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Chapter 12

Patterns in Life: Diversity and Classification

Think It Over

- What do you understand by biodiversity?
- How does the grouping of organisms help us understand diversity?
- On what basis, are plants and animals classified?
- How does classification help address problems in farming?

Have you ever wondered why some plants can survive long droughts while others cannot? Or, how certain insects protect crops while others damage them?

The Earth is home to an enormous variety of life forms. From microscopic organisms invisible to the naked eye to giant trees, from glowing jellyfish to soaring eagles, life exists in countless forms and habitats—from the snow-clad Himalayas to the coral reefs of the Andaman Sea. This immense variety of living organisms is known as **biodiversity**. Biodiversity is essential for life on the Earth. Every organism plays a role in keeping nature stable and functioning. Microscopic algae in the oceans release most of the oxygen we breathe. Fungi and bacteria decompose fallen leaves, and convert waste into manure, making the soil fertile. Birds, bees and bats pollinate flowers, while plants capture sunlight to prepare food that support nearly all life on the planet. These interconnections help sustain ecosystems and make the Earth suitable for living organisms.

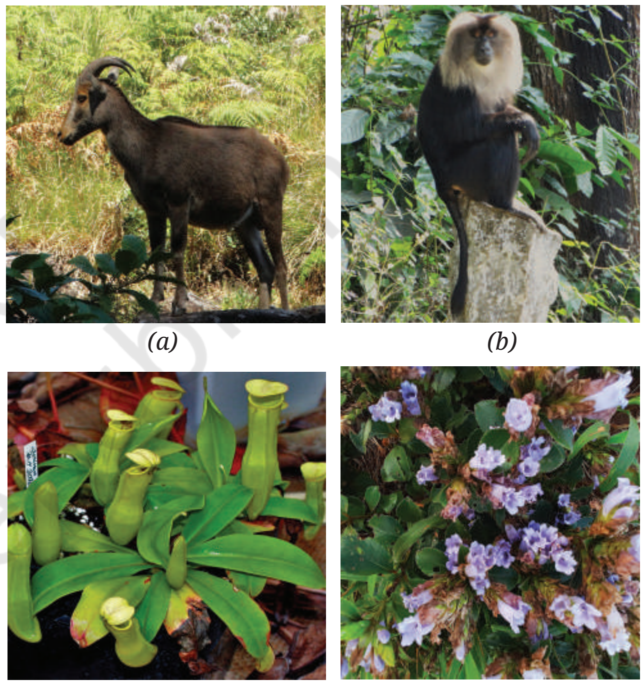
Humans, too, depend on biodiversity for food, shelter, medicines and livelihoods. For centuries, farmers relied on their practical knowledge to conserve diverse crop varieties with useful characteristics, such as drought tolerance, pest resistance and their ability to grow in nutrient poor soils. They realised that diversity reduces the risk of crop failure and strengthens food security.

In such a vast diversity, organisms share certain similarities while also showing many differences. To study diversity systematically, scientists group and classify organisms based on their shared characteristics and evolutionary relationships. Classification helps us understand how organisms are related, how they function and how we can use this knowledge in activities, such as ecosystem management, biodiversity conservation, sustainable farming, and so on.

12.1 India as a Biodiversity Hotspot

The natural landscape of our country is diverse — with mountains in the north, desert in the west, rainforests in the North East India, plateaus in the south, and long coastlines along the Arabian Sea and the Bay of Bengal. Each of these regions has distinct soil types and different climatic conditions like temperature and rainfall.

These diverse habitats together support a wide variety of species. Some of these species are restricted to particular regions of the world and are not found naturally anywhere else. Such species are called **endemic species**. For example, Nilgiri tahr (Fig. 12.1a), Lion-tailed macaque (Fig. 12.1b), Indian variety of the pitcher plant — *Nepenthes khasiana* (Fig. 12.1c) and *Neelakurinji* (Fig. 12.1d) are found only in India.



(a) (b) (c) (d)

Fig. 12.1: (a) Nilgiri tahr, (b) Lion-tailed macaque, (c) Nepenthes khasiana, and (d) Neelakurinji

Regions that support a large number of endemic species and have undergone significant habitat loss are known as biodiversity hotspots. These areas are particularly important for biodiversity conservation. Regions, such as the Western Ghats, Indo-Burma (including North East India), the Himalayas, Sundaland (including the Nicobar Islands), are some examples of global biodiversity hotspots. These areas are especially rich in number and in the diversity of organisms. Protecting these regions is equally important, as they support food webs and help ecosystems remain healthy.

12.2 How has the Biodiversity Evolved?

The biodiversity that we see today on the Earth was not always the same. Small differences among individuals affected their chances of survival and reproduction by helping them adapt to changed conditions. These differences accumulated over many generations and gave rise to new forms of life.

The diversity we see today is therefore, an outcome of continuous changes occurring over a vast span of time, shaped by interactions between organisms and their surroundings. The study of this biological diversity is possible through a systematic framework that is provided by classification.

India's Scientific Contributions

Some ancient Indian traditions, such as the *Sangam Tinai* classification of landscapes and the protection of sacred groves, demonstrate a sophisticated literary and cultural understanding of landscapes, and their biota. These customs effectively preserved locally diverse habitats, aligning with contemporary ecological principles, even if it is not articulated as a formal ecological theory.

12.3 How to Classify Organisms?

Activity 12.1: Let us compare and classify

Fig. 12.2 shows the diversity of animals in an ecosystem. **Observe** the image carefully. Can you guess how the organisms are grouped in the image?

