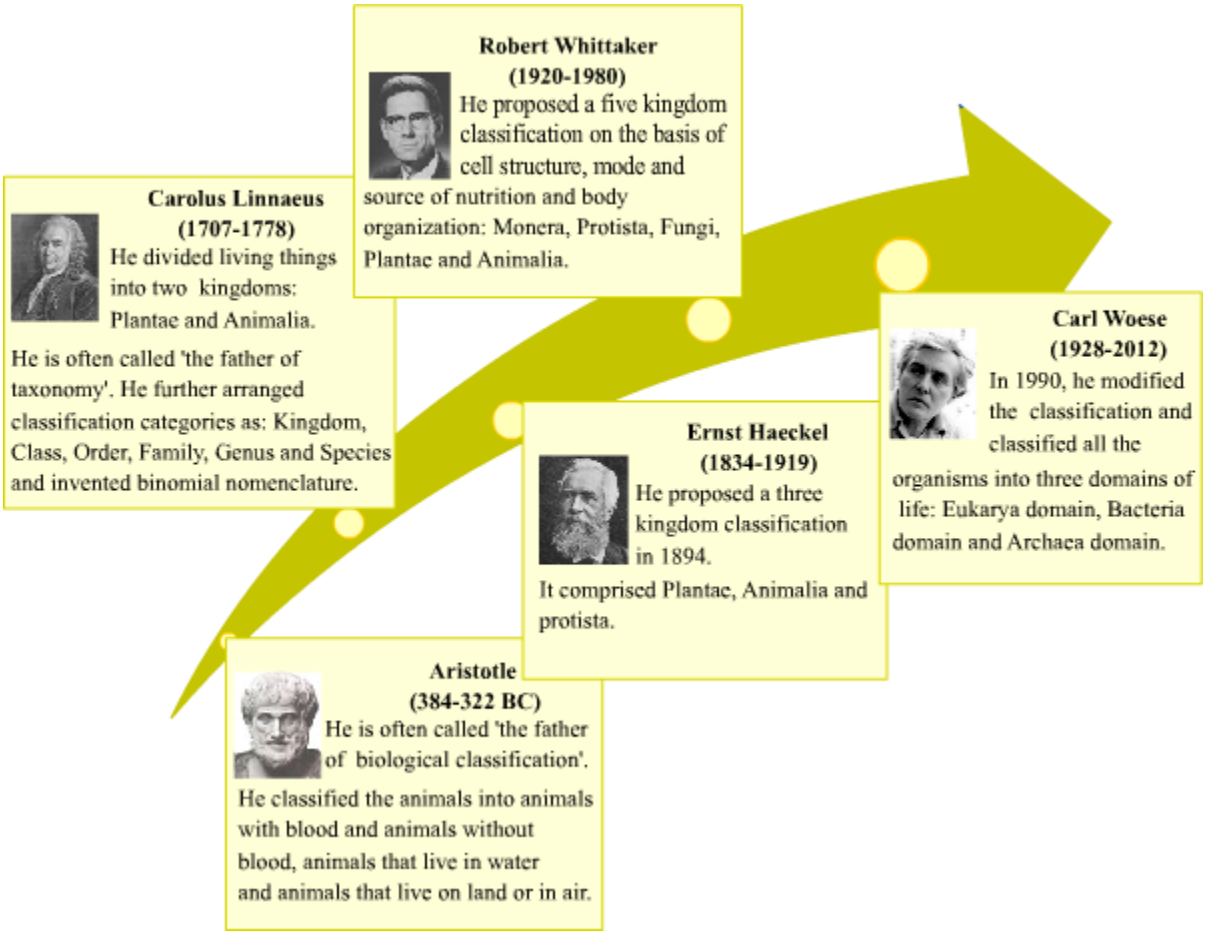
Five Kingdom Classification

Basis of Classification

History of Biological Classification

Let us read about the history of biological classification.



The early contribution towards classification is also seen in writings of many ancient Indian philosophers and sages. The important ones among them are:

Charaka: (600 B.C)

Charaka was one of the great ancient sages of India. He was a philosopher, astronomer and a physician. He has mentioned about 340 types of plants and 200 types of animals in his book named “Charaka Samhita”. This book is considered as the most authoritative and ancient writing in ayurveda available today. He is known as the **father of medicine** for his contribution in the field of ayurveda.

Parashara: (100 B.C)

Parashara, a great ancient sage has given detailed description of plants in his book “Vrikshaayurveda”. He has classified plants into several ‘ganas’ on the basis of characteristic of flowers. The description given by the Parashara about the classification of these plants is very close to the modern classification.

In his another book named “Krishiparashara” he has explained about the benefits of farming. The farmers can manage and plan various activities of farming by studying this book. For example, according to him, the winds arising from the north or west can bring rainfall while as winds from the east and south do not bring any rainfall.

Solved Examples

Medium

Example 1:

What are the drawbacks of the classification given by Aristotle?

Solution:

The criteria used by Aristotle for classification are superficial and do not reflect the natural relationships. It is a misleading system of classification. In the classification given by Aristotle, many unrelated organisms are placed in the same group on the basis of their habitats (dwelling places).

For example, corals, whales, octopuses, starfish and sharks are placed in the same group because they are sea-dwelling organisms. Further, closely related organisms are placed in different groups simply because of the differences in their habitats. Characteristics which are more fundamental than habitat need to be made the basis for classifying the various organisms.

Hard

Example 2:

What are the three domains of life classified by Carl Woese?

Solution:

In 1990, Carl Woese modified biological classification by dividing all organisms into the following three broad domains of life: Eukarya domain, Bacteria domain and Archaea domain.

- **Archaea domain**: This includes prokaryotes living in extreme conditions, which are considered to be the oldest species of organisms on Earth. The kingdom Archaebacteria is under this domain.

- **Bacteria domain**: This includes prokaryotes and all bacteria apart from the ones classified as archaebacteria. The kingdom Eubacteria is under this domain.

- **Eukarya domain**: It includes the kingdoms Fungi, Plantae, Animalia and Protista.

Basis of Classification

Guidelines for deciding the characteristics to be used in classification

- While making groups, we need to decide which characteristics are responsible for the more fundamental differences among organisms.

- The characteristics that account for the broadest divisions among living organisms should be independent of any other characteristics in their effects on the forms and structural functions of the organisms.

  Within the broadest groups, smaller subgroups are decided by picking up the next set of differentiating characteristics. This process of classification within each group can then continue using new characteristics each time.

- A characteristic used in a subgroup is dependent upon the characteristic that precedes it in the classification hierarchy.

What is meant by 'characteristic'?

A characteristic is a particular form or structural function. For example, having five fingers on each hand is a characteristic.

Principles of Classification

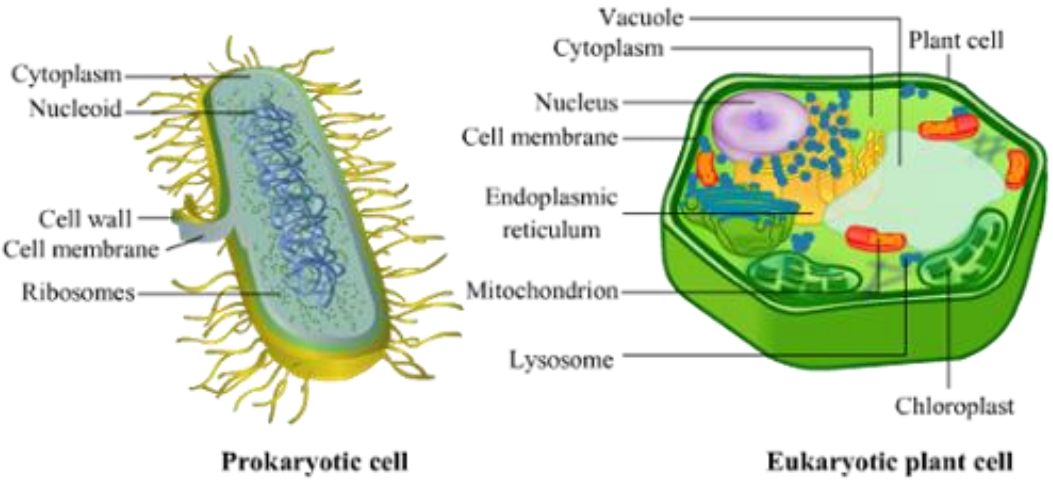
Certain principles of classification that are followed today and which were also the basis of Whittaker's five kingdom classification are as follows:

- **Nature of cell**
- **Cellularity**
- **Mode of nutrition**

We will study each of them one by one.

Nature of cell: This is the primary and fundamental characteristic on which the first division of organisms is made. This is because it gives rise to another feature called **cellularity**. The nature of a cell relates to the presence or absence of membrane-

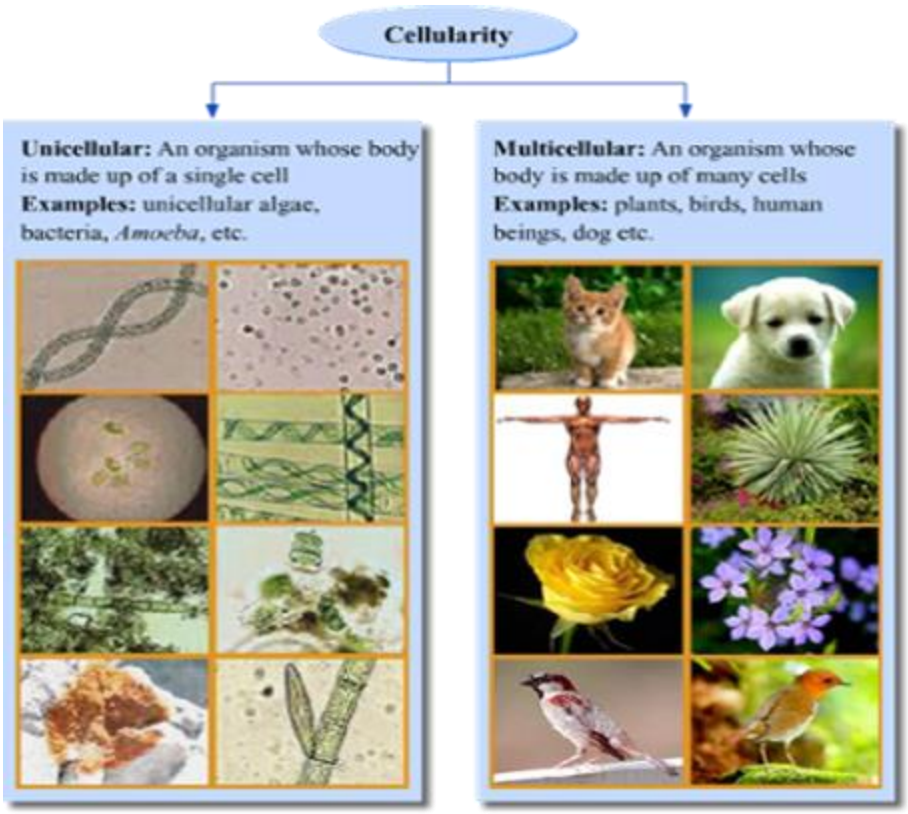
bound organelles in it. So, on this basis, we can classify living organisms into two broad categories—**prokaryotes** and **eukaryotes.**



Eukaryotes and Prokaryotes

Characteristics	**Prokaryotes**	**Eukaryotes**
Cell size	They are small in size.	They vary in size and are generally larger than those of prokaryotes.
Nucleus	A nucleus with a nuclear membrane is absent.	A well-defined nucleus with a nuclear membrane is present.
Membrane-enclosed organelles	Organelles like mitochondria and plastids, which have a membrane around them, are absent.	Membrane-enclosed organelles like mitochondria and plastids are present.
Cell wall	It is usually present and is composed of peptidoglycan	It is usually present in plant cells and is composed of cellulose.
Genetic material	It is present as nucleoid.	It is present inside the nucleus.
Examples	Bacteria and blue-green algae	Protozoans, Fungi, plants and animals

Cellularity: It is the state or condition that defines the number of constituent cells of whole organisms. On this basis, organisms are classified as unicellular and multicellular organisms.



