PREFACE

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

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

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

I wish the venture all success.

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

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Four Year Undergraduate Degree Programme

Under National Higher Education Qualifications Framework (NHEQF) & Curriculum and Credit Framework for Undergraduate Programmes

Bachelor of Science (Honours) in Zoology

Programme Code : NZO

Course Type: Discipline Specific Core (DSC)

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: Course Writer :

Dr. Sudipta Das
Associate Professor, Department of Zoology
School of Sciences, NSOU

: Course Editor :

Prof. C. R. Sahu,
Retd. Professor, Department of Zoology,
University of Kalyani

: Format Editor :

Mr. Ashif Ahamed
Assistant Professor of Zoology, NSOU

Netaji Subhas Open University

UG: Zoology (DSC)

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UNIT 1 ❑ Basic concepts of five kingdom classification - domains of life, General characteristics of Protista, Parazoa and Metazoa

Structure

1.1 ❑ Objective

After studying this unit the learners will get an overall idea about five and more kingdoms of life, domains of life, general characteristics of Protista, Parazoa and Metazoa.

1.2 ❑ Basic concepts of five kingdom classification

In biology, a **kingdom** of life is a taxonomy rank that is below domain and above phylum. In other words, it is a broad classification of organisms according to their characteristics. A **kingdom** is a taxonomic rank composed of smaller groups called phyla (or divisions, in plants). It serves as one of the primary ranks for organizing and grouping living organisms based on their shared characteristics and evolutionary history.

The classification begins with the highest rank, the domain, and progresses through kingdoms » phyla » classes » orders » families » genera » species. Kingdoms represent a

level of classification that encompasses a broad range of organisms with significant similarities, and they are further divided into more specific categories as we move down the taxonomic hierarchy.

In 1969, Robert H. Whittaker proposed the **five-kingdom system** of classification that distinguished between kingdoms according to cellular organization and mode of nutrition. According to this system:

1. Members of the **Kingdom Monera** are the bacteria and the cyanobacteria. They are distinguished from all other organisms by being prokaryotic.
2. Members of the **Kingdom Protista** are eukaryotic and consist of single cells or colonies of cells. This kingdom includes Amoeba, Paramecium, and many others.
3. Members of the **Kingdom Plantae** are eukaryotic, multicellular, and photosynthetic. Plants have walled cells and are usually nonmotile.
4. Members of the **Kingdom Fungi** are also eukaryotic and multicellular. They also have walled cells and are usually nonmotile. Mode of nutrition distinguishes fungi from plants. Fungi digest organic matter extracellularly and absorb the breakdown products.
5. Members of the **Kingdom Animalia** are eukaryotic and multicellular, and they usually feed by ingesting other organisms or parts of other organisms. Their cells lack walls and they are usually motile.

But in recent years, new information has challenged the five kingdom classification system. The emerging picture is that the five previously described kingdoms do not represent distinct evolutionary lineages.

Carl Woese and his colleagues proposed **six-kingdom system** of classification dividing prokaryotes into Eubacteria and Archaebacteria in 1977. The distinction arises from ribosomal RNA structure. This model leads to six kingdoms.

Thomas Cavalier-Smith and his colleagues propose seven kingdoms:

Bacteria, Archaea, Protozoa, Chromista, Plantae, Fungi, and Animalia.

One eight kingdom system divides the Eubacteria into Negibacteria (Gram negative bacteria) and Posibacteria (Gram positive bacteria). Another system of eight Kingdoms is Eubacteria, Archaebacteria, Archezoa, Protozoa, Chromista, Plantae, Fungi, and Animalia. In this system, the Archezoa are protozoa that lack mitochondria.

The United States and Canada often use a system of six kingdoms: Animalia, Plantae, Fungi, Protista, Archaea or Archaebacteria, and Bacteria or Eubacteria.

Biology texts in Great Britain, India, Brazil, Greece, and several other countries use a system with five kingdoms: Animalia, Plantae, Fungi, Protista, and Monera. Some American and Canadian texts also classify organisms into five kingdoms.

1.3 ❑ Kingdoms of Life

The system of 6 kingdoms breaks Monera into Archaea or Archaebacteria and Bacteria or Eubacteria, but it is otherwise the same as the 5 kingdom

Classification**:**

- Animalia
- Plantae
- Fungi
- Protista
- Archaea or Archaebacteria
- Bacteria or Eubacteria

Animalia, Plantae, Fungi, and Protista are all eukaryotes. Monera (Archaea and Bacteria) are prokaryotes.

- **Animalia**

Animals are multicellular creatures that eat other organisms for nutrition. Animals vary widely in size and usually use sexual reproduction

- **Plantae**

Plants are multicellular organisms that made their own food via photosynthesis. The primary producers. Plants are classified according to whether they are vascular or nonvascular, flowering or nonflowering, and other characteristics.

- **Fungi**

Fungi include both unicellular and multicellular forms. Unlike plants, fungi do not perform photosynthesis. Instead, they decompose organic material and absorb nutrients.

- **Protista**

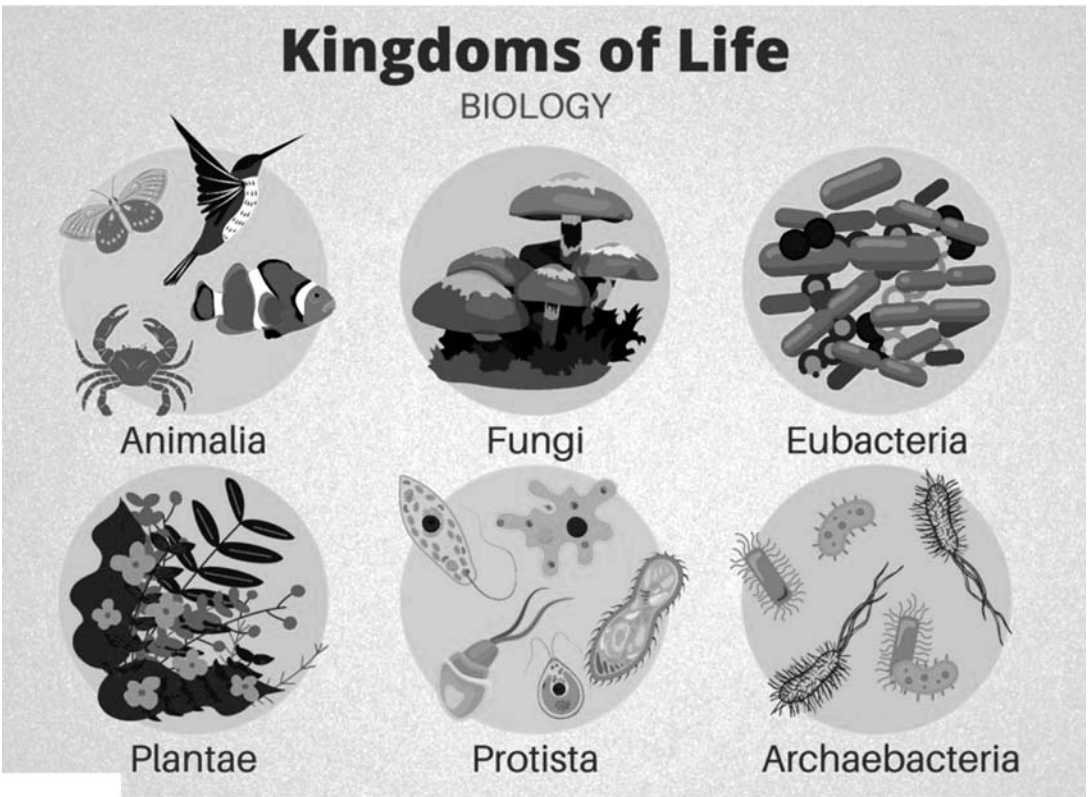
Protists or protozoa are single-celled eukaryotes. However, some species aggregate into masses. Unlike the cells of plants or fungi, they lack cell walls. Many are capable of movement. Some perform photosynthesis.

- **Archaea or Archaebacteria**

Archaebacteria are a group of microorganisms considered to be an ancient form of life that evolved separately from the bacteria and blue-green algae, and they are sometimes classified as a kingdom. Hyperthermophilic (i.e., high-temperature-loving) archaebacteria, found in extreme environments, such as hydrothermal vents or submarine hydrothermal areas (thrive at temperatures in the range 80-110°C, and they are unable to grow below 60°C). Various extremely thermophilic archaebacteria exhibit optimum growth at above 80°C.

- **Bacteria or Eubacteria**

The eubacteria or true bacteria are microscopic unicellular prokaryotes.



1.4 ❑ Domains of Life (Bacteria, Archaea, Eukarya)

The Earth is about 4.6 billion years old and microbial life is thought to have first appeared between 3.8 and 3.9 billion years ago; in fact, 80% of Earth's history was exclusively microbial life. Microbial life is still the dominant life form on Earth. It has been estimated that the total number of microbial cells on Earth on the order of 2.5 X 10^{30} cells, making it the major fraction of biomass on the planet.

The primitive living world was classified into two primary domains of **Eukaryotes (Eukarya)** and **Prokaryotes (Bacteria)** based on microscopic characteristics such as the presence or absence of membrane-bound nuclei and other cellular organelles. In 1977, American microbiologist and physicist **Carl Richard Woese** and his co-workers discovered the third domain of life, **Archaea** based on differences in the sequences of nucleotides in the cell's ribosomal RNAs (rRNA), as well as the cell's membrane lipid structure and its sensitivity to antibiotics. This became widely accepted as the third domain in 1990. **Woese** reorganized the Tree of Life (ToL) into three separate Domains: Eubacteria (true bacteria), Archaea and Eukarya, and pioneered a novel view of the biological world.

The conclusions drawn out of research conducted by Woese that led to the differentiation of archaea from bacteria are listed as:

Both of them differed in **16S rRNA** genes. Archaea possesses **three RNA polymerases** while bacteria have only **one.**

Archaeal cell walls consist of **pseudopeptidoglycan** however, bacterial cell walls are made of **peptidoglycan and lipopolysaccharide (LPS).**

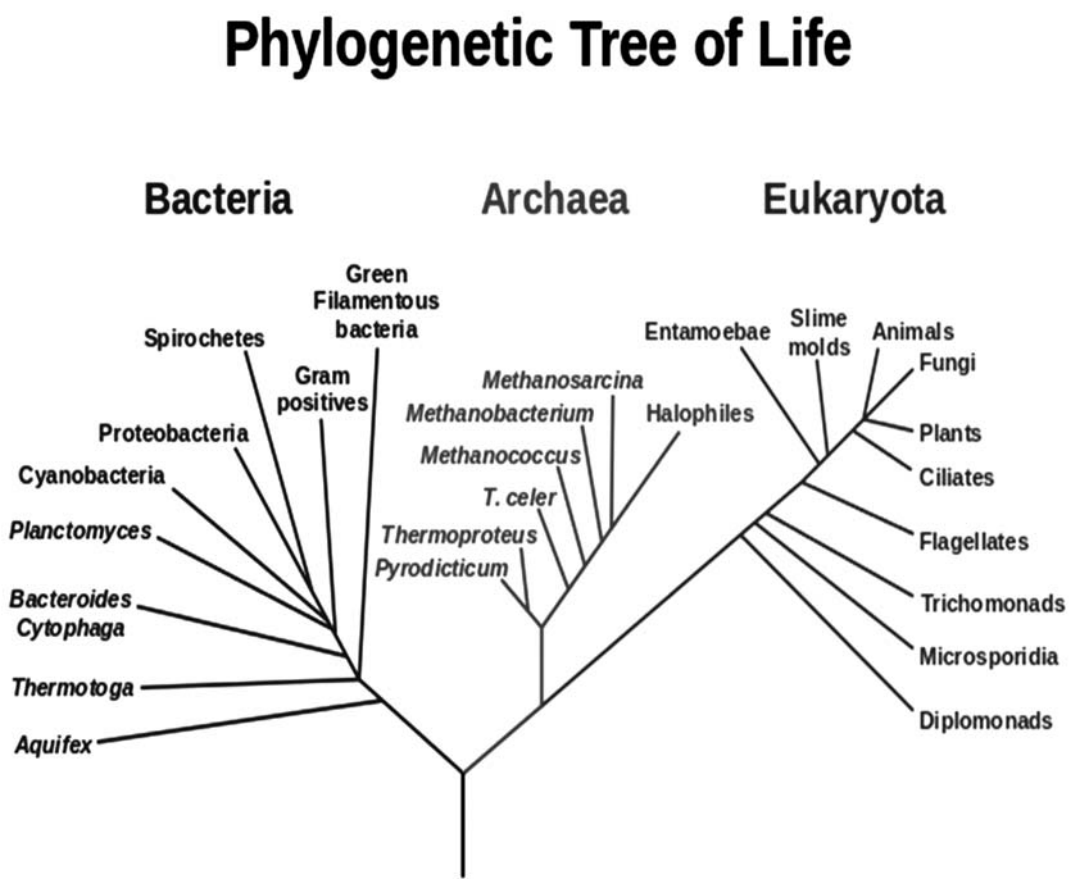
Archaea shared **more close** phylogenetic evolutionary relationship with eukaryotes than with bacteria.

Comparing rRNA structure is especially useful because rRNA molecules, throughout nature, carry out the same function, their structure changes very little over time. Therefore, similarities and dissimilarities in rRNA nucleotide sequences are a good indication of how related or unrelated different cells and organisms are.

The three domain system, is an evolutionary model of phylogeny. Phylogeny refers to the evolutionary relationships between organisms.

There are various hypotheses as to the origin of all cells. Because all cells are similar in nature, it is generally thought that all cells came from a common ancestor cell termed

the **last universal common ancestor (LUCA),** also known as the theoretical ancestor of Bacteria, Archaea and Eukarya.. These LUCAs eventually evolved into three different cell types, each representing a domain. Thus the three domains of life are the ***Archaea,*** the ***Bacteria,*** and the ***Eukarya*.**



A phylogenetic tree of living things, based on RNA data and proposed by Carl Woese, showing the separation of bacteria, archaea, and eukaryotes.

The Archaea (archaebacteria)

The Archaea possess the following characteristics:

1. Archaea are prokaryotic cells.
2. Unlike the Bacteria and the Eukarya, the Archaea have membranes composed of branched hydrocarbon chains (many also containing rings within the hydrocarbon chains) attached to glycerol by ether linkages (Figure).
3. The cell walls of Archaea contain no peptidoglycan.

4. Archaea are not sensitive to some antibiotics that affect the Bacteria, but are sensitive to some antibiotics that affect the Eukarya.
5. Archaea contain rRNA that is unique to the Archaea as indicated by the presence molecular regions distinctly different from the rRNA of Bacteria and Eukarya.

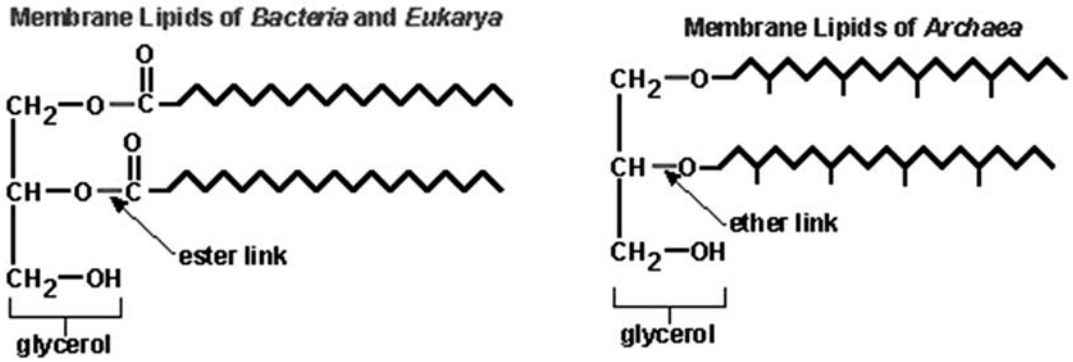


Figure 1: Membrane Lipids of Archaea, Bacteria, and Eukarya. The Bacteria and the Eukarya have membranes composed of unbranched fatty acid chains attached to glycerol by ester linkages. The Archaea have membranes composed of branched hydrocarbon chains attached to glycerol by ether linkages.

Archaea often live in extreme environments and include methanogens, extreme halophiles, and hyper thermophiles. One reason for this is that the ether-containing linkages in the Archaea membranes is more stable than the ester-containing linkages in the Bacteria and Eukarya and are better able to withstand higher temperatures and stronger acid concentrations.

The Bacteria (eubacteria)

Bacteria (also known as eubacteria or "true bacteria") are prokaryotic cells that are common in human daily life, encounter many more times than the archaebacteria. Eubacteria can be found almost everywhere and kill thousands upon thousands of people each year, but also serve as antibiotics producers and food digesters in our stomachs. The Bacteria possess the following characteristics:

1. Bacteria are prokaryotic cells.
2. Like the Eukarya, they have membranes composed of unbranched fatty acid chains attached to glycerol by ester linkages (Figure 1).
3. The cell walls of Bacteria, unlike the Archaea and the Eukarya, contain peptidoglycan.

4. Bacteria are sensitive to traditional antibacterial antibiotics but are resistant to most antibiotics that affect Eukarya.
5. Bacteria contain rRNA that is unique to the Bacteria as indicated by the presence molecular regions distinctly different from the rRNA of Archaea and Eukarya.

Bacteria include mycoplasmas, cyanobacteria, Gram-positive bacteria, and Gram-negative bacteria.

The Eukarya (eukaryotes)

The Eukarya possess the following characteristics:

1. Eukarya have eukaryotic cells.
2. Like the Bacteria, they have membranes composed of unbranched fatty acid chains attached to glycerol by ester linkages (Figure).
3. Not all Eukarya possess cells with a cell wall, but for those Eukarya having a cell wall, that wall contains no peptidoglycan.
4. Eukarya are resistant to traditional antibacterial antibiotics but are sensitive to most antibiotics that affect eukaryotic cells.
5. Eukarya contain rRNA that is unique to the Eukarya as indicated by the presence molecular regions distinctly different from the rRNA of Archaea and Bacteria.

The Eukarya are subdivided into the following four kingdoms:

1. **Protista Kingdom**: Protista are simple, predominately unicellular eukaryotic organisms. Examples includes slime molds, euglenoids, algae, and protozoans.
2. **Fungi Kingdom**: Fungi are unicellular or multicellular organisms with eukaryotic cell types. The cells have cell walls but are not organized into tissues. They do not carry out photosynthesis and obtain nutrients through absorption. Examples include sac fungi, club fungi, yeasts, and molds.
3. **Plantae Kingdom**: Plants are multicellular organisms composed of eukaryotic cells. The cells are organized into tissues and have cell walls. They obtain nutrients by photosynthesis and absorption. Examples include mosses, ferns, conifers, and flowering plants.
4. **Animalia Kingdom**: Animals are multicellular organisms composed of eukaryotic cells. The cells are organized into tissues and lack cell walls. They do not

carry out photosynthesis and obtain nutrients primarily by ingestion. Examples include all invertebrates and vertebrates.

1.5 ❑ General characteristics of Protista / Protoctista

Protists are simple eukaryotic organisms that are neither plants nor animals or fungi. Protists are unicellular in nature but can also be found as a colony of cells. Most protists live in water, damp terrestrial environments, or even as parasites. The term 'Protista' is derived from the Greek word "protistos", meaning "the very first". These organisms are usually unicellular and the cell of these organisms contain a nucleus which is bound to the organelles. Some of them even possess structures that aid locomotion like flagella or cilia.

The primary feature of all protists is that they are eukaryotic organisms. This means that they have a membrane-enclosed nucleus. Other characteristic features of Kingdom Protista are as follows:

1. These are usually aquatic, present in the soil or in areas with moisture.
2. Most protist species are unicellular organisms, however, there are a few multicellular protists such as kelp. Some species of kelp grow so large that they exceed over 100 feet in height. (Giant Kelp).
3. Just like any other eukaryotes, the cells of these species have a nucleus and membrane-bound organelles.
4. They may be autotrophic or heterotrophic in nature. An autotrophic organism can create their own food and survive. A heterotrophic organism, on the other hand, has to derive nutrition from other organisms such as plants or animals to survive.
5. Symbiosis is observed in the members of this class. For instance, kelp (seaweed) is a multicellular protist that provides otters, protection from predators amidst its thick kelp. In turn, the otters eat sea urchins that tend to feed on kelp.
6. Parasitism is also observed in protists. Species such as Trypanosoma protozoa can cause sleeping sickness in humans.
7. Protists exhibit locomotion through cilia and flagella. A few organisms belonging to kingdom Protista have pseudopodia that help them to move.
8. Protista reproduces by asexual means. The sexual method of reproduction is extremely rare and occurs only during times of stress.

1.6 ❑ General characteristics of Parazoa

Parazoa is derived from two Greek roots that mean next to (=para) and animals (=zoa). They are separate from the other animals because of their simple organization without organ systems. Parazoans ("beside animals") do not display tissue-level organization, although they do have specialized cells that perform specific functions. The parazoan level of organization is a loose association of cells and structural elements that behave almost as a cellular aggregate rather than a multicellular organism. Sollas (1884) coined Parazoa as a formal name to distinguish them from the Metazoa (the other animals). Parazoa includes organisms of the phyla Porifera and Placozoa. Sponges are the most well-known parazoa. They are aquatic organisms classified under the phylum Porifera with about 15,000 species worldwide. Although multicellular, sponges only have a few different types of cells, some of which may migrate within the organism to perform different functions.

Phylum Placozoa contains only one known living species *Trichoplax adhaerens*. A second species, *Treptoplax reptans*, has not been observed in more than 100 years. Placozoans are very tiny animals, about 0.5 mm in diameter. *T. adhaerens* was first discovered creeping along the sides of an aquarium in an amoeba-like fashion. It is asymmetrical, flat, covered with cilia, and able to adhere to surfaces. *T. adhaerens* has a very simple body structure that is organized into three layers. An upper cell layer provides protection for the organism, a middle meshwork of connected cells enable movement and shape change, and a lower cell layer functions in nutrient acquisition and digestion. Placozoans are capable of both sexual and asexual reproduction. They reproduce primarily by asexual reproduction through binary fission or budding. Sexual reproduction occurs typically during times of stress, such as during extreme temperature changes and low food supply.

1.7 ❑ General characteristics of Metazoa

The Metazoa or the multicellular animals have achieved their structural diversity by varying their cells that have become specialized to perform different functions. These cells are normally incapable of independent existence. Members of Metazoa possess a complex multicellular structural organization which may include the presence of tissues, organs and organ systems. In the life history of metazoans, typically a fertilized egg passes through a blastula stage in the course of its early embryonic development before changing into an adult. Since metazoans are multicellular they are relatively larger in size than unicellular protozoans. Naturally, their nutritional requirements are more and they have to search for

food. Consequently, locomotion in metazoans is highly developed and for this purpose they have evolved contractile muscular elements and nervous structures.

1. Metazoans are multicellular animals.
2. Metazoans are generally seen in naked eyes.
3. Body of Metazoa is differentiated into cells which may transform into tissues, organs and systems in most cases.
4. Single animal can perform different types of functions by different systems in most groups.
5. Metazoan cells are interdependent and cannot survive in isolated condition.
6. Individual cell of Metazoa is covered by also cell membrane or plasmalemma.
7. Pellicle is absent in Metazoa.
8. Cytoplasm is present in Metazoa.
9. Chloroplast is present in some species (sponges).
10. Contractile vacuoles found only in freshwater sponges.
11. Many cells are mono or multi-ciliated.
12. Cilia and flagella have same ultra-structures.
13. Digestion intracellular or extracellular or both in some.
14. Food vacuole is absent in Metazoa.
15. Lower groups of metazoans do not possess circulatory, respiratory and excretory structures.
16. Haemoglobin, haemocyanin, haemoerythrin, and chlorocruorin—all respiratory pigments present in many groups of Metazoa.
17. Gonads present except a few lower metazoan groups.
18. Motile larvae in their life cycle.
19. The developmental stages possess the embryonic blastula and gastrula stages.

1.8 ❑ Questions

- Naik,

1.9 ❑ Suggested readings

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UNIT 2 ❑ Subkingdom Protozoa – General Characteristics and Classification up to Classes

Structure

2.1 ❑ Objective

From this unit learners will learn the diversity, general characteristics and classification of subkingdom Protozoa up to classes.

2.2 ❑ Introduction

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

2.3 ❑ General characteristics of protozoa

1. Protozoa are small, generally microscopic, primitive unicellular animals with eukaryotic organization.

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

2.4 ❑ Classification of protozoa

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

protozoa of previous classification scheme to the rank of subkingdom. Under subkingdom protozoa there are **seven phyla.**

Phylum : Sarcomastigophora

Phylum : Labyrinthomorpha

Phylum : Apicomplexa

Phylum : Microspora

Phylum : Ascetospora

Phylum : Myxozoa

Phylum : Ciliophora

Classification in outline (up to classes)

Subkingdom : Protozoa

Phylum 1. Sarcomastigophora

Subphylum 1 Mastigophora

Class 1 Phytomastigophora

Class 2 Zoomastigophora

Subphylum 2 Opalinata

Class 1 Opalina

Subphylum 3 Sarcodina

Superclass 1 Rhizopoda

Class 1 Lobosea

Class 2 Acarpomyxea

Class 3 Acrasea

Class 4 Eumycetozoea

Class 5 Plasmodiophore

Class 6 Filosea

Class 7 Granuloreticulosea

Class 8 Xenophyophorea

Superclass 2 Actinopoda

Class 1. Acantharea

Class 2. Polycystinea

Class 3. Phaedarea

Class 4. Heliozoea

Phylum 2. Labyrinthomorpha

Class Labyrinthulea

Phylum 3. Apicomplexa

Class 1. Perkinsea

Class 2. Sporozoea

Phylum 4. Microspora

Class 1. Rudimicrosporea

Class 2. Microsporea

Phylum 5. Ascetospora

Class 1. Stellatosporea

Class 2. Paramyxea

Phylum 6. Myxozoa

Class 1. Myxosporea

Class 2. Actinosporea

Phylum 7. Ciliophora

Class 1. Kinetofragminophorea

Class 2. Oligohymenophorea

Class 3. Polymenophorea

Classification with characters (upto classes)

Phylum 1. Sarcomastigophora

1. Locomotory organelles are either flagella or pseudopodia or both.
2. Nucleus is of one type, except in Foraminiferida.

3. No spore formation.
4. Reproduction asexually but when sexually it is by synagamy.

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

Subphylum 1. Mastigophora

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

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

(ii) Zoomastigophorea

Class Phytomastigophorea

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

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

Class Zoomastigophorea

1. Chromatophores or chlorophil absent.
2. Nutrition heterotrophic (holozoic or saprozoic), Reserve food is glycogen.

3. Presence of one to many flagella. Some possess undulating membrane.
4. Parasitic, commensal or symbiotic.

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

Subphylum 2. Opalinata

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

The subphylum includes a single class-Opalinatea.

Class 1. Opalinatea

Characters are same as subphylum Opalinata.

Examples : *Opalina, Zelleriella, Protoopalina*

Subphylum 3. Sarcodina

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

Superclass Rhizopoda

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

The superclass includes 12 classes.

Class 1. Lobosea

1. Pseudopodia lobose type (lobopodia).

2. Usually uninucleate.

Examples : *Entamoeba, Amoeba, Chaos*.

Class 2. Acarpomyxea

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

Examples : *Leptomyxa, Rhizamoeba, Corallomyxa*.

Class 3. Acrasea

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

Examples : *Acrasis*.

Class 4. Eumycetozoea

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

Examples : *Protostelium, Dictyostelium*.

Class 5. Plasmodiophorea

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

Examples : *Plasmodiophora, Sorosphaera*.

Class 6. Filosea

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

2. No spores or flagellate stages known.

Examples : *Gromia, Nuclearia, Euglypha*.

Class 7. Granuloreticulosea

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

Examples : *Elphidium, Fusulina*.

Class 8. Xenophyophorea

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

Examples : *Psammetta, Stannophyllum*.

Superclass 2. Actinopoda

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

The superclass includes 4 Classes—

Class 1. Acantharea

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

Examples : *Acanthocolla, Psuedolithium*.

Class 2. Polycystinea

1. Skeleton mostly siliceons, made up usually of solid elements.
2. Capsular membrane composed usually of polygonal plates.
3. Marine planktonic.

Examples : *Plagonium, Eucoronis, Octodendron*

Class 3. Phaeodarea

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

Examples : *Astracantha, Sagospheera.*

Class 4. Heliozoea

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

Examples : *Clathrulina, Actinophrys, Gymnosphaera*.

Phylum 2. Labyrinthomorpha

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

This phylum includes only one class—

Class 1. Labyrinthulea

Characters are same as phylum.

Examples : *Labyrinthula, Thraustochytrium*.

Phylum 3. Apicomplexa

1. Presence of apical complex which can be seen under electron microscope.
2. Anterior apical complex consisting of polar ring(s), rhoptries, micronemes, conoid and subpellicular microtubles at some stage.
3. Micropore(s) generally present at some stage.
4. Clilia absent
5. Reproduction generally by syngamy, some reproduce asexually.
6. All are parasitic.

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

Class 1. Perkinsea

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

Example : *Perkinsus*.

Class 2. Sporozoa

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

Examples : *Monocystis*, *Gregarina*, *Plasmodium*, *Eimeria*, *Babesia.*

Phylum 4. Microspora

1. Unicellular spores, each with imperforate wall.
2. Sporoplasm with one or two nuclei.

3. Simple or complex extrusion apparatus always with polar tube and polar cap.
4. Mitochondria absent.
5. Diamorphic in sporulation sequence (often but not usually).
6. Obligatory intracellular parasites in nearly all major animal groups.

This Phylum includes two classes—(i) Rudimicrosporea and (ii) Microsporea

Class 1. Rudimicrosporea

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

Examples : *Amphiacantha, Metchnikovella.*

Class 2. Microsporea

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

Examples : *Nosema, Amblyospora, Encephalitozoon.*

Phylum Ascetospora

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

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

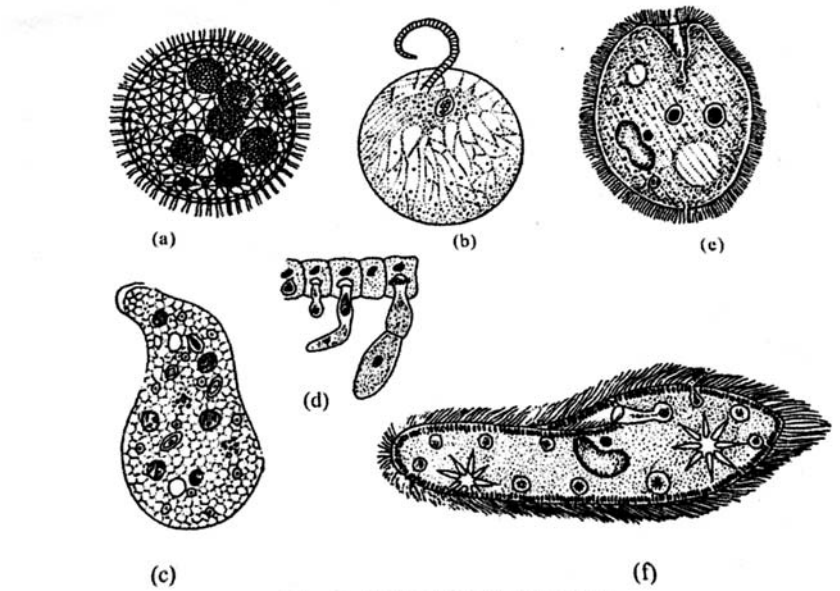

Fig. 2.1: Some Important Protozoa
(a) *Volvox*, (b) *Noctiluca*, (c) *Pelomyxa*, (d) *Gregarina*, (e) *Balantidium*, (f) *Paramoecium*

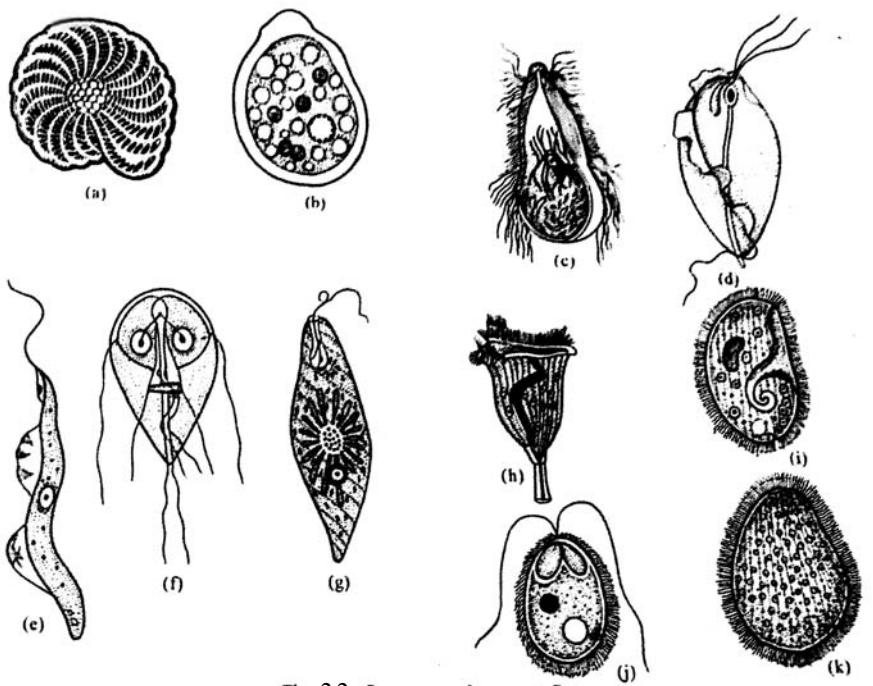

Fig. 2.2: Some more Important Protozoa
(a) *Elphidium*, (b) *Entamoeba*, (c) *Trichonympha*, (d) *Trichomonas*, (e) *Trypanosoma*, (f) *Giardia*
(g) Euglena, (h) Vorticella (i) Nyctotherus (j) Chlamydomonas (k) Opalina

Class 1. Stellatosporea

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

Examples : *Marteilia, Haplosporidium, Urosporidium.*

Class 2. Paramyxea

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

Example : *Paramyxa*.

Phylum 6. Myxozoa

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

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

Class 1. Myxosporea

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

Exampla : *Myxidium, Myxobolus*.

Class 2. Actinosporea

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

Example : *Triactinomyxon*.

Phylum 7. Ciliophora

1. Simple cilia or compound ciliary organelles are seen at least one stage of life cycle.
2. Subpellicular infraciliature present even when cilia absent.
3. Presence of two types of nuclei with rare exception.
4. Contractile vacuole typically present.

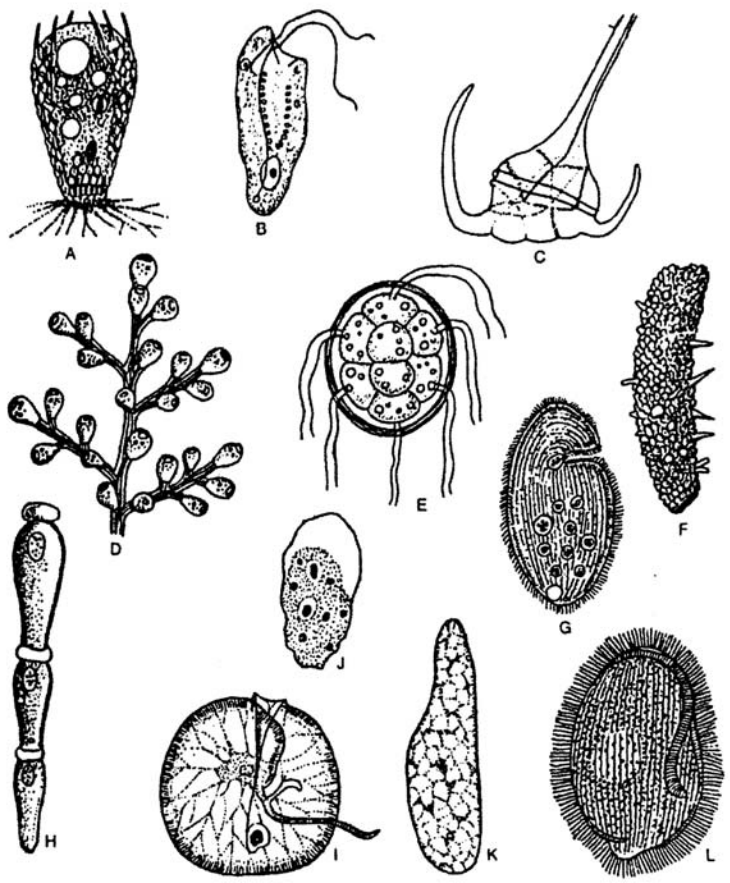

Fig. 2.3 Representatives of Phylum Protozoa Note the variety of forms in the Phylum Protozoa (after Hyman). A. *Euglypha.* B. *Chilomonas.* C. *Ceratium.* D. *Zoothamnium.* E. *Pandonna.* F. *Saccorhiza.* G. *Plagiopyla.* H.*Greganna.* I. *Ivoctiluca.* J. *Myxidium.* K. *Sarcocystis.* L. *Nyctotherus* (nor drawn up to scale).

5. Nutrition heterotrophic.
6. Asexual reproduction by transverse binary fission. Budding and multiple fission also occur.
7. Sexual reproduction involves conjugation, autogamy and cytogamy.

8. Most species are free living, but many are commensal, some truely parasitic and large number found as symphorionts on variety of hosts.

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

Class 1. Kinetofragminophorea

1. Cytopharyngeal apparatus commonly prominent.
2. Compound ciliature typically absent.

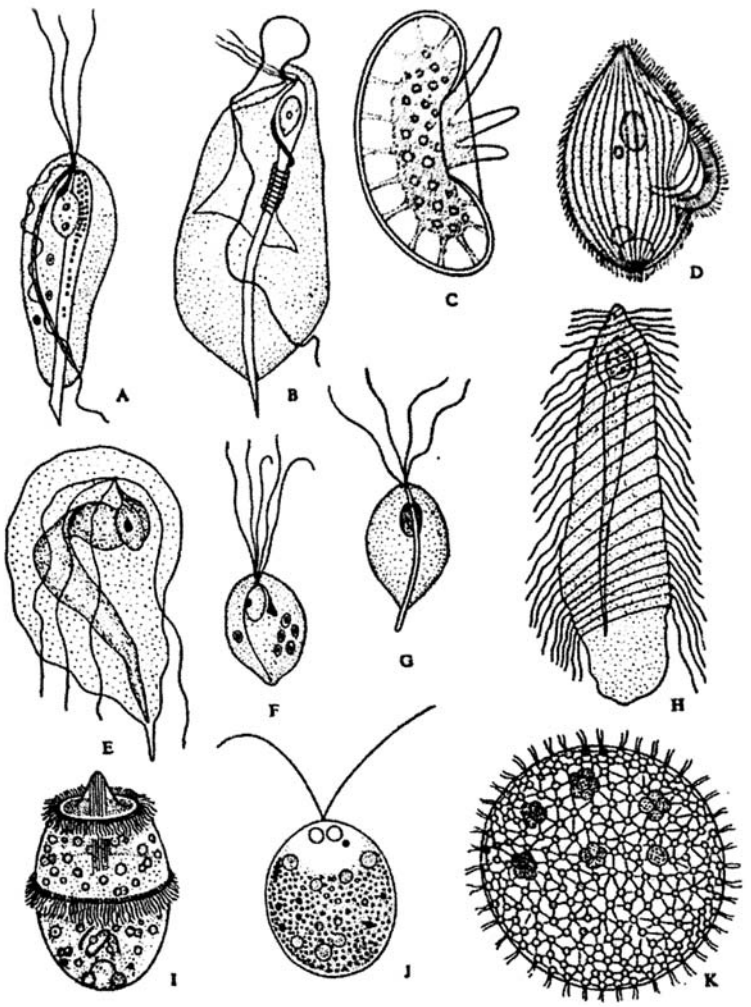

Fig. 2.4 : A few examples of Phylum Protozoa (after various sources). A. Tritrichomonas augusta. B. Macrotnchomonas lighti. C. Arcella vulgans. D. Belphansma latentium. E. Saccinobaculus doroaxostylus. F. Hexamastix termopsidis. G. Monocercomonas verrens. H. Holomastigoloides hemigymnum. I. Didinium sp. J. Chlamydomonas sp. K. Volvox colony.

3. Oral infraciliature only slightly distinct from somatic infraciliature.
4. Cytostome often apical (or subapical) or mid-ventral, on surface of body or at bottom of atrium or vestibulum.

Examples : *Balantidium, Rasbena, Didinium*.

Class 2. Oligohymenophorea

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

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

Class 3. Polymenophorea :

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

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

2.5 ❑ Questions

- Naik,

2.6 ❑ Suggested readings

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UNIT 3 ❑ Phylum Porifera – General Characteristics and Classification up to Class

Structure

3.1 ❑ Objective

By studying this unit learners would be able to understand about general charactertistics and classification of phylum Porifera with examples.

3.2 ❑ Introduction

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

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

3.3 ❑ General Characteristics

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

14. Most sponges are monoecious (hermaphrodite) but dioeceous forms also exist. Reproduction occurs asexually by buds and gemmules and sexually by typical ova and sperms.
15. Fertilization internal but cross fertilization is the rule.
16. Cleavage is holoblastic and development is indirect through two types of free-swimming cliated larvae, the **amphiblastula** and **Parenchymula** (also called **Parenchymella**). Majority of the sponges possess the second type of larva.
17. Spongs possess great power of regeneration.

3.4 Classification of Phylum Porifera (upto class)

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

1. Class : Calcarea or calcispongiae

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

Characters :

1. Comparatively smaller in size, most are less than 10 cm in height, solitary or colonial.
2. Body shape is usually cylindrical or vase like but may be lamellate or massive type.
3. The osculum is narrow, terminal and provided, with oscular fringe.
4. All the spicules are of same size (not differentiated into megascleres and microscleres) and are usually separate. Spicules are **monaxons** or **tetraxons**. Tetraxon spicules loss one ray to become triradiate.

5. Spongin fibers are absent.
6. All three forms of body organization (or grades of structures) such as asconoid, syconoid and leuconoid, occur among calcarians).
7. Mostly dull coloured, although brilliant yellow, red and lavender species are known.
8. Exclusively marine, exist throughout the oceans of the world, but most are restricted to relatively shallow coastal waters.

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

2. Class Hexactinellida or Hyalospongiae :

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

Characters :

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

7. They are exclusively marine and occur chiefly in deeper waters of all seas and in the Antartic they are the dominant sponges.

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

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

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

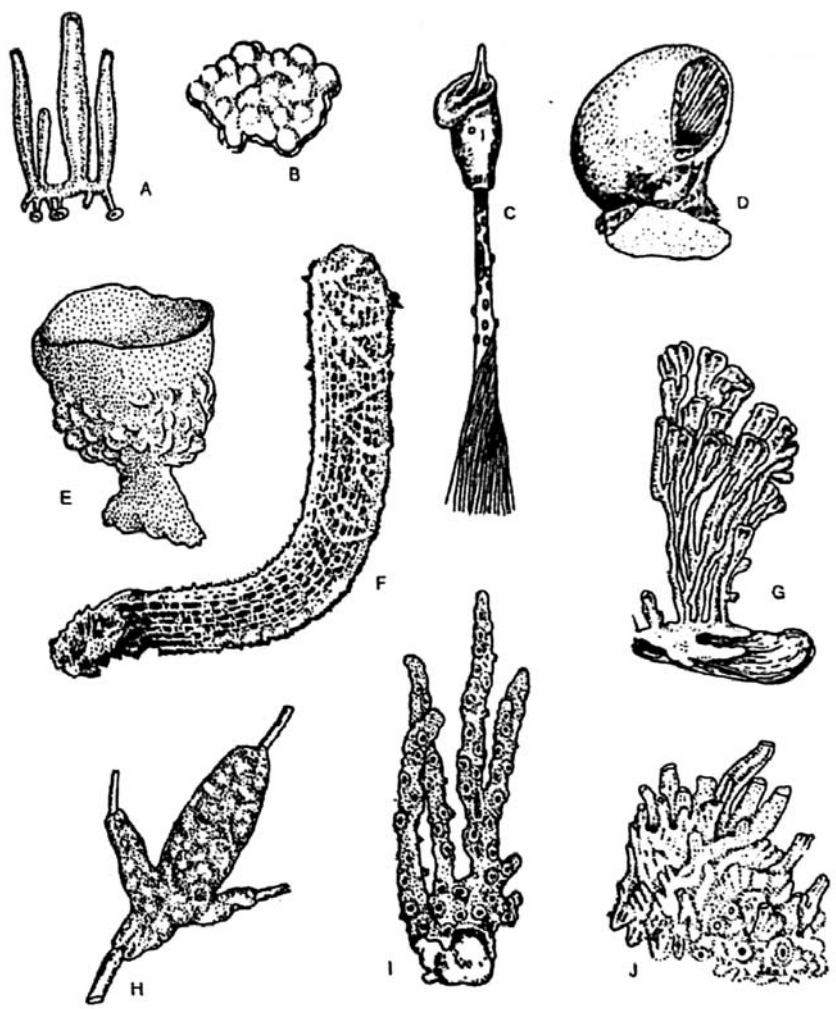

Fig. 3.1 : A few examples of Phylum Porifera (after Hyman). A. Laucosolenia, B. Oscarella, C. Hyalonema D. Craniella (A part removed to show inner radiating appearance). E. Poterion (Neptune's goblet). F. Euptectella (Venus's flower basket). G. Microciona. H. Spongilla (Freshwater sponge). 1. Haliclona. J. Halichondria (not drawn up to scale).

Characters :

1. Members of this class are highly organized, varying from small to large size and may be solitary or colonial.
2. The body is compact, often massive and brightly coloured. Shape is variable being rounded, oval, cup-like, funnel like or cushion like.
3. The skeleton is composed of siliceous spicules or spongin fibers or a combination of both or none i.e. skeletonless (Genus *Oscarella* is unique in lacking both spicules and spongin fibers).
4. The spicules are **monaxon** or **tetraxon**, never triaxons (hexactines).
5. The spicules (when present) may be divisible into large megascleres and smaller microscleres.
6. The canal system is complicated and of leuconoid type only.
7. Choanocyte cells are restricted to small, rounded flagellated chambers.
8. Most widely distributed sponges occuring from the tidal zone down to abyssal depths.

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

3.5 ❑ Questions

- Naik,

3.6 ❑ Suggested readings

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UNIT 4 ❑ Phylum Cnidaria – General Characteristics and Classification up to classes

Structure

4.1 ❑ Objective

By studying this unit learners would be able to understand about general charactertistics and classification of phylum Cnidaria with examples.

4.2 ❑ Introduction

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

4.3 ❑ General Charadcteristics of Cnidaria

1. Cnidarians are multicellular animals with tissue grade of organization.
2. They are aquatic, mostly marine except a few freshwater forms.
3. They are sessile or free swimming and solitary or colonial.

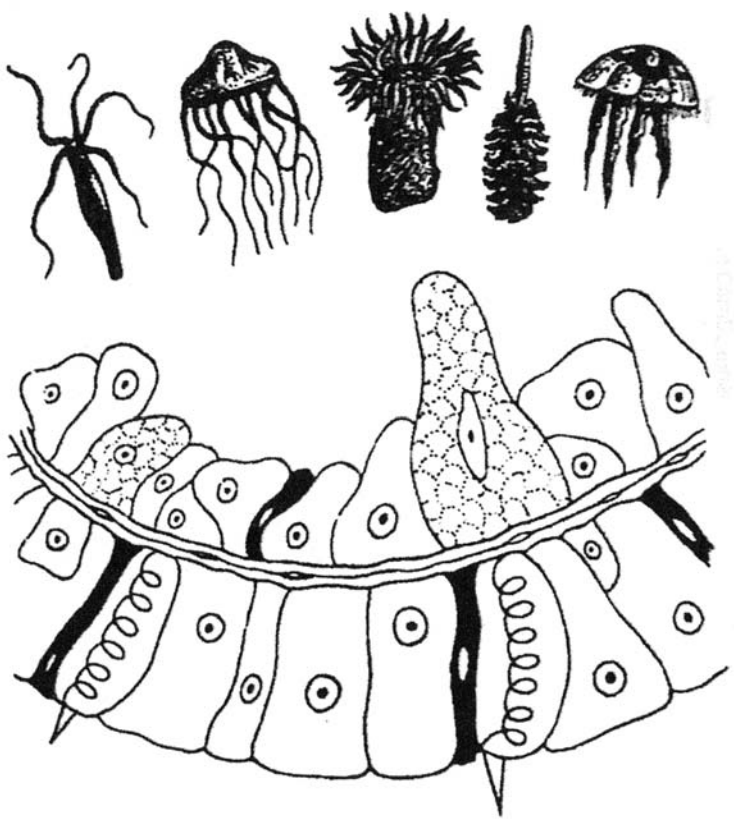

Fig. 4.1 : All cnidarians have two layers of cells.

4. Body radially symmetrical, some are biradial.
5. Cnidarians are diploblastic with outer **epidermis** (developed from embryonic ectoderm) and inner **gastrodermis** (developed from embryonic endoderm) separated by a non-celllular jelly-like layer called **mesoglea** or partly cellular **mesenchyme** derived primarily from ectoderm.
6. The body wall encloses a single, central, blind sac-like body cavity lined by the endoderm, called **gastrovascular cavity** or **coelenteron**, with the mouth as the only opening. Mouth is encircled by short and slender tentacles arranged in one or more whorls. Mouth also functions as anus.
7. Presence of highly specialized intra-cellular structures–the **cnidoblasts** (or **nematoblasts**) containing stinging organelles called **namatocysts** or **cnidae**. Cnidoblasts are located in epidermis specially in tentacles. Cnidoblasts

are unique to the members of the phylum and the phylum name Cnidaria has been cointed for them. They serve for defence, offence, food capture and adhension.

8. Cnidarians are carnivorous, digestion is both intracellular and extracellular.
9. Respiratory, circulatory and excretory organs are absent. Gas exchange is performed by diffusion.
10. Nervous stystem is of primitive type consisting of diffused network of unpolarized nerve cells.
11. In cnidaria two different body forms may exist–a **"medusa"** (representing sexual phase) adapted for pelagic existence and a **"polyp"** (asexual phase) adapted for benthic existence.
12. Reproduction by both asexual and sexual modes. Asexual reproduction by budding and sexual reproduction by the formation of ova and sperm. Development often involves a bilaterally symmetrical ciliated "planula" larva.
13. In some forms life cycle exhibits the phenomena of **metagenesis** in which the asexual polypoid, sessile generation alternates with sexual medusoid, free swimming generation, both being diploid phases.

4.4 ❑ Classification of Cnidaria

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

Class Hydrozoa Class Scyphozoa Class Cubozoa Class Anthozoa Classification with characters (upto classes)

Class Hydrozoa :

1. Exclusively polyploid or exclusively medusoid or both forms in the life cycle.
2. Mesoglea acellular or non-cellualr and jelly like.
3. Gastrovascular cavity without stomodium, septa or nematocysts bearing gastric filaments.

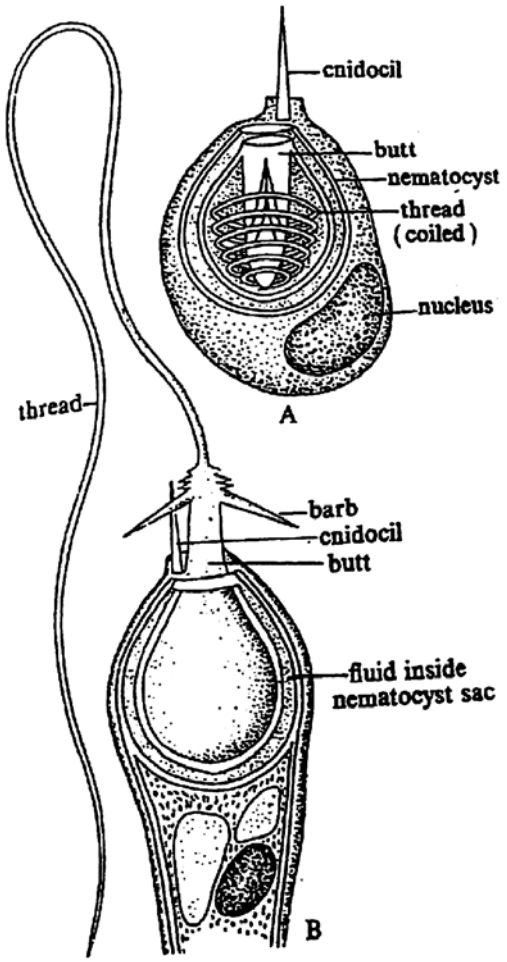

Fig. 4.2 : Detail structure of cnidoblast of Hydra. A Undischarged, B. Discharged.

4. Namatocysts are confined to the epidermis only.
5. Medusa with a true muscular velum which improves swimming efficiency.
6. Reproductive cells usually ectodermal in origin and discharged to the exterior directly.
7. Metagenesis distinct.
8. Mostly colonial and marine, a few solitary and freshwater.
9. Phenomenon of polymorphism is common.

Class Hydrozoa includes about 3000 species.

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

Class Scyphozoa :

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

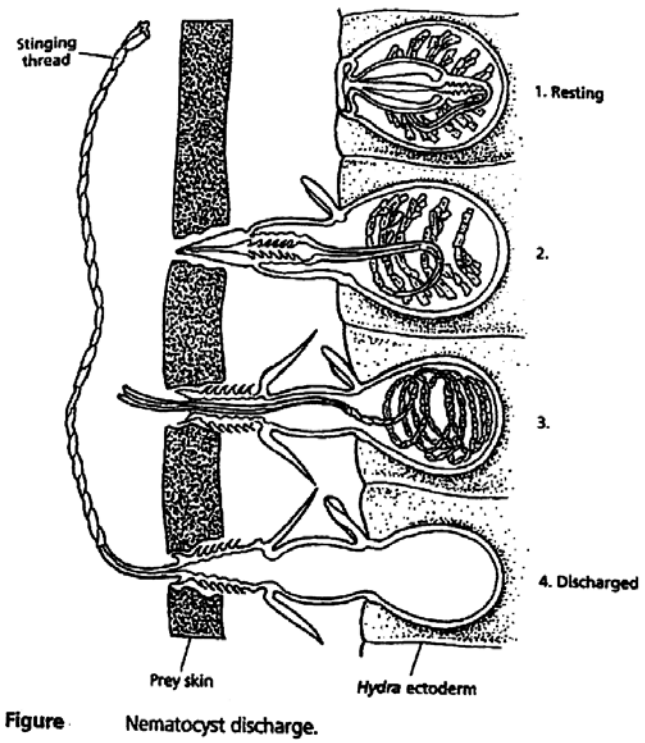

Fig. 4.3 : Nematocyst discharge.