Fig. 12.2: Day and night view of an ecosystem

1. Ponder on the questions given below:
   - Which animals can you identify in the given picture?
   - Where are they seen?
   - Which animals in the picture seem active:
     (i) during the day?
     (ii) during the night?
     (iii) both during the day and the night?
2. Record your observations in Table 12.1.

Table 12.1: Observation table for recording the data

Organism (draw or write name)	Where do you see it? (flying high in air/flying near the ground/tree/water/forest floor)	When does it appear to be active? (day/night/unsure)	Any visible feature(s)
Owl	Tree	Night	Feathers

3. Now, try grouping the same organisms in more than one way. Each time change the criterion you are using for grouping (Table 12.2).

Table 12.2: Grouping the organisms

The grouping criterion	Which organisms fit in this group?	What feature or pattern helped you decide?
Carnivore	Eagle, tiger, leopard	Eating habits

You may notice that the same organism can fit into different groups depending on the criterion you choose. This leads to an important question: how do scientists decide which features to use while grouping the living organisms? This question leads us to the idea of classification, a systematic way of organising the Earth's living diversity.

Pause and Ponder

1. If many organisms share common features, could they also share a common ancestry?

12.3.1 Some criteria to classify living organisms

Scientists often look at broad and easily visible features, and then look at more detailed features. They use a number of characteristics to group living organisms, some of which are given below:

1. External features — visible characteristics, such as shape, size and body organisation.
2. Mode of nutrition — autotrophic or heterotrophic.
3. Internal structures — skeletal patterns, presence or absence of organs and different types of tissues.
4. Cell structure — whether the organism is unicellular or multicellular, the cell is eukaryote or prokaryote, presence or absence of cell wall.
5. Ecological role — producer, consumer, or decomposer.
6. Reproduction — asexual and/or sexual methods.
7. Genetic similarity — similarities in inherited features, which scientists study in detail using DNA.

These features help in understanding the similarities and differences among organisms. Similar features in organisms suggest that they have evolved from common ancestors.

12.4 The Need for Classification

Imagine walking into a huge library where thousands of books are scattered all over the floor. You want to read the book, *On the Origin of Species* by Charles Darwin. Where would you begin? Without arranging books into subjects, authors, or sections, finding any book would be difficult. In the same way, the Earth is home to millions of organisms. Therefore, classifying these organisms systematically helps us in understanding them better.

(a) Rufous-necked hornbill

(b) Oriental Pied hornbill

(c) Great hornbill

(d) Wreathed hornbill

Fig. 12.3: Four different species of hornbill found in the Pakke Tiger Reserve

Activity 12.2: Let us read a case study

Carefully read the given case study of Pakke Tiger Reserve.

The Pakke Tiger Reserve in Arunachal Pradesh is a forest where scientists have recorded nearly 300 bird species, which is striking given that India as a whole has about 1,300 bird species. Pakke is also known for supporting four species of hornbills — the Rufous-necked Hornbill, the Oriental Pied Hornbill, the Great Hornbill, and the Wreathed Hornbill (Fig. 12.3). These large birds nest only in large, old trees with suitable cavities and feed on specific fruits. As a result, different hornbill species are found in different parts of the forest depending on tree size and fruit availability. Studying such patterns allows scientists to ask precise questions about biodiversity, such as —

- How are species distributed within a forest? Which plants and animals are closely linked?
- How does classifying the four hornbill species help us understand biodiversity?

Think and discuss the case based on the following questions —

(i) How can scientists keep track of so many species?

(ii) The four hornbills look similar in some ways. What features can help scientists distinguish them from one another?

(iii) What would happen if the large, old trees disappeared from the forest?

Many organisms show similarities in their external features, internal structure (such as tissues and organs) and cellular organisation. To make the study of such vast diversity easier, scientists group organisms based on their similarities and/or differences. This grouping helps to organise information, understand relationships among organisms and study life in a systematic manner. This scientific system of grouping living organisms is known as **biological classification**.

Biological classification helps us in various ways, such as —

1. It makes the study of living organisms more organised and systematic.
2. It helps us understand the similarities and differences among living beings.
3. It helps us understand how different organisms are related to one another and how they interact.
4. It helps us in identifying and naming the newly discovered organisms.
5. It supports biodiversity conservation by identifying the organisms that are under the threat of extinction.

6. It allows scientists all over the world to discuss about organisms using a common system.

India's Scientific Contributions

The *Rigveda* and the *Brihat Samhita* classify animals on the basis of their habitat (terrestrial, aquatic and aerial), behaviour patterns and ecological roles.

12.5 Biological Classification Systems Over Time

In the previous section, you have learnt to identify various criteria for classifying the huge biodiversity in the world. Scientists have developed different classification systems over time, based on the knowledge available.

Aristotle, around the 4th century BCE, grouped animals based on their habitat — land, water and air. He also grouped them based on their external appearances. However, this system had limitations because it relied mainly on easily observable external characteristics. In the 18th century, scientists introduced the two kingdom system. All living organisms were divided into Plantae and Animalia.

Plantae — organisms that do not move from one place to another and synthesise their own food.

Animalia — organisms that move from one place to another and depends on other organisms for food.

But this system created confusion. Where should organisms like *Amoeba*, *Paramecium* and bacteria be placed? *Amoeba* and *Paramecium* move like animals but are unicellular and heterotrophic. However, plants and animals are multicellular organisms. To address this, scientists added a third kingdom, Protista, to include unicellular microscopic organisms.