Solved Examples

Medium

Example 1:

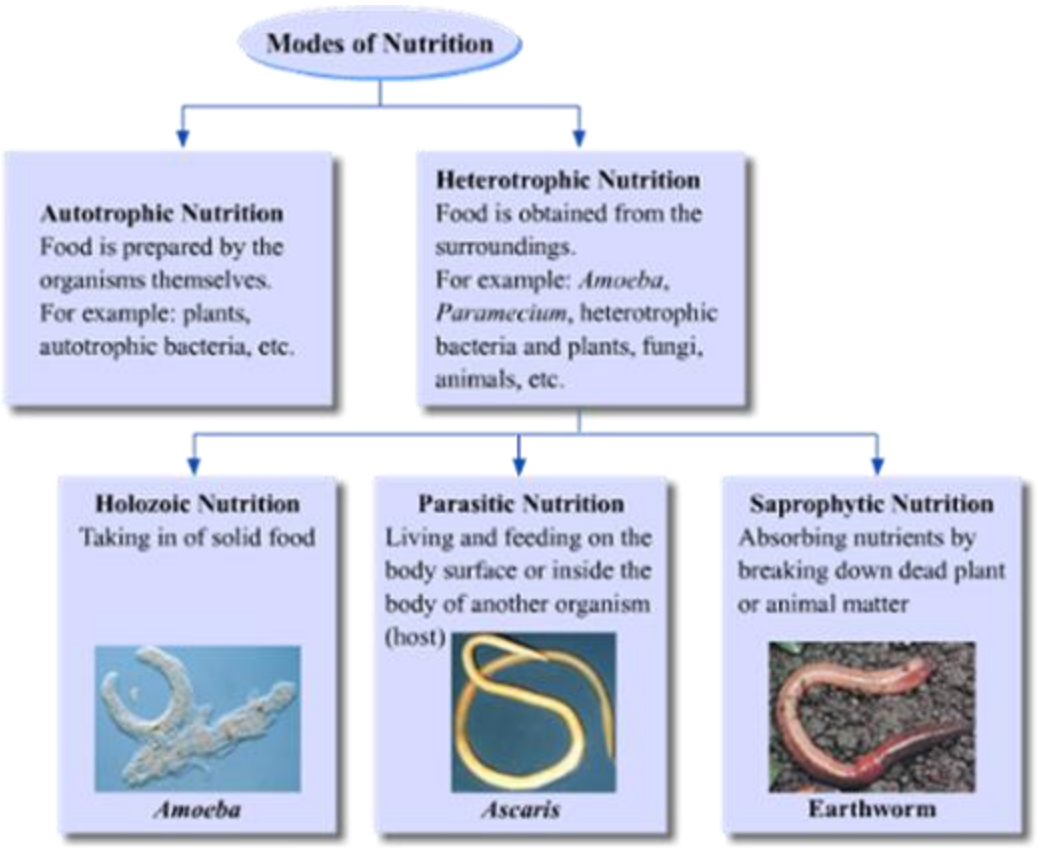
What is division of labour?

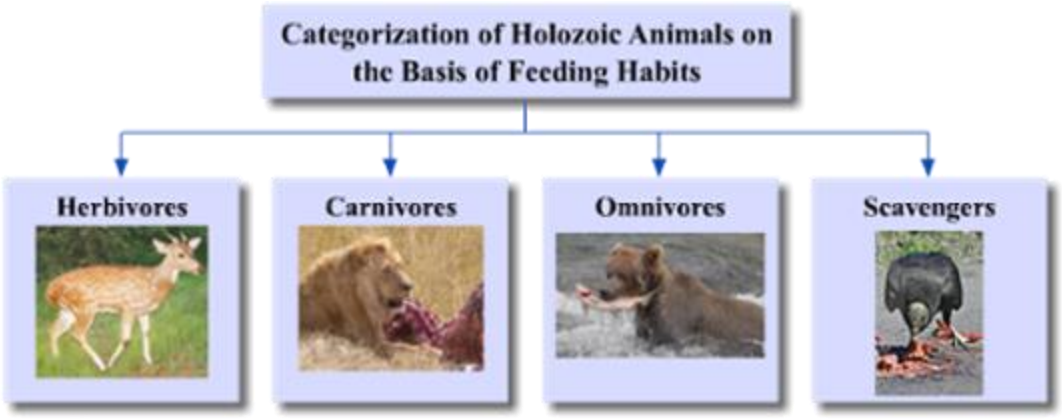
Solution:

A multicellular organism is made up of more than one cell. These cells use the principle of division of labour to carry out the different life processes of the organism. In multicellular organisms, division of labour refers to how different cells/ tissues/ organs/ organ systems are in charge of taking care of specific life processes.

For example, the respiratory system helps the body in obtaining oxygen from the air and supplying it to the rest of the body. Unicellular organisms do not show division of labour.

Mode of nutrition: This is also a basis for differentiating between different organisms. The ability to manufacture their own food makes the body designs of plants different from those of animals.





Solved Examples

Medium

Example 2:

Why do you think the characteristics of body designs are not used for making broad groups?

Solution:

The characteristics of body designs used for classifying plants are very different from those used for classifying animals. This is because their basic body designs differ depending on their need to make their own food (plants) or to acquire it (animals). Therefore, design features (such as having a skeleton) are used while making subgroups rather than broad groups.

Solved Examples

Easy

Example 1:

What is taxonomy?

Solution:

The science of classification of organisms is called taxonomy.

Medium

Example 2:

Define all taxonomic ranks.

Solution:

The different taxonomic ranks are kingdom, phylum, class, order, family, genus and species.

Kingdom is the topmost unit of classification, followed by phylum, class, order, family, genus and species. A number of phyla having common characters are placed in the same kingdom.

For example, the phyla Arthropoda, Platyhelminthes and Mollusca belong to the kingdom Animalia.

Phylum is the taxonomic division of living organisms which contains one or more classes. In the hierarchy of classification, phylum comes after kingdom and before class. A number of classes having common characters are placed in the same phylum. For example, the classes Crustacea, Insecta and Arachnida belong to the phylum Arthropoda. Phylum is called ‘division’ in case of plants.

Class is the taxonomic division of living organisms which contains one or more orders. In the hierarchy of classification, class comes after phylum and before order. A number of orders having common characters are placed in the same class. For example, the

orders Diptera (e.g., flies), Hymenoptera (e.g., ants) and Orthoptera (e.g., grasshoppers) belong to the class Insecta.

Order is the taxonomic rank after class and before family. A number of families having common characters are placed in the same order. For example, the families Culicidae (mosquitoes) and Muscidae (houseflies) belong to the order Diptera.

Family is the taxonomic rank after order and before genus. A number of genera having common characters are placed in the same family. For example, the genus *Aedes* and the genus *Anopheles* are part of the family Culicidae.

Genus is the taxonomic rank lower than family and higher than species. It is used in the classification of living organisms and fossils.

Species is the fundamental unit of taxonomic classification. A species is defined as a group of organisms that have some common characteristics and are capable of interbreeding. For example, *Aedes aegypti* is a mosquito species belonging to the genus *Aedes*.

Example 3:

What is binomial nomenclature? Mention its importance also.

Solution:

Binomial nomenclature refers to the naming of species. In this system, the name of a species is made up of two words—the genus name and the species name. For example, the scientific name of Rose is *Rosa canina*, wherein '*Rosa*' is the genus name and '*canina*' is the species name.

Importance of binomial nomenclature:

It helps avoid confusions that can be created when one attempts to use common names to refer to a particular species. There can be many common names for a particular species, but the binomial nomenclature for that species remains the same.

Did You Know?

How do we decide the names of organisms?

There are different codes of nomenclature, i.e., sets of rules and recommendations which deal with the naming of organisms. Two examples of such codes of nomenclature are the **International Code of Botanical Nomenclature** (ICBN) for plants and the **International Code of Zoological Nomenclature** (ICZN) for animals.

In **binomial nomenclature** the first word is always capitalized, but the second is not. Also, both words should be italicized.

Hierarchy refers to the organization or classification of things in order of rank or importance. Let us understand this concept with the help of a couple of examples.

Suppose you have a glass jar that contains many buttons of varying colours and sizes. How will you sort these buttons?

The buttons can be sorted by considering their characteristics from the least specific to the most specific. Initially, the buttons can be grouped by looking at their colours. Next, the buttons of the same colour can be stacked according to their relative sizes.

Finally, if we want to group the exactly same buttons, then we can consider the number of holes present in the buttons of the same size and colour. In this way we can sort the buttons.

Here are some details regarding the location of a boy named Arif.

State: New Delhi; country: India; house number: 106; sector number: 39; planet: Earth; block: A; area: Kashmiri Gate

Can you develop a hierarchy of the points of his location in comparison to the hierarchy of the taxonomic categories?

The comparable hierarchy is given as follows:

Kingdom − Planet (Earth)

Phylum/Division − Country (India)

Class − State (New Delhi)

Order − Area (Kashmiri Gate)

Family − Sector (39)

Genus − Block (A)

Species − House number (106)

Mnemonics for hierarchy of classification

KINGDOM → PHYLUM → CLASS → ORDER → FAMILY → GENUS → SPECIES

Kings Play Chess On Flat Glass Surfaces

OR

Kids Prefer Candy Over Fresh Green Spinach

Five Kingdoms of Classification

Introduction to the Five Kingdom Classification

We have learned about the history of biological classification previously. We have learned how Aristotle classified living organisms on the basis of superficial similarities such as habitat. Consequently, many unrelated organisms got grouped together and many organisms with similarities got divided.

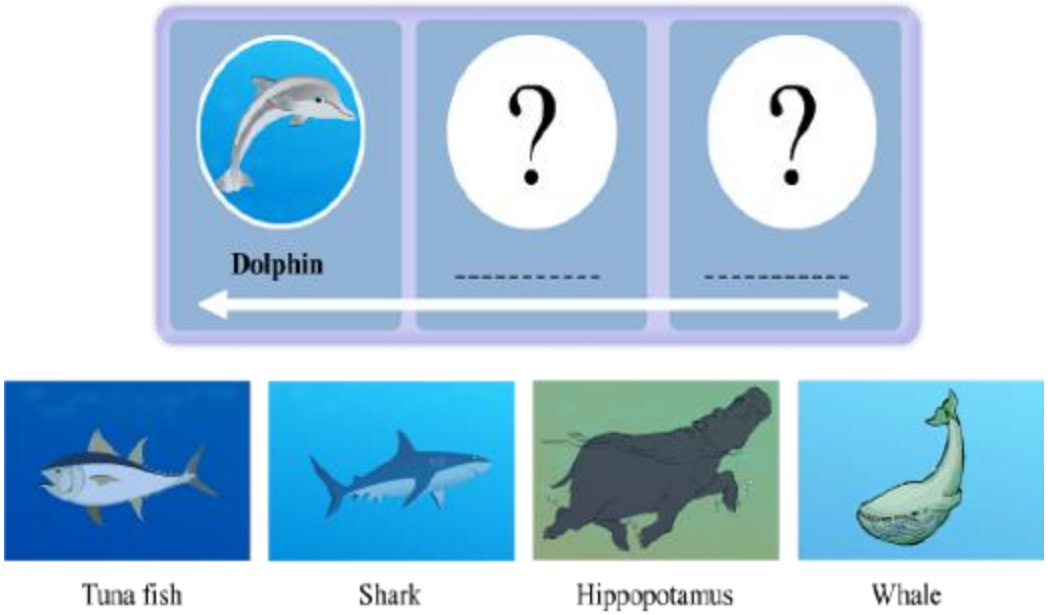
This system of classification did not prove useful in studying about the diverse life forms on Earth. Later, many other scientists came up with their own systems of classification. Among these, the one that is popularly followed today is the **five kingdom classification** by Robert Whittaker.

We have already studied about some of the basic characteristics used by Whittaker to classify living organisms. These are nature of cell, cellularity and mode of nutrition. In this lesson, we will study how Whittaker used these characteristics to make broad divisions called kingdoms.

Introduction to the Five Kingdom Classification

But before that, let us test how smart you are!

Among the given organisms, choose two that are closely related to the dolphin.



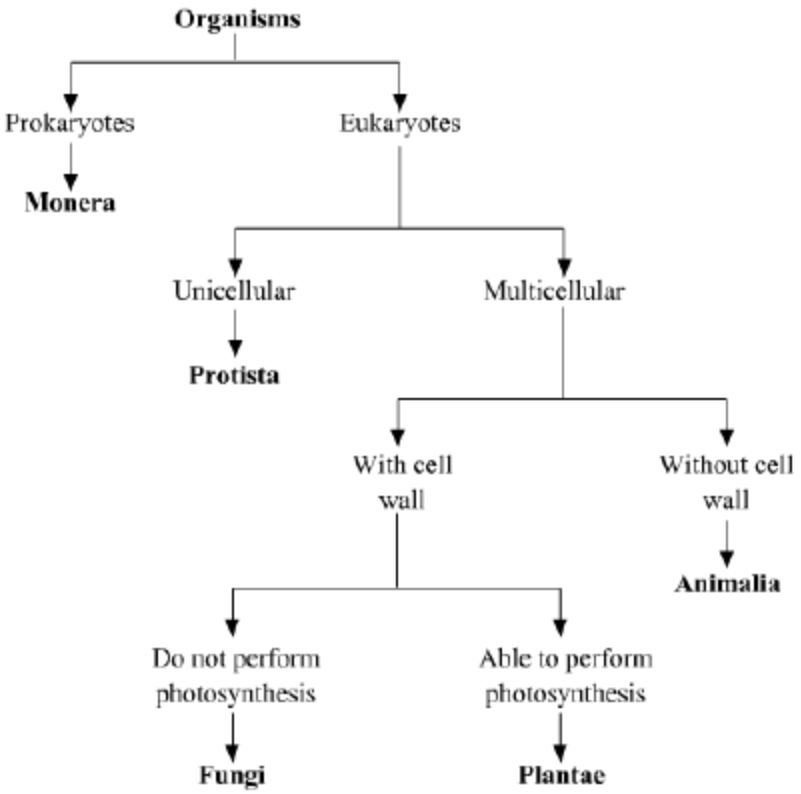
On the basis of Aristotle's method of classifying organisms according to their habitats, the dolphin should be closely related to the tuna fish, the shark and the whale. However, this method of classification is not correct.