2. Mesoglea is cellular and thick.
3. Endodermal gastric tentacles are present.
4. Nematocyst containing cnidoblast cells are found both in the epidermis and gastrodermis.
5. Gastrovascular cavity without stomodium but with endodermal gastric filaments or tentacles.
6. Velum absent.
7. Sense organs usually in the form of tentaculocysts.
8. Gonads are endodermal in origin and gametes are shed in the gastrovascular cavity.

Fig. 4.4 : Some Important Cnidarians.
(a) *Protohydra,* (b) *Stylaster,* (c) *Millepora,* (d) *Clavularia,* (c) *Clytia,* (f) *Cerianthus,* (g) *Anthomustus,* (h) *Gorgonia,* (i)*Telesto,* (j) *Praya,* (k) *Acropora,* (l) *Nausuthar,* (m) *Corallium,* (n) *Hydra,* (o) *Velella,* (p) *Physalia,* (q) *Pennatulla,* (r) *Taelia,* (s) D*urelia,* (t) *Fungia*

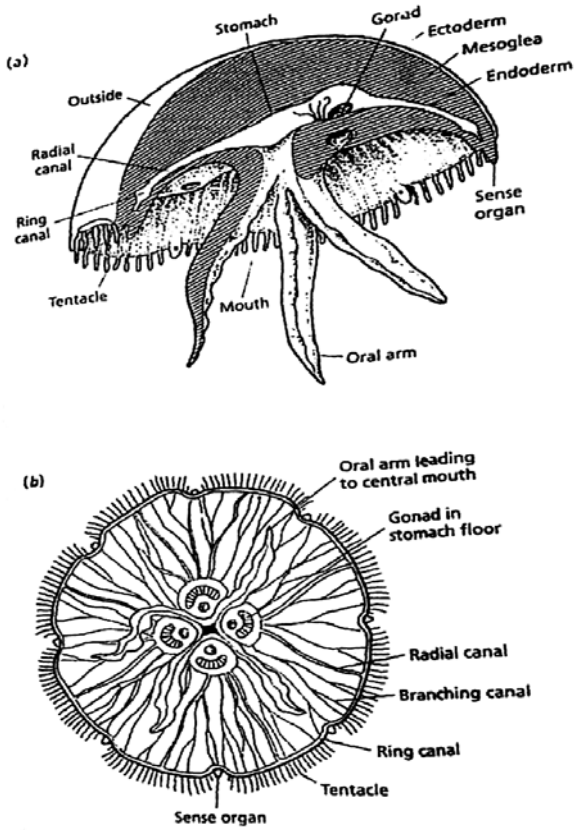

Fig. 4.5 : The structure of a jellyfish (scyphozoan): (a) side view, with shaded part in section, (b) oral view.

9. Polypoid stage usually absent or represented by small polyp, the scyphistoma which gives rise to medusae by transverse fission or *strobilization*.
10. All are marine, solitary, free swimming or attached by aboral stalk. The class Scyphozoa includes about 200 species.

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

Class Cubozoa :

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

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

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

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

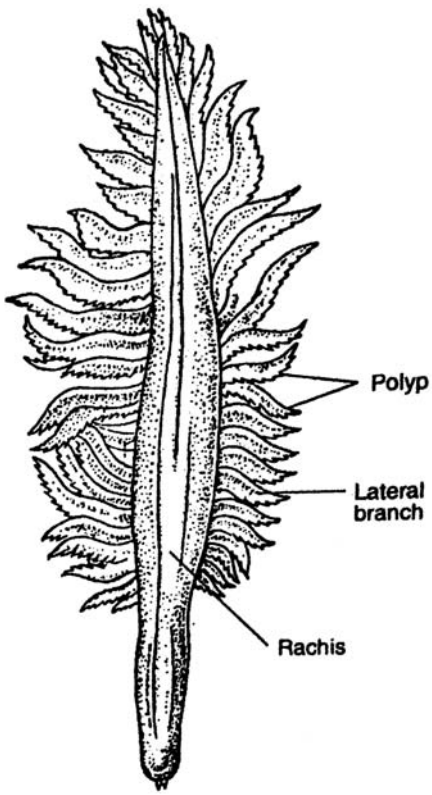

Fig. 4.6 : Sea-pen (*Pennatula)*–a typical example of Octocorallia.

Class Anthozoa or Actinozoa :

1. Exist only in polypoid form, medusa phase is absent.
2. Body cylindrical with hexamerous or octamerous biradial or radiobilaterial symmetry.
3. Mesoglea cellular with fibrous connective tissue and amoeboid cells.
4. **Stomodaeum** strongly developed and posses **siphonoglyphs** (ciliated grooves in the stomodaeum).

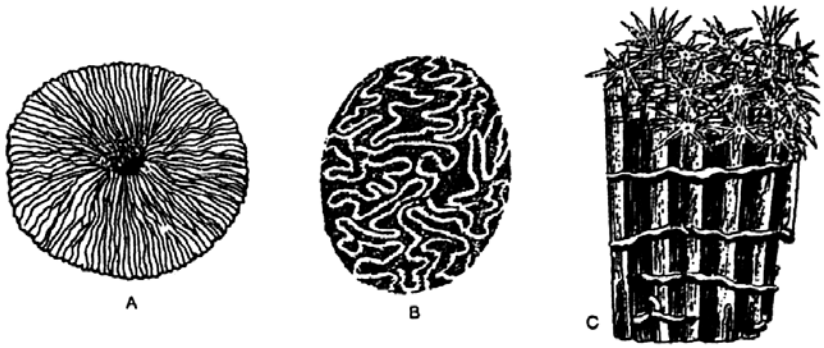

Fig. 4.7: Different tyhpes of Anthozoan Corals. (After Kaestner). A. *Fungia* (Mushroom coral). B. *Meandrina* (Brain coral). C. *Tubipora* (organ Pipe coral).

5. The oral end of the body is expanded radially into an oral disc bearing hollow tentacles surrouding the mouth in the centre.
6. Gastrovascular cavity is divided into compartments by complete or incomplete septa or mesenteries.
7. Mesenteries bear nematocysts at their free inner edges (gastrodermal or endodermal)
8. Skeleton either external or internal. Exoskeleton may be of calcium carbonate which often forms massive corals.
9. Gonads are gastrodermal (endodermal) in origin and develop in the mesenteries.
10. Gametes are discharged into coelenteron, fertilization external.
11. The fertilized eggs develop into a planula larva that metamorphoses to form the polyp.
12. Members are solitary or colonial, mostly colonial, exclusively marine.

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

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

4.5 ❑ Questions

- Naik,

4.6 ❑ Suggested readings

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UNIT 5 ❑ Concept of body axis and symmetry, coelom, pseudocoelom and segmentation.

Structure

5.1 ❑ Objective

After studying this unit the learners will to get a clear idea about body axis and symmetry, coelom, pseudocoelom and segmentation.

5.2 ❑ Body axis and symmetry

A fundamental aspect of an animal's bauplan ("a structural plan or design") is its overall shape or geometry. Symmetry refers to the regular arrangement of the body structures relative to the axis of the body. In other words symmetry means an arrangement of body parts into geometrical designs. The concept of symmetry is fundamental to understanding animal organization. Symmetry describes how the parts of an animal are arranged around a point or an axis.

Body symmetry can be generally determined from the external appearance of an animal but other features of a body plan typically require a more detailed examination. Animals that can be bisected or split along at least one plane, so that the resulting halves are similar to one another, are said to be symmetrical. For example, a prawn can be bisected vertically through its midline, head to tail, to produce right and left halves that are mirror images of one another. A few animals have no body axis and no plane of symmetry and they cannot be divided into like parts by a plane, and are said to be asymmetrical.

All animals are either asymmetrical or symmetrical. In animal kingdom five types of symmetry are recognized. These are–

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

1. Asymmetry or asymmetrical animals: A few animals have no body axis and no plane of symmetry and they cannot be divided into like parts by a plane, and are said to be asymmetrical. Examples of asymmetrical animals are most sponges, some protists, particularly the amoeboid forms, and few others.

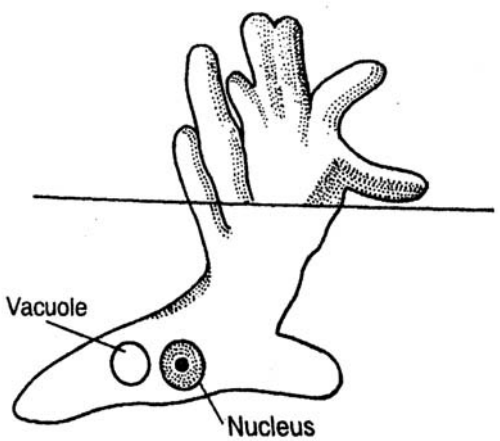

Fig. 5.2 Diagram of *Amoeba* showing the asymmelrical symmetry.

2. Spherical symmetry: It is the simplest form of symmetry, seen in animals whose bodies lack an axis and have the form of a sphere, with the body parts arranged concentrically around or radiating from, a central point (Fig.). Here any plane passing through the centre divides a body into equivalent or mirrored halves. In other words, in spherical symmetry the body parts radiate out from a central point and an infinite number of planes passing through the central point can divide a spherically symmetrical organism into similar halves. Spherical symmetry is rare in animals and is seen chiefly among some unicellular animals e.g. radiolarian protozoa. Spherical forms are best suited for floating and rolling. This type of symmetry is suited for free-floating forms or animals showing rolling movements with almost all points on the surface having an equal opportunity to perceive the stimulus. Organisms with spherical symmetry share an important functional attribute with asymmetrical organisms, in that, both groups lack polarity. That is, there exist no clear differentiation along an axis. In all other forms of symmetry, some level of polarity has been achieved; and with polarity comes specialization of body regions and structures (Brusca and Brusca, 2003).

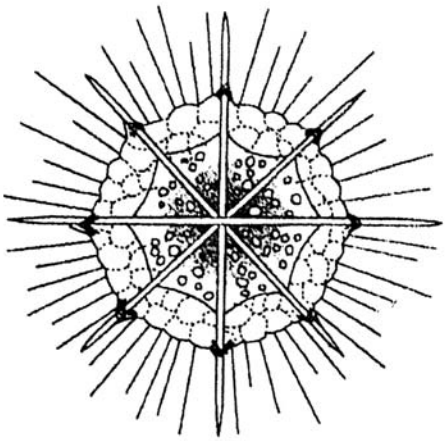

Fig. 5.1 Diagram of a radiolarian showing the spherical symmetry.

3. Radial symmetry: An organism with radial symmetry has one main axis around which its body parts are arranged. A perfectly radially symmetrical animal can be divided into two roughly equal halves by any one of many vertical planes passing through the central axis (by any plane that contains the main axis) (Fig.). The animal exhibiting radial symmetry has the general body form of a cylinder with one main axis around which the various body parts are arranged equally around the axis in such a way that any plane passing through the central axis divides the organism into equal or similar halves or antimeres. The animals with radial symmetry do not have anterior and posterior sides or dorsal and ventral surfaces. They have a mouth bearing oral side or oral surface and the opposite side (side away from the mouth) is called aboral side or aboral surface. In the animal kingdom, radially symmetrical phyla are Porifera, Cnidaria, Ctenophora and Echinodermata. Out of these only Cnidaria and Ctenophora exhibit a fundamental radial symmetry. Both the phyla were grouped together under the Division **Radiata.** Special forms of radial symmetry are observed in different groups of animals such as–

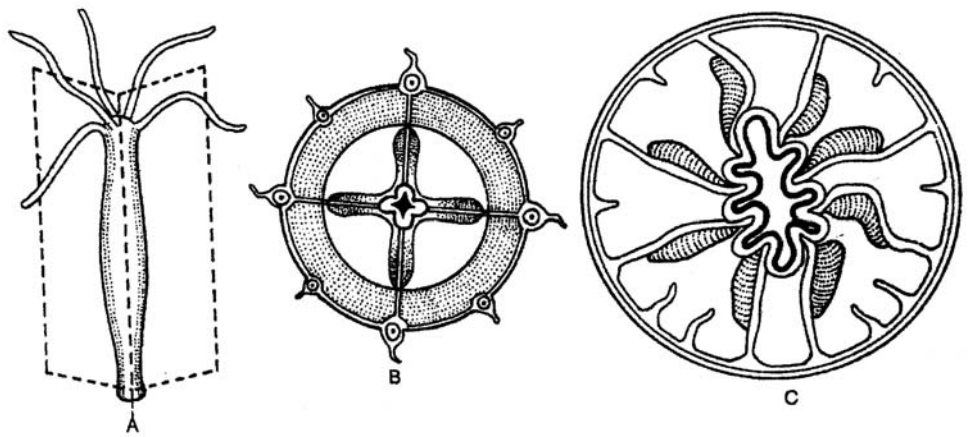

Fig. 5.3 : Diagrams showing the different forms of radial symmetry. A. Radial symmetry (hydra). B. Tetramerous radial. symmetry (Jelly fish). C. octomerous radial symmetry (a octocorallian polyp).

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

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

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

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

4. Biradial symmetry: It is variant form of radial symmetry in which, because of some specialized portions of body, only two planes passing through the longitudinal axis can divide the animal into two similar halves. Common examples of biradial animals are ctenophores and many sea anemones. Radial and biradial animals are usually sessile, free-floating or weakly swimming. Radial animals, with no anterior or posterior end, can interact with their environment in all directions.

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

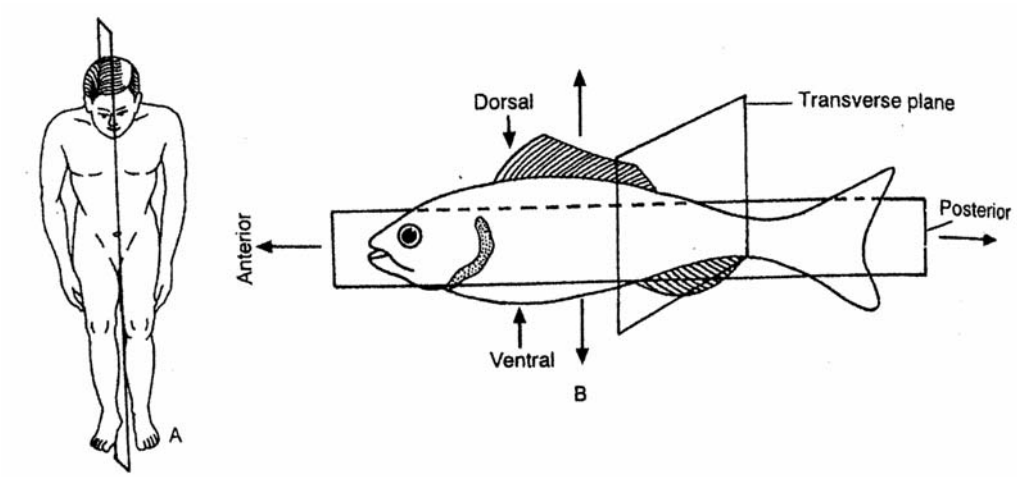

Fig. 5.4 : A diagram showing the bilateral symmetry in man. B. A fish showing the different planes of bilateral symmetry.

invertebrates and both lower chordates and vertebrates. Adult echinoderms, though radially symmetrical (pentamerous) have larvae that are bilateral. This is because they have evolved from bilaterally symmetrical ancestors. Bilateral symmetry is a common characteristic of animals that move rapidly through their environments.

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

As mentioned earlier bilateral symmetry is strongly correlated with cephalization: the concentration of sensory organs and nervous tissues in a head at the anterior end of the animal. Cephalization is favoured because the anterior end of a freely moving animal typically encounters new environments first. The first phylum of animal kingdom to exhibit bilateral symmetry is phylum Platyhelminthes.

The protistans show all four types of symmetry while the metazoans show only two, viz. radial and bilateral symmetry. The type of symmetry is related to the kind of life an animal leads and their needs in relation to the type of environment in which they live. Sessile or free floating animals require an all-round knowledge of the environment and are thus radially symmetrical. The sense organs are peripherally present in them i.e. equally distributed all around the edge of the animal. This enables them to receive stimuli equally from all directions. On the other hand, the bilaterally symmetrical animals move in a particular direction and their sense organs are crowded at the end which reaches the new environment first(the anterior end). This has led to cephalization (mentioned earlier). Cephalization is always accompanied by formation of anterioposterior axis.

Body planes of bilateral animals

The entire body of a bilateral animal can be divided into three planes such as– (a) **Mid sagittal**, (b) **Frontal** and (c) **Transverse**.

A longitudinal plane that passes along the axis of the body to separate the animal in right and left halves, is called the **mid sagittal plane**. Any longitudinal plane passing perpendicular to the mid-sagittal plane and separating the upper (dorsal) from the underside (ventral) is called **a frontal plane**. Any plane that cut across the body perpendicular to the main body axis and the mid sagittal plane is called a **transverse plane** (or simply, **a**

cross section). In bilaterally symmetrical animals the term **lateral** refers to the sides of the body, or to structures away from (to the right and left of) the midsagittal plane. The term **medial** refers to the midline of the body, or to structures on, near, or toward the mid sagittal plane. Besides **lateral** (right and left sides), an upper or **dorsal surface** and a lower or **ventral surface**, an **anterior end** (the end which usually moves forward during locomotion and bears head and mouth) and **posterior end** (the end opposite to anterior) are also recognizable in most bilateral animals.

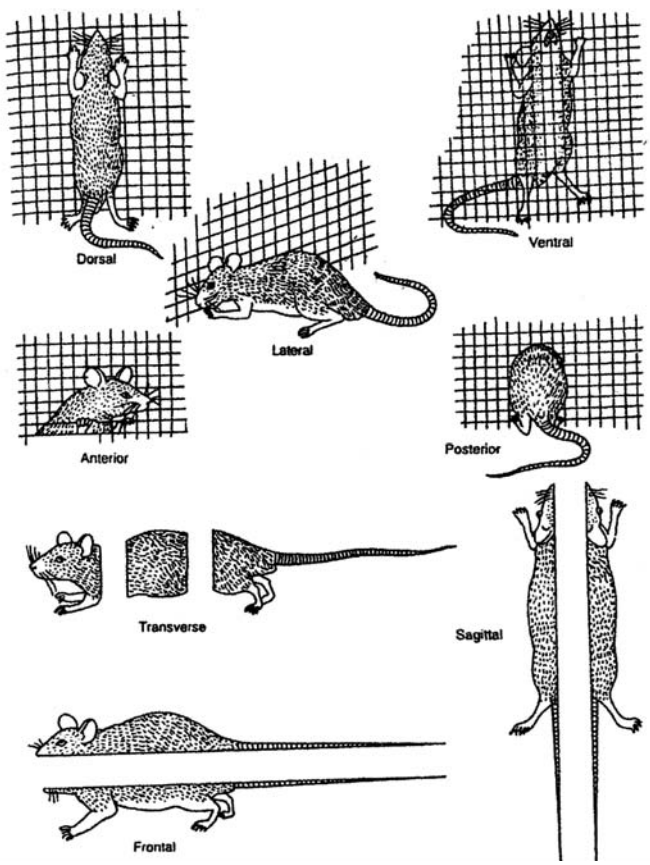

Fig. 5.5 : For the convenience of study, the animal body is divided into a number of regions–dorsal, ventral, lateral anterior and posterior. The entire body may also be divided into three planes, transverse, frontal and sagittal.

Some terminologies

Aboral -The end opposite the mouth.

Oral -The end containing the mouth.

Anterior -The head end; usually the end of a bilateral animal that meets its environment.

Posterior -The tail end

Caudal- Toward the tail

Cephalic -Toward the head

Distal -Away from the point of attachment of a structure on the body (e.g., the toes are distal to the knee)

Proximal -Toward the point of attachment of a body (e.g., the hip is proximal to the knee)

Dorsal- The back of an animal; usually the upper surface; synonymous with posterior for animals that walk upright

Ventral- The belly of an animal; usually the lower surface; synonymous with anterior for structure on the animals that walk upright

Inferior- Below a point of reference (e.g., the mouth is inferior to the nose in humans)

Superior -Above a point of reference (e.g., the neck is superior to the chest)

Lateral -Away from the plane that divides a bilateral animal into mirror images

Medial (median) - On or near the plane that divides a bilateral animal into mirror images

5.3 ❑ Coelom and Pseudocoelom

The embryonic tissue layers of eumetazoa are called germ layers and it is from these germ layers that all adult structures develop. The germ layers initially form as outer and inner sheets or masses of embryonic tissue, termed **ectoderm** and **endoderm** respectively. In the embryogeny of the radiate phyla Cnidaria and Ctenophora, only these two germ layers develop (or if a middle layer does develop, it is produced by the ectoderm, is largely noncellular, and is not considered a true germ layer). These animals are regarded as **diploblastic** (Greek diplo, “two”; blast, “bud” or “sprout”). In the embryogeny of most animals, however, a third cellular germ layer, the **mesoderm**, arises between the ectoderm and the endoderm; these metazoan groups are said to be **triploblastic.** The evolution of a mesoderm greatly expanded the evolutionary potential for animal complexity.

One of the major trends in the evolution of the triploblastic Metazoans has been the development of a fluid-filled cavity between the outer body wall and the digestive tube;

that is, between the derivatives of the ectoderm and the endoderm. Triploblastic animals are organized into several subgroups based on the presence or absence of a body cavity and, for those that possess one, the kind of body cavity present. A body cavity is a fluid-filled space in which the internal organs can be suspended and separated from the body wall. Body cavities are advantageous because they 1. Provide more room for organ development. 2. Provide more surface area for diffusion of gases, nutrients, and wastes into and out of organs. 3. Provide an area for storage. 4. Often act as hydrostatic skeletons. 5. Provide a vehicle for eliminating wastes and reproductive products from the body. 6. Facilitate increased body size. Of these, the hydrostatic skeleton deserves further comment. Body-cavity fluids give support, while allowing the body to remain flexible.

Three major grades of construction are recognizable among the triploblastic Metazoans: **acoelomate, blastocoelomate or pseudocoelomate, and eucoelomate or** simply **coelomate.**

The **acoelomate** grade (Greek a, "without"; coel, "hollow, cavity") occurs in several triploblastic phyla: Platyhelminthes, Entoprocta, Gnathostomulida, and Gastrotricha. In these animals, the mesodermally derived tissues form a relatively solid mass of cells between ectodermally and endodermally derived tissues. Some cells between the ectodermal epidermis (body wall) and endodermal digestive tract (gut wall) of acoelomate animals are loosely organized cells called parenchyma. Parenchymal cells are not specialized for a particular function. Parenchyma is derived from embryonic connective tissue and is important in assimilation and transport of food and in disposal of metabolic wastes.

In nearly all other triploblastic animals, an actual space develops as a fluid-filled cavity between the body wall and the gut. In many animals (e.g., annelids, arthropods, mollusks, echinoderms and chordates), this cavity arises within the mesoderm itself and is completely enclosed within a thin lining called the peritoneum, which is derived from the mesoderm. Such a cavity is called a **true coelom (eucoelom).** Thus coelom is a body cavity completely surrounded by mesoderm.

Several groups of triploblastic Metazoa (e.g. rotifers, roundworms, and others) possess small or large body cavities that are neither formed from the mesoderm nor fully lined by peritoneum or any other form of mesodermally derived tissue. Such a cavity used to be called a **pseudocoelom** (Greek pseudo, "false"; coel, "hollow, cavity"). A pseudocoelom is thus a body cavity not entirely lined by mesoderm (figure). A pseudocoelom means false coelom in reference to mesoderm only partially surrounding the cavity, instead of completely surrounding it, as in a true coelom.

In some coelomates (protostomes) the coelom forms by the splitting of the mesodermal cell mass (schizocoely). In the schizocoelous plan, mesodermal cells fill the blastocoel (space between the developing ectoderm and endoderm) forming a solid band of tissue around the gut or archenteron. Then, through programmed cell death, space opens inside the mesodermal band (splitting of the mesodermal band) (Figure). This new space is a coelom. Protostomes traditionally include animals in the phyla Platyhelminthes, Nematoda, Mollusca, Annelida, Arthropoda, and others.

In deuterostome coelomates (the deuterostomes, includes animals in the phyla Echinodermata, Hemichordata, Chordata, and others) the coelom forms from outpocketings of the archenteron (the cavity which results from gastrulation and will give rise to the gut lumen); the pockets or pouches grow and later separate or get disconnected from the archenteron and fuse to form the coelom, the inner wall surrounds the developing alimentary canal or gut and the outer layer lines the developing body wall. Those two layers become the future mesoderm.This type of coelom formation is enterocoely and the coelom is known as enterocoelous coelom.

A coelom made by enterocoely is functionally equivalent to a coelom made by schizocoely, and are represented as such in the eucoelomate body plan. Both kinds of coelomic cavities are bounded by mesoderm and lined with a peritoneum, a thin cellular membrane derived from mesoderm.

The two different patterns of origin of coelom are another expression of the protostome - deuterostome dichotomy in evolution. The coelom is of great significance in animal evolution. It is a stepping stone for evolution of more complex and larger forms.

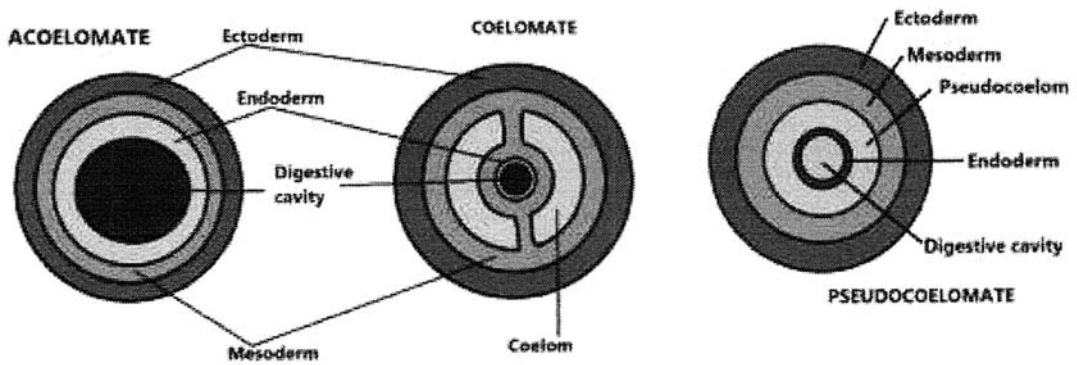

Fig. 5.6 Section of acoelomate, coelomate and pseudocoelomate animals.

The name protostome is derived from the Greek words “Proto” meaning first and “Stoma” which means mouth. In protostomes, the blastopore first gives rise to the

mouth during embryonic development. In deuterostomes, the blastopore gives rise to the anus.

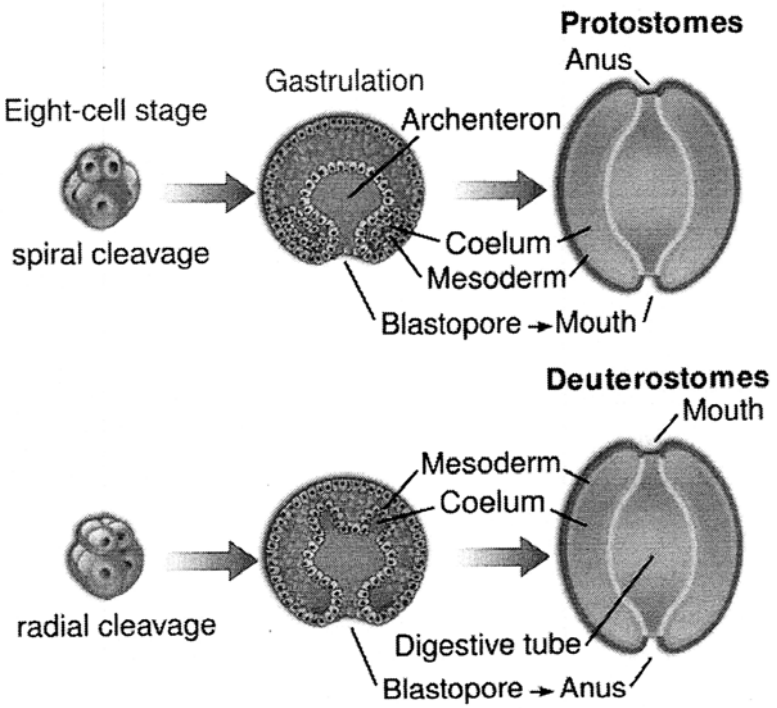

Fig. 5.6 Development of Coelom. A) Schizocoelous origin in Protostomes B) Enterocoelous origin in Deuterostomes.

5.4 ❑ Segmentation

Segmentation in biology is the division of some animal and plant body plans into a series of repetitive segments. Segmentation in zoology is the condition of being constructed of a linear series of repeating parts, each being a metamere. In other words **segmentation is the serial repetition of similar organs, tissues, cell types or body cavities along the anterior posterior (A-P) axis of bilaterally symmetric animals (bilaterians).**

All members of three large animal phyla are metameric: Annelida, Arthropoda, and Chordata. The first two exhibit conspicuous segmentation in the adult. Among the chordates, the repetitive metameric pattern is evident in muscles, vertebrae, and ribs of the adult (*e.g.*, fishes), but in others external segmentation has been lost and internal segmentation is best seen in the embryo (embryological somites).

Essentially, metameric segmentation is an internal, mesodermal phenomenon, the body musculature and coelom being the primary segmental divisions; this internal segmentation imposes a corresponding segmentation on the nerves, blood vessels, and excretory organs. Segments of the tapeworm (proglottids) are formed so differently from the segments of the other three groups that zoologists do not admit tapeworms to be metamerically segmented animals. Segmentation in tape worms is quite different from that seen in the others. We can observe that segmentation in tape worm is superficial, a series of ring like creases develop in the cuticle and the body wall which facilitate bending and telescoping of the body. But this segmentation is strictly ectodermal and this segmentation is a reproductive adaptation. Since the metamerism of Annelida and Arthropoda and that of Chordata probably arose independently, metamerism does not itself imply relationships between the groups; however, the particular metamerism within each group clearly demonstrates the derivative relationship of its members. Segmentation of the body plan is important for allowing free movement and development of certain body parts. Segmentation divides a body into a series of compartment each of which can be regulated independently. This leads to regional specialization of segments thus leading to rapid evolution of higher grade of organization. Metamerism helps in locomotion in several ways. It facilitates lateral movement of the body. Since metameric segmentation results in compartmentalization of the body, the coordination of muscular action can be restricted to a few segments at a time thereby increasing the locomotory efficiency. Thus metameric segmentation is thought to have arisen as an adaptation to more efficient locomotion.

Additional readings on segmentation:

Segmentation, also called metamerism, is a common feature of metazoans. Segmentation is a serial repetition of similar body segments along the longitudinal axis of the body. Each segment is called a metamere or somite. In forms such as earthworms and other annelids, in which metamerism is most clearly represented, the segmental arrangement includes both external and internal structures of several systems. Although in the past zoologists considered that true segmentation was found in only three phyla, namely the annelids, the arthropoda and the chordates, it is widely recognized that segmentation is more widespread than previously thought. Some other animals, such as onychophores (velvet worms), tardigrades (water bears), and kinorhynchs (mud dragons) are also segmented. Discussions of the evolution of segmentation are complicated by the fact that there does not appear to be a concensus on what constitute a “segmental” body plan. Generally a distinction is made between true segmentation and serial repetition. Serial repetition includes simple repeated structures. For example, a strobilizing cnidarian (e.g. scyphozoan) is composed of repeated units, each of which will bud off to become a

complete individual. Also, rotifers have an annulated outer cuticle and chitons contains serially repeated shell plates. "True" segmentation includes repeated units along with antero-posterior body axis of an animal and each unit is composed of combination of structures from both ecdoderm and mesodermal origin such as excretory organs, muscles, gonads, blood vesssls, nerves, appendages, coelomic cavities and septa (Scholtz, 2002). This definition suggests a certain amount of integration of a reiterated developmental program that is not likely have arisen by fragmentation or simple modification of existing structures. The body plans of annelids, arthropods and chordates are usually distinguished from other animals with serial repetition and are known as the "eusegmented" animals. Among the distinct proposals explaining the origins of segmentation is the hypothesis that there is a single origin of segmentation in the Metazoa. In this case, the Urbilateria, the ancestral primitive bilateral animal that gave rise to both the protostomes and the deuterostomes (De Robertis and Sasai, 1996), was a segmented animal. Monophyly of segmentation has been proposed historically and has recently received support based upon molecular data of developmental characters (Kimmel, 1996; De Roberitis, 1997; Carroll et al. 2001). But if segmentation is monophyletic, we are faced with the challenge of explaining loss of segmentation in numerous taxa throughout the Metazoa. Independent origins of segmentation have also been proposed, in which chordates evolved segmentation independently from annelids and arthropods, which shared a common segmented ancestor. This theory has had support through most of the 20th century. Support for an independent origin of segmentation between chordates and annelids/arthropods has been based in part on functional arguments, in which segmentation arose for distinct locomotory purposes in the ancestor of modern day annelids and arthropods and chordates (Clark, 1964). In annelids, a segmented body plan has been cited as advantageous for burrowing, because the hydroskeletal advantages of isolating a subset of segments from the rest of the body. This proposal is also not universally accepted i.e. not beyond criticism.

5.5 ❑ Questions

- Naik,

5.6 ❑ Suggested readings

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UNIT 6 ❑ Phylum Platyhelminthes and Phylum Nematoda – General characteristics and Classification up to classes

Structure

6.1 ❑ Objective

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

6.2 ❑ Introduction

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

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

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

6.3 ❑ General Characters of Phylum Platyhelminthes

1. Triploblastic, acoelomate (without a body cavity) and bilaterally symmetrical animals.
2. Body soft, unsegmented and dorsoventrally flattened.
3. Body shows organ grade organization.
4. Body shape varies from moderately elongated flattened shape to long flat ribbon-like and leaf-like. Length of the body may be extremely elongated in some and may reach as much as 10 to 15 metres.
5. Metameric segmentation and skeletal structures are absent. Psdudometamerism is seen in some members.
6. The anterior and of the body is differentiated into a head.
7. Body is covered with syncytial one layered partly ciliated epidermis; while in parasitic forms (trematodes and cestodes) the outer body covering is cuticle.
8. Adhesive structures like hooks, spines and suckeers and adhesive secretions common in parasitic forms.

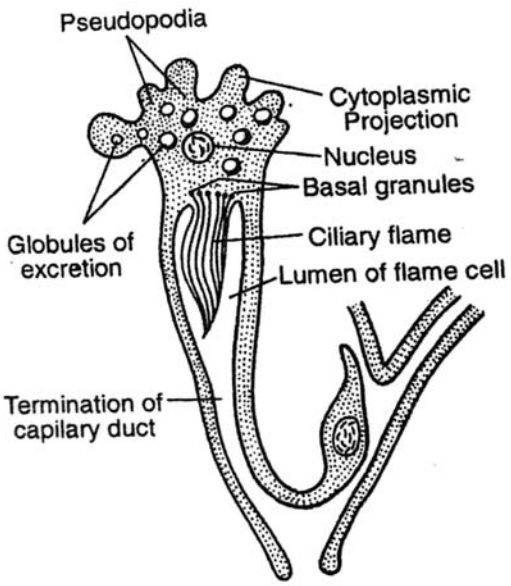

Fig. 6.1 Structure of a flame cell.

9. Mouth is the single opeing of the digestive tract and the anus is absent. Digestive tract is totally absent in some.
10. No respiratory and circulatory systems. Respiration is **aerobic** in free living forms but **anaerobic** in parasitic flatworms. Gaseous exchange by diffusion.
11. The nervous system is most primitive type, ladder like, comprising of a pair of anterior gaglia with longitudinal nerve cords connected by transvers nerves.
12. Sense organs in the form of eye spots and chemoreceptors in free living forms.
13. The excretory system consists of *protonephridia* with **flame cells**. Absent in some primitive forms.
14. Sexes are mostly united; i.e. **hermaphrodite** or **monoecious**, but the digenean flukes are **gonochoristic** (separate sexes).
15. Reproductive system is complex and highly evolved in most forms. Asexual reproduction by fission also occurs in many free living forms.
16. Fertilization internal, may be cross or self fertization.
17. Development may be direct or indirect. In some parasitic forms development is very elaborate, involving several larval stages and hosts.

18. **Parthenogenesis** and **polyembryony** are common in trematodes and cestodes.
19. Flatworms are either **free-living** (turbalarians) or **ecto** or **endocommensals** or **endoparasites**.
20. They occur in all major habitats, aquatic and terrestrial and in the tissues of other animals.

6.4 ❑ Classification

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

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

Classification with Characters (upto Classes) :

Class Turbellaria (L. turbella = a little string)

1. Turbellarians are mostly free-living and aquatic, great majority are marine and mostly benthic, a few are terrestrial but confined to humid areas. Some are brightly colourd.
2. Body size ranges from a few milimetres to 50 centimetres.
3. Body unsegmented, flattened and covered with ciliated cellular or syncytial epidermis, containing mucous secreting cells and rod-shaped bodies called **rhabdites**.
4. Locomotion by cilia and muscular undulations.
5. Presence of epidermal gland cells which help in adhesion, mucous secretion and other secretory functions.
6. Mouth opeing ventral, located at the end of an eversible pharynx which leads into a sac-like lobed or much branched intestine. Suckers absent.
7. Respiration by body surface.

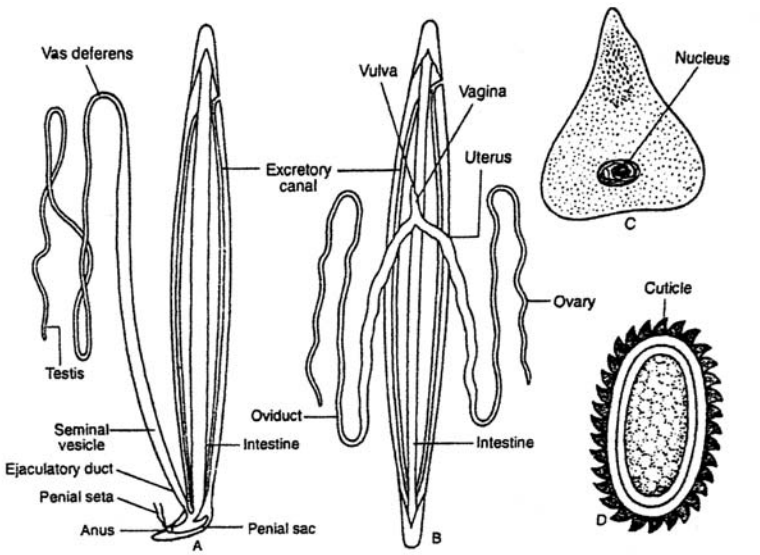

Fig. 6.2 : A showing the excretory system and male reproductive system of *Ascaris,* B. Female reproductive system of *Ascaris.* C. Spematozoon of *Ascaris.* D. Egg of *Ascaris.*

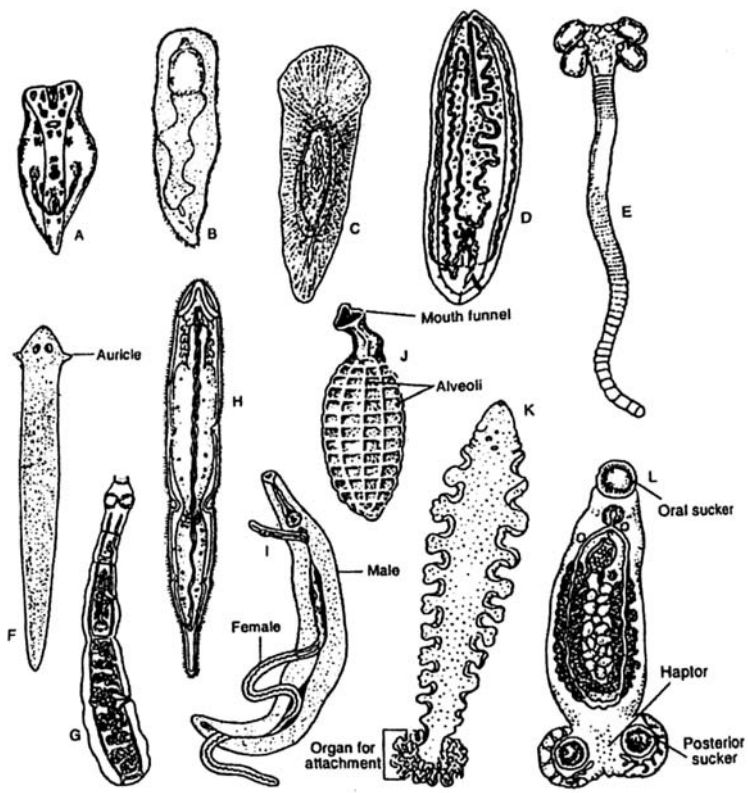

Fig. 6.3 : Representatives of Phylum Platyhelminthes (not drawn up to scale). A. *Convolute.* B. *Plaglostomum.* C. *Notaplana.* D. *Amphiline.* E. *Phyllobothrium.* F. *Dugesia.* G. *Echinococcus.* H. *Stenomum. I. Schislosoma.* J. *Aspidogaster.* K. *Gyrocolyle.* L. *Sphyranura.*

8. Several pairs of longitudinal nerve cords, associated with peripheral nerve nets and cerebral ganglion constitute the nervous system.
9. Number of pigment cups, ocelli and statocysts are the sensory organs.
10. Excretory system includes flame cells in most cases.
11. Mostly **hermaphrodite**, with internal fertilization. Many reproduce asexually by means of budding or transverse fission and show high power of regeneration.
12. Development is direct in most speices. A free-swimming larval stage **Muller's larva** is present in some forms (in a few polyclads).

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

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

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

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

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

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

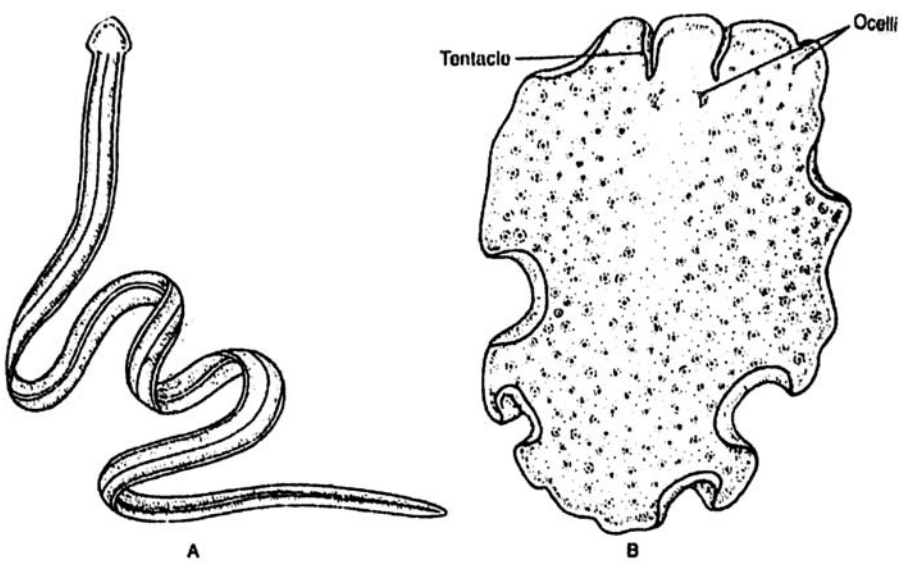

Fig. 6.4 : A terrestrial triclad flatworm, Bipalium, B. A marino Polyclad flatworm, oligoclado.

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

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

1. All are highly specialized endoparasites of vertebrates, and are commonly called **tapeworms**.
2. Body flat elongated and ribbon like, covered by a non-ciliated syncytial tegument (cuticle) having microvilli-like projectons. Rhabdites are absent.
3. Body is differentiated into three regions-head or **scolex**, **neck** and **strobila** or body.
4. Scolex usually with hooks and suckers for adhesion or attachment to the host.
5. Neck is very short and narrow. It is proliferative giving rise to the body or strobila.
6. Strobila consists of linearly arranged number of segment-like sections called **proglottids**.
7. Mouth, digestive tract and sense organs are absent.
8. Each mature proglottid contains one or two sets of male and female sex organs. Thus tapeworms are hermaphrodite.
9. Life cycle complicated with one or more intermediate hosts.
10. Embryos and larvae posses hooks.

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

6.5 ❑ General characteristics of phylum Nematoda

1. Nematoda (G. nema = thread; eidos = form) include widely distributed aquatic or terrestrial, free living or parasitic roundworms.
2. Body is slender, elongated and cylindrical (hence the name roundworm) with both ends gradually tapering.

3. Bilaterally symmetrical, triploblastic unsegmented animals.
4. A thick and flexible cuticle enclosed the body and lines the pharynx, hindgut and other body openings. Cuticle moulted periodically.
5. Mouth is located at somewhat rounded anterior end and is surrounded by lips and sensila of various sorts. There may be six lip like lobes in primitive marine forms and only three lips in terrestrial and parasitic species. Primitively the anterior end and lips bear 18 sensilla.
6. Body wall without circular muscles and made entirely of longitudinal muscle fibres arranged in four bands.
7. Body cavity is pseudocoel filled with parenchyma in most cases. Pseudocoel is small or non-existent in most small free living species but voluminous in large forms (e.g. *Ascaris*).
8. Complete digestive tract with distinct mouth and anus. Digestion extracellular.
9. Blood vascular system and respiratory orgns absent.
10. Excretory system without flame cells or nephridia. Excretion is performed by general body surface, excretory canal system or by excretory gland cells (called *renette cells*).
11. Nervous system comprises of a brain in the form of a circumpharyngeal nerve ring with dorsal, ventral and lateral nerves.
12. Principal sense organs (sensillae) are papillae, setae, amphids and phasmids, all of which are associated with cilia.
13. Sexes are separate (dioecious) but hermaphrodites, such as the well studied *Caenorhabditis elegans*, are not uncommon. Males are often smaller than females, and the posterior end of the male may be curved like a hook or broadened into a fan-shaped copulatory aid, called a *bursa*.
14. Fertilization internal, sperms lack flagella and are amoeboid.
15. Cleavage pattern neither spiral or radial but strongly determinate. Development is direct.
16. Nematodes have successfully adapted to nearly every ecosystem and are very widely distributed invertebrates.

6.6 ❑ Classification of phylum Nematoda

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

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

Class Adenophorea (Aphasmida) :

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

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

Class Secernentea (Phasmida) :

1. Presence of pore-like amphids in the lateral lips (amphids open to outside by pores).
2. In the caudal region presence of paired phasmids.
3. Excretory system canal-like and comparatively more complex.
4. Males possess single testis.
5. Many parasitic forms are members of this class and the free-living speices largely inhabit soil.

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

6.7 ❑ Questions

- Naik,

6.8 ❑ Suggested readings

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UNIT 7 ❑ Phylum Annelida – General characteristics and Classification up to classes

Structure

7.1 ❑ Objective

From this unit learners will learn the diversity, general characteristics and classification of phylum Annelida up to class.

7.2 ❑ Introduction

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

7.3 ❑ General characteristics

1. Triploblastic and bilaterally symmetrical coelomates.
2. Body soft, elongated, vermiform (worm-like) and ringed appearance (L. annellus = a ring).

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

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

7.4 ❑ Classification of Annelida

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

Phlylum Annelida includes three classes–

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

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

Characters :

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

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

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

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

1. Mostly terrestrial and fresh water forms with secondarily marine representatives.
2. Head indistinct, prostomium small, without eyes and other sensory structures.
3. Body segmented, parapodia absent but possess segmentally arranged setae embedded in the integument.
4. Clitelum present. It is glandular and secretes cocoon for the eggs.
5. Usually no respiratory organ except a few. Gas exchange through moist body wall by diffusion.
6. Most are scavengers, feed on dead organic matters, particularly vegetation. Digestive tract straight.

7. Excretory system metanephridial type.
8. Circulatory system well developed (basically similar to that of polychaetes). Respiratory pigment haemoglobin, dissolved in plasma.
9. Hermaphrodites with well developed reproductive systems, limited to a few anterior segments.
10. There is copulation and reciprocal transfer of sperm (cross fertilization occurs externally within a cocoon).

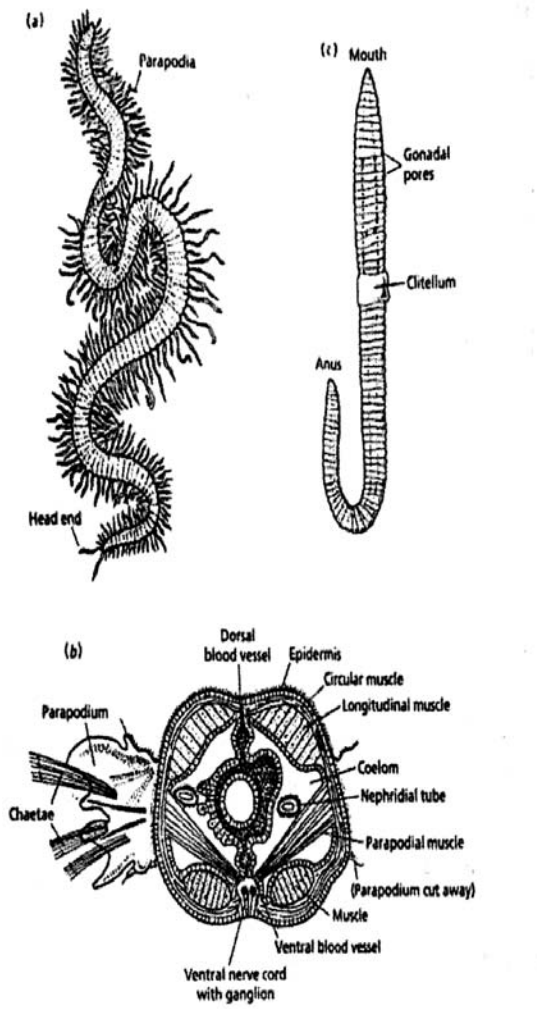

Fig. 7.1 : External views and transverse section (T.S.) diagrams to show the characteristic features of the three main classes of annelids: (a) *Trypanasyllis zebra,* a polychaete; (b) T.S. *Nereis;* (c) *Lumbricus terrestris,* an obligochaete.

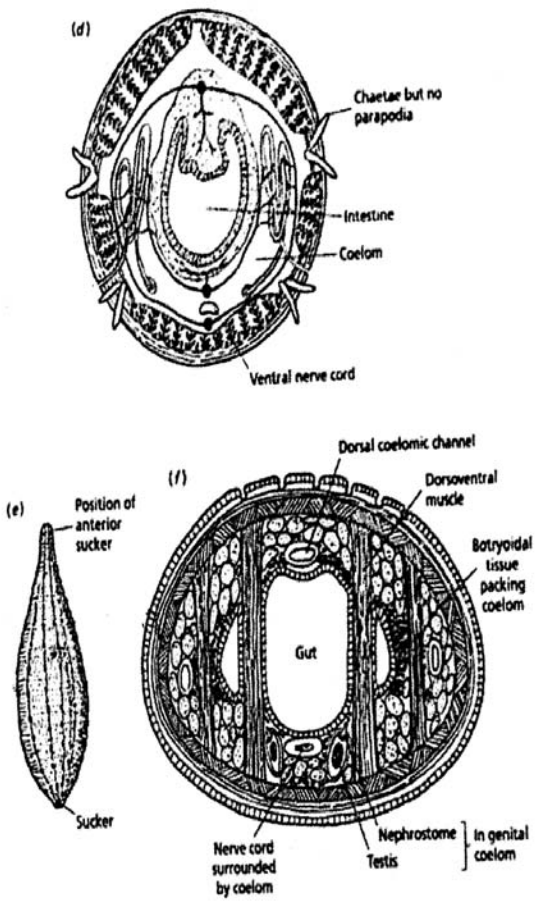

Fig. 7.2 : (cont.) (d) T. S. Lumbricus; 9e) a leech, viewed dorsally; (f) T. S. leech.

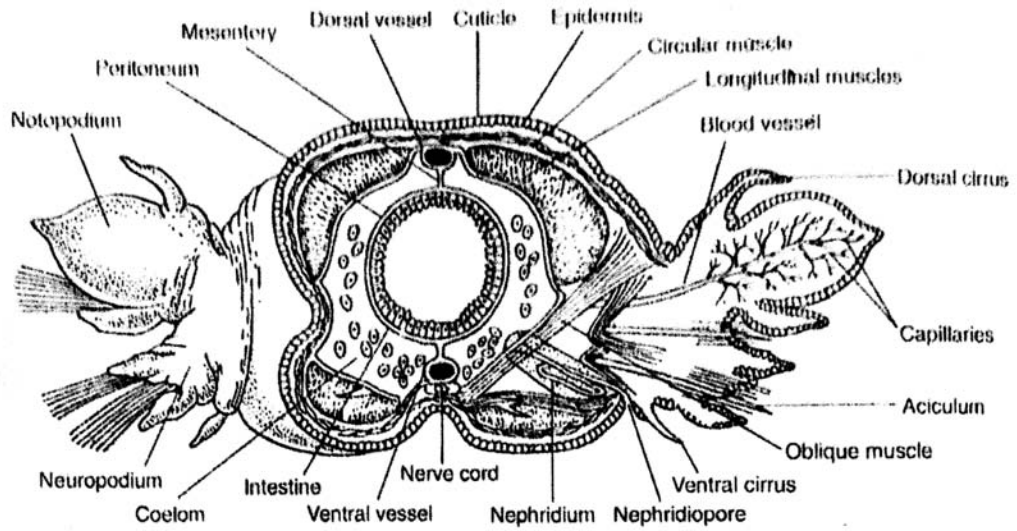

Fig. 7.2: Diagrammatic view of different structures in a segment of *Nereis*. Left side of the figure depicts an entire parapodium and the remaining part is shown in cross section (after various sources).