As microscopes improved, scientists noticed an important difference. An *amoeba* has a true nucleus (membrane-bound) but bacteria do not. Since both are unicellular but very different, bacteria were placed in a separate kingdom called the Monera. This led to a four kingdom classification system — Plantae, Animalia, Protista and Monera. The kingdom Protista includes mostly unicellular organisms with a true nucleus. Later, scientists noticed that fungi like mushrooms, do not move like plants but have a heterotrophic mode of nutrition. They obtain nutrients by absorption, many absorb nutrients from dead and decaying matter (though some are symbiotic and some are parasitic). Therefore, fungi were placed in a separate kingdom. This resulted in the five kingdom classification, which includes Monera, Protista, Fungi, Plantae and Animalia (Fig. 12.4).

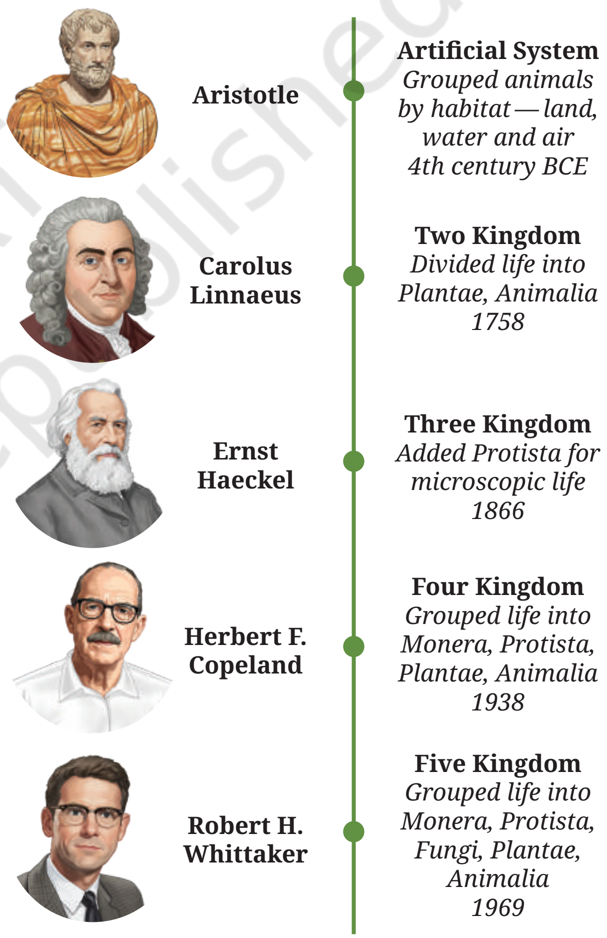


Fig. 12.4: Timeline of the classification systems

12.6 Five Kingdom Classification

In the five kingdom classification, all life forms are grouped based on certain common features.

