solitary(*Ascidia*) or colonial (*Pyrosoma*). Body is un-segmented and covered by a **test** or **tunic** composed of **cellulose**[1] which is uncommon in animals. Coelom is absent. However, an ectoderm-lined **atrial cavity**, surrounds the pharynx, into which gill slits, anus and genital ducts open. Ventral side of the pharynx possesses an **endostyle**, which is believed to be the forerunner of the thyroid gland of a vertebrate (see Glossary). Atrium leads to the exterior by a dorsal or posterior atrial aperture. Digestive tract is complete. Two to numerous gill slits are found in the pharyngeal wall. Circulatory system is of **open type**. There is a simple, tubular, **ventral heart** which alternately reverses the direction of the flow of blood. Nervous system is represented in the adult by a single dorsal 'ganglion'. They are **bisexual** or **hermaphrodites.** Development generally includes a free-swimming **tadpole larva** with a tail, a dorsal hollow nerve cord, and a notochord confined to the tail, hence the name **urochordata**.

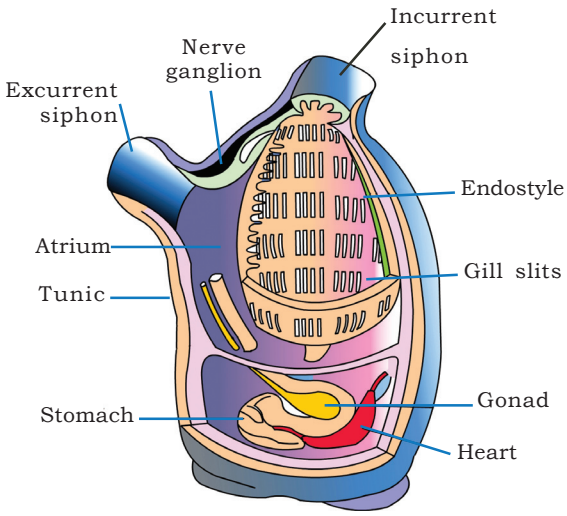


Fig. 4.4 *Ascidia*– Internal organisation

e.g. *Ascidia, Salpa, Doliolum, Pyrosoma* and *Oikopleura.*

Is it necessary to know the life history of an ascidian to consider it a chordate?

[1] Ref. Integrated Principles of Zoology 12th Edition by Hickman and Biology 9th Edition by Raven and Johnson.

4.2 Subphylum-Cephalochordata

(Gr. *kephale*- head; L. *chorda*- cord)

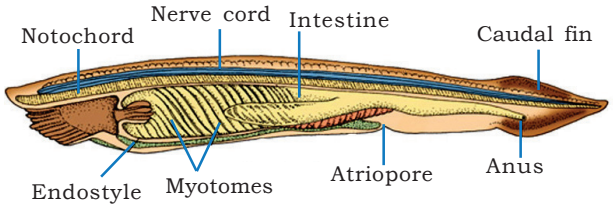


Fig. 4.5 *Branchiostoma*

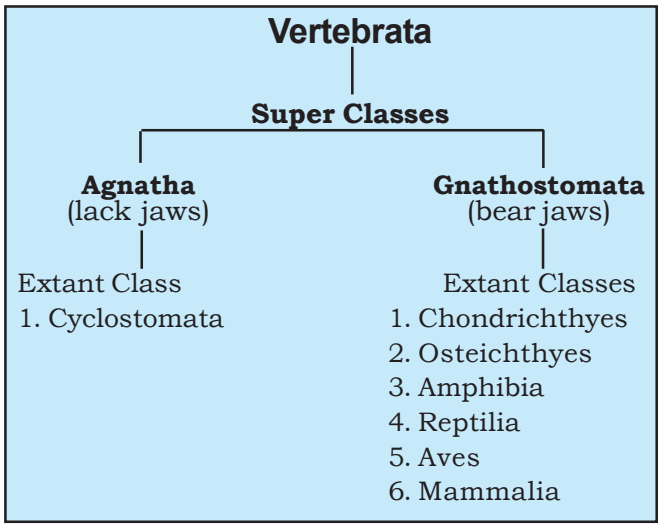
Cephalochordates are marine animals which lead a burrowing mode of life in shallow sea waters. They are small 'fish like', translucent forms with median fins but without paired fins. They are often described as **typical chordates**, because they possess the principal chordate characters such as **notochord**, **tubular nerve cord** and **pharyngeal slits** throughout their life. The notochord extends from the posterior end to the anterior end of the body beyond the nerve cord. Muscles occur as **myotomes** (blocks of muscles). The coelom is **enterocoelic**. They are **ciliary** or **filter feeders**. The pharynx is surrounded by an ectoderm lined cavity called **atrium**. An **endostyle** is present along the ventral wall of the pharynx. Exchange of respiratory gases occurs mostly across the **external body surface**. Circulatory system is of **closed type** and heart, blood corpuscles and respiratory pigment are absent. Excretion is performed by solenocytes of protonephridiae type. Numerous gonads without gonoducts are present in the pharyngeal region. **Fertilization is external** and development is **indirect** (involves a free swimming larval form).

e.g. *Branchiostoma* (amphioxus or lancelet)

Branchiostoma is often described as a typical chordate. Justify

4.3 Subphylum-Vertebrata/ Craniata

Classification of subphylum Vertebrata



The members of the subphylum Vertebrata possess notochord during the embryonic period which is replaced partly or wholly by a cartilaginous or bony vertebral column in the adult. It is true that "**all vertebrates are chordates but all chordates are not vertebrates**". Besides the basic chordate characters, vertebrates have paired appendages which may be 'fins' or 'limbs' and they are with or without jaws. Heart is ventral, muscular with two, three or four chambers. **Mesonephric** or **metanephric** kidneys are the organs of excretion and osmoregulation.

4.4 Super Class: Agnatha (Gr. *A*- without; *gnathos*- jaw)

They are jawless primitive fish like aquatic vertebrates without paired appendages. The internal ear bears one or two semicircular canals. Notochord persists in the adult.

Agnatha includes the extant class **Cyclostomata** besides the extinct class **Ostracodermi**.

4.4.1 Class: Cyclostomata (Gr. *cyklos*- circular; *stoma*- mouth)

Cyclostomes are jawless aquatic (marine or freshwater) forms. Body is scaleless, long, slender and eel-like. Endoskeleton is cartilaginous. Vertebrae are represented by imperfect neural arches in some. Mouth is circular and suctorial. Tongue bears **horny teeth**. Respiratory organs include six to fifteen pairs of gill slits. Heart is **two-chambered** as in fishes. **Renal portal system is absent**. Kidneys are **mesonephric**.

e.g. *Petromyzon* (lamprey) and *Myxine* (hag fish/slime eel).

Fig. 4.6 *Petromyzon*

Marine **lampreys** migrate to freshwater for spawning (anadromous migration). After spawning they die. Their larvae are **ammocoete** metamorphose into adults and return to the sea.

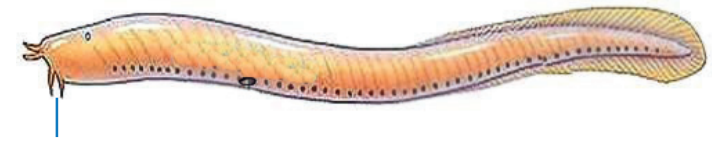


Fig. 4.7 *Myxine*

Hagfishes are exclusively marine. They are considered scavengers because they feed on dead or dying fish. When disturbed hag fish releases a milky fluid from its mucous sacs which becomes slime on contact with sea water. Development is direct.

4.5 Super Class: Gnathostomata (Gr. *gnathos*- jaw; *stoma*- mouth)

They are vertebrates with jaws. They possess paired appendages (pectoral and pelvic fins or fore and hind limbs) and internal ears with three semicircular canals each. Notochord is replaced partly or wholly by the vertebral column.

Gnathostomata includes **jawed fishes** (Pisces) and **Tetrapods** (Amphibia, Reptilia, Aves and Mammalia).

- Pisces and Amphibia constitute the group **Ichthyopsida**
- Reptilia and Aves constitute the group **Sauropsida**.

4.5.1 Pisces (L. *piscis*- fish)

Fishes, the 'first jawed vertebrates', are completely aquatic and gill breathing animals. The extinct jawless fishes, the **ostracoderms** gave rise to the earliest jawed fishes during the **Silurian** period. **Devonian** period is considered the '**Golden age of fishes**', because they emerged as the predominant group during that time. They constitute the most **diverse** and **largest** vertebrate group. They show variation in their body size, shape, and colour. They are one of the economically most important animal groups to mankind. **Coelacanths** (marine) and **Dipnoi** (fresh water) are the extant 'lobe finned' fishes. **Sharks**, **rays** and **ray-finned fishes** account for the bulk of living fishes. Osteolepid fishes which are of the same group as Latimeria are believed to be in the line of evolution of the next higher group of vertebrates, the amphibians. The study of fishes is known as **Ichthyology**.

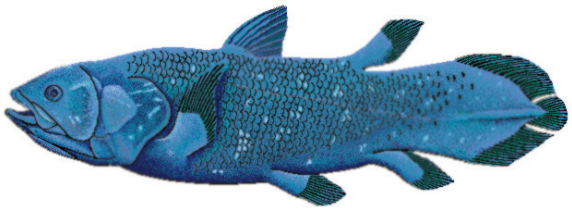


Fig. 4.8 *Latimeria chalumnae*

Name the fish which was thought to be extinct until 1938, but later found to be living in small numbers.

General characters

- Fishes are completely aquatic poikilothermic (cold blooded) animals.
- Body of a fish is usually streamlined and differentiated into head, trunk and tail.
- Exoskeleton consists of **mesodermal** scales or bony plates. A few are scaleless.
- Endoskeleton may be cartilaginous or bony. Skull is **monocondylic**. Vertebrae are **amphicoelous** (centrum is concave at both anterior and posterior faces).
- Locomotion is assisted by unpaired (median and caudal) fins along with paired (pectoral and pelvic) fins.
- Mouth is **ventral** or **terminal**. Teeth are usually **acrodont, homodont** and **polyphyodont**.
- Exchange of respiratory gases is performed by the **gills**. Heart is 'two chambered' and is described as **branchial heart** as it supplies blood only to the gills. The circulation is single circulation as blood reaches the heart only once, in the course of each circulation, making the heart a **venous heart** (heart receives only venous/deoxygenated blood from the body parts).

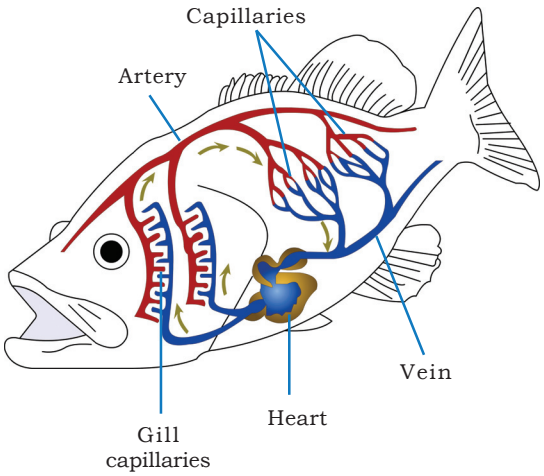


Fig. 4.9 Circulation of blood in a fish- schematic representation

- ❖ Kidneys are **mesonephric**. Fishes are mostly **ammonotelic** and some are **ureotelic** (cartilaginous fishes).
- ❖ Cranial nerves are 10 pairs. **Meninx primitiva** is the only 'meninx' enveloping the central nervous system.
- ❖ Internal ear consists of three semicircular canals. **Lateral-line sensory system** (to detect movement and vibration in the surrounding water) is well-developed. Eyes are without eyelids and each eye ball is protected by a **nictitating membrane**.
- ❖ Sexes are separate. Fertilization is internal or external. Development may be direct or indirect.

Pisces include two extant classes i.e. **Chondrichthyes** and **Osteichthyes**.

4.5.2 Class - Chondrichthyes / Cartilagenous fishes)
(**Gr. *chondros***- cartilage; ***ichthys***- fish)

They are marine fishes which possess cartilaginous endoskeleton. Caudal fin is **heterocercal** (asymmetrical both externally and internally). Skin is covered by dermal **placoid** scales also called dermal denticles. Sharks are highly predaceous. Respiratory gaseous exchange is performed by five to seven **lamelliform** gills, without operculum, on each side. Air bladder is absent, and so they have to swim constantly to avoid sinking (bony fishes have 'air bladder' acting as a 'hydrostatic organ' helping the fish float easily at the desired level without much expenditure of energy). Cartilaginous fishes are **ureotelic** and store urea in their blood to maintain osmotic concentration of body fluids (physiological uraemia). In males, pelvic fins bear **claspers** to facilitate internal fertilization. They are mostly **viviparous**.

e.g. *Scoliodon* (dog fish), *Pristis* (saw fish), *Carcharodon* (great white shark), *Dasyatis / Trygon* (sting ray; possesses poison sting), *Torpedo* (electric ray; dorsal muscles are modified into electric organs), *Sphyrna* (hammer - headed shark).

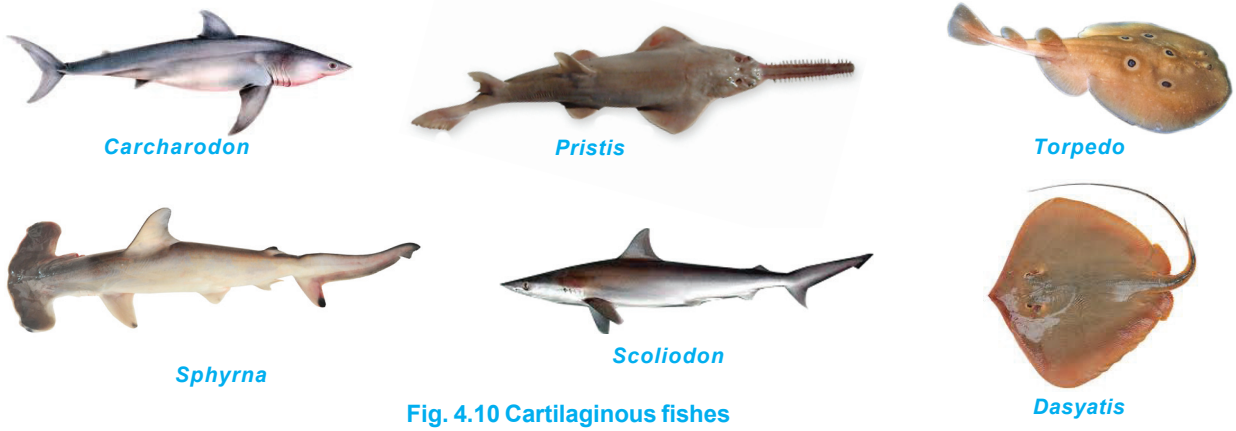


Fig. 4.10 Cartilaginous fishes

Why are sharks ureotelic, while most of the bony fishes are ammonotelic?

4.5.3 Class - Osteichthyes (Gr. *osteon-* bone; *ichthys-* fish)(**Bony fishes**)

They are bony fishes which live in all kinds of aquatic habitats. Caudal fin is **homocercal** (symmetrical externally and asymmetrical internally) in **teleost fishes** and **diphycercal** (symmetrical both externally and internally) in lung fishes and *Latimeria*. Exoskeleton is in the form of **cosmoid**, **ganoid**, **cycloid** or **ctenoid scales**. Mouth is usually **terminal**. Respiratory gaseous exchange is performed by four **filamentous gills** covered by an **operculum**, on each side. An air bladder is present with or without connection to the gut. It is either helpful in gas exchange (lung fishes) or in maintaining buoyancy (hydrostatic function) in most of the 'ray-finned' fishes. They are mostly **ammonotelic**. Sexes are separate. Fertilization is generally external. Most forms are **oviparous**.

Examples:Marine fishes: *Exocoetus* (flying fish), *Hippocampus* (sea horse; male has a brood pouch), *Echeneis* (sucker fish); Fresh water fishes: *Catla* (katla), *Labeo* (Rohu), *Clarias* (magur); Aquarium fishes: *Betta splendens* (Siamese fighting fish), *Pterophyllum* (angel fish).

"Teleostians are the most successful group of fishes". Explain why?

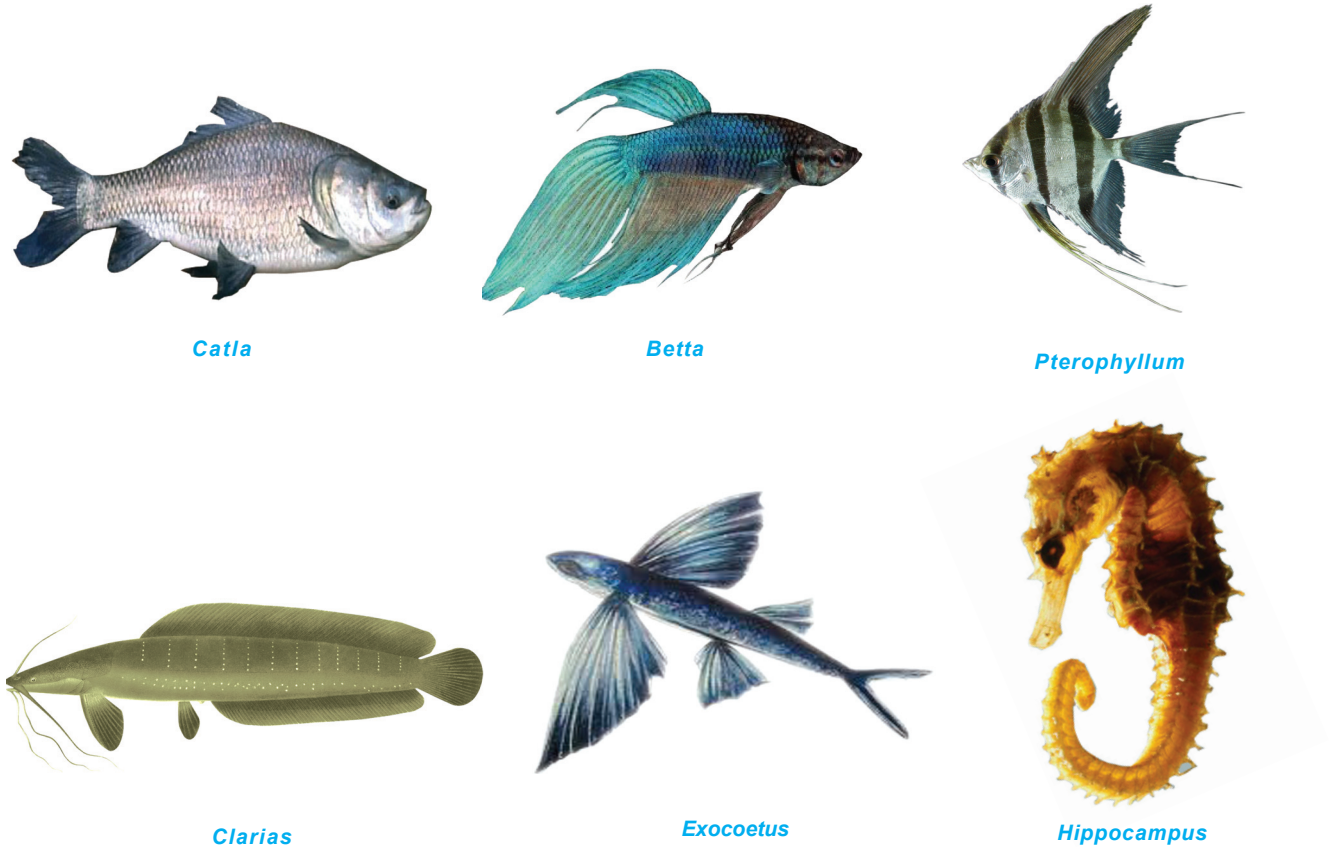


Fig. 4.11 Bony fishes

4.6 TETRAPODA (GR. *TETRA*-FOUR; *PODOS*-FOOT)

They are mostly terrestrial but some are **aquatic** or **amphibious** animals. They are characterised by the presence of two pairs of **pentadactyl limbs** usually. Lungs are the principal organs of respiratory gas exchange (in most of the amphibians, skin is the principal site of gaseous exchange).

Tetrapoda includes four classes: **Amphibia**, **Reptilia**, **Aves** and **Mammalia**.

4.6.1 Class: Amphibia (Gr. *amphi*-both; *bios*-life)

Amphibians are the first vertebrates to come out of water and 'walk' on land. They are the tetrapods which have the ability to live in the aquatic habitat of their ancestors, the fishes (osteolepids) and in the terrestrial habitat that they first invaded. They flourished during the **carboniferous** period. They could not become completely terrestrial animals as they are still tied to **aquatic habitat** for **reproduction** and **development** (because the eggs of amphibians dry out quickly if laid on land and they do not have a 'shell' to suit the hard surface on land). The living amphibians are **anurans** or **salientians** (frogs and toads), **urodeles/caudates** (salamanders and newts) and **apodans** (caecilians/blind worms). The study of amphibians is known as **batrachology**.

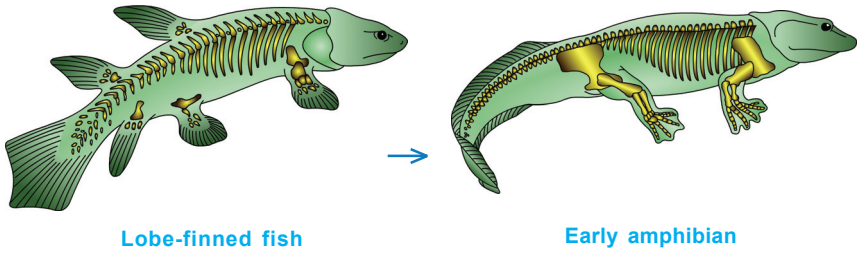


Fig. 4.12 Origin of an amphibian

I. General characters

- They are the **first tetrapods** and lead a **dual mode of life**, i.e. on land and in freshwater.
- Body is divided into distinct '**head**' and '**trunk**'. Tail may or may not be present.
- Skin is **soft**, **scale-less** (except the members of Apoda), **moist** and **glandular**.
- The body bears two pairs of **equal** or **unequal pentadactyle** limbs (caecilians are limbless)
- Skull is **dicondylic** as in mammals. Vertebrae are mostly **procoelous** (centrum is concave at its anterior face only) in the anurans, **amphicoelous** in the caecilians and usually **opisthocoelous** (centrum is concave at its posterior face) in the urodeles. **Sternum** appeared for the first time in the amphibians.
- Mouth is large; teeth are **acrodont**, **homodont** and **polyphyodont**.
- Respiratory gaseous exchange is mostly **cutaneous**; **pulmonary** and **bucco-pharyngeal** respirations also occur. Branchial respiration is performed by larvae and some adult urodeles.

- Heart is three-chambered with **sinus venosus** and **conus arteriosus**[2]. Three pairs of aortic arches and well-developed portal systems are present; erythrocytes are nucleate.
- Kidneys are **mesonephric**; adult amphibians are **ureotelic**.
- Meninges are the inner **piamater** and outer **duramater**; cranial nerves are 10 pairs.
- Middle ear consists of a single ear ossicle, the **columella auris** which is the modified '**hyomandibula**' of the fishes. **Tympanum**, **lacrimal** and **harderian** glands[3] appeared for the first time in the amphibians.
- Sexes are separate and fertilization is mostly external. Development is mostly indirect.

  e.g. *Ichthyophis* (limbless amphibian), *Bufo* (toad), *Rana* (frog), *Hyla* (tree frog), *Rhacophorus* (flying frog), *Salamandra* (salamander).

There are no amphibians which are completely adapted to terrestrial environment with reference to completing their life cycle. Justify.

Ichthyophis *Salamandra* *Rhacophorus*

Fig. 4.13 Amphibians

II. Frog

Frog and toad are tailless amphibians that belong to the order **Anura**/ **Salientia**.

1. Habitat and Habit: They live in a variety of environments. Most of the frogs live in or near water, whereas the toads are well-adapted to comparatively dry environments. All the adult frogs and toads are **carnivores**. ***Rana tigrina*** is the most common Indian frog which is popularly known as **Indian bull frog**. Frogs and toads are **poikilothermic anamniotes** (cold-blooded animals and do not develop amnion).

2. Hibernation and Aestivation: During adverse environmental conditions such as severe winter or dry hot summer season, frogs bury themselves in the soft and damp mud, to tide over the adverse climatic conditions. They slow down their metabolism during those periods. They survive on glycogen and fat reserves. They perform only cutaneous respiration during those periods. The period of inactive life during winter is

[2] Ref. Integrated Principles of Zoology 12th Edition by Hickman

[3] Lacrimal and Harderian glands are associated with the eyes.

called **hibernation** or '**winter sleep**' and the period of inactive life during summer is called **aestivation** or '**summer sleep**'.

3. Camouflage: Frogs are not easily spotted by their enemies as they can change the colour of their skin to match with that of their surroundings. They have the ability to change their colour to hide from enemies and it is called camouflaging.

III. *Rana tigrina*

Class : Amphibia

Order : Anura/ Salientia

Family : Ranidae

The body of frog is somewhat spindle shaped and slightly flattened dorsoventrally. Skin of frog is **thin**, **scaleless** and kept **moist** by the mucus glands. It is attached loosely to the underlying muscles at certain points only. The skin on the dorsal surface is generally olive-green with irregular dark spots. On the ventral surface, the skin is uniformly pale yellow. Frog never drinks water but absorbs it through the skin.

1. Body Divisions

The body of a frog is divisible into **head** and **trunk**. The neck and tail are absent. Above the snout, a pair of external nostrils is present. The eyes are bulged and covered by a nictitating membrane that protects them while in water. Behind each eye, a membranous tympanum (ear drum) receives sound waves. The forelimbs and the hind limbs help in swimming, walking, leaping and burrowing. The hind limbs bear five digits each. They are larger and more muscular than the forelimbs, which bear four digits. Feet have webbed digits and the web helps in swimming.

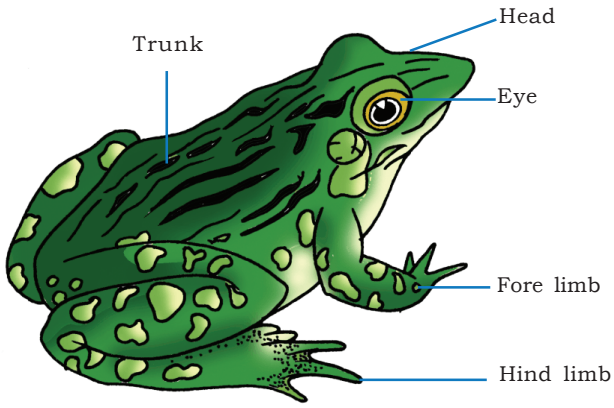


Fig. 4.14 External features of frog

Frog exhibits sexual dimorphism. Male frog can be distinguished by the presence of sound amplifying **vocal sacs** and also a **copulatory pad** on the first digit of each forelimb (copulatory pads are absent in female frogs).

2. Coelom and Viscera

The body cavity of frog accommodates different internal organs or **viscera**, which are covered by visceral peritoneum.

3. Digestive System

The digestive system consists of **alimentary canal** and **digestive glands**. The alimentary canal is short, because frog is a carnivore.

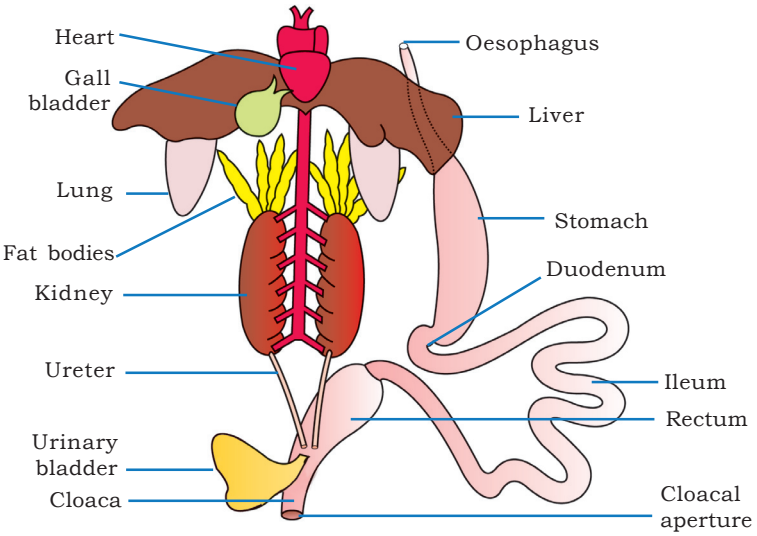


Fig. 4.15 Diagram showing digestive system and some visceral organs

A. Alimentary Canal

It begins with the mouth which is a wide, semi-oval slit bound by the upper and lower jaws. Mouth opens into a large, wide and shallow **bucco-pharyngeal cavity**. It shows teeth along the margin of the upper jaw, a muscular and bifid tongue which is attached in front and free behind. It opens into a short **oesophagus** which merges gradually with the **stomach**. The stomach is a broad, thick-walled tube that occupies the left side of the body cavity. The anterior and posterior ends of the stomach are provided with **cardiac** and **pyloric sphincters** respectively. The stomach is an organ for the **storage** and **digestion of food**. The small intestine consists of the proximal part, the **duodenum** and the distal long and coiled part, the **ileum**. The ileum opens into the **rectum** which is also called the **large intestine**. It is a short, wide tube that opens into the cloaca through the **anus**, which is guarded by the anal sphincter. Cloaca is a small chamber, which serves as a common passage for the digestive and urinogenital systems. It opens out through the cloacal aperture at the posterior end of the trunk between the hind limbs.

B. Digestive glands

Gastric glands of the stomach are microscopic and secrete the gastric juice. **Liver** is the 'largest gland' and it opens into the duodenum through hepato-pancreatic duct as it collects pancreatic juice also on the way. It secretes bile, which is stored in the gall bladder. Bile has no digestive enzymes, but contains bile salts and pigments. **Pancreas** is an irregular, elongated **mixed gland**[4], situated between the stomach and the duodenum. It produces pancreatic juice. **Intestinal glands** secrete the 'intestinal juice' (also called succus entericus).

[4] Pancreatic islets of Langerhans secrete hormones such as insulin and glucagon.

C. Feeding and Digestion: The tongue is an organ of food capture. Digestion begins in the stomach by the action of gastric enzymes in the presence of HCl. Partly digested acidic food, called **chyme** is passed through the pylorus into the small intestine, where it is mixed with **bile juice**, **pancreatic juice** and **intestinal juice**. Bile emulsifies fats, while pancreatic and intestinal enzymes complete the digestion of carbohydrates, proteins and lipids. The digested food is absorbed through the 'villi' and microvilli in the inner wall of the intestine. The undigested solid wastes move into the rectum and pass out through the cloacal aperture via the anus and cloacal sac.

4. Respiratory System

Frog uses three types of respiratory surfaces. They are the skin, mucous lining of bucco-pharyngeal cavity and inner lining of the lungs.

a) **Cutaneous respiration:** It is the most important of the three types. The scaleless skin in frog is thin, **moist** and **vascular**. The skin is permeable to O_2 and CO_2. The O_2 dissolved in mucous film/moisture on the surface of the body diffuses into the blood capillaries in exchange of CO_2. Skin should be moist for cutaneous respiration.

b) **Bucco-pharyngeal respiration:** Respiratory exchange of gases occurs through moist, vascular lining of its bucco-pharyngeal cavity in addition to skin and lungs when it is on land.

c) **Pulmonary respiration:** When frog is on land it also breathes through its lungs. The lungs are pink coloured highly vascular sac-like organs. During the pulmonary respiration the bucco-pharyngeal cavity acts like a '**force pump**'. Due to the elevation of bucco-pharyngeal cavity the air forces through the glottis and enters the lungs, where exchange of gases takes place. After the exchange of gases, the floor of the bucco-pharyngeal cavity is lowered and the air from the lungs goes out via bucco-pharyngeal cavity and nostrils.

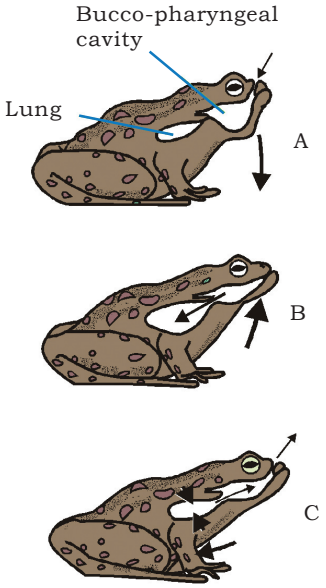


Fig. 4.16 Steps during pulmonary respiration

5. Blood Vascular System

The blood vascular system consists of the heart, blood vessels and blood. The heart is a muscular organ situated in the antero-ventral part of the body cavity. It has two separate atria and a single undivided ventricle. It is covered by a double layered membrane called **pericardium**. A triangular chamber called **sinus venosus** joins the right atrium on the dorsal side. It receives blood through three **vena cavae**(caval veins). The ventricle opens into the **conus arteriosus** (Ref: NCERT) on the ventral

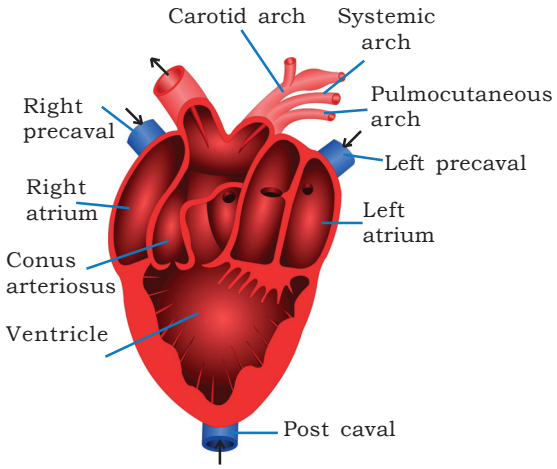


Fig. 4.17 Frog heart

side. The conus arteriosus bifurcates into two branches and each of it divides into three aortic arches namely **carotid**, **systemic** and **pulmocutaneous**. Blood from the heart is distributed to all parts of the body by the branches of aortic arches. Three major veins collect blood from the different parts of the body and carry it to the sinus venosus. Circulation is described as 'Incomplete Double' circulation.

Portal Systems: Special venous connections between the intestine and liver as well as lower parts of the body and kidneys are present in frog. These are called hepatic and renal portal veins, respectively.

Blood: Blood is composed of plasma and cells. The blood cells are **erythrocytes**, **leucocytes** and **thrombocytes**. RBCs are nucleate. WBCs are nucleated amoeboid cells which help in defence. Thrombocytes help in **haemostasis** (stopping of bleeding).

Lymphatic system: In addition to the blood vascular system, frog has a lymphatic system. The lymphatic system consists of **lymph**, **lymph channels** and **lymph nodes**. Lymph is different from blood. It lacks RBCs and contains fewer proteins, than those in the blood.

6. Integrating System

Control and co-ordination of body systems is highly developed in frog. It includes both nervous and endocrine systems. The chemical integration of various organs of the body is achieved by the hormones, which are secreted by the endocrine glands. The prominent endocrine glands found in frog are **pituitary**, **thyroid**, **parathyroid**, **thymus**, **pineal body**, **pancreatic islets**, **adrenal glands** and **gonads**.

The nervous system is organised into a **central** (brain and spinal cord), **peripheral** (cranial and spinal nerves) and **autonomous** (sympathetic and parasympathetic) nervous systems.

Brain is enclosed in a bony structure called brain box (cranium). The brain is divided into **fore brain**, **mid brain** and **hind brain**. The fore brain includes two **olfactory lobes** (*concerned with sense of smell*), two **cerebral hemispheres** (*control of voluntary actions*) and **diencephalon** (*perception of heat, cold, pain and integrity of autonomous system*)

Mid brain is represented by a pair of **optic lobes** (***corpora bigemina***). The **optic lobes** are associated with the *sense of sight*. The hind brain consists of **cerebellum** (*maintains equilibrium*) and **medulla oblongata** (*controls involuntary movements*). Medulla oblongata passes out through the foramen magnum and continues as spinal cord which is enclosed in the neural canal of the vertebral column. The spinal cord acts as the '**middle man**' between the **brain** and **effectors**.

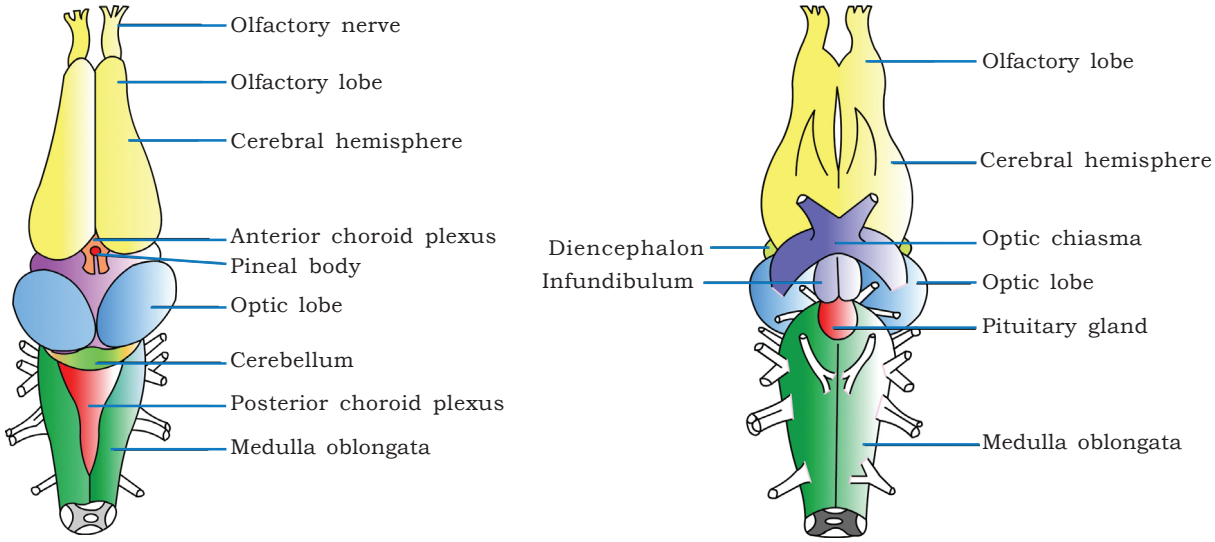


Fig. 4.18 Frog Brain

7. Special senses

Frog has sense organs such as the organs of **touch**, **taste**, **smell**, **sight** and **hearing**. The well-organised structures among them are eyes, internal ears and the rest are 'cellular aggregations' around **nerve endings**. The receptors of touch (sensory pupillae) occur in the **skin**. Organs of taste are called **taste buds** that lie on small papillae of tongue. The organs of smell are a pair of **nasal chambers.**

The organs of sight are a pair of **eyes** located in the orbits of the skull. Eyes are protected by eyelids. The upper eyelid is immovable. The lower eyelid is folded into a transparent **nictitating membrane**, which can be drawn across the surface of the eye. The **retina** of the eye contains both **rods** and **cones**. Cones provide 'colour vision' and rods are helpful in 'dimlight vision'.

Ear is useful for **hearing** and **balance**. It consists of a middle ear closed externally by a large **tympanic membrane** (ear drum) and a **columella** that transmits vibrations to the inner ear. The inner ear consists of a **utriculus** with three **semicircular canals** and a small **sacculus**.

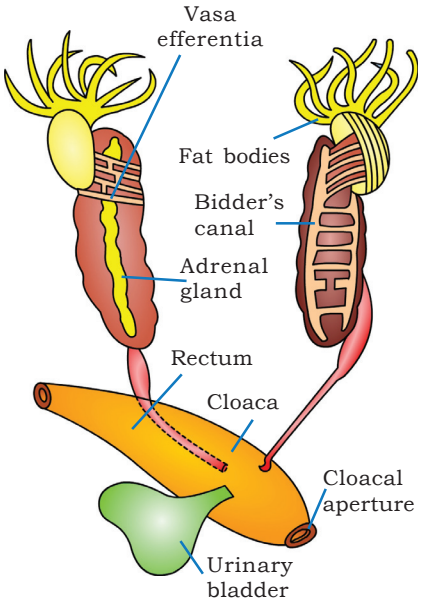
8. Excretory System

The elimination of the nitrogenous wastes and the maintenance of water and salt balance are performed by a well-developed excretory system. It consists of a pair of **kidneys**, **ureters**, a **urinary bladder** and a **cloaca**.

The kidneys are elongated, flat and dark red coloured structures situated a little posteriorly in the body, one on either side of the vertebral column. They are covered by peritoneum on their ventral (lower) surface only (retroperitoneal). An adrenal gland is found along the mid ventral surface of each kidney. The functional units of the kidney are **uriniferous tubules** or **nephrons**. From the posterior outer margin of each kidney,

a mesonephric or **Wolffian** duct arises. The ureters act as '**urino-genital ducts**' in males because both urine and male gametes pass through them. However, in the females, the oviducts and ureters are separate. Ureters open into the cloaca by sphincter apertures. A thin walled urinary bladder, present ventral to the rectum, opens into the cloaca. The chief nitrogenous waste in frog is urea, hence, it is said to be '**ureotelic**'.

Do you know - urea is mostly formed in the liver and excreted by the kidney.



4.19 Frog : Male reproductive system

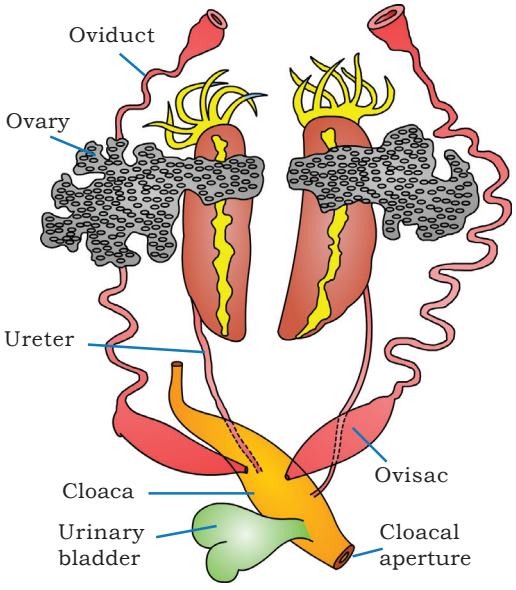


Fig. 4.20 Frog : Female reproductive system

9. Reproductive System

The male reproductive system consists of a pair of yellowish and ovoid testes, which are attached to the kidneys and dorsal body wall by a double fold of peritoneum called **mesorchium**. Each testis is composed of innumerable **seminiferous tubules** which are connected to form 10 to 12 narrow tubules, the **vasa efferentia**. They enter the kidneys and open into the **Bidder's canal** which is connected to the ureter through transverse canals of the kidney. The urino-genital ducts of both the sides open into the cloaca.

The female reproductive system consists of a pair of ovaries, oviducts and cloaca. The ovaries are attached to the kidneys and dorsal body wall by a double fold of peritoneum called **mesovarium**. The ovaries have no functional connection with the kidneys. The oviducts are two long, white and convoluted tubes. Their anterior ends form funnel-like openings called Ostia. The posterior ends of oviducts enlarge into **ovisacs** before they open into the cloaca separately.

During **amplexus**, the mass of eggs and the mass of sperms released by the female and the male are called **spawn** and **milt** respectively. Fertilization is external and takes place in water. Development involves an aquatic gill breathing, herbivorous larval stage called **tadpole**, which metamorphoses into an air breathing, carnivorous

adult frog. Tadpole of frog resembles a fish pertaining to taking in water and respiring through gills[5].

Majority of the tetrapods possess an amnion during their development. Frogs are also tetrapods. Do their embryos too possess amnion? If not why?

10. Economic Importance of Frogs

Frogs are beneficial to mankind because they are insectivorous and help in reducing the insect population. In some countries such as China and Japan, the muscular thighs of frogs are used for human consumption.

4.6.2. Reptilia (L. *reptilis* - creeping)

Reptiles are ectothermic (organisms that regulate their body temperature largely by exchanging heat with their surroundings; cold-blooded) amniotes. The extinct **labyrinthodont** amphibians gave rise to reptiles during the carboniferous period. They emerged as the dominant vertebrate group during the **Mesozoic era** (Golden age of reptiles). Most reptiles lay water tight '**cleidoic**' eggs (covered by porous calcareous shell - to allow the passage of air to provide oxygen) on land with extra embryonic membranes namely **amnion**, **allantois**, **chorion** and **yolk sac**, which make the egg an independent 'life support system'. Thus, the '**amniotic egg**' helped the reptiles to abandon ties with their ancestral aquatic habitat. In addition to cleidoic eggs, the evolution of 'dry scaly skin' to prevent water loss, two pairs of pentadactyl limbs with clawed digits for moving on land, pulmonary breathing and internal fertilization are the key adaptations that led to the success of reptiles. The class reptilia includes the extinct **dinosaurs** (terrible lizards) and the extant **chelonians**, **crocodilians**, **snakes**, **lizards** and **Sphenodon**. The study of poikilothermic tetrapods is called **herpetology.**

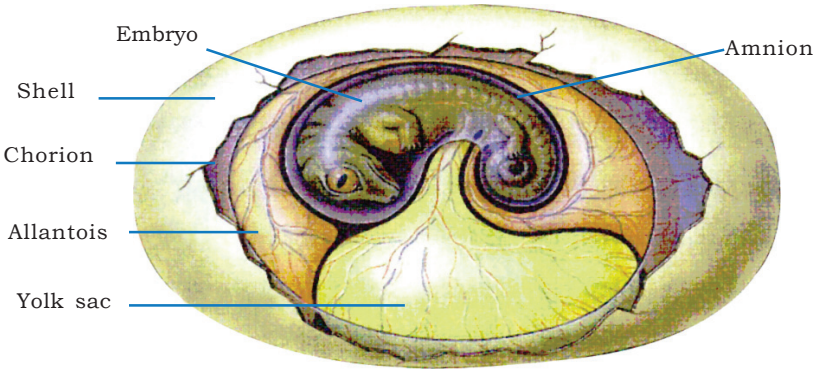


Fig. 4.21 Amniotic egg

What changes in the design of egg and embryo allowed reptiles to lay eggs on land? Why are their eggs often called 'amniotic eggs'?

[5] Haeckel proposed that organisms during their embryonic development repeat/recapitulate some of their ancestral characters, even though they are non-functional. This is referred to as BIOGENETIC LAW/THEORY OF RECAPITULATION. It states 'ontogeny repeats phylogeny' (ontogeny: developmental history, phylogeny: ancestral history)

General Characters

- They are the first true terrestrial, usually creeping or burrowing, amniotic tetrapods.
- Body is divided into **head**, **neck**, **trunk** and **tail**.
- Skin is rough and dry. The exoskeleton occurs in the form of horny epidermal **scales**, **shields**, and **claws** (which appeared for the first time in reptiles).
- Dentition is **acrodont**, **homodont** and **polyphyodont** (thecodont in crocodiles as seen in the mammals). Chelonians are 'edentate'.
- Skull is **monocondylic** and many have **temporal fossae**. Each half of the lower jaw is formed by **six bones**. Vertebrae are mostly **procoelous**. The first two cervical vertebrae are specialized into **atlas** and **axis** to facilitate independent movement of the head from the rest of the body; sacral vertebrae are **two** in number.
- The exchange of respiratory gases takes place only through lungs. They use **ribs** and **intercostal muscles** in ventilation (this feature developed in the reptiles for the first time in the vertebrate evolution). In turtles, gaseous exchange takes place through the **vascular cloacal wall**.
- Heart is incompletely four-chambered, except in the crocodiles, in which the heart is four-chambered. **Sinus venosus** is present but **conus arteriosus** is absent. The three aortic arches arise directly from the ventricle. Erythrocytes are nucleate.
- Kidneys are **metanephric**. **Mesonephric duct** (Wolffian duct) of the embryo functions as 'vas deferens' in the males. They are **'uricotelic**' (uricotelism is an adaptation to conserve water).
- Cranial nerves are 12 pairs, except in the snakes (10 pairs)
- **Tympanic membrane** is found at the inner border of the external auditory meatus. Middle ear has a single ear ossicle called **columella auris**. **Jacobson's organs**, the specialized olfactory structures, are highly developed in **lizards** and **snakes**.
- Males usually possess a muscular copulatory organ, except in the rhynchocephalians. Lizards and snakes have a pair of **hemipenes** (penis is formed by the apposition of the two hemipenes).
- Cloaca is three-chambered as seen in birds. They are the anterior **coprodaeum**, middle **urodaeum** and posterior **proctodaeum**.
- Fertilization is internal; mostly oviparous (some snakes are viviparous). Eggs are **megalecithal** and **cleidoic**. Cleavage is **meroblastic**[6] and **discoidal**. During development, extra embryonic membranes are formed as in birds and mammals.

In what ways are the reptiles structurally and functionally more suited for the terrestrial mode of life than their predecessors?

[6] The amount of the yolk in the egg influence the mode of cleavage.

The extant reptiles are grouped into four orders

1. **Chelonia** - *Chelone* (marine green turtle), *Testudo* (terrestrial form), *Trionyx* (fresh water form)
2. **Rhynchocephalia** - *Sphenodon* (a 'living fossil', endemic to New Zealand)
3. **Crocodilia** - *Crocodylus palustris* (Indian crocodile or maggur), *Alligator* (alligator), *Gavialis gangeticus* (Indian gavial or gharial)
4. **Squamata**
   a) Lizards : *Hemidactylus* (wall lizard), *Chameleon, Draco* (flying lizard)
   b) Snakes
   i) Poisonous snakes: *Naja naja* (cobra), *Ophiophagus hannah* (King cobra), *Bungarus* (krait), *Daboia/ Vipera russelli* (chain viper)
   ii) Non-poisonous snakes: *Ptyas* (rat snake), *Tropidonotus* (grass snake or pond snake)

Naja naja *Chameleon* *Chelone*

Crocodylus *Ptyas* *Sphenodon*

Fig. 4.22 Reptiles

Fig. 4.23 Theropod reptile (Imaginary diagram)

4.6.3 Class - Aves (L. *avis*-bird)

The class Aves includes a few extinct and a large number of extant birds. They are feathered, bipedal endothermic vertebrates. Modern flying birds have undergone modifications in their morphological, anatomical and physiological features as adaptations to suit their aerial mode of life. Feathers, wings, powerful breast musculature, **pneumatic bones**, endothermy with high metabolic rate, keen sense of vision, etc., are the major 'flight adaptations' which enabled them to evolve as '**the masters of air**' (**J. Z. Young**).

The presence of typical reptilian characters such as epidermal **scales on legs**, **presence of interclavicle**, **uricotelism**, **megalecithal eggs**, **development with the four extra embryonic membranes** in modern living birds, convinced **T. H. Huxley** to describe them as '**Glorified reptiles**'. The demands of flight paved the way for the evolution of a similar general body form in many flying birds. **Theropod reptiles** of the **Jurassic Period** gave rise to birds which got modernised in the **Cretaceous Period**. The study of birds is known as **ornithology**. **Dr. Salim Ali** is a world famous **Indian ornithologist** ('Bird man of India').

Justify the statement - "Birds are glorified reptiles".

I. General Characters

- Body is streamlined and is distinguished into **head**, **neck**, **trunk** and **rudimentary tail**.

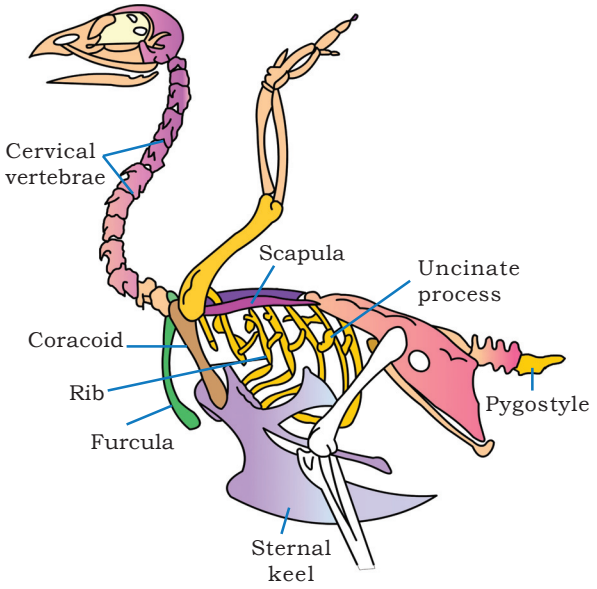


Fig. 4.24 Bird - skeleton

- The fore limbs are modified into 'wings' and hind limbs are adapted for walking, running, swimming, perching (sitting on a branch) etc.
- Skin is dry and devoid of glands, except for the oil gland or **preen gland** or **uropygial gland** at the base of the tail.
- Exoskeleton consists of epidermal feathers (a unique feature), scales on legs, claws on toes and horny covering on the beak (**rhamphotheca**).
- Endoskeleton is fully ossified. Long bones are hollow with air cavities (pneumatic). Skull is **monocondylic**. Vertebrae are heterocoelous. The last thoracic, lumbar, sacral and anterior few caudal vertebrae are fused to form a **synsacrum**. It is fused with

pelvic girdle to provide support to hind limbs. A few posterior most caudal vertebrae are fused to form the **pygostyle** that provides **support to the tail feathers**. Sternum has a **keel/carina** for the attachment of flight muscles (except in the ratite birds). Both the clavicles are fused with the interclavicle to form a 'V' – shaped bone, called **furcula** or '**wish bone**' or '**Merry thought bone**'. Ribs are **double headed** as in the crocodiles and therian mammals.

- All modern flying birds are provided with powerful **breast muscles** (flight muscles), chiefly the **pectoralis major** and **pectoralis minor**.
- **Teeth are absent** in the extant birds. Oesophagus is often dilated into a crop for the storage of food. Stomach is usually divided into glandular **proventriculus** and muscular **gizzard** (grinding mill). Cloaca is **three chambered** as in reptiles.
- Respiratory system consists of compact, spongy, undistensible lungs 'without alveoli'. The lungs are associated with **air sacs**. Air sacs facilitate 'continuous oxygenation' of blood and 'pneumaticity' of bones (a unique feature). Voice box is **syrinx** that lies at the junction of the trachea and bronchi.
- Heart is four chambered. **Sinus venosus** and **conus arteriosus** are absent as in mammals. Only **right systemic arch** is present. **Renal portal system** is reduced. Erythrocytes are nucleate as in reptiles.

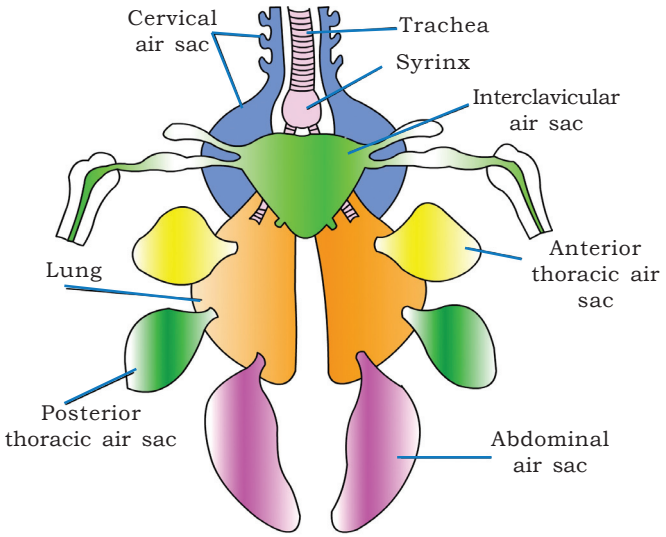


Fig. 4.25 Bird - air sacs

From your knowledge of the flying birds, what chief feature might have contributed for their successful aerial mode of life?

