M.Sc. (Zoology)
I - Semester
350 11

ANIMAL DIVERSITY
Author
Dr Pradeep Kumar, Research Associate-III, Department of Pediatrics, Army Hospital Research & Referral, New Delhi

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## INTRODUCTION

### BLOCK I: CLASSIFICATION OF ANIMALS

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14.7 Self Assessment Questions and Exercises
14.8 Further Readings
Animal diversity refers to the animal evolution that began in the ocean over 600 million years ago with tiny creatures that probably do not resemble any living organism today. The animal classification system characterizes animals based on their anatomy, morphology, evolutionary history, features of embryological development, and genetic makeup. Taxonomy is that branch of biology which deals with the identification and naming of organisms. The ancient Greek philosopher Aristotle apparently began the discussion on taxonomy. During the 1700s, Swedish botanist Carolus Linnaeus classified all then-known organisms into two large groups: the kingdoms Plantae and Animalia. The Linnaean hierarchical classification system of nomenclature is still used today — termed as the binomial system of genus and species — and established as a discipline taxonomy. Robert Whittaker in 1969 proposed five kingdoms: Plantae, Animalia, Fungi, Protista, and Monera. Other schemes involving an even greater number of kingdoms have lately been proposed, however most biologists employ Whittaker’s five kingdoms. The vast panorama of animal life, how animals function, live, reproduce, and interact with their environment, is exciting, fascinating and inspiring. Zoology is the scientific study of animal life, its origins and relationships, and includes the study of genetics and biochemistry. The genetic study of DNA from various animals and plants can provide insights into their evolutionary history.

The diversity of life is one of the most striking aspects of our planet. Hence knowing how many species inhabit Earth is among the most fundamental yet elusive questions in science. However, the answer to this question remains obscure as efforts to sample the world’s biodiversity to date have been limited. Animal evolution began in the ocean over 600 million years ago with tiny creatures that probably do not resemble any living organism today. Since then, animals have evolved into a highly diverse kingdom. Although over one million extant (currently living) species of animals have been identified, scientists are continually discovering more species as they explore ecosystems around the world. The number of extant species is estimated to be between 3 and 30 million.

The identified animal species have been placed in ten phyla. Many of these species are pests of crops, domestic animals, and household goods and materials. In the economy of nature, these species have close association with a number of other animals that act as predators and exercise a check on their population increase. Animal pests belonging to these phyla are further placed under different classes, orders and families. Their classification is necessary not only for their identification, but also for the understanding of their feeding and breeding habits, their modes of multiplication, their seasonal activity and hibernation, the duration of their life-cycles and the number of generations in a year. Practically all the pests and most of their enemies are included in the four phyla, viz., Chordata, Mollusca, Nemathelminthes and Arthropoda.
This book, *Animal Diversity*, is divided into four blocks, which are further subdivided into fourteen units. The first unit introduces to the diversity of animals while typological, biological and evolutionary species have been discussed in the following unit. The third unit deals with the concept of taxonomy. Major divisions of animal kingdom are focused on in the fourth unit while the fifth unit explains the protozoa. Porifera is discussed in the sixth unit while seventh unit deals with coelenterata. Eighth units discusses helminth parasites. And annelida has been explained in the following unit. Arthropoda has been explained in the tenth unit while eleventh units focuses on mollusca and echinodermata. Twelfth unit discusses prochordates and vertebrates while thirteenth unit introduces you to amphibians and reptiles. The last unit discusses aves and mammals.

The book follows the self-instructional mode wherein each unit begins with an ‘Introduction’ to the topic. The ‘Objectives’ are then outlined before going on to the presentation of the detailed content in a simple and structured format. ‘Check Your Progress’ questions are provided at regular intervals to test the student’s understanding of the subject. ‘Answers to Check Your Progress Question’, a ‘Summary’, a list of ‘Key Words’ and a set of ‘Self Assessment Questions and Exercises’ are provided at the end of each unit for effective recapitulation.
Block - I
Classification of Animals

Unit 1 Introduction to Animal Diversity

Structure
1.0 Introduction
1.1 Objectives
1.2 Diversity of Animals: An Introduction
1.3 Principles of Classification
1.4 Types of Classification
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1.0 INTRODUCTION

Animal diversity refers to the animal evolution that began in the ocean over 600 million years ago with tiny creatures that probably do not resemble any living organism today. The animal classification system characterizes animals based on their anatomy, morphology, evolutionary history, features of embryological development, and genetic makeup. Taxonomy is that branch of biology which deals with the identification and naming of organisms. The ancient Greek philosopher Aristotle apparently began the discussion on taxonomy. During the 1700s, Swedish botanist Carolus Linnaeus classified all then-known organisms into two large groups: the kingdoms Plantae and Animalia. The Linnaean hierarchical classification system of nomenclature is still used today — termed as the binomial system of genus and species — and established as a discipline taxonomy.

In this unit, you will learn about the diversity of animals, standard principles and types of classification system, binomial nomenclature and Linnaeus system of classification.

1.1 OBJECTIVES

After going through this unit, you will be able to:

- Explain that why the animals are of diverse nature
NOTES

1.2 DIVERSITY OF ANIMALS: AN INTRODUCTION

Animals are highly diverse. Members of the animal kingdom are among the most conspicuous living things in the world. Animal evolution began in the ocean over 600 million years ago with tiny creatures that probably do not resemble any living organism today. Since then, animals have evolved into a highly diverse kingdom. Although over one million extant (currently living) species of animals have been identified, scientists are continually discovering more species as they explore ecosystems around the world. The number of extant species is estimated to be between 3 and 30 million.

But what is an animal? While we can easily identify dogs, birds, fish, spiders, and worms as animals, other organisms, such as corals and sponges, are not as easy to classify. Animals vary in complexity—from sea sponges to crickets to chimpanzees—and scientists are faced with the difficult task of classifying them within a unified system. They must identify traits that are common to all animals as well as traits that can be used to distinguish among related groups of animals. The animal classification system characterizes animals based on their anatomy, morphology, evolutionary history, features of embryological development, and genetic makeup. This classification scheme is constantly developing as new information about species arises. Understanding and classifying the great variety of living species helps in understanding how to conserve the diversity of life on earth.

Animals are the eaters or consumers of the earth. They are heterotrophs and depend directly or indirectly on plants, photosynthetic Protists (algae), or autotrophic bacteria for nourishment. Animals are able to move from place to place in search of food. In most, ingestion of food is followed by digestion in an internal cavity.

1. Multicellular Heterotrophs: All animals are multicellular heterotrophs. The unicellular heterotrophic organisms called Protozoa, which were at one time regarded as simple animals, are now considered to be members of the kingdom Protista, the large and diverse group.

2. Diverse in Form: Almost all animals (99%) are invertebrates, lacking a backbone. Of the estimated 10 million living animal species, only 42,500 have a backbone and are referred to as vertebrates. The animal kingdom includes about 35 phyla, most of which occur in the sea. Far fewer
phyla occur in fresh water and fewer still occur on land. Members of the three phyla, namely the Arthropoda (spiders and insects), Mollusca (snails), and Chordata (vertebrates), dominate animal life on land.

3. **No Cell Walls**: Animal cells are distinct among multicellular organisms because they lack rigid cell walls and are usually quite flexible.

4. **Active Movement**: The ability of animals to move more rapidly and in more complex ways than members of other kingdoms is perhaps their most striking characteristic and one that is directly related to the flexibility of their cells and the evolution of nerve and muscle tissues.

5. **Sexual Reproduction**: Most animals reproduce sexually. Animal eggs, which are non-motile, are much larger than the small, usually flagellated sperm. In animals, cells formed in meiosis function directly as gametes. The haploid cells do not divide by mitosis first, as they do in plants and fungi, but rather fuse directly with each other to form the zygote.

6. **Embryonic Development**: Most animals have a similar pattern of embryonic development. The zygote first undergoes a series of mitotic divisions, called cleavage, and becomes a solid ball of cells, the morula, then a hollow ball of cells, the blastula. In most animals, the blastula folds inward at one point to form a hollow sac with an opening at one end called the blastopore. An embryo at this stage is called a gastrula.

### 1.3 PRINCIPLES OF CLASSIFICATION

The broad classification of Animalia or animal kingdom is based on the following common fundamental features.

- **Levels of Organisation**
- **Symmetry**
- **Diploblastic and Triploblastic Organisation**
- **Coelom Development**
- **Segmentation of the Body**
- **Presence or Absence of Notochord**

#### Levels of Organisation

Though all members of Animalia are multicellular, all of them do not exhibit the same pattern of organisation of cells. For example, in sponges, the cells are arranged as loose cell aggregates, i.e., they exhibit cellular level of organisation. Some division of labour (activities) occur among the cells. In coelenterates, the arrangement of cells is more complex. Here the cells performing the same function are arranged into tissues, hence is called tissue level of organisation. A still higher level of organisation, i.e., organ level [organ level of organisation] is exhibited by members
of Platyhelminthes and other higher phyla where tissues are grouped together to form organs, each specialised for a particular function.

In animals like Annelids, Arthropods, Molluscs, Echinoderms and Chordates, organs have associated to form functional systems, each system concerned with a specific physiological function (Refer Figure 1.1). This pattern is called organ system level of organisation. Organ systems in different groups of animals exhibit various patterns of complexities. For example, the digestive system in Platyhelminthes (incomplete digestive system) has only a single opening to the outside of the body that serves as both mouth and anus, and is hence called incomplete. A complete digestive system has two openings, mouth and anus.

Similarly, the circulatory system may be of two types: open type in which the blood is pumped out of the heart and the cells and tissues are directly bathed in it and closed type in which the blood is circulated through a series of vessels of varying diameters (arteries, veins and capillaries).

**Symmetry**

Animals can be categorised on the basis of their symmetry. Sponges are mostly asymmetrical, i.e., any plane that passes through the centre does not divide them into equal halves. When any plane passing through the central axis of the body divides the organism into two identical halves, it is called radial symmetry. Coelenterates, Ctenophores and Echinoderms have this kind of body plan. Animals like Annelids, Arthropods, etc., where the body can be divided into identical left and right halves in only one plane, exhibit bilateral symmetry. Figure 1.2 illustrates the concept of radial symmetry in star fish and bilateral symmetry in cockroach.
Diploblastic and Triploblastic Organisation

Animals in which the cells are arranged in two embryonic layers, an external ectoderm and an internal endoderm, are called diploblastic animals, e.g., Coelenterates. An undifferentiated layer, mesoglea, is present in between the ectoderm and the endoderm. Those animals in which the developing embryo has a third germinal layer, mesoderm, in between the ectoderm and endoderm, are called triploblastic animals (Platyhelminthes to Chordates).

Coelom

Presence or absence of a cavity between the body wall and the gut wall is very important in classification. The body cavity, which is lined by mesoderm is called coelom. Animals possessing coelom are called coelomates, examples include Annelids, Molluscs, Arthropods, Echinoderms, Hemichordates and Chordates.

In some animals, the body cavity is not lined by mesoderm, instead the mesoderm is present as scattered pouches in between the ectoderm and endoderm. Such a body cavity is called pseudocoelom and the animals possessing them are
called pseudocoelomates, example includes Aschelminthes. The animals in which the body cavity is absent are called acoelomates, such as Platyhelminthes.

**Segmentation**

In some animals, the body is externally and internally divided into segments with a serial repetition of at least some organs. For example, in earthworm, the body shows this pattern called metameric segmentation and the phenomenon is known as metamerism (Refer Figure 1.5).

**Notochord**

The notochord is a flexible rod made out of a material similar to cartilage. If a species has a notochord at any stage of its life cycle, it is, by definition, a chordate.
In vertebrates the notochord becomes part of the vertebral column. Notochord is typically a mesoderm, i.e., the middle layer of cells or tissues of an embryo, or the parts derived from this, such as cartilage, muscles, and bone. These are the derived rod-like structure formed on the dorsal side [posterior] during embryonic development in some animals. Animals with notochord are called chordates and those animals which do not form this structure are called non-chordates, namely Porifera to Echinoderms.

![Fig. 1.6 Notochord](image)

**Check Your Progress**

1. Why are animals highly diverse?
2. What does the animal classification system characterizes?
3. On what broad classification the Animalia or animal kingdom is based?
4. How the animals can be categorised on the basis of symmetry?
5. Differentiate between diploblastic and triploblastic animals.
6. What is notochord? Which species has a notochord?

### 1.4 TYPES OF CLASSIFICATION

Classification is a system of naming objects or entities by common characteristics. In a biological sense, classification is the systematic grouping of organisms based on structural or functional similarities or evolutionary history. A process of establishing, defining, and ranking taxa within hierarchical series of groups. Not surprisingly, biologists classify organisms into different categories mostly by judging degrees of apparent similarity and difference that they can see. The assumption is that the greater the degree of physical similarity, the closer the biological relationship. To discover unknown organism, taxonomists consider the following points.

1. They begin their classification by looking for anatomical features that appear to have the same function as those found on other species.
2. They determine whether or not the similarities are due to an independent evolutionary development or to descent from a common ancestor. If the latter is the case, then the two species are probably closely related and should be classified into the same or near biological categories. Natural selection and other processes have led to a staggering diversity of organisms. Biologists have identified and named about 1.5 million species so far and 2-100 million additional species are yet to be discovered.

The classification system that scientists use today was developed by Carl Linnaeus in the 18th century. This system is known as binomial classification. It uses Latin names, so scientists around the world can use the same names without confusion. The first part of an organism’s scientific name is its genus, and the second part is the species as shown below in the example.

Classification enables us to explore the evolutionary origins of an organism. Two organisms in the same genus are generally very similar, and are therefore likely to share an ancestor in the recent past. For example, the genus Canis includes domestic dogs, jackals, coyotes and wolves. Two organisms in the same kingdom, for example dogs and spiders may share some common characteristics, but are different in many ways. Consequently, their common ancestor is likely to be in the distant past.

Taxonomy is the part of science that focuses on naming and classifying or grouping organisms. The Swedish naturalist named Carolus Linnaeus is considered the ‘Father of Taxonomy’ because, in the 1700s, he developed a way to name and organize species that we still use today.

**A Hierarchical Classification System**

A hierarchical system is used for classifying organisms up to the species level. This system is called taxonomic classification. The broadest classifications are by domain and kingdom; the most specific classification is by genus and species. The hierarchical groupings in between include phylum, class, family, and order as shown in Figure 1.7.

In biology, ‘genus’ is the taxonomic classification lower than ‘family’ and higher than ‘species’. In other words, genus is a more general taxonomic category than is species. For example, the generic name for *Genus Ursus* represents brown bears, polar bears and black bears.

The *Species* name, also called ‘Specific Epithet’, is the second part of a scientific name, and refers to one species within a genus. A species is a group of organisms that typically have similar anatomical characteristics and, in sexual
reproducers, can successfully interbreed to produce fertile offspring. In the genus *Ursus*, there are a number of different bear species, including *Ursus arctos*, the brown bear, *Ursus americanus*, the American black bear and *Ursus maritimus*, the polar bear.

**Fig. 1.7 Hierarchical Classification System**

The binomial aspect of this classification system means that each organism is given two names, a ‘generic name,’ which is called the genus (plural = genera) and a ‘specific name,’ the species. Together the generic and specific names of an organism are its scientific name. Having a universal system of binomial nomenclature allows scientists to speak the same language when referring to living things, and avoids the confusion of multiple common names that may differ based on region, culture or native language. When written, a scientific name is always either italicized, or, if hand-written, underlined. The genus is capitalized and the species name is lower case. For example, the proper format for the scientific name of humans is *Homo sapiens*.

During his lifetime, Linnaeus collected around 40,000 specimens of plants, animals, and shells. He believed it was important to have a standard way of grouping and naming species. So in 1735, he published his first edition of *Systema Naturae* (The System of Nature), which was a small pamphlet explaining his new system of the classification of nature. He continued to publish more editions of *Systema Naturae* that included more named species. In total, Linnaeus named 4,400 animal species and 7,700 plant species using his binomial nomenclature system. The tenth edition of *Systema Naturae* was published in 1758 and is considered the most important edition. Its full title in English is System of nature through the three kingdoms of nature, according to classes, orders, genera and species, with characters, differences, synonyms, places.
1.5 LINNAEUS’S CLASSIFICATION SYSTEM

In 1735, Carl Linnaeus published his *Systema Naturae*, which contained his taxonomy for organizing the natural world. Linnaeus proposed three kingdoms, which were divided into classes. From classes, the groups were further divided into orders, families, genera (singular: genus), and species. An additional rank beneath species distinguished between highly similar organisms. While his system of classifying minerals has been discarded, a modified version of the Linnaean classification system is still used to identify and categorize animals and plants.

In *Systema Naturae*, Linnaeus classified nature into a hierarchy. He proposed that there were three broad groups, called kingdoms, into which the whole of nature could fit. These kingdoms were animals, plants, and minerals. He divided each of these kingdoms into classes. Classes were divided into orders. These were further divided into genera (genus is singular) and then species. We still use this system today, but we have made some changes. Linnaeus also published the ‘*Imperium Naturae*’ in 1758 version (10th edition) for classification system.

Today, we only use this system to classify living things. (Linnaeus included non-living things in his mineral kingdom.) Also, we have added a few additional levels in the hierarchy. The broadest level of life is now a domain. All living things fit into only three domains: Archaea, Bacteria, and Eukarya. Within each of these domains there are kingdoms. For example, Eukarya includes the kingdoms Animalia, Fungi, Plantae, and more. Each kingdom contains phyla (singular is phylum), followed by class, order, family, genus, and species. Each level of classification is also called a taxon (plural is taxa).

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*Linnaeus’s System of Classification*

**Original Linnaean Classification System**

When identifying an object, Linnaeus first looked at whether it was animal, vegetable, or mineral. These three categories were the original domains. Domains
were divided into kingdoms, which were broken into phyla (singular: phylum) for animals and divisions for plants and fungi. Phyla or divisions were broken into classes, which in turn were divided into orders, families, genera (singular: genus), and species. Species were further divided into subspecies.

According to the 1758 version (10th edition) of the *Imperium Naturae*, the Linnaeus classification system for 'Animal Kingdom' was as follows.

**Animal Kingdom**
- Class 1: Mammalia (Mammals)
- Class 2: Aves (Birds)
- Class 3: Amphibia (Amphibians)
- Class 4: Pisces (Fish)
- Class 5: Insecta (Insects)
- Class 6: Vermes (Worms)

**Check Your Progress**

7. On what biological sense the classification as the systematic grouping of organisms is based?
8. Which classification system the scientists use today?
9. What does classification help us to explore?
10. Define the term taxonomic classification.
11. What does the binomial aspect of Linnaeus classification system specify?

**1.6 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS**

1. Animals are highly diverse. Members of the animal kingdom are among the most conspicuous living things in the world. Animal evolution began in the ocean over 600 million years ago with tiny creatures that probably do not resemble any living organism today. Since then, animals have evolved into a highly diverse kingdom.

2. The animal classification system characterizes animals based on their anatomy, morphology, evolutionary history, features of embryological development, and genetic makeup. This classification scheme is constantly developing as new information about species arises.

3. The broad classification of Animalia or animal kingdom is based on the following common fundamental features.
   - Levels of Organisation
4. Animals can be categorised on the basis of their symmetry. When any plane passing through the central axis of the body divides the organism into two identical halves, it is called radial symmetry. When the body can be divided into identical left and right halves in only one plane, exhibit bilateral symmetry.

5. Animals in which the cells are arranged in two embryonic layers, an external ectoderm and an internal endoderm, are called diploblastic animals, e.g., Coelenterates. Those animals in which the developing embryo has a third germinal layer, mesoderm, in between the ectoderm and endoderm, are called triploblastic animals, such as Platyhelminthes to Chordates.

6. The notochord is a flexible rod made out of a material similar to cartilage. If a species has a notochord at any stage of its life cycle, it is, by definition, a chordate. In vertebrates the notochord becomes part of the vertebral column.

7. Classification is a system of naming objects or entities by common characteristics. In a biological sense, classification is the systematic grouping of organisms based on structural or functional similarities or evolutionary history. A process of establishing, defining, and ranking taxa within hierarchical series of groups.

8. The classification system that scientists use today was developed by Carl Linnaeus in the 18th century. This system is known as binomial classification. It uses Latin names, so scientists around the world can use the same names without confusion. The first part of an organism’s scientific name is its genus, and the second part is the species as shown below in the example.

9. Classification enables us to explore the evolutionary origins of an organism.

10. A hierarchical system is used for classifying organisms up to the species level. This system is called taxonomic classification.

11. The binomial aspect of this classification system means that each organism is given two names, a ‘generic name,’ which is called the genus (plural = genera) and a ‘specific name,’ the species. Together the generic and specific names of an organism are its scientific name.

1.7 SUMMARY

- Animals are highly diverse. Members of the animal kingdom are among the most conspicuous living things in the world.
Animal evolution began in the ocean over 600 million years ago with tiny creatures that probably do not resemble any living organism today. Since then, animals have evolved into a highly diverse kingdom.

Animals vary in complexity—from sea sponges to crickets to chimpanzees—and scientists are faced with the difficult task of classifying them within a unified system.

The animal classification system characterizes animals based on their anatomy, morphology, evolutionary history, features of embryological development, and genetic makeup. This classification scheme is constantly developing as new information about species arises.

All animals are multicellular heterotrophs. The unicellular heterotrophic organisms called Protozoa, which were at one time regarded as simple animals, are now considered to be members of the kingdom Protista, the large and diverse group.

Almost all animals (99%) are invertebrates, lacking a backbone. Of the estimated 10 million living animal species, only 42,500 have a backbone and are referred to as vertebrates.

The animal kingdom includes about 35 phyla, most of which occur in the sea. Members of the three phyla, namely the Arthropoda (spiders and insects), Mollusca (snails), and Chordata (vertebrates), dominate animal life on land.

The ability of animals to move more rapidly and in more complex ways than members of other kingdoms is perhaps their most striking characteristic and one that is directly related to the flexibility of their cells and the evolution of nerve and muscle tissues.

In animals, cells formed in meiosis function directly as gametes. The haploid cells do not divide by mitosis first, as they do in plants and fungi, but rather fuse directly with each other to form the zygote.

Most animals have a similar pattern of embryonic development. The zygote first undergoes a series of mitotic divisions, called cleavage, and becomes a solid ball of cells, the morula, then a hollow ball of cells, the blastula.

In most animals, the blastula folds inward at one point to form a hollow sac with an opening at one end called the blastopore. An embryo at this stage is called a gastrula.

The broad classification of Animalia or animal kingdom is based on the common fundamental features, namely levels of organisation, symmetry, diploblastic and triploblastic organisation, coelom development, segmentation of the body and presence or absence of notochord.

In animals like Annelids, Arthropods, Molluscs, Echinoderms and Chordates, organs have associated to form functional systems, each system concerned with a specific physiological function.
• The circulatory system may be of two types, open type in which the blood is pumped out of the heart and the cells and tissues are directly bathed in it and closed type in which the blood is circulated through a series of vessels of varying diameters (arteries, veins and capillaries).

• Animals can be categorised on the basis of their symmetry. Sponges are mostly asymmetrical, i.e., any plane that passes through the centre does not divide them into equal halves.

• When any plane passing through the central axis of the body divides the organism into two identical halves, it is called radial symmetry.

• When the body of the organism can be divided into identical left and right halves in only one plane, then it exhibit bilateral symmetry.

• Animals in which the cells are arranged in two embryonic layers, an external ectoderm and an internal endoderm, are called diploblastic animals, e.g., Coelenterates.

• Animals in which the developing embryo has a third germinal layer, mesoderm, in between the ectoderm and endoderm, are called triploblastic animals (Platyhelminthes to Chordates).

• Presence or absence of a cavity between the body wall and the gut wall is very important in classification. The body cavity, which is lined by mesoderm is called coelom.

• In some animals, the body cavity is not lined by mesoderm, instead the mesoderm is present as scattered pouches in between the ectoderm and endoderm. Such a body cavity is called pseudocoelom and the animals possessing them are called pseudocoelomates.

• In some animals, the body is externally and internally divided into segments with a serial repetition of at least some organs. For example, in earthworm, the body shows this pattern called metameric segmentation and the phenomenon is known as metamerism.

• The notochord is a flexible rod made out of a material similar to cartilage. If a species has a notochord at any stage of its life cycle, it is, by definition, a chordate. In vertebrates the notochord becomes part of the vertebral column.

• Classification is a system of naming objects or entities by common characteristics.

• In a biological sense, classification is the systematic grouping of organisms based on structural or functional similarities or evolutionary history.

• The classification system that scientists use today was developed by Carl Linnaeus in the 18th century. This system is known as binomial classification and uses Latin names.
• Classification enables us to explore the evolutionary origins of an organism.
• Taxonomy is the part of science that focuses on naming and classifying or grouping organisms.
• The Swedish naturalist named Carolus Linnaeus is considered the ‘Father of Taxonomy’ because, in the 1700s, he developed a way to name and organize species that we still use today.
• A hierarchical system is used for classifying organisms up to the species level. This system is called taxonomic classification.
• The Species name, also called ‘Specific Epithet’, is the second part of a scientific name, and refers to one species within a genus.
• A species is a group of organisms that typically have similar anatomical characteristics and, in sexual reproducers, can successfully interbreed to produce fertile offspring.
• The binomial aspect of the classification system means that each organism is given two names, a ‘generic name,’ which is called the genus (plural = genera) and a ‘specific name,’ the species. Together the generic and specific names of an organism are its scientific name.

1.8 KEY WORDS

• Animal classification system: It characterizes animals based on their anatomy, morphology, evolutionary history, features of embryological development, and genetic makeup.
• Radial symmetry: When any plane passing through the central axis of the body divides the organism into two identical halves, it is called radial symmetry.
• Bilateral symmetry: When the body of the organism can be divided into identical left and right halves in only one plane, then it exhibit bilateral symmetry.
• Diploblastic animals: Animals in which the cells are arranged in two embryonic layers, an external ectoderm and an internal endoderm, are called diploblastic animals.
• Triploblastic animals: Those animals in which the developing embryo has a third germinal layer, mesoderm, in between the ectoderm and endoderm, are called triploblastic animals.
• Notochord: The notochord is a flexible rod made out of a material similar to cartilage.
1.9 SELF ASSESSMENT QUESTIONS AND EXERCISES

NOTES

Short-Answer Questions

1. Define the term animal diversity.
2. What do you mean by levels of organisation in classification system?
3. What is the significance of coelom?
4. Which organism has body segmentation?
5. What is the significance of notochord?
7. What does the hierarchical classification system specify?
8. Who is Carl Linnaeus? What classification system he has given?

Long-Answer Questions

1. Explain that why the animals are of diverse nature and complex.
2. Discuss with the help of examples on what characteristics the animal classification system is based. Does this classification scheme constantly develops as and when new information about species arises.
3. Analyse the various principles of classification with the help of examples.
4. Explain the different types of classification system giving suitable examples of each type.
5. Discuss the taxonomical system of classification with the help of examples. How organisms are classified into kingdoms and phyla, and then to the species level?
6. What is the advantage of using a binomial system to name species? In the classification of organisms, which is the correct order of ranks? Give examples for each type.
7. What is the significance of binomial nomenclature? Explain giving significant points.
8. Discuss the significance of Linnaeus system of classification. Which classification system the scientists use even today.
10. ‘Taxonomy is the part of science that focuses on naming and classifying or grouping organisms’. Justify the statement giving appropriate examples.
1.10 FURTHER READINGS


UNIT 2  SPECIES CONCEPT

2.0  INTRODUCTION

The species is one of the most fundamental units in biology. In biology, a species is typically the basic unit of classification and is often defined as the largest group of organisms in which any two individuals of the appropriate sexes can produce fertile offspring. All species are given a name having two parts termed as binomial nomenclature. The first part of a binomial is the genus to which the species belongs while the second part is called the specific name or the specific epithet. Typological species states the concept of observed diversity that the universe reflects while the morphological species traditionally have been described and identified on the basis of morphological criteria. Species of organisms that are placed under the morphological group have similar morphological and clearly distinguishable characteristics from organisms of other groups. The ecological species defines that the organisms are adapted to the resources they exploit and the habitats they occupy.

In this unit, you will learn the fundamental concepts of species that can be distinguished on the basis of their exceptional typology, biology and evolutionary characteristics.

2.1  OBJECTIVES

After going through this unit, you will be able to:

- Understand the significance of species concept
- Define what typological species are
- Analyse the concept of biological species
- Discuss about the evolutionary species
2.2 SPECIES: FUNDAMENTAL THEORY

The species is one of the most fundamental units in biology. However, there are different concepts of what is meant by the term 'species' that reflect diverse goals and priorities on the part of scientists. In biology, a species is the basic unit of classification and a taxonomic rank, as well as a unit of biodiversity (Refer Figure 2.1). A species is often defined as the largest group of organisms in which any two individuals of the appropriate sexes can produce fertile offspring, typically by sexual reproduction. All species are given a name having two parts termed as binomial nomenclature. The first part of a binomial is the genus to which the species belongs and the second part is called the specific name or the specific epithet.

Fig. 2.1 Hierarchy of Biological Classification - Eight Major Taxonomic Ranks

Species were observed and specified from the time of Aristotle until the 18th century as fixed kinds that could be arranged in a hierarchy, i.e., the great chain of being. In the 18th century, the Swedish scientist Carl Linnaeus classified organisms according to shared physical characteristics. He established the idea of a taxonomic hierarchy of classification based upon observable characteristics and intended to reflect natural relationships. In addition, the 19th century biologists defined that species could evolve given sufficient time. In 1859, Charles Darwin in his book, 'The Origin of Species' has explained that how species could arise by natural selection, which later recognized as the theory of natural selection.
Species Concept

NOTES

Genetic variability is due to mutations and recombination. Genes can sometimes be exchanged between species by horizontal gene transfer so that new species can arise rapidly through hybridisation and polyploidy and species may become extinct for diverse reasons.

Figure 2.1 illustrates the hierarchy of biological classifications that is based on the eight major taxonomic ranks. A genus contains one or more species.

Species Concept

Biologists have not been able to agree on exactly what a species is, or how species should be abstractly defined - the controversy is theoretical, not practical. Under most circumstances, there are no practical problems when defining species. Practical problems do arise when species are recognized and identified based on phenotypic characters. If we accept that species have evolved from a common ancestor, then we would expect that there may be some conditions in which organisms are phenotypically intermediate. Variation poses most of the practical problems of species recognition using phenotypic characters. Geographic variation also creates difficulties. If a species varies geographically, then a significant characteristic for species recognition in one place may become useless in another place.

Species are mainly recognized on the basis of phenotypic characters. Ring species are species with a geographic distribution that forms a ring and overlaps at the ends. Principally, a ring species is a situation in which two populations which do not interbreed are living in the same region and connected by a geographic ring of populations that can interbreed. Famous examples of ring species are the herring and lesser black-backed gulls in Northern Europe and the *Ensativa* salamanders of California (Refer Figure 2.2).

Fig. 2.2 *Ensativa* Salamanders: Example of Ring Species
Figure 2.2 illustrates the various subspecies of *Ensatina salamanders* of California that exhibit morphological and genetic differences all along their range. They all interbreed with their immediate neighbours with one exception: where the extreme ends of the range overlap in Southern California, *E. klauberi* and *E. eschscholtzii* do not interbreed.

**Chronspecies** are different stages in the same evolving lineage that existed at different points in time. Evidently, chronospecies present a problem for the biological species concept. For example, it is not really possible to figure out whether a *trilobite* living 300 million years ago would have interbred with its ancestor living 310 million years ago. Figure 2.3 illustrates the *trilobite* lineage that is evolved gradually over time.

![Fig. 2.3 Trilobite Lineage Evolved Gradually Over Time](image)

Can *trilobite* A be considered as a separate species from *trilobite* D, and if so, then from where the lineage can be divided into separate species.

Cuvier in 1829 defined species as ‘The assemblage or grouping descended from one another or from common parents and of those who resemble one another’.

The species is the fundamental category of taxonomic hierarchy and the building blocks of classification. It is an artefact of human thought to create order in diversity. Species are defined by species concepts. Many different concepts exist because the variation of life seen in nature is diverse and complex and the philosophical views of taxonomists differ to great extent and hence not one concept or definition is satisfactory and unanimously accepted by all. A brief review of selected species concepts is therefore necessary before one can decide what concept or combination of concepts will be valuable in classifying a specific group under study.

According to Mayr (1976), the species must have the following characteristics:

1. Species characters are adaptive.
2. Species are evolved and evolving.
3. Species differ genetically.
4. Species differ ecologically.
According to Slobodchikoff (1976), the species must have the following:

1. All organisms to be sorted into discrete groups, i.e., should have operational component.
2. Account for morphological, behavioural, ecological, physiological and genetic differences among populations included within a species.
3. Account for differences between population groups of different species.
4. Apply to all forms of genetic continuity and types of reproduction.
5. Consistent with the theoretical framework of evolution.

But today, greater emphasis on the dynamic concept of species is given. Various attempts have been made to define a species, and different species concepts are recognised. Grant (1981) identified the following five different types of species:

1. Taxonomic Species (Morphological Species or Phenetic Species).
2. Biological Species (Genetic Species).
4. Successional Species (Palaeospecies or Chronospecies).
5. Biosystematic Species (Ecospecies, Coenospecies).

However, presently, the following well recognized species concept has been adopted, i.e., the species concept based on typological, biological and evolutionary features.

Typological species, taxonomic species, morphological species or phenetic species concept is mainly based on the work of Aristotle, accordingly to which each species has an intrinsic nature that make up the species, i.e., has essential properties with defined characteristics and accidental properties that individual vary from one another. The taxonomists describe a given species based on the morphological properties, by designating a Type specimen, according to the International Code of Zoological Nomenclature. A species name provides a convenient method of communicating information about a group of organisms. It is therefore, recognised as the morphological species concept.

Typological Species Concept

According to typological species concept the observed diversity of the universe reflects the existence of a limited number of underline ‘universals’ or ‘types’. Individuals do not stand in any special relation to each other being merely expressions of the same type.

Essentialism Species Concept

Variation is considered as irrelevant phenomena. This species concept was the concept of Linnaeus and his followers but it goes back to the philosophy of Aristotle and Plato. This species concept is called essentialism species concept. According to this concept, species can be recognized by their essential
characters and these are expressed in their morphology. It is also sometimes called morphological species concept. Species consists of similar individuals. Each species is separated from all the other by sharp discontinuity. Each species is constant through time. There are strict limits to possible variations within any one species. The concept is rejected because of following two practical reasons:

1. Individuals are frequently found in nature that are clearly conspecific in spite of striking difference resulting from sexual dimorphism, age, and polymorphism.
2. There are species in nature that differ hardly in morphology but are reproductively isolated.

**Morphological Species Concept**

Species traditionally have been described and identified on the basis of morphological criteria, a classification system referred to as the morphological or typological species concept. Species are groups of individuals that are morphologically similar and clearly distinguishable from individuals of other groups. Species had traditionally been defined by reference to a morphological type. Usually any geographic variation among members of the group was not detected or simply ignored.

It became apparent that what appeared to be distinct morphological species at the local level were merely one in a series of morphologically intergrading populations on a broader geographic scale. Geographic variation became commonplace, and species were viewed as multi-population systems distributed over a broad geographic range. Emphasis shifted from characterizing individuals from local populations to describing population systems.

The morphological species concept is also known as the morphospecies and classical phenetic species. The term phenetic refers to characters of an organism that can be observed and measured for Linnaean species concepts. This concept defines a species as a group of organisms whose morphological and phenetic characters differ from that of other groups of organisms. The degree of morphological variation is therefore used to determine whether certain individuals belong to the same or a different species. Although the morphological species concept does not examine the species in reproductive terms that the morphological discontinuities recognized between species do reflect biological limits of isolation, commonality of interbreeding and genetic divergence due to the connection between character cohesion and dispersal mechanisms.

The morphological species concept could be misleading, as it may lead to the recognition of new species when polymorphic diversity within a species is encountered, or the recognition of a single species when morphologically very similar species are encountered or when two populations have only recently evolved from a common ancestor. It does not treat species as historical entities that form lineages, which means that the definition of a species will change as the species changes through time and descent.
Species Concept

**Ecological Species Concept**

Organisms are basically adapted to the resources they exploit and the habitats they occupy. The ecological species concept emphasizes ecologically based natural selection in the maintenance of species. The members of a species differ each other for many features but all members together form a unit, interact as a unit with other species in any environment.

The morphological species concept could be misleading, as it may lead to the recognition of new species when polymorphic diversity within a species is encountered, or the recognition of a single species when morphologically very similar species are encountered or when two populations have only recently evolved from a common ancestor. It does not treat species as historical entities that form lineages, which means that the definition of a species will change as the species changes through time. Typically, species is defined as a clusters of organisms utilizing different ecological niches, as formulated by Van Valen (1976), “A species is a lineage (or a closely related set of lineages) which occupies an adaptive zone minimally different from that of any other lineage in its range and which evolves separately from all lineages outside its range”.

Only species that occupy sufficiently different niches can coexist, and should their niches be the same or nearly so, the superior competitor could drive the inferior competitor to extinction (Ridley, 2004). Coyne & Orr (2004) find this problematic and argue that the species forced to extinction was not a species at all. They also state that some groups can coexist as distinct entities in sympathy without gene flow, even if their adaptive zones are identical. Andersson (1990), however, finds it justifiable to use habitat differences as a criterion to decide whether or not to give taxonomic recognition to a morphotype for which phenetic criteria are not conclusive, as Retief et al. (2008) found with Euclea sekhukhuniensis, which was previously thought to be a hybrid between two different species which occupied different habitat types. The subsequent new species was an ecologically adapted taxon which evolved through natural selection in an ecotone.

**Biological Species Concept**

The biological species concept states that species are groups of interbreeding natural populations that are reproductively isolated from other such groups (Mayr, 2002). This concept rests on the hypothesis of cohesion (a group of interbreeding populations) and reproductive isolation (individuals seek and recognize one another for mating and so prevent gene flow between different populations) according to Stuessy (1990) and Mayden (1997). Interbreeding is therefore of prime importance in evolution, and breeding determines whether morphological or ecological divergence can occur. Organisms remain similar because they interbreed often enough and distinct morphological units arise that are maintained by barriers that prevent interbreeding with other related organisms (Donoghue, 1985). The biological species concept is only applicable to sexually reproducing organisms.
Species Concept

(\textit{Mayr}, 2002) and poses difficulties in the determination of interbreeding among populations, the real extent of gene flow among populations and in determining reproductive barriers (\textit{Stuessy}, 1990). It is not applicable to the species of flowering plants that show interspecific hybridization or to asexual and allopatric forms (\textit{Gornall}, 1997; \textit{Stuessy}, 1990). \textit{Stuessy} (1990) is of the opinion that the biological species concept is not needed for practical taxonomy, but for evolutionary taxonomy from which evolutionary hypotheses can be developed and to stimulate workers dealing with preserved specimens to consider and discuss broader evolutionary implications of the relationships they see and document. It has been suggested that the biological species concept should be revised as reproductive isolation is an epiphenomenon of secondary interest, but this idea is rejected on the basis that our current knowledge of the genetics of speciation is still insufficient (\textit{Rundle et al.}, 2001).

\textbf{Phenetic Species Concept}

Phenetic species concept describes the relationships between organisms based on overall similarities and differences, without weighting the characters that are considered to be derived from a common ancestor. The resulting groups or clusters can then be defined as a species (\textit{Stuessy}, 1990). The phenetic species concept defines a species as a group of organisms that are phenetically similar and distinct from other groups of organisms (\textit{Mayden}, 1997; \textit{Ridley}, 2004). It treats species as classes and not lineages and should the species change through decent, then the species have to be revised (\textit{Mayden}, 1997). Phenetics links closely with numerical taxonomy. Numerical taxonomy mathematically analyses the variation in a large number of characters in a group of organisms. Numerical taxonomists therefore define a species as a set of organisms of phenetic distinctness. This approach is problematic as several methods may be used to recognize phenetic clusters and these methods can result in different clusters, necessitating an arbitrary choice between different procedures (\textit{Ridley}, 2004). \textit{Ridley} is of the opinion that the biological, phenetic and ecological species concepts are related, because individuals that are adapted to similar niches are most likely to be phenetically similar, because they share phenetic characters that are used to exploit the ecological resource. Individuals that interbreed are also likely to be phenetically similar.

\textbf{Phylogenetic Species Concept}

Phylogenetics is the study of the stages in the evolutionary history of organisms. An outgrowth of this, and the general need among researchers for a lineage definition of a species that is process free, has led to the development of the phylogenetic species concept (\textit{Mayden}, 1997; \textit{Coyne & Orr}, 2004).

However four phylogenetic species concepts are currently recognized, that is, the \textbf{Hennigian Species Concept}, the \textbf{Autapomorphic Species Concept}, the \textbf{Genealogical Species Concept} and the \textbf{Phylogenetic Species Concept}, each placing emphasis on a different aspect of the \textit{phylogenetic theory} (\textit{Davis}, 2004).

\textbf{NOTES}
Species Concept

The most accepted version is the phylogenetic species concept of Cracraft (1983), where species are defined as a group of organisms which are diagnosably distinct and which have a genealogical pattern of ancestry and descent. Diagnosably distinct groups are recognized on the basis of one or more diagnostic characters. These diagnostic characters are mainly morphological, but any attributes of the organism, for example DNA sequences, can be used (Cracraft, 1989; Coyne & Orr, 2004). This is problematic as it would imply that, for example, every population with a slight difference in colour, or a single nucleotide difference in the DNA sequence, is a different species, which would increase the number of species recognized tremendously and illogically (Coyne & Orr, 2004). Unlike the Autapomorphic version which argues that the species should be monophyletic and recognized on the basis of apomorphic characters, Cracraft (1989) argues that the phylogenetic species recognized will be monophyletic, unless there is an error, and that it is not necessary for the diagnostic characters to be apomorphic since species may be distinct from other species and yet not possess characters that can be hypothesized as derived. Cracraft (1989) is of the opinion that it provides a theoretically coherent ontology for systematic and evolutionary biology.

Evolutionary Species Concept

The most theoretically significant of the species concepts that accommodates all types of organisms, according to Mayden (1997), is the evolutionary species concept, as defined by Wiley (1978). Wiley’s evolutionary species concept defines a species as a single lineage which maintains its identity from other lineages and has its own evolutionary tendencies. The concept does not consider species as classes, nor does it focus on species as ecological entities. It does not require knowledge of changes in a specific mate recognition system nor are there thresholds for particular attributes needed for the existence of a species. Reproductive isolation is considered a derived attribute from plesiomorphic status of reproductive compatibility and reproductive success is uninformative (Mayden, 1997). The concept is therefore capable of dealing with species as spatial, temporal, genetic, epigenetic, ecological, physiological, phenetic and behavioural entities (Coyne & Orr, 2004). The above overview of the different species concepts is only brief, giving the general idea of the concepts as well as the main pros and cons, but there are various authors who have published numerous papers that give lengthy discussions about the application of each concept.