If you consider evolutionary history, then you will realize that the dolphin is closely related to the hippopotamus and the whale, and not to the tuna fish and the shark. To understand why this is so, read on about Whittaker's five kingdom classification.

Five Kingdom Classification

In 1969, Robert Whittaker classified all organisms present on Earth into five major groups called kingdoms. This is known as the five kingdom classification.

Here is a branch diagram that shows how Whittaker used the fundamental characteristics of nature of cell, cellularity and mode of nutrition for classifying different life forms into the five kingdoms.



It is clear from the above diagram that the first organisms to evolve were the prokaryotes. Eukaryotes evolved next and, after a period of time, some of the unicellular eukaryotes evolved into multicellular organisms.

This agrees with the fact that classification of life forms is closely related to their evolution. Further categorization of multicellular eukaryotes is then made on the bases of the presence or absence of cell wall and the mode of nutrition.

Five Kingdom Classification

Kingdom Monera

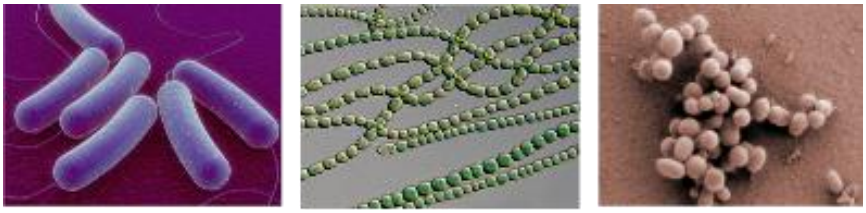
You do wash your hands before eating anything, don't you? Why do you think this is important?

Washing our hands before eating is important because most of the time our hands carry germs. Germs are basically the different types of bacteria, fungi, protozoans, viruses, etc. Most of them cannot be seen with the naked eye.

Bacteria and other organisms such as the blue-green algae (cyanobacteria) are grouped in **kingdom Monera**. The organisms of this kingdom are called prokaryotes.

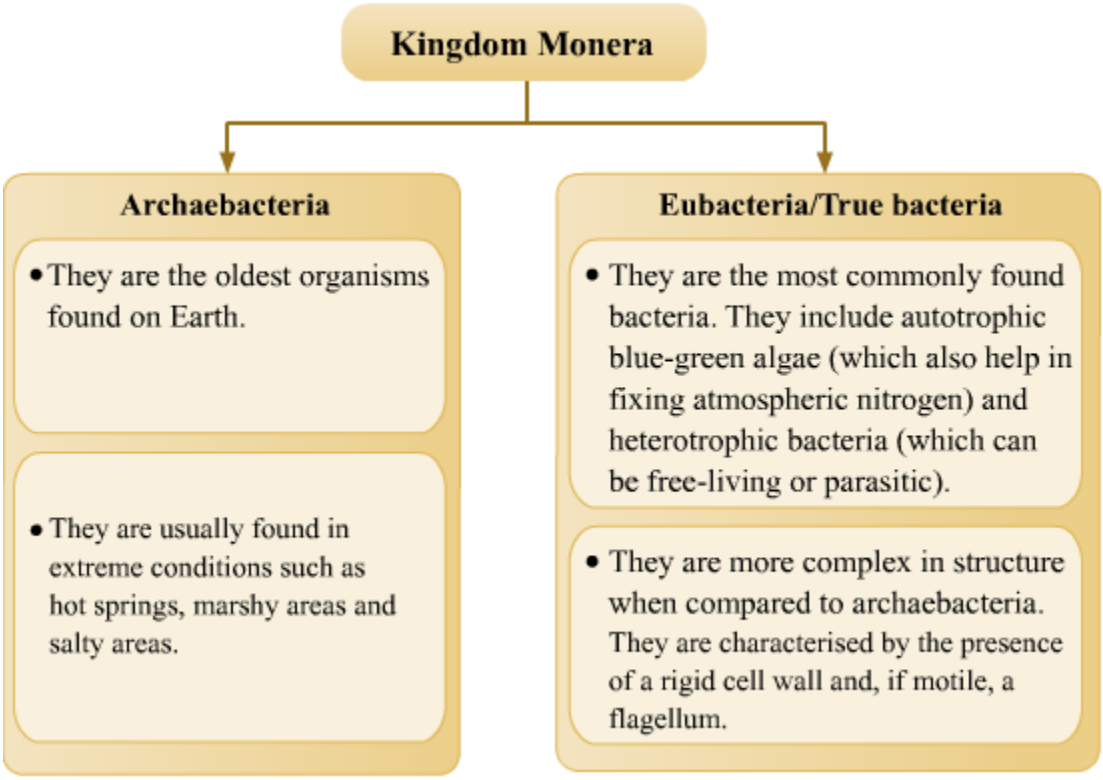
General features of monerans

- There is an absence of a well-defined nucleus and other membrane-bound cell organelles in monerans, i.e., they show a prokaryotic organisation.
- All monerans are unicellular organisms; they do not have any multicellular body design.
- The cell wall may be present (as in bacteria and blue-green algae) or absent (as in *Mycoplasma*).
- The mode of nutrition could be **autotrophic** (as in blue-green algae and some bacteria) or **heterotrophic** (as in most bacteria and *Mycoplasma*).
- Examples of monerans: bacteria, blue-green algae, *Mycoplasma*



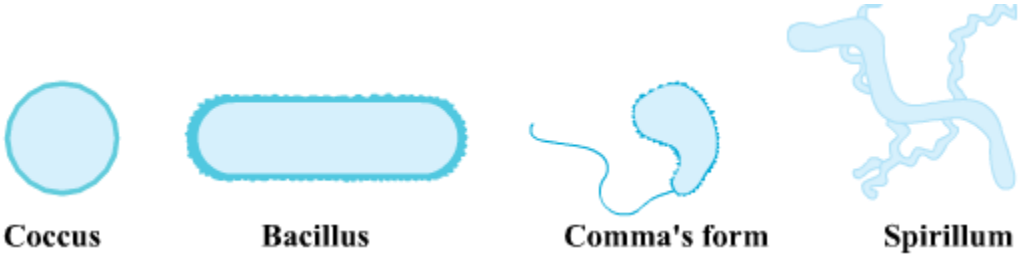
Bacteria | Blue-green algae | *Mycoplasma*

Kingdom Monera



Know More

Bacteria have different shapes, such as



General features of protists

- All protists are single-celled eukaryotes.
- They have a well-defined nucleus and other membrane-bound cell organelles.
- Protists form a link between plants, animals and fungi.
- They can be autotrophic (e.g., diatoms) or heterotrophic (e.g., protozoans).
- Some protists have cilia or flagella which help in locomotion.
- Examples of protists: *Amoeba*, *Paramecium*, **slime moulds**, *Euglena*

Whiz Kid

Interesting Fact

Kingdom Protista was initially known as ‘Protoctista’ which means ‘first established beings’. The term ‘Protista’ was coined later by Ernst Haeckel in 1866.

Know More

What are cilia and flagella?

Cilia are hair-like projections while flagella are lash-like appendages. Both cilia and flagella help in locomotion in prokaryotic and eukaryotic cells. Basically, cilia and flagella have the same structure. However, cilia occur in greater number (as in *Paramecium*) than flagella. In fact, some organisms may have only a single flagellum (e.g., *Euglena*).

Classification of Protists

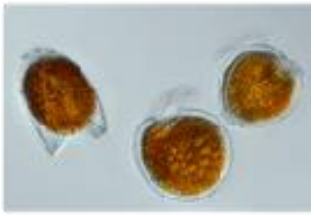
On the basis of mode of nutrition and movement, protists are classified as:

- Plant-like protists
- Animal-like protists
- Fungus-like protists

Plant-like protists

- They are the major producers of energy.
- They contain chlorophyll and carry out photosynthesis. Thus, they have autotrophic mode of nutrition.

Diatoms



Dinoflagellates

Classification of Protists

Animal-like protists

- They exhibit pseudopodia, cilia or flagella.
- They are found in water, soil and other habitats.
- They can be free-living or parasitic.
- They have heterotrophic or saprophytic mode of nutrition.

Paramecium

Amoeba

Fungus-like protists

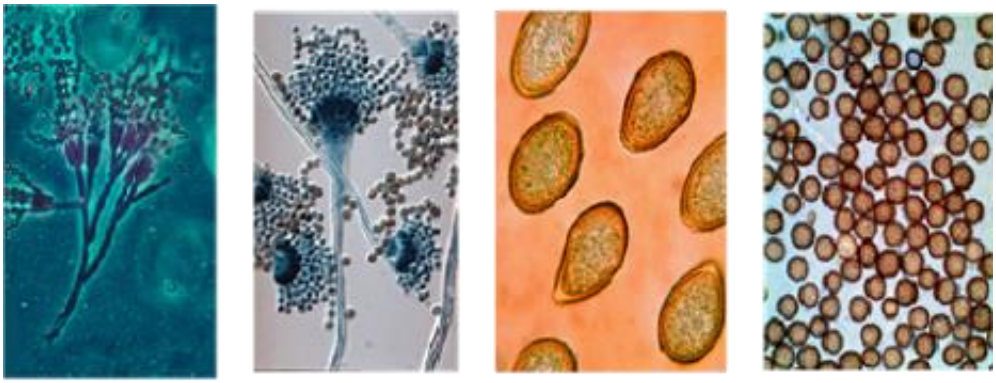
- They include slime moulds.
- They are heterotrophs or decomposers.

Slime mould

Kingdom Fungi

General features of fungi

- They are multicellular eukaryotic organisms. Some exceptions of unicellular fungi are yeasts.
- They are heterotrophic organisms and obtain nutrition from decaying organic matter; so, they are called saprophytes.
- The body of a fungus consists of **mycelium**, which is made up of multicellular filamentous hyphae.
- The cell wall is made up of a tough complex sugar called **chitin**.
- Examples of some commonly known fungi: *Penicillium*, *Aspergillus*, *Puccinia*, *Ustilago*



Penicillium *Aspergillus* *Puccinia* *Ustilago*

Importance of fungi

- They are used for producing antibiotics.
- Yeasts are used in the manufacture of bread and beer.
- Some fungi decompose organic matter and enhance the fertility of soil.
- Fungi such as mushroom are also consumed as food.

Know More

Some fungi live in a mutually beneficial relationship with cyanobacteria or green algae to form lichens. This kind of relationship is called **symbiosis**.

Lichens grow very slowly. A colony of lichens in the Arctic takes around 1000 years to grow two inches!

Kingdoms Plantae and Animalia

General features of plants

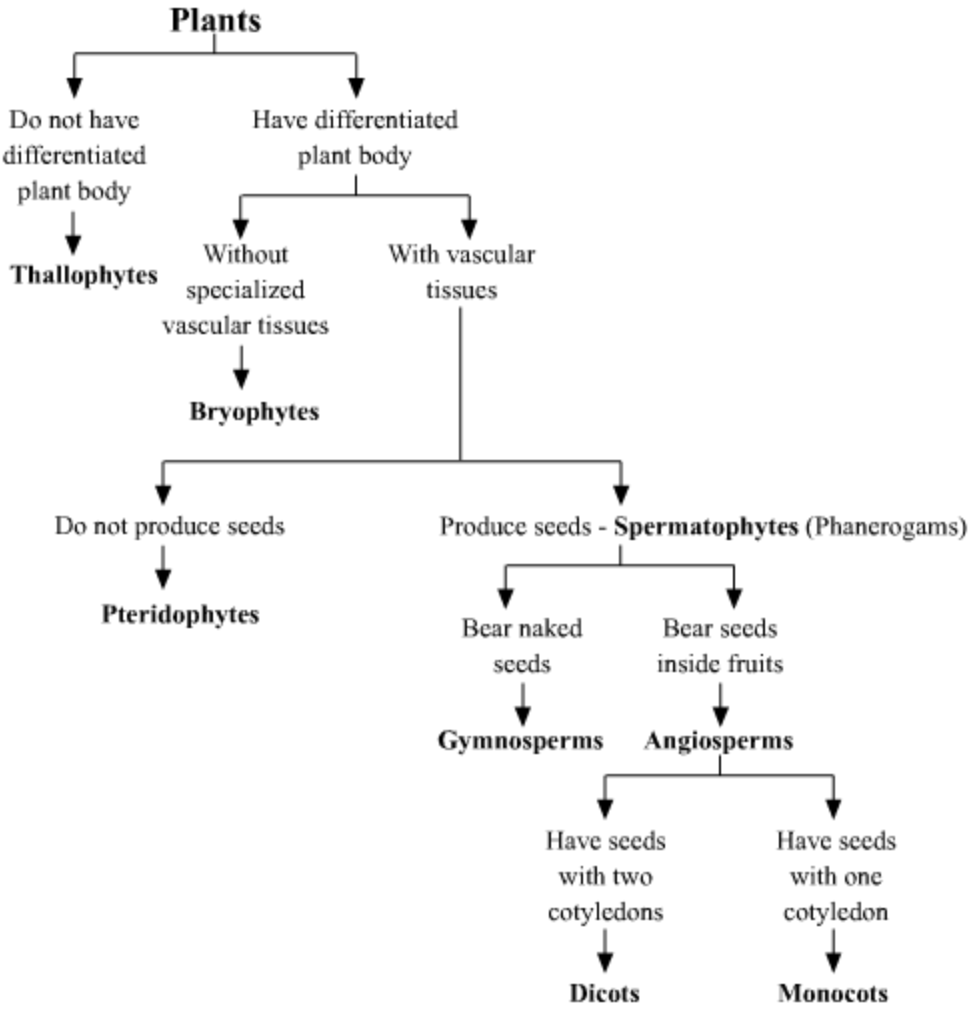
- They are multicellular eukaryotic organisms.
- The cell wall is made up of cellulose.
- Most plant cells contain chlorophyll pigments. Hence, they are autotrophic.
- They are non-motile.