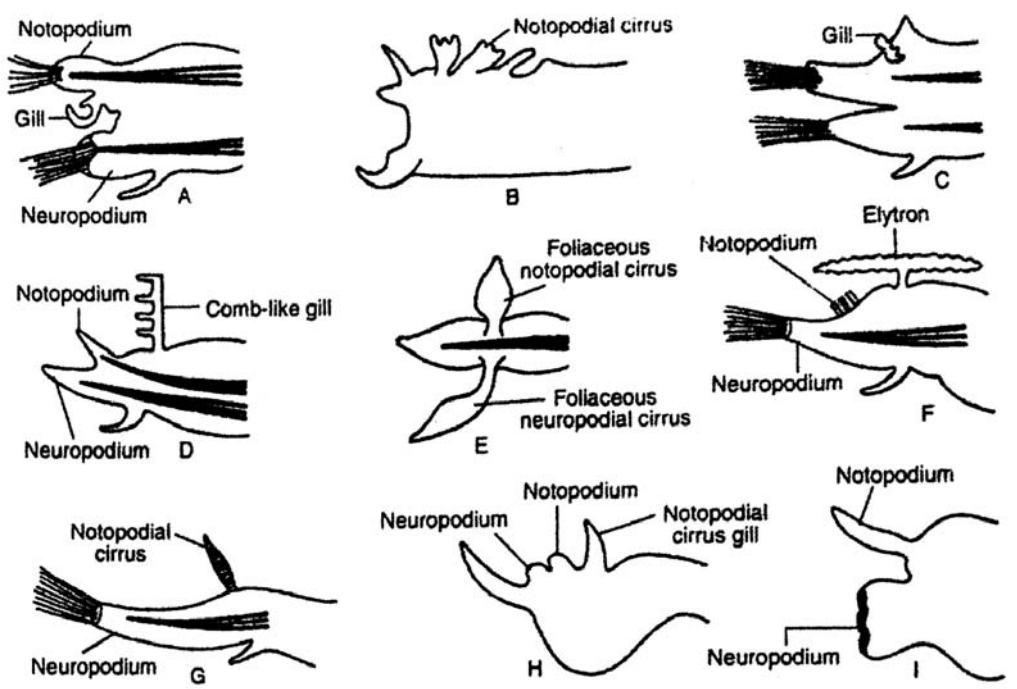

Fig. 7.3: Showing the modification of parapodia in different annelids. A. Parapodium of *Nepthys*. The notopodium gives a curved gill on its underside. B. Parapodium of *Amphinome*. The notopodium is indistinct. C. Parapodium of *Glycera*. D. Parapodium of *Eunice*. It is uniramous with reduced notopodium. The notopodial cirrus acts as the comb-like gill. E. Parapodium of *Phyllodoce*. The cirri are foliaceous. F. Parapodium of *Polynoe*. The notopodium is not developed. An elytron is present. G. Parapodium of *Syllis*. Notopodium is entirely absent. H. Parapodium of *Scoloplos*. Both the neuropodium and notopodium are reduced. I. Parapodium of *Sebella*. Cirri are absent.

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

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

Class Hirudinea (L. hirudo = leech)

1. Most are freshwater, some are marine or terrestrial some are ectoparasites, blood suckers or carnivorous (predaceous).
2. Dorsoventrally flattened and elongated body with definite number of segments. Each segment subdivided externally into 2 to 4 secondary rings or annuli. Head indistinct.
3. Parapodia, setae and cephalic appendages are absent.
4. Presence of two suckers–a small **anterior or head sucker** surrounding the mouth and a large powerful **posterior sucker**, both are situated ventrally. Clitellum present but never conspicuous except during reproductive periods.
5. Mouth opens on the ventral surface of anterior sucker, while anus opens dorsal to the posterior sucker. Just within the mouth cavity are three large, oval blade—like jaws each bearing a large number of small teeth along the edge. As the animals suck blood their salivary glands secrete an anticoagulant called **hirudin**. In most forms the stomach is provided with 1 to 11 pairs of **lateral caeca**.

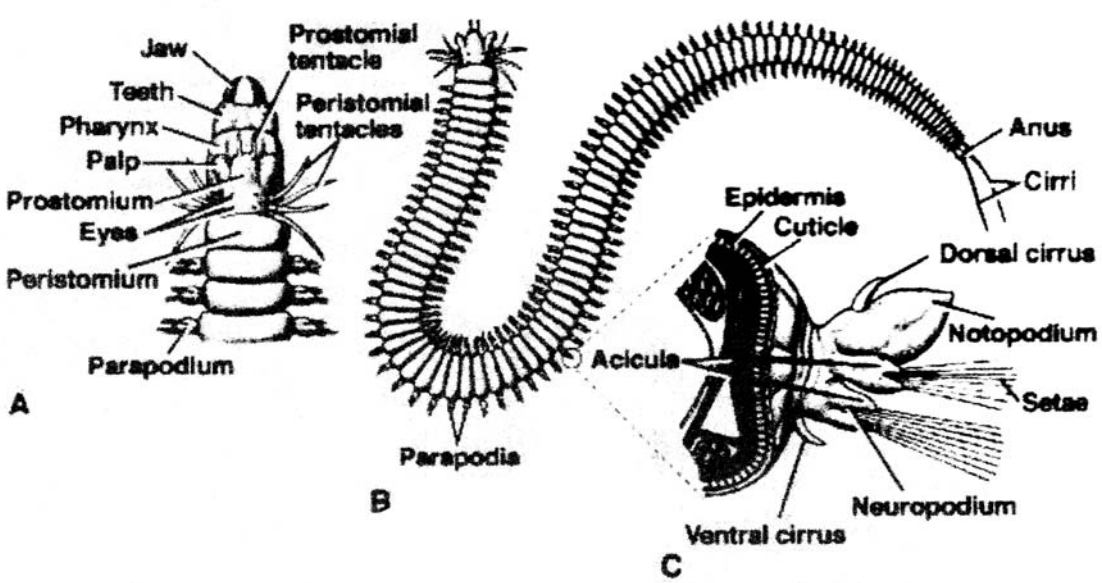

Fig. 7.4 Polycheat body Part: A. Prosotomium, B: Neries, C: Parapodium

6. Coelom is greatly reduced due to the presence of connective tissue, called **botryoidal tissue** and is represented by haemocoelomic sinuses.
7. The septa are greatly reduced. Metamerism is shown by paired nephridia and ganglia of the ventral nerve cord.
8. Hermaphrodite, with several pairs of testes, a pair of ovaries and a single `genital opeing. Gonads and gonoducts restricted to anterior few segments.
9. Fertilization internal (cross fertilization).
10. Development direct (no larval form), eggs are usually laid in cocoons, secreted by the clitellum.

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

7.5 ❑ Questions

- Naik,

7.6 ❑ Suggested readings

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UNIT 8 ❑ Phylum Arthropoda – General characteristics and Classification up to class

Structure

8.1 ❑ Objective

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

8.2 ❑ Introduction

Phylum Arthropoda is the largest phylum in the animal world and this phylum represents a vast assemblage of animals with hard exoskeletons and jointed appendages. The phylum includes more species and more individuals than all other groups of animals combined. Over 85 percent of all known animal species described to date are belong to the phylum

Arthropoda (Fig. 8.1 and 8.2). No other phylum of animals can rival the arthropods in success i.e. they are considered the most successful animals on Earth and it is due to the tremendous adaptive diversity that has enabled them to survive in virtually every habitat. Its members occupy a large ecological niche and inhabit virtually all types of environments on the planet i.e. from snow covered mountain peaks to the depth of the ocean. In other words, they have been most successful in colonizing terrestrial, aquatic, and aerial habitats. They consume the greatest varieties of food. Their success as terrestrial animal is probably due to the evolution of water conserving excretory sysems and gaseous exchange organs and the development of a desiccation resistant impermeable epicuticle. Many members of this phylum are closely related with different aspects of human life like food, health, etc. and thus have great economic importance. Many familiar species belong to the phylum Arthropoda—insects, spiders, scorpions, centipedes, and millipedes on land; crabs, crayfish, shrimp, lobsters, and barnacles in water. The class Insecta by itself represents almost three quarters of all described animal species (Fig.).

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

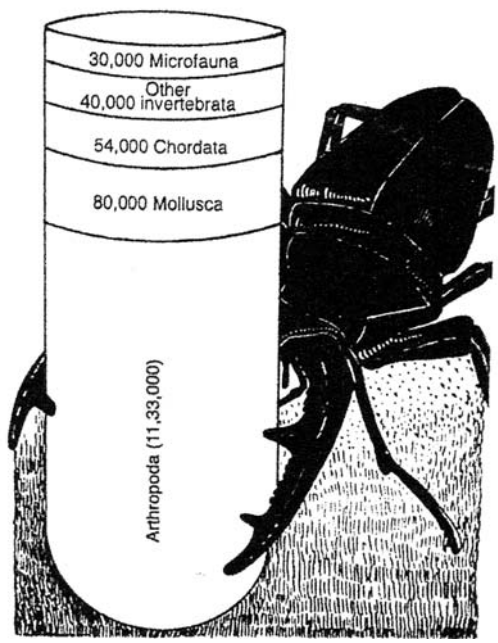


Fig. 8.1 : In the animal world, the Phylum Arthropoda includes the largest number of species. All of them possess metameric segmentation, hard chitinous exoskeleton and jointed legs. Number shown against each group denotes the approximate number of species.

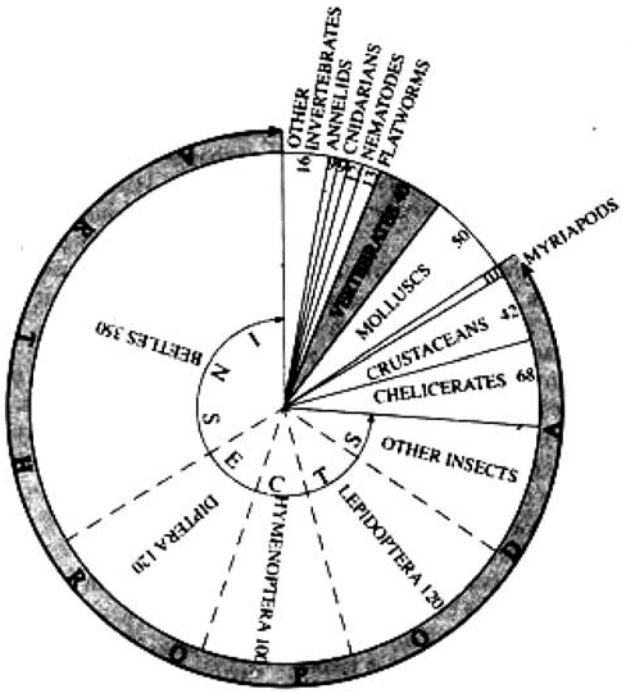


Fig. 8.1 : Phyhum wise representation of animals in the animal kingdom (only arthropods are represented class and order wise).

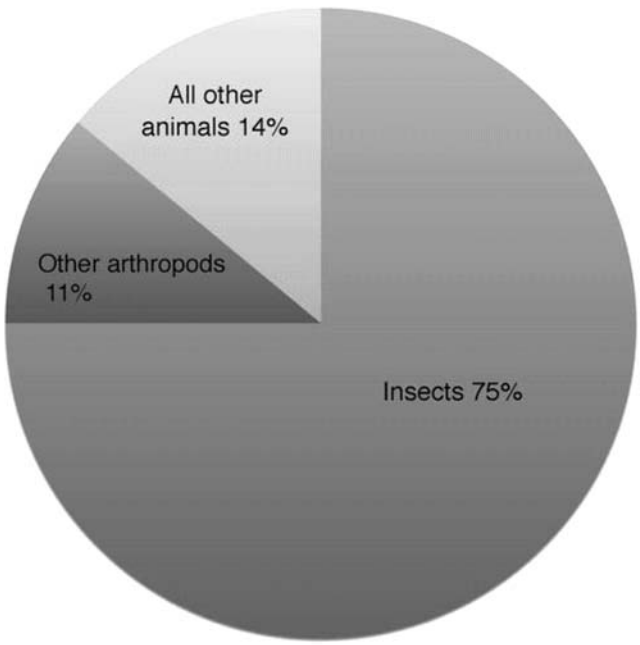


Fig. 8.2 : Proportion of species in the kingdom Animalia, which are arthropods versus all other animals. The vast majority of arthropods are insects.

8.3 ❑ Characteristic Features of Arthropods

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

13. Central nervous system consists of a dorsally placed anterior ganglionic mass (brain) connected to double ventral nerve cords running through all segments and forming paired ganglia in each segment.

14. Sensory organs comprise of simple or compound eyes (found in many crustaceans and most insects) and chemoreceptors, tactile receptors, balancing and auditory organs. Each compound eye is made up of several visual units or omatidia (sing.omatidium).

15. Cilia are entirely absent from all parts of the body.

16. Sexes are usually separate (dioecious or gonochoristic); some hermaphrodite. Sexual dimorphism is seen in many

17. Eggs are centrolecithal and cleavage usually superficial.

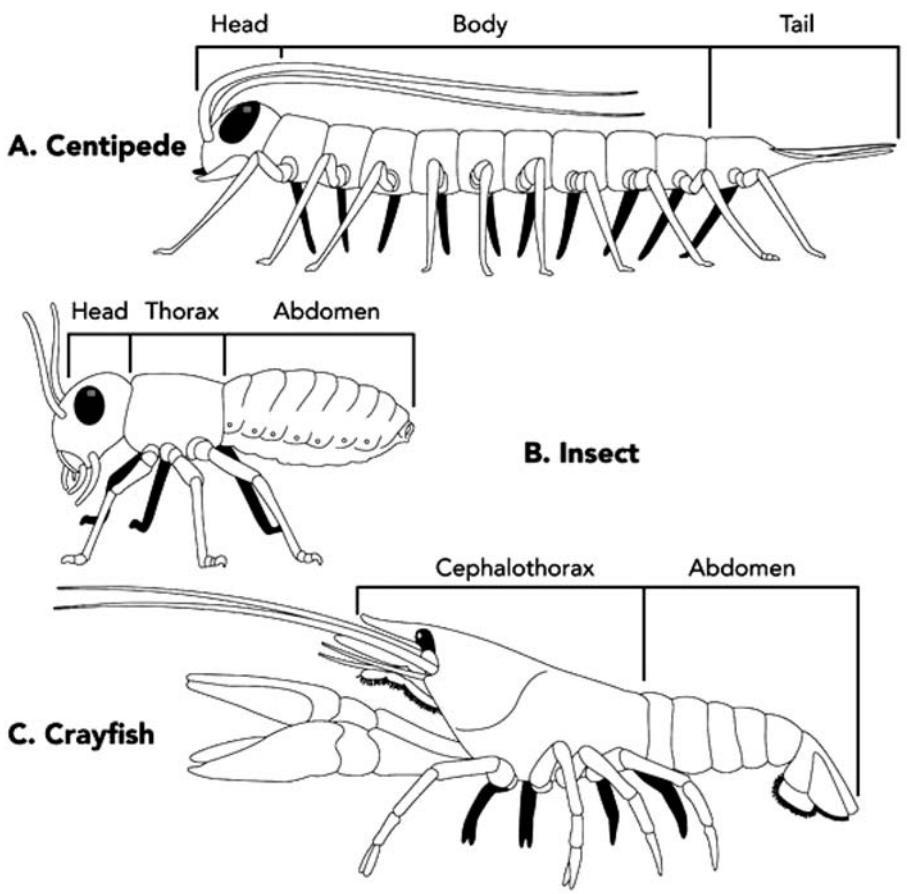


Fig. 8.3 : Examples of arrangement of segments in three types of arthropods: (A) Centipede (B) Insect (C) Crayfish

18. Fertilization usually internal. Oviparous or ovoviviparous.
19. Development is usually indirect involving one or more larval forms. Absence of ciliated larvae.
20. Parthenogenesis is seen in some members of Insecta, Branchiopoda and Copepoda.
21. Parental care is well marked in some species.

8.4 ❑ Classification of the Phylum Arthropoda

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

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

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

8.4.1. Subphylum Trilobita

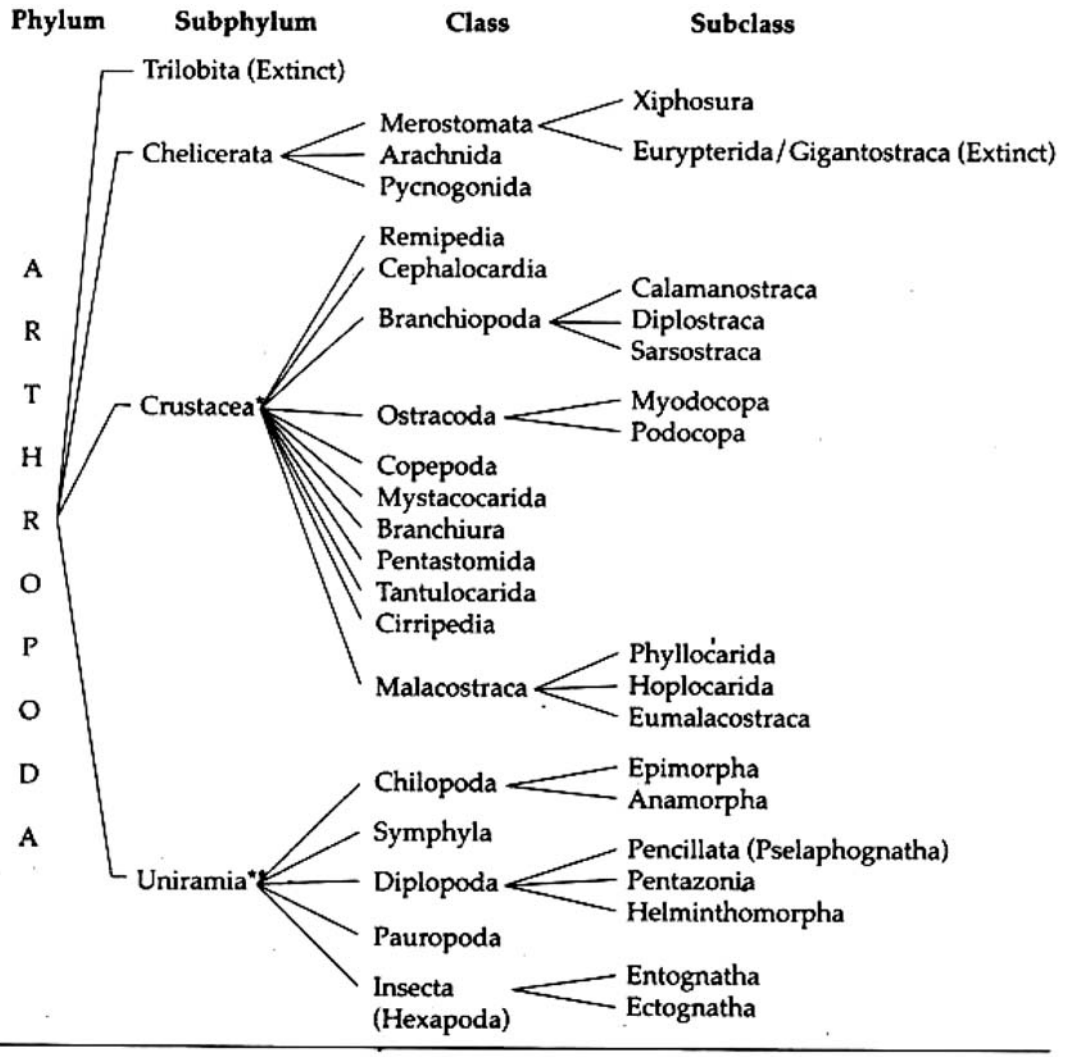
Classification with Characters:

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

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

Characters:

1. Extinct marine arthropods.
2. Body more or less oval and flattened from above downwards.



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

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

3. Body is divided into three regions:

   (i) The anterior head or cephalon, (ii) The middle region trunk or thorax and (iii) A posterior pygidium.

4. Each region of the body is divided into 3 lobes by two longitudinal furrows, hence the animals derive their name Trilobites or three-lobed form.

5. Size varies from 10 mm to 60 cm.

6. Head and pygidium were covered by an un-jointed calcareous exoskeleton, called carapace.
7. Presence of a pair of compound eyes, found laterally on the anterior part of the body.
8. A pair of many-jointed antennae represents the pre-oral appendage.
9. Post-oral appendages are uniform, biramous and unspecialized. The innermost branch of each appendage was without long setae and was probably adapted for walking and the outermost branch had long filaments used for swimming or filtering food materials. The two branches are sometimes called endopodite and exopodite also.
10. Each leg has 8 segments.
11. The anal opening was on the last segment of the pygidium.

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

Examples:

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

8.4.2. Subphylum Chelicerata [Gk. chele = claw]

Classification with Characters:

1. Heterogenous group of arthropods, in all of which pre-oral antennules or first antennae are absent (nonantennate). Chelicerates are the only arthropods which lack antennae.
2. Bilaterally symmetrical. Body shape varying from elongated to almost spherical.
3. Body is divided into two parts— anterior cephalothorax or prosoma, which is wholly or partly covered by a dorsal carapace and a posterior abdomen (or opisthosoma) with no distinct head. Opisthosoma without legs.
4. Appendages uniramous. Cephalothorax possesses five postoral segments, each with a pair of appendages. First pair of appendages on the first postoral segment is called chelicerae(helps in feeding), one pair of chelate leg-like or feeler like 'pedipalps' (helps in various functions) and four pairs of walking legs. . The chelicerae become pre-oral in position and bears a terminal chela.
5. Chelicerates have no jaws (mandibles); hence may be called amandibulates.

6. Each chelicera is jointed and bears a terminal chela.
7. Abdomen (opisthosoma) consists of 12-13 segments and a telson (telson and many abdominal segments are absent in certain forms).
8. Second abdominal segment bears genital aperture which remains covered by a modified abdominal appendage, called operculum.
9. Compound eyes in most cases degenerated.
10. Median ocelli or simple eyes present.
11. Mouth anteroventral. Gut straight. From the mid gut region arise two to many pairs of digestive diverticula which secrete enzymes that intracellularly digest and absorb food.
12. Development generally direct, juvenile with the full complement of limbs.
13. Primarily marine arthropods, although most living forms are terrestrial.

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

(i) Class Merostomata

(ii) Class Arachnida

(iii) Class Pycnogonida.

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

Characters:

1. Marine forms with fairly developed compound eyes, present laterally.
2. Head and thorax are fused into a single unit—the prosoma or cephalothorax covered by a single sheet of exoskeleton, the carapace.
3. First pair of appendages on the prosoma, first one is the Chelicerae followed by 5 pairs of appendages, the walking legs.
4. Prominent caudal spine, called telson, present at the end of the body, used as a lever in pushing and balancing during locomotion.
5. Respiratory organs are gills (book- gills), which are borne on the plate-like appendages of the mesosoma.
6. Adults crawl on earth with the face downwards, but young can swim actively.

Examples:

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

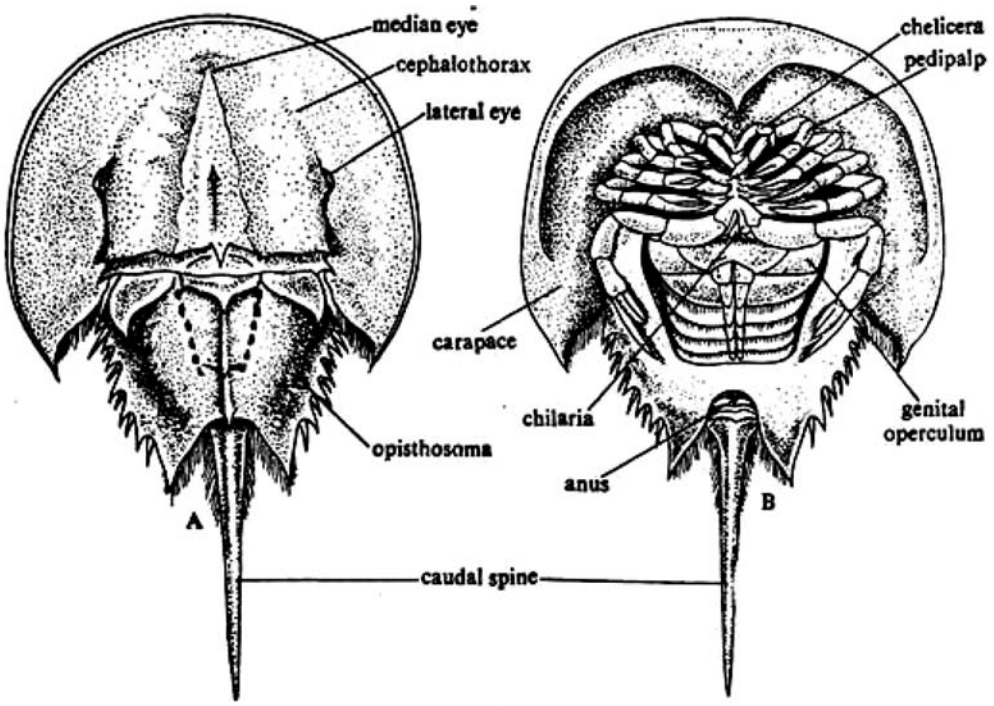


Fig. 8.4 : External features of Limulns. A. Dorsal view, B. Ventral view

Class 3. Arachnida [Gk. arachne = spider] About 70,750 species; Size: 0.25 mm – l8 cm.

Characters:

1. Body divided into two regions— cephalothorax (Prosoma) and abdomen. Prosoma un-segmented, usually covered dorsally by a solid carapace. . In some arachnids (ticks and mites), the prosoma and opisthosoma have fused together and the entire dorsal surface is covered by a single carapace.
2. Eyes usually simple. Compound eyes when present are degenerated.
3. Two pairs of jointed cephalic appendages-chelicerae and pedipalpi present. The first pair of cephalic appendages, known as chelicerae, which are preoral and the 2nd pair, the pedipalps, are postoral and serve partly as jaws.
4. Four pairs of thoracic legs present.

5. Abdomen generally without appendages but modified appendages in some. Some arachnids (the spiders) bear up to 4 pairs of small abdominal appendages called spinneret.
6. Antennae absent.
7. Large arachnids (scorpions, some spiders) possess book lung as respiratory organs; small forms (psuedoscorpions, some spiders, mites) possess tracheae. In some arachnid species, both book lungs and tracheae and book lungs are present.
8. Eyes usually simple. Compound eyes either absent or degenerated. For most arachnids the sensory hairs are the primary sense organs
9. The heart is highly developed in large species with book lungs and the blood contains haemocyanin.
10. Excretory organs are Malpighian tubules or coxal glands or both.
11. Sexes separate. Single or paired gonads that lie in the abdomen. Fertilization is internal.
12. Eggs yolky and centrolecithal.
13. Development direct, not accompanied by metamorphosis.
14. Arachnids are carnivorous and except a few secondarily aquatic forms, most of them are terrestrial.
15. Predator arachnids use poison or silk in prey capture.

About 98% of the living chelicerates (Subphylum Chelicerata) belong to class Arachnida.

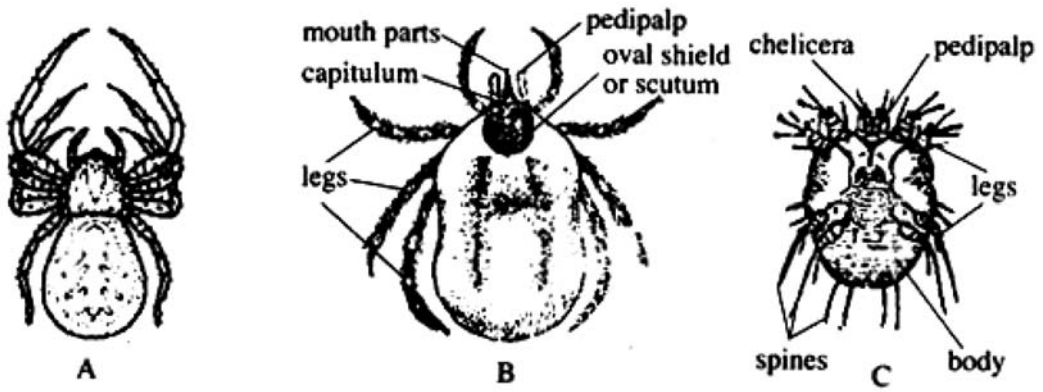


Fig. 8.5 : A. *Aranea*, B. *Ixodes* (female sheep-tick, dorsal view), C. *Sarcoptes scabei* (female's ventral view).

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

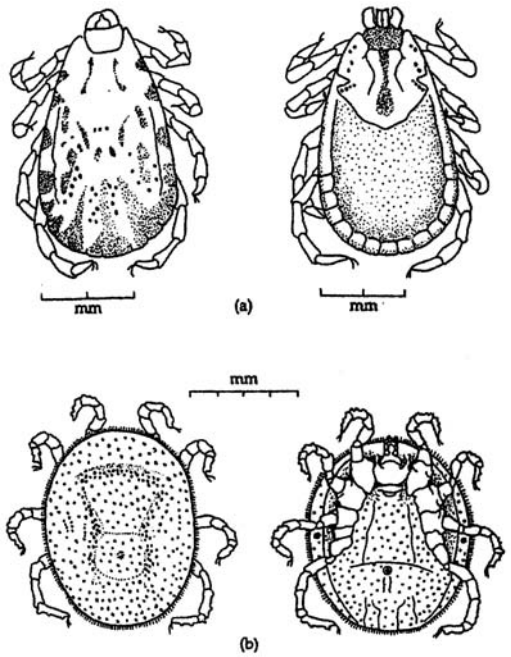


Fig. Ticks (a) Hard tick. Dermace tor andersoni (male left, female right). (b) Soft tick; Omithodoros moubata (dorsai aspect left, ventral aspect right).

Additional reading:

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

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

Characters:

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

Examples:

Nymphon, Pycnogonum, Colossendeis.

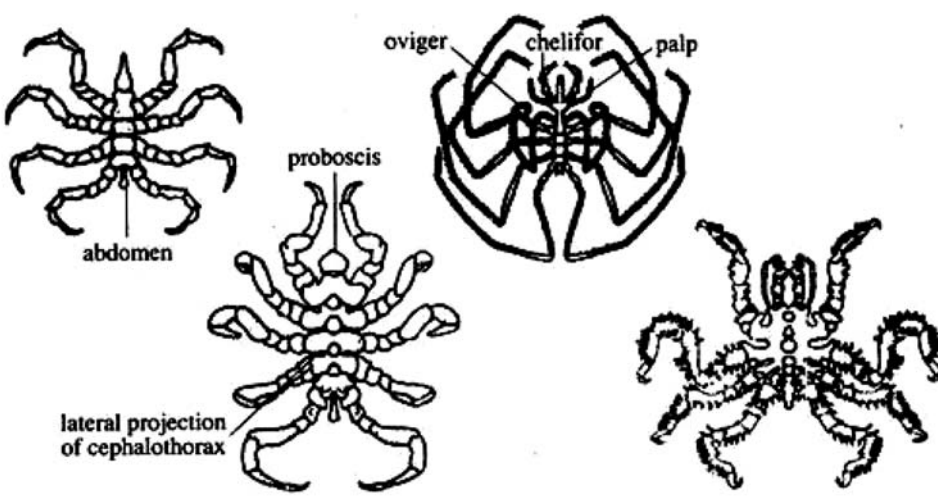


Fig. 8.6: Pycnogonan body forms.

8.4.3. Subphylum Crustacea

Crustacea: (In Latin crusta means a hardshell): About 44,000 described species (about 3000 Indian species).

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

Classification with Characters:

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

   Carapace covers all or part of the body. Exoskeleton often calcareous.

2. Head bears five pairs of appendages. Crustanceans are unique among arthropods in having **two pairs of antennae** (first pair of antennae is called antennules).

   Presence of two pairs of antennae is a distinguishing feature of crustaceans. Other cephalic appendages are a pair of mandibles and two pairs of maxillae.

4. Thorax usually with eight pairs and abdomen usually with six pairs of appendages. Appendages undergo various modifications. Last segment of abdomen is telson.

5. Thoracic and abdominal appendages are typically biramous i.e. the two branches are of different size and shape, and become adapted for different functions.

6. Head bears a pair of compound eyes (in some located on movable jointed stalk) and a small median dorsal naupliar eye (a characteristic feature of the naupliar larva of crustaceans and therefore referred to as the naupliar eye).

7. Sense organs, other than eyes include statocysts, sensory hairs and proprioceptors.

8. Brain formed by the fusion of first four embryonic ganglia and is connected with ventral nerve cord by oesophageal connectives.

9. Vascular system consists of a contractile heart, arteries and haemocoelomic spaces.

10. Respiration by means of gills or by general body surface. Gills are typically associated with the appendages but the location, number and form vary greatly.

11. Excretory organs are a pair of blind sacs in the haemocoel of the head and they open onto the bases of the second pair of antennae (antennal glands or

green glands) or the second pair of maxillae (maxillary glands). These are the modification of coelomoducts.

12. Most crustaceans are dioecious (sexes separate). Distinct sexual dimorphism present. Copulation and egg brooding are very common.
13. Eggs are mostly centrolechithal i.e., yolk present in the central part of the egg.
14. Cleavage is superficial. Development through various larval forms like Nauplius, Cypris, Megalopa, Zoea, etc. The earliest hatching stage is a naupliar larva bearing a single median eye and three pairs of body appendages.
15. Mainly aquatic, mostly marine, many freshwater and some have invaded into terrestrial condition.

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

Crustanceans are one of the most popular invertebrate groups, even among non-biologists, for they include some the world's most delicious food items, such as lobsters, crabs and shrimps. There are more than 67000 described living species of crustacea (Brusca and Brusca, 2003). They exhibit an incredible diversity of form, habit and size. The smallest known crustaceans are less than 100 µm in length and live on the antennules of copepods (a group of crustacea). The largest are Japanese spider crabs (*Macrocheira kaempferi*), with leg span of 4 metres and giant Tasmanian crabs (*Pseudocarcinus gigas*) with carapace width of 46 cm. The heaviest crustaceans are probably American lobsters (*Homarus americanus*), which attained weights in excess of 20 kilograms. Crustancens are found at all depths in every marine, brackish and freshwater environment on Earth. A few have become successful on land, the most notable being sow bugs and pill bugs (the terrestrial isopods). Crustaceans occupy an important position in aquatic food chains.

The subphylum Crustacea is divided into 11 classes:

1. Class Remipedia,
2. Class Cephalocarida,
3. Class Branchiopoda,
4. Class Ostracoda,
5. Class Copepoda

6. Class Mystacocarida,
7. Class Branchiura,
8. Class Pentastomida,
9. Class Tantulocaride,
10. Class Cirripedia and
11. Class Malacostraca.

Class 1. Remipedia:

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

Characters:

1. Marine animals with small (range up to 30 mm in length), elongated, worm like and translucent body.
2. Body comprises of a short, carapace-less cephalothorax, followed by a trunk of 20-30 similar segments each with a pair of leaf-like, lateral biramous appendages.
3. They are carnivorous and the first pair of trunk appendages are modified as prehensile maxillipeds for feeding. Other trunk appendages help in swimming.
4. Eyes absent
5. Telson with caudal rami.
6. Hermaphrodite. Development still unknown.

They are the inhabitants of tropical marine caves.

Examples:

Lasionectes, Speleonectes.

Class 2. Cephalocarida [Approx. 9 species]:

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

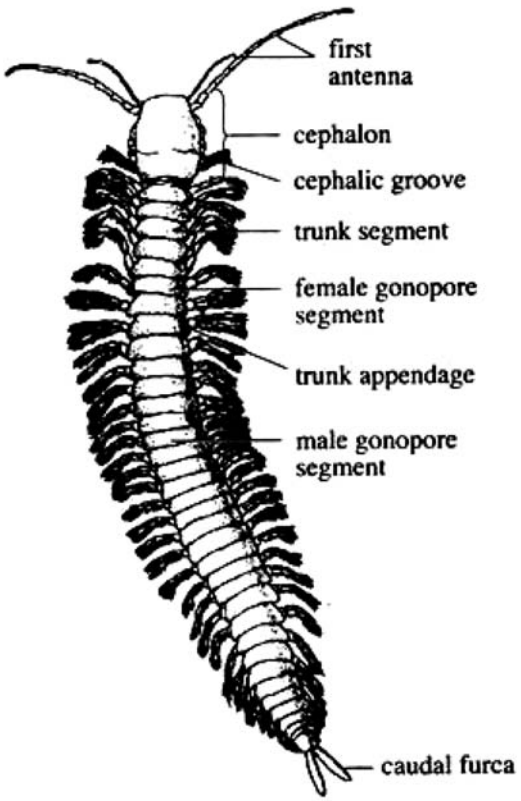


Fig. 8.7: Spciconectes tulumensis.

Characters:

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

8. Although compound eyes are present they are blind as these eyes are buried in the head.
9. Hermaphrodite and development includes metanauplius stage.

Examples:

Hutchinsoniella, Lightiella.

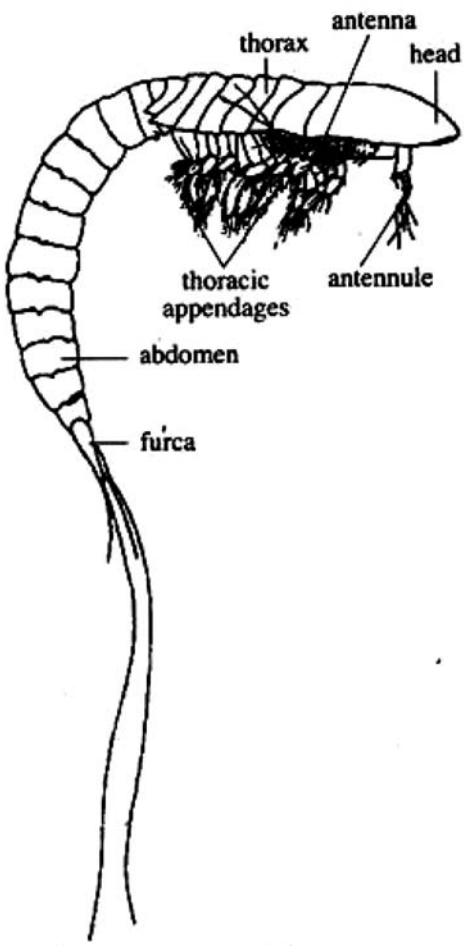


Fig. 8.8: Hutchinsonicllа (lateral view).

Class 3. Branchiopoda (Gk. branchiona fin); About 800 described species

Characters:

1. Small crustaceans mainly restricted to fresh water, a few are marine.
2. Trunk appendages are uniform, flattened and leaf-like.

3. Coxa is provided with a flattened epipod that serves as a gill and hence the name “gill feet”.

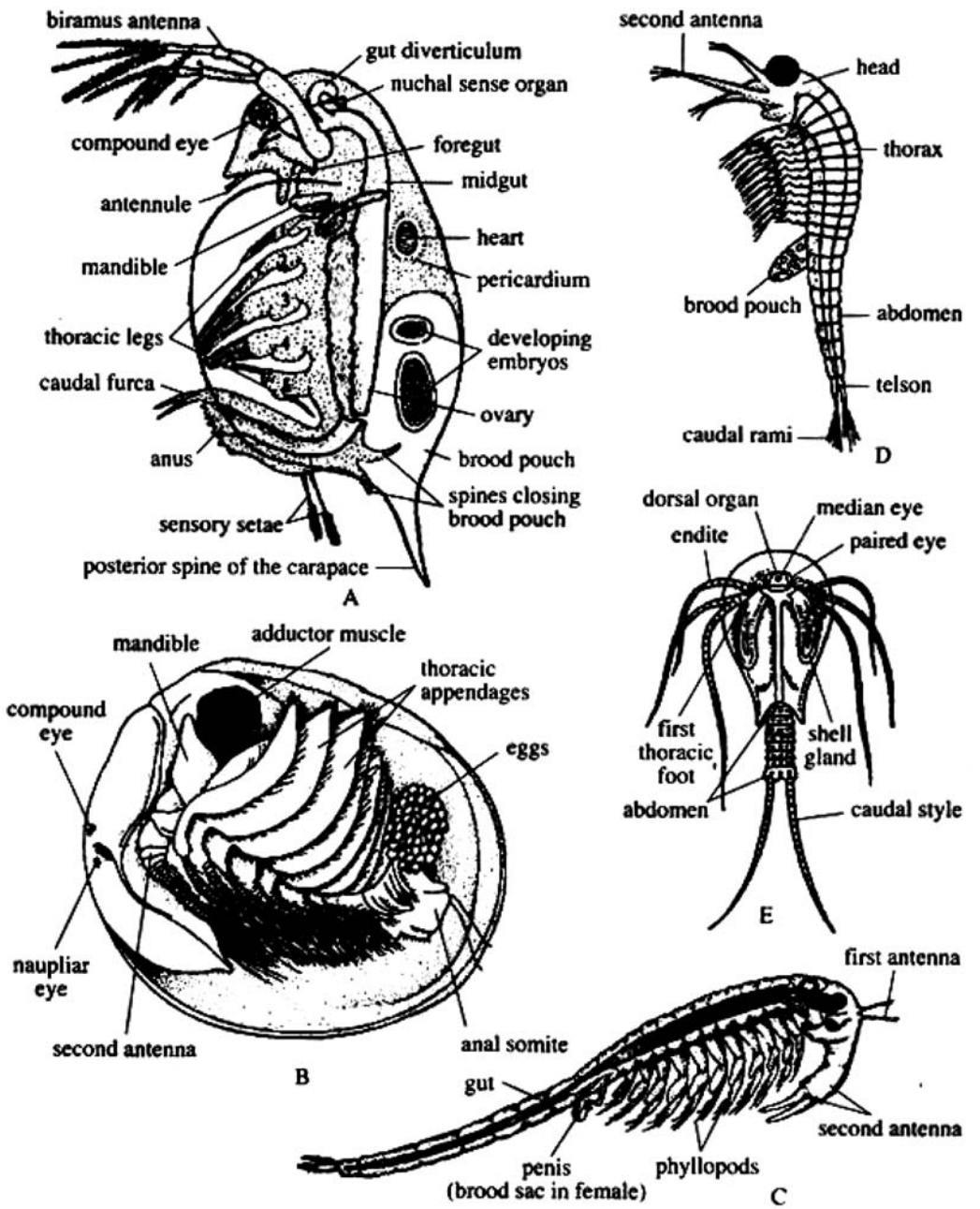


Fig. 8.9: A. Daphnia, B. Lynccus (lateral view with the left value removed), C. *Branchinccta* (fairy shrimp), D. *Artcmia* (brine shrimp), and E. Triops.

4. Presence of one pair un-jointed or jointed caudal styles.
5. Carapace either absent or shield-like or bivalve.
6. First antennae and maxillae are small or vestigial and in some cases absent.
7. Mandibular palp either rudimentary or absent.
8. Excretion by maxillary glands or shell glands.
9. Branchiopods brood their eggs.

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

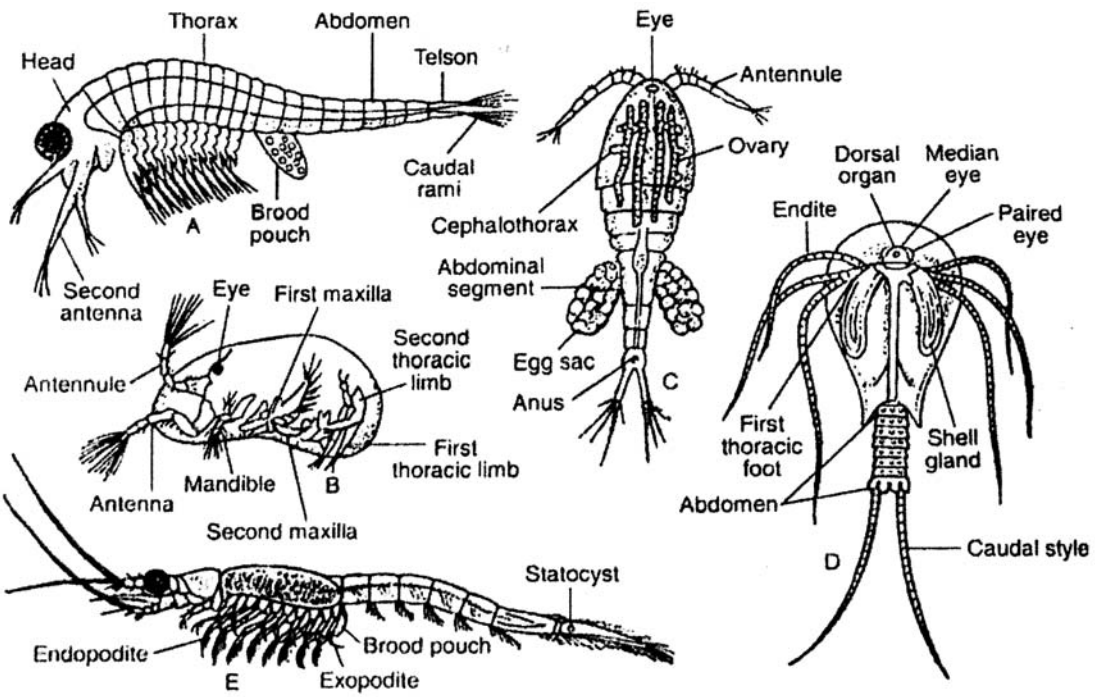


Fig. Some important crustanceans. a. *Artonia* B. Cypris. C. *Cyclops.* D. *Triops.* E. *Mysis* (from various sources)

Class 4. Ostracoda (Gk. ostrakodes – testaceous resembling a shell); About 7000 known species

Characters:

1. Body enclosed within a hinged bivalved (often calcareous) carapace.
2. Head large, forms half of the body volume and contains four appendages-

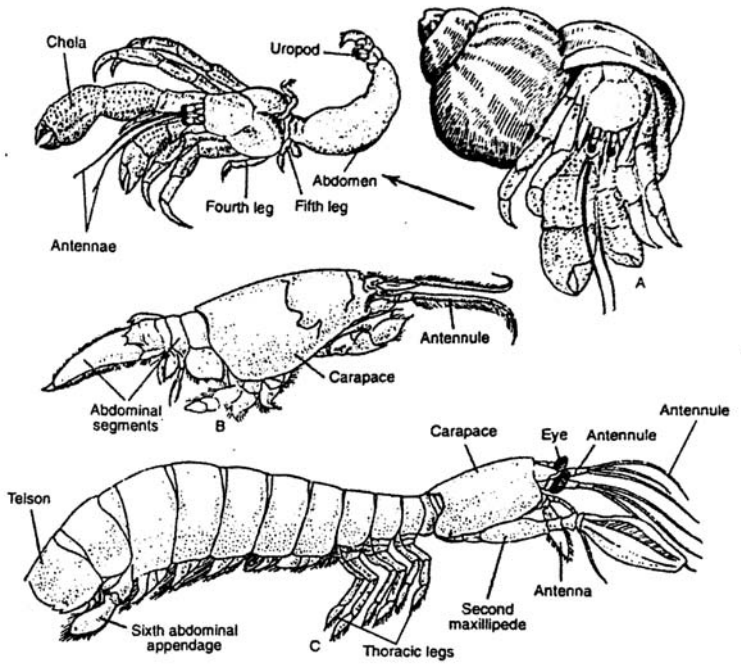


Fig. Some important crustaceans (contd.) A. *Eupagurus*. B. *Hippa*. C. *Squilta*. Arrow indicates the body of *Eupagurus* outside the moltuscan shell.

antennules, antennae, mandibles and first maxillae. Antennae modified for swimming.

3. Trunk reduced having no more than two pairs of appendages.
4. Gills absent. Gas exchange is integumentary (cutaneous).
5. Eyes may or may not be present.
6. Males are rare and the second antennae of the males serve as clasping organs.
7. Ostracods are small crustaceans sometimes referred to as mussel or seed shrimp. They are widely distributed in the sea and in all types of freshwater habitats.

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

Class 5. Copepoda (Gk. kope = handle) About 8,500 known species

Characters:

1. Mostly small with cylindrical bodies.
2. Body with well-marked segments.

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

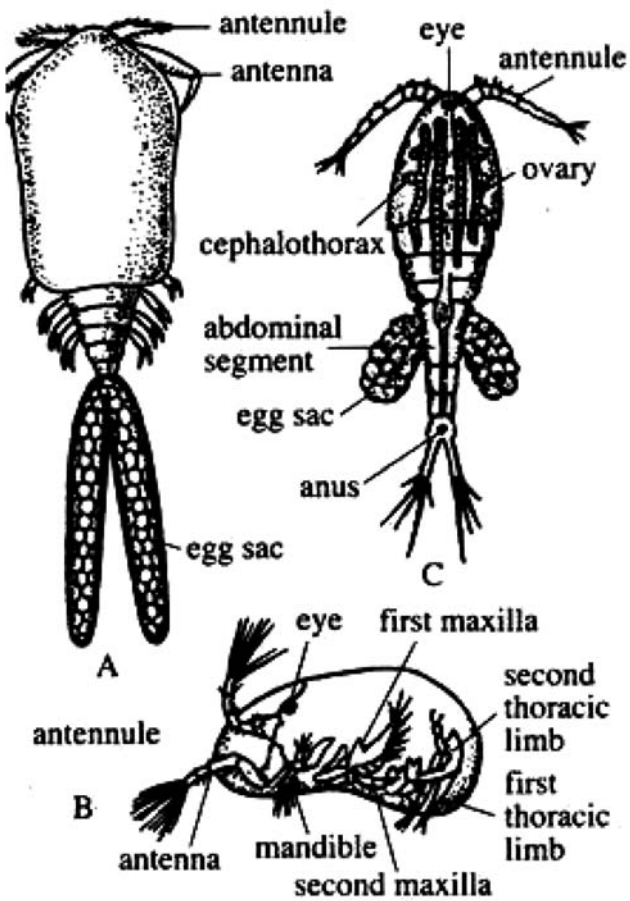


Fig. 8.10: A. *Ergasilus,* B. *Cypris,* C. *Cyclops.*

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

Examples:

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

Class 6. Mystacocarida Approx. 8 known species

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

Characters:

1. Marine interstitial crustaceans with elongated, pigment less body.
2. Length of the body always within 1 mm.
3. Head is divided into a small anterior and a large posterior portion.
4. Cylindrical bodies with distinct cephalic appendages.
5. Trunk is made of ten segments of which the first five bear appendages, the first one being the maxilliped. Two caudal styles work as pincers.
6. Only nauplius eye persists and the compound eyes absent.
7. Sexes separate, development through nauplius stage.

Examples:

Derocheilocaris sp., Ctenocheilocharis sp. These are the only two genera.

Class 7. Branchiura About 130 known species

Characters:

1. Dorsoventrally flattened body with suctorial mouth.
2. Broad shield-like carapace covers the cephalothorax.
3. Both pairs of antennae reduced and modified for attachment.
4. Sessile compound eyes present.
5. 5 pairs thoracic appendages.

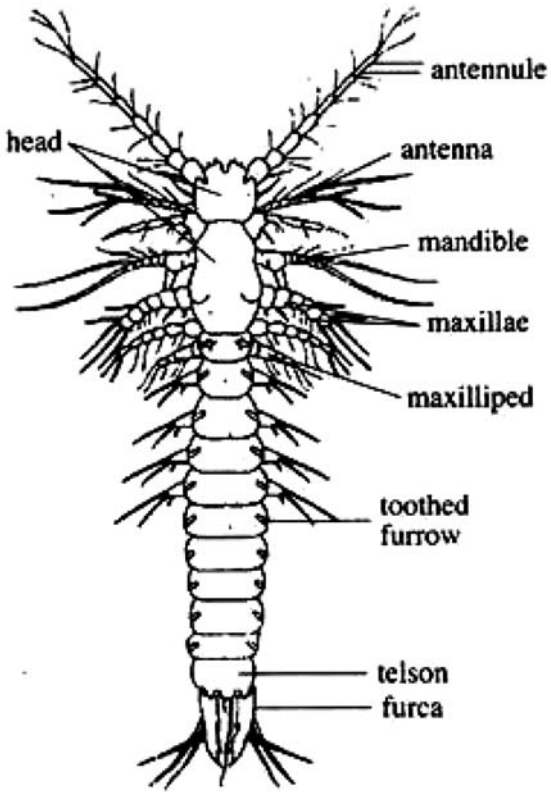


Fig. 8.11: *Derocheilocaris*

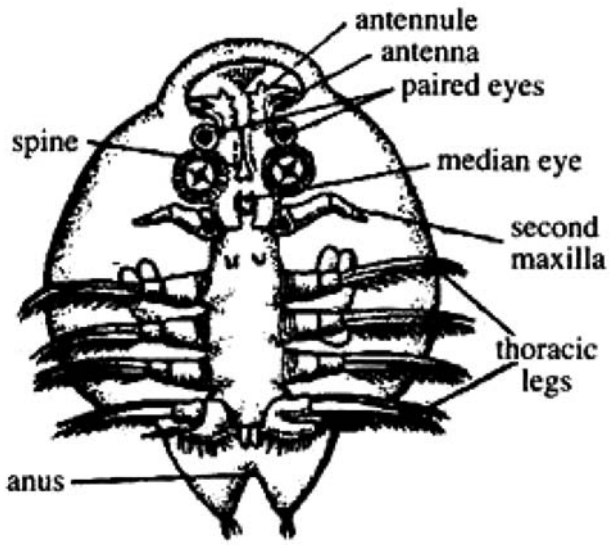


Fig. 8.12: *Argulus*

6. Abdomen small, bilobed and un-segmented.
7. Flagella present in the appendages of some body segments.
8. Fifth body segment bears the genital apertures.
9. Males have two testes but females possess a single ovary.

Branchiurans are small, ectoparasites of marine and fresh water fishes. Commonly called fish lice.

Examples:

Argulus, Dolops, Chonopelti, Dipteropeltis.

Table 8.1 : Indian Argulus

1. *Argulus bengalensis* [Malda District (W. Bengal)]
2. *Argulus puthenvalensis* (Puthenvali, Wdaymperoor, Kerala).
3. *Argulus siamensis* (Rajahmundry, Andhra Pradesh)
4. *Argulus foliaceous* (Different parts of India)

Class 8. Pentastomida Approx. 100 known species

There are about 90 parasitic species of pentastomids.

Characters:

1. Body worm like, and bears five short, anterior protuberances. Four of these projections are leg-like bearing chitinous hooks or claws, used for clinging to the host tissues. The central projection is a snout-like process bearing the mouth.
2. Length ranges from 2 to 13 cm, the females are 10 cm in length.
3. Body covered by a non-chitinous cuticle and exhibits annular markings over the abdomen in the adult.
4. Most of the systems, such as digestive, excretory and reproductive are modified to adapt the endoparasitic life.
5. They are gonochoristic, i.e., the sexes are separate. Fertilization internal.
6. Larva possesses 2-3 pairs of un-jointed Legs.
7. Completion of the life history requires intermediate host.