Difficulties in Application of Biological Species Concept

There are three most serious difficulties faced in the application of biological species concept. Following are the difficulties in applying biological species concept.

Insufficient Information

Sexual dimorphism, age differences, polymorphism and other such types of variations often give rise to doubts as to whether a certain morphotype is a separate species or only a pheron within a variable population. Proper studies of life-history,
population analysis, etc., can unmask such doubts. However, such difficulties are also faced by the neontologists who normally work with preserved material and by the paleontologists who also must assign phena to species.

2. Uniparental Reproduction

Self-fertilization, parthenogenesis, pseudogamy, vegetative reproduction, are some forms of uniparental reproduction that do not fulfill the criteria of interbreeding. As per definition, a population is an interbreeding group, and, therefore, the term population in ‘an asexual biological population’ is a contradiction. The biological species concept based on the presence or absence of interbreeding between populations is, therefore, inappropriate for uniparental reproducing organisms.

How to solve this dilemma has been discussed by Simpson (1961) and by Mayr (1963). Fortunately, there are usually well-defined morphological discontinuities among kinds of uniparentally reproducing organisms. These discontinuities are apparently produced by natural selection among the various mutants, which occur in the asexual clones.

3. Evolutionary Intermediacy

It is important for a taxonomist to have a thorough knowledge of all stages of differentiation between the individual variant and the well-characterised distinct biological species. Many species pass through intermediate stages like biotypes, races, subspecies, ecotypes or semi-species.

In such incipient speciation, populations will be found which are in the process of becoming separate species and have acquired some but not yet all of the attributes of distinct species. The taxonomist, thus, may encounter various difficulties which may result from such evolutionary intermediacy.

Check Your Progress

1. Define the term species.
2. What is the Charles Darwin theory of natural selection?
3. Explain ring species with the help of an example.
4. What are Chronospecies?
5. State the species characteristics defined by Mayr.

2.3 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The species is one of the most fundamental units in biology. However, there are different concepts of what is meant by the term ‘species’ that reflect diverse goals and priorities on the part of scientists. In biology, a species is
1. The basic unit of classification and a taxonomic rank, as well as a unit of biodiversity.

2. In 1859, Charles Darwin in his book, ‘The Origin of Species’ has explained that how species could arise by natural selection, which later recognized as the theory of natural selection.

3. Ring species are species with a geographic distribution that forms a ring and overlaps at the ends. Principally, a ring species is a situation in which two populations which do not interbreed are living in the same region and connected by a geographic ring of populations that can interbreed. Famous examples of ring species are the herring and lesser black-backed gulls in Northern Europe and the Ensatina salamanders of California.

4. Chronospecies are different stages in the same evolving lineage that existed at different points in time. Evidently, chronospecies present a problem for the biological species concept. For example, it is not really possible to figure out whether a trilobite living 300 million years ago would have interbred with its ancestor living 310 million years ago.

5. According to Mayr (1976), the species must have the following characteristics:
   - Species characters are adaptive.
   - Species are evolved and evolving.
   - Species differ genetically.
   - Species differ ecologically.

2.4 SUMMARY

- The species is one of the most fundamental units in biology. However, there are different concepts of what is meant by the term ‘species’ that reflect diverse goals and priorities on the part of scientists.
- In biology, a species is the basic unit of classification and a taxonomic rank, as well as a unit of biodiversity.
- All species are given a name having two parts termed as binomial nomenclature. The first part of a binomial is the genus to which the species belongs and the second part is called the specific name or the specific epithet.
- Species were observed and specified from the time of Aristotle until the 18th century as fixed kinds that could be arranged in a hierarchy, i.e., the great chain of being.
- In the 18th century, the Swedish scientist Carl Linnaeus classified organisms according to shared physical characteristics. He established the idea of a taxonomic hierarchy of classification based upon observable characteristics and intended to reflect natural relationships.
The 19th century biologists defined that species could evolve given sufficient
explained that how species could arise by natural selection, which later
recognized as the theory of natural selection.

- Genetic variability is due to mutations and recombination. Genes can
  sometimes be exchanged between species by horizontal gene transfer so
  that new species can arise rapidly through hybridisation and polyploidy and
  species may become extinct for diverse reasons.

- Variation poses most of the practical problems of species recognition using
  phenotypic characters.

- Geographic variation also creates difficulties. If a species varies
  geographically, then a significant characteristic for species recognition in
  one place may become useless in another place.

- Ring species are species with a geographic distribution that forms a ring and
  overlaps at the ends. Principally, a ring species is a situation in which two
  populations which do not interbreed are living in the same region and
  connected by a geographic ring of populations that can interbreed.

- Chronospecies are different stages in the same evolving lineage that existed
  at different points in time. Evidently, chronospecies present a problem for
  the biological species concept.

- Cuvier in 1829 defined species as ‘The assemblage or grouping descended
  from one another or from common parents and of those who resemble one
  another’. The species is the fundamental category of taxonomic hierarchy
  and the building blocks of classification.

- According to Mayr (1976), the species must have the following
  characteristics:
  1. Species characters are adaptive.
  2. Species are evolved and evolving.
  3. Species differ genetically.
  4. Species differ ecologically.

- The taxonomists describe a given species based on the morphological
  properties, by designating a Type specimen, according to the International
  Code of Zoological Nomenclature.

- A species name provides a convenient method of communicating information
  about a group of organisms. It is therefore, recognised as the morphological
  species concept.

- Species traditionally have been described and identified on the basis of
  morphological criteria, a classification system referred to as the morphological
  or typological species concept. Species are groups of individuals that are
morphologically similar and clearly distinguishable from individuals of other groups.

- The biological species concept states that species are groups of interbreeding natural populations that are reproductively isolated from other such groups.
- Phenetic species concept describes the relationships between organisms based on overall similarities and differences, without weighting the characters that are considered to be derived from a common ancestor.

### 2.5 KEY WORDS

- **Species:** The species is one of the most fundamental units in biology, i.e., it is the basic unit of classification and a taxonomic rank, as well as a unit of biodiversity.
- **Ring species:** These are species with a geographic distribution that forms a ring and overlaps at the ends. Principally, a ring species is a situation in which two populations which do not interbreed are living in the same region and connected by a geographic ring of populations that can interbreed.
- **Chronospecies:** These are different stages in the same evolving lineage that existed at different points in time.
- **Phenetic species:** This concept describes the relationships between organisms based on overall similarities and differences, without weighting the characters that are considered to be derived from a common ancestor.

### 2.6 SELF ASSESSMENT QUESTIONS AND EXERCISES

**Short-Answer Questions**

1. What is the significance of species?
2. Explain the concept of species categorisation.
3. What are the eight major taxonomic ranks of biological classification?
4. Define the Grant system of species types.
5. State the typological species concept.
6. What is morphological species concept?
7. Explain the biological species concept.
8. What does ecological species concept emphasizes?
Long-Answer Questions

1. Discuss the species concept with the help of appropriate examples.
2. Explain the taxonomic hierarchy of classification based upon observable characteristics and natural relationships.
3. Describe the unique characteristic features of the ring species and the chronospecies with the help of real-world examples.
4. Discuss the significant characteristic features to distinguish between the typological species, taxonomic species, morphological species and the phenetic species concepts.
5. Analyse the concept of ecological series.
6. Explain the characteristic features of biological series.
7. What difficulties are faced by taxonomists and biologists in application of biological species concept? Explain with the help of examples.

2.7 FURTHER READINGS

UNIT 3 TAXONOMIC CHARACTERS AND THEORIES OF TAXONOMY

Structure
3.0 Introduction
3.1 Objectives
3.2 Taxonomic Characters and Theories
3.3 Numerical Taxonomy
3.4 Cladistics
3.5 Molecular Taxonomy
3.6 Answers to Check Your Progress Questions
3.7 Summary
3.8 Key Words
3.9 Self Assessment Questions and Exercises
3.10 Further Readings

3.0 INTRODUCTION

Taxonomy is the field of biology which deals with the nomenclature, identification, and classification of organisms. There are over one million known species on Earth and the taxonomists are responsible for identifying, naming, and classifying all these different species. Systematics is a discipline of biology that explicitly examines the natural variation and relationships of organisms, and which includes the field of taxonomy. Numerical taxonomy or taximetrics is more appropriately referred to as phonetics as it refers to the application of various mathematical procedures to numerically encoded character state data for organisms under study. Cladistics is a method that classifies organisms based on the order in which different evolutionary lines branch off from one another. Molecular taxonomy uses nucleotide-sequence data to determine the evolutionary relationships of different organisms.

In this unit, you will learn about the taxonomic characters and theories of taxonomy including the numerical taxonomy, cladistics and molecular taxonomy.

3.1 OBJECTIVES

After going through this unit, you will be able to:

- Understand the basic concept of taxonomic characters
- Define the different theories of taxonomy
3.2 TAXONOMIC CHARACTERS AND THEORIES

Taxonomy is the field of biology which deals with the nomenclature, identification, and classification of organisms. There are over one million known species on Earth and probably several million more not yet identified. Taxonomists are responsible for identifying, naming, and classifying all these different species. Systematics is a discipline of biology that explicitly examines the natural variation and relationships of organisms, and which includes the field of taxonomy. Systematics also deals with the relationships of different groups of organisms, as most systematicists strive to construct natural classification systems reflecting evolutionary relationships. Many biologists use the terms taxonomy and systematics interchangeably.

Taxonomy is the practice and science of classification. It is usually organized by supertype-subtype relationships, i.e., generalization-specialization relationships or parent-child relationships. A hierarchical taxonomy is a tree structure of classifications for a given set of objects. At the top of this structure is a single classification, the root node, which applies to all objects. Nodes below this root are more specific classifications that apply to subsets of the total set of classified objects.

Earth today is home to more than 8 million different species. This number is constantly changing, however, as new species are discovered at an outstanding rate. Biologists called taxonomists have devised a carefully developed scheme to organize these myriad species. In the mid-1700s, Carolus Linnaeus, a Swedish physician and botanist, published several books in which he described thousands of plant and animal species. Linnaeus grouped the species according to their reproductive parts and developed the two-part binomial taxonomy system of categorizing organisms according to genus and species. Linnaeus’s work remains valid. It has been combined with the work of Charles Darwin in the field of evolution to form the foundation of modern taxonomy. Darwin’s theory of evolution states that all modern species are derived from earlier species and that all organisms, past and present, share a common ancestry. Darwin’s theory of evolution, which has become a unifying theme in biology, is the organizing principle of modern taxonomy.

Taxonomists classify organisms in a way that reflects their biological ancestry. Because the ancestral relationships are complex, the taxonomic schemes are also complex and often the subject of revision. Despite their complexity, the taxonomic schemes provide considerable insight into the unity and diversity of life. The term ‘classification’ is synonymous with the word ‘taxonomy’.

All organisms in the living world are classified and named according to an international system of criteria that dates to the early part of the twentieth century.
The rules of classification establish a procedure to be followed when a new species is identified and named. Fundamentally, the rules of classification can be applied only to formal scientific names and not to common names.

The scientific name of any organism, called the binomial name, has two elements. For example, humans have the binomial name *Homo sapiens*. The name of any species is two words: the name of the genus, followed by the species. For humans, *Homo* is the genus and *sapiens* is the species name. The genus name is generally a noun, while the species name is an adjective. Thus, *Homo sapiens* literally translates as ‘human knowing’ or more simply ‘intelligent human’.

The generally accepted criterion for defining a species is that organisms of the same species interbreed under natural conditions to yield fertile offspring. Individuals of different species normally do not mate. If they are forced to mate, either the mating is unsuccessful or the offspring are sterile. For example, a horse (*Equus caballus*) can be mated to a donkey (*Equus assinus*), and the result will be a mule. However, mules are sterile and cannot reproduce. Thus, the horse and donkey are classified as different species. A quarter horse and a thoroughbred can mate and produce a fertile offspring. Therefore, both are classified as the same species: *Equus caballus*.

For humans, there is only one living species, *Homo sapiens*. However, in past ages, other species, such as *Homo erectus*, may have coexisted with *Homo sapiens*. *Homo erectus* is considered a separate species because presumably it could not mate with *Homo sapiens*.

The classification scheme provides a mechanism for bringing together various species into progressively larger groups. Taxonomists classify two species together in the same genus (the plural is genera). For example, the horse *Equus caballus* and the donkey *Equus assinus* are both placed in the genus *Equus*. Similar genera are brought together to form a family. Similar families are classified within an order. Orders with similar characteristics are grouped in a class. Related classes are grouped together as divisions or phyla (the singular is phylum). Phyla are used for animals and animal-like organisms. The largest and broadest category used to be the kingdom, but this has been usurped by the taxonomic category domain.

The classification of a human shows how the classification scheme works. Working from the top down, the human is classified first in the domain *Eukarya* because it is composed of eukaryotic cells. Next is kingdom *Animalia* because it has the properties of animals. Animals are then divided into at least 38 phyla, one of which is *Chordata*. Members of this phylum all have backbones at some time in their lives.

Members of the phylum *Chordata* are then subdivided into various classes. Humans belong to the class *Mammalia*, together with other mammals, all of which possess mammary glands and nurse their young. The Mammalia are then divided into several orders, one of which is *Primates*. Humans belong to the order
Primata along with other primates, such as gorillas and monkeys. The order Primata is subdivided into several families, one of which is Hominidae, the family that includes humans. Within the family of Hominidae is the genus Homo, which includes several species, for example Homo sapiens.

**Importance of Taxonomy**

Taxonomy is a branch of science that deals with the classification of the living organisms based on certain traits. Taxonomy entails the description, naming, and classification of living things. It helps us categorize organisms so that we can more easily communicate biological information. Taxonomy uses hierarchical classification as a way to help scientists understand and organize the diversity of life on our planet Earth. Hierarchical classification basically means that we classify groups within larger groups. Following are the importance of taxonomy:

- Base of Research and Studies
- Use in Medicine
- Agriculture and Pest Management
- Identification of Local Fauna and Flora
- Identification of Pests
- Identification of Natural Endemic Species
- Establishing the Order of the Physical Development
- Fisheries
- Conservation

In addition, taxonomy is a significant aspect of biodiversity. As it helps to ascertain the number of living beings on Earth. More than one million of species of plants and animals have been discovered and classified so far. Taxonomy aims to classify the living organisms. Millions of organisms are classified scientifically in categories, which helps to have a better understanding. It helps us to get an idea of the traits present in plants and animals.

**Nomenclature**

Linnaeus’ system of classification made a major impact on the world in terms of naming diversity and organizing the information. There are four different codes of nomenclature but we deal primarily with the International Code for Zoological Nomenclature (ICZN). Following are the four different codes of nomenclature that are followed today.

- International Code of Zoological Nomenclature
- International Code of Botanical Nomenclature
- International Code of Nomenclature of Bacteria
- International Code of Nomenclature for Cultivated Plants
General Objectives

Following are some general objectives of scientific nomenclature and codes.

- **Uniqueness**: The name of a particular organism gives one immediate access to all of the known information about the particular taxon. Every name must be unique because it is the key to the entire literature relating to the species or higher taxon in question. If several names have been given to the same taxon, there must be a clear-cut method whereby it can be determined which of the names has validity.

- **Universality**: Scientific communication would be made very difficult if we had only vernacular names for taxa in innumerable languages in order to communicate with each other. To avoid this scientists have adopted an international agreement for a single language 'Latin' and a single set of names for biological diversity to be used on a worldwide basis.

- **Stability**: As recognition symbols of diversity, names of organisms would lose much of their usefulness if they were changed frequently and arbitrarily. Various Codes for nomenclature consider Latin to be an essential language.
  - Taxa at the level of species are named with binomials, consisting of generic and specific epithets or names that together equal the species name.
  - Taxa above the level of species are Supraspecific Taxa and are Uninominals.
  - Taxa below the level of species are Subspecies and are Trinominals.

Nomenclature

Each species is placed into a genus. Generic names are Latin nouns. Names of species are Latin adjectives in agreement with the nouns 'Generic epithet' or are nouns in apposition. Generic names (epithets) always begin with a capital letter while species names (epithets) always begin with lower-case letter, for example *Homo sapiens*.

Scientific names do not include diacritical marks but may be hyphenated, such as *Erimystax x-punctata*.

Author’s Names

All generic and specific epithets have authors, the name(s) of the person(s) who first officially described them in a publication. You will often see scientific names with an author’s name following it. This is often confusing to non-taxonomists but is really important because it is very useful in tracing the history of applications of names through time. Scientific names with very similar spellings can usually be distinguished from one another when an author’s names is included.

*Rhinacloa pallipes* Reuter
*Rhinacloa pallidipes* Maldonado
Dates of Authorship

Dates of official descriptions can also be included with scientific names to further clarify situations and locate relevant literature.

- *Macrocoleus femoralis* Reuter, 1879
- *Cyrtocapsus femoralis* Reuter, 1892
- *Psallopsis femoralis* Reuter, 1901

Author’s Names in Parentheses

If the species in question in a particular classification is in the genus in which it was described the author’s name(s) do not appear in parentheses.

- *Notropis cardinalis* Mayden

However, if the species in a classification is in a genus other than the one in which it was described the author’s name(s) appear in parentheses.

- *Luxilus cardinalis* (Mayden)

In the botanical literature the same applies but the author’s name(s) in parentheses may be followed by another name of the author who moved the species to its genus of current placement.

- *Ceratozamia boliviana* Brongn.
- *Zamia boliviana* (Brongn.) A. DC.

Different Usages of the Same Name

In some instances in zoology authors may use a scientific name differently than the person (author) who originally described the species. In such a case the scientific name, as listed in catalogs and other writings, is separated from users name by a colon.

- *Phytocoris marmoratus* Blanchard
- *Phytocoris marmoratus* Stonedahl

Basic Rules for Code

**Priority:** This is a simple concept, the first name applied to a taxon is the name that will be used. Often, taxonomists, systematists, ecologists, behavioural biologists, and others encounter multiple names that appear to relate to the same taxon, say a species. It can also result from researchers not fully understanding variation within a species or that the different looking things are different stages in a life cycle or different sexes, for example parrot fishes, aphids.

Priority relates to date of publication or mailing date (public availability) and involves only date, not page or line precedence. If the day is not determinable then the accepted date is the lst day of the smallest time unit (week, month, year) that can be determined. Older valid names have priority over newer valid names; the
oldest valid name of a taxon takes precedence over all other names of a taxon. In zoology priority extends to ranks of the Superfamily and below.

Priority is not intended to upset stability because stability of classification is one of the basic objectives of biological classification. Thus, in instances where a name change would cause much confusion the codes provide provisions that permit the conservation of a younger and well-established name. In zoology the ICZN has the power to suppress an older name and make the younger name the valid name for the taxon.

Priority extends back to particular taxonomic works for each group of organisms. Names applied before these specified works are not considered valid names. The baseline priority for zoological nomenclature begins with Linnaeus' *Systema Naturae*, 10th edition, considered published 1 January 1758. Any works published in 1758 or after are considered published.

For spiders the baseline priority dates to the work of Clerck (1757).

Baseline priority for botanical names dates to Linnaeus’ *Species Plantarum* (1753).

**Availability:** Whereas priority is a comparatively objective criterion, availability is more nebulous. With reference to the different codes most names would be considered ‘available’ if they meet the following four criteria.

- Appear in a work published after 1753 for plants and 1758 for most animals.
- Meet the criteria for publication designated by the codes.
- Are written in the Latin alphabet (today in English except for plants).
- Are binominal (if referring to species).

The codes also require other things depending upon the code.

**Publications:** Publications are of following types.

- **Acceptable or Okay Publications**
  - Must be issued publically for the purpose of providing a permanent scientific record.
  - Must be obtainable, when first issued, free of charge or by purchase.
  - Must have been produced in an edition containing simultaneously obtainable copies by a method that assures numerous identical copies.
    - Before 1986, must be via ink on paper, i.e., conventional printing or mimeographing (latter okay or acceptable in zoology but not in botany).
    - After 1985 can be via photocopying or any other ‘unconventional’ method but must include a statement that nomenclatural content is for permanent, public, scientific record therein.
Forbidden Publications

- Distribution on microfilm, computer printouts, or pre-1986 photocopies.
- A mention of a name at a scientific meeting.
- Labelling specimens deposited in a museum.
- The distribution of proof sheets (zoology).
- Deposition of document (e.g., thesis) in a collection of documents, a library, or other archive.
- Distribution only to colleagues or students of a note, even if printed, in explanation of an accompanying illustration.

Type Concept

Species-group types represent a single specimen to which a name is attached. This provides an objective criterion for establishment of usage of that name. Species-group types are recognized in the codes as primary types and include the following possibilities.

- **Type Locality**: All types of species and subspecies are tied to a spatial location called the type locality.
- **Holotype**: Single specimen designated by the author(s) of the name at the time of publication of the original description.
- **Paratype**: Commonly designated in descriptions of new species as specimens being studied by the author in the description of the new species or subspecies and designated by that person at the time of publication of the original description. These specimens are valuable as reference materials that are deposited at multiple, dedicated museums or institutions.
- **Syntypes**: A group of specimens thought to represent a species, as designated or indicated by the author(s) of the original description. These specimens may sometimes be referred to as the 'Type Series'. Cotypes are sometimes used in the same way. If syntypes exist for a species only from this series can a lectotype be designated. Many early descriptions of species were based on syntypes because the requirement for a holotype designation or indication did not exist.
- **Lectotype**: One of the syntypes chosen by the original or subsequent author(s) to function as the name bearer. Primary types are customarily deposited in recognized institutions dedicated to the long-term maintenance of collections.
- **Topotype**: Specimen(s) collected from the same location as the holotype (perhaps at the same time). These specimens are useful at the time of designating a Neotype.
- **Neotype**: A specimen later designated to replace a holotype or other primary type if the latter can be documented as lost or destroyed.
Genus Group Type

These types represent species, comprised of names and not specimens. Traditionally authors did not designate types of genera; modern codes, however, require that for a generic or subgeneric name to become available a type species must be designated by the author describing the new genus or subgenus.

- **Monotypy**: The genus has only one species included in it at the time that they type species is designated and is thus monotypic. If other species are added to the genus before a type is designated then the type can only be the original species that existed in the genus.

- **Subsequent Designation**: If more than one species was originally included in a new genus the type can be selected either by the original author or at a later time by another person.

- **Indication**: An original indication of a type is one that the author of the name indicates via illustration or other means and is referred to as typus or typicus.

- **Tautonymy**: When a new genus and species is described with the same name for the genus and species epithet it becomes the type. An example is *Bison bison*.

Family Group Names Types

Genera form the types in these groups. Family group names are subject to the rules of homonymy, in that no two can be spelled identically, even though they may be based on different, although similar, generic names. Just because a generic name on which the oldest family-group name is based is in synonymy, this does not invalidate the family group name. For example:

Insect suborder **Heteroptera** the family **Velocipedidae** contains a single valid genus **Scotomedes**. The generic name on which the family name is based, **Velocipes**, is a junior synonym of **Scotomedes**.

Homonyms

This basic principle refers to the application of the same name to different taxa. Our codes of nomenclature state that NO two names above the species-group level may be the same in zoology or botany, although names may be duplicated between the two fields. Homonyms are of following different types:

- **Senior Homonyms**: The available name on the basis of priority.

- **Junior Homonyms**: A preoccupied name (not in use) on the basis of priority or by a ruling by a nomenclatorial body.

- **Primary Homonyms**: In a species-group (species, subspecies, etc.) these are names that are the same and were proposed in the same genus-group
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Naming of Species

The format for writing scientific names is standardized and internationally accepted. ‘Scientific nomenclature’ refers to various names according to a specific field of study. This article is the first in a series on scientific nomenclature within specific kingdoms. Typically, animals and plants are identified by common and scientific names. Common name are used locally and may vary by region or country. Scientific name are unique names used by the scientific community to accurately and universally identify species. A species, by definition, is the combination of both the genus and specific epithet and not just the epithet. For example, we can use the general term ‘gray wolf’ but we cannot use just Canis lupus to describe this animal. Canis lupus is a species. Thus the classifications go from general ‘Animalia’ to specific ‘C. lupus’. Following are some examples of names that are commonly used.

- **Descriptive Name:** giganticus; globosa; alba; nigrus; longipinnis; macrocephalus; filamentosus
- **Ecological Names:** subterraneus; arboricola; parasitus
- **Geographical Names:** keralensis; andhraensis; bengalensis; indicus
- **Patronymic Names:** silasi, johni, blochi, horai, dayi
- **Names Without Meaning:** fantana; kalona; gentana
- **Undesirable Names:** Should be avoided (long names; facetious names causing religious or personal offence).
- **Other Kinds of Names:** Host organisms- rosae, lantanae OR mythological name ‘arjunai’
- **Local Names:** phasa; phutuni, para, savala

Biological Taxonomy

Taxonomy, in Ancient Greek ‘taxis’ meaning ‘arrangement’ and ‘nomia’ meaning ‘method’, is the science of defining and naming groups of biological organisms on the basis of shared characteristics. Organisms are grouped together into taxa (singular: taxon) and these groups are given a taxonomic rank; groups of a given rank can be aggregated to form a super-group of higher rank, thus creating a taxonomic hierarchy. The principal ranks in modern use are domain, kingdom, phylum, class, order, family, genus and species. The Swedish botanist Carl

Linnaeus is regarded as the ‘Father of Taxonomy’, as he developed a system known as Linnaean taxonomy for categorization of organisms and binomial nomenclature for naming organisms.

The term ‘alpha taxonomy’ is primarily used today to refer to the discipline of finding, describing, and naming taxa, particularly species. *William Bertram Turrill* introduced the term ‘alpha taxonomy’ in a series of papers published in 1935 and 1937 in which he discussed the philosophy and possible future directions of the discipline of taxonomy. Taxonomic name is the unique ID of a taxon and facilitates communication about taxa, such as,

1. Identification and Describing Species
2. Biodiversity Mapping and Cataloging Life
3. Standardization of Model Organisms
4. Classification of Organisms on the Criteria - Evolutionary, Utilitarian, Geographic, etc.

‘Beta taxonomy’ (= systematics) is the science of understanding the relationships among taxa. It is the grammar of biology. Taxonomy provides a relational link between and amongst biological phenomena. Typically, ‘beta taxonomy’ is an understanding of the biological meaning of variation and of the evolutionary origin of groups of related species is even more important for the second stage of taxonomic activity, the sorting of species into groups of relatives ‘taxa’ and their arrangement in a hierarchy of higher categories.

### 3.3 NUMERICAL TAXONOMY

Numerical taxonomy is a classification system in biological systematics which deals with the grouping by numerical methods of taxonomic units based on their character states. It aims to create a taxonomy using numeric algorithms like cluster analysis rather than using subjective evaluation of their properties.

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

According to *Heywood* the numerical taxonomy may be defined as the numerical evaluation of the similarity between groups of organisms and the ordering of these groups into higher ranking taxa on the basis of these similarities. The period from 1957 to 1961 saw the development of first methods and of theory of numerical taxonomy.
Numerical taxonomy is the method of classifying organisms with the help of numerical methods. This method clarifies and illustrates the degree of relationship among the organisms in an unbiased manner. The organisms are arranged in their respective taxa based on the similarities and differences. Nowadays, numerical taxonomy is a very important in modern systematics. The main aim of numerical taxonomy is to classify organisms using numeric algorithms. The period from 1957 to 1961 saw the development of first methods and theory of numerical taxonomy.

Michel Adanson, a French botanist, planned to assign numerical values to the similarities between organisms and he proposed that equal weightage should be given to all the characters while classifying plants. He used as many characters as possible for the classification, and these classifications came to be known as Adansonian classifications.

Later, Robert R. Sokal and Peter H. A. Sneath in 1963 divided the field into phenetics in which classifications are based on the patterns of overall similarities and cladistics in which classifications are based on the branching patterns of the estimated evolutionary history of the taxa. Numerical taxonomy was however largely developed and popularized by Sneath and Sokal.

Principles of Numerical Taxonomy

Numerical taxonomy involves following two aspects.

- **Construction of Taxonomic Groups:** In numerical taxonomy, first, individuals are selected and their characters spotted out. There is no limitation to the number of characters to be considered. However, the larger the number of characters, better is the approach for generalization of the taxa.

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

- **Discrimination of the Taxonomic Groups:** When the taxonomic groups chosen for the study show overlapping of characters, discrimination should be used to select them. Discrimination analysis can be done by various techniques, specially devised for such purposes. Numerical taxonomy is thus, based on certain principles, also called neo Adansonian principles.

  Following seven principles of numerical taxonomy have been enumerated by Sneath and Sokal:

    (i) The greater the content of information in the taxa, and more the characters taken into consideration, the better a given classification system will be.
(ii) Every character should be given equal weightage in creating new taxa.

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

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

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

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

(vii) Phenetic similarity is the base of classifications.

Merits of Numerical Taxonomy

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

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

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

3. The number of existing biological concepts have been reinterpreted in the light of numerical taxonomy.

4. Numerical taxonomy allows more taxonomic work to be done by less highly skilled workers.

Demerits of Numerical Taxonomy

Numerical taxonomy can however prove to be disadvantageous from the following points of view:

1. The numerical methods are useful in phenetic classifications and not phylogenetic classifications.

2. The proponents of ‘biological’ species concept, may not accept the specific limits bound by these methods.
3. Character selection is the greatest disadvantage in this approach. If characters chosen for comparison are inadequate, the statistical methods may give less satisfactory solution.

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

Applications of Numerical Taxonomy

Numerical taxonomy has been successfully applied in the following studies:

1. Study of similarities and differences in bacteria, other micro-organisms and several animal groups.

2. Delimitation of several angiospermic genera like Oryza, Sarcostemma Solarium, and other groups including Farinosae of Engler and a few others.

3. In the study of several other angiospermic genera including Apocynum, Chenopodium, Crotalaria, Cucurbita, Oenothera, Salix, Zinnia, Wheat cultivars, Maize cultivars, etc.

4. Phytochemical data from seed protein and mitochondrial DNA RELP studies has been numerically analyzed by Mondal et al. to study the interspecific variations among eight species of Cassia L. Based on the results of electrophoretic patterns, the degree of Pairing Affinity (PA) or similarity index was calculated by the following formula, according to the method of Sneath and Sokal and Romero Lopes et al.:

\[
PA = \frac{\text{Bands common to species A and B}}{\text{Total bands in A and B}} \times 100
\]

Separate dendograms expressing the average linkage were computed using the cluster method UPGMA, which showed that the eight species could be placed into two categories or clusters (Refer Figure 3.1) with C. alata, C siamea, C. fistula and C. reginera, all being trees or large shrubs and characterized by the absence of foliar glands on petiole or rachis and presence of dense axillary terminal racemes greater than 30 cm long, being clustered into one group, whereas the other four species, i.e., C. occidentalis, C. sophera, C. mimosaoides and C. tora, forming the other cluster, all being herbs or undershrub’s and characterized by the presence of short corymbose racemes less than 10 cm long and with foliar glands, either on petiole or rachis.
3.4 CLADISTICS

Cladistics is a method that classifies organisms based on the order in which different evolutionary lines branch off from one another. It was first proposed in the 1950s by Willi Hennig, a German entomologist. Subsequently, many other scientists have made Hennig’s original method more practicable by developing various cladistic numerical algorithms, some of which are very sophisticated. Cladistics is currently the most widely used method of classification.

Cladistics possibly determine the branching points of different evolutionary lines, when there is not a complete fossil record and often have only living species for constructing a classification system. The theory of cladistics relies upon the fact that all new species evolve by descent with modification. In other words, cladistics determines the evolutionary branching order on the basis of shared derived characteristics. It does not use shared primitive characteristics as a basis for classification, since these may be lost or modified through the course of evolution. To establish which characters are primitive and which are derived, cladistic classification generally relies upon one or more outgroups, species hypothesized to be primitive ancestors of all the organisms under study.

The distinction between shared derived and shared primitive characteristics in cladistic classification can be explained with the help of an example. The common mammalian ancestor of humans, cats, and seals had five digits on each hand and foot. Thus, the presence of five digits is a shared primitive characteristic and cladistics does not segregate humans and cats, which have five digits on their
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It is important to note that a cladistic classification is not based on the amount of evolutionary change after the branching off of an evolutionary line. For example, although chimpanzees and orangutans appear more similar to one another than either does to humans, cladistic classification places humans and chimpanzees together since they share a more recent common ancestor than chimpanzees and orangutans. Such comparative studies help to discover that why human morphology evolved so rapidly, relative to that of chimpanzees and orangutans.

Thus, cladistic refers to the study and classification of species based on evolutionary relationships. Fundamentally, the cladistic approach discriminates among possible phylogenetic trees by considering the various possible pathways of evolutionary changes and then choosing the tree that requires the least complex explanation for all of the available data. Thus,

- Cladistic approach compares homologous traits, also called characters, which may exist in two or more character states.
- Shared primitive character or symplesiomorphy.
- Shared by two or more different taxa and inherited from ancestors older than their last common ancestor.
- Shared derived character or synapomorphy.
- Shared by two or more species or taxa and has originated in their most recent common ancestor.

3.5 MOLECULAR TAXONOMY

The classification of organisms on the basis of the distribution and composition of chemical substances in them. Molecular techniques in the field of biology have helped to establish genetic relationship between the members of different taxonomic categories.

Molecular phylogenetics refers to the study of evolutionary relationships among biological entities (individuals, populations, species, or higher taxa), by using a combination of molecular data (such as, DNA and protein sequences, presence or absence of transposable elements, and gene-order data) and statistical techniques. Fitch and Margoliash (1967) made first phylogenetic tree based on molecular data.

Phylogenetic Tree

The phylogenetic tree was so close to the already established phylogenetic trees. The taxonomists realized significance of molecular data and this made them
understand that other traditional methods are although important but molecular evidences could be final or confirmatory evidences. Phylogenetic studies assess the historical processes which affect relationships and phylogeographic studies assess the geographical distributions. Phylogenetic and phylogeographic studies started with the introduction of mtDNA markers in population genetic analyses.

**Molecular Markers**

Molecular markers can be characterized as Type I and Type II Markers.

1. Type I Markers are associated with genes of known function. Allozyme markers are Type I Markers as the proteins they encode are associated with some functions.

2. Type II Markers are associated with genes of unknown function. Microsatellites and other neutral markers are type II markers unless they are associated with genes of some known function.

**Allozyme**

Allozyme electrophoresis is a method which can identify genetic variation at the level of enzymes that are directly encoded by DNA. Protein variants called allozymes originate from allelic variants and they will differ slightly in electric charge. Allozymes are codominant markers having been expressed in a heterozygous individual in a Mendelian way.

**Mitochondrial DNA Markers**

Mitochondrial DNA is non-nuclear DNA in the cell having located in within organelles in the cytoplasm called mitochondria. Mitochondrial DNA is maternally inherited with a haploid genome. The entire genome undergoes transcription as one single unit. They are not subjected to recombination and thus they are homologous markers.

**Microsatellites**

A microsatellite is a simple DNA sequence which is repeated several times across various points in the DNA of an organism. These repeats are highly variable and these loci can be used as markers.

**Single Nucleotide Polymorphisms**

Single nucleotide polymorphisms arise due to single nucleotide substitutions (transitions/transversions) or single nucleotide insertions/deletions. These point mutations give rise to different alleles with alternative bases at a particular nucleotide position. SNPs are the most abundant polymorphisms in the genome (coding and non-coding) of any organism.
DNA Microarrays or DNA Chips

DNA microarray consists of small glass microscope slides, silicon chip or nylon membranes with many immobilized DNA fragments arranged in a standard pattern. A DNA microarray can be utilized as a medium for matching a reporter probe of known sequence against the DNA isolated from the target sample which is of unknown origin. Species-specific DNA sequences could be incorporated to a DNA microarray and this could be used for identification purposes. DNA extracted from a target sample should be labelled with a specific fluorescent molecule and hybridized to the microarray DNA. When the hybridization is positive a fluorescent signal is detected with appropriate fluorescence scanning/imaging equipment.

Arbitrary Nuclear DNA Markers

Arbitrary markers are used when we target a segment of DNA of unknown function. The widely used methods of amplifying unknown regions are RAPD (Random Amplified Polymorphic DNA) and AFLP (Amplified Fragment Length Polymorphism) DNA.

Specific Nuclear DNA Markers

Variable Number of Tandem Repeat is a segment of DNA that is repeated tens or even hundreds to thousands of times in nuclear genome. They repeat in tandem; vary in number in different loci and differently in individuals. There are two main classes of repetitive and highly polymorphic DNA; minisatellite DNA referring to genetic loci with repeats of length 9-65 bp and microsatellite DNA with repeats of 2-8 bp (1-6) long. Microsatellites are much more numerous in the genome of vertebrates than minisatellites.

Expressed Sequence Tags (ESTs)

ESTs are single-pass sequences which were generated from random sequencing of cDNA clones. ESTs can be used to identify genes and analyze their expression by means of expression analysis. Fast and reliable analysis can be made for the genes expressed in particular tissue types under specific physiological conditions or developmental stages. Differentially expressed genes could be identified using cDNA microarrays in a systematic way. ESTs are most valuable for linkage mapping.

Advantages of Molecular Data

Following are the advantages of molecular data:

- Molecular entities are strictly heritable.
- The description of molecular characters is unambiguous.
- There is some regularity to the evolution of molecular traits.
- Molecular data are amenable to quantitative treatment.
• Homology assessment is easier than with morphological traits.
• Molecular data are robust to evolutionary distance.
• Molecular data are abundant.
• Less time consuming in analysis.

Check Your Progress

1. Define the term taxonomy.
2. What is hierarchical taxonomy?
3. Explain how taxonomists classify organisms?
4. How are the living organisms classified and named? Give example.
5. Can taxonomists classify two species together in the same genus? How?
6. Define the Linnaeus’ system of classification and the four different codes of nomenclature.
7. What is numerical terminology?
8. Explain the terms molecular techniques and molecular phylogenetics.

3.6 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. Taxonomy is the field of biology which deals with the nomenclature, identification, and classification of organisms. Systematics is a discipline of biology that explicitly examines the natural variation and relationships of organisms, and which includes the field of taxonomy.

2. A hierarchical taxonomy is a tree structure of classifications for a given set of objects. At the top of this structure is a single classification, the root node, which applies to all objects. Nodes below this root are more specific classifications that apply to subsets of the total set of classified objects.

3. Taxonomists classify organisms in a way that reflects their biological ancestry. Because the ancestral relationships are complex, the taxonomic schemes are also complex and often the subject of revision. Despite their complexity, the taxonomic schemes provide considerable insight into the unity and diversity of life. The term 'classification' is synonymous with the word 'taxonomy'.

4. All organisms in the living world are classified and named according to an international system of criteria that dates to the early part of the twentieth century. The rules of classification establish a procedure to be followed when a new species is identified and named. Fundamentally, the rules of classification can be applied only to formal scientific names and not to common names. The genus name is generally a noun, while the species name is an adjective.
The name of any species is two words: the name of the genus, followed by the species. Thus, the scientific name of any organism, called the binomial name, has two elements. For example, humans have the binomial name *Homo sapiens*, where *Homo* is the genus and *sapiens* is the species name.

5. The classification scheme provides a mechanism for bringing together various species into progressively larger groups. Taxonomists classify two species together in the same genus (the plural is genera). For example, the horse *Equus caballus* and the donkey *Equus asinus* are both placed in the genus *Equus*. Similar genera are brought together to form a family and similar families are classified within an order. Orders with similar characteristics are grouped in a class and the related classes are grouped together as phyla (the singular is phylum).

6. Linnaeus’ system of classification made a major impact on the world in terms of naming diversity and organizing the information. There are four different codes of nomenclature but we deal primarily with the International Code for Zoological Nomenclature (ICZN). Following are the four different codes of nomenclature that are followed today.

- International Code of Zoological Nomenclature
- International Code of Botanical Nomenclature
- International Code of Nomenclature of Bacteria
- International Code of Nomenclature for Cultivated Plants

7. Numerical taxonomy is a classification system in biological systematics which deals with the grouping by numerical methods of taxonomic units based on their character states. It aims to create a taxonomy using numeric algorithms like cluster analysis rather than using subjective evaluation of their properties.

8. Molecular techniques in the field of biology have helped to establish genetic relationship between the members of different taxonomic categories. Molecular phylogenetics refers to the study of evolutionary relationships among biological entities (individuals, populations, species, or higher taxa), by using a combination of molecular data (such as, DNA and protein sequences, presence or absence of transposable elements, and gene-order data) and statistical techniques. *Fitch and Margoliash* (1967) made first phylogenetic tree based on molecular data.

3.7 SUMMARY

- Taxonomy is the field of biology which deals with the nomenclature, identification, and classification of organisms. There are over one million known species on Earth and probably several million more not yet identified. Taxonomists are responsible for identifying, naming, and classifying all these different species.
Systematics is a discipline of biology that explicitly examines the natural variation and relationships of organisms, and which underlies the field of taxonomy.

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Systematics is a discipline of biology that explicitly examines the natural variation and relationships of organisms, and which underlies the field of taxonomy.
• Uniqueness is the name of a particular organism gives one immediate access to all of the known information about the particular taxon. Every name must be unique because it is the key to the entire literature relating to the species or higher taxon in question.

• Species-group types represent a single specimen to which a name is attached. This provides an objective criterion for establishment of usage of that name.

• All types of species and subspecies are tied to a spatial location called the type locality.

• Tautonymy is when a new genus and species is described with the same name for the genus and species epithet it becomes the type. An example is *Bison bison*.

• Family group names are subject to the rules of homonymy, in that no two can be spelled identically, even though they may be based on different, although similar, generic names.

• The term ‘alpha taxonomy’ is primarily used today to refer to the discipline of finding, describing, and naming taxa, particularly species. *William Bertram Turrill* introduced the term ‘alpha taxonomy’ in a series of papers published in 1935 and 1937 in which he discussed the philosophy and possible future directions of the discipline of taxonomy.

• ‘Beta taxonomy’ is an understanding of the biological meaning of variation and of the evolutionary origin of groups of related species is even more important for the second stage of taxonomic activity, the sorting of species into groups of relatives ‘taxa’ and their arrangement in a hierarchy of higher categories.

• Numerical taxonomy is a classification system in biological systematics which deals with the grouping by numerical methods of taxonomic units based on their character states. It aims to create a taxonomy using numeric algorithms like cluster analysis rather than using subjective evaluation of their properties.

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

• Numerical taxonomy is the method of classifying organisms with the help of numerical methods. This method clarifies and illustrates the degree of relationship among the organisms in an unbiased manner.

• Cladistics is a method that classifies organisms based on the order in which different evolutionary lines branch off from one another.
• Cladistics possibly determine the branching points of different evolutionary lines, when there is not a complete fossil record and often have only living species for constructing a classification system.

• Molecular techniques in the field of biology have helped to establish genetic relationship between the members of different taxonomic categories.