- Kidneys are **metanephric** and **three-lobed**. Urinary bladder is absent[7] except in ostrich. Birds are **uricotelic** like the reptiles.
- Brain is large. Olfactory lobes are reduced. Cranial nerves are 12 pairs.
- Eyes possess **sclerotic plates**. A comb shaped vascular 'pecten' projects from the retina into the **vitreous humour** (except in kiwi). Middle ear has a single ear ossicle, the **columella auris**. Olfactory sense is usually poor, except in kiwi.
- Sexes are separate. Testes are paired, but the ovary and oviduct of the right side are almost completely atrophied in a **mature female**. Copulatory organ is absent in males except in **ratites**, **ducks**, **geese**, etc.

[7] Loss of urinary bladder is believed to be one of the adaptations to reduce body weight of a bird.

❖ All birds are oviparous. Eggs are megalecithal and cleidoic. Fertilization is internal. Cleavage is **meroblastic** and **discoidal** as in reptiles. Hatchlings are **altricial** in the flying birds and **precocial** in the flightless birds.

e.g. *Corvus* (crow), *Columba* (pigeon), *Psittacula* (parrot), *Pavo* (peafowl; National bird of India), *Aptenodytes* (penguin), *Neophron* (vulture), *Coracias benghalensis*(blue jay; State bird of A.P.); *Struthio* (ostrich)

Struthio

Aptenodytes

Pavo

Psittacula

Coracias

Neophron

Fig. 4.26 Birds

Fig. 4.27 *Archaeopteryx* (imaginary diagram)

II. The 'Lizard bird'

Archaeopteryx lithographica (ancient bird; lizard bird) is the Jurassic fossil bird. It possesses some reptilian and avian characters, hence considered the '**connecting link**' between reptiles and birds.

Do you consider *Archaeopteryx* the 'connecting link' between the 'Belly creepers' and 'the Masters of air'. If so, how?

III. Ratitae / Palaeognathae

They are modern flightless running birds. They are 'discontinuous' in their distribution like the **lung fishes** and **marsupials**. They are characterized by the presence of reduced wings, a raft like sternum without keel and males with penis. They do not possess **syrinx**, **clavicles** and usually **preen gland**. They show discontinous distribution.

e.g. *Struthio camelus* (African ostrich), *Kiwi* (National bird of New Zealand), *Rhea* (American ostrich), *Dromaeus* (Emu), *Casuarius*.

4.6.4 Class - Mammalia (L. *mamma*-breast)

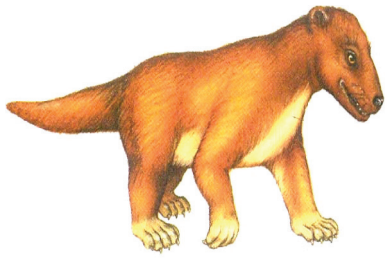


Fig. 4.28 Therapsid reptile (imaginary diagram)

The class mammalia consists of extinct and extant animals including humans. They are hairy, homeothermic amniotes. They nourish their young with milk secreted by specialised mammary glands from which the word 'mammalia' was coined. They show lot of variations in size and shape. The smallest of all the mammals is the recently discovered **ketti's hognosed bat / 'Bumblebee bat'** in Thailand (weight- 2gms) and the biggest is **Balaenoptera musculus** (blue whale) weighing more than 130 tons. Extinct 'mammal like' **therapsid reptiles** gave rise to the early mammals in the **Triassic period**. **Coenozoic era** is referred to as '**the age of mammals**' as they became the predominant tetrapod group during this era. Mammals fall under three categories namely **monotremes** (egg laying mammals), **marsupials** (pouched mammals) and **eutherians** (true placentals). Intelligence and 'parental care' have reached their climax in mammals. The study of mammals is known as **mammology**.

General characters

- The body is divided into head, neck, trunk and tail.
- Body is covered by hair, which is one of the unique characters of mammals. Hair is reduced in **whales**, **armadillos** etc. Hair is present at least in some stage of development in all mammals.
- Skin is glandular and consists of **sweat glands**(sudoriferous), **scent glands** and **sebaceous** glands. **Mammary glands** are modified sweat glands.
- Skull is **dicondylic**. Each half of the lower jaw consists of a 'single' bone, the **dentary**. Most mammals have **seven cervical vertebrae**, six in *Choloepus* (two-toed sloth) and *Trichechus* (manatee) and nine in *Bradypus* (three-toed sloth). Sacral vertebrae are **two** to **five**. Vertebrae are of the **amphiplatyan** type (centrum is flat at both faces). Ribs are double-headed.
- Buccal cavity is separated from the upper nasal cavity by a secondary palate. Teeth are **thecodont**, **heterodont** and **diphyodont**. Four pairs of salivary glands are present in association with the buccal cavity(3 pairs in man).
- Respiratory gaseous exchange occurs through lungs. Glottis is guarded by **epiglottis**. **Larynx** is the sound-producing organ.
- Heart is four-chambered. Oxygenated and de-oxygenated types of blood are completely separated. Only the left systemic arch is present. **Renal portal system** is absent. Mature RBC is circular, biconcave and **enucleate**.
- Mammals have a relatively large brain when compared to that of other animals in relation to body size. The four optic lobes constitute **corpora quadrigemina**. The two halves of cerebrum are connected by **corpus callosum**. The CNS is enveloped

by three meninges. The middle menix called, **arachnoid membrane**, is present in mammals only. Cranial nerves are twelve pairs.

- ❖ Eyes have movable eye lids with 'eye lashes'. External ear has a large fleshy and cartilaginous flap called **pinna**. Middle ear possesses three ear ossicles. They are **malleus**, **incus** and **stapes**. **Cochlea** of the internal ear is **spirally coiled** and bears the '**organ of Corti**' which is the receptor of sound.
- ❖ Functional kidneys are bean shaped and **metanephric**. Nephron has **loop of Henle** which helps in the formation of concentrated urine. Mammals are 'ureotelic'.
- ❖ Sexes are separate. Sexual dimorphism is generally well-marked. Testes are usually found in scrotal sacs outside the abdomen. Intra-abdominal testes are found in the **monotremes**, **cetaceans** (whales and dolphins), **sea cows**, **elephants**, etc. Males have copulatory organ called **penis**.
- ❖ Fertilization is internal. Mammals, except the monotremates, are viviparous. Development is intra-uterine. Developing embryo is attached to the uterine wall of the mother by a **placenta**, for nutrition and respiration (absent in the monotremes).

Examples

Ornithorhynchus (duckbilled platypus), *Macropus* (Kangaroo), *Pteropus* (flying fox), *Camelus* (camel), *Macaca* (monkey),*Rattus* (rat), *Canis* (dog), *Felis* (cat), *Elephas* (elephant), *Equus* (horse), *Delphinus* (common dolphin), *Balaenoptera* (blue whale), *Panthera tigris* (tiger; National Animal of India), *Panthera leo* (lion), *Antelope* (state animal of A.P)

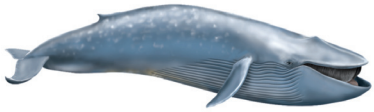
Do you know - The monotremes inspite of being 'egg laying mammals', also feed their young ones with milk?

Do you know - The gestation is very short in marsupials and the young one after birth crawls into the pouch and grows sucking milk. Some call it a 'mammary foetus'.

Ornithorhynchus

Macropus

Pteropus



Balaenoptera

Panthera tigris

Antelope

Fig. 4.29 Mammals

GLOSSARY

CHORDATA

Atrium: One of the chambers of the heart; the tympanic cavity of ear; the spacious ectoderm-lined cavity, enclosing the pharynx in most tunicates and cephalochordates.

Creatine phosphate: A high-energy phosphate compound, found in the muscles of vertebrates and some invertebrates, used to regenerate ATP.

Endostyle: Mucous secreting longitudinal ciliated groove present on the ventral wall of the pharynx of tunicates, cephalochordates, and larvae of the jawless fishes, useful for accumulating and moving food particles to the oesophagus.

Filter feeding: Any feeding process by which particulate food is filtered by the ciliary action from the water in which it is suspended e.g. Protochordates, Sponges and Bivalves

Mesonephros: It is the functional kidney of the adult fishes, amphibians and the embryos of the 'amniotes'.

Pelagic animals: Animals living in open oceans or seas, freely floating.

Portal system: A system of large veins beginning and ending in a plexus of capillaries e.g. hepatic and renal portal systems of vertebrates.

Retrogressive metamorphosis: Metamorphosis of a larva with advanced characters into a degenerate adult e.g. Ascidians, *Sacculina*.

Solenocyte: It is a tubular terminal flame cell like structure of a protonephridium. It has one or more flagella, which drive the excretory fluid along the tubule. They are found in cephalochordates.

PISCES

Acrodont: Having teeth attached to the edge of the jawbone without sockets.

Claspers: They are formed from the posterior portion of pelvic fins in male cartilaginous fish. They serve as intromittent organs used to channel semen into the female's cloaca during mating.

Coelacanth: An ancient, extant bony fish of the group Rhipidistia which was thought to be extinct until 1938, but was rediscovered in 1938, off the coast of South Africa. At present , there are two living species of the genus 'Latimeria'.

Ctenoid scale: A fish scale having marginal projections that resemble the teeth of a comb, found in many teleost fishes.

Cycloid scale: A fish scale which is thin and shows concentric lines of growth, without serrations on the margin, found in lung fishes and some teleost fishes.

Dipnoi: They are a group of fish commonly known as 'lung fishes' , their lungs being modified air bladders. e.g. *Protopterus*, *Neoceratodus* and *Lepidosiren*.

Ganoid scales: Thick, bony scales of some primitive bony fishes such as Acipenser.

Ostracoderms: Extinct palaeozoic fishlike jawless vertebrates, characterized by a heavily armoured body; considered the ancestors of the jawed fishes.

Placoid scales: The type of scales found in cartilaginous fishes, with a basal plate of dentine embedded in the skin and a backward-pointing spine, tipped with vitrodentine.

Polyphyodont: A type of dentition in which the teeth are naturally shed many times

and replaced during the lifetime of vertebrates.

Ray finned fishes: They are a highly diverse group of aquatic vertebrates. Over half of all living vertebrate species are ray finned fishes.

AMPHIBIA

Alveolus: A small cavity or pit, such as a microscopic air sac of the lungs, terminal part of an alveolar gland, or bony socket of a tooth in the jaws of mammals and crocodiles.

Amplexus: The copulatory embrace of frogs or toads during which the male and female shed their gametes.

Chyme: Semifluid mass of partly digested food formed in the stomach.

Columella auris: A small rod like bone in the middle ear of frogs, reptiles and birds that transmits sound to inner ear; homologous to the mammalian stapes (modification of the hyomandibula of the fishes).

Conus arteriosus: It is a single, wide arterial vessel leaving the ventricle and passing ventrally over the right atrium. It is absent in the amniotes.

Dura mater: It is the outermost, toughest, and the most fibrous of the three membranes (meninges) covering the brain and the spinal cord.

Harderian gland: A gland associated with eye; the fluid it secretes varies in different groups of animals. In some animals it acts as an accessory gland to the lacrimal gland; secreting a fluid that lubricates the nictitating membrane.

Labyrinthodontia: A group of extinct amphibians typically resembles heavy-bodied salamanders and crocodiles. They have folded enamel and dentine at the base of conical teeth. e.g. Eryops.

Lacrimal glands: These are paired glands, one in each eye. They secrete watery fluid (tears), which contains lysozyme.

Opisthocoelous vertebra: In this type, the centrum is convex at the anterior face and concave at the posterior face; found in the urodeles.

Piamater: It is the delicate, inner most and vascularized membrane (meninx) enveloping the brain and spinal cord. It forms the choroid plexuses.

Sinus venosus: An enlarged region between the vena cavae and the right atrium. In the heart of frog, the pacemaker is the sinus venosus, (the 'SA node'in the heart of a mammal is believed to be an evolutionary remnant of the sinus venosus.)

REPTILIA

Allantois: It is one of the four extra embryonic membranes of the amniotes. It participates in respiration and excretion in sauropsids and also in the formation of placenta in most of the therians.

Amnion: It is the innermost of the extra embryonic membranes. It is a fluid-filled sac enclosing the embryo in the amniotes. It is protective in function (protection from shock and desiccation).

Chorion: It is the outermost extra embryonic membrane that surrounds the embryo of amniotes. It participates in the formation of placenta along with allantois in the placental mammals.

Hemipenis (plural: hemipenes): It is one of the pairs of intromittent organs of male squamates (snakes and lizards)

Meroblastic cleavage: It is a partial cleavage which occurs in the megalecithal eggs. The cleavages are

restricted to a disc like cytoplasmic area near the animal pole. e.g. sauropsids and monotremes.

Metanephros: It is the functional kidney of adult amniotes. It is the most efficient type of kidney.

Sauropsida: It is a group of amniotes, which includes all extinct and living reptiles and birds .

Temporal fossae: These are shallow depressions in the temporal regions of the skull of many reptiles, which provide space for the insertion of muscles.

AVES

Altricial hatchling: It is the hatchling of carinate bird which is 'incapable of moving around on its own soon after hatching'.

Carinate birds: These are the birds with a 'keeled sternum' for the insertion of flight muscles. e.g. flying birds.

Heterocoelous vertebra: It is the type of vertebra in which the articulating surfaces of the vertebral centrum are 'saddle-shaped'.

Pecten: It is a pigmented, vascular, and comblike process that projects into the vitreous humour from the retina at the point of entrance of the optic nerve in the eyes of birds and some reptiles.

Precocial young: It is the hatchling of a ratite bird, which is 'capable of moving around on its own soon after hatching'.

Theropods: The extinct bipedal carnivorous dinosaurs that gave rise to birds at the beginning of the Jurassic period.

Vitreous humour: It is the clear gel that fills the space between the lens and the retina of the eyeball of humans and other vertebrates

MAMMALIA

Cochlea: A tubular cavity of the inner ear containing the essential organs of hearing; occurs in crocodiles, birds and mammals. In the eutherians, it is spirally coiled with 'organ of Corti'- a specialized region for sound perception.

Diphyodont dentition: It is the type of dentition in which two sets of teeth are formed. They are deciduous and permanent sets of teeth which are formed successively.

Heterodont dentition: It is the type of dentition in which the teeth are differentiated into cutting, tearing, and grinding teeth.

Malleus: The outer ear ossicle which is attached to the tympanum in the middle ear of mammals (modification of the articular bone of the ancestors).

Placenta: The vascular structure, formed from embryonic and maternal tissues , through which the embryo and foetus are nourished while in the uterus.

Sebaceous glands: These are a type of mammalian epidermal glands associated with the hair follicles. They secrete 'sebum' which keeps the skin and hair smooth and lustrous.

Stapes: Stirrup-shaped, inner most ossicle of the middle ear in mammals (modification of hyomandibula); Smallest bone in the body of a mammal.

Sudoriferous glands: These are epidermal glands of the skin whose secretion (sweat) helps in excretion and thermoregulation; found only in mammals.

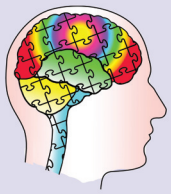
Therapsids: These are mammal-like extinct reptiles that gave rise to mammals during the 'Triassic period'.

VERY SHORT ANSWER QUESTIONS

1. List out the characters shared by chordates and echinoderms.
2. Write four salient features of cyclostomes.
3. What is the importance of endostyle in lancelets and ascidians?
4. Name the type of caudal fin and scales that are present in a shark and Catla, respectively.
5. What is the importance of air bladder in fishes?
6. How do you justify the statement- heart in fishes is a branchial heart.
7. What are claspers? Which group of fishes possesses them?
8. How does the heart of an amphibian differ from that of a reptile?
9. Name the structures that appeared for the first time in amphibians, in the course of evolution.
10. How do you distinguish a male frog from a female frog?
11. What is force pump in frog? Why is it named so?
12. What are corporabigemina? Mention their chief function.
13. Distinguish between mesorchium and mesovarium.
14. Distinguish between milt and spawn.
15. What are the Golden ages of the first jawed vertebrates and the first amniotes?
16. Name two poisonous and non-poisonous snakes found in south India.
17. In which features does the skin of a reptile differ from that of a frog.
18. Describe a cat and a lizard on the basis of their chief nitrogenous wastes excreted.
19. Name the four extra embryonic membranes.
20. What are Jacobson's organs? What is their function?
21. What are pneumatic bones? How do they help birds?
22. What is 'wish bone'? What are the skeletal components that form it?
23. What is continuous oxygenation of the blood? How is it made possible in birds?
24. Distinguish between the crop and the gizzard in birds.
25. Distinguish between altricial and precocial hatchlings.
26. In which group of animals do we find three ear ossicles on each side and what are their names from the inner most to the outermost?
27. How does a mature RBC of a mammal differ from that of other vertebrates?
28. Name the characteristic type of vertebrae found in reptiles, birds and mammals.
29. Name the three meninges. In which group of animals do you find all of them?
30. Name the vertebrate groups in which renal portal system is absent.

SHORT ANSWER QUESTIONS

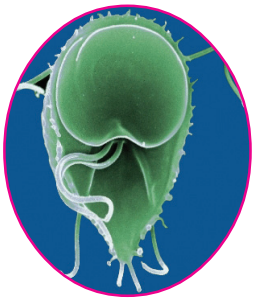
1. Give three major differences between chordates and non-chordates, and draw the sketch of a chordate's body showing those features.
2. Name the four hallmarks of chordates, and explain the principal function of each of them.
3. Describe the features of a tunicate that reveals its chordate identity .
4. Compare and contrast sea squirts and lancelets.
5. List out eight characteristics that help distinguish a fish from the other vertebrates.
6. Compare and contrast cartilaginous and bony fishes.
7. Describe the structure of the heart of frog.
8. Write eight salient features of the class Amphibia.
9. Describe the male reproductive system of frog with the help of a labelled diagram.
10. Write short notes on organs of special senses in frog.
11. List out the salient features of exo and endoskeleton in reptiles.
12. List out the extant orders of the Class Reptilia. Give two examples for each Order.
13. What are the modifications that are observed in birds that help them in flight?
14. What are the features peculiar to ratite birds? Give two examples of ratite birds.
15. Mention the most important features of nervous system and sense organs in mammals.
16. Write short notes on the following features of the eutherians.
    a) Dentition.
    b) Endoskeleton.
17. Give an example for each of the following.
    a) A viviparous fish
    b) A fish possessing electric organs
    c) A fish possessing poison sting
    d) an organ which regulates buoyancy in the body of a fish
    e) An oviparous animal with milk producing glands
18. Mention two similarities between
    a) Aves and mammals
    b) A frog and a crocodile
    c) A lizard and a snake
19. Name the following animals
    a) A limbless amphibian
    b) The largest of all living animals
    c) An animal possessing dry and cornified skin
    d) 'National Animal' of India
20. Write the generic names of the following.
    a) An oviparous mammal
    b) Flying fox
    c) Blue whale
    d) Kangaroo.



For ignited minds

- NOT FOR EVALUATION

1. *Amphioxus* is described as a typical chordate. When the urochordates are also chordates (protochordates along with the cephalochordates), why can't we call the urochordates also 'typical' chordates?
2. There is a marked morphological difference between the 'jawless fishes' and 'jawed fishes', with reference to their movement in water. Can you guess what it could be?
3. Our heart receives deoxygenated blood through the caval veins. The heart of a fish too, receives deoxygenated blood. Why do scientists describe the heart of fish only, as a venous heart? Why not ours too?
4. Why did Romer describe the 'lung fishes' as the 'uncles of amphibians'? Can you throw light on the evolutionary considerations that led him state so?
5. In terms of expenditure of energy, which group of fishes will have to spend more energy to keep afloat at a particular level in the column of water? - the cartilaginous fishes or the bony fishes.
6. If a frog is kept on land for some time (by not allowing it to go into water), what do you think will happen? If somebody suggests-it dies, do you agree with him? Give reason.
7. The larva of frog has a long coiled gut. When it metamorphoses into a young frog what will happen to the gut? Give reason for your assumption.
8. When the egg of a frog develops into a tadpole larva, why should not be the same case, with respect to the egg of a reptile, bird or an egg laying mammal?
9. Amniotes are well adapted for terrestrial life. How can you support the popular belief that the ancestors of the amniotes were aquatic organisms? (Clue: Biogenetic law)
10. Amniotes possess mesonephric kidneys during their embryonic stage for some time. Later they are replaced by the metanephric kidneys. However certain remnants of the embryonic mesonephric system persist in the male amniotes. What are those remnants in your view?
11. Reptiles are uricotelic. What do you expect a marine turtle to be - ammonotelic?/ureotelic? uricotelic? Can you substantiate your answer with probable reasons?
12. You have read the units on Aves and Mammalia in that order in your text book. Do you agree with that order? If so, what is the basis? If not, how do you explain?
13. You know that nitrogenous waste products in animals include ammonia, urea, uric acid, guanine etc. How do you account for the reasons why some organisms send waste in the form of ammonia, others urea and yet others uric acid?
14. If an egg of a hen is coated with varnish (egg A) and another one non-coated normal egg (egg B) are incubated for 21 days, what do you expect regarding the outcome or end result.
15. Why do marsupials occur in Australia and America only? Why not in other places? What possible reasons can you think of? (Clue: Theory of continental drift)
16. Bats are not closely related to birds. Yet they can fly. What do you call such a phenomenon of evolution?(Clue: Expected answer is related to type of evolution)
17. When the R.B.C of all other vertebrates are necleate, the highly evolved mammals possess enucleate R.B.C. (Nucleus is extruded during maturation). What physiological advantages do you see in such R.B.C. Give a logically sound answer.



Giardia lamblia 'Grand oldman of intestine'- a human intestine dwelling flagellate.

Unit

5

Locomotion and Reproduction

... In search of prey and perpetuation

Locomotion

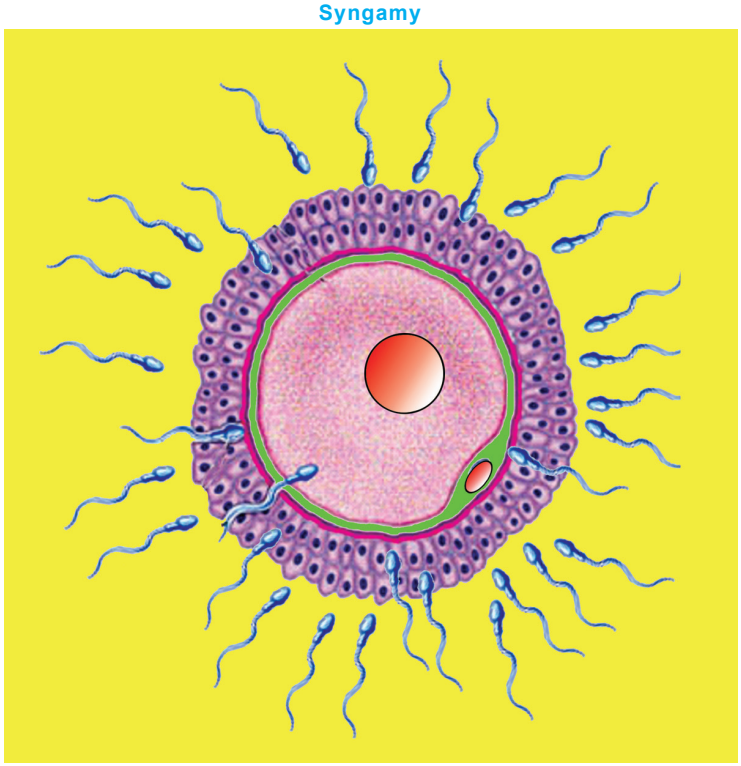
In our day-to-day life we move our limbs, jaws, eyelids, tongue, etc. without any change in the position or location of our body. Plants perform tropic movements in response to stimuli of light and gravity. These movements do not result in any change in the place or location of the body of an organism.

Locomotion is defined as the voluntary movement of an organism from one place to another either in search of food or shelter or mate or to escape from the predators. Walking, running, climbing, swimming, crawling, flying, etc., are the different forms of locomotory movements exhibited by various types of animals. Locomotory structures may also be used for the collection of food. For example, protists such as Amoeba and Paramecium use their locomotor structures (pseudopodia and cilia, respectively) for the collection of food also. The above facts suggest that movements and locomotion cannot be studied separately; they may be linked by stating that "all locomotions are movements, but all movements are not locomotions". The method of locomotion performed by animals varies with their habitats and the demand of the situation.

Reproduction

It is defined as a biological process in which an organism gives rise to young ones (offspring) similar to itself (perpetuation of the race) The offspring grow, mature into adults and in turn produce their offspring. Thus, there is a cycle of birth, growth and death. Reproduction enables the continuity of the species, generation after generation. There is a large diversity in the biological world and each organism has evolved its own mechanism to multiply and produce offspring. The organism's habitat, its internal physiology and several other factors are collectively responsible for its mode of reproduction. Based on the participation of one organism or two in the process of reproduction, it is of two types, asexual and sexual.

Syngamy



(Sperm meets the ovum by its lashing movements)

Locomotion and Reproduction in Protozoa

5.1 Locomotion in Protozoa

Though the protozoans are acellular and mostly microscopic, they are versatile in their locomotion. The free living aquatic protozoans move through the water, whereas some parasitic forms move through the body fluids of their hosts. Locomotion in protozoans is performed by cellular extensions such as **pseudopodia**, short hair-like organelles, the **cilia**, whip-like organelles, the **flagella** and the contractile fibrils, the **myonemes**.

5.1.1 Pseudopodia

These are found in **rhizopods**. The pseudopodia are temporary extensions of cytoplasm that develop in the direction of the movement. These temporary structures are useful to move on the substratum as our legs do, hence the name 'pseudopodia'. There are four kinds of pseudopodia namely **lobopodia** (blunt finger-like) as in *Amoeba* and *Entamoeba*, **filopodia** (fibre-like) as in *Euglypha*, **reticulopodia** (net-like) as in *Elphidium* and **axopodia** or **heliopodia** (sun ray-like) as in *Actinophrys*.

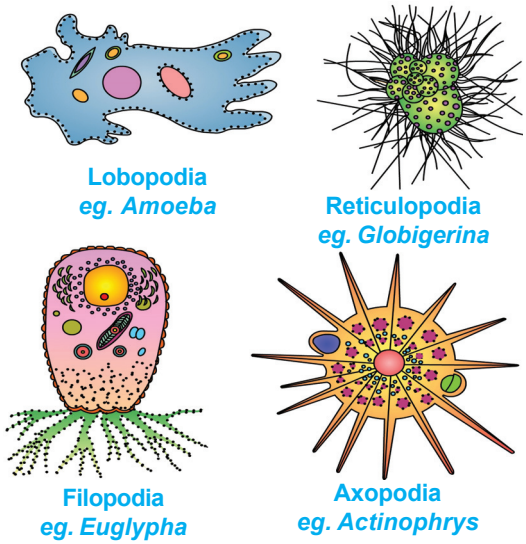


Fig. 5.1 Types of Pseudopodia

Pseudopodium is formed by the conversion of gel (viscous outer endoplasmic part) to sol (fluid-like inner endoplasmic part) and vice-versa. There are different theories on the formation of pseudopodium. The sol-gel transformation theory is the most accepted theory. Opinions differ on the site of contraction that pushes the pseudopodium forwards. Allen's theory of 'Front contraction' or 'Fountain zone' theory is

Plasmagel $\xrightarrow{+H_2O(Solation)}$ Plasmasol $\xrightarrow{-H_2O(Gelation)}$ Pseudopodium ⟶ Displacement of the body in the forward direction

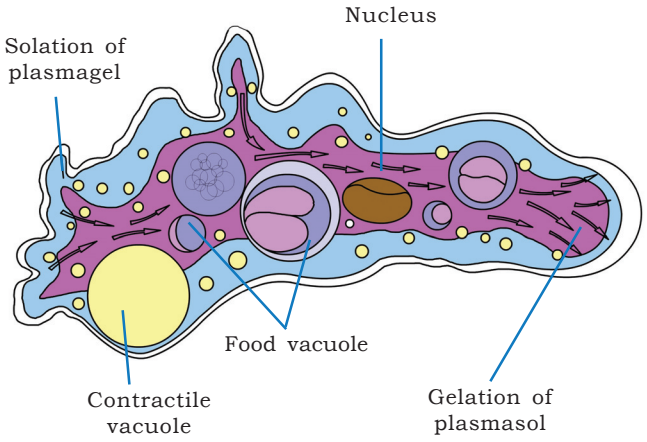


Fig. 5.2 Amoeba-locomotion

considered to be more appropriate. However modern research brings in the role of actin and myosin molecules too.

The pseudopodial or amoeboid movement is performed by ***Amoeba***, ***Entamoeba***, ***Polystomella***, ***Actinophrys***, etc. Amoeboid locomotion is probably the most primitive and the slowest type of locomotion.

In addition to protozoans, amoeboid locomotion is performed by amoeboid cells, macrophages, neutrophils, etc., of higher metazoans.

5.1.2 Flagella

The long whip-like locomotor organelles are called flagella (sing. flagellum). These are found in the **mastigophoran protozoans** (mastig – whip; phoran - bearer). Bacteria also possess flagella, which are structurally different from those of the eukaryotes The movement of spermatozoa of animals involves flagellar movement.

I. Structure

The structural components of a typical flagellum include axoneme, microtubules, dynein arms, inner sheath, outer sheath, radial spokes, lateral appendages (such as mastigonemes or flimmers) and a basal granule (kinetosome).

i. **Axoneme/ axial filament:** It is the central, longitudinal, microtubular structure of cilium and flagellum. It is surrounded by a membrane which is continuous with plasma membrane. All the components of the axoneme are embedded within the matrix.

ii. **Microtubules:** An axoneme is made up of 2 central 'singlets' and 9 peripheral 'doublets(9+2 array)'. These are formed by the protein called **tubulin**. Each peripheral doublet consists of an outer 'A' and the inner 'B' tubules. So, the peripheral tubules are actually 9 microtubular doublets. (The microtubule 'A' is smaller but complete whereas 'B' is larger and incomplete). The peripheral doublets are interconnected by 'linkers' called **nexins.**

iii. **Dynein arms:** The 'A' tubule of each peripheral doublet bears paired arms along its length, called dynein arms (Dyne - pulling like a dynamo). The dynein arms of 'A' tubule face the tubule 'B' of the adjacent doublet. They are oriented in the

same direction (clockwise) in all microtubules. The dynein arms are considered '**protein motor molecules**'. They are made of the protein, **dynein**.

iv. **Inner and outer sheaths:** The two central singlets are enclosed by a fibrous inner sheath and the peripheral doublets are enclosed by an outer sheath (an extension of plasma membrane). The central singlets do not reach below the level of the pellicle or plasmalemma.

v. **Radial spokes:** They are elastic fibres that connect the inner sheath, with the 'A' tubule of each doublet. They resemble the spokes that connect the rim of the wheel of a bicycle with the centre, hence the name 'radial spokes/ radial bridges'. The nine radial spokes limit the extent of sliding past of the doublets, during bending movements.

vi. **Basal granule / kinetosome:** It is the cell organelle involved in the formation of a flagellum /cilium. The basal granule is a modified centriole. It is also called **kinetosome** [kineto - moving; soma - body] or **basal body** or **blepharoplast**. It is present in the ectoplasm. The basal granule is a cylindrical body, formed by '9' peripheral triplets arranged in a circle. The tubules of each triplet are designated A, B and C from the center towards the periphery. Both 'A' and 'B' cross the basal

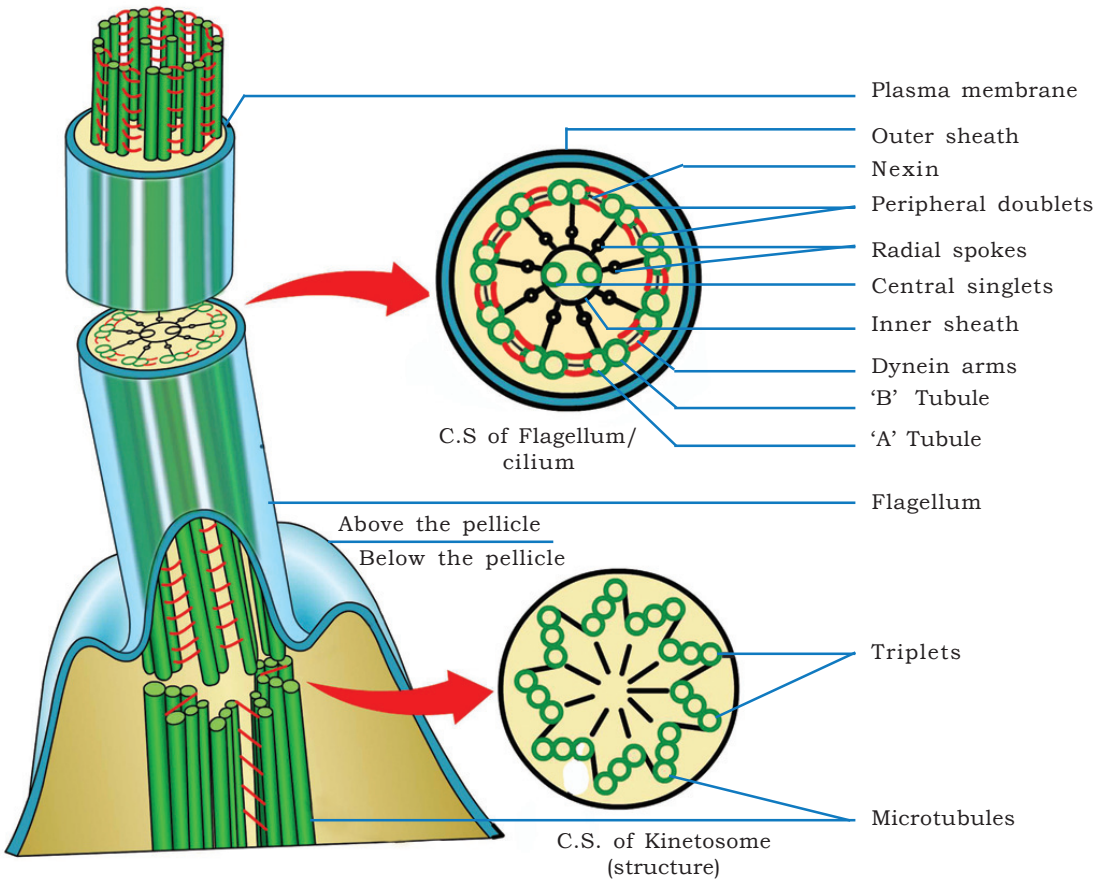


Fig. 5.3 Structure of a flagellum/ cilium

plate and continue as peripheral doublet above the pellicle in the axoneme. However, the tubule C terminates at the basal plate. Thus the '**triplets**' of the basal granule are converted into the flagellar/ciliary '**doublets**'. There are no central microtubules in the basal granule. The basal granule is also connected to the plasma membrane and nucleus by communication tubules, called **rootlets.** The rootlets can pull the flagellum and alter its orientation.

vii. **Lateral appendages:** Some flagella bear one or two or many rows of short, lateral hair like fibrils called lateral appendages, also called '**mastigonemes**'.

II. Types of Flagella

Based on the presence or absence and/or the number of rows of lateral appendages, five types of flagella are recognised.

a. **Stichonematic:** This flagellum bears one row of lateral appendages on the axoneme. E.g. ***Euglena*** and ***Astasia***.

b. **Pantonematic:** This flagellum has two or more rows of lateral appendages on the axoneme. E.g. ***Peranema*** and ***Monas***.

c. **Acronematic:** This type of flagellum does not bear lateral appendages and the terminal part of the axoneme is naked without the outer sheath at its tip. E.g.:***Chlamydomonas*** and ***Polytoma***.

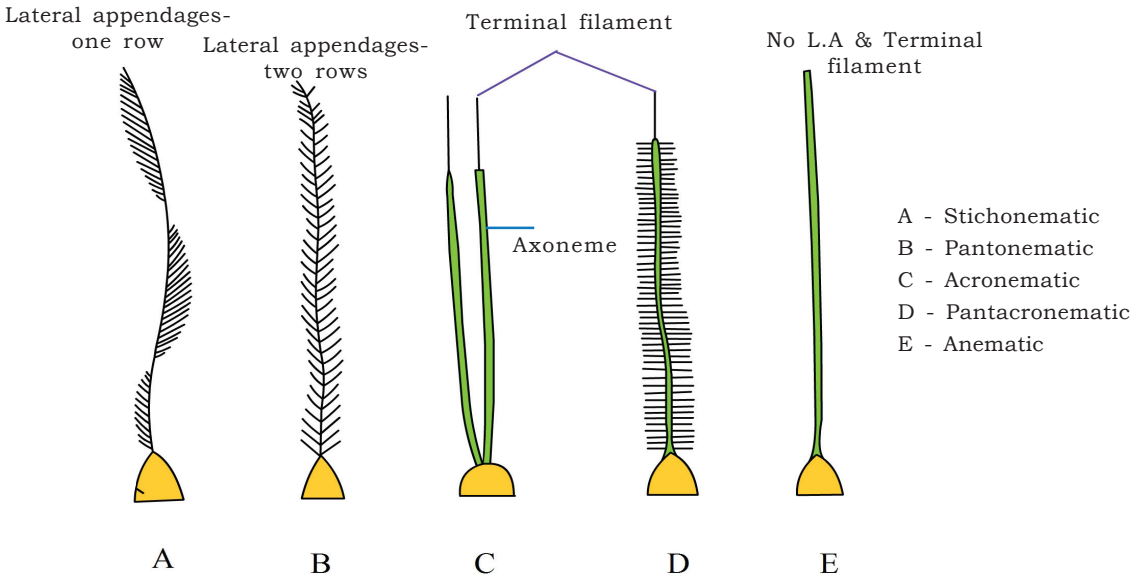


Fig. 5.4 Types of flagella

d. **Pantacronematic:** This type of flagellum is provided with two or more rows of lateral appendages and the axoneme ends in a terminal naked filament. E.g. ***Urceolus***.

e. **Anematic** or **simple:** In this type of flagellum, lateral appendages and terminal filament are absent. Hence, it is called anematic (a-no; nematic-threads)

e.g. ***Chilomonas* and *Cryptomonas***

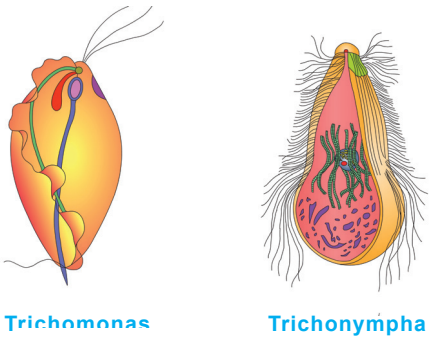


Fig. 5.5 Flagellates

III. Number of flagella

In the mastigophorans, the number of flagella varies from species to species. ***Euglena*** has two flagella (one long and one short), ***Trypanosoma*** has a single long flagellum arising at the rear end of the body. Four flagella are found in ***Trichomonas***, four pairs in ***Giardia*** and many in ***Trichonympha***.

5.1.3 Cilia

I. Structure

Cilia are small hair-like structures found in ciliate protists, epithelial lining of respiratory tract, genital ducts, ventricles of brain etc. In the primitive ciliates like ***Paramecium***, the entire body is covered by cilia and in the advanced ciliates, such as ***Vorticella***, cilia are restricted to the peristomial region. In the suctorians such as ***Acineta***, the cilia are confined to the 'juvenile stages' only (The adults possess suctorial tentacles which help in feeding).

Cilia arise from the basal granules situated in the ectoplasm below the pellicle. Cilia are similar to flagella in their ultra structure. Cilia serve as organelles of locomotion, food collection and also act as sensory structures.

II. Infraciliary system

It is located just below the pellicle in the ectoplasm of a ciliate. It includes **kinetosomes**, **kinetodesmal fibrils** and **kinetodesmata**. The kinetosomes are present at the bases of cilia in transverse and longitudinal rows. The kinetodesmal fibrils are connected to the kinetosomes and run along the right side of each row of kinetosomes as a 'cord of fibres' called **kinetodesmata**. *A longitudinal row of kinetosomes together with kinetodesmata constitute a unit called '**kinety**'.*

All the kineties together form an infraciliary system, which is connected to a '**motorium**', located near the cytopharynx. The infraciliary system and motorium form the 'neuromotor system' that controls and coordinates the movement of cilia.

III. Differences between Flagella & Cilia

Flagella	Cilia
1) Long whip-like	1) Short hair-like
2) One, two, four or many	2) Many
3) Flagella normally originate at the anterior end.	3) Cilia are found all over the body surface or confined to peristomial region.
4) Flagella do not unite to form cirri.	4) In some ciliates, the cilia fuse to produce cirri, or undulating membrane and membranelles,
5) Flagella perform "undular" movement	5) Cilia perform "pendular" movement

5.1.4 Myonemes

They are the contractile fibrils present below the pellicle in the ectoplasm. They occur in flagellates, apicomplexans and ciliates.

5.2 Flagellar and Ciliary Movement

5.2.1 Swimming locomotion

This type of locomotion in protozoans is brought about by **flagella** and **cilia.** Flagella and cilia are also called '**undulipodia**' by Hyman. They are useful in bringing about locomotion in water and the body fluid of hosts in the case of a few parasites. Bending movement of a flagellum is brought about by the sliding of microtubules past each other due to the functioning of '**dynein arms**' utilising ATP. A flagellum pushes the fluid medium at right angles to the point of its attachment, by its bending movement.

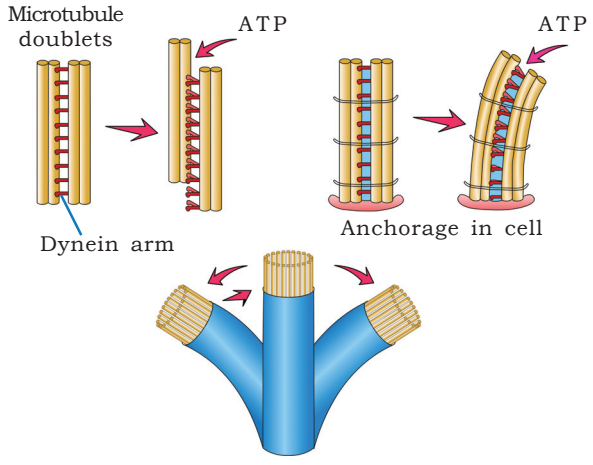


Fig 5.6 Bending of microtubules

Bending movement of flagella and cilia

Dynein arms show a complex cycle of movements using energy provided by ATP (dynein arms are the sites of ATPase activity in the cilia and flagella). The dynein arms of each doublet attach to an adjacent doublet *and pull* the neighbouring doublet. So the doublets slide past each other in opposite directions. The arms release and reattach a little farther on the adjacent doublet and again 'pull'. As the doublets of a

flagellum or cilium are physically held in place by the radial spokes, the doublets cannot slide past much. Instead, they curve and cause bending of flagellum or cilium. Such bending movements of flagella and cilia play an important role in the flagellar and ciliary locomotion.

If, nexins and radial spokes of an axoneme in a flagellum/cilium are subjected to enzymatic digestion and provided with ATP, what happens to the doublets?

5.2.2 Flagellar locomotion

Flagellum shows undulation movements, sidewise lash movements and spiral gyration movements.

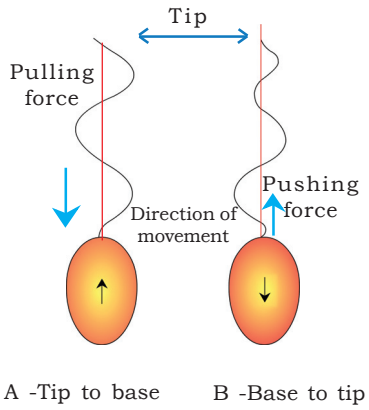


Fig. 5.7 Undular movement of a flagellum

a) **Undulation movements:** Undulatory movements from the base to the tip causes *a* ***pushing force*** (like the propeller of a boat) and the organism is *pushed* backwards(undular movement). Undulation from the tip to the base causes a **pulling force** (like the propeller of an aeroplane) and the organism is *pulled* forwards. If the flagellum bends to one side and shows a wave like movement from the base to the tip, the organism moves laterally in the opposite direction.

b) **Sidewise-lash movement:** The flagellar movement of many organisms is a sidewise-lash which consists of two 'strokes' namely the **effective** or **propulsive stroke** and the **recovery stroke**.

(i) **Effective stroke:** Flagellum becomes rigid and starts bending to one side beating against the water. This beating against water is at right angles to the body axis and the organism moves forwards (the direction of movement is parallel to the surface of the body).

(ii) **Recovery stroke:** Flagellum becomes comparatively soft so as to offer least resistance to water and moves backwards to its original position. It is called 'recovery stroke'.

c) **Simple conical gyration movements:** In simple conical gyration movement, a flagellum turns like a screw. This exerts the propelling action that pulls the organism forwards through water with a spiral **rotation** around the axis of movement and **gyration** on its own axis.

5.2.3 Ciliary Locomotion

Ciliary locomotion is observed in ciliates. It is performed by bending movements of the cilia. Cilium also shows swift back and forth movements during locomotion as in the case of a flagellum. These are called *effective* and *recovery* strokes respectively. Cilium moves the water parallel to the surface of its attachment like that of a *paddle* or *pendular movement.* The movement of water may also be described as perpendicular to the axis of cilium.

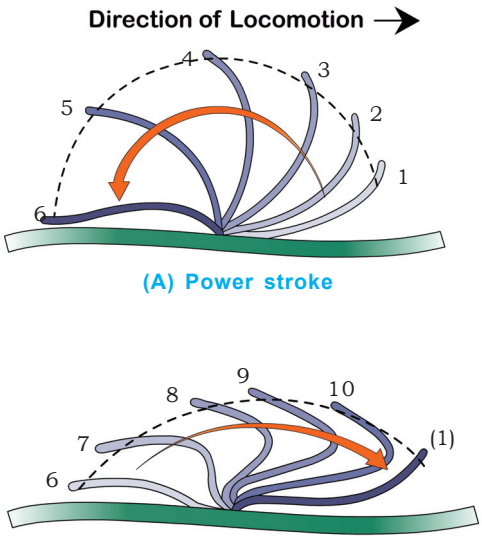


Fig. 5.8 (A) Effective stroke
(B) Recovery stroke

a) **Effective stroke:** Cilium bends backwards and beats against the water. It is called the 'effective stroke'. Body moves forwards in this stroke, as cilium pushes the water backwards. Cilium moves like *pendulum* or a *paddle.(pendular movement)*

b) **Recovery stroke:** The cilium after the effective stroke, comes to its original position by its backward movement without any resistance. It is called 'recovery stroke'.

In ***Paramecium*** cilia show two types of coordinated movements.

a. **Synchronous movement:** Cilia in a transverse row beat simultaneously in one direction. It is called **synchronous movement**.

b. **Metachronous movement:** The sequential movement of cilia, in a longitudinal row, one after the other in one direction is called **metachronous movement**. This movement passes like a wave. It resembles the movement of plants in a paddy field due to the blow of wind from one direction to the other. The ciliary locomotion is coordinated by the *infraciliary system* through a neuromotor centre called motorium, present near the cytopharynx. Ciliary locomotion is faster than flagellar locomotion. Hence, ciliates are the fastest protozoans.

Flagella are responsible for the movement of the organism, whereas cilia bring out movement of either the organism or the surrounding fluid as seen in ciliary mode of feeding in certain organisms.

5.2.4 Gliding Locomotion

The small zig-zag movement in some protozoans caused by the contraction and relaxation of myonemes present below the pellicle in the ectoplasm is called **gliding locomotion.** **Myonemes** are contractile fibrils which are similar to the myofibrils of higher protozoans. e.g. ciliates, flagellates etc.

Is it correct to say 'all undulipodia' do not show undular movements?

5.3 Asexual Reproduction

When an offspring is produced by a single parent without the involvement of gamete formation, the reproduction is **asexual.** In this method, a single individual (parent) is capable of producing the offspring. As a result, the offspring are not only identical to one another but also exact copies of their parent. The term '**clone**' is used to describe such morphologically and genetically similar individuals. Asexual reproduction is widespread among different organisms. It is common in members of Protista, Bacteria, Archaea and in multicellular organisms with relatively simple organisation. The offspring show '**uniparental inheritance**' without any genetic variations.

5.3.1 Asexual Reproduction in Protozoans

The methods of asexual reproduction that occur in many protozoans are binary fission and multiple fission.

5.3.2 Binary Fission

It is the most common method of asexual reproduction in protozoans. It occurs during **favourable conditions**. It is the division of the parent cell into two daughter individuals. It involves the division of nucleus (karyokinesis) followed by the division of the cytoplasm (cytokinesis). The plane of fission differs in different protozoans. Based on the axis of cytokinesis, the binary fission is chiefly classified into longitudinal and transverse fissions.

I. Longitudinal Binary Fission

It is seen in flagellates such as ***Euglena***, ***Trypanosoma*** etc. In this type of binary fission, the body divides into two halves longitudinally, hence called longitudinal **binary fission**.

Euglena possesses two flagella arising from two basal granules, one contractile vacuole, stigma, paraflagellar body (photoreceptor), cytostome, cytopharynx and reservoir anteriorly, nucleus in the centre and chromatophores around the nucleus and myonemes beneath the proteinous pellicle.

During the process of binary fission, the nucleus, basal granules, chromatophores, cytoplasm undergo division. The nucleus divides by **mitosis** into two daughter nuclei. Then the kinetosomes and the chromatophores also divide. At first, a longitudinal groove develops in the middle of the anterior end. This groove extends gradually towards the posterior end until

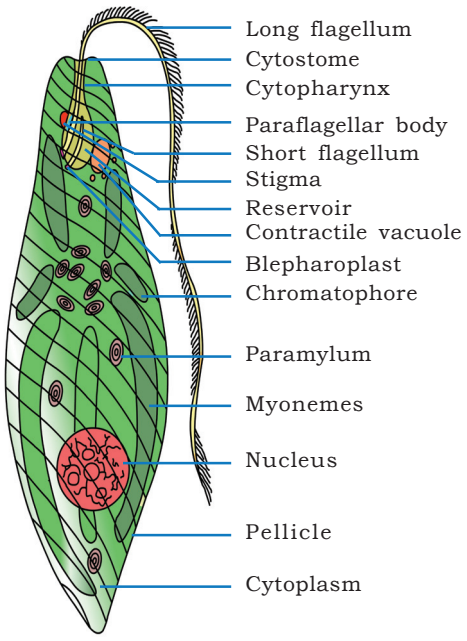


Fig. 5.9 Euglena

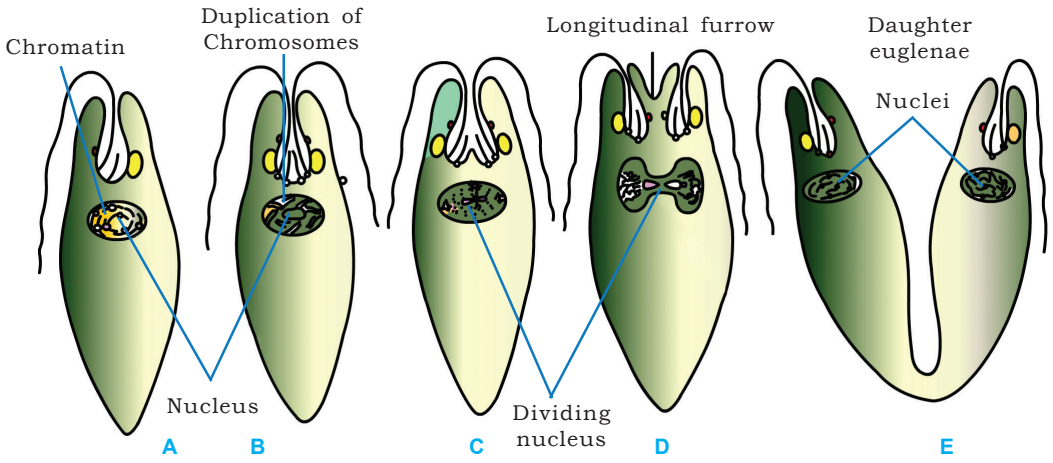


Fig. 5.7 Longitudinal binary fission in *Euglena* - different stages

the two daughter individuals are separated. One daughter ***Euglena*** retains the parental flagella. The other daughter individual develops new flagella from the newly formed basal granules. The stigma, paraflagellar body and contractile vacuole of the parent disappear. They develop afresh in both the daughter euglenae. **The longitudinal binary fission is known as symmetrogenic division,** because the two daughter euglenae resemble each other like '**mirror images**'.

II. Transverse Binary Fission

It is performed by ***Paramecium***, commonly called "slipper animalcule". It has an oral groove, cytostome and cytopharynx in the oral surface. It also has one macronucleus (**polyploid**) and one micronucleus (**diploid**), two contractile vacuoles (anterior and posterior), trichocysts, infraciliary system and many cilia on the body.

During favourable conditions, ***Paramecium*** stops feeding after attaining its maximum growth. At first the micronucleus divides by **mitosis** and the macronucleus divides into two daughter nuclei by **amitosis**. The oral groove disappears. After karyokinesis, a transverse constriction appears in the middle of the body, which deepens and divides the parent cell into two daughter individuals, the anterior **proter** and the posterior **opisthe**. The proter receives the anterior contractile vacuole, cytopharynx and cytosome from its parent individual. It develops posterior contractile vacuole and a new oral groove. The **opisthe** receives the posterior contractile vacuole of its parent. It

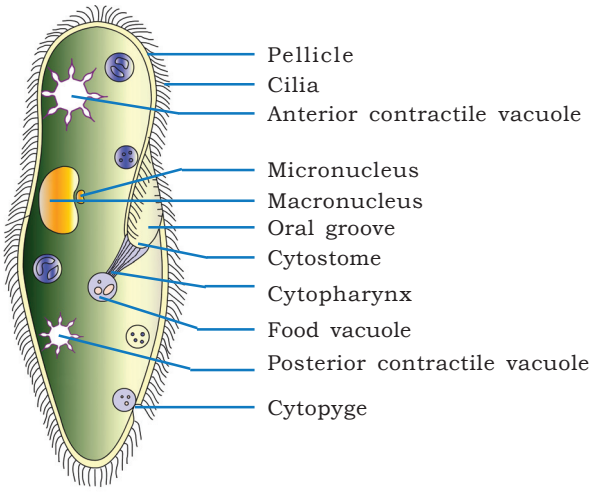


Fig 5.8 Paramecium

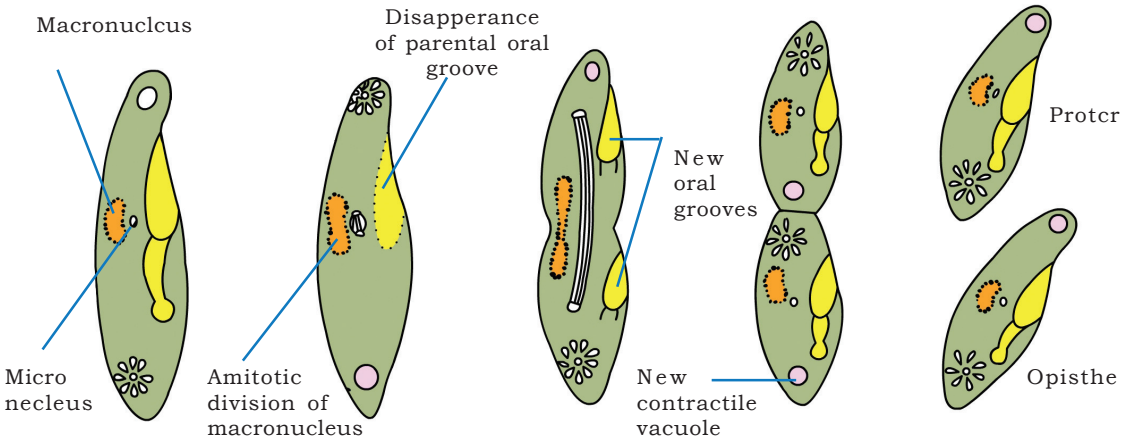


Fig. 5.9 Stages of transverse binary fission in Paramecium

develops a new anterior contractile vacuole, cytopharynx, cytostome and a new oral groove. Binary fission is completed in almost two hours, in favourable conditions and ***Paramecium*** can produce four generations of daughter individuals by binary fission in a day.