Activity 12.3: Let us study

1. Study the concept map (Fig. 12.5).
2. List the criteria which form the basis of five kingdom classification.

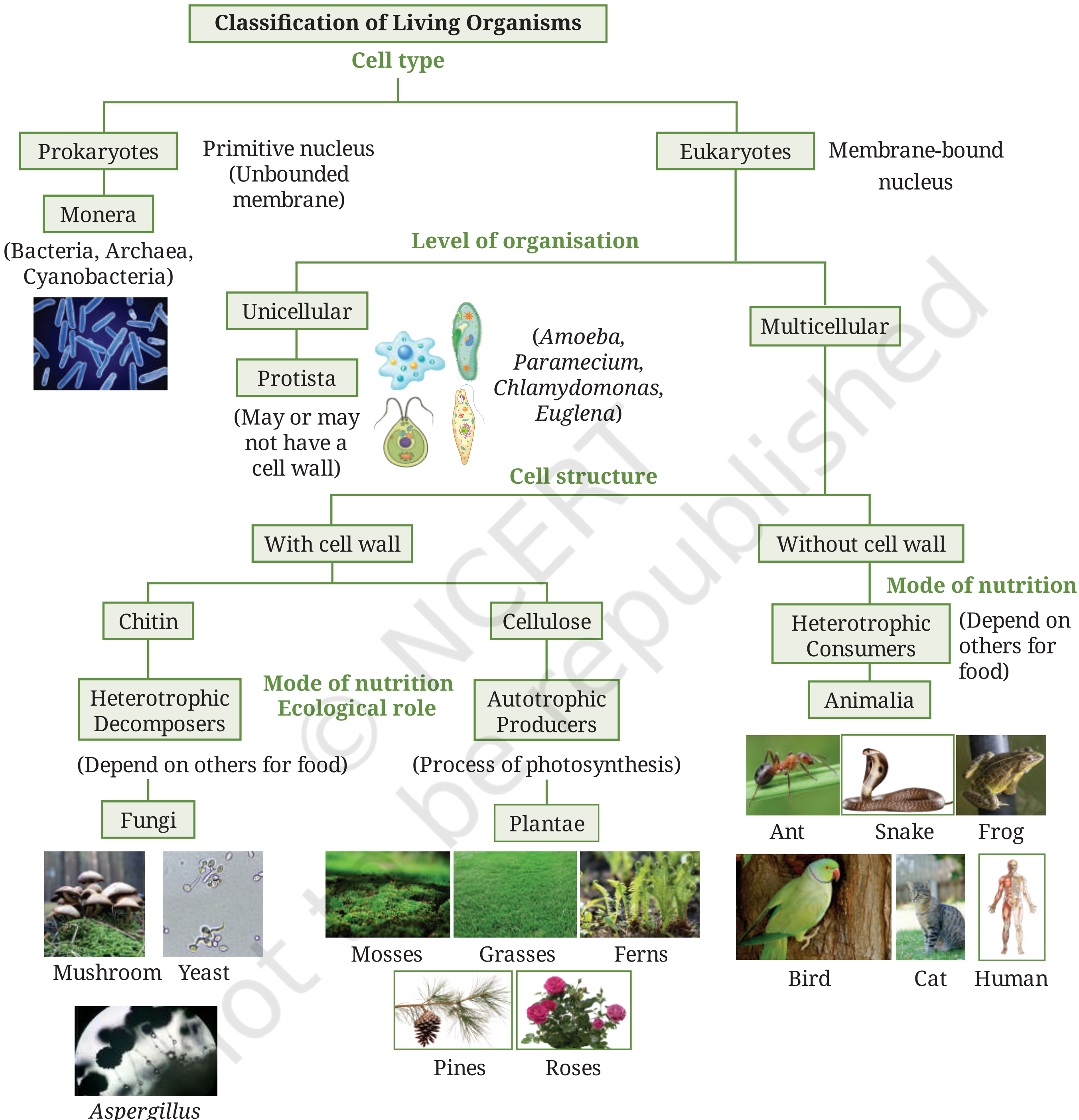


Fig. 12.5: Five kingdom classification

3. **Compare** the criteria you have listed after studying the concept map and the criteria given below:
   - Cell type — prokaryote or eukaryote
   - Cell structure — presence or absence of a cell wall

- Level of organisation — unicellular or multicellular
- Mode of nutrition — autotrophic or heterotrophic

12.6.1. Kingdom Monera — Unicellular prokaryotes

Activity 12.4: Let us explore

1. In the school laboratory, observe the available permanent slides of bacteria and cyanobacteria under the microscope.
2. Compare them with Fig. 12.6.

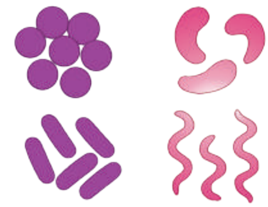


Fig. 12.6 Members of the Kingdom Monera

What do you observe? Bacteria and cyanobacteria are single-celled prokaryotes that are grouped under Monera (Fig. 12.6). Bacteria are found everywhere, including soil, water, air, hot springs and other extreme environments where most organisms cannot survive and even inside the human bodies. They are also found in the gut of ruminants and are responsible for the production of biogas from the dung of these animals. Some bacteria are harmful (pathogens) and cause diseases but many are useful like *Lactobacillus* and *Rhizobium*. Cyanobacteria are autotrophs and decomposers. In addition to nutrient cycling, some bacteria also break down pollutants like oil, pesticides, sewage, and so on.

Threads of Curiosity

Cyanobacteria (blue-green algae) were among the first organisms to produce oxygen through photosynthesis. About 2.5 billion years ago, oxygen accumulated in the atmosphere, made the Earth suitable for other forms of life. Fossils of ancient cyanobacteria are found in structures called **stromatolites**. They were found in Rajasthan and Madhya Pradesh. They provide some of the earliest evidence of life on the Earth.

Bridging Science and Society

Ram Bux Singh is popularly known as the 'Father of Modern Biogas'. He was a pioneering Indian scientist who contributed to the development of biogas technology. In 1957, he established India's first scientifically designed biogas plant at Ramnagar, Sitapur, Uttar Pradesh, which marked the beginning of systematic modern biogas research in the country. He later worked extensively on developing low-cost, efficient biogas plants for rural areas. He also served as an international consultant and helped set up biogas plants in several countries. His lifelong efforts played a crucial role in promoting renewable energy, waste management and sustainable development through technology.

12.6.2 Kingdom Protista — Unicellular eukaryotes

All single-celled eukaryotes without cell wall or with cell wall made up of cellulose are grouped under the kingdom protista. They are microscopic and highly diverse organisms. You can study some of these protists (Fig. 12.7) by making a slide from hay infusion as explained below.

Activity 12.5: Let us make

To make a hay infusion, follow the steps given below —

1. Collect a small sample of grass after the lawn has been mowed, or collect straw or fodder.
2. Take a small glass bottle and fill one fourth of it with the grass, straw or fodder.
3. Fill the bottle with stagnant water or pond water and mix it with the collected plant material.
4. Cover the bottle with a muslin cloth and tie it using a thread.
5. Keep the bottle aside undisturbed for a week.

Fig. 12.7: Microscopic illustration of common protists

Pause and Ponder

2. How can a single-celled organism carry out all its life processes when billions of cells are required to perform similar functions in multicellular organisms like us?

6. Slightly open the mouth of the bottle by removing the muslin cloth, just enough to insert a dropper inside it and carefully take a drop of water.
7. Put the drop of water on a clean slide and observe it under a microscope.

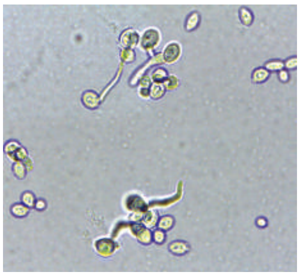
Caution: The hay infusion may smell bad. Therefore, take precaution during lab exercises.

- Wear a lab coat, mask and hand gloves.
- Discard the hay infusion after autoclaving.

Do you notice moving organisms in the drop of water under the microscope? Can you **identify** them by comparing them with Fig. 12.7?

Protista includes single-celled eukaryotic organisms that live in water or moist places (Fig. 12.7). Some are autotrophic and others are heterotrophic. Protists are an important link in aquatic food chains, some produce oxygen while others serve as food for small animals. Some protists function as decomposers and help in nutrient cycling.