• Molecular phylogenetics refers to the study of evolutionary relationships among biological entities (individuals, populations, species, or higher taxa), by using a combination of molecular data (such as, DNA and protein sequences, presence or absence of transposable elements, and gene-order data) and statistical techniques. *Fitch and Margoliash (1967)* made first phylogenetic tree based on molecular data.

3.8 KEY WORDS

- **Taxonomy**: Taxonomy is the field of biology which deals with the nomenclature, identification, and classification of organisms. Systematics is a discipline of biology that explicitly examines the natural variation and relationships of organisms, and which includes the field of taxonomy.

- **Hierarchical taxonomy**: A hierarchical taxonomy is a tree structure of classifications for a given set of objects. At the top of this structure is a single classification, the root node, which applies to all objects. Nodes below this root are more specific classifications that apply to subsets of the total set of classified objects.

- **Species-group types**: It represent a single specimen to which a name is attached. This provides an objective criterion for establishment of usage of that name.

- **Type locality**: All types of species and subspecies are tied to a spatial location called the type locality.

- **Tautonymy**: When a new genus and species is described with the same name for the genus and species epithet it becomes the type, such as *Bison bison*.

- **Numerical taxonomy**: It is the method of classifying organisms with the help of numerical methods which clarifies and illustrates the degree of relationship among the organisms in an unbiased manner.

- **Cladistics**: It is a method that classifies organisms based on the order in which different evolutionary lines branch off from one another.
3.9 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answers Questions
1. Explain the importance of taxonomic characters.
2. What role does it play in binomial nomenclature?
3. What are the basic rules for code?
4. Explain the significance of biological taxonomy.
5. Define the different theories of taxonomy.
6. Explain numerical taxonomy giving appropriate examples.
7. List the merits and demerits of numerical taxonomy.
8. When is cladistics used?
9. What is molecular taxonomy?
10. Give the advantages of molecular data.

Long-Answers Questions
1. Briefly explain the significance of taxonomic characters giving appropriate examples.
2. Discuss the various theories of taxonomy as given by different scientists.
3. Explain the rules of nomenclature and coding with the help of examples.
4. Differentiate between acceptable and forbidden publications.
5. How the species are named? Explain with the help of examples.
6. Briefly explain the significance and principles of numerical taxonomy.
7. Explain the various applications of numerical taxonomy.
8. Discuss the role of cladistics in taxonomy.
9. Explain the importance of molecular taxonomy. Also discuss the significance of phylogenetic tree and different markers.

3.10 FURTHER READINGS


**UNIT 4 MAJOR DIVISION AND SUBDIVISION OF ANIMAL KINGDOM**

**Structure**
- 4.0 Introduction
- 4.1 Objectives
- 4.2 Divisions of Animal Kingdom
- 4.3 Animal Architecture
- 4.4 Symmetry
- 4.5 Coelom in Animals
- 4.6 Answers to Check Your Progress Questions
- 4.7 Summary
- 4.8 Key Words
- 4.9 Self Assessment Questions and Exercises
- 4.10 Further Readings

**4.0 INTRODUCTION**

The phylum is the largest formal taxonomic category in the Linnaean classification of the animal kingdom. Animal phyla are often grouped together to produce additional, informal taxa intermediate between the phylum and the animal kingdom. These taxa are based on embryological and anatomical characters that reveal the phylogenetic affinities of different animal phyla. From Aristotle's time to the late 1800s it was traditional to assign every living organism to one of two kingdoms: plant or animal. However, the two kingdom system had many problems. R.H. Whittaker proposed the five kingdom classification in 1969. The most common system of classification in use today is the five kingdom classification by Whittaker.

In this unit, you will learn about the major divisions and subdivisions of the animal kingdom, animal architecture, cephalization symmetry, bilateral and radial symmetry, and coelom in animals.

**4.1 OBJECTIVES**

After going through this unit, you will be able to:
- Explain the major divisions and subdivisions of the animal kingdom
- Understand the animal architecture, internal structure
- Define what cephalization symmetry is
Major Division and Subdivision of Animal Kingdom

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- Analyse the specifications for bilateral and radial symmetry
- Discuss about coelom in animals

4.2 DIVISIONS OF ANIMAL KINGDOM

The phylum is the largest formal taxonomic category in the Linnaean classification of the animal kingdom. Animal phyla are often grouped together to produce additional, informal taxa intermediate between the phylum and the animal kingdom. These taxa are based on embryological and anatomical characters that reveal the phylogenetic affinities of different animal phyla. Zoologists in the past have recognized subkingdom Protozoa, which contains the primarily unicellular phyla, and the subkingdom Metazoa, which contains the multicellular phyla.

From Aristotle’s time to the late 1800s it was traditional to assign every living organism to one of two kingdoms: plant or animal. However, the two kingdom system had serious problems. Although it was easy to place rooted, photosynthetic organisms, such as trees, flowers, mosses, and ferns among the plants and to place food-ingesting, motile forms, such as insects, fishes, and mammals among the animals, unicellular organisms presented difficulties (Protozoan Groups). Some forms were claimed both for the plant kingdom by botanists and for the animal kingdom by zoologists. An example is *Euglena*, which is motile, like animals, but has chlorophyll and photosynthesis, like plants. Other groups, such as bacteria, were rather arbitrarily assigned to the plant kingdom.

R.H. Whittaker organized the organisms into five kingdoms. He classified organisms on the basis of cell structure, mode, and source of nutrition and body design. The five kingdoms proposed by *Whittaker* are *Monera*, *Protista*, *Fungi*, *Plantae*, and *Animalia*.

Kingdom Animalia

Kingdom Animalia consists of all animals. The animal kingdom is the largest kingdom among the five kingdoms. Animals are multicellular eukaryotes. But they do not have a cell wall or chlorophyll like plants. Hence, members of the animal kingdom have a heterotrophic mode of nutrition. Kingdom Animalia has been classified into 10 different phyla based on their body design or differentiation (Refer Figure 4.1). The different subphylum of the animal kingdom are as follows:

1. Porifera
2. Coelenterata (Cnidaria)
3. Platyhelminthes
4. Nematoda
5. Annelida
6. Arthropoda
7. Mollusca
8. Echinodermata
9. Protochordata
10. Vertebrata

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**Fig. 4.1 Different Phylum of the Animal Kingdom**

**Subphylum Porifera**

Porifera means organisms with holes. They are commonly known as Sponges. Features of the poriferan are:

1. Non-motile, multicellular organisms with the hard outer skeleton.
2. Have a porous body.
3. Pores on the bodies create a canal system which helps in circulation of substances.
4. Not differentiated into head and tail; do not have a well-developed organ or organ system.
5. Follow marine habitat.
Examples of subphylum Porifera includes Spongilla, Sycon, etc.

**Fig. 4.2 Sponges**

**Subphylum Coelenterata (Cnidaria)**

The term Coelenterata is derived from the Greek word ‘kilos’ which means hollow-bellied. Their features are:

1. Have a hollow body cavity.
2. The body is differentiated into two ends.
3. Includes all aquatic animals.
4. The body is made of two layers of cells: inner and outer linings.
5. Live in colonies (corals) as well as solitary (Sea anemone).

Examples of subphylum Coelenterata includes Hydra, Jellyfish, etc.

**Fig. 4.3 Hydra**
Subphylum Platyhelminthes

Platyhelminthes are commonly known as Flatworms. Their features are:

1. Dorsoventrally flattened body.
2. Complex and have differentiated body structure.
3. Tissues are differentiated from three layers of cells and are triploblastic.
4. Do not have true internal cavity or coelom.
5. Have bilateral symmetry.
6. Either free-living (Planaria) or parasitic (Liver Flukes).

Examples of subphylum Platyhelminthes includes Tapeworm, Planaria, etc.

Subphylum Nematoda

Phylum Nematoda consists of Nematodes or Round Worms. Their features are:

1. Nematodes have a cylindrical body.
2. Bilaterally symmetrical and triploblastic.
3. Have pseudocoelom, a false body cavity.
4. Parasitic and causes diseases, such as elephantiasis, ascariasis, etc.

Examples of subphylum Nematoda includes Ascaris, Wuchereria, etc.

Fig. 4.4 Flatworm

Fig. 4.5 Ascaris
Subphylum Annelida

Annelids are commonly known as Segmented or Ringed Worms. They have the following features:

1. Have a segmented cylindrical body.
2. The body is differentiated into head and tail.
3. Bilaterally symmetrical and triploblastic.
4. Have a true body cavity.

Examples of subphylum Annelida includes Earthworm, Leech, etc.

![Fig. 4.6 Nereis](image)

Subphylum Arthropoda

Arthropod means jointed legs. Animals which have jointed appendages belong to this phylum. This is the largest phylum in the animal kingdom. Other features are:

1. They are bilaterally symmetrical.
2. Have jointed appendages, exoskeleton, and a segmented body.
3. Have well-differentiated organ and organ system.
4. Have an open circulatory system, but do not have differentiated blood vessels.

Examples of subphylum Arthropoda includes Spiders, Butterflies, and Mosquitoes.

![Fig. 4.7 Spider](image)
Subphylum Mollusca

Phylum Mollusca consists of a large group of animals. Their features are:

1. Bilaterally symmetrical and triploblastic.
2. Less segmented body.
3. Well-developed organ and organ system.
4. Open circulatory system.
5. limbs are present.

Examples of subphylum Mollusca includes Snails and Octopus.

Subphylum Echinodermata

The term Echinodermata is derived from the Greek words, echinos meaning hedgehog and derma meaning skin. Thus, echinoderms are spiny-skinned animals.

1. Radial symmetry and triploblastic.
2. Have true coelom.
3. Have hard calcium carbonate skeleton structure.

Example of subphylum Echinodermata includes Sea Urchins, Starfish, etc.
Major Division and Subdivision of Animal Kingdom

NOTES

Subphylum Protochordate

Protochordates have the following features:
1. Bilaterally symmetrical and triploblastic.
2. Have true coelom.
3. Habitat is marine.
4. The notochord is present at some stages of lives.

Example of subphylum Protochordates includes Balanoglossus, Amphioxus, etc.

Fig. 4.10 Amphioxus

The notochord is a long supporting structure that separates the nervous tissues from the gut. It runs along the back of an animal and is a place for muscle attachment that helps in movement.

Subphylum Vertebrata

Phylum Vertebrata consists of animals with a true vertebral column. They have an internal skeleton where muscles are attached and help in movement. Other features are:
1. Bilaterally symmetrical, triploblastic, coelomates and the segmented body.
2. The body design is complex and well-differentiated.
3. The body has an organ and organ system level of organization.
4. Possess notochord.

Vertebrates are further grouped into five classes, namely Pisces, Amphibia, Reptilia, Aves, Mammalia.

General characteristics of the Kingdom Animalia are as follows:
- Animals are eukaryotic, multicellular and heterotrophic organisms.
- They have multiple cells with mitochondria and they depend on other organisms for food.
- Habitat - Most of the animals inhabit seas, fewer are seen in fresh water and even fewer on land.
- There are around 9 to 10 million animal species that inhabit the earth. Only 800,000 species are identified.
- Biologists recognize 36 phyla in the animal’s kingdom.
Major Division and Subdivision of Animal Kingdom

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Size - The sizes of animal’s ranges from a few celled organism like the mesozoons to animals weighing many tons like the blue whale.

Animal Bodies - Bodies of animals are made of cells organized into tissues which perform specific functions. In most animals’ tissue are organized into complex organs, which form organ systems.

Cell Structure - The animal cell contains organelles like the nucleus, mitochondria, Golgi complex, ribosomes, endoplasmic reticulum, lysosomes, vacuoles, centrioles, cytoskeleton.

Animals are made up of many organ systems that aids in performing specific functions that are necessary for the survival of the organism.

Organ systems are skeletal system, muscular system, digestive system, respiratory system, circulatory system, excretory system, reproductive system, immune system and the endocrine system.

Body Symmetry - Most of the animals are bilaterally symmetrical, while primitive animals are asymmetrical and cnidarians and echinoderms are radially symmetrical.

Locomotion - Most animals have the ability to move, they show rapid movement when compared to plants and other organisms.

Respiration - It is a gaseous exchange of taking in oxygen and giving out carbon dioxide. This process takes place in organs of respiration like the lungs, gills, book gills and book lungs and some animals skin is also used for respiration.

Digestion - Animals ingest food, and digestion takes place in the internal cavity like the digestive system in animals, in primitive animals vacuoles are for digestion.

Nervous System - Sensory mechanism and the coordination of the organ systems is carried on by the nervous system. In animals the nervous system comprises of nerve ganglions, or brain, spinal cords and nerves.

Circulatory System - The distribution of nutrients, exchange of gases and removal of wastes takes place in the circulatory system. This system comprises of the heart, blood vessels and the blood.

Excretory System - Removal of wastes from kidneys.

Skeletal System - support and protection is provided by the skeletal system.

Reproductive System - Most animals reproduce sexually, by the fusion of haploid cells like the eggs and the sperms.

Glands of the endocrine system help in control and coordination of the body system.
4.3 ANIMAL ARCHITECTURE

The architecture of animal kingdom typically follows the systematic pattern,

Cell → Tissue → Organ → Organ System

Tissue Structure and Function

A tissue is a group of similar cells specialized for performing a common function. Different types of tissues have different structures that are suited to their functions.

Tissues are classified into following four main categories:

- Epithelial
- Connective
- Muscle
- Nervous

Epithelial Tissue

Epithelial tissue covers the outside of the body and lines organs and cavities within the body. It can be classified as follows:

- Squamous, Cuboidal, Columnar
- Simple vs. Stratified
Fig. 4.12 Epithelial Tissues: Squamous, Cuboidal, Columnar
Connective Tissue

Connective tissue functions mainly to bind and support other tissues. It contains sparsely packed cells scattered throughout an extracellular matrix.

Muscle Tissue

Muscle tissue is composed of long cells called muscle fibers capable of contracting in response to nerve signals.

- Smooth
- Skeletal
- Cardiac
Nervous Tissue

- Nervous tissue senses stimuli and transmits signals throughout the animal.
- A neuron (nerve cell) receives signals at the dendrites and sends them out via the axons.

![Diagram of Nervous Tissue](image)

**Fig. 4.15 Nervous Tissue**
**Complexity and Body Size**

- Increased complexity allows for an increase in body size.
- Larger size decreases the surface area to volume ratio.
- Necessitates complex systems for respiration, nutrition, and excretion – diffusion not adequate.
- Buffers environmental fluctuation.
- Escape predators.

**Fig. 4.16 Size Diversity in Animals**

- Cost of maintaining body temperature is less per gram of body weight than in small animals.
- Energy costs of moving a gram of body weight over a given distance is less for larger animals.
Body Plans

One way in which zoologists categorize the diversity of animals is according to general features of morphology and development. A group of animal species that share the same level of organizational complexity is known as a grade.

- **Protoplasmic Grade of Organization** – Protists are the simplest eukaryotes, but they still carry out life functions and show division of labour among the various cell structures. Metazoans are multicellular animals that have cells specialized for particular functions. This is the Cellular Grade of Organization. Shown by the simplest metazoans – Volvox, Sponges.

- **Cell-Tissue Grade** – Usually, specialized cells are grouped together and perform their common function as a coordinated unit, a tissue. For example, Jellyfish.

- **Tissue-Organ Grade** – Tissues are then assembled into organs like the heart (primarily muscle tissue, but connective, nervous, and epithelial also present). For example, Flatworms.

- **Organ-System Grade** – In the highest level of organization, organs work together as organ systems like the circulatory system.

Animal Body Plans

- Body plans are constrained by ancestry, major features may become modified, but are rarely lost.

- Animal body plans differ in their grade of organization, body symmetry, number of germ layers, and type of body cavity.
4.4 SYMMETRY

Spherical Symmetry

- Spherical symmetry occurs when any plane passing through the center divides the body into mirror image halves.
- Mostly found among the protists.

Radial Symmetry

Radial symmetry applies when more than two planes passing through the longitudinal axis can divide the organism into mirror image halves. For example, Jellyfish.

Biradial Symmetry

Biradial symmetry – two planes will divide the organism. For example, Comb Jellies.
Bilateral Symmetry

- Bilateral symmetry is found in organisms where one plane can pass through the organism dividing it into right and left halves.
- Better for directional movement.
- Monophyletic group called Bilateria.

Regions of a bilaterally symmetrical animal are,
- Anterior-Posterior (Transverse Plane)
- Dorsal-Ventral (Frontal Plane)
- Left-Right (Sagittal Plane)
- Proximal-Distal
- Medial-Lateral
Radiata

- The Cnidarians (Jellyfish, Corals and Sea Anemones) and Ctenophores (Comb Jellies), the radial or biradial animals, comprise the Radiata.
- No front/back.
- Weak swimmers.
- Can interact with environment in all directions.

Developmental Patterns

- Sponges develop only to blastula stage, then reorganize to form adult.
- Gastrulation allows animals to proceed to tissue level organization.
- Diploblastic – 2 germ layers.
- Cnidarians, Ctenophores.
- Triploblastic – 3 germ layers.
Other Key Features of Body Plans

- Segmentation is a serial repetition of similar body segments along the body.
- Each segment is a metamere or somite.
- May include external and internal components.
- Obscured in many animals, like humans.
-permits greater body mobility and complexity of structure and function.

Fig. 4.23 Developmental Patterns

Fig. 4.24 Segmentation in Annelida, Arthropoda and Chordata
Components of Metazoan Bodies

Extracellular components are noncellular components of metazoan animals, such as body fluids and extracellular structural elements.

4.5 COELOM IN ANIMALS

A coelom (Greek: coel = hollow cavity) is a fluid-filled cavity between the alimentary canal and the body wall lined on all sides by mesoderm. The peritoneal cavity in our abdomen is one part of our coelom and there are similar spaces around our heart and lungs. However, the type of coelom (or even its existence) differs among groups of animals both in its structure and mode of development. There are three structural types of body plans related to the coelom.

1. Acoelomates, in which no coelomic cavity exists. Examples are Flatworms (Platyhelminthes), Coelenterates and Sponges. Only a gut, coelenteron or spongocoel exists in these animals and there is no other cavity.

2. Pseudocoelomates, in which a body cavity exists in addition to alimentary canal, but it is lined by mesoderm only on the outer body wall side and not around the gut. Examples are Round Worms (Nemathelminthes) and some minor phyla grouped under Aschelminthes.

3. Coelomates or Eucoelmates. They are true coelomates in which the coelom is lined both on the inside of the body wall as well as around the gut by mesoderm. Animals with a true coelom also have mesenteries, which suspend the body organs within the coelom. Animals higher to Round Worms, such as Annelids, Arthropods, Mollusks, Echinoderms and Chordates fall in this category. The true coelomates are of the following types.

   (i) Schizocoelomates are true coelomates in which the body cavity originates by splitting of mesodermal tissue at the time of gastrulation. This method of coelom formation is called schizocoelous (Greek: schizo = split), and occurs in animals like annelids, arthropods and mollusks. Sometimes the schizocoelom is filled with blood and is called haemocoel as in Arthropods and Mollusks.

   (ii) Enterocoelomates. In most deuterostomes, such as Chordates and Echinoderms, the coelom originates by out-pouching of the archenteron during gastrulation. Each pouch then expands and its mesoderm lines the gut on the inner side and body wall on the outer side. This method of coelom formation is called enterocoelous. Segmentation, Cephalization and Tagmosis Segmentation, also known as metamerization, is the structural grouping of parts of an animal body into discrete segments.
Cephalization means that there is a head, and therefore a concentration of sensory organs, feeding organs, and centers of neural integration near the anterior end of the animal. While at first seeming a bit simplistic, cephalization has tremendous implications for animals. Tagmosis occurs in segmented animals where groups of segments are organized into functional units. A good example is in Arthropods, where segments are grouped into body regions like the head, thorax, and abdomen, each having its own suite of functions.

**Fig. 4.25 Types of Coelom in Animals**

**Cephalization**
- Bilateral symmetry is associated with cephalization, differentiation of a head.
- Nervous tissue, sense organs, and often the mouth are located in the head.
- Advantages for organisms moving head first – directional movement.
- Elongation along anteroposterior axis.
Major Division and
Subdivision of Animal
Kingdom

NOTES

Check Your Progress

1. Give R.H. Whittaker five kingdom system of classification.
2. How is Kingdom Animalia classified?
3. List the different subphylum of the animal kingdom.
4. Name the five classes that belong to Vertebrates group.
5. Give the architecture pattern of animal kingdom.
6. What is tissue? What are its different types?
7. What is bilateral symmetry?
8. Define coelom.
9. Explain the terms cephalization and tagmosis.

4.6 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. R.H. Whittaker organized the organisms into five kingdoms. He classified organisms on the basis of cell structure, mode, and source of nutrition and body design. The five kingdoms proposed by Whittaker are Monera, Protista, Fungi, Plantae, and Animalia.

2. Animals are multicellular eukaryotes. But they do not have a cell wall or chlorophyll like plants. Hence, members of the animal kingdom have a heterotrophic mode of nutrition. Kingdom Animalia has been classified into 10 different phyla based on their body design or differentiation.

3. The different subphylum of the animal kingdom are as follows:
   - Porifera
   - Coelenterata (Cnidaria)
   - Platyhelminthes
   - Nematoda
   - Annelida
   - Arthropoda
   - Mollusca
   - Echinodermata
   - Porifera
   - Vertebrata

4. The Vertebrates are grouped into five classes, namely Pisces, Amphibia, Reptilia, Aves, Mammalia.
5. The architecture of animal kingdom typically follows the systematic pattern, Cell → Tissue → Organ → Organ System

6. A tissue is a group of similar cells specialized for performing a common function. Different types of tissues have different structures that are suited to their functions. Tissues are classified into following four main categories:
   - Epithelial
   - Connective
   - Muscle
   - Nervous

7. Bilateral symmetry is found in organisms where one plane can pass through the organism dividing it into right and left halves.

8. A coelom (Greek: *coel* = hollow cavity) is a fluid-filled cavity between the alimentary canal and the body wall lined on all sides by mesoderm. The peritoneal cavity in our abdomen is one part of our coelom and there are similar spaces around our heart and lungs. However, the type of coelom (or even its existence) differs among groups of animals both in its structure and mode of development.

9. Cephalization means that there is a head, and therefore a concentration of sensory organs, feeding organs, and centers of neural integration near the anterior end of the animal. While at first seeming a bit simplistic, cephalization has tremendous implications for animals. Tagmosis occurs in segmented animals where groups of segments are organized into functional units.

4.7 SUMMARY

- The phylum is the largest formal taxonomic category in the *Linnaean* classification of the animal kingdom.
- Animal phyla are often grouped together to produce additional, informal taxa intermediate between the phylum and the animal kingdom. These taxa are based on embryological and anatomical characters that reveal the phylogenetic affinities of different animal phyla.
- *R.H. Whittaker* organized the organisms into five kingdoms. He classified organisms on the basis of cell structure, mode, and source of nutrition and body design. The five kingdoms proposed by *Whittaker* are Monera, Protista, Fungi, Plantae, and Animalia.
- Animals are multicellular eukaryotes. But they do not have a cell wall or chlorophyll like plants. Hence, members of the animal kingdom have a heterotrophic mode of nutrition. Kingdom Animalia has been classified into 10 different subphyla based on their body design or differentiation.
- Porifera means organisms with holes. They are commonly known as Sponges.
• The term Coelenterata is derived from the Greek word ‘kilos’ which means hollow-bellied.
• Platyhelminthes are commonly known as Flatworms. Complex and have differentiated body structure. Tissues are differentiated from three layers of cells and are triploblastic.
• Phylum Nematoda consists of Nematodes or Round Worms. Nematodes have a cylindrical body. Bilaterally symmetrical and triploblastic.
• Annelids are commonly known as Segmented or Ringed Worms. Bilaterally symmetrical and triploblastic.
• Arthropod means jointed legs. Animals which have jointed appendages belong to this phylum. This is the largest phylum in the animal kingdom.
• The term Echinodermata is derived from the Greek words, echinos meaning hedgehog and derma meaning skin. Thus, echinoderms are spiny-skinned animals.
• The notochord is a long supporting structure that separates the nervous tissues from the gut. It runs along the back of an animal and is a place for muscle attachment that helps in movement.
• Phylum Vertebrata consists of animals with a true vertebral column. They have an internal skeleton where muscles are attached and help in movement.
• Vertebrates are further grouped into five classes, namely Pisces, Amphibia, Reptilia, Aves, Mammalia.
• The architecture of animal kingdom typically follows the systematic pattern, Cell → Tissue → Organ → Organ System
• A tissue is a group of similar cells specialized for performing a common function. Different types of tissues have different structures that are suited to their functions.
• Tissues are classified into following four main categories:
  o Epithelial
  o Connective
  o Muscle
  o Nervous
• Muscle tissue is composed of long cells called muscle fibers capable of contracting in response to nerve signals.
• Energy costs of moving a gram of body weight over a given distance is less for larger animals.
• Protists are the simplest eukaryotes, but they still carry out life functions and show division of labour among the various cell structures. Metazoans are multicellular animals that have cells specialized for particular functions.
• Usually, specialized cells are grouped together and perform their common function as a coordinated unit, a tissue.
• In the highest level of organization, organs work together as organ systems like the circulatory system.
• Spherical symmetry occurs when any plane passing through the center divides the body into mirror image halves.
• Radial symmetry applies when more than two planes passing through the longitudinal axis can divide the organism into mirror image halves.
• Bilateral symmetry is found in organisms where one plane can pass through the organism dividing it into right and left halves.
• A coelom (Greek: coel = hollow cavity) is a fluid-filled cavity between the alimentary canal and the body wall lined on all sides by mesoderm. The peritoneal cavity in our abdomen is one part of our coelom and there are similar spaces around our heart and lungs. However, the type of coelom (or even its existence) differs among groups of animals both in its structure and mode of development.
• Cephalization means that there is a head, and therefore a concentration of sensory organs, feeding organs, and centers of neural integration near the anterior end of the animal. While at first seeming a bit simplistic, cephalization has tremendous implications for animals.
• Tagmosis occurs in segmented animals where groups of segments are organized into functional units.

4.8 KEY WORDS

• **Porifera:** It means organisms with holes. They are commonly known as Sponges.
• **Coelenterata:** The term Coelenterata is derived from the Greek word ‘kilos’ which means hollow-bellied.
• **Arthropod:** Arthropod means jointed legs. Animals which have jointed appendages belong to this phylum. This is the largest phylum in the animal kingdom.
• **Notochord:** The notochord is a long supporting structure that separates the nervous tissues from the gut. It runs along the back of an animal and is a place for muscle attachment that helps in movement.
• **Tissue:** A tissue is a group of similar cells specialized for performing a common function. Different types of tissues have different structures that are suited to their functions.
4.9 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. List the major divisions and subdivisions of the animal kingdom.
2. What do you mean by animal architecture?
3. Give the features of Annelida, Mollusca and Arthropoda.
4. Define the terms cephalization and symmetry.
5. Differentiate between bilateral and radial symmetry.
6. What is coelom in animals?

Long-Answer Questions

1. Briefly explain the major divisions and subdivisions of the animal kingdom giving appropriate examples.
2. Discuss the significance of animal architecture on the basis of cephalization and symmetry.
3. Explain the significance of symmetry in animals. Define bilateral and radial symmetry with the help of examples.
4. Briefly explain about the coelom in animals with reference to Coelomata, Acoelomata and Psudocoelomata.

4.10 FURTHER READINGS

UNIT 5 PROTOZOA

5.0 INTRODUCTION

Protozoa (also Protozoan, plural Protozoans) is an informal term for single-celled eukaryotes, either free-living or parasitic, which feed on organic matter, such as other microorganisms or organic tissues and debris. Historically, the Protozoa were regarded as ‘one-celled animals’ or ‘single-celled animals’, because they often possess animal-like behaviours, such as motility and predation, and lack a cell wall. The Protozoa are defined as single-celled organisms that can move independently and feed by heterotrophy. Goldfuss coined the term Protozoa which in ‘Greek’ means ‘First Animals’ (Proto = First; zoans = Animals). Hyman and other zoologists preferred to call them as acellular animals. A number of protozoan pathogens are human parasites, causing diseases, such as malaria (by Plasmodium), amoebiasis, giardiasis, amoebic dysentery, etc.

In this unit, you will study about Protozoa, the general characteristics of Protozoa, classification up to class level, Protozoan parasites, such as Entamoeba and Plasmodium. You will also learn about the diseases caused by parasites, namely Amoebiasis, Giardiasis, African sleeping sickness, Leishmaniasis, Toxoplasmosis, Malaria, Babesiosis, Trichomoniasis.
5.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the general characteristics of Protozoa
- Classify Protozoa up to class level
- Understand what Protozoa n parasites are
- Explain the features of Entamoeba and Plasmodium

5.2 GENERAL CHARACTERISTICS OF PROTOZOA

The animals included in phylum Protozoa can be defined as microscopic and acellular animalcules without tissues and organs. They have one or more nuclei. Protozoa exist either singly or in colonies. Almost about 50,000 species are known till date. Anton Van Leeuwenhoek was the first to observe Protozoa (Vorticella convellaria) under a microscope. He called them animalcules. Goldfuss coined the term Protozoa which in ‘Greek’ means ‘First Animals’ (Proto = First; zoans = Animals). Hyman and other zoologists preferred to call them as acellular animals.

Protozoa are single celled organisms. They come in many different shapes and sizes ranging from an Amoeba which can change its shape to Paramecium with its fixed shape and complex structure. They live in a wide variety of moist habitats including fresh water, marine environments and the soil.

General Characteristics of Protozoa

Protozoa are eukaryotic, unicellular microorganisms, which lack cell wall. The major distinguishing characteristics of Protozoa are given below:

1. The Protozoans are minute, generally microscopic and eukaryotic organisms.
2. They are the simplest and primitive of all the animals with very simple body organization, i.e., Protoplasmic Grade of Organization.
3. They do not have cell wall, some however, possess a flexible layer, a pellicle, or a rigid shell of inorganic materials outside the cell membrane.
4. They have the ability during their entire life cycle or part of it to move by locomotor organelles or by a gliding mechanism.
5. They have heterotrophic mode of nutrition, whereby the free-living forms ingest particulates, such as Bacteria, Yeast and Algae, while the parasitic forms derive nutrients from the body fluids of their hosts.

6. They are unicellular with some colonial and multicellular stages.

7. Most are microscopic.

8. All symmetries are present within members of the group.

9. No germ layers are present.

10. No organs or tissues are formed, but specialized organelles serve many of these functions.

11. These are solitary (Euglena), or colonial (Proteospongia).

12. They may be free living (Amoeba) or symbiotic (Parasitic, Mutualistic or Commensalistic).

13. Body symmetry is symmetrical (Actinopodeans) or radial (sessile forms) or bilateral (Giardia) or absent (Amoeba).

14. Locomotion is brought about by pseudopodia or flagella or cilia or myonemes.

15. Exchange of respiratory gases takes place by diffusion through the general body surface. Respiration is anaerobic in some parasitic forms.

16. Excretion occurs by diffusion across general body surface or by contractile vacuoles. Contractile vacuoles serve mainly for Osmoregulation and are common in freshwater forms.

17. Asexual reproduction takes place by binary fission or multiple fission or plasmotomy or budding.

18. Sexual reproduction takes place by syngamy or conjugation.

5.3 CLASSIFICATION OF PROTOZOA

Phylum Protozoa is a large and varied group. This phylum has a number of problems in its classification. As per one of the classification given out by Hyman, Hickman and Storer, this phylum is divided into two subphyla on the basis of organs of locomotion. These two subphyla are further divided into 5 classes. Most accepted classification of Protozoa is given by B.M. Honigberg and others based on the
scheme given by the committee on Taxonomy and Taxonomic problems of the society of Protozoologists divides this phyla into 4 subphyla as shown in Figure 5.1.

![Classification of Protozoa](image.png)

**Fig. 5.1 Classification of Protozoa**

The following is the classification as proposed by Honigberg and his group.

**SUBPHYLUM I: SARCOMASTIGOPHORA**

(In Greek ‘Sarcodes’ = Fleshy; ‘mastix’ = Whip; ‘phoros’ = Bearing)

The locomotion in this subphylum is brought about by flagella or pseudopodia or both. Other important feature of this subphylum is the presence of monomorphic nuclei. This subphylum is further divided into following 3 super classes.

**Superclass 1: Mastigophora (In Greek Mastix = Whip; phoros = Bearing)**

The body of the animals belonging to this super class is covered by pellicle. The locomotory organelles are flagella. In this super class the asexual reproduction occurs by longitudinal binary fission. This super class includes 2 classes:

**Class 1: Phytomastigophora (In Greek Phyton = Plant; Mastix = Whip; phoros = Bearing)**

They have chromatophores with chlorophyll. The nutrition in these organisms is mainly holophytic which takes place by phototrophy. These are free living organisms. The reserve food in these organisms is in the form of starch or paramylon. These organisms may have 1 or 2 flagella. Examples include Euglena, Ceratium, Noctiluca.
Class 2: Zoomastigophora (In Greek Zoon = Animal; Mastix = Whip; phoros = Bearing)

These organisms do not have chlorophyll bearing chromatophores. These are mostly parasitic. The nutrition in these organisms is holozoic or saprozoic. The reserved food is in the form of glycogen. They may have one to many flagella. Examples include Leishmania, Trypanosoma, Trichomonas, Trichonympha.
**Superclass 2: Opalinata**

The organisms belonging to this super class live as commensals or parasites in the gut of anurans. Their body is covered by oblique rows of cilia-like flagella. These organisms may have 2 or many nuclei also the nuclei are monomorphic. They undergo asexual reproduction by binary fission or by syngamy. Sexual reproduction takes place by anisogamy. Examples include Opalina, Zelleriella.

![Fig. 5.4 Opalina ranarum](image)

**Superclass 3: Sarcodina (In Greek Sarcode = Fleshy)**

The locomotion in the organism belonging to this super class is brought about by pseudopodia. Their body is amoeboid without definite pellicle. The nutrition is holozoic or saprozoic. This super class is further divided into 3 classes.

**Class 1: Rhizopodea (In Greek Zoon = Animal; mastix = Whip; phoros = Bearing)**

The pseudopodia of the animals in this class are in the form of lobopodia, filopodia or reticulopodia without axial filaments. This class includes amoebas, foraminiferans and mycetozoa. These animals are mostly free living and a few are also parasitic. In amoebas, the body is naked; in foraminiferans the body is covered by porous calcareous shell. Examples include Amoeba, Entamoeba, Elphidium.
Class 2: Piroplasmea

The animals belonging to this class are parasitic. Locomotory structures are absent in this class. Spores are also absent. These are the small parasites in the red blood cells of vertebrates. Example include Babesia.

Class 3: Actinopodea (In Greek Actis = Ray; podos = Foot)

The pseudopodia of the animals belonging to this class are in the form of axopodia with axial filaments, radiating from the spherical body. These are planktonic. This class includes Heliozoans, Radiolarians and Acanthareans. Radiolarians and Acanthareans are marine forms whereas Heliozoans are both marine and fresh water forms. Skeletons of Radiolarians have siliceous shells. The shells of dead Radiolarians accumulate on the ocean floor to form Radiolarian Ooze. Examples include Collozoum, Actinophrys, Acanthometra.

SUBPHYLUM II: SPOROZOA (In Greek Spora = Seed; zoion or zoon = Living Being, Animal)

The animals belonging to this subphylum are exclusively endoparasites. Special locomotory organelles are absent in these animals. Sometimes pseudopodia are present which are useful only for ingestion of food. Sporozoites are merozoites bear anterior apical complex that helps penetrate host cells. This subphylum includes 3 classes.

Class 1: Telospora

The Sporozoites are long in these animals. Reproduction is both asexual and sexual. They are blood and gut parasites of vertebrates. Sexual reproduction is by isogamy or anisogamy. Examples include Monocytis, Eimera, Plasmodium.
Protozoa

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Class 2: Toxoplasmea
In this class reproduction is only asexual type which takes place by internal budding where two daughter cells are produced within the mother cell and the mother cell is finally destroyed in the process of reproduction. Spores are absent. Example include Toxoplasma.

Class 3: Haplosporea
The spores in this class are amoeboïd. Also reproduction is only asexual type taking place through multiple fissions. Examples include Haplosporidium, Ichthyosporidium.

SUBPHYLUM III: CNIDOSPORATA (In Greek Knide = Nettle; spora = Seed)
The animals belonging to this subphylum are parasitic. Special kind of locomotory organelles are absent in these animals. Spores are present with one or more polar filaments. Polar filaments are special and unique features of these animals. When these spores infect a host, the polar filament is discharged and it gets attached to the host tissue. This subphylum includes 2 classes.

Class 1: Myxosporidea
The spores of the animals of this class are large and develop from several nuclei. These are generally extracellular parasites. The spores of this class have two polar filaments and have two to three valves. Example include Myxobolus.

Class 2: Microsporidea
The spores of the animals of this class are small and are developed from only one nucleus. These spores have single valve. These are generally intracellular parasites. Many of the animals of this class have a single polar filament. Example include Nosema bombycis.

SUBPHYLUM IV: CILIOPHORA (In Latin Cilium = Eyelid with Lashes; phoros = Bearing)
Ciliophorans are complex of all the Protozoans. The locomotory organelle of all the animals of this subphylum is cilia. These cilia also help in feeding at some stage of the life cycle of the animals. The nuclei of these organisms are dimorphic. Macronucleus is vegetative and polyploid. Micronucleus is reproductive and diploid. Asexual reproduction takes place by binary fission. Sexual reproduction takes place by conjugation. Only one class Ciliatea is included in this subphylum.

Class 1: Ciliatea
The locomotory organelles of these animals are numerous hair-like cilia. One or more contractile vacuoles are present in these forms. The nucleus is dimorphic.
including both macronucleus and micronucleus. Examples include Paramoecium, Vorticella, Balatidium.

Types of Protozoa

Based on the mode of nutrition, Protozoa are of the following two types:

1. **Free Living Protozoa**: They ingest particulates, such as Bacteria, Yeast and Algae.

2. **Parasitic Protozoa**: They derive nutrients from the body fluids of their hosts.

Economic Importance of Protozoa

1. Food to sea animals.
2. Some feed on algae so form a link in food chain.
3. They are used in research study to know cell function like reproduction.
4. In case of termites, they help in digestion.
5. With the stony shells they get fossilized to form limestone and chalk.
6. There are many Protozoans that cause diseases in man, such as Giardiasis, Malaria, Amoebiasis, African sleeping sickness, Leishmaniasis, Toxoplasmosis, Babesiosis, Trichomoniasis, etc.

5.4 PROTOZOA N PARASITIC DISEASES

1. **AMOEBIASIS**

This disease is caused by the sarcodeina group of Protozoa. They secrete enzymes that are then absorbed by the tissue of the host. Amoebiasis is transmitted through
Protozoa

contact with infected feces. Food and water contaminated by feces is the most common route of transmission, however, oral contact with fecal matter can also cause infection. Sometimes there are no visible symptoms but some common ones include loose stools with varying amounts of blood and an inflamed colon. This disease is treatable with an antibiotic, such as Metronidazole.

2. GIARDIASIS

This disease is also transmitted through oral contact of feces as the parasite is found in fecal matter. If hands are not properly washed after using the bathroom or changing a diaper, it is easy to come into contact with this parasite. Drinking water which has been contaminated by this parasite or even ingesting contaminated swimming water can cause Giardiasis. Symptoms include mucusy stools, diarrhoea, nausea, abdominal pain and upset stomach. This disease is treatable with an antibiotic, such as Metronidazole.
3. AFRICAN SLEEPING SICKNESS

African sleeping sickness is a disease caused by the Protozoa, which are carried by the Tsetse Fly and are transmitted to Humans through Tsetse Fly bites. This disease is fairly damaging to the human body and can cause serious illness. Symptoms of this disease include confusion, seizures, insomnia, personality changes, weight loss, slurred speech and trouble talking or walking.

**Sleeping Sickness, African** (African trypanosomiasis)
(Protista: Trypanosomatidae)

![Fig. 5.8 Giardiasis](image)

![Fig. 5.9 Sleeping Sickness](image)
4. LEISHMANIASIS

This disease is caused by the Leishmania parasite. These parasites are found mainly in southern Europe, the tropics and subtropics. The most common form of this disease being spread is through the bite of a Sand Fly, which carries the parasite. External Leishmaniasis will affect the skin and internal Leishmaniasis affects the inner organs, such as the spleen and liver. Those parasites that affect the skin cause sores, which will enlarge and become deeper as the disease progresses without treatment. Internal infection will cause weight loss, organ enlargement, fever and extremely high or low blood levels.

![Diagram of Leishmaniasis](image)

5. TOXOPLASMOSIS

Toxoplasmosis is caused by one of the most common parasites in the world, according to the Mayo Clinic. Many of the people infected by this disease do not have any symptoms. However, for those who have weak immune systems, such as infants and people suffering from chronic illnesses, this parasite can cause serious illness. Infants who are born to mothers who carry the infection can experience complications at birth. Other symptoms include body aches, fatigue, fever, sore throat and swollen lymph nodes. Symptoms are very similar to flu like symptoms and this disease can sometimes be mistaken for the flu.
6. MALARIA

Malaria is a very common disease in some countries and is spread through mosquito bites of mosquitoes that have been infected by one of the many different malaria-causing parasites. In the United States, there are more than 1300 cases of malaria reported. This is mainly reported by individuals travelling to or coming from the South Asian subcontinent or the sub-Saharan Africa who may be carrying the parasite. Malaria symptoms include headache, chills, tremors, aches and shaking.

7. BABESIOSIS

This disease is caused by the Babesia parasite that is transmitted through ticks. It can also be transmitted through blood transfusions of donors who carry the Babesia parasite. This parasite is common throughout the United States, in cities, such as New England, New Jersey, New York, Wisconsin and Minnesota. Those individuals infected with the Babesia parasite may not experience any symptoms. However, common signs and symptoms include nausea, body aches, fatigue, fever, chills, weight loss and a decreased appetite. For those who are already suffering from health problems and those who have a compromised immune system, this disease can be life threatening and cause serious health problems.
8. TRICHOMEONIASIS

This disease is caused by the Protozoan parasite, *Trichomonas vaginalis*. This disease is most commonly transmitted sexually. Symptoms of this disease differ per gender. In women, vaginitis may occur which will cause white green discharge, inflammation of vagina, vulva and malodorous. Men may experience a burning while urinating. This disease is treatable with an antibiotic, such as Metronidazole.

5.5 FEEDING AND NUTRITION OF PROTOZOA

1. **Heterotrophs**: Obtain food from external sources cannot synthesis its own.
2. **Photoautotrophs**: Photoautotroph are organisms that carry out photosynthesis. Using energy from sunlight, carbon dioxide and water are converted into organic materials to be used in cellular functions, such as biosynthesis and respiration.
3. **Mixotrophs**: Can switch between heterotrophy and autotrophy, depending on conditions.