8. Pentastomids are popularly known as Tongue worms or sometimes referred to as “five mouths”.

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

Remarks:

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

Examples:

*Raillietiela, Cephalobaena, Armillifer, Linguatula (*Tongue worm*), Porocephalus*

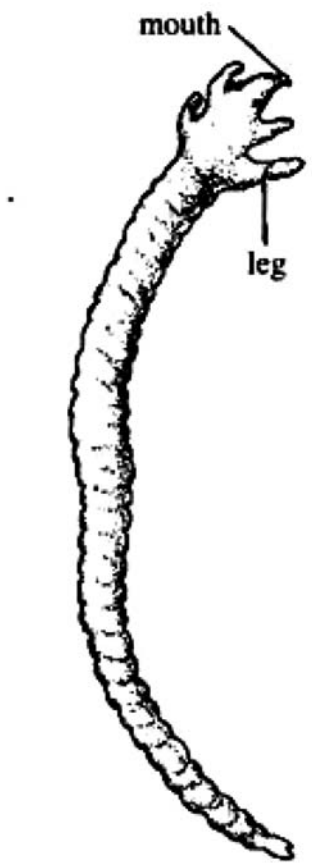


Fig. 8.13: *Cephalobacna* (from the lung of a snake)

Class 9. Tantulocarida–Approx. 5 known species

About twelve species have been identified under this class.

Characters:

1. Tantulocarids are minute ectoparasites on other deep water marine crustaceans.
2. The adult male remains permanently attached to the host by an oral disc.
3. Thorax six segmented bearing five pairs of biramous limbs and a posterior uniramous one.
4. Abdomen two to six segmented and limbless.

Examples:

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

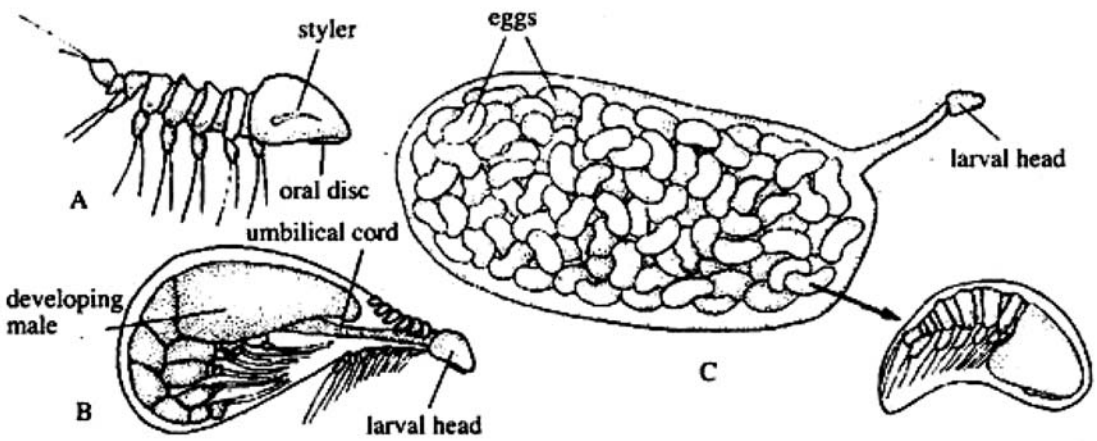


Fig. 8.14: Body form of tantulocarids : A. tantulus larvs, B. male developing within larval body and attached to the host via the larval head and 'umbilical cord', C. adult female filled with eggs, together with detail of larva developing within an egg.

Class 10. Cirripedia (L. cirrus = curled, pedis = foot). Approx. 1000 known species

Characters:

1. Cirripedes are either sessile or parasitic marine animals.
2. Adults are sedenteric.
3. Body is poorly segmented and abdomen almost absent, with only a pair of caudal style.

4. Both pairs of antennae reduced or absent.
5. Six pairs biramous filamentous appendages present.
6. Body enclosed within a bivalved carapace with calcareous plates on it.
7. Adults without eyes and antennae.
8. Gills are lacking and the excretory organs are maxillary glands.
9. Usually hermaphrodite.
10. Development comprises of the nauplius larva that passes through a second larva, the cypris.
11. Cirripedes are familiarly known as barnacles.

Examples:

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

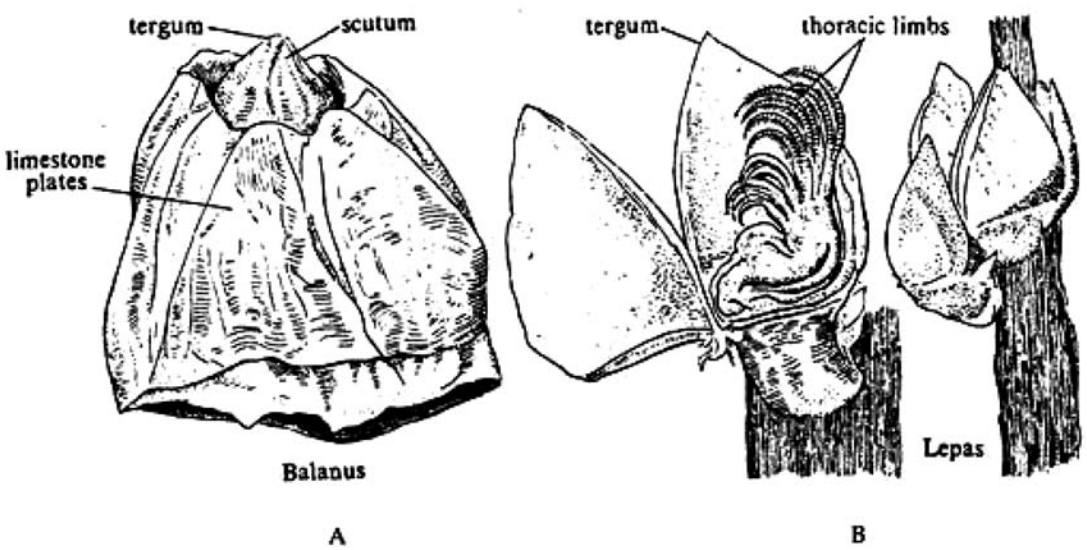


Fig. 8.15: A. *Balanus* and B. *Lepas*.

Remarks:

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

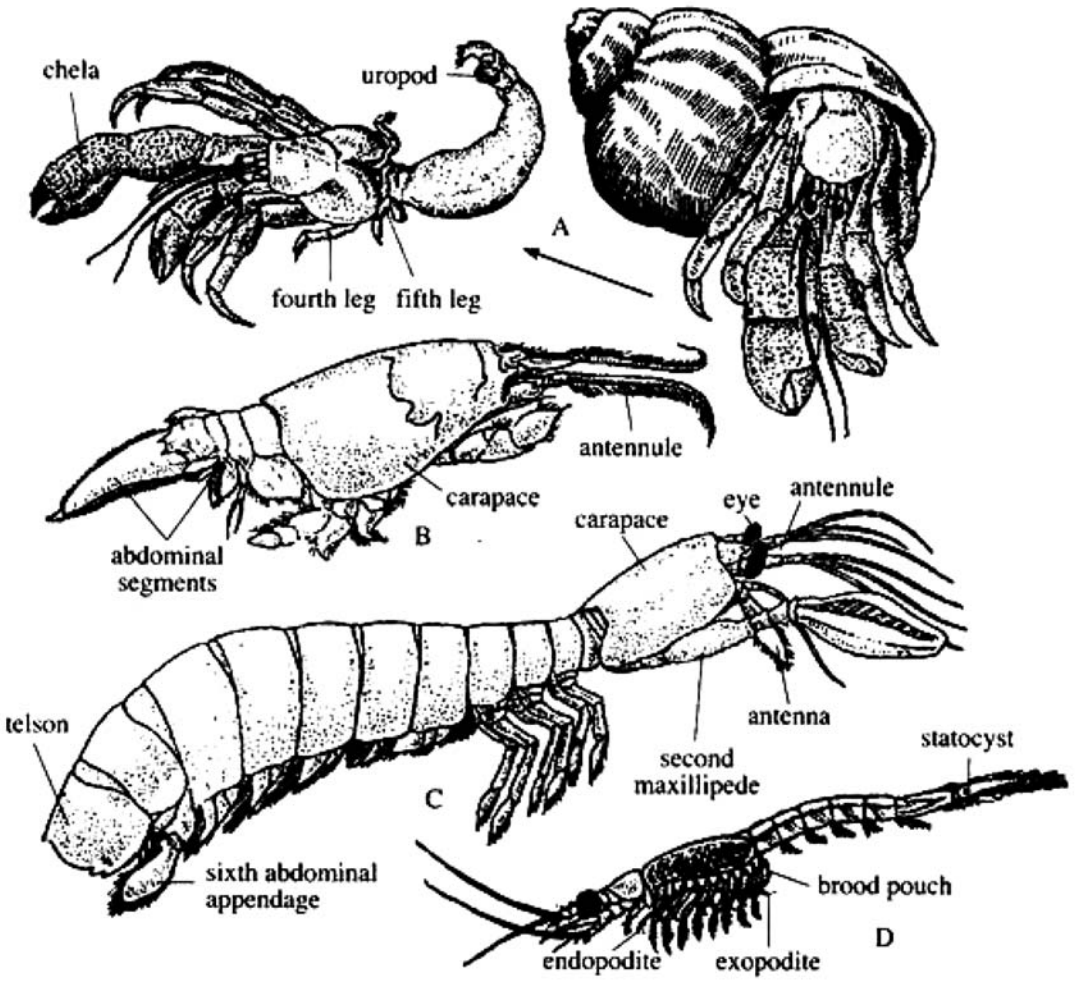


Fig. 8.16: A. *Eupagurus* (Arrow indicates the body of *Eupagurus* outside the molluscan shel), I, B. *Hippa*, C. *Spuilla*, D. *Mysis*.

Class 11. Malacostraca (Gk. malakos = soft + ostracon = a shell) Over 20,000 spcies.

Characters:

1. Body comprises of a head, an eight segmented thorax and a six segmented abdomen. All the fourteen segments bear appendages.
2. Thoracic and abdominal appendages distinct from one another.
3. The posterior thoracic limbs being walking legs (pereiopods), the first five pairs of abdominal ones forming swimming organs (pleopods).

4. Antennule with two-many-jointed flagella.
5. Carapace covers the head and at least some thoracic segments.
6. Mandible with a palp.
7. The foregut in most malacostracans is modified as a two-chambered stomach bearing triturating teeth and comb-like filtering setae.
8. Compound eyes present in most species.
9. Male and female gonopores on the bases of 6th and 8th thoracic appendages.

This is the largest class of crustacea, containing about 40,000 living species. The class displays a great diversity of body forms and include crabs, lobsters, crayfish, shrimp, krill, woodlice, amphipods, mantis shrimp and many other less familiar animals.

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

Examples:

Macrobrachium rosenberghii (giant fresh water prawn), *Penaeus monodon* (giant tiger prawn), *Squilla* (mantis shrimp), *Panulirus* (lobster), *Mysis, Eupagurus* (hermit crab), *Scylla serrata* (mud crab), *Carcinus maenas* (shore crab - one invasive species) *Cancer Euphausia* (Antarctic krill), *Hippa Oniscus, Nebalia, Paranebolia. Squilla, Gonodactylus, Lysiosquilla, Penaeus, Lucifer, Lithodes, Anaspides, Allanaspides, Bathynella, Tanais, Apseudes and Neotanais,* Penaeid shrimps (e.g., *Penaeus, Funchalia, Parapenaeus, Metapenaeopsis, Metapenaeus),* Sergestid shrimp (*Sergestes, Lucifer, Acetes*).

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

8.4.4. Subphylum Uniramia

(Latin: unus, one; ramus, branch)

Classification with Characters:

1. Body divided into head and trunk. The trunk either bear pairs of walking legs, or it may be differentiated into thorax and abdomen, with the abdominal appendages greatly reduced or missing.

2. Appendages strictly uniramous i.e. appendages have only one branch. Head appendages comprise of one pair each of antennae, mandibles and maxillae and in some groups a second pair of maxillae.
3. Mandibles un-jointed and without palp.
4. Presence of a single pair of antennae is an important character.
5. Gas exchange takes place with the help of tracheal system.
6. Excretory organs are Malpighian tubules.

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

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

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

The subphylum is divided into 5 classes:

These are:

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

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

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

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

Characters:

1. Body usually elongated and dorsoventrally flattened.
2. Head bears a pair of antennae, a pair of mandibles and two pairs of maxillae. The antennae are long filiform (long and thin).

3. Trunk comprising of 15 to more than 181 segments each bearing a single pair of uniramous walking legs, the last two segments being legless.
4. The paired appendages of the first trunk segment modified into prehensile (grasping) poison claws or pincers, known as forcipules.
5. The sense organ, 'Organs of Tomosvary' is present as a single pair at the base of the antennae.
6. Segment in front of telson is called genital segment.

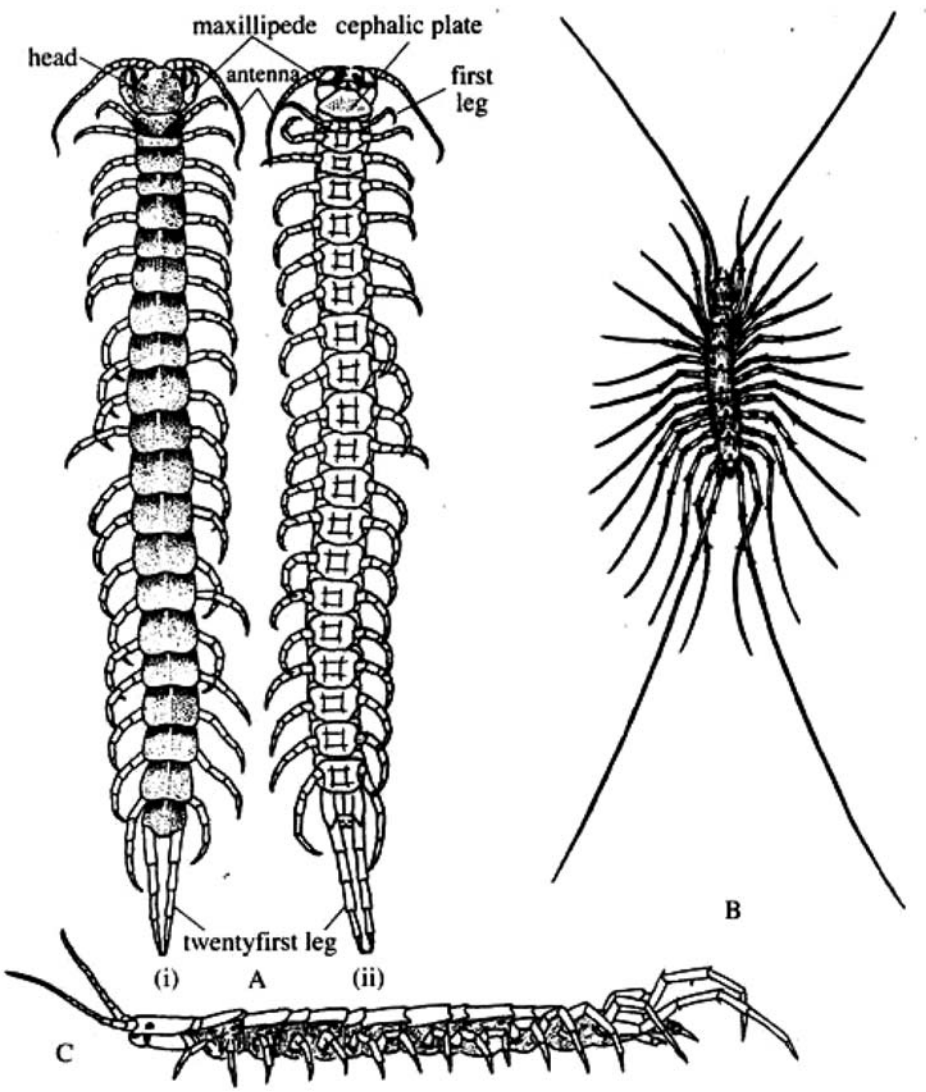


Fig. 8.17: A. External features of Scolopendra (i) Dorsal view, (ii) Ventral view, B. *Scutigera*, C. Lithobius.

7. The genital segment of both sexes usually carries a pair of small appendages (gonopods) which help in reproduction.
8. Respiration takes place by trachea.
9. Excretion by a pair of Malpighian tubules.
10. Sexes separate.
11. Members of this class are nocturnal, carnivorous (usually predatory and mostly venomous) and terrestrial, distributed throughout the world in both temperate and tropical regions, residing in soil and humus, beneath stones, bark and logs. Generally called centipedes or hundred-leggers.

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

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

Characters:

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

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

Examples: *Scolopendrilla, Scutigerella.*

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

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

Characters:

1. Elongated and segmented forms.
2. Trunk with a large number of leg- bearing segments.
3. First trunk segment (collum) is legless and next three segments with a single pair of legs in each segment and the rest double segments (diplosegments formed from the fusion of two originally separate somites) bear 2 pairs of legs in each.
4. Antennae club shaped and seven segmented.
5. Maxillae are united to form gnathochilarium. Second pair of maxillae is absent.
6. Eye simple; consist of several simple flat-lensed ocelli arranged in a group or patch (ocellaria) on each side of the head. Eyes may be totally absent (flat-backed millipedes). Many possess 'Organs of Tomosvary'.
7. Tracheae are mostly un-branched tubes.
8. Gonads unpaired but reproductive ducts are paired.
9. Gonopores are located at the anterior end of the trunk (third trunk segment).

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

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

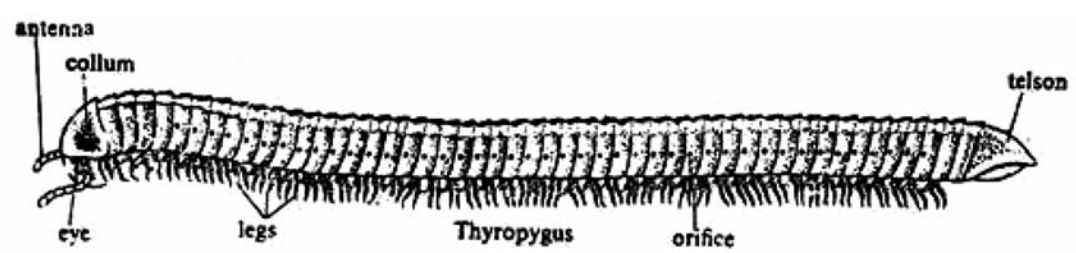


Fig. 8.18: *Julus*

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

Class 4. Pauropoda (Pauropods):

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

Characters:

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

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

They are widespread in both tropical and temperate regions.

Examples: *Pauropus*, *Decapauropus*

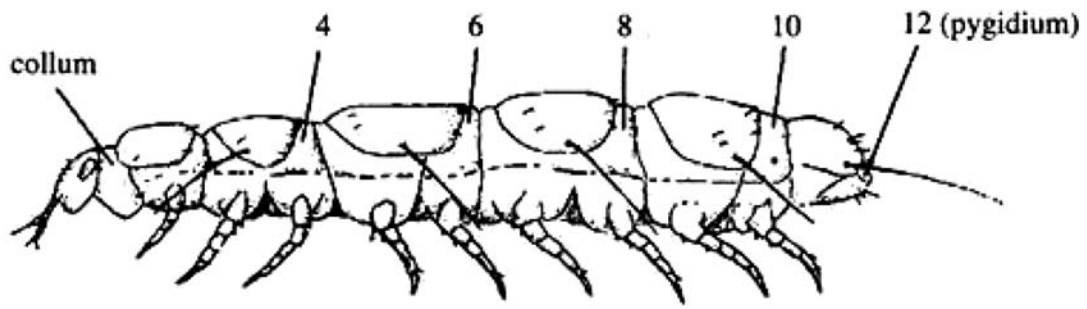


Fig. 8.19: *Pauropus*(lateral view).

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

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

Characters:

1. Body consists of three distinct tagmata (regions)—head, thorax and abdomen.
2. Head is formed by the fusion of six segments and its appendages are a single pair of antennae, a pair of mandibles and two pairs of maxillae. .
3. Each body segment has four basic regions. The dorsal surface is called the tergum (or notum), the two lateral regions are called the pleura (singular: pleuron) and the ventral aspect is called the sternum.
4. In adults, the thorax includes 3 segments—prothorax, mesothorax and metathorax and each segment bears one pair of walking legs.

   Hence, called Hexapoda for the three pairs of thoracic legs.
5. In winged insects, the mesothorax and metathorax bear a pair of wings in each segment.
6. A pair of compound eyes present.
7. Paired appendages absent in the adult abdomen.
8. Foregut is commonly subdivided into an anterior pharynx, an esophagus, a crop and a narrow proventriculus. The proventriculus is variable in structure and function, in different insects depending upon the nature of food taken.
9. Most insects possess a pair of salivary or labial glands.
10. Respiratory organs are in the form of tracheae which are extensively developed. (Insects breathe by taking in air through spiracles into tracheal tubes. These tubes branch into smaller networks of tubes called tracheoles that branch directly into the tissues of the insect for gas exchange. There is no active pumping of air, but any small movement in the insect body leads to airflow throughout the trachea.)
11. The chief excretory organs are Malpighian tubules which remain closely associated with alimentary canal.
12. Gonoducts open at the posterior end of the abdomen.
13. Development usually pass through complicated metamorphosis but in some cases it may be direct.

Examples:

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

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

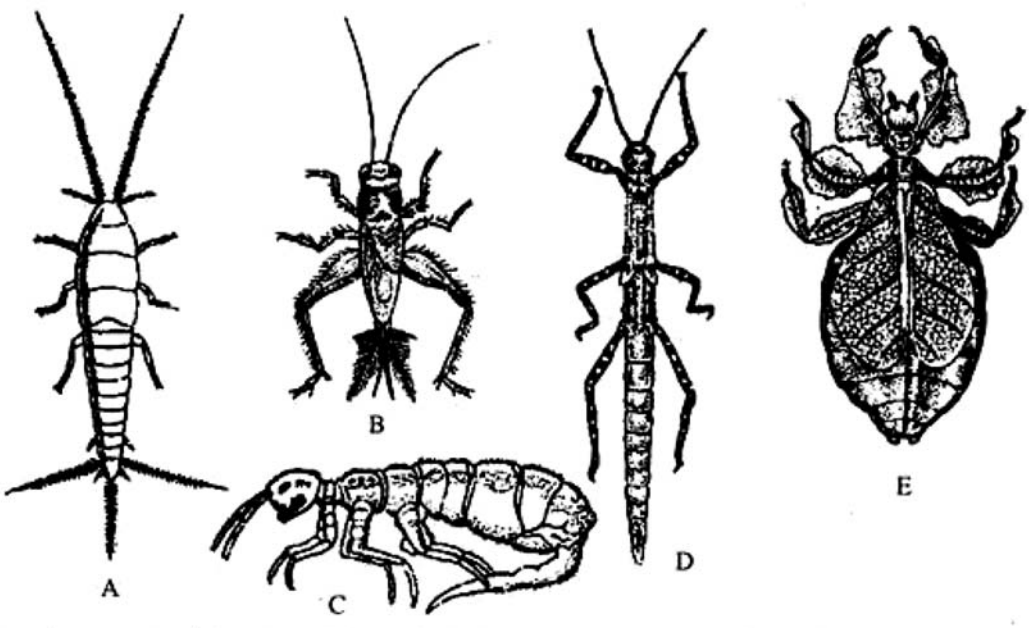


Fig. 8.20: A. Silver fish (*Lepisma*), B. House cricket (*Acheta*), C. Springtail (*Isotoma*), D. Stick insect (*Carausius*), and E. Leaf insect (*Phyllium*).

8.5 ❑ Questions

- Naik,

8.6 ❑ Suggested readings

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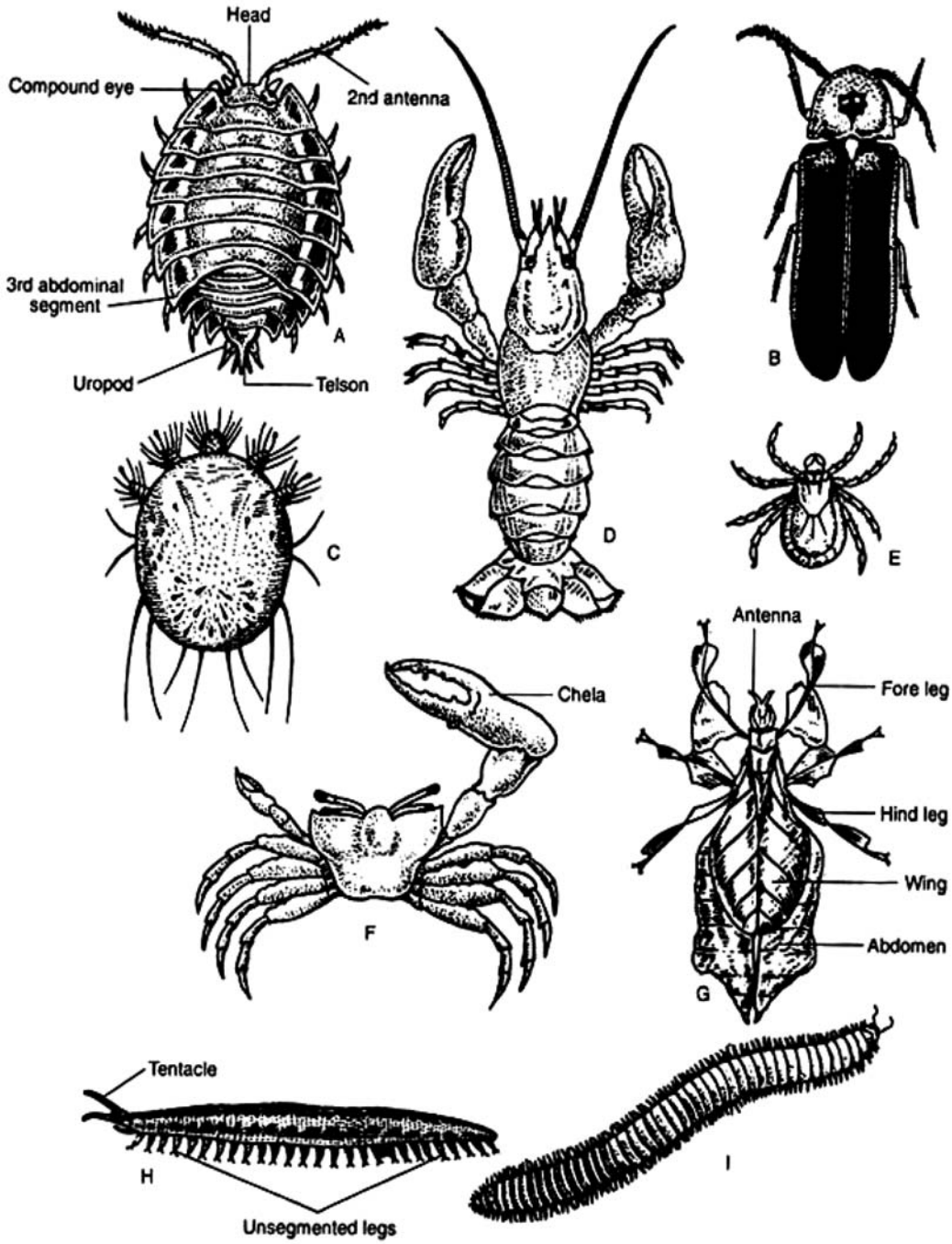

Fig. 8.21: Representative of Phylum Arthropoda (not drawn up to scale). A *Oniscus* (wood louse). B. (fire-fly). C. *Sarcoptes* (itch mite). D. *Astacus* (cray-fish). E. *Tick.* F. *Gelasimus* (fiddler-crab). G. (leaf-insect). H *Peripatus*. I. *Julus* (millipede).

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UNIT 9 ❑ Phylum Mollusca – General Characteristics and Classification up to classes

Structure

9.1 ❑ Objective

From this unit learners will learn the diversity, general characteristics and classification of phylum Mollusca up to classes.

9.2 ❑ Introduction

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

9.3 ❑ General Characteristics

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

2. Soft body (L.mollis = soft) covered by a thick muscular fold or sheet of skin, the mantle or *pallium* which forms a cavity, the mantle cavity. It encloses the visceral mass and secretes the shell. Presence of mantle is the unique feature of all molluscs.
3. Exoskeleton, in the form of calcareous shell, is present in most, in some forms shell absent and in some shell is internal.
4. Presence of ventral muscular foot which helps in locomotion and may be secondarily modified in some forms.
5. Cephalization well marked in class Gastropoda and class Cephalopoda but in other classes the head is small or poorly differentiated.

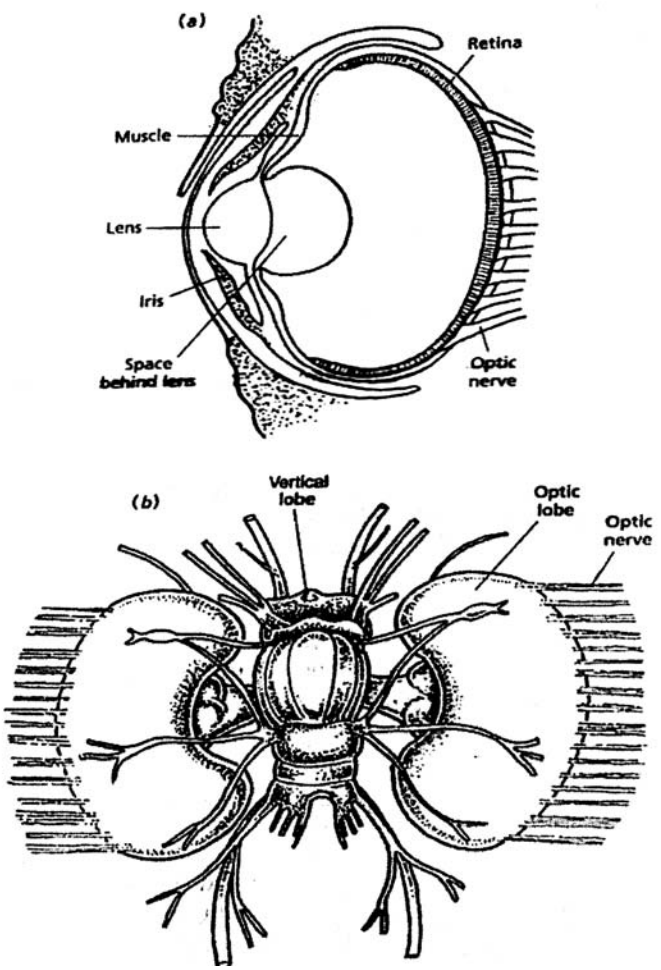

Fig. 9.1 : (a) The eye of a cephalopod; (b) the brain of an octopus in dorsal

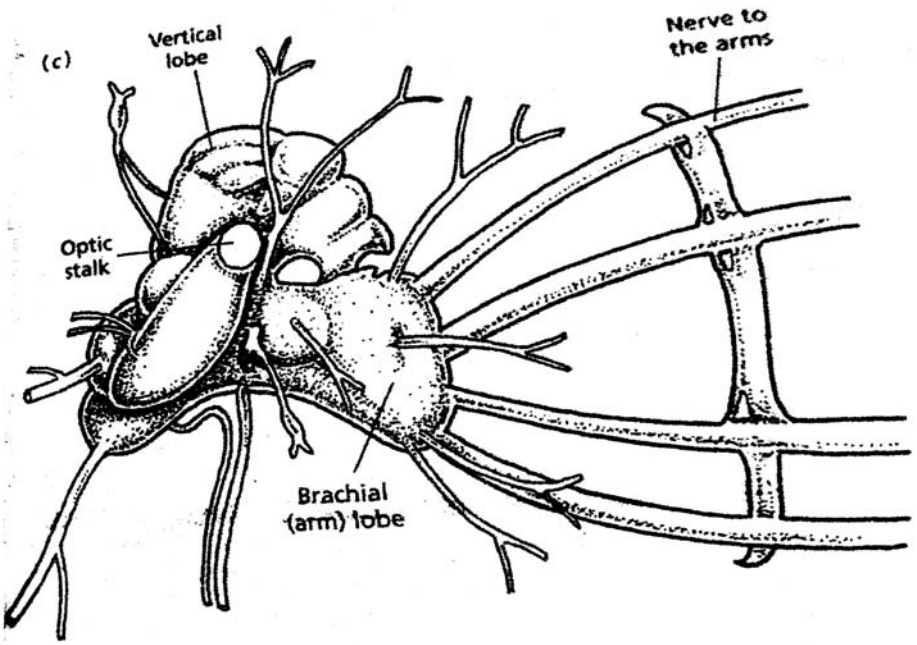

Figure (cont.) : (c) the brain of an octopus in lateral view.

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

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

9.4 ❑ Classification

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

Phylum Mollusca is divided into following *seven classes:*

(1) Class Aplacophora;

(2) Class Polyplacophora;

(3) Class Monoplacophora;

(4) Class Gastropoda;

(5) Class Bivalvia;

(6) Class Schaphopoda;

(7) Class Cephalopoda.

Classification with Characters (upto Classes) :

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

1. Primitive worm like marine molluscs with no shell.
2. Elongated bilaterally symmetrical body covered by cuticle.
3. Foot absent or reduced to a ventral ridge.
4. Mantle thick with calcareous spiculaes or scales.
5. Head is poorly developed, without eyes or sensory tentacles.
6. Digestive tube straight, radula may be present or not.

7. Gills are either absent or reduced to a pair and located in posterior mantle cavity.
8. Nervous system primitive with distinct brain and nerve cords.
9. No separate excretory organs, vascular system rudimentary.
10. Most aplacophorans are hermaphrodites. Development direct or through trocophroe larva.

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

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

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

They are called the armadillos of the sea.

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

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

1. Body bilaterally symmetrical and metamerically segmented but the segmentation is internal.
2. Dorsal side is covered by a single piece of shield-like shell (hence the name Monoplacophora).
3. Foot ventral with a flat creeping sole and with 8 pairs of pedal retractor muscles.
4. Mouth antero-median and anus postero-median.

5. Head is without eyes and tentacles.
6. Mantle covers the dorsal surface of body.
7. Radula well developed.
8. 5 to 6 pairs of gills (monopectinate ctenidia) are serially arranged in pallial groove on either side of the foot.
9. Six pairs of nephridia and two pairs of gonads.
10. Sexes separate, fertilization external.
11. Development indirect.

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

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

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

1. A muscular and broad foot is present below the digestive system and visceral mass.
2. Visceral mass is twisted at 180º in an anticlockwise direction **(torsion),** relative to the head and foot.
3. Shell single, spirally twisted. Shell reduced or absent in some.
4. Head well differentiated with one or two pairs of tentacles and eyes.
5. Mantle cavity contains a single pair of bipectinate ctenidia. In some ctenidia absent and mantle cavity functions as ***pulmonary sac*** or ***lung*****.**
6. Buccal cavity with an *odontophore* and a redula bearing rows of chitinous teeth.
7. Anus is usually situated anteriorly close to mouth.
8. A chemo-receptive sense organ, called *osphradium* is present in the mantle cavity.
9. Nervous system contains distinct paired cerebral buccal pleural, pedal, parietal and visceral ganglia.

10. On the upper surface of the foot in some forms there may be an operculum which closes the shell aperture.
11. Sexes separate (dioecious) in most forms while some are monoecious (hermaphroditic).
12. Development includes trochophore and veligar larval stages.

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

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

Class Bivalvia (Pelecypoda or Lamellibranchiata)

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

1. Bivalves are laterally compressed and possess a shell composed of two valves, hinged together dorsally, that completely enclose the body.
2. The foot, like the remainder of the body, is laterally compressed, usually hatchet or plough-share shaped, hence the name Pelecypoda, meaning

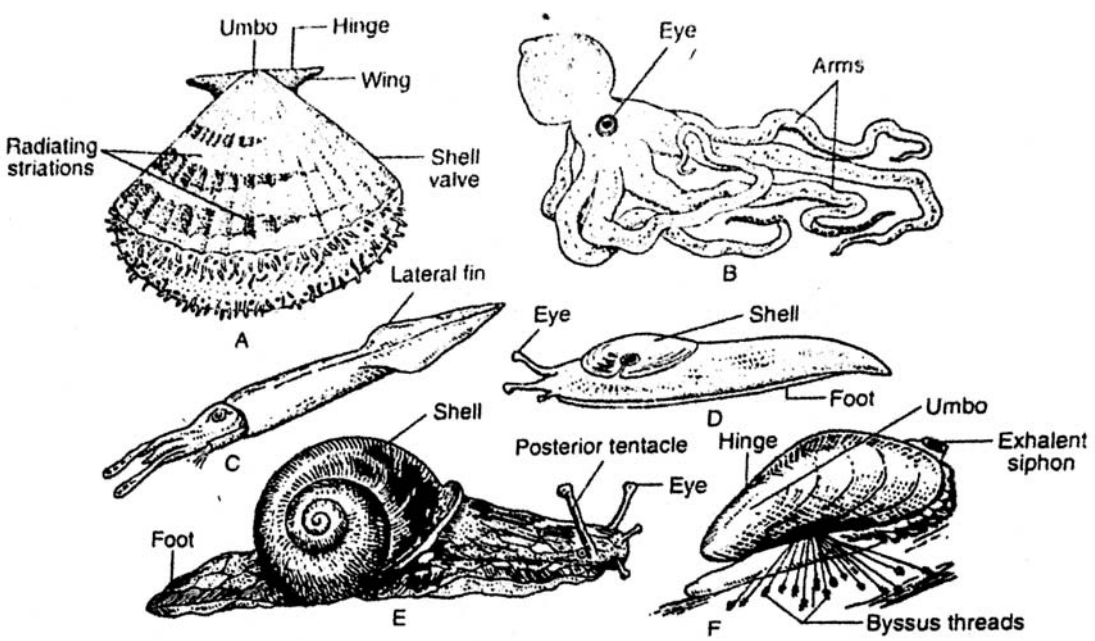

Fig. 9.2 : Some members of Phylum Mollusca (not drawn up to scale), A. Pecten (scallop), B. Octopus. C. Loligo (squid). D. Limax (slug). E. Helix (Roman snail). F. Mytilus (sea-mussel).

"hatchet foot". Foot is antero-ventral, commonly used for crawling or burrowing purposes.

3. There is no cephalization i.e. head, tentacles and eyes are absent.
4. Mouth is provided with two pairs of labial palps, most are ciliary feeders or filter feeders radula absent.
5. Mantle consists of paired leaf-like right and left lobes which secrete the shell. Posterior-edges of mantle often fused to form inhalent and exhalent siphons.
6. Gills or ctenidia are paired, well developmed and plate-like, hence the name lamellibranchiata. They are often specialized to assist in feeding (food collection).
7. Nervous system consists of four pairs of ganglia cerebral, pleural, pedal and visceral. Cerebral and pleural of each side usually fused into a cerebropleural ganglian.
8. Sense organs are statocyst and osphradium.
9. Mostly unisexual, some bisexual. Fertilization external.
10. Development indirect through *trochophore* and *veliger* larvae.

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

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

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

8. Gonad unpaired and kidneys paired.
9. Sexes separate, fertilization external.
10. Eggs planktonic, both trochophore and veliger larval stage in life cycle.

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

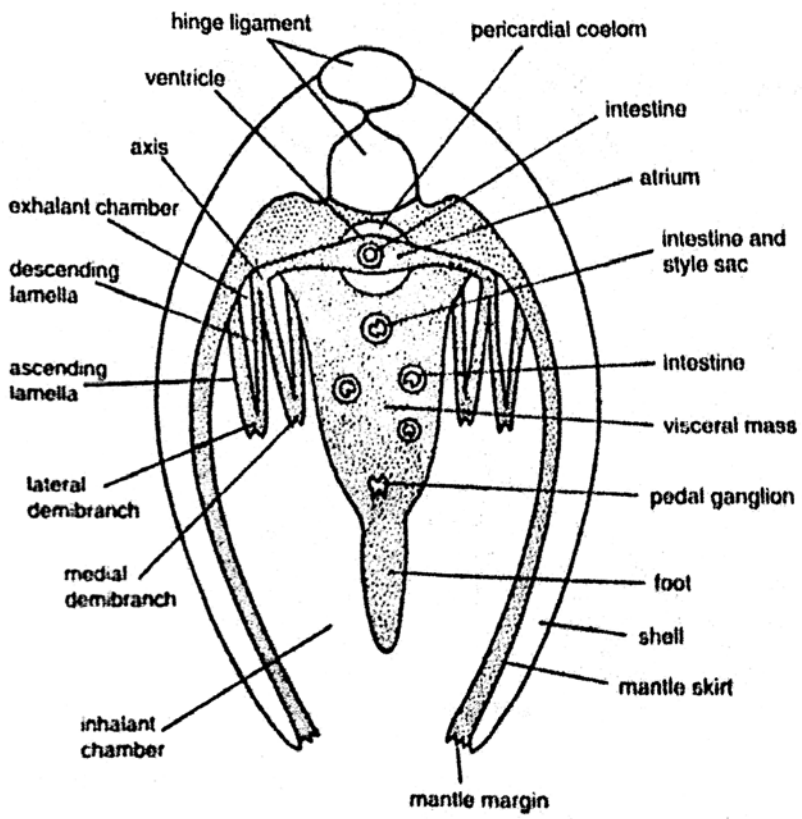

Fig. 9.3 : Bivalve mollusc. Cross section of a generalized Lamellibranch (after Ruppert, et al., 2004)

Examples : ***Dentalium***, ***Cadulus***, ***Antalis***.

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

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

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

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

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

9.5 ❑ Questions

- Naik,

9.6 ❑ Suggested readings

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UNIT 10 ❑ Phylum Echinodermata – General characteristics and Classification up to classes

Structure

10.1 ❑ Objective

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

10.2 ❑ Introduction

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

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

10.3 ❑ General Characteristics

1. The echinoderms are exclusively marine, free living non-colonial and mostly bottm-dwellers.
2. They are triploblastic, unsegmented, enterocoelous coelomate animals.
3. Adults exhibit radial symmetry, usually pentamerous i.e. the body can usually be divided into five parts arranged around a central axis, but their larvae are bilaterally symmetrical.
4. Adults generally do not have anterior and posterior ends. Instead body is distinguishable into oral (bearing the mouth) and aboral (not bearing the mouth) surfaces, without any differentatiated head.
5. Most echinoderms possess a well developed internal skeleton composed of calcareous ossicles. Commonly the skeleton bears projecting spines or tubercles that give the body surface a warty or spiny appearnace, hence the name echinoderm, meaning “spiny skin” (Gr. echinos = hedgehog; derma = skin).
6. The oral surface of the body is marked by five equidistant radiating grooves, called ambulacra, originating from the mouth, with intervening interabmulacra.
7. Coelom spacious, developed as outgrowths of the archenteron (enterocoelous type).
8. Digestive tract is mostly a coiled tube with the anus placed on the aboral surface.
9. A characteristic coelomic Water Vascular Sysem (WVS) or ambulactal system is present. It performs many functions such as feeding, locomation and respiration, etc.
10. Presence of tubular contractile tube feet or podia used as locomotory organ and or feeding organ.
11. The blood vascular system also called haemal or blood (lacunar system) is present. It is well developed in Echinoids and Holothuroids.
12. Nervous systems simple, consisting of a circum-oral ring and radial nerve along each ambulacrum.

13. No definite respiratory and excretory system in most cases. Respiration is done through body wall, podia, respiratory tree and papulae.
14. Specialized sense organs are poorly developed.
15. Sexes are usually separate (gonochoristic). Reproductive tracts are very simple. Fertilization is usually external in sea water.
16. Eggs are typically homolecithal, cleavage radial and indeterminate, development through bilaterally symmetrial larvae which undergo metamorphosis into radially symmetrial adults.

10.4 ❑ Classification of phylum Echinodermata upto classes

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

According to them phylum Echinodermata is divided into four subphyla–

Subphylum Homalozoa (Extinct)

Subphylum Crinozoa — Class Crinoidea

Subphylum Asterozoa — Class Asteriodea, Class Ophiuroidea and Class Concentricycloidea

Subphylum Echinozoa — Class Echinoidea and Class Holothuroidea

All members of Subphylum *Homalozoa* are extinct.

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

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

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

Classification with Characters :

Subphylum Homalozoa (Extinct) :

Paleozoic echinoderms lacking any evidence of radial symmetry.

Example : *Enoploura*

Subphylum Crinozoa :

1. Radially symmetrical echinoderms with a globoid or cup-shaped theca and 5-10 brachioles or arms.
2. Mostly attached, with oral surface directed upward.

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

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

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

This class includes both extinct and living forms

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

Sub-phylum Asterozoa :

1. Radially symmetrical, free moving (unattached) echinoderms.
2. Body composed of a flattened central disc and radially arranged arms.

3. Oral surface directed downward. On the oral surface in the ambulacral groove, tube feet are present.
4. Anus and madreporite aboral.

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

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

1. Body star shaped, arms not sharply set off from the central disc.
2. Ambulacral grooves are open and a large coelomic cavity is present in relatively wide arms.

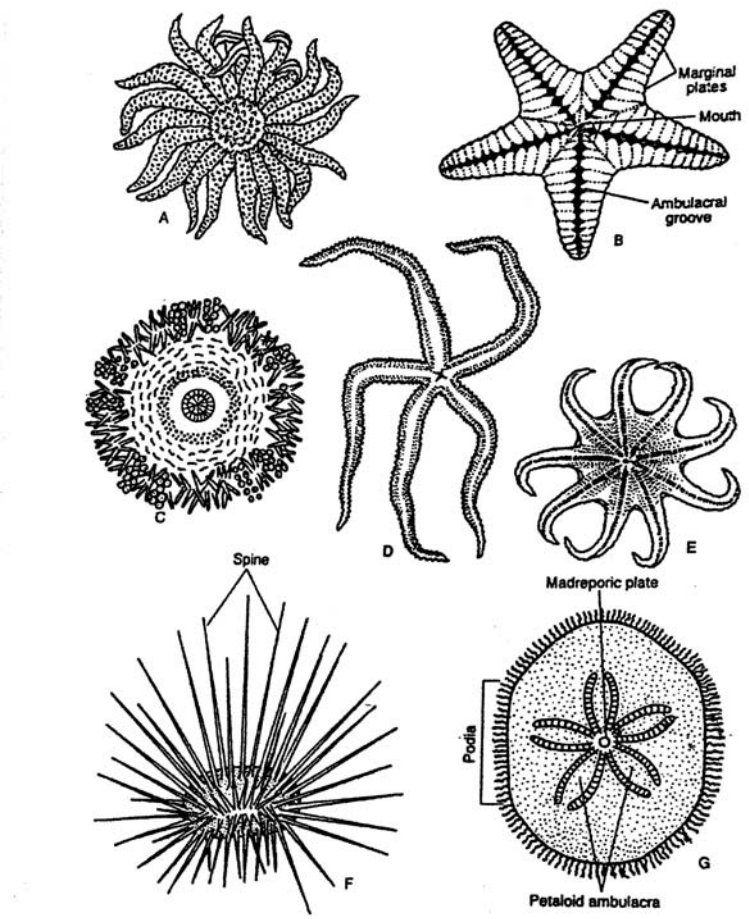

Fig. 10.1 : Some important echinoderms. A. *Heliaster.* B. *Ctenodiscus.* C. *Arbacia.* D. *Zoroaster.* E. *Solaster.* F. *Diadema.* G. *Clypeaster.*

3. Each ambulacral groove contains two to four rows of tube feet or podia. Tube feets with or without suckers.
4. Oral and aboral surfaces are distinct. Oral surface directed downward and aboral surface upward.
5. Madreporite and anus are present on the aboral surface.
6. Pedicellariae are present.
7. Larval forms are ***bipinnaria*** and/or ***brachiolaria.***

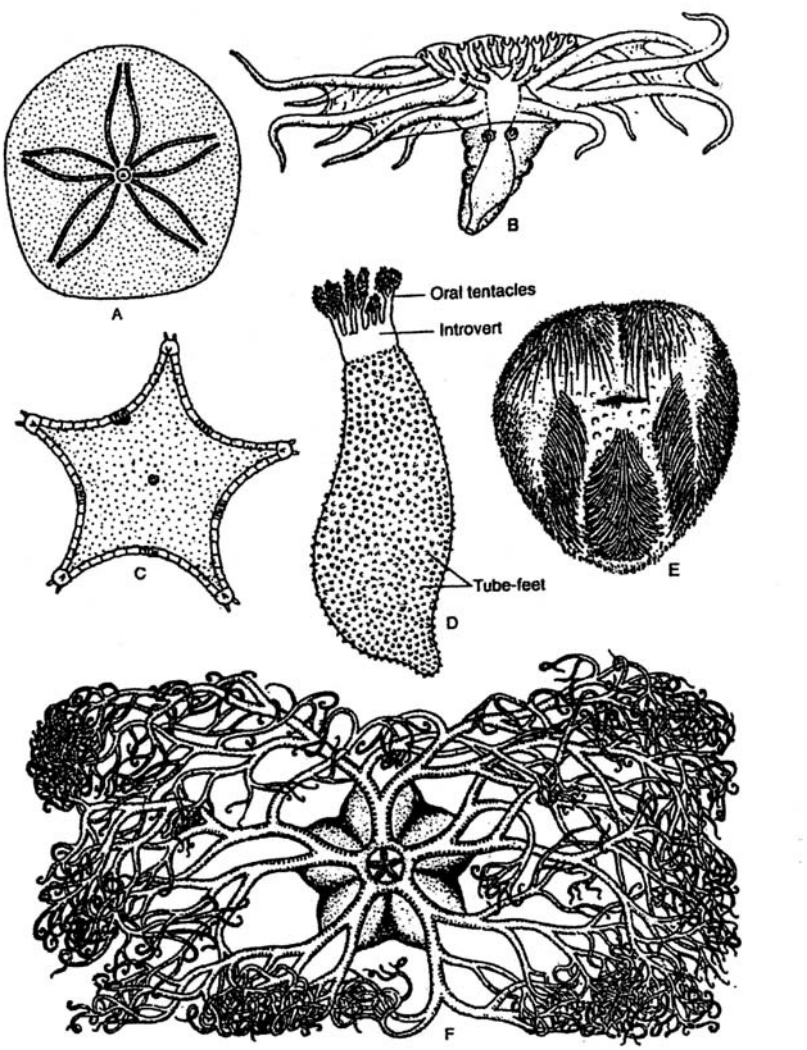

Fig. 10.2 : Some important Echinoderms (contd.). A *Laganum.* B. *Pelagothuria.* C. *Porcellanaster.* D. *Thyone.* E. *Echinocardium.* F. *Gorgonocephalus.*

The members of this class are generally called sea stars :

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

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

1. Body pentamerous and star-shaped.
2. Arms sharply set off from the central disc. Arms are elongated and flexible.
3. Ambulacral grooves absent, tube feet without suckers.
4. No spacious prolongations of the coelom into the arms. Arms largely filled with vertical ossicles.
5. Mouth and madreporite are situated on the oral surface of the body. Anus is lacking.
6. Pedicellariae absent.
7. Larva is ***Ophiopluteus*****.**

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

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

Class Concentricycloidea (L. concentric rings)

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

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

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

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

1. Radially symmetrical globoid or discoid echinoderms without arms or brachioles (small arm-like processes).
2. Mostly unattached.
3. Madreporite and anus remain on the aboral side.
4. Hydrocoel forms a ring around the mouth.

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

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

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

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

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

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

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

10.5❑ Questions

- Naik,

10.6❑ Suggested readings

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UNIT 11 ❑ Origin of Chordates and Vertebrates, Protochordates - General characteristics and Classification up to classes

Structure

11.1 ❑ Objective

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

- the salient features of chordates.
- different theories relating with the origin of chordates.
- different views about the origin of chordates.
- the Garstang's theory of origin of chordates.

- the general characteristics of Hemichordata, Urochordata and Cephalochordata.
- the larval forms in protochordates.
- an idea about tornaria and tadpole larva.
- the retrogressive metamorphosis in *Ascidia.*

11.2 ❑ Introduction

The phylum Chordata comprised of a varied group of diverse animals ranging from ascidian to man. This phylum is known to have three unique features such as for the presence of notochord, dorsal, tubular (hollow) nerve cord and pharyngeal gill slits. The fourth chordate characteristic is a postanal tail (a postanal tail extends posteriorly beyond the anal opening).

1. Dorsal hollow nerve cord

The central nervous system of the chordates is present dorsally in the body. It is in the form of a longitudinal, hollow or tubular nerve cord lying just above the notochord and extending lengthwise in the body. The nerve cord or neural tube is derived from the dorsal ectodermal neural plate of the embryo and encloses a cavity or canal called neurocoel. Nerve cord is present in chordates throughout embryonic and adult life.In vertebrates, the anterior region of nerve cord is specialized to form a cerebral vesicle or brain which is enclosed by a protective bony or cartilaginous cranium. The posterior part of nerve cord becomes the spinal cord and protected within the vertebral column. The tubular nerve cord and its associated structures are largely responsible for chordate success. This central nervous system is associated with the development of complex systems for sensory perception, integration, and motor responses.

2 Notochord or chorda dorsalis

The notochord (Gk. noton, the back L. chorda, cord), is an elongated, supportive rod-like flexible structure extending the length of the body. It is present immediately beneath the nerve cord and just above the digestive canal. It originates from the endodermal roof of the embryonic archenteron. Structurally, it is composed of large number of specialized fluid-filled vacuolated cells. This arrangement gives the notochord some turgidity, which prevents compression along the anteroposterior axis. At the same time, the notochord is flexible enough to allow lateral bending, as in the lateral undulations during swimming. In some chordates this structure persists throughout life. Protochordates have a typical

notochord. . In most adult vertebrates it is partially or completely replaced by a 'backbone' or vertebral column. It is made up of separate bony elements or vertebrae.

3 Pharyngeal gill slits.

In all the chordates, at some stage of their life history, a series of paired lateral gill clefts or gill slits perforate through the pharyngeal wall of the gut behind the mouth. These are variously termed as pharyngeal, branchial and visceral clefts or pouches. They serve primarily for the passage of water from the pharynx to outside, thus bathing the gills for respiration. The water current secondarily aids in filter feeding by retaining food particles in the pharynx. In protochordates (e.g. *Branchiostoma*) and lower aquatic vertebrates, the gill slits are functional throughout life. But, in higher vertebrates, they disappear or become modified in the adult with the acquisition of pulmonary respiration.

The above three common features appear during early embryonic life of all the chordates. But all the three features rarely persist in the adult (e.g. *Branchiostoma)*. Often they are modified or even lost in the adult stages of higher chordates. The notochord disappears during development in most vertebrates, while the nerve cord and the pharyngeal clefts or their derivatives remain in the adult. The three common chordate characters were probably characteristic of the ancestral chordates. They distinguish chordates from all other animals and appear to reveal their common ancestry.