12.6.3 Kingdom Fungi — Multicellular, heterotrophic eukaryotes with a cell wall



(a) Yeast

Aspergillus

(c) Mushrooms

Fig. 12.8: Common fungi

Fungi are mostly multicellular eukaryotes with cell walls made of chitin. They do not make their own food. They either absorb nutrients from dead or decaying matter through fine filaments (which together form a network known as mycelium). Most of the fungi are saprophytes and therefore, they play a very important ecological role as decomposers, that means, they feed on dead organic matter, such as fallen leaves, twigs or dead organisms. They break down the complex organic matter into simpler substances and make them readily available in soil as minerals. Some of the fungi establish a mutualistic (symbiotic) relationship with other organisms while others live as parasites, and cause diseases in plants and animals. They reproduce both sexually and asexually, often by forming spores, and grow best in warm and moist conditions.

Yeast (Fig. 12.8a) and bread mould are common fungi. However, yeast is a unicellular organism, since its cell wall is made up of chitin, it has been put under fungi. Mushrooms (Fig. 12.8c) are macroscopic fungi that reproduce by spores. Some fungi like *Aspergillus* (Fig. 12.8b) and *Penicillium* are used to make enzymes and antibiotics. Fungi are important decomposers and help recycle nutrients. Without them, the decay of dead plants and animals would be greatly reduced, adversely affecting the soil fertility and ecological balance.

Bridging Science and Society

Wild edible mushrooms are a valuable dietary food with high nutritional and medicinal values. They are important forest resources used and conserved by many communities, including tribal communities in India. These communities possess traditional knowledge about the edible and poisonous mushrooms based on folk taxonomy. Some wild mushrooms are used as sources of food and some as medicine for treating various ailments. Nowadays, mushroom cultivation is becoming a promising vocation for livelihood. Mushroom farming is easy and accessible due to its minimal space requirement, low investment and fast cycle (30 – 45 days).

12.6.4 Kingdom Plantae — Multicellular, autotrophic eukaryotes with a cell wall

Plants are multicellular, autotrophic organisms that perform photosynthesis. Their cells have a rigid cell wall primarily made up of cellulose, which provides support and protection. All plants belong to the kingdom Plantae. Plants form the base of most of the food chains and release oxygen which is essential for life on the Earth. Kingdom Plantae is further divided into five classes.

Grade 7 Curiosity Chapter 10

Plantae

Class

Thallophyta | Bryophyta | Pteridophyta | Gymnosperm | Angiosperm

Thallophyta (algae) — Primitive plants

Thallophytes (*thallos* means undifferentiated body and *phyton* means plant) are among the simplest plant forms and are mostly found in water or moist environments. They form a thallus, a simple body that allows direct exchange of gases, nutrients and water with the surroundings. They are well-adapted to aquatic habitats. An example of Thallophyta is *Spirogyra* (Fig. 12.9).

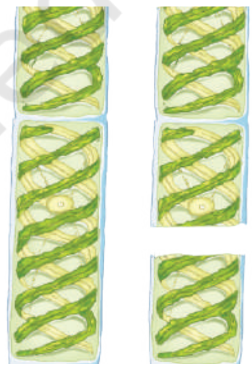


Fig. 12.9: Spirogyra

Bridging Science and Society

Have you ever seen white-green patches on the tree trunk, damp walls or stones? What do you think about these patches? Visit a village and talk to an elderly person about these patches. They recognise these patches as an indicator of a pollution-free environment. In fact, the lichens change their colour with air pollutants. Based on their colour, researchers can find out the concentration of pollutants in the air. Therefore, they are natural bioindicators for the measurement of air quality. Villagers also collect these as forest produce for utilisation in their daily life. Some types of lichen, commonly called *patthar ke phool* are used as a spice, while some are used as medicines, and also for making dyes since ancient times to give maroon, violet, or burgundy colour to woollen and silk fabrics. Biologically, these are symbiotic (mutual associations of two organisms) — one partner is an autotrophic alga and the other one is a heterotrophic fungus. Fungal partners provide protection, and algal partners photosynthesise and provide food. Some lichens are poisonous, so it is important to classify and identify them properly for safe and proper utilisation.

Bryophyta — First steps on land, still need water

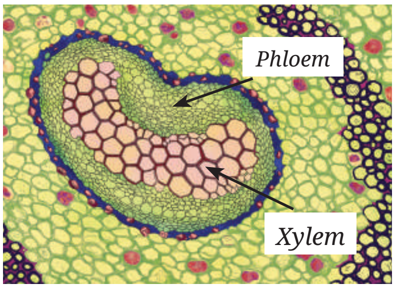
Bryophytes (*bryon* means moss and *phyton* means plant), such as mosses and liverworts (Fig. 12.10), which represents an important shift from water to land. You might have seen them as large green mats on damp rocks or even on the walls of some old buildings, or even on soil surfaces as green mats. Bryophytes have a more differentiated body as compared to thallophytes. They have root-like structures called **rhizoids,** and may possess stem-like and leaf-like simple structures. Bryophytes survive in moist and shady places, growing as green mats on the soil, especially during the monsoons. Examples of Bryophytes include *Marchantia* and moss (Fig. 12.10).

(a) Marchantia

(b) Moss

Fig. 12.10: Members of class Bryophyta

(a)



(b)

Fig. 12.11: (a) Fern, and (b) cross section of a fern stem

Pause and Ponder

3. Which plant features reduce their dependence on water but still require moist conditions?
4. Why do taller plants need specialised transport tissues?
5. How do seeds and fruits affect, where and how plants can survive?

Fig. 12.12: Cone of pine

Activity 12.6: Let us explore

1. Observe some bryophytes with the help of a hand lens. Collect them in a watch glass.
2. Put a drop of water on it and observe it under a dissecting microscope. A dissecting microscope enables us to view magnified images of live specimens.