Nutrition occurs in following four phases:
- Ingestion
- Digestion – Mechanical and/or Chemical
- Absorption
- Elimination

Digestion typically intracellular. Food is phagocytized and a food vacuole is created. Digestive enzymes are dumped into vacuole.
Check Your Progress
1. Which animals are included in phylum Protozoa?
2. What are Protozoa?
3. How excretion occurs in Protozoa?
4. State the most accepted classification of Protozoa.
5. Define Class Phytomastigophora giving example.
6. Explain Class Rhizopoda with the help of example.
7. What are Ciliophorans?
8. Based on the mode of nutrition, what are the types of Protozoa?
9. Name the diseases that are caused in man due to Protozoans.

5.6 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The animals included in phylum Protozoa can be defined as microscopic and acellular animalcules without tissues and organs. They have one or more nuclei. Protozoa exist either singly or in colonies. Almost about 50,000 species are known till date. *Anton Van Leeuwenhoek* was the first to observe Protozoa (*Vorticella convallaria*) under a microscope. He called them animalcules. *Goldfuss* coined the term Protozoa which in ‘Greek’ means ‘First Animals’ (*Proto* = First; *zoans* = Animals). *Hyman* and other zoologists preferred to call them as acellular animals.

2. Protozoa are single celled organisms. They come in many different shapes and sizes ranging from an Amoeba which can change its shape to Paramecium with its fixed shape and complex structure. They live in a wide variety of moist habitats including fresh water, marine environments and the soil.

3. Excretion occurs in Protozoa by diffusion across general body surface or by contractile vacuoles. Contractile vacuoles serve mainly for Osmoregulation and are common in freshwater forms.

4. Most accepted classification of Protozoa is given by *B.M. Honigberg* and others based on the scheme given by the committee on Taxonomy and Taxonomic problems of the society of Protozoologists divides this phyla into 4 subphyla.

5. Class Phytomastigophora (In Greek *Phyton* = Plant; *Mastix* = Whip; *phoros* = Bearing). They have chromatophores with chlorophyll. The nutrition in these organisms is mainly holophytic which takes place by phototrophy. These are free living organisms. The reserve food in these organisms is in
the form of starch or paramylon. These organisms may have 1 or 2 flagella. Examples include Euglena, Ceratium, Noctiluca.

6. Class Rhizopodea (In Greek Zoon = Animal; mastix = Whip; phoros = Bearing) The pseudopodia of the animals in this class are in the form of lobopodia, filopodia or reticulopodia without axial filaments. This class includes amoebas, foraminiferans and mycetozoa. These animals are mostly free living and a few are also parasitic. In amoebas, the body is naked; in foraminiferans the body is covered by porous calcareous shell. Examples include Amoeba, Entamoeba, Elphidium.

7. Ciliophorans are complex of all the Protozoans. The locomotory organelle of all the animals of this subphylum is cilia. These cilia also help in feeding at some stage of the life cycle of the animals. The nuclei of these organisms are dimorphic. Macronucleus is vegetative and polyploid. Micronucleus is reproductive and diploid. Asexual reproduction takes place by binary fission. Sexual reproduction takes place by conjugation. Only one class Ciliatea is included in this subphylum.

8. Based on the mode of nutrition, Protozoa are of the following two types:
   • Free Living Protozoa: They ingest particulates, such as Bacteria, Yeast and Algae.
   • Parasitic Protozoa: They derive nutrients from the body fluids of their hosts.

9. There are many Protozoans that cause diseases in man, such as Giardiasis, Malaria, Amoebiasis, African sleeping sickness, Leishmaniasis, Toxoplasmosis, Babesiosis, Trichomoniasis, etc.

5.7 SUMMARY

- The animals included in phylum Protozoa can be defined as microscopic and acellular animalcules without tissues and organs. They have one or more nuclei.
- Protozoa exist either singly or in colonies. Almost about 50,000 species are known till date. Anton van Leeuwenhoek was the first to observe Protozoa (Vorticella convallaria) under a microscope. He called them animalcules. Goldfuss coined the term Protozoa which in ‘Greek’ means ‘First Animals’ (Proto = First; zoans = Animals). Hyman and other zoologists preferred to call them as acellular animals.
- Protozoa are single celled organisms. They come in many different shapes and sizes ranging from an Amoeba which can change its shape to Paramecium with its fixed shape and complex structure. They live in a wide variety of moist habitats including fresh water, marine environments and the soil.
The Protozoans are minute, generally microscopic and eukaryotic organisms. They are the simplest and primitive of all the animals with very simple body organization, i.e., Protoplasmic Grade of Organization.

- No organs or tissues are formed, but specialized organelles serve many of these functions.
- Protozoans are solitary (Euglena), or colonial (Proteospongia).
- Protozoans may be free living (Amoeba) or symbiotic (Parasitic, Mutualistic or Commensalistic).
- Body symmetry is symmetrical (Actinopodeans) or radial (sessile forms) or bilateral (Giardia) or absent (Amoeba).
- Locomotion is brought about by pseudopodia or flagella or cilia or myonemes.
- Exchange of respiratory gases takes place by diffusion through the general body surface. Respiration is anaerobic in some parasitic forms.
- Excretion occurs by diffusion across general body surface or by contractile vacuoles. Contractile vacuoles serve mainly for Osmoregulation and are common in freshwater forms.
- Most accepted classification of Protozoa is given by B.M. Honigberg and others based on the committee on Taxonomy and Taxonomic problems of the society of Protozoologists divides this phylum into 4 subphyla.

Class Phytomastigophora have chromatophores with chlorophyll. The nutrition in these organisms is mainly holophytic which takes place by phototrophy. These are free living organisms. The reserve food in these organisms is in the form of starch or paramylon. These organisms may have 1 or 2 flagella. Examples include Euglena, Ceratium, Noctiluca.

Class Rhizopodea, the pseudopodia of the animals in this class are in the form of lobopodia, filopodia or reticulopodia without axial filaments. This class includes amoebas, foraminifera and mycetozoa. These animals are mostly free living and a few are also parasitic. Examples include Amoeba, Entamoeba, Elphidium.

Types of diseases caused by Protozoa are Amoebiasis, Giardiasis, African sleeping sickness, Leishmaniasis, Toxoplasmosis, Malaria, Babesiosis, Trichomoniasis, etc.

Ciliophorans are complex of all the Protozoans. The locomotory organelle of all the animals of this subphylum is cilia. The nuclei of these organisms are dimorphic. Asexual reproduction takes place by binary fission. Sexual reproduction takes place by conjugation. Only one class Ciliatea is included in this subphylum.
• Amoebiasis disease is caused by the sarcodina group of Protozoa. They secrete enzymes that are then absorbed by the tissue of the host.
• Giardiasis disease is transmitted through oral contact of feces as the parasite is found in fecal matter. Symptoms include mucusy stools, diarrhoea, nausea, abdominal pain and upset stomach.
• Heterotrophs obtain food from external sources cannot synthesis its own.
• Photoautotrophs are organisms that carry out photosynthesis. Using energy from sunlight, carbon dioxide and water are converted into organic materials to be used in cellular functions, such as biosynthesis and respiration.
• Mixotrophs can switch between heterotrophy and autotrophy, depending on conditions.
• Nutrition occurs in the four phases, which are Ingestion, Digestion – Mechanical and/or Chemical, Absorption and Elimination.

5.8 Key Words
• Protozoans: The Protozoans are minute, generally microscopic and eukaryotic organisms. They are the simplest and primitive of all the animals with very simple body organization, i.e., Protoplasmic Grade of Organization.
• Heterotrophs: Obtain food from external sources cannot synthesis its own.
• Photoautotrophs: Photoautotroph are organisms that carry out photosynthesis. Using energy from sunlight, carbon dioxide and water are converted into organic materials to be used in cellular functions, such as biosynthesis and respiration.
• Mixotrophs: Can switch between heterotrophy and autotrophy, depending on conditions.

5.9 Self Assessment Questions and Exercises

Short-Answer Questions
1. Define the term Protozoa.
2. Explain the significant features of Protozoa.
3. Name the 4 subphylum of Protozoa.
4. List the classes of Protozoa.
5. What are Protozoan parasites? Name the diseases caused by them.
6. Give the economic importance of Protozoa.
7. How will you identify that the person is suffering from Amoebiasis and Giardiasis?
8. Define the feeding and nutrition process of Protozoa.

Long-Answer Questions

1. Briefly explain the general characteristics of Protozoa giving appropriate examples of each type.
2. How the Protozoans are classified? Give examples.
3. Discuss all the subphylum and classes of Protozoa giving appropriate examples of each type.
4. Describe what Protozoan parasites are?
5. Write short notes on the following. Also draw and label diagram to show the life cycle:
   - Amoebiasis, Giardiasis, African sleeping sickness, Leishmaniasis, Toxoplasmosis, Malaria, Babesiosis, Trichomoniasis

5.10 FURTHER READINGS

UNIT 6 PORIFERA

6.0 INTRODUCTION

The name Porifera (In Latin Porus = Pore; Ferro = To Bear) comes from (1836). Linnaeus and Lamarck have classified the sponges under zoophytes or polyps and regarded them as allied to anthozoan coelenterates. Porifera include the sponges which are most primitive of multicellular animals, they are sessile, plant-like animals, they are fixed to some submerged solid rock or shell and are incapable of any movement. Fundamentally, the Porifera are exclusively marine except for a single family of freshwater species.

In this unit, you will learn about the general characters and classification of Porifera, structure of Leucosolenia, canal system in sponges and types of spicules in sponges.

6.1 OBJECTIVES

After going through this unit, you will be able to:

- Discuss the general features of Porifera
- Understand the system of classification for Porifera
- Explain the structure of Leucosolenia
- Define the canal system in sponges
- Analyse the spicules in sponges
6.2 PORIFERA: GENERAL FEATURES AND CLASSIFICATION

The name Porifera (In Latin Porus = Pore; Ferro = To Bear) comes from (1836). Linnaeus and Lamarck have classified the sponges under zoophytes or polyps and regarded them as allied to anthozoan coelenterates. Porifera include the sponges which are most primitive of multicellular animals, they are sessile, plant-like animals, they are fixed to some submerged solid rock or shell and are incapable of any movement. Fundamentally, the Porifera are exclusively marine except for a single family of freshwater species.

Their shape may be cylindrical, branching, vase-like or globular, some are dull in colour but most are brightly coloured, they have red, orange, purple, green or yellow colour. The body is perforated by pores and canals but there are no organs, such as mouth or nervous system. Though sponges are multicellular animals their cells do not form organised tissues. They usually have an endoskeleton of separate spicules. Digestion takes place within the cells. Because of their endoskeleton and obnoxious ferments they are generally not eaten by animals. Sponges are cultivated for commercial purposes. Approximately 10,000 species of sponges are known at present.

Definitions of Sponges

1. The Porifera may be defined as, “Asymmetrical or radially symmetrical multicellular organisms with cellular grade of organisation without well-defined tissues and organs; exclusively aquatic; mostly marine, sedentary, solitary or colonial animals with body perforated by pores, canals and chambers through which water flows; with one or more internal cavities lined with choanocytes; and with characteristic skeleton made of calcareous spicules, siliceous spicules or horny fibres of spongin”.

2. A phylum of primitive invertebrate animals comprising the sponges and having a cellular grade of construction without true tissue or organ formation but with the body permeated by canals and chambers through which a current of water flows and passes in its course through one or more cavities lined with choanocytes.

Etymology:- From the Latin porus for pore and Ferre to bear, hence an animal with pores.

Characteristics of Porifera: 1) No definite symmetry. 2) Body multicellular, few tissues, no organs. 3) Cells and tissues surround a water filled space but there is no true body cavity. 4) All are sessile, (live attached to something as an adult). 5) Reproduce sexually or asexually, sexual reproduction can be either gonochoristic or hermaphroditic. 6) Has no nervous system. 7) Has a distinct larval stage which is planktonic. 8) Lives in aquatic environments, mostly marine. 9) All are filter feeders. 10) Often have a skeleton of spicules.
MORPHOLOGY

The morphology of Porifera can be defined as having following types of differentiated cells.

- **Pinacocytes**: Outer cells covering sponge; equivalent of epiderm.
- **Porocytes**: Cells which line the pores of the sponge; through which water is drawn.
- **Choanocytes**: Similar to choanoflagellates; cell of collar which create water current and collect food matter or sticky contractile collar; may also produce sperm.
- **Amoebocytes**: Amoeba-like cells found throughout the sponge; store, digest and transport food, excrete wastes, secrete skeleton and also may give rise to buds in asexual reproduction; there are several different types:
  - **Large Amoebocytes**: Distribute food to other cells of sponge; move by way of pseudopods.
  - **Archeocytes**: Undifferentiated sponge cells that can give rise to more differentiated cells, such as pinacocytes, porocytes or oocytes.
- **Scleroblasts**: Produce spicules of two types.
- **Calcoblasts**: Make calcium carbonate spicules.
- **Silicoblasts**: Make silicious spicules.

Body Structure

A sponge, being a filter-feeding animal, has thousands of little pores and canals running through its body. Water is drawn in and shunted throughout its tissue for filtration. In fact, the vast number of pores in a sponge’s body are actually where the phylum derives its name from, i.e., ‘Porifera’ literally means ‘Bearing Pores’.

![Fig. 6.1 Body Structure of Sponge](image-url)
The most abundant pores, called **ostia**, are used to draw water into the animal’s interior cavity, called the **spongocoel**. Other cells, such as the **osculum** are exit pores that expel filtered water out of the organism. Once water passes through the ostia, and into the organism, it usually enters a series of canals that connect little chambers within the tissue, called **radial canals**. The surface of these canals is lined with specialized cells, called **choanocytes**, whose sole purpose is to filter any organic particulate out of the water for feeding or, if the season is right, to filter eggs and sperm out of the water during reproductive spawning events.

### 6.3 TYPES OF CANAL SYSTEM OF PORIFERA

The body of the sponge is traversed by numerous canals opening to the outside by many minute pores. These canals and pores of sponge constitute the Canal System. There are four types of Canal System in Sponges. They are as follows.

**ASCON TYPE**

It is the simplest type of Canal system. It is exhibited by sponges like Olynthus and Leucosolenia. These animals are cylindrical in shape. The body wall is formed of three layers, namely an outer ectoderm, a middle merenchyme and an inner choanocytes. The wall contains many pores called Ostia. These pores are intracellular because each pore is formed by the perforation of a single cell called Porocyte. All the ostia open into a central cavity called Spongocoel which is outside at the free end and by a large circular opening called Osculam. The beating of the flagella of the choanocytes creates a water current. The water flows in the following route.

\[
\text{Ostia} \rightarrow \text{Spongocoel} \rightarrow \text{Osculam}
\]

**SYCON SPONGE-CANAL TYPE**

Sycon is a sedentary sponge. It leads an aquatic life. The body of sycon shows Pores and Canals which form a complex canal system. It is called Sycon Type of Canal System. It is useful to draw water current inside the body. These water currents bring in food and oxygen. The body wall of sycon contains outer dermal layer and inner choanoderm. In between these two layer mesenchyme is present. The body wall is folded regularly and develop a regular canal system.

1. **Ostia**: The body wall is folded. In between two folds an incurrent canal is present. The opening of incurrent canal shows a pore membrane. This will show one or two ostia, through which water enters into the incurrent canals. The ostium is surrounded by myocytes. These amoebocytes will work as sphincters. They can close these openings or open them to regulate the inflow of water.

2. **Incurrent Canals**: In between two folds of the body wall an incurrent canal is present. These canals end blindly towards inside. This is lined inside by pinacocytes. These are flat cells and are contractile.
3. **Prosopyles:** The incurrent canal opens into the radial canal through Prosopyles.

4. **Radial Canals:** In between two incurrent canals a radial canal is present. It ends blindly to the exterior. It leads into excurrent canal internally.

5. **Apopyle:** Radial canal opens into excurrent canal through an opening called Apopyle. The apopyle is also surrounded by Myocytes.

6. **Excurrent Canal:** It is short and wide chamber. It opens into Spongocoel. This canal is lined with flat epithelial cell like the spongocoel. The board opening between excurrent canal and spongocoel is also called internal ostium.

7. **Spongocoel:** The central part of the cylinder of sycon will show a hollow cavity called Spongocoel. It is lined with epithelial cells. At the apex it opens out through Osculum.

Because of the action of flagella of choanocytes water is drawn into the body. This is called incurrent water. This brings in food and oxygen. Hence it is called nutritive current. The water that goes out of the osculum is called excurrent water.

**Functions of Sponge Canal System**

1. It brings constant supply of water into the body and helps in respiration.
2. Water brings with in small food particles which are used by the sponge.
3. It helps in the process of reproduction.
4. It helps in the process of discarding waste matter out of the body.

**Incurrent Canal → Prosopyle → Radial Canal → Apopyle → Spongocoel → Osculum**

![Fig. 6.2 Process of Discarding Waste Matter out of the Body](image-url)
6.4 SPICULES: MEANING, CLASSIFICATION AND DEVELOPMENT

Meaning of Spicules

The spicules or sclerites are definite bodies, having a crystalline appearance and consisting in general of simple spines or of spines radiating from a point. They have an axis of organic material around which is deposited the inorganic substance, either calcium carbonate or hydrated silica. They present a great variety of shape and as reference to the shape is essential in the description of sponges, a large terminology exists.

Classification of Spicules

First, spicules are of two general kinds—megascleres and microscleres. The spicules are further classified according to the number of their axes and rays. Words designating the number of axes end in axons, those referring to the number of rays end in actine or actinal.

1. Megascleres

The megascleres are the larger skeletal spicules that constitute the chief supporting framework of the sponge. There are five general types of megasclere spicules, viz., 1. Monaxons, 2. Tetraxons, 3. Triaxons, 4. Polyaxons and 5. Spheres.

(i) Monaxons: These are formed by growth in one or both directions along a single axis, which may be straight or curved. When growth has occurred in one direction only, the spicule is called monactinal monaxon or style.

(ii) Tetraxons: Tetraxon spicules are also called tetractines and quadri radiates. They consist typically of four rays, not in the same plane, radiating from a common point. The four rays of the tetraxon spicule may be more or less equal, in which case the spicule is called a calthrops.

Fig. 6.3 Spicules and Spongin: A- Moniactinal Monaxon, B- Diactinal Monaxon, C- Curved Monaxon, D- Curved Monaxon with Hooked Ends, E- Tetraxon, F- Triradiate, G- Calthrops, H- Hexactinal Triaxon, I and J- Polyaxon, K- Spongin Fibres
(iii) **Triaxons**: The triaxon or hexactinal spicule consists fundamentally of three axes crossing at right angles, producing six rays extending at right angles from a central point.

(iv) **Polyaxons**: These spicules in which several equal rays radiate from a central point.

(v) **Spheres**: These are rounded bodies in which growth is concentric around a centre.

(vi) **Desma**: A special type of megasclere known as desma occur in a number of sponges. A desma consists of an ordinary minute monaxon, triadiate or tetraxon spicule, termed the crepis, on which layers of silica have been deposited irregularly.

**Higher Classification of Sponges**

There are following 4 classes of sponges:

1. **Class Calcarea**
   - Found in shallow coastal waters.
   - All are marine.
   - Having calcareous spicules.

2. **Class Hexactinellida - Glass Sponges**
   - Chiefly live in 500-1000 meter depth.
   - Are syconoid sponges.
   - All are marine.
   - Having six-rayed (hexasters) siliceous spicules.

3. **Class Demospongiae**
   - Spicules are silicious if present otherwise skeleton is made of spongin or both.
   - Various shapes, some are huge.
   - All are Leuconoid, all but two families are marine. Spongillidae and Metaniidae are freshwater with about 300 freshwater species; in North America are about 27 species in 11 genera (most belong to Spongillidae).
   - This is the group from which we get our commercial sponges.
   - Having siliceous spicules and spongin fibres.

4. **Class Sclerospongiae**
   - Have silicious spicules and sponging.
   - Also have an outer covering composed of calcium carbonate.
   - Are leuconoid sponges.
Check Your Progress

1. Explain the term Porifera.
2. Define the shape and function of Porifera.
3. Give definition of Porifera.
4. What are Amoebocytes?
5. What is sponge?
6. Define canal system in sycon.
7. What are the types of spicules?

6.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. The name Porifera (In Latin Porus = Pore; Ferro = To Bear) comes from (1836). Linnaeus and Lamarck have classified the sponges under zoophytes or polyps and regarded them as allied to anthozoan coelenterates. Porifera include the sponges which are most primitive of multicellular animals, they are sessile, plant-like animals, they are fixed to some submerged solid rock or shell and are incapable of any movement. Fundamentally, the Porifera are exclusively marine except for a single family of freshwater species.

2. Their shape may be cylindrical, branching, vase-like or globular, some are dull in colour but most are brightly coloured, they have red, orange, purple, green or yellow colour. The body is perforated by pores and canals but there are no organs, such as mouth or nervous system. Though sponges are multicellular animals their cells do not form organised tissues. They usually have an endoskeleton of separate spicules. Digestion takes place within the cells. Because of their endoskeleton and obnoxious ferments they are generally not eaten by animals.

3. The Porifera may be defined as, “Asymmetrical or radially symmetrical multicellular organisms with cellular grade of organisation without well-defined tissues and organs; exclusively aquatic; mostly marine, sedentary, solitary or colonial animals with body perforated by pores, canals and chambers through which water flows; with one or more internal cavities lined with choanocytes; and with characteristic skeleton made of calcareous spicules, siliceous spicules or horny fibres of spongion”.

4. Amoebocytes are Amoeba-like cells found throughout the sponge; store, digest and transport food, excrete wastes, secrete skeleton and also may give rise to buds in asexual reproduction; there are several different types.
5. A sponge, being a filter-feeding animal, has thousands of little pores and canals running through its body. Water is drawn in and shunted throughout its tissue for filtration. In fact, the vast number of pores in a sponge’s body are actually where the phylum derives its name from, i.e., “Porifera” literally means ‘Bearing Pores’.

6. Sycon is a sedentary sponge. It leads an aquatic life. The body of sycon shows Pores and Canals which form a complex canal system. It is called Sycon Type of Canal System. It is useful to draw water current inside the body. These water currents bring in food and oxygen. The body wall of sycon contains outer dermal layer and inner choanoderm. In between these two layer mesenchyme is present. The body wall is folded regularly and develop a regular canal system.

7. Spicules are of two general kinds—megascleres and microscleres. The spicules are further classified according to the number of their axes and rays. Words designating the number of axes end in axons, those referring to the number of rays end in actine or actinal.

6.6 SUMMARY

- The name Porifera (In Latin Porus = Pore; Ferro = To Bear) comes from (1836). Linnaeus and Lamarck have classified the sponges under zoophytes or polyps and regarded them as allied to anthozoan coelenterates.
- Porifera include the sponges which are most primitive of multicellular animals, they are sessile, plant-like animals, they are fixed to some submerged solid rock or shell and are incapable of any movement. Fundamentally, the Porifera are exclusively marine except for a single family of freshwater species.
- Their shape may be cylindrical, branching, vase-like or globular, some are dull in colour but most are brightly coloured, they have red, orange, purple, green or yellow colour.
- The body is perforated by pores and canals but there are no organs, such as mouth or nervous system. Though sponges are multicellular animals their cells do not form organised tissues.
- They usually have an endoskeleton of separate spicules. Digestion takes place within the cells. Because of their endoskeleton and obnoxious ferments they are generally not eaten by animals.
- Sponges are cultivated for commercial purposes. Approximately 10,000 species of sponges are known at present.
- The Porifera may be defined as, “Asymmetrical or radially symmetrical multicellular organisms with cellular grade of organisation without well-defined tissues and organs; exclusively aquatic; mostly marine, sedentary, solitary or colonial animals with body perforated by pores, canals and chambers
A sponge, being a filter-feeding animal, has thousands of little pores and canals running through its body. Water is drawn in and shunted throughout its tissue for filtration. In fact, the vast number of pores in a sponge’s body are actually where the phylum derives its name from, i.e., ‘Porifera’ literally means ‘Bearing Pores’.

- Sycon is a sedentary sponge. It leads an aquatic life. The body of sycon shows Pores and Canals which form a complex canal system. It is called Sycon Type of Canal System. It is useful to draw water current inside the body. These water currents bring in food and oxygen.

- The spicules or sclerites are definite bodies, having a crystalline appearance and consisting in general of simple spines or of spines radiating from a point. They have an axis of organic material around which is deposited the inorganic substance, either calcium carbonate or hydrated silica.

- Spicules are of two general kinds—megascleres and microscleres. The spicules are further classified according to the number of their axes and rays. Words designating the number of axes end in axons, those referring to the number of rays end in actine or actinal.

### 6.7 KEY WORDS

- **Porifera**: These include the sponges which are most primitive of multicellular animals, they are sessile, plant-like animals, they are fixed to some submerged solid rock or shell and are incapable of any movement.

- **Porocytes**: Cells which line the pores of the sponge; through which water is drawn.

- **Choanocytes**: Similar to choanoflagellates; collared cells with flagella which create water current and collect food matter or sticky contractile collar; may also produce sperm.

- **Amoebocytes**: Amoeba-like cells found throughout the sponge; store, digest and transport food, excrete wastes, secrete skeleton and also may give rise to buds in asexual reproduction; there are several different types.

- **Archeocytes**: Undifferentiated sponge cells that can give rise to more differentiated cells, such as pinocytes, porocytes or oocytes.

- **Sponge**: A sponge, being a filter-feeding animal, has thousands of little pores and canals running through its body. Water is drawn in and shunted throughout its tissue for filtration.
6.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions
1. Give the classification system of Porifera.
2. Define the body structure of Porifera.
3. What are Porococytes and Choanocytes?
4. What is sponge?
5. List the functions of sponge canal system.
6. Explain the canal system in sponges.
7. What are spicules in sponges?

Long-Answer Questions
1. Briefly explain the classification system and general characteristic features of Porifera.
2. Discuss the body structure and canal system in Porifera giving appropriate examples and diagrams.
3. What are spicules in sponges? Explain its various types with the help of diagram of each type.

6.9 FURTHER READINGS


UNIT 7 COELENTERATA

Coelenterata is an obsolete term encompassing the animal phyla Cnidaria (Coral Animals, True Jellies, Sea Anemones, Sea Pens, and Their Allies) and Ctenophora (Comb Jellies). The name comes from the Greek ‘Koilos’ meaning ‘Hollow’ and ‘Enteron’ meaning ‘Intestine’, referring to the hollow body cavity common to these two phyla. They have very simple tissue organization, with only two layers of cells (External and Internal), and radial symmetry. The examples are Corals, which are typically colonial, and Hydra, Jelly Fish and Sea Anemones which are solitary. Coelenterata lack a specialized circulatory system relying instead on diffusion across the tissue layers.

All coelenterates are aquatic, mostly marine. The body form is radially symmetrical, diploblastic and does not have a coelom. The body is surrounded by sensory tentacles equipped with either nematocysts or colloblasts to capture mostly planktonic prey. Many Cnidaria exhibit polymorphism, wherein different types of individuals are present in a colony for different functions. These individuals are called Zooids. These animals generally reproduce asexually by budding, though sexual reproduction does occur in some groups.

In this unit, you will learn about the general characteristic features of Coelenterata, structure of Obelia colony, polymorphism in coelenterates, and Corals and Coral Reefs.

7.0 OBJECTIVES

After going through this unit, you will be able to:

- Define the characteristic features of Coelenterata
- State the classification system for Coelenterata

7.1 OBJECTIVES

- Define the characteristic features of Coelenterata
- State the classification system for Coelenterata
Coelenterata

- Analyse the habit and habitat of Coelenterata
- Explain the structure of Obelia colony
- Discuss how polymorphism occurs in Coelenterates
- Explain what Corals are
- Describe how Corals forms Coral Reefs

### 7.2 COELENTERATA: AN INTRODUCTION

Coelenterata is an obsolete term encompassing the animal phyla Cnidaria (Coral Animals, True Jellies, Sea Anemones, Sea Pens, and Their Allies) and Ctenophora (Comb Jellies). The name comes from the Greek ‘Koilos’ meaning ‘Hollow’ and ‘Enteron’ meaning ‘Intestine’, referring to the hollow body cavity common to these two phyla. They have very simple tissue organization, with only two layers of cells (External and Internal), and radial symmetry. The examples are Corals, which are typically colonial, and Hydra, Jelly Fish and Sea Anemones which are solitary. Coelenterata lack a specialized circulatory system relying instead on diffusion across the tissue layers.

All Coelenterates are aquatic, mostly marine. The body form is radially symmetrical, diploblastic and does not have a coelom. The body has a single opening, the hypostome, surrounded by sensory tentacles equipped with either nematocysts or colloblasts to capture mostly planktonic prey. These tentacles are surrounded by a spacious cavity called the gastrovascular cavity or Coelenteron. Digestion is both intracellular and extracellular. Respiration and excretion are accomplished by simple diffusion. A network of nerves is spread throughout the body. Many Cnidaria exhibit polymorphism, wherein different types of individuals are present in a colony for different functions. These individuals are called Zooids. Coelenterates have two basic zooids, polyp and medusa. All other types of zooids are modifications of these two types of zooids. These animals generally reproduce asexually by budding, though sexual reproduction does occur in some groups.

#### Definition

The Coelenterates can be defined as,

1. “A phylum of invertebrate animals including the Jellyfishes, Hydras, Sea Anemones and Corals which show the characteristic features of Coelenterata, i.e., the phylum comprising the Coelenterates”.
2. “Coelenterates are typically invertebrate animals, which show a very simple level tissue organisation. They are aquatic animals and are mostly found in marine environments, attached to the rocks at the bottom of the ocean. A few species are also found in freshwater habitats. Coelenterates can be found solitary or in colonies, as sedentary or free swimming”.

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Self-Instructional Material
3. “Coelenterates can be called as the simplest animal group that has true tissues and have the characteristic Coelenteron or the gastrovascular cavity”.

**Cnidaria** (pronounced nidadia) is a phylum under Kingdom Animalia containing over 11,000 species of animals found exclusively in aquatic (freshwater and marine) environments. They are a predominantly marine species. The Cnidaria as a group of animals are well known to many people under their common names, such as Sea Anemones, Corals, Jellyfish, Hydras, Sea Whips, Sea Fans and Sea Pansies are all Cnidarians.

The name Cnidaria has now replaced the older term of Coelenterata (pronounced selenterata) which these days is often applied to both the Cnidaria and the Ctenophora together, these two phyla are also known as the Radiate Animals because they both have radial or biradial symmetry. The word Cnidaria refers to Cnidocysts, specialised cells which contain the Nematocysts, the stinging organelles that allow the Cnidaria to subdue their prey.

Fundamentally, the Cnidaria are the oldest of the true metazoan phyla. A fossil Hydrozoan from South Australia called *Ediacara* is 700 million years old, while numerous fossil Cnidarians exist from the Cambrian 500 million years ago. The Cnidarians, particularly the corals often make up an important component of the shallow marine fauna of tropical and subtropical seas. All the Cnidaria are aquatic and nearly all are marine. Corals because of their shallow marine environment and their habit of accumulating a mineralized skeleton (Coralite) tend to fossilize well and we know quite a bit about their evolution.

The Cnidarian body is basically a U shape with intact walls that surround a central digestive area and a mouth at the opening, generally surrounded by tentacles, there is no distinct anus. In *Anemones* the mouth faces up, and in *Jellyfish* it faces down. The Cnidarians show a more complicated arrangement of cell layers as well as a greater range of cell types than the Porifera. Their bodies show two distinct layers of cells and thus they are called ‘Diploblastic Animals’. The two cell layers are an outer Epidermis or Ectoderm, and an inner Gastrodermis or Endoderm. These two layers are separated by the mesoglea a non-cellular fibrous jelly like material that is thin in some groups, such as the Hydras but can be quite thick in other, such as the Jellyfish where it helps provide negative buoyancy (makes the animal more likely to float). The *Ectoderm* consists of five basic cell types, Epitheliomuscular cells which supply some of the muscular capabilities of the animal, Interstitial cells which are basic cells that give rise to the other cell types, **Cnidocytes**, Mucous Glands and Sensory or Nerve cells. The Endoderm consists of three or four basic cell types, Namely Gastromuscular cells which help digest food items and provide some muscle power, Gland cells that secrete enzymes for digestion, Mucous cells and in Anemones but not in Hydras, Cnidocytes.

One of the most important distinguishing characteristics of the phylum are the Nematocysts. Nematocysts, and their enclosing Cnidocysts occur in about
24 different forms, the differences play a functional role in the classification of the phylum. A Cnidocyst is a cell that secretes a Nematocyst within it. A basic Nematocyst is a capsule made of something like chitin within which rest a coiled thread. This thread can be shot out of the capsule to encounter prey items, or in some cases to repel predators.

Corals and the Coral Reefs they form are important breeding areas for fish, some of which are commercially important, they are also important in terms of biodiversity because of the wide range of creatures that live preferentially, or only in or near Coral Reefs which are considered among the most beautiful and colourful places on the planet Earth. The reef building corals live in a delicate balance with the dinoflagellate *Symbiodinium microadriaticum* which have a very narrow temperature range within which they produce new coral skeleton faster. This temperature range is 23 to 29 degrees C, or 73 to 84 degrees F. There are fears that global warming could have a disastrously destructive effect on the world's remaining Coral Reefs.

The Cnidaria come in two basic forms, a 'Polyp' form typified by the Sea Anemones and a 'Medusa' form typified by Jellyfish. Usually the Polyps are tube shaped and sedentary with a ring of tentacles around the mouth, while the Medusae are umbrella or bell shaped, free living and have a central projection on the inside of the umbrella which supports the mouth and their tentacles around the rim of the umbrella.

The Cnidarians are either carnivores or omnivorous filter feeders. The carnivorous forms do not hunt their prey, instead they use various 'sit and trap' or 'float/swim and trap' strategies, using their Nematocysts, which are not only found on the stinging tentacles but can be all over the animals body, to stun and or kill their prey.

**Characteristic Features of Phylum Coelenterata**

- Diploblastic body with two layers of cells, outer layer called ectoderm or epidermis and the inner layer known as the endoderm or gastro dermis. There is a non-cellular layer that is the mesoglea in between the ectoderm and the endoderm.
- Phylum Coelenterate characteristics is they have a single opening into the body which acts as both the mouth and anus which functions in taking food and expelling wastes.
- Coelenterates contain body cavity known as the Coelenteron, where the digestion of food occurs. The name Coelenterata for these animals is coined due to this character.
- They are multicellular organisms, exhibiting tissue grade of the organisation.
- They show radial symmetry.
Coelenterate

- They have a single opening in the body through which food is taken in and also waste is expelled out.
- The opening in the body is surrounded by tentacles.
- Digestion takes place in the body cavity which is the Coelenteron.
- They can live in marine or freshwater habitats.
- They can be solitary or live in colonies. Each individual is a Zooid.
- These organisms show two morphological forms – Polyps and Medusa.
- Polyps contain exoskeleton and endoskeleton.
- The skeletons are composed of calcium carbonate.
- Most of the coelenterates are carnivorous in nature with a few exceptions such as the s corals. They get their food from other animals that live symbiotically within them.
- Digestion is both intracellular and extracellular.
- Tentacles have special structures known as the nematocysts which help in capturing and paralyzing prey. Coelenterates simply wave their tentacles and when a prey comes in contact, the nematocysts inject the toxin that paralyses or kills the prey. Nematocysts are the most distinguishing feature of this phylum.
- Coelenterates do not have sensory organs.
- Respiration and excretion occur through simple diffusion.
- The circulatory system is absent.
- Asexual reproduction is seen in polyps, through budding and sexual reproduction is seen in medusa form, through gametes.
- All Coelenterates are aquatic and mostly are marine in nature, found from the shallow water to the depths of the abyss. Some species of the class hydrozoans are found in freshwater ponds and lakes.

There are about 10,000 species of **Cnidarians** divided between 3 classes **Hydrozoa, Scyphozoa and Anthozoa**. The following Table 7.1 illustrates the form, habitat and genera of each type.

**Table 7.1 Hydrozoa, Scyphozoa and Anthozoa**

<table>
<thead>
<tr>
<th>Class</th>
<th>Life Style</th>
<th>Form</th>
<th>Habitat</th>
<th>Genera</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrozoa</td>
<td>Solitary or Colonial, Sessile as Adult</td>
<td>Sexual Polyps and Asexual Medusa either of which may be absent.</td>
<td>Freshwater and Marine</td>
<td>Hydra, Obelia, Physalia, Tabularia</td>
</tr>
<tr>
<td>Scyphozoa</td>
<td>Solitary, nearly All Free Swimming</td>
<td>Sexual Medusa with a reduced or Absent Polyp</td>
<td>Marine only</td>
<td>Aurelia, Cassiopeia, Chironex, Rhizostoma</td>
</tr>
<tr>
<td>Anthozoa</td>
<td>Solitary or Colonial Sessile as Adult</td>
<td>Polyp only</td>
<td>Marine only</td>
<td>Adamsia, Cerianthus, Gorgonia, Renilla</td>
</tr>
</tbody>
</table>
Examples of Cnidarians

1. **Hydra**
   - Class Hydrozoa
   - Spend most of life as a Polyp
   - No Medusa stage

2. **Jellyfish/Scyphozoa**
   - Class Scyphozoa
   - Jellyfish go through the same life-cycle stages as Hydrozoans.
   - In Scyphozoans, the Medusa is large and longer living, and the Polyp stage is restricted to a tiny larval stage.
   - The nematocysts (stinging threads on tentacles) of most Jellyfish are harmless to humans, but a few can cause painful stings.

3. **Sea Anemones and Corals**
   - Class Anthozoa
   - Anthozoans have only the Polyp stage in their life cycle.

Cnidarian Characteristics

**Body Plan**
- Radially symmetrical body with a single opening.
- Opening will allow food to enter and wastes to leave.
- Surrounding the mouth is a ring of tentacles (usually contains stinging cells).
- Tentacles contain nematocysts; when touched, the nematocyst thrusts out a spring-loaded poisonous thread into its prey, paralyzing or trapping it.
- Separating the outer ectoderm from the inner endoderm is a layer of mesoglea. Mesoglea offers support for the animal.
- The body has two alternate but similar body forms.

**Polyps**
- Usually attached to some object with the mouth and tentacles directed upwards.
- Sessile (non-motile stuck to the bottom).

**Medusa**
- Is free swimming with the mouth and tentacles directed downwards, can change shape.
- Nematocysts fire on contact; after paralyzing its prey, it pushes the food into its mouth with its tentacles.
Difference between Medusa and Polyp

- Medusa is a free-swimming stage while Polyp is a sessile form.
- Medusa are prominent in Scyphozoans while Polyps are the only forms in the Anthozoans.
- Medusa is the reproductive stage and Polyp is the asexual stage of Hydrozoans.
- Medusa has its mouth directed downwards while Polyp has it directed upwards.
- Medusa has a pneumatophore but it is not in Polyp.
- Polyp has a simple and mostly uniform body shape while the shapes are slightly different among Medusa.
- Mesoglea is thicker in Medusa than in Polyp.
- Tentacles are more prominent in Medusa than in Polyp.

Various Body Systems

- **Digestion:** Food is pushed into the central cavity where gland cells release enzymes in order to digest food. Other cells of the endoderm will then absorb the digested nutrients. Indigestible material will then be eliminated out of the mouth.
- **Circulation:** There is no true circulatory system. Food nutrient particles will be passed through the central cavity by body movements and by flagellated cells in the endoderm. Thus the cavity is involved in both digestion and circulation. This cavity is called the gastrovascular cavity.
- **Respiration and Excretion:** Both take place by diffusion with the water that bathes the tissues.
Coelenterata

NOTES

1. **Nervous:** There is a limited amount of nervous and sensory tissue. This nerve net is used for co-ordination. Sensory cells are sensitive to touch and various chemicals.

2. **Muscular:** Lack muscle cells, but epidermal cells can contract and change shape when stimulated.

3. **Reproduction:** The reproduction is of following types.
   - **Asexual:** Many Polyps will reproduce by budding, this may form new Polyps or Medusa.
   - **Sexual:** Medusa reproduces sexually. Testes will produce sperm which travel through the water to the ovary which has produced eggs. The fertilized eggs are released out of the mouth to develop into ciliated larvae (Planulæ), this stage will usually develop into a young Polyp. Some Cnidarians, such as Hydra, Sea Anemone have Polyps that can also reproduce sexually.

4. **Advantages of Motile and Non-Motile Stages/Forms in Life Cycle**
   - If motile, organism can find new food; if non-motile, you stay in one place and you can run out of food.
   - Advantage of being sessile (non-motile) is that they can hide from predators and they do not have to worry about washing ashore.
   - **Disadvantage** of being motile is that you can easily get carried away by the water currents.

5. **Ecological Roles of Cnidarians**
   - Form symbiotic relationships with other animals.
   - Coral Reefs are shelter for many marine animals. They contain tunnels, caves, and deep channels in which animals live.
   - Coral Reefs provide habitat for many fish and food for many other animals that produce valuable shells, pearls, and jewelry.
   - Protect land from erosion by reducing wave action. If destroyed, large amounts of shoreline maybe washed away.
   - Medical research of chemicals produced by many Cnidarians, such as New Antibiotics, New Anticancer Chemicals, etc.

6. **7.3 POLYMORPHISM IN CNIDARIA (COELENTERATE)**

Coelenterate animals may show a number of zooids. They are of different forms. They take up different functions. Polymorphism is one of the Coelenterate animals characteristics feature. A polymorphic colony contains many individuals called zooids. This phenomenon is called polymorphism and such a colony is called...
NOTES

Self-Instructional Material

Coelenterata

Polymorphic Colony. Polymorphism denotes division of labour among the zooids of the individual. They are mainly of two types - Medusa and Polyp.

Medusa: Medusa is a mobile life cycle stage of the species belonging to the Cnidaria phylum. Species of the Hydrozoa class exist in Medusa form or Jellyfish. Morphologically, a Medusa is formed by a bell capable of muscular contractions which enables the Medusa to swim. Tentacles with a different morphology from those of Polyps, Photoreceptors, and Gravity-Sensing Statocytes surround the bell. Hydrozoa class members additionally possess a manubrium, which is a tube hanging down from the bell with the mouth at its end. The space extending between the base of the manubrium into the bell consists of the gastric cavity. Medusa reproduce sexually. Medusa development varies within the classes of the Cnidaria phylum. In Hydrozoa class members, Medusa are formed by budding. The evagination of the endoderm and ectoderm is followed by the proliferation of ectodermal epithelial cells at the tip of the bud, forming an internal cavity. The cavity then opens, tentacles grow, and the tissue attaching the medusa to the parent polyp constricts releasing the newly formed Medusa.