The transverse binary fission is also called **homothetogenic fission**, because the plane of fission is at right angles to the longitudinal axis of the body. As it occurs at right angles to the kineties, it is also called **perkinetal** fission (across the Kinetia).

5.3.3 Multiple Fission

It is the division of the parent body into many smaller individuals (Multi – many; Fission – splitting). Normally multiple fission occurs during **unfavourable** conditions. During the multiple fission, the nucleus first undergoes repeated mitotic divisions without cytokinesis. This causes the formation of many daughter nuclei. Then the cytoplasm also divides into as many number of bits as there are nuclei. Each cytoplasmic bit encircles one daughter nucleus. This results in the formation of many smaller individuals from a single parent organism.

There are different types of multiple fissions in protozoans such as **schizogony**, **male gametogony**, **sporogony** in ***Plasmodium***, ***sporulation*** in ***Amoeba,*** etc.

5.4 Sexual Reproduction

When two mature individuals (of opposite sex) participate in the reproductive process involving fusion of male and female gametes (**the products of meiosis** usually), it is called **sexual reproduction.** These haploid gametes fuse to form the diploid zygote, which develops into the new organism. It is an elaborate, complex and slow process compared to asexual reproduction. Because of the fusion of male and female gametes, sexual reproduction results in offspring that are not identical to the parents or amongst themselves.

5.4.1 Sexual reproduction in Protozoans

It takes place by the fusion of 'pronuclei' (haploid gametic nuclei) with or without the formation of gametes. Genetic recombination occurs in sexual reproduction during the formation of pronuclei or gametic nuclei (due to **meiotic crossovers**) and also due to the fusion of gametes from two different individuals. Sexual reproduction in protozoans occurs by syngamy. Conjugation, 'a process of nuclear reorganisiation that occurs in some ciliates' also brings about a kind of sexual multiplication of the organism.

5.4.2 Syngamy

It is the fusion of two gametes.

i) The fusion of similar gametes is called **isogamy** e.g. *Monocystis*.

ii) The fusion of dissimilar gametes is called '**anisogamy**' e.g. *Plasmodium*.

iii) **Hologamy** is the fusion of two mature organisms which do not form gametes but behave as gametes. e.g. *Trichonympha*.

* Union of pronuclei of the gametes is called '**amphimixis**' and the resultant nucleus is called **synkaryon**.

5.4.3 Conjugation

It is observed in ciliate protozans such as *Paramecium* and *Vorticella.* Wichterman defined conjugation as a temporary union between **two senile** ciliates that belong to two different 'mating types' for the exchange of nuclear material and its reorganization. It restores the **vigour** and **vitality** which are lost due to chromosomal imbalance in their macronuclei caused by repeated **amitotic** divisions. Unfavourable conditions also induce conjugation.

GLOSSARY

Phototropism: It is the tendency of an organism to move towards or to move away from the source of light stimulus.

Organelle: A living component of the cell with a specific structure and function. e.g., Mitochondrion, Lysosome, Ribosome, Golgicomplex, etc.

Heliopodia: These are sunray-like pseudopodia present all over the surface of the body, as in 'sun animal cules' (*Actinophrys, Actionsphaerium).*

Tubulin: A protein with which the microtubules of cytoskeleton are formed.

Kinetosome: It is a modified centriole from which the cilium or flagellum is formed.

Suctoria: Advanced ciliate protozoans, which possess suctorial tentacles in the adult condition and cilia in the juvenile stages. e.g *Acineta.*

Senile: Becoming old.

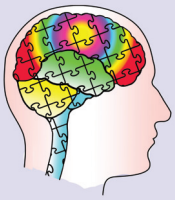
Nexin links: Proteins that connect the 'A' tubule of one doublet with the 'B' tubule of the next doublet in a clockwise manner in an axoneme are called nexin links. They maintain the integrity of the axoneme by holding doublets together.

VERY SHORT ANSWER TYPE QUESTIONS

1. Draw a labelled diagram of T.S of flagellum.
2. List any two differences between a flagellum and a cilium.
3. What are dynein arms? What is their significance?
4. What is a kinety?
5. Distinguish between synchronous and metachronous movements.
6. Why do we refer to the offspring, formed by asexual method of reproduction, a clone?
7. Distinguish between proter and opisthe.
8. How is sexual reproduction advantageous in evolution?
9. Distinguish between lobopodium and filopodium. Give an example to each of them.
10. Define conjugation with reference to ciliates. Give two examples.

SHORT ANSWER TYPE QUESTIONS

1. Name the system that controls the fastest swimming movement of protozoans and write its components.
2. Write the mechanism of bending of flagellum and explain effective and recovery strokes.
3. What are lateral appnedages? Based on their presence and absence, write the various types of flagella giving at least one example for each type.
4. Describe the process of transverse binary fission in *Paramecium.*
5. Describe the process of longitudinal binary fission in *Euglena.*
6. Write a short note on multiple fission.
7. Give an account of pseudopodia.
8. Give an account of the ultra structure of an axoneme.
9. Draw a neat labelled diagram of ***Euglena***.
10. Draw a neat diagram of ***Paramecium*** and label its important structures/ components.



For ignited minds

- NOT FOR EVALUATION

1. If, a row of lateral appendages is added to the flagellum of chilomonas, what type of flagellum does it transform into, hypothetically speaking?
2. What are the structures associated with locomotion that occur in higher animals such as man?
3. What is the primary source of energy for any type of movement, be it in lower organism or higher organism?
4. Why should conjugation occur in ciliates only, why not in other protozoans. **(CLUE)**: In the heteronuclear organisms, the vegetative nucleus divides **amitotically**.
5. If the dynein arms are immobilized, do flagella or cilia or both stop functioning?
6. What are the two structures which fix the doublets of a cilium/flagellum and keep them in position or in other words maintain the integrity of microtubules?
7. There is some indication concerning certain gametes of higher organisms, that at least indicate the origin of higher animals from some simple protits. **Can you explain this concept?**
8. *Euglena* has chromatophores. Yet zoologists consider it an animal. From the few things you have learnt in this lesson about *Euglena*, what features speak in favour of the view of zoologists?
9. A *Paramecium* can produce more daughter paramecia at the end of conjugation. The same *Paramecium* can produce a clone of daughter *paramecia* through multiplication by binary fission. Is there any difference between the two types of daughter paramecia? Discuss with your teacher and find whether your answer is correct or not?.

   [CLUE- Production of a clone does not involve pronuclei].
10. All undulipodia (**Hyman's terminology**) do not show undular movement. Do you agree with the statement. If so, how?
11. The total number of microtubules present above the level of pellicle of a flagellum is 20.
12. The total number of microtubules present in the kinetosome is 27 (3×9)
13. The 9 **radial spokes** in an axoneme prevent undue sliding of peripheral doublets.
14. The tubules that connect kinetosome to the plasma memberane and nucleus are called *rootlets*.
15. The flagellate with highest number of flagella is *Trichonympha*.
16. Cilia and flagella arise from kinetosomes, their **progenitors**.
17. Flagella and cilia are considered **homologous** and **analogous organelles**.
18. The dynein arms are the sites of activity of **ATPase**, which releases energy from ATP.
19. **Uniparental** inheritance is involved in asexual reproduction, whereas **biparental** inheritance is involved in sexual reproduction.
20. The first stage in the life of a sexually reproducing organism is a **totipotent** diploid cell, the **zygote**.

Dr. Yellapragada Subba Rao,
Wonder-man of **Miracle Drugs**

Unit

6

Biology in Human Welfare

THE '*UNINVITED GUESTS*' AND THE '*SILENT EPIDEMICS*' THEY CAUSE
- A PEEP INTO THE WORLD OF **PARASITES** vis-à-vis **MAN**

At least one-third of all animal species are estimated to be parasites according to one estimation. In ancient Greece, a person, who flattered and amused the host in return for free meals (a ***professional dinner guest***), was used to be called a parasite.

It is stated that the single most '***undiagnosed health challenge'*** in the ***history of the human race*** is '***parasites***'. More than 130 types of parasites are known to invade humans as hosts. As many people are not aware of the presence of certain parasites until it is too late to be helped, parasitism is described as a '***Silent Epidemic'***. **Most parasites tend to disturb the immunological system.**

Diseases such as ***malaria***, ***polio***, ***plague***, ***amoebiasis***, ***dengue***, ***filariasis***, ***taeniasis,*** are more common in the ***tropical countries***. Due to the efforts of WHO, Small Pox was wiped out decades ago. Plague, which killed millions in the past, is almost a ***part of history now***. However malaria is still evading control. Education on personal hygiene, providing proper sanitation facilities by the local administrations, will go a long way in preventing many tropical diseases.

Did the parasite come first or the host? It is believed that certain organisms enter the body of another organism accidentally and settle in it, slowly turning into a parasite. Have you ever heard that in the course of evolution, certain ***prokaryotic organisms*** entered the bodies of ***eukaryotes*** and remained in them for ever, acting as integral parts of the eukaryote's cells, and even playing a vital role in the life of

the eukaryote. ***Can you guess one such prokaryote?*** Did it ever occur to you that **mitochondria** could be one such type of prokaryotes?

On the other hand, the youth are getting addicted to ***drugs*** and ***alcohol*** – an influence of the western culture, spread by the television and movies. The harmful effects of ***tobacco*** are well publicised nowadays and the youth are sufficiently educated on that.

Wonder-man of Miracle Drugs

Probably many of you might not have heard the name of **Dr. Yellapragada Subba Rao**, 'the greatest Indian Biochemist' who made a dynamic impact in the field of Biochemistry and Medicine with a large number of discoveries which transformed the medical science and saved millions of people from deadly diseases.

Dr. Yellapragada Subba Rao was born in a poor family at Bhimavaram in West Godavari district of Andhra Pradesh. While he was studying in Madras Medical College, his elder brother and younger brother died of **'Tropical sprue'** disease in the span of 8 days. He was deeply affected and decided to invent a medicine to cure 'Sprue'. So he went to USA and took admission in the 'Harvard School of Tropical Medicine'. Later he joined as Director in 'Lederle Research Laboratory' (now PFIZER), USA and continued there till his last breath.

His contributions in Biochemistry and Medicine

His contributions include: The discovery of **ATP** and **phosphocreatine** as the sources of energy in muscle contraction, **folic acid**, which is used in the treatment of **tropical sprue** that killed his two brothers, **anti-cancer** drug **Methotrexate**, which is also used in the treatment of non-cancerous diseases such as **rheumatoid arthritis** and **psoriasis, diethyl carbamazine-DEC (**popular brand name-**hetrazan)**, the only effective drug in treating **filariasis,** the world's first **Tetracycline** antibiotic **Aureomycin** which is the only drug effective in treating **cholera, plague, typhus fever, trench fever,** etc., and **isonicotinic acid hydrazide,** an effective medicine in treating **tuberculosis.**

Biology in Human welfare: Introduction

Biology is the youngest of the Natural Sciences. Progress in Physics and Chemistry proceeded much faster than in Biology. However, the 20th century and certainly the 21st century have demonstrated the utility of biological knowledge in furthering human welfare, medical field, agriculture and animal husbandry. The discovery of antibiotics, synthetic or plant-derived drugs, anaesthetics, diagnostic procedures, etc. have changed the medical practice on one hand and the human health on the other hand. Life expectancy of human beings has dramatically changed over the years due to the advancement in Biology. Biology also helps us to cope up with the changes that take place in our body due to various types of parasitic, bacterial, viral, fungal and other infections. It also educates people on use/abuse of tobacco, drugs, alcohol etc. These are briefly described in the following chapters of this unit.

6.1 Parasitism and Parasitic Adaptations

Every living organism in this universe has an instinct to survive, for which, they require two basic needs - food and shelter. You know pretty well that green plants can prepare their own food materials in their body through photosynthesis, using CO_2 and H_2O as raw materials **(autotrophs)**. But animals cannot prepare their own food materials in their body. Hence they must depend on plants or other animals for their survival **(heterotrophs)**.

Certain animals are described as parasites as they survive at the cost of the other animals, called hosts. In such an association, the hosts tend to reject or resist the parasites. Concurrently the parasites have to evolve mechanisms to counteract and neutralize the host's defence in order to be successful with in the host. For this purpose, the parasites have developed many special adaptations such as the loss of unnecessary sensory organs, formation of organs for adhesion, high reproductive capacity, etc.

6.1.1 Parasitism

An intimate association between two organisms of different species in which, 'one is benefited and the other one is often adversely affected' is called **parasitism.** The word parasitism comes from a Greek word *'parasitos'* (*para* - at the side of; *sitos* - food or grain) which means '*one eating at another one's table*'. The organism that obtains nourishment is called the **'parasite'** (the gainer) and the organism from which the nourishment is obtained is called the **'host'** (the loser).

I. Types of parasites

Based on the interaction between the host and the parasite, various types of parasites are recognised. Some of them are listed below.

i) **Ectoparasite:** A parasite that lives on the surface of the host's body is called ectoparasite.

e.g. head lice and itch mites on humans, ticks on dogs, copepods on marine fishes, etc.

The female mosquito is not considered an obligate parasite though it needs human blood for fertility. Can you explain why?
Discuss with your teacher about the food habits of mosquitoes.

ii) **Endoparasite:** A parasite that lives inside the body of the host is called endoparasite. Based on the place where they live, they are again classified into three types, namely:

a) **Cytozoic (intracellular) parasites:** They live within the host's cells.

e.g. *Plasmodium vivax* in man, *Nosema notabilis* in *Sphaerospora polymorpha*, etc.

b) **Histozoic (intercellular) parasites:** They live in between the cells of the tissues and organs of the host.

e.g. *Wuchereria bancrofti, Entamoeba histolytica,* etc.

c) **Coelozoic parasites:** They live within the cavities of the host's body. They are called enterozoic if they live in the alimentary canal.

e.g. *Ascaris lumbricoides*

iii) **Hyperparasite** (Parasite in/on a parasite)**:** It is a parasite which lives in/on the body of another parasite.

e.g. *Nosema notabilis* (a cnidosporan parasite) lives in *Sphaerospora polymorpha* (also a cnidosporan parasite) which lives in the urinary bladder of toad fish.

iv) **Monogenetic parasite:** It is a parasite which completes its life cycle in only one host.

e.g. *Entamoeba histolytica*, *Ascaris lumbricoides,* etc.

v) **Digenetic parasite:** It is a parasite which requires at least two hosts to complete its life cycle.

e.g. *Plasmodium vivax*, *Wuchereria bancrofti,* etc.

NOTE: Parasites living in the gut of the host are called 'enterozoic parasites'. *Ascaris* is **enterozoic** and **coelozoic**, where-as *Entamoeba* is **enterozoic** and **histozoic**.

II. Types of Hosts

i) **Primary host** or **Definitive host:** It is the host that harbours the adult stage or sexually mature stage of a parasite or the host in which the parasite undergoes sexual reproduction.

e.g. Man for *Wuchereria bancrofti,* female *Anopheles* for *Plasmodium,* etc.

ii) **Intermediate host** or **Secondary host:** It is the host that harbours the developing 'larval or immature or asexual' stages of a parasite or the host in which the parasite undergoes asexual reproduction.

e.g. Man for *Plasmodium*, female *Culex* for *Wuchereria,* etc.

iii) **Reservoir host:** It is the host that lodges the infective stages of a parasite in its body when the human host is not available. In the reservoir host, the parasite neither undergoes development nor causes any disease.

e.g. Monkey for *Plasmodium,* African antelope (*Gnu*) for *Trypanosoma gambiense, etc.*

III. Vector

It is an organism (generally an insect) which transfers the infective stages of a parasite from one main host to another. Vectors are of two types, namely:

i) **Mechanical vector:** It is the vector, which merely transfers the infective stages of a parasite but no part of the parasitic development takes place in it.

e.g. House flies and cockroaches in the case of *Entamoeba.*

ii) **Biological vector:** It is the vector in which the parasite undergoes a part of the development before it gets transferred to another host.

e.g. Female *Anopheles* mosquito in the case of *Plasmodium* and female *Culex* mosquito in the case of *Wuchereria.*

6.1.2 Parasitic adaptations

Parasites have evolved special adaptations to meet the requirements and lead successful life in the hosts.

- In order to live in the host, some parasites have developed structures like hooks, suckers, rostellum, etc., for **'anchoring'**. **e.g.** *Taenia solium*
- Some intestinal parasites have developed **protective cuticle** to withstand the action of the digestive enzymes of the host. **e.g.** *Ascaris lumbricoides*
- Some intestinal parasites produce **'anti enzymes'** to neutralize the effect of host's digestive enzymes. **e.g.** *Taenia solium*
- Some parasites live as **'obligatory anaerobes'** as the availability of oxygen is very rare for them. **e.g.** *Entamoeba histolytica*, *Taenia solium,* etc.
- Some intestinal parasites live as **'facultative anaerobes'** i.e., if oxygen is not available, they live anaerobically and if oxygen is available, they respire aerobically. **e.g.** *Ascaris lumbricoides*
- The morphological and anatomical features are greatly simplified while emphasizing their **reproductive potential**. For example, an *Ascaris* lays nearly two lakh eggs per day. In *Taenia solium* the body is divided into 700 to 900 proglottids of which each proglottid acts as a unit of reproductive system and releases approximately 35,000 eggs.
- The life cycles of endoparasites are more complex because of their extreme specialization. For example, life cycle of certain parasites like *Fasciola hepatica* (sheep liver fluke) is very complex involving many developmental stages and

intermediate hosts, to increase the chances of reaching a new definitive host.

- Certain parasites like *Entamoeba* develop cysts to tide over the unfavourable conditions like desiccation while reaching the new host.
- Some parasites elude production of vaccines against them (smart parasites!) as they keep changing their surface antigens form time to time.

  e.g. *Plasmodium*, HIV, etc.

Do you know: In villages, the eggs of ducks are mixed with those of hen and allowed to be incubated by hen- a kind of human induced 'brood parasitism'!

6.1.3 Effects of parasites on hosts

In general, the parasites cause weakening of the body of their hosts by causing the deprivation of nutrients, fluids and metabolites as they compete with their hosts for the same. They may also cause pathological effects in their hosts such as

- **Parasitic castration:** Some parasites cause the degeneration of gonads of the host, making it sterile. This effect is called **parasitic castration**.

  e.g. *Sacculina* (root headed barnacle, a crustacean) causes the degeneration of gonads in the crab *Carcinus maenas.*
- **Neoplasia:** Some cause an abnormal growth of the host cells in a tissue to form new structures. This effect is called **neoplasia** which leads to cancers.

  e.g. Some viruses
- **Gigantism:** Some parasites cause an abnormal increase in the size of the host. This effect is called **gigantism**.

  e.g. The larval stages of *Fasciola hepatica* cause gigantism in snail (an intermediate host)
- **Hyperplasia:** Some parasites cause increase in the **number of cells**. This effect is called **hyperplasia**.

  e.g. *Fasciola hepatica* in the bile duct of sheep
- **Hypertrophy:** Some parasites cause an abnormal increase in the **volume/size** of the infected host cells. This effect is called **hypertrophy**.

  e.g. RBC of man infected by *Plasmodium*
- Most of the parasites cause various types of diseases like
  i) African sleeping sickness by *Trypanosoma gambiense*
  ii) Delhi boils/Tashkent ulcers/Oriental sores by *Leishmania tropica*
  iii) Kala azar/Dum dum fever/Visceral leishmaniasis by *Leishmania donovani*
  iv) Malaria by *Plasmodium sps*
  v) Elephantiasis by *Wuchereria bancrofti.*

'An ideal parasite should be able to thrive within the host without harming it'. Do you believe in it? Then why didn't Natural Selection lead to the evolution of such totally harmless parasites? Clue: Think of the phenomenon of 'Ecolological balance in nature

6.2 Health and Disease

6.2.1 Health

The term health is very frequently used by everybody. How do we define it? For a long time, **'health'** was considered a state of body and mind where there was a balance of certain 'humors' according to **'Good humor'** hypothesis. This is what early Greeks like Hippocrates as well as the Indian Ayurveda system of medicine asserted. According to this hypothesis, it was thought that persons with **'black bile'** belonged to **hot personality** and **would have fevers**. This idea was arrived at by 'a pure reflective thought'. The discovery of 'the circulation of blood by William Harvey using experimental method' and 'the demonstration of normal body temperature using thermometer in persons with black bile' disproved the 'Good humor' hypothesis.

In later years, biology stated that mind influences our immune system through neural system and endocrine system and that our immune system maintains our health. Hence, mind and mental status can affect our health. **Health** is a state of complete physical, mental and social well-being and not merely 'absence of any disease' or 'absence of physical fitness'.

Of course, our health may be affected by–

i) **Genetic disorders** – deficiencies with which a child is born or the defects inherited by the child from its parents.

ii) **Infections** – by either animal parasites or bacteria or virus or fungi.

iii) **Life style** – type of food and water we take, timings of food intake, amount of rest and exercise we give to our bodies, habits such as smoking, drug and alcohol abuse, etc.

When people are healthy, they are more efficient at work. This increases productivity and brings economic prosperity. Health also increases longevity of people and reduces infant and maternal mortality. Balanced diet, personal hygiene and regular exercise are very important to maintain good health. Since times immemorial, yoga has been practiced to achieve physical and mental health. Awareness about diseases and their effect on different bodily functions, vaccination against infectious diseases, proper disposal of biological wastes, control of vectors and maintenance of hygienic food and clean water resources are necessary for achieving good health.

6.2.2 Disease

Any change from the normal state of health that causes discomfort or disability is called **disease**. When the functioning of one or more organs or systems of the body is adversely affected characterized by various signs and symptoms, we say that we are not healthy or we have a disease. Diseases can be broadly grouped into two types namely - infectious and non-infectious.

i) **Infectious diseases:** The diseases which are easily transmitted from one person to another are called infectious diseases. These are caused by pathogens. These are very common and every one of us might have suffered from any of these diseases, at sometime or the other.

e.g. Amoebic dysentery, Malaria, Elephantiasis, Typhoid, Pneumonia, Common cold, Ringworm, etc.

ii) **Non-infectious diseases:** The diseases which are not transmitted from one person to another and are not caused by pathogens are called non-infectious diseases.

e.g. Genetic disorders, kidney problems, heart problems, etc.

6.2.3 Common Parasites causing diseases in man

A wide range of forms that belong to protozoans, helminths, bacteria, fungi, viruses, etc., could cause diseases in man. Such disease causing forms are called pathogens. The pathogens can enter our body by various means, multiply and interfere with normal vital activities, resulting in morphological and physiological damage. A few representative members from different groups of pathogenic organisms are discussed here along with their life cycle, pathogenicity, treatment and preventive measures against the diseases caused by them.

6.2.3.1 Entamoeba histolytica

I. Systematic position

Phylum : Protozoa

Subphylum : Sarcomastigophora

Class : Rhizopodea.

Do you know the reason for the death of the famous Mughal emperor **Akbar** and the most famous Telugu King **Sri Krishna Devaraya**?

Entamoeba histolytica (Gr: *entos* - within; *amoibe* - change; *histos* - tissues; *lysis* - dissolve) is a microscopic and monogenetic parasite that inhabits the large intestine and causes ***amoebic dysentery*** or ***amoebiasis*** in man. The mode of infection is through contaminated food and drinking water. House flies, cockroaches, etc., act as 'mechanical vectors'.

It is cosmopolitan in distribution but more common in the tropical and subtropical regions of the world. It is common in the people of rural and densely populated urban areas wherever the hygienic conditions are poor.

II. Structure

Entamoeba histolytica passes through three distinct stages in its life cycle, namely:

i) Trophozoite stage

ii) Precystic stage and

iii) Cystic stage

1. Trophozoite stage: It is the most active, motile, feeding and ***pathogenic stage*** that lives in the mucosa and sub-mucosa membranes of the large intestine. It moves with the help of a single blunt finger like pseudopodium called lobopodium which is produced in the advancing end. The body of the trophozoite is surrounded by plasmalemma. Its cytoplasm is differentiated into an outer clear, viscous, non-granular ectoplasm and the inner fluid like, granular endoplasm. Ribosomes, food vacuoles and a vesicular, **cartwheel shaped nucleus** are present in the endoplasm. However contractile vacuoles, endoplasmic reticulum, Golgi apparatus and mitochondria are absent. The absence of mitochondria indicates the '***obligate anaerobic nature***' of *Entamoeba histolytica.* It produces the proteolytic enzyme called histolysin due to which the species name '***histolytica***' was assigned to it. Due to the effect of this enzyme, the mucosa and sub-mucosa of the gut wall are dissolved releasing some amount of blood, tissue debris which are ingested by the trophozoites. Hence, the food vacuoles are with erythrocytes, fragments of epithelial cells and bacteria. The mode of nutrition is ***holozoic***. Presence of '**RBC in food vacuoles**' and cartwheel shaped nucleus are the characteristic features of the trophozoites of *Entamoeba histolytica.*

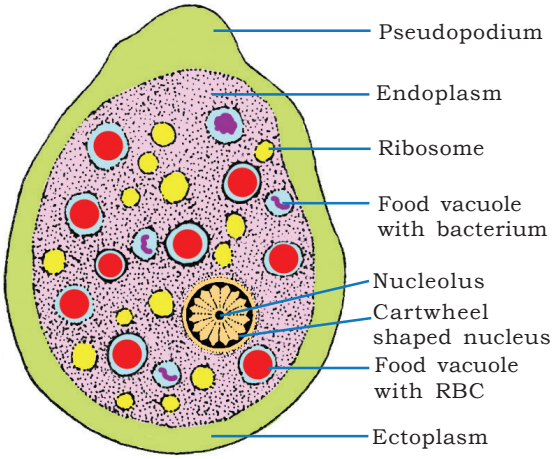


Fig. 6.1 Trophozoite Stage

2. Precystic stage: It is the non-feeding and non-pathogenic stage of *Entamoeba histolytica* that is found in the lumen of the large intestine. It is a small, spherical or oval, non-motile form. The cytoplasm of the precystic stage stores ***glycogen granules*** and ***chromatoid bars*** (made of ribonucleo protein) which act as reserve food.

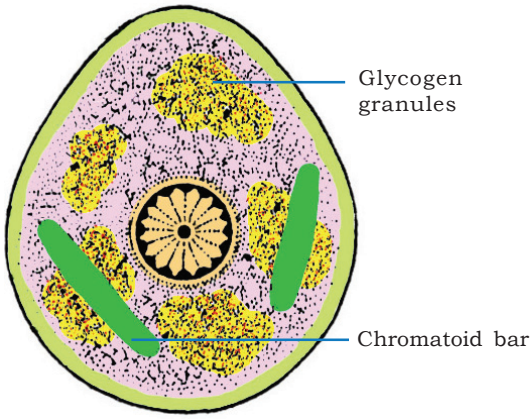


Fig. 6.2 Precystic stage

3. Cystic stage: It is round in shape and is surrounded by a thin, delicate and highly resistant cyst wall. It is found in the lumen of the large intestine. The process of development of cyst wall is called ***encystation*** which is a means to tide over the unfavourable conditions that the parasite is going to encounter while passing to a new host. Soon after encystation, the nucleus undergoes two successive series of mitotic divisions to

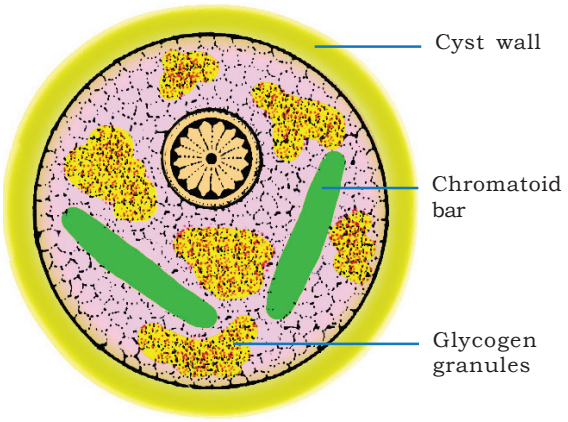


Fig. 6.3 Cystic stage

form **four daughter nuclei.** This type of cystic stage is called **tetra nucleate cyst** or **mature cyst** which is '**the stage infective to man**'.

III.Life cycle:

The trophozoites undergo binary fissions in the wall of the large intestine and produce a number of daughter entamoebae. They feed upon the bacteria and the host's tissue elements, grow in size and again multiply. After repeated binary fissions, when the trophozoites increase in number, some of the young ones enter the lumen of the large intestine and transform into ***precystic stages***. Here, the precystic stages transform into ***cystic stages*** which in turn develop into ***tetranucleate cysts***. The entire process is completed only in a few hours. These tetranucleate cysts come out along with the faecal matter and can remain alive for about 10 days. These cysts reach new host through contaminated food and water. They pass into the small intestine of a new human host where the cyst wall gets ruptured by the action of the enzyme trypsin, releasing the ***tetranucleate amoebae***. Such tetranucleate excystic amoebae are called **metacysts.**

The four nuclei of the metacyst undergo mitotic divisions and produce eight nuclei. Each nucleus gets a bit of the cytoplasm and thus eight daughter entamoebae or '**metacystic trophozoites**' are produced. These young ones develop into feeding stages called trophozoites. They invade the mucous membrane of the large intestine and grow into ***mature trophozoites***.

IV. Pathogenicity

1. Intestinal amoebiasis

The trophozoites 'dissolve' the mucosal lining by **histolysin**, go deep into sub-mucosa and cause ulcers. These ulcers contain cellular debris, lymphocytes, red blood corpuscles and bacteria. It leads to the formation of abscesses in the wall of large intestine. Ultimately it results in stool with blood and mucous. This condition is called **amoebic dysentery** or **intestinal amoebiasis** or **tropical amoebiasis.**

2. Extra-intestinal amoebiasis

Some times, the trophozoites may rupture the wall of capillaries, enter the blood stream and primarily reach the liver where they may cause 'abscesses' (some call it 'secondary amoebiasis). From there, they may go to lungs, heart, brain, kidneys, gonads, etc., and cause abscesses in those parts leading to ***severe pathological conditions***.

3. Some people do not exhibit any symptoms. Such people are called '***carriers*** *or* ***asymptomatic cyst passers'*** as their stool contains the tetranucleate cysts. They help in spreading the parasites to other persons.

In your view what could be the substance that forms the wall of the cyst in *Entamoeba histolytica*? Is it chitin/ protein/ lipid?

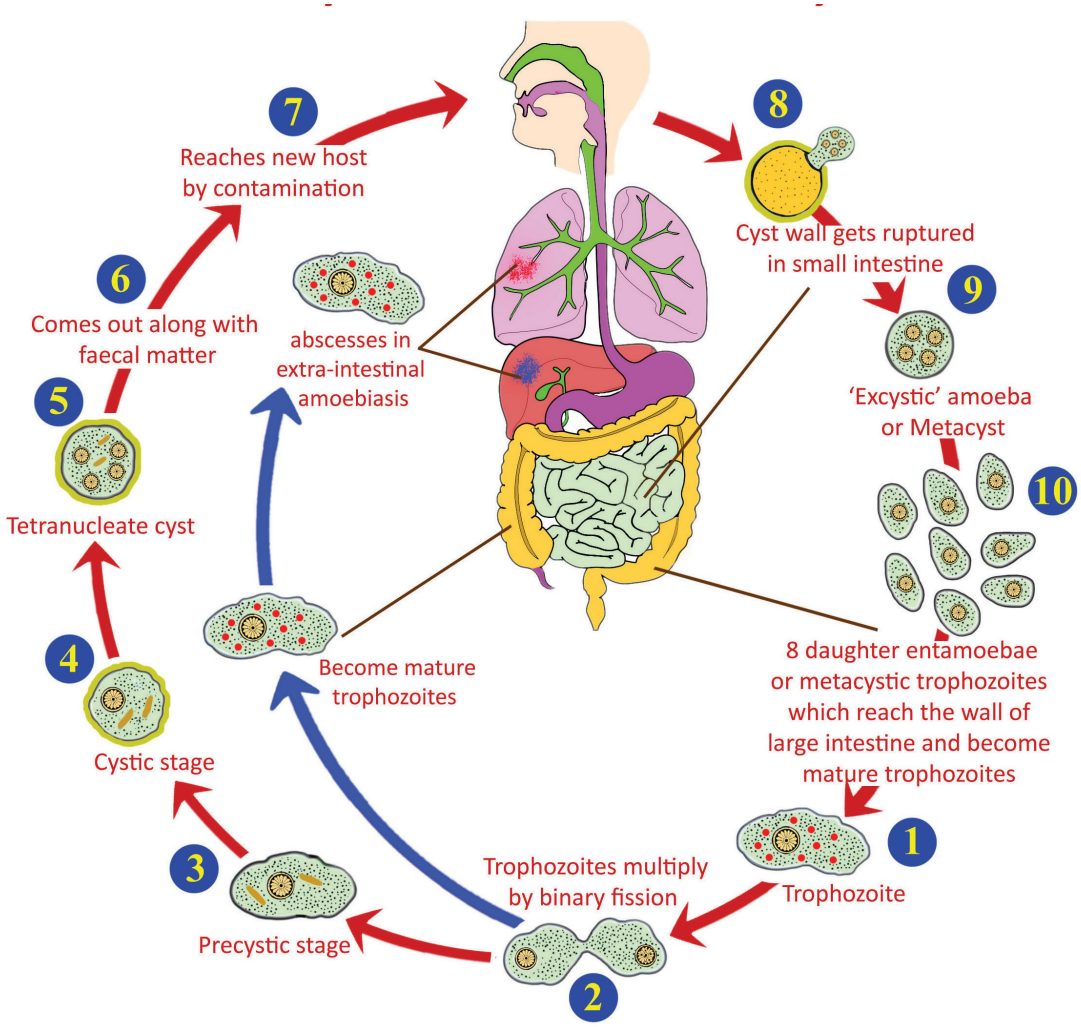


Fig. 6.4 Life cycle of *Entamoeba histolytica*

V. Prophylaxis

The following hygienic habits help prevent spread of this disease:

i) Using boiled and filtered water
ii) Washing hands, fruits and vegetables properly
iii) Using septic tank toilets

In some cases, a permanent cure for amoebiasis is very hard to achieve as it frequently recurs unless the complete course of medication prescribed by a qualified medical practitioner is used.

6.2.3.2 *Plasmodium vivax*

Systematic position

Phylum : Protozoa
Subphylum : Apicomplexa (Sporozoa)
Class : Telosporea
Genus : *Plasmodium*
Species : *vivax*

Do you know the reason for the death of **'Alexander the Great'**? No one was able to defeat **Alexander,** but the tiny Indian mosquitoes 'defeated' him. Do you know how?

Among the protozoans, *Plasmodium* is one of the most harmful parasites of man. It is a ***digenetic***, **intracellular parasite** that lives in the ***liver cells*** and ***RBC*** of man. (It is **extracellular** in mosquito). Its **primary host** is the female ***Anopheles*** mosquito and the **secondary host** is man. Reservoir host is monkey. The infective stage is **sickle shaped sporozoite** and the mode of infection is **inoculation**.

Four species of *Plasmodium* cause four types of malaria in man. They are

i) *Plasmodium vivax* – benign tertian malaria
ii) *Plasmodium falciparum* – malignant tertian malaria
iii) *Plasmodium ovale* – mild tertian malaria
iv) *Plasmodium malariae* – quartan malaria

Of all these four species, *Plasmodium vivax* is the most common and most widely distributed malaria parasite. Hence its life cycle along with pathogenicity, treatment and preventive measures are briefly described here.

I. History of Malaria

The term '**Malaria**' is taken from Italian language which means 'bad air' (*Mala* - bad; *aria* - air) as it was thought that malaria was due to foul air. ***Charles Laveran***, a French military doctor discovered *Plasmodium* in the blood of a malaria patient. ***Sir Patrick Manson***, a Scottish doctor while working on elephantiasis, suggested that malaria might be spread by mosquitoes. ***Sir Ronald Ross***, a British army doctor, while working in Secunderabad, A.P., India, identified the oocysts of *Plasmodium* in the stomach wall of female *Anopheles* mosquito on the 20th of August. In recognition of this work, Ross was awarded the ***Nobel Prize*** in 1902 and 20th August of every year is celebrated as ***World Mosquito Day.*** April 25th is the World Malaria day by WHO (from 2007). ***G.B. Grassi*** and others have described the life cycle of *Plasmodium vivax* in the female *Anopheles* mosquito.

II. Structure of sporozoite

The ultra-structure of the sporozoite of *Plasmodium vivax* was studied by **Garnham**. It is sickle shaped with a swollen middle part and pointed at both ends of its body. It measures about 15 microns in length and one micron in width. The body is covered by an elastic pellicle with **'microtubules'** which help in the wriggling movements of the sporozoite. The cytoplasm contains cell organelles such as Golgi complex, endoplasmic reticulum, mitochondria and a nucleus. Cytoplasm also shows many convoluted tubules of unknown function throughout the length of the body. It contains a cup like depression called ***apical cup*** at the anterior end into which a pair of ***secretory organelles*** opens. They secrete a cytolytic enzyme, which helps in the penetration of sporozoite into the liver cells.

The life cycle of *Plasmodium* is completed in two hosts as mentioned earlier.

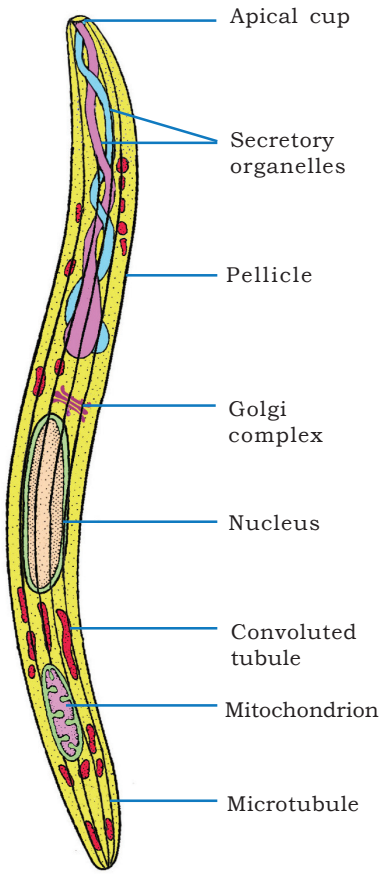


Fig. 6.5 Structure of sporozoite

III. Life cycle of *Plasmodium* in man (The human phase)

In man, the *Plasmodium* reproduces by asexual reproduction called **schizogony**. It occurs in liver cells (hepatocytes) as well as in RBC. In liver cells, it is called **hepatic schizogony** and in RBC it is called **erythrocytic schizogony.**

1. Hepatic schizogony

This was discovered by **Shortt** and **Garnham**. Whenever, a mosquito infected by *Plasmodium* bites a man, nearly 2000 sporozoites are released into the blood of man through its saliva. Within half an hour, they reach the hepatocytes where they undergo **pre-erythrocytic** and **exo-erythrocytic cycles**.

A. Pre-erythrocytic cycle

Whenever the sporozoites reach the liver cells, they transform into **trophozoites**. They feed on the contents of the hepatic cells, assume spherical shape and attain the maximum size. This stage is called **schizont** stage. Its nucleus divides several times mitotically, followed by the cytoplasmic divisions resulting in approximately 12,000 daughter individuals called **cryptozoites** or the **1st generation merozoites.** They enter the sinusoids of the liver by rupturing the cell membrane of the schizont and the liver cells. This entire process is completed approximately in 8 days. Now these first generation merozoites have two options i.e. they can enter either fresh liver cells and continue exo-erythrocytic cycle or they can enter RBC and continue erythrocytic cycle.

Have you ever given a sample of blood for blood test? Did you observe how doctor takes the sample of your blood? Do you find any similarity between that and the bite of mosquito?

B. Exo-erythrocytic cycle

If the cryptozoites enter the fresh liver cells, they undergo the changes similar to that of the pre-erythrocytic cycle and produce the second generation merozoites called **metacryptozoites**. These are of two types- the smaller **micro-metacryptozoites** and larger **macro-metacryptozoites.** This entire process is completed approximately in two days. The macro-metacryptozoites attack fresh liver cells and continue another exo-erythrocytic cycle, whereas the micro-metacryptozoites always enter blood stream and attack fresh RBC to continue repeated erythrocytic cycles producing merozoites.

Prepatent period

The interval between 'the first entry of *Plasmodium* into the blood in the form of sporozoites and the second entry of *Plasmodium* into the blood in the form of cryptozoites is called **prepatent period.** It lasts approximately 8 days. During this period, the host does not show any clinical symptoms of the disease. It is only a means of multiplication.

2. Erythrocytic Schizogony

A. Cycle of Golgi

It was first described by ***Camillo Golgi***. Hence it is also called **'Golgi cycle'**. This cycle is initiated either by the cryptozoites of pre-erythrocytic cycle or the micro-metacryptozoites of exo-erythrocytic cycle. In the fresh RBC, these stages assume spherical shape and transform into ***trophozoites***. It develops a small vacuole which gradually enlarges in size, pushing the cytoplasm and nucleus to the periphery. Now the *Plasmodium* looks like a **finger ring**. Hence this stage is called **signet ring stage**. Soon it loses the vacuole, develops pseudopodia and becomes ***amoeboid stage*** (late trophozoite stage). With the help of pseudopodia, it actively feeds on the contents of the RBC and increases in size. As a result, the RBC grows almost double the size. This process is called ***hypertrophy.*** The malaria parasite digests the globin part of the ingested haemoglobin and converts the soluble haem into an insoluble crystalline **haemozoin.** It is called the '***malaria pigment***' which is a disposable product. During this stage, small red coloured dots appear in the cytoplasm of the RBC known as **Schuffner's dots**. These are believed to be the antigens released by the parasite. Now the *Plasmodium* loses the pseudopodia, increases further in size, occupies the entire RBC and becomes a schizont. It undergoes schizogony similar to that of the pre-erythrocytic cycle and produces 12 to 24 erythrocytic merozoites. They are arranged irregularly in the RBC form. Finally the erythrocyte bursts and releases the merozoites along with haemozoin into the blood. This cycle is completed approximately in 48 hours.

Incubation Period

The period between 'the entry of *Plasmodium* into the blood in the form of sporozoite and the first appearance of symptoms of malaria in man' is called **incubation period**. It is approximately 10 to 14 days.

B. Formation of gametocytes

After repeated cycles of erythrocytic schizogony, when the number of fresh RBC decreases, some merozoites enter the RBC and transform into gametocytes instead of continuing the erythrocytic cycle. This process generally takes place when the RBCs are present in ***spleen*** and ***bone marrow***.

The gametocytes are of two types namely, smaller **microgametocytes** or **male gametocytes** and larger **macrogametocytes** or **female gametocytes.** The gametocytes cannot undergo further development in man as the temperature and pH of the blood of man are not suitable for further development. These gametocytes reach the blood circulation and wait to reach the next host. They degenerate and die if they are not transferred to mosquito within a week.

IV. Life cycle of *Plasmodium* in mosquito (The mosquito phase) – Ross cycle

When a female *Anopheles* mosquito bites and sucks the blood of a malaria patient, the gametocytes along with the other stages of the erythrocytic cycle reach the crop of mosquito. Here all the stages are digested except the gametocytes. Further part of the life cycle consists of:

i) Gametogony
ii) Fertilization
iii) Formation of Ookinete & Oocysts
iv) Sporogony

i) Gametogony: The formation of male and female gametes from the gametocytes is called **gametogony.** It occurs in the lumen of the crop of mosquito.

a. Formation of male gametes: During this process, the nucleus of microgametocyte divides into eight daughter nuclei called ***pronuclei*** which reach the periphery. The cytoplasm is pushed out in the form of eight flagella like processes. Into each flagellum like process, one pronucleus enters and forms a **micro gamete** or **male gamete**. These male gametes show lashing movements like those of flagella and get separated from the cytoplasm of microgametocyte. This process is called **exflagellation**.

b. Formation of female gamete: The female gametocyte undergoes a few changes and transforms into a female gamete. This process is called ***maturation.*** The nucleus of the female gamete moves towards the periphery and the cytoplasm at that point forms a projection. This projected region is called the ***fertilization cone***.

Do you know: Why a minimum of ten days is required for the occurrence of the first symptoms of malaria in man after the entry in the form of sporozoites?

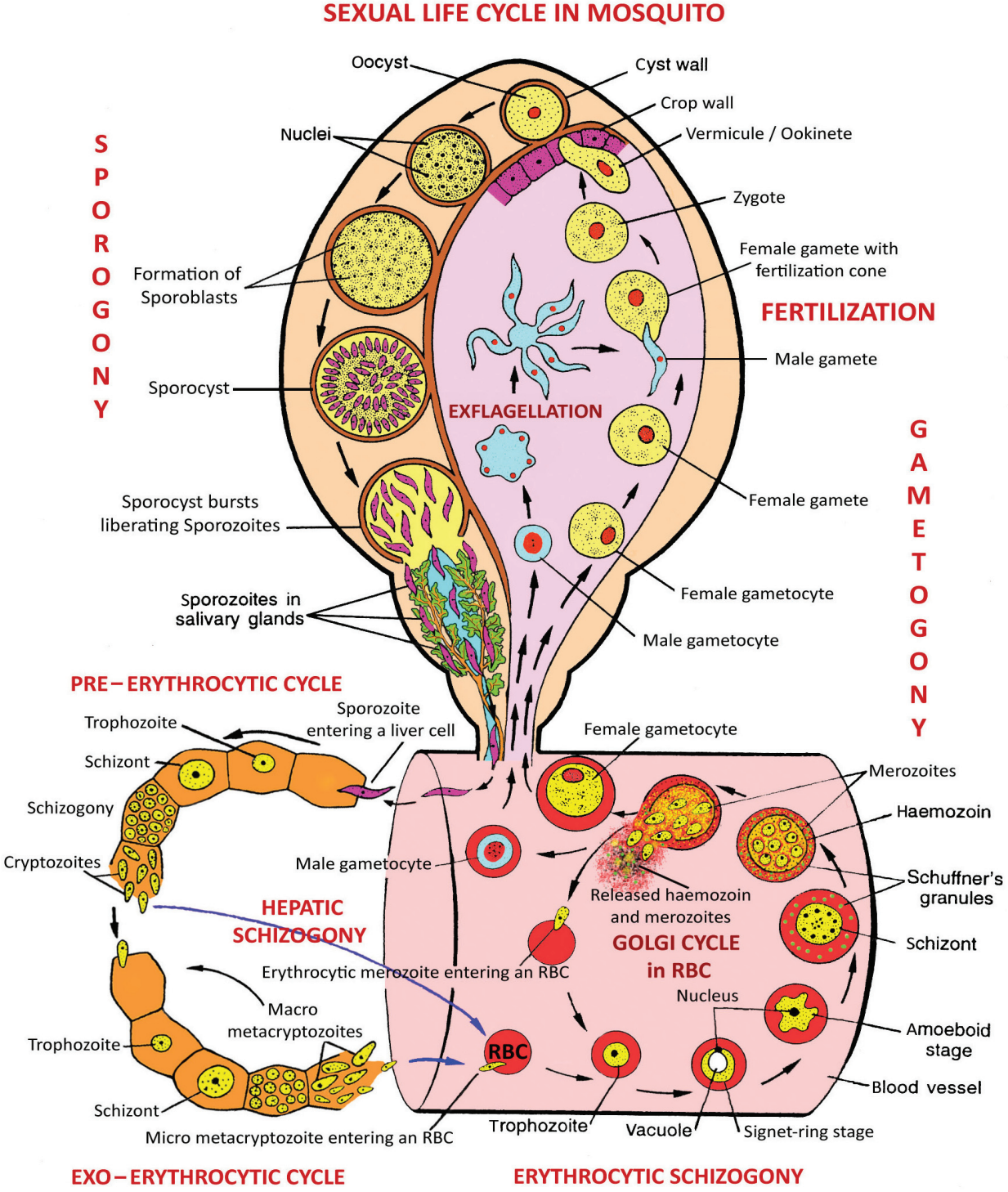


Fig. 6.6 Life cycle of *Plasmodium vivax*

ii) **Fertilization:** The fusion of male and female gametes is called fertilization. It also occurs in the lumen of the crop of the mosquito. When an actively moving male gamete comes into contact with the fertilization cone of the female gamete, it enters it. The pronuclei and cytoplasm of these two gametes fuse with each other, resulting in the formation of a synkaryon. Since the two gametes are dissimilar in size, this process is known as **anisogamy**. The female gamete that bears the synkaryon is called the **zygote** which is round and non-motile.

iii) **Formation of ookinete and oocysts:** The zygote remains inactive for some time and then transforms into a long, slender, motile, vermiform **ookinete** or **vermicule** within 18 to 24 hours. It pierces the wall of the crop and settles beneath the ***basement membrane***. It becomes round and secretes a cyst around its body. This encysted ookinete is now called **oocyst**. About 50 to 500 oocysts are formed on the wall of the crop and appear in the form of small nodules. (Sir Ronald Ross identified these oocysts for the first time).

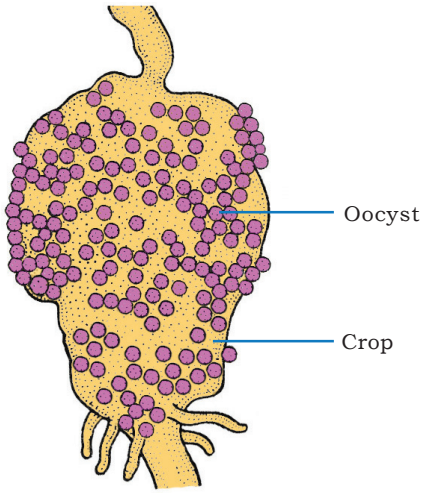


Fig. 6.7 Oocycts of *Plasmodium* on the crop of female *Anopheles*

iv) **Sporogony:** The formation of sporozoites in the oocysts is called ***sporogony***. According to Bano, the nucleus of the oocyst first undergoes reduction division followed by repeated mitotic divisions resulting in the formation of sporoblasts. The nucleus of the sporoblast divides and forms several nuclei. Each nucleus is surrounded by a little bit of the cytoplasm and transforms into a sickle shaped sporozoite. Oocyst with such sporozoites is called **sporocyst**. When this sporocyst ruptures, about 10,000 sporozoites are liberated into the haemocoel of the mosquito. From there, they travel into the salivary glands and are ready for infection. The life cycle of *Plasmodium* in mosquito is completed in about 10 to 24 days.

Plasmodium exhibits alternation of generations in its life cycle. Can this statement be justified? How?

V.Pathogenicity

Plasmodium vivax causes benign tertian malaria. The clinical symptoms of this disease include bouts of fever which can be expressed in three stages namely cold stage, hot stage and sweating stage.

Cold stage: Chills, shivering, headache and giddiness.

Hot stage: High temperature of the body , rapid breathing and an increase in the pulse rate.

Sweating stage: Profuse sweating followed by lowering of the body temperature to the normal level.

Anaemia and ***splenomegaly*** are noticed in a chronic malaria patient. Relapse of malaria may also be noticed some times.

Why does the spleen enlarge in the case of chronic malaria patient?

Ans: In case of repeated infections, spleen shows an abnormal immune response and enlarges. (Tropical splenomegaly syndrome)

Relapse of malaria: Some of the stages of macro-metacryptozoites may survive for a long period in liver as dormant stages called **hypnozoites.** Reactivation of these hypnozoites leads to the initiation of fresh erythrocytic cycles resulting in the new attacks of malaria. This is referred to as **relapse of malaria.**

There are certain people who are immune to malaria. Do you know what the reason is for immunity against malaria ? (Ask your teacher to explain immunity to malaria in people heterozygous for sickle cell anaemia).

VI. Treatment

Malaria can be cured by **quinine** which is an alkaloid extracted from the bark of *Cinchona officinalis.*

VII. Prophylaxis

- Spraying of DDT, BHC, etc., insecticides at intervals in mosquito breeding places like pools, ponds, ditches and stagnant water.
- Introduction of larvivorous fishes like *Gambusia,* insectivorous plants like *Utricularia* into the places where mosquitoes breed.
- Avoiding mosquito bite by using mosquito nets, mosquito repellents, etc.
- Spraying of kerosene, pyrethrum oil, etc., on stagnant water.

6.2.3.3 *Ascaris lumbricoides*

Do you know the reason for giving the species name '*lumbricoides*' for *Ascaris*?

Clue : There is an earthworm called *Lumbricus*

Phylum : Nematoda

Class : Phasmidia

Ascaris lumbricoides is commonly called the **common round worm**. It is one of the most common entericparasites of man. It is monogenetic, dimorphic, pseudocoelomate parasite that lives in the small intestine of man, more frequently in children. It is cosmopolitan in distribution. Mode of infection is through contaminated food and water. Infective stage is the embryonated egg with the **2nd stage rhabditiform larva.**

I. Structure: Sexes are separate and the sexual dimorphism is distinct. In both males and females, the body is elongated and cylindrical. Mouth is present at the extreme anterior end and is surrounded by three chitinous lips. Close to the mouth mid ventrally, there is a small aperture called excretory pore.

1. Male: It has a curved posterior end which is considered the tail. The posterior end possesses a cloacal aperture and a pair of equal sized chitinous '**pineal spicules'** or '**pineal setae'** which serve to transfer the sperms during copulation.

2. Female: It has a straight posterior end, the tail. The female genital pore or vulva is present mid ventrally at about one third the length from mouth. The anus is present a little in front of the tail end.