It was and is still a genuine paradox to the systematic position as to what evolutionary changes in the general organization of animal body led to the emergence of chordates. Since later part of the nineteenth century various conflicting views have been proposed to explain the origin of chordates. The views tracing the origin of chordates from a number of invertebrate phyla have been discarded and the echinoderm theory having an utmost relevance with and holding key to chordate ancestry.

11.3 ❑ Echinoderm theory of origin of chordates

Among the major phyla of non-chordates, the echinoderms are the most striking evidence of chordate ancestry. Larval forms usually represent past ancestral forms. Larval evidence strongly suggests that the protochordates evolved as small, bilaterally symmetrical animals possessing many of the features of larval echinoderms, or the hemichordates but lacking specializations of either the fully formed chordates (or vertebrates) or the echinoderms. With the assumption of redial symmetry and sessile mode, these form give rise to echinoderms, but some of them retained the original bilateral symmetry and by developing gill slits, better musculature and notochord give rise to the chordates. Evidence

based biochemical analysis provides strong relationship between the echinoderms and the chordates. The similarity of blood serum, muscle chemistry and the presence of phosphocreatinine and phosphoarginin as suppliers of energy to muscles in both echinoderms and chordates claimed much closer relationship between the two groups. These two components are not present together in other invertebrate phyla.

11.4 ❑ Views of different scientists on the origin and ancestry of chordates

Based on the research supports, the view of the Echinoderm theory of origin of chordates is more pertinent. The following are the views of the scientists:

1) The theory given by **Johannes Muller (1860)** is based on the comparative studies of larval stages of echinoderms and hemichordates. Tornaria larva of hemichordates resembles echinoderm larvae of bipinnaria, auricularia, dipleurula and doliolaria, which all possess ciliary/ bands and apical tuft of cilia may insight a clue about the origin of chordate.

2) **Garstang's neotenous larva theory (1894)** proposed that the ancestry of chordates and of the vertebrates is to be traced during the larval stages of the invertebrates rather than in their adults. He advocated that "if the ciliated bands of the auricularia larva of the sea-cucumber were to become accentuated and rise up as ridges leaving a groove between them, and if these ridges were to fuse, converting a groove into a tube, a structure would be produced which has all the relations of a nervous system". Garstang's theory further asserts that if the larval forms of such animals persisted and become sexually mature, they would provide exactly the necessary material for the evolution of the chordates.

3) Some authors advocated that the similarity between the larval forms was the result due to similar ecological factors. **H. B. Fell (1965)** concludes that the similarity of the free swimming larvae of some echinoderms and *Balanoglossus* provides no concrete evidence of common ancestry. Gregory (1951) states that *Balanoglossus* may not be a chordate at all and that its bag like ciliated swimming larva is merely a parallel adaptation for securing suitable location for their sessile adults.

4) **N. J. Berrill (1955)** suggests the following larval sequence for the ancestry of chordates: Echinoderm → auricularia → hemichordate-tornaria → protochordate ascidian tadpole → permanently free swimming chordate. This view agrees

with Garstang's theory but not in the manner in which Garstang assumes the changes to have taken place. However, Berrill's view places the ascidians is the main line of the origin of chordates, at least as larva.

5) **Hyman (1959)** and others also believe that the pterobranchs (Hemichordate) may be similar to the common ancestor of both the echinoderms and the hemichordates.

6) British Musium palaeontologist **Richard Jefferies (1975)** opined that the origin of chordates is to be found among the carpoid fossils (subphylum-Homalozoa; phylum- Echinodermata) which have an echinoderm like skeleton of calcite known as "Calcichordate theory". In his theory, Jefferies argued that two of the carpoid orders, the "Cornutai" and "Mitrata" should be placed in a separate subphylum "Calcichordata" which had echinoderm affinities are actually more closely related to the early chordates. Jefferies states that a cephalodiscus like hemichordate gave rise to two lines of evolution, one by losing the gill slits and elaborating the tentacles towards the echinoderms and the other by losing the tentacles and elaborating the left gill slits toward the early chordates whose earliest representatives was the carpoid comuta.

7) **Barrington (1979)** states the "The view that larval biology contains the key to chordate ancestry is highly speculative, although it does not lack biological plausibility. It is not the only way of looking at the problem".

8) **Young (1981)** states that the Bateson (1886)-Garstang (1894) theory of the origin of chordates is correct. The chordates are related to the sessile lophophore feeders which in course of time acquired the pharyngeal gill slits and their larva to have muscles, a notochord and a nerve tube. Then by paedomorphosis the sessile stage disappeared and the chordates began the course of evolution.

9) **Pough, Heiser and McFarland (1990)** commented about the phylogenetic affinities of chordates and invertebrates remain uncertain. Although the weight of evidence favours deuterostomes as the group from which chordates arose, no living adult or larval deuterostomes can yet be identified as their closest living relatives. Although genomic approaches to chordate phylogenies suggested to the traditional euchordata view: vertebrates and cephalochordates as sister groups to the exclusion of basal tunicates and placed vertebrates and tunicates as sister groups. This theory has received support from alfactores hypothesis (Dunn et al, 2008) In the foregoing views of different scientists it may say that

Bateson (1886)-Garstang (1894) theory of the origin of chordates is correct (Young, 1981). Romer (1965, 1970) pointed out that the chordates have arisen from some sort of echinoderm like ancestors. His ancestral prototype is a sessile filter-feeder which acquired pharyngeal gill-slits and their larval forms possessed muscles, notochord and nerve tube. Then by paedomorphosis the sessile stage disappeared and the free chordates started their evolution. However, in-spite of this generally agreed proposition, an element of uncertainty still remains due to lack of adequate concrete evidences. Furthermore, Garstang's dipleurula theory were more accepted.

Additional reading on Origin and Ancestry of Chordates:

Chordates evolved sometime during Cambrian period, 500 million years ago during Cambrian explosion, almost at the same time when invertebrates were beginning to evolve. They may have evolved from some freshwater forms as Chamberlain (1900) pointed out that all modern chordates possess glomerular kidneys that are designed to remove excess water from body. However, early fossils of chordates have all been recovered from marine sediments and even modern protochordates are all marine forms. Also glomerular kidneys are also found in some marine forms such as myxinoids and sharks. That makes the marine origin of chordates more plausible.

Chordates evolved from some deuterostome ancestor (echinoderms, hemichordates, pogonophorans etc.) as they have similarities in embryonic development, type of coelom and larval stages. Fossils of the earliest vertebrates are known from the Silurian-Devonian period, about 400 million years ago.

The following theories have been put forwarded to explain the origin of chordates:

1. Echinoderm Origin. The theory was given by Johannes Muller (1860) and is based on the comparative studies of larval stages of echinoderms and hemichordates. Tornaria larva of hemichordates resembles echinoderm larvae such as Bipinnaria, Auricularia, Dipleurula and Doliolaria, which all possess ciliary bands and apical tuft of cilia. Johannes Muller, W. Garstang and DeBeers proposed that echinoderm larvae gave rise to chordates by neoteny. Also like chordates, echinoderms are also deuterostomes and possess mesodermal skeletal elements.

The discovery of fossil echinoderms called Calcichordata from Ordovician period (450 milion years) further confirms echinoderm ancestry of chordates. Calcichordates were asymmetrical animals which demonstrate affinities with both echinoderms and chordates but their skeleton is made of $CaCO_3$ whereas in vertebrates the bones are made of hydrated

calcium and phosphate. They had large pharynx with a series of gill slits, each covered with flaps for filter feeding, a small segmented body and a postanal tail. A perforated pharynx for filter feeding appears to have evolved in diverse groups of animals during Cambrian-Orodovician periods when planktons were abundant in water.

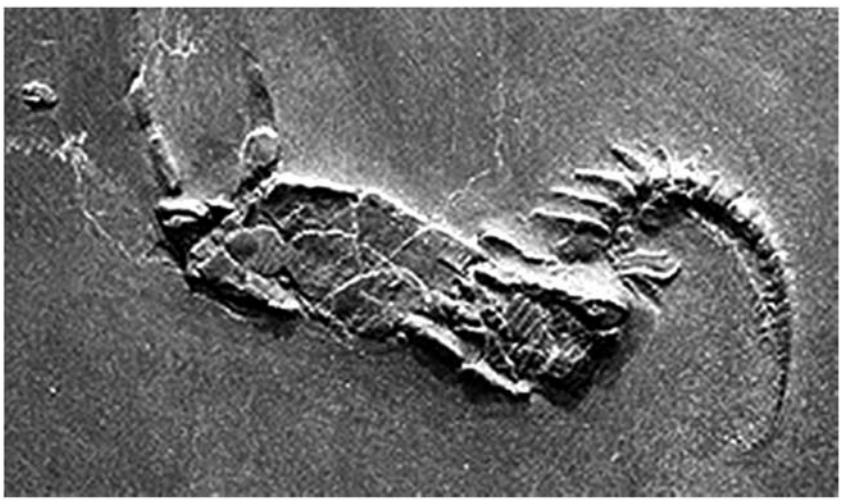
2. Hemichordate Origin. Romer (1959) suggested that ancestral deuterostomes were sedentary tentacle feeders whose mucous-laden ciliated tentacles served to trap planktons as they were waved in water as do the modern lophophorates and pterobranch hemichordates, *Cephalodiscus* and *Rhabdopleura.* By some mutation pharyngeal gill slits evolved in these ancestors, which made the pharynx sieve-like to trap planktons as the water current passed through it. Extant pterobranchs possess both ciliated arms and pharyngeal gill slits. Tornaria larva of hemichordates shows phylogenetic relationship with echinoderm larvae and hemichordates also show affinities with chordates.

3. Urochordate Origin. W. Garstang (1928) and N.J. Berrill (1955) gave importance to the tadpole-like larva of urochordates which carries typical chordate characters, namely, a notochord in tail along with segmented myotomes, dorsal hollow nerve cord, sense organs and pharyngeal gill slits. Garstang (1928) suggested that chordates evolved from some sessile filter feeding urochordate by the larval stage evolving into adult by neoteny and by losing the sedentary adult stage.

4. Cephalochordate Origin. Chamberlain (1900) studied the primitive and advanced characters of cephalochordates and proposed that while extant cephalochordates possess all chordate characters in typical state, they also show some primitive features of non-chordates, such as, absence of heart, head, sense organs, respiratory pigment, filter-feeding mode of food capture and excretion by solenocytes. Fossils of 60 specimens from mid-Cambrian of the earliest chordate, *Pikaia gracilens* have been discovered from Burgess Shale in British Columbia, Canada. (*Pikaia gracilens* was a primitive cephalochordates and considered as oldest known fossil chordate dated to approximately 505 million years ago).The Amphioxus-like fossils show streamlined, ribbon-shaped, 5 cm long body having notochord in the posterior two-third of body and myomeres. It has a small head with two tentacles and gill slits in the neck region. Other chordate-like fossils are: *Cathaymyrus* from early Cambrian sediments in China and *Palaeobranchiostomata* from early Permian from South Africa that appears to be more similar to Amphioxus.

5. Combined theory. E.J.W. Barrington (1965) combined all the above theories and proposed that the common ancestor of echinoderms and chordates was a sessile ciliary arm feeder that lived in the plankton-rich environment of the Cambrian. Modern Crinoidea

(Echinodermata), Pogonophora and Pterobranch hemichordates evolved from a similar ancestor by retaining the original mode of feeding, perhaps because they continued to inhabit the same environment as occurred in ancestral days. However, pharyngotremy (perforation of pharynx with gill slits) must have evolved in a large number of groups at that time, which must have been much more superior method of food gathering by filtering water through pharynx as compared to ciliated arm feeding. Hence, the sedentary Protoascidians of that time lost ciliated arm feeding and adopted pharyngeal filter feeding as the only method of food gathering. Sometime later, when the plankton population in water declined, free-swimming tailed larva of these urochordates did not metamorphose and became a neotenic adult, since free-swimming mode was superior in food searching at a time of food scarcity. Cephalochordate-like ancestors evolved by perfection and expansion of chordate characters that were already present in the ascidian tadpole larva. We already have fossils of such primitive chordates, e.g. *Pikaia gracilens* from mid-Cambrian. *Pikaia gracilens* was a primitive cephalochordates and considered as oldest known fossil chordate dated to approximately 505 million years ago.



Oldest known fossil chordate

Origin of Chordates - Origin of chordates certainly lies somewhere amongst the invertebrates but the question is from which group of invertebrates? Many theories have been put forwarded and a brief discussion may be done on a few of the more notable ones as well as at the most recent theory supported by K. Kardong.

Derivation from echinoderms and hemichordates (acorn worms) There are several theories that are based on similarities seen in echinoderms (starfish, sea cucumbers and sea urchins), hemichordates (acorn worms), urochordates, (tunicates or sea squirts)

and cephalochordates (amphioxus). The strongest support for all of these theories is that all are deuterostomes.

Garstang's Theory

At the end of the last century, Garstang put forward the idea that chordates evolved from echinoderms through the hemichordates (acorn worms) and urochordates (tunicates) to cephalochordates and vertebrates. While the adults of these various phyla are extremely different and share few if any structural similarities, an evolutionary progression can be seen in their larvae. His theory was that selection acted on the larval stages to produce new forms. In the case of the hemichordates and urochordates, the "new' larvae ultimately gave rise to sessile adults that were very different. Ultimately, however, through paedomorphosis (or the retention of larval traits into sexual maturity) they gave rise to the cephalochordates and vertebrates.

Dipleuruloid Theory

This theory, put forward by Malcolm Jollie, is similar to that put forward by Garstang with the primary distinction that rather than maintaining that each group arose successively from the next, it maintains that each arose from a common ancestor - a small ciliated, bilateral organism now extinct. He proposed that this ancestor gave rise to the echinoderms, hemichordates and a prechordate that was a predator with a differentiated head, a pharynx with gill slits, and a large mouth. The urochordates and cephalochordates evolved such that their active larval form gave rise to a sessile filter feeding life style while the vertebrates evolved towards an even more active lifestyle.

Derivation from cephalochordates Gutmann's Theory

In opposition to this, Gutmann proposed that the ancestral form of the chordates were the cephalochordates (amphioxus like) and that the tunicates, hemichordates and echinoderms are advanced forms all derived from this ancestor to fill specific niches. He proposed that the vertebrates also arose from the cephalochordates along another distinctive line.

Derivation from a protochordate ancestor Current (Kardong's) Theory

The most current theories now not only employ anatomical and embryological data but also employ new molecular data obtained from DNA analysis. This data would suggest that the ancestor of the vertebrates first gave rise to two groups. One group ultimately

gave rise to both the echinoderms and hemichordates while the other group gave rise to the urochordates, cephalochordates and vertebrates. Except for details, this theory does not differ significantly from the Dipleuruloid theory put forward by Jollie. Remember, however, that even these theories remain controversial.

While a great deal is known about modern chordates, including the lower forms, their origin remains obscure. Scientists have not succeeded in determining which lower forms have given rise to them. Their early ancestors most likely were soft-bodied and left no definite fossil remains. They must have originated prior to Cambrian period as the oldest fossils of known vertebrates have been discovered in late Cambrian strata. Most scientists consider that the chordates have originated from invertebrates. Several theories attempt to explain the origin of chordates from non-chordate groups, but they have serious drawbacks and are far from being satisfactory. One theory advocates the descent of Chordates from the Echinodermata as such. The remarkable similarities between the echinoderm (bipinnaria) and hemichordate (tornaria) larvae is taken as good evidence for common ancestry. Garstang suggested that probably free-swimming auricularian larvae of some ancestral echinoderms evolved into chordates through paedogenesis, i.e., prolongation of larval life without undergoing metamorphosis and reproducing sexually. Most zoologists (Romer, Berril, Barrington, etc.) now favour the deuterostome line of chordate evolution, according to which the phyla Echinodermata, Hemichordata and Chordata show common ancestry on embryological and biochemical evidences. The protochordates provide the connecting link between early chordate ancestors and verebrates. The differentiation probably occurred much earlier than Cambrian period. The earliest traces of vertebrates have been found in the rocks of late Cambrian and Ordovician. A number of fishes followed in Silurian and became abundant in the Devonian. The subsequent periods show the evolution of amphibians, reptiles, birds and mammals.

Echinoderm-Hemichordate Theory on origin of chordates: This theory infers origin of chordates, hemichordates and echinoderms from a common ancestor. This theory is based on the following evidences:

a) **Embryological evidence:** Both echinoderms and chordates have enterocoelic coelome, mesoderm and deuterostomous mouth. There is resemblance between the bipinnaria larva of certain echinoderms and the tornaria larva of hemichordates. In echinoderms chordates the central nervous system develops from a dorsal strip of ectoderm.

b) **Serological evidence:** A close similarity exists between the proteins of the body-fluid of chordates and echinoderms. Hence the chordates are more related

to echinoderms.The radial symmetry of adult echinoderms will disprove their relationship with the bilaterally symmetrical chordates but in echinoderms radial symmetry is secondarily developed from a basically bilateral symmetry larva. Both the primitive and the early echinoderm larvae show bilateral symmetry.

The generalised chordate ancestry is as follows: This was suggested by N.J.Berrill, (1953) in his book "The origin of Vertebrates". Echinodermata-Auricularia larva-Hemichordata— Tornaria larva-Protochordata-Ascidian tadpole larva-Free swimming Chordate. Hyman (1959) and others concluded that all the three groups have a common ancestor, Echinoderms and hemichordates branched off from a common evolutionary line which ended in the chordate group.

11.5 ❑ General characteristics of Protochordates (Hemichordata, Urochordata and Cephalochordata)

The Protochordates

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

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

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

11.5.1 Hemichordata (Gk., hemi, half; chorde, cord)

The phylum Hemichordata represents a group of lowest invertebrate chordate having profound phylogenetic significance. This phylum consists of marine worms that share some, but not all of the characteristics of chordates. These animals have pharyngeal gill slits and

a dorsal nerve cord, which is usually solid. The three body parts are proboscis, collar and trunk. What was once thought to be a notochord is no longer considered homologous. This group forms a sort of structural bridge between the nonchordates and chordates. They are particularly significant because they share some characteristics of both the echinoderms and the chordates. Therefore, they are sometimes thought of as an offshoot from an early common ancestor. Along the wall of their pharynx is a series of gill slits, one of the key characteristics that identify the chordates. In addition, they have a ciliated larval stage that is very similar to that of some echinoderms.

General Characteristics:

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

14) Fertilisation external. Development mostly indirect through a free swimming tornaria larva. Direct development is also found in some forms.

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

Classification of Hemichordata

The Phylum Hemichordata includes two classes:

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

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

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

Characters:

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

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

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

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

Characters:

1. Sedentary, solitary or colonial, tubicolous marine animals (Living inside secreted chitinous tubes).

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

Examples: *Rhabdopleura*. *Cephalodiscus*, *Atubaria*.

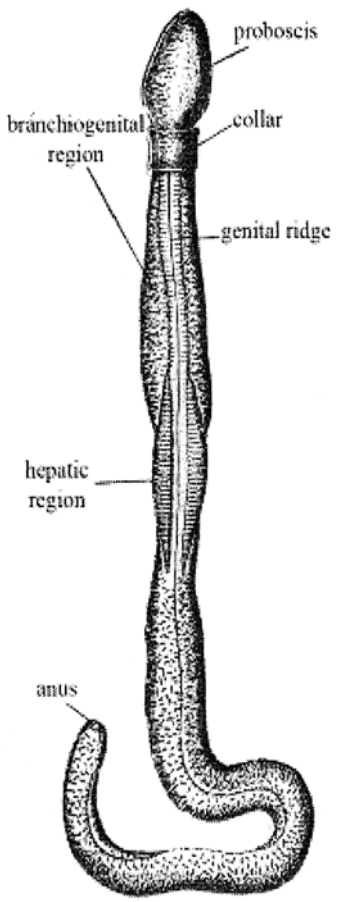


Fig. 11.1 : External Structures of *Balanoglossus*

Additional information on Hemichordates:

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

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

The members of the phylum Urochordata exhibit a high degree of diversity in form,

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

General characteristics:

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

The heart is unusual because it periodically reverses the direction in which it pumps blood. Blood contains cells but not erythrocytes.

12) Excretion is performed by nephrocytes, neural gland and pyloric glands.
13) In adult the nervous system is represented by single dorsal ganglion.
14) Mostly bisexual (hermaphrodite). Fertilization is external. Asexual reproduction by budding.

15) Development indirect, through tadpole larva. Metamorphosis is retrogressive.

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

Classification of Urochordata

The subphylum is divided into three classes namely:

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

Characteristics of Class Ascidiacea

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

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

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

The class Ascidiacea contains about 2000 species

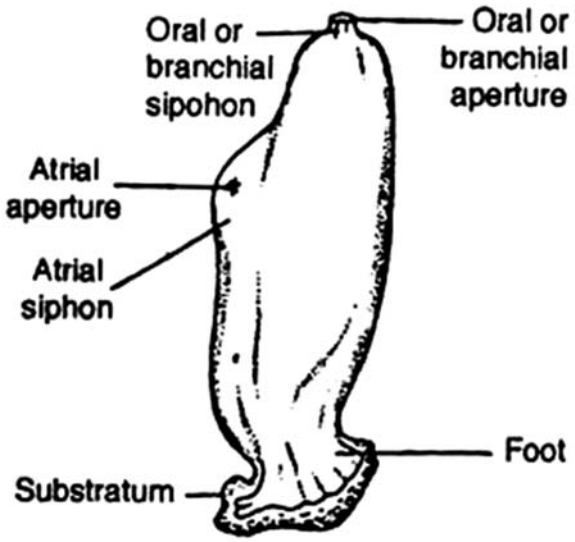


Fig. 11.2 : External organisation of adult *Ascidia*

Fig. 11.3: Ascidis andamanensis

Examples: *Ascidia, Ciona , Herdmania* .

Characteristics of Class Thaliacea

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

The class Thaliacea contains about 70 species.

Examples: *Salpa , Doliolum,*

Characteristics of Class Larvacea (Apendicularia)

The Larvaceans, sometimes called the Apendicularians, are small animals quite different in form to the rest of the urochordates and have the following characteristics:

1) These are tiny marine planktonic (mass of floating organisms) uro-chordates, found worldwide.

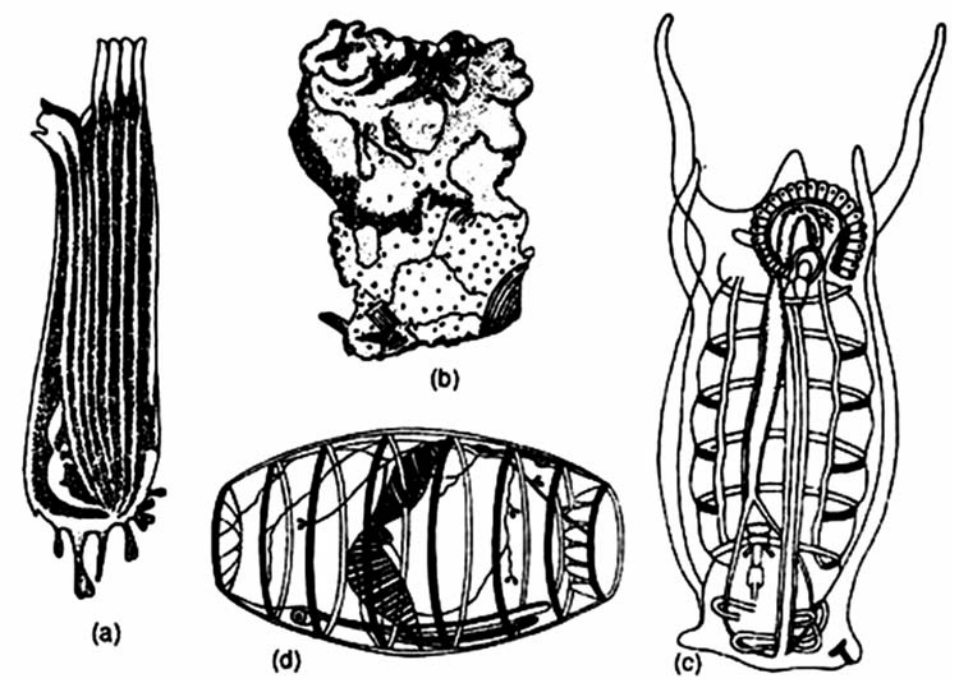


Fig. 11.4 : Some members of Urochordata : (a) *Ciona,* (b) *Herdmania,* (c) *Salpa* and (d) *Doliolum*

2) Body consists of a basically oval trunk and a relatively long thin tail. Tail is supported by notochord which is retained all through the animal's life, unlike the rest of the urochordates where it is lost before maturity.

3) The tail has large striped muscle cells attached to it and used for swimming.

4) The trunk holds major body organs.

5) They produce a remarkable feeding apparatus (house) that consists of three components: screens, filters and expanded gelatinous matrix.

The 'house' encases the trunk or body, but not the tail. Disturbed or actively feeding larvaceans abandon their old house and builds a new one.

6) Larva like that of tunicates, metamorphoses to adult.

7) All species, except one, are monoecious, and most of these are protandrous.

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

Examples:*Oikopleura* , *Appendicularia.*

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

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

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

General characteristics:

1) Small fish like (lancet-shaped) translucent marine chordates.
2) Notochord well developed and persist throughout life of the animal. It runs the length of the animal from the tail to the tip of the head, hence the name Cephalochordata.
3) The body is laterally compressed and tapered at both ends with post anal tail. They are commonly called "lancelets" for the shape of the body.
4) Body muscles are in a series of V-shaped blocks of striated muscle fibres running throughout the body, called the myotomes which are separated from each other by sheet or layer of connective tissue, the myosepta or myocoma.
5) The body is provided with a dorsal fin, which joined to a somewhat caudal fin present round the tail. A ventral fin runs along the mid ventral line lying between caudal fin and atriopore.Paired fins absent.
6) At the anterior end an oral hood bears more than twenty stiff buccal or oral cirri or tentacles. The mouth is kept hidden within the oral hood.
7) The posterior wall of the oral hood is defined as velum.
8) On the lateral sides of the body there are numerous gill-slits (to trap food particles during filter feeding) which remain partly covered by the lateral folds of the body.
9) Presence of wheel organ adjacent to mouth.

10) Alimentary canal is long. It includes a large pharynx with many gill-slits. The anus is situated of the left side of the ventral fin.

11) The atrium opens to the exterior through a round atriopore located closed to the anterior end of the ventral fin.

12) Closed circulatory system and a specialed heart is lacking.

13) Blood is colourless without any respiratory pigment.

14) Excretory organs are paired protonephridia with solenocytes.

15) Sexes are separate. Gonads are metamerically arranged and without gonoducts.

16) Fertilization external. Fertilized eggs develop into free swimming larvae.

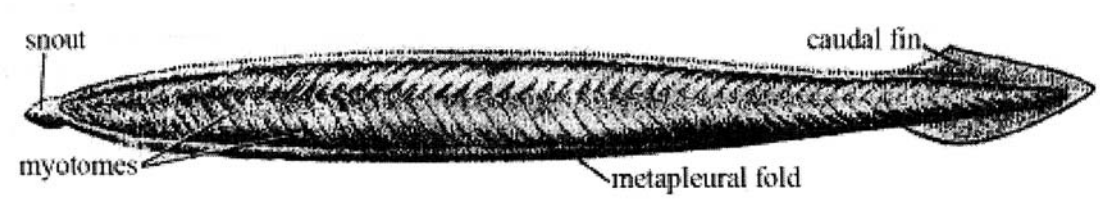


Fig. 11.5 : A diagrammatic view of *Branchiostoma* (*Amphioxus*)

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

Classification of Cephalochordata

The subphylum Cephalochordata comprises a single class **Lepitocardii** with two genera:

Branchiostoma [Approx. 16 species]

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

Branchiostoma lanceolatum (Amphioxus)

Asymmetron [Approx. 7 species]

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

Asymmetron cultellum

11.5.4 Larval forms in protochordates

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

Tornaria larva of *Balanoglossus*

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

General characteristics of tornaria larva are:

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

Tadpole larva of *Ascidia*

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

1) Highly motile and does not take food from the outside.
2) The body is more or less oval in outline.
3) Body divisible into head and tail region.
4) The whole body is covered by tunic.
5) The head is elliptical and has three adhesive papillae or chain warts.
6) The tail is laterally compressed and pointed terminally.

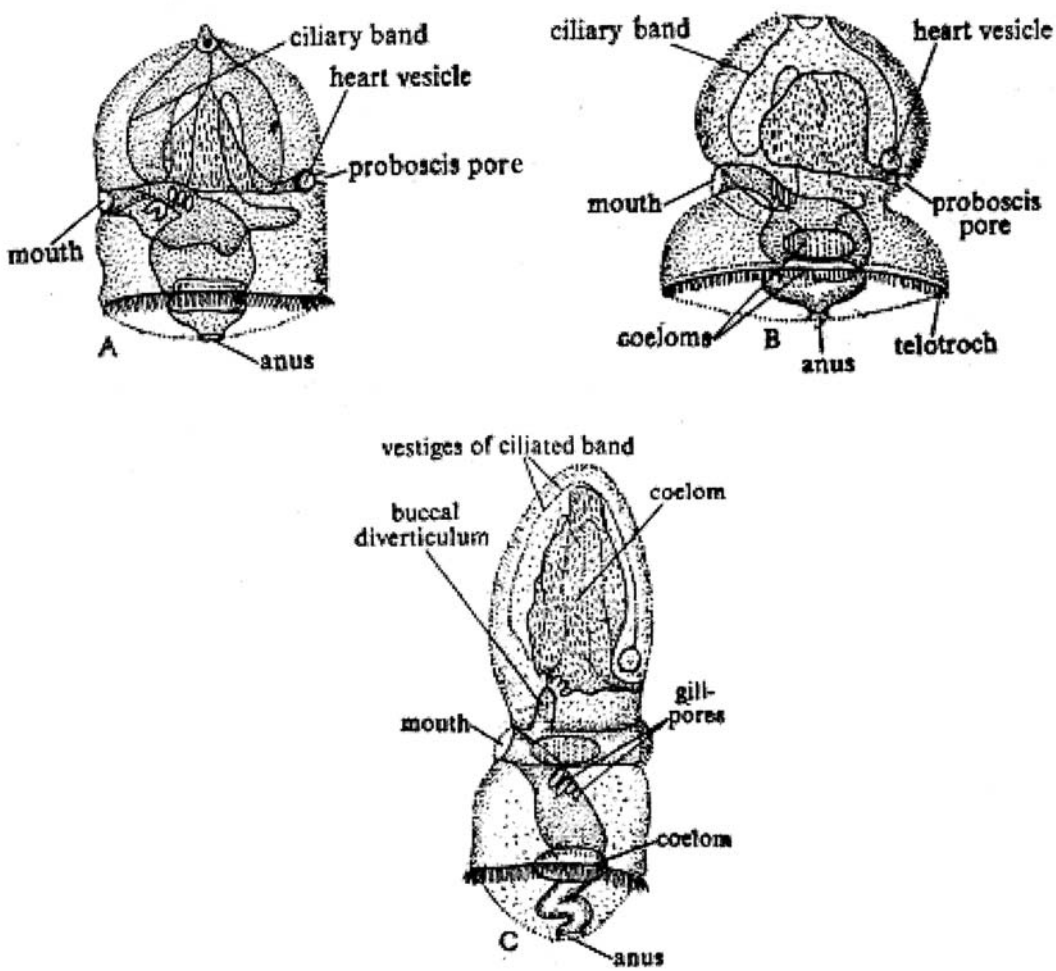


Fig. 11.6 : (A) A full drown Tornaria larve; (B-C) Stages of subsequent metamorphosis of tornaria larva

7) The tail is provided with caudal fin.

8) The dorsal and ventral fins are continuous along the tail and are marked with striae.

9) The central nervous system is situated dorsal to the notochord.

10) A single median eye is present.

11) An otocyst, the organ of balance is situated in the ventral side.

12) The notochord is restricted only in the tail region.

13) Segmental muscle bands are present in the tail region.

14) The mouth is present and the alimentary canal is rudimentary.

15) Well developed pharynx is sac like.

16) A fully developed endostyle and two pairs of gill slits are present.

17) Non-functional heart with epicardia lies beneath the endostyle.

18) The paired atrial sacs are present.

19) Just after hatching the tadpole larva becomes positively phototactic and negatively geotactic.

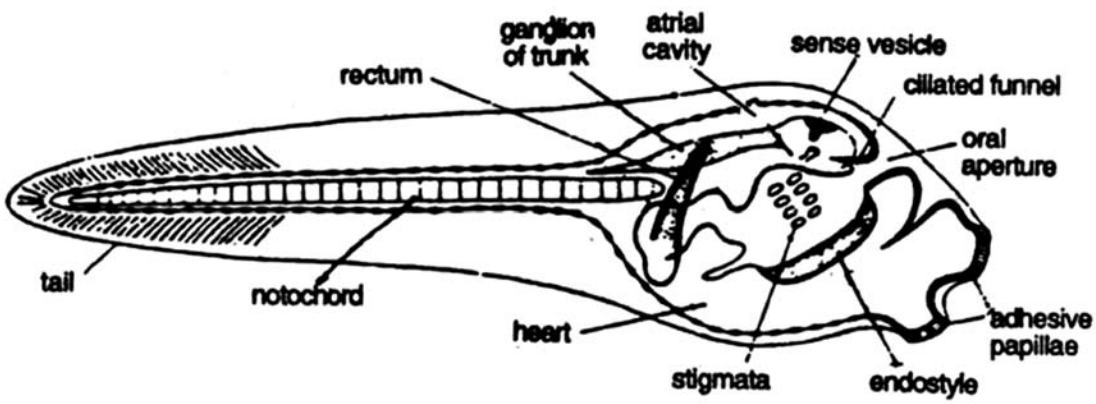


Fig. 11.7 : Ascidia sp. A free swimming tadpole larva

11.6 ❑ Retrogressive metamorphosis in Urochordata

The subphylum Urochordata constitutes an unique group of animals under the phylum Chordata. In urochorates, the notochord is confined to the tail region in the adult stage,

thus named as Urochordata. This subphylum is sub-divided into three classes: (i) Ascidiacea; (ii) Thaliacea; and (iii) Larvacea or Appendicularia. The unique example of this group is *Ascidia. Ascidia* is a hermaphroditic animal, known for its indirect development; i.e., the development is accompanied by metamorphosis. Metamorphosis in most animals, is a progressive process. But, in *Ascidia* the developmental events are largely retrogressive. In *Ascidia*, a highly developed tadpole larva, in course of ontogenic development transforms into a sessile and degenerated adult. The metamorphosis in *Ascidia* shows a peculiar scheme of retrogression of a complex and well organized larval form to a simpler degenerated adult amply speak for the retrogressive metamorphosis in *Ascidia.*

In Ascidian metamorphosis, two sets of changes occur: (i) the disappearance of notochord, nerve chord and muscle bands; (ii) formation of stigmata, specialization of pharynx, over development of atrium etc.

The essence of retrogressive metamorphosis in Ascidia is therefore; (i) the differential growth and disappearance of histologically differentiated larval tissues; and (ii) the formation of the adult structures from the residual larval tissue.

A. Pre-larval stages:

1) The egg are small and almost yolkless.
2) The segmentation is holoblastic and nearly equal at the initiation.
3) Gastrulation occurred by invagination.
4) The gastrula after about three days transformed into free swimming tadpole larva.
5) The tadpole larva has all the characteristics of chordate organization.

B. Larval stages:

1) The tadpole larva is very active and do not take food from outside.
2) The body is more or less oval in outline.
3) Body divisible into two regions; i.e., head and tail.
4) The whole body is covered by tunic
5) The tail is laterally compressed and pointed terminally and provided with caudal fin.
6) The dorsal and ventral fins are continuous along the tail and marked with striae.

7) The central nervous system is situated dorsal to the notochord.
8) The notochord is restricted in the tail region.
9) A single median eye is present.
10) An otocyst, the organ of balance is situated in the ventral side.
11) The mouth and the alimentary canal is rudimentary
12) The pharynx is sac like and is well developed.
13) A fully developed endostyle and two pairs of gill slits present.
14) Non-functional heart with epicardia lies beneath the endostyle.

C. Metamorphosis and emergence of the adult:

The free swimming tadpole larva after a short period of free existence fixes itself to sea weeds or stones by adhesive papillae and immediately falls a victim of first degeneration and undergoes progressive and retrogressive changes during its development.

I. Progressive changes:

1) The branchial chamber becomes enlarged and the number of stigmata are enhanced;
2) The post pharyngeal portion of the gut gets divided into different parts;
3) The atrium becomes more extensive;
4) The development of velum is observed;
5) The gonads and gonoducts appear from the mesoderm.

II. Retrogressive changes:

1) The length of the tail becomes greatly diminished.
2) The nerve chord becomes restricted to the trunk region and is ultimately reduced to a solid nerve ganglion;
3) The notochord becomes coiled, disorganized and finally disappeared;
4) The trunk becomes broadened;
5) The number of the striae are diminished and become restricted to certain regions;
6) The muscle band also become degenerated;
7) The tail is further shortened;

8) Shifting of the mouth is caused by the rapid growth of the region between the adhesive papillae;

9) The tail becomes more shortened and partially withdrawn into the test.

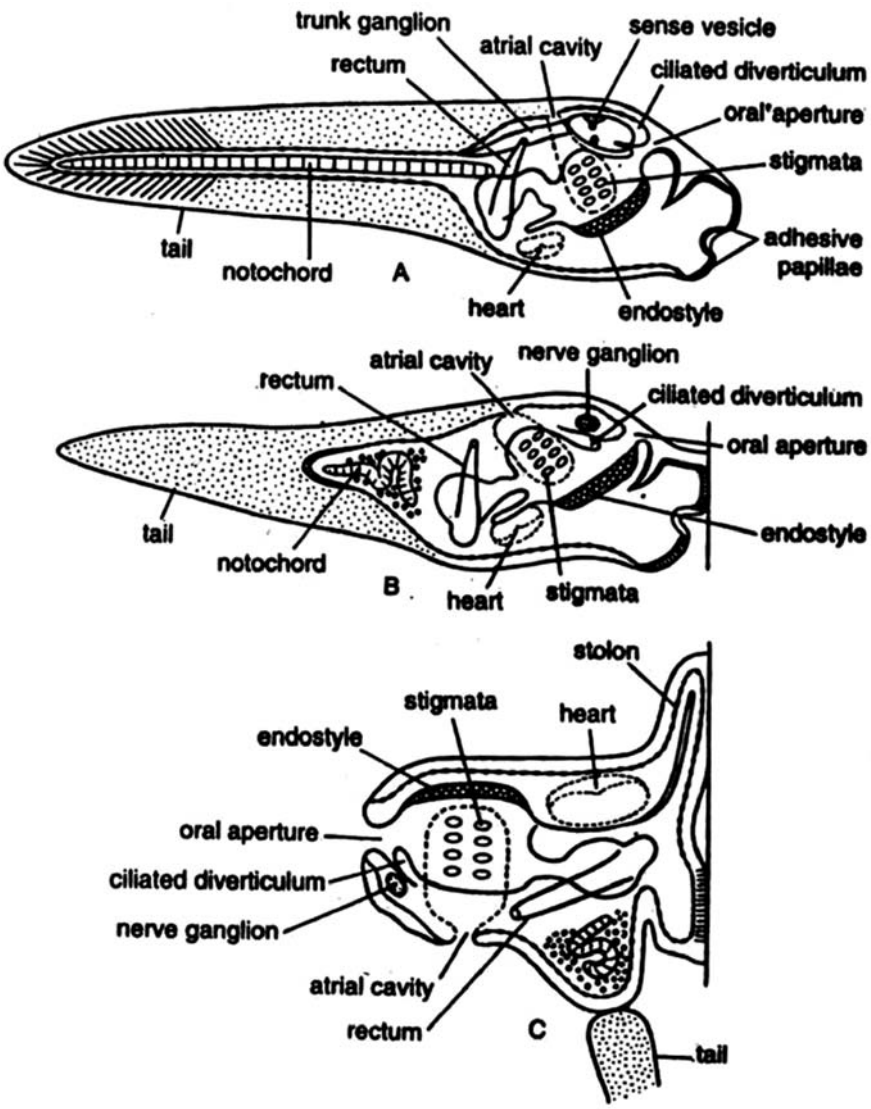


Fig. 11.8 : Ascidia sp. Metamorphosis – free talled larva into a fixed ascidian

11.7 ❑ Questions

- Naik,

11.8 ❑ Suggested readings

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UNIT 12 ❑ Emergence of Agnatha (jawless vertebrate) and Gnathostomata (vertebrate with jaw)

Structure

12.1 ❑ Objective

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

- the distinction between Agnatha and Gnathostomata
- the salient features of agnathans.
- the general characteristics of Cyclostomata.
- the classification of Cyclostomata.
- the salient features of ammocoetes larva.

12.2 ❑ Introduction

Subphylum Vertebrata belongs to phylum Chordata. It got its name from the vertebral column present in the animals and categorised under Vertebrata. The vertebral column develops at the adult stage from the notochord which is a rod-like structure of mesodermal origin found in the embryonic stage. Vertebrates are triploblastic and possess a well-developed organ system. Vertebrates are further classified into two divisions. They are **Agnatha** and **Gnathostomata**. Agnatha are those animals which lack jaws and

Gnathostomata are those with jaws. Division Agnatha includes the most primitive vertebrates. Along with the jaws they also lack exoskeleton and paired appendages.

Gnathostomata or jawed vertebrates is divided into two super classes called Pisces and Tetrapoda. There are six classes in Gnathostomata and they are Chondrichthyes, Osteichthyes, Amphibia, Reptilia, Aves and Mammals. Thus all the vertebrates from jawed fishes to mammals are gnathostomes.

The division Agnatha is divided into two classes— class **Ostracoderm** (currently extinct) and class **Cyclostomata**.

The class **Ostracoderm** includes the earliest known vertebrates which are extinct. They appeared in the Ordovician period and became extinct by the end of the Devonian period. Members had well-developed dermal scales due to which they were called armoured fishes.

12.3 ❑ General characteristics of class Cyclostomata

The word 'Cyclostomata' has been derived from two words 'cyklos' meaning circular and 'stome' meaning mouth. Thus the class Cyclostomata includes circular-mouthed jawless fishes. The class Cyclostomata comprises of the most primitive living vertebrates represented by the lampreys and hagfishes. 'The cyclostomes', in general, show the curious admixture of primitive, specialised and degenerated characters.

1) They have an elongated eel-like and smooth body without scales. They possess a compressed tail.
2) The mouth is circular or disc-shaped (without jaws) and suctorial (rasping or sucking type).
3) The paired fins are absent. Associated girdles are also absent. But median fins (with cartilaginous fin rays), like the dorsal fin, anal fin and caudal fins are present.
4) No paired appendages.
5) The skin is soft and smooth and devoid of scales.
6) The exoskeleton is absent. The endoskeleton is cartilaginous without bones (cranium is also cartilaginous).
7) The notochord is persistent throughout life. Small, crooked neural arches over the notochord serve as a representation for the vertebral column.

8) The digestive system is devoid of any stomach.

9) The nostril is single and median.

10) Cyclostomes have 6 - 15 pairs of pharyngeal gill slits. They are placed in a sac like pouches.

11) The heart is two-chambered, one auricle and one ventricle.

12) The cerebellum is small.

13) Spleen is absent.

14) The lateral line acts as a sense organ (detect the waves and current in water). There is only one olfactory sac present which helps in detecting the sense of smell. Membranous labyrinths are the only structures present in the ear.

15) The ninth and tenth cranial nerves are absent.

16) The sexes are separate with the exception of some hagfishes which are hermaphrodites. In them both male and female sex organs are present, although male sex organs mature prior to female sex organs (protandry).

17) Excretory system consists of a pair of mesonephric kidney.

18) Development may be direct or indirect through ammocoetes larva.

Although well-adapted to marine environments, cyclostomes move to freshwater for spawning (release or deposition of eggs). They show anadromous condition. Adult cyclostomes die after spawning. As soon as the process of metamorphosis is concluded, the larval forms return back to the ocean.

12.4 ❑ Classification of Cyclostomata

The class Cyclostomata is further sub-divided into two orders:

1) Order **Petromyzontia** (exemplified by Lampreys) and

2) Order **Myxinoida** (represented by Hagfishes).

Order-l: Petromyzontia

Characteristics:

1) Both the larval form and adult are marine and freshwater in habitat.

2) They have a ventral mouth with many horny teeth.

3) The mouth is present in the buccal funnel.
4) The buccal funnel is suctorial and shows horny teeth.
5) The nostril is present dorsally and no connection with the pharynx.
6) Eyes are functional.
7) Seven pairs of gill slits are present.
8) Well developed dorsal fin is present.
9) Branchial basket is complete.
10) Brain is well developed.
11) Pineal eye is well developed.
12) Ear has two semicircular canals.
13) The development is indirect.

Examples: *Petromyzon* (sea-lamprey); *Lampetra fluviatilis* (common lamprey)

Order - 2: Myxinoidea

Characteristics:

1) They are found exclusively in the marine environment.
2) They have a terminal mouth with few teeth.
3) Buccal funnel is absent.
4) They possess 6-14 pairs of gill slits.
5) The nasal sac opens into pharynx through a canal.
6) Eyes are vestigial and few in number.
7) Dorsal fin is either absent or very small and weak.
8) Branchial basket is poorly developed.
9) Brain is of primitive type.
10) Pineal eye is reduced.
11) Ear has only one semicircular canal.
12) The hag-fishes are all marine in habitat.
13) Eggs are large and few in number.

Example: *Myxine glutinosa* (Atlantic hag fish or slime eel).

Petromyzon marinus is often referred to as sea lamprey. It is native to the Northern Hemisphere and is a parasitic lamprey. Petro, which means 'stone,' and myzon, which means 'sucking,' are the roots of the genus name *Petromyzon*, while *marinus* is Latin for 'of the sea.' Lampreys usually live in sea and migrate to the river for the purpose of spawning. After spawning they usually die. In the river system the lampreys do not eat, anything, but live on the accumulated sub cutaneous fat that provides the nourishment. They migrate to the river usually in autumn while the sexual maturity is attained in winter. But the breeding occurs in spring. Some of them migrate a few miles upstreams for the purpose of spawning. The brook lampreys (represented by the genus *Lampetra*) have the peculiar habit of nest building at the bottom of the river where the eggs are laid. Adults are semi-parasites on larger, jawed fishes to which they attach themselves by the help of suctorial buccal funnel which acts as the vacuum cup. While attached to the fishes, they rasp the flesh by the horny teeth on the buccal funnel and 'tongue' apparatus. Thus they derive nutrition from the host body. Hagfishes are minor pests of commercial food fisheries of the North Atlantic, but lampreys, because of their parasitic habit, have been a serious pest of food fisheries in the Great Lakes in North America, where they have reduced the numbers of lake trout and other species. Agnathans are otherwise of little economic importance. The group is of great evolutionary interest, however, because it includes the oldest known craniate fossils and because the living agnathans have many primitive characteristics.

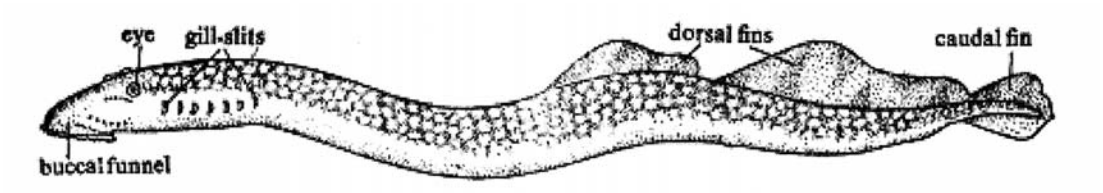

Fig. 12.1 : External structures of *Petromvzon*

12.5 ❑ Development of lamprey

The eggs of lamprey are telolecithal, having a large amount of yolk. Cleavage is holoblastie but unequal resulting in the formation of blastula. Blastula consists of micro and macromeres. Invagination in blastula gives rise to gastrula. Gastrulation occurs by invagination and the blastopore takes up a postero-dorsal position and becomes converted into arms. The development of the central nervous system is peculiar in lampreys. It

develops as a solid cord or keel which hollows to form the lumen of the nerve cord. This process is called as thickened keel method. After about twenty-one days a young larval form hatches out as the ammocoetes larva.

12.5.1 Salient features of Ammocoetes larva

1) Ammocoetes is a freshwater larva of *Petromyzon.*
2) Transparent and eel like body.
3) It lives inside U-shaped burrow. At times it comes out of burrow.
4) Colour is muddy brown.

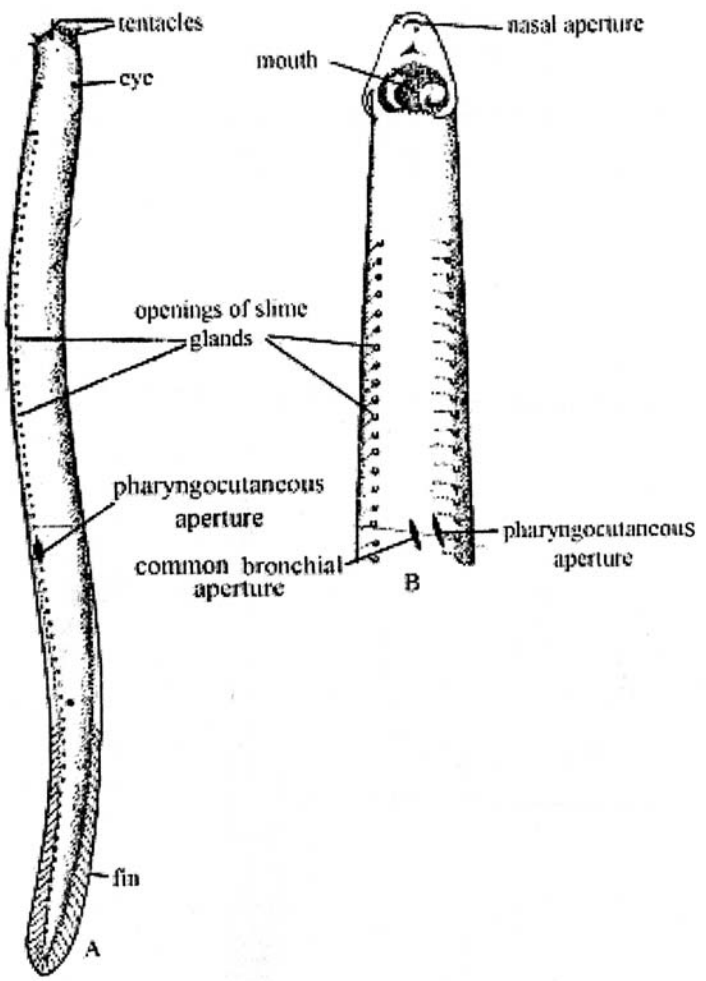

Fig. 12.2 : Structure of the hagfish. (A) Dorsal view of an entire *Myxine*; (B) Ventral view of anterior end of *Myxine*.

5) Body is divisible into head, trunk and a tail.

6) Suctorial buccal funnel absent.

7) Oral hood surrounds the mouth in the place of the buccal funnel.

8) Trunk has a single dorsal fin.

9) Tail has a caudal fin which is in continuation of the dorsal fin.

10) Teeth are absent but several branched buccal tentacles surrounded the mouth.

11) The alimentary canal includes a mouth, buccal cavity, pharynx, intestine and anus.

12) A velum is present between the buccal cavity and the pharynx.

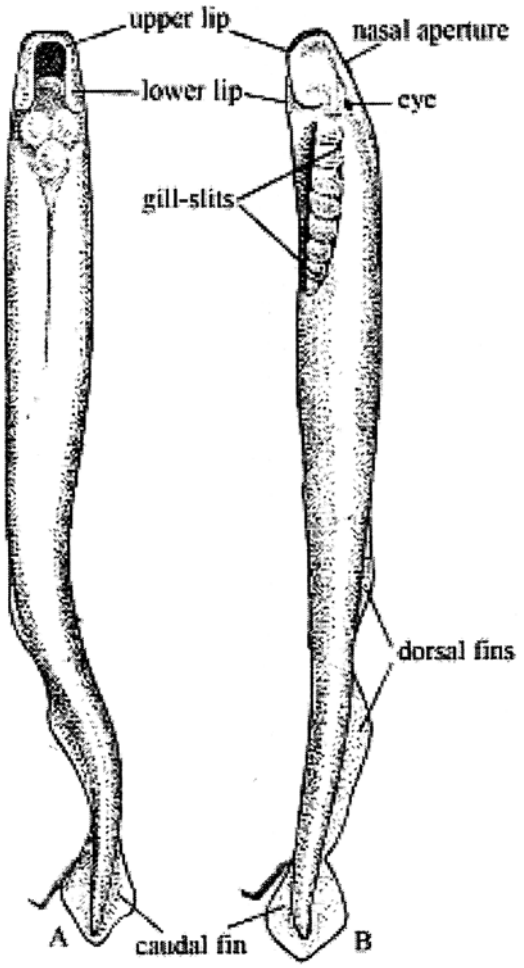

Fig. 12.3 : Anatomical organisation of Ammocoetes larva of *Petromyzon;* A. Ventral view B. Lateral view.

13) The pharynx has an endostyle, a pair of peripharyngeal bands and a hypopharyngeal groove.

14) Eyes are vestigial and concealed below the skin.

15) Pineal eye is well developed.

16) Trunk has seven pairs of gill-slits just behind the head.

17) Liver, bile duct and gall bladder are present.

18) Heart with pericardium is present.

19) It exhibits filter feeding.

20) Respiratory current goes into the pharynx through mouth and comes out through gill-slits.

21) Kidney Protonephric.

Additional readings

Chordates are characterized by a hollow dorsal nerve cord, a notochord, pharyngeal gill slits, and a postanal tail at some point in their development. The flexible notochord anchors internal muscles and allows rapid, versatile movement.

Characteristics of Vertebrates Vertebrates (subphylum Vertebrata) are chordates with a spinal column. The name vertebrate comes from the individual bony segments called vertebrae that make up the spine. Vertebrates differ from the tunicates and lancelets in two important respects:

1. Vertebral column. In vertebrates, the notochord is replaced during the course of embryonic development by a bony vertebral column. The column is a series of bones that encloses and protects the dorsal nerve cord like a sleeve (figure 48.8).