General features of animals

- They are multicellular eukaryotes.
- The cell wall is absent.
- Animal cells do not contain chloroplast. Hence, they have heterotrophic mode of nutrition.

Introduction to Plant Kingdom

Classification of Plants



Classification of Plants

After going through the branch diagram on previous slide, can you point out the bases on which plants are classified?

Plants are classified in terms of the following characteristics.

- Differentiation of plant body into roots, stem and leaves
- **Vascular tissues**
- Production of seeds
- Covering of seeds
- Number of **cotyledons** in a seed

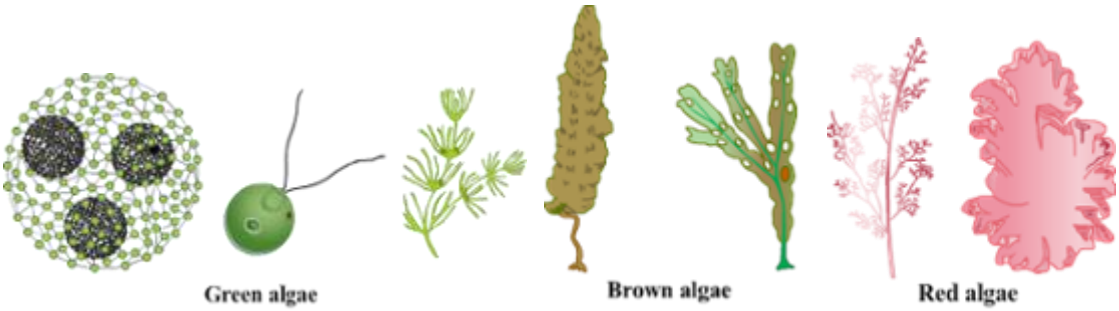
Let us now study each division of the plant kingdom in detail.

Division Thallophyta

The word ‘Thallophyta’ comprises the words ‘thallus’ meaning ‘undifferentiated body’ and ‘phyton’ meaning ‘plant’.

General features of thallophytes

- The plant body of a thallophyte is not differentiated into roots, stem and leaves.
- Thallophytes are mostly aquatic. They can be green or non-green.
- They do not bear flowers and seeds. They reproduce by means of asexually produced spores.
- Thallophytes are essentially algae.
- Algae are economically important. Several algae are used as sources of food.
- **Algin**, extracted from brown algae, is used in making dairy products.
- **Seaweeds** are commercially used for making cosmetics, pharmaceuticals, etc.
- Examples of algae: Based on the pigment they contain, algae are further classified as green algae, brown algae, red algae, etc.



Know More

Division of algae

Let us read about the different classes of algae listed in this table.

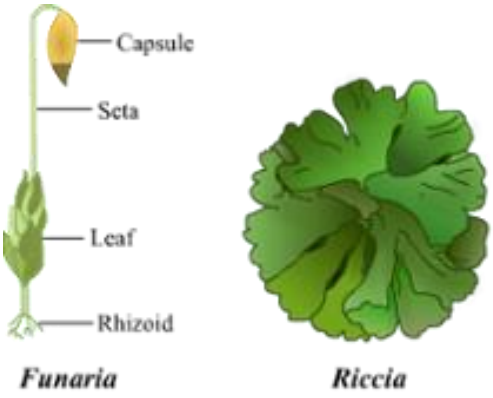
Classes	Common names	Major pigments	Cell wall	Habitat
Chlorophyceae	Green algae	Chlorophyll *a* and *b*	Cellulose	Fresh water, **brackish** water, salt water
Phaeophyceae	Brown algae	Chlorophyll *a* and *c*, fucoxanthin	Cellulose and algin	Fresh water (rarely), brackish water, salt water
Rhodophyceae	Red algae	Chlorophyll *a* and *d*, phycoerythrin	Cellulose and pectin	Fresh water (sometimes), brackish water, salt water

Division Bryophyta

The word ‘Bryophyta’ comprises the words ‘bryon’ meaning ‘moss’ and ‘phyton’ meaning ‘plant’.

General features of bryophytes

- They are the first plants to live on land, but require moist conditions to survive. For this reason they are called ‘the amphibians of plant kingdom’.
- They are non-vascular, i.e., they do not have specialized vascular tissues (xylem and phloem) for the conduction of water and food.
- They lack true roots, stem and leaves. But, they show more body differentiation than thallophytes.
- They have **rhizoids** instead of true roots.
- They do not bear flowers and seeds.They reproduce both sexually as well as asexually.
- Bryophytes exhibits 'alternation of generations' in which gametophytic phase (haploid) alternates with sporophytic phase (diploid).
- Liverworts and mosses have been found to be good indicators of environmental conditions. Some aquatic mosses can be used as indicators of calcium content in water.
- Some mosses prevent soil erosion. Certain mosses also provide fuel.
- Examples of bryophytes: *Riccia*, *Marchantia*, *Funaria*

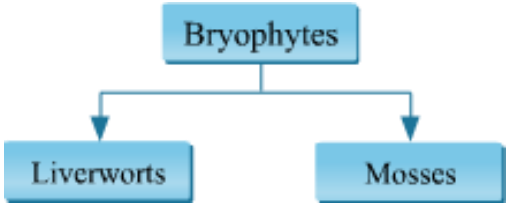


Did You Know?

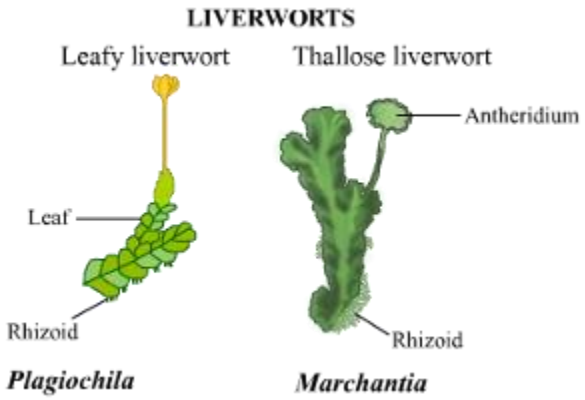
Sphagnum or peat moss can soak up to twenty-five times its weight of water. This is why it is used as a soil conditioner.

Know More

Classes of bryophytes

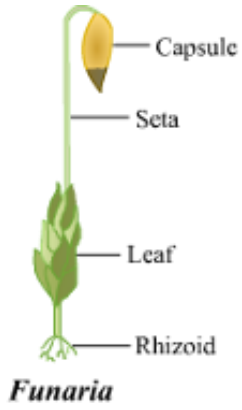


General features of liverworts



- They are non-vascular, spore-producing land plants.The thallus is dorsiventrally flattened.
- Filamentous structures called rhizoids anchor most liverworts to their substrata.
- Liverworts are of two types: thallose liverworts and leafy liverworts.
- A thallose liverwort has a dorsiventrally lobed thallus.
- Leafy liverworts look very similar to mosses, but their leaves are arranged in rows. Seta and capsule are the structures that help in the production of spores.
- Examples of liverworts: *Riccia*, *Plagiochila*, *Marchantia*

General features of mosses



- A moss has an erect thallus that is differentiated into root-, stem- and leaf-like structures. Its leaves are spirally arranged.
- Mosses are often **epiphytes**.
- Moist and shady areas are their more common habitats. Some of them are found on rocks and in arid locations.
- Seta and capsule are the structures that arise from the main plant body and help in the production of spores. They develop from the zygote.
- Examples of mosses: *Funaria*, *Pogonatum*

Division Pteridophyta

The word ‘Pteridophyta’ comprises the words ‘pteris’ meaning ‘fern’ and ‘phyton’ meaning ‘plant’.

General features of pteridophytes

- The plant body of a pteridophyte is differentiated into roots, stem and leaves.
- Pteridophytes are found in cool, damp and shady places.
- They have specialized tissues for the conduction of water and food.
- They have **inconspicuous** or less-differentiated reproductive organs. For this reason they are categorised as **Cryptogamae** or **cryptogams**.
- They produce naked **embryo** called spores.
- Pteridophytes are economically important. They are used for medicinal purposes.
- They act as soil binders. They are also frequently grown as ornamental plants.
- Examples of pteridophytes: *Dryopteris, Salvinia*, *Equisetum*

Know More

Evolutionarily, pteridophytes are the first terrestrial plants to possess vascular tissues, i.e., xylem and phloem.

Cryptogamae and Phanerogamae

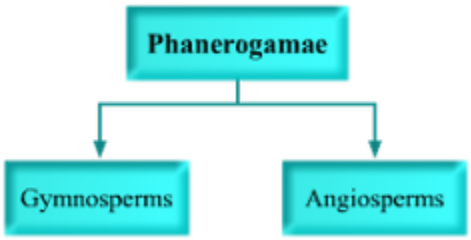
Do you know what plants can be categorised as Cryptogamae or cryptogams?

The word ‘Cryptogamae’ comprises the words ‘kryptos’ meaning ‘hidden’ and ‘gamos’ implying ‘reproduction’. This category includes all plants having hidden or inconspicuous reproductive parts. Cryptogams are flowerless and seedless plants that reproduce through spores (also called naked embryos). Thallophytes, bryophytes and pteridophytes are all cryptogams, i.e., spore-producing plants.

Let us now look at another category of plants called **Phanerogamae or phanerogams.**

The word ‘Phanerogamae’ comprises the words ‘phaneros’ meaning ‘visible’ and ‘gamos’ implying ‘reproduction’. This category consists of plants with well-differentiated and visible reproductive tissues that ultimately make seeds.

The seed of a phanerogam consists of the embryo along with stored food which helps in the initial growth of the embryo during germination. Gymnosperms and angiosperms (plants belonging to the division Spermatophyta) are phanerogams, i.e., seed-producing plants.



Class Gymnospermae

The word ‘Gymnospermae’ comprises the words ‘gymno’ meaning ‘naked’ and ‘sperma’ meaning ‘seed’.

General features of gymnosperms

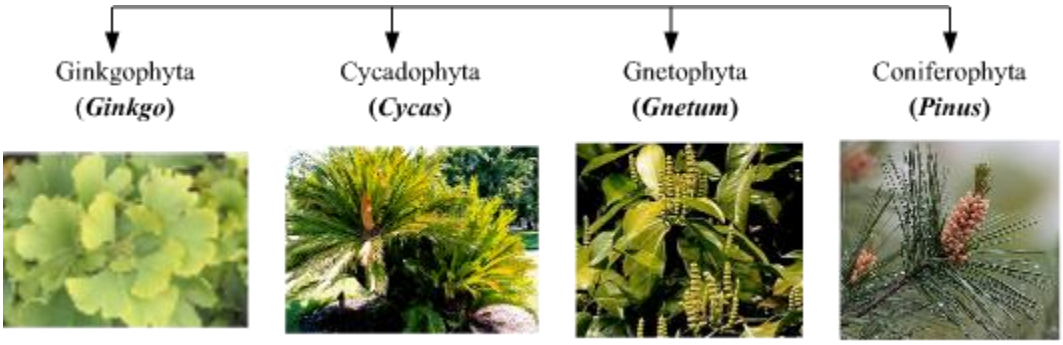
- They are seed-bearing, non-flowering plants. They are more primitive than angiosperms.
- They produce naked seeds, i.e., the seeds are not enclosed inside fruits.
- Instead of flowers, they have male and female cones.
- They are perennial, evergreen plants that grow as woody trees or bushy shrubs.
- A gymnosperm has a tap-root system.
- It has vascular bundles, but the xylem lacks **vessels** and the phloem lacks **companion cells**.
- Gymnosperms are economically important.
- The trees are used for timber.
- The resin obtained from the trees is used in varnishes, medicines, ointments, etc.
- They are also used as ornamental plants.
- Examples of gymnosperms: *Pinus*, cedar, fir, juniper, *Cycas*

Cycas

Know More

The tallest tree in the world is a gymnosperm named *Sequoia sempervirens* (coast redwood), which belongs to the genus *Sequoia* .