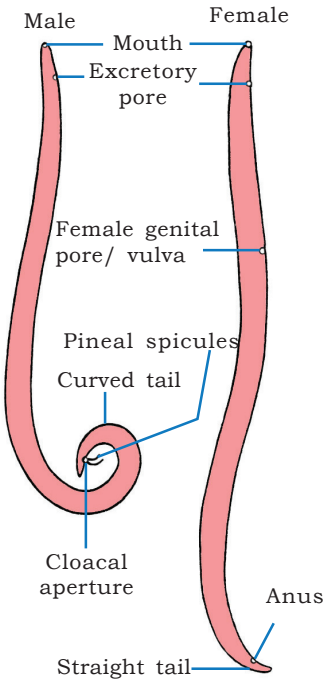


Fig. 6.8 *Ascaris lumbricoides*

II. Life history

Copulation takes place in the small intestine of man. After copulation, the female releases approximately two lakh eggs per day. Each egg is surrounded by '**a protein coat**' with rippled surface. Hence the eggs of *Ascaris* are described as **'mammillated eggs'.** The protein coat is followed by a chitinous shell and a lipid layer internally. These eggs are passed out along with faecal matter. In the moist soil, development takes place inside the egg leading to the formation of the **1st stage rhabditiform larva** is produced. It undergoes the **1st moulting** and becomes the **2nd stage rhabditiform larva** which is the stage '**infective to man**'. They reach the alimentary canal of man through contaminated food and water.

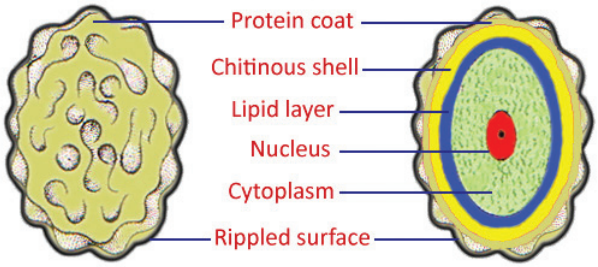


Fig. 6.9 Mammillated eggs of *Ascaris*

Do you know: 'If the conditions are favourable, the embryonated eggs of *Ascaris* can remain viable for about 6 years in moist soil'. Can you guess the reason for this?

In the small intestine, the shell gets dissolved and the 2nd stage larva is released. Now it undergoes **extra intestinal migration.** First it reaches the liver through the hepatic portal vein. From there it reaches the heart through the post caval vein. It goes to the lungs through the pulmonary arteries. In the alveoli of the lungs it undergoes the **2nd moulting** to produce the **3rd stage larva**. It undergoes the **3rd moulting** so that the **4th stage larva** is produced in the alveoli only. It leaves the alveoli and reaches the small intestine again, through the bronchi, trachea, larynx, glottis, pharynx, oesophagus and stomach. In the small intestine, it undergoes the

4th moulting (final moulting) to become a young one which attains sexual maturity within 8 to 10 weeks.

III. Pathogenicity

The disease caused by *Ascaris lumbricoides* is called **'ascariasis'.** The disease is asymptomatic if the number of worms is less. A heavy infection can cause nutritional deficiency and severe abdominal pain. It also causes stunted growth in children.

> Try to find out the reason for stunted growth noticed in children due to *Ascaris lumbricoides* infection. (It is believed to produce certain substances which inhibit the Human Growth Hormone)

IV. Prophylaxis: Same as that of *Entamoeba*.

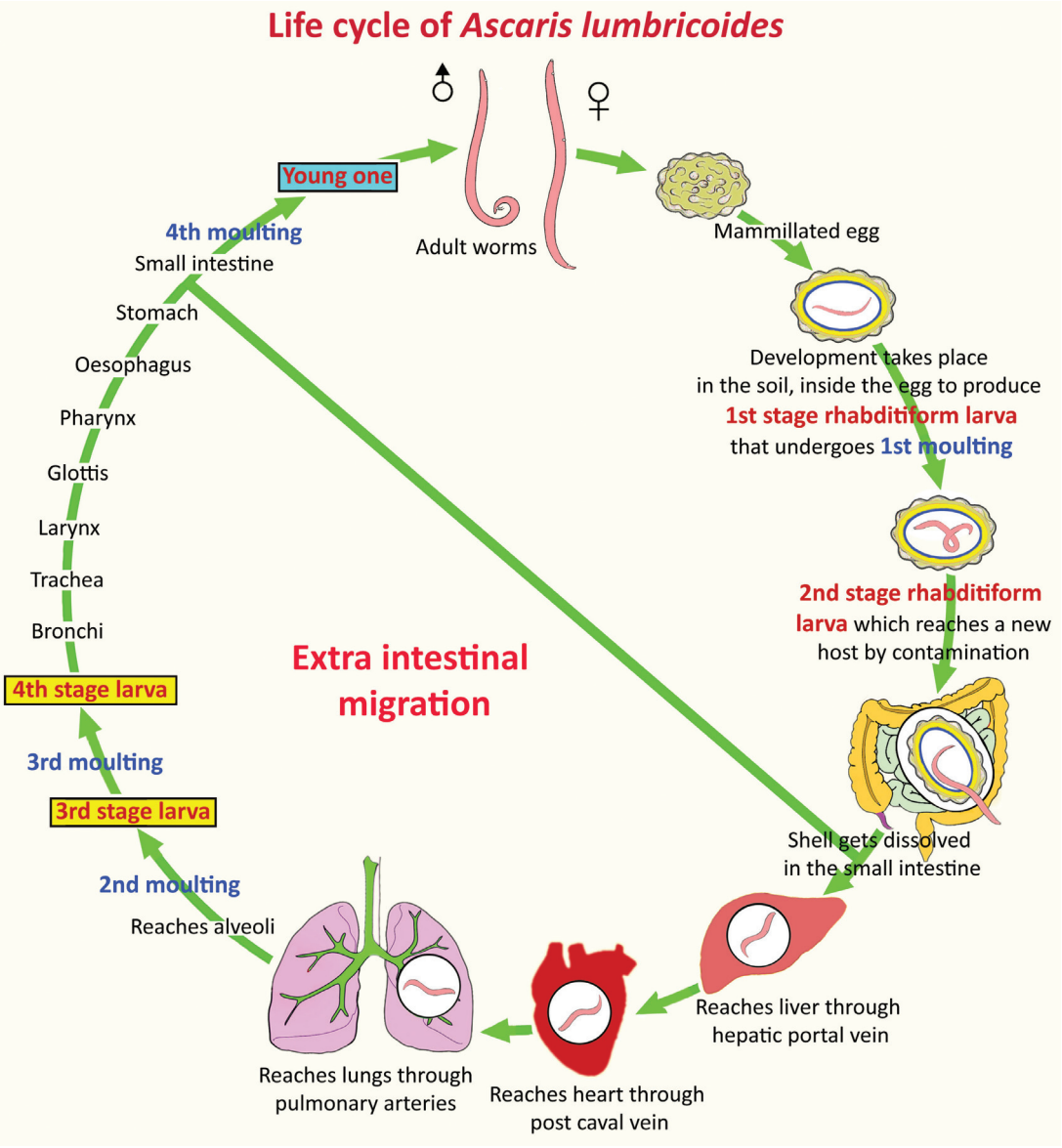


Fig. 6.10 Life cycle of *Ascaris lumbricoides*

6.2.3.4 *Wuchereria bancrofti*

Phylum : Nematoda

Class : Phasmidia

Wuchereria bancrofti is commonly called the filarial worm as it causes filariasis in human beings. It is a digenetic, dimorphic, pseudocoelomate and histozoic parasite that lives in the lymph vessels of man. **Sir Patrick Manson** identified **female *Culex*** mosquito as its secondary host.

I. Structure

Sexes are separate and the sexual dimorphism is distinct. The body is long, narrow, filiform and creamy-white in colour. The anterior end is blunt and the posterior end is pointed. Mouth is present at the anterior end and is without any lips.

1.Male worm: Its posterior end is curved with a cloacal aperture. A pair of unequal, chitinous '**pineal spicules'** or '**copulatory spicules'** is present in the cloacal region.

2.Female worm: Its posterior end is straight. Anus is present near the posterior end. The female genital pore or vulva is present mid ventrally at about one third the length from the mouth. It is **ovoviviparous**.

Fig. 6.11 A case of elephantiasis

II. Life cycle

As we already discussed, it completes its life cycle in two hosts namely man and female *Culex* mosquito.

1. In man

Both male and female worms are found coiled together in the lymphatic vessels of man. After copulation the female releases the sheathed microfilaria larvae into the lymph of man. Each sheathed microfilaria larva measures 0.2 to 0.3 mm in length. It is surrounded by a loose cuticular sheath which is supposed to be the modified shell. They migrate to the blood circulation and reside in the deeper blood vessels during the day time. They move to the peripheral blood circulation during the night time between 10.00 pm and 4.00 am. This tendency is referred to as **'nocturnal periodicity'.** When a female *Culex* mosquito sucks the blood of an infected person, they enter the gut of mosquito. They die if they are not transferred to mosquito **within 70 days**.

Could you guess the reason for nocturnal periodicity of sheathed microfilaria?

2. In mosquito

In the midgut of mosquito, the sheath of the larva is dissolved within 2 to 6 hours of the infection. The ex-sheathed microfilaria larva penetrates the gut wall

and reaches the haemocoel of mosquito. From there, it reaches the **'thoracic muscles'** and transforms into a '**sausage shaped larva**' within two days. It is called the **first stage larva** or **first stage microfilaria.** This undergoes two moultings within 10 to 20 days and transforms into a long, infective **'3rd stage microfilaria'**. It reaches the labium of the mosquito.

Why can't we consider the sheathed microfilaria larva the 1st stage microfilaria though it is the first stage produced in the life cycle of *Wuchereria*?

Note : A larva is a self supporting immature young one. Until the embryo can feed on its own, it can not be considered a larva.

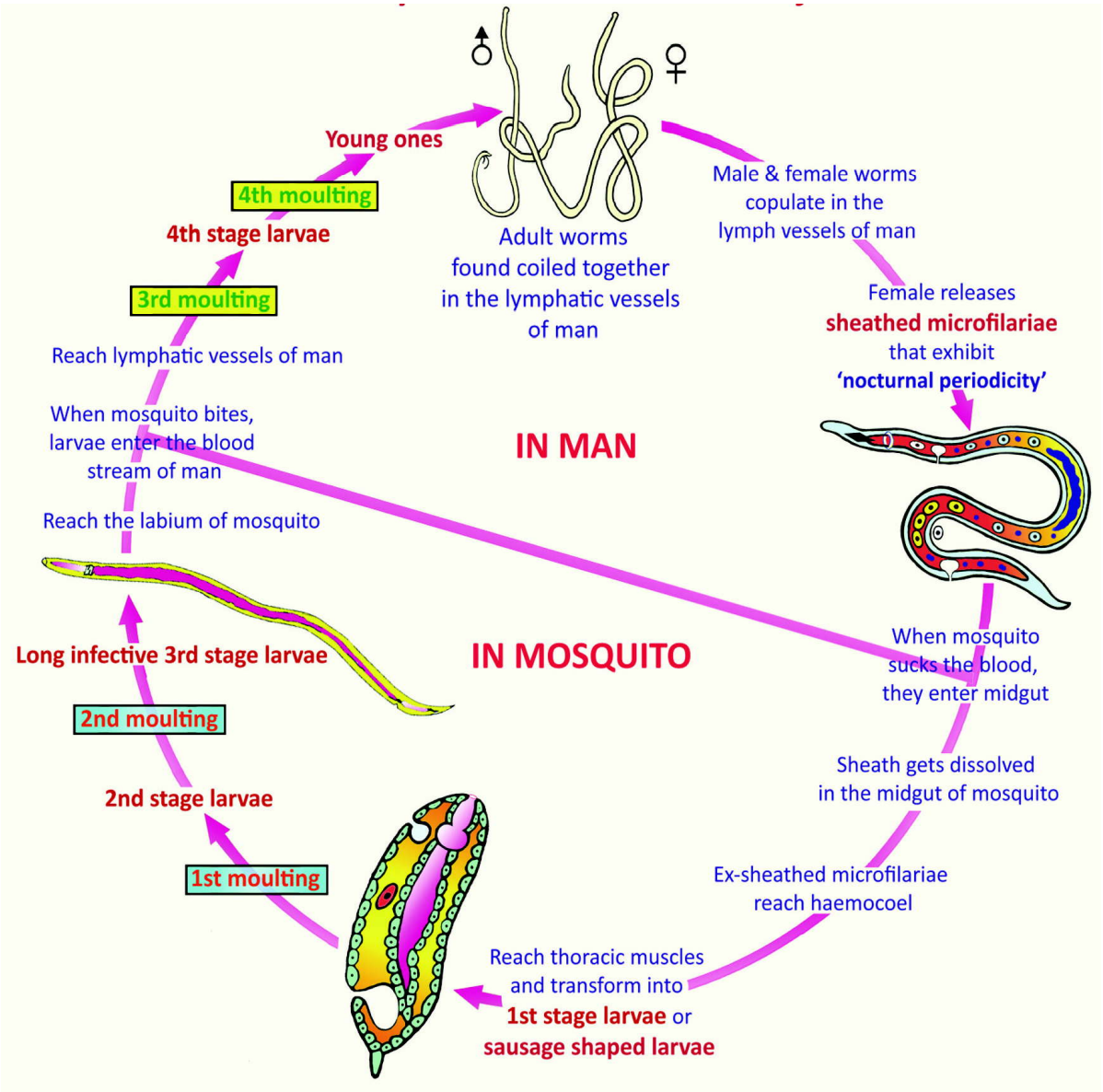


Fig. 6.12 Life cycle of *Wuchereria bancrofti*

3. In man after the infection

When an infected mosquito bites a man, the 3rd stage microfilaria larvae enter the blood circulation of man and finally reach the lymphatic vessels. Here they undergo the 3rd and the 4th moultings to produce young filarial worms. They attain sexual maturity within 5 to 18 months.

III. Pathogenicity

Light infection causes filarial fever which is characterised by headache, mental depression and increase in the body temperature. In general, the infection of filarial worm causes inflammatory effect in lymph vessels and lymph glands. Inflammation of the lymph vessels is called **lymphangitis** (*Gr., angeos - vessels, itis* - inflammation) and that of lymph glands is called **lymphadenitis** (*Gr., adenos - gland, itis* - inflammation). In the case of heavy infection, the accumulation of dead worms blocks the lymph vessels and lymph glands resulting in immense swelling. This condition is called **lymphoedema** (*Gr., oiedema - a swelling*) which is noticed in the extremities of limbs, scrotum of males and mammary glands in females. Fibroblasts accumulate in these tissues and form the fibrous tissue. In severe cases, the sweat glands of the skin in the affected regions disintegrate and the skin becomes rough. This terminal condition is referred to as **'elephantiasis'.**

IV. Prophylaxis: Same as that of *Plasmodium*.

6.3 Brief Account of some other Diseases

6.3.1 Bacterial diseases

i) **Typhoid fever:** It is caused by *Salmonella typhi* which is a Gram negative bacterium. It mainly lives in the small intestine of man and then migrates to other organs through blood. It can be confirmed by **Widal test**.

Mode of infection: Contamination through food and water.

Symptoms: Sustained fever with high temperature upto 104°F, weakness, stomach pain, constipation, headache and loss of appetite. Intestinal perforation and death may also occur in severe cases.

A classic case in medicine: Mary Mallon nicknamed Typhoid Mary, was a cook by profession and was a typhoid carrier. She continued to spread this disease for several years through the food she prepared.

ii) **Pneumonia:** It is caused by Gram positive bacteria such as ***Streptococcus pneumoniae*** and ***Haemophilus influenzae***. They infect the alveoli of lungs in human beings.

Mode of infection: Contamination by inhaling the droplets/aerosols released by an infected person or even by sharing the utensils with an infected person.

Symptoms: The alveoli get filled with fluid leading to severe problems in respiration. In severe cases, the lips and finger nails may turn gray to bluish in colour.

6.3.2 Viral Diseases

It is not an exaggeration to say that there is no person in this world who has not suffered from cold at least once in his life time.

Common cold: It is caused by **Rhino virus** group of viruses. They infect nose and respiratory passage but not lungs.

Mode of infection: Contamination by direct inhalation of the droplets resulting from cough or sneezes of an infected person or indirectly through contaminated objects such as pens, books, cups, door-knobs, computer keyboard or mouse etc.

Generally all the medicines that are used against cold cause drowsiness. Try to find out the reason for this from your family doctor.

Symptoms: Nasal congestion, discharge from nose, sore throat, hoarseness, cough, headache, tiredness, etc., which usually last for 3-7 days.

Do you know: 'Cold' treated is cured in just **ONE** week, and 'cold' untreated is cured in **SEVEN DAYS**. What is the implied meaning?

6.3.3 Fungal Diseases

Fig. 6.13 Ringworm infection

Ringworm: It is one of the most common infectious diseases in man. It is caused by many fungi belonging to the genera ***Microsporum, Trichophyton*** and ***Epidermophyton.*** Heat and moisture help these fungi grow in the skin folds such as those in the groin or between the toes.

Mode of infection: Contamination by using towels, clothes or combs of the infected persons or even from soil.

Symptoms: Appearance of dry, scaly, usually round lesions accompanied by intense itching on various parts of the body such as skin, nails and scalp.

6.3.4 Prophylaxis

i) **In the case of bacterial & viral diseases:** The advancements made in biological science have armed us to deal with many infectious diseases effectively. The immunization programmes by the use of vaccines have enabled us to completely eradicate a deadly disease like smallpox. A large number of other infectious diseases like polio, diphtheria, pneumonia and tetanus have been controlled to a large extent by the use of vaccines.

ii) **In general:** Biotechnology is at the verge of making available newer and safer vaccines. Discovery of antibiotics and various other drugs has also enabled us to treat infectious diseases effectively.

6.4 Tobacco, Drugs and Alcohol abuse (TDA Abuse)

Recent surveys and statistics show that the use of tobacco, drugs and alcohol has been on the rise especially among the youth. This is really a cause of concern as it could result in many harmful effects. Proper education and guidance would enable the youth to safeguard themselves against these dangerous habits and follow healthy lifestyles. Any addict requires counselling and medical help to get rid of the habit.

6.4.1 Tobacco

Tobacco has been used by human beings for more than 400 years. It contains a large number of chemical substances including **nicotine**, an alkaloid. While buying cigarettes one cannot miss the statutory warning printed on the packet **'Smoking is injurious to health'**.

Mode of abuse: It is smoked or chewed as 'gutkha' or used in the form of 'snuff'.

Effect: Smoking increases the carbon monoxide (CO) level and reduces the oxygen level in the blood. Nicotine stimulates the adrenal gland to release adrenaline and nor-adrenaline into blood. These hormones raise the blood pressure and increase the heart rate. Smoking is associated with bronchitis, emphysema, coronary heart disease, gastric ulcers and increases the incidence of cancers of throat, lungs, urinary bladder etc. Smoking also paves the way to addiction to hard drugs[1]. Yet, smoking is very prevalent in society, both among the young and old. Tobacco chewing is associated with increased risk of cancer of the oral cavity.

Do you think **passive smoking** is also dangerous? Why?

6.4.2 Drugs

Drugs are the chemical substances used in the treatment, cure and prevention of diseases so as to enhance one's physical or mental well being. For hundreds of years, several plants, fruits and seeds with hallucinogenic properties have been used in folk-medicine, religious ceremonies (such as '**bhang**' on the **'Holi festival'** day) and rituals all over the globe. ***When these are taken for a purpose other than the medicinal use or in excess amounts that impair one's physical or psychological functions, it constitutes 'drug abuse'.***

Fig. 6.14 Opium poppy

The drugs commonly abused are **opioids**, **cannabinoids** and **coca alkaloids**. Majority of them are obtained from flowering plants but some are obtained from certain fungi.

1. **Opioids:** These are the drugs obtained from opium poppy plant *Papaver somniferum* (vernacular name**: 'Nallamandu**

[1] *Hard drugs refer to morphine, heroin, cocaine, etc.*

mokka'). They bind to specific opioid receptors present in our central nervous system and gastrointestinal tract. Some of the opioids are morphine, heroin, etc.

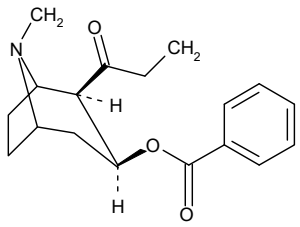


Fig. 6.15 Structure of morphine

i) **Morphine:** It is extracted from the dried latex of the unripe seed capsule (pod) of poppy plant. It occurs as colourless crystals or a white crystalline powder.

Mode of abuse: Generally it is taken orally or by injection.

Effect: It is a very effective sedative and painkiller. It is very useful in patients who have undergone surgery.

ii) **Heroin:** It is a white, bitter, odourless and crystalline compound, obtained by the **acetylation of morphine.** Chemically it is **diacetylmorphine.** It is commonly called '**smack'**.

Mode of abuse: Generally it is taken by **'snorting'** and injection.

Effect: Heroin is a depressant and slows down the body functions.

Fig. 6.16 Leaves of *Cannabis*

2. **Cannabinoids:** These are a group of chemicals obtained from Indian hemp plant *Cannabis sativa* (vernacular name: **Ganjai mokka).** They interact with cannabinoid receptors present in the brain. The flower tops, leaves and the resin of this plant are used in various combinations to produce marijuana, hashish, charas and ganja. These days, cannabinoids are being abused by even some sports-persons (doping).

Mode of abuse: These are generally taken by **inhalation** and **oral ingestion.**

Effect: Show their effects on cardiovascular system of the body.

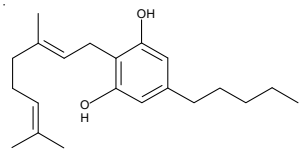


Fig. 6.17 Structure of cannabinoid molecule

3. **Coca alkaloid** or **Cocaine:** It is a white, crystalline alkaloid that is obtained from the leaves of Coca plant *Erythroxylum coca*, native to South America. It is commonly called **'coke** or **crack'.**

Mode of abuse: It is usually snorted

Effect: It has a potent stimulating action on the central nervous system as it interferes with the transport of the neuro-transmitter **'dopamine'**. Hence it produces a sense of euphoria and increased energy. (NCERT Text) Excessive consumption of crack causes hallucinations.

Fig. 6.18 A branch of *Datura*

4. Other well-known plants with hallucinogenic properties are *Atropa belladonna* and *Datura.* Certain drugs like 'Barbiturates (sleeping pills), Amphetamines (cause sleeplessness), Benzodiazepines (tranquilizers), Lysergic acid diethyl amides (LSD) and other similar drugs, normally used as medicines to treat patients with mental illnesses like depression, insomnia, etc.,' are often abused.

6.4.3 Adolescence and TDA abuse

1. Adolescence: It is the time period between the beginning of puberty and the beginning of adulthood. In other words, it is the bridge linking childhood and adulthood. The age between 12-18 years is considered **'adolescence period'**. It is both 'a period and a process' during which a child becomes mature. It is accompanied by several biological and behavioural changes. Thus, adolescence is a very **'vulnerable phase'** of mental and psychological development of an individual.

2. TDA abuse: Curiosity, desire for adventure and excitement, experimentation, are the common causes for the motivation of youngsters towards the use of tobacco, drugs and alcohol. The first use of drugs or alcohol may be out of curiosity or experimentation, but later the person starts using them to escape facing problems. Recently 'stress from the pressure to excel in academics or examinations' has played a significant role in alluring the youngsters to try certain drugs. Television, movies, newspapers and internet also help promoting this wrong perception. Other factors that are associated with tobacco, drug and alcohol abuse among adolescents are unstable or unsupportive family structures and peer pressure.

The consumption of drugs in any form is a non bailable offence. But the seeds of *Opium* are easily available in any provision store. They are treated in such a way that they can never germinate. They are generally used in the preparation of some curries. What are they? **Clue:** Find the Telugu name of poppy seeds.

6.4.4 Addiction and Dependence

The TDA abuse leads to addiction and dependence.

1. Addiction: It is a psychological attachment to certain effects such as euphoria. The most important thing one fails to realise is, the inherent **'addictive nature'** of tobacco, drugs and alcohol. With the repeated use of TDA, the tolerance level of the receptors present in our body increases. Consequently the receptors respond only to higher doses leading to greater intake and addiction. However it should be clearly borne in mind that **use of TDA even once, can be a fore-runner to addiction.** Thus, the addictive potential of tobacco, drugs and alcohol pull the users into a vicious circle leading to their regular use (abuse) from which they may not be able to get out. In the absence of any guidance or counseling, people get addicted and become dependent on them.

2. Dependence: It is the tendency of the body to manifest a characteristic and unpleasant condition (withdrawal syndrome) if the regular dose of drugs or alcohol is abruptly discontinued. The withdrawal syndrome is characterised by anxiety, shakiness (tremors), nausea and sweating which may be relieved when the regular use is resumed again. Dependence leads the patients to ignore all social norms.

6.4.5 Adverse effects of drugs and alcohol abuse

The immediate adverse effects of drugs and alcohol abuse are manifested in the form of reluctant behaviour, vandalism and violence. Excessive doses of drugs may lead to coma and death due to respiratory or heart failure or cerebral haemorrhage. A combination of drugs or their intake along with alcohol generally results in overdosing and even death. **The most common warning signs of drug and alcohol abuse among the youth include 'drop in academic performance, lack of interest in personal hygiene, depression, fatigue, aggressive behaviour, loss of interest in hobbies, change in sleeping and eating habits, fluctuations in weight, appetite, etc'.**

Those who take drugs intravenously are much more likely to acquire serious infections such as HIV, HBV (Hepatitis-B virus), etc., as the viruses are transferred from one person to another by the sharing of infected needles and syringes. The chronic use of drugs and alcohol damages nervous system and liver. The use of drugs and alcohol during pregnancy is also known to affect the foetus adversely.

Some sports-persons take drugs such as anabolic steroids to enhance their performance. The side-effects of the use of these drugs in females include masculinisation, increased aggressiveness, mood swings, depression, abnormal menstrual cycles, excessive hair growth on the face and body and the enlargement of clitoris. In males it includes acne (pimples), increased aggressiveness, mood swings, depression, reduction in the size of testicles, decreased sperm production, kidney and liver dysfunction, enlargement of breasts, premature baldness and the enlargement of the prostate gland.

6.4.6 Prevention and Control

The age-old adage of **'Prevention is better than cure'** holds true here also. Some of the measures useful for prevention and control of TDA abuse among the adolescents are:

i) **Avoid undue parental pressure:** Every child has his/her own choice, capacity and personality. The parents should not force their children to perform beyond their capacity by comparing them with others in studies, games, etc.

ii) **Responsibility of parents and teachers:** They should look for the danger signs and counsel such students who are likely to get into the 'trap'.

iii) **Seeking help from peers:** If peers find some one abusing drugs or alcohol, immediately it should be brought to the notice of their parents or teachers so that they can guide them appropriately.

iv) **Education and counselling**: Educating and counselling the children to face problems, stress and failures as a part of life.

v) **Seeking professional and medical help:** A lot of help is available in the form of highly qualified psychologists, psychiatrists and de-addiction and rehabilitation programmers.

GLOSSARY

Abscess: A wound consisting of a localized collection of pus surrounded by inflamed tissue

Abuse: Improper or excessive use.

Alkaloid: Natural bases containing nitrogen, found in plants. e.g. Quinine

Alveoli of lungs: Tiny sacs for holding air in the lungs in which the exchange of gases takes place

Anabolic steroids: Technically known as anabolic-androgen steroids (AAS) or colloquially as 'steroids', are the drugs that mimic the effects of 'testosterone and dihydrotestosterone in the body'. They increase protein synthesis within cells, which results in the buildup of cellular tissue (anabolism), especially in muscles.

Anaemia: Deficiency of red blood cells or haemoglobin

Appetite: A feeling of hunger

Bout: An instance of something lasting for a short period as in bout of fever

Clinical symptoms: Noticeable symptoms of a disease

Cloaca: The cavity at the end of the digestive tract into which the intestinal, genital, and urinary tracts open in the case of vertebrates (only intestinal and genital ducts open in the case of invertebrates)

Constipation: Irregular and infrequent or difficult egestion

Coprophagous: Feeding on faecal matter

Cosmopolitan: Occurring in many parts of the world

Emaciation: Extreme leanness

Epidemic: Spreading of an infectious disease, affecting many people over a wide area

Epidemiology: The branch of medical science dealing with the transmission and control of disease

Euphoria: A temporary feeling of an exaggerated joy, well-being, pride and optimism associated with drugs and alcohol; or an absence of depression

Faeces: Solid indigested product discharged through anus

Filiform: Resembling a thread

Folk-medicine: Treatment given by some aged local people (naatu vaidyam in Telugu)

Giddiness: A feeling that you are about to fall; a reeling sensation

Groin: The junction of the inner part of the thigh with the trunk together with the adjacent region and often including the external genitals

Hallucinations: Illusionary perception; a sensory experience of something that does not exist outside the mind, caused by physical and mental disorders

Hoarseness: Harshness of the throat

Inflammation: A response of body tissues to injury or irritation, characterized by pain, swelling, redness and burning sensation

Instinct: Inborn pattern of behaviour

Intravenous: Direct injection into the vein using a needle and syringe

Lesion: An injury to living tissue

Liver sinusoids: Tiny blood filled spaces in the liver

Masculinisation: Development of features like those of males

Moultings: Periodic shedding of the cuticle or the outer skin in some animals or larval stages

Nasal congestion: Blockage of nose

Neuro-transmitter: A neuro-chemical that transmits nerve impulses across a synapse

Ovoviviparous: Producing eggs that hatch within the body but the juveniles do not draw any nourishment from the mother

Pathogen: Any disease-producing agent

Peer: A person who is of equal standing with another in a group; a friend or a classmate

Phasmids: Caudal sensory organs present in nematodes

Pronucleus: Nuclei of the sperm and ovum before their union to form synkaryon

Quagmire: A soft wet area of low-lying land that sinks underfoot (quag means **'oobi/ oobi nela'** in Telugu)

Rituals: The prescribed procedure for conducting religious ceremonies

Sausage shaped: More or less a long-brinjal shaped

Schizogony: A type of multiple fission that occurs in many apicomplexan protozoans during asexual cycle

Snorting: An act of forcible inhalation of drugs

Splenomegaly: An abnormal enlargement of the spleen

Stool: Faecal matter

Synkaryon: Nucleus of the zygote

Thrive: Live/grow vigorously

Tranquilizers: A drug used to reduce stress or tension without reducing mental clarity

Tropical sprue: A chronic disorder that occurs in both children and adults; nutrients are not properly absorbed; symptoms include foul-smelling diarrhoea and emaciation

Ulcer: A circumscribed inflammatory lesion on the skin or an internal mucous membrane resulting in the necrosis of tissue

Vaccine: Immunogen consisting of a suspension of weakened or dead pathogenic cells injected in order to stimulate the production of antibodies in the host body

Vandalism: Deliberate destruction, defacement or damage of public or other people's property

Vermiform: Long, thin and cylindrical or resembling a worm

Vesicular nucleus: Nucleus with a nucleolus and large amounts of euchromatin

Vicious circle: One trouble leads to another that aggravates the first

Vulnerable: Susceptible to attack or temptation

Welfare: Something that aids or promotes

SOME MORE COMMON DISEASES

i) **Bronchitis:** Inflammation of the membranes lining the bronchial tubes

ii) **Chikungunya:** It is a viral disease caused by *Chikungunya virus* (CHIKV) which is a heat sensitive RNA virus
Mode of infection: Inoculation through the bite of *Aedes aegypti* which bites during the day time.
Symptoms: Fever upto 104^0F, chills, vomiting, nausea, headache and **severe joint pains** and sometimes it is accompanied with rashes

iii) **Diphtheria:** It is caused by a gram-positive bacillus bacterium *Corynebacterium diphtheriae*. It primarily affects the mucous membranes of the respiratory tract.
Mode of infection: Contamination through airborne respiratory droplets or by direct contact with nasopharyngeal secretions
Symptoms: Sore throat, fever, malaise, hoarseness, difficulty in swallowing or in breathing

iv) **Dysentery:** It is an intestinal inflammation, especially in the colon, caused by *Shigella*, a gram negative bacterium
Mode of infection: Contamination through food & water

Symptoms: Abdominal pain, nausea, vomiting, watery diarrhea which can contain blood, mucus or pus, painful egestion and dehydration

v) **Emphysema:** an abnormal condition of the lungs marked by decreased respiratory function due to the rupture of alveoli

vi) **Plague:** Bubonic plague is the most common form of plague. It is caused by a Gram-negative bacterium *Yersinia pestis*

Mode of infection: Inoculation through the bites of an infected flea (*Xenopsylla cheopis*)

Symptoms: Swollen, tender lymph glands, Fever, Chills, Headache and weakness

vii) **Polio:** It is caused by *Poliomyelitis* virus which is a single-stranded RNA virus

Mode of infection: Contamination through the stool of the infected person.

Symptoms: Inflammation of nerve cells of the brain stem and spinal cord resulting in the impairment of legs.

viii) **Smallpox:** It is caused by the ***Variola*** virus.

Mode of infection: Contamination through the tiny drops of an infected person's saliva that comes when the patient talks, coughs or sneezes.

Symptoms: Formation of small pus-filled blisters through out the body, fever, headache, backache, and feeling tired.

ix) **Tetanus:** It is an infectious disease caused by contamination of wounds from a Gram-positive bacterium *Clostridium tetani* or its spores present in the soil.

Mode of infection: Contamination through soil or dust.

Symptoms: Tetanus results in severe, uncontrollable muscle spasms as in lockjaw.

Muscle spasm: a painful and involuntary muscular contraction.

VERY SHORT ANSWER TYPE QUESTIONS

1. Define parasitism and justify this term.
2. Distinguish between vector and a reservoir host.
3. Distinguish between mechanical vector and biological vector.
4. What is a hyper-parasite? Mention the name of one hyper-parasite.
5. What do you mean by parasitic castration? Give one example.
6. What are the endo-parasitic adaptations observed in *Fasciola hepatica*?
7. Define neoplasia. Give one example.
8. Define the most accurate definition of the term 'health' and write any two factors that affect the health.
9. Distinguish between infectious and non-infectious diseases. Give two examples each.
10. *'Entamoeba histolytica* is an obligatory anaerobe'. Justify.
11. Distinguish between precystic stage and cystic stage *of E. histolytica.*
12. What is the reserve food in the precystic and early cyst stages of *Entamoeba histolytica*?
13. A person is suffering from bowel irregularity, abdominal pain, blood and mucus in stool, etc. Based on these symptoms, name the disease and its causative organism.
14. On the advice of a doctor, a patient has gone to a clinical laboratory for the examination of a sample of faeces. The lab technician, on observing the stool of the patient diagnosed that the patient was suffering from amoebiasis. Write any two

characteristic features based on which the technician came to that conclusion.

15. Define 'asymptomatic cyst passers' with reference to *Entamoeba histolytica*.
16. What are the stages *of Plasmodium vivax* that infect the hepatocytes of man?
17. Define prepatent period. What is its duration in the life cycle of *Plasmodium vivax*?
18. Define incubation period. What is its duration in the life cycle of *Plasmodium vivax*?
19. What are Schuffner's dots? What is their significance?
20. What are haemozoin granules? What is their significance?
21. What is exflagellation and what are the resultant products called?
22. Why is the syngamy found in *Plasmodium* called anisogamy?
23. What is ookinete? Based on the 'sets of chromosomes' how do you describe it?
24. A person is suffering from chills and shivering and high temperature. These symptoms are cyclically followed by profuse sweating and return to normal body temperature. Based on these symptoms, name the disease and its causative organism.
25. Describe the methods of biological control of mosquitoes.
26. The eggs of *Ascaris* are called 'mammillated eggs'. Justify.
27. What is meant by nocturnal periodicity with reference to the life history of a nematode parasite you have studied?
28. Distinguish between lymphadenitis and lymphangitis?
29. 'Elephantiasis is the terminal condition of filariasis'. Justify.
30. In which way does tobacco affect the respiration? Name the alkaloid found in tobacco.
31. Define drug abuse.
32. From which substances 'Smack' and 'Coke' are obtained?
33. 'Many secondary metabolites of plants have medicinal properties. It is their misuse that creates problems'. Justify the statement with an example.
34. Why are cannabinoids and anabolic steroids banned in sports and games?
35. Mention the names of any four drugs which are used as medicines to treat patients with mental illness like depression, insomnia, etc.' that are often abused

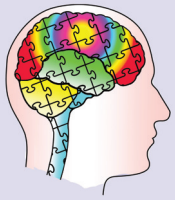
SHORT ANSWER TYPE QUESTIONS

1. What is the need for parasites to develop special adaptations? Mention some special adaptations developed by the parasites.
2. Distinguish between hypertrophy and hyperplasia with an example for each.
3. Describe the structure of a trophozoite *of Entamoeba histolytica.*
4. Explain the life cycle of *Entamoeba histolytica.*
5. Write a short note on the pathogenicity *of Entamoeba histolytica.*
6. Describe the structure of sporozoite of *Plasmodium vivax.*
7. Describe the cycle *of* Golgi in the life history of *Plasmodium vivax.*
8. Explain the pathogenicity of *Wuchereria bancrofti* in man.

9. Write short notes on typhoid fever and its prophylaxis.
10 Write short notes on pneumonia and its prophylaxis.
11. Write short notes on common cold and its prophylaxis.
12. Write short notes on ringworm and its prophylaxis.
13. What are the adverse effects of tobacco?
14. Write short notes on opioids.
15. Write short notes on cannabinoids.
16. Write short notes on cocaine.
17. Why in adolescence is considered vulnerable phase?
18. Distinguish between addiction and dependence.
19. 'Prevention is better than cure'. Justify with regard to TDA abuse.

LONG ANSWER TYPE QUESTIONS

1. Explain the structure and life cycle of *Entamoeba histolytica* with the help of neat and labelled diagrams.
2. Describe the life cycle of *Plasmodium vivax* in man.
3. Describe the life cycle of *Plasmodium vivax* in mosquito.
4. Describe the life cycle of *Ascaris lumbricoides* with the help of a neat and labelled diagram.
5. Describe the 1ife cycle of *Wuchereria bancrofti.*



For ignited minds

- NOT FOR EVALUATION

1. Why should *Anopheles* only be the vector for *Plasmodium* when there are several other types of mosquitoes in the world ?
2. The epithelium surrounding the wall of the gut is called peritoneum. Inflammation of peritoneum is called peritonitis. From the information provided above, which of the following can possibly cause peritonitis in man? (List: *Plasmodium , Wuchereria, Entamoeba and Ascaris*).
3. If there is swelling in both the legs, it is probably a problem related to heart or kidneys. If there is a swelling in only one leg what should a doctor suspect, in your opinion.
4. Can housefly be both mechanical and biological carrier of pathogens?
5. Hypothetically if the sausage shaped larva (First stage larva) of *Wuchereria bancrofti* is introduced into blood of man , what can be expected as further consequence?
6. Probably Ronald Ross could have missed his Nobel Prize ,had there not been a scientist by the name Patrick Manson was not born before Ross. If your answer is 'probably, yes' how do you offer an explanation in favour of your view?
7. If human stool has 'live trophozoites' of a parasite, in a sample of stool under examination, how can you identify them as those of *Entamoeba histolytica?* (if you are provided with the right stains and microscope required)
8. In the case of a suspected filarial patient why is the patient admitted in the hospital and a sample of blood is taken from him around midnight.
9. If all the female *Culex* mosquitoes in the world are hypothetically killed will there be filariasis in the world, any more ?
10. If the salivary glands of all female mosquitoes are hypothetically removed, what important effects can be expected? Can you think of at least two important effects?
11. Can you guess the expansion of 'COLD'?

    Common obstructive lung disease.

William Kirby- *an English Biologist, famous for his enormous work in Entomology. He is called the '**Founder of Entomology**'.*

Unit

7

Periplaneta americana

(Cockroach)

Cockroach belongs to the phylum Arthropoda and the class Insecta. Insecta is the largest class of animals in the Kingdom –Animalia. These are terrestrial animals but adapted to live in all habitats, except in deep waters of the seas. Insects are distinguished from other arthropods in possessing three ***tagmata*** in the body and three pairs of legs. The study of insects is called ***Entomology*****.**

Cockroach is an abundantly and easily available insect. It also exhibits all the characteristic features of the class **Insecta**. Besides this, its large size of the body makes it a convenient specimen, for dissection and demonstration. Therefore it is an excellent example for the study of insects.

Cockroach is a common household pest that contaminates our food with its excreta. It can transmit a number of bacterial diseases by contaminating food materials. These are mostly the inhabitants of the tropical countries. However some species are found in the temperate regions. The two common species of cockroaches found in India are: *Blatta orientalis* and ***Periplaneta americana***.

Periplaneta americana - type study

7.1 Habitat and Habit

Classification
Phylum - Arthropoda
Class – Insecta
Order – Orthoptera
Family – Blattidae
Genus – *Periplaneta*
Species - *Americana*

Periplaneta americana, was a native of the tropical America. Now it has become a *cosmopolitan* insect. The name *Periplaneta americana* was coined by **Burmeister**. It is usually found in kitchens, hotels, bakeries, warehouses, etc., It is a ***nocturnal*** insect (it comes out of its hiding places to feed at night times). During the day time it remains inactive and takes rest. Its flattened form of the body enables it to enter small crevices in the floor or walls. It is an ***omnivorous*** insect, eating all types of food. It locates its food by the sense of smell. *Periplaneta* is a ***cursorial*** (swift runner) animal.

Why do cockroaches take rest during day time?

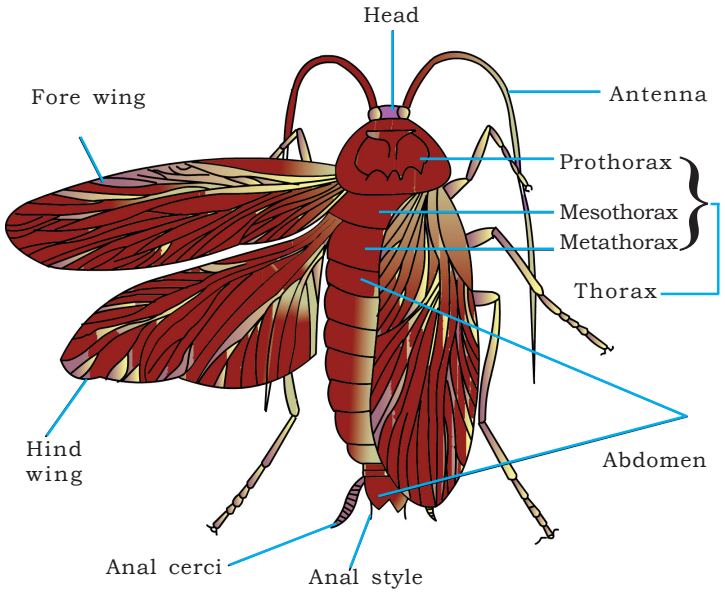


Fig. 7.1 *Periplaneta* (Male): External features

7.2 External Features (Morphology)

Cockroach has an elongated, narrow, elliptical, dorso-ventrally depressed body. It exhibits bilateral symmetry. The wings extend beyond the tip of the abdomen in the males. The colour is reddish brown with a light yellow area around the edges of the pronotum. The complete body is externally covered by a ***chitinous cuticle*** which constitutes the **exoskeleton**. The cuticle is secreted by the underlying cells of the

hypodermis[1]. It is coated externally by a thin layer of wax, impermeable to water. The **oenocytes**, are believed to secrete ***wax***. The cuticle protects the body, prevents loss of water, provides rigidity and offers place for the attachment of muscles. It consists of small plates or **sclerites**, which are joined by soft, flexible **arthrodial membranes**.

1. Body Divisions: The body of cockroach is distinctly segmented and consists of three ***tagmata*** (morphologically distinct parts of the body) namely head, thorax and abdomen.

A. Head: The head of cockroach is small and triangular. It is called **hypognathous** because it lies hanging almost at right angles to the body with the posterior wider part upwards, and the mouthparts directed down-wards.

The head of cockroach is formed by the fusion of six embryonic segments. It is movably attached to the thorax by a short neck or **cervicum**. It is covered by a number of sclerites which fuse to form a capsule. The top of the head between the eyes is called **vertex**. The vertex has two sclerites called '**epicranial plates'** connected by an '**epicranial suture'**. Below the vertex, the sclerites covering the head in front are – a large **frons**, a narrow rectangular **clypeus** and a movable **labrum**. Covering the sides of the head, below the compound eyes are the 'cheek sclerites' or '**genae'.** At the back of the head capsule there is a large opening called **occipital foramen**. It is bordered by a sclerite called **occiput**. The occipital foramen forms a passage for the oesophagus, aorta, nerve cord and tracheae. At the base of each **antenna**, a small whitish speck called **fenestra** or 'ocellar spot' or 'simple eye' is present. Appendages are absent in the first and third segments of the head. The second segment bears a pair of long, slender and segmented **antennae**, one on each side of the head. The antennae are tactile and olfactory

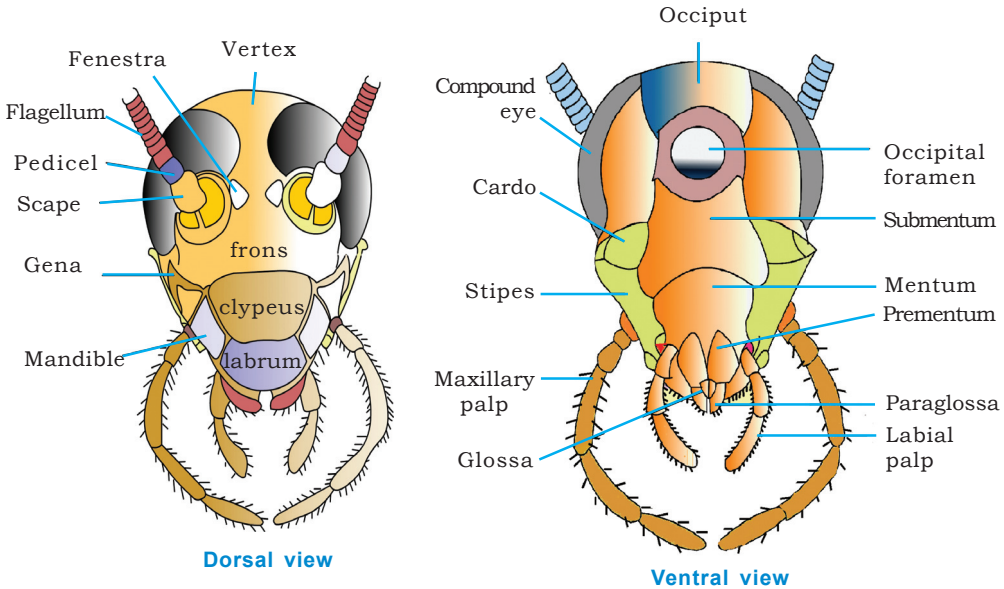


Fig. 7.2 *Periplaneta*: Head dorsal and ventral View

[1] It is the epidermis below the cuticle, hence called hypodermis

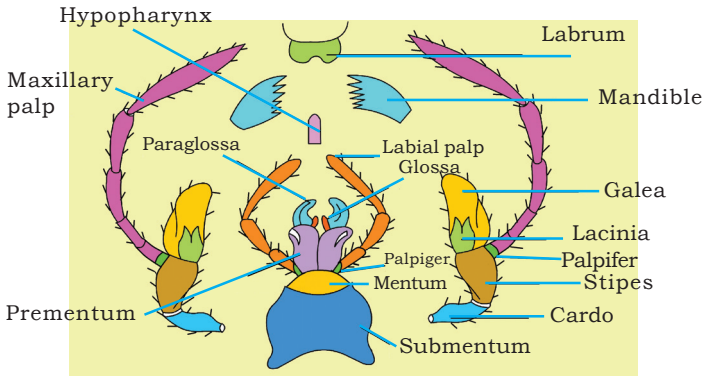


Fig. 7.3: *Periplaneta:* Mouth parts

in function. The fourth segment bears a pair of **mandibles**. The fifth segment has a pair of '**first maxillae**'. The sixth segment bears a pair of '**second maxillae'**, which fuse to form the **labium** (also called 'lower lip').

Mouthparts

The mouthparts of *Periplaneta* are of **Biting** and **Chewing** type. These are the movably articulated appendages surrounding the mouth. They include a pair of mandibles, a pair of first maxillae, a pair of second maxillae or labium and a tongue or **hypopharynx** and an upperlip, the labrum. They enclose a space called the '**preoral cavity**'.

Labrum (upper lip)

The labrum is a vertical, rectangular plate, movably connected with the clypeus. It forms the anterior wall of the preoral cavity and is also called the 'upper lip'. It bears '**gustatory sensillae**' on its inner surface. The labrum serves to hold the food and helps in tasting it.

Mandibles

A pair of triangular, hard, unjointed, chitinised mandibles is present on the sides of the mouth, connected with the genae. The inner margins of mandibles have teeth like structures. These teeth help to masticate the food. Two pairs of muscles called **adductor** and **abductor** muscles help in the movement of the mandibles. Each mandible has incising and grinding teeth.

First maxillae

A pair of first maxillae is situated on the sides of the mouth immediately behind the mandibles. Each maxilla is 'biramous' and consists of three parts: the protopodite, endopodite, and the exopodite. **Cardo** and **stipes** constitute the protopodite. A five jointed maxillary palp, arising from a sclerite called **palpifer**, on the outer side of the stipes, constitutes the exopodite. The maxillary palps are used for cleaning the antennae and the front pair of legs. From the distal end of the stipes, internal to the maxillary palp, arises the endopodite. Each endopodite has two parts, an outer broad hood-like **galea** and inner pincer-like (resembling a forceps) **lacinia.** Maxillae serve to hold the food and bring it to the mandibles.

Second maxillae (Labium or Lower lip)

The second pair of maxillae lies behind the first pair. Both the second maxillae fuse to form a broad plate like **labium** or **lower lip**. It consists of three parts: the upper

submentum, the middle mentum and the lower prementum. A three segmented labial palp, arising from a sclerite called **palpiger**, is present one on each side of the prementum. It prevents the food from falling, and pushes it into the preoral cavity.

The distal end of the prementum bears a pair of '**paraglossae** (comparable to **galeae** of the first maxilla**)**, a pair of **'glossae'** (comparable to **laciniae** of the first maxilla). The glossae and paraglossae together constitute the **ligula**.

Hypopharynx (Tongue or Lingua): The hypopharynx is a rod like, grooved chitinous structure, hanging in the preoral cavity between the first maxillae. The hypopharynx is also called 'tongue' or '**lingua**'. It bears the opening of the *'efferent salivary duct'*.

Note: Biting and chewing type of mouth parts are believed to be the most primitive type (as most larvae of insects possess such type of mouth parts).

Why are the mouthparts of cockroach called biting and chewing type?

Neck (cervicum)

Neck is short, slender, flexible tube (a part or extension of the thorax) that connects the head with the thorax. It is supported by ***four cervical sclerites***. It is not a 'tagma' of the body. It helps in the movement of the head.

B. Thorax: The thorax is the second 'tagma' of the body. It consists of three segments: prothorax, mesothorax, and metathorax. Each segment of the thorax is covered by four sclerites -one on the dorsal side (called **tergum** or **notum**), one on the ventral side (called **sternum**) and two (called **pleura**), on the lateral sides. The tergum of the prothorax is called **pronotum**. It is the largest sclerite of the body and covers the neck and a little part of the head. The terga on the mesothorax and metathorax are called **mesonotum** and **metanotum** respectively. The sclerites of each segment are joined by thin, soft, flexible membranes called arthrodial membranes, which permit movement, between the segments.

Legs: There are three pairs of jointed, walking legs in cockroach, attached one pair to each thoracic segment on the ventral side. The legs are connected with the pleura and sterna of the thoracic segments. According to the segment that bears them, they are called prolegs, mesolegs and metalegs. All the legs are similar in structure. Each leg is made up of five segments or **podomeres**. The different podomeres (from the base to the tip) are serially: **coxa, trochanter**, **femur**, **tibia** and **tarsus.**

The coxa connects the leg with the thorax. The trochanter is *movably attached* to the coxa, and *fused* with the femur. The femur and tibia bear chitinous bristles. The joints of tarsus are **tarsomeres** which bear soft pads called **plantulae** on their inner surface. The terminal joint of the tarsus, ends in a pair of **claws**. Between the claws there is a soft hairy pad called **pulvillus** or **arolium**.

Wings: Two pairs of wings, the fore wings and the hind wings, are present in cockroach. The forewings are thick, opaque and leathery. They do not help in flight, but cover and protect the hind wings when they are not in use. They are called **tegmina** (singular: **tegmen**). The hind wings are broad, thin, transparent and delicate.

They help in flight and remain folded below the tegmina when not in use. The wings of cockroach contain a network of hollow **veins** or **nervures**.

C. Abdomen: The abdomen consists of **ten** segments. Each segment is covered by the dorsal tergum, the ventral sternum and the two lateral pleura or pleurites. There are ten terga but only nine sterna as the tenth sternum is absent. The eighth tergum in the male and both eighth and ninth terga in the female are not visible as they are overlapped by the seventh tergum. The tenth tergum extends beyond the posterior end of the body and has a deep notch / groove in the middle of its free end. In the male nine sterna are visible whereas in the female, only seven sterna are visible. The seventh, eighth and ninth sterna together form a **brood pouch**. The brood pouch has two parts the anterior **genital chamber** or **gynatrium** and posterior **oothecal chamber**.

The posterior end of the abdomen has a pair of **anal cerci**, a pair of **anal styles** and gonapophyses in the males. Anal cerci are jointed (15 segmented) and arise from the lateral sides of the tenth tergum and are found in both the sexes. The anal styles are without joints and arise from the ninth sternum (seen only in the males). The **gonapophyses** are small chitinous processes arising from the ninth sternum in the males and eighth and ninth sterna in the females. They are the external genital organs. The **anus** is at the posterior end of the abdomen in the 10^{th} segment. The genital aperture in male is present just below the anus on one of the **gonapophyses** and in female it is located on the **eighth sternum**.

Body wall: The body wall consists of three layers: **cuticle**, **epidermis** or **hypodermis** and **basement membrane**. The cuticle is the outer most layer. It is again differentiated into three layers, namely, an outer thin, waxy **epicuticle**, middle thick **exocuticle** made of tough pigmented chitin and an inner much thick **endocuticle,** made of soft layers of **chitin**. The articular membranes lack the exocuticle and so they are flexible. The epidermis lies below the cuticle. It comprises a single layer of columnar cells resting on the basement membrane. It secretes the cuticle. The basement membrane is the inner most layer of the body wall. The cuticle protects the delicate internal organs and prevents the loss of water by evaporation and provides surface for the attachment of muscles.

How does the cuticle help in preventing the loss of water?
What makes the articular membrane flexible?

Body cavity and coelom

The body cavity / perivisceral cavity of *Periplaneta* is not a true coelom and it is not lined by peritoneum. It is called **'haemocoel'** as it is filled with blood or haemolymph. The schizocoelom is restricted to the spaces around the reproductive organs.

Why is the body cavity of a cockroach not a true coelom but a haemocoel?

Fat bodies

The haemocoel contains many large sized fat bodies. These bodies are also called **corpora adiposa**. These are similar to the liver of the vertebrates in certain functions. A fat body has many lobules containing four types of cells namely **trophocytes** (store food) **mycetocytes** (contain symbiotic bacteria), **oenocytes** (synthesise and store lipids), **urate cells** (store uric acid).

7.3 Locomotion

Periplaneta has double mode of locomotion.1-Running (cursorial locomotion) 2-Flying.