Polyps: Polyp is sedentary. It shows mouth and tentacles at the free end. Fundamentally, the Polyp is a sessile life cycle stage of the species belonging to the Cnidaria phylum. Adult Corals and Sea Anemones are examples of Polyps. A Polyp is formed by a tube with a mouth surrounded with tentacles, referred to as a head and is attached to the bottom with a foot-like disk. Mouth and tentacles face towards the water. Polyp reproduction can occur either sexually or asexually. In the example of Corals, separated sexes where some Corals are males and others are females exist, while other Coral species are hermaphrodites with an individual being both male and female. Asexual reproduction occurs by budding through the evagination of a circular area of tissue including the endoderm and ectoderm. Sexual reproduction occurs by spawning. At a given time following the secretion of pheromones, Corals release a big number of sexual cells in the water.

Thus, the Medusa is free swimming. Hydra is a Monomorphic form. It is represented by Polyp form. It performs all functions. Obelia like animals show two forms, Polyp nutritive zooid and Medusa reproductive zooid. This is called dimorphic organism.

In a colony of Obelia:
1. Hydranth (a Polyp Stage)
2. Blastostyle (Asexually, Reproducing Zooid)
3. Medusa (Present).

Polymorphic Tendency in Siphonophora Animals

The polymorphic tendency reached its peak in Coelenterate organisms belonging to order ‘Siphonophora’ of class ‘Hydrozoa’. Many Siphonophora organisms will show complicated structures. Structure of a typical Siphonophora organism can be defined as follows.
Coelenterates

NOTES

Self-Instructional Material

Polymorphism Siphonophora

In Hydrozoan Coelenterates polymorphic tendency is well developed. The order Siphonophora organisms are exhibiting this tendency to a maximum extent. In a generalised Siphonophora organism several forms are seen. These forms or zooids are developed from Polyps or Medusa. These individual zooids are attached to a common stalk called Coenosarc.

Polypoid Zooids are:
1. Gastro Zooids
2. Dactylo Zooids
3. Gono Zooids

**Gastro Zooids:** The Nutritive Polyps are called Gastro Zooids. They alone take up nutrition in the colony. They are tubular. A mouth is present at the tip of the hypostome. Near the base of a Gastro Zooid usually a single, long and contractile tentacle arises. It shows batteries of Nematocysts. Lateral branches are present called tentilla. Gastro Zooids catch the prey and digest it. The digested food is thrown into the Coenosarcal canal.

**Dactylo Zooids:** They are called Palpons, feelers or tasters. They resemble the Gastro Zooids. They do not show mouth. Their basal tentacle is unbranched. In Physalia, the tentacle is very long. In Velella and Porpita the margin of the colony bears long and hollow tentacles. These zooids are protective in function. They bear batteries of Nematocysts.

**Gono Zooids:** The reproductive zooids are called Gono Zooids. They have no mouth. In Physalia the Gono Zooid shows branched stalk, bearing clusters of Gonophores (Gonopalpon). Gono Zooids produce Medusae called Gonophores.

Medusoid Zooids are:
1. Pneumatophore
2. Nectocalyces
3. Bracts
4. Gonophores

**Pneumatophores:** It functions as a float. It is an inverted Medusa bell. The walls are two layered and highly muscular. The epidermal lining becomes glandular to form a gas gland. The gas gland secretes gas into the air-sac.

- The pneumatophore is small in Halistemma.
- The pneumatophore is very large in Physalia.
- It is disc-shaped in Porpita.

**Nectocalyces:** These are swimming-bells. They are Medusoid. Mouth, manubrium, tentacles and sense organs are absent. They are helpful in swimming.
**Bracts:** They are also known as Hydrophyllia. They are leaf-like. In Halistenema a bract covers the Zooids of a Cormidium. In Siphonophora many examples can explain polymorphism.

### 7.4 CORAL REEFS

Coral Reefs are diverse underwater ecosystems held together by calcium carbonate structures secreted by Corals. Coral Reefs are built by colonies of tiny animals found in marine waters that contain few nutrients. Most Coral Reefs are built from stony Corals, which in turn consist of Polyps that cluster in groups. The Polyps belong to a group of animals known as Cnidaria, which also includes Sea Anemones and Jellyfish. Unlike Sea Anemones, Corals secrete hard carbonate exoskeletons which support and protect the Coral Polyps. Most reefs grow best in warm, shallow, clear, sunny and agitated waters. Coral Reefs are rocky mounds and/or ridges formed in the sea by living things through the accumulation and deposition of Limestone (Calcium Carbonate). These underwater palaces are home to more species of Fishes, Corals, and many other types of marine life than any other ocean habitat. Coral Reefs also provide many valuable services to humans. Food, shoreline protection, and medicines are just a few of these benefits. These are also the best places to visit if you want to experience marine life.

![Fig. 7.2 Coral Reefs](image-url)

**What are Coral Reefs?**

Hard Corals extract abundant calcium from surrounding seawater and use this to create a hardened structure for protection and growth. Coral Reefs are therefore created by millions of tiny Polyps forming large carbonate structures, and are the basis of a framework and home for hundreds of thousands, if not millions, of other species. Coral Reefs are the largest living structure on the planet Earth, and the only living structure to be visible from space.
Types of Coral Reefs

Most reef scientists generally recognize three major types of Coral Reefs are:

1. Fringing Reefs
2. Barrier Reefs
3. Atolls

It was Charles Darwin who originally classified Coral Reefs as to their structure and morphology, and described them as follows:

1. Fringing Reefs lie near emergent land. They are fairly shallow, narrow and recently formed. They can be separated from the coast by a navigable channel (which is sometimes incorrectly termed a “lagoon”).
2. Barrier Reefs are broader and lie farther away from the coast. They are separated from the coast by a stretch of water which can be up to several miles wide and several tens of metres deep. Sandy islands covered with a characteristic pattern of vegetation have sometimes formed on top of a Barrier Reef. The coastline of these islands is broken by passes, which have occupied the beds of former rivers.
3. Atolls are large, ring-shaped Reefs lying off the coast, with a lagoon in their middle. The emergent part of the Reef is often covered with accumulated sediments and the most characteristic vegetation growing on these Reefs consists of coconut trees. Atolls develop near the sea surface on underwater islands or on islands that sink, or subside.

Check Your Progress

1. What are Coelenterates?
2. Give definition of Coelenterates.
3. What are the two basic forms of Cnidaria?
4. Define the role of tentacles.
5. What are Polyps and Medusa?
6. What are Coral Reefs?

7.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. All Coelenterates are aquatic, mostly marine. The body form is radially symmetrical, diploblastic and does not have a coelom. The body has a single opening, the hypostome, surrounded by sensory tentacles equipped with either nematocysts or colloblasts to capture mostly planktonic prey.
2. The Coelenterates can be defined as, “Coelenterates are typically invertebrate animals, which show a very simple level tissue organisation. They are aquatic animals and are mostly found in marine environments, attached to the rocks at the bottom of the ocean. A few species are also found in freshwater habitats. Coelenterates can be found solitarily or in colonies, as sedentary or free swimming”.

3. The Cnidaria come in two basic forms, a ‘Polyp’ form typified by the Sea Anemones and a ‘Medusa’ form typified by Jellyfish. Usually the Polyps are tube shaped and sedentary with a ring of tentacles around the mouth, while the Medusae are umbrella or bell shaped, free living and have a central projection on the inside of the umbrella which supports the mouth and their tentacles around the rim of the umbrella.

4. Tentacles have special structures known as the nematocysts which help in capturing and paralyzing prey. Coelenterates simply wave their tentacles and when a prey comes in contact, the nematocysts inject the toxin that paralyses or kills the prey. Nematocysts are the most distinguishing feature of this phylum.

5. The Polyps and Medusa are defined as follows.
   Polyps
   - Usually attached to some object with the mouth and tentacles directed upwards.
   - Sessile (non-motile stuck to the bottom).
   Medusa
   - Is free swimming with the mouth and tentacles directed downwards, can change shape.
   - Nematocysts fire on contact; after paralyzing its prey, it pushes the food into its mouth with its tentacles.

6. Hard Corals extract abundant calcium from surrounding seawater and use this to create a hardened structure for protection and growth. Coral Reefs are therefore created by millions of tiny Polyps forming large carbonate structures, and are the basis of a framework and home for hundreds of thousands, if not millions, of other species.

7.6 SUMMARY

- Coelenterata is an obsolete term encompassing the animal phyla Cnidaria (Coral Animals, True Jellies, Sea Anemones, Sea Pens, and Their Allies) and Ctenophora (Comb Jellies).
- The name comes from the Greek ‘Koilos’ meaning ‘Hollow’ and ‘Enteron’ meaning ‘Intestine’, referring to the hollow body cavity common to these
two phyla. They have very simple tissue organization, with only two layers of cells (External and Internal), and radial symmetry. The examples are Corals, which are typically colonial, and Hydra, Jelly Fish and Sea Anemones which are solitary.

- Coelenterata lack a specialized circulatory system relying instead on diffusion across the tissue layers.
- All Coelenterates are aquatic, mostly marine. The body form is radially symmetrical, diploblastic and does not have a coelom. The body has a single opening, the hypostome, surrounded by sensory tentacles equipped with either nematocysts or colloblasts to capture mostly planktonic prey.
- Coelenterates are typically invertebrate animals, which show a very simple level tissue organisation. They are aquatic animals and are mostly found in marine environments, attached to the rocks at the bottom of the ocean. A few species are also found in freshwater habitats. Coelenterates can be found solitarily or in colonies, as sedentary or free swimming.
- Coelenterates can be called as the simplest animal group that has true tissues and have the characteristic Coelenteron or the gastrovascular cavity.
- Cnidaria (pronounced nidaria) is a phylum under Kingdom Animalia containing over 11,000 species of animals found exclusively in aquatic (freshwater and marine) environments: they are a predominantly marine species. The Cnidaria as a group of animals are well known to many people under their common names, such as Sea Anemones, Corals, Jellyfish, Hydras, Sea Whips, Sea Fans and Sea Pansies are all Cnidarians.
- The Cnidaria come in two basic forms, a 'Polyp' form typified by the Sea Anemones and a 'Medusa' form typified by Jellyfish. Usually the Polyps are tube shaped and sedentary with a ring of tentacles around the mouth, while the Medusae are umbrella or bell shaped, free living and have a central projection on the inside of the umbrella which supports the mouth and their tentacles around the rim of the umbrella.
- Tentacles have special structures known as the nematocysts which help in capturing and paralyzing prey. Coelenterates simply wave their tentacles and when a prey comes in contact, the nematocysts inject the toxin that paralyses or kills the prey. Nematocysts are the most distinguishing feature of this phylum.
- There are about 10,000 species of Cnidarians divided between 3 classes Hydrozoa, Scyphozoa and Anthozoa.
- Polyps: Usually attached to some object with the mouth and tentacles directed upwards. Sessile (non-motile stuck to the bottom).
- Medusae: Is free swimming with the mouth and tentacles directed downwards, can change shape. Nematocysts fire on contact; after paralyzing its prey, it pushes the food into its mouth with its tentacles.
• Coral Reefs are diverse underwater ecosystems held together by calcium carbonate structures secreted by Corals. Coral Reefs are built by colonies of tiny animals found in marine waters that contain few nutrients. Most Coral Reefs are built from stony Corals, which in turn consist of Polyps that cluster in groups.

• Most reefs grow best in warm, shallow, clear, sunny and agitated waters. Coral Reefs are rocky mounds and/or ridges formed in the sea by living things through the accumulation and deposition of Limestone (Calcium Carbonate). These undersea palaces are home to more species of Fishes, Corals, and many other type of marine life than any other ocean habitat.

7.7 KEY WORDS

• Coelenterates: These are aquatic, mostly marine; body form is radially symmetrical, diploblastic and does not have a coelom.

• Tentacles: These are special structures known as the nematocysts which help in capturing and paralyzing prey.

• Polyps: Usually attached to some object with the mouth and tentacles directed upwards. Sessile (non-motile stuck to the bottom).

• Medusa: Is free swimming with the mouth and tentacles directed downwards, can change shape. Nematocysts fire on contact; after paralyzing its prey, it pushes the food into its mouth with its tentacles.

• Coral Reefs: These are diverse underwater ecosystems held together by calcium carbonate structures secreted by Corals.

7.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. Define the term Coelenterate.
2. Give any five characteristic features of Coelenterata.
3. What is the significance of Corals?
4. Define the structure of Obelia colony.
5. What is polymorphism in coelenterates?
6. Define the terms Corals and Coral Reefs.

Long-Answer Questions

1. Discuss about the Phylum Coelenterata with reference to its position in Animal Kingdom.
**NOTES**

2. Briefly explain the characteristic features of Phylum Coelenterata giving appropriate examples.
3. Explain the ecological roles of Cnidarians.
4. Describe Coelenterata with reference to structure of Obelia colony.
5. Discuss polymorphism features in Coelenterates giving appropriate examples of each type.
6. Explain the significance of Corals and Coral Reefs in Ecology and Medical Sciences.

### 7.9 FURTHER READINGS


UNIT 8 HELMINTH PARASITES

8.0 INTRODUCTION

The name Platyhelminthes was derived from the Greek “platys” flat and helminthes worms. Gagenbaur 1859 coined the word Platyhelminthes for the flat worms which are considered as the most primitive of all helminthes. This group includes free living or parasitic forms. Minot (1876) separated nemertines from flat-worms and group them as phylum Platyhelminthes. The branch of biology study of helminthes is known as Helminthology. The simplest animals that are bilaterally symmetrical and triploblastic (composed of three fundamental cell layers) are the Platyhelminthes, the flatworms. Flatworms have no body cavity other than the gut (and the smallest free-living forms may even lack that!) and lack an anus; the same pharyngeal opening both takes in food and expels waste. Because of the lack of any other body cavity, in larger flatworms the gut is often very highly branched in order to transport food to all parts of the body. The lack of a cavity also constrains flatworms to be flat; they must respire by diffusion, and no cell can be too far from the outside, making a flattened shape necessary.

8.1 OBJECTIVES

After going through this unit, you will be able to:

- Get an overview of helminth parasites and their characteristics
- Discuss classes of Phylum Platyhelminthes
- Understand adaptations in parasites
- Know about Nematode parasites
8.2 PHYLUM PLATYHELMINTHES: HELMINTH

General Characteristics

- They are soft bodied, unsegmented worms.
- They show bilateral symmetry and dorsiventrally flat worms.
- They show three germinal layers i.e. ectoderm, mesoderm and endoderm.
- The epidermis is soft, syncytial. It is ciliated in Turbellaria. It is covered by cuticle in Trematoda and Cestoda worms.
- **Exo or Endo skeleton is completely absent.**
- The parasite shows suckers or hooks or both for attachment to the host body.
- They are the first animals to illustrate the development of organ system.
- A true body cavity or **coelom is absent**, and the space between the body organs is filled with loose parenchyma.
- **Muscular system is well developed.** It is mesenchymal in origin. The system consists of circular, longitudinal and oblique muscles beneath the epidermis.
- The alimentary canal is either absent or highly branched. Anus is absent.
- Circulatory and respiratory systems are absent.
- Excretory system consists of flame bulbs or flame cells or **protonephridia** connected to the excretory ducts.
- Asexual multiplication and alternation of generations are seen in some examples.
- Nervous system and sense organs are poorly developed.
- Usually hermaphrodite animals.
- Fertilization is internal and development may be direct or indirect.
- May be free living (Turbellaria), ectoparasitic or endoparasitic. A few may be commensals.

Check Your Progress

1. Write two characteristics of Helminthes.
2. Name three germinal layers in Helminthes.
8.3 CLASSIFICATION OF PHYLUM PLATYHELMINTHES

Phylum Platyhelminthes is divided into three classes: The following classification done by Hymen based on Platyhelminthes characteristics

1. CLASS I - TURBELLARIA
2. CLASS II - TREMATODA
3. CLASS III - CESTODA

1. CLASS I - TURBELLARIA
   1. Mostly free-living forms found in fresh or sea waters or on land.
   2. Body is unsegmented and dorsoventrally flattened.
   3. Epidermis is cellular or syncytial.
   4. Intestine is either absent (Acoela) or simple and sac-like (Rhabdocoela) or branched.

Order (1): Acoela: They are marine and small. Mouth and pharynx are simple or absent. Oviducts 2 yolk glands are absent. Ex: Convoluta.

Order (2): Rhabdocoela: They are small. A digestive bud is present and intestine is sac-like. Many are free swimming. Reproductive organs are present Ex: Microstomum, Tennencephala.

Order (3): Alloeocoela: Small sized worms are included in this order. Intestine is simple or branched. They are mostly marine Ex: Otoplana, Bothnoplana.

Order (4): Tricladida: Dorsiventrally flat body is seen. Intestine has two lateral limbs and one median limb. Genital aperture is simple. Ex: Bipalium. Planaria.

![Fig. 8.1 Planarola, Liverfluke, Tape Worm]
Helminth Parasites

Order (5): Polycladida: These are leaf-like turbellarians. Intestine shows a number of branches. Genital apertures are separate. Ex: Thysanozoan, Planocera.

Fig. 8.2 Planaria (Flat Worm)

2. CLASS II - TREMATODA

These are commonly known as flukes. These are ectoparasitic or endoparasitic forms. Body is unsegmented and elongated. Adhesive organs are, one or two suckers without hooks and spines. Digestive tract is bifurcated and highly diverticulated. Anus is absent. Trematoda class or “trematodes” are commonly known as flukes. Flukes are flat worms. Parasitic flukes live in the intestine, tissue or in the blood. Their life cycle begins when molluscs such as snails get infected with fluke larvae. The first stage larvae are called miracidia. They have tail-like structures, cilia, for moving and finding molluscs. Depending on the fluke species the larva goes through different developmental stages which are:

$\text{Miracidium} \rightarrow \text{sporocyst} \rightarrow \text{redia} \rightarrow \text{cercaria} \rightarrow \text{mesocercaria} \rightarrow \text{metacercaria}$

Adulthood is reached inside the final host, humans. Adults reproduce either sexually or asexually. Eggs exit the body with the feces and infect new molluscs.

Fasciola Hepatica - Liver Fluke - Fasciola hepatica is a flat worm that eats your blood and liver.

Fig. 8.3 Liver Fluke
Fasciolopsis Buski - Intestinal Fluke. Fasciolopsis buski is a parasitic fluke that lives in your small intestine causing fasciolopsiasis (disease).

Paragonimus Westermani - Lung Fluke. Paragonimus westermani is a lung fluke. It causes a parasitic disease called paragonimiasis. Symptoms, diagnosis, treatment and pictures.

Schistosoma - Blood Flukes. Find information such as Schistosoma life cycle, symptoms, diagnosis and treatment as well as pictures and videos. Schistosoma (blood flukes) cause schistosomiasis (snail fever) in humans.

3. CLASS 3 - CESTODA
Totally endoparasitic forms. Body covered with thick cuticle. Mouth, digestive tract and sense organs are absent. Fertilization is internal. It is divided into 2 subclasses. The body of the cestodes, also known as tapeworms, has lost the typical turbellarian form. Although there are a few unsegmented species, the bulk of a typical cestode body consists of a series of linearly arranged reproductive segments called proglottids. There is no mouth or digestive system; food is absorbed through the cuticle. Adults live in the digestive tract of vertebrates, and larval forms encyst in the flesh of various vertebrates and invertebrates. Cestoda - Tapeworms - Diphyllobothrium Latum - Fish Tapeworm - Hymenolepis Nana - Dwarf Tapeworm - Taenia Saginata - Beef Tapeworm - Taenia Solium - Pork Tapeworm. The body of an adult tapeworm is virtually a reproductive factory. Behind a small securing knob, called a scolex, which bears a circle of hooks or other attachment organs, the proglottids constantly bud off and gradually enlarge. As they mature they become filled with male and female reproductive organs. Cross-fertilization takes place with adjacent worms or neighboring proglottids; in some cases self-fertilization occurs. In some species the ripe proglottids, filled with eggs, are shed. In others the fertilized eggs leave the adult host in the feces. If the eggs are consumed by the intermediate host, the life cycle continues. Tapeworm species that infest human intestines as adults include Taenia saginata, T. solium, the dwarf tapeworm, Hymenolepis nana, and the fish tapeworm, Diphyllobothrium latum, which can reach lengths of up to 50 ft. (15 m)

Fig. 8.4 Tape Worm
Protonephridia (Excretory System): A protonephridium (proto = “first”) is a network of dead-end tubules lacking internal openings found in the phyla Platyhelminthes, Nemertea and Rotifera. The ends are called flame cells (if ciliated) or solenocytes (if flagellated); they function in osmoregulation and ionoregulation, respectively. The terminal cells are located at the blind end of the protonephridium. Each cell has one or more cilia and their beating inside the protonephridial tube creates an outward going current and hence a partial pressurization in the blind of the tube. Because of this, pressurization drives waste fluids from the inside of the animal, and they are pulled through small perforations in the terminal cells and into the protonephridium. The perforations in the terminal cell are large enough for small molecules to pass, but larger proteins are retained within the animal. From the bottom of the protonephridium the solutes are led through the tube, formed by the canal cells, and exits the animal from a small opening formed by the nephridiopore. Selective reabsorption of useful molecules by the canal cells occurs as the solutes pass down the tubule. Protonephridia are generally found in basal organisms such as flatworms. Protonephridia likely first arose as a way to cope with a hypotonic environment by removing excess water from the organism (osmoregulation). Their use as excretory and ionoregulatory structures likely arose secondarily. These are excretory systems in phyla Platyhelminthes and are also called blind tubules. These tubules bear a tuft of cilia or flagellum. An organ of excretion in flatworms: a hollow cup-shaped cell containing a bunch of cilia or flagellum, whose movement draws in waste products and wafts them to the outside.

Fig. 8.5 Protonephridia

Check Your Progress
3. What worms are included in Alloeocoela?
4. What is Fasciola hepatica?
5. How is food absorbed in tapeworms?
8.4 PARASITIC ADAPTATION IN PLATYHELMINTHES

- Fitness of an organism to its environment
- It is the characteristic which results in suitable and convenient morphological and functional correlation between an organism and its environment

Parasitic Adaptation

Platyhelminthes have undergone profound adaptation to suit their parasitic modes of life. These adaptations, parasitic adaptations, are of morphological & physiological nature.

1. Morphological Adaptations
   A. Body covering
   B. Organs of adhesion
   C. Organs of locomotion
   D. Organs of nutrition (Trophic organs)
   E. Neurosensory system
   F. Reproductive system

A. Body Covering

Thick tegument frequently provided with scales affords suitable protection to the parasite. This thick protoplasmic layer is continually renewed by mesenchymal cells forming it.

B. Organs of Adhesion

- For a firm grip on/in the host’s body, some special organs of adhesion are needed
- Flatworms are variously armed with suckers, hooks & spines
- Suckers may be with/without hooks/spines

C. Organs of Locomotion

- Locomotion is actually an effort of procuring food
- But parasites habitually inhabit such places in host’s body, where sufficient food is available without effort
- Thus, organs of locomotion such as cilia of turbellarians- absent in parasitic forms
- Locomotory organs present in free living larvae of parasitic forms
- Miracidium possess cilia & cercaria bears a tail for locomotion
D. Organs of Nutrition (Trophic Organs)

- Food of parasite comprises readily available & digested/semi digested food of the host
- Elaborate organs of nutrition not needed
- Trematodes have an incomplete gut & in most cases a suckorial pharynx for sucking food
- An eversible pharynx is present in free living turbellarians
- In cestodes, parasite freely bathes in digested food of host which is absorbed directly
- Thus, total absence of alimentation in tapeworms

E. Neurosensory System

- Need for quick & efficient-response to stimuli is associated with free active life & not with a quiet parasitic life in a safe environment
- In parasites therefore, there is preferred reduction of nervous system & a total absence of sense organs
- But the free living miracidium possesses eye spots

F. Reproductive System

- Best developed system in helminth parasites, designed & preferred to meet the need for tremendous egg production
- Parasitic flatworms with a few exceptions like Schistosoma, are monoecious (hermaphrodite)
- Hermaphroditism is of distinct advantage to the parasite because:
  1. It ensures copulation even when a few individuals are present
  2. After copulation both individuals lay eggs, doubling the rate of production
  3. In absence of companion parasite can reproduce offspring
- In cestodes reproductive system is much more elaborate & each mature proglottid possesses 1 or 2 complete sets of male & female genitalia
- In gravid proglottid all other organs of the system degenerate to make room for the uterus which becomes highly enlarged & branched to accommodate large number of eggs

2. Physiological Adaptations

a. Protective mechanism
b. Anaerobic respiration
c. Osmoregulation
d. High fertility
a. **Protective mechanism**

- Inside the alimentary canal the parasites have to protect themselves from the action of digestive juices of host
- Tapeworms accomplish this:
  1. By stimulating walls of gut to secrete mucus, it forms a protective clothing around parasite
  2. By secreting anti-enzymes to neutralize the digestive enzymes of host
  3. By probably continually renewing their protective body covering i.e., tegument

b. **Anaerobic Respiration**

- Environment in gut & bile ducts is devoid of free oxygen
- Flatworms inhabiting these places, therefore, respire anaerobically by breaking down glycogen

c. **Osmoregulation**

- Osmotic pressure of endoparasite’s body fluids, especially in case of trematodes is almost the same as that of host
- This renders osmoregulation unnecessary
- But in intestinal tapeworms, osmotic pressure is little higher
- This permits ready absorption of host’s digested food by tapeworms

d. **High Fertility**

- Eggs produced by a parasitic flatworm face a very uncertain future while passing through the complex life cycle, these potential offsprings face several hazards as a result of which a very small percentage of total eggs produced reaches adulthood
- This threat to the very existence of species is suitably met by parasite which in its life time may produce eggs in millions

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**8.5 PHYLUM NEMATODA**

The nematodes or roundworms constitute the phylum Nematoda. They are a diverse animal phylum inhabiting a very broad range of environments. Nematode species can be difficult to distinguish, and although over 25,000 have been described, of which more than half are parasitic, the total number of nematode species has been estimated to be about 1 million. Unlike the phyla Cnidarians and Platyhelminthes (flatworms), nematodes have tubular digestive systems with openings at both ends.
Characteristics of Phylum Nematoda

1. Body bilaterally symmetrical, cylindrical in shape
2. Body covered with a secreted, flexible, nonliving cuticle
3. Motile cilia and flagella completely lacking; some sensory endings derived from cilia present
4. Muscles in body wall running in longitudinal direction only
5. Excretory system of either one or more gland cells opening by an excretory pore, a canal system without gland cells, or both gland cells and canals together; flame cell protonephridia lacking
6. Pharynx usually muscular and triradiate in cross section
7. Male reproductive tract opening into rectum to form a cloaca; female reproductive tract opening a separate gonopore
8. Fluid in pseudocoel enclosed by cuticle forming a hydrostatic skeleton.

Morphology

Like mollusks, nematodes are triploblastic (having three primary germ layers: the ectoderm, mesoderm, and endoderm) protostomes. However, unlike mollusks, which have a true coelom (exocoelom; fluid filled body cavity with a complete lining derived from the mesoderm), the nematodes have a pseudocoelom (a “false cavity,” whereby tissue derived from the mesoderm only partly lines the fluid filled body cavity). In nematodes, as with rotifers (Phylum Rotifera), the body cavity is lined on the inside by endoderm and on the outside by mesoderm (Towle 1989). Nematodes are thin and are round in cross section, though they are actually bilaterally symmetric. Most bilaterally symmetrical animals have a true coelom, unlike the nematodes. Nematodes are one of the simplest animal groups to have a complete digestive system, with a separate orifice for food intake and waste excretion, a pattern followed by all subsequent, more complex animals. As a pseudocoel, the body cavity lacks the muscles of coelomate animals that force food down the digestive tract. Nematodes thus depend on internal/external pressures and body movement to move food through their digestive tracts. The mouth is often surrounded by various flaps or projections used in feeding and sensation. Excretion is through a separate excretory pore.

Fig. 8.6 Nematoda
Nematodes have no circulatory or respiratory systems, so they use diffusion to breathe and for circulation of substances around their body. Nematodes have a simple nervous system, with a main nerve cord running along the ventral side. Sensory structures at the anterior end are called amphids, while sensory structures at the posterior end are called phasmids.

**Parasitic Nematodes**

Common and scientific names means of infection; prevalence in humans.

**Hookworm** (*Ancylostoma duodenale*)

Contact with juveniles in soil that burrow into skin; common in southern states and *Necator americanus* Hookworms. The most common hookworms are *Ancylostoma duodenale* and *Necator americanus*. Adults attach to the walls of the jejunum and females lay large numbers of eggs that are passed out with the feces. The eggs hatch in the soil and infect man by usually burrowing through the soles of the feet. The larvae then migrate to infect the heart and lungs before passing into the tracheae, pharynx and then the small intestine.

**Pinworm** (*Enterobius vermicularis*)

Inhalation of dust with ova and by contamination with fingers; most common worm parasite in United States, *Enterobiasis*. *Enterobiasis vermicularis* is a small thread-like “pinworm” mainly infecting young children. The female emerges to the perianal region usually at night and lays some 10,000-15,000 eggs and then dies. In the process they cause severe pruritus (itching). The embryonated eggs are infectious on ingestion and hatch in the duodenum. The larvae pass to the cecum where they mature into adults. Because of the pruritus, children often re-infect themselves from eggs under their fingernails. Bedding is also a source of infection and can be a means of spreading the organism in families and institutions such as orphanages and boarding schools.

**Intestinal Roundworm** (*Ascaris lumbricoides*)

Ingestion of embryonated ova in contaminated food; common in rural areas of Appalachia and southeastern states. *Ascariasis*. Adult worms of *Ascaris lumbricoides* live in the small intestine where they lay large numbers of eggs that are passed out with the feces. Unlike the hookworms, the eggs are the infectious form in which the larvae develop. When ingested, the eggs hatch in the jejunum, penetrate the mucosa and are carried through the hepatic circulation to the heart and lungs. They again enter the stomach via the tracheae and esophagus before growing to adulthood in the small intestine. Pneumonitis and intestinal obstruction may accompany heavy infestations.

**Trichina Worm** (*Trichinella spiralis*)

Ingestion of infected muscle; occasional in humans throughout North America. *Trichinosis*. *Trichinella spiralis* is the cause of *trichinosis* in man. The
nematode circulates between rats and pigs with man becoming infected from eating raw or inadequately cooked pork products. Encysted larvae in the meat ex cyst (hatch) in the intestine and develop into minute adults in the mucosa. These mature and the females deposit larvae that then migrate through the tissues to reach skeletal muscles in which they encyst. Human infections may be asymptomatic but can include fever, orbital edema, myalgia and eosinophilia. In the extreme, infection can be fatal through myocarditis or encephalitis.

**Whipworm (Trichuris trichiura)**

Ingestion of contaminated food or by unhygienic habits; usually common wherever Ascaris is found. *Trichuriasis. Trichuris trichiura* ("whipworm") inhabits the cecum where they attach to the mucosa. Eggs from the mature worms are passed with the feces and develop in the soil. When swallowed, the eggs hatch in the small intestine and the developing larvae pass directly to their attachment sites in the large intestine. Heavy infections can cause abdominal pain and chronic bloody diarrhea that may result in rectal prolapse.

**Nematodes - The Filariases**

These are arthropod (insect)-borne infections caused by filarial worms. The classic example is elephantiasis caused by *Wuchereria bancrofti*. Larvae of *W. bancrofti* develop in the mosquito and, as in malaria, human infection results from the bite of the insect. When bitten, the larvae (as male and female forms) pass through the thread-like adults, 4-8 cm long, in the lymphatic glands. After mating the females develop eggs and larvae that are released as microfilariae into the peripheral circulation. The localization of the adult filariae in the lymph glands causes obstructions in the lymphatic drainage. This then results in the grossly disfiguring condition of elephantiasis that typically involves massive swelling of the legs, scrotum and other extremities.

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**Check Your Progress**

6. What are the examples of hookworms?

7. What is Nematodes - the filariases?

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**8.6 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS**

1. (i) Circulatory and respiratory systems are absent. (ii) Nervous system and sense organs are poorly developed.

2. They show three germinal layers i.e. ectoderm, mesoderm and endoderm.

3. Small sized worms are included in this order. Intestine is simple or branched. They are mostly marine Ex: Otoplana, Bothnoplana.
4. Liver Fluke - Fasciola hepatica is a flat worm that eats your blood and liver.
5. Food is absorbed through the cuticle.
6. The most common hookworms are Ancylostoma duodenale and Necator americanus.
7. These are arthropod (insect)-borne infections caused by filarial worms. The classic example is elephantiasis caused by Wuchereria bancrofti.

8.7 SUMMARY
- Helminthes are soft bodied, unsegmented worms.
- They are the first animals to illustrate the development of organ system.
- Phylum Platyhelminthes is divided into three classes: TURBELLARIA, TREMATODA and CESTODA.
- Platyhelminthes have undergone profound adaptation to suit their parasitic modes of life. These adaptations, parasitic adaptations, are of morphological & physiological nature.
- The nematodes or roundworms constitute the phylum Nematoda. They are a diverse animal phylum inhabiting a very broad range of environments.

8.8 KEY WORDS
- Morphology: The study of the forms of things, in particular.
- Parasite: An organism which lives in or on another organism (its host) and benefits by deriving nutrients at the other’s expense.
- Platyhelminthes: A phylum of invertebrates that comprises the flatworms.

8.9 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions
1. Draw a neat and clean diagram of Fasciola- Liver fluke.
2. Write a short note on Cestoda.
3. How do morphological adaptations occur in parasites?
4. How do physiological adaptations occur in parasites?

Long-Answer Questions
1. Discuss general characteristics of Helminth.
2. What are the classes of Helminth? Explain.

4. Write characteristics of phylum Nematoda.

8.10 FURTHER READINGS


UNIT 9 ANNELIDA

9.0 INTRODUCTION

The annelids, also known as the ringed worms or segmented worms, are a large phylum, with over 22,000 extant species including rag worms, earthworms, and leeches. The species exist in and have adapted to various ecologies – some in marine environments as distinct as tidal zones and hydrothermal vents, others in fresh water, and yet others in moist terrestrial environments. Most of the 20th century Annelida was split into three major groups; Polychaeta, Oligochaeta (earthworms etc.) and Hirudinea (leeches). Earthworms and leeches are the familiar annelids for most people, but polychaetes comprise the bulk of the diversity of Annelida and are found in nearly every marine habitat, from intertidal algal mats downwards. There are even pelagic polychaetes that swim or drift, preying on other plankton, and a few groups occurring in fresh water and moist terrestrial surroundings.

In this unit, you will learn about general characteristics of annelida and their classes.
9.1 OBJECTIVES

After going through this unit, you will be able to:

- Understand general characteristics of Annelida
- Discuss classes of Annelida
- Understand metamerism in Annelids

9.2 ANNELIDA

Main Characters Nature

Annelida are triploblastic, symmetrical, coelomata and segmented metazoa.

Habit and Habitat

Annelida are mostly aquatic, marine or fresh water, burrowing or living in tubes, some free living forms.

External Features

- The most important feature of annelida is their metameric segmentation. (External segmentation)
- Segmentation is indicated externally by circular constrictions or grooves on the body wall.
- Outer covering of the body is cuticle secreted by the underlying epidermis.
- Appendages, when present are unjointed.
- Locomotory organs are segmentally arranged, paired setae or chaetae.

Internal Features

- Body wall is contractile, consists of an outer epidermis, circular and longitudinal muscles.
- The gut, longitudinal blood vessels and the nerve cord extend throughout the body length, whereas other structures are repeated in each segment.
- Important character of annelida is the development of series of coelomic compartments in their body between the gut and the body wall.
- The Coelom is a cavity, which develop within the mesoderm and is lined by mesodermal cells.
- Segmented musculature plays an important part in locomotion of Annelids.

Systems of Body

- Alimentary canal is tube like extending straight from mouth to anus.
- Respiration through general body surface, by gills in some forms.
- Blood vascular system is closed type.
- Blood is red due to haemoglobin.
- Excretory organs are Nephridia usually one pair in each segment.
- Nervous system consists of dorsal brain and longitudinal ventral nerve cord.
- Sexes may be united or separate.
- Development is direct when sexes are united and indirect when sexes are separate. EXAMPLES: Nereis, Earthworm and Leeches etc.

### Check Your Progress
1. What is the habitat of annelida?
2. What is the most important feature of annelida?

## 9.3 Classification of Phylum Annelida

Phylum Annelida is divided into four classes:

1. **Polychaeta**
2. **Oligochaeta**
3. **Hirudinea**
4. **Archiannelida**

### 9.3.1 Class 1 Polychaeta

(Polys: many; chaite: hair)

- Habitat: They are marine, terrestrial, and freshwater.
- Archetypical protostome development (schizocoely).
- True coelomates (schizocoelomates).
- Bilaterally symmetry; segmented worms.
- Complete digestive system.
- Closed circulatory system.
- Well-developed nervous system.
- Excretory system: Both metanephridia and protonephridia.
Lateral epidermal setae with each segment.
- Diocicious or hermaphroditic.
- Fertilization: external

Locomotory Organs
The Polychaetes possess paired parapodia functioning as locomotory appendages, are present only in the class Polychaeta.

Prostomium
Usually there is a distinct head or prostomium bearing sensory and feeding appendages.

Mode of Life
The Polychaetes may be carnivorous, scavengers, or filter feeders.

Reproduction
The sexes are separate and fertilization of eggs takes place outside body. Their free swimming larva is called Trochophore.

Respiration
The respiration takes place through the body surface in many but in some gills may be present as respiratory organs.

Examples: Some well-known examples of marine polychaetes are Nereis, Syllis, Arenicola and Sabella. Nereis lives beneath stones and in crevices of rocks.

9.3.2 Class 2 Oligochaeta
(Oligos: few, chaite: hair)
- Habitat: mostly terrestrial and few are freshwater
- Body metamerically segmented
- Clitellum present
- Hermaphrodite but cross fertilization occur
- Fertilization: external
- Cocoon formation occur

Examples: Pheretima posthuma (Earthworm), Lumbricus, Stilaria, Tubifex

Locomotory Organs
The Oligochaetes possess fewer numbers of setae as compared to the Polychaetes. The setae help the earth worms in crawling.

Sense Organs
Their anterior end lacks eyes, or sensory appendages.
At sexual maturity, all of the oligochaetes develop in several segment, glandular epithelium, called Clitellum.

**Mode of Life**
- Oligochaetes live either in fresh water or on land.
- There is no free swimming larval stage in their development.
- Majority of oligochaetes are scavengers, feeding on decomposing organic matter.
- Some fresh water species feed on algae.
- Burrowers like earthworm ingest a large quantity of soil, digest the organic matter and the living fauna.

**Respiration**
Respiration takes place through their general body surface. Some aquatic species possess anal gills.

**Economic Importance**
Earthworms increase the fertility of soil by physically over turning it. They ingest the soil, break it down and deposit it in the form of casts. The over turned soil is relatively in proportions of total nitrogen, organic carbon, calcium, magnesium and phosphorus.

9.3.3 Class 3 Hirudinea
(Hirudo: leech)
- Habitat: primarily freshwater annelids but some are marine, terrestrial and parasitic.
- The body has definite number or segments.
- The tentacles, parapodia and setae are totally absent.
- They are hermaphrodite.
- Fertilization: internal and a larval stage is absent.

**Examples:** Hirudinaria (Leech)

**Body Segments**
Unlike polychaetes and oligochaetes, the number of body segment in leeches is fixed at 34.

**Suckers**
The anterior and posterior body segments are fused to form suckers.
**Locomotion**
Leeches either swim or crawl.

**Respiration**
Respiration generally takes place through the body surface. Leaf-like gills may be present.

**Parasitic Nature**
Most leeches feed by sucking blood of aquatic invertebrates and vertebrates.

### 9.3.4 Class 4 Archiannelida
(Arch; first)
- Habitat: They are strictly marine.
- The body is long and worm-like.
- The setae and parapodia normally absent.
- They may be unisexual or hermaphrodite.
- The development: indirect forming trochophore larva.
- It is a small group of marine worms.
- They are not segmented externally and don’t have bristles.
- They live in the sea and show annelid characteristics to a minor extent.
- Their development is also characterized by Trochophore Larva.

**Examples:** Protodrillus, Dinophilus, Protodrilus

#### Check Your Progress
3. What is the habitat of Polychaeta?
4. Give two examples of Oligochaeta.

### 9.4 METAMERISM IN ANNEIDS

The body of Annelids is divided into a number of segments longitudinally. All the segments look alike. They are called metameres and this is called metamerism. In these segments all systems are repeatedly arranged. Usually the metamerism is confined to the trunk region of the organisms. Cephalic and anal regions may not show metameric nature in the cephalic region sense organs are concentrated, where in the anal region new segments are produced in front of anal segment.
1. Metamerism first observed in Annelida in the animal kingdom.
2. Most successful animals of animal kingdom like arthropoda and chordate will also show metameristic segmentation.
3. In annelids the metameristic segmentation is both external and internal. The body is divided into a number of segments which contain all body organs repeatedly but the alimentary canal is long and straight tube extending through all the segments.
4. In arthropods the segmentation is external.
5. In chordates the segmentation is internal.

**Significance of Metamerism**

1. Metameristic segmentation helps the animals in their locomotion.
2. The segments will show high structural development which gave scope for evolution.

**Check Your Progress**

5. What are metameres?
6. What kind of segmentation is seen in chordates?

**9.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS**

1. Annelida are mostly aquatic, marine or fresh water, burrowing or living in tubes, some free living forms.
2. The most important feature of annelida is their metameristic segmentation. (External segmentation).
3. They are marine, terrestrial, and freshwater.
4. Pheretima posthuma (Earthworm) and Lumbricus.
5. The body of Annelids is divided into a number of segments longitudinally. All the segments look alike. They are called metameres.

6. Internal.

9.6 SUMMARY

- Annelida are triploblastic, symmetrical, coelomata and segmented metazoa.
- Annelida are mostly aquatic, marine or fresh water, burrowing or living in tubes, some free living forms.
- The body of Annelids is divided into a number of segments longitudinally. All the segments look alike. They are called metameres and this is called metamerism.
- Metameric segmentation helps the animals in their locomotion.

9.7 KEY WORDS

- **Annelida**: Annelida is a group commonly referred to as segmented worms, and they are found worldwide from the deepest marine sediments to the soils in our city parks and yards.
- **Coelom**: The principal body cavity in most animals, located between the intestinal canal and the body wall.
- **Metazoa**: A major division of the animal kingdom that comprises all animals other than protozoans and sponges. They are multicellular animals with differentiated tissues.

9.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

**Short-Answer Questions**

1. Explain body system of annelids.
2. Write a short note on hirudinea.
3. Write a short note on archiannelida.
4. What is the significance of metamerism?

**Long-Answer Questions**

1. Discuss external features of annelida.
2. Discuss internal features of annelida.
3. Explain classification of phylum annelida.
4. What do you understand by metamerism in annelids?