Four Major Plant Divisions within Gymnosperms



Class Angiospermae

The word ‘Angiospermae’ comprises the words ‘angio’ meaning ‘covered’ and ‘sperma’ meaning ‘seed’.

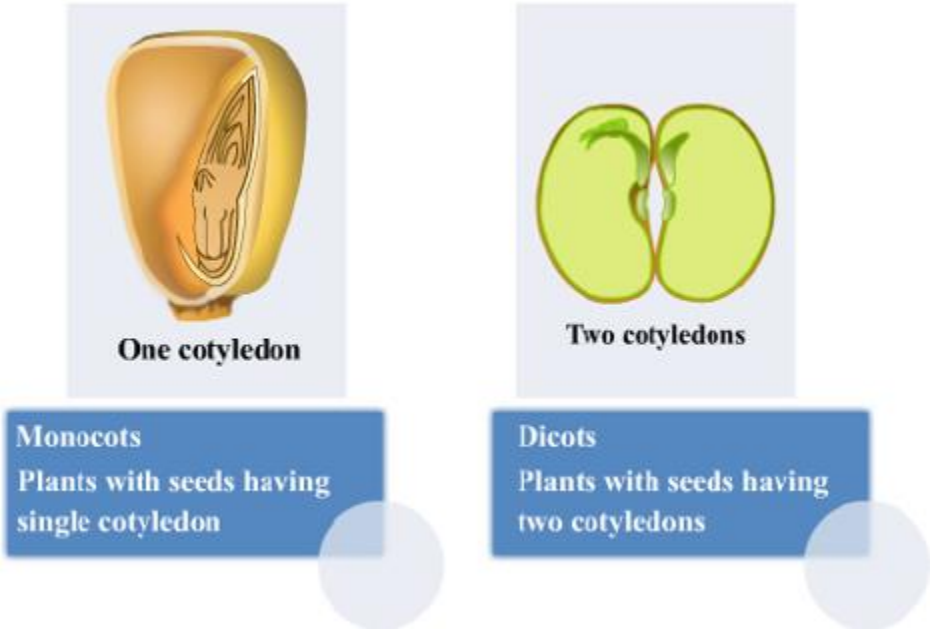
General features of angiosperms

- They are flowering plants in which seeds are enclosed inside fruits.
- They include around 250000 species of plants.
- They are the most recent and highly evolved group of plants.
- They bear flowers that consist of four **whorls**—**calyx**, **corolla**, **androecium** and **gynoecium**.
- The seeds develop inside the ovary, which develops into a fruit.
- Angiosperms are economically important.
- Most angiosperms provide a significant amount of **livestock** feed.
- They are the sources of paper, wood, fibre, medicines and perfumes.
- Many angiosperms are used for decorative purposes.

Class Angiospermae

General features of angiosperms

- The embryos in the seeds have structures called cotyledons or seed leaves. These cotyledons emerge and become green when the seeds germinate.
- On the basis of cotyledons, angiosperms are divided into two groups as shown in the figure.



- Examples of angiosperms: all flowering plants like rose, mango, wheat, maize etc.

Know More

Interesting Facts

- In dicot trees such as mango and guava, the trunk and the old branches increase in girth each year by forming a new layer that replaces the old bark and causes it to peel off.
- Monocot trees such as palm and coconut do not increase in girth because no new wood is formed in them.

Finding Cotyledons

Activity Time

- Place a few bean, sunflower, wheat and corn seeds in water for one night. This will make them tender, making it easier for the seed coat to come off.

The seeds can then be split easily.

- Remove the seed coat from each soaked seed. Then, try to split the seed into two equal parts using a toothpick.
- **Which seeds can be broken into two equal parts?**
- Bean and sunflower seeds can be broken into two equal parts as they have two cotyledons. Such seeds are called dicots.
- Wheat and corn seeds cannot be broken into two equal parts as they have only one cotyledon. Such seeds are called monocots.

Solved Examples

Medium

Example:

What are the differences between monocots and dicots?

Solution:

Monocots	Dicots
The embryo in a monocot seed has one cotyledon.	The embryo in a dicot seed has two cotyledons.
The sepals or petals are in multiples of three.	The sepals or petals are in multiples of four or five.
The stem vascular bundles are scattered.	The stem vascular bundles are arranged in a ring.
The leaves have parallel venation.	The leaves have reticulate venation.
They have fibrous or adventitious roots.	They have a tap-root system.

Kingdom Animalia – Invertebrata

Kingdom Animalia

Can you divide these animals into different groups along with the reasons for each division?

The animals can be grouped as follows:

1. **Fish and seahorse**: They are exclusively water-inhabiting animals. They breathe through gills.

2. **Chimpanzee and monkey**: They have mammary glands and produce young ones.

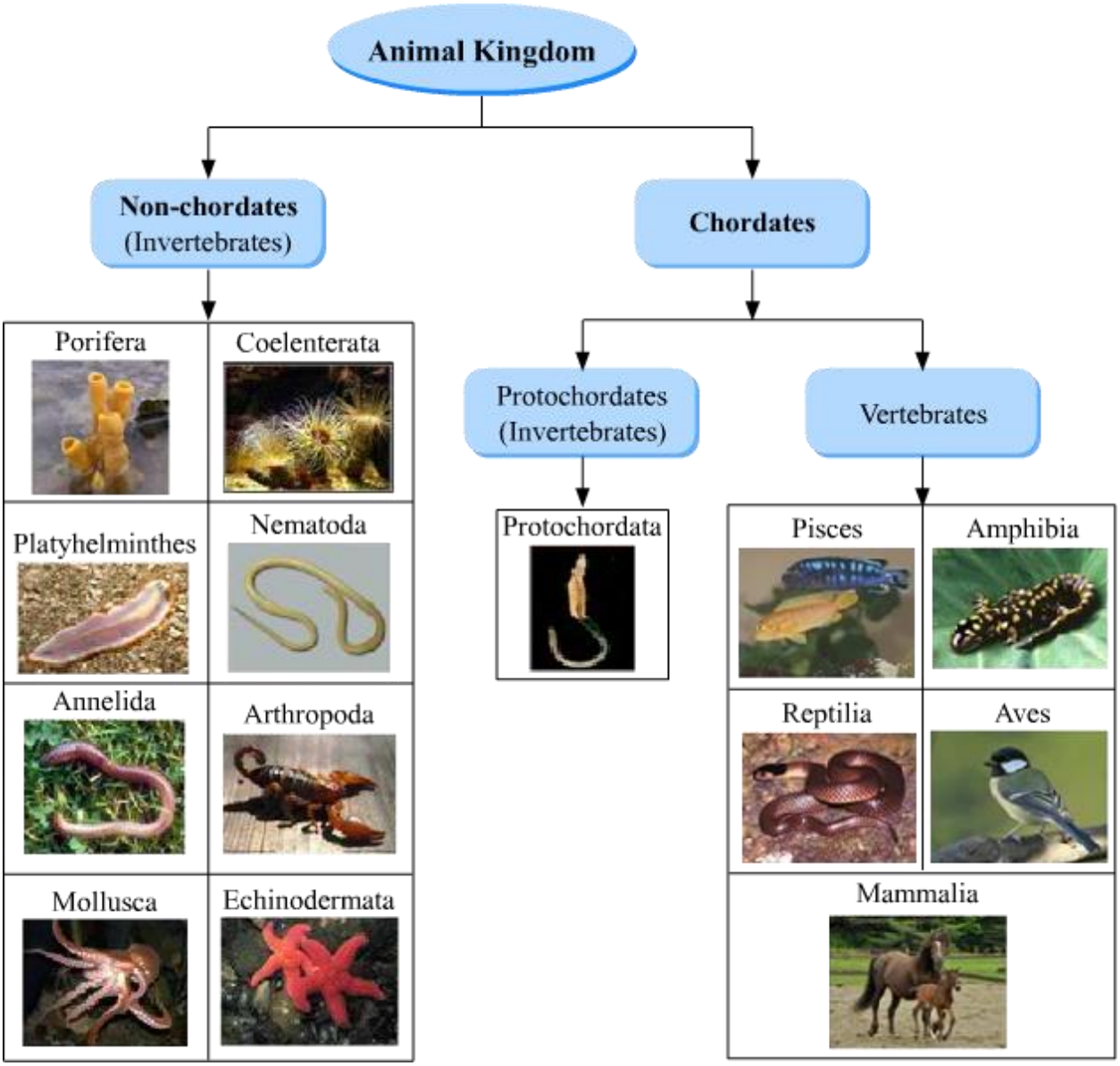
3. **Pigeon and sparrow**: They are warm-blooded animals. They lay eggs and have feathers on their bodies.

4. **Lizard and snake**: They are cold-blooded animals. They lay eggs and have scales on their bodies. They breathe through lungs.

What do we learn from the above activity?

We learn that characteristics can be compared to discover the similarities between various organisms, and then these organisms can be classified into groups based on the similarities.

Classification of the Animal Kingdom



The two broad divisions—non-chordates and chordates—are made on the basis of the presence or absence of the notochord. These groups are then further divided into sub-groups on the basis of other features of body organization.

Let us study in detail about the various characteristics used for classifying the organisms in the animal kingdom.

Bases of Animal Classification

Certain fundamental features that are common to various organisms in the animal kingdom are used as the bases for classifying them. These are as follows:

- Level of organization

- Symmetry
- Diploblastic and triploblastic organization
- Coelom
- Segmentation
- Notochord

Levels of organization

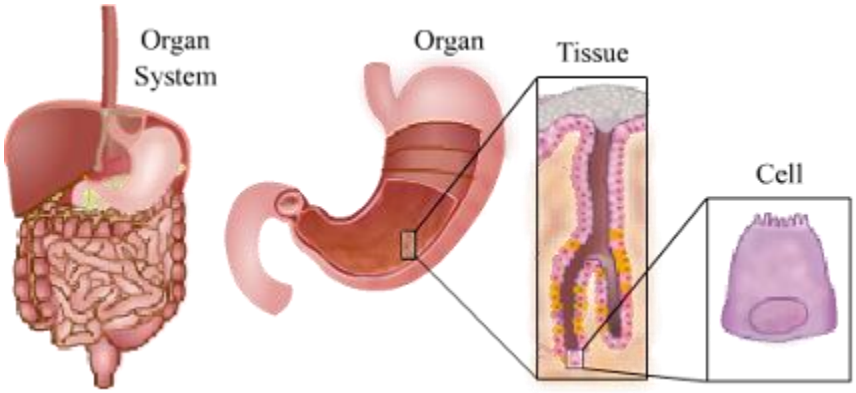
Though all members of kingdom Animalia are multicellular, all of them do not exhibit the same pattern of organisation of cells. The different levels of organization are as follows:

- Cellular level of organization (Example: Porifera)
- Tissue level of organization (Example: Coelenterata)
- Organ level of organization (Example: Platyhelminthes)
- Organ system level of organization (Examples: Nematoda, Annelida, Arthropoda, Mollusca, Echinodermata and chordates)

Bases of Animal Classification

Levels of organization

- **Cellular level of organization**: It is a loose aggregation of cells in which the cells are functionally different from one another.
- **Tissue level of organization**: In this, different cells performing similar functions are arranged into tissues.
- **Organ level of organization**: Here, different tissues are organized into organs and each organ is specialized for a particular function.
- **Organ system level of organization**: At this level, organs associate to form functional systems and each system is concerned with a specific physiological function.



Two types of circulatory systems are found in the organ system level of organisation.

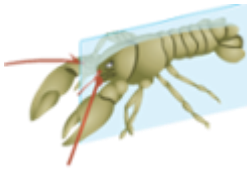
- **Open type**: Blood vessels are absent in this circulatory system. Blood is pumped out of the heart and the cells and tissues are directly bathed in it.

- **Closed type**: In this circulatory system, blood is circulated through vessels of varying diameters (arteries, veins and capillaries).