1. Running or cursorial locomotion

Cockroach is a cursorial insect and it can run on the ground with the help of legs. During walking or running cockroach forms two **tripods** with the legs. Each tripod is formed by foreleg and hind leg of one side and middle leg of the other side. During locomotion, the three legs of one tripod are kept on the ground and the other three legs of another tripod are carried forward. In this process, the foreleg and the hind leg of the tripod pull and push the body while the middle leg acts as a **pivot**. Thus cockroach moves using the two tripods alternately. The animal does not slip back as plantulae, pulvilli and claws provide grip. The claws and the arolium help in locomotion on **rough surfaces** whereas plantulae are useful on **smooth surfaces**.

How is each tripod of cockroach formed during locomotion?

2. Flying: Though cockroach is a cursorial insect, it can fly over short distances with the help of its wings. While flying the first pair of wings is stretched out at right angles to the body. The second pair of wings is moved up and down during flight. Wings are elevated by the contraction of dorsoventral muscles. Contraction of the dorso-longitudinal muscles and relaxation of the dorsoventral muscles depresses the wings.

7.4 Digestive System of *Periplaneta*

The digestive system of cockroach consists of an alimentary canal and the associated glands. The preoral cavity, surrounded by the mouth parts, is present in front of the mouth. The hypopharynx divides it into two chambers called **cibarium** (anterior) and **salivarium** (posterior).

I. Alimentary canal

The alimentary canal of cockroach is a long tube and is coiled at some places. It extends between the mouth and the anus. It is divided into three regions, namely, foregut

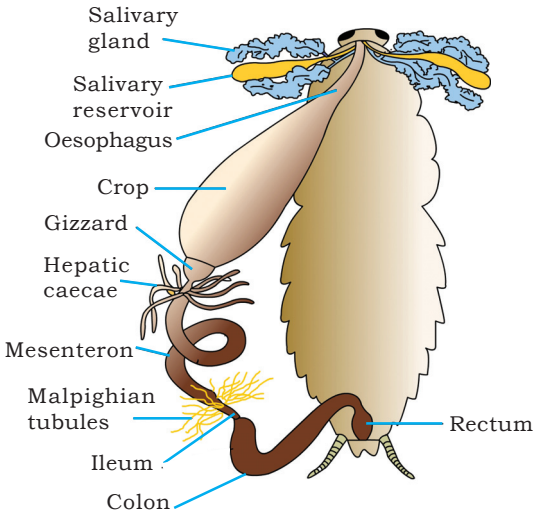


Fig. 7.4 *Periplaneta* : Digestive system

or **stomodaeum**, midgut or **mesenteron** and hindgut or **proctodaeum**. The foregut and hindgut are internally lined by ectoderm. The mesenteron is lined by the endodermal cells.

1. Foregut or stomodaeum

The foregut includes pharynx, oesophagus, crop, and gizzard. It is internally lined by a chitinous cuticle. Mouth opens into the **pharynx**, which in turn leads into a narrow tubular oesophagus. The **oesophagus** opens behind into a thin walled distensible sac called **crop**. The crop serves as a reservoir for storing food. Its outer surface is covered by a network of tracheae.

Behind the crop there is a thick walled muscular **proventriculus**, or **gizzard**. The chitinous inner lining of the gizzard has six powerful teeth, which form an efficient grinding apparatus. Behind each tooth is a hairy pad, which bears backwardly directed bristles. Among these plates, food is thoroughly ground into fine particles. These food particles are filtered by the bristles. The gizzard thus acts both as a **grinding mill** and also as a **sieve**. There is a membranous projection of the gizzard in to the mesenteron in the form of a funnel called **stomodeal valve**. This valve prevents the entry (regurgitation)of food from the mesenteron back into the gizzard.

2. Midgut (mesenteron or ventriculus)

The midgut is a short and narrow tube behind the gizzard. It is also called **mesenteron** or **ventriculus**. Between the ventriculus and the gizzard, arising from ventriculus, there are six to eight finger like diverticula called **hepatic caecae.** They are helpful in digestion and absorption of the digested food materials. Ventriculus is functionally divided into an anteriors

The secretory part of the ventriculus has many gland cells and it secretes several enzymes. The 'bolus' of food in the mesenteron is enveloped by a chitinous and porous membrane called **peritrophic membrane**, which is secreted by the mid gut. The peritrophic membrane is a network of chitin fibrils in a glycoprotein matrix, secreted by cells in the anterior region of the midgut.

Digested food is absorbed into the blood through the peritrophic membrane in the posterior absorptive region of the ventriculus. The peritrophic membrane protects the wall of the ventriculus from hard food particles in the food . The opening of the ventriculus into the hindgut is controlled by a **sphincter muscle**. It prevents entry (regurgitation) of undigested food and uric acid from the hindgut into the midgut.

Which part of the alimentary canal produces the peritrophic membrane around the food bolus in Periplaneta?

3. Hindgut or proctodaeum

The hindgut is a long coiled tube, consisting of three regions namely **ileum**, **colon** and **rectum**. It is internally lined by chitinous cuticle. The ileum that lies behind the mesenteron is a short tube. Six bundles of fine yellow, blind tubules called **Malpighian tubules** open into the ileum near the junction of mesenteron and ileum. Malpighian tubules are excretory in function. Ileum collects uric acid from the malpighian tubules and undigested food from the mesenteron. Ileum opens behind into a long coiled tube called colon. Colon leads into a short and wide rectum, which opens out through the anus. Rectum bears on its inner side six longitudinal folds called rectal papillae. They are concerned with the reabsorption of water from the undigested food.

II. Digestive glands

The digestive glands associated with the alimentary canal of cockroach are salivary glands, hepatic caecae and glandular cells of the mesenteron.

1. Salivary glands

There is a pair of salivary glands attached to the ventrolateral sides of the crop, one on each side. Each salivary gland has two lobes. Each lobe of salivary gland has many lobules called **acini**. Each acinus is a group of secretory cells called ***zymogen cells*** with a small ductule. The ductules of both the lobes of a salivary gland unite to form a **common salivary duct** on each side.

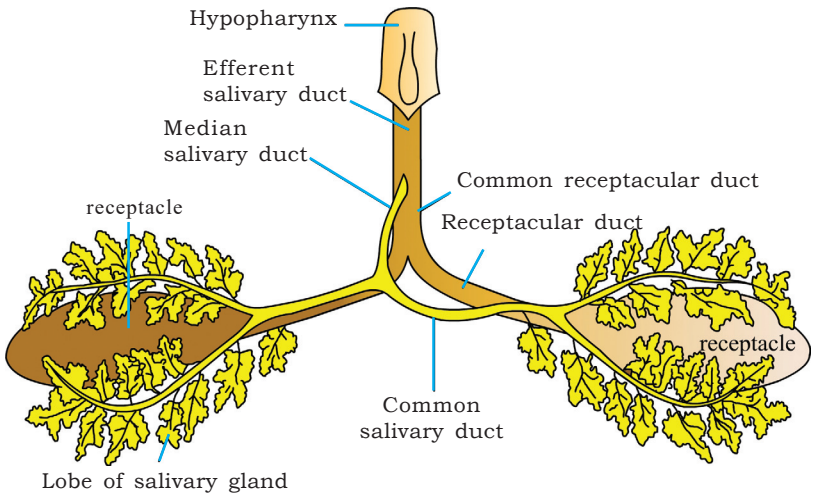


Fig. 7.5 *Periplaneta* : Salivary glands

The two common salivary ducts are joined to form the **median salivary duct.** Between the two lobes of a salivary gland of each side is a sac called **salivary receptacle** that stores saliva. It leads into a **receptacular duct**, or 'reservoir duct'. The receptacular ducts of both the sides are united to form a **common receptacular duct**, or 'common reservoir duct'. The median salivary duct opens into the common receptacular duct. Later these two form an **efferent salivary duct**. The efferent salivary duct opens at the base of the hypopharynx. Acinar cells secrete saliva, which contains starch digesting enzymes such as **amylase**.

2. Hepatic caecae

The hepatic caecae are also termed 'midgut caecae'. They contain secretory and absorptive cells.

3. Glandular cells of the mesenteron

The glandular cells of the mesenteron secrete enzymes such as **maltase**, **invertase**, **proteases** and **lipase**.

III. Physiology of Digestion

a) **Food collection:** Cockroach is an **omnivorous** insect. It feeds on all types of organic matter. It locates the food by the olfactory sensillae of antenna, labial palps and maxillary palps. The food is seized with the help of forelegs, labrum and labium. It is passed to the mandibles for biting and chewing. The laciniae, galeae, glossae and paraglossae hold the food during chewing. The labrum and labium prevent the food from falling down. The food is mixed with saliva during mastication.

b) **Digestion:** After swallowing, the food passes through the pharynx and oesophagus, and reaches the crop. In the crop, food is mixed with digestive juices that are regurgitated into it through the grooves of the gizzard. Hence, most of the food is digested in the crop. The partly digested food is filtered by the bristles of the gizzard and later it passes through the stomodeal valve into the ventriculus.

The enzyme amylase of the salivary juice converts starches into **disaccharides**. **Invertase** or sucrase digests sucrose into **glucose** and **fructose**. Maltase converts maltose into **glucose**. The enzyme lipase digests lipids into **fatty acids** and **glycerol**. Proteases digest proteins into amino acids. Cellulose of the food is digested by the enzyme **cellulase** secreted by the microorganisms present in the hindgut of cockroach. Cellulose is converted into glucose.

In the ventriculus, the digested food is absorbed. The undigested food is passed into the ileum, colon, and then reaches the rectum, where water is reabsorbed by rectal papillae. Then the remaining material is finally **defaecated** as **dry pellets**, through the anus.

The crop of *Periplaneta* does not secrete any digestive enzymes, but most of the food is digested in it. Explain how it is possible?

7.5 Circulatory System of *Periplaneta*

The circulatory system helps in the transportation of digested food, hormones etc., from one part to another in the body. Periplaneta has an **open type** of circulatory system as the blood, or haemolymph, flows freely within the body cavity or haemocoel. Blood vessels are poorly developed and open into spaces. Visceral organs located in

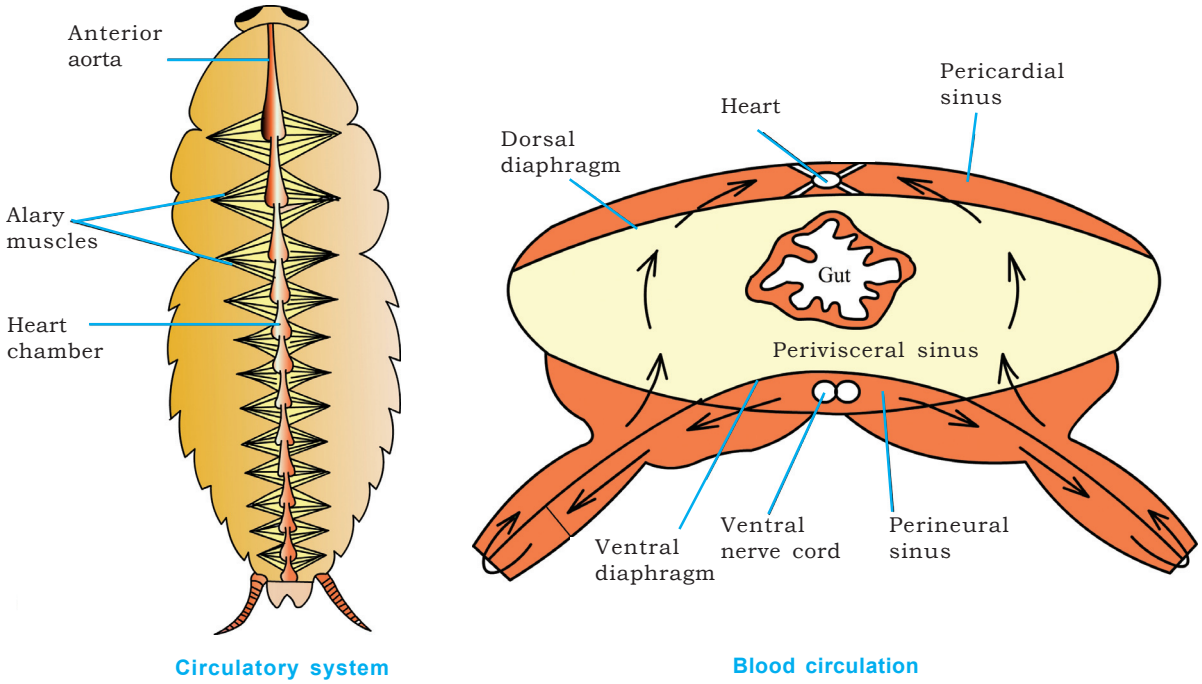


Fig. 7.6 *Periplaneta* : Circulatory system

the haemocoel are bathed in the haemolymph. The three main parts associated with the blood circulatory system of *Periplaneta* are the haemocoel, heart, and blood.

1. Haemocoel: The haemocoel of cockroach is divided in to three sinuses by two muscular, horizontal membranes, called **dorsal diaphragm** or 'pericardial septum' and **ventral diaphragm.** Both the diaphragms have valvular pores. There is a series of paired triangular muscles, called **alary muscles.** Every segment has one pair of these muscles situated on the lateral sides of the body. These are attached to the pericardial septum by their broad bases and to the terga by their pointed ends or apices. The three sinuses of the haemocoel are known as **pericardial haemocoel** or the '***dorsal sinus*',** the **perivisceral haemocoel** or the '**middle sinus**' and **sternal haemocoel** or '**ventral sinus**' or '**perineural sinus**'. The middle sinus is very large as it encloses most of the visceral organs. The dorsal and ventral sinuses are small in size and they enclose **heart** and **nerve cord**, respectively.

2. Heart

The heart lies in the pericardial haemocoel or dorsal sinus. It is a long, muscular, contractile tube found along the mid dorsal line, beneath the terga of the thorax and abdomen. It consists of 13 chambers. Every chamber opens into the other present in front of it through valvular openings. Three of the thirteen chambers are situated in the thorax and ten in the abdomen. Its posterior end is closed while the anterior end

is continued forward as the anterior **aorta**. At the posterior side of each chamber, except the last, there is a pair of small apertures called '***ostia***' one on each side. Ostia have valves which allow the blood to pass only into the heart from the dorsal sinus.

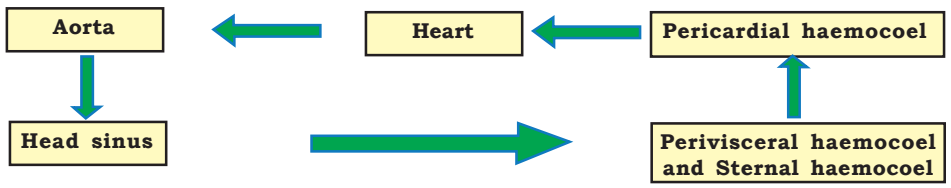
3. Circulatory fluid

The circulatory fluid of *Periplaneta* is colourless and is called **haemolymph**. It consists of a fluid called plasma, and free corpuscles or haemocytes, which are 'phagocytic'. The phagocytes are large in size and can 'ingest' foreign particles such as bacteria. There is no respiratory pigment in the blood and so it plays no major role in respiration. The important functions of the blood are:

1. It absorbs digested food from the alimentary canal and distributes it to the rest of the body.
2. It brings nitrogenous wastes from all parts of the body to the excretory organs for their elimination.
3. It carries defensive phagocytes to the places of infection where they engulf the germs and disintegrating tissue parts.
4. It transports secretions of the ductless glands to the target organs.

4. Circulation of blood

The blood flows forward in the heart by the contractions of its chambers. At the anterior end of the heart, the blood flows into the aorta and from there it enters the sinus of the head. From the head sinus, the blood flows into the perivisceral and sternal sinuses. On contraction of the alary muscles the pericardial septum is pulled down. This increases the volume of the pericardial sinus. Hence blood flows from the perivisceral sinus into the pericardial sinus through the appertures of the pericardial septum. On relaxation of the alary muscles, the pericardial septum moves upwards to its original position. This forces the blood, to enter the chambers of the heart through the ostia from the pericardial sinus.



Course of circulat ion of blood in *Periplaneta*

7.6 Respiratory System of *Periplaneta*

Due to the absence of respiratory pigment, the blood of cockroach is colourless and it cannot carry oxygen to different tissues. Therefore a tracheal system is developed to carry the air directly to the tissues. The respiratory system of cockroach consists of stigmata, tracheae and tracheoles.

1.Stigmata or **spiracles:** The tracheal system communicates with the exterior by ten pairs of openings called **stigmata** or **spiracles**. The first two pairs of spiracles are present in the thoracic segments, one pair in the mesothorax and one pair in the metathorax. The remaining eight pairs are present in the first eight abdominal segments. Spiracles are located in the pleura of their respective segments. The respiratory system in insects is classified on the basis of number and nature of spiracles. The respiratory system of cockroach is **polypneustic** (as there are more than 3 pairs of spiracles) and the spiracles are **holopneustic** (as all of them are functional). All spiracles are valvular and each of them is surrounded by a chitinous ring called **peritreme**. All spiracles bear small hair like structures called **trichomes** to filter the dust particles. Each spiracle opens into a small chamber called **atrium.**

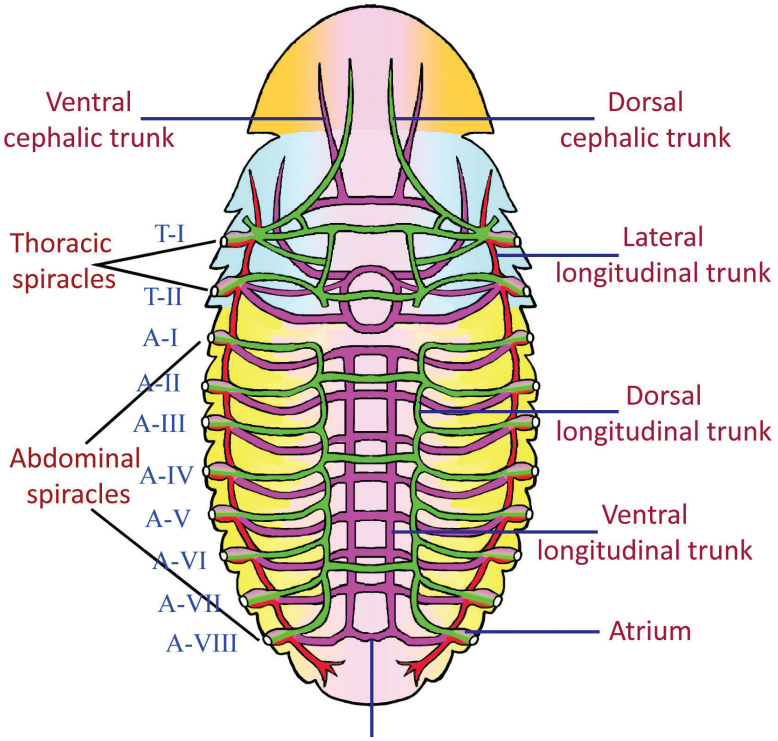


Fig. 7.7 *Periplaneta* : Tracheal system

2. Tracheae: From the atrium of each **thoracic spiracle** several horizontal tracheae run inside. They join with each other in the thorax to form many tracheal trunks like dorsal cephalic, ventral cephalic trunks and their branches. These branches enter all organs of the head. The thoracic region contains lateral longitudinal trunks also. The **abdominal spiracles** lead into atria. From the atrium of each abdominal spiracle three tracheal tubes arise. All these tracheal tubes of one side open into three separate longitudinal tracheal trunks. They are **lateral, dorsal** and **ventral longitudinal trunks.** Lateral longitudinal trunks are the longest tracheal trunks. The three pairs of longitudinal tracheal trunks of both the sides are interconnected by many **commissural tracheae**. From all the tracheal trunks several branches are given out, and they enter different organs. Each tracheal branch ends in a special cell called **tracheole cell**.

The wall of the tracheae is made of three layers. They are an outer **basement membrane,** a middle one cell thick **epithelium** and an inner layer of cuticle called **intima.** The intima is produced into **spiral** thickenings called **taenidia**. The taenidia keep the tracheae always open and prevent it from collapsing.

2. Tracheoles

The terminal cell of trachea is called **tracheoblast** or **tracheole cell.** It has several intracellular tubular extensions called **tracheoles**. Tracheoles are devoid of intima and taenidia. They are formed of a protein called **trachein.** Tracheolar fluid is present inside the tracheoles. The level of the tracheolar fluid varies with the metabolic activity of the insect. It is more when the insect is inactive and completely reabsorbed into the tissues, when the insect is more active. Tracheoles reach tissues/ cells and are intimately associated with mitochondria of the cells (to supply oxygen to them).

Which structures prevent the tracheae from collapsing?

4. Mechanism of respiration

Respiration includes two events, viz., inspiration and expiration. The muscles helpful are **dorsoventral muscles** and **ventral longitudinal muscles**. Dorsoventral muscles are the principal muscles of respiration.

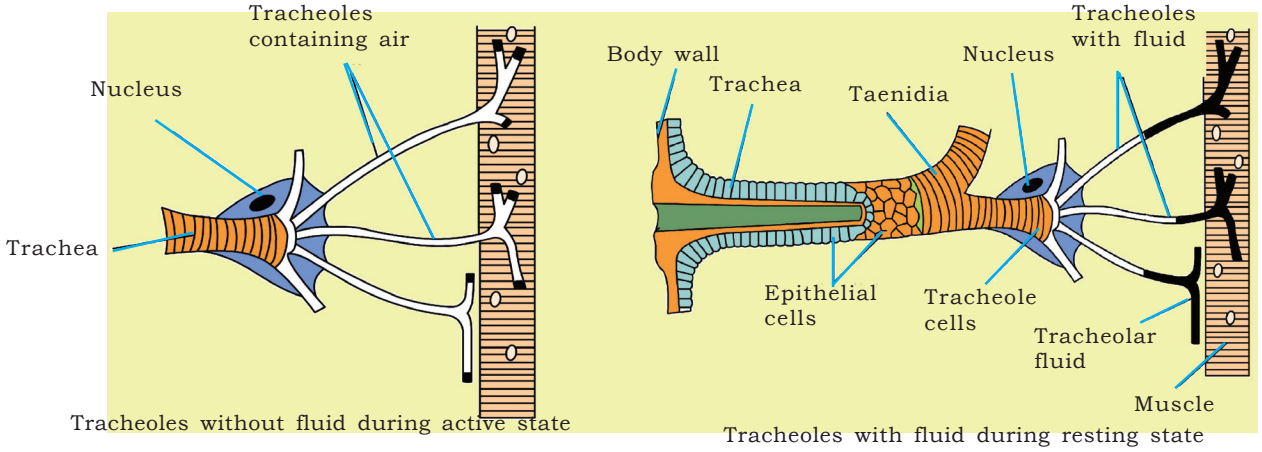


Fig. 7.8 *Periplaneta* : Tracheoles showing movement of tracheolar fluid during respiration

A. Inspiration

Taking in of air is called **inspiration**. It is effected by the relaxation of the dorsoventral muscles and ventral longitudinal muscles. Due to the relaxation of the dorsoventral muscles, tergal plates are elevated and the volume of the body cavity increases. Due to the relaxation of the ventral longitudinal muscles, the telescoped segments come to the **normal position**. So the volume of the body cavity increases in the longitudinal axis. As air is drawn in due to the relaxation of the muscles, the process is a 'passive' process. During inspiration the thoracic spiracles are kept open and the abdominal spiracles are kept closed.

B. Expiration

Sending out air from the body is called **expiration.** On contraction the dorsoventral muscles depress the tergal plates. Body cavity decreases in size and pressure increases. Due to the contraction of the ventral longitudinal muscles, the segments are telescoped and the volume of the body cavity decreases in the longitudinal axis increasing the pressure further. As this process involves the contraction of muscles, expiration is described as an active process. During expiration thoracic spiracles are closed and abdominal spiracles are kept open.

5. Exchange of gases

As air enters the tracheoles, oxygen from the air is taken into the cells and CO_2 is released into haemolymph. The CO_2 from the haemolymph mostly goes out through the inter-segmental membranes of the body wall. Cockroach and some other insects such as grasshoppers and beetles exhibit the phenomenon of **discontinuous ventilation**. In this mode of respiration continuous exchange of gases is interrupted by extended periods during which spiracles remain closed. The expulsion of CO_2 from the body occurs **in bursts**, when the spiracles are open. The exchange of gases depends on the metabolic rate and temperature. When air enters the tracheoles, oxygen diffuses faster into the tissues due to its high partial pressure. At the same time the carbon dioxide of tissues, instead of passing into the tracheal system, goes into the haemolymph. Carbon dioxide is carried more quickly into the haemolymph due to its greater solubility in it. This CO_2 accumulates near the spiracles and diffuses into the artial chambers near the spiracles and goes out in **'bursts'** through the *abdominal spiracles*. **Opening and closing of spiracles is influenced by CO_2 tension in haemolymph and oxygen tension in the tracheae**.

Which factors regulate the opening and closure of spiracles in *Periplaneta*?

7.7 Excretory System of *Periplaneta*

The excretory system of cockroach helps in eliminating the nitrogenous wastes from the body in the form of **uric acid.** So *Periplaneta* is called a **uricotelic** animal. The structures associated with excretory function are: **Malpighian tubules**, **Fat bodies**, **Uricose glands**, **Nephrocytes** (Ref. NCERT) and **Cuticle**.

1. Malpighian tubules : The malpighian tubules are long, unbranched yellowish tubules, attached at the extreme anterior end of the hindgut, lying freely in the haemolymph, but do not open into it, being blind at the free ends. They are 100-150 in number arranged in 6-8 bundles, each bundle having 15-25 tubules. **Marcello Malpighi**, described these tubules and called them **vasa varicosa**. **Meckel** called them **Malpighian tubules**. Each tubule is lined by a single layer of glandular epithelium with a ***brush border*** on the inner surface. The 'distal portion' of the tubule is **secretory** and the 'proximal part' is **absorptive** in nature.

The glandular cells of the malpighian tubules absorb water, salts, CO_2 and nitrogenous wastes from the haemolymph and secrete them into the lumen of the tubules. The cells of the proximal part of the tubules reabsorb water and certain inorganic salts. By the contraction of the tubules urine is pushed into the ileum. More water is reabsorbed from it, when it moves in to the rectum and almost solid uric acid is excreted along with faecal matter.

The removal of nitrogenous waste material through the alimentary canal helps in complete reabsorption of water from the wastes and formation of dry uric acid. It is an adaptation for **conservation of water** which is very important in terrestrial organisms.

Is sending out nitrogenous wastes in the form of uric acid advantageous to cockroach? If so, how?

2. Fat bodies: Fat body is a lobed white structure. Urate cells present in these bodies are associated with excretion in a way. These cells absorb and store uric acid throughout the life. This is called **'storage excretion'** as they remain stored in the urate cells of the **corpora adiposa**.

3. Uricose glands: Uric acid is stored in **uricose gland** or **utriculi majores** of the mushroom gland in male cockroach. It is discharged during copulation.

4.Cuticle: Some nitrogenous waste materials are deposited on the cuticle and eliminated during moulting.

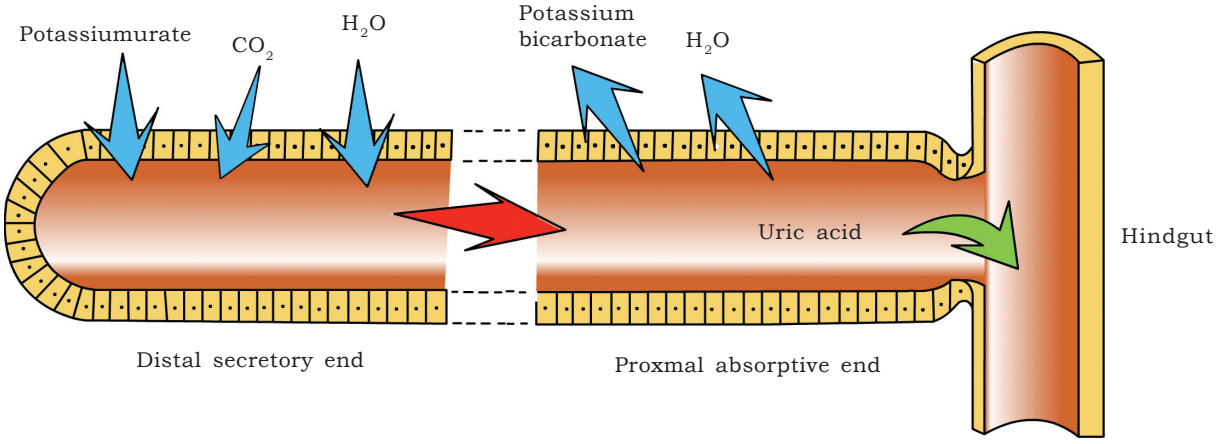


Fig. 7.9 *Periplaneta* : Excretory process in malpighian tubule

7.8 Nervous System and Sense Organs of *Periplaneta*

The nervous system of cockroach consists of central nervous system, peripheral nervous system and autonomous nervous system.

7.8.1 Nervous System

I. Central Nervous System

It consists of a **nerve ring**, and a **ganglionated double ventral nerve cord**.

1. Nerve ring

The nerve ring, which is present around the oesophagus, is formed by the following.

A. Brain

Brain lies above the oesophagus. The brain is mainly a sensory and an endocrine centre. Three lobes of the brain are **protocerebrum, deutocerebrum** and **tritocerebrum**. The protocerebrum receives sensory impulses from the compound eyes through optic nerves; deutocerebrum receives sensory impulses from antennae through antennal nerves; and tritocerebrum receives sensory impulses from the labrum. Hence brain is principally '**sensory**' in nature.

B. Sub-oesophageal ganglion

It lies below the oesophagus. It is the principal *motor center,* that controls the movements of ***mouthparts***, ***legs*** and ***wings***. It is formed by the fusion of ***paired ganglia*** of mandibular, maxillary and labial segments of the head.

C. Circum-oesophageal connectives

A pair of circum-oesophageal connectives is present around the oesophagus, connecting the tritocerebrum with the sub-oesophageal ganglion/ sub oesophageal ganglia.

2. Ventral nerve cord

The two ventral nerve cords are solid and ganglionated. They arise from the sub-oesophageal ganglion and extend upto the 7th abdominal segment. The two

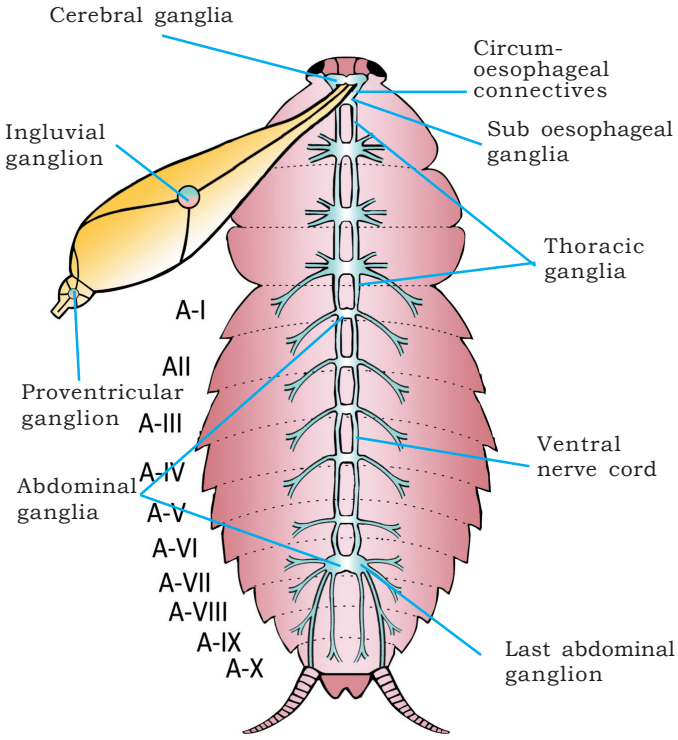


Fig. 7.10 *Periplaneta* : Nervous system

nerve cords remain separate except at the ganglia. Three thoracic ganglia are present, one in each thoracic segment. In addition, there are six abdominal ganglia. The first to the fourth abdominal segments have one abdominal ganglion each. The 5th abdominal segment has no ganglion. The serially 5th abdominal ganglion is present in the 6th segment. The serially 6th abdominal ganglion is present in the 7th segment. The last or the 6th abdominal ganglion is the *largest* of all the abdominal ganglia. It is formed by the fusion of the ganglia of the 7th, 8th, 9th, and 10th abdominal segments.

II. Peripheral Nervous System

It consists of nerves arising from the central nervous system .It receives a pair of, **optic nerves**, from the compound eyes, a pair of **antennal nerves,** from the antennae and a pair of **labral nerves**, from the labrum. Motor neurons of the frontal nerve to the **frontal ganglion** join the sensory neurons of the labral nerve to form the **labro-frontal nerve** arising from the tritocerebrum. Sub-oesophageal ganglion gives off motor nerves to the mandibles, maxillae, labium, wings and legs . It is the principal 'motor centre' in the body.

Thoracic ganglia supply nerves to the parts of their respective segments. Metathoracic ganglia send nerves to the first abdominal segment also. Nerves from the first four abdominal ganglia supply to the organs of the segments 2-6 serially (the 1st to the 4th ganglia innervate segments 2nd to 5th respectively). The 5th ganglion present in the 6th segment innervates the organs of the 6th segment. All organs present in 7th to 10th segments receive nerves from the last abdominal ganglion (present in the 7th segment). The organs include the reproductive organs, copulatory appendages besides anal cerci.

If the sub-oesophageal ganglion is damaged hypothetically, which parts of the cockroach are affected?

III. Autonomous Nervous System

This system is also called **stomatogastric nervous system** or 'visceral nervous system'. It controls the visceral organs, particularly the muscles of the alimentary canal, and the heart. Autonomous nervous system includes four ganglia, a **frontal ganglion** on the dorsal wall of the pharynx, in front of the brain, **hypocerebral ganglion** or occipital ganglion above the oesophagus, behind the brain, a **visceral ganglion** or **ingluvial ganglion** on the wall of the crop and a **proventricular ganglion** on the gizzard. These ganglia contain the 'somata' of the post ganglionic motor neurons. Preganglionic motor neurons of tritocerebrum go to the frontal ganglion as labro-frontal and frontal nerve. Frontal ganglion is connected to the hypocerebral ganglion by a '**recurrent nerve**'. Hypocerebral ganglion is connected to the visceral ganglion and in turn the visceral ganglion is connected to proventricular ganglion.

The movements of which organs in cockroach are controlled by its autonomous nervous system?

7.8.2 Sense organs

In cockroach, various structures like antennae, labrum, maxillary palps, labial palps, compound eyes, simple eyes (**fenestrae**) etc., are sensory in nature. These structures contain various receptors like chemoreceptors, mechanoreceptors, photoreceptors, thermoreceptors, etc. Simple eyes and **ommatidia** of a compound eye are photoreceptors. **Sensillae** are the units of cuticular receptors and chemoreceptors**.** **Scolopidia** are the subcuticular units of mechanoreceptors of **chordo-tonal organs** (**Johnston's organs** in the antennal pedicels and flagella, **subgenual organs** on the proximal parts of tibiae and **tympanal organs** on the anal cerci; they are sensitive to movement of flagella of antennae , ground vibrations and sound vibrations respectively).

I. Compound eye

A pair of dark kidney shaped compound eyes is present on the dorsolateral sides of the head, one on each side. Each compound eye is composed of about 2000 functional units called **ommatidia**, which are optically independent. The outer surface of the compound eye is divided into about 2000 hexagonal areas called **facets**. Each facet is the outermost portion of a corrsesponding ommatidium.

1. Structure of an Ommatidium

Each typical ommatidium is an elongated sub unit of the compound eye, consisting of the following parts.

1. **Cornea:** It is the outermost part of an ommatidium and corresponds to a 'hexagonal facet' of the compound eye. It is a biconvex, transparent part of the cuticle and allows light to pass through it. Cornea is secreted by specialized **corneagen cells** of the epidermis. Cornea is a 'refractive' region of an ommatidium.
2. **Corneagen cells** or **lenticular cells:** These are two transparent specialized epidermal cells that secrete cornea.

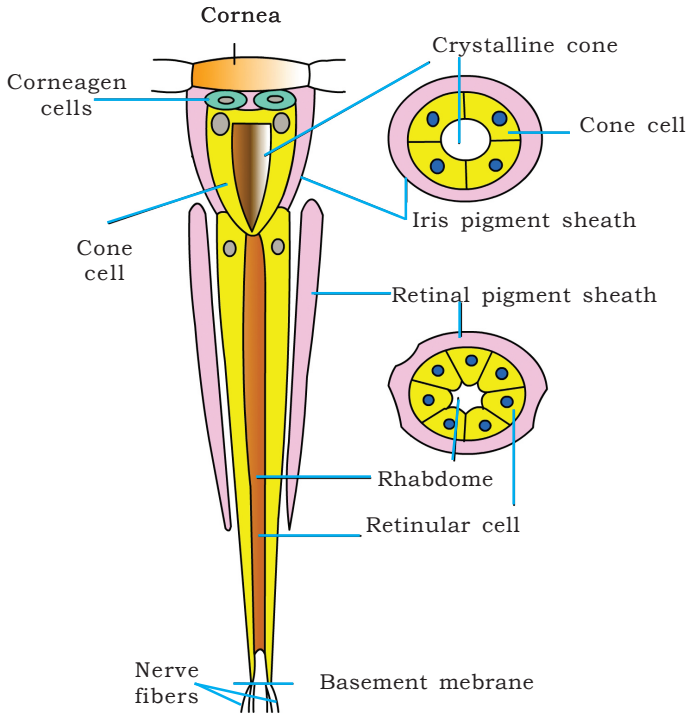


Fig. 7.11 Structure of a typical ommatidium

3. **Vitrellae** or **cone cells (Semper cells):** These are four transparent more or less conical cells that lie below the corneagen cells. They surround the transparent crystalline cone. Crystalline cone is secreted by the cone cells.
4. **Crystalline cone:** It is the transparent conical structure that is secreted by the vitrellae and is surrounded by them. Light absorbing dark primary pigment cells surround the vitrellae. The region containing the cornea and crystalline cone constitute the **dioptrical** or 'focussing region' of the ommatidium. Crystalline cone focuses the light on to the next part of the ommatidium.
5. **Retinulae:** These are the innermost and elongated cell of an ommatidium. They are seven in number. They rest on the basement membrane. Each cell bears microvilli towards the inner surface. Microvilli of each retinular cell collectively form a **rhabdomere** that contains photoreceptor pigments. These rhabdomeres fuse along the axis of the ommatidium to form the **rhabdome** in the centre. Retinulae are the nerve cells from which sensory nerve fibers leave as the optic nerve to the protocerebrum. They are the **photoreceptor** cells of the ommatidium. Rhabdome and retinulae form the retinal or receptor region. Receptor region is surrounded by seven secondary pigment cells, which absorb light and serve to isolate each ommatidium from the rest (retinal pigment sheath).

2. Functioning of an ommatidium: The position of retinulae below the vitrellae or cone cells, is different in diurnal and nocturnal insects. The two types of images formed in ommatidia of the diurnal and nocturnal insects are the **apposition image** and **superposition image**, respectively.

A. Apposition image: These images are formed in diurnal insects like houseflies in which the retinulae lie immediately below the vitrellae and crystalline cone. These are surrounded by secondary pigment cells, which absorb light rays and prevent them from passing to the adjoining ommatidium. In this type, light rays entering the cornea of a single ommatidium only converge on the rhabdome. Thus, a small part of the visual field is focused on to the receptor part in each ommatidium. The total image formed by the compound eye is a **mosaic** of several **small images.** Such an image is called **apposition image** because it is formed by the juxtaposition of small parts of the visual field. This type of vision is called **mosaic vision.**

B. Superposition image: These images are formed in nocturnal insects like **cockroach** in which the retinulae are present deep below the vitrellae and crystalline cone. Retinal sheath is absent. Therefore, the rhabdome and retinulae of an ommatidium receive not only light rays that enter through its own cornea but also light rays that enter through the corneas of the adjoining ommatidia. This results in the overlapping of images. The image formed by overlapping of images is called '***superposition image***'. It is a '*blurred (nor clear) image*'.

II. Ocelli: At the base of each antenna is a fenestra which represents a simple eye or ocellus. Each ocellus consists of a single corneal facet. These are not involved in image formation but are very sensitive to changes in light intensity.

III. Other sense organs

a. **Olfactory sensillae** (a type of chemo receptors)**,** which are sensitive to smell, are present on the **maxillary palps**, **labial palps** and **antennae**.

b. **Gustatory sensillae** (a type of chemoreceptors), which are sensitive to taste, are present on the **labrum**, **maxillary palps** and **labial palps**.

c. **Thermoreceptor sensillae** (receptors of temperature) occur on the 1st, 2nd, and 3rd segments of the 'tarsi' of the legs.

How is the overlapping of images prevented in diurnal insects?

7.9 Reproductive System of *Periplaneta*

Periplaneta is dioecious, or unisexual, and both the sexes have well developed reproductive organs. The sexual dimorphism is evident both externally and internally. The female is different from the male in respect of short and broad abdomen, presence of brood pouch and absence of anal styles.

7.1.2 Male Reproductive System

The male reproductive system consists of a pair of **testes.** These are elongated and lobed structures lying one on each lateral side in the **fourth** to **sixth abdominal segments**. They are embedded in the fat bodies. From the posterior end of each testis, there starts a thin duct, the **vas deferens**. The two vasa deferentia run backwards and inwards to open into a wide median duct, the **ductus ejaculatorius** in the seventh segment. A characterstic **mushroom shaped gland** is present in the 6th and 7th abdominal segments which functions as an accessory reproductive gland.

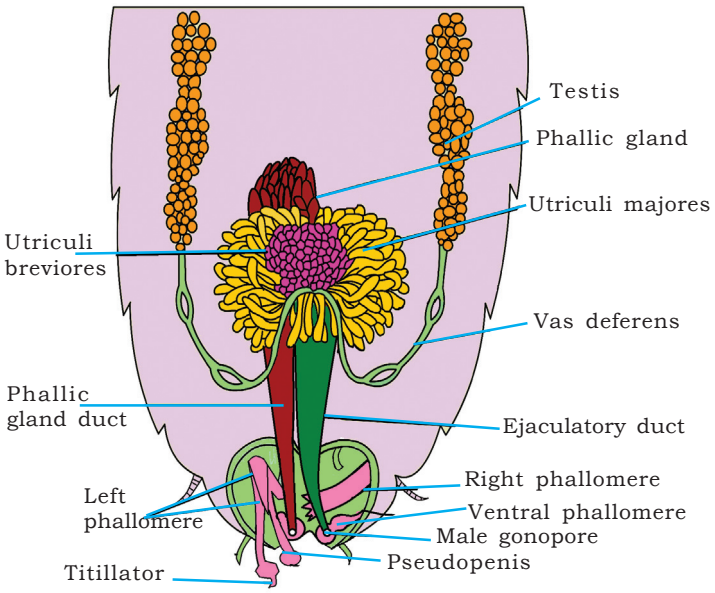


Fig. 7.9 *Periplaneta* : Male reproductive system

The gland consists of two types of tubules: **i)** long slender tubules, the **utriculi majores** or 'peripheral tubules'. **ii)** Short tubules, the **utriculi breviores**. Secretion of utriculi majores forms the inner layer of the spermatophore while that of utriculi breviores nourishes the sperms. These tubules open into the anterior part of the **ejaculatory duct**.

The **seminal vesicles** are present on the ventral surface of the ejaculatory duct. These sacs store the sperms in the form of bundles called **spermatophores**. The ejaculatory duct is a muscular tube that extends posteriorly and opens at the **gonopore** or the 'male genital pore' on the ventral phallomore. The duct of **phallic** or **conglobate gland** also opens near the gonopore. Its function is still not known. Surrounding the male genital opening there are three chitinous and asymmetrical structures called **phallic** organs or **gonapophyses** or **phallomeres** which help in copulation. These are the male external genitalia. The term phallow refers to 'penis'. The left phallomere bears a pseudopenis and titillator.

Note: Ejaculatory duct is believed to secrete the middle layer and the conglobate gland secretes the outer layer of a spermatophore.

7.9.2 Female Reproductive System

The female reproductive system of *Periplaneta* consists of a pair of ovaries, a pair of oviducts, vagina, spermathecae, spermathecal papilla, and colleterial glands.

Ovaries

A pair of large **ovaries** lies laterally in 2 to 6 abdominal segments. They are light yellow in colour surrounded by fat bodies. Each ovary consists of eight tubules called ovarian tubules or **ovarioles**. Each ovariole consists of a tapering anterior filament called **germarium**, and a posterior wider **vitellarium**. The germarium contains various stages of developing ova, and the vitellarium contains mature ova with yolk. The tapering ends of the ovarioles of each ovary unite to form a single thread which attaches to the dorsal body wall. The ovarioles, at their posterior end unite to form a short wide **oviduct**. The oviducts unite to form a very short median **vagina**. The vertical opening of the vagina is called female genital pore. It opens into a large genital pouch on the eighth sternum. A spermatheca or '**receptaculum seminis**', consisting of a left-sac like and a right filamentous caecum, is present in the 6th segment which opens by a median aperture on a small spermathecal papilla in the dorsal wall of the genital pouch on the ninth sternum. In a fertile female, the spermatheca contains spermatophores, received during copulation.

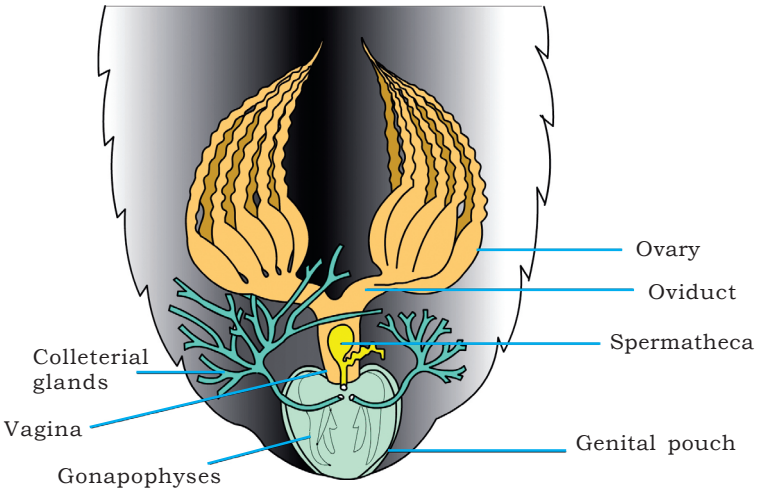


Fig. 7.9 *Periplaneta* : Female reproductive system

A pair of branched **colleterial glands** is present behind the ovaries. These glands open in to the genital pouch separately, just above the

spermathecal aperture. Secretion of the two collaterial glands forms a hard egg case called **ootheca** around the eggs.

Genital or brood pouch is formed by 7th, 8th, and 9th abdominal sterna. The sternum of the seventh segment is boat shaped and forms the floor and side walls of the genital pouch. The sterna of the eighth and ninth segments,which are tucked into the seventh segment, constitute the anterior wall and the roof of the genital pouch, respectively. The genital pouch has two chambers the anterior 'gynatrium' or **genital chamber** and posterior 'vestibulum' or **oothecal chamber.**

Three pairs of plate like chitinous structures called gonapophyses are present around the female genital aperture. These gonapophyses guide the ova into oothecal chamber acting as ovipositors. These are the *female external genitalia*, which help in copulation also.

7.9.3 Life history

The fertile female produces certain **pheromones** (chemical substances useful in chemocommunication) , that attract the males for copulation. Copulation occurs during summer and it takes place during the night time. For copulation the male and female cockroaches bring their posterior ends very close. The male deposits a spermatophore on the spermathecal papilla of the female with the help of its phallomeres.

In *Periplaneta* sixteen eggs mature at a time and are passed into genital chamber.Fertilisation occurs in the gynatrium. The secretions of collaterial glands form the egg case or **ootheca** around the fertilized eggs in the oothecal chamber. The ootheca is dark reddish to blackish brown capsule. It contains 16 eggs arranged in two rows of eight each. The oothecae are deposited at a suitable warm and dark place. On an average, female produces 9-10 oothecae. The development of eggs occurs inside the ootheca. Cockroach is **paurometabolous**, which means the development (metamorphosis) is gradual through nymphal stages. The eggs in ootheca undergo cleavage resulting in blastula followed by gastrula. Further development results in the formation of a **nymph**. It (nymph) is a young cockroach hatching from the ootheca. It resembles the adult, except in size, colouration, sexual immaturity and absence of wings. After hatching, the nymphs feed and undergo a series of 13 moultings or ecdyses. Shedding of exoskeleton is called '**moulting**' or '**ecdysis**'. After the last ecdysis the nymph grows into fully formed adult, with wings (the nymphs bear small wing pads).

Note: Moulting permits growth in the size of the nymph.

What do you name the young one of a cockroach which resembles the adult except in size, wings, colour and genitalia?

GLOSSARY

Abdomen: Third or posterior division (tagma) of an insect

Antenna: A sensitive feeler from the animals head; tactile and olfactory in function

Appendage: A movable projecting part of the body; mouth parts are modified appendages.

Arolium: A soft hairy pad between claws in the leg of cockroach.

Arthropod: A phylum of segmented invertebrates with jointed legs.

Biramous: Possessing two branches e.g. the exopodite and endopodite.

Blastula: Embryonic stage with blastocoel, which is also called the 'primary body cavity'.

Cephalic: Relating or to the head.

Cervix: Neck.

Chitin: A polysaccharide-protein complex; a horny substance.

Copulation: Sexual process/union for the transfer of sperm from one to another of mating partner.

Cursorial: Swift runner.

Cuticle: External skeletal structure of the insect's body; it has epicuticle, mesocuticle and endocuticle.

Dioecious: Species population in which male and female organs occur in separate individuals.

Dioptric region: The part that focuses light rays on to the inner part of an ommatidium .

Ecdysis: Shedding of the outer body layer (cuticle).

Germarium: Tapering anterior filament of an ovariole.

Haemocoel: The body cavity of an arthropod or a mollusk filled with haemolymph; derived from the blastocoels of the embryo ; also called the 'primary body cavity'

Nervures: Tubular hollow network of the wing of a cockroach.

Ootheca: A hard purse like structure containing eggs in two rows.

Ovariole: A single tubule of an ovary containing developing eggs.

Paurometabolic: Gradual development/ metamorphosis by the nymphal stages of certain insects.

Podomere: A segment of an arthropod leg.

Pulvillus: A soft hairy pad between claws.

Sternum (plural: sterna): A ventral sclerite of a body segment of insects such as a cockroach.

Tagma (plural: tagmata): One of the regions of the body of an insect; division of the body into different regions is called tagmatisation.

Tergum (plural: terga) : Dorsal sclerite of the body segment of an insect.

VERY SHORT ANSWER TYPE QUESTIONS

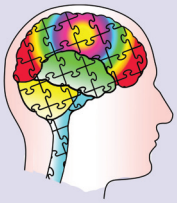
1. What are the structures with which cockroach walks on smooth surfaces and on rough surfaces respectively?
2. How is a tripod formed with reference to locomotion in cockroach?
3. Name the muscles that help in elevating and depressing the wings of a cockroach?
4. Name the different blood sinuses in cockroach?
5. How are the fat bodies similar to the liver of the vertebrates?
6. Which part of the gut secretes the peritrophic membrane in cockroach?
7. In which part of the gut of cockroach, water is reabsorbed?
8. Write the names of mouthparts in cockroach that help in biting and tasting the food.
9. What are alary muscles?
10. What is haemocoel?
11. Why is the blood of *Periplaneta* called haemolymph?
12. What is the function of haemocytes found in the blood of *Periplaneta*?
13. Write important functions of blood in *Periplaneta*?
14. What are trichomes? Write their functions.
15. Why is the respiratory system of cockroach called polypneustic and holopneustic system?
16. What is intima?
17. During inspiration which spiracles are kept open and which are kept closed?
18. Which factors regulate the opening of the spiracles?
19. The nitrogenous wastes in *Periplaneta* are removed from the body through alimentary canal. Why?
20. How do fat bodies help in excretion?
21. Which structure of cockroach acts as sensory and endocrine centre?
22. Distinguish between scolopidia and sensillae.
23. Which of the abdominal ganglia is the largest and why?
24. Why is the brain called the principal sensory centre in cockroach?
25. Distinguish between apposition image and superposition image.
26. List out the characters that help in understanding the difference between male and female cockroaches.
27. What is the function of mushroom gland in cockroach?
28. Compare the utriculi majores and utriculi breviores of the mushroom gland functionally.
29. What are gonapophyses?
30. How is colleterial gland helpful in reproduction of *Periplaneta*?

SHORT ANSWER TYPE QUESTIONS

1. Draw a neat labeled diagram of the mouthparts of cockroach?
2. Describe the physiology of digestion in cockroach?
3. Draw a neat labeled diagram of the salivary apparatus of cockroach?
4. Describe the structure and function of the heart in Periplaneta?
5. Describe the process of blood circulation in Periplaneta?
6. What are different excretory organs in Periplaneta? Describe the process of excretion in detail.
7. How does Periplaneta conserve water? Explain it with the help of excretion in it?
8. Draw a neat and labeled diagram of ommatidium.
9. Describe the male reproductive system of cockroach.
10. Describe the female reproductive system of cockroach?

LONG ANSWER TYPE QUESTIONS

1. Describe the digestive system of cockroach with the help of a neat labelled diagram?
2. Describe the blood circulatory system of *Periplaneta* in detail and draw a neat and labelled diagram of it?
3. Describe the respiratory system of cockroach with the help of neat and labelled diagrams?
4. Describe the reproductive system of *Periplaneta* and draw neat and labeled diagrams of it.



For ignited minds

- NOT FOR EVALUATION

1. Do you know that animals send out nitrogenous wastes in the form of ammonia, urea, uric acid, guanine, etc. Ammonia is the ***most toxic substance*** and it can be sent only in very dilute form. It requires loss of more water (urine is hypotonic). Some fishes excrete ammonia (ammonotelic), as availability of water is not a problem for them. Urea is relatively less toxic and it can be sent out with relatively less water. Frog, earthworm etc., send out wastes mostly in the form of urea(ureotelic).
   ***Note*:** Do you know that urea is formed mostly in our liver via the ornithine cycle? Uric acid is the least toxic substance and so it can be sent out in a concentrated form. So, animals such as reptiles, birds and insects for which conservation of water is very important send the wastes in the form of semisolid uric acid crystals (uric acid is insoluble in water, unlike ammonia and urea). Aquatic reptiles such as turtles excrete 'urea' like the mammals. However urine cannot be concentrated due to lack of Henle's loops in their nephrons. Now listout various types of aminals depending on the nitrogenous waste excreted and state reasons for their nature.
2. When prawn, scorpion etc., have an oxygen carrying pigment in their haemolymph, why is it not seen in the blood of cockroach? Think of it.
3. When the labrum is removed or labral nerves are cut off, cockroach does not lose its ability/sense of tasting food. Why?
   CLUE – Recall: functions of all appendages.
4. Why do insects moult in the early part of their life?
   CLUE: It has something to do with growth.
5. The compound eye of cockroach, in a way, is a better adaptation for survival, than the human eye. Do you agree with the statement? If so how do you substantiate? CLUE: As a human being, you can concentrate on only a particular part of your visual field only at a time, even though your visual field is much more larger/ wider.
6. What happens if the serially fifth abdominal ganglion is hypothetically damaged in a cockroach? The functioning of organs of which abdominal segment is affected?
7. What do you call the units of the mechanoreceptors in organ such as anal cerci?
8. If 20% of the ommatidia are damaged in each compound eye, a diurnal insect can see only 80% of the visual field. Do you agree with the statement? If so explain.
9. Why is storage of uric acid in corpora adiposa called storage excretion?
10. Of the following organs – antennae, mandibles, maxillae, legs and wings, which do you think is taxonomically significant when we think of insect such as a cockroach?
11. If the labro-frontal nerve is severed (cut off), will it affect the circulation of blood? How?
12. If the seminal receptacle of a cockroach is removed, and if copulation occurs soon after its removal what will be the effect on the reproductive ability of that cockroach?
13. The heart of a chordate is said to be myogenic (which means contraction is intiated in itself). If the heart is removed from the body it will keep beating provided some nourishing liquids such as Ringers solution is pumped through it. Will the same thing happen with the heart of the cockroach? Explain.
14. You know striated muscles appeared for the first time in the arthropods during evolution. Muscles need endo-skeletal parts for attachment. Cockroach does not have an endo-skeleton comparable to that of a chordate. Do you know how this problem of attachment surfaces is solved in cockroach? (Clue: Cuticle of cockroach shows inward extensions sich as abodemes).
15. If the mesothoracic wings such as apodemes of a cockroach are removed, do you think it can still fly? If so, give reasons.