How do they **differ** from the leaves that you usually observe in your surroundings?

Bryophytes require water for reproduction. Therefore, they are called the 'amphibians' of the plant kingdom. They show how plants began to colonise land, while remaining dependent on moisture.

Pteridophyta — Adaptation to land and having structural transport system

Look at Fig. 12.11a. What changes do you observe in the plant structure as compared to thallophytes and bryophytes? Pteridophytes (pteris derived from *pteron* means feather and *phyton* means plant), such as ferns, possess true roots, stems and leaves. How do you think that the transport of water and food takes place in all parts of these plants? One possible explanation is that ferns have specialised transport tissue. How can you test this explanation? A cross section of the stem of a fern can be cut and seen under a microscope. You may also observe a permanent slide of a cross section of a fern stem available in your school laboratory. The cross section shows vascular tissues, xylem and phloem, which transport water and food, respectively, throughout the plant (Fig. 12.11b). Pteridophytes require aquatic conditions for reproduction and do not produce seeds.

Activity 12.7: Let us compare

1. Recall the cross section of the sunflower stem you have studied in Chapter 3 (Fig. 3.7).
2. Compare the cross section of the stem of a fern, a pteridophytic plant (Fig. 12.11) with a cross section of sunflower stem you studied in Chapter 3 (Fig. 3.7).
3. What difference do you observe in the vascular tissue of the fern stem and of the stem of higher plants? Write your observations. Share and discuss them in class.

Gymnosperms — Reproduction without water

Gymnosperms (*gymnos* means naked and *spermos* means seed), such as pines (Fig. 12.12) and cycads are well-adapted to cold and dry regions. Their needle-like or scale-like leaves reduce water loss and withstand harsh conditions. They produce seeds, which protect the developing embryo and contain stored food. Gymnosperms do not require aquatic conditions for fertilisation. Their seeds are not enclosed in fruits and are often exposed on cones.

Angiosperms — Efficient reproduction and seed dispersal

Angiosperms (*angeion* means vessel and *spermos* means seeds) or flowering plants, represent plants with the most complex body organisation.

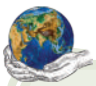
Grade 6 Curiosity Chapter 2

They produce flowers and fruits (Fig. 12.13). Flowers attract pollinators, increasing the efficiency of reproduction, while fruits help spread seeds to new locations. These features allow angiosperms to occupy a wide range of environments. Therefore, they are the most diverse plant group on the Earth.

Fig. 12.13: An angiosperm tree (Gulmohar)

Activity 12.8: Let us discuss

Collect different leaves from your surroundings, and observe their shape and venation. Group them as monocots or dicots. **Discuss** how their structures help them adapt in different conditions to survive.



Bridging Science and Society

One of the earliest scientific books on Indian plants, *Hortus Malabaricus*, was compiled in the 17th century by Hendrik van Rheede with the help of Itty Achudan (an Indian Herbalist, Botanist and Physician) and other local experts. It describes hundreds of plant species and their medicinal uses, showing how traditional knowledge and science can work together.

Different plant groups present different ways of solving problems, each with advantages and challenges or exceptions for survival.

Activity 12.9: Let us study

1. Carefully study the salient features of each plant group.
2. **Analyse** the salient features, and write the advantages for survival of the group and the exceptions or challenges faced in the given columns.

Table 12.3: Classes of Kingdom Plantae with their advantages and challenges

Plant groups and salient features	Advantages of the group for survival	Exceptions/ Challenges
Thallopyta • Their body is like a thallus which facilitates easy absorption of water and nutrients, and exchange of gases from the surroundings.	• Simple plant body facilitates survival and its dispersal in water.	• They cannot live on land. ________ ________
Bryophyta • Unlike algae, this group of plants began to colonise land but with strong dependence on moisture. • Plant body shows slight differentiation in body parts but not in root, stem, or leaves. • They lack vascular tissues for transporting water and food. • They require water for reproduction, as male reproductive cells must swim to reach female cells.	• They are plant amphibians. • Their body is adapted to live on moist land. ________ ________	• They always need moisture. ________ ________
Pteridophyta • Pteridophytes possess true roots, stems and leaves. • They have vascular tissues (xylem and phloem) that transport water and food throughout the plant. • They still depend on water for reproduction. • They do not produce seeds.	• They live on land. • They transport food and water to all parts of the plant. ________ ________	• Reproduction does not take place without water. ________ ________

Gymnosperm • They live on land. • They have needle-like leaves which reduce water loss. • Water is not essential for fertilisation. • Their seeds are not enclosed in fruits and are exposed on cones.	• Leaves are adapted for dry conditions. • They do not require water for reproduction. • They form seeds for continuity of life. ______________ ______________	• Seeds are not covered in the form of fruits. ______________ ______________
Angiosperm • They possess well-developed roots, stems and leaves. • They undergo sexual reproduction through flowers. • Their seeds are enclosed within fruits. • Their seeds disperse through insects or birds, animals, wind, or water.	• They produce flowers, fruits and seeds. • They have a well-developed system for reproduction. • They produce seeds for continuity of life. • Their seeds are covered. ______________ ______________	• Reproduction is dependent on pollination by different agents. • They have complex processes through a well-developed tissue system. ______________ ______________

From algae to angiosperms, plant groups show a sequence of structural changes that help plants meet the challenges of life on land. Early plants relied on water for support and reproduction. Gradually, plant groups evolved transport tissues, seeds and flowers.

Overall, the diversity of plant forms reflects multiple ways of balancing growth, transport, reproduction and survival in different environments.