Bases of Animal Classification

Symmetry

Symmetry is defined as balance between distribution of duplicate body parts and shapes. On the basis of body symmetry, animals can be categorised as: Asymmetrical, bilaterally symmetrical or radially symmetrical

Asymmetrical organisms	**Bilaterally symmetrical organisms**	**Radially symmetrical organisms**
These organisms do not show any body symmetry. Any plane passing through the centre does not divide them into two equal parts.	These organisms show bilateral body symmetry. In their case, the body can be divided into two equal parts by only one plane. The two parts are approximately identical and mirror images of each other.	These organisms show radial body symmetry. In their case, the body can be halved when cut anywhere along the central axis. In this type of body plan, there is a regular arrangement of body parts in the body around the central axis. So, we can divide body into halves in many ways.
Examples : Sponges	**Example :** Platyhelminthes & chordates	**Examples :** Coelenterates and echinoderms
		

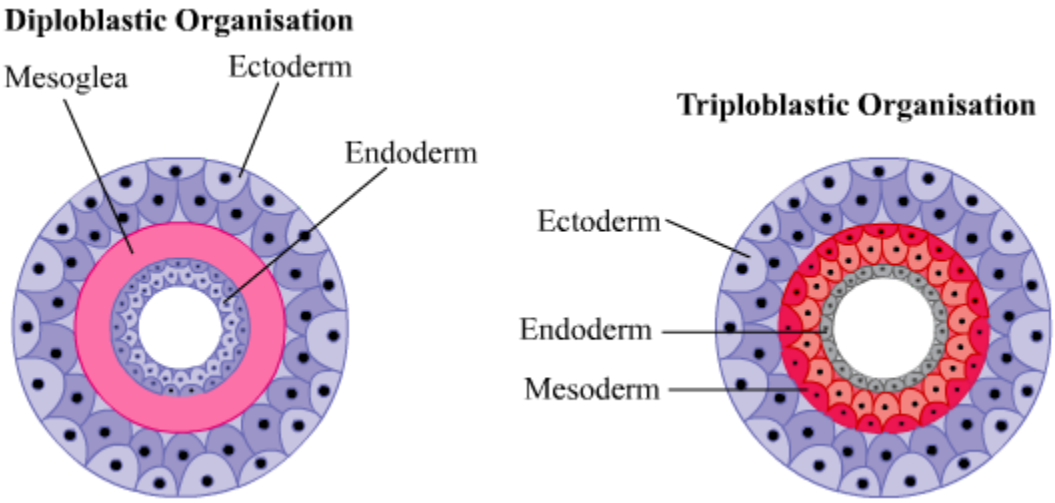
Bases of Animal Classification

Diploblastic and triploblastic organization

The animals in which cells are arranged in two embryonic layers—an external ectoderm and an internal endoderm—are called **diploblastic animals**.

In these animals, an undifferentiated mass of tissue called mesoglea fills the space between the ectoderm and the endoderm. Coelenterates are diploblastic animals.

The animals in which the developing embryo has three germinal layers, viz. the ectoderm, the mesoderm and the endoderm, are called **triploblastic animals**. Platyhelminthes and all chordates are triploblastic animals.



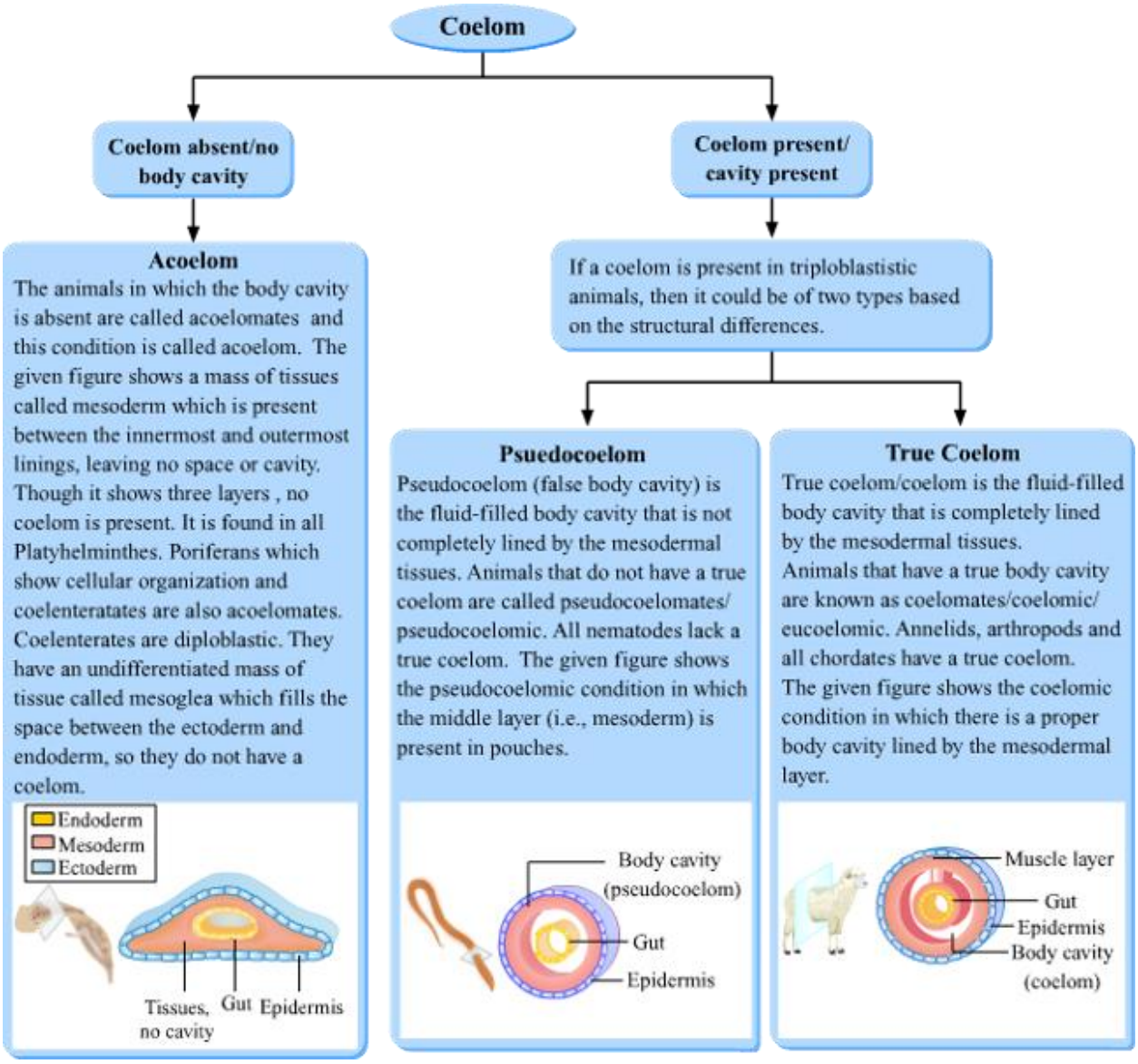
Bases of Animal Classification

Coelom

The presence or absence of a cavity called coelom is very important in the classification of animals. Coelom is the space or cavity between the body wall and the gut wall where the internal organs are suspended.

Although body cavity can also include any space inside the body (such as the space inside internal organs), it is the coelom which is used for the purpose of classification.

Coelom is the space enclosed by the mesodermal cell. Thus, only triploblastic animals can have a coelom. However, not all triploblastic animals actually show this characteristic. Hence, there can be two conditions with respect to coelom.



Know More

True coelom can be categorized further as schizocoelom and enterocoelom on the basis of developmental differences.

Schizocoelom

Schizocoelom arises from mesodermal split. This body cavity is formed from blocks of mesoderm around the gut which enlarge and hollow out. Animals belonging to the phyla Annelida, Mollusca and Arthropoda display this type of true coelom.

Enterocoelom

Enterocoelom arises from outpocketing of the embryonic gut (endoderm). This body cavity is formed by outpocketings of the primitive gut which break off and form the coelom. Animals belonging to the phyla Echinodermata and Chordata display this type of true coelom.

Bases of Animal Classification

Segmentation

Certain animals have a body that is externally and internally divided into segments, with a serial repetition of at least some organs. Such segmentation is called metameric segmentation and this phenomenon is known as **metamerism**. For example, the body of an earthworm shows metameric segmentation.

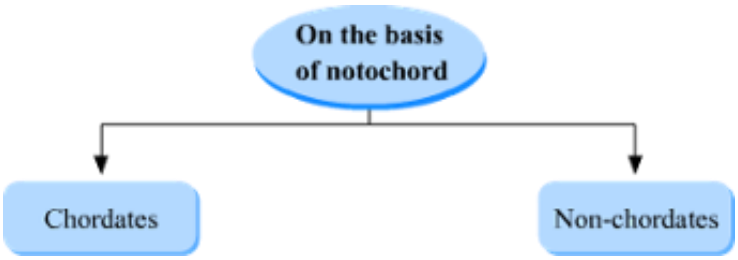
Earthworm

Notochord

Notochord is a rod-like structure consisting of vacuolated cells. It originates from the mesoderm. It is formed on the **dorsal** side in some animals. It separates the nervous system from the gut and also acts as a support.

Based on the presence or absence of the notochord, animals are categorized as chordates and non-chordates.

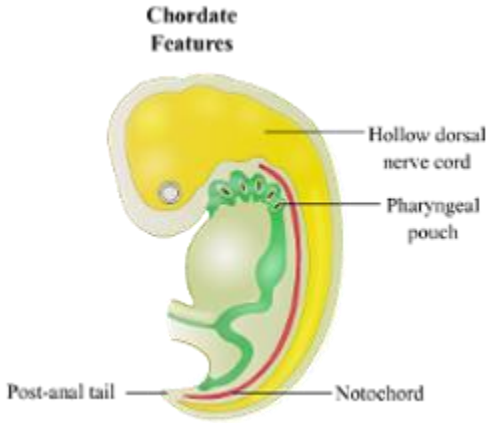
Bases of Animal Classification



Non-chordates: These organisms do not have a notochord. Animals belonging to the phyla Porifera, Coelenterata, Platyhelminthes, Nematoda, Annelida, Arthropoda, Mollusca and Echinodermata are all non-chordates.

Chordates: These organisms have a notochord. *Amphioxus*, *Herdmania* and all vertebrates (of the classes Pisces, Amphibia, Reptilia, Aves and Mammalia) are chordates.

The given figure shows the embryo of a chordate along with the location of the notochord.



Non-Chordates

Let us now study about the characteristic features of the first eight phyla of kingdom Animalia, i.e., Porifera, Coelenterata, Platyhelminthes, Nematoda, Annelida, Arthropoda, Mollusca and Echinodermata.

Phylum Porifera

The word 'Porifera' means 'organisms with holes'. These organisms are commonly called sponges.

General features of poriferans

- They are mostly marine organisms except *Spongilla*.
- They are non-motile and found attached to rocks.
- They show cellular level of organization and minimal differentiation.
- Majority of sponges are asymmetrical.
- Their bodies are porous. The holes or pores are called ostia. These pores lead to the canal system which allows the circulation of water throughout the body. The pores enable food and oxygen to enter the body.
- These animals have a hard outside layer or skeleton.

- Examples of poriferans: *Sycon*, *Spongilla*, *Euspongia*, *Euplectella*

Sycon *Euspongia* *Spongilla*

Did You Know?

- There are approximately 5000 different species of sponges.
- A sponge can contain around 16000 other animals inside itself.
- One of the first anti-cancer drugs was isolated from a sponge. In 1959, the anti-cancer drug called cytosine arabinoside was extracted from a sea sponge named *Cryptotethya crypta.* Recently, sponges have received much attention from pharmaceutical companies as the many chemicals produced by these organisms help fight infections, inflammations, diabetes and gastrointestinal ailments.

[[//mn:know]]

Non-Chordates

Phylum Coelenterata

The word ‘Coelenterata’ means ‘hollow gut’. This phylum is also known as Cnidaria.

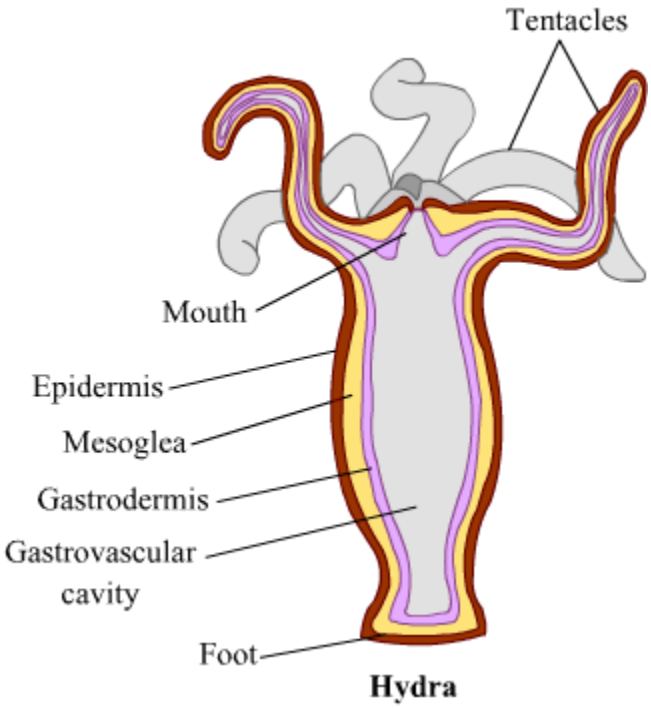
General features of coelenterates

- They are exclusively marine animals.
- They have a tissue level of organization, and lack organs and organ systems.
- Most of these animals have radial symmetry.
- The body of a coelenterate consists of two cell layers—the ectoderm (the outer layer) and the endoderm (the inner layer). Hence, it is the first diploblastic animal.
- Since a coelenterate is diploblastic, the body cavity called coelom is absent. (The coelom is found between the gut wall and the body wall of triploblastic animals.) Its body has a sac-like body cavity with a single opening to the outside for ingestion and egestion.

- Some of the coelenterate species live in colonies (e.g., corals), while others have a solitary life span (e.g., *Hydra*).

Non-Chordates

- Examples of coelenterates: *Hydra*, *Obelia*, *Aurelia* (jellyfish), *Metridium* (sea anemone)



Hydra

Did You Know?