2. Head. In all vertebrates but the earliest fishes, there is a distinct and well-differentiated head, with a skull and brain. For this reason, the vertebrates are sometimes called the craniate chordates (Greek kranion, “skull”).

In addition to these two key characteristics, vertebrates differ from other chordates in other important respects:

a) Neural crest. A unique group of embryonic cells called the neural crest contributes to the development of many vertebrate structures.

b) Internal organs. Among the internal organs of vertebrates, livers, kidneys, and endocrine glands are characteristic of the group. The ductless endocrine glands secrete hormones that help regulate many of the body's functions. All vertebrates have a heart and a closed circulatory system. In both their circulatory and their excretory functions, vertebrates differ markedly from other animals.

c) Endoskeleton. The endoskeleton of most vertebrates is made of cartilage or bone. Cartilage and bone are specialized tissue containing fibres of the protein collagen compacted together. Bone also contains crystals of a calcium phosphate salt. The vertebrate endoskeleton makes possible the great size and extraordinary powers of movement that characterize this group.

The first vertebrates evolved in the oceans about 470 million years ago. They were jawless fishes with a single caudal fin. The appearance of a hinged jaw was a major advancement, opening up new food options, and jawed fishes became the dominant creatures in the sea. Their descendants, the amphibians, invaded the land. Salamander-like amphibians and other, much larger now-extinct amphibians were the first vertebrates to live successfully on land. Amphibians, in turn, gave rise to the first reptiles about 300 million years ago. Within 50 million years, reptiles, better suited than amphibians to living out of water, replaced them as the dominant land vertebrates. With the success of reptiles, vertebrates truly came to dominate the surface of the earth. Many kinds of reptiles evolved, ranging in size from smaller than a chicken to bigger than a truck. Some flew, and others swam. Among them evolved reptiles that gave rise to the two remaining great lines of terrestrial vertebrates, birds (descendants of the dinosaurs) and mammals. Dinosaurs and mammals appear at about the same time in the fossil record, 220 million years ago. For over 150 million years, dinosaurs dominated the face of the earth. Over all these centuries (think of it— over a million centuries!) the largest mammal was no bigger than a cat. Then, about 65 million years ago, the dinosaurs abruptly disappeared, for reasons that are still hotly debated. In their absence, mammals and birds quickly took their place, becoming in turn abundant and diverse. The history of vertebrates has been a series of evolutionary advances that have allowed vertebrates to first invade the sea and then the land.

12.6 ❑ Questions

- Naik,

12.7 ❑ Suggested readings

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UNIT 13 ❑ Pisces - General characteristics and Classification up to orders

Structure

13.1 ❑ Objective

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

- the characteristics of Pisces.
- the general characteristics of class Placodermi
- the general characteristics and classification of class Chondrichthyes.
- the general characteristics and classification of class Osteichthyes.
- the classification of Pisces up to order.

13.2 ❑ Introduction

Fishes are aquatic cold blooded vertebrates which exploit the aquatic habitat and become a “sentinel organism” of the water bodies. Fishes constitute the first group of

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

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

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

13.3 ❑ General characteristics of Pisces

1. Aquatic, either freshwater or marine, herbivorous or carnivorous, cold blooded (poikilothermous), oviparous or ovoviviparous vertebrates.
2. Body usually streamlined, spindle-shaped, some are elongated snake-like and a few are dorsoventrally compressed, and differentiated into head, trunk and tail.

3. Locomotion by paired pectoral and pelvic fins along with median dorsal and caudal fins, supported by true dermal fin-rays. Muscular tail used in propulsion.
4. Exoskeleton of dermal scales, denticles or bony plates (in Placodermi) covering body surface. Placoid in Chondrichthyes and ganoid, cycloid or ctenoid in Osteichthyes.
5. Endoskeleton is cartilaginous or bony. The notochord in usually replaced by vertebrae. Presence of well-developed skull and a system of visceral arches, of which the first pair forms the upper and lower jaws, the latter movably articulated with the skull.
6. Muscles arranged into segments called myotomes, with separate dorsal and ventral parts.
7. Lateral line system is well developed.
8. Nostrils are paired but do not open into pharynx except Dipnoi. Nasal capsules are partly separate in Chondrichthyes and completely separate in Osteichthyes.
9. Tympanic cavity and ear ossicles are absent. Internal ear with three semicircular canals.
10. Alimentary canal with definite stomach and pancreas and terminates into cloaca which serves as a common outlet for rectum, renal and reproductive ducts.
11. Organs of respiration are gills. Gill-slits 5 to 7 pairs, naked or covered by an operculum.
12. Heart is venous and two chambered, i.e., one auricle and one ventricle. Sinus venosus and renal and portal systems present. Erythrocytes nucleated.
13. Brain with usual five parts. Cranial nerves ten pairs.
14. Kidneys mesonephric. Excretion mostly ammonotelic, in some ureotelic.
15. Sexes separate. Gonads typically paired. Gonoducts open into cloaca or independently.
16. Fertilisation internal or external. Females of Chondrichthyes are oviparous or ovoviviparous and of Osteichthyes are mostly oviparous and rarely ovoviviparous or viviparous. Eggs with large amount of yolk. Cleavage meroblastic.
17. Extra-embryonic membranes are absent.
18. Development usually direct without or with little metamorphosis.

13.4 ❑ Outline Classification of Pisces

About 40,000 species of fishes are known. Various workers have proposed different schemes of classification of fishes. However, no classification has been universally accepted because of confusion due to large number of fishes and great diversity in their shape, size, habits and habitat.

Jordan (1923) divided fish-like vertebrates into six classes. Among the more recent authors Goodrich (1930), Berg (1940), Grasse (1958) and Romer (1959) have given a detailed classification of fishes.

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

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

13.5 ❑ General characteristics of class Placodermi (Extinct) [Gk. plaks = a flat plate; derma = skin] (Silurian — Permian)

The earliest known jawed vertebrates are represented by a group of fossil fishes called placoderms which appeared during the Silurian period. These fossil fishes exhibit many structural peculiarities and are included under the class Placodermi or Aphetohyoidea. The placoderms present wide range of adaptive radiation and flourished well in the Devonian and Carboniferous periods, but all of them became extinct by the end of Permian. The placoderms possess many pecu-liar and specialised characteristics and are regarded as the progenitors of the modern fishes. Although the placoderms form a heterogeneous group of fishes, the following features characterize the class.

The characteristic features are:

1. The body is protected by heavy bony armour, a feature which has given the name ‘placodermi’ to the group.
2. The hyoid arch is unspecialized and does not take part in jaw suspension.

3. The jaws are attached with the skull by their own processes. This peculiar type of jaw attachment is called autostylic. (This is also called aphetohyoidean condition; because of this characteristic the placo-derms are also called Aphetohyoidea. Such type of jaw attachment is regarded as the most primitive type of jaw attachment.
4. The spiracle is typically a gill-slit which is present anterior to the unmodified hyoid arch.
5. The paired fins are usually present.

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

1. Mostly marine and carnivorous/predaceous.
2. Body fusiform and streamlined.
3. Fins both median and paired, all supported by fin-rays. Pelvic fins bear claspers in male which help in reproduction. Caudal fin or tail is heterocercal i.e. two lobes of the fin are unequal (except *Chlamydoselachus* and *Chimaera*, where tail is of isocercal type).
4. Skin is tough and covered with minute placoid scales. In some, the skin is naked and bears mucous glands.
5. Endoskeleton entirely cartilaginous often calcified, without true bones. Notochord persistent. Vertebrae complete and separate. Pectoral and pelvic girdles present.
6. In living forms, the sutures are absent in the skull.
7. Olfactory sacs do not open into pharynx. Membranous labyrinth (internal ear) with three semicircular canals. Lateral line system present.
8. Mouth ventral. Jaws are armoured with rows of sharp teeth. Teeth are modified placoid scales. Stomach J-shaped. Intestine with spiral valve.
9. By gills. Gills are of lamellar type. Gill slits are separate and without gill cover (operculum). In holocephalans the gill openings are covered by an opercular flap. Gill-slits 5 to 7 on each side. No air-bladder.
10. Respiration posterior part of kidney is excretory in function. Excretion ureotelic.

11. Heart two chambered (one auricle and one ventricle). Sinus venosus and conus arteriosus present. Both renal and hepatic portal system present.
12. Brain with large olfactory lobes and cerebellum. Cranial nerves ten pairs.
13. Kidneys opisthonephric (only Cloaca present. Its aperture serves as a common outlet for rectum, renal and reproductive ducts.
14. Sexes separate. Male usually possesses claspers. Gonads paired. Gonoducts open into cloaca.
15. Fertilisation internal. Oviparous or ovoviviparous. Eggs large, yolky. Cleavage meroblastic.
16. Development direct, without metamorphosis.

13.7 ❑ Classification of class Chondrichthyes up to orders

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

(i) Elasmobranchii (ii) Holocephali

Subclass 1. Elasmobranchii

Characters:

1. 5-7 pairs gill openings separately open to the exterior.
2. Body is covered by placoid scales.
3. Tail is mostly heterocercal type.
4. Spiracle is present.
5. Spiral valve present in the intestine.
6. High concentration of urea and trimethylamine oxide (TMAO) in the blood. Little water is drunk by the marine elasmobranchs and some water enters through the gills, hence little amount of urine is formed.
7. Males with pelvic claspers (Myxopterygia).
8. Jaw suspension mostly hyostylic type.

Examples: Sharks (*Scoliodon*), rays (*Trygon*) and skates (*Rhinobatus*). They are mostly marine and highly predaceous. Some elasmobranchs have entered into the rivers and lakes, and live permanently there. Some species of *Carcharhinus* found in the Lake

Nicaragua, and in the Ganges and Zambesi. Four elasmobranch species found in the Perak River in Malayasia, though they are not permanent resident but enter regularly from the sea. The Amazon sting ray, *Potamotrygon* is a permanent resident in the Amazon.

The subclass Elasmobranchii is divided into 3 orders:

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

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

Characters:

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

They were predaceous, marine shark-like fishes.

Example: *Cladoselache.*

2. Selachii (Gk. selakhe = a shark)

Characters:

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

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

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

Order 3. Batoidea:

Characters:

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

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

Subclass 2. Holocephali:

Characters:

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

The subclass Holocephali is divided into two orders: **(i) Bradyodonti and (ii) Chimaerae.**

Order 1. *Bradyodonti (extinct)

Characters:

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

Example: *Bradyodontus*

Order 2. Chimaerae

Characters:

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

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

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

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

The characteristic features of class Osteichthyes are:

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

13.9 ❑ Classification of class Osteichthyes up to orders

The classification of class Osteichthyes described here has been largely followed after

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

The class Osteichthyes is divided into two subclasses:

(i) Actinoptrygii and (ii) Sarcopterygii.

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

The characteristic features are:

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

The subclass is divided into 3 superorders:

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

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

Characters:

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

7. Spiracle present. The superorder includes two orders:

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

Order 1. Polypteriformes

Characters:

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

Example:*Polypterus* (Bichir).

Order 2. Acipenseriformes

Characters:

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

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

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

Characters:

1. Internal skeleton bony.
2. Intermediate ray-finned fish, transitional between Chondrostei and Teleostei.

3. Body covered with cycloid scales in *Amia* and rhomboid scales in *Lepisosteus*. Generally the scales have lost their shiny ganoid covering.
4. Dorsal fin and pelvic fins are present very near to the caudal fin.
5. Mouth opening small.
6. Spiracle absent.

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

Order 1. Amiiformes

Characters:

1. Body covered with thin, overlapping cycloid scales.
2. Caudal fin abbreviated heterocercal but rounded in outline.
3. Long dorsal fin.
4. Vertebral centra non-opisthocoelous.
5. Premaxillary not protractile, firmly articulated with the cranium.
6. Snout normal rounded.
7. Spiracles and clavicles absent.
8. Presence of a single swim-bladder.

Example: *Amia* (Bowfin).

Order 2. Lepidosteiformes

Characters:

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

Examples: *Lepidosteus* or *Lepisosteus* (Garpike).

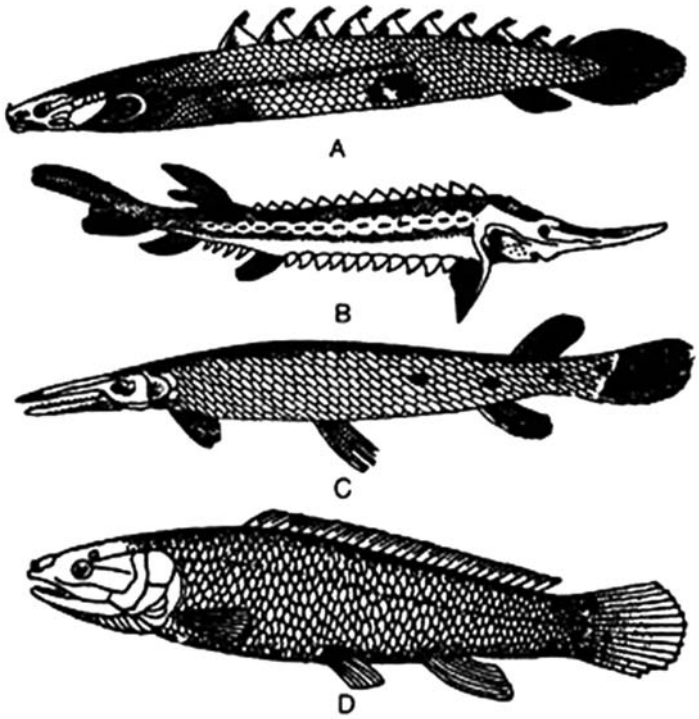

Fig. 13.1 : A. *Polypterus,* B. *Acipenser,* C. *Lepidosteus,* D. *Amia.*

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

Characters:

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

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

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

This superorder includes following orders:

Order 1. Clupeiformes

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

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

Order 2. Scopeliformes

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

Example: *Harpodon* (Bombay duck).

Order 3. Cypriniformes

1. Fins either without spines or dorsal, anal and pectoral have a spine each.
2. Ventral (pelvic) fins abdominal.
3. Air-bladder connected with the pharynx by a duct (Physostomous or open type swim bladder).

4. A peculiar Webarian apparatus, connecting the internal ear with the air-bladder, present.

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

Division I. Cyprini

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

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

Division II. Siluri

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

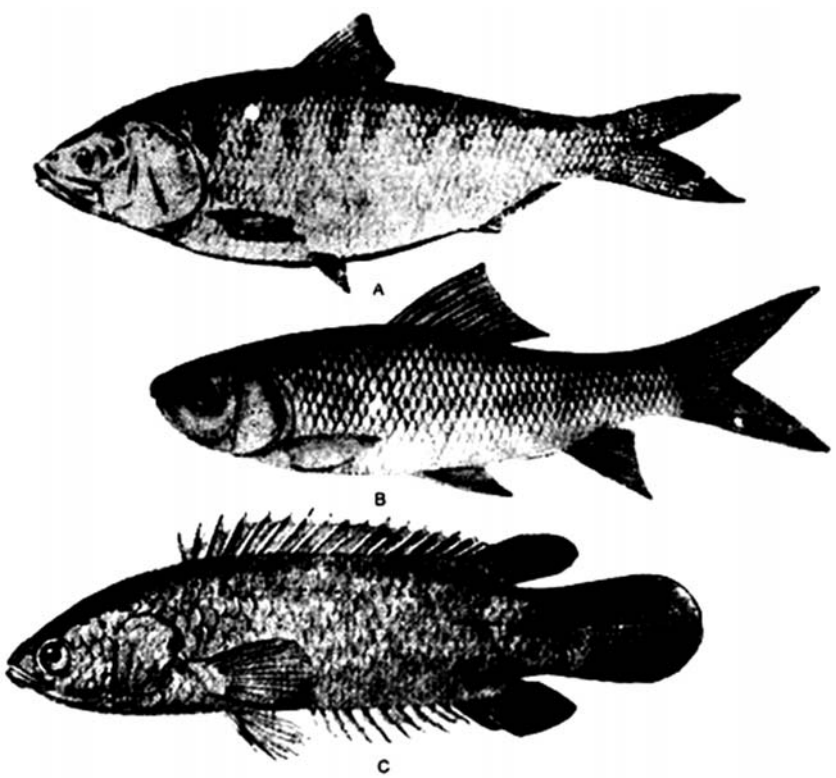

Fig. 13.2 : A. *Tenutosa ilisha,* B. *Labeo mhtia,* C. *Anabas testudineus.*

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

Order 4. Anguiliformes

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

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

Order 5. Beloniformes

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

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

Order 6. Syngnathiformes

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

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

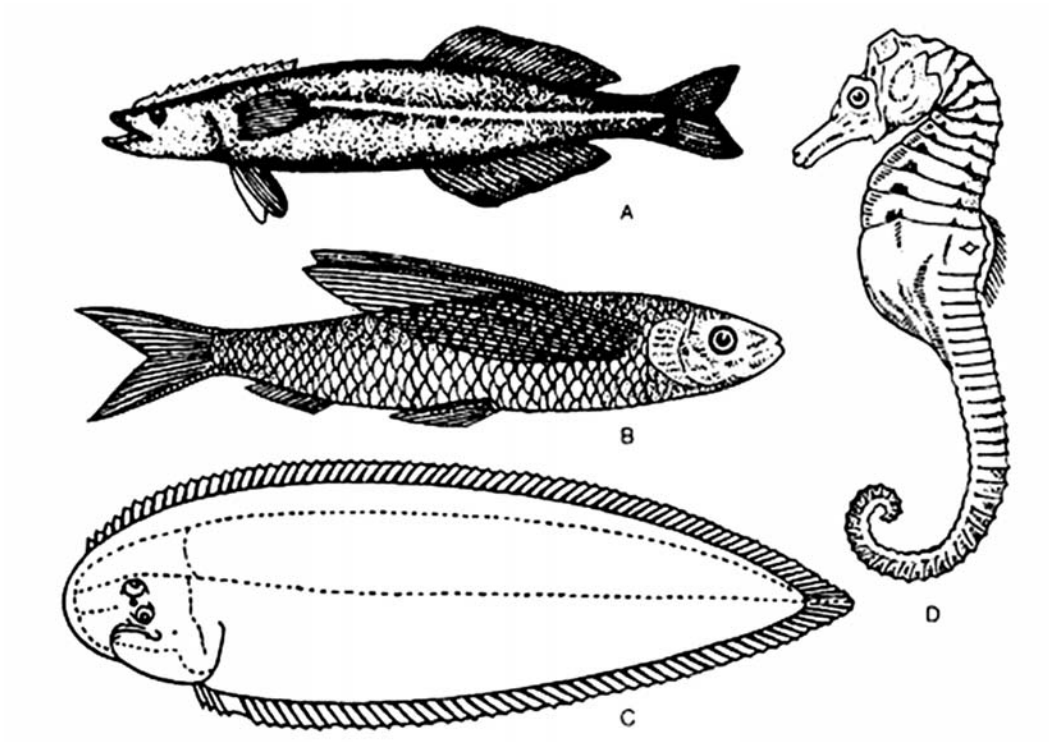

Fig. 13.3 : *Echeneis* (Suckerfish), B. *Exocoetus* (Flying fish), C. *Cynoglossus* (Indian flat fish). D. *Hippocampus* (Sea horse)

Order 7. Ophiocephaliformes or Channiformes

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

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

Order 8. Symbranchiformes

1. Body elongated eel-like or snake-like devoid of scales.

2. Dorsal, caudal and anal fins continuous. Pectoral fins absent.
3. Fins without spines
4. Gill-slits single or join to form a transverse ventral slit.
5. Air-bladder absent.

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

Order 9. Mastacembeliformes

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

Examples: *Mastacembelus, Macrognathus*.

Order 10. Perciformes

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

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

Order 11. Scorpaeniformes

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

Example: *Pterois* (Scorpion fish).

Order 12. Pleuronectiformes

1. Bottom dwellers.

2. Body flat, lying on one side, adapted for bottom living.
3. Head asymmetrical.
4. Both eyes present on the upper or dorsal side and close to each other.
5. Dorsal and anal fins fringing the body and along the caudal encircle the body. Fins usually without spines.
6. Air-bladder absent in adults.

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

Order 13. Echeneiformes

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

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

Order 14. Tetradontiformes

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

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

Order 15. Lophiiformes

1. First ray of spinous dorsal fin placed on the head is transformed into a fishing organ consisting of a rod (illicium) and a lure called esca.

2. Mouth large with long pointed teeth.
3. Body with minute scales or scaleless.
4. Pelvic fins present or absent. Pectorals well developed.
5. Air-bladder absent.
6. Luminescent organs present.

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

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

1. Paired fins leg-like or lobed, with a fleshy, bony central axis covered by scales. Scales have a characteristic cosmoid layer.
2. Dorsal fins two, caudal fin heterocercal with an epichordal lobe.
3. Olfactory sacs usually connected to mouth cavity by internal nostrils or choanae.
4. Swim-bladder is modified into lung in some.
5. Intestine with spiral valve.

Subclass Sarcopterygii has been divided into two orders- (i) **Crossopterygii** and (ii) **Dipnoi.**

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

1. Body covered with large cycloid scales with enamelled surface.
2. The tail is diphycercal with a median lobe.
3. Presence of two dorsal fins of which the posterior one has a fleshy lobe. The paired fins have also fleshy lobes.
4. Presence of an internal nostril (Choana). Internal nares present or absent.
5. Notochord persists and vertebrae unossified.
6. Teeth with labyrinthine structure.
7. Respiration is performed by gills.

8. Swim-bladder is highly reduced and is neither hydrostatic nor a respiratory organ.

Example: *Latimeria chalumnae* (Coelacanth)

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

1. Body is covered by thin, large cycloid scales.
2. Paired fins with basal fleshy structures.

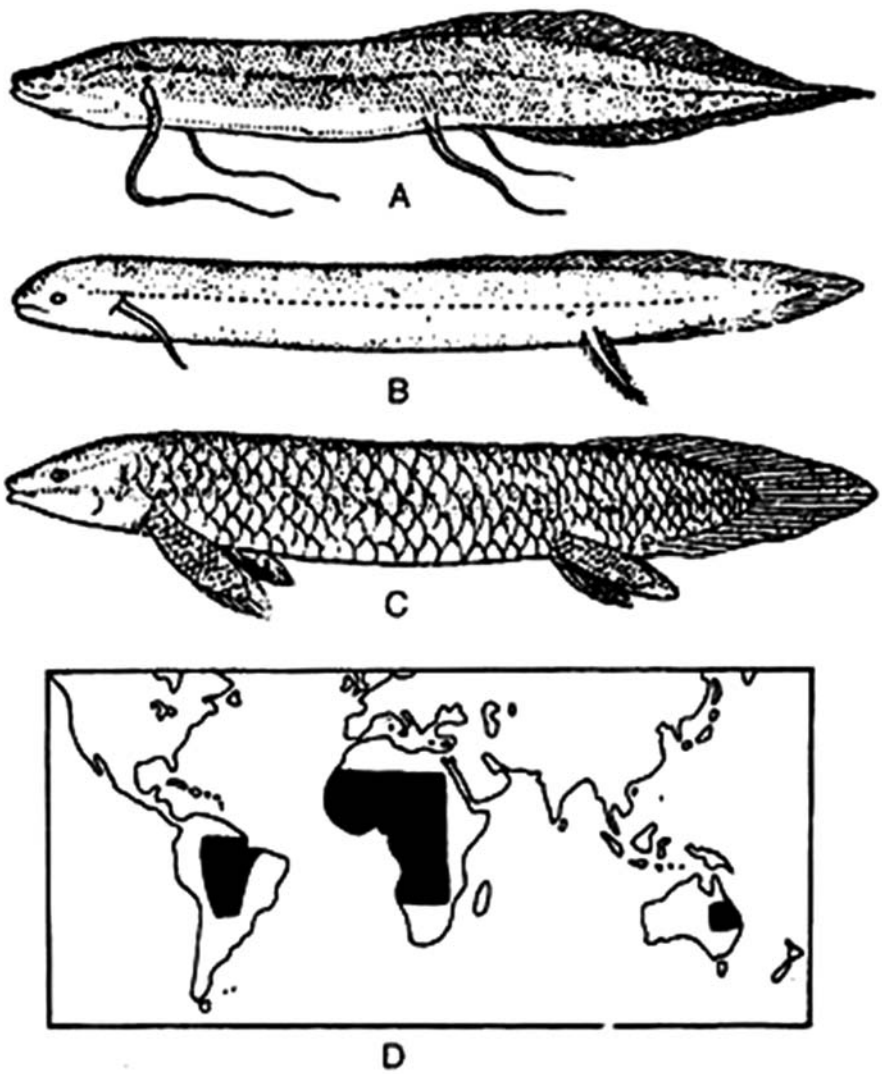

Fig. 13.4 : A. *Protopterus* (Arican), B. *Lepidosiren* (South American), C. *Neoceratodus* (Australian), D. Black areas of the map showing the distribution of three living lung fishes.

3. Caudal or tail fin symmetrical (diphycercal), with no trace of separate dorsal fins.
4. Single gill-slit on either side, covered by operculum.
5. Presence of two internal nostrils; spiracles absent.
6. Swim-bladder single or paired, modified into lung which is used in respiration.
7. Pulmonary and systemic circulation separate.
8. Small denticles are fused to form crushing tooth-plates.
9. Dermal bones on the skull.
10. Notochord remaining as an unconstricted rod.

Examples: Lung fishes - *Protopterus* of Africa, *Lepidosiren* of S. America and *Neoceratodus* of Australia.

There are three genera of Dipnoans found living till date. These lung fishes are mainly inhabitants of rivers and large lakes, they all breathe air. *Protopterus* lives in the large lakes of tropical Africa. *Neoceratodus* lives only in the Burnett and Mary rivers in Queensland, Australia. *Lepidosiren* lives in the rivers of tropical South America.

13.10 ❑ Questions

- Naik,

13.11 ❑ Suggested readings

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UNIT 14❑ Amphibia - General characteristics and Classification up to orders

Structure

14.1❑ Objective

From this unit learners will learn the diversity, general characteristics and classification of class Amphibia up to order.

14.2❑ Introduction

Amphibia, the first vertebrates to become partly adapted to life on land. In other words from evolutionary point of view they are the first vertebrates which tried to conquer land. They are a group of cold blooded (ectothermic or poikilothermic)) vertebrate animals characterized by their ability to exploit both aquatic and terrestrial habitats. The name *amphibia*, derived from the Greek *amphibios* meaning "living a double life," reflects this dual life strategy—though some species are permanent land dwellers, while other species have a completely aquatic mode of existence. Many adult amphibians are better adapted to life on land than in water, but their larval phases are entirely aquatic.Amphibians occur on all continents except Antarctica, but they are absent from many oceanic islands. Amphibians are tetrapods (Gk. tetra, four; podos, foot). The term tetrapod is a nontaxonomic designation that applies to all vertebrates other than fishes, and most tetrapods exhibit adaptations for life on land. They are known for moist glandular

skin devoid of epidermal scales, pentadactyle limbs, and presence of middle ear. This group arose in the Devonian period about 340 million years ago and was completed by the reptiles in course of time. The three thousand modern species are a mere remnant of this once-diverse group. Modern amphibians belong to three orders: Urodela or Caudata, the newts and salamanders; Anura or Salientia, the frogs and toads; and Gymnophiona or Apoda, the caecilians. Study of amphibians is known as Batrachology.

14.3 ❑ General characteristics and classification up to orders

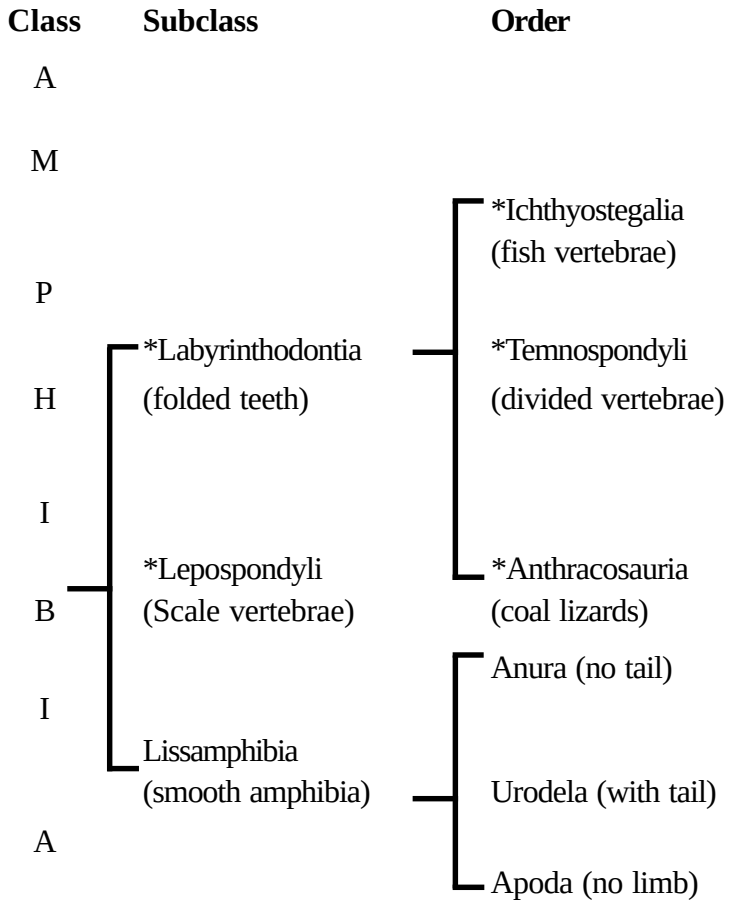
14.3.1 General characteristics of class Amphibia

1. Cold blooded (ectothermic or poikilothermic) vertebrates.
2. Amphibious in nature, viz., live both land as well as in water.
3. Body is divisible into head and trunk. Tail may be present in some amphibians.
4. Skin smooth, moist and glandular; integument modified for cutaneous respiration.
5. Usually without scales, in some apodans dermal scales are present and these are embedded in the skin (e.g., Caecilians).
6. Paired fins are absent. Unpaired fins may be present. Two pairs of limbs are used for locomotion except Caecilians.
7. The gills are present at least in the larval stage; some adult forms also carry external gills in addition to lungs (e.g., *Necturus, Proteus*).
8. Skull is dicondylic, i.e., with two occipital condyles for articulation with vertebral column.
9. The respiratory organs are bucco-pharyngeal cavity, skin, gills and/or lungs. Forms with aquatic larvae lose gills at metamorphosis but some retain gills and an aquatic existence throughout life.
10. The heart is three chambered, having two auricles and one ventricle. Presence of sinus venosus and conus arteriosus.
11. Kidneys are mesonephric or opisthonephric . Larvae and tailed amphibians (e.g., salamander) are ammonotelic. Frogs and toads are ureotelic.
12. Alimentary canal, urinary and reproductive tracts open into a common chamber called cloaca which opens outside through cloacal aperture.
13. Ear consists of internal and middle ear. Tympanum /eardrum (outer membrane) covers the middle ear.

14. Eyes are often with eye lids. In some eyes are lidless, reduced and covered by the skin or by the maxillary bones (caecilians).
15. Ten pairs of cranial nerves are present.
16. Lateral line system is found during their development.
17. Fertilization mostly external in frogs and toads but internal via a spermatophore in most salamanders and caecilians.
18. Moderately yolky eggs (mesolecithal) with jellylike membrane covering.
19. Predominantly oviparous, some ovoviviparous or viviparous; metamorphosis usually present.

14.3.2 Schematic diagram and Classification of living amphibians

The following classification is based on Young (1981). * marked subclasses and orders are extinct now, thus not been included here.



Class Amphibia is divided into following three subclasses:

1. ***Labyrinthodontia** (folded teeth) Extinct
2. ***Lepospondyli** (scale vertebrae) Extinct
3. **Lissamphibia** (smooth amphibia) Extant/Living

All the living amphibians are included under subclass Lissamphibia

Sub-class: Lissamphibia (Gk. lissos =smooth) (smooth amphibia)

General characteristics:

1. Found throughout the tropical and temperate areas of the world.
2. Possess a broad skull, the orbits enlarged into cheek and temporal regions.
3. Teeth are fang-like, i.e., pedicellate.
4. Vertebrae are monospondylics (i.e., wanting separate intercentra).
5. In the ear, auricular operculum and columella are present.
6. Scale-less smooth skin possess numerous glands.
7. Respiration through skin.

This sub class includes only three living orders: **Anura, Urodela and Gymnophiona**

Order-1: Anura (Gk. a= without; oura= tail) (Sometimes referred to as Salientia; L. saliens=leaping)

General characteristics:

1. These animals are short, four-legged, stout bodied and tailless.
2. They possess well developed eyelids and distinct tympanum
3. Large eyes are situated well ahead of the head.
4. Wide mouth, may or may not possesses tongue.
5. Hind limbs are longer and muscular and end in webbed feet.
6. Frontal and parietal bones of the skull are joined to form a single bone called frontoparietal.
7. Mandible is devoid of teeth.
8. There are five to nine pre-sacral vertebrae in the vertebral column.

9. The post-sacral vertebrae are fused to form a rod-like structure, called urostyle.
10. Vertebrae always possess zygapophyses and transverse processes except the atlas.
11. The tibia and fibula are fused at least proximaily and distally.
12. Fertilization is almost always external, and eggs and larvae are typically aquatic. Larval stages, called tadpoles, have well-developed tails. Tadpole larva metamorphoses to adult.

Anurans live in most moist environments, except in high latitudes and on some oceanic islands. A few even occur in very dry deserts.

Examples: *Duttafrinus melanostictus* (common Indian toad), *Hyla annectans*(tree frog), *Rana tigrina* (Indian Bull frog), *Rhacophorus malabaricus, Bufo melanostictus.* The distinction between "frog" and "toad" is more vernacular than scientific. "Toad" usually refers to anurans with relatively dry and warty skin that are more terrestrial than other members of the order.

The largest frog is the West African *Gigantorana goliath* (body length more than 30 cm). Largest American frog is the bullfrog (*Rana catesbiana*) (20 cm body length).

Order-2: Urodela (L.oura= tail; delos= showing or visible) or Caudata (Gk. caudos, =tail)

General characteristics:

1. These animals are lizard-like in appearance, with distinct head and a well-developed tail throughout life.
2. There are two pairs of weak limbs in the body.
3. In aquatic forms a lateral line system is present.
4. Small eyes are without lids. In cave- dwellers, eyes are lost.
5. Usually four pairs of aortic arches are present.
6. The columella in the middle ear is absent.
7. Kidney is opisthonephric type.
8. In the skull, cartilaginous elements are only found in occipital region.
9. The vomer and palatine are fused to form vomero-palatine.

10. Vertebrae may be amphicoelous or opisthocoelous, with ribs.
11. Simple pectoral girdle is composed of cartilage.
12. There is a Y-shaped bone epipubis attached to the pubis. .
13. They often possess external gills, a tail fin, larval dentition, and a rudimentary tongue
14. Fertilization is generally internal. .
15. The aquatic larval stage usually metamorphoses into a terrestrial adult. Many other undergo incomplete metamorphosis and are paedomorphic (e.g., Necturus); that is, they become sexually mature while still showing larval characteristics.

Examples: *Tylototriton verrucosus (*Only Indian urodele, also known as Darjeeling salamander), *Ambystoma, Triton, Necturus, Salamandra, Triturus.*

Additional information

Members of the order Urodela or Caudata are the salamanders. Most terrestrial salamanders live in moist forest-floor litter and have aquatic larvae. A number of families live in caves, where constant temperature and moisture conditions create a nearly ideal environment. Salamanders in the family Plethodontidae are the most fully terrestrial salamanders in that their eggs are laid on land, and the young hatch as miniatures of the adult. Members of the family Salamandridae are commonly called newts. They spend most of their lives in water and frequently retain caudal fins. Salamanders range in length from only a few centimeters to 1.5 m. The Japanese giant salamander, *Andrias japonicas* grows to a length of 5 feet. It is the largest living amphibia. The largest North American salamander is the hellbender (*Cryptobranchus alleganiensis*), which reaches lengths of about 65 cm. Most salamanders have internal fertilization. Males produce a pyramidal, gelatinous spermatophore that is capped with sperm and deposited on the substrate. Females pick up the sperm cap with the cloaca and store the sperm in a special pouch, the spermatheca. Eggs are fertilized as they pass through the cloaca and are usually deposited singly, in clumps, or in strings. Larvae are similar to adults but smaller. They often possess external gills, a tail fin, larval dentition, and a rudimentary tongue. The aquatic larval stage usually metamorphoses into a terrestrial adult. Many other salamanders undergo incomplete metamorphosis and are paedomorphic (e.g., *Necturus*); that is, they become sexually mature while still showing larval characteristics. The famous larva of *Ambystoma tigrinum is* Axolotl.

Order-3: Gymnophiona (Gk. gymnos=naked; ophineos=like a snake) Also known as Apoda ((Gk.a=absent; podos=foot)

General characteristics:

1. These are worm-like, limbless burrowing creatures.
2. Body smooth, slimy and externally segmented by a series of annular grooves within which small, granular dermal scales are embedded.
3. Lidless eyes are reduced and covered by the skin or by the maxillary bones, thus, caecilians are probably nearly blind.
4. A peculiar conical flap-like retractile (protrusible) sensory (chemosensory organs) tentacle between their eyes and nostrils may transport chemicals from the environment to olfactory cells in the roof of the mouth.
5. Both the tympanum and tympanic cavity are absent.
6. Tongue is fused with the floor of the mouth cavity.
7. Tail, if present, is short and conical.
8. Skull is solid and compact. Maxilla and palatine fused to form maxillopalatine.
9. Teeth are present on the premaxilla, maxillopalatine, vomer and dentaries.
10. Vertebrae are amphicoelous and with persistent notochord.
11. Pectoral and pelvic girdles are absent. There is no sternum.
12. Intestine is straight.
13. Only right lung is well developed.
14. Only pulmonary and systemic arches are present.
15. Fertilization may be external or internal.
16. The eggs are large and yolky.

Examples: *Ichthyophis* (India), *Uraeotyphlus malabaricus* (South India), *Gegenophis* (South India).

Members of the order Gymnophiona are known as the caecilians. Zoologists have described about 160 species confined to tropical regions. Caecilians are wormlike burrowers that feed on worms and other invertebrates in the soil. The total length of the

restored specimen is about 65 cm. 21 species of caecilians under 4 genera and 3 families are so far known from India, mainly concentrate in the Western Ghats but also in the Eastern Ghats and North Eastern India.

14.4 ❑ Questions

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UNIT 15❑ Reptilia- General characteristics and Classification up to living orders

Structure

15.1❑ Objective

From this unit learners will learn the diversity, general characteristics and classification of class Reptilia up to orders.

15.2❑ Introduction

Reptiles are the true land vertebrates that left the habit of going to water for laying eggs. In fact, the emergence of reptiles as the true land-dwelling vertebrates offers the greatest dramatic event in the course of evolution. Reptiles are thus regarded as first true land adapted animals (as they began to lay eggs in terrestrial conditions as a first step towards successful land adaptation). To protect the embryo from desiccation the embryo was covered by extra embryonic membranes like amnion, chorion, allantois and yolk sac. Due to presence of amnion as one of the extra embryonic membranes reptiles are regarded as **first amniote animals.** Reptiles, birds and mammals are known as **amniota** (amphibian and fishes lack these membranes, hence are called **anamniota**). The amniotic egg has played an important role in vertebrates' successful invasion of terrestrial habitats, it is one of many reptilian adaptations that have allowed members of this class to flourish on land.

They had evolved from ancient labyrinthodont amphibians during Carboniferous period, about 270 million years ago. The reptiles dominated the earth in their early phase of evolutionary history in Mesozoic Era (the age of reptiles which lasted for more than 165 million years,) and are represented today by a few divergent specialised forms. Like amphibia reptiles are also tetrapod vertebrates that either have four limbs or limbless snakes.

Reptiles are poikilothermic or ectothermic (organisms, having a body temperature that varies with the temperature of its surroundings), true terrestrial animals (breath by lungs, gills totally absent), although some are adapted to aquatic life. Their bodies are covered with dead dry cornified epidermal scales and scutes and digital tips are usually provided with claws and they appear to be crawling or creeping during locomotion, hence the name Reptilia (L. reptus, to creep or to crawl). Most reptiles are oviparous, although some of them are viviparous. Living representatives of the class Reptilia include the turtles, lizards, snakes, worm lizards, crocodilians, and the tuatara. The existing reptiles belong to four out of the dozen or more main lines that have exis-ted. The most successful modern forms are placed in the order Squamata, the lizards and snakes, the latter being of relatively recent appearance in their present state. Secondly, the tuatara, *Sphenodon* of New Zealand is a relic surviving with little change from the Triassic beginnings of this group. Thirdly, the crocodiles are an older offshoot from the stock from which the modern birds were derived. Finally, the tortoises and turtles (Chelonia) have retained, in some respects, the organization of still earlier times. These four modern types are all that remain of the reptiles that flourished throughout the Mesozoic, culminating in the giant dinosaurs of the Jurassic and Cretaceous. The study of reptiles is called herpetology.

15.3 ❑ General characteristics and classification up to living orders

1) Skin is dry, cornified and usually covered by epidermal scales or scutes. Skin glands are absent except a few integumentary scent glands secreting pheromones to attract opposite mates during breeding seasons.

2) Skeleton well ossified; Vertebrae are procoelous.

3) Sternum is greatly developed with ribs (sternum absent in snakes).

4) Single external nasal opening is present on the snout.

5) Vomero-nasal organ (organ of Jacobson) is well-developed.

6) Single occipital condyle (a protuberance where the skull attaches to the first vertebra, the atlas).

7) Two pairs of pentadactyle limbs which end in clawed digits. Limbs reduced or absent in snakes and limbless lizards and paddle like in marine turtles.

8) The cloaca opening is either transverse or longitudinal.

9) A post-anal tail is present.

10) The heart is composed of two auricles and a partially divided ventricle (in crocodile the ventricle is completely divided, thus heart is four chambered).

11) Respiration always by lungs. In marine turtles, cloacal respiration occurs.

11) Presence of twelve pairs of cranial nerves.

12) The kidney is metanephric type.

13) Males possess copulatory organs except *Sphenodon*.

14) Eggs are much yolky, laid on land. The calcareous shell serves for protection against desic-cation and external injury. The shell is porous for gaseous exchange.

15) Fertilization is internal.

16) Cleavage meroblastic. Embryos are provided with extra--embryonic membranes, like amnion, chorion, yolk sac and allantois. Reptiles are thus amniotes.

17) Most reptiles are oviparous, although some species of squamates are viviparous.

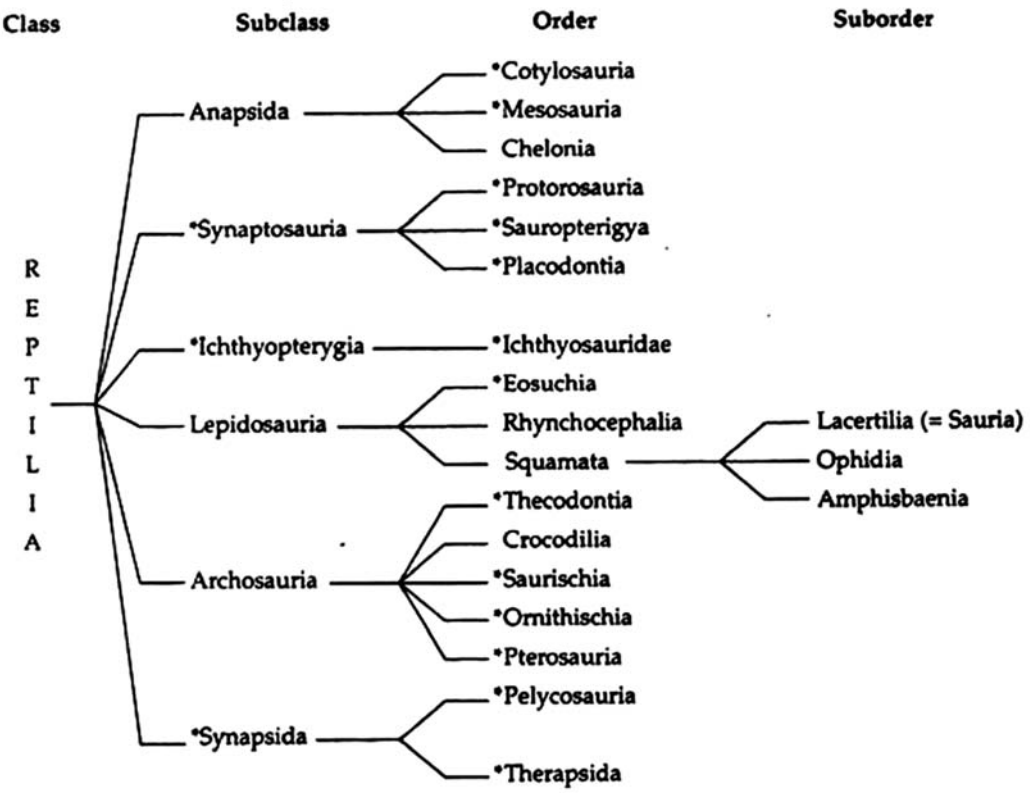
18) Parental care is noticed in some.

Reptiles are ectothermic or heliothermic (Gk.helios =sun) animals. They use solar energy either directly or indirectly for temperature regulation.

15.3.2 Classification of class Reptilia with characters up to orders

Although different scientists classified Reptilia based on the characters of different reptilians, but here the classificatory scheme proposed in **'The life of vertebrates' by J. Z. Young (1981)** is followed. The detail discussion on general characteristics is made only for extant (living) orders. The (*) marked sub-classes and orders are considered as extinct.

Classification scheme of Reptilia



*indicates extinct groups

Out of above 17 orders under 6 subclasses**, only 4 living orders are there.**

Subclass-1: Anapsida (without an arch)

General characters:

1. The skull is devoid of fossae in the temporal region (behind the eyes).
2. The roof of the skull is solid (all skull bones are firmly united to each other).

The members of the extinct order **Cotylosauria** under this subclass are considered as **"stem reptiles"** from which other reptiles have probably been evolved.

Order: Chelonia (Testudinata) (Gk. Chelone = a tortoise; L.testudines=a tortoise)

General characters:

1) Body is dorsoventrally flattened and more or less elliptical.

2) Body is encased by a convex dorsal shield like **carapace** and a flat ventral plate, **plastron**. The shell is externally protected either with polygonal scutes or leathery scales.

3) Neck, limbs and tail are retractile. Tail is very short.

4) Limbs are weak pentadactyle and modified into paddles in marine forms.

5) In adults, teeth are absent and the jaws are covered by sharp horny plates.

6) In the skull, quadrate bone is immovably articulated, i.e., monimostylic.

7) Thoracic vertebrae and ribs are usually fused with carapace.

8) Pectoral girdle consists of a scapula, a long pro-coracoid, and a coracoid.

9) The pelvic girdle is composed of ilium, ischium, and pubis.

10) The cloacal opening is longitudinal. In male the copulatory organ remains attached to the ventral wall of cloaca.

11) They are oviparous animals.

Examples: *Trionyx* (Indian soft shell turtle), *Chelone* (Green turtle), *Testudo*, *Dermochelys* (Leather back turtle) *Lepidochelys olivacea* (Olive Ridley turtle) etc.

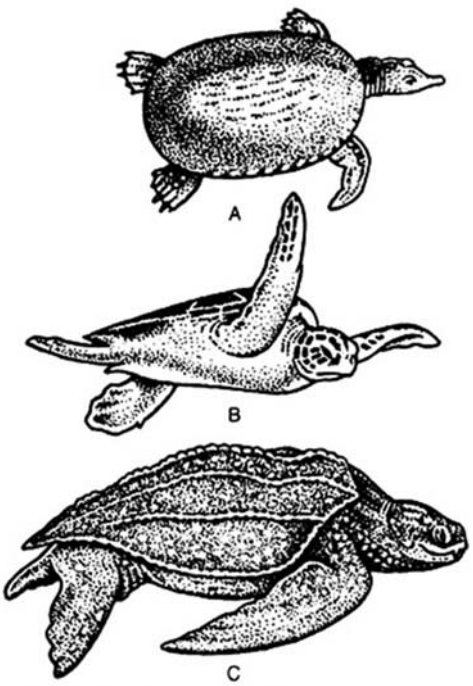


Fig. 15.1 : A. Tryonix, B. *Chelone*, C. *Dermochelys*

II. Subclass-2: Lepidosauria (Gk., lepis = scale; sauros = lizard)

General Characters:

1) The skull of this group is diapsid type with two temporal vacuities.
2) Lizard-like reptiles with scaled skin.

This subclass includes two living orders-

(i) Rhynchocephalia and **(ii) Squamata.**

Order-1: Rhynchocephalia (Gk., rhynchos = a beak/snout; kephale = a head)

Beaked upper jaw.

General characters:

1) Body is lizard like, measuring about 70 cm in length, dull olive green in colour with yellow spots above and whitish below.
2) Dorsal side is covered by small granular scales and on the ventral side the scales are trans-formed into transverse square plates of larger size.
3) Tail is laterally compressed and crested with power of regeneration if lost.
4) At the dorsal side a median row of erective spines (frill) extends from the top of the head to the tip of the tail but is interrupted at the neck region (Fig.).
5) The eyes are large, dark brown in colour with vertical pupil.
6) The teeth are of acrodont type and are fused with the subsequent bone (primitive feature).
7) Vomerine teeth are present in youngs but in adults these are replaced by pads.
8) The skull is typically built on the lepidosaurian plan (diapsid skull) and composed of paired premaxillae, nasals, frontals, and parietals.The quadrate is immovable. A parietal foramen is present.
9) An epipterygoid bone (the bone connecting ptreygoid and parietal) is present.
10) A so- called proatlus is present.
11) Vertebrae have amphicoelous centra with intercentra and persistent notochord (primitive feature).
12) Almost all the vertebrae possess chevron bone.

13) Abdominal ribs are present (primitive feature). The ribs are single headed and bony.

14) The three main arches instead of emerging independently from the ventricle, come off by a short common trunk (primitive feature).

15) The brain is simple with a very well developed parietal organ (third eye) or pineal eye (primitive feature).The third eye is made up of a lens, a retina with a nerve connected to the brain, but iris is absent.

16) The cloacal aperture is a transverse slit.

17) Males do not have copulatory organ.

18) The fertilized eggs take over a year to hatch.

Examples: *Sphenodon punctatus* and *Sphenodon guntheri*. (Only two species are known).

Sphenodon is the oldest surviving lepidosaurian reptile and because of its retention of many primitive characteristics of its extinct relatives (that radiated mostly during the early Mesozoic era but declined toward the end of the Mesozoic), it is considered as a living fossil. They are popularly known as “Hatteria” or “Tuatara”. Tuatara is a Maori word. Maori is a tribe of New Zealand. Several species of tuataras were once widespread throughout the two main islands of New Zealand but the two living species are now restricted to about 20 small islands off the cost of New Zealand. *Sphenodon* represents one of the slowest rates of morphological evolution known among vertebrates. They are slow-growing animals with long lives; one is recorded to have lived 77 years.

The third eye of *Sphenodon* does not form retinal image. It helps to recognize environmental photoperiods for seasonal and circadian rhythms (biological rhythms). It may also help with orientation and navigation.

Order-2: Squamata (Latin, sqamatus = scaly)

General characters:

1) The skull of these animals bears superior temporal fossa.

2) The maxilla, palatine and pterygoid are immovably articulated with the skull.

3) The quadrate is movable.

4) Lower jaw is composed of several pieces of bones.

5) Teeth are either acrodont or pleurodont type and are borne usually on the maxillae, premaxillae and palatines.

6) Skin with keratinized epidermal scales or plates, which shed at regular intervals.

7) Organ of Jacobson is well-developed.

8) Vertebrae are of procoelous type and possess chevron bone.

9) The ribs are single-headed.

10) Cloacal aperture is a transverse slit.

All lizards and snakes are included in this order. The lizards and snakes possess distinct characteristic features.

This order Squamata is divided into three suborders — Lacertilia, Ophidia, and Amphisbaenia.

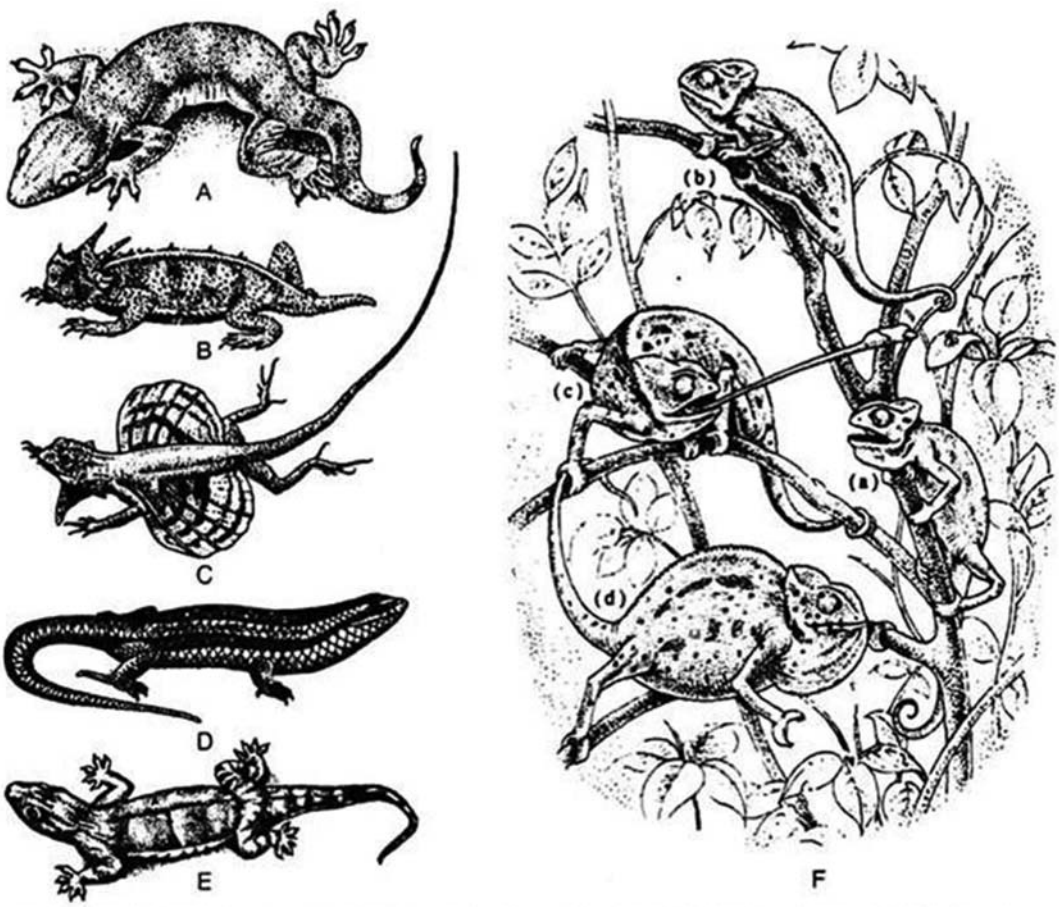


Fig. 15.2 : A. *Gekko*, B. *Pharynosoma*, C. *Draco*, D. *Mabuya*, E. *Hemidactylus*, F. *Chamaeleo* (= Chamaeleon)

Examples of sub order Lacertilia (commonly known as Lizards): *Phrynosoma* (the horned toad lives in the deserts of Mexico and South-western USA) *Chamaeleo* (= *Chamaeleon) zeylanicus* (Only Indian species) *Leiolepis, Uromastyx hardwickii* (found in the arid zones of Rajasthan, Punjab and U.P.). *Calotes versicolor* (Garden lizard of India), *Draco* (Flying lizard) *Moloch horridus* (Thorny devil or spiny lizard of Australia), *Gekko* (Giant house lizard of India) *Hemidactylus* (Common house lizard), *Mabuya* (Common shink) (*Ophisaurus gracilis* (known as Burmese glass snake, is the only Indian limbless lizard), *Varanus bengalensis, Heloderma* (USA, the only poisonous lizard of the world).