9.9 FURTHER READINGS


UNIT 10 ARTHROPODA

10.0 INTRODUCTION

In this unit, you will learn about general characteristics of arthropoda and its classes. Arthropod, any member of the phylum Arthropoda, the largest phylum in the animal kingdom, which includes such familiar forms as lobsters, crabs, spiders, mites, insects, centipedes, and millipedes. About 84 percent of all known species of animals are members of this phylum. Arthropods are represented in every habitat on Earth and show a great variety of adaptations. Several types live in aquatic environments, and others reside in terrestrial ones; some groups are even adapted for flight.

The evolutionary ancestry of arthropods dates back to the Cambrian period. The group is generally regarded as monophyletic, and many analyses support the placement of arthropods with cycloneuralians (or their constituent clades) in a superphylum Ecdysozoa. Overall, however, the basal relationships of Metazoa are not yet well resolved. Likewise, the relationships between various arthropod groups are still actively debated.

Arthropods contribute to the human food supply both directly as food, and more importantly indirectly as pollinators of crops. Some species are known to spread severe disease to humans, livestock, and crops.

10.1 OBJECTIVES

After going through this unit, you will be able to:

- Get an overview of general characteristics of Arthropoda
- Understand classification of Arthropoda
### 10.2 ARTHROPODA

#### Main Characters
- Arthropoda is the largest Phylum of the animal kingdom including 10,000 species of different types of animals.
- The word Arthropods is derived from Greek Arthos – Jointed and Podos – Foot.

#### Habit and Habitat
Arthropodes have undergone an adaptive radiation for aerial, aquatic, terrestrial and parasitic environment. They are widely distributed in each and every place of the world.

#### Nature
Arthropoda are bilaterally symmetrical, metamerically segmented metazoa.

#### External Features
- Their body is covered by an exo-skeleton of chitin and protein.
- They possess paired jointed appendages.
- Their metamers are not alike but are specialized and their number is generally fixed.
- The head is well developed.

#### Internal Features
- Musculature is not continues but comprises separates striped muscles.
- The coelomic space in Arthropods is occupied by the blood vascular system and is thus called Haemocoel.
- Digestive tract is complete; mouth and anus lie at the opposite end of the body.
- Circulatory system is open with dorsal heart and arteries but without capillaries.
- Respiration through general body surface, by gills in aquatic forms, trachea or book lungs in terrestrial forms.
- Excretion by Malpighian tubules or Coelomducts.
Arthropoda

- Sexes are generally separate and sexual dimorphism is often exhibited by several forms. Fertilization is internal.
- Development is usually indirect through the larval stage.
- Nervous system of arthropods is quite similar to that of annelids and consists of dorsal anterior brain and a double ventral nerve cord.

Check Your Progress
1. What is the nature of arthropoda?
2. What is Haemocoel?

10.3 CLASSIFICATION OF ARTHROPODA

Phylum Arthropoda is divided into following five classes:

1. Class Merostomata
   - Almost all members of the class Merostomata are extinct. The only living merostomes, the king Crabs have survived.
   - The animals are horse-shoe shaped.
   - The long spike like tail that extends, posteriorly is used in locomotion. It is called -Telson.
   - They feed on mollusks, worms and other invertebrates that they find on the ocean floor.
   - King Crabs a horse-shoe crabs have a tough-Carapace jointed to a smaller abdomen.
     *E.g.* Limulus Polyphemus (King Crab)

2. Class Arachnida
   - This class includes spiders, scorpions, mites, ticks and many other terrestrial arthropods.
   - The Arachnid body consists of a cephalothorax and abdomen.
   - Cephalothorax is comprised of fused head and thorax.
   - Arachnids have six pairs of jointed appendages.
   - Most Archnids are carnivorous and prey upon insects and other small arthropods.
Respiration in arachnids takes place either by trachea or book lungs or by both.
They are mainly terrestrial arthropods.
They have no antenna.
Cephalothorax is non-segmented.
E.g.: Scorpions, Ticks and Mites, and Spiders

3. Class Crustacea
- They live both in marine and fresh waters.
- A few are terrestrial. Crustaceans are unique among arthropods in possessing two pairs of antenna.
- They always have one pair of mandibles and two pairs of maxillae around the mouth.
- Mandibles are usually adapted for biting and chewing. Maxillae are used for holding the food.
- Their body is divided into three distinct parts, i.e., the head, thorax and abdomen. Respiration usually takes place through gills associated with appendages.
- The sexes are usually separate and the reproduction is sexual.
- The thoracic and abdominal appendages may be variously modified for walking, swimming, feeding, respiration or as accessory reproductive structures.
E.g.: Sacculina (Parasitic Crustacean), Astacus (Cray-Fish), Prawns, Shrimps, Lobsters and Crabs, etc.

4. Class Myriapoda
- All the animals are terrestrial.
- Their body is divided into a head and an elongated trunk with many segments.
- Each segment bears one or two pairs of legs.
- They are carnivorous/herbivorous.
- Eyes may present or absent.
E.g.: Millipedes and Centipedes, etc.
5. Class Insecta (Hexapoda)

Insecta is the largest class of the animal kingdom.

<table>
<thead>
<tr>
<th>Arthropoda</th>
<th>Arachnids</th>
<th>Crustaceans</th>
<th>Myriapods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arthropods are the biggest group of invertebrates. All arthropods have an external skeleton that protects their body. They also have many legs.</td>
<td></td>
<td></td>
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</tr>
<tr>
<td><strong>Insects</strong></td>
<td><strong>Arachnids</strong></td>
<td><strong>Crustaceans</strong></td>
<td><strong>Myriapods</strong></td>
</tr>
<tr>
<td>- 6 legs</td>
<td>- 8 legs</td>
<td>- 10 legs</td>
<td>- 8 legs</td>
</tr>
<tr>
<td>- 2 body parts (head, thorax and abdomen)</td>
<td>- 2 pair of antennae</td>
<td>- 2 pair of antennae</td>
<td>- 1 pair of antennae</td>
</tr>
<tr>
<td>- 3 pairs of wings</td>
<td>- 4 pairs of wings (1 pair of forewings and 2 pairs of hindwings)</td>
<td>- 5 pairs of wings (3 pairs of forewings and 2 pairs of hindwings)</td>
<td>- 2 pairs of wings</td>
</tr>
<tr>
<td>- 2 pairs of legs</td>
<td>- 8 legs</td>
<td>- 10 legs</td>
<td>- 8 legs</td>
</tr>
</tbody>
</table>

Habit and Habitat

In their adaptive radiation, approximately an 8,500,000 species of insecta have occupied all types of terrestrial habitat. Some live in fresh water, however one small group is marine.

Nature and Adaptations

- The great success of insects can be attributed partly to the development of flight in them.
- Flight has provided them the great capacity of dispersal, access to food sources, and favorable habitat and escape from enemies.
- Corresponding to their number of species, there exists a huge variation in their structural and biological adaptations.

External Features

- All insects have their body divided into three well-defined regions i.e. the head, thorax and abdomen.
- There is always a pair of antenna on the head.
- The thorax always consists of three segments: (a) Prothorax (b) Mesothorax (c) Metathorax.
Each thoracic segment bears a pair of legs.
- Head consists of six fused segments and a pair of compound eyes and mouth parts.
- Abdomen comprises 7-11 segments and devoid of appendages.

**Mouth Parts**
The feeding appendages consist of three pairs: (a) Mandibles (b) First Pair of Maxilla (c) Second Pair of Maxilla

The second pair of maxillae have fused together to form the LABIUM, or lower lip

The upper lip is formed by the projections head and is called the LABRUM.

**Types:** The mouth appendages have been greatly modified to form five basic types of pattern: (i) Biting (ii) Chewing (iii) Piercing (iv) Sucking (v) Siphoning or Sponging.

**Internal Features**

- Heart is elongated, tubular and divided into chambers situated in the abdomen. Excretion takes place through Malpighian tubules.
- Liver is absent but salivary glands are usually present.
- Respiration is by TRACHEA.
- External gills may be present as accessory respiratory organs in some aquatic insects.

**Reproduction**
Reproduction is sexual in most insects. However it takes place parthenogenetically, i.e., eggs developing without being fertilized by sperms in a number of insects, e.g.: Aphids and Termites, etc.

**Metamorphosis**
The development of insects after hatching from egg into adult stage involves considerable growth and in some cases drastic morphological changes. The entire post-hatching development is termed as Metamorphosis.

(A) **Incomplete Metamorphosis**
In some insects the immature form that hatch from the egg are essentially similar in shape to their adults, but are smaller in size, lack wings and reproductive organs. They attain adult characters after some growth period. This type of metamorphosis
is called Incomplete Metamorphosis. Three stages are Egg $\rightarrow$ Nymph $\rightarrow$ Adult. For example Cockroach, Grasshopper, Bugs, etc.

(B) Complete Metamorphosis

In this type the animal shows following stages during its complete development: Egg $\rightarrow$ Larva $\rightarrow$ Pupa $\rightarrow$ Adult. For example Mosquito, Butterfly, House fly etc.

Economic Importance of Insects

Insects are of very great importance to man.

Beneficial Insects

1. Apis, the honey bees produce honey and also give wax.
2. Insects bring about the cross-pollination.
3. Bombyx and Eupterote are silk-moths and produce silk.
4. The larvae of Lucila and Pharmia are used in wound healing of bones.
5. Some insects feed upon and destroy harmful insects.
6. Some insects are Scavengers

Harmful Insects

1. Many types of mosquitoes, flies, fleas, lice and bugs transmit diseases to man and animals.
2. Human food is spoiled by cockroaches, ants and flies.
3. Tinea and Teniola are cloth-moths and destroy cloths.
4. Tenebrio is mealworm. They eat meal, flour and grains.
5. Lepisma destroy the books.
6. Termites destroy books and wood.
Check Your Progress

3. Give an example of Merostomata.
4. Give an example of Crustacea.

10.4 RESPIRATION IN ARTHROPODA

Arthropods constitute three-fourth of the animal kingdom and inhabit a variety of habitats. They breathe air as well as water and some are accomplished amphibians. Their respiratory organs vary according to their way of living as described below.

Respiratory Organs of Crustaceans (Prawn)

In smaller crustaceans, such as Copepods and Ostracods oxygen simply diffuses through the body surface since small animals have larger surface area as compared to the body mass. In majority of crustaceans gills are the chief respiratory organs. In prawn gills are enclosed in a gill chamber on each side of the cephalothorax and are covered by a carapace, inner side of which is called branchiostegite and has vascularised respiratory epithelium. Epipodites are highly vascularised leaf-like membranous structures attached on the coxa of the three maxillipeds. They carry out respiratory function. The gills are regarded as primary respiratory organs and they are three types in prawn, namely podobranchs, arthrobranchs and pleurobranchs.

Podobranchs are one pair of small gills that are attached on the coxa of the second maxillipedes.

Arthrobranchs are two pairs, one smaller and the other larger, attached to the arthrodial membrane of the third maxillipedes.

Pleurobranchs are 5 pairs of arched gills attached in the gill chamber on the outer margin of cephalothorax, just dorsal to the walking legs. The gill lamellae are flat, plate-like arranged parallel to each other like the pages of a book. Water current flows through the gill chamber by the action of scaphognathite which is a fan-like appendage of maxilla and lies near the entrance of the gill-chamber. It is also called baler as it forces water over the gill chamber. Fresh water enters the gill chamber from behind in the form of a current. The highly vascularised gill-plates are covered with permeable membrane for the passage of gases.

Respiratory Organs of Arachnids (Scorpion)

Scorpion breathes air through four pairs of book lungs or pulmonary sacs that open to the outside through four pairs of stigmata on the ventral side of mesosoma. Book lungs are sac-like structures, within which there are delicate folds that are arranged like the leaves of a book. These folds are richly supplied with blood. The four pairs of book lungs are located in the third, fourth, fifth and sixth mesosomal...
Arthropoda

NOTES

segments. Each book lung consists of an air cavity or atrial chamber on the ventral side which opens to the outer side by a slit-like spiracle or stigmata that opens on the ventro-lateral side of the sternum. Dorsal part of book lung consists of nearly 150 vertical folds or lamellae arranged like leaves of a book. Each lamella is a hollow structure, made of two thin layers of respiratory epithelium. The air breathing in the book-lungs is effected by the action of the dorso-ventral and atrial muscles. Contraction of the dorso-ventral muscles compresses the pulmonary chamber so that the air from the chamber is forced out through the stigmata. When the atrial muscles contract the book-lungs expand creating vacuum and sucking fresh air in through the stigmata.

Respiratory Organs of Insects (Cockroach)

Great majority of insects breathe air by means of an elaborate and most efficient gas exchange system made of branching elastic air tubes or tracheae called the tracheal system. In majority of insects tracheal system serves for transport of oxygen and carbon dioxide. Each trachea is an air tube lined with epithelial cells and spiral ridges called the taenidia. Tracheae open externally by small openings called spiracles through which the air enters the system. The tracheae are branched into finer branches called tracheoles which are air capillaries without inner taenidial ridges. Breathing is affected by the paired tergo-sternal muscles which connect dorsal side of body with the ventral side and hence their contraction compresses the abdominal cavity forcing air to move out. Relaxation of these muscles brings the abdominal cavity into its original shape, sucking the air into the tracheal tubes. In many aquatic insects such as mayfly and dragon fly larvae there are tracheal gills for respiration in water. Tracheal gills are leaf-like extensions on the terminal abdominal segments that carry respiratory epithelium. Inside the body of cockroach there are three pairs of parallel longitudinal tracheal trunks, one dorsal, one ventral and one pair lateral in position, which are connected together by transverse commissures. The cuticular lining of these tracheae is spirally thickened to form taenidia which prevent the tracheal tubes from collapsing.

Tracheoles profusely branch and anastomose and penetrate in all parts of body and connect to the muscle and tissue cells. Tracheoles have a diameter of only 1 micron only and their cavities are intracellular and walls are very thin and devoid of cuticular thickenings. Instead they are lined by a protein called trachein and are usually filled with a fluid in which oxygen dissolves and diffuses to the tissues. The tracheal system carries oxygen directly to the body cells and does not require blood to transport it. Generally there are 10 pairs of spiracles in insects, two pairs are thoracic and eight pairs are abdominal.

Metamorphosis in Insects

Insect life cycle is generally complex involving several stages of the larval and pupal development. Adults are generally quite different from the larval forms. When
the larvae undergo considerable change to become adults it is called metamorphosis. Insects show various types of metamorphosis as described below.

1. Paleometabola, Ametabola or Pnamorhosis: This type of metamorphosis occurs in orders Protura, Diplura, Colliebola and Thysanura that include insects such as telson-tails, campodeids, spring tails and silverfish. The nymph upon hatching from the egg is similar to the adult in general morphology but there are only 8 abdominal appendages and cerci are lesser in number. Size is small. As the nymph grows and molts its segments in abdomen increase gradually to become 11 in adult. These nymphs live in the same environment as the adult and feed on the same diet as the adult. The insects are wingless both in larval as well as in adult stages. Some biologists do not consider it as metamorphosis or called it Anamorphosis as there is little change during development.

2. Hemimetabola: There are 15 orders of insects which demonstrate this kind of metamorphosis in which juveniles are similar to the adults and there is a gradual change from nymphs to adults. The transformation takes place in the growth of wings as external buds and development of secondary sexual characters. Nymphs generally live in the same environment as the adults. The examples are: grasshoppers, locusts, cockroaches, dragon flies, Mayflies, earwigs, lice, bugs, thrips etc. Hemimetabola includes two categories as given below.

   (i) Heterometabola: These insects do not show any dormant stage during development and nymphs are active throughout their growth stage. Wings develop externally.

   (a) Archimetabola: Those insects whose larvae are aquatic while adults are a flying terrestrial insects show differences in the morphology of their nymphal stages owing to their aquatic habitat. Such nymphs are called NAIAIDS which are generally carnivorous in habit. Examples are: Odonata (dragon and damsel flies), Ephemeroptera (Mayflies) and Plecoptera (Stoneflies). The larvae breathe with tracheal gills attached on the tip of abdomen. The last nymphal instar climbs on a blade of grass and molts outside water to give rise to adult.

   (b) Paurometabola: The immature stage is called a nymph and lives in the same habitat as the adult and eats similar food. The examples are: Orthoptera (grass hoppers and locusts), Dictyoptera (cockroaches and mantids), Hemiptera (bugs) and lice. The wings develop externally and become larger after each molt and size gradually increases. There is no dormant stage in the development.
(ii) **Neometabola**: This type of metamorphosis is found in Thysanoptera and coccids. Nymphs live in the same environment as the adults and feed on the same kind of food. But they have a dormant or resting stage after the larval development is completed. This dormant stage is different from the pupal stage of the Holometabolous insects as there is no covering or cocoon or pupal case outside the resting larva. Owing to this unique development, thrips are assigned a different category of Neometabola.

3. **Holometabola**: This type of metamorphosis is found in endopterygotes, namely, Lepidoptera, Hymenoptera, Coleoptera, Siphonoptera, Diptera, and Trichoptera etc. Larvae and adults are completely different in general feature and eat different type of food and live in a different type of habitat. The larva after completing its development transforms into a dormant stage called pupa, which is sometimes enclosed inside a cocoon made of silken threads. The development of the adult takes place inside the pupal case and cannot be seen from outside. The adult is a flying insect that emerges after rupturing the pupal case. This type of development can be seen in silkworm, butterflies, houseflies and beetles.

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**Check Your Progress**

5. What are epipodites?
6. What is tracheal system?

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**10.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS**

1. Arthropoda are bilaterally symmetrical, metamerically segmented metazoa.
2. The coelomic space in Arthropods is occupied by the blood vascular system and is thus called Haemocoel.
3. King crab.
5. Epipodites are highly vascularised leaf-like membranous structures attached on the coxa of the three maxillipeds. They carry out respiratory function.
6. Great majority of insects breathe air by means of an elaborate and most efficient gas exchange system made of branching elastic air tubes or tracheae called the tracheal system.
10.6 SUMMARY

• Arthropoda is the largest Phylum of the animal kingdom including 10,000 species of different types of animals.
• Arthropodes have undergone an adaptive radiation for aerial, aquatic, terrestrial and parasitic environment.
• Arthropoda are bilaterally symmetrical, metamERICally segmented metazoan.
• Phylum Arthropoda is divided into following five classes: Merostomata, Arachnida, Crustacea, Myriapoda, and Insecta (Hexapoda).
• Insecta is the largest class of the animal kingdom.
• Reproduction is sexual in most insects.
• The development of insects after hatching from egg into adult stage involves considerable growth and in some cases drastic morphological changes. The entire post-hatching development is termed as Metamorphosis.
• Arthropods constitute three-fourth of the animal kingdom and inhabit a variety of habitats. They breathe air as well as water and some are accomplished amphibians.

10.7 KEY WORDS

• Metamorphosis: The process of transformation from an immature form to an adult form in two or more distinct stages.
• Reproduction: The production of offspring by a sexual or asexual process.
• Arthropoda: A large phylum of invertebrate animals that includes insects, spiders, crustaceans, and their relatives. They have a segmented body, an external skeleton, and jointed limbs, and are sometimes placed in different phyla.
• Haemocoel: the primary body cavity of most invertebrates, containing circulatory fluid.

10.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

Short-Answer Questions

1. What are external features of insects?
2. Discuss nature and habitat of arthropod.
3. Discuss respiratory organs of crustaceans.

4. Discuss respiratory organs of arachnids.

**Long-Answer Questions**

1. Discuss internal and external features of arthropoda.

2. Explain classification of arthropoda.

3. Describe metamorphosis in insects.

4. Discuss economic importance of insects.

**10.9 FURTHER READINGS**


UNIT 11 MOLLUSCA

Structure
11.0 Introduction
11.1 Objectives
11.2 Mollusca
   11.2.1 Classification of Mollusca
   11.2.2 Economic Importance of Mollusks
   11.2.3 Shells in Mollusca
11.3 Echinodermata
   11.3.1 Classification of Echinodermata
   11.3.2 Water Vascular System of Starfish
   11.3.3 Echinodermata Larval Forms
11.4 Answers to Check Your Progress Questions
11.5 Summary
11.6 Key Words
11.7 Self Assessment Questions and Exercises
11.8 Further Readings

11.0 INTRODUCTION

Mollusca is the second largest phylum of invertebrate animals. The members are known as molluscs or mollusks. Around 85,000 extant species of molluscs are recognized. The number of fossil species is estimated between 60,000 and 100,000 additional species.

Molluscs are the largest marine phylum, comprising about 23% of all the named marine organisms. Numerous molluscs also live in freshwater and terrestrial habitats. They are highly diverse, not just in size and in anatomical structure, but also in behaviour and in habitat. The phylum is typically divided into 8 or 9 taxonomic classes, of which two are entirely extinct. Cephalopod molluscs, such as squid, cuttlefish and octopus, are among the most neurologically advanced of all invertebrates—and either the giant squid or the colossal squid is the largest known invertebrate species. The gastropods (snails and slugs) are by far the most numerous molluscs and account for 80% of the total classified species.

In this unit, you will learn about the general characteristics of mollusc and its classes. Further you will learn about water vascular system in Echinodermata.

11.1 OBJECTIVES

After going through this unit, you will be able to:
- Understand the general characteristics of Mollusca
- Discuss classes of Mollusca
11.2 MOLLUSCA

General Characteristics

- Soft-bodied invertebrate covered with protective mantle that may or may not form a hard, calcium carbonate shell
- Includes chitons, snails, slugs, clams, oysters, squid, octopus and nautilus
- Second largest animal phylum
- Have a muscular foot for movement which is modified into tentacles for squid and octopus
- Complete, one-way digestive tract with a mouth and anus
- Have a fully-lined coelom
- Cephalization - have a distinct head with sense organs and brain
- Have a scraping, mouth-like structure called the radula
- Go through free-swimming larval stage called trochophore

Fig. 11.1 Trochophore Larva

- Body organs called visceral mass lie below mantle
- Have circulatory, respiratory, digestive, excretory, nervous and reproductive systems
- Bilaterally symmetrical
- Most have separate sexes that cross-fertilize eggs
- Gills between the mantle & visceral mass are used for gas exchange
11.2.1 Classification of Mollusca

Includes 4 Classes

1. Polyplacophora (chitons)
2. Gastropoda (snails, slugs, nudibranchs, conchs and abalone)
3. Pelecypoda or Bivalvia (clams, oysters, and mussels)
4. Cephalopoda (squid, octopus, and nautilus)

1. Class Polyplacophora

Characteristics
- All marine
- Have a shell divided into 8 over-lapping plates
- Live on rocks along seashore feeding on algae

2. Class Gastropoda

Characteristics
- Head has a pair of retractable tentacles with eyes located at the ends
- Have a single shell or valve (snails) or none (slugs)
- Known as univalves

Snails
- May be marine, freshwater, or terrestrial
- Aquatic snails breathe through gills and use their radula to scrape algae for food
- Terrestrial snails use their mantle cavity as a modified lung and saw off leaves
- Retreat into shell in dry periods and seals opening with mucus
- Have open circulatory system
- Secrete mucus and use muscular foot to move
- Land snails are hermaphrodites
- Aquatic snails have separate sexes
- Use internal fertilization

3. Class Bivalvia or Pelecypoda

Characteristics
- Sessile or sedentary
Mollusca

NOTES

• Includes marine clams, oysters, shipworms, and scallops and freshwater mussels
• Filter feeders
• Have two-part, hinged shell (2 valves)
• Have muscular foot that extends from shell for movement
• Scallops clap valves together to move
• Shell secreted by mantle and made of 3 layers — outer horny layer protects against acids, middle prismatic layer made of calcium carbonate for strength and inner pearly layer next to soft body
• Mantle secretes substance called “mother of pearl” to surround irritants like grains of sand? Oldest, raised part of shell called umbo
• Powerful anterior and posterior adductor muscles open and close shell
• Lack a distinct head
• Have an incurrent and excurrent siphon that circulate water over the gills to remove food and oxygen

Fig. 11.2 Bivalvia

4. Class Cephalopoda

Characteristics

• Includes octopus, squid, cuttlefish, & chambered nautilus
• All Most intelligent mollusk
• Well-developed head
• Active, free swimming predators
• Foot divided into tentacles with suckers
• Use their radula & beak to feed
• Closed circulatory system
• Lack an external shell
Highly developed nervous system with vertebrate-like eyes
Separate sexes with internal fertilization

11.2.2 Economic Importance of Mollusks

- Used by humans for food
- Pearls from oysters
- Shells used for jewelry
- Do crop and garden damage
- Serve as intermediate hosts for some parasites such as flukes

11.2.3 Shells in Mollusca

Shells are lovely natural objects, equals in beauty to any flower or butterfly; they are more than just pretty baubles found on beaches. They are the exterior skeletons (exoskeletons) of a group of animals called mollusks. The word “mollusk” means “soft-bodied;” an exterior skeleton is very important to these creatures, providing them with shape and rigidity, and also with protection, and sometimes camouflage, from predators. Mollusks are classified into major groupings according to the characteristics of their shells. Snails (Gastropoda) have a single shell which spirals outward and to one side as it grows. Most Cephalopoda (octopi and squid) have no shell, but the Chambered Nautilus of that group has a shell. This shell does coil, but it coils flatly, in a single plane. Tusk shells (Scaphopoda) also have a single shell, but it does not coil at all; it grows in a narrow and very slightly curved cone shape. Bivalves (Bivalvia), including oysters, clams, scallops and mussels, have two parts to their shells that enclose their tender bodies like the two halves of a hinged box. Chitons (Polyplacophora) are little armored tanks, with a row of eight overlapping plates protecting them. The Neopilina (Monoplacophora), are deep-sea “living fossils;” they have a single shell which hardly coils at all, but fits over their bodies like a protective cup. (Some gastropods (the limpets) have shells like this too, but their body structure is very different.) Last are the deep-sea wormlike Aplacophora, with no shell at all, but little calcareous spines on their bodies.

Mollusks make their shells from calcium they derive from their environment, either the food they eat or the water they dwell in. When a tiny mollusk hatches from its egg, it comes into the world equipped with a tiny shell. This shell is actually a part of the animal, growing as it grows, accommodating its needs. Each different species of mollusk makes a shell that is, in most cases, unique to it alone. Indeed, this uniqueness of form is partly what allows amateur shell collectors (conchologists) and professional scientists who study mollusks (malacologists) to determine a mollusk’s species. Each species is destined genetically to develop the same type of shell its progenitors did. But, just as with humans, there are many distinct differences. Food, climate, environment, accident, and the mollusk’s particular heredity all play their parts in making each shell an individual.
Check Your Progress

1. Give two general characteristics of molluscs.
2. Give an example of Gastropoda.
3. What are shells?

11.3 ECHINODERMATA

Characteristics

- All marine
- Known as spiny-skinned animals
- Endoskeleton known as the test is made of calcium plates or ossicles with protruding spines
- Includes sea stars, brittle stars, sand dollars, sea urchins and sea cucumbers
- Undergo metamorphosis from bilateral, free-swimming larva to sessile or sedentary adult
- Larval stage known as dipleurula or bipinnaria
- Adults have pentaradial (5 part) symmetry
- Lack segmentation or metamerism
- Coelomate
- Breathe through skin gills as adults
- Capable of extensive regeneration Bipinnaria Larva
- Ventral (lower) surface called the oral surface and where mouth is located
- Dorsal (upper) surface known as aboral surface and where anus is located
- Have a nervous system but no head or brain in adults
- No circulatory, respiratory, or excretory systems
- Have a network of water-filled canals called the water vascular system to help move and feed
- Tube feet on the underside of arms help in moving and feeding
- One-way digestive system consists of mouth with oral spines, gut, and anus
- Deuterostomes (blastopore becomes the anus) ? Separate sexes
- Reproduce sexually and asexually
11.3.1 Classification of Echinodermata

Includes 5 Classes

1. Crinoidea - sea lilies and feather stars
2. Asteriodea - starfish
3. Ophiuroidea - basket stars and brittle stars
4. Echinoidea - sea urchins and sand dollars
5. Holothuroidea - sea cucumbers

1. Class Crinoidea

Characteristics
- Sessile
- Sea lilies and feather stars
- Have a long stalk with branching arms that attach them to rocks and the ocean bottom
- Can detach & move around
- Mouth & anus on upper surface
- May have 5 to 200 arms with sticky tube feet to help capture food (filter feeders) & take in oxygen
- Common in areas with strong currents and usually nocturnal feeders

2. Class Asteriodea

Characteristics
- Usually sedentary along shorelines - Starfish or sea stars
- Come in a variety of colors
- Prey on bivalve mollusks such as clams and oysters
- Have 5 arms that can be regenerated - Arms project from the central disk
- Mouth on oral surface (underside)

3. Class Echinoidea

Characteristics
- Includes sea urchins and sand dollars
- Internal organs enclosed by endoskeleton or test made of fused skeletal plates
- Body shaped like a sphere (sea urchin) or a flattened disk (sand dollar)
Mollusca

- Lack arms
- Bodies covered with movable spines
- Have a jaw-like, crushing structure called Aristotle’s lantern to grind food
- Use tube feet to move

NOTES

Sea Urchins
- Spherical shape Live on ocean bottom
- Scrape algae to feed
- Long, barbed spines make venom for protection

Sand Dollars
- Flattened body
- Live in sand along coastlines
- Shallow burrowers
- Have short spines

Feeding and Digestion
- Tube feet attach to bivalve mollusk shells and create suction to pull valves apart slightly
- Starfish everts (turns inside out) its stomach through its mouth and inserts it into prey
- Stomach secretes enzymes to partially digest bivalve then stomach withdrawn & digestion completed inside starfish

Other Body Systems
- No circulatory, excretory, or respiratory systems
- Coelomic fluid bathes organs & distributes food and oxygen
- Gas exchange occurs through skin gills and diffusion into the tube feet
- No head or brain
- Have a nerve ring surrounding the mouth that branch into nerve cords down each arm
- Eyespots on the tips of each arm detect light
- Tube feet respond to touch

Reproduction
- Separate sexes
- Two gonads (ovaries or testes) in each arm produce eggs or sperm
- Have external fertilization
• Females produce up to 200,000,000 eggs per season
• Fertilized eggs hatch into bipinnaria larva which settles to the bottom after 2 years and changes into adult
• Asexually reproduce by regenerating arms

11.3.2 Water Vascular System of Starfish

Introduction
The water vascular system is a modified part of coelom and consists of a system of sea water filled canals having certain corpuscles. It plays most vital role in the locomotion of the animals and comprises madreporite stone canal, ring canal, radial canal, Tiedemann’s body, lateral canals & tube feet.

1. Madreporite: - The madreporite is a rounded calcareous plate occurring on the aboral surface of the central disc in inter-radial position. Its surface bears a number of radiating, narrow, straight or wavy grooves or furrows. Each furrow contains many minute pores at its bottom. Each pore leads into a very short, fine, tubular pore-canal. Which passes inward in the substance of the madreporite. There may be about 200 pores and pore-canal. The pore-canals unite to form the collecting canals. Which open into an ampulla beneath the madreporite.

2. Stone Canal: - The ampulla opens into an “S” shaped stone canal. The stone canal extends downwards (orally) and opens into a ring canal, around the mouth. The walls of stone canal are supported by a series of calcareous ringed. The lumen of stone canal is lined by very tall flagellated cells in embryonic stages and young Asterias, the stone canal remains a simple tube but in adult Asterias, lumen of stone canal possesses a prominent ridge with two spirally rolled lamellae.

3. Ring Canal: - The Ring canal or water ring is located to the inner side of the peristomial ring of ossicles and directly above (aboral) to the hyponeural ring sinus. It is wide and pentagonal or five sided.

4. Tiedemann’s Bodies: - The ring canal gives out inter radially nine small, yellowish, irregular or rounded glandular bodies called racemose or Tiedemann’s bodies from its inner margins. The Tiedemann’s body rest upon the peristomial ring of ossicles. The actual function of tiedemann’s bodies is still unknown, however they are supposed to be lymphatic glands to manufacture the amoebocytes of the water vascular system.

5. Polian Vesicles: - The ring canal gives off on its outer side in the inter radial position one, two or four little, pear shaped, thin walled contractile bladder or reservoirs with long necks called polian vesicles. They are supposed to regulate pressure inside ambulacral system and to manufacture amoeboid cells of ambulacral system.
6. **Radial Canal**: From its outer surface the ring canal gives off a radial water canal into each arm that runs throughout the length of the arm and terminates as the lumen of terminal tentacle. In the arm the radial water canal runs immediately to the oral side of the ambulacral muscles.

7. **Lateral Canal**: In each arm, the radial canal gives out two series of short, narrow, transverse branches called lateral or radial canals. Each lateral canal is attached to the base of a tube foot and it’s provided with a valve to prevent backward flow of fluid into the radial canal.

8. **Tube Feet**: As already mentioned, there are four rows of tube feet in each ambulacral groove. A tube foot is a hollow elastic, thin walled, closed cylinder or sac-like structure having an upper sac-like ampulla, a middle tubular podium & a lower disc-like sucker. The ampulla lies within the arm, projecting into the coelom above the ambulacral pore which is a gap between the adjacent ambulacral ossicles for the passage of the podium. The tube feet are the chief locomotory and respiratory organ of Asterias.

**Function of Water Vascular System**

The water vascular system has three main functions. They are as follows:

1. **Locomotion**: The water vascular system is used mainly for locomotion. The inner wall of the water vascular canals are provided with cilia. The beating of the cilia causes the seawater to enter through the madreporite. Finally, the seawater reaches the tube feet and their ampullae. The ampullae contract; the valves at the junction of the lateral canals and tube feet, prevent the flow of water into radial canals. The water is forced into the podia. The podia are elongated and protected out through the ambulacral groove. Then the suckers are applied to the substratum. The tube feet now contract & push the body forward. The water from the tube feet is pushed into the ampulla. Hence, the tube feet shorten. The suckers are released. Then the ampulla contracts & the whole process is repeated.

2. **Food Capture**: The tube feet are used to capture the prey. The suckers are used to open the shells of molluscas.

3. **Attachment**: The Starfish can be attached to the rocks by the tube feet.

**11.3.3 Echinodermata Larval Forms**

Echinoderms are unisexual animals. Sexual dimorphism is absent. Fertilisation takes place in water. The development may be direct or indirect. If the development is indirect it includes larva stages. In different classes of echinoderms, different types of larvae complete the development. The larval form is bilaterally symmetrical. It undergoes metamorphosis and radial symmetrical adult is developed.

**Class of Phylum Echinodermata Larval form**

1. Asterioidea

2. Ophiuroidea
3. Echinoidea

4. Holothuroidea


1. Bipinnaria Larva: It is the larva form seen in the life history of Star fish. The fertilised egg is homolecithal. It undergoes holoblastic cleavage and develops into blastula and gastrula stages. The gastrula elongates in length and it gives rise to Bipinnaria larva.
   - It is a bilaterally symmetrical free swimming pelagic larva.
   - The pre-oral region is elongated. Post-oral region is broad. The anterior end forms pre-oral lobe. The ciliated band at the pre-oral lobe forms into 2 separate bands, Pre-oral band of cilia, and post oral band of cilia. These 2 bands of cilia are drawn into many arms. They are nothing to do with the arms of the star fish. They are, 1) Ventro-median arm. 2) A pair of pre-oral arm. 3) Median dorsal arm. 4) A pair of antero-dorsal arm. 5) A pair of posterio-dorsal arm. 6) A pair of posterio-lateral arm. 7) A pair of post oral arm. 8) The digestive system is developed with mouth and anus. This larva resembles Tomaria larva of Balanoglossus. This larva slowly grows into the next larval form called Brachiolaria larva.

2. Brachiolaria Larva: Bipinnaria larva swims for few weeks in the sea water. It finally transforms into next larval stage called Brachiolaria larva.
   - It is bilaterally symmetrical larva.
   - It is pelagic larval form, it shows 3 brachiolar arms with suckers. They are one median and two lateral in position.
   - At the tip of brachiolar arms adhesive structures will make their appearance and they are for attachment.
   - The larva shows all the arms that are seen in the Bipinnaria, but these arms are very long and hanging. These ciliated arms will be helpful for swimming in the water.
   - The digestive system is completely developed with definite stomach and intestine. This larva after swimming few settle-on a solid object and gets attached to it by its adhesive arms. Posterior end of the larva enlarges and lifts to the right-side. From this rudiments of 5 arms will arise. Thus slowly the larva metamorphosis into an adult.

3. Auricularia Larva: In Holothuroidea this larval form is seen.
   - It is a free swimming pelagic larva.
   - Arms are absent. Alimentary canal is developed. It opens with mouth and ends with anus.
   - Intestine is curved.
In Japan and Bermuda very big auricularia larval forms are developed. They are 15 mm in length. Usually this larva is 1 mm in length.

Ciliated bands are well-developed. Ciliated band continues through oral loop and anal loop.

Check Your Progress

4. How does echinodermata reproduce?
5. Give an example of Asteriodea.
6. What is ring canal?
7. What is brachiolaria larva?

11.4 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. (i) Soft-bodied invertebrate covered with protective mantle that may or may not form a hard, calcium carbonate shell, (ii) Have a fully-lined coelom.
2. Snail.
3. Shells are lovely natural objects, equals in beauty to any flower or butterfly, they are more than just pretty baubles found on beaches. They are the exterior skeletons (exoskeletons) of a group of animals called mollusks.
4. Echinodermata reproduces sexually & asexually.
5. Starfish.
6. The Ring canal or water ring is located to the inner side of the peristomial ring of ossicles and directly above (aboral) to the hyponeural ring sinus. It is wide and pentagonal or five sided.
7. Bipinnaria larva swims for few weeks in the sea water. It finally transforms into next larval stage called Brachiolaria larva.

11.5 SUMMARY

- Mollusk are second largest animal phylum.
- Mollusk includes 4 classes. 1. Polyplacophora (chitons) 2. Gastropoda (snails, slugs, nudibranchs, conchs and abalone) 3. Pelecypoda or Bivalvia (clams, oysters, and mussels) 4. Cephalopoda (squid, octopus, and nautilus).
- The water vascular system is a modified part of coelom and consists of a system of sea water filled canals having certain corpuses.
- Echinoderms are unisexual animals. Sexual dimorphism is absent. Fertilisation takes place in water. The development may be direct or indirect. If the development is indirect it includes larva stages.
11.6 KEY WORDS

- **Larva**: An immature form of other animals that undergo some metamorphosis.
- **Mollusk**: Mollusk, also spelled mollusc, any soft-bodied invertebrate of the phylum Mollusca, usually wholly or partly enclosed in a calcium carbonate shell secreted by a soft mantle covering the body.
- **Phylum**: A principal taxonomic category that ranks above class and below kingdom, equivalent to the division in botany.

11.7 SELF ASSESSMENT QUESTIONS AND EXERCISES

**Short-Answer Questions**
1. What is the economic importance of mollusks?
2. Write a short on shells in mollusca.
3. Write characteristics of echinoidea.
4. What are the function of water vascular system?

**Long-Answer Questions**
1. What are general characteristics of mollusca?
2. Discuss classes of mollusca.
3. What are general characteristics of echinodermata?
4. Discuss classes of echinodermata.
5. What are the classes of phylum echinodermata larval form?

11.8 FURTHER READINGS


Prochordates and Vertebrates

NOTES

BLOCK - IV
VERTEBRATES

UNIT 12 PROCHORDATES AND VERTEBRATES

Structure
12.0 Introduction
12.1 Objectives
12.2 Phylum Chordata
  12.2.1 Classification of Phylum Chordata
12.3 Prochordates
  12.3.1 General Characteristics of Protochordata
  12.3.2 Subphylum Urochordata
  12.3.3 Cephalochordata
  12.3.4 Hemichordata
12.4 Craniata (Vertebrata)
12.5 Answers to Check Your Progress Questions
12.6 Summary
12.7 Key Words
12.8 Self Assessment Questions and Exercises
12.9 Further Readings

12.0 INTRODUCTION

Phylum Chordata is probably the most notable phylum, as all human beings and other animals and birds that are known to you, fall under this phylum. The most distinguishing character that all animals belonging to this phylum have is the presence of notochord. The Phylum Chordata includes the well-known vertebrates (fishes, amphibians, reptiles, birds, mammals). The vertebrates and hagfishes together comprise the taxon Craniata. The remaining chordates are the tunicates (Urochordata), lancelets (Cephalochordata), and, possibly, some odd extinct groups. With few exceptions, chordates are active animals with bilaterally symmetric bodies that are longitudinally differentiated into head, trunk and tail. The most distinctive morphological features of chordates are the notochord, nerve cord, and visceral clefts and arches.

12.1 OBJECTIVES

After going through this unit, you will be able to:
- Get an overview of protochordata and vertebrates
• Discuss characteristics of protochordata and vertebrates
• Know classes of protochordata and vertebrates

12.2 PHYLUM CHORDATA

A chordate is an animal belonging to the phylum Chordata; chordates possess a notochord, a hollow dorsal nerve cord, pharyngeal slits, an endostyle, and a post-anal tail, for at least some period of their life cycle. Chordates are deuterostomes, as during the embryo development stage the anus forms before the mouth. They are also bilaterally symmetric coelomates with metameric segmentation and a circulatory system.

Characteristics of Chordates

In chordates, four common features appear at some point during development: a notochord, a dorsal hollow nerve cord, pharyngeal slits, and a post-anal tail.

1. A Notochord
2. A Dorsal Hollow Nerve Cord
3. Pharyngeal Slits
4. Post-Anal Tail

1. Notochord

The chordates are named for the notochord: a flexible, rod-shaped structure that is found in the embryonic stage of all chordates and also in the adult stage of some chordate species. It is located between the digestive tube and the nerve cord, providing skeletal support through the length of the body. In some chordates, the notochord acts as the primary axial support of the body throughout the animal’s lifetime. In vertebrates, the notochord is present during embryonic development, at which time it induces the development of the neural tube which serves as a support for the developing embryonic body. The notochord, however, is replaced by the vertebral column (spine) in most adult vertebrates.

2. Dorsal Hollow Nerve Cord

The dorsal hollow nerve cord derives from ectoderm that rolls into a hollow tube during development. In chordates, it is located dorsally (at the top of the animal) to the notochord. In contrast to the chordates, other animal phyla are characterized by solid nerve cords that are located either ventrally or laterally. The nerve cord found in most chordate embryos develops into the brain and spinal cord, which comprise the central nervous system.

3. Pharyngeal Slits

Pharyngeal slits are openings in the pharynx (the region just posterior to the mouth) that extend to the outside environment. In organisms that live in aquatic
environments, pharyngeal slits allow for the exit of water that enters the mouth during feeding. Some invertebrate chordates use the pharyngeal slits to filter food out of the water that enters the mouth. In vertebrate fishes, the pharyngeal slits develop into gill arches, the bony or cartilaginous gill supports. In most terrestrial animals, including mammals and birds, pharyngeal slits are present only during embryonic development. In these animals, the pharyngeal slits develop into the jaw and inner ear bones.