The entire world and its ecology is your precious possession

'LIVE AND LET LIVE'

Unit

8

Ecology and Environment

The 'Address and 'Profession' of organisms - A holistic approach to the study of organisms

The branches of Biology such as 'morphology' and 'anatomy' give us a fairly good picture of organisms. However **Modern Biology** lays stress on studying the habitat, environment - organism relationship (**Ecology**) to get a more comprehensive idea of life. Ecology deals with the study of organisms and their interrelationships (biotic factors) and interactions with the surrounding environment (abiotic factors). Interactions between the organisms and the environment limit the distribution of life. The study of ecology encompasses different levels – organism, population, community, ecosystem, etc., An important feature that may not be easily noticeable to the eye of an observer is – the 'steady state' an organism maintains (homeostasis), with reference to its surrounding abiotic factors. This type of homeostasis is achieved by morphological, physiological and behavioural adjustments /mechanisms. Whichever organism is adapted better to its environment 'on a long term basis' is offered '**POSITIVE NATURAL SELECTION PRESSURE**'**.** Thus ecological adaptations play an important role in '**SPECIATION**'. For example animals such as polar bears grow thicker coat of 'fur' during winter to insulate the body from the cooler environment.Some insects add 'glycerol' (anti-freezing agent) to their haemolymph to avoid freezing in winter.Certain animals show behavioural adaptations to survive –e.g. lizards 'bask' in the sun to warm up their body when sunlight is available and enter shade /burrows when it is very hot out side. Many cold blooded animals are '**temperature conformers**' and they change their temperature depending on that of the surroundings. Homeostasis of water (because water is the most important

constituent of protoplasm) is exhibited by all organisms including the microscopic **protists** and **bacteria**.

An eminent animal ecologist, **ODUM**, used the ***analogy*** to explain an organism's place and its function thus- IF AN ORGANISM'S HABITAT (place where it lives) IS ITS '***ADDRESS***', ITS ECOLOGICAL ROLE/FUNCTION (also called '**niche**') IS THE '***PROFESSION***' OF THE ORGANISM. Underlying all these aspects there are two things that are critically essential to support life on the Earth –

a) Bio-geochemical Cycles nvolve uptake of various nutrients /minerals into the body, grow and ultimately return them to the environment to be '*recycled*' by other organisms, again and again.Thus 'life' comes from nature and goes back to nature – ***NATURE'S FUNDAMENTAL PRINCIPLE***, so to say.

b) The flow of 'ENERGY', mostly from the Sun, from one type of organism to another, 'uni-directionally', also has a major role to play in the LIFE on the Earth. It is important to 'preserve nature' without disturbing it too much, in the true spirit of by 'THINK GLOBALLY AND ACT LOCALLY' – a 'call' to the human race, given by the environmentalists in the **EARTH SUMMIT** of **Rio de Janeiro -** United Nations Conference on Environment and Development (***UNCED***).

There is an inbuilt '**hierarchy**' in organisms with reference to other neighbouring organisms and the environment in which they live **– individuals** –**populations** – **communities**- **ecosystems**- **biosphere** (global ecosystem). Mutations, gene recombinations, Natural selection process, etc., have important roles in the origin and distribution of organisms.With the origin of modern man, dispersal of organisms by man himself has become a part of this entire ecological world – the so called '**Human Effect**'. Exploring the ecology of organisms is a multidimensional, multidisciplinary task. It involves the study of 'population dynamics' and various allied factors such as natality, mortality,competition, predation, disease, space, food, shelter, influencing survival and propagation. Hunting, habitat destruction, overexploitation, modification of the environment by pollutants (**anthropogenic:** meaning '**man made**'), etc., are going to play a vital role in deciding the very existence of man on this planet. Let us not neglect the '**Greenhouse Effect**' and the related '**Global Warming'**, destruction of the **ozone layer** in the stratosphere due to excessive use of chlorofluorocarbons (**CFC**s) – each one is going to affect **life** in its own way gradually diminishing chances of survival. Do your part to save mankind from the brink of disaster.

Lastly - **can you guess what your address and profession are ?** Your address is the 'terrestrial environment' and your profession is, you are a 'CONSUMER' (Primary or secondary) and you are **perhaps** turning out to be '**self destroyer'** due to rapid urbanisation and 'conspicuous consumption' (over consumption).

Ecology and its Importance

Our living world is fascinatingly diverse and amazingly complex. We can try to understand its complexity by investigating processes at various levels of biological organization -macromolecules, cells, tissues, organs, individual organisms, population, communities and ecosystems and biomes.

8.0.1 What is Ecology?

Ecology is a subject which deals with the study of the interactions among organisms and between the organisms and their physical (abiotic) environment. The word 'ecology' was derived from the Greek term 'oikos' which means 'house', and 'logos' meaning 'study'. Ecology was defined by **Ernst Haeckel** as "**the study of the relationship of organisms with their environment**". The environmental science, ecology, has two main branches- **autecology**, and **synecology**. Autecology is the ecology of a single species / population in relation to its environment. It is also known as '**species**' (**population**) **ecology'**. Species ecology deals with the dynamics of 'species populations ' and how these populations interact with their surrounding environment. It also deals with the study of changes in population sizes (**population dynamics**), over a period of time. Synecology is a branch of ecology that deals with the structure, development, and distribution of '**ecological communities'**. A **community**, as you perhaps know, is a group of organisms of different species living together and interacting with the surrounding environment. Synecology / community ecology deals with the interrelationships between organisms of different species living in a specified area and their interactions with their surrounding environment. It takes into consideration the functional roles of different organisms of the community and also the **community dynamics**.

8.0.2 Importance of Ecology

Civilization initiated with the use of fire and making of tools which led to the modifications in the environment. Gradually the technological advancement changed the life styles and human beings totally forgot their responsibilities to their surroundings. The negligence or ignorance towards 'natural resources' and the

'**mother nature**', gradually led to the disintegration of nature. To overcome this problem, it is time that humans act and save the nature for the future generations. The knowledge of organisms, environment, and the interrelationships is vital for the conservation of the Nature.

8.1 Organisms and Environment

Ecology at the organism level is essentially **physiological ecology** which tries to understand how different organisms are adapted to their environments in terms of not only survival but also reproduction. You may have learnt in earlier classes how the rotation of our planet around the Sun and the tilt of its axis cause annual variations in the intensity and duration of light and temperature, resulting in the occurrence of distinct seasons. These variations together with annual variations in precipitation (rainfall) account for the formation of the major '**biomes**' such as **desert**, **rain forest** and **tundra**.

Regional and local variations within each biome lead to the formation of a wide variety of habitats. On the planet Earth, life exists not just in a few favourable habitats only but even in extreme and harsh habitats such as the hot Rajasthan desert, rain-soaked Meghalaya forests, deep ocean trenches, fast flowing streams, polar regions, high mountain tops, hot thermal springs, and stinking 'compost pits', to name a few. Even our intestine is a **unique habitat** for hundreds of species of microbes.

What are the key elements that lead to so much variation in the physical and chemical conditions of different habitats?

The most important ones are temperature, water, light and soil. We must remember that the physico-chemical (**abiotic**) components alone do not characterize the habitat of an organism completely; the habitat includes **biotic components** also - pathogens, parasites, predators and competitors - of the organism with which they interact constantly. We assume that over a period of time, organisms evolved adaptations for survival and reproduction, in their habitats through **Natural Selection**.

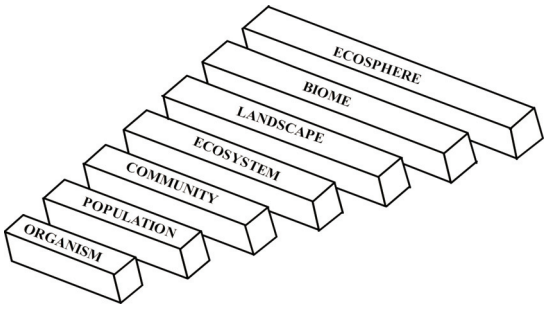


Fig. 8.1 Levels of organization

8.1.1 Levels of organization

Ecology is basically concerned with four levels of biological organization-**organisms**, **populations**, **communities** and **biomes**. In this chapter we explore ecology at organism and population levels.

Ecological Hierarchy means arrangement into a '**graded series**'. Ecological organization consists of eleven integrative levels, ranging from Cell to Ecosphere - cell, tissue, organ, organ- system, organism, population, community, ecosystem, landscape, biome and ecosphere (also called Biosphere).

1. Population

Population is a group of organisms of the same species, living in a specific area at a specific time. For example, the fish belonging to the species *Catla catla* living at a given time, in a pond constitute a 'population'. In the same way, the people (*Homo sapiens*) of India in 2012 form the **Indian population**. Populations are regulated by a set of factors such as **natality**, **mortality**, and **population density**.

2. Community

It is an association of the interacting members of populations of different autotrophic and heterotrophic species in a particular area. In a community, generally one or a few species dominate with reference to their numbers or size. Generally, a community is named after its dominant population. For example, the Himalayan region (at the altitude of 5000 to 8000 ft.) is dominated by the pine group plants – **deodar trees.** So, it is described as the **Pine-Deodar community**.

Fig. 8.2. Pine-deodar community

3. Ecosystem

It is the next level of organization above the level of *biological* ***community***. An ***ecosystem*** is a functional unit of the biosphere in which members of the community interact among themselves and with the surrounding environment, involving '***flow of energy***' forming a well defined **trophic structure**. An ecosystem can be as small as an aquarium or a tiny puddle. Ecosystems sometimes may overlap, as the boundaries of an ecosystem are flexible.

Fig. 8.3 Ecosystem

4. Landscape

It is the unit of land containing different ecosystems (mosaic of ecosystems) surrounded by natural boundaries. It is the level of organization higher than 'ecosystem'.

5. Biome

A 'biome' is a **large community of plants and animals** that occupies a vast **region**. There are 'terrestrial biomes' and 'aquatic biomes'. Terrestrial biomes are characterized by **specific climate** and **dominant vegetation** e.g. tropical rain forest, desert, coniferous forest, tundra etc. Aquatic biomes include freshwater biomes and marine biomes.

6. Ecosphere (Biosphere)

All the habitable zones on the Earth constitute the ecosphere or biosphere. It is the part of the Earth that supports 'life'. It extends several kilometers above the Earth's surface into the atmosphere and extends several kilometers below the ocean's surface. The biosphere comprises all of the Earth's biomes.

8.1.2 Environment

Environment is the sum total of biotic and abiotic factors present around the organisms influencing them in various ways. Any component of the environment that influences the organism is called **environmental factor**. The environmental factors are of three types i) climatic, ii) topographical, iii) edaphic.

i) Climate refers to average weather conditions like temperature, humidity, cloud cover, wind velocity, rainfall, etc.

ii) Topography refers to the surface features (physical features such as elevation / altitude) of a place or region. The topography affects the climatic conditions of the region.

iii) Edaphic factors are related to the soil, and they influence the life of organisms. The main edaphic factors include soil texture, pH, content of organic matter, water, etc.

8.1.3 Habitat and Medium

Ecologically, **habitat** is the place in which an organism lives. It is comparable to the '**address**' of a person (as mentioned in the introduction page to ecology). For instance, the habitat of fish is a pond,lake,sea etc.,,the habitat of a lion is forest, the habitat of *Ascaris* is the 'small intestine' of man, and so on. The **water** surrounding the body of a fish is called the **medium** and the medium of a lion is the **air** around it's body.

8.1.4 Niche

Within a community, each organism occupies a particular biological role or **niche**. Niche is the **functional role** of an organism in an ecosystem (comparable to the '**profession**' of a person,as mentioned in the introduction). It describes the relational position of a species in its ecosystem. For example, the ecological niche of a rose bush growing in the backyard includes absorbing light, water and nutrients for photosynthesis, releasing oxygen into the atmosphere, providing shelter and food for other organisms (e.g. **aphids**) – **in short the 'rose bush' is a 'producer'**.

8.2 Ecosystem- Elementary Aspects

An 'ecosystem' consists of both **structural** components and **functional** components. The structural components of ecosystem are of two types – **abiotic** and **biotic** factors. Abiotic factors are again of two types- physical and chemical factors. The physical factors are light, temperature, soil, pressure, etc., Oxygen, carbon dioxide and the various mineral nutrients in the soil / water constitute the chemical factors. These physical and chemical factors affect the life of the organisms present in an ecosystem. Energy transfer and recycling of minerals constitute trhe functional aspect of an ecosystem.

8.2.1 Light

Since plants produce food through photosynthesis, a process which is possible only when sunlight is available as a source of energy, we can easily understand the importance of light for all living organisms, particularly the 'autotrophs'. Many species of small plants (herbs and shrubs) growing in forests are adapted to photosynthesize optimally under very low light conditions because they are constantly overshadowed by tall trees with well spread branches. Many plants are also dependent on sunlight to meet their **photoperiod requirement** for flowering.

For many animals, light is important in that they use the diurnal and seasonal variations in the **intensity** and **duration** (**photoperiod**) of light, as cues (indicators) for timing their foraging (collection of food), reproductive and migratory activities. The availability of light on land is closely linked with that of temperature since the sun is the source of both. But, deep in the oceans, the environment is always dark and its inhabitants do not experience light . The spectral quality of solar radiation is also important for life. The UV component of the spectrum is harmful to many organisms. All the colour components of the visible spectrum are not available for marine plants, living at different depths of the seas.

I. Biological effects of light

Light is an ecological factor that shows its influence on many biological phenomena and activities like pigmentation, movement, vision, metabolism, etc.,

1. Effect of light on pigmentation

Light influences the colour of the skin. The animals which live in regions of low intensity of light such as caves, have less pigmentation than that of the animals exposed to light. For example a cave dwelling amphibian, **Proteus anguinus**, has pale coloured skin because of less pigmentation. When it is brought into sunlight the skin colour turns *dark* over a period of time.

2. Effect of light on direction and rate of movement

Response shown by an organism to changes in light is called **photoresponse**. The major photoresponses of motile organisms include:

i) **Phototaxis** is oriented locomotor movement of an organism towards or away from the direction of light as seen in euglenas(positive response), cockroaches(negative response) and,

ii) **Photokinesis** is the influence of light on non- directional movement of organisms as seen in the larvae of Pinnotheres macculatus- the mussel crab, in which intensity of light influences the velocity of the movement of the organism.

Phototropism: The orientation to light of a non-motile organism such as a plant or plant part is called phototropism. For example the growth mediated bending of plants towards sunlight is due to phototropism.

3. Influence of Light on Vision and Behavior

Light is essential for vision, to procure food, self protection, identification and selection of the mate for sexual reproduction. It also influences the behaviour of organisms. Some animals are active during the 'day time' (**diurnal** animals **e.g**. majority of the birds, reptiles and mammals. Others, which are active during night time are called **nocturnal** animals e.g**.** earthworms, cockroaches, etc.,

4. Effect of light on metabolism

The intensity of light influences the rate of metabolism in animals. At lower intensities of light the rate of metabolism slows down, where as in higher intensities it increases.

5. Effect of light on biological rhythms

By definition rhythm is a change that is repeated with similar pattern in a time frame. In the bodies of organisms many behavioural activities are repeated at regular intervals and these are called 'biological rhythms'.

Biological rhythms that occur in a time period of 24 hours are **circadian rhythms**. If the biological rhythms repeat annually (every year), they are called **circannular rhythms**. They are controlled by '**biological clocks**' present in many living organisms. Light has a role in setting or resetting the biological clocks.

6. Effect of 'photoperiod' on animals (photoperiodism)

The duration of the light hours / exposure to light in a day is known as **photoperiod.** The response of organisms for the photoperiod is called **photoperiodism**. The response to photoperiod often centers on reproduction and survival(production of flowers, the migration of birds etc.,). The specific day length which is essential for the

initiation of seasonal events is called '**critical photoperiod**'. The length of critical photoperiod is not the same in all the species, it varies from species to species and also within the same species inhabiting at various latitudes. For example, when winter sets in Siberia, the light available time period in a day decreases, and so some birds migrate all the way to the new **feeding** and **breeding grounds** in various parts of India. When it is summer time back in Siberia, they migrate back to their homeland.

Exposure of young fowls in poultry to more lighted hours in a day induces speedy maturity and the egg laying process. It is a familiar example to most of us.

Bioluminescence: Production of light by certain living organisms is called bioluminescence. The light emitted by living organisms is devoid of infrared rays, and so it is called '*cold light*'. Some Jelly fishes (cnidarian), *Chaetopterus* (annelid), firefly (arthropod), squids (mollusc), *Pyrosoma* (protochordate),and some fishes produce bioluminescence.It is believed to *influence life* in the dark habitat by providing intra-specific communication, sexual attraction,attracting the prey, sending protective warning signals, etc.

II. Effect of UV Rays

The short wave lengths of light ranging from 100 nm to 380nm are called **Ultraviolet rays**. UV radiation is classified into three categories: UVC light (100nm to 280 nm), UVB (280nm to 320nm) and UVA (320nm to 380nm). UV radiation kills the microorganisms present on the body surfaces of animals. UV radiation helps in the conversion of sterols present in the skin into vitamin D in mammals. Compared to UVA rays, UVB and UVC rays are more harmful to organisms.

8.2.2 Temperature

Temperature is a measure of the intensity of heat. The temperature on land or in water is not uniform. On land the temperature variations are more pronounced when compared to the aquatic medium, because land absorbs or loses heat much quicker than water. The temperature on land depends on seasons and the geographical area on this planet. Temperature decreases progressively when we move from the equator to the poles. Altitude also causes variations in temperature. For instance, the temperature decreases gradually as we move to the top of the mountains.

I. Thermal Stratification

Temperature variations occur with seasonal changes in the temperate regions. These differences in the temperature form 'thermal layers' in water. These phenomena are called **thermal stratifications.**

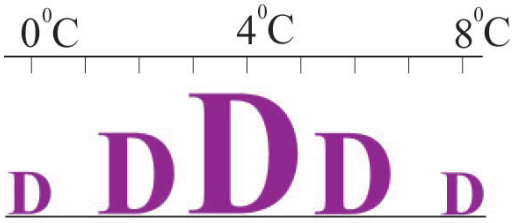


Fig. 8.4 Density decreases above or below 4°C

Water shows maximum density at 4°C. Rise or fall of temperatures above or below 4°C decreases its density. This **anomalous property** of water and the seasonal variations in temperature are responsible for the thermal stratification in temperate lakes.

Summer stratification

During summer in temperate lakes, the density of the surface water decreases because of increase in its temperature (21-25°C). This 'upper more warm layer' of a lake is called epilimnion. Below the epilimnion there is a zone in which the temperature decreases at the rate of 1°C per meter in depth, and it is called **thermocline** or **metalimnion**. The bottom layer is the **hypolimnion**, where water is relatively cool, stagnant and with low oxygen content (*due to absence of photosynthetic activity*).

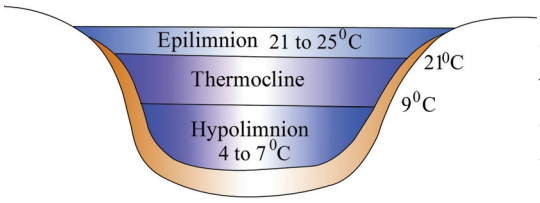


Fig. 8.5 Summer stratification in a lake

During **autumn** (also called **Fall**), the epilimnion cools down, and the surface water becomes heavy when the temperature is 4°C,and sinks to the bottom of the lake. Overturns bring about 'uniform temperature' in lakes during that period. This circulation during the autumn is known as the **fall overturn** or **autumn overturn**. The upper oxygen rich water reaches the hypoliminion and the nutrient rich bottom water comes to the surface.Thus there is uniform distribution of nutrients and oxygen in the lake.

Winter stratification /stagnation

The 'Fall' is followed by 'Winter'. In this season the surface water cools down. The upper water freezes when the temperature reaches 0°C. Below the upper icy layer, the cool (4°C) water occupies the lake. The aquatic animals continue their life below the icy layer. At lower temperatures the activity of bacteria and the rate of oxygen consumption by aquatic animals decrease. Hence, organisms can survive below the frozen upper water without being subjected to '**hypoxia**' (low oxygen availability). In the 'Spring season' the temperatures start rising. When it reaches 4°C, the

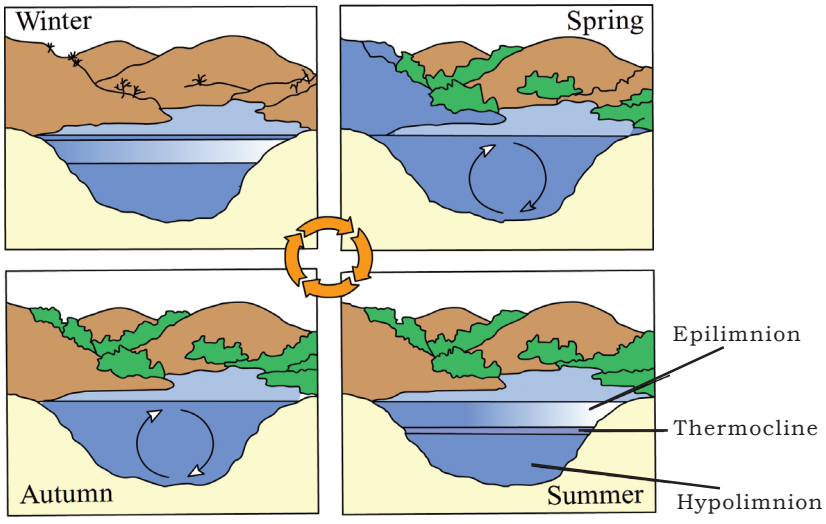


Fig. 8.6 Stratification in temperate lakes

water becomes more dense and heavy and sinks to the bottom, taking 'oxygen rich water' to the bottom.The upper oxygen rich water sinks down and the bottom 'nutrient rich water' reaches the surface.It is called '**spring overturn'** . The lakes which show overturns twice a year are called '**dimictic lakes'**. Thus 'stratifications' and 'overturns' help survival of organisms at all levels in deep lakes, as they help in redistribution of oxygen.

II. Biological effects of Temperature

1. Temperature Tolerance

A few organisms can tolerate and thrive in a wide range of temperatures they are called **eurythermal** (e.g. all homoeotherms), but, a vast majority of organisms are restricted to a narrow range of temperatures (such organisms are called **stenothermal** e.g. fishes and coral animals). The levels of thermal tolerance of different species determine their geographical distribution.

2. Temperature and Metabolism

Temperature affects the *working of enzymes* and through it, the **basal metabolism**, and other physiological functions of organism. The temperature at which the metabolic activities occur at the climax level is called the '**optimum temperature'**. The lowest temperature at which an organism can live indefinitely is called **minimum effective temperature**. If an animal or plant is subjected to a temperature below the minimum effective limit, it enters into a condition of inactiveness called **chill coma**. The metabolic rate increases with the rise of temperature from the **minimum effective temperature** to **optimum temperature**.

The maximum temperature at which a species can live indefinitely in an active state is called **maximum effective temperature**. If the temperature is raised above the maximum effective temperature, the animals enter into '**heat coma**'. The maximum temperature varies much in different animals.

3. van't Hoff's rule

van't Hoff, a Nobel Laureate in thermochemistry, proposed that, with the increase of every 10^0C, the rate of metabolic activities doubles. This rule is referred to as the **van't Hoff's rule**. van't Hoff's rule can also be stated in reverse saying that the reaction rate is halved with the decrease of every 10^0C. The effect of temperature on the rate of a reaction is expressed in terms of **temperature coefficient** or $\mathbf{Q_{10}}$ value. Q_{10} values are estimated taking the ratio between **the rate of a reaction at X^{0}C** and **rate of reaction at (X-10^{0}C)**. In the 'living systems' the Q_{10} value is about 2.0. If the Q_{10} value is 2.0, it means, for every 10^0C increase, the rate of metabolism doubles.

4. Cyclomorphosis

The cyclic seasonal morphological variations among certain organisms is called **cyclomorphosis**. This phenomenon has been demonstrated in the cladoceran (a sub group of crustacea) *Daphnia (water flea)*. In the winter season the head of *Daphnia* is 'round' in shape (typical or non-helmet morph). With the onset of the spring season, a small 'helmet'/'hood' starts developing on it. The helmet attains the maximum size in summer. In 'autumn' the helmet starts receding. By the winter season, the head becomes round. Some scientists are of the opinion that **cyclomorphosis** is a seasonal adaptation to changing densities of the water in lakes – in summer as the water is less dense *Daphnia* requires a larger body surface to keep floating easily. During winter the water is more dense, and so it does not require a larger surface area of the body to keep floating. Others believe that these cyclic changes are adaptations to **'stabilize the movement'** in water. Compared to the 'typical morphs', the 'helmeted morphs' can **resist the water currents better** to stay in the water rich in food materials.

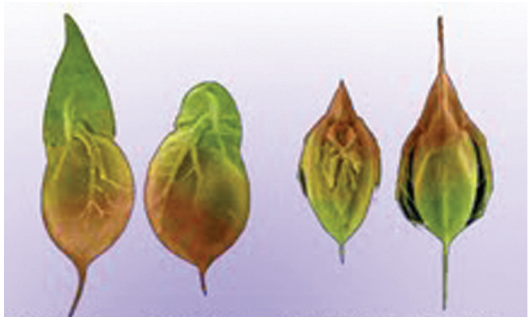


Fig. 8.7 Cyclomorphosis in Daphnia

5. Temperature adaptations

Temperature adaptations in animals can be dealt under three heads a) Behavioural adaptations, b) Morphological and Anatomical adaptations and c) Physiological adaptations.

a. Behavioural adaptations

Some organisms show behavioural responses to cope with variations in their environment. **Desert lizards** manage to keep their body temperature fairly constant by behavioural means. They 'bask' (staying in the warmth of sunlight) in the sun and absorb heat when their body temperature drops below the comfort zone, but move into shade when the temperature starts increasing. Some species are capable of burrowing into the soil to escape from the excessive heat above the ground level.

b. Morphological and anatomical adaptations

In the polar seas, aquatic mammals such as the seals have a thick layer of fat (**blubber**) that acts as an **insulator** and reduces the loss of body heat, underneath their skin.

The animals which live in colder regions have larger body size with greater mass. The body mass is useful to generate more heat. As per **Bergmann's rule** mammals and other warm blooded animals living in colder regions have less '**surface area to body volume ratio'**, than their counterparts living in the tropical regions.

The small surface area helps to conserve heat by reducing the surface area of heat loss. For instance, the body size of American moose / Eurasian elk (*Alces alces),* increases with the latitudes in which they live. [1]Moose of northern part of Sweden shows 15-20% more **body mass** than the same species (counterparts) living in the southern Sweden.

Mammals from colder climates generally have shorter earlobes and limbs (extremities of the body) to minimize heat loss. Large earlobes and long limbs increase the surface area without changing the body volume. This is known as **Allen's rule**. For instance, the polar fox, ***Vulpes lagopus*** (formerly called *Alopex lagopus),* has short extremities to minimize the heat loss from the body. In contrast, the desert fox, *Vulpes zerda*, has large ear lobes and limbs to facilitate better 'heat loss' from the body.

c. Physiological adaptations

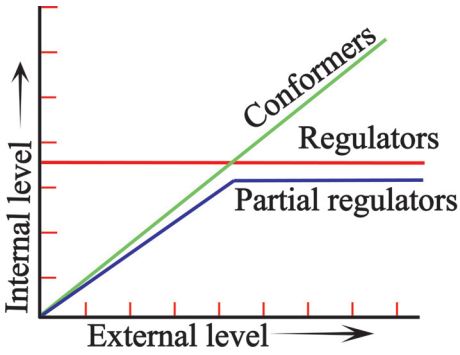
In most animals, all the physiological functions proceed 'optimally' in a narrow temperature range (in humans, it is 37^{0}C). However there are microbes (**archaebacteria**) that flourish in hot springs and in some parts of deep seas, where temperatures far exceed 100^{0}C. Many fish thrive in Antarctic waters where the temperature is always below zero. Having realized that the abiotic conditions of many habitats may vary over a time period, we now ask - **How do the organisms living in such habitats manage with stressful conditions?** One would expect that during the course of millions of years of their existence, many species would have evolved a relatively constant internal (within the body) environment. It permits all biochemical reactions and physiological functions to proceed with maximal efficiency and thus, enhance the overall 'fitness' of the species. This constancy, could be chiefly in terms of **optimal temperature** and **optimal osmotic concentration** of body fluids. So the organism should try to maintain the constancy of its internal environment (homeostasis) despite varying external environmental conditions that tend to upset its homeostasis. This is achieved by the processes described below.

(i) Regulate

Some organisms are able to maintain homeostasis by physiological (sometimes behavioural also) means which ensures constant body temperature, constant osmotic concentration, etc., All birds and mammals, and a very few lower vertebrate and invertebrate species are indeed capable of such regulation (**thermoregulation** and **osmoregulation**). Evolutionary biologists believe that the 'success' of mammals is largely due to their ability to maintain a constant body temperature and thrive whether they live in Antarctica or in the Sahara desert.

The mechanisms used by most mammals to regulate their body temperature are similar to the ones that we, the humans use. We maintain a constant body

[1] *The traditional example of comparison between the large sized polar bear and the small sized tropical black bear to support Bergmann's rule, is not acceptable to some Modern Ecologists as these bears belong to two different Genera, altogether (i.e., not the same species to be compared).*



temperature of 37^{0}C. In summer, when the outside temperature is more than our body temperature, we sweat profusely. The resulting **'evaporative cooling'** brings down the body temperature. In winter when the temperature is much lower than 37^{0}C, we start to **shiver** (a kind of exercise which produces heat and raises the body temperature – a type of body's own defence mechanism against low temperatures). Plants, on the other hand, do not have such mechanisms to maintain internal temperatures.

(ii) Conform[2]

Majority (99 percent) of animals cannot maintain a constant internal environment. Their body temperature changes with the ambient (surrounding) temperature. In aquatic animals, the osmotic concentration of the body fluids changes along with that of the surrounding water. Such animals are described as '**conformers**'.

(iii) Partially regulate[3]

Animals such as 'camels' can be 'conformers' up to a particular range of temperature and 'regulator' afterwards. So, they are described as 'partial regulators' or 'partial conformers'

Why did not the conformers evolve to become regulators?

Thermoregulation is energetically 'expensive' for many organisms. This is particularly true in small animals like shrews and humming birds. Heat loss or heat gain is a function of the surface area. Since small animals have a larger surface area relative to their volume, they tend to lose body heat very fast when it is cold outside; then they have to spend much energy to generate body heat through metabolism. This is the main reason why very small animals are rarely found in the 'polar regions'. During the course of evolution, the costs and benefits of maintaining a constant internal environment are taken into consideration. Some species have evolved the ability to regulate, but only over a limited range of environmental conditions, beyond which they simply conform.

If the stressful external conditions are localized or remain only for a short duration, the organism has two other alternatives.

(iv) Migrate

The organism can move away temporarily from the 'stressful habitat' to a more 'hospitable' (comfortable) area and return when the stressful period is over. In human

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[2] *Adapt from one condition to a new or different conditions.*

[3] *There are no perfect regulators or perfect conformers. There are different intermediate grades among animals.*

analogy (comparison), this strategy is comparable a person moving from Delhi to Shimla for the duration of summer. Many animals, particularly birds, during winter undertake long-distance migrations to more hospitable areas. Every winter, many places in India including the famous Keoladeo or **Keoladeo Ghana National Park** (Formerly - Bharatpur bird sanctuary) in Rajasthan and Pulicat Lake in Andhra Pradesh host thousands of 'migratory birds' coming from Siberia and other extremely cold northern regions.

(v) Suspend life activities

In bacteria, fungi and lower plants, various kinds of thick- walled spores are formed which help them survive unfavourable conditions. They germinate(come out of the spore wall and produce a normal active organism) on the return of suitable environmental conditions.

Plant Examples : In higher plants, seeds and some other vegetative reproductive structures serve as means ***to tide over periods of stress*** besides helping in dispersal - they germinate to form new plants under favourable moisture and temperature conditions. They do so by reducing their metabolic activity and going into a state of 'dormancy'.

Some animals can avoid the stress by escaping in 'time'(migration is- escaping in 'space'). The familiar case of 'polar bears' going into ***hibernation*** during winter is an example of ***escape in time***. Some snails, fish and frongs go into ***aestivation*** to avoid summer-related problems-heat and desiccation.

6. Diapause

Certain organisms show delay in development, during periods of unfavourable environmental conditions and spend some period in a state of 'inactiveness' called '**diapause**'. This dormant period in animals is a mechanism to survive extremes of temperature, drought, etc. It is seen mostly in insects and embryos of some fish**.** Under unfavourable conditions many zooplankton species in lakes and ponds are known to enter diapause (Ref:NCERT Text Book).

8.2.3 Water

Water is another important factor influencing the life of organisms. Life is unsustainable without water. Its availability is so limited in deserts that only certain **special adaptations** make it possible for them to live there. You might think that organisms living in oceans, lakes and rivers should not face any water -related problems, but it is not true. For aquatic organisms the quality (chemical composition, pH, etc.,) of water becomes important. **The salt concentration (measured as salinity in parts per 1000) is less than 5 in inland waters, and 30-35 in the seawater.** Some organisms are tolerant to a wide range of salinities (**euryhaline**), but others are restricted to a narrow range (**stenohaline**). Many freshwater animals cannot live for long in sea water and vice versa because of the osmotic problems, they would face.

1. Adaptations in freshwater habitat

Animals living in freshwaters have to tackle the problem of **endosmosis**. The osmotic pressure of freshwater is very low and that of the body fluids of freshwater organisms is much higher. So water tends to enter into bodies by endosmosis. To maintain the balance of water in the bodies, the freshwater organisms acquired several adaptations such as, contractile vacuoles in the freshwater protozoans, large **glomerular kidneys** in fishes, etc., They send out large quantities of urine, along which some salts are also lost. To compensate the 'salt loss' through urine, freshwater fishes have 'salt absorbing' '**chloride cells**' in their gills. The major problem in freshwater ponds is - in summer most of the ponds dry up. To overcome this problem most of the freshwater protists undergo **encystment**. The freshwater sponges produce asexual reproductive bodies, called **gemmules**, to tide over the unfavourable conditions of the summer. The 'African lungfish', *Protopterus*, burrows into the mud and forms a 'gelatinous cocoon' around it, to survive, in summer.

2. Adaptations in marine habitat

Seawater is high in salt content compared to that of the body fluids. So, the marine animals continuously tend to lose water from their bodies by **exosmosis** and face the problem of dehydration. To overcome the problem of water loss, marine fishes have **aglomerular kidneys** with less number of nephrons. Such kidneys minimize the loss of water through urine. To compensate water loss the marine fish drink more water, and along with this water, salts are added to the body fluids and disturb the internal equilibrium. To maintain salt balance (**salt homeostasis**) in the body, they have **salt secreting chloride cells** in their **gills**. Marine birds like **sea gulls** and **penguins** eliminate salts in the form of salty fluid that drips through their nostrils. In turtles the ducts of chloride secreting glands open near the eyes. Some cartilaginous fishes retain **urea** and **trimethylamine oxide** (TMO) in their blood to keep the body fluid **isotonic** to the sea water and avoid dehydration of the body due to exosmosis.

3. Water related adaptations in brackish water animals

The animals of brackish water are adapted to withstand wide fluctuations in salinity. Such organisms are called **euryhaline** animals. The migratory fishes such as **salmon** and **Hilsa** are **anadromous** fishes i.e., they migrate from the sea to freshwater, for breeding ; Anguilla bengalensis is a **catadromous** fish i.e., it migrates from the river to sea, for breeding. In these fishes their **glomerular kidneys** are adjusted to changing salinities. The chloride cells are adapted to **excrete** or **absorb** salts depending on the situation. On entering the river salmon drinks more freshwater to maintain the concentration of body fluids equal to that of the surround water.

4. Water related adaptations for terrestrial life

In the absence of an external source of water, the **kangaroo rat** of the North American deserts is capable of meeting all its water requirements through oxidation of its internal fat (in which water is a by product-*metabolic water*). It also has the ability to concentrate its urine, so that minimal volume of water is lost in the process of removal of their excretory products.

Plant Example: Many desert plants have a thick cuticle on their leaf surfaces and have their stomata arranged in deep pits to minimize water loss through transpiration. They also have a special photosynthetic pathway ([4]CAM) that enables their stomata to remain closed during day time. Some desert plants like *Opuntia*, have no leaves - they are reduced to spines -and the photosynthetic function is taken over by the flattened stems to reduce loss of water (Ref: NCERT Text BooK).

8.2.4 Soil

The nature and properties of soil in different places vary depending on the climate, and the *'weathering'*[5] processes involved. Various characteristics of the soil such as soil composition, grain size and aggregation determine the percolation and water holding capacity of the soils. These characteristics, along with the parameters such as pH, mineral composition etc., determine to a large extent the vegetation in any area. This in turn dictates the type of animals that can be supported. Similarly, in the aquatic environment, the sediment-characteristics often determine the type of benthic animals that can live there.

8.2.5 Pressure

Pressure is another factor that changes dramatically with depth in the ocean. Organisms on land face less than one 'atmosphere' of pressure at the sea level. Since water is much heavier than air, marine organisms are under much more pressure than those on land. The pressure in water increases at the rate of 1 atmosphere per 10m depth.The organisms living in such extreme environments show a wide range of biochemical adaptations. Some organisms possess adaptations that are physiological and allow them to respond quickly to a stressful situation. If you had ever been to any high altitude place (e.g. >3,500m **Rohtang Pass** near **Manali** and **Manasarovar**, in Tibet) you must have experienced what is called ***altitude sickness***. Its symptoms include **nausea** (vomiting sense), **fatigue** (tiredness) and **heart palpitations** (abnormality in heart beat). This is because in the low atmospheric pressure of high altitudes, the body does not get enough oxygen. But, you gradually get acclimatized and overcome the altitude sickness. How did your body solve this problem? The body compensates low oxygen availability by increasing red blood cell production and increasing the rate of breathing. (Note: **decreasing the binding capacity of haemoglobin** as mentioned in *NCERT Text Book, Page-226*).

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[4] *Crassulacean Acid Metabolism Pathway.*

[5] *Weathering is a collective term for the processes by which rock at or near the earth's surface is disintegrated and decomposed by the action of wind, water etc., to form soil.*

8.3 Population Interactions

Can you think of any natural habitat on earth that is inhabited just by a single species? There is no such habitat and such a situation is unimaginable. For any species, the minimal requirement is one more species on which it can feed. Even a plant species, which makes its own food, cannot survive alone; it needs soil microbes to break down the organic matter in soil and return the inorganic nutrients for absorption. And then, how will the plant manage pollination without an animal agent? It is obvious that in nature, animals, plants and microbes do not and cannot live in isolation but interact in various ways to form a **biological community**. Even in minimal communities, many interactive linkages exist, although all may not be readily visible.

8.3.1 Inter-specific Interactions

Inter-specific interactions arise from the interaction of populations of two different species. They could be beneficial, detrimental or neutral (neither harmful nor beneficial) to one of the species or both. Assigning a '+' sign for beneficial interaction, '–' sign for detrimental and '0' for neutral interaction, let us look at all the possible outcomes of inter-specific interactions.

The interactions between species are grouped into six types. They are mutualism, commensalism, parasitism and amensalism. Both the species benefit in **mutualism** and both lose in **competition** in their interactions with each other. The interaction where one species is benefitted and the other is neither benefitted nor harmed is called **commensalism.** In **amensalism** on the other hand one species is harmed whereas the other is unaffected. In both **parasitism** and [6]**predation**' only one species benefits (parasite and predator, respectively) and the interaction is detrimental to the other species (**host** and **prey**, respectively). Predation, parasitism and commensalisms share a common characteristic - the interacting species live closely together.

Table 8.1: Population Interactions-Types

Name of Interaction	Species A	Species B
Mutualism	+	+
Competition	–	-
Predation	+	-
Parasitism	+	-
Commensalism	+	0
Amensalism	–	0

[6] *Predation is not an association (it is a feeding strategy). It is an interaction between two different species. The predator gets benefit at the cost of the prey.*

8.3.2 Predation

What would happen to all the energy fixed by autotrophic organisms if the community has no animals to eat the plants? You can consider predation as nature's way of transferring the energy fixed by plants to higher trophic levels. When we think of predator and prey, most probably it is the tiger and the deer that readily come to our mind, but a sparrow eating any seed is also a type of predator (a seed predator-also called **granivore**). Although animals eating plants are categorized separately as herbivores, they are, in a broad ecological context, not very different from predators.

Besides acting as 'conduits'/ 'pipelines' for energy transfer across trophic levels, predators play other important roles. They keep the prey populations under control. In the absence of predators, the prey species could achieve very high population densities and cause instability in the ecosystem. Predators have different types of functions to play in nature. They include:

A. Predator as a biological control agent

The prickly pear cactus introduced into Australia in the early 1920s caused havoc by spreading rapidly into millions of hectares of rangeland (vast natural grass lands). Finally, the invasive cactus was brought under control only after a cactus-feeding predator (a moth) was introduced into the country. **Biological control** methods adopted in agricultural pest control are based on the ability of the predators to regulate prey populations.

B. Predators maintain 'species diversity'

Predators also help in maintaining species diversity in a community, by reducing the intensity of competition among competing prey species. In the rocky intertidal communities of the American Pacific Coast, the starfish *Pisaster* is an important predator. In a field experiment, when all the starfish were removed from an enclosed intertidal area, more than 10 species of invertebrates became extinct within a year in that experimental area, because of increased **inter - specific competition**.

C. Predators are prudent (practical) pertaining to preys

If a predator is too efficient and overexploits its prey, then the prey might become extinct and following it, the predator will also become extinct due to lack of food. This is the reason why predators in nature are 'prudent'.

Prey species have evolved various defenses to lessen the impact of predation. They include :

a) **Preys fool (deceive) or avoid their predators**: Some species of insects and frogs are cryptically-coloured (**camouflaged**) to avoid being detected easily by the predator. Some are poisonous and therefore avoided by the predators.

b) **Preys defend by becoming distasteful to predators**: The **Monarch butterfly** is highly distasteful to its predator (bird) because of a special chemical present in its

body. Interestingly, the butterfly acquires this chemical during its **caterpillar *stage*** by feeding on a ***poisonous weed***.

c) **Plants too have their defensive mechanisms**: For plants, herbivores are the predators. Nearly 25 per cent of all insects are known to be **phytophagous** (feeding on plant sap and other parts of plants). The problem is particularly severe for plants because, unlike animals, they cannot escape from their predators. Plants therefore have evolved a variety of morphological and chemical defences against herbivores.

i) **Thorns** (Acacia, Cactus, etc.,) are the most common morphological means of defense. Many plants produce and store chemicals that make the herbivore sick when they are eaten, inhibit feeding or digestion, disrupt its reproduction or even kill it.

ii) You must have seen the weed Calotropis growing in abandoned fields. The plant produces highly poisonous **cardiac glycosides** and that is why you never see any cattle or goats browsing on this plant.

iii) A wide variety of chemical substances that we extract from plants on a commercial scale(**nicotine**, **caffeine**, **quinine**, **strychnine**, **opium**, etc.,) are produced by them actually as defences against grazers and browsers.

8.3.3 Competition

When Darwin spoke of the struggle for existence and survival of the fittest in nature, he was convinced that **interspecific competition** is a 'potent force' in the process of organic evolution, involving Natural Selection. It is generally believed that competition occurs when closely related species compete for the same resources that are limited, but this is not entirely true.

I. Competition among Unrelated Species

Firstly, unrelated species could also compete for the same resource (Interspecific competition). For instance, in some **shallow** South American lakes visiting **flamingos** and resident **fishes** compete for their common food, the suspended **zooplankton** in the shallow waters. Secondly, resources need not be limiting for competition to occur. In **interference competition**, the feeding efficiency of one species might be reduced due to the interfering and inhibitory presence of the other species, even if resources (food and space) are abundant. Therefore, competition is best defined as a process in which the fitness of one species (measured in terms of its **'r'**- the intrinsic rate of increase) is significantly lower in the presence of another species.

II. Competitive exclusion

It is relatively easy to demonstrate in laboratory experiments, as **Gause** and other experimental ecologists did. When the resources are limited, the competitively superior species will eventually eliminate the other species e.g. the Abingdon tortoise in Galapagos

Islands became extinct within a decade after goats were introduced on the island, actually due to the greater browsing efficiency of the goats.

III. Competitive release

Another evidence for the occurrence of competition in nature comes from what is called '**competitive release**'. Competitive release occurs when one of the two competing species is removed from an area, thereby releasing the remaining species from one of the factors that limited its population size. A species, whose distribution is restricted to a small geographical area because of the presence of a competitively superior species, is found to expand its distributional range dramatically when the **competing species** is experimentally removed. This is due to the phenomenon called '**competitive release**'. **Connell**'s 'field experiments' showed that, on the rocky sea coasts of Scotland, the larger and competitively superior barnacle Balanus dominates the intertidal area, and excludes the smaller barnacle Chathamalus from that zone. When the dominant one is experimentally removed, the populations of the smaller ones increased. In general, herbivores and plants appear to be more adversely affected by competition than the carnivores (Ref: NCERT text book).

IV. Coexistence, rather than exclusion

Gause's principle of '**Competitive Exclusion**' states that two closely related species competing for the same resources cannot co-exist indefinitely and the **competitively inferior one** will be eliminated in due course of time. This may be true if resources are limiting, but not otherwise.

More recent studies point out that species facing competition might evolve mechanisms that promote **co-existence** rather than competitive exclusion. One such mechanism is '**resource partitioning**'. If two species compete for the same resource, they could avoid competition by choosing, for instance, different times for feeding or different foraging (food collecting) patterns. **MacArthur** showed that five closely related species of warblers (a kind of birds) living on the same tree were able to avoid competition and co-exist due to behavioural differences in their foraging activities.

8.3.4 Parasitism

Considering that the parasitic mode of life ensures free 'lodging' and 'meals', it is not surprising that parasitism has evolved in so many taxonomic groups from plants to higher vertebrates. Many parasites have evolved to be **host-specific** (they can parasitize only a specific species of host) in such a way that both host and the parasite tend to **co-evolve**; that is, if the host evolves special mechanisms for rejecting or resisting the parasite, the parasite has to evolve mechanisms to 'counteract' and 'neutralize' them, in order to continue successful parasitic relationship with the same host species. In order to lead successful parasitic life, parasites evolved special adaptations, such as:

a. Loss of sense organs (which are not necessary for most parasites).

b. Presence of adhesive organs such as suckers, hooks to cling on to the host's body parts.

c. Loss of digestive system and presence of high reproductive capacity.

d. The life cycles of parasites are often **complex**, involving one or two intermediate hosts or vectors to facilitate parasitisation of their primary hosts.

e.g.-1: The human liver fluke depends on two **intermediate** (secondary) **hosts** (a **snail** and a **fish**) to complete its life cycle.

e.g.-2: The malaria parasite needs a vector (mosquito) to spread to other hosts.

Majority of the parasites harm the host; they may reduce the survival, growth and reproduction of the host and reduce its population density. They might render the host more vulnerable to predation by making it physically weak.

The Types of Parasites

I. Ectoparasites: These parasites feed on host organism while remaining outside the body of the host. The most familiar examples of this group are the ***lice*** on humans and **ticks** on dogs. Many marine fish are infested with ectoparasitic copepods.

Plant examples: *Cuscuta*, a parasitic plant that is commonly found growing on hedge plants, has lost its chlorophyll and leaves in the course of evolution. It derives its nutrition from the host plant which it parasitises. (Ref: NCERT Text Book)

II. Endoparasites: Endoparasites are those that live inside the host's body at different sites (liver, kidney, lungs, red blood cells, etc.,). The life cycles of endoparasites are more complex because of their extreme specialization. Their morphological and anatomical features are greatly simplified while emphasizing (stressing on) their reproductive potential.

III. Brood parasitism: Certain birds show a special type of parasitism, in which the 'parasitic bird' lays its eggs in the nest of its host and lets / allows the host to incubate them. During the course of evolution, the eggs of the parasitic bird have evolved to resemble the host's egg in size and colour to reduce the chances of the host bird detecting the foreign eggs and ejecting them from the nest. This is treated as a special type of parasitism by some

Try to follow the movements of the cuckoo (koel) and the crow in your neighborhood park during the breeding season (spring to summer) and watch brood parasitism in action (NCERT Text Book).

8.3.5 Commensalism

This is the interaction in which one species benefits and the other is neither harmed nor benefited. Barnacles growing on the back of a whale benefit while the whale derives no noticeable benefit.

The 'cattle egret' (a kind of bird) and 'grazing cattle' living in close association, is a good example of commensalism. The egrets always forage close to where the cattle are grazing because the cattle, as they move, stir up and drive out insects, from the vegetation thus helping the egrets to find and catch the insects. Another example of commensalism is the interaction between **sea anemone** that has tentacles with **stinging cells** and the '**clown fish**' that lives among them. The fish gets protection from predators, as the predator stays away from the stinging tentacles of the anemone. The anemone does not derive any visible benefit by 'hosting' the clown fish.

Plant example :An orchid growing as an epiphyte on a mango branch, gets the benefit of exposure to light,while the mango tree does not derive any noticeable benefit (Ref: NCERT Text Book)

8.3.6 Mutualism

This type of interaction benefits both the interacting species.

The most common examples of mutualism are found in plant-animal relationships. Plants need the help of animals for **pollinating** their flowers and **dispersing** their seeds. Animals obviously have to be paid '**fees**' for the services that plants derive from them. Plants offer rewards in the form of **pollen** and **nectar** for pollinators and juicy and nutritious **fruits** for seed dispersing animals.

Fig. 8.8 Commensalism

Now you can see why plant-animal interactions often involve **co-evolution** of the mutualists, that is, the evolutions of the flower and its pollinator species are tightly linked with one another.

Plant Examples: Lichens represent an intimate mutualistic relationship between a fungus and photosynthesising algae or cyanobacteria. Similarly, the **mycorrhizae** are associations between fungi and the roots of higher plants. The fungi help the plant in the absorption of essential nutrients from the soil while the plant in turn provides the fungi with energy-yielding carbohydrates (Ref: NCERT Text Book).

Fig. 8.9 Mutual relationship between fig tree and wasp (a) Fig flower is pollinated by wasp; (b) Wasp laying eggs in a fig fruit

In many species of fig trees, there is a one-to-one relationship with the pollinator species of **wasp** It means that a given fig species can be pollinated only by its '**partner' wasp** species and no other species. The female wasp uses the fruit not only as a site for oviposition (**egg-laying site**), but also uses the developing seeds within the fruit for nourishing its larvae. The wasp pollinates the flowers of the fig plant while searching for suitable egg-laying sites. In return for the favour of pollination the fig offers the wasp some of its developing seeds, as food for the developing wasp larvae.

Fig. 8.10 Showing bee a pollinator on orchid flower

Orchids show a high degree of diversity of floral patterns.Many of them have evolved to attract the right pollinator insect (bees and bumblebees) and ensure pollination by it. Not all orchids offer rewards. The Mediterranean orchid *Ophrys* employs '**sexual deceit**' to get pollination done by a specific species of bee. One petal of its flower resembles the female of the bee in size, colour and markings. The male bee is attracted to the 'petal' as it presumes it to be the female, '**pseudocopulates**' with the flower, and during that process, it is dusted with pollen from the flower. When the same bee 'pseudocopulates' with another flower, it transfers the pollen to it. Here you can see how **co-evolution** operates in nature. If the female bee's colour patterns change even slightly, for any reason in the course of evolution, pollination success will be reduced, unless the orchid flower **co-evolves** and alters the resemblance of its petal to the changed female bee.

8.4. Ecosystems and Their Components

An 'ecosystem' is a **functional unit of nature,** where living organisms interact among themselves and also with the surrounding physical environment. Ecosystem varies greatly in size from a small pond to a large forest or a sea. Many ecologists regard the entire **biosphere** as a 'global ecosystem', as a composite of all local ecosystems on Earth. Since this system is too big and complex to be studied at one time, it is convenient to divide it into two basic categories, namely natural and artificial. The natural ecosystems include **aquatic ecosystems** of water and **terrestrial ecosystems** of the land. Both types of natural and artificial ecosystems have several subdivisions.

8.4.1 The Natural Ecosystems

These are naturally occurring ecosystems and there is no role of humans in the formation of such types of ecosystems. These are categorized mainly into two types - aquatic and terrestrial ecosystems.

8.4.2 Aquatic Ecosystems

Based on the **salinity** of water, three types of aquatic ecosystems are identified- marine, freshwater, and estuarine.

i. **The Marine Ecosystem**: It is the largest of all the aquatic ecosystems. It is the most stable ecosystem

ii. **Estuarine Ecosystem:** Estuary is the zone where river joins the sea. Sea water ascends up into the river twice a day (effect of high tides and low tides). The salinity of water in an estuary also depends on the seasons. During the rainy season out flow of river water makes the estuary less saline and the opposite occurs during the summer.Estuarine organisms are capable of withstanding the '**fluctuations**' in salinity.

iii. **The Freshwater Ecosystem:** The freshwater ecosystem is the smallest aquatic ecosystem. It includes rivers, lakes, ponds, etc., It is divided into two groups- the **lentic** and **lotic.** The still water bodies like ponds, lakes, reservoirs, etc., fall under the category of **lentic ecosystems**, whereas, streams, rivers and flowing water bodies are called **lotic ecosystems**.The communities of the above two types are called lentic and lotic communities respectively. The study of freshwater ecosystem is called as **limnology**.

8.4.3 Lake Ecosystem

To understand the fundamentals of an aquatic ecosystem, let us take a 'lake' as an example. This is fairly a self-sustainable unit and rather a simple example that explains even the complex interactions that exist in an aquatic ecosystem.