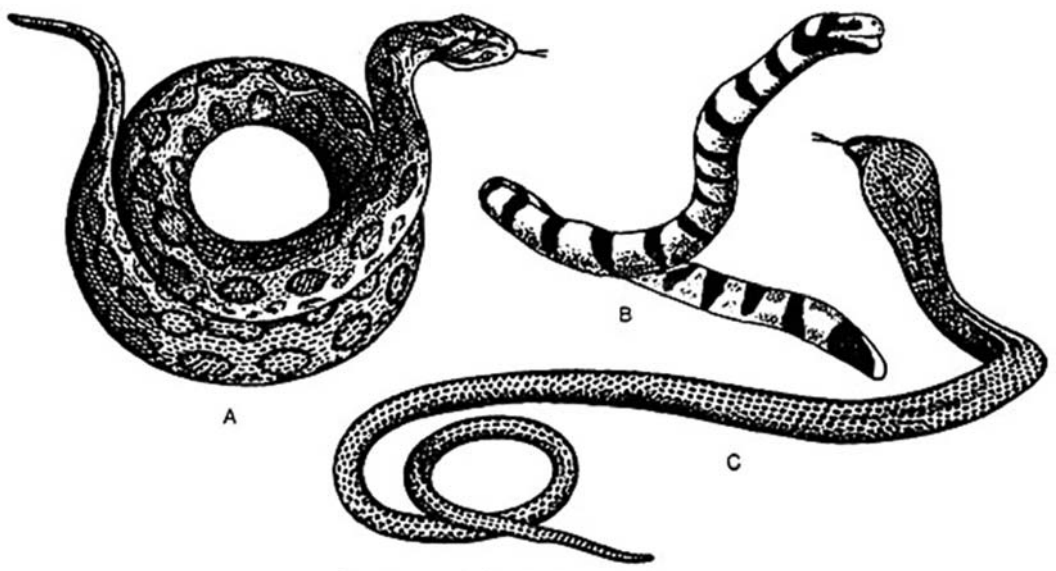


Fig. 15.3 : A. *Python,* B. *Hydrophis,* C. *Naja*

Examples of sub order Ophidia (commonly known as Snakes):

Python molurus (Indian rock python) *Boa constrictor* (Boa), *Eryx johni* (Red sand boa), *Typhlops acutus* (beaked Indian blind snake), *Ptyas mucosus* (rat snake), *Chrysopelea oruata* (flying snake), *Elachistodon westermanni* (Indian egg eater snake), *Naja naja* (Cobra) , *Bungarus* (Krait), *Vipera russelli* (India, russells viper), *Hydrophis* (Sea snake) etc.

Examples of sub order Amphisbaenia*: Amphisbaena fuliginosa* (South America and West Indies), *Blanus* (Medite-rranean region). They can crawl easily in both backward and forward direction.

Subclass-2: Archosauria (Ruling reptiles)

General characters:

1) The skull is of diapsid type and lacked inter-parietal and parietal foramina.
2) Presence of anteorbital fenestra (opening in the skull anterior to the orbit).
3) Some forms are toothless and in others only palatal teeth are lost.
4) The lower jaw is with vacuities between dentary and angular.
5) In some advanced forms bipedality (two footed locomotion) was well marked and the girdles were modified accordingly.

This subclass includes only one living order: Crocodilia

Order: Crocodilia /Loricata (Latin: Crocodilus = a crocodile)

Among the major groups of reptiles, the order Crocodilia includes the largest forms of living reptiles.

General characters:

1) Predatory (carnivorous), Semi-aquatic reptiles.
2) Large, solidly built, lizard-like body. Swim by the undu-lation of powerful laterally compressed tail.
3) They creep on land with the help of their less powerful limbs.
4) Pentadactyle limbs, forelimb possesses webbed digits. Forelimbs usually with five digits; hind limbs with four digits.They creep on land with the help of their less powerful limbs.
5) Long flattened snouts. Eyes, ears, and nostrils at the top of the head.
6) They have conical, peg-like teeth and a powerful bite. Teeths are thecodont, present on premaxi-llae, maxillae and dentaries.
7) The skin is thick and bears epidermal scales. The scales are supported by dermal bones or scutes.
8) The quadrate is large and immovable.
9) Vertebrae are either amphicoelous or procoelous type. The caudal vertebrae are provided with chevron bones.

10) The vertebral column is divisible into cervical, thoracic, lumbar, sacral and caudal regions.

11) Sternal and abdominal ribs are present. Sternal ribs have uncinate process. Most of the ribs are double-headed.

12) They have a four chambered heart.

13) An incipient diaphragm is situated between thoracic and abdominal wall.

14) The eyes are provided with pecten.

15) The cloacal aperture is longitudinal.

16) Males are provided with single and median erectile copulatory organ. A clitoris is present in female.

17) Females lay eggs in holes or in mounds and unlike most other reptiles, care for their hatched young.

Examples: *Alligator mississippiensis* (American), *A. sinensis* (China), *Crocodylus palustris* (Indian), *C. porosus* (salt water crocodile of Indo-pacific region), *C. niloticus* (Nile River), *Gavialis gangeticus* (Gharials of India, Ganga River). *Crocodylus porosus* can reach over 6 meters (19.7 feet) in length and weigh over 1000kg.

15.4 ❑ Questions

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15.5 ❑ Suggested readings

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UNIT 16 ❑ Class Aves. General characteristics and Classification up to orders

Structure

16.1 ❑ Objective

From this unit learners will learn the diversity, general characteristics and classification of class Aves up to order.

16.2 ❑ Introduction

Birds are traditionally classified as members of the class Aves (L. avis, bird). They are a group of endothermic vertebrates, characterized by feathers, toothless beaked jaws, hard shelled eggs, a four-chambered heart, a high metabolic rate, appendages modified as wings,a vertebral column modified for flight and a strong light weight skeleton (bones lightened by numerous air spaces). They constitute a highly specialized group of vertebrates exhibiting adaptations for flight and have attained the peak of evolutionary perfection. They are essentially “glorified reptiles” and the discovery of fossil of Archaeopteryx, amply speaks about the reptilian origin of birds. The evidence indicates that crocodilians and birds are more closely related to each other. Many species of birds are economically important as food for human consumption and raw material in manufacturing process. Domesticated and undomesticated birds (poultry and game) being important sources of eggs, meat, and feathers. Peacock is the national bird of our country. The birds are the

most beautiful among the animals. They show courtship, nest building, parental care, migration and territorial behaviour.

16.3 ❑ General characteristics and classification up to orders

16.3.1 General characters of class Aves

1) Birds are bipedal and warm blooded (homeothermous or endothermic) animals i.e., they are able to maintain a constant body temperature.

2) Most of them can fly except flightless birds (e.g., Ostrich).

3) Birds have spindle-shaped body which is highly aero dynamically suitable and covered with fea-thers (presence of feathers is monopoly to class Aves). Body has three distinct divisions with a flexible neck.

4) Fore limbs are modified as wings, which is powered by strong flight muscles. The hind-limbs are adapted for walking, hopping, grasping, perching, wading and swimming and usually bear four, sometimes three and rarely two clawed digits. Legs bear horny epidermal scales.

5) Mouth is provided with a specialised and projecting exoskeletal derivative called beak or bill provided with horny sheath. Teeth are absent in Birds. Beaks are adapted to many ways of feeding; seed-crushing, fruit-scooping, flesh-tearing, nectar-sipping, wood-chiselling and so on.

6) Except uropygium gland (preen gland or oil gland), at the base of the tail, no skin gland is present.

7) Endoskeleton is fully ossified (bony) and the long bones are spongy or hollow with air cavities (pneumatic) to reduce body weight.

8) The skull is monocondyllc, i.e., with one occipital condyle; sutures obliterated.

9) Pelvic girdleis fused with a number of lumbar and sacral vertebrae forming synsacrum, which is only seen in birds.

10) Tail vertebrae few and compressed posteriorly forming pygostyle in modern birds.

11) Sternum enlarged, usually with a median keelfor the attachment of flight muscles. The clavicle and inter clavicle join to form V-shaped furcula. This keeps the wings away.

12) Brain is better developed than that of reptiles. Cerebrum, cerebellum and optic lobes are quite large. Eyes of birds possess pecten. Birds have 12 pairs of cranial nerves.

13) The lungs are spongy and inelastic and connected to thin-walled air sacs for supplement respiration. Specialised respiratory system performs double respiration.

14) The larynx does not act as a voice box. Voice is produced by a special sound producing organ, the syrinx situated at the lower end of the trachea near the origin of the two bronchi.

15) The heart is four-chambered with two auricles and two ventricles. Only right aortic arch is present. Sinus venosus is absent. Renal portal system is very much reduced. Unlike mammals, red blood corpuscles are nucleated, oval and biconvex.

16) The alimentary canal has additional chambers, the crop and gizzard. The crop stores and softens the food; however, the gizzard helps in crushing and churning the food.

17) Cloaca is divided into three chambers — coprodeum, urodeum and proctodeum.

18) Kidney is metanephric type. Excreta is semisolid. Urinary bladder is absent except *Rhea Americana* (American Rhea— also called "South American Ostrich". This isthe only bird that has urinary bladder). Birds are uricotelic (chief nitrogenous waste is uric acid).

19) Females usually with only left ovary and oviduct.

20) Fertilization is internal. Birds are oviparous animals having eggs with large amount of yolk, telolecithal. Cleavage is meroblastic.

21) During embryonic development four types of extra-embryonic membranes appear. These are, amnion, chorion allantois and yolk sac. Birds are thus amniota.

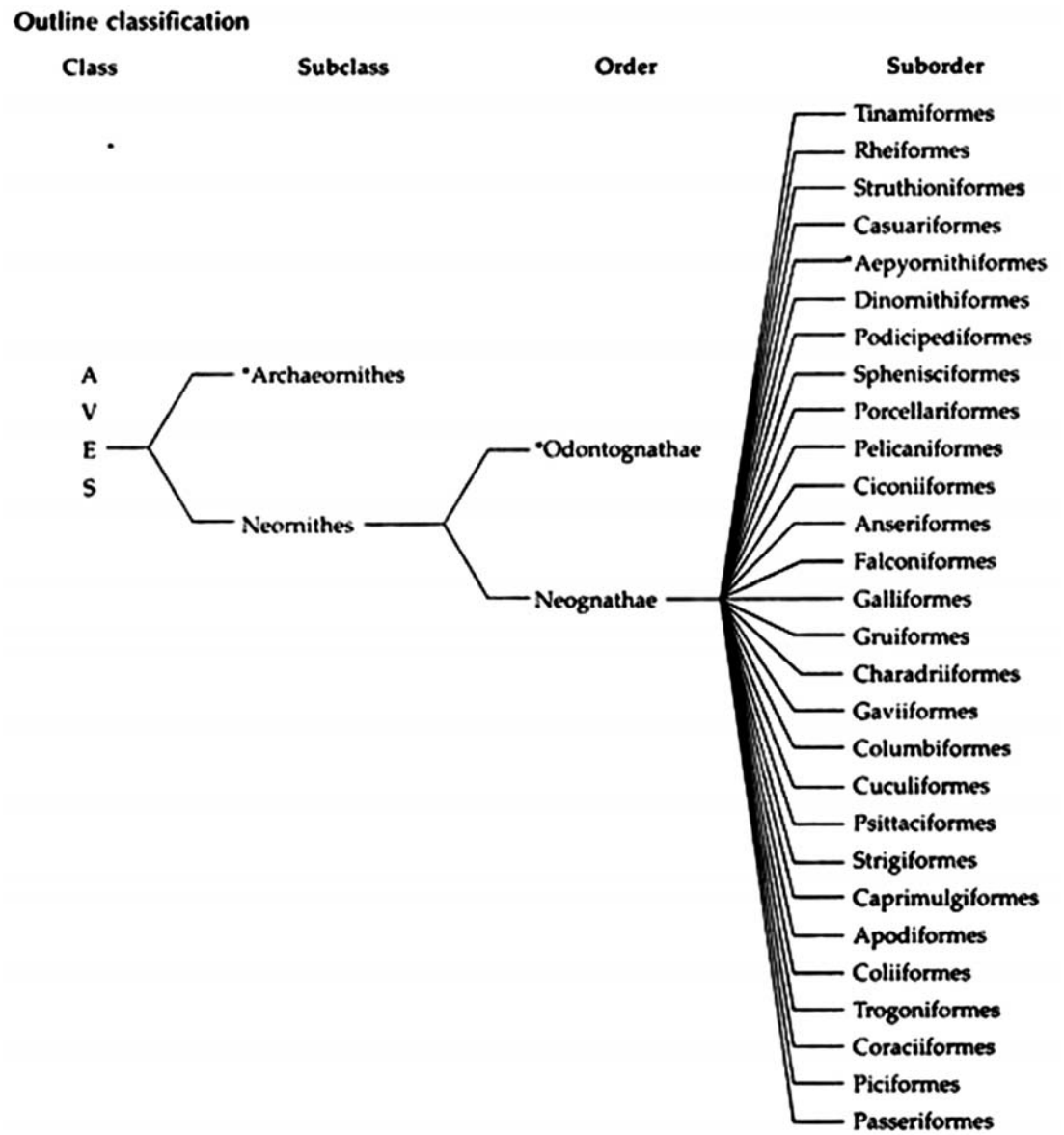
22) Many birds show sexual dimorphism.

23) Parental care is well marked in almost all birds.

16.3.2 Classification of class Aves with characters up to orders

Classification scheme

As in other chordates, Class Aves is also classified in various ways by various authors. The scheme of classification adopted here is based on Young (1981).



Class Aves has been divided into two subclasses:

1. Subclass *Archaeornithes and ***2. Subclass Neornithes***

1. Subclass *Archaeornithes [Gk. Archios = ancient + ornithos = bird] (extinct)

This subclass includes most primitive, fossil birds of Jurassic period and are known from Germany.

Characters:

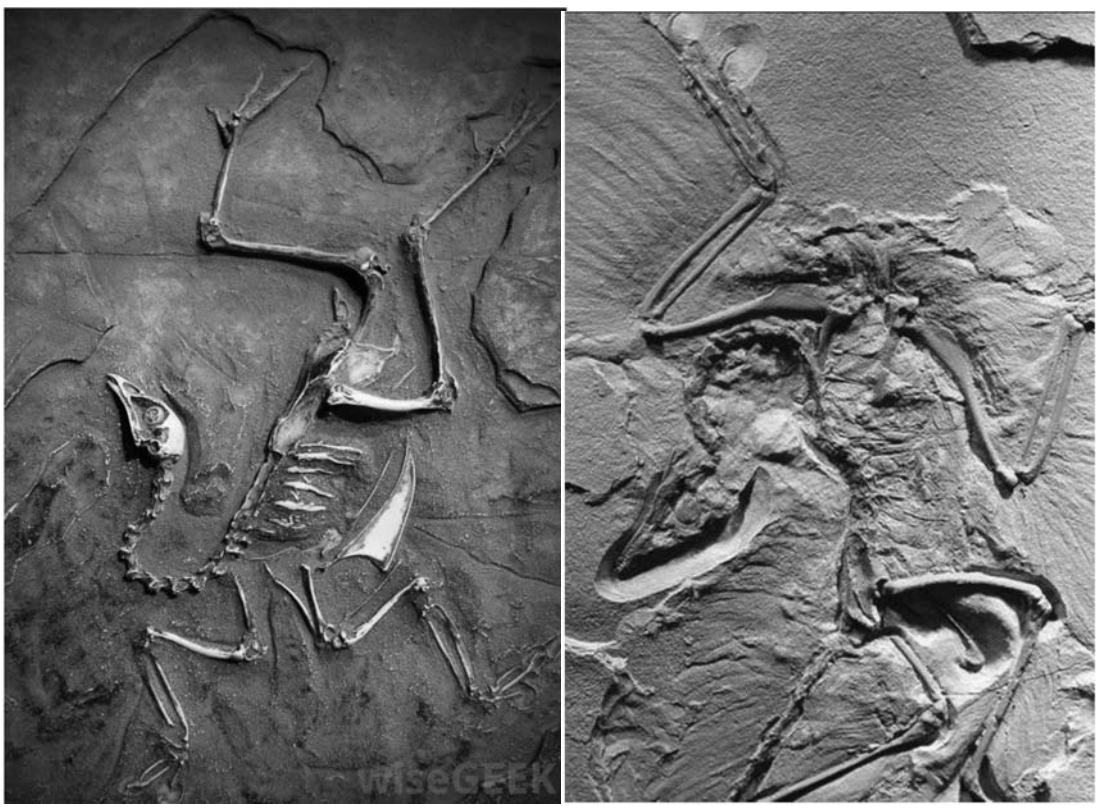
1) Wings had primitive feathers.
2) Tail feathers were arranged in a row along each side of a long tail.
3) The tail was long and slender with 21 separate vertebrae.
4) The forelimbs were modified as wings.
5) The carpals and metacarpals were free. The hand had three clawed digits.
6) The beak was well-developed. Thirteen pairs of conical socketed teeth were present in the upper jaw and three pairs of similar teeth were present in the lower jaw.
7) The skull had round cranium and a single occipital condyle.
8) The zygomatic arch was fairly deve-loped.
9) The parietals were completely fused and inter-parietal foramen was absent.
10) The inter-orbital septum was slightly developed and the orbit was provided with sclerotic ossicles.
11) The quadrates were small.
12) The mandible was a complex skeletal structure,
13) The vertebrae were amphicoelous.
14) Thoracic ribs were without uncinate processes.
15) The pygostyle was absent.
16) The abdominal ribs were present like *Sphenodon.*
17) Flat sternum was devoid of keel.
18) The pectoral girdle has rudimentary coracoid, distinct T-shaped interclavicle and narrow curved scapula.
19) The pelvic girdle had large plate-like ilium, having distinct pre- and post acetabular regions. The ischium had a thin foramen. The pubis was narrow, rod- like and backwardly directed.
20) The synsacrum was absent and the sacral region consisted of six vertebrae.
21) Humerus was short and stout. The ulna was stronger than radius. The carpals and metacarpals were free excepting the 3rd metacarpal which was fused with carpal.

22) The tibia and fibula were separate and were of equal length. Each foot was made up of tarsometatarsus and four digits.

23) Small and opposable hallux resembled that of modern birds.

24) These fossil birds had long, slender and smooth cerebral hemisphere. The cerebellum was small and placed behind the mid-brain. In spite of this reptilian feature of brain, it is assumed that these birds were warm-blooded.

The subclass includes single genus of fossil bird having a single species, ***Archaeopteryx lithographica***.



Fossil *Archaeopteryx*

2. Subclass Neornithes [Gk. Neos= modern] (Cretaceous — Recent)

This subclass-includes remaining fossil and living birds.

1) In most of these birds, the short tail has a terminal pygostyle with semi circularly arranged feathers.

2) In most members, the teeth are absent.

3) The metacarpals and carpals unite to form carpometacarpus.

4) Digits are usually clawed.

5) Well-developed sternum bears a distinct **keel or carina.**

6) Generally 13 or less caudal vertebrae are present.

The subclass includes two super orders:

Odontognathae (extinct) **and Neognathae** (extant)**.**

1. Superorder Odontognathae (Gk. Odontos = teeth + gnathos = jaw) Cretaceous birds

This superorder includes fossil birds which flourished during Cretaceous period to explore the resources of the sea.

Characters:

1) All the members were flightless and adapted to aquatic life.

2) All these birds were provided with teeth.

3) The brain was more like modern birds than the reptiles.

4) The quadrate was single and basipterygoid process was absent.

5) The pectoral girdle was much reduced and clavicles were not united.

6) The bones of the pelvic girdle were free posteriorly. They were absolutely flight-less birds.

7) The forelimb was represented only by humerus.

8) The strongly built hind limbs were with laterally directed feet having webbed toes.

9) Presence of a short tail and reduced hand.

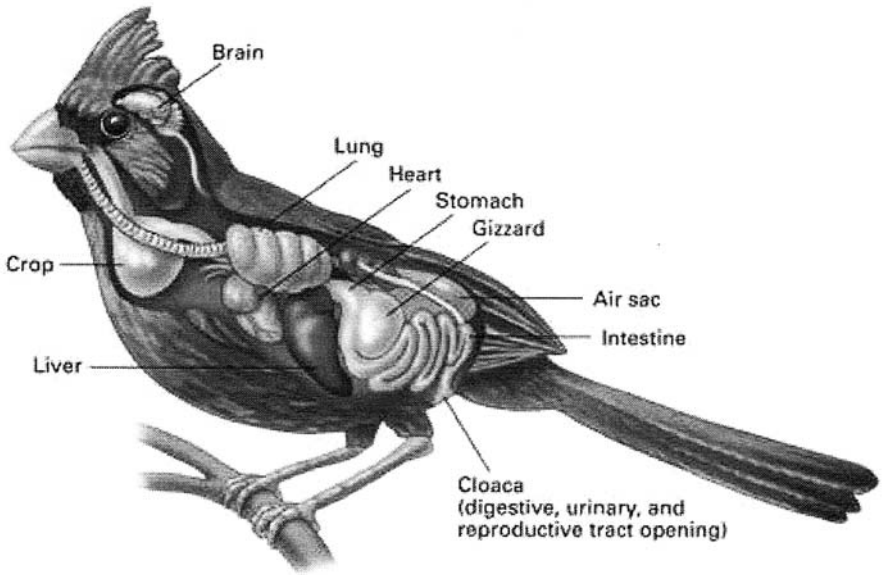
The examples are *Hesperornis,Baptornis, Neogaeornis* and *Ichthyornis.*

*Hesperornis*h had reduced wings and jaws modified to catch fish. They were divers.

2. Superorder Neognathae [Gk. Neos = modern]

Characters:

1) The slender vomer separates the palatines imperfectly.



Fossil *Archaeopteryx*

2) The palatines are protruded posteriorly to be in contact with the base of the cranium and remain movably articulated with small pterygoids. This type of jaw arrangement is known as **neognathous** condition.

3) Except some the sternum is well-developed and with **keel.**

Some flightless birds such as ostrich, cas-sowary and kiwi are included under this superorder Neognathae recently. Parker and Haswell (1964) and many other zoologists included these ratites or flightless birds under the superorder Palaeognathae for the primitive structure of the palate.

This superorder includes following 28 orders of which only one is extinct.

1. Order Tinamiformes (tinamous)

Characters:

1) Their wings are smaller in comparison to body size. Therefore, they are not good flier.

2) The size varies from that of Quail to a Partridge.

3) Tail is either absent or very small. Pygostyle is degenerated. When chased, these terrestrial birds run and can fly a short distance.

4) The keel is present, but the appearance of palate is palaeognathous.

5) Legs are tall and powerful with strong musculature.

6) The eggs have peculiar shining white shell and are incubated by the males.

The birds under this order are found in Southern Mexico, Central and South America.

The order includes a single family Tinamidae having more than forty-five species. The most common species are *Crypturellus variegatus* (Variegated Tinamon) and *Eudromea elegans* (Crested Tinamon) and T*inamus* (Running birds of South America).

2. Order Rheiformes (Rheas)

Characters:

1) Large flightless birds. The height of a male bird is about 165 cm.

2) Very few feathers are present on head and neck regions.

3) Sternum without keel.

4) Each hind limb has three clawed toes which are webbed at the base.

5) During breeding season, the males select and segregate with 3-7 females to form a harem.

6) The nest is dug by the male and all the females lay eggs in the same nest. Nearly fiftylemon-yellow eggs are laid in a season and the male incubates themfor about 40 days.

These birds are found in South America. These running birds live in groups. Food varies from vegetable products to insects.

Examples: *Rhea americana,* and *Pteronemia pennata*.

3. Order Struthioniformes (Gk. struthio = ostrich)

Characters:

1) Flightless, terrestrial omnivorous birds. The height is nearly 240 cm and weight is about 136 kg. It is considered as the largest living bird in the world.

2) Feathers are without after shaft.

3) Head comparatively small, long neck is devoid of feathers.

4) Prominent eyes have lashes on the upper eyelid.

5) Wings are small and usually kept folded during running, but may be expanded to work as a brake or steering.

6) Two wing fingers are clawed which are used for defence.

7) Tail feathers are replaced by long tail coverts.

8) Very powerful legs that are armoured, with strong third and fourth digits (only 2 toes).

9) Keel is absent in sternum.

10) Presence of pubic symphysis. Pygostyle absent.

These birds are distributed in Africa and Arabian countries.

The order includes ostriches, *Struthio camelo* which is well-adapted to live in desert condition.

4. Order Casuariiformes

Characters:

1) Flightless, terrestrial, running herbivore birds with comparatively small or ill-developed wings supported by a single digit.

2) It attains a height of 180 cm.

3) Neck has incomplete lining of feathers and body densely feathered.

4) Legs are tall and well-developed. Each hind limb is provided with three toes, of which the inner one is built up as a defensive structure.

5) The colouration in both the sexes is deep brown.

6) All the feathers have after shafts of equal length to the main quill.

7) Emu is monogamous.

8) The male digs the nest and sits over the first brood of eggs. The female sits over the second brood.

9) Number of eggs may be fifteen or more and the eggs are green in colour.

10) The incubation period is 60 days.

The birds enjoy distribution in Australia, New Guinea and East India.

Examples: *Dromicieus* (Emu), *Casuarius* (Cassowary) — both are Australian species.

Cassowary (*Casuarius casuarius*) lives a solitary life in the dense tropical forests of Australia, New Guinea and East India. Several species of Cassowary are available and their height may be 135 cm. Feathers look like furs. Stiff and rod-like wing feathers hang

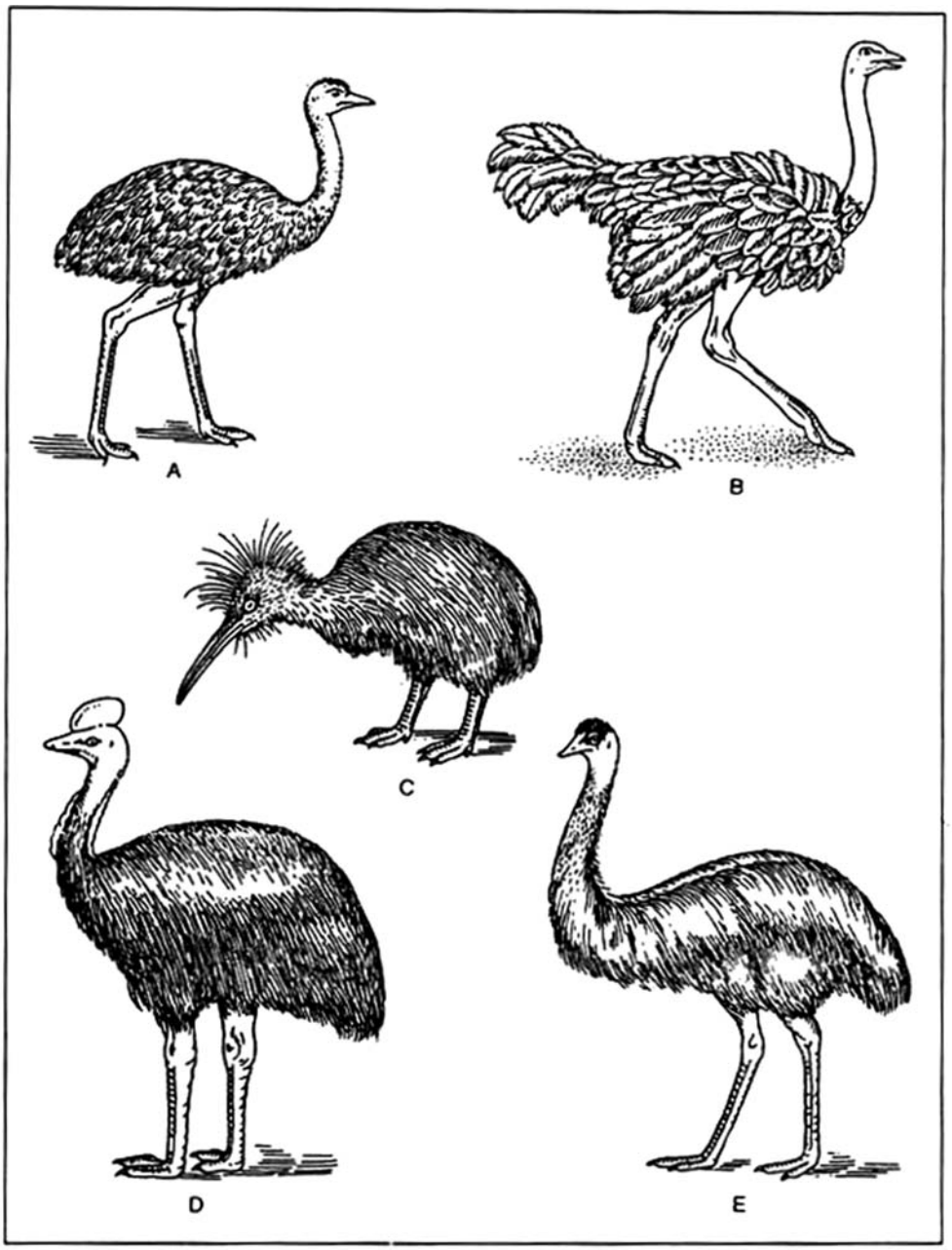


Fig. 16.3 : A. Rhea (*Rhea americana*). B. Ostrich (*Struthio camelo*). C. Kiwi (*Apteryx australis*). D. Cassowary (*Casuarius casuarius*). E. Emu (*Dromaeus novae-hollandiae*).

over the side of the body. The head and neck are partly covered by feathers and have bright colouration. In some forms the neck bears identically coloured wattles. In all forms, the head has a horny helmet to help in advancing through dense jungle. The hind limbs are similarly built as in Emu.

5. Order Aepyornithiformes: Extinct

Characters:

1) These large, extinct running birds of Madagascar are commonly called 'Elephant birds' (*Aepyornis*).
2) Some attained the height of 300 cm and their eggs measured 30.5 cm x 24.5 cm.
3) The wings were small.
4) The hind limbs having four toes were strongly built.

Example : *Aepyornis*

6. Order Dinornithiformes:

This order includes fossil and living running birds of New Zealand which are called Moas (*Dinornis)* and kiwi, *Apteryx* .

Characters:

1) Relatively small, hen like, nocturnal, omnivorous running birds. The size varies widely and some attained the height of 300 cm.
2) In most, wings degenerated with vestigeal humerus, and keel absent.
3) Body plumage fluffy, hair-like, without after shafts,tail is absent.
4) Beaks long and slender with nostril at the tip.
5) Eyes are very small in comparison to body size.
6) The kiwis are nocturnal and eat insects, worms and vegetable matters.

Examples: *Apteryx* (kiwi), *Dinornis* (maos, extinct)

7. Order Podicipediformes (grebes)

Characters:

1. Aquatic birds, almost unable to walk on land and are flightless.

2. Reduced tail has degenerated tail feathers.
3. Legs with webbed feet are placed posteriorly.
4. They build nest in floating vegetation on lakes, lay small number of white eggs.

Examples: *Podiceps* (Grebes or Dabclien),*Aechmophorus* (Large western grebe), *Podilymbus* (Pied-billed grebe) and *Centropelara*(Short winged grebe).

8. Order Sphenisciformes (Penguins)

Members of this order are mainly confined to the southern hemisphere.

Characters:

1. They lost the power of flight and became specialised for aquatic life.
2. The body is perfectly suited for diving and swimming. For this purpose, the body is stream-lined.
3. They swim by means of forelimbs, modified into flippers and webbed hind limbs. Hind limbs are also used for walking on the shore.
4. The integument is provided with thick fatty insulating layer and feathers form compact outer covering.
5. The bones, excluding certain skull bones, are solid and air-sacs are absent.
6. Monogamous in nature and one egg is laid at a time.
7. Male takes considerable part in incubating and rearing up of the young.

There are 18 penguin species of which only two live exclusively in the Antarctic. Penguins are distributed in Southern part of South America, South Africa, Australia, Galapagos regions and Antarctic regions. The well-known species are *Aptenodytesforsteri* (Emperor penguin), *Aptenodytespatagonica* (King penguin), *Pygoscelisadeliae* (Adelie penguin), *Eudyptescrystatus* (Rockhopper penguin), *Eudyptula minor* (Fairy penguin), *Eudyptulaalbosignata* (White flippered penguin) and *Spheniscusdemersus* (Jackars penguin). Food includes fishes, crustaceans and squ-ids. These are gregarious birds and nesting results in a large colony.

9. Order Procellariiformes (tube nosed seabirds, albatrosses, shearwaters, petrels)

All the members are marine and come to land only during breeding season and build nest in holes or crevices in the ground.

Characters:

1. These birds are highly modified for oceanic pelagic life; some of them are very large.
2. The wings are long in comparison to the size of the body (wing span may be over three metres) and are specialised for soaring flight.
3. Plumage compact and oily.
3. Hook-like beaks are characteristic feature.
4. Tail is small in size.
5. They lay only one egg at a time, often in burrows.

Examples: *Diomedea* (Albatrosses), *Puffinus* (Shear water), *Fulmarus* (Petrels), *Pelecanoides* (Diving petrels)

10. Order Pelecaniformes (pelicans and allies)

The distribution is cosmopolitan. All are aquatic and fish eaters.

Characters:

1. These are aquatic birds, much modified for diving and fishing. Voracious fish-eaters. They exhibit spectacular dives when fishing.
2. Size is usually large, wings are very long.
3. Webbed feet, each consists of four digits.
4. Beaks are very long having wide gap. A gular pouch or throat is present, except in tropical birds
5. Hind limb has four digits which are completely webbed.
6. They make nest in colonies on rocks or trees and feed the nestlings by regurgitated food.
7. The eggs are usually unspotted and covered with a rough chalky substance.

Examples: *Phalacrocorax* (Cormorants), *Pelecanus* (Pelicans), *Morus* (Gannets) *Sula* (Boobies).

11. Order Ciconiiformes (herons, storks, and allies)

The distribution is cosmopolitan.

Characters:

1. These are large, long-legged birds, living mostly in marshes. The legs are adapted for walking on marshes and mudflats.
2. Beak and neck are long in size. The pattern of beak varies but in all, the beak has sharp-cutting edges.
3. All are strong flyers and some of them perform extensive migrations.
4. Four toes are present in each foot, which are webbed only in flamingos.
5. Food capture involves careful obser-vation and speedy striking by the action of mobile neck and beak.
6. Nests are usually in colonies and may be used year after year.
7. Eggs are few and unspotted.

Examples: *Ciconia* (Storks), *Ardea* (Herons), *Phoenicopterus* (Flamingos).

12. Order Anseriformes (L. Anser = goose) (screamers, waterfowl)

Characters:

1. All are efficient fliers and almost cosmopolitan in distribution.
2. This group of birds are specialised for aquatic life.
3. The characteristic flattened bill is externally covered by hard epidermis.
3. Beak is provided with special tactile organ to help in selecting food. Tongue fleshy
4. Legs short and all the toes are webbed.
5. Eggs are usually white or pale in colour and the nest is usually built on the ground.

Examples: *Anas* (Ducks), *Cygnus* (Swans) *Anser* (Goose).

13. Order Falconiformes (L. Falco = falcon)(diurnal birds of prey)

The distribution is widespread throughout the world excepting Antarctica. It includes the birds which are adapted for day-time preda-tory life.

Characters:

1) Powerful, predaceous birds, distributed almost everywhere except Antarctica.

1. Body is strongly built with prominent hook-like curved beak with cutting edge and powerful feet, provided with curved, pointed claws in the digits.
2. The lower beak remains enclosed by the upper beak.
3. The base of the upper beak bears wart-like variedly coloured protuberance, called cere, which is pierced by nostrils.
4. Feathers are stiff and cover the legs excepting the digits.
5. Eyes laterally placed and with extremely sharp power of vision.
6. They lead solitary life or live in pairs. Mostly monogamous. Females incubate eggs. The males feed the females during incubation
7. The eggs, few in number, are usually spotted.
8. Nests are generally made on cliffs, tree tops or other inaccessible places.

Examples: Vultures (*Sarcogyps, Cymnogyphs, Sarcoramphus, Aegypius, Gyps*), Kites (*Mileres, Haliastur, Ictinia*), Eagles (*Aquila,Hieraaetus, Harpia, Haliaetus*), Buzzards (*Buteo*), Harriers (*Circus*), True hawks (*Accipiter*), Ospreys (*Pandion*), Falcons (*Falco*) and Secretary bird (*Sagittarius*).

14. Order Galliformes (L. Gallus = cock) (chicken like birds)

The distribution is cosmopolitan. Various types of birds are included in this order, the largest one is 225 cm in length and smallest size is 12.5 cm in length.

Characters:

1. Gregarious, usually non-migratory, ground dwelling game-birds, cosmopolitan in distribution.
2. The head is small but body is compact.
3. The legs are massive, clawed and used for scratching the soil to search food.
4. Three toes are anteriorly directed and one is posteriorly directed.
5. In most members, the wings are short and round. For this reason these birds cannot fly well, but all are good runners.
6. The beaks are strongly built and arched, most suitable for picking up grains and seeds.
7. Sexual dimorphism is noted.

8. Males are aggressive polygamous and do not take part in nest building and maintenance of youngs.

It includes seven families and well-known examples are Megapodes (*Leipoa*), Curassows (*Crax, Mitu, Oreophasis*), Grouse (*Lagopus, Tetrao, Lyrurus*), Partridges (*Perdix;Alectoris*), Quail (*Coturnix*), True Pheasants (*Phasianus, Chrysolophus, Lophura, Callus, Argusianus, Pavo*), Guinea fowl (*Acryllium, Namida*), Turkeys (*Melagris*) and Hoatzins (*Opisthocomus*).

15. Order Gruiformes (L. Grus = crane) (cranes and allies)

Characters:

1. Small size, weak flight, or flightless.
2. Omnivorous birds, primarily aquatic but some have settled in grassland, some are reed-dwellers.
3. Toes are not webbed.
4. Nest may be built on the ground.

Examples: *Grus* (Cranes), *Crex* (Corn-crake), *Gallinula*(Moorhens), *Fulica* (Coots), *Otis* (Bustard).

16. Order Charadriiformes (plovers, gulls, sandpipers, terns, puffins, auks, and allies)

Characters:

1. They have long legs with three clawed digits in each leg. Toes usually webbed, at least at the base.
2. Plumage dense and firm.
3. They possess long bills and feed chiefly on small invertebrates.
4. The birds live mainly on the ground, open watery places or marshes.
5. They are usually gregarious out of breeding reason and are often very numerous on the sea-shore.

Examples: *Metopidius*(*Jacana*),*Capella* (Snipe), Gallinago(Snipe),*Calidris* (Sandpipers), *Larus* (Gulls), *Jacana,Plautus* (Auks), *Vanellus* (Lapwings), *Charadrius*(True plovers), *Metopidius*(Jacanas) *Sterna paradisaea*(Arctic terns) *Fratercula*(Puffins).

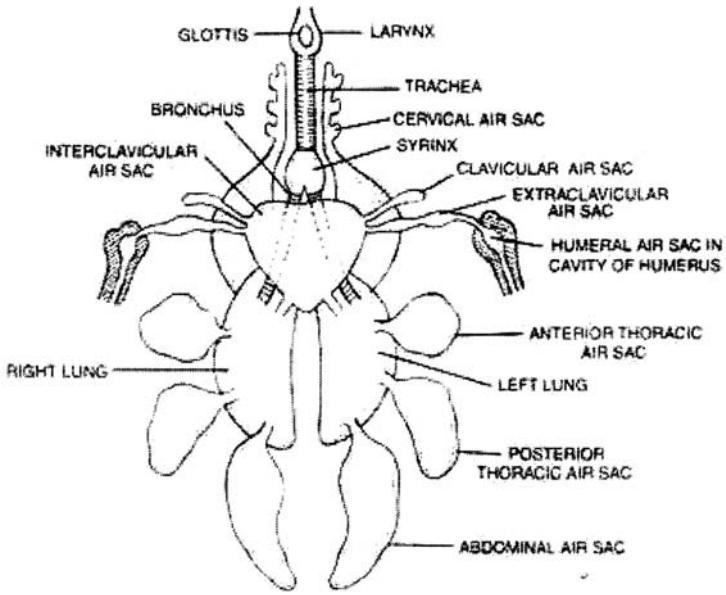
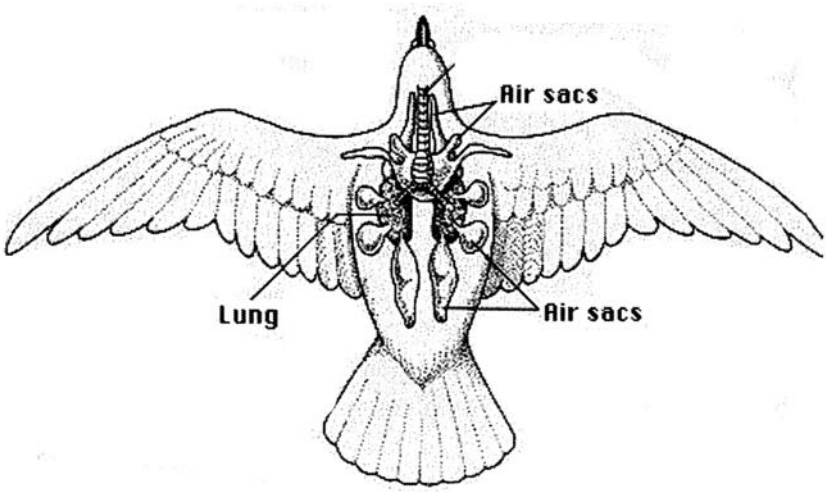


Fig. 16.4 : Respiratory System of a bird.



These birds enjoy universal distribution excepting polar regions. This order includes variety of forms which live near water, some live on shore, some on aquatic leaves and some have become aquatic. The feet show various modifications according to habitats.

17. Order Gaviiformes (loons)

Characters:

The birds are distributed in North America, Europe and Arctic region. They are fully adapted for aquatic life and are expert in swimming and diving.

1. Piscivorous birds adapted for diving and swimming. They are known as divers or loons.
2. The neck is long. Legs are posteriorly placed and completely encased with skin.
3. The digits webbed; wings short and very weak and they cannot fly.
4. The legs are posteriorly placed and completely encased within skin.
5. The bones are not fully pneumatic.
6. The wings are short and it flies very rarely. But once in air they can fly effectively.
7. Eggs are laid in nests among piles of vegetation.

During summer these birds stay in freshwater but in winter shift to salt-waters. The brightly coloured body has similar pattern in both the sexes except during breeding season. All the wing feathers moult together, for this reason these birds pass through a flightless period.

Due to its inability to move on land, these birds are helpless on land. Eggs are laid in nests among reeds. The well-known examples are *Gavia stellata* (Red-throated diver loon), *Gavia immer* (Great northern diver or Common loon) and *Gavia adacusi* (White-billed Diver or Yellow- billed loon).

18. Order Columbiformes (L. Columbia = a dove) (pigeons and doves)

Characters:

1. The birds under the order are present throughout the world excepting Polar Regions. All the members are adapted to land life.
2. These are tree living, grain or fruit eating birds.
3. The wings are long, pointed and enable the birds to make sustained flight at a great speed.
4. Bills short and slender; the base of beak covered by a soft skin bearing longitudinal slit-like nostril called cere.
5. The head and neck are small and the compact body is supported by small legs.
6. Each foot has four toes, of which three are forwardly directed and one is backwardly directed.

7. In pigeons and doves, the basal part of the beak has a covering of soft skin which bears longitudinal slit-like nos-trils.
8. Both the sexes are alike.
9. They are monogamous but live in groups.
10. Young are born under-developed and are nourished by'pigeon's milk'secreted by the crop of both sexes during breeding season.

Examples: *Columba livia* (Rock pigeon), *Streptapelia* (Dove), *Ectopistes* (Passenger pigeon), *Ducula* (Imperial pigeon), *Raphus = Didus* (The Dodo was a large-sized pigeon of the island Mauritius but was exterminated by man in seventeenth century).

19. Order Cuculiformes (L. Cuculus = Cuckoo) (cuckoos and allies)

Characters:

1. These are good flyers and possess broad wings.
2. Legs possess four clawed digits — two anteriorly and others backwardly placed. Feet are not adapted for grasping (cannot climb).
3. Bill moderate, tail long.
4. Females lay eggs in the nest of other birds (foster species) like crow.
5. The eggs are strongly mimetic with those of the host.

These birds are distributed in the tropical and subtropical regions but concentrated in temperate regions.

Examples: *Cuculus* (Common cuckoo),*Chalecites, Geococcyx* (Road runner).

20. Order Psittaciformes (L. Psittacus = Parrot) (parrots, lorikeets, cockatoos, kea and kakapo)

They are distributed in the tropical region but concentrate in Australia, New Zealand and South America. All the members are specially adapted for arboreal life and can also climb.

Characters:

1. Adapted for arboreal life and can also climb.
2. Loud-voiced birds, chiefly frugivorous with brilliant plumage of green, blue, yellow or red.

3. Beak stout, narrow, sharp-edged, and hooked at the tip used for climbing. The beaks are used to help in climb-ing and feet are also used as 'hand' to hold the food.
4. The upper mandible is movably articulated with the frontal bone of the skull.
5. The first and fourth digits are backwardly directed (Zygodactylous), thus provide better aid to grasp the branch.
6. They live in flocks but are strictly monogamous. The nest is usually built in the hollows of the tree. Youngs are nourished till the attainment of maturity.
7. Excepting a few parrots (*Geopsittacus*) all are diurnal.

Examples: *Psittacus* and *Psittacula* (Parrot), *Conurosis* (Parakett*)*, *Kakatoe* and *Probosciger* (Cockatoo), *Trichoglossus* (Loriket), *Ara* (Mackaw), *Agapornis and Prittacula (*Love birds), *Melopsittacus* (Budgerigar), *Nestor* (Kea).

21. Order Strigiformes (L. Strix = Screech owl + form) (owls)

They enjoy universal distribution. All these birds are nocturnal and live by hunting small animals (e.g., rodents). Like diurnal birds of prey, beaks and claws are strongly built. The construction of wing feathers is such that they produce noiseless flight.

Characters:

1. These are specialised for hunting at night.
2. Plumage soft-textured. The contour feathers are loosely arranged and extend up to the digits.
3. Head large and round. The beak is short.
4. Eyes are large and round.Both the eyes are directed forwards. With the help of neck, it can move its head up to 180°.
5. The retina contains principally rod cells and are adapted only to perceive low intensity of light.
6. The ear openings are placed on the lateral sides of the head and can be closed at will.
7. Feet adapted for grasping, claws very sharp and strong.
8. These birds depend more on auditory function than vision during hunting. The prey is swallowed whole.

9. Eggs are white. Nests are built in holes of trees or buildings.

Examples: *Athene* (Little owl), *Tyto* (Barn owl), *Strix* (Tawny or Wood owl), Nyctea (Snowy or White owl), *Bubo* (Eagle owl), *Glaucidium* (Pygmy or Dwarf owl), *Asio* (Long-eared owl), *Speotyto* (Burrowing owl).

22. Order Caprimulgiformes (L. Caprimulgus = goat sucker + form) (nightjars, frogmouths)

Characters:

1. Colouration protective, helps the bird in concealing.
2. Plumage soft-and the arrangement of feathers is like that of owl and they are silent-fliers.
3. Nocturnal birds feeding on insects and other small animals during twilight.
4. Legs and feet small and weak, not adapted for grasping.
5. Bills are small, delicate, but the mouth opening wide and margined with long moustache or bristle-like feathers with specialised sensory receptors.

The distribution is tropical, subtropical and temperate zones

Examples: Caprimulgus (Nightjars), Podargus (Frogmouth), Nyctibius (Wood-nightjars).

23. Order Apodiformes (Gk. Opous = footless + form) (swifts, hummingbirds)

The members of this order are called the swifts and humming birds. The swifts are seen throughout the world but humming birds are seen only in Central America.

1. Legs very short, feet very small, wings pointed and bills small and weak (swifts) or slender with long tubular tongue (humming birds).
2. In swifts the mouth is broad and eyes are large.
3. In humming birds, plumage is brilliant, iridescent, specially on head and neck of males.
4. Swifts are insectivorous and have very large mouth, adapted for feeding on wings.They can fly very swiftly.
5. Tongue of the humming birds is tubular and long, they feed on nectar by tubular protrusible tongue and needle-like bill.

6. In humming birds wings can perform hovering movement.
7. Nests are made in holes or by attaching bracket, sleeve or pocket like structures on trees, cliffs or buildings.
8. The eggs are white, and the youngs are helpless at birth.

Examples: Swifts (*Apus, Chaetura*), crested swifts (*Cypsiurus*) and Humming birds (*Archilochus, Selasphorous, Patagona, Mellisuga, Loddigeria*). The smallest living bird is bee humming bird.

24. Order Coliiformes (Gk. Colius = Genus of the mouse bird) (colies, or mousebirds)

Characters:

1. Small body, with short legs, sharp curved clawsin the digits.
2. The first and fourth toes reversible, which help in creeping on trees.
3. The feathers are soft and look like hairs. Usually a crest is present on the head.
4. Around the nostrils the base of the bill is fleshy.
5. They always remain in a group of twenty or thirty.

Examples:It includes a single family Coliidae and the example is mouse-bird (*Colius*).

25. Order Trogoniformes (Gk. Trogon = gnawing + form) (trogons)

Characters:

1. The feathers are soft and flight is noiseless.
2. The beak is short, and stout with bristle like feathers in its base.
3. Distal end of the beak is hook-like curved.
4. The foot has peculiar arrangement of toes, the first and second are directed backwards while the third and fourth are anteriorly directed.
5. Long and stiff tail supports against vertical surface at the time of digging.

Examples: The order includes a single family Trogonidae and well-known examples are Trogons (*Harpactes, Haplodermes, Trogon, Calures*) and Quatjal (*Pharomechrus*). They are distributed in Asia, Africa and tropical parts of America. They lead a soli-tary life in dense forest and capture insects in the early morning and during twilight.

26. Order Coraciiformes (L. Corax = raven) (kingfishers, bee eaters, rollers, hoopoes, hornbills)

Characters:

1. In most members the wings and legs are short.
2. The beak is longand well-developed.
3. In some forms, a few anteriorly direc-ted toes are fused (Syndactylous) and, in others, one of the toes is reversed (Zygodactylous).
4. The body is brightly coloured and nests are built up as holes in the treesand the eggs are white.

Examples: Kingfishers (*Alcedo, Ispidina, Dacelo, Tanysiptera, Halcyon, Chlorocerle, Ceryle*), Todies, Motmots, Bee-eaters (*Merops*), Cuckoo-roller, Rollers (*Coracias*), Ground rollers, Hoopers (*Upupa*), Wood hoopers and Hornbills (*Bucerosjockus, Anthracoceros*). The distribution is cosmopolitan, especially in the tropical climates. The members belong-ing to this group exhibit varied structures.

27. Order Piciformes (L. Picus = a Woodpecker + form) (woodpeckers and allies)

Characters:

1. The most important character is the occurrence of zygodactylous feet, second and third toes are directed forward and the first and fourth are pointed backwards.
2. Usually insectivorous but some forms may be vegetarian.
3. Highly specialised in climbingand wood-boring.
4. Beak is very hard and powerful.
5. Tongue is long and protrusible and used for removing insects from beneath the bark.
6. Tail feather stiff with pointed tips, used to support the bird as it climbs the tree trunk.

Examples: Jucamars, Puff birds (*Notharcus*), Barbets (*Megalaima*), Honey-guide (*Indicator*), Toucans (*Ramphastos*) and Woodpeckers (*Dinopium, Picus, Picoides*), Dendrocopos (*Sphyrapicus, Melanerpes, Fynx*). They are distributed throughout the world

excepting Australia and Polar Regions. Most members prepare nest in holes but one family (Indicatoridae) lays eggs in the nests of other birds.

28. Order Passeriformes (L. Passer = a sparrow + form) (songbirds, or perching birds)

Characters:

1. Small perching birds or passerines, adapted to various habitats and distributed widely.
2. They are generally four-toed birdsand the four digits remain in the same level. First digit is posteriorly placed and others are anteriorly.
3. All are adapted for land life and adapted to various habitats, they practise various modes of feeding.
4. The digits are typically arranged to allow the gripping of the perch (Their feet are adapted for perching on thin stems and twigs).
5. Most have a highly developed syrinx.
6. They have a complicated nesting behaviour.
7. Eggs are coloured and elaborate-ly marked.
8. The young are altricial (requiring significant parental care).

Examples: *Corvus* (Crow), *Sturnus* (Starling), *Fringilla* (Finch), *Passer* (House-sparrow), *Lanius* (Shrike), *Sylvia* (Warbler), *Troglodyes* (Wren), *Hirundo* (Swallow) *Ploceus* (Weaver-birds), *Luscinia* (Nightingale), *Chaetorhyncus* (Drongo), *Paradisea* (Birds of Paradise), *Pica* (Magpie).

Some of the common birds are broad bills, pittas, larks, crows, thrushes, nuthatches, sparrows, finches, swallows, shrikes, bulbuls, cuckoo, wood-warblers, fly catchers, wrens, etc.