4. Post-Anal Tail

The post-anal tail is a posterior elongation of the body, extending beyond the anus. The tail contains skeletal elements and muscles, which provide a source of locomotion in aquatic species. In some terrestrial vertebrates, the tail also helps with balance, courting, and signaling when danger is near. In humans and other apes, the post-anal tail is present during embryonic development, but is vestigial as an adult.

12.2.1 Classification of Phylum Chordata

The Phylum Chordata is divided into two groups which are: 1. Acraniata (Protochordata) 2. Craniata (Vertebrata)

![Phylum Chordata Diagram]

Check Your Progress

1. What is Chordata?
2. What are the classes of Chordata?

12.3 PROCHORDATES

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 and the Subphyla Urochordata and Cephalochordata. The Phylum Hemichordata 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. Acorn worms are examples of hemichordates. The Urochordates and Cephalochordates are protochordates, but belong to the Phylum Chordata.

12.3.1 General Characteristics of Protochordata

- Elastic, solid, unsheathed rod-like structure of vacuolated turgid cells called notochord is present may be throughout the life or only during early embryonic development mentioned above.
- Their central nervous System is dorsal, hollow and single which is different from non-chordata as their CNS is ventral, solid and double.
- Paired pharyngeal gill slits (pharynx is perforated by gill slits) is present which takes part in circulation of water for respiration and in higher chordates, they occur only in embryonic stage.
- Ventral heart is present and gut lies ventral to nerve cord.
- Post-anal tail is present and if present then it’s for balancing.
- They are bilaterally symmetrical, triploblastic, and coelomate with organ system level of organisation.
- Urochordata and cephalochordata which are acraniates are considered as primitive and often referred to as protochordates or non-vertebrate chordates.

12.3.2 Subphylum Urochordata

The Urochordata, sometimes known as the Tunicata, are commonly known as 'sea squirts.'

General Characteristics

- Possesses a Notochord, a hollow nerve cord and a post anal tail.
- Body has more than two cell layers and includes tissues and organs.
- Has a U shaped gut.
- Body has no coelomic body cavity.
- Body wholly enclosed in a ‘tunic’ of secreted protein and cellulose-like material.
- Are hermaphroditic, normally with only one ovary and testis.
- Has a nervous system composed of an anterior ganglion from which individual nerves issue.
- Has no excretory organs.
- Has a distinct larval stage.
- All are filter feeders.
Prochordates and Vertebrates

NOTES

- Live in marine environments.
- About 2,000 species currently known.

12.3.3 Cephalochordata

Cephalochordata includes two genera, 1. Asymmetron and 2. Branchiostoma (Amphioxus).

Cephalochordates are small fish like animals which show Chordate characters. The notochord extends the entire length of the body. They show a dorsal, tubular neural tube without a definite brain.

General Characteristics

- Body is fish-like and is useful for burrowing and swimming.
- It has a head.
- It shows a tail.
- Appendages are absent.
- Dorsal, caudal and ventral fins are present.
- Body-wall shows one-cell thick, non-ciliated epidermis, dermis, connective tissue, striated muscle and parietal peritoneum.
- It has no exoskeleton.
- Notochord extends from the anterior end to posterior end.
- Enterocoelic coelom is present. However, reduced in the pharyngeal region by atrium.
- Alimentary canal is long. It includes a large pharynx with many gill-slits ciliary mode of feeding is developed.
- Gills will perform respiration.
- Circulatory system is closed.
NOTES

Self-Instructional Material

Prochordates and Vertebrates

- Heart and respiratory pigments are absent.
- Hepatic portal system is present.
- Excretory system shows paired protonephridia with solenocytes.
- Brain is not present
- Two pairs of cerebral and several pairs of spinal nerves are present.
- Sexes are separate. Gonads are metamerically arranged and without gonoducts.
- Asexual reproduction will not take place.
- Fertilization is external.

12.3.4 Hemichordata

General Characteristics

- Solitary and colonial, mostly tubicolous, exclusively marine.
- Body soft, fragile, vermiform and divisible into proboscis, collar and trunk.
- Body wall with a single-layered epidermis.
- Coelom enterocoelous, divisible into protocoel, mesocoel and metacoel.
- Buccal diverticulum, earlier considered as notochord, present in the proboscis.
- Digestive tract complete; in the form of straight or U-shaped tube.
- Gill-slits, when present, are paired and one to numerous.

Fig. 12.2 Hemichordata

Check Your Progress

3. What are two genera of Cephalochordata?
4. What is notochord?
Vertebrates 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:

- **Vertebral Column.** In vertebrates, the notochord is replaced during the course of embryonic development by a bony vertebral column.
- **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.**

**Neural Crest.** Neural crest cells then migrate to various locations in the developing embryo, where they participate in the development of a variety of structures.

**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.

**Endoskeleton.** The endoskeleton of most vertebrates is made of cartilage or bone. Cartilage and bone are specialized tissue containing fibers of the protein collagen compacted together. Bone also contains crystals of a calcium phosphate salt. Bone forms in two stages. First, collagen is laid down in a matrix of fibers along stress lines to provide flexibility, and then calcium minerals infiltrate the fibers, providing rigidity. The great advantage of bone over chitin as a structural material is that bone is strong without being brittle. The vertebrate endoskeleton makes possible the great size and extraordinary powers of movement that characterize this group.

This group is sub-divided into two sub-phyla, which are as follows: a) Sub-Phylum Agnatha (Mouth without Jaws) b) Sub-Phylum Gnathostomata (Mouth with Jaws)

**A) Sub-Phylum Agnatha (Mouth without Jaws)**

- This is a small group of marine vertebrates also known as-Cyclostomes.
- Superficially they resemble the fish but lack the jaw so they are often known as-Jawless Fishes.
- They have rounded suckorial mouth with many rings of teeth.
Prochordates and Vertebrates

B) Sub-Phylum Gnathostomata (Mouth with Jaws)

- It is a large group of vertebrates with both upper and lower jaw.
- Teeth may be present or absent. Gnathostomata are divided into two super classes, which are as follows: i) Pisces (Fishes) ii) Tetrapoda

(I) Super Class Pisces (Fishes)

Fishes are oldest aquatic vertebrates found all over the globe. Nearly 500 million years ago the first fish appeared on the earth. Today fishes make up the largest group of vertebrates with 24,000 species. Fishes have their habitats in lakes, streams, oceans, and estuaries. In 1991 it was estimated that 2546 species of fish populated the world. Out of which 969 belong to genera, 254 families, and 40 orders. Around 80% of fish population around the globe was represented by the Indian fishes. Fishes are capable of living in both fresh and marine water. Fishes are cold blooded animals in the world that are covered with scales and equipped with a pair of fins to swim in the water. Unlike other animals in the world fishes do not have lungs as their breathing organ. Fishes are provided with a special organ called gills which are used for respiration. With the help of gills they draw oxygen from the water and into the blood stream. Fishes reproduce by laying eggs. To learn more about the characteristic of the fish please refer to: Characteristic of fish. Fish has a streamlined body which helps them to move through the water quickly. To keep them safe from the enemies they have dark color on the top and light color on the bottom. They can change color rapidly and reflective cells in their skin discoloration. The size of the fish ranges from an inch to sixteen feet. To know more about the structure of fish and their activity refer to the FISH ANATOMY.

Characteristics of Class Pieces (Aquatic Adaptations in Fish)

Some live in freezing Arctic seas, others in warm freshwater lakes, and still others spend a lot of time out of water entirely. However varied, all fishes have important characteristics in common:

- **Vertebral Column.** All fishes have an internal skeleton with a spine surrounding the dorsal nerve cord, although it may not necessarily be made of bone. The brain is fully encased within a protective box, the skull or cranium, made of bone or cartilage.

- **Single-Loop Blood Circulation.** Blood is pumped from the heart to the gills. From the gills, the oxygenated blood passes to the rest of the body, and then returns to the heart. The heart is a muscular tube-pump made of four chambers that contract in sequence.
**Prochordates and Vertebrates**

- **Nutritional Deficiencies.** Fishes are unable to synthesize the aromatic amino acids and must consume them in their diet. This inability has been inherited by all their vertebrate descendants. The remarkable success of the bony fishes has resulted from a series of significant adaptations that have enabled them to dominate life in the water. These include the swim bladder, lateral line system, and gill cover. 1. **Swim Bladder.** Although bones are heavier than cartilaginous skeletons, bony fishes are still buoyant because they possess a swim bladder, a gas-filled sac that allows them to regulate their buoyant density and so remain suspended at any depth in the water effortlessly. Gas exchange occurs across the wall of the swim bladder and the blood vessels located near the swim bladder. A variety of physiological factors controls the exchange of gases between the blood stream and the swim bladder. 2. **Lateral Line System.** Although precursors are found in sharks, bony fishes possess a fully developed lateral line system. The lateral line system consists of a series of sensory organs that project into a canal beneath the surface of the skin. 3. **Gills.** Fishes are water-dwelling creatures and must extract oxygen dissolved in the water around them. They are located at the back of the pharynx and are supported by arches of cartilage. Blood moves through the gills in the opposite direction to the flow of water in order to maximize the efficiency of oxygen absorption.

**All the species of the fish found in the world are classified into the following three groups.** They are: 1. Agnatha - jawless fish 2. Chondrichthyes - cartilaginous fish 3. Osteichthyes - bony fish.

1. **AGNATHA**

**Phylum: Chordate**

**Subphylum Vertebrata**

Agnatha are jawless fish and lack paired fins. They also lack the internal skeleton system. They have a circular tooth mouth (cyclostomian) by which they bore the body of their victim and suck their blood. These are classified into two major types. They are Hagfish and Lampreys.

**Characteristic of Agnatha**

- Jaws are absent
- Paired fins are absent
- Bony scales and skin plates were present in the ancient species but are absent in the living species
- Gill pouches are present. They have seven or more pouches. Stomach is absent in the digestive system.
2. CHRONDRICHTHYYES

Phylum: Chordate
Subphylum Vertebrata

Fearsome predators and harmless mollusc eaters are the members of the
Chrondrichthyes. The member of the cartilaginous fish poses true bone and also
poses a skeleton made up of cartilage.

Only the teeth of this species and rarely the vertebrae are calcified. Sharks,
Skates, and Rays make up the group of chrondrichthyes.

CHARACTERISTICS

- These fishes are exclusively marine.
- The exoskeleton in the form of placoid scales.
- Their endoskeleton is cartilaginous and are called Cartilage
- Jaw suspension is amphistylic or hyostylic.
- 5-7 pairs of gills are present.
- External gill openings are separate. They are not covered by operculum.
- Heterocercal caudal fin is seen.
- Males show claspers for copulation.
- Air-bladder is absent in these fishes.

3. OSTEICHTHYYES

Phylum: Chordate
Subphylum Vertebrata

About 30000 species of bony fish are found in this class. Fishes that belong to this
species are spindle shaped, oval in section and flattened. Skins are protected by
protective scales. Some fishes of this category have actual lungs to breathe and
also have sharp eyesight. These bony fishes have a special gas filled chamber
called airbladder housed under the skeleton to allow them to remain buoyant.
Another adaptation is operculum, a bone on the sides of the fish to protect the
chambers that house the gills. Bony fish are again classified into ray finned and
lobe finned fish. Ray finned fish have thin, flexible skeleton rays. Lobe finned fish
have muscular fins supported by bones. Bony fish fertilizes either internally or
externally. Two types of eggs are laid by the bony fish. They are the eggs that float
and the eggs that sink.

Characteristic of Osteichthyes

- These fishes are marine, fresh water and brackish water
Prochordates and Vertebrates

NOTES

- Cycloid, ctenoid or ganoid scales will form the exoskeleton
- Endoskeleton bony
- Jaws suspension is autostylic
- Operculum is present
- Claspers are absent
- Usually air bladder is present.
- Have more or less bony skeleton and numerous vertebrae.
- Mucous glands and embedded dermal scales are present in the skin.
- Have paired fins
- Jaws are present. Gill arches support the gills and are protected by the operculum Lungfish, Eels, Acrp, Lizardfish, Silversides and Salmon form the class of bony fish

<table>
<thead>
<tr>
<th>Classes</th>
<th>Cyclostomata</th>
<th>Osteichthyes</th>
<th>Chondrichthyes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Body</td>
<td>Snake like</td>
<td>Fusiform, spindle shaped</td>
<td>Bony</td>
</tr>
<tr>
<td>Skeleton</td>
<td>Cartilaginous</td>
<td>Cartilaginous</td>
<td>body is covered with paired scales (plate shaped)</td>
</tr>
<tr>
<td>Mouth</td>
<td>Succorial</td>
<td>Mouth ventral, Nostril does not open in buccal cavity</td>
<td>Jaw bears teeth or may be absent.</td>
</tr>
<tr>
<td>Gill slits</td>
<td>4-15 pairs</td>
<td>5-7 pairs</td>
<td>unusual, fertilization is external</td>
</tr>
<tr>
<td>Reproduction</td>
<td>Lamprey is bisexual, and</td>
<td>Lamprey is bisexual, and</td>
<td>Lamprey is bisexual, and</td>
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<td></td>
<td>Hagg fish in unusual,</td>
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<td>male fertilization is</td>
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<td></td>
<td>abnormal</td>
<td>abnormal</td>
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</tr>
<tr>
<td>Examples</td>
<td>Lamprey, Hagg fish</td>
<td>Skate, Electric ray that</td>
<td>Trout, Perch, Cod, etc.</td>
</tr>
<tr>
<td>Importance</td>
<td>Used in biological research to study origin of fish</td>
<td>Used as food</td>
<td>Fish oil is obtain from the liver and it contain vitamin A &amp; D</td>
</tr>
</tbody>
</table>

(ii) SUPER CLASS TETRAPODA

It includes following classes:

a) Class Amphibian
b) Class Reptilian
c) Class Aves
d) Class Mammalia

a) CLASS AMPHIBIAN

- This class includes the animals that came out of the water and established a successful life on land.
They took advantages of the improved possibilities by remaining close to water, by keeping a soft and moist skin, by developing lungs and by evolving a bony skeleton with a strong vertebral column and four legs.

They cope with seasonal changes by burrowing during extreme cold and save water by sealing themselves in a mucous envelop on dry land.

The bony endoskeleton is the main body support.

The notochord is absorbed during development? Breathing is mostly by means of skin and also lung, and also by lining of buccal cavity.

In larva the breathing is mostly by means of external or internal gills.

The circulatory system shows a three chambered heart, with two atria and one ventricle.

The amphibians are Cold Blooded

(Poikilothermic) that is having internal temperature that very with the environment.

Eggs and sperms are laid in water and fertilization is external. E.g.: Frog and Toads, Salamanders, Newts, Mud puppies etc.

b) CLASS REPTILIA

General Characters
The earliest reptiles evolved from the amphibians.

Habit and Habitat
Reptiles are generally well adapted to life on land, in semi-dry, completely dry and even desert habitat.

Nature
- All reptiles lay their eggs on land.
- They are cold-blooded animals and are less active during low temperature.

Structural Features
- They possess dry skin covered with epidermal scales.
- In some lizards and crocodiles, small bony plates develop below the epidermal scales.
- The skeleton is built on the same plane as that of amphibians, but is much stronger to support their body weight.
- Respiration takes place exclusively through lungs.
- Heart is three chambered, two auricles and one incompletely divided ventricle. (In Crocodiles, the ventricle is completely divided into two chambers.)
Prochordates and Vertebrates

NOTES

- The excretion takes place through kidneys. The reptiles secrete much of their waste products in form of non-toxic—Uric-Acid.

Reproduction

- In most reptiles fertilization is internal.
- Eggs are provided with a shell and are laid on land.
- The early development of embryo takes place on the large quantities of yolk and albumin present in the egg.
- Due to the presence of a protective membrane called and AMNION in the egg, reptiles are included in the—Amniota Group of Vertebrates.
- Example: Alligators, Crocodile, Snake, Turtle and Gecko etc.

c) CLASS AVES (BIRDS)

Evolution

- Aves have evolved from reptiles.
- As they acquired the capability of true flight they were able to exploit the aerial environment and became the largest class of terrestrial vertebrates.

Habit and Habitat

The birds live from pole to pole in all type of ecological zones. They all breed on land.

Flight and Adaptation

- Feathers differentiate birds from all other vertebrates.
- Feathers originated as extraordinary development of Reptilian scales.
- Instead of growing all over the body and spreading evenly, the feathers grow in definite tracts.
- The feathers play an important role in the thermoregulation of birds. They trap air, which is a bad conductor of heat and so prevent loss of body heat.
- To fly efficiently the birds have reduced their body weight in a variety of ways.
- Many bones become hollow, thin and light.
- Synsacrum and pygostyle are formed by the fusion of vertebrae and give strength to skeleton.
- Birds possess strong muscles to control the use of wing in flight.

Adaptation for Communication

- They possess large eyes with well-developed sight.
- The birds communicate with members of their species with sound signals for which the sense of hearing is well developed.
Structural Features

- The great mobility of neck is helpful in feeding, nest building, preening and defence.
- There are developed a number of types of bills according to their feeding habits.
- The digestive system of birds is compact and can accommodate large quantity of food.
- The food is stored for a short period in the crop. Gizzard possess thick muscular wall with horny lining, small stones swallowed by birds are passed on the gizzard for grinding the food.
- The Syrinx or sound-producing organ is found in no other vertebrate except the birds. It is located at the junction between the trachea and the paired bronchi.
- The lungs of birds are small, solid, spongy and slightly distensible. They are in contact with a number of air sacs.

Migration in Birds

A large number of species of birds exhibit a deep-rooted phenomenon of migration, during which they travel long distances from their summer breeding homes towards areas of warm climate.

d) CLASS MAMMALIA

General Characters

- Early mammals are originated from reptiles.
- The distinctive characteristic of mammals are at the highest grade of development in animal kingdom.

Habit and Habitat

Mostly terrestrial, a few aquatic.

Nature

- They are warm-blooded animals.
- They can maintain a fairly high body temperature and so can successfully survive in colder areas of the world.

Temperature Regulation

- Heat is generated by high metabolic rate of their body and is lost by increasing blood circulation in the skin and evaporation of sweat.
- The mammalian body temperature is maintained at 35°C-40°C.
Prochordates and Vertebrates

NOTES

Apparent Feature
- All mammals possess hair on skin.
- Sweat glands and sebaceous glands are present on skin.
- Mammary glands secrete milk in females.
- External ears (Pinna) are present.
- Teeth are heterodont i.e. not uniform.
- The different types of teeth are: Incisors, Canine, Premolars, and Molars.

Skeletal System
- Skull with two occipital condyles is present.
- Lower jaw is composed of single bone on each side.
- Vertebrae are—Gastrocentrous, composed of three pieces i.e. the centrum and two epiphyses. Digits of fore and hind limbs are usually five.
- Cervical (Neck) vertebrae are seven.

Internal Features
- A thick muscular septum—Diaphragm is present between abdomen and thoracic cavity.
- Heart is four-chambered.
- R.B.Cs are non-nucleated.
- Brain with four optic lobes.
- Kidney is metanephrous.
- The stomach is simple sac but rarely complicated.

Reproduction
- Mammals give birth to young ones (Viviparous), which are nourished by parents. Except Prototherians that lay eggs.
- Fertilization is internal.
- Development of eggs occurs in the uterus of female, where the developing embryo develops relationship with mother (Placenta).
- After the birth of the child, the mother nourished her young ones.

Check Your Progress
5. What are craniate Chordates?
6. Give examples of Chondrichthyans.
7. Give examples of Amphibians.
12.5 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. A chordate is an animal belonging to the phylum Chordata; chordates possess a notochord, a hollow dorsal nerve cord, pharyngeal slits, an endostyle, and a post-anal tail, for at least some period of their life cycle.

2. The Phylum Chordata is divided into two groups which are: 1. Acraniata (Protochordata) 2. Craniata (Vertebrata).


4. Elastic, solid, unsheathed rod-like structure of vacuolated turgid cells called notochord is present may be throughout the life or only during early embryonic development mentioned above.

5. 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.

6. Sharks, Skates, and Rays make up the group of chondrichthyes.

7. Frog and Toads, Salamanders, Newts, Mud puppies, etc.

12.6 SUMMARY

- A chordate is an animal belonging to the phylum Chordata; chordates possess a notochord, a hollow dorsal nerve cord, pharyngeal slits, an endostyle, and a post-anal tail, for at least some period of their life cycle.

- The Phylum Chordata is divided into two groups which are: 1. Acraniata (Protochordata) 2. Craniata (Vertebrata).

- 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.

- Protochordata is composed of the Phylum Hemichordata and the Subphyla Urochordata and Cephalochordata.

- 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.

- This group of vertebrates is sub-divided into two sub-phyla, which are as follows: a) Sub-Phylum Agnatha (Mouth without Jaws) b) Sub-Phylum Gnathostomata (Mouth with Jaws).
12.7 KEY WORDS

- **Chordata**: A large phylum of animals that includes the vertebrates together with the sea squirts and lancelets. They are distinguished by the possession of a notochord at some stage during their development.
- **Protochordata**: A major division of Chordata comprising the Hemichordata, Urochordata, and usually the Cephalochordata.
- **Vertebrate**: An animal of a large group distinguished by the possession of a backbone or spinal column, including mammals, birds, reptiles, amphibians, and fishes.

12.8 SELF ASSESSMENT QUESTIONS AND EXERCISES

**Short-Answer Questions**

1. Write a short note on sub-phylum Agnatha.
2. Write a short note on sub-phylum Gnathostomata.
3. What are the characteristics of class Pieces?
4. What are the structural features of reptilian?

**Long-Answer Questions**

1. What are the general characteristics of Protochordata?
2. Explain characteristics of Chordates.
3. Discuss subphylum Urochordata.
4. Discuss Cephalochordata.
5. Explain characteristics of Vertebrates.

12.9 FURTHER READINGS


UNIT 13 AMPHIBIANS AND REPTILES

13.0 INTRODUCTION

In this unit, you will get an overview of amphibians and reptiles. Amphibians are ectothermic, tetrapod vertebrates of the class Amphibia. Modern amphibians are all Lissamphibia. They inhabit a wide variety of habitats, with most species living within terrestrial, fossorial, arboreal or freshwater aquatic ecosystems. Thus amphibians typically start out as larvae living in water, but some species have developed behavioural adaptations to bypass this. The young generally undergo metamorphosis from larva with gills to an adult air-breathing form with lungs. Amphibians use their skin as a secondary respiratory surface and some small terrestrial salamanders and frogs lack lungs and rely entirely on their skin. They are superficially similar to lizards but, along with mammals and birds, reptiles are amniotes and do not require water bodies in which to breed. With their complex reproductive needs and permeable skins, amphibians are often ecological indicators; in recent decades there has been a dramatic decline in amphibian populations for many species around the globe.

Reptiles are tetrapod animals in the class Reptilia, comprising today’s turtles, crocodilians, snakes, amphisbaenians, lizards, tuatara, and their extinct relatives. The study of these traditional reptile orders, historically combined with that of modern amphibians, is called herpetology.

Because some reptiles are more closely related to birds than they are to other reptiles (e.g., crocodiles are more closely related to birds than they are to lizards), the traditional groups of “reptiles” listed above do not together constitute a monophyletic grouping or clade (consisting of all descendants of a common ancestor).
13.1 OBJECTIVES

After going through this unit, you will be able to:

- Define and discuss amphibians
- Define and discuss reptiles

13.2 AMPHIBIANS

Herpetology is the study of reptiles and amphibians.

- 4000+ species
- Gave rise to modern land vertebrates
- Amphibian means "double life"
- Larvae start life in H₂O with gills, adults are terrestrial with lungs

Evolutionary adaptations for life on land

- Stronger bones
- Lungs and breathing tubes
- Sternum (breastbone) and ribs to protect internal organs

History

Carboniferous Period = Age of Amphibians, 360-290 million years ago. Climate changes caused habitats to disappear. 3 orders of amphibians survive today:
1. Frogs and Toads
2. Salamanders
3. Caecilians

Form and Function in Amphibians

- Feeding: larva = herbivore, adults = mostly carnivore Digestive tract; mouth > esophagus > stomach > small intestines > large intestine (colon) > cloaca
- Respiration: larva = skin and gills, adult = lungs and some through skin
  Many terrestrial salamanders = no lungs at all, through skin and mouth cavity
- Circulation: double loop system 3 chamber heart right atrium, left atrium, and ventricle
  Compare Single to Double Loop Circulation Single:
  Heart —→ Gills —→ Body Double: Heart —→ Lungs —→ Heart —→ Body.
Excretion: kidneys filter liquid waste = urine
Kidneys > Ureters > Small Urinary Bladder > cloaca

Reproduction: females lay eggs in water, male deposits sperm over eggs
Tadpoles - Herbivorous, Aquatic, Single Loop Circulation, Gills
Frogs - Carnivorous, Terrestrial or Aquatic, Double Loop, Lungs
Yolk of egg nourishes developing embryo Larvae commonly called tadpoles,
metamorphosis is the process by which tadpoles become adults
A few species will care for their eggs by incubating their young in their mouth, on their
back, or stomach.

Response: well developed nervous and sensory system.
1. Eyes move in socket and have a protective structure = nictitating membrane
   is a transparent membrane that covers the eye when the frog is in the water
2. Tympanic membrane = eardrums
3. Lateral Line systems = detect water movement (vibrations)
Amphibian’s characteristics

- Amphibians have a backbone. They are vertebrates.
- Amphibians are cold-blooded. They cannot regulate their own body temperature. Amphibians spend at least part of their lives in water and on land.
- Amphibians do not have scales and their skin is permeable (molecules and gases can pass through).
- Amphibians have gills for at least part of their lives. Some species have gills only as larvae, while others can have gills throughout their lives.
- Most amphibians go through metamorphosis. Amphibians are frogs, toads, salamanders, caecilians and newts. Some common amphibians are bullfrogs, American toads, mole salamanders and hellbenders.

Amphibian Taxonomy

Kingdom: Animalia  
Phylum: Chordata  
Subphylum: Vertebrata  
Class: Amphibia

1. Order Urodela (Salamanders and Newts) long bodies and tails, lives in moist woods. Mud puppy keeps gills and lives in water all their lives
2. Order Anura (Frogs and Toads) hop/jump with legs, adult has no tail
3. Order Apoda (Caecilians) legless with fishlike scales

ORDER 1. ANURA

This order Anura includes frogs and toads.

- They can live in water and on land.
- The fore limbs are small, the hind limbs are long.
- In the adult stage tail is absent
- They show a pair of eyes. Tympanic membranes.
- Their Life history includes a larval stage called tad-pole larva.

ORDER 2. URODELA

This order includes Salamanders and newts. These urodelans are more in North America. Hence North America is called Head Quarters of Urodela.

- The body is divisible into head, trunk and tail. Only in these amphibia tails is present. Hence these are called Urodela.
Amphibians and Reptiles

- The fore limbs and hind limbs are equal.
- The body’s not covered by scales.
- In some adults the gills are present.
- Some forms show neoteny and paedogenesis.

In North India only one species is available. Tilototriton venvcosa. In South India urodelan animals are absent. 1. Necturus 2. Proteus (Mud puppy). (Blind salamander) 3. Molge (Newt). 4. Amblystoma

ORDER 3. APODA

- These animals are limbless. Hence they me called Apoda.
- The body is long and snake like. Hence it is called gymnophiona. The body is divisible into head and hunk. Tail is absent
- On the head two eyes are present. They covered by skin and scales. Hence they are blind (Caecilians).
- Lungs are asymmetrical.
- The skin shows minute cycloid scales. In the male apoda animals copulatory organs present. 6) Fertilization is internal. 1. Ichthyophis (Limbless amphibian). 2. Gegenophis (Limbless amphibian). 3. Uraeotyphlus.

Parental Care in the Members of Class Amphibia

Amphibian include anurans, urodelans and apodans. In all these groups of amphibians we come across with a great deal of parental care. Amphibians show several mechanisms to protect their eggs and developing young ones because they lay few eggs. Parents protect the eggs and early developmental stages in two ways. 1) They construct nests 2) Direct Nursing. The female Ichthyophis glulinosa will dig a hole in the moist soil near a pond. It will deposit eggs in it. Around this egg mass, the mother will coil and protect the egg mass from the enemies.

Parental Care in Organisms of Urodela

In some urodela amphibians the eggs are very small. They hatch end directly develop into larva. In those organisms parental care is not required. a) Protection by Nests: - Salamandrella keyserlingi will construct a gelatinous bag like structure. It is attached to an aquatic plant below the water. In this bag eggs are stored. Thus they are protected by the Nest. ii) Autodax will lay eggs in a dry hole on the soil or in a hole on a free. The parents also live in the hole and protect the egg and the larvae developed from them. b) Direct Nursing by Parents I) Amphiuma, (Congo eel) The mother will coil around the eggs and protect them.

Parental Care in Anura Amphibians

In Anura amphibians the parental care is reached its peak. Many organisms will exhibit parental care. a) Protection by Nests: Many frogs and toads build nests in which the eggs are laid and developed. This is a primitive method of parental
Amphibians and Reptiles

NOTES

Self-Instructional Material

care. In these organisms the larva comes out in a very early embryonic stage which requires some kind of protection in the very early stages of development, hence the parent will build nests. i) Hyla Faber: - It is Brazilian free frog. The female will construct the nest in the shallow waters of a pond. The female will dig a hole of 8 to 10 cm depth. The mud which comes out of it is used by the female Hyla to construct a wall around the hole. This wall is raised above the level of water. Female Hyla will make the inner surface of this Nursery smooth and even the female will lay eggs in this nursery. The eggs and larval forms are protected inside this structure. ii) Rhacophorus malabaricus. It is called chunam frog. It lays eggs on the branches or leaves of a tree which will be hanging over a pond. These larvae after hatching from eggs will fall into the pond water and undergo metamorphosis.

Check Your Progress

1. What is herpetology?
2. Give examples of anura.
3. Give examples of urodela.

13.3 REPTILES

Reptiles do not form a distinct evolutionary group as birds and mammals do. Rather, the Class Reptilia consists of four orders which are very different from each other. For example, lizards are more closely related to birds than to turtles! As a result, reptiles are as easily defined by what they aren't as by what they are. Living species of the class Reptilia are placed in four orders. The order Testudines includes turtles, the order Squamata includes lizards and snakes, the order Crocodylia contains crocodiles and alligators, and the order Rhynchocephalia contains the lizard-like tuatars. As opposed to mammals and birds, reptiles have neither fur nor feathers, but scales. Reptiles cannot be confused with amphibians because reptiles have dry, water-proof skin and eggs, as well as internal fertilization and more advanced circulatory, respiratory, excretory, and nervous systems. Reptiles evolved from labyrinthodont amphibians 300 million years ago. The success of this terrestrial vertebrate group is due in large part to the evolution of shelled, large-yolked eggs in which the embryo has an independent water supply. This advance, as well as the development of internal fertilization, enabled reptiles to be the first vertebrates to sever their ties with water. They radiated out across the landscape, diversifying quickly and becoming the dominant life form on the planet during the Mesozoic Era, otherwise known as the age of the reptiles.
**Key Characteristics of Reptiles**

All living reptiles share certain fundamental characteristics, features they retain from the time when they replaced amphibians as the dominant terrestrial vertebrates. Among the most important are:

1. **Yolk Sac** provides food from the yolk for the embryo via blood vessels connecting to the embryo’s gut. The **allantois** surrounds a cavity into which waste products from the embryo are excreted. All modern reptiles (as well as birds and mammals) show exactly this same pattern of membranes within the egg. These three classes are called amniotes.

2. **Dry Skin.** Living amphibians have a moist skin and must remain in moist places to avoid drying out. Reptiles have dry, watertight skin. A layer of scales or armor covers their bodies, preventing water loss. These scales develop as surface cells fill with keratin, the same protein that forms claws, fingernails, hair, and bird feathers.

3. **Thoracic Breathing.** Amphibians breathe by squeezing their throat to pump air into their lungs; this limits their breathing capacity to the volume of their mouth. Reptiles developed pulmonary breathing, expanding and contracting the rib cage to suck air into the lungs and then force it out.

4. **The Circulatory System** of reptiles is improved over that of fish and amphibians, providing oxygen to the body more efficiently. The improvement is achieved by extending the septum within the heart from the atrium partway across the ventricle. This septum creates a partial wall that tends to lessen mixing of oxygen-poor blood with oxygen-rich blood within the ventricle. In crocodiles, the septum completely divides the ventricle, creating a four-chambered heart, just as it does in birds and mammals (and probably in dinosaurs).

5. All living reptiles are **ectothermic**, obtaining their heat from external sources. In contrast, **endothermic** animals are able to generate their heat internally. In addition, **homeothermic** animals have a constant body temperature, and **poikilothermic** animals have a body temperature that fluctuates with ambient temperature.

**Reproduction**

While the process of copulation and egg-laying differs slightly among reptiles, they share the ability to produce a large-yolked, shelled egg. This evolutionary innovation allowed them to dominate the terrestrial landscape for 100 million years. Some lizards and snakes have advanced a step further, evolving the ability to retain their eggs internally until they have hatched, and giving birth to fully developed young (this is called vivipary). Most reptiles, however, lay eggs which have leathery shells which are resistant to drying. Inside, the amnion encloses the embryo in a protected, moist environment in which nourishment is supplied by the yolk sac, and metabolic waste is stored by the allantois. Parental care is very rare in reptiles. In most species, the young are independent from the moment they’ve hatched.
Amphibians and Reptiles

NOTES

Poikilothermic

Reptiles are poikilothermic, which means that they cannot regulate heat internally (as opposed to birds and mammals which are homoeothermic). However, the name “cold blooded” is a misnomer, because reptiles can maintain high body temperatures by relying on external sources of heat. Reptiles bask in the sun to increase their body temperature or hide in their burrows or in water to cool down. At northern latitudes, during cold periods, reptiles are dormant from a few days to several months, their body processes slowed until temperatures increase.

Terrestrial Adaptations

- Dry, watertight skin covered by scales made of a protein called keratin to prevent desiccation (water loss)
- Toes with claws to dig and climb
- Geckos have toes modified into suction cups to aid climbing
- Snakes use scales & well-developed muscular & skeletal systems to move
- Lungs for respiration. Double circulation of blood through heart to increase oxygen to cells. Partial separation in ventricle to separate oxygenated & deoxygenated blood
- Ectothermic - body temperature controlled by environment
- May bask or lie in sun to raise body temperature or seek shade to lower body temperature; known as thermoregulation
- Water conserved as nitrogen wastes excreted in dry, paste-like form of uric acid crystals

Modern Reptiles

- Only 4 living orders remain
- Found worldwide except in coldest ecosystems
- Orders include —— Rhynchocephalia (tuatara lizard), Chelonia (turtles and tortoises), Squamata (lizards & snakes), and Crocodilia (alligators, caimans, and crocodiles)

1. Rhynchocephalia

- Only one living species, Sphenodon punctatus, (tuatara lizard) Live on islands off the coast of New Zealand
- Spiny crest running down back
- Grows up to 60 cm in length. Has 3rd eye on top of head (parietal eye) that acts as a thermostat
- Most active when temperatures are low (nocturnal)
Amphibians and Reptiles

2. Chelonia

- Includes turtles and tortoises
- Aquatic, but lay eggs on land
- Body covered with shell composed of hard plates and tough, leathery skin
- Carapace or dorsal surface of shell fused with vertebrae and ribs
- Plastron is ventral shell surface
- Shape of shell modified for habitat
- Dome shaped shell helps to retract head and limbs in tortoises

3. Crocodilia

- Includes crocodiles, alligators, caimans, and gavials
- Direct descendants of Archosaurs
- Carnivorous (wait for prey to come near & then aggressively attack)
- Eyes located on top of head so they can see when submerged
- Nostrils on top of snout to breathe in water
- Valve in back of mouth prevents water from entering airway when feeding underwater
- No parental care of young in most species except Nile crocodile that carry young in their jaws and guards nest
- Crocodiles are tropical or subtropical, usually nocturnal, reptiles found in Africa, Asia, South America and southern Florida

4. Squamata

- Includes snakes and lizards
- Snakes probably evolved from lizards during the Cretaceous period
- Snakes have 100-400 vertebrae each with a pair of ribs and attached muscles for movement
- Interaction of bone, muscles, and skin of snakes allows them 3 ways to move — lateral, rectilinear, and side winding

Lateral Undulations

- Most common
- Head moves side to side causing wave of muscular contractions
- Snake uses sides of its body to push off of ground
- Snake moves forward in S-shaped path
NOTES

**Rectilinear Movements**
- Muscular force applied to belly and not sides of snake
- Scutes or scales on belly catch on rough surfaces
- Body relaxes and then moves forward slowly

**Sidewinding**
- Used by some desert snakes
- Sideways movement of body
- Head vigorously flung from side to side
- Whiplike motion moves body along

**Swallow Prey Whole**
- Jaws unhinge for mouth to stretch
- Small teeth used to hold prey in mouth
- Windpipe thrust into throat while swallowing so snake can swallow and breathe
- Swallowing may take several hours
- Saliva begins digestion during swallowing
- Constrictors wrap body around prey and squeeze them to death (boas, pythons, etc.)

**Snakes May Inject Venom or Poison**

1. *Hemotoxin* - poisonous proteins attacking red blood cells (water moccasin and rattlesnake)
2. *Neurotoxin* - poison that works on nervous system affecting heart rate & breathing (copperhead)

Venomous snakes with 3 types of fangs — rear-fanged, front-fanged, & hinge-fanged snakes. Rear-fanged snakes bite prey and use grooved back teeth to guide venom into puncture (boomslang). Front-fanged snakes inject poison through 2 small front fangs that act like a hypodermic needle (cobra)

**Biting Mechanism in Snakes**

There are altogether more than 2600 species of snakes all over the world including the marine forms, and, out of which only 300 species are poisonous. Number of species diminishes progressively through the Polar Regions. In India, there are 330 species only and among them only 69 species are poisonous. As per record of the W.H.O., nearly 30000 to 40000 persons die of snake bite in the world every year. Biting mechanism: The biting apparatus taking part in the biting process are — 1. Poison glands 2. Poison ducts, and 3. Poison teeth or Fangs. Now, they are being described below in detail.
There is one pair of poison glands each one is situated on either side of the upper jaw. The poison glands are actually the parotid glands. Each poison gland is sac-like in appearance. They are held in position by some ligaments. With the help of anterior ligament, the gland is attached with the maxilla. The posterior ligament is present between the gland and the quadrate. In addition to these, fan-shaped ligaments are also situated between the side walls and squamosoquadrate junction. Each poison gland is provided with a narrow duct at its anterior portion which passes along the side of the upper jaw, loops over itself and finally opens at the base of the fang. There is one pair of fangs in the upper jaw. They are enlarged maxillary teeth which are very sharp and pointed. There is great power of regeneration (when lost for some reason). On the basis of structure and position, the fangs are of the following types:

1. **Proteroglyphous Type**: The fangs are comparatively small and they are present in front of the maxillae. The fang has a groove all along its anterior face. Examples: Cobra, Krait, Sea snakes and Coral snakes.

2. **Stenoglyphous Type**: The fangs are movable and turned inside. Poison canal runs through the fang and opens at the tip. Examples: Vipers and Rattle snakes.

3. **Opisthoglyphous Type**: The fangs are small and lie at the back portion of maxillae. The fang has a groove along its posterior face. Examples: Some colubrid snake (African tree snakes)

4. **Aglyphous type**: Aglyphous dentition is present in the non-poisonous snakes.

**Associated Bones and Muscles**

There are some important bones and muscles which are directly or indirectly associated with the mechanism of biting. In the skull, maxillae, quadrate, pterygoid, squamosals, ectopterygoids and palatines are movably articulated. Premaxillae are very much reduced. Sqamosals are loosely attached to cranium. The joint of quadrate and lower jaws acts as fulcrum. Quadrates are also loosely articulated with the cranium, pterygoid and lower jaw. Ectopterygoid is a transverse bone. The important muscles are Digastric muscle, Anterior and Posterior temporalis muscles and Protractor-Pterygoid or Sphenopterygoid muscle. In addition to these, there are two more muscles associated with the poison glands. These are Masseter muscle and Mandibular constrictor muscle. The gastric muscle is attached with the squamosal bone anteriorly and with the base of the lower jaw (articular) posteriorly. The Sphenopterygoid muscle is attached to the Sphenoidal region anteriorly and dorsal surface of the Pterygoid posteriorly. Anterior and Posterior temporalis muscles are attached to the side walls of the cranium and the lower jaw.

**Opening and Closing of Mouth (Process of Biting)**

(i) When the digastric muscle contracts, the mandible is lowered and the skull along with the upper jaws goes up. As a result, the mouth opens. (ii) The distal end of the quadrate is pushed forward which thrusts the pterygoid, palatine and transverse bar. (iii) Contraction of the Sphenopterygoid muscle also contributes to the above process.
and Pterygoid is pulled forward and ectopterygoid is pushed upward. (iv) The upward movement of ectopterygoid brings about a rotation of maxilla on its own axis and as a result fangs are erected. (v) The mouth closes by the contraction of anterior temporalis and pterygoid muscles. Fangs pierce into the skin of the victim. (vi) Muscles associated with the poison gland (masseter and mandibular) contract and the poison is squeezed into the body of the victim through the poison ducts and fangs.

**Snake Poison (Venom)** Snake venom is complicated mixture of many organic compounds, for example — Protcolysins, Cardiotoxins, Haemorrhagin, Neurotoxins and Antibactericidum etc. Various symptoms are shown by the victim of snake bite by different snakes. In the cobra bite the victim feels pain, weakness and difficult breathing. There is profuse salivation and frequent vomiting. The victim also becomes much lethargic. There is nervous breakdown also. In Krait venom the victim feels pain in abdomen, rest symptoms are like cobra. In the case of viper poison, swelling at the place of biting is very common, also rupture of endothelium, hemorrhage and blood clotting are very common signs. Low blood pressure and heart failure are also common. Some Common Poisonous Snakes 1. *Naja tripudians* 2. *Naja bungarus* (*Naja naja*) 3. *Bungarus fasciatus* 4. *Bungarus niger* Some Common Non Poisonous Snakes: However, many harmless-to-humans snakes, like *Hognose* snakes, *Garter snakes* and *Rat snakes* for example, do produce toxins that are scientifically or technically venomous. *Boas*, *pythons*, bull snakes and *king snakes* are examples of truly non-venomous snake species.

![Snake Mouth Diagram](image)

**Adaptations for Reptiles to Live on Land**

Reptiles separated from their water-dwelling ancestors and climbed onto land during the Paleozoic era, over 280 million years ago. When that era gave way to the Mesozoic, following a mass planetary extinction, reptiles survived and continued to evolve. They dominated the earth between 248 and 213 million years ago and live on today as modern-day snakes, turtles, lizards, crocodiles and even birds.
**Reptile Skin:** Reptile skin contains keratin, a water-resistant substance that maintains hydration. Reptiles also have scales to keep in moisture and help avoid skin damage, though the scales are sometimes too small to be visible. This feature is most evident in turtles, whose scales fuse to form a shell, while you can see a bird’s scales on its feet and in the form of feathers.