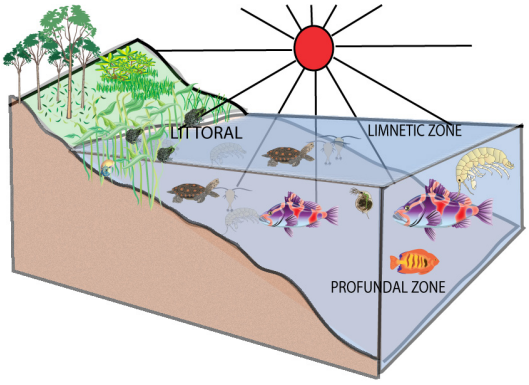


Fig. 8.11 Lake Ecosystem

Lakes are large inland water bodies containing standing/still water (Recall: Lentic community). They are deeper than ponds (pond is not an ideal example as it is very shallow). Most lakes contain water throughout the year. In deep lakes, light cannot penetrate more than 200 meters, in depth. They are vertically stratified in relation to light intensity, temperature, pressure, etc., Deep water lakes contain three distinct zones namely, i) littoral zone, ii) limnetic zone, and iii) profundal zone.

- **Littoral zone**: It is the shallow part of the lake closer to the shore. Light penetrates up to the bottom. It is 'euphotic' (having good light), has rich vegetation and higher rate of photosynthesis, hence rich in oxygen.
- **Limnetic zone**: It is the open water zone away from the shore. It extends up to the **effective light penetration level**, vertically. The imaginary line that separates the limnetic zone from the profundal zone is known as **zone of compensation/ compensation point/ light compensation level**. It is the zone of effective light penetration. Here the rate of photosynthesis is equal to the rate of respiration. Limnetic zone has no contact with the bottom of the lake.
- **Profundal zone**: It is the deep water area present below the limnetic zone and beyond the depth of effective light penetration. Light is absent. Photosynthetic organisms are absent and so the water is poor in oxygen content.It includes mostly the anaerobic organisms which feed on detritus.

The organisms living in lentic habitat are classified into **pedonic** forms, which live at the bottom of the lake and those living in the open waters of lakes, away from the shore vegetation are known as **limnetic forms**.

Biota (animal and plant life of a particular region) of the littoral zone

Littoral zone is rich with pedonic flora (especially up to the depth of the effective light penetration). At the shore proper '**emergent vegetation**' is abundant with firmly fixed roots in the bottom of the lake and shoots and leaves are exposed above the level of water. These are **amphibious plants**. Certain emergent rooted plants of littoral zone are the cattails (*Typha*), bulrushes (Scirpus), arrowheads (*Sagittaria*). Slightly deeper are the rooted plants with floating leaves, such as the water lilies (*Nymphaea*), *Nelumbo, Trapa, etc.* Still deeper are the submerged plants such as *Hydrilla, Chara, Potamogeton,* etc.,The free floating vegetation includes *Pistia, Wolffia, Lemna* (duckweed), *Azolla, Eichhornia,* etc.

The **phytoplankton** of the littoral zone composed of diatoms (*Coscinodiscus, Nitzschia, etc.*), green algae (*Volvox, Spirogyra, etc.*), euglenoids (*Euglena, Phacus,etc.*), and dinoflagellates (*Gymnodinium, Cystodinium, etc.*).

Animals, the **consumers** of the littoral zone, are abundant in this zone of the lake. These are categorized into zooplankton, neuston, nekton, periphyton, and benthos. The **zooplankton** of the littoral zone consists of 'water fleas' such as *Daphnia*, rotifers and ostracods.

The animals living at the *air-water interface* constitute the '**neuston**'. They are of two types, the epineuston and hyponeuston. Water striders (*Gerris)*, beetles, water bugs *(Dineutes*) form the **epineuston/supraneuston** and the **hyponeuston/ infraneuston** includes the 'larvae of mosquitoes'.

The animals such as fishes, amphibians, water snakes, terrapins, insects like 'water scorpion' (*Ranatra)*, 'back swimmer' (*Notonecta*), 'diving beetles' (*Dytiscus*), capable of swimming constitute the **nekton**.

The animals that are attached to / creeping on the aquatic plants,such as the 'water snails', 'nymphs of insects', 'bryozoans', 'turbellarians', 'hydras', etc., constitute the '**periphyton**'.

The animals that rest on or move on the bottom of the lake constitute the '**benthos**' e.g., red annelids, chironomid larvae, cray fishes, some isopods, amphipods, clams, etc.

Biota of the limnetic zone

Limnetic zone is the largest zone of a lake. It is the region of rapid variations of the level of the water, temperature, oxygen availability, etc., from time to time. The limnetic zone has autotrophs (photosynthetic plants) in abundance. The chief autotrophs of this region are the phytoplankton such as the **euglenoids, diatoms, cyanobacteria, dinoflagellates** and **green algae**. The consumers of the limnetic zone are the zooplanktonic organisms such as the copepods.Fishes, frogs, water snakes, etc., form the limnetic **nekton.**

Biota of the profundal zone

It includes the organisms such as decomposers (bacteria), *chironomid* larvae, *Chaoborus* (**phantom larva**), red annelids, clams, etc., that are capable of living in low oxygen levels. The decomposers of this zone decompose the dead plants and animals and release nutrients which are used by the biotic communities of both littoral and limnetic zones.

The lake ecosystem performs all the functions of any ecosystem and of the biosphere as a whole, i.e., conversion of inorganic substances into organic material, with the help of the radiant solar energy by the autotrophs; consumption of the autotrophs by the heterotrophs; decomposition and mineralization of the dead matter to release them back for reuse by the autotrophs (**recycling of minerals**).

8.4.4 The Terrestrial Ecosystems

The ecosystems of land are known as terrestrial ecosystems. Some examples of terrestrial ecosystems are the forest, grassland and desert.

i. **The Forest Ecosystems:** The two important types of forests seen in India are i) tropical rain forest and ii) tropical deciduous forests.

ii. **The Grassland Ecosystems:** These are present in the Himalayan region in India. They occupy large areas of sandy and saline soils in Western Rajasthan.

iii. **Desert Ecosystems:** The areas having less than 25cm rainfall per year are called deserts. They have characteristic flora and fauna. The deserts can be divided into two types – hot type and cold type deserts. Thar Desert in Rajasthan is the example for hot type of desert. Cold type desert is seen in Ladakh.

8.4.5 Artificial Ecosystems

These are man-made ecosystems such as agricultural or agro-ecosystems. They include cropland ecosystems, aquaculture ponds and aquaria.

8.5 Food Chains, Food Web, Productivity and Energy Flow

An ecosystem consists of structural and functional components. The structural components are **abiotic** and **biotic** factors. You have studied various abiotic components like light, temperature, water, pressure etc., of ecosystem in the previous lessons. The biotic components of an ecosystem are composed of producers, consumers, and decomposers. The functional components of ecosystem are **cycling of nutrients** and the **flow of energy**. Let us look at these components in a more integrated manner and see how the flow of energy takes place within these components of the ecosystem.

8.5.1 Biotic Factors

1. Producers

The green plants in the ecosystem-terminology are called **producers.** They synthesize the food by using solar energy (photo autotrophs). Certain bacteria such as Iron and Sulphur bacteria are **chemoautotrophs**. They fix carbon dioxide by using the energy obtained by the breaking down of certain chemical substances. In a terrestrial ecosystem, the major producers are the herbaceous and woody plants. Likewise, primary producers in an aquatic ecosystem include various species like microscopic phytoplanktonic organisms, algae and some higher plants. The producers form the first trophic level in most food chains. They constitute the main source of food for the organisms of the second/ next higher trophic level, the 'consumers' .

2. Consumers

All animals depend on plants (directly or indirectly) for their food needs. They are hence called consumers and also **heterotrophs**. If they feed on the producers - (the plants) they are called **primary consumers**. If the animals eat other animals, which eat plants or plant products, they are called **secondary consumers**. Likewise, there may be **tertiary consumers** too. Obviously the primary consumers are the herbivores. Some common herbivores are insects, birds and mammals in the terrestrial ecosystem and arthropods and molluscs in the aquatic ecosystems.

3. Decomposers

You may have heard of the earthworm being referred to as the farmer's 'friend'. This is so because they help in the breakdown of complex organic matter as well as in loosening of the soil (making the soil porous). Similarly, decomposers break down complex organic matter into simple inorganic substances like carbon dioxide, water and nutrients and the process is called **decomposition**. Plant parts such as leaves, bark, flowers and dead remains of animals, including their faecal matter, constitute the **detritus**. Detritus is the '**raw material**' for '**decomposition**'.

The important steps in the process of decomposition are **fragmentation**, **leaching**, **catabolism**, **humification** and **mineralization**.

Detritivores (e.g. earthworm) break down detritus (litter) into smaller particles and this process is called **fragmentation**. By the process of **leaching**, water soluble inorganic nutrients go down into the soil and get precipitated as unavailable salts. Bacterial and fungal enzymes degrade detritus into simpler inorganic substances. This process is called **catabolism**.

It is important to note that all the above steps in decomposition operate simultaneously on the detritus. Humification and mineralization occur during decomposition in the soil. Humification leads to accumulation of a dark coloured amorphous substance called **humus** that is highly resistant to microbial action and undergoes decomposition at an extremely slow rate. Being colloidal in nature it serves as a **reservoir of nutrients**. The humus is further degraded by some microbes and release of inorganic nutrients occurs by the process known as **mineralization.** (Ref: NCERT Text Book pages 243-244)

Decomposition

Decomposition is largely an oxygen-requiring process. The rate of decomposition is controlled by chemical composition of the detritus and *climatic factors*. In a particular climatic condition, decomposition rate is slower if detritus is rich in **lignin**

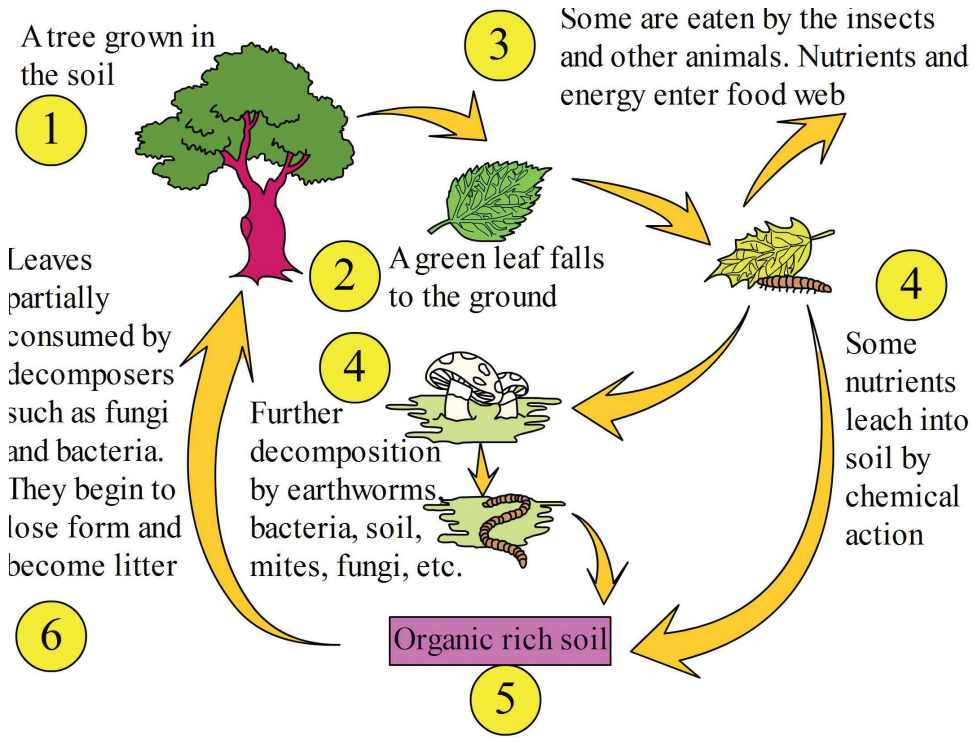


Fig. 8.12 Diagrammatic representation of decomposition cycle in a terrestrial ecosystem (NCERT)

and **chitin**, and quicker, if detritus is rich in **nitrogen** and water -soluble substances like **sugars**. Temperature and soil moisture are the most important climatic factors that regulate decomposition through their effects on the activities of soil microbes. Warm and moist environment favours decomposition whereas **low temperature** and **anaerobic environment** 'inhibit' the decomposition resulting in build up of organic materials. As most of the decomposers are very small microscopic forms, they are also called 'micro-consumers'.

8.5.2 The Food Chains

Energy flows into biological systems (ecosystems) from the Sun. The biological systems of environment include several food levels called **trophic levels**. A trophic level is composed of those organisms which have the same source of energy and having the same number of steps (energy storing and transfer steps) away from the sun. Thus a plant's trophic level is **one**, while that of a herbivore - **two**, and that of the first level carnivore - **three**. The second and third levels of the carnivores occupy **fourth** and **fifth** trophic levels respectively.

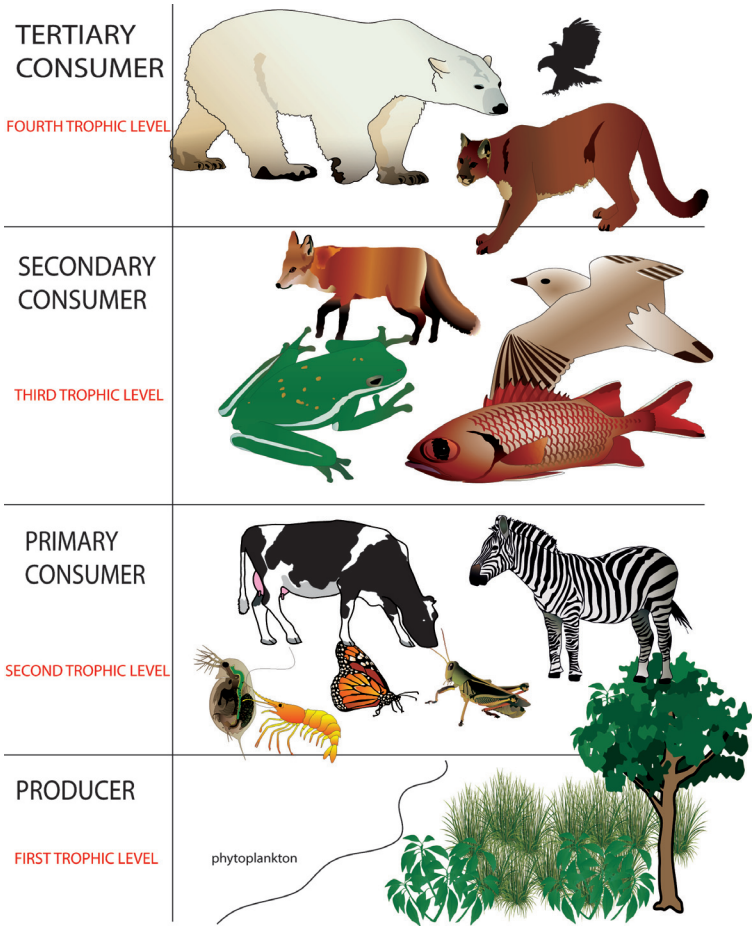


Fig. 8.13 Trophic levels in an ecosystem

A given organism may occupy more than one trophic level simultaneously because of its food habits. One must remember that the trophic level represents a functional level. A given species may occupy more than one trophic level in the same ecosystem at the same time; for example, a sparrow is a primary consumer when it eats seeds, fruits, and a secondary consumer when it eats insects and worms (omnivore).

The food energy passes from one trophic level to another trophic level mostly from the lower to higher trophic levels. When the path of food energy is 'linear', the components resemble the 'links' of a chain, and it is called '**food chain**'. Generally a food chain ends with decomposers. The three major types of food chains in an ecosystem are Grazing Food Chain, Parasitic Food Chain and Detritus Food Chain.

I. Grazing Food Chain

It is also known as predatory food chain. It begins with the green plants (producers) and the second, third and fourth trophic levels are occupied by the herbivores, primary carnivores and secondary carnivores respectively. In some food chains there is yet another trophic level – the climax carnivores. The number of trophic levels in food chains varies from 3 to 5 generally. Some examples for grazing food chain (**GFC**) are given below.

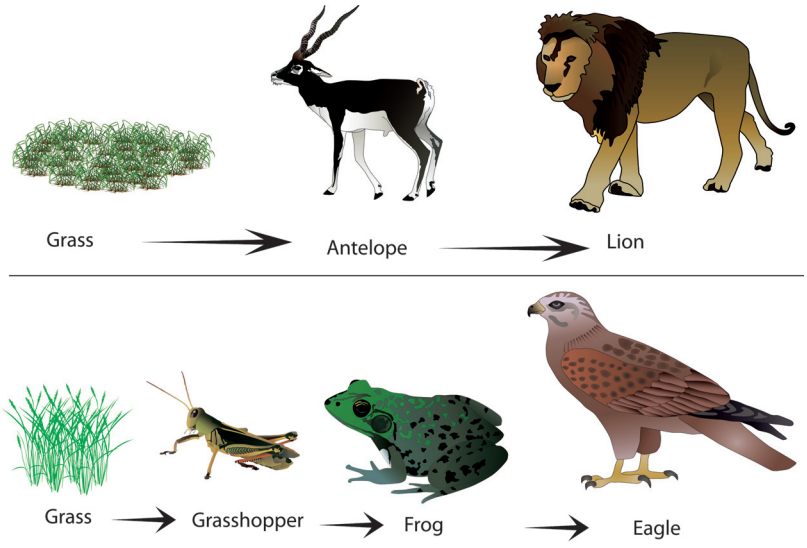


Fig. 8.14 Grazing food chain

I trophic level	II trophic level	III trophic level	IV trophic level	V trophic level
Rosebush →	Aphids →	Spiders →	Small birds →	Hawk
Grass →	Grasshopper →	Frog →	Snake →	Hawk
Plants →	Caterpillar →	Lizard →	Snake	
Phytoplankton →	Zooplankton →	Fish →	Bird	
Grass →	Goat →	Man		

II. Parasitic food chain

Some authors included the 'Parasitic Food Chains' as a part of the GFC. As in the case of GFCs, it also begins with the producers, the plants (directly or indirectly). However, the food energy passes from large organisms to small organisms in the parasitic chains. For instance, a tree which occupies the 1st trophic level provides shelter and food for many birds. These birds host many **ecto-parasites** and **endo-parasites**. Thus, unlike in the predator food chain, the path of the flow of energy includes fewer, large sized organisms in the lower trophic levels, and numerous, small sized organisms in the successive higher trophic levels.

III. Detritus Food Chain

The detritus food chain (**DFC**) begins with dead organic matter (such as leaf litter, bodies of dead organisms and faeces of animals). It is made up of **decomposers** which are **heterotrophic organisms**, mainly the 'fungi' and 'bacteria'. They meet their energy

and nutrient requirements by degrading dead organic matter or detritus. These are also known as **saprotrophs** (sapro: to decompose).

Decomposers secrete digestive enzymes that breakdown dead and waste materials (such as faeces) into simple absorbable substances. Some examples of detritus food chains are:

1. Detritus (formed from leaf litter)-Earthworms -Frogs -Snakes
2. Dead animals -Flies and maggots -Frogs -Snakes

In an aquatic ecosystem, GFC is the major 'conduit' for the energy flow. As against this, in a terrestrial ecosystem, a much larger fraction of energy flows through the detritus food chain than through the GFCs. Detritus food chain may be connected with the grazing food chain at some levels. Some of the organisms of DFC may form the prey of the **GFC** animals. For example, in the detritus food chain given above, the earthworms of the **DFC** may become the food of the birds of the **GFC**. It is to be understood that food chains are not 'isolated' always.

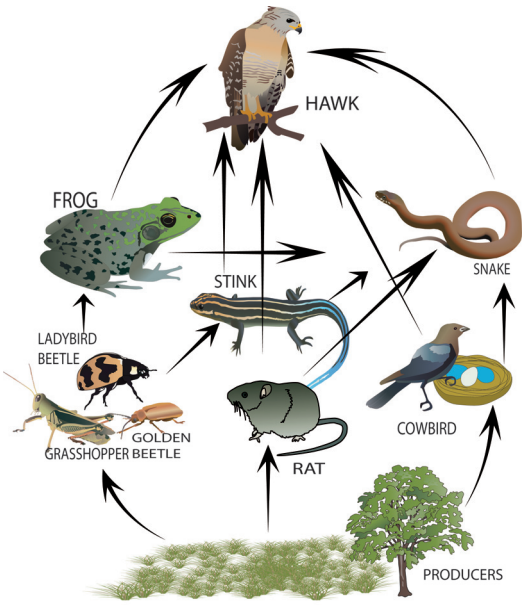


Fig. 8.15 A simple food web

8.5.2.1 Food Web

In a simple GFC the food energy flows through in **linear trophic levels**. However, in an ecosystem the feeding relationships are never that simple. The feeding interrelationships become more complex because of the omnivores present in the ecosystem. For instance man, birds and some other animals are '**omnivores**', by their feeding habits. In such cases it is difficult to place an animal in a simple / single food chain as they have many interconnections with the animals of other food chains. These natural interconnections of food chains form a 'net-work' called ' **food web'.**

8.5.3 Energy Flow

Except for the deep sea **hydro-thermal ecosystem**[7], sun is the only source of energy for all ecosystems on Earth. Of the incident solar radiation less than 50 per cent of it is **photosynthetically active radiation** (PAR). We know that plants and photosynthetic bacteria (autotrophs), fix Sun's radiant energy to synthesise food from simple inorganic materials. Plants capture only 2-10 percent of the PAR and this small amount of energy sustains the entire living world. So, it is very important to know how the solar energy captured by plants flows through different organisms of an ecosystem. All heterotrophs are dependent on the producers for their

[7] *Hydrothermal systems in the deep ocean, do not have light, and chemical energy supports life (chemoautotrophs), instead of sunlight.*

food, either directly or indirectly. The law of conservation of energy is the **first law of thermodynamics**. It states that energy may transform from one form into another form, but it is neither created nor destroyed. The energy that reaches earth is balanced by the energy that leaves the surface of the earth as invisible heat radiation.

The energy transfers in an ecosystem are essential for sustaining life. Without energy transfers there could be no life and ecosystems. Living beings are the natural proliferations that depend on the continuous inflow of concentrated energy.

Further, ecosystems are not exempted from the Second Law of thermodynamics. It states that no process involving energy transformation will spontaneously occur unless there is degradation of energy. As per the second law of thermodynamics - the energy degraded is in the form of unavailable heat energy, and constitutes the **entropy** (energy lost or not available for work in a system). The organisms need a constant supply of energy to synthesize the molecules they require. The transfer of energy through a food chain is known as **energy flow**. A constant input of mostly solar energy is the basic requirement for any ecosystem to function. The important point to note is that the amount of energy available decreases at successive trophic levels. When an organism dies, it is converted to detritus or dead biomass that serves as a source of energy for the decomposers. Organisms at each trophic level depend on those at the lower trophic level, for their energy demands.

Each trophic level has a certain mass of living material at a particular time, and it is called the **standing crop**. The standing crop is measured as the **mass** of living organisms (**biomass**) or the number of organisms per unit area. The biomass of a species is expressed in terms of fresh or dry weight (dry weight is more accurate – because water contains no usable energy).

The 10 percent Law

The 10 percent law for the transfer of energy from one trophic level to the next was introduced by Lindeman (the Founder of the modern Ecosystem Ecology). According to this law, during the transfer of energy from one trophic level to the next,only about 10 percent of the energy is stored/ converted as body mass / biomass. The remaining is lost during the transfer or broken down in catabolic activities (Respiration). Lindeman's rule of trophic efficiency/ Gross ecological efficiency is one of the earliest and most widely used measures of ecological efficiency. For example, if the NPP (Net primary production) in a plant is 100 kJ, the organic substance converted into **body mass** of the herbivore which feeds on it is 10 kJ only. Similarly the **body mass** of the carnivore-I is 1 kJ only.

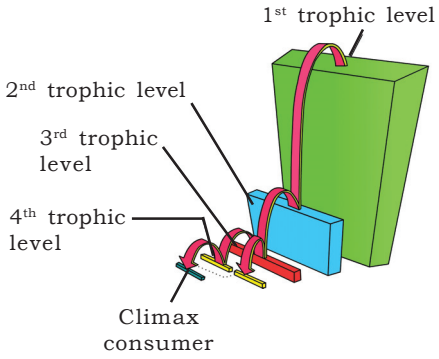


Fig. 8.16 Energy flow in an ecosystem

8.5.4 Productivity

The **rate of production** of biomass is called **productivity**. It can be divided into **primary** and **secondary** productivities.

I. **Primary productivity** is defined as the amount of biomass or organic matter produced per unit area over a period of time by plants, during photosynthesis. It can be divided into gross primary productivity (GPP) and net primary productivity (NPP).

a) **Gross primary productivity** of an ecosystem is the rate of production of organic matter during photosynthesis. A considerable amount of GPP is utilized by plants for their catabolic process (respiration).

b) **Net primary productivity** Gross primary productivity minus respiratory loss (R), is the net primary productivity (NPP). On average about 20-25 percent of GPP is used for the catabolic (respiratory) activity.

GPP - R = NPP

The net primary productivity is the biomass available for the consumption of the heterotrophs (herbivores and decomposers).

II. **Secondary productivity** is defined as the rate of formation of new organic matter by consumers.

8.5.5 Ecological Pyramids (Eltonian pyramids)

You must be familiar with the shape of a pyramid. The base of a pyramid is broad and it narrows down towards the apex. The trophic relationship is expressed in terms of numbers; biomass or energy arranged one on the top of its lower trophic level, resulting in a pyramidal shape. It is a graphical representation of the trophic structure and function of an ecosystem. The base of each pyramid represents the **producers** or the first trophic level,while the apex represents the tertiary or top level / top order consumer. The three types of ecological pyramids that are usually studied are (a**) pyramid of number**; (b) **pyramid of biomass** and (c) **pyramid of energy**. These pyramids were first represented by **Elton,** hence the name **ELTONIAN pyramids/ Ecological pyramids**.

Any calculations of energy content, biomass, or numbers has to include all organisms at that trophic level. No generalizations we make will be true if we take only a few individuals of any trophic level into account. In most ecosystems, all the pyramids- of numbers, energy and biomass are **upright** i.e., producers are more in number and biomass than the herbivores, and herbivores are more in number and biomass than the carnivores. Also energy (available) at a lower trophic level is always more than that at a higher level.

There are exceptions to this generalization. In the case of a parasitic food chain, the pyramid of numbers is **inverted**. A large tree (single producer) may support many

herbivores like squirrels, and fruit eating birds. On these herbivores many ectoparasites such as ticks, mites and lice (secondary consumers) may live. These secondary consumers may support many more top level consumers and also the hyperparasites. Thus in each trophic level from the bottom to the top, the numbers of organisms increase, and form an 'inverted pyramid' of **numbers**.

The pyramid of **biomass** in sea is also generally inverted because the biomass of fishes far exceeds that of phytoplankton (Ref: NCERT Text Book).

Pyramid of **energy** is always **upright**, and can never be inverted, because when energy flows from a particular trophic level to the next higher trophic level, some energy is always lost as heat (thus at every step). Each bar in the energy pyramid indicates the amount of energy present at each trophic level in a given time or annually per unit area.

Limitations of Ecological Pyramids

However, there are certain limitations of ecological pyramids, such as –

i) it does not take into account the same species belonging to two or more trophic levels,

ii) It assumes a simple food chain, something that almost never exists in nature,

iii) it does not accommodate a food web, iv) moreover, saprophytes are not given any place in ecological pyramids even though they play a vital role in the ecosystem.

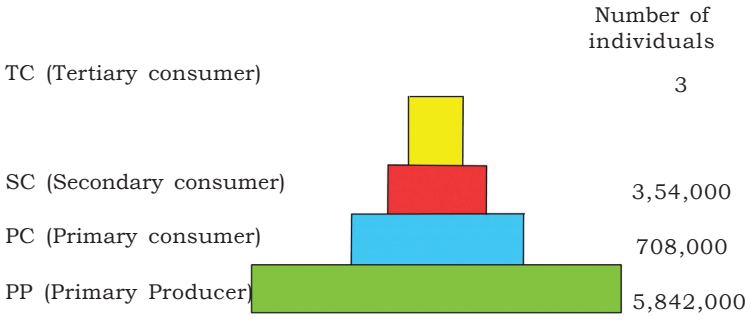


Fig. 8.17 (a) Pyramid of Numbers in a grassland ecosystem. NOTE: Only 3 top-carnivores are supported in an ecosystem based on production of nearly 6 million plants.Also NOTE that the pyramid of numbers of a parasitic food chain is inverted.

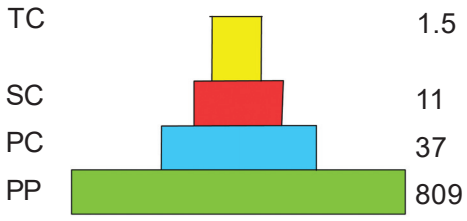


Fig. 8.17 (b) Pyramid of biomass shows a sharp decrease in biomass at the higher trophic levels. NOTE: Pyramid of biomass is upright normally.

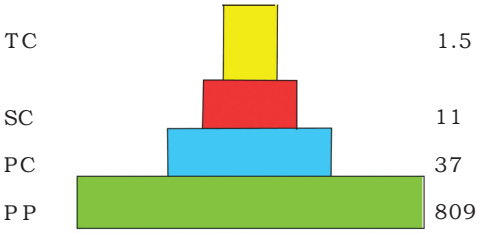


Fig. 8.17 (c) An ideal pyramid of energy which is an always upright pyramid. NOTE: primary producers convert only 0.5% of the energy absorbed from the sunlight available to them are into GPP

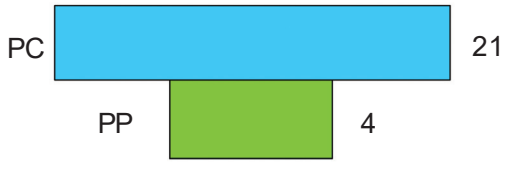


Fig. 8.17 (d) Inverted pyramid of biomass-small standing crop of phytoplankton supports large standing crop of zooplankton(at certain times) NOTE: Algal blooms are followed by their death due to short life span depleting their numbers(temporarily).

8.6 Nutrient Cycles

Organisms need a constant supply of nutrients to grow, reproduce and regulate various body functions. The amount of nutrients, such as carbon, nitrogen, phosphorus, calcium, etc., present in the soil at any given time, is referred to as the **standing state**. It varies in different kinds of ecosystems and also on a seasonal basis.

Nutrients are never lost from the ecosystems. They are recycled again and again, indefinitely. The movement of nutrient elements through the various components of an ecosystem is called '*nutrient cycling*'. Such cycles are called biogeochemical cycles (bio: living organism, geo: rocks, air, water).

Nutrient cycles are of two types:

(a) gaseous and

(b) sedimentary.

In a gaseous cycle, elements move through the atmosphere. Main reservoirs are atmosphere and oceans (via evaporation). e.g. carbon cycle and nitrogen cycle.

In a sedimentary cycle, elements move from the earth's crust to water and to sediment. Main reservoirs are the soil and sedimentary rocks. e.g. phosphorous cycle and sulphur cycle.

8.6.1 Carbon Cycle

The element carbon constitutes 49 percent of the dry weight of organisms and is next only to water. Among the total carbon quantity present on the Earth, 71 percent is found dissolved in oceans. This 'oceanic reservoir' regulates the amount of carbon dioxide in the atmosphere. It will be interesting to know that the atmosphere contains only about 1 percent of the total global carbon.

'**Fossil fuels**' also represent reservoirs of carbon. Carbon cycling occurs through atmosphere, ocean and through living and dead organisms. carbon is fixed in the biosphere through photosynthesis. A considerable amount of carbon returns to the atmosphere as CO_2 through respiratory activities of the producers and consumers. Decomposers also contribute substantially to CO_2 pool by their processing of waste materials and dead organic matter of land or oceans. Some amount of the fixed carbon is lost to sediments and removed from circulation. Burning of wood, forest fires combustion of organic matter, fossil fuels, volcanic activity etc., are additional sources for releasing CO_2 into the atmosphere.

Human activities have significantly influenced the carbon cycle. Rapid de-forestation and massive burning of fossil fuel for energy and transport have significantly increased the rate of release of carbon dioxide into the atmosphere. (see greenhouse effect at 8.8.4)

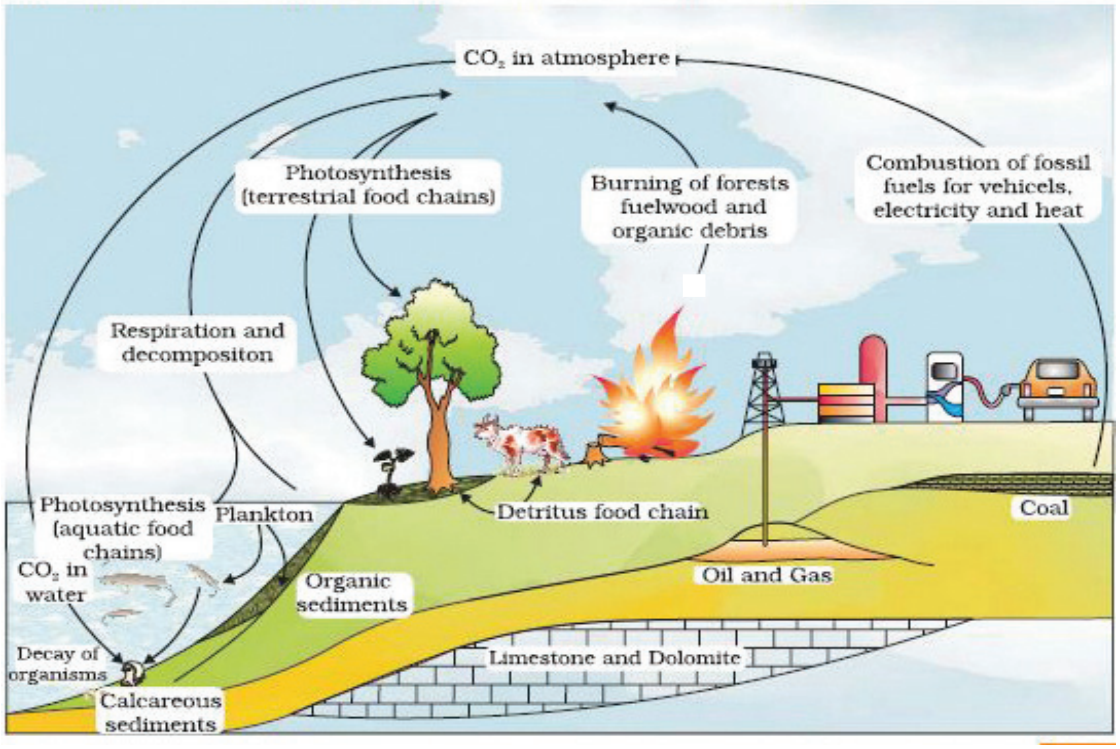


Fig. 8.18 Simplified model of carbon cycle in the biosphere

8.6.2 Nitrogen Cycle

Apart from carbon, hydrogen and oxygen, nitrogen is the most prevalent element in living organisms. Nitrogen is a constituent of amino acids, proteins, hormones, chlorophylls and many of the vitamins. Plants compete with microbes for the limited nitrogen that is available in the soil. Thus nitrogen is a 'limiting nutrient' for both natural and agricultural ecosystems.

Nitrogen exists in molecular state. The process of conversion of nitrogen (N_2) into nitrites and nitrates is called **nitrogen fixation**. In nature lightening and ultra violet radiation provide enough energy to convert nitrogen to nitrogen oxides NO, NO_2,

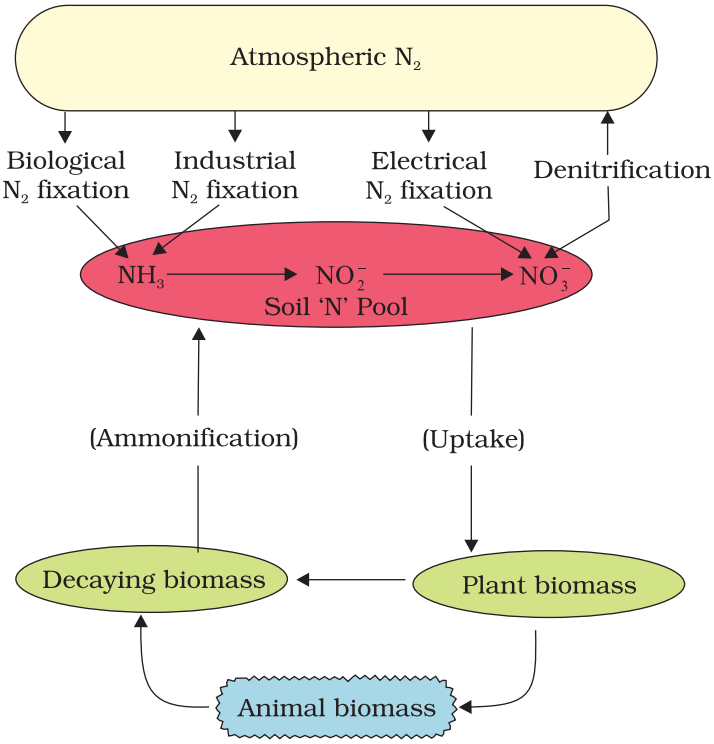


Fig. 8.19 The nitrogen cycle showing relationship between the three main nitrogen pools – atmosphere, soil and biomass

N_2O. Industrial combustions, forest fires, auto-mobile exhausts and power generating stations are also sources for atmospheric nitrogen oxides. Decomposition of organic nitrogen of dead plants and animals into ammonia is called 'ammonification'. Most of the ammonia is converted into nitrites and nitrates by soil bacteria by the following reaction.

$$2NH_3 + 3O_2 \rightarrow 2NO_2^- + 2H^+ + 2H_2O$$

$$2NO^-_2 + O_2 \rightarrow 2NO_3^-$$

Ammonia is first oxidized to nitrite by bacteria such as ***Nitrosomonas*** and ***Nitrosococcus***. Nitrites are further oxidized to 'nitrates' with the help of bacteria such as ***'Nitrobacter'***. These steps constitute '**nitrification**'. These nitrifying bacteria are *chemoautotrophs*.

The nitrate thus formed is absorbed by plants and is transported to the leaves. In leaves it is reduced to ammonia that finally forms the 'amine' group of amino acids. Nitrates present in the soil are also reduced to nitrogen by the process of 'denitrification'. Denitrification is carried out by bacteria such as ***Pseudomonas*** *and* ***Thiobacillus.***

8.6.3 Phosphorus Cycle

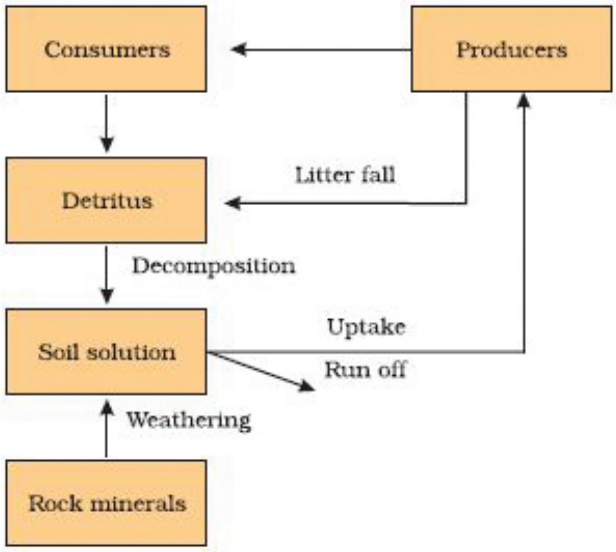


Fig. 8.20 A simplified model of phosphorus cycling in a terrestrial ecosystem

Phosphorus is a major constituent of biological membranes, nucleic acids and cellular energy transfer systems. Many animals also need large quantities of this element to make **shells**, **bones** and **teeth**. The natural reservoir of phosphorus is rock, which contains phosphorus in the form of 'phosphates'. When rocks are '**weathered**', minute amounts of these phosphates dissolve in soil solution and are absorbed by the roots of plants. Herbivores and other animals obtain this element from plants. The waste products and the dead organisms are decomposed by 'phosphate-solubilising bacteria' releasing phosphorus. Unlike carbon cycle, there is no respiratory release of phosphorus into the atmosphere.

8.7 Population

In nature, animals of any species which live as isolated single individuals are very rare. Majority of them live in groups, in a well defined geographical area. They share or compete for similar resources and interbreed to produce fertile offspring. Such a group of individuals is called a population. Though the term interbreeding implies sexual reproduction, generally a group of individuals resulting from even asexual reproduction is also considered a **'population'** in ecological terms. e.g. all the frogs living in a lake, rats in an abandoned dwelling, teakwood trees in a forest, bacteria on a *culture plate,* lotus plants in a pond and Paramecia in a pond.

It is a well known fact that an individual organism is the one that has to adjust to a changed environment. But it is also important to know that Natural Selection operates at the level of population in evolving the desired traits. Population ecology is, therefore, an important area of ecology because it links ecology to population genetics and evolution.

8.7.1 Population Attributes

A population has certain attributes that an individual organism does not exhibit.

1. **Natality (**Birth rate**)** and **Mortality (**Death rate**):** An individual may have birth and death, but a population has **birth rate (natality)** and **death rate (mortality)**. Natality is the number of new individuals produced in a unit time, per unit population. Mortality is the number of deaths that occurred in a unit time, per unit population. In a population these rates refer to *per capita* (per individual) births and deaths, respectively. The rate refers to change in numbers (increase or decrease) with respect to members of the population in unit time. Here is an example. If, in a pond there were 20 frogs last year and through reproduction 8 new frogs are added, taking the current population to 28, we calculate the birth rate as 8/20 = 0.4 offspring per frog per year. If 4 individuals in a laboratory population of 40 fruit-flies died during a specified time interval, say a week, the death rate in the population during that period is 4/40 = 0.1 individuals, per fruit-fly per week.
2. **Immigration and Emigration: Immigration** is the number of individuals of the same species that have come into the habitat/population from elsewhere/ another population during the time period under consideration. Immigration contributes to an increase in the population size.

   Emigration is the number of individuals of population which left the habitat/ population and gone elsewhere during the time period under consideration. Due to emigration the size of the population decreases.

3. **Sex ratio:** Another characteristic that influences the growth of a population is the *sex ratio*. An individual is either a male or a female, but a population has a sex ratio (e.g., 60 percent of the population are males and 40 percent population are females).
4. **Age distribution:** A population at any given time is composed of individuals of different ages. If the age distribution (percent individuals of a given age or age group) is plotted for the population, the resulting structure is called an **'age pyramid'**. For human population, the age pyramids generally show age distribution of males and females in a combined diagram. The shape of the pyramids reflect the 'status' of the population whether it is growing, stable or declining.

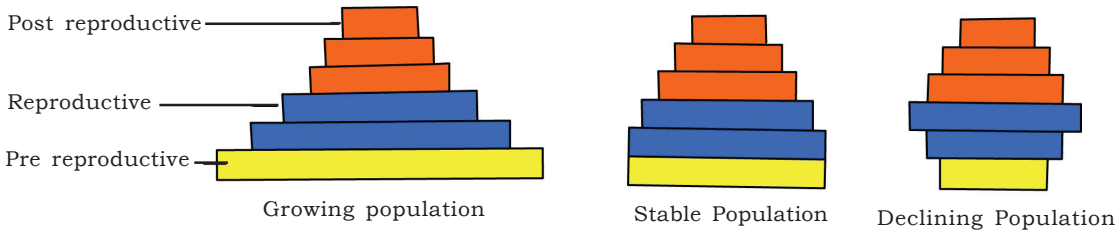


Fig. 8.21 Age pyramids

5. **Population size** or **Population density:** Population size, more technically called population density (designated as N) is the number of individuals per unit area (on land) or unit volume (in water).

Population density need not necessarily be measured in numbers only. Generally the most appropriate measure of population density is the total number. But in some cases it is either meaningless or difficult to determine. For example: Imagine there are 200 ***Parthenium*** plants and only a single huge banyan tree covering a large part in a particular area. If a statement is given that the population density of banyan is low relative to that of *Parthenium,* it amounts to underestimating the enormous role of the Banyan tree in that community. In such cases, the percent cover or biomass is a more meaningful measure of the population size. Total number is again not an easily adoptable measure if the population is huge and counting is impossible or very time-consuming. Sometimes, for certain ecological investigations, there is no need to know the absolute population densities; relative densities serve the purpose equally well. For instance, counting the number of fish caught per trap is good enough to measure its total population density in the lake. We mostly estimate population sizes indirectly, without actually counting them or seeing them. The tiger census in our National Parks and Tiger Reserves is often based on 'pug marks' and 'fecal pellets'. The size of the population provides a lot of information on the status of the species in the habitat. In the investigation of certain ecological processes in a population, change in the population size can be taken as an important parameter. e.g., the outcome of inter-specific competition, the impact of a predator, the effect of a pesticide application, etc., In nature, population size could be as low as <10 (Siberian

cranes at Bharatpur wetlands (Keoladeoghana National Park) in any year) or go into millions (***Chlamydomonas*** in a pond).

8.7.2. Population Growth

The size of a population for any species is not a static parameter. It keeps changing in time, depending on various factors including availability of food, 'predation pressure' and '**environmental resistance**'. These changes in population density provide information whether it is '*flourishing* or *declining*'. Whatever might be the ultimate reasons, the density of a population in a given habitat during a given period, fluctuates due to changes in four basic processes/ factors. **Natality** and **immigration** contribute to an increase in population density where as **mortality** and **emigration** lead to a decrease.

(i) **Natality** refers to the number of births during a given period in the population that are added to the initial number of individuals.

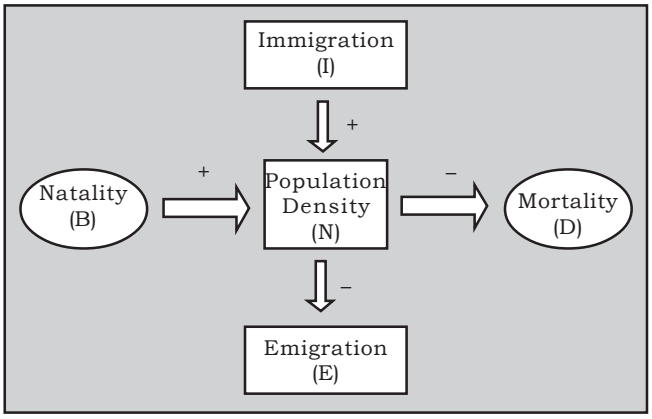
(ii) **Mortality** is the number of deaths in the population during a given period.

(iii) **Immigration** is the number of individuals of the same species that have come into the habitat/ population from elsewhere/ another population during the time period under consideration.

(iv) **Emigration** is the number of individuals of the population who left the habitat / population, during the time period under consideration.

So, if **"N"** is the population density at a given time **'t'**, its density at the time **t + 1 is** $N_{t+1} = N_t + \{(B + I) - (D + E)\}$

It can be seen from the above equation that population density will increase if the number of births plus the number of immigrants **(B + I)** is more than the number of deaths plus the number of emigrants **(D + E),** otherwise it will decrease. Under normal conditions, births and deaths are the most important factors influencing population density, the other two factors assuming importance only under special conditions. For instance, if a new habitat is just being colonised, immigration may contribute more significantly to the population growth than the factors affecting population density birth rate.



Growth Models

Does the growth of a population with time show any specific and predictable pattern? Uncontrolled growth of human population and resultant problems in our country are seriously concerning our planners. Therefore naturally we are curious to know whether different animal populations in nature behave the same way or

show some restraints on growth. Perhaps we can learn a lesson or two from nature on how to control population growth.

(i) Exponential growth: Resource (**food** and **space**) availability is essential for the unhindered growth of a population. Ideally, when resources in the habitat are unlimited (environmental resistence is almost nil), each species has the potential ability to grow in number, as Darwin observed while developing his theory of Natural Selection. In such conditions, the population grows in an '**exponential**' or '**geometric**' fashion. If in a population of size **N**, the birth rates (not total number but *per capita* births) are represented as ***b*** and death rates (again, *per capita* death rates) as ***d***, then the increase or decrease in **N (dN/dt)** during a unit time period **t** will be:

$$\frac{dN}{dt} = (b-d)N$$

Let

(b–d) = r, then

$$\frac{dN}{dt} = rN$$

The **'r'** in this equation is called the '***intrinsic rate of natural increase***' and is a very important parameter chosen for assessing impacts of any biotic or abiotic factor on population growth.

To give you some idea about the range of **r** values, for the Norway rat, the **r** is 0.015, and for the flour beetle- it is 0.12. In 1981, the **r** value for human population in India was **0.0205**. To calculate 'r', we need to know the rates of birth and death.

The above equation describes the exponential or geometric growth pattern of a population (see figure) and results in a J-shaped curve when we plot **N** in relation to time. Using the principles of calculus, we can derive the integral form of the exponential growth equation as

$N_t = N_o e^{rt}$ where

N_t = Population density after the time **t** ;

N_o = Population density at the time zero (initial time);

r = Intrinsic rate of natural increase

e = The base of natural logarithms (2.71828)

Any species growing exponentially under unlimited resource conditions can reach enormous population densities in a short time. Darwin showed how even a slow growing animal like elephant could reach enormous numbers in the absence of '**natural checks**'.

(ii) Logistic growth: No population of any species in nature has at its disposal unlimited resources to permit exponential growth. This leads to competition between individuals for limited resources. Eventually, the 'fittest' individual will

survive and reproduce. The governments of many countries have also realised this fact and introduced various control measures to limit growth of human population. In nature, any given habitat will have enough resources to support a maximum possible number, beyond which no further growth is possible. Let us call this limit as nature's **carrying capacity (K)** for that species in that habitat.

A population growing in a habitat with limited resources show initially a **lag phase**, followed by phases of **acceleration** and **deceleration** and finally an **asymptote/ stability**, when the population density reaches the carrying capacity. A plot of **N** in relation to time **(t)** results in a **sigmoid curve**. This type of population growth is called **Verhulst-Pearl Logistic Growth** (see figure) and is described by the following equation:

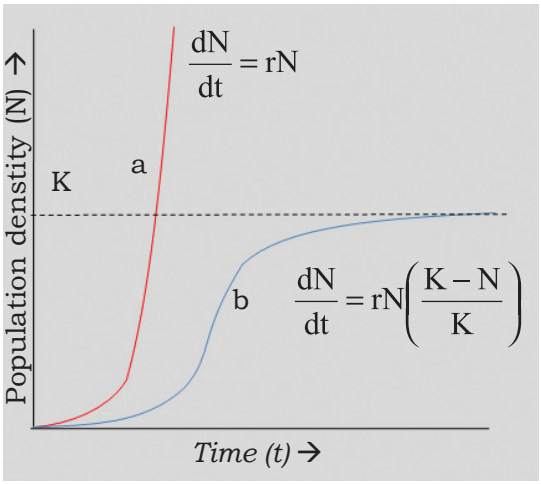
$$\frac{dN}{dt} = rN\left[\frac{K-N}{K}\right]$$

Where

N = Population density at the time t

r = Intrinsic rate of natural increase

K = Carrying capacity



Population growth curve
'a' : when resources are not limiting the growth plot is exponential.
'b' : when resources are limiting the growth. plot is logistic,
'K' : is carrying capacity

Since resources for growth for most animal populations are fixed and become limiting sooner or later, the logistic growth model is considered a more realistic one.

Population Growth curves: Curve **'a'** shows the *exponential growth* in population when resources are unlimited; Curve **'b'** shows the logistic growth in population when resources are a limiting factor where **K** is the *carrying capacity*.

8.7.3 Life history variation

Populations tend to maximise their reproductive fitness in their habitats. This is also called Darwinian fitness (high **'r'** value). Under a particular set of selection pressures, organisms evolve towards the most efficient reproductive strategy. Some organisms breed only once in their lifetime (e.g. Pacific salmon fish, bamboo plant) while others breed many times during their lifetime (e.g. most birds and mammals). Some produce a large number of small-sized offspring (e.g. Oysters, pelagic fishes) while others produce a small number of large-sized offspring (e.g. birds, mammals). The question is – which traits are desirable for maximising fitness? Currently this is an important area of research in ecology. Ecologists suggest that life history traits of organisms have evolved in relation to the constraints imposed by the abiotic and biotic components of the habitat in which they live.

8.8 Environmental Issues

Pollution

With an enormous increase in human population over the last 100 years, there is a heavy demand for food, water, clothing, home, roads, transport facilities and other innumerable commodities needed by man. To meet the demand man is exerting tremendous pressure on natural resources, thereby causing **environmental pollution.**

Pollution is an undesirable change in the physical, chemical or biological characteristics of the environment due to natural causes and human activities. Any deviation from the natural composition of the environment which causes adverse effects is also described as pollution. The agents which cause pollution are called **pollutants**.

Types of pollution

More commonly pollution is classified according to the type of environment that is affected. Mainly there are three types. 1. Air Pollution 2. Water Pollution and 3. Soil Pollution.

8.8.1 Air Pollution and its control

Earth is surrounded by an envelope of air consisting of various gases which is called atmosphere. As a blanket of gases atmosphere acts as a thermal insulator and regulates the temperature on the earth by selectively absorbing U.V.rays of solar radiation. The composition of the main gases in dry air by volume is Nitrogen **78.09%**, Oxygen **20.94%,** Argon **0.93%**, Carbon dioxide **0.03%**. Life cannot exist on earth without oxygen. Air pollutants cause injury to all living organisms. They reduce growth and yield of crops. They are harmful to the respiratory system of humans and animals. Increase in the concentration of pollutants or duration of exposure increase the harmful effects on the organisms.

The major air pollutants

1. Carbon monoxide (CO)

It is produced mainly due to incomplete combustion of fossil fuels. Automobiles are a major cause of CO pollution in larger cities and towns. Automobile exhausts, fumes from factories, emissions from power plants, forest fires and even burning of fire-wood contribute to CO pollution. Haemoglobin has greater affinity for CO and so CO competitively interferes with oxygen transport. CO causes symptoms such as **headache** and **blurred vision** at lower concentrations. In higher concentrations, it leads to coma and death.

2. Carbon Dioxide (CO_2)

Carbon dioxide is the main pollutant that is leading to **global warming**. Plants utilize CO_2 for photosynthesis and all living organisms emit carbon dioxide in the process of respiration. With rapid urbanization, automobiles, aeroplanes, power plants, and other human activities that involve the burning of fossil fuels such as gasoline, carbon dioxide is turning out to be an important pollutant of concern.

3. Sulphur Dioxide (SO_2)

It is mainly produced by burning of fossil fuels. Melting of sulphur ores is another important source for SO_2 pollution. Metal smelting and other industrial processes also contribute to SO_2 pollution. Sulphur dioxide and nitrogen oxides are the major causes of **acid rains**, which cause acidification of soils, lakes and streams, and also accelerated corrosion of buildings and monuments. High concentrations of sulphur dioxide (SO_2) can result in breathing problems in asthmatic children and adults. Other effects associated with long-term exposure to sulphur dioxide, include respiratory illness, alterations in the lungs' defenses and aggravation of existing cardiovascular problems.