This is the largest order, which includes 5,100 known species (60% of all birds). All are collectively known as Perching birds or Passerines. They enjoy worldwide distribution. To this order belong many birds with beautiful songs such as thrushes, warblers, mockingbird, meadowlark, and hosts of others.

16.4 ❑ Questions

- Naik,

16.5 ❑ Suggested readings

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UNIT 17 ❑ Class Mammalia - General characteristics and Classification up to order.

Structure

17.1 ❑ Objective

From this unit learners will learn the diversity, general characteristics and classification of class Mammalia up to orders.

17.2 ❑ Introduction

Mammals (Latin mamma means "breast") are vertebrate animals constituting the class-Mammalia, and is characterized by the presence of mammary glands which in females produce milk for feeding (nursing) their young, brain with a neocortex (a region of the brain), fur or hair, and three middle ear bones. These characteristics distinguish them from birds and reptiles, from which they diverged in the late Triassic period. The modern mammalian orders arose in the Paleogene and Neogene periods of the Cenozoic era, and have been among the dominant terrestrial animal groups from 66 million years ago to the present. Mammals are amazingly diverse animals. Most mammals are intelligent, with some possessing large brains, self-awareness and use tools. They live in nearly every available habitat on Earth—including deep seas, tropical rainforests, and deserts—and they range in size from one-ounce shrews to 200-ton whales.

17.3 ❑ General characteristics and classification up to orders

17.3.1 General characteristics of class Mammalia

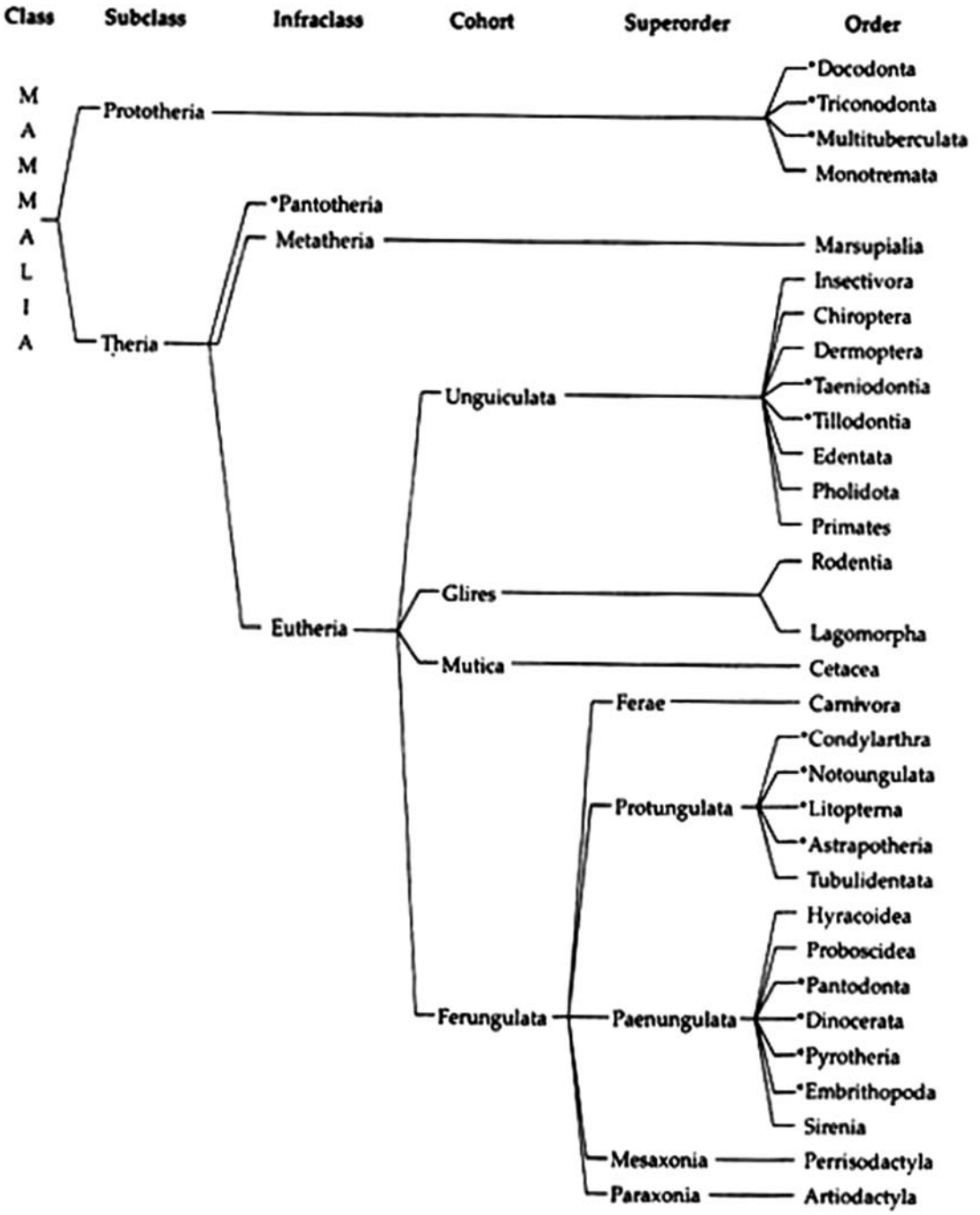
1. Endothermal homoeotherm animals.
2. Body of mammals is covered by epidermal hair except whales in which hairs are temporarily present in the embryos**.**
3. Integumentary glands are — sweat (sudoriferous), sebaceous (oil), scent (odoriferous) glands.
4. Mammary glands are present to supply milk for the nourishment of suckling young. These are probably specialised sweat glands. It is well-developed in adult females. Nipples or teats are absent in monotremes.
5. External fleshy pinna is present in most mammals (absent in Cetacea and Sirenia).
6. The skull has double occipital condyles.
7. Number of cervical vertebrae is typically seven, except a few mammals.
8. The lower jaw or mandible is made up of a single piece of bone, called dentary.
9. Middle-ear contains three-ear ossicles—malleus (the articular), incus (the quadrate) and stapes (the hyomandibular). Internal ear with spirally coiled cochlea (not coiled in monotremes). The ear ossicles conduct sound from the tympanic mem-brane to the inner ear.
10. Dentition heterodont, thecodont and diphyodont (In toothed whales the teeth are homodont). Heterodont dentition is marked by the presence of inci-sors, canines, premolars and molars. Thecodont teeth means each tooth is lodged in an alveolar socket of the jaw bone. Diphyodont teeth, i.e., only two sets of teeth—first set is milk or lacteal teeth which is replaced by permanent teeth.
11. Generally acoelous or amphiplatyn type vertebra.
12. Double headed ribs, i.e., the ribs articulate with vertebrae by two heads— the capitulum and tuberculum.
13. Paired forelimbs and hind limbs are present in mammals. The digits of the limbs are provided with either claw or nail or hoof.
14. Eyes with upper and lower eyelids and often with eyelashes. Nictitating membrane is translucent and hairless; it is vestigial in higher mammals.

15. A muscular diaphragm is present in between the thoracic and abdominal cavities.
16. The four-chambered heart is highly powerful. Sinus venosus and conus arteriosus are absent.
17. Only left aortic arch is present in the arterial system. .
18. Mature RBCs are non-nucleated, biconcave and usually circular in form.
19. Cerebral hemispheres are very large and highly convoluted.
20. Corpus callosum, the transverse band of nerve fibres connecting the two cerebral hemispheres, is present (absent in monotremes and rudimentary in marsupials).
21. Corpora quadrigemina, the four optic lobes on the dorsal side of the midbrain, is present.
22. Cerebellum is large, complex and solid.
23. Cranial nerves twelve pairs.
24. Kidneys are metanephric type. All most all mammals are ureotelic (chief nitrogenous waste is urea).
25. There is a single urinary bladder in mammals.
26. Testes remain in scrotal sacs in most.
27. Eggs are small, with little or no yolk (except in Monotremata). The eggs of monotremes are macrolecithal and telolecithal.
28. Mammals are Viviparous, i.e., they give birth to alive youngs except the monotremes which are oviparous.

17.3.2 Classification of class Mammalia with characters up to orders

Scheme of Classification:

Like other chordates, the classification of mammals is controversial and complex. There are several schemes of classification that exists in different literatures. But none of the existing classifications is beyond criticism. However, in the present text, classificatory scheme of mammals as proposed by **J. Z. Young (1981)** is followed. This classification scheme has been followed more or less by all the eminent authors.In the scheme all the groups up to order are mentioned. But, for description, only living groups are considered. The extinct groups are marked with asterisks **(*).**


Class
Subclass
Infraclass
Cohort
Superorder
Order
MAMMALIA
Prototheria
Theria
*Pantotheria
Metatheria
Eutheria
*Docodonta
*Triconodonta
*Multituberculata
Monotremata
Marsupialia
Unguiculata
Glires
Mutica
Ferungulata
Insectivora
Chiroptera
Dermoptera
*Taeniodontia
*Tillodontia
Edentata
Pholidota
Primates
Rodentia
Lagomorpha
Cetacea
Ferae
Protungulata
Paenungulata
Mesaxonia
Paraxonia
Carnivora
*Condylarthra
*Notoungulata
*Litopterna
*Astrapotheria
Tubulidentata
Hyracoidea
Proboscidea
*Pantodonta
*Dinocerata
*Pyrotheria
*Embrithopoda
Sirenia
Perrisodactyla
Artiodactyla

Class Mammalia has been divided into two subclasses:

1. Subclass Prototheria and **2. Subclass Theria**

Subclass — Prototheria (Greek: protos = first, therion = beast or a wild animal)

General Characters:

1. The females lay eggs.
2. The mammary glands lack teats or nipples.
3. External pinna absent.
4. In childhood, teeth are present but adults lack teeth.
5. Ribs are single headed.
6. The testes are abdominal.
7. The ureters open into a urinogenital sinus (do not open into the urinary bladder) which remains communicated with the alimentary canal—hence a distinct cloaca. The cloaca receives the openings of reproductive ducts.

This subclass includes four orders of which only order **Monotremata** is the living order, others are extinct.

Order — Monotremata (Gk. monos = single + trematos = hole)

The monotremes occupy a most interes-ting position among mammals because of their distribution, anatomical peculiarities and systematic position. The monotremes differ from other mammals by having many peculiar characters, some of which are typically mammalian. The reptilian and mammalian characters present in the monotremes lead one to think that mammals have evolved from reptiles putting a step on the Monotremes.

General Characters:

1. Body is covered over with soft hairs (platypus). Hairs on the dorsal side may be coarse or spine-like (echidna).
2. Digits end in sharp claws and are webbed.
3. Mammary glands are devoid of teats. The tubular glands open in shallow depression on the ventral side.
4. Pinna is distinct but small.

5. Nictitating membrane is present.
6. Tail may be present or absent.
7. In males, poison spur is present on the hind legs.
8. Teeth are replaced by a horny pad in adults. Youngs possess teeth. Dental for-mula in young stage is i = 0/5, c = 1/1, p = 2/2, m = 3/3.
9. Sutures are obliterated in the skull.
10. The cerebrum of brain is smooth and does not cover the cerebellum. Corpus callosum is absent.
11. They are not fully homoeothermic, body temperature varies in between 25°-28°C.
12. Nasal and pre-maxilla are drawn out into a rostrum. Upper jaw is produced into depressed beak in Platypus and pointed rostrum in Echidna.
13. Pectoral girdles resemble that of reptiles.
14. 'T'-shaped interclavicle is present in the sternum corresponding to that of reptiles.
15. In pelvic girdle epipubic bone is present. 16. Paired oviducts open directly into cloaca.
16. Eggs are provided with much yolk and the egg shell is leathery. Eggs undergo meroblastic cleavage.

Examples: *Ornithorhynchus anatinus*(duck-billed platypus), *Tachyglossus aculeatus*(echidna or spiny ant-eater), *Zaglossus zaglossus, Z. bruijnii, Z. nigroaculeata*

The monotremes occupy a most interesting position among mammals, because of their distribution, anatomical peculiarities and systematic position. Both the reptilian and mammalian characters are present in monotremes, which lead to consider them as connecting link. Only three genera of monotremes are found in Australia, Tasmania and New Guinea.

Additional information:

Only three living genera including six species (Griffiths, 1978) are found today. They are duck-billed platypus, spiny ant-eater (= echidna) and pro-echidna. The duck-bill is also known as the water mole or duck mole. It has a single species — *Ornithorhynchus*

anatinus. It is found in Australia, Tasmania and New Guinea. The platypus is highly adapted for aquatic life and is also known as the water mole or duck mole. The echidna or spiny ant-eater includes also a single species, *Tachyglossus aculeatus*, and ranges from New Guinea to Tasmania. The clawed feet in Echidna are used for breaking the ant's nest. The large and sticky tongue in Echidna is employed for ant-eating purposes. Feet are used for walking, digging and swimming. The male possesses a hollow tarsal spur (a cone-shaped hard projection on the tarsal region of the hind limb) connected with a crural gland, whose secretion is poiso-nous. The poison and the spur are probably used in territorial conflicts. The poison may be used to immobilize a female during copulation. The proechidna (*Zaglossus zaglossus, Z. bruijnii, Z. nigroaculeata*) is found only in New Guinea.

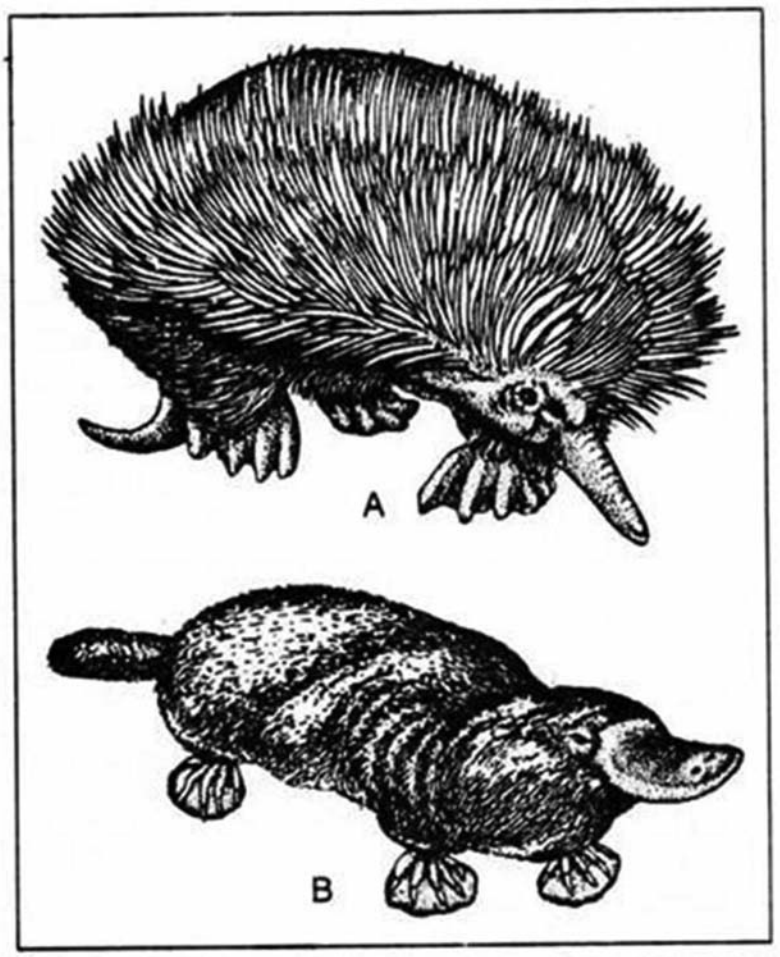


Fig. 17.1 : Some prototnerian mammals. A. *Tachyglossus* (Echidna). B. *Ornithorhynchus* (Platypus).

Subclass — Theria (Greek: therion = beast)

General Characters:

1. Female members of this subclass do not lay eggs but give birth to young ones.
2. Mammary glands are provided with nipples or teats.
3. Pinna or external ear is present.
4. Teeth are present throughout the life period.
5. At the end of the digestive tract an anus is present.
6. Ribs possess two heads for articulation with vertebrae.
7. The ureters open directly into the urinary bladder.
8. Testes are situated in the scrotum.

This subclass includes three infraclasses-**Infraclass Pantotheria, Infraclass Metatheria and Infraclass Eutheria,** of which Infraclass Pantotheria is extinct.

Infraclass Metatheria (Greek: Meta = next to)

General Characters:

1. The youngs are born in an immature con-dition and undergo further development in the marsupium of females.
2. Mammary gland with teats opens into the marsupium.
3. Epipubic bone of the pelvic girdle protects the marsupial sac.
4. Placenta is choriovitelline type. No true chorioallantoic placenta except in *Perameles* (Bandicoot).

This infraclass includes single order, Order — **Marsupialia**

Order — Marsupialia (Latin: Marsupium = a sac)

General Characters:

1. Body in covered with soft fur.
2. Pinna is well developed.
3. Most of the female members possess marsupium. The marsupium is supported by two epipubic or marsupial bones.

4. Tail is well-developed and helps in balancing.
5. A strange specialization is seen in the hind foot. The second and third toes are slender and remain enclosed in a sheath of skin. These two together are known as syndactylous digits which form a sort of two-pronged comb. The fourth toe is the largest. All digits end in claws.
6. Forelimbs are shorter than the hind limbs.
7. Dentition is heterodont, thecodont and monophyodont (excepting last premolars). Number of incisors vary. There are five upper incisors and four lower incisors. Dental formula is i = 5/4, c = 1/1, p = 3/3, m= 4/4.
8. Atlas is incomplete and is provided with cartilage in the ventral incomplete side.
9. Caudal vertebrae are with 'chevron bone' excepting in Koala and Wombat.
10. An epipubic bone for the support of the marsupium is present but it is not homologous to reptilian epipubic bone.
11. Brain is small with little convolutions.
12. Corpus callosum is either absent or poorly developed.
13. Anal and urinogenital apertures are enclosed by a common sphincter muscle.
14. Oviducts remain separate and uterus and vagina are paired.
15. The glans penis is bifurcated. The scrotum lies in front of the penis.
16. Youngs are born alive in an immature state. Youngs are taken by the mother in her marsupium where the embryos remain attached to the nipples of the mother.

Fig. 17.2 : Macropus (Kangaroo) in sitting posture. Note that the young is placed in the marsuplum.

Examples: *Macropus* (Kangaroo), *Didelphis* (Opossum), *Thylacinus*

(Tasmanian wolf – the mystery marsupials), *Myrmecobius* (Banded ant-eater), *Nottoryctes* (Marsupial mole), *Petaurus* (Flying opossum), *Phascolarctos* (Koala bear), *Vombatus* (Wombat), etc.

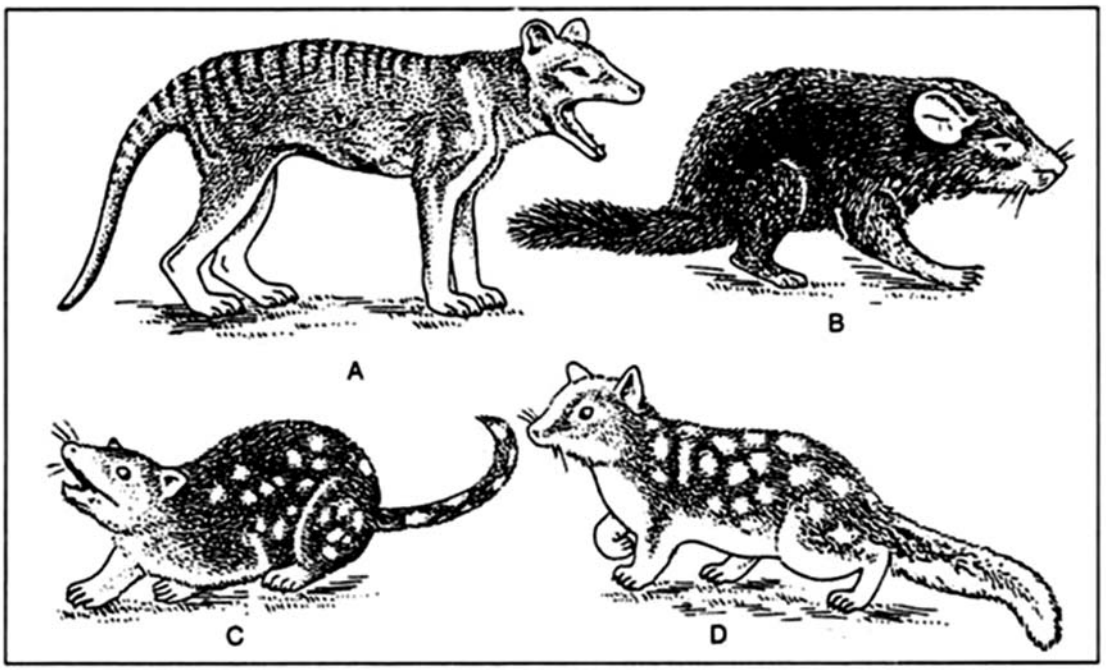


Fig. 17.3 : (A-D): Some camivorous marsupials. A. Tasmanian wolf (Thytacinus), B. Tasmanian devil (Sarcophilus), C. Tasmanian tiger cat (Dasyuropus), D. Eastern native cat (Dasyurus).

Infraclass — Eutheria or Placentalia (Greek: eu = true) True mammals/Placental mammals

General Characters:

1. The young are born as miniature adult and go through a considerable period of prenatal growth.
2. A highly-organised allantoic placenta attaches firmly with the uterine wall during developmental period.
3. Brain is highly-developed, cerebral hemispheres have well-developed neopallial region. The two hemispheres are connected by corpus callosum. Cerebellum is also well-developed.
4. The tympanic bone is ring-like and forms a tympanic bulla.

5. Dental formula is i = 3/3, c = 1/1, pm = 4/4, m = 3/3. In some forms there are modifications in dental formula, and in some cases teeth are absent.
6. Epipubic bone in the pelvis is absent.
7. The anal and urinogenital apertures are separate.

This infraclass is divided into **4 cohorts: 1. Cohort: Unguiculata; 2. Cohort: Glires; 3. Cohort: Mutica; 4. Cohort: Ferungulata**

Cohort 1. Unguiculata:

General Characters:

1. These eutherians possess nails or claws in their digits.

This Cohort contains eight orders, of which two are extinct.

Order 1 — Insectivora (Latin: insecta= insects; voro = to eat) Hedgehogs, Shrews, Moles, Tenrecs

Insectivores are the earliest and primitive of all eutherians. They are believed to be ances-tors of all other placental mammals and are persisting unchanged from Cretaceous period. They are distributed in Asia, Africa, Europe and North America. These small, terrestrial and nocturnal insectivores are stamped with many primitive and some specialized characters:

General Characters:

1. Body covered with hair. In some hairs on the dorsal side are modified into spines (Hedgehog).
2. Nocturnal animals with long snout and are insectivorous.
3. Typical dental formula is 3.1.4.3/3.1.4.3 (primitive characters).
4. Skull is constricted in the middle.
5. The zygomatic arch and bony palate are incomplete. The tympanic bulla is absent.
6. Teeth have sharp molar cusps.
7. Each limb possesses five digits with claws.
8. Locomotion is plantigrade type.
9. Caecum in the intestine is small or absent.

10. Mammary glands are many and are distributed all along the two milk-lines on the ventral surface.
11. Uterus is bicornuate type.
12. Scrotum is absent and the testes are internally situated.

Examples: *Talpa* (Mole), *Tupaia* (Tree- shrew), *Erinaceus* (Hedgehog), *Sorex* (Shrew), *Desmana* (Water mole), *Chrysochloris* (Golden mole), *Neomys* (Water shrew).

Remark:

The ordinal name Insectivora is somewhat misnomer since it implies that members of this taxon feed exclusively upon insects, while it is true that most members of the Insectivora feed upon invertebrates in soil litter, many of which are insects. Again some members of the group feed on fish, others on crustaceans and still others on small verte-brates (Eisenberg and Gould, 1984).

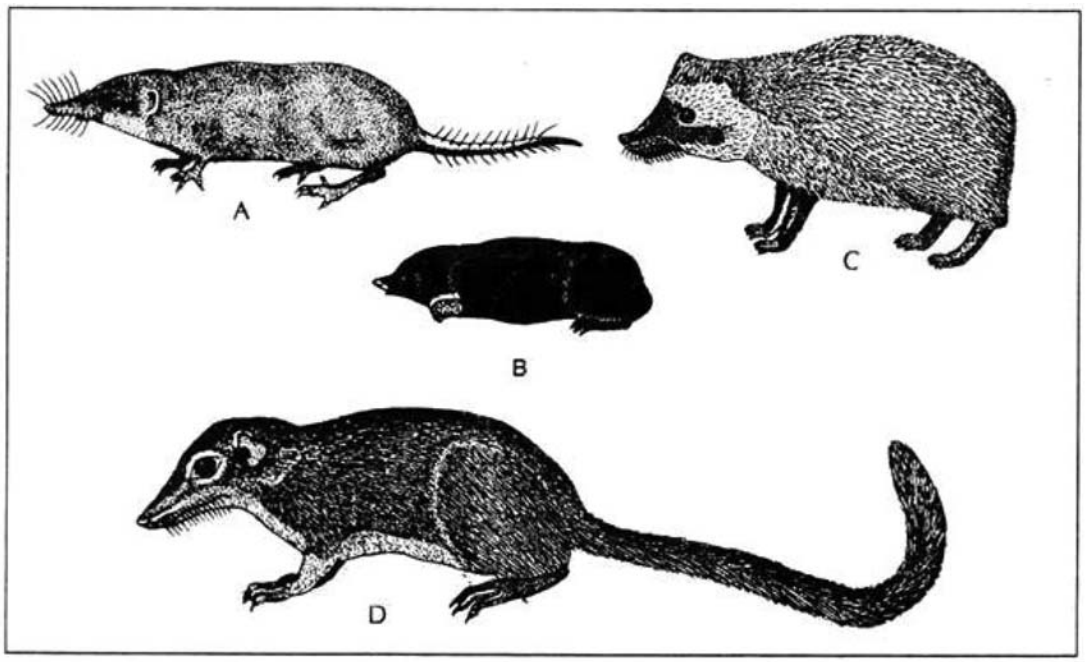


Fig. 17.4 : Soma members of insectivores. A Shrew (*Suncus*), B. Mole (*Talpa*), C. Hedgehog (*Paraechinus*), D. Tree shrew (*Tupaia*).

Order 2 — Chiroptera (Greek: cheir = hand; pteron = wing)

Members belonging to this order are the only mammals which have mastered true flight like birds.

General Characters:

1. The forelimbs are modified to form wings.
2. The bones of the digits of the forelimbs are elongated except pollex. These bones support a membrane that runs between forelimbs and hind limbs. This mem-brane is called as patagium.
3. An inter-femoral membrane is present between the femurs. It is supported by a cartilaginous calcar of the ankle.
4. A short tail is often included in the inter--femoral membrane.
5. The wings are peculiar by having direct arterio-venous connections.
6. The first digit of the forelimb (Pollex) is small, free from the wing and bears a claw.
7. The hind limbs are weak, thus making the bats helpless on ground. The foot has five-clawed digits and the bats hang upside down with the hind limbs.
8. Pinna is well-developed and, in many, complicated foliaceous nose folds, called auricular appendage, around the nose are present.
9. These are nocturnal animals. They are able to fly and catch prey in the dark with the help of their special radar system, (they can pursue prey ignoring their own sense of vision). This capacity is called echolocation.
10. The sutures of the skull is obliterated.
11. The ribs are flat and fused with the vertebrae to become rigid during flight.
12. The sternum is provided with a flat keel for the attachment of pectoral muscle.
13. The hind limbs are rotated, so the knee is directed backward.
14. The brain has smooth cerebral hemispheres which do not cover the cerebellum.
15. The testes are abdominal in position.
16. Only one young is born at a time.

Examples: *Pteropus* (Fruit bat, also known as flying fox), *Rhinolophus* (Horseshoe bats), *Desmodus* (Vampire bats), *Vespertilio* (European bats). Fruit bat (*Pteropus*) is the member of suborder Megachiroptera and others are member of suborder Microchiroptera. The chiropterans are the only mammals that truly fly, by flapping their wings. The bats are numerous and their distribution is worldwide.

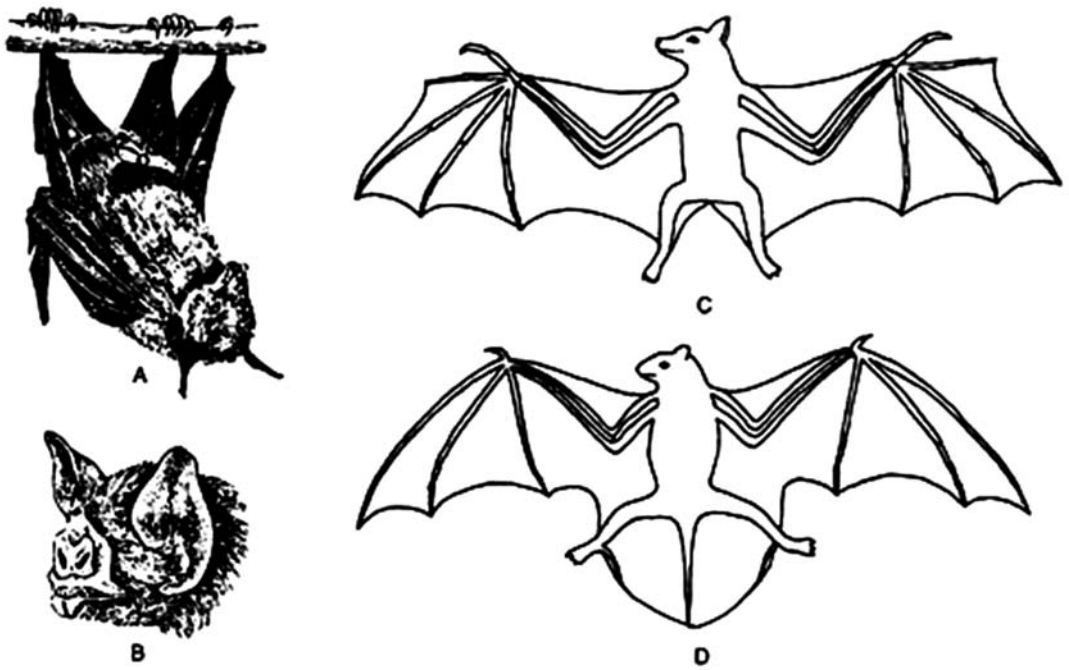


Fig. 17.5 : A. *Pteropus* (Fruit bat), B. Head of *Desmodus* (Vampire bat). C. & D. Diagrammatic figure of *Pteropus* and *Vespertilio*, respectivey. Note the patagium between the hid limbs in two groups of bats and the presence of tail in the latter.

Order 3. Dermoptera (L. Derma = skin + pteron = wing), Flying Lemurs

There is a double fold of furred skin, called patagium or parachute membrane stretched on either lateral side between neck, limbs, body and tail.

The Dermopterans evolved along a sepa-rate line from the primitive insectivores during Eocene. The present-day dermopterans are found in Malay, Philippines and East Indies.

General Characters:

1. These are herbivorous, tree-living and their size is like that of a large squirrel.
2. The lower incisors are combed.
3. The tympanic ring forms the bulla and the lower margin of the external auditory meatus.
4. Brain is primitive and the optic lobes are not covered by cerebrum.
5. The most important feature is the presence of broad folds of hairy skin stretched on either lateral side between neck, limbs, body and tail, with which it glides long distances from one tree to another.

Examples: Flying Lemurs or Colugo -*Cynocephalus* (= Galeopithecus) *variegatus* of East Indies and *C. volans* of Malay and Philippines.

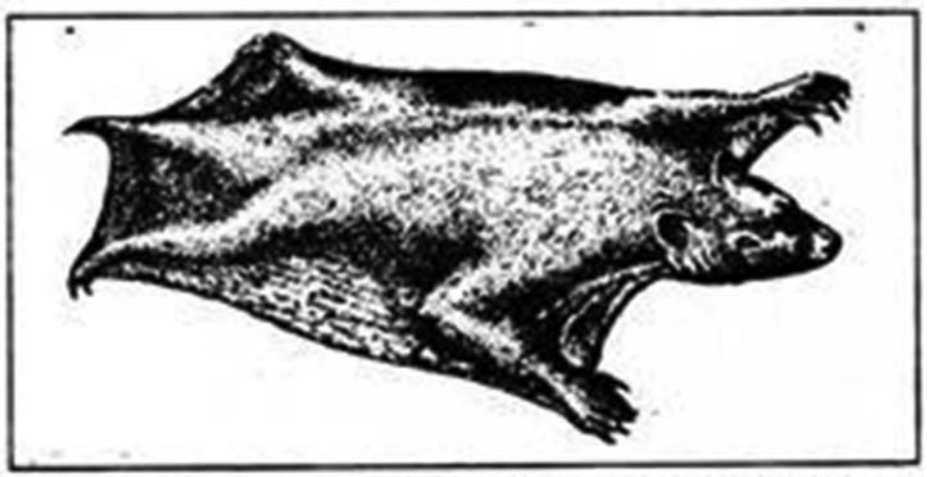


Fig. 17.6 : A flying lemur, *Cynocephalus* (= Galecoplthecus).

Order 4.*Taenodontia and Order 5.*Tillodontia are extinct.

Order 6. Edentata (Latin: e/ex = without; dens = tooth)

General Characters:

1. Incisors and canines are absent but molars are long and similar in appearance.
2. Enamel and root of the teeth are absent but pulp cavity is persistent.
3. Tongue is sticky in nature.
4. Skull is small in comparison to body size.
5. The zygomatic arch is reduced or absent.
6. Olfactory lobe of the brain is well-developed.
7. In the pectoral girdle, clavicle is present but the coracoid and acromion are fused.
8. In the pelvic girdle, ischium is united with anterior caudal vertebrae.
9. Posterior thoracic and lumbar vertebrae are with additional pair of zygapophyses.

Examples: *Dasypus* (Nine banded armadilo**),** *Myrmecophaga jubata* (Giant ant-eater), *Cyclopes* (Two toed ant-eater), *Bradypus* (Three toed sloth), *Choloepus* (Two-toed sloth).

Order 7. Pholidota (Greek: pholis = scale) Pangolins or ant eaters

General Characters:

1. On the dorsal side of the head, body and tail horny scales are present in an imbricated fashion.Few hair peep through these scales.
2. The ventral side of the body is covered with hair.
3. Eyes are small and pinna is ill-developed.
4. Skull is long and cylindrical.
5. The facial part is prolonged to form a short muzzle.
6. Tongue is long, sticky and protrusible and is retained in a sac.
7. Teeth are absent.
8. Tail is long, tapering and prehensile.
9. Limbs are short but powerful, there are five clawed-digits in each limb.
10. The claws of the forelimbs are curved and sharp.
11. Locomotion by hind limb is plantigrade in nature.
12. They have the power to curl themselves like an armoured ball when disturbed.
13. They are ant eaters and termite eaters.

Examples: *Manis crassicaudata* (Indian Pangolin), *M. pentadactyla* (Chinese Pangolin).

Order 8. Primates (Latin: primus = first; Primate = One first in rank)

General Characters:

1. Body is covered with thick hair except the palm, sole and some parts of the face.
2. Neck is short and mobile.
3. Forelimbs are shorter than hind limbs.
4. Pentadactyl limbs possess digits and all the digits end in flat nails.
5. The pollex or thumb, hallux or first toe are smaller than other digits and are opposable.

6. Locomotion is of plantigrade type.
7. Tail is present in most forms.
8. Highly developed brain possesses much convoluted cerebral hemispheres.
9. The eyes are directed forward and the vision is binocular and stereoscopic.
10. Teeth show reduction in number.
11. The skull is more inclined to the verte-bral axis.
12. Zygomatic arch is complete.
13. Foramen magnum faces downward.
14. Mammae are two and thoracic in posi-tion.
15. Testes lie in scrotal sac.
16. Usually one young is born at a time and parental care is required for a long time after birth

Examples: *Homo sapiens sapiens* (modern man), *Gorilla*, *Presbytis* (langur), *Macaca* (Rhesus monkey, Macaque), *Papio* (babon), *Hylobates* (gibbon), *Pongo* (orangutan), *Pan* (chimpanzee), *Callithrix* (= *Hapale*) (marmoset), *Loris* (loris), *Lemur*(lemur), etc.

The term 'primate' carries with it the implication that the animals in the group are not only the nearest to man but are also in some sense the first or most completely developed members of the animal world. But these are not so specialized as they are believed to be.

The primates have retained many primitive and generalized eutherian characters. They are primarily arboreal and return to land as a secondary condition. These are omnivorous in habit.

Cohort 2. Glires:

General Characters:

1. Teeth are specialized for gnawing with continually growing incisors.
2. Presence of diastema.
3. Skull is long and low.
4. Temporal fossae widely open to the orbit.

5. Brain is small with small and smooth cerebral hemispheres.
6. Limbs are pentadactyle. Forelimbs are shorter than hind limbs.
7. Radius and ulna are separate.

This cohort is divided into two orders — **Rodentia and Lagomorpha.**

Order 1. Rodentia (Latin: rodere = to gnaw)

General Characters:

1. Body is covered with soft hair.
2. Eyes are small but pinna is well-deve-loped.
3. Single pair of large, chisel-shaped incisors in both the upper and lower jaws.
4. Canine and anterior premolars are absent, thus forming a gap called diastema, between incisors and cheek teeth.
5. There are two premolars in the upper jaw and one in lower jaw.
6. Dentition is modified for chewing and gnawing. Jaw muscles are also well developed for gnawing.
7. Intestine and caecum are large.
8. Limbs are provided with blunt claws.
9. Forelimbs are smaller than the hind limbs.
10. Locomotion is of plantigrade type.
11. The scapula is provided with acromion process.
12. Testes are inguinal.
13. Females possess abdominal teats.
14. Prolifically reproducing animals.

Examples: *Funambulus palmarum* (three striped palm squirrel), *Funambulus pennanti* (five striped palm squirrel), *Sciurus* (squirrel), *Citellus* (Ground squirrel),

Fig. 17.7 : *Cavia* (Guineapig)

Petaurista petaurista (common giant flying squirrel), *Rattus rattus* (common house rat), *Mus musculus* (house mouse), *Bandicota indica* (bandicoot rat), *Bandicota bengalensis* (Indian mole- rat), *Heterocephalus* (naked rat of Africa) *Hystrix* (porcupine), *Cavia* (Guinea- pig), *Bathyergus* (mole-rat), *Cricetus* (hamster), *Mesocricetus* (golden hamster), *Castor* (Beaver), *Geomys* (Pocket gopher), *Marmota* (Moarmot, woodchuck).

Order 2. Lagomorpha (Latin: lagos = hare; morph = form) Rabbits and Hares

General Characters:

1. Body is covered with soft hair.
2. Eyes are large and pinna is long.
3. Pentadactyle limbs possess clawed dig-its. Hind limbs are larger than forelimbs.
5. The upper lip is provided with a cleft in the middle.
6. Tail is almost vestigial.
7. Masseter muscles are enormously developed but temporal muscles are weak.
8. Maxillae are laterally fenestrated.
9. There are two pairs of incisors in the upper jaw, while it is one pair in lower jaw.
10. The incisors of the upper jaw are unequal. A larger pair situated in front and smaller pair lie behind the front pair.
11. Canines are absent and diastema is present.
12. There are three premolars in upper jaw and two in lower jaw.
13. Scapula is with acromion and metacromion process.
14. Tibia and fibula are fused.
15. Testes lie inside the scrotum.
16. Mammary glands are abdominal in posi-tion.

Examples: *Lepus* (hare), *Oryctolagus* (rabbit), *Lepus nigricollis* (Indian hare), *Ochotona roylei* (Himalayan mouse hare), *Caprologus hispidus* (hispid hare of Himalaya).

Cohort — Mutica:

General Characters:

1. The body is without hairs except a few sensory bristles around snout in some species.
2. These animals lack vocal cords and are known as silent animals. But can emit sound for various purposes, which is called 'whale song'.
3. These animals are completely aquatic in all stages of life.
4. A subdermal fatty layer called blubber is present in all.

This Cohort includes only one order **Cetacea.**They are highly specialized mammals and show complete divergence from their primitive eutherian ancestors.

Order — Cetacea (Latin: cetas = whale) Balen whales, Toothed whales, Porpoises

General Characters:

1. Large, torpedo shaped body, devoid of hair except a few sensory bristles around snout in some species.
2. The skin is smooth and skin glands are absent.
3. The nictitating membrane of eye, pinna of ear and nail of the digits are absent.
4. Forelimbs are modified to form flippers, hind limbs are absent.
5. The nasal openings are asymmetrical, located far back on the upper surface of the head and can be closed by valves.
6. The tail terminates in a horizontal fin, called fluke that moves up and down. It is a neomorphic structure.
7. Dorsal fin is fleshy; it is also a neomorphic structure.
8. A thick subcutaneous fat layer, called blubber, is present. It acts as heat insulator and reservoir of food.
9. Teeth may be present or absent.
10. The cranium is dorsoventrally flattened and the facial part is elongated.
11. Cervical vertebrae are fused to form a bony mass.

12. Sacral vertebrae are absent. 16. Caudal vertebrae are with chevron bones.
13. Ribs lack heads.
14. Humerus is short, stout and its head moves freely in the glenoid cavity.
15. Number of digits are either reduced to four or increased to more than five (hyperdactyly). Numbers of phalanges are more than the usual number in second and third digits (hyperphalangy).
16. The lungs are highly elastic and exten-sible.
17. Brain is highly developed but olfactory lobe is reduced.
18. Two mammary glands are located in the inguinal area.
19. Single, large, well-formed young is born at a time.

Examples: *Platanista* (Ganges dolphin), *Physeter* (sperm whale), *Delphinus* (common dolphin), *Phocaena* (Porpoise), *Orcinus* (killer whale), *Balaenoptera* (Blue whale), *Balaena* (right whale).

Cohort 4. Ferungulata

A large number of mammals which are both herbivorous and carnivorous in habit are included in this cohort.

General Characters:

1. Modern carnivores and herbivores (hoofed mammals), all are members of this group.
2. From the fossil records it is evident that all of them arose from a common mammalian stock during Palaeocene period.

The cohort Ferungulata is divided into **five super orders** for the convenience of classification.

1. Superorder **Ferae**; 2. Superorder **Protoungulata**; 3.Superorder **Paenungulata**; 4.Superorder **Mesaxonia**; 5. Superorder Paraxonia

Superorder — Ferae:

All the living members of this group are carnivorous.This superorder includes single order –**Order Carnivora.**

Order — Carnivora (Latin: carno = flesh; voro = to eat): Dog, Cat, Fox, Tiger, Lion, Bear, Civet, Seals

This order includes the strongest and most formidable of all terrestrial mammals.

General characters:

1. Most of them are terrestrial, some forms are aquatic. Terrestrial forms have strongly built limbs. In aquatic forms, the distal part of forelimb is modified into paddles and the hind limbs are directed backwards.
2. Pentadactyle limbs, with digits ending in sharp claws and claws may be retractile.
3. Locomotion is either digitigrade or plantigrade type.
4. Brain is highly developed. Intelligence in the form of mental alert-ness and coordinated actions is evident.
5. Sense of smell is well developed. Intestine is short and caecum is small or absent.
6. Skull is short and high. Sagittal (longitudinal) and lambdoidal (transverse) crests are well-developed.
7. Zygomatic arch is strongly built.
8. Each jaw possesses three pairs of incisors. Canines are large, sharp and pointed.
9. The last upper premolar and first lower molar have transformed into chisel shaped blades, and act as scissors. They are jointly known as carnassial teeth (absent in seals).
10. The atlas is large and is provided with wing like lateral processes.
11. Thoracolumbar vertebrae are 20 to 21 in number.
12. Sternum is long narrow and made up of 8 to 9 sternibrae. Sternal ribs are not calcified.
13. Testes are present in scrotal sac.
14. Mammae are abdominal in position.
15. Placenta is deciduate and zonary.
16. Uterus is bicornuate in shape.

Examples: *Canis domesticus (Dog), Canis lupas* (Wolf), *Canis aureu* (Jackel), *Vulpes bengalensis* (Indian Fox), *Ursus* (Bear), *Procyon* (Raccon), *Ailurus* (Panda),

Ailuropoda (Giant Panda), *Viverra* (Civet), *Herpestes* (Mongoose), *Hyaena* (Hyena), *Meles*(Badger),*Felis domesticus* (Cats), *Felis tigris*(Tiger),*Felis onca*(Jaguar),*Felis cougar*(Puma),*Panthera leo*(Lion), *Panthera perdus*(Leopard),*Acinonyx jubatus*(Cheetah), *Eumetopias* (Sea lion), *Odobenus* (Walrus), *Phoca* (Seal), *Mephitis* (Shunk), *Lutra*(Otter), etc.

Superorder — Protongulata

This superorder includes five orders but except one order — **Tubulidentata,** all others are extinct.

Order — Tubulidentata (Latin: tubulus = small tube; dens = teeth)

General Characters:

1. Body is covered by a dull-grey skin with unevenly distributed hair.
2. Head is elongated to form a tubular snout.
3. Pinna is long in size.
4. Limbs are strong. Forelimbs are with four digits and hind limbs possess five digits. All the digits end in claws.
5. Mouth small with long, protrusible tongue.
6. Incisors and canines are absent. The cheek teeth are 4 or 5 in number, which lack enamel but a coating of cement is present.
7. These are ant-eater in habit.

Example: There is only one representa-tive species present till now. *Orycteropus afer* (aardvark) living in Africa and known as cape ant-eater.

Superorder — Paenungulata

General Characters:

1. They are all herbivorous animals.
2. The legs are with long upper segments, ulna and fibula complete.
3. They possess several digits, with nail but no well-marked hoofs.
4. The incisors and canine become reduced to single pair of large tusks in each jaw and the molars are specialized for grinding, with development of cross-ridges.

Simpson (1945) suggested the name Pae-nungulata (= near ungulates).

This superorder includes seven orders but except three- Order **Hyracoidea,** Order **Proboscidea** and Order **Sirenia,**rest four are extinct.

Order — Hyracoidea (Greek: hyrax = shrew; eides = form) Hyraxes

General Characters:

1. These are small, rabbit-like animals, with short tail and short pinna.
2. Locomotion is plantigrade type.
3. Forelimbs possess four functional digits and fifth one remains as vestige.
4. There are three digits in each hind limb. First and third digits possess hoof while second digit is clawed.
5. Single pair of large and curved upper incisors with persistent root is present. Canines are absent.
6. The lower incisors are comb-like and four in number.
7. There is a diastema and seven grinding molariform teeth of bunoselenodont type, with transverse ridges.
8. The stomach is constricted in the middle. Gall bladder is absent.
9. The caecum has a pair of caecal pouches.
10. Mammae are pectoral in position and two in number.
11. Testes are abdominal in position.
12. Uterus is paired; the placenta has an annular avascular allantois and haemochorial in nature.

Examples: *Procavia* (= *Hyrax*), *Dendrohyrax* (Tree hyrax).

Order — Proboscidea (Latin Proboskis=trunk) Elephants

General Characters:

1. These are largest living land vertebrates.
2. Thick skin (pachyderm) with scanty hair.
3. Fusion and elongation of the nose and upper lip have resulted in the formation of a large muscular prehensile and very sensitive trunk or proboscis. Nostrils are situated at the tip of the trunk.

4. Dentition is highly characteristic. There is a single pair of incisors in upper jaw. Incisors are absent in lower jaw. The upper incisors have no root and they grow continually to form two long tusks. Tusks are made of ivory which is a specialized dentine.
5. Premolars and canines are absent. The immensely large hypsodont molars with numerous sharp transverse ridges are parts of the powerful grinding apparatus.
6. Eyes are small but pinna is large.
7. Pentadactyle limbs are pillar-like. Digits are hoofed.
8. Skull is massive. Sutures of the skull are obliterated.
9. Cervical region is short. Ribs are 20 in number.
10. The weight of the head is reduced by extensive development of air sinuses.
11. Cerebral hemispheres are convoluted but do not cover the cerebellum.
12. Stomach and intestine are simple. There is no special chamber in stomach for fermentation of herbaceous food.
13. The caecum is long and sacculated and there is an ileocaecal sphincter.
14. Testes are abdominal in position.
15. Single pair of mammae, pectoral in position.
16. Only one young is born at a time. Gestation period 22 months.

Examples: Only two genera- *Elephas and Loxodonta. Elephas maximus* is Indian elephant and *Loxodonta africana* is African elephant.

Order — Sirenia (Greek: siren = sea nymph)

General Characters:

1. These are herbivorous animals, highly adapted for aquatic life.
2. They have a streamlined body form, with few hair and thick blabber.
3. The muzzle is round and the upper lip is protruding.
4. Nostrils are located on the upper surface of head and are provided with valves.
5. Neck is short and pinna is absent. Eyes are small with muscular eyelids.
6. The forelimbs are large with five digits which are webbed, nail- less and joined to form paddles.

7. There are no hind limbs and the pelvic girdle remains only as small rods.
8. Number of cervical vertebrae in Manatee (*Manatus*) is only six.
9. Caudal vertebrae are numerous, flattened and with wide transverse processes.
10. A strong terminal horizontal fin is pre-sent.
11. Ribs are round and the diaphragm is oblique.
12. Lungs contain large air sacs.
13. Brain is small and the ventricles are exceptionally large.
14. The front parts of the jaw carry no teeth at the front, but have horny pads. The teeth form a series of pegs, with two transverse ridges.
15. Stomach is complex and intestine is very long.
16. Testes are abdominal. Uterus is bicornuate.
17. Placenta shows a zonary arrangement and haemochorial structure,
18. The young are born in water and nursed at pectoral teats.

Examples: *Dugong* (= *Halicore*) (Sea cow), *Manatus* (= *Trichechus*) (Manatee).

Superorder — Mesaxonia

Axis of the limb passes through the third digit (middle axis). This is called the mesaxonic condition. The remaining digits are reduced. This superorder includes only one order- Order **Perissodactyla.**

Members are called **odd toed mammals.**

Order — Perissodactyla (Greek: perissos = odd; daktylos = finger) Horses, Asses, Zebras, Rhinos, Tapirs

General Characters:

1. These are large, herbivorous mammals having streamlined body.
2. The neck and facial parts are elongated. Horns are absent in most forms.
3. Tail is with long tuft of hair.
4. The powerful limbs are suitable for fast movement.
5. Of the five digits, the first and fifth digits are lost. The second and fourth digits remain as splints. The middle or third digit is stout and is provided with hoof.

This type of foot is known as mesaxonic foot. The hoof is intact, not bifurcated (hence called odd toed).

6. The upper part of both the limbs are reduced and lower part of the limbs are elongated.
7. The third metatarsal of the hind limb is long and erect and is known as cannon bone. The third metacarpal is longest.
8. Skull is elongated. The nasals are large.
9. The incisors are three in each quadrant of the jaws. The incisors having pit on the free surface.
10. The canine may be reduced or absent and there is often a diastema.
11. The molars have developed an elaborate grinding surface with the formation of a longitudinal ectoloph along the outer edge of the upper molar and parallel transverse ridges, the protoloph and metaloph.
12. Ulna and fibula are reduced.
13. The femur is provided with a prominent process on the other surface of the shaft. The process is called third trochanter.
14. Stomach is simple and undivided. Intestine is long.Caecum is large and sacculated. Digestion of cellulose takes place by symbionts in the caecum and large intestine.
15. Brain is relatively small and macrosmatic type. Olfactory lobes are highly developed.
16. Testes are usually abdominal.
17. Mammae are inguinal.
18. Uterus is bicornuate. Placenta is of diffuse epitheliochorial type, with a large allantoic sac.
19. The yolk sac grows to a large size and forms a yolk sac placenta during the early part of the development.

Examples: *Equus cabalus* (Horses), *Equus hemionus*(Asses), *Equus zebra* (Zebras),*Tapirus* (Tapirs), *Rhinoceros unicornis* (Indian and Javan rhino) *Rhinoceros bicornis* (African two horned rhinos), *Dicerorhinus sumatrensis*((two toed Sumatran rhinos).

Superorder — Paraxonia

Axis of the limb passes through the third and fourth digits. This is called the **paraxonic condition**. The remaining digits are reduced.

This superorder includes only one order- Order **Artiodactyla.**

Members are called **even toed mammals.**

Order — Artiodactyla (Greek: artios = even; daktylos = finger) Cattle, Buffalo, Goat, Sheep, Deer, Pig, Hippo, Camel, Yak

General Characters:

1. These are even toed ungulates and latest mammalian herbivores.
2. Neck is elongated but tail is small.
3. Usually possess a pair of epidermal horns. Horns may be hollow or solid and are located on the frontal bone of the skull.
4. The characteristic of the limbs is the equal development of third and fourth digits, with reduction of the rest. Axis of the body passes through the third and fourth digits. This type of foot is known as paraxonic foot.
5. Gait is digitigrade type. Hoofs have developed on the toes i.e. on third and fourth digits (hoofs are two in number, hence called even toed).
6. The eyes are large with horizontal pupil.
7. Pinna is large with an acute sense of hearing.
8. Tongue is long, mobile, prehensile and pointed.
9. The facial part of the skull is elongated.
10. The upper incisors are lost, which crop up by means of the lower incisors biting against the hardened gum of the pre- maxilla.
11. The canines form tusks in some.
12. Molars are of hypsodont and solenodont (moon-tooth).
13. Stomach is complicated and divided into several chambers.
14. Intestine is short and a short caecum is present.
15. Mammae are abdominal or inguinal in position and may be more than one pair.

16. Brain is moderately developed. The olfactory organ and related parts of the brain are well-developed.
17. The uterus is bicornuate type.
18. Placenta of pig is of diffused epithelio-chorial type. In ruminants there is a cotyledonary placenta, but the contact between maternal and foetal tissues is never very close (Syndesmochorial) and the allantois is usually large.

Examples: *Sus* (Pig), *Hippopotamus* (Hippo), *Camelus* (Camel,), *Giraffa* (Giraffe), *Gazella* (Gazelles), *Bos gaurus*(Gaur or Indian bison), *Bos grunniens* (Yak*)*,(Cattle,), *Bubalus bubalis* (Wild buffalo) *Bison bison*(American bison), *Capra* (Goat), *Ovis* (Sheep),*Lama pacos*(Alpaca),*Antilope cervicapra*(Black buck),Axis(Cheetal), *Moschus* (Musk deer), *Ceruus* (Red deer), *Dama* (Fallow deer), *Rangifer* (Rein deer),

17.4❑ Questions

- Naik,

17.5❑ Suggested readings

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