**Kidney:** Living on land means limited access to drinking water, so reptiles’ kidneys have adapted. They conserve water by producing less urine in more concentrated forms.

**Reproduction:** Laying soft-shelled eggs is safe in water, but land-dwelling creatures require a different reproductive strategy. Scientists think this is why reptiles evolved a hard shell around their eggs, and why some no longer lay eggs at all. In many types of snakes the eggs hatch internally, and babies are born live.

**Adapting Lungs:** In place of gills was a significant step in reptiles’ migration to land. While amphibians all have gills at some stage in their development, either temporarily during the larval stage or permanently through adulthood, reptiles are born with fully developed lungs.

**Basking:** For cold-blooded creatures on land, survival requires more than just physical changes. Since a reptile’s temperature depends on its surroundings, it basks on rocks to warm its blood for hunting. Without a place to bask, reptiles can’t get enough blood flow, as anyone who keeps reptiles as pets can verify. Reptiles kept in captivity must have access to warming lights and heat-absorbent surfaces to substitute for a natural basking environment.

**Legs:** Not all reptiles have legs now, but they all needed them to become land-dwelling creatures. This was once a topic for debate due to the legless nature of snakes. Though scientists knew that snakes once had legs, they could not determine whether they lost their limbs before or after migrating to land. Scientists at Penn State resolved this issue in 2004 by comparing DNA between snakes and their closest genetic relatives. They determined that snakes lost their legs after they left the water, possibly to enable their burrowing habits, but that snakes, like all reptiles, initially required legs to relocate to land habitats.

**Mesozoic Era: Age of the Dinosaurs**

The Mesozoic Era was the time from 248 million to 65 million years ago. During the Mesozoic, the Earth was very different than it is now. The climate was warmer, the seasons were very mild, the sea level was higher, and there was no polar ice. Even the shape of the continents on Earth was different; the continents were jammed together at the beginning of the Mesozoic Era, forming the supercontinent of Pangaea, but would start breaking apart toward the middle of the Mesozoic Era.

Toward the beginning of the Mesozoic Era there was a depleted ecosystem world-wide. Many of the old life forms had just gone extinct in the Permian Extinction, the world’s largest mass extinction. This depleted state was followed
by an explosion of new life forms, which included the dinosaurs and mammals, and later in the Mesozoic, the birds and flowering plants.

The dinosaurs and the mammals appeared during the Triassic period, roughly 225 million years ago. The dinosaurs went extinct 65 million years ago. The Mesozoic Era lasted about 180 million years, and is divided into three periods, the Triassic, the Jurassic, and the Cretaceous. Each of these periods is divided into many epochs and ages. Mesozoic means “Middle Animal” and is sometimes called the age of reptiles. The term Mesozoic was coined John Phillips in 1840.

The world’s life forms were very different during the Mesozoic than either before or after. During the Mesozoic, dinosaurs dominated the Earth. After the Mesozoic, the Cenozoic or the “Age of Mammals” began. Forty percent of the known dinosaurs date from the last 15 million years of the Cretaceous period.

The earliest period of the Mesozoic Era was the Triassic period (248 - 208 million years ago), in which the first small dinosaurs and mammals developed. The Triassic began after a major extinction had wiped out most of the life forms on Earth. The end of the Triassic was also marked by a worldwide extinction, although minor in comparison.

The second period was the Jurassic period (208-146 million years ago), in which the dinosaurs began to flourish. Giant sauropods appeared along with many other dinosaurs. The first primitive birds and flowering plants (angiosperms) appeared.

The third Mesozoic period was the Cretaceous period (146-65 million years ago), which saw the height of the dinosaurs and the development of flowering plants. It ended with another extinction and the demise of the dinosaurs and many other prehistoric animals.

Check Your Progress

4. What do you mean by poikilothermic?
5. Give examples of Chelonia.
6. What are Stenoglyphous type of fangs?
### 13.4 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. Herpetology is the study of reptiles and amphibians.
4. Reptiles are poikilothermic, which means that they cannot regulate heat internally (as opposed to birds and mammals which are homoeothermic).
5. Turtles and tortoises.
6. Stenoglyphous type: The fangs are movable and turned inside. Poison canal runs through the fang and opens at the tip. Examples: Vipers and Rattle snakes.

### 13.5 SUMMARY

- Amphibian means -double life.
- Amphibians are cold-blooded. They cannot regulate their own body temperature. Amphibians spend at least part of their lives in water and on land.
- Anura includes frogs and toads.
- Urodela order includes Salamanders and newts.
- Apoda are limbless.
- Parents protect the eggs and early developmental stages in two ways. 1) They construct nests 2) Direct Nursing.
- Reptiles do not form a distinct evolutionary group as birds and mammals do. Rather, the Class Reptilia consists of four orders which are very different from each other.
- While the process of copulation and egg-laying differs slightly among reptiles, they share the ability to produce a large-yolked, shelled egg.
- Reptiles are poikilothermic, which means that they cannot regulate heat internally (as opposed to birds and mammals which are homoeothermic).
- Rhyncocephalia (tuatara lizard), Chelonia (turtles & tortoises), Squamata (lizards & snakes), & Crocodilia (alligators, caimans, and crocodiles).
13.6 KEY WORDS

- **Amphibian**: A cold-blooded vertebrate animal of a class that comprises the frogs, toads, newts, salamanders, and caecilians. They are distinguished by having an aquatic gill-breathing larval stage followed (typically) by a terrestrial lung-breathing adult stage.

- **Reptile**: A vertebrate animal of a class that includes snakes, lizards, crocodiles, turtles, and tortoises. They are distinguished by having a dry scaly skin and typically laying soft-shelled eggs on land.

13.7 SELF ASSESSMENT QUESTIONS AND EXERCISES

**Short-Answer Questions**

1. Write a short note on the history of amphibians.
2. Discuss parental care in Anura amphibians.
3. What are terrestrial adaptations of reptiles?

**Long-Answer Questions**

1. Discuss form and functions in amphibians.
2. Explain characteristics of amphibians.
3. Explain characteristics of reptiles.

13.7 FURTHER READINGS


UNIT 14 AVES AND MAMMALS

Structure
14.0 Introduction
14.1 Objectives
14.2 Aves
14.2.1 Classification of Aves
14.2.2 How Birds Fly-Flight -Adaptations in Birds
14.2.3 Bird Migration
14.3 Class Mammalia
14.3.1 Main Characteristics of Mammals
14.3.2 Classification of Mammals
14.3.3 General Classification of Mammals
14.3.4 Aquatic Adaptations
14.4 Answers to Check Your Progress Questions
14.5 Summary
14.6 Key Words
14.7 Self Assessment Questions and Exercises
14.8 Further Readings

14.0 INTRODUCTION

In this unit, you will learn about aves and mammals in detail. The vertebrate class Aves includes the birds, an extremely distinctive and successful clade, with an estimated 9000 species worldwide, including the snowy owl pictured here. Although descended from the dinosaurs, birds have evolved remarkable specializations for flight: a unique one-way breathing system, light yet strong hollow bones, a skeleton in which many bones are fused or lost, powerful flight muscles, and — most importantly — feathers.

Mammals are vertebrate animals constituting the class Mammalia, and characterized by the presence of mammary glands which in females produce milk for feeding (nursing) their young, a neocortex (a region of the brain), fur or hair, and three middle ear bones. These characteristics distinguish them from reptiles and birds, from which they diverged in the late Triassic, 201-227 million years ago. There are around 5,450 species of mammals. The largest orders are the rodents, bats and Soricomorpha (shrews and others). The next three are the Primates (humans, apes, monkeys, and others), the Cetartiodactyla (whales and even-toed ungulates), and the Carnivora (cats, dogs, seals, and others).
14.1 OBJECTIVES

After going through this unit, you will be able to:

- Define and discuss Aves and Mammals
- Know about classes of Aves and Mammals
- Learn about adaptive behavior of Aves and Mammals

14.2 AVES

General Characteristics

- Presence of feather, beak and forelimb in form of wing.
- Hind limb adapted to clasping, walking and swimming.
- No glands on skin (only oil gland at tail base).
- Hollow bones (pneumatic).
- Air sacs connected to lungs to supplement respiration.
- Crop and gizzard are additional chambers in digestive system.
- Warm blooded. - Heart four chambered.
- Sexes separate. - Fertilisation internal and development direct. - E.g. 
  *Columba, Psittacula* etc.

14.2.1 Classification of Aves

Subclass ARCHAEORNITHES (Ancient Birds)

Order Archaeopterygiformes, *Archaeopteryx*; *Archaeornis*. Extinct

Fossil birds as connecting link between reptiles & birds. Skull rounded like birds; feathers on wings and tail; pelvis and fore and hind limb bones bird-like. Tail long, without pygostyle; bones not pneumatic; thecodont teeth; amphicoelous vertebrae; ribs without uncinate process; tibia and fibula separate; all digits with claws.

Subclass NEORNITHES (True Birds)

Superorder ODONTOGNATHAE (Toothed birds)

1. Order Hesperornithiformes, *Hesperornis*. Extinct

Duck like, flightless swimming birds with webbed toes and thecodont teeth in jaws; keel and furcula absent; skull bones fused; heterocelous vertebrae; wings reduced, incapable of flight; found in cretaceous period; body 90 cm long.
   Gull-like flying birds with few teeth and fish-catching beak; keel and furcula present; vertebrae amphicoelous; carpometacarpus formed in fore limb; body 20 cm long.

**Superorder PALEOGNATHAE (=RATITAE)**

   Head and neck without feathers; feet with two toes; height up to ten feet and weight up to 150 kg; male incubates eggs.

   Head and neck feathered; feet with 3 toes, webbed at base; smaller than African ostrich; eggs lemon yellow, incubated by male.

3. **Order Casuariformes**, Emu (*Dromaeus novohollandae*), Cassowary (*Casuarius casuarius*), found in Australia and New Guinea. 4 species.
   Brownish colour; 180 cm tall; aftershaft on feathers; monogamous; cassowaries are brightly colored with horny helmet on the head.

4. **Order Apterygiformes**, Kiwi (*Apteryx australis; A. hoasti; A. oweni*).
   New Zealand. Feathers hair-like; wings reduced; tail absent; long beak with nostrils at the tip; acute sense of smell; nocturnal and burrowing birds; lay one egg at a time in burrows.

5. **Order Tinamiformes**, Tinamous (*Eudromea elegans; Crypturellus variegatus*). found in South America, south of Mexico; 50 species. Partridge-like birds, cryptically coloured; not tail; can fly short distances; keel present; palate paleognathous; male incubates eggs which are laid in a nest on ground.

6. **Order Dinornithiformes**, Moa (*Dinornis*). **Extinct** in 13th century in New Zealand. Twelve feet tall; stout birds with long neck and legs; wings rudimentary; 3 clawed digits on feet.

7. **Order Aepyornithiformes**, Elephant birds (*Aepyornis; Mullerornis*). **Extinct**. Lived in Madagascar nearly 2000 years ago; height 7-10 feet; body heavily built; legs long and stout with 4 toes; wings rudimentary; eggs 30 cm long.

8. **Order Diatrymiformes**, Diatryma. **Extinct** in USA, France, Britain. Seven feet tall birds with massive head and sharp tearing beak; hallux small; pelvis large; preyed upon small mammals that they ran down.
Superorder IMPENNAE

1. Order Sphenisciformes, Penguins (*Spheniscus; Aptenodytes; Eudyptes*), 15 species. Found in southern hemisphere and Antarctica; body streamlined; feather compact, scalelike; fatty insulating layer under the skin; air sacs absent; wings modified, paddle-like for swimming; toes webbed for swimming; beak fish-eating; one egg laid at a time which is incubated on the feet; gregarious.

Superorder NEOGNATHAE (=CARINATAE)

1. Order Gaviiformes, Divers and loons. Aquatic birds that catch fish and crustaceans by diving; toes webbed; legs short and set far back; migratory. There are two species, *Gavia arctica* and *G. stellata* recorded in India.

2. Order Podicipitiformes, Grebes (*Podiceps, Podilymbus*). 17 species. Aquatic birds with rudimentary tail; bill compressed, pointed; front toes with broad lateral vane-like lobes; nails broad and flattened; feed on fish and crustaceans. Migratory.

3. Order Procellariformes, Albatross (*Diomedea*), Shearwater (*Puffinus*). 81 species. Ocean birds with a wing span up to 11 feet; beak long, hooked at tip; wings narrow, long and pointed; feet webbed with strong hind claw; tail short and rounded; hallux reduced or absent; soaring and migratory birds.

4. Order Pelecaniformes, Pelicans, cormorants, frigate birds. 50 species. Large birds with short legs and large webbed toes; upper mandible flattened and hooked at tip; lower mandible has a pouch of loose skin; tail short; food mainly fish.

5. Order Ciconiiformes, Herons, Egrets, Storks, Flamingos. 117 species. Long legs and long slender, flexible neck; bill long straight, sharp and dagger-like; middle and outer toes webbed at base; many migratory.

6. Order Anseriformes, Ducks, Swans, Geese, Teals, Pochards. 149 species. Large conspicuous water birds; bill broad, flat with comb-like margin for straining food particles; wings usually narrow and pointed; tail short; feet webbed; tongue thick and fleshy; migratory.

7. Order Falconiformes, Vultures, Kite, Eagle, Buzzard, Hawk, Falcons. 274 species. Birds of prey; beak short, upper mandible longer and hooked at tip for tearing flesh; feet strong and powerful, with hooked claws; hallus strong; predators or scavengers.

8. Order Galliformes, Game birds, Megapods, Patridges, Quail, Turkey, Hoatzins, Guinea Fowl, Fowls, Peacocks, Pheasants. 240 species. Terrestrial; legs stout and unfeathered; hind tarsus with a spur in male; claws short, strong and blunt; beak short and stout; legs adapted for running.
<table>
<thead>
<tr>
<th>Order</th>
<th>Examples</th>
<th>Species</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>9. Order Gruiformes</td>
<td>Crane, Rail, Bustard</td>
<td>185</td>
<td>Small to large ground birds or shore birds; hallux absent; keel is reduced; have weak power of flight; slight web on toes; feed on fish, reptiles and mollusks.</td>
</tr>
<tr>
<td>10. Order Charadriiformes</td>
<td>Plovers, Lapwings, Sandpipers, Pranticole, Gulls, Terns.</td>
<td>293</td>
<td>Waders and good fliers; beak variously modified; hallux small or absent; anterior toes webbed; terns have forked tail and short legs; feed on fish.</td>
</tr>
<tr>
<td>11. Order Columbiformes</td>
<td>Pigeons, Doves, Sandgrouse, Dodo.</td>
<td>301</td>
<td>Grain or fruit-eating birds; slender beak; legs for perching; eggs pure white; youngs are fed on milky food produced in crop; base of beak covered with a soft swollen membrane in which lie the nostrils.</td>
</tr>
<tr>
<td>12. Order Psittaciformes</td>
<td>Parrots, Macaws, Cocatoo, Parakeet.</td>
<td>317</td>
<td>Fruit eating birds; bills stout and strongly hooked; upper mandible movable; tongue thick and fleshy; feet zygodactylous; tail pointed.</td>
</tr>
<tr>
<td>13. Order Cuculiformes</td>
<td>Cuckoo, Koel, Brainfever bird, Crow-pheasant.</td>
<td>143</td>
<td>Feet zygodactylous; young do not grow down feathers; brood parasitic; lay their eggs in the nest of other birds; wings long and pointed; migratory.</td>
</tr>
<tr>
<td>14. Order Strigiformes</td>
<td>Owls (Bubo, Strix, Nyctea, Tyto).</td>
<td>132</td>
<td>Nocturnal birds of prey hunting small mammals and reptiles; eyes large, directed forward; upper eyelid large; beak short and hooked; sharp; ear opening large; neck highly flexible; fight soundless.</td>
</tr>
<tr>
<td>15. Order Caprimulgiformes</td>
<td>Nightjars, Oil birds, Frogmouths.</td>
<td>92</td>
<td>Bill short, flexible with enormous gape; wings long; bristles around nostrils; nocturnal birds, feeding on insects on wing; eggs are laid on ground in a bush.</td>
</tr>
<tr>
<td>16. Order Apodiformes (=Micropodiformes)</td>
<td>Swifts, Hummigbirds.</td>
<td>388</td>
<td>Gregarious, insectivorous birds, adapted for rapid flight; wings long and narrow; tail short and deeply forked; gape of mouth very large; beak short and hooked; feet with-4 toes, all directed forward; legs weak; capable of flying backward.</td>
</tr>
<tr>
<td>19. Order Coraciiformes</td>
<td>Kingfishes, Bee-eaters, Rollers, Hoopoe, Hornbill.</td>
<td>192</td>
<td>Three front toes are joined at base; beak long heavy and sharply pointed; nest is built in tree hole; highly variable species.</td>
</tr>
</tbody>
</table>
20. Order **Piciformes**, Woodpeckers, Honey guide, Toucans. 377 species. Insectivorous; birds, adapted for climbing on tree trunks; feet zygodactylous; beak strong adapted for wood cutting; tongue very long, armed with spines at tip; tail feathers strong to support the body; eggs are laid in tree hole.

21. Order **Passeriformes**, Perching birds. Pitta, Flycatchers, Lyre-birds, Skylarks, Swallows, Wagtails, Shrikes, Bulbul, Wren, Babblers, Warblers, Tailor-birds, Nightingale, Tit, Nuthatch, Sunbirds, Tanager, Starlings, Grackle, Oriole, Drongo, Magpie, Jay. 5,110 species. More than half of total number of bird species are included in this order. Feet adapted for perching; front toes are free and hallux long and movable; highly variable species, adapted for various habitats.

### 14.2.2 How Birds Fly - Flight - Adaptations in Birds

One of the requirements for heavier-than-air flying machines is a structure that combines strength with light weight. This is true for birds as well as planes. Birds have many physical features, besides wings, that work together to enable them to fly. They need lightweight, streamlined, rigid structures for flight. The four forces of flight – weight, lift, drag and thrust – affect the flight of birds.

#### Physical Features

Flying birds have:
- lightweight, smooth feathers – this reduces the forces of weight and drag
- a beak, instead of heavy, bony jaws and teeth – this reduces the force of weight
- an enlarged breastbone called a sternum for flight muscle attachment – this helps with the force of thrust
- light bones – a bird’s bones are basically hollow with air sacs and thin, tiny cross pieces to make bones stronger – this reduces the force of weight
- a rigid skeleton to provide firm attachments for powerful flight muscles – this helps with the force of thrust
- a streamlined body – this helps reduce the force of drag
- Wings – these enable the force of lift.

#### Wings

The shape of a bird’s wing is important for producing lift. The increased speed over a curved, larger wing area creates a longer path of air. This means the air is moving more quickly over the top surface of the wing, reducing air pressure on the top of the wing and creating lift. Also, the angle of the wing (tilted) deflects air downwards, causing a reaction force in the opposite direction and creating lift.
Larger wings produce greater lift than smaller wings. So smaller-winged birds (and planes) need to fly faster to maintain the same lift as those with larger wings. Wing loading tells you how fast a bird or plane must fly to be able to maintain lift: wing loading = weight/wing area (kilograms per square metre). A smaller wing loading number means the bird/plane can fly more slowly while still maintaining lift and is more manoeuvrable.

**Gliding**

When a bird is gliding, it doesn’t have to do any work. The wings are held out to the side of the body and do not flap. As the wings move through the air, they are held at a slight angle, which deflects the air downwards and causes a reaction in the opposite direction, which is lift. But there is also drag (air resistance) on the bird’s body, so every now and then, the bird has to tilt forward and go into a slight dive so that it can maintain forward speed.

**Soaring**

Soaring flight is a special kind of glide in which the bird flies in a rising air current (called a thermal). Because the air is rising, the bird can maintain its height relative to the ground. The albatross uses this type of soaring to support its multi-year voyages at sea.

**Flapping**

Birds’ wings flap with an up-and-down motion. This propels them forward. The entire wingspan has to be at the right angle of attack, which means the wings have to twist (and do so automatically) with each downward stroke to keep aligned with the direction of travel.

Different birds have different adaptive features to meet their flight needs:

- Some birds are small and can manipulate their wings and tail to manoeuvre easily, such as the fantail (piwakawaka).
- The hawk, with its large wingspan, is capable of speed and soaring.
- Gannets and seabirds are streamlined to dive at high speeds into the ocean for fish.
- Godwits, although small, are equipped to fly long distances.

**More Adaptations**

- Light in weight, light bones. Feathers, wings for flight.
- Hollow bones.
- Streamline body.
- No urinary bladder.
- Air Sacs, respiratory adaptations.
Adaptations Body Shape

Birds have short, light and compact body as compared to other animals. Most organs and large muscles are located near the center of gravity, which is slightly below and behind the wings to provide better balance during flight.

Feathers

Contour feathers cover the body and make it streamlined and decrease drag. Down feathers and soft and meant for insulation. Primary feathers are on the wings and are also called remiges, which help in flight and also provide wing shape. Tail feathers are called rectrices which stretch sideways so that tail can be used like a rudder for turning and balancing.

Skeleton

The evolution of flight has endowed birds with many physical features in addition to wings and feathers. One way to reduce weight in birds is by the fusion and elimination of some unnecessary bones and the pneumatization of the remaining ones. Not only are some bones of birds hollow but many of the larger ones are connected to the air sacs of the respiratory system.

Metabolism

Birds have high metabolism and endothermy for quick generation of power and for maintenance of high body temperature. Birds require large amounts of energy for flight, and need efficient oxygen circulation in high altitudes. The highest flight recorded for a bird was 11,274 m (37,000 ft.) when a Ruppell’s griffon vulture collided into a commercial airline over western Africa (Martin, 1987). Birds normally maintain a body temperature of 38.0°C to 42.0°C (100.4°F-107.6°F) (Brooke and Birkhead, 1991).

Respiratory System

The respiratory system of birds is adapted to the energy demands of flight. A bird’s respiratory system is proportionately larger and much more efficient than in other animals, since flight is a more demanding activity than walking or running. An average bird’s respiratory system occupies about one-fifth of its body volume, while in an average mammal it is only about one-twentieth. Lungs of birds are less flexible, and relatively small, but they are interconnected with a system of large, thin-walled air sacs in the front and in the posterior portions of body.

14.2.3 Bird Migration

Bird migration refers to the regular (and often seasonal) journeys to and from a given area undertaken by all or part of a bird population. Not all bird species (or even populations within the same species) are migratory. In contrast to more
irregular movements such as emigration, nomadism, and invasion, which are made in response to changes in food availability, habitat, or weather, bird migration is marked by its cyclical pattern. The most common pattern among the migratory birds of Europe and North America involves flying north to breed in the temperate or arctic summer and returning to wintering grounds in warmer regions to the south. However, other patterns of migration have been observed: In tropical regions, for example, some species migrate in response to the cycle of wet and dry seasons. In mountainous areas, like the Himalayas, vertical movements may occur from higher breeding grounds to lower altitudes with less exposure to harsh winter weather.

**Why Do Birds Migrate?**

Birds migrate to move from areas of low or decreasing resources to areas of high or increasing resources. The two primary resources being sought are food and nesting locations. Birds that nest in the Northern Hemisphere tend to migrate northward in the spring to take advantage of burgeoning insect populations, budding plants and an abundance of nesting locations. As winter approaches and the availability of insects and other food drops, the birds move south again. Escaping the cold is a motivating factor but many species, including hummingbirds, can withstand freezing temperatures as long as an adequate supply of food is available.

**Different Types of Bird Migration**

While the exact birds that participate in different migration patterns can be subject to interpretation and may gradually change as migration patterns evolve, the most common migrations include:

- **Seasonal**: This well-known and widespread migration is predictable based on seasonal changes, as birds move between breeding and non-breeding ranges. The height of these migration periods are during spring and fall, though in some areas the change between wet and dry seasons are migration indicators.
- **Latitudinal**: This migration is between areas of different latitudes from north to south and vice versa. This is the most common migration type with many neotropical migrants. The exact direction of migration is often determined by geographic features, however, such as mountain ranges and available habitats.
- **Longitudinal**: Similar to latitudinal migration, this type of movement is a change between different longitudes from east to west or west to east. This is a common type of migration for many birds in Europe, where geographic features encourage birds to move longitudinally rather than latitudinally.
- **Altitudinal**: Birds that breed in tall mountains often exhibit altitudinal migration. This type of migration is the move to lower elevations in winter,
when harsh weather and deep snowfall may make staying at upper elevations impossible. Birds that use altitudinal migration may not venture far in terms of overall mileage, but just a few hundred feet of elevation can make a great difference in habitats.

- **Loop**: Birds that follow an annual circle are loop migrants. This migration includes two distinctly different routes to and from breeding grounds, often taking advantage of varied resources at different times of the year. For example, rufous hummingbirds follow a coastal route in spring on their way from Mexico to Alaska, but take advantage of mountain wildflowers on an interior southbound route in autumn. Loop migration is also common with many seabirds and shorebirds as they use seasonal variations in wind patterns to aid their flight.

- **Nomadic**: This movement is less predictable and can be erratic depending on available food and water resources. Nomadic birds tend to stay within the same range but may be completely absent from parts of that range when resources are scarce, but will return when the habitat becomes more suitable. Types of birds that migrate nomadically include waxwings, phainopeplas, zebra finches and black swans.

- **Irruptive**: Bird irruptions are highly unpredictable but spectacular migrations that bring large numbers of birds into unusual areas, most often in winter. Unlike nomads, irruptive birds may be found far outside their expected ranges during this type of migration, but the reason is the same – the search for suitable food and water resources. Types of migrating birds that exhibit irruptive patterns include redpolls, varied thrushes, evening grosbeaks, crossbills and snowy owls.

- **Dispersal**: While not always considered a true migration, bird dispersal is nonetheless relatively predictable and seasonal, though only once a year. In this migration, juvenile birds are forced away from their hatching grounds and must seek out their own territories as their parents continue to use the same range. This is more common among birds that are year-round residents of the same range and will defend their territories throughout the year, such as woodpeckers.

### Advantages of Migration in Birds

- **Food**: There are many reasons for participating in game farming. It can be an enjoyable hobby and means of increasing bird population (Ralph et al., 2007). Wild game may have a different flavor and texture than domestic meat. But wild game can be delicious if properly prepared.

- **Ornament**: Neanderthals exploited birds for the use of the feathers or claws as personal ornaments (Finlayson et al., 2012). Many bird species display
elaborate ornaments including feather structures such as facial plumes, crests, and tail streamers and bare part ornaments such as bill plates, knobs and wattles during their breeding seasons.

- **Recreation and Tourism**: Nature based tourism and recreation, such as the viewing of wildlife, is popular and often occurs in protected areas (Newsome al., 2002; Higginbottom, 2004). This is a common benefit of birds. Game viewing attracts people to conservation areas for complete relaxation. Many migratory birds.

- **Production of Oil**: Production of oil Game birds are capable of synthesizing oil. Nutritional Information for 3 ounces of raw wild game reviewed that game bird ranging from 103 to 188 calories is capable of producing 2-9g fat and 1-2g saturated fat (Nash, 2003).

- **Conclusion**: Birds form one of the common examples of migratory animals. In turn the huge numbers of migratory birds represent an important component of the food chain whether, native or non-native species. Their beautiful plumage, crests, tail streamers, bill plates and wattles contributes to uniqueness of birds existence during breeding seasons making, bird species an excellent source of recreation that is capable of generating millions of dollars for nations due their diverse nature and distribution.

### Check Your Progress

1. What are physical features of flying birds?
2. Why wings are important?

### 14.3 CLASS MAMMALIA

Mammals are defined as vertebrates that possess hairs and mammary glands for feeding young. They also possess a four-chambered heart, a large cerebral cortex, and three distinctive bones: incus, malleus and stapes in the middle ear, a diaphragm for breathing, heterodont and thecodont dentition, limbs attached under the body, dicondylic skull and acoelous vertebrae. The class Mammalia is classified into three subclasses, 28 Orders, 161 Families, 747 Genera and 4939 Species

#### 14.3.1 Main Characteristics of Mammals

- **Endothermy**: - maintain high, constant body temperature through their metabolism
- **Pelage**: - hair or fur made of protein called keratin covering all or part of the body for insulation and camouflage
• **Four Chambered Heart** (two atria and two ventricles) keep oxygenated & deoxygenated blood from mixing; double circulation
• **Mammary Glands** in females are modified sweat glands that make milk containing sugars, proteins and fats to nourish young
• **Single Jawbone**
• **Specialized Teeth** for biting, cutting and chewing
• **Highly Developed Brain** (large cerebrum)
• **Diaphragm** - muscle below lungs that aids respiration
• Most are **Viviparous** (live birth)
• **Uterus** in females where young develop
• **Placenta** lines uterus and provides nutrients and gas and waste exchange for developing young
• **Have sweat glands** for cooling and **scent glands** for attracting mates and marking territories

### 14.3.2 Classification of Mammals

Mammals are the largest class in the animal world. Mammals are of different types and can be distinguished into marine mammals, smaller mammals and larger mammals. Mammals belong to the class mammalia. Since mammals are of different types they are classified into three subclass based on their reproduction. They are 1. Eutheria, 2. Metatheria and 3. Prototheria.

#### 1. Eutheria

Mammals that give birth to their young ones directly belong to the subclass Eutheria. The young ones form as an embryo in the mother stomach and grow there for a certain period of time. This subclass consists of 19 orders. Best example and well known of this class are humans, dogs and cats.

- Insectivora (moles, shrews)
- Dermoptera (flying lemurs)
- Chiroptera (bats)
- Cetacea (whales)
- Carnivora (cats, bears, dogs, otters, seals, sea lions)
- Tubulidentata (aardvarks)
- Proboscidea (elephants)
- Hyaenidae (hyraxes)
- Primates (monkeys, lemurs, bush babies, aye-ayes)
Aves and Mammals

- Xenarthra or Edentata (armadillos, anteaters, sloths)
- Pholidota (pangolins)
- Lagomorpha (rabbits, hares, pikas)
- Rodentia (mice, rats, squirrels, porcupines, beavers, voles, hamsters)
- Sirenia (manatees, dugongs)
- Perissodactyla (horses, donkeys, zebras, rhinoceroses, tapirs)
- Artiodactyla (pronghorns, deer, camels, gazas, goats, giraffes, hippopotami, pigs, peccaries, chevrotains, musk-deer, cows)
- Scandentia (tree shrews)
- Macroscelidea (Elephant)

2. Metatheria

Mammals that belong to this subclass also give birth to their young ones but the young ones are born immature. So they jump into their mother pouch and stay there till they are mature. Metatheria subclass contains seven orders with 250 species. Marsupials and kangaroo are the best example for this subclass.

- Didelphimorphia (New World opossums)
- Paucituberculata (South American rat opossums)
- Microbiotheria (colocolo)
- Dasyuromorphia (dasyurids, thylacines)
- Peramelemorphia (bandicoots)
- Notoryctemorphia (marsupial moles)
- Diprotodontia (kangaroos, koalas, wombats, possums)

3. Prototheria

Prototheria consists of egg laying animals and are also known as monotremes. This subclass consists of six species all in one order. Monotremata (platypus and echidna)

14.3.3 General Classification of Mammals

Although mammals are classified in to class, subclass, and order the scientist have classified on the general basis. This general classification makes it easy to learn about the mammals’ class and their distinguished features.

Animals

- Lion
- Tiger
- Dog
Order Marsupials
- Found in New Guinea, Australia, & the Americas
- Dominate animal in Australia due to lack of competition from placental mammals
- Known as pouched animals
- Pouch called marsupium
- Viviparous (live birth)
- Tiny, immature young must crawl to mother’s pouch after birth
- Young attach to mammary gland nipple to nurse until able to survive outside of pouch
- Includes opossum, kangaroo, wombat and koala

Order Primates
- Chimpanzee
- Gorilla
- Monkey
- Orangutan
- Lemur

Order Rodents
- Largest mammal order (40% of all species)
- Found everywhere except Antarctica
- Includes squirrels, chipmunks, gophers, rats, mice and porcupines
- Have two instead of four incisors
- Teeth continue to grow throughout their life
- Feed on hard seeds, twigs, roots and bark
- Gnawing keeps incisors sharp
- High reproductive capacity
- Guinea pig and capybaras are two rodents found in South America
- Squirrels, Mice and Porcupines

Order Lagomorphs
- Includes rabbits, hares and pikas
- Found worldwide
• Have a double row of upper incisors and two large front teeth backed up by two smaller teeth
• Continuous growing teeth
• Herbivores

**Order Cetaceans**
• Whales, Dolphins

**Order Carnivore**
• Found worldwide
• Includes **cats, dogs, raccoons, bears, hyenas, & otters**
• Meat eaters (**carnivores**) mainly
• Many feed on both plants and animals (**omnivores**)
• Have **long canine teeth** and strong jaws
• **Clawed toes** for seizing and holding prey
• Keen sense of sight and smell
• Long limbs for running fast

**Order Primates**
• Includes 2 main groups — Prosimians and Anthropoids
• Most are omnivores
• Have teeth suitable for a varied diet
• Prosimians include lemurs, tarsiers, and lorises
• Anthropoids include monkeys, apes, and humans
• Anthropoids have a larger brain
• Show more complex behaviors than other animals
• Highly organized social groups. Gorilla is the largest primate
• Have 2 forward-facing eyes for depth perception
• Have grasping hands and most with grasping feet
• Some have a grasping tail for life in trees
• Live in a variety of habitats

**Other Mammals**
• Seals
• Seal Lions
• Warlus
Mammals are primarily terrestrial animals. However, some of them have adopted an aquatic mode of life. The aquatic mammals have evolved from terrestrial mammals. The fact that all of them are not gill-breathers but breathe air through lungs, indicate their original terrestrial mode of life.

All the aquatic mammals are really terrestrial lung-breathing forms which have reverted to an aquatic life, and they have done so with remarkable success, the whales being the most successful. They have reverted to water probably because of extreme competition on land for food and shelter.

There are several aquatic mammals. Aquatic mammals belong to several orders of Mammalia.

Depending on the degree for aquatic adaptation the aquatic mammals have been divided into the following categories:

1. Amphibious Mammals

These mammals do not live permanently in water. They live on land but go into water for food and shelter. They show only partial aquatic adaptations such as:
   (i) Small external ears,
   (ii) Webbed feet,
   (iii) Flattened nails,
   (iv) Subcutaneous fat.

The mammals of this category include the beaver (Castor), musk rat (Ondatra), nutria (Myocaster), otter (Lutra), mink (Mustela) and many others. The amphibious mammals belong to several orders of mammalia such as Carnivora, Rodentia, Artiodactyla, Marsupialia, Monotremata, etc.

2. Aquatic Mammals

The mammals under this category spend most of the time in water and usually come to land for reproduction. The typical examples are seals and hippopotamus.

3. Marine Mammals

These mammals never come to land and are perfectly at home in water. The typical examples are whales.

14.3.4 Aquatic Adaptations

The adaptations or specialisations of truly aquatic mammals (Cetacea and Sirenia) are divided into 3 major categories:

A. Modifications of original structures,
B. Loss of structures, and
C. Development of new structures.
A. Modifications of Original Structures

1. Body Shape

In aquatic mammals, body shape is of prime importance. The external fish-like form, elongated head, indistinct neck and tapering streamlined body offers little resistance and swims rapidly through water.

2. Large Size and Weight

In aquatic mammals, the large size and body weight help the aquatic mammals. Whalebone whale may grow up to 35 meters in length and weigh about 150 tons. Large size reduces skin friction and loss of heat, but creates no problem for support in water due to buoyancy.

3. Flippers

In aquatic mammals, the forelimbs are transformed into skin-covered, un-jointed paddles or flippers, having no separate indication of fingers. These paddles or flippers can move as a whole only at the shoulder joint. The broad and flattened paddles or flippers serve as balancers and provide stability during swimming.

4. Hyperdactyly and Hyperphalangy

In aquatic mammals, extra digits (hyperdactyly) and extra phalanges (hyperphalangy) up to 14 or more in some forms, serve to increase the surface area of flippers for greater utility for swimming in water.

5. High and Valvular Nostrils

In aquatic mammals, the nostrils are placed far back on the top of head so that animal can breathe air without raising head much out of water. The nostrils can also be closed by valves during diving under water.

6. Mammary Ducts

In aquatic mammals, during lactation, ducts of mammary glands dilate to form large reservoirs of milk, which is pumped directly into mouth of young by the action of special compressor muscle. This arrangement facilitates suckling of young under water.

7. Oblique Diaphragm

In aquatic mammals, oblique diaphragm makes the thoracic cavity larger dorsal and barrel-shaped for providing more space to lungs for expansion.

8. Large Lungs

In aquatic mammals, large unlobulated and highly elastic lungs ensure taking down maximum air for submergence. Like swim bladders of fishes, the dorsal lungs also serve as hydrostatic organs in maintaining a horizontal posture during swimming.
9. Intra-Narial Epiglottis

In aquatic mammals, elongated, tubular and intra-narial epiglottis, when embraced by the soft palate, provides a continuous and separate air-passage, thus, allowing breathing and feeding simultaneously.

10. Endoskeleton

In aquatic mammals, the cranium becomes small but wider to accommodate the short and wide brain. The facial part of skull projects forming elongated snout or rostrum.

The zygomatic arches are reduced. Due to reduced neck, the cervical vertebrae are fused into a solid bony mass. Zygaphyses are reduced. Sacrum is also reduced. Ribs become arched dorsally to increase thoracic cavity. Bones are light and spongy. In Cetacea, bones are filled with oil.

11. Teeth

In toothed whales, teeth are monophyodont, homodont and numerous, as many as 250. This helps in capturing or seizing prey, prevent its escape and swallowing it without mastication. Usually, the mobility of jaws is reduced as they have no function in mastication.

B. Loss of Structures

In aquatic mammals, there is a loss of a few structures which are usually present in other mammals.

These are as follows:

1. There is a loss of hairs. Skin surface usually remains smooth and glistening due to loss of hairs except for a few sensory bristles on snout or lips in some cases.
2. Pinnae are also absent. Presence of hairs and pinnae may obstruct or impede the ever flow of water over body surface and interfere with the speed and elegance of movement through water.
3. Nictitating membranes, eye cleansing glands, lacrimal glands and all kinds of skin glands (sweat and sebaceous) are also absent because they would have been useless under water.
4. Skin loses its muscles and nerves due to thickening and immobility.
5. Hind limbs are represented only by button-like knobs in the foetus but disappear in the adult.
6. Pelvis is also rudimentary.
7. Fingernails are absent except for traces in foetus.
8. Scrotal sacs are also absent and testes remain inside abdomen.

C. Development of New Structures

1. Tail Flukes

In aquatic mammals, some large, lateral or horizontal expansions of the skin develop on tail. These expansions are called tail flukes. These are not supported by fin-ray. Their up and down strokes not only propel the body through water but enable rapid return to the surface for breathing after prolonged submersion.

2. Dorsal Fin

In most Cetacea develop an unpaired adipose dorsal fin without internal skeletal support. It serves as a rudder or keel during swimming.

3. Blubber

In aquatic mammals, the blubber is the thick subcutaneous layer of fat, which compensates for the lack of hairy covering. Blubber acts as a heat insulator. It not only retains the warmth of the body but also provides a ready reservoir of food and water during emergency.

The fat also reduces the specific gravity of the animal, thus, imparting buoyancy. Blubber also provides an elastic covering to allow changes in body volume during deep diving and also counteracts the hydrostatic pressure.

4. Baleen

In whalebone whales, teeth are absent. Instead, the upper jaw carries two transverse rows of numerous triangular fringed horny plates of baleen or whalebone. These serve as an effective sieve for straining plankton (mostly krill) which forms their chief food.

5. Foam

Foam is a fine emulsion of fat, mucus and gas. Each middle ear cavity sends an inner pneumatic prolongation, which meets with the fellow on the other side below the skull. These extensions contain foam. It probably serves to insulate sound and improves audition or hearing under water.

6. Melon

In some aquatic mammals, the melon is a receptor present in front of nostrils. It consists of a fatty mass traversed by muscle fibres. It possibly serves to detect pressure changes in water.
7. Harderian Glands

In aquatic mammals, eyes under water remain protected by a special fatty secretion of Harderian glands.

Check Your Progress

3. What are the classes of Mammals?
4. What are amphibious Mammals?

14.4 ANSWERS TO CHECK YOUR PROGRESS QUESTIONS

1. Flying birds have lightweight, smooth feathers – this reduces the forces of weight and drag and a beak, instead of heavy, bony jaws and teeth – this reduces the force of weight.

2. The shape of a bird’s wing is important for producing lift. The increased speed over a curved, larger wing area creates a longer path of air.


4. These mammals do not live permanently in water. They live on land but go into water for food and shelter.

14.5 SUMMARY

- Birds have feather, beak and forelimb in form of wing.
- Bird migration refers to the regular (and often seasonal) journeys to and from a given area undertaken by all or part of a bird population. Not all bird species (or even populations within the same species) are migratory.
- Mammals are defined as vertebrates that possess hairs and mammary glands for feeding young.
- Mammals that give birth to their young ones directly belong to the subclass Eutheria. The young ones form as an embryo in the mother stomach and grow there for a certain period of time.
- Mammals that belong to Metatheria also give birth to their young ones but the young ones are born immature. So they jump into their mother pouch and stay there till they are mature. Metatheria subclass contains seven orders with 250 species. Marsupials and kangaroo are the best example for this subclass.
Prototheria consists of egg-laying animals and are also known as monotremes. This subclass consists of six species all in one order. Monotremata (platypus and echidna).

Amphibious mammals do not live permanently in water. They live on land but go into water for food and shelter.

Aquatic mammals under this category spend most of the time in water and usually come to land for reproduction. The typical examples are seals and hippopotamuses.

Marine mammals never come to land and are perfectly at home in water. The typical examples are whales.

In aquatic mammals, elongated, tubular and intra-narial epiglottis, when embraced by the soft palate, provides a continuous and separate air-passage, thus, allowing breathing and feeding simultaneously.

14.6 KEY WORDS

- **Ave**: A class of vertebrates which comprises the birds.
- **Mammal**: A warm-blooded vertebrate animal of a class that is distinguished by the possession of hair or fur, females that secrete milk for the nourishment of the young, and (typically) the birth of live young.

14.7 SELF ASSESSMENT QUESTIONS AND EXERCISES

**Short-Answer Questions**
1. Discuss flight adaptation in aves.
2. Describe adaptive radiation in mammals.
3. Write a short note on migration of birds.
4. Write general characteristics of eutheria.

**Long-Answer Questions**
1. Discuss general characteristics of aves.
2. Explain classes of aves.
3. Discuss general characteristics of mammals.
4. Explain classes of mammals.
14.8 FURTHER READINGS


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