- There are more than 2000 coral reefs in the world.
- The Great Barrier Reef is the world's largest coral reef. It is composed of around 3000 individual corals extending to around 2600 km.

Non-Chordates

Phylum Platyhelminthes

Another name for platyhelminthes is ‘flatworms’. This is because their bodies are dorsoventrally flattened, and so they have a leaf-like or ribbon-like appearance.

General features of platyhelminthes

- They are mostly parasitic (e.g., tapeworms, liver flukes). However, some may be free-living (e.g., *Planaria*).

- They show an organ level of organization.
- They show bilateral symmetry.
- The body of a platyhelminth consists of not only the ectoderm and the endoderm but also the mesoderm (the layer of cells found between the outer and inner layers). Therefore, it is the first triploblastic animal.
- True body cavity or coelom is absent.
- Examples of platyhelminthes: *Planaria, Fasciola* (liver fluke), *Taenia solium* (tapeworm).

Planaria

Liver fluke

Tapeworm

Solved Examples

Medium

Example 1:

Do you know what causes liver rot disease?

Solution:

Liver fluke found in the liver and bile ducts of sheep and goats causes the complete breakdown of liver cells. This is known as liver rot disease. It is a serious disease in animals and can be fatal.

Example 2:

Why are fully developed organs not found in platyhelminthes?

Solution:

A platyhelminth has three layers of cells from which differentiated tissues can be made, which is why it is called triploblastic. This allows the outer and inner body linings to be made along with some organs. Thus, there is some degree of tissue formation.

However, there is no true internal body cavity or coelom in which well-developed organs can be accommodated. Hence, platyhelminthes do not have fully developed organs.

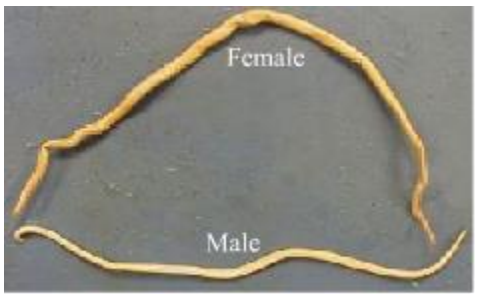
Non-Chordates

Phylum Nematoda

Another name for nematodes is ‘roundworms’.

General features of nematodes

- They are parasitic animals which cause diseases such as elephantiasis (filarial worms) and usually live in the intestine.
- A nematode has a cylindrical body with tapering ends.
- Nematodes have an organ system level of organization, but no real organs are formed due to the absence of a true coelom.
- They are bilaterally symmetrical and triploblastic.
- A false body cavity or pseudocoelom is present.
- Examples of nematodes:*Ascaris*, *Wuchereria* (filarial worm), *Ancylostoma* (hookworm)



Ascaris

Wuchereria

Non-Chordates

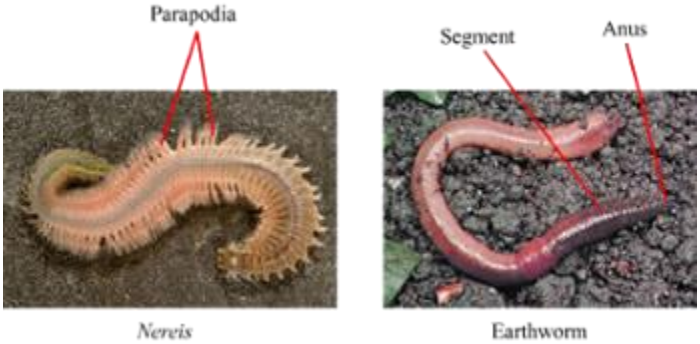
Phylum Annelida

Annelids are commonly called segmented worms.

General features of annelids

- They occur in both terrestrial and aquatic environments. They may be free-living or parasitic.

- They have an organ system level of organization.
- They are bilaterally symmetrical.
- An annelid possesses true organs inside its body structure.
- They are triploblastic animals. They are the first animals to possess a true body cavity or coelom (schizocoelom).
- They have metameric segmentation with extensive organ differentiation. The segments of the body are lined up one after the other from head to tail. Some of them have appendages called parapodia that help in locomotion.
- Examples of annelids: *Pheretima* (earthworm), *Hirudinaria* (leech), *Nereis*



Did You Know?

- Earthworms do not have eyes, but they have light receptors to sense light. These receptors help them differentiate between light and darkness.
- Earthworms are only found in humid conditions because they respire through their skin. They have a covering of mucus which allows dissolved oxygen to move into blood.

Non-Chordates

Phylum Arthropoda

The word ‘Arthropoda’ means ‘animals with jointed legs’. It is the largest phylum of the animal kingdom and includes more than 900000 species.

General features of arthropods

- They are found everywhere on Earth.
- An arthropod has a segmented body like that of an annelid. The body is divided into three regions—the head, the thorax and the abdomen.
- The body is covered by an exoskeleton made of chitin.
- Arthropods have an organ system level of organization.
- They show bilateral symmetry. They are triploblastic animals. Schizocoelom is present.
- They have certain advanced features.
- A distinct head is present. There are jointed legs for moving around.

- An open circulatory system is present, i.e., blood does not flow in well-defined blood vessels. Thus, their coelomic cavity is filled with blood.
- Examples of arthropods: crab, *Palaemon* (prawn), insect, spider, scorpion, centipede, millipede, cockroach, housefly, mosquito

Cockroach Butterfly Housefly Prawn

Non-Chordates

Phylum Mollusca

It is the second largest phylum after arthropods. Its members are commonly called soft-bodied animals.

General features of molluscs

- Though mostly present in seas, they may be found in freshwater or on land as well.
- The body of a mollusc is unsegmented like those of an annelid and an arthropod.
- They have an organ system level of organization.
- They show bilateral symmetry.
- A mollusc has an open circulatory system and possesses kidney-like organs for excretion.
- Molluscs are triploblastic animals.
- The coelomic cavity (schizocoelom) is reduced to a cavity called haemocoel, through which the hemolymph (function similarly as blood of vertebrates) circulates.
- The body is divided into an anterior head, a ventral muscular foot and a dorsal visceral mass.
- The soft body is covered by a hard shell.
- A mollusc has a distinct foot for moving around.
- Examples of molluscs: *Octopus*, *Pila* (freshwater snail), *Unio* (freshwater mussel), *Sepia* (cuttlefish), *Loligo* (squid)

Chiton *Octopus* *Pila* *Unio*

Non-Chordates

Phylum Echinodermata

The word ‘Echinodermata’ is derived from two Greek words: ‘echinos’ which means ‘hedgehog’ and ‘derma’ which means ‘skin’. They are commonly called spiny-skinned animals.

General features of echinoderms

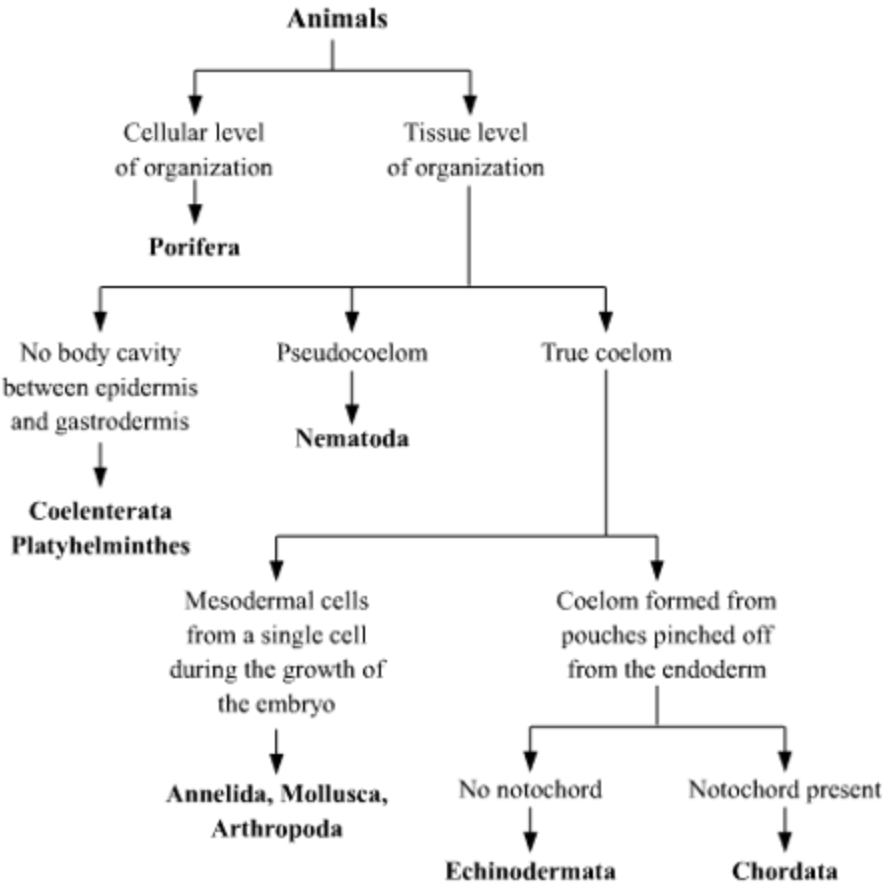
- They are exclusively free-living marine animals.
- They may be globular or cylindrical in shape.
- They have an organ system level of organization.
- They are triploblastic animals.
- They are coelomates and possess an enterocoelom.
- In the larval stage, they have bilateral symmetry and as adults, they have radial symmetry.
- The body of an echinoderm has a spiny outer covering made up of calcium carbonate.
- Echinoderms use a powerful water-driven tube system for moving around.
- Examples of echinoderms:*Asterias* (starfish), *Echinus* (sea urchin), *Holothuria* (sea cucumber), *Ophiura* (serpent star), *Antedon* (feather star)

Sea urchin

Starfish

Ophiura

Summary of Classification



Kingdom Animalia - Vertebrata

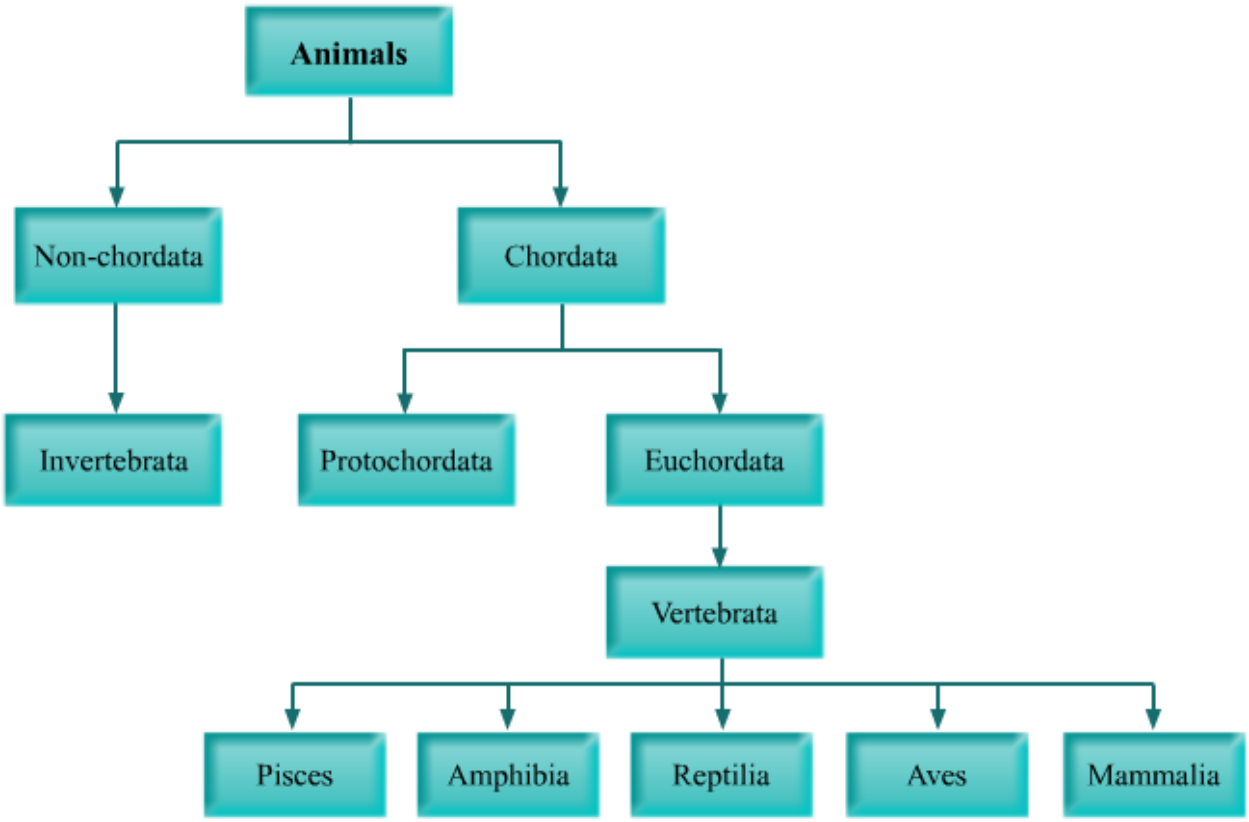
Phylum Chordata

We know that kingdom Animalia is divided into chordates and non-chordates based on the presence or absence of the **notochord**.