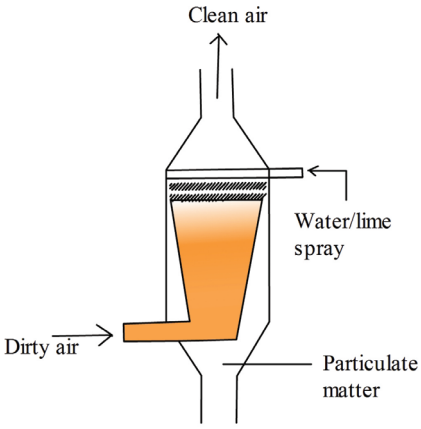


Fig. 8.22 Scrubber

To control SO_2 pollution, the emissions are filtered through scrubbers*. Scrubbers are devices that are used to clean the impurities in exhaust gases .

4. Nitrogen Oxides

Nitrogen oxides are considered to be major primary pollutants. The source is mainly automobile exhaust. The air polluted by nitrogen oxides is not only harmful to humans and animals, but also dangerous for the life of plants. Nitrogen oxide pollution also results in **acid rains** and formation of **photochemical smog**. The effect of nitrogen oxides on plants include the occurrence of necrotic spots on the surface of leaves. Photosynthesis is affected in crop plants and the yield is reduced. Nitrogen oxides combine with volatile organic compounds by the action of sunlight to form secondary pollutants called **Peroxyacetyl nitrate** (PAN) which are found especially in photochemical smog*. They are powerful irritants to eyes and respiratory tract.

* Photochemical smog is a type of air pollution caused by reactions between sunlight and pollutants such as hydrocarbons and nitrogen dioxide. Photochemical smog can be extremely harmful, leading to irritations of the respiratory tract(respiratory illness) and eyes.

*' Scrubbers' are air pollution control devices used to remove some particulates or gases from industrial exhausts. The term is used to describe systems that inject a dry reagent into a polluted exhaust stream to 'wash out'/ 'neutralise' acid gases. Lime stone slurry is often used in scrubbers (slurry means a thin mixture of insoluble substances such as cement, dust, etc., with water)

5. Particulate matter/Aerosols

Tiny particles of solid matter suspended in a gas or liquid constitute the 'particulate matter'. 'Aerosols' refer to particles and/or liquid droplets and the gas together (**a system of colloidal particles dispersed in a gas***). Combustion of 'fossil fuels' (petrol, diesel, etc.,), fly ash produced in thermal plants, forest fires, cement factories, asbestos mining and manufacturing units, spinning and ginning mills etc., are the main sources of particulate matter pollution. According to the **Central Pollution Control Board (CPCB)** particles of 2.5 micrometers or less in diameter are highly harmful to man and other air breathing organisms.

* These microscopic solids or liquid droplets that are so small and can get deep into the lungs cause decreased lung function, aggravated asthma, premature death in people with heart or lung disease, development of chronic bronchitis; irregular heartbeat, etc.

Electrostatic precipitator is a widely used 'filter' for removing particulate matter from the exhaust of thermal power plants. It can remove 99% particulate matter. It has high voltage electrodes which produce a 'corona' that releases electrons. These electrons attach to dust particles making them negatively charged. These are collected by **collecting plates** which attract the charged particles. The air flowing between the plates is kept in low velocity so as to allow the dust particles to settle on plates. Thus clean air is released into the atmosphere.

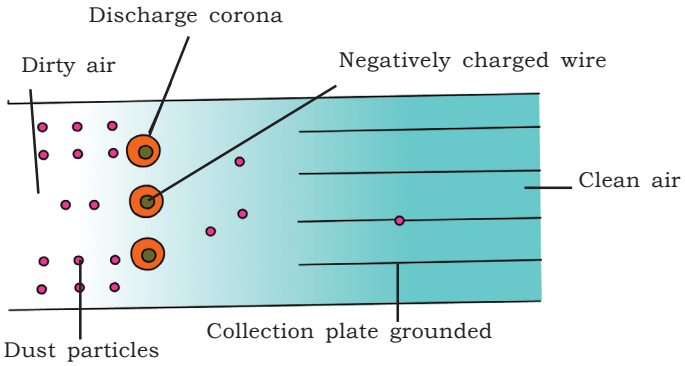


Fig 8.23 Electrostatic precipitator

Measures to control Air Pollution caused by automobiles

1. Proper maintenance of automobiles along with use of diesel or unleaded petrol.
2. Fitting '**catalytic converters**' to the automobiles having expensive metals namely platinum, palladium and rhodium as catalysts which reduce emission of poisonous gases.

Noise Pollution

In India, **Air (Prevention and control of pollution) Act** came into force in 1981. In 1987 it was amended to include noise also as an air pollutant. Undesirably high sounds constitute **noise pollution**. Sound is measured in units called decibels (dB). The human ear is sensitive to sounds ranging from **0 to 180 dB**. **0 dB** is **threshold**

limit of hearing and **120 dB** is threshold limit for sensation of pain in the ear. Any noise above **120 dB** is considered to be a noise pollution. A brief exposure to extremely high sound level, **(150 dB** or more generated by jet planes while taking-off) may damage eardrums causing permanent hearing impairment.Even long term exposure to a relatively lower level of noise of cities may also cause hearing impairment. Noise also causes auditory fatigue, anxiety, sleeplessness (**insomnia**), increased heart beat, altered breathing pattern thus causing considerable stress to humans.

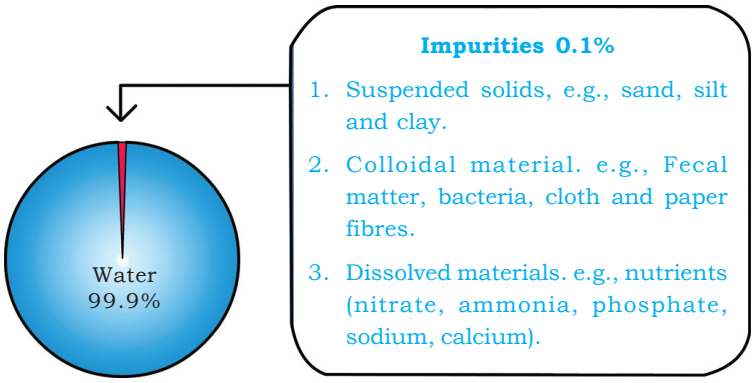
8.8.1.1 Controlling vehicular air pollution: A case study

Delhi leads the country not only as the National Capital but also in it's level of air pollution. Air pollution problem in the city of Delhi reached such a serious stage that a public interest litigation (court case) was filed in the Supreme Court of India. Under the directions of the Apex Court, the Government took various measures to control air pollution. The entire fleet of public transport buses were switched over to using compressed natural gas (**CNG**) as 'fuel' instead of diesel by the end of 2002. CNG is cheaper than petrol or diesel. It is the most efficient fuel and burns almost completely or very little of it is left un-burnt in automobiles. Simultaneously parallel steps such as phasing out of old vehicles, using **unleaded** and **low sulphur petrol** and diesel, using catalytic converters in vehicles, application of stringent pollution level norms for vehicles etc., were taken by the Government. The efforts paid well and the air quality of Delhi has significantly improved.

The Government of India, through a new **Auto Fuel Policy** has laid out a roadmap to cut down vehicular pollution in Indian cities. More stringent norms for fuels are specified to steadily reduce the sulphur and the content of aromatics in petrol and diesel fuels. Euro -II norms, for example, stipulate that sulphur be controlled at 350 ppm (parts-per-million) in diesel, and 150 ppm in petrol. Aromatic hydrocarbons are to be contained (limited) at 42 per cent of the concerned fuel. The goal, according to the roadmap, is to reduce sulphur to 50 ppm in petrol and diesel and bring down the level of the aromatic hydrocarbons to 35 per cent. Correspondingly/concurrently, engines of vehicles also are to be upgraded. The **Bharat Stage - III** (equivalent to **Euro-III norms**) is currently in place in many cities such as Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur and Agra, etc. All automobiles in these major cities should have met **Euro-IV norms** by April 1, 2010.

8.8.2 Water pollution and its control

Ancient civilizations flourished along river banks. Primitive life evolved in water only. The bodies of organisms contain water to the extent of nearly 90% of their body weight. Sea water constitutes 97% of water available on the planet. Fresh water which is required for our utility constitutes only about 3%.



Inferior quality of water, caused by pollution of natural waters is a major problem world is facing today. It is posing a serious threat in developing countries and India, of course, is not an exception. Many water bodies in general and almost all the rivers in India are grossly polluted either by sewage or discharge of industrial effluents.

8.8.2.1 Ganga Action Plan

The holy river Ganga along with its 2500 kms. stretch, has been receiving for decades, millions of gallons of untreated domestic sewage from many cities and towns and also toxic industrial effluents from thousands of industries. As a result, it is becoming a ***stinking dump*** of various toxic substances. The water is becoming unfit for drinking and cultivation. Kanpur, Allahabad, Varanasi, Patna, and Kolkata are identified to be the main centres for causing pollution of rivers. Government of India launched a plan in 1985 with the aim of purifying the waters of river Ganga (**Ganga Action Plan**). Due to change of scope of river pollution control works, the Govt. of India renamed the programme as **National River Conservation Project / Plan,** instead of Ganga Action Plan, which is now spread in 165 towns of 17 different states.

The major water pollutants

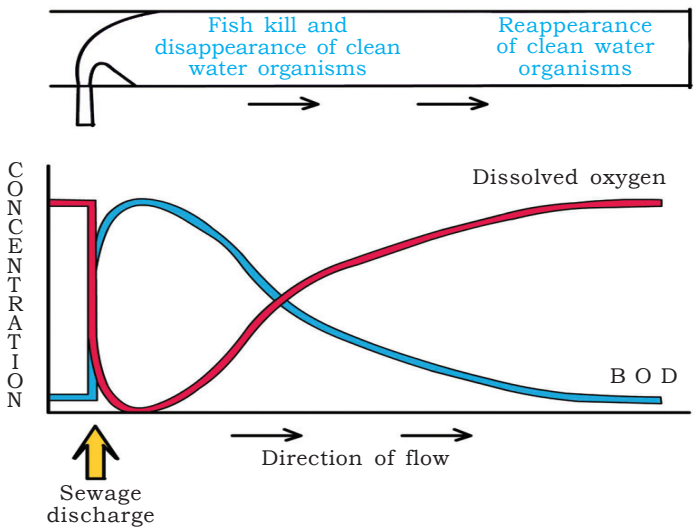


Fig. 8.23 Effect of sewage discharge on some important characteristics of a river

1. Domestic Sewage

Sewage is the major source of water pollution in large cities and towns. It mainly consists of human and animal excreta and other waste materials. It is usually released into freshwater bodies or sea directly. As per the regulations the sewage has to be passed through **treatment plants** before it is released into the water courses. Only 0.1 percent of impurities from domestic sewage are making these water sources unfit for human consumption. In the treatment of sewage, solids are easy to remove.

Removal of dissolved salts such as nitrates, phosphates and other nutrients and toxic metal ions and organic compounds is much more difficult. Domestic sewage primarily contains biodegradable organic matter, which will be readily decomposed by the action of bacteria and other microorganisms.

Biological Oxygen Demand (BOD)

BOD is a measure of the content of biologically degradable substances in sewage. The organic degradable substances are broken down by microorganisms using oxygen. The demand of oxygen is measured in terms of the oxygen consumed by microorganisms over a period of 5 days (**BOD 5**) or seven days (**BOD 7**). BOD forms an index for measuring **pollution load** in the sewage. Microorganisms involved in biodegradation of organic matter in water bodies consume a lot of oxygen, and as a result there is a sharp decline in dissolved oxygen causing death of fish and other aquatic animals.

Algal blooms

Presence of large amounts of nutrients in waters also causes excessive growth of planktonic algae and the phenomenon is commonly called 'algal blooms'. Algal blooms impart distinct colour to the water bodies and reduce the quality of water. It also causes mortality of fish. Some algae which are involved in algal blooms are toxic to human beings and animals.

Excessive growth of aquatic plants such as the *common water hyacinth* (*Eichhornia crassipes*), the world's most problematic aquatic weed which is also called '**Terror of Bengal**' causes blocks in our water ways. They grow faster than our ability to remove them. They grow abundantly in **eutrophic** water bodies (water bodies rich in nutrients) and lead to imbalance in the ecosystem dynamics of the water body.

Sewage arising from homes and hospitals may contain undesirable pathogenic microorganisms. If it is released untreated into water courses, there is a likelihood of outbreak of serious diseases, such as dysentery, typhoid, jaundice, cholera etc.,

2. Industrial Effluents

Untreated industrial effluents released into water bodies pollute most of the rivers, fresh water streams, etc., Effluents contain a wide variety of both inorganic and organic pollutants such as oils, greases, plastics, metallic wastes, suspended solids and toxins. Most of them are non-degradable. Arsenic, Cadmium, Copper, Chromium, Mercury, Zinc, and Nickel are the common heavy metals discharged from industries.

EFFECTS: Organic substances present in the water deplete the dissolved oxygen content in water by increasing the **BOD**(Biological oxygen demand) and **COD**(Chemical oxygen

demand). Most of the inorganic substances make the water unfit for drinking. Outbreaks of dysentery, typhoid, jaundice, cholera etc., are caused by sewage pollution.

Biomagnification

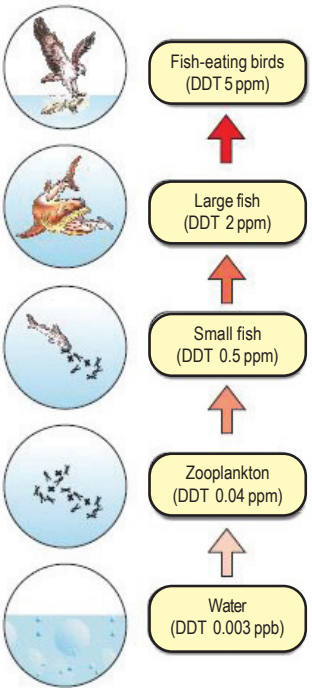


Fig. 8.24 Biomagnification of DDT in an aquatic food chain

Increase in the concentration of the pollutant or toxicant at successive trophic levels in an aquatic food chain is called **Biological Magnification** or **Bio-magnification**. This happens in the instances where a toxic substance accumulated by an organism is not metabolized or excreted and thus passes on to the next higher trophic level. This phenomenon is well known regarding DDT and mercury pollution.

As shown in the Fig. 8.24, the concentration of **DDT** is increased at successive trophic levels starting at a very low concentration of **0.003 ppb** (ppb = parts per billion) in water, which increased to a high concentration of **5 ppm** (ppm = parts per million) in fish-eating birds, through bio-magnification (It can reach maximum upto 25 ppm). High concentrations of DDT disturb **calcium metabolism in birds**, which causes thinning of egg shell and their premature breaking, eventually causing decline in bird populations.

Eutrophication

Natural **ageing** of a lake by nutrient enrichment of its water is known as **eutrophication**. In a young lake, the water is cold and clear, supporting little life. Gradually nutrients such as nitrates and phosphates are carried into the lake via streams, in course of time. This encourages the growth of aquatic algae and other plants. Consequently the animal life proliferates, and organic matter gets deposited on the bottom of the lake. Over centuries, as silt and organic debris piles up, the lake grows shallower and warmer. As a result, the aquatic organisms thriving in the cold environment are gradually replaced by warm-water organisms. Marsh plants appear by taking root in the shallow regions of the lake. Eventually, the lake gives way to large masses of floating plants (bog) and finally converted into land.

A ***bog*** is a wet, spongy, acidic ground composed of decayed vegetable matter.

Depending upon the climatic conditions, size of the lake and other factors, the natural ageing of a lake may span thousands of years. However, pollutants from human activity (**anthropogenic**) radically accelerate the aging process. This phenomenon is called '**Cultural** or **Accelerated eutrophication**'.

During the past century, lakes in many parts of the earth have been severely eutrophied by sewage, agricultural and industrial wastes. The prime contaminants

are nitrates and phosphates, which are the '**chief plant nutrients'**. The dissolved oxygen which is vital to other aquatic life is depleted. At the same time, other pollutants flowing into the lake may poison the whole population of fish, whose decomposing remains further deplete the dissolved oxygen content in the water.

Thermal pollution

Water is used as a coolant in Thermal power plants and other industies. Hot water flowing out of industries also constitute an important category of pollutants. Thermal waste water eliminates sensitive organisms (**stenothermal** organisms such as fish- especially the juveniles) downstream and may enhance the growth of plants and fish in extremely cold areas but, only after causing damage to the indigenous flora and fauna.

8.8.2.2 A Case Study Of Integrated Waste Water Treatment

Wastewater including sewage can be treated in an integrated manner, by combining both artificial and natural processes. A good example for such an initiative comes from the town of **Arcata,** situated along the northern coast of **California**. In collaboration with biologists from the Humboldt State University, the people of the town created an integrated waste water treatment process within a natural system. The cleaning of waste water is done in two stages.

1. In the **first stage**, the conventional sedimentation, filtering and chlorination treatments are given. Even after this treatment, the waste water contains lots of harmful pollutants such as dissolved heavy metals.
2. In the **second stage**, the water is discharged into a series of six connected marshes over 60 hectares of marshland seeded with appropriate plants, algae, fungi and bacteria as suggested by biologists. These flora of the marshland **neutralise**, **absorb** and **assimilate the pollutants**. As the water flows through the marshes, it is purified in a natural way and can be used for cultivation or other purposes.

The marshes also constitute a ***sanctuary,*** with a high level of **biodiversity** in the form of fishes, animals and birds that inhabit the area. A citizens' group called **Friends of the Arcata Marsh** (FOAM) are responsible for the upkeep and safeguarding of the wonderful project.

Ecological Sanitation - 'Ecosan Toilets'

Generally it is assumed that removal of wastes requires water, which means **creation of sewage**. If water is not used to dispose off human waste like excreta, and if one didn't have to flush the toilet after its use, a large amount of water can be saved. This is already a reality. Ecological sanitation is a sustainable system for handling human excreta, using **'Dry composting toilets'**. This is a practical, hygienic, efficient and cost-effective solution to human waste disposal. The key point to note here is that,

with this composting method, human excreta can be recycled into a resource (as natural fertiliser), which reduces the need for chemical fertilizers. 'EcoSan' toilets are in use in many parts of Kerala and Sri Lanka.

8.8.3 Soil Pollution (Land Pollution)

Soil or land pollution is mainly due to solid wastes and agro-chemicals such as fertilizers and pesticides.

Solid Wastes

Any thing (substance/material/articles/goods) that is thrown out as waste in solid form is referred to as **solid waste**. Municipal solid wastes are wastes from homes, offices, institutions, shops, hotels, restaurants etc., in towns and cities.

The municipal solid wastes generally consist of paper, food wastes, plastics, glass, metals, rubber, leather, textile, etc., The wastes are **burnt to reduce the volume** of the wastes. But generally wastes are not completely burnt and left as open dumps which often serve as the breeding grounds for rats and flies. As the substitute for open-burning dumps, **sanitary landfills** are adopted. In a sanitary landfill, wastes are dumped in a depression or trench after compaction, and covered with dirt everyday. There is a danger of seepage of chemicals and pollutants from these landfills, which may contaminate the underground water resources.

The best solution is to develop awareness in the society on these environmental issues. All wastes that we generate can be categorized into three types (a) **bio-degradable**, (b) **recyclable** and (c) **non-biodegradable**. It is important that all garbage generated should be sorted out category wise. The reusable or recyclable material has to be separated out and utilised.(Rag-pickers in the streets are doing a great job of separation of materials for recycling.) The biodegradable materials can be put into deep pits in the ground and be left for natural breakdown. The remaining non-biodegradable waste left over is to be disposed off properly.

The prime goal should be to reduce our garbage generation. But we are increasing the use of non-biodegradable products. We are packaging products of our daily use such as milk and water also in polythene bags. In cities and towns, many purchased things are packed in **polystyrene** and **plastic** packets. Thus we are contributing heavily to environmental pollution. State Governments across the country are trying to educate people on the reduction in use of plastics and use of **eco-friendly packaging**. We can do our bit by using carry-bags made of cloth or other natural fibres when we go for shopping and by refusing polythene bags.

i) Hospital Wastes

Hospitals generate hazardous wastes that contain disinfectants, harmful chemicals and also pathogenic micro-organisms. Such wastes also require careful treatment and

disposal. The use of ***incinerators*** (to burn wastes) is essential for disposal of hospital waste.

ii) Electronic wastes (e-wastes):

Irreparable computers and other electronic goods constitute the modern day pollutants called electronic wastes (e-wastes). E-wastes are buried in landfills or incinerated. Over half of the e-wastes generated in the developed world are exported to developing countries, mainly to China, India and Pakistan, where metals like copper, iron, silicon, nickel and gold are recovered during recycling process. Unlike developed countries, which have specifically built facilities for recycling of e-wastes, recycling in developing countries often involves manual participation thus exposing workers to toxic substances present in e-wastes. Eventually recycling is the only solution for the treatment of e-wastes provided it is carried out in an **environmental friendly** manner.

8.8.3.1 A Case Study Of Remedy For Plastic Waste

A Bangalore based plastic sack manufacturer **Ahmed Khan**, found an ideal solution to the ever-increasing problem of accumulating plastic waste. He is in the field of producing plastic sacks for more than 20 years. A few years ago, he realised the threat posed by plastic waste. As a remedy, his company developed a fine powder of recycled plastic mixture named **polyblend**. Polyblend is mixed with the **bitumen** that is used to lay roads. In collaboration with R.V.College of Engineering and the Bangalore City Corporation, Ahmed Khan proved that the life of roads laid with **polyblend** and **bitumen** mixture is tripled. It is observed that polyblend enhanced the bitumen's water repellant properties, and helped increase its road life. The raw material for creating polyblend is any plastic film waste. The cost of plastic waste given to rag pickers rose from Rs. 0.40 per kg to Rs.6 as was offered by Khan. Using Khan's technique, several roads have already been laid in Bangalore. Khan's company will soon be running short of plastic waste in Bangalore, to produce Polyblend. Thanks to innovations like Polyblend, we could find at least one way to overcome the problem of plastic wastes.

iii) Agro-chemicals and Their Effects

In the wake of the **Green Revolution**, use of inorganic fertilisers and pesticides has increased many times, for enhancing crop production. Pesticides, herbicides, fungicides, etc., are being increasingly used. They are also toxic to non-target organisms such as earthworms, nitrogen fixing bacteria,etc., that are important components of soil eco-system. Moreover due to bio-magnification, the harmful chemicals pose a great threat to human health. Indiscriminate use of fertilizers will lead to increased drain of nutrients into the nearby aquatic ecosystems causing eutrophication and the consequent effects.

8.8.3.2 Case Study of organic farming

Integrated organic farming is a ***zero-waste*** procedure, where recycling of waste products is efficiently carried out. Wastes originated from one process are used as nutrients for other processes. This allows the maximum utilisation of resource and increases the efficiency of production. A method practiced by **Ramesh Chandra Dagar**, a farmer in Sonipat, Haryana, is a very good example for this. He integrated bee-keeping, dairy management, water harvesting, composting and agriculture in a chain of processes. All these processes support one another and allow an extremely economical and sustainable venture. Crop waste and cattle excreta (dung) are used to create ***compost***, which can be used as a natural fertilizer. Natural ***bio-gas*** generated in the process can be used for meeting the energy needs of the farm. Enthusiastic about spreading information and helping in the practice of integrated organic farming, Dagar has created the **Haryana Kisan Welfare Club.**

iv) Radioactive wastes

Initially, nuclear energy was considered a non-polluting way for generating electricity. Later on, it was realised that the use of nuclear energy has two very serious inherent problems. The first is **accidental leakages**, as occurred in the **Three Mile Island** (**USA**) and **Chernobyl** (**Russia**)and the second is the **safe disposal** of radioactive wastes.

Radiation, that is released from nuclear waste is extremely dangerous to biological organisms, because it induces mutations. Exposure to high doses of nuclear radiation can lead to cancers (e.g.leukemia)., Therefore, nuclear waste is an extremely **potent pollutant** and has to be dealt with utmost caution. Storage of nuclear wastes should be done in suitably shielded containers and buried deep in the soil or oceans (about 500 meters). Even when done so,geological upheavals can bring them up, some day and cause radiation.

8.8.4 Green house effect and global warming

The term '**Greenhouse effect**' has been derived from a phenomenon that occurs in a 'greenhouse'. Greenhouse is a small glass house and is used for growing plants especially during winter. In a greenhouse the glass panel allows the passage of light into it, but does not allow heat to escape (as it is reflected back). Therefore, the greenhouse warms up, very much like inside a car that has been parked in the sun for a few hours.

The greenhouse effect is a naturally occurring phenomenon that is responsible for heating of the Earth's surface and atmosphere. It would be surprising to know that without greenhouse effect the average temperature of the Earth's surface would have been a chilly –18^{o} C rather than the present average of 15^{o}C.

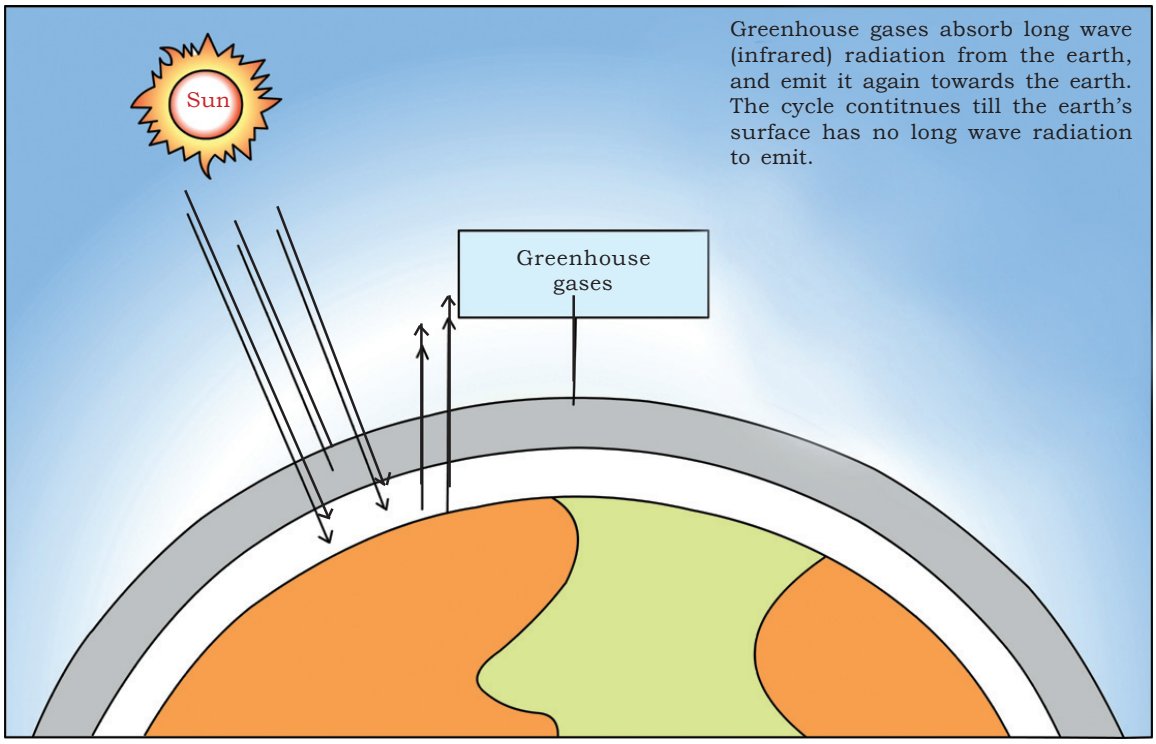


Fig. 8.25 Sunlight energy at the outermost atmosphere

When sunlight reaches the outermost layer of the atmosphere, clouds and gases reflect about one-fourth of the incoming solar radiation, and absorb some of it. Almost half of the incoming solar radiation falls on the Earth's surface and heats it up, while a small proportion is reflected back. The Earth's surface reflects heat in the form of infrared radiation but part of this does not escape into space as atmospheric gases (e.g., carbon dioxide, methane, etc.,) absorb a major fraction of it. The molecules of these gases radiate heat energy, and a major part of which again comes back to the Earth's surface, thus ***heating it up once again***. The above-mentioned gases – **carbon dioxide** and **methane** are commonly known as **greenhouse gases**, because they are responsible for the **greenhouse effect**.

Increase in the level of greenhouse gases has led to considerable heating of the Earth leading to **global warming**. During the past century, the temperature of the Earth has increased by 0.6 ^{O}C, most of it during the last three decades. Scientists believe that this rise in temperature is leading to severe changes in the environment. Global warming is causing climatic changes (e.g. such as **El Nino effect***) and is also responsible for the melting of polar ice caps and other snow caps of mountains such as the Himalayas. Over many years, this will result in a rise in sea levels, all over the world, that can submerge many coastal areas in the world. The total spectrum of

* El nino is unusual weather phenomena caused due to rise in temperature of the surface waters of the Pacific ocean in different parts of the world. Its effects are experienced all over the world and more so in the South American countries

changes that global warming can bring about is a subject that is still under active research.

Global warming – Control measures

1. The measures include cutting down use of fossil fuels.
2. Improving efficiency of energy usage.
3. Planting of trees, and avoiding deforestation.
4. Slowing down the growth of human population.

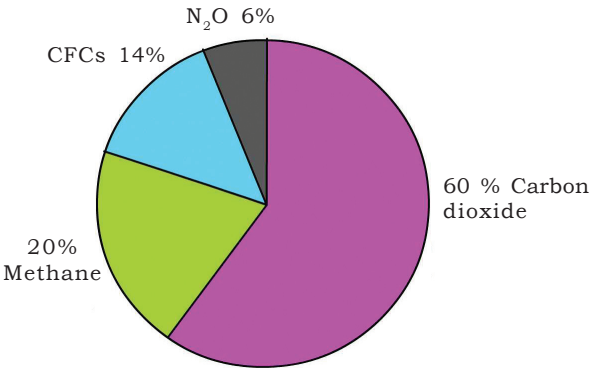


Fig 8.26 Relative contribution of various green house gases to total global warming

Kyoto Protocol

International initiatives are also being taken to reduce the emission of greenhouse gases into the atmosphere. To save earth from the dangers of 'global warming', an international conference was held at Kyoto, Japan (1997). As of September 2011, 191 countries have signed and ratified the protocol. As per this resolution it is decided to achieve the goal of reducing **green house emissions** into the atmosphere by 2008-12 to the levels of 1990.

8.8.5 Ozone depletion in the stratosphere

Ozone, formed in the lower atmosphere (troposphere) is known as **'bad ozone'** which harms plants and animals. Ozone found in the upper part of the atmosphere called the stratosphere is known as '**good ozone**', and it acts as an efficient **shield** by absorbing ultraviolet radiation from the sun. UV rays are highly injurious to living organisms. DNA and proteins of living organisms preferentially absorb UV radiation, and its high energy breaks the chemical bonds within these molecules. The thickness/ columnar density of the ozone in a **column of air** is measured in terms of **Dobson units** (DU). Ozone gas is continuously formed by the action of UV rays on molecular oxygen and is unstable. It is degraded into molecular oxygen in the stratosphere. There will be generally a balance between production and degradation of ozone in the stratosphere. Of late, the balance has been disrupted due to enhancement of ozone degradation by chlorofluorocarbons **(CFCs)**. CFCs are widely used as refrigerants and coolants. CFCs discharged into the lower strata of the atmosphere, move upward and reach the stratosphere. In the stratosphere, Cl atoms are released from CFC molecules by the action of UV rays. These Cl atoms act as catalysts and degrade ozone molecules and release **molecular oxygen**. As the Cl atoms are not consumed in this reaction, they continue to degrade ozone molecules. Hence, whatever CFCs are added to the stratosphere, they have permanent and continuing effects on the levels of ozone. The

depletion of ozone is particularly marked over the **Antarctic region**. This has resulted in the formation of a large area of thinned ozone layer, commonly called as the '**ozone hole**' (Figure).

UV radiation with wavelengths shorter than that of UV-B, are almost completely absorbed by Earth's atmosphere, provided that the ozone layer is intact. But **UV-B damages DNA and may induce mutations**. It causes ageing of skin, damage to skin cells resulting in **skin cancers**. In human eye, cornea absorbs **UV-B** radiation, and a high dose of **UV-B** causes inflammation of **cornea**, called **snow-blindness** formation of cataract, etc., Such exposure may permanently damage the cornea.

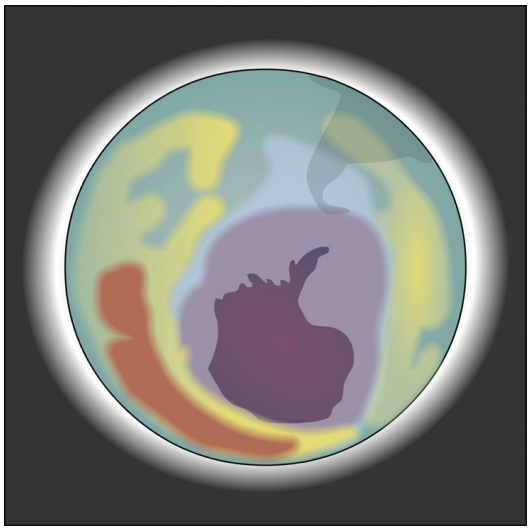


Fig. 8.27 Ozone hole is the area above Antarctica, shown in purple colour, where the ozone layer is the thinnest. Ozone thickness is given in dobson units (see carelfully the scale shown in colour violet or red). The ozone hole over Antarctica develops each year between late August and early October. *Curstesy: NASA*

Montreal Protocol

Understanding the deleterious effects of depletion of ozone, an international treaty, known as the **Montreal Protocol**, was signed at Montreal (Canada) in **1987** (became **effective in 1989**) to control the emission of pollutants/ substances responsible for ozone depletion. Subsequently many more efforts have been made and protocols have laid down definite roadmaps, separately for developed and developing countries, for reducing the emission of CFCs and other ozone depleting chemicals.

8.8.6 Degradation by improper resource utilisation and maintenance

The degradation of natural resources can occur, not just by the action of pollutants but also by improper resource utilisation practices.

i) **Soil erosion** and **desertification**: The development of the fertile **top-soil** takes centuries. But, it can be removed very easily due to human activities like over-cultivation, unrestricted grazing, deforestation and poor irrigation practices, resulting in the formation of arid patches of land. When large barren patches extend and meet over time, a desert is created. Internationally, it has been recognised that **desertification** is a major problem nowadays, particularly due to increased urbanisation.

ii) **Water-logging** and **soil salinity:** Irrigation without proper drainage of water leads to water-logging in the soil. Besides affecting the crops, water-logging draws salt to the surface of the soil (**salinisation of the top soil**). The salt then is deposited as a thin crust on the land surface or starts collecting at the roots of the plants.

This increased salt content is inimical (unfavourable) to the growth of crops and is extremely damaging to agriculture. Water-logging and soil salinity are some of the problems that have come in the wake of the Green Revolution.

iii) **Deforestation**: Deforestation is the conversion of forested areas to non-forested ones. According to an estimate, almost forty per cent forests have been lost in the tropics, compared to only one per cent in the temperate regions. At the beginning of the twentieth century, forests covered about **30** per cent of the land of India. By the end of the century, it shrunk to **19.4** per cent, whereas the **National Forest Policy (1988)** of India has recommended **33** percent forest cover for the plains and 67 per cent for the hills as ideal or desirable.

A number of human activities contribute to deforestation. One of the major reasons is the conversion of forest to agricultural land so as to feed the growing human population. Trees are axed for timber, firewood, cattle ranching and for several other purposes. **Slash** (cut) and **burn agriculture**, commonly called as **Jhum cultivation** in the north-eastern states of India and ***podu*** in other parts, has also contributed to deforestation. In slash and burn agriculture, the farmers cut down the trees of the forest and burn the plant remains. The ash serves as a fertiliser and the land is then used for farming or grazing cattle. After cultivation, the area is abandoned for several years to allow its recovery. The farmers then move on to other areas and repeat this process.

Consequences of deforestation

1) Enhanced carbon dioxide concentration in the atmosphere because trees that could hold a lot of carbon in their biomass (use CO_2 for photosynthesis) are lost with deforestation.
2) Loss of biodiversity due to habitat destruction.
3) Disturbed hydrological cycle.
4) Soil erosion.
5) Desertification in extreme cases.

Reforestation

Reforestation is the process of restoring a forest that once existed but was destroyed at some point of time in the past. Reforestation may occur naturally in a deforested area. However, we can speed it up by planting trees(saplings) with due consideration to biodiversity that existed earlier in that area.

8.8.6.1 Case Study of People's Participation in the Conservation of Forests

Amrita Devi Bishnoi wildlife protection Award

People's participation in 'protecting forests ' has a long history in India. In 1731, the king of Jodhpur in Rajasthan asked one of his ministers to arrange wood for constructing a new palace. The minister and workers went to a forest near a village, inhabited by Bishnois, to cut down trees. The **Bishnoi community** is known for its peaceful co-existence with nature. The effort to cut down trees by the king was thwarted by the Bishnois. A Bishnoi woman **Amrita Devi** showed exemplary courage by hugging a tree and daring king's men to cut her first before cutting the tree. The tree mattered much more to her than her own life. Sadly, the king's men did not heed to her pleas, and cut down the tree along with Amrita Devi. Her three daughters and hundreds of other Bishnois followed her, and thus lost their lives in their effort to save trees. Nowhere in history do we find a commitment of this magnitude when human beings sacrificed their lives for the cause of the environment. The Government of India has recently instituted the "**Amrita Devi Bishnoi Wildlife Protection Award**" for individuals or communities from rural areas that have shown extraordinary courage and dedication in protecting wildlife.

The Chipko Movement of Garhwal Himalayas

In 1974, local women showed enormous bravery in protecting trees from the axe of contractors by hugging the trees. People all over the world have acclaimed the **Chipko movement**. Realising the significance of participation by local communities the Government of India in 1980s has introduced the concept of **Joint Forest Management** (**JFM**) so as to work closely with the local communities for protecting and managing forests. In return for their services to the forest, the communities get the benefit of various forest products (e.g., fruits, gum, rubber, medicine, etc.).

Indian Government passed Environment (Protection) Act in 1986; Water (Prevention and Control of Pollution) Act in 1974.

GLOSSARY

Autecology: ecology of individual species

Basking: Exposing the body to sun light, to gain temeprature.

Benthos: It refers to all the attached, creeping or burrowing organisms that inhabit the bottom of rivers, lakes and sea.

Biomass: The total mass of living material within a specified area at a given time.

Blubber: It is a specialized subcutaneous layer of fat found only in marine mammals. It is almost continuous across the body of marine mammals but absent on appendages.

Brakish water: An intermediate zone between freshwater and marine water.

Camouflage Concealing coloration (e.g., melanism) and morphology (e.g. stick insects) as defence against predation

Chemoautotrophs: These comprise bacteria that obtain energy from the oxidation of simple inorganic compounds and can use the energy released to assimilate CO_2 and transfer the energy into organic compounds. E.g. *Thiobacillus* species.

Climate: The climate of an area can be described by its mean values of temperature, rainfall, wind speed.

Community: The total living biotic component of an ecosystem, including plants, animals and microbes.

Competitive exclusion: It is often known as Gause principle.

Cyclomorphosis: Cyclic change in phenotype, such as seasonal changes in morphology, particularly conspicuous among cladoceran crustacean and rotifers.

Detritus: Non living organic matter. Usually refers to particulate matter to that of plant rather than animal origin. E.g. leaf litter.

Diapause: It is a condition of arrested growth or reproductive development common in many organisms, particularly insects, during unfavourable conditions.

Dimictic Lake: The lake that undergoes two periods of complete vertical mixing, usually in the spring and the fall. During the summer dimictic lakes are thermally stratified.

Edaphic factors: The physical, chemical and biotic characteristics of the soil that influence plant growth and distribution.

Estuary: It is a place where river joins the sea. The water in an estuary is subjected to seasonal variations in salinity. The water is called brackish water. The animals living there are euryhaline.

Gemmules: These are the internal buds that appear in the asexual reproduction of sponges. Gemmules are made up of amoebocytes and covered by a layer of spicules, and can survive in unfavourable conditions.

Leaching: Removal of soluble components by flowing water from soil.

Mycorrhizae: The symbiotic association of mycelium of a fungus with the roots of a seed plant.

Osmotrophic nutrition: Intake of pre-digested food material through the body surface.

Pedonic forms: The organisms which depend on substratum (or support) in an aquatic ecosystem.

Periphyton: The communities of tiny organisms like protozoa, insect larvae, snails that live on the surfaces of aquatic plants.

Savannas: Grassland region with scattered trees in subtropical and tropical regions.

Standing crop: The mass of vegetation in a given area at one particular time. Although most of often applied to plant material, the term includes animal biomass.

Denitrificaion: Denitrification is a microbially facilitated process of nitrate reduction that may ultimately produce molecular nitrogen (N_2) through a series of intermediate gaseous nitrogen oxide products.

Decomposer: Decomposers (or saprotrophs) are organisms that break down dead or decaying organisms, and in doing so carry out the natural process of decomposition.

Sedimentary: Formed by the accumulation and consolidation of mineral and organic fragments that have been deposited by water, ice, or wind.

Asymptote: A line which approaches nearer to some curve than assignable distance, but, though infinitely extended, would never meet it.

Chemo-autotroph: An organism (typically a bacterium or a protozoan) that obtains energy through chemical process, which is by the oxidation of electron donating molecules from the environment, rather than by photosynthesis.

Mortality: Death rate or the number of individuals that died in a population in a unit time.

Natality: Birth rate or the number of individuals produced in a population in unit time.

Acid rains: Acid rain is a rain or any other form of precipitation that is unusually acidic.

Algal bloom: An algal bloom is a rapid increase or accumulation in the population of algae (typically microscopic) in an aquatic system.

Biodegradable: Capable of being broken down especially into harmless products by the action of living things (as microorganisms).

Biological Oxygen Demand (BOD): The amount of dissolved oxygen needed by aerobic biological organisms in a body of water to break down organic material present in a given water sample at certain temperature over a specific time period.

Chemical Oxygen Demand (COD): A test procedure based on the chemical decomposition of organic and inorganic contaminants dissolved or suspended in water.

Chloro fluoro carbons (CFC): Any of various halocarbon compounds consisting of carbon, hydrogen, chlorine, and fluorine, once used widely as aerosol propellants and refrigerants. Chlorofluorocarbons are believed to cause depletion of the atmospheric ozone layer.

Deforestation: The removal of a forest or stand of trees where the land is thereafter converted to a non-forest use.

Eutrophication: A process whereby water bodies, such as lakes, estuaries, or slow-moving streams receive excess nutrients that stimulate excessive plant growth (algae, periphyton attached algae, and nuisance plants and weeds).

Fungicides: Substance or preparation, as a spray or dust, used for destroying fungi.

Herbicides: Chemicals used to kill unwanted weeds.

Incinerator: a furnace or apparatus for burning trash, garbage, etc., to ashes.

Land fills: Landfill is a carefully engineered depression in the ground (or built on top of the ground, resembling a football stadium) into which wastes are dumped.

Pesticides: Chemicals used to kill pests, especially insects.

Photochemical smog: A type of air pollution produced when sunlight acts upon motor vehicle exhaust gases to form harmful substances such as ozone (O_3), aldehydes and peroxyacetylnitrate (PAN).

Polyblend: Physical mixture of two or more polymers. Such blends usually yield products with favorable properties of both components.

Scrubber: Scrubbers are commonly used to eliminate potentially harmful dust and pollutants from exhausts. In scrubbers, a liquid, in general water added with active chemicals is sprayed in to the air flow. Aerosol and gaseous pollutants in the air stream are removed by either absorption or chemical reactions with the water solution.

Sewage: Domestic waste water containing various solid and liquid waste materials including human excreta.

Soil erosion: The washing away of soil by the flow of water or wind

Thermal Pollution: Water Pollution caused by hot water coming out from industries, thermal power plants etc., which is harmful to aquatic organisms.

Ultraviolet-B (UV-B): One of the three types of invisible light rays (together with ultraviolet-A and ultraviolet-C) given off by the sun. Although ultraviolet-C is the most dangerous type of ultraviolet light in terms of its potential to harm life on earth, it cannot penetrate earth's protective ozone layer. Therefore, it poses no threat to human, animal or plant life on earth as long as ozone layer is intact. Ultraviolet-A and ultraviolet- B, on the other hand, do penetrate the ozone layer in attenuated form and reach the surface of the planet. UV-A rays cause cells to age and can cause some damage to cells' DNA. They are linked to long-term skin damage such as wrinkles, but are also thought to play a role in some skin cancers. UVB rays can cause direct damage to the DNA, and are the main rays that cause sunburns. They are also believed to cause most skin cancers.

VERY SHORT ANSWER TYPE QUESTIONS

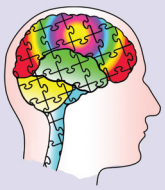
1. Define the term ecology and its branches.
2. Define a community?
3. What is an ecosystem?
4. What is a biome? Name any two biomes you studied.
5. Explain the difference between the 'niche' of an organism and its 'habitat'.
6. How does your body solve the problem of altitude sickness, when you ascend tall mountains?
7. What is the effect of light on body pigmentation?
8. Distinguish the terms phototaxis and photokinesis.
9. What is photoperiodism?
10. Mention the advantages of some UV rays to us.
11. What is cyclomorphosis? Explain its importance in *Daphnia.*
12. What are 'regulators"?
13. What are 'conformers'?
14. Define commensalism. Give one example.
15. Define mutualism. Give one example.
16. What is camouflage? Give its significance.
17. What is Gause's principle? When does it applicable?
18. Distinguish between lotic and lentic habitats.
19. Distinguish between phytoplankton and zooplankton.
20. Distinguish between neuston and nekton.
21. Explain the process of 'leaching'
22. What is PAR?
23. What is the percentage of PAR, in the incident solar radiation.
24. Explain the terms GPP, NPP.
25. Distinguish between upright and inverted ecological pyramids.
26. Distinguish between primary and secondary productivity.
27. Which air pollutants are chiefly responsible for acid rains?
28. What is BOD?
29. What is biological magnification?
30. Why are incinerators used in hospitals?

SHORT ANSWER TYPE QUESTIONS

1. What is summer stratification? Explain.
2. What is the significance of stratification in lakes?
3. Explain vant' Hoff rule.
4. Unlike mammals the reptiles cannot tolerate environmental fluctuations in temperature. How do they adapt to survive in desert conditions?
5. How do terrestrial animals protect themselves from the danger of dehydration of bodies?
6. How do marine animals adapt to hypertonic seawater?
7. Distinguish between euryhaline and stenohaline animals.
8. An orchid plant is growing on the branch of mango tree. How do you describe this interaction between the orchid and mango tree?
9. Predation has a significant role in maintaining of species diversity-discuss.
10. Discuss competitive release.
11. Explain brood parasitism with a suitable example.
12. How do predators act as biological control?
13. Explain the different types of aquatic ecosystems.
14. Explain the terms saprotroph, detritivores, and mineralizers.
15. Define decomposition and describe the process and products of decomposition.
16. What is primary productivity? Give a brief description of the factors that affect primary productivity.
17. Define ecological pyramids and describe with examples, pyramids of numbers and biomass.
18. What are the deleterious effects of depletion of ozone in the stratosphere?
19. Describe 'Green House Effect'?
20. Write critical notes on the following:
    a) Eutrophication
    b) Biological magnification
    c) Ground water depletion and ways for its replenishment

LONG ANSWER TYPE QUESTIONS

1. Write an essay on temperature as an ecological factor.
2. Write an essay on water as an ecological factor.
3. Describe lake as an ecosystem giving examples for the various zones and the biotic components in it.
4. Describe different types of food chains that exist in an ecosystem.
5. Give an account of flow of energy in an ecosystem.
6. List out the major air pollutants and describe their effects on human beings ?
7. What are the causes of water pollution and suggest measures for control of water pollution ?



For ignited minds

- Not For Evaluation

1. All types of UV rays are not useless to man. How do you defend the statement?
2. Elephant is a large sized animal and an herbivore. How do you justify it?
3. Lakes in temperate countries are much better places for aquatic life than the tropical lakes. Do you agree with above statement? Explain.
4. Even though different kinds of plants live in a lake, there is a sort of 'war' between some species, which is not visible to the naked eye. Justify the comment giving an example.
5. With reference to representation of biomasses in food pyramids, what happens when algae 'bloom' and after a month or two the algae start dying, as they have completed their life cycles.
6. "All photosynthetic organisms are autotrophs, but all autotrophs are not photosynthetic." How do you substantiate this statement.
7. Based on the laws of thermodynamics, guess if bioluminescence influences the 'energy homeostasis' in the body. *(Clue: bioluminescence is a catabolic process, in a way.)*
8. If the body mass of a tertiary carnivore is 10 KJ, and if the photosynthetic organisms which provide food for it utilize 20% of their produce in their catabolism, what will be the GPP taking into consideration the 10% law.
9. Why do marine birds excrete salts through nasal passages?
10. Can a fungus become a part of the predator chain? If so, can you give an example?

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Board of Intermediate Education, A.p., Hyderabad
Syllabus Of Intermediate I Year
Zoology- I (w.e.f 2012-13)

Name of Topics and sub topics	No of Periods
UNIT- I: ZOOLOGY – Diversity of Living World 1.1 What is life? 1.2 Nature, Scope & meaning of zoology 1.3 Branches of Zoology 1.4 Need for classification- Zoos as tools for the study of taxonomy 1.5 Basic principles of Classification: Biological system of classification- (Phylogenetic classification only) 1.6 Levels or Hierarchy of classification 1.7 Nomenclature – Bi & Trinominal 1.8 Species concept 1.9 Kingdom Animalia 1.10 Biodiversity – Meaning and distribution (Genetic diversity, Species diversity, Ecosystem diversity(alpha,beta and gama), other attributes of biodiversity, role of biodiversity, threats to biodiveristy, methods of conservation, IUCN Red data books, Conservation of wild life in India – Legislation, Preservation, Organisations, Threatened species	16
UNIT- II : Structural organization in Animals 2.1 Levels of organization, Multicellularity: Diploblastic & Triploblastic conditions 2.2 Asymmetry,Symmetry: Radial symmetry, and Bilateral symmetry **(Brief account giving one example for each type** from the representative phyla) 2.3 Acoelomates, Pseudocoelomates and Eucoelomates :- Schizo & Entero coelomates **(Brief account of formation of coelom)** 2.4 Tissues: Epithelial, Connective, Muscular and Nervous tissues. (make it a little more elobarative).	18

UNIT- III: Animal Diversity - I *INVERTEBRATE PHYLA General Characters – Strictly restrict to 8 salient features onlyClassification up to Classes with two or three examples – Brief account only* 3.1 Porifera 3.2 Cnidaria 3.3 Ctenophora 3.4 Platyhelminthes 3.5 Nematoda 3.6 Annelida (Include Earthworm as a type study strictly adhering to NCERT text book) 3.7 Arthropoda 3.8 Mollusca 3.9 Echinodermata 3.10 Hemichordata	**18**
UNIT- IV: Animal Diversity-II : Phylum: Chordata General Characters – Strictly restrict to 8 points onlyClassification up to Classes - Brief account only with two or three examples 4.1 Sub phylum: Urochordata 4.2 Sub phylum: Cephalochordata 4.3 Sub phylum : Vertebrata 4.4 Super class: Agnatha 4.4.1 Class Cyclostomata 4.5 Super class: Gnathostomata 4.5.1 Super class pisces 4.5.2 Class: Chondricthyes 4.5.3 Class: Osteichthyes 4.6 Tetrapoda 4.6.1 Class: Amphibia (Include Frog as a type study strictly adhering to NCERT text book) 4.6.2 Class: Reptilia 4.6.3 Class: Aves 4.6.4 Class: Mammalia	**18**

UNIT- V: LOCOMOTION & REPRODUCTION IN PROTOZOA 5.1 Locomotion: Definition, types of locomotor structures pseudopodia (basic idea of pseudopodia without going into different types), flagella & cilia **(Brief account giving two** examples each) 5.2 Flagellar & Ciliary movement – Effective & Recovery strokes in *Euglena*, Synchronal & Metachronal movements in Paramecium. 5.3 Reproduction: Definition, types. Asexual Reproduction: Transeverse binary fission in *Paramecium* & Longitudinal binary fission in *Euglena.* Multiple fission 5.4 Sexual Reproduction.	**12**
UNIT - VI : Biology in Human Welfare 6.1 Parasitism and parasitic adaptation 6.2 Health and disease: introduction (follow NCERT) Life cycle, Pathogenecity, Treatment & Prevention (Brief account only) 1. Entamoeba histolytica 2. Plasmodium vivax 3. Ascaris lumbricoides. 4. Wuchereria bancrofti 6.3 Brief account of pathogenecity, treatment & prevention of Typhoid, Pneumonia, Common cold, & Ring worm. 6.4 Drugs and Alcohol absuse	**20**
UNIT- VII: Type study of Periplaneta americana 7.1 Habitat and habits 7.2 External features 7.3 Locomotion 7.4 Digestive system 7.5 Respiratory system 7.6 Circulatory system 7.7 Excretory system 7.8 Nervous system – sense organs, structure of ommatidium. 7.9 Reproductive system	**15**

UNIT- VIII : Ecology & Environment	40
8.1 Organisms and Environment: Ecology, population, communities, habitat, niche, biome and ecosphere (definitions only) 8.2 Ecosystem: Elementary aspects only Abiotic factors- Light, Temperature & Water (Biological effects only), Ecological adaptations 8.3 Population interactions 8.4 Ecosystems: Types, Components, Lake ecosystem 8.5 Food chains, Food web, Productivity and Energy flow in Ecosystem, Ecological pyramids – Pyramids of numbers, biomass and energy. 8.6 Nutritient cycling – Carbon, Nitrogen, & Phosphorous cycles (Brief account) 8.7 Population attributes: Growth, Natality and Mortality, Age distribution, Population regulation. 8.8 Environmental issues	

BOARD OF INTERMEDIATE EDUCATION, A.P, HYDERABAD

MODEL QUESTION PAPER

Time : 3 hrs **Max Marks : 60**

SECTION – A (10 x 2 = 20)

Answer all the questions. Every answer should be restricted to four lines only.

1. Explain tautonymy. Give one example.
2. Name two larval forms of sponges
3. What is endostyle? What is its function?
4. What is biological magnification?
5. What is paurometabolous development? Give one example.
6. What is lymph? How does it differ from plasma?
7. Define mutualism? Give one example.
8. The head of cockroach is said to be hypognathous. Justify the statement
9. What is nocturnal periodicity? Give one example.
10. What is nitrogen fixation? Give one example of an organism that fixes nitrogen.

SECTION – B (6 x 4 = 24)

Answer any six questions. Every answer should be restricted to twenty lines only.

11. Describe the system of binominal nomenclature
12. Mention the general characters of Holothuroidea
13. Mention the general characters of the class Amphibia
14. Give an account of flagellar locomotion.
15. Draw a neat labelled diagram of a multipolar neuron.
16. In your view what motivates youngsters to take to alcohol or drugs and how can this be avoided?
17. Give an account of Haversian system of a compact bone.
18. Give an account of transverse binary fission

SECTION – C (2 x 8 = 16)

Answer any two questions. Every answer should be restricted to sixty lines only.

19. Describe the mosquito phase of the life history of *Plasmodium vivax*
20. Describe the digestive system of *Periplaneta americana*. Add a note on physiology of digestion.
21. Give an account of the flow of energy in an ecosystem.