12.6.5 Kingdom Animalia — Multicellular, heterotrophic eukaryotes

Animals are multicellular and heterotrophic organisms. They depend on other organisms for their food. Most animals exhibit the characteristics of locomotion, rapid response to stimuli and coordinated behaviour. These abilities allow animals to actively search for food, avoid predators and interact dynamically with their surroundings.

One of the major criteria for classifying animals is the presence or absence of a notochord, which is a flexible rod-shaped structure. Based on the absence or presence of the notochord, animals are classified into two groups — non-chordata (invertebrata) and chordata. In some chordates, notochord acts as a precursor for the development of the vertebral column. The chordata is further classified as protochordata and vertebrata.

Invertebrates — Animals without a notochord

Invertebrates lack a notochord, yet they show a wide range of body organisation, from a simple structure to complex organ systems. Studying invertebrates allows us to trace how the animal body gradually changed over time, leading to advancement in traits like movement, diverse feeding habits, and enhanced control and coordination, while also introducing exceptions and new challenges.

Porifera (pore-bearers) — Multicellularity without tissues

Sponges (Fig. 12.16a) represent one of the simplest animal body plans. They are multicellular but lack organisation of tissues and organs. Numerous pores in their body allow water to continuously flow through it, bringing food particles and oxygen directly to individual cells, carrying the waste away. Sponges remain fixed in one place and are found in aquatic environments. Do you think they would be able to survive on land? Why or why not?

Threads of Curiosity

Research studies show that one kilogram of sponge can filter up to 24,000 litres of sea water per day.

Cnidaria — True tissues and active feeding

Cnidarians, such as *Hydra* (Fig. 12.14), jellyfish (Fig. 12.16b) and corals show a major change in body organisation. Tissue-level organisation is present in them which allows specialised cells to perform specific functions, such as tentacles, which are used for capturing prey. Unlike poriferans, cnidarians can catch their prey using tentacles instead of depending on water currents to bring food particles inside through pores. However, cnidarians possess a single opening that functions for both food intake and waste removal. Can you hypothesise what limitations this body structure might have?

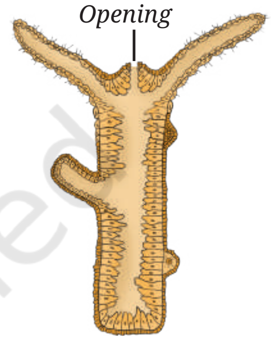


Fig. 12.14: Longitudinal section of hydra showing tissue level organisation

Platyhelminthes (flatworms) — Bilateral symmetry and directional movement

Flatworms show organisational advancement through bilateral symmetry (organism's body can be divided into two halves along one plane), in which the body has distinct head-tail and front-back regions. This body organisation allows better coordination of movement and this is the beginning of directional activity. Their flattened bodies permit efficient diffusion of gases without specialised respiratory organs but there is still a single opening for food intake and waste elimination.

Many flatworms have adopted a parasitic lifestyle. Hooks and suckers are present in the parasitic forms which helps them to attach firmly to the host tissues for obtaining nutrients (Fig. 12.16c).

Bridging Science and Society

Some infectious diseases are caused by parasitic worms. They enter our bodies through contaminated water and food. They live inside our body, especially in the alimentary canal (the digestive system). These worms take nutrients from our body and live like parasites (the organism that lives in or on another organism is called the host). For this reason, it is suggested to wash your hands properly, maintain personal hygiene and good sanitary habits, consume properly cooked food and boiled or filtered drinking water.

Nematoda (roundworms) — Efficient body design with two openings

Roundworms have elongated, cylindrical bodies (Fig. 12.16d). This body structure allows their efficient movement through soil, water, or host tissues. This body form increases the range of environment in which roundworms can survive, despite relatively simple internal organisation. The body has two openings (mouth and anus). The organ system level of body organisation is distinct in male and female worms.

Annelida (segmented worms) — segmentation and body cavities

Annelids, such as earthworms (Fig. 12.16e), represent a notable development in body organisation. Their bodies are cylindrical and are divided into segments. What advantages segmentation might offer to an organism? Observing how an earthworm moves may help you form a hypothesis. They possess organ system level of organisation. Presence of muscles help them in locomotion, and nerve cord helps in control and coordination.

Segmentation allows greater flexibility and more precise control of movements. A body cavity is also present in them as shown in Fig. 12.15.

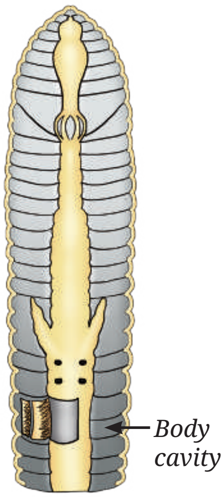


Fig. 12.15: Internal structure of an earthworm: Organ formation and body cavity

Arthropoda — Jointed appendages and an external skeleton

Arthropods (*arthro* means limbs and *poda* means appendages) includes insects, crabs (Fig. 12.16f) and spiders. They have segmented bodies with different segments specialised for different functions. A defining structural feature of arthropods is the development of a hard external skeleton (rigid external covering). What advantages can the outer covering provide?

This outer covering provides protection, reduces water loss and supports powerful muscles, allowing arthropods to survive in dry and exposed environments.

Pause and Ponder

6. An earthworm (annelida) and a beetle (arthropoda), both have segmented bodies but the beetle has a hard external skeleton. How does the beetle's external skeleton help it survive?