General features of chordates

- They have a notochord.
- They have a dorsal nerve cord.
- They are bilaterally symmetrical and triploblastic.
- They possess a true coelom (enterocoelom).
- They have paired gill pouches.

Phylum Chordata is sub-divided into the sub-phyla **Protochordata** and **Vertebrata** based on the developmental features of the notochord.



Sub-phylum Protochordata

This group includes animals that have a notochord. This feature may not be present at all stages of their life cycle. Further, the notochord may not run the entire length of a protochordate's body.

The word 'proto' means 'primitive'. This indicates that protochordates are the ancestors of the modern-day chordates.

General features of protochordates

- They are exclusively marine animals. They often live in burrows.
- They show an organ system level of organization and are triploblastic.
- The body cavity is enterocoelom.
- The body of a protochordate is not segmented and is bilaterally symmetrical.
- A notochord is present in some or all stages.
- Examples of protochordates: *Amphioxus*, *Herdmania*, *Balanoglossus*

Amphioxus

Balanoglossus

Interesting Facts

- In *Herdmania,* the notochord appears only in the tail of the larva and disappears in the adult.
- In *Amphioxus,* the notochord extends until the anterior end of the body and is present throughout its life.

Sub-Phylum Vertebrata

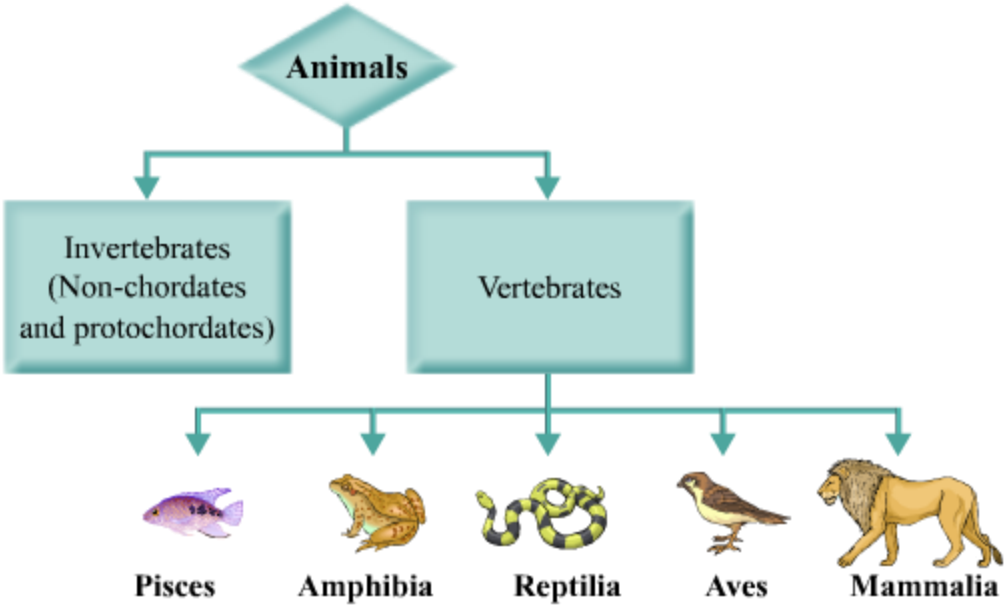
The members of sub-phylum Vertebrata are advanced chordates.

General features of vertebrates

- A notochord is present only in the embryonic stage.
- In an adult vertebrate, the notochord is replaced by a vertebral column consisting of ring-like bones called vertebrae.
- An internal skeleton is present along with the vertebral column. This allows for a completely different distribution of muscle attachment points to be used for movement.
- Vertebrates have a muscular heart with two, three or four chambers.
- They are bilaterally symmetrical and triploblastic.
- Examples of vertebrates: fishes, amphibians, reptiles, birds and mammals

Concept Builder

Invertebrates and Vertebrates

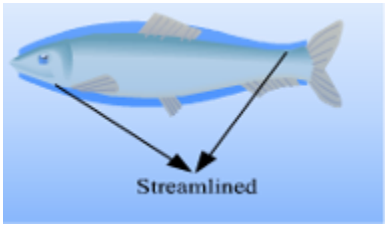


The Vertebrates

Class Pisces

Class Pisces includes fishes.

General features of fishes



They are exclusively aquatic animals. They have special adaptive features to live in water, like a streamlined body and a tail for movement.

Fins are present but limbs are absent. The skin of a fish is covered with scales. Fishes obtain oxygen dissolved in water with the help of gills.

They are **cold blooded** animals and are also called ectotherms/pokiliotherms. They have a two-chambered heart. They lay eggs.

Examples of fishes: *Scoliodon* (dogfish/shark), Tuna, *Rohu*.

Shark

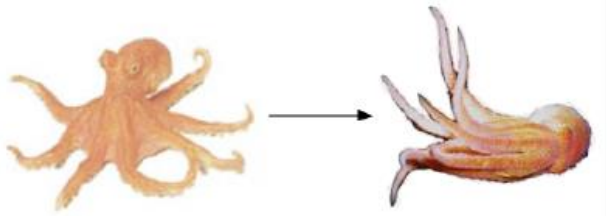
Rohu

The skeletons of some fishes (e.g., shark, ray) are made entirely of cartilage. These fishes are called **cartilaginous fishes**.

The skeletons of some fishes (e.g., *Rohu*, *Catla*) are made of both bone and cartilage. These fishes are called **bony fishes**.

Whiz Kid

An octopus is capable of streamlining its body while swimming.



Know More

Pisces is further divided into three classes:

Agnatha
(Jawless fish)

- Oldest known vertebrates
- The only surviving members of this class are the hagfish and lampreys.
- All members have sucking circular mouth without jaws.

Hagfish

Chondrichthyes
(Cartilaginous fish)

- Members have cartilaginous skeleton and streamlined body.
- Thay have to swim continuosly to avoid sinking due to the absence of air bladder.
- Example:*Scoliodon* (dogfish)

Scoliodon

Osteichthyes
(Bony fish)

- They are found in both marine and freshwater.
- Members have bony endoskeleton and streamlined body with mouth terminally placed
- Example:Seahorse, rohu

Seahorse

Class Amphibia

The word ‘Amphibian’ can be understood by breaking it into two parts: ‘amphi’ which means ‘two’ or ‘both’ and ‘bios’ which means ‘life’. So, amphibians are animals that can live both on land and in water.

General features of amphibians

- The adults are terrestrial. They were the first vertebrates to occupy land.
- They live in damp places.
- The adults respire through lungs or skin, while the larvae respire through gills.
- They lay eggs in water.
- They are cold blooded animals.
- They have a three-chambered heart.
- The skin of an amphibian has mucus glands. Scales are absent.
- Examples of amphibians:toad, frog, salamander

Toad

Frog

Salamander

Solved Examples

Medium

Example 1:

Why are toads, frogs and salamanders called amphibians?

Solution:

The word ‘amphibian’ is derived from the Greek words ‘*amphi*’ which means ‘two’ or ‘both’ and ‘*bios*’ which means ‘life’. Thus, amphibians are animals that have a dual mode of life, which is the case with toads, frogs and salamanders.

Their dual modes of life are as follows:

- The larval stage is fish-like since they are aquatic. The larva has a tail, which aids it in swimming. Also, it has gills for respiration.
- The adult stage is terrestrial. The adult moves with limbs and respires through lungs and skin.

Example 2:

What is the difference between a toad and a frog?

Solution:

Toad	Frog
It has a rough, dry and warty skin.	It has a smooth and moist skin and this makes it look ‘slimy’.
It has a wider body.	It has a narrower body.
It has lower, ball-shaped eyes.	It has higher, rounder and bulgier eyes.
It has shorter, less powerful hind legs.	It has longer, more powerful hind legs.
It runs or takes small hops rather than jump.	It takes long high jumps.

Class Reptilia

Reptiles are called so because they creep or crawl on land.

General features of reptiles

- The body of a reptile is divisible into the head, the neck and the trunk. The tail is well-developed in some and reduced in others.
- Limbs are present, but are reduced or absent in case of snakes.
- The skin is covered with scales.
- Reptiles are cold-blooded animals.
- Most of them have a three-chambered heart, except crocodiles which have a four-chambered heart.
- They respire through lungs only.
- They lay eggs on land.
- Examples of reptiles: lizard, snake, turtle, chameleon

Snake

Turtle

Chameleon

Did You Know?

- The king cobra is the largest venomous snake in the world. It is approximately 12 feet long.
- Most snakes swallow their prey alive. However, a poisonous snake kills its prey with its venom before swallowing it.

Class Aves

Class Aves includes all birds.

General features of birds

- Most of them have feathers.
- They possess a beak.
- Forelimbs are modified into wings for flight.
- Hind limbs are modified for walking and clasping.
- Bones are hollow.
- They are **warm blooded** animals and are also called endotherms/homeotherms.
- The heart is four-chambered.
- Respiration occurs through lungs only.
- They lay eggs.
- Examples of birds: sparrow, parrot, crow, pigeon

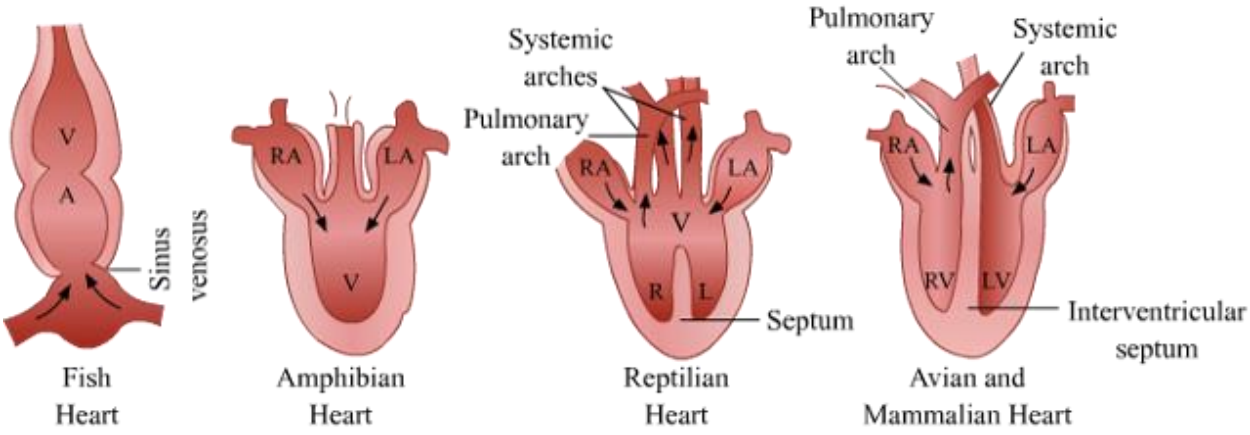
Sparrow

Parrot

Crow

Know More

The Heart in Different Vertebrates



Solved Examples

Medium

Example 1:

What is the difference between cold-blooded and warm-blooded animals?

Solution:

A cold-blooded animal does not have a definite body temperature. It alters its body temperature in tune with that of the outside environment. Fishes, amphibians and reptiles are cold blooded. A warm-blooded animal, on the other hand, has a definite body temperature. This temperature does not alter according to the outside temperature. Birds and mammals are warm-blooded.

Class Mammalia

Class Mammalia includes a variety of animals that have milk-producing glands (mammary glands) to nourish their young ones.

General features of mammals

- They are found in a variety of habitats like deserts, forests, mountains, etc.
- Some of them can fly.
- They have two pairs of limbs for walking, running or flying.
- The skin of a mammal has hair as well as sweat glands. The hair protects it in winters and the sweat glands keep its body cool in summers. These features are of particular importance as a mammal is a warm-blooded animal.
- Mammals respire through lungs.
- They have a four-chambered heart.

- They give birth to young ones and, so, are called **viviparous**. There are some mammals that lay eggs, e.g., Platypus, Echidna.Such mammals are called **oviparous mammals**.
- Two sets of teeth—milk teeth and permanent teeth—develop in the lifetime of a mammal. The teeth are of different types, i.e., heterodont.
- Examples of mammals:human, bat, whale, rat, cat


Bat


Whale


Rat

Solved Examples

Medium

Example 1:

How do bats locate their prey?

Solution:

Bats locate and catch their prey by the mechanism called echolocation. While hunting, a bat produces a constant stream of high-pitched sounds. When these sound waves hit an insect or another animal, the echoes bounce back to the bat. The echoes guide it to the prey. The time interval between the sounds and the echoes helps the bat to determine its distance from the prey.

Example 2:

Why are bats not placed under class Aves?

Solution:

Bats are not placed under class Aves in spite of their capability to fly. This is because they possess many characteristics that are specific to the animals belonging to class Mammalia. These include: the presence of hair and mammary glands, and the condition of being viviparous (i.e., giving birth to their young ones).