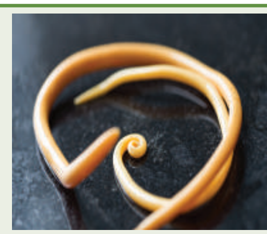
Image	 (a)	 (b)	 (c)	 (d)
	Porifera	Cnidaria	Platyhelminthes	Nematoda
Habitat	Water (Marine)	Water (Fresh and marine)	Water/inside host	Soil/water/inside host
Level of organisation	Cellular	Tissue	Organ	Organ system (digestive system)
Skeleton	X	X	X	X

Fig. 12.16: The animal kingdom

Mollusca — Organ system level organisation with soft bodies

Molluscs, such as snails (12.16g), squids and octopuses show organ system level organisation with soft bodies. In many molluscs, the development of a shell provides protection to these soft bodies. Their body is segmented with a distinct head, a muscular foot and a hump.

This group shows how a basic body plan can be modified in different directions depending on environmental demands.

Echinodermata — Internal support without a notochord

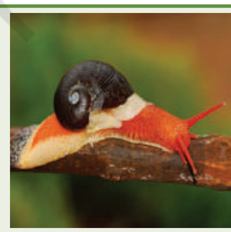
Echinoderms (*echinos* means spiny and *derma* means skin), such as starfish (Fig 12.16h) and sea urchins possess a hard internal skeleton made of calcium carbonate. Although they lack a notochord, this internal skeleton provides them protection and controlled movement. Their body organisation is quite like that of more complex animals, showing a gradual shift towards internal skeletal support.

Looking across invertebrates

From sponges to echinoderms, animal body structure shows a pattern of increasing complexity in body organisation. New structural features improve feeding, movement and protection but often introduce new challenges. These help explain survival in diverse environments.

Protochordates — The appearance of the notochord

Protochordates (like *Amphioxus*) possess a notochord at least once during their life. This structure provides internal support without restricting movement and represents a crucial change in body organisation. Protochordates are a primitive type of chordates which help us understand how animals with a notochord may have arisen from simpler forms.

 (e)	 (f)	 (g)	 (h)
Annelida	Arthropoda	Mollusca	Echinodermata
Moist soil/water	Land/water	Water/moist land	Marine water
Organ system	Organ system	Organ system	Organ system
X	Exoskeleton	Exoskeleton	Endoskeleton

Vertebrates — Animals with a backbone

Vertebrates possess a vertebral column (backbone), an internal skeletal structure that supports the body and protects vital organs, such as the brain and the spinal cord. This internal framework allows a larger body size, efficient movement and the development of complex organ systems. Vertebrates show advanced sensory abilities and coordinated behaviour.

Vertebrates are classified into five groups, namely fish, amphibians, reptiles, birds and mammals based on the broad patterns of their habitat use, body covering and reproduction.

Bridging Science and Society

How do forests with rich and highly diverse flora and fauna work as a barrier and reduce the impact of disasters?

Forests with rich biodiversity play a vital role to create physical, biological and chemical barriers to protect against challenges. Some of the examples are as follows:

- Large diversity of trees in mangrove forests helped during the super cyclone that hit Orissa in 1999. Villages with more mangroves experienced less destruction.
- Rich biodiversity generally correlates with lower tick-borne disease risk. In the Western Ghats of India, where forest diversity acts as a biological barrier against Monkey Fever (Kyasanur Forest Disease, KFD), as many animals are the hosts where the virus cannot replicate inside their bodies.
- Diverse microorganisms in forest soils and plant roots absorb, transform, or break down pollutants. This improves water quality and protects ecosystems. Mangrove soils trap sediments and heavy metals, preventing pollution from spreading into oceans and rivers.

12.7 Adaptations as Outcomes of Structural Change

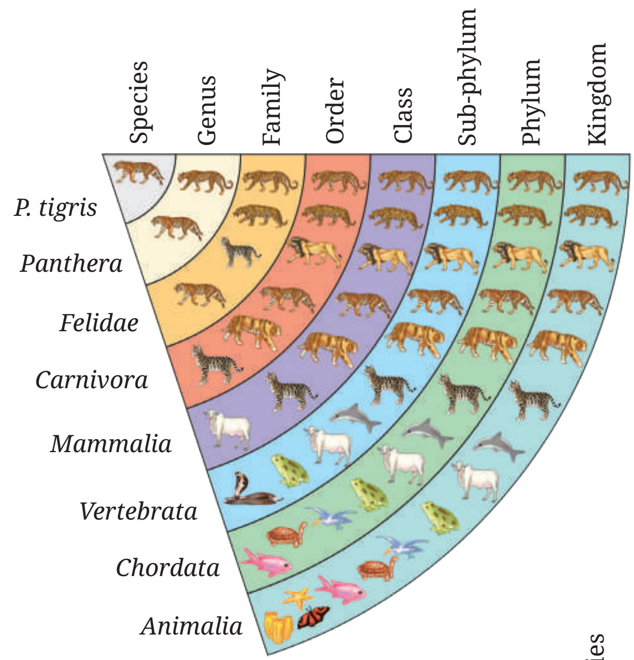
The diversity seen in animals today are outcomes of changes in the body structure over long periods of time. Fins and gills allow fish to move and breathe in water. Feathers and hollow bones make flight possible in birds. Fat storage in camels and thick fur in polar bears illustrate how structural features support survival under extreme conditions. In mammals, mammary glands represent an additional structural and functional change that improves the survival of young ones. These features are interconnected and reflect how different vertebrates tackle the challenges of survival in different environments. All these characteristics show that animal diversity reflects a wide range of body forms found in organisms living under different environmental conditions.

12.7.1 The hierarchical nature of classification

Observe and analyse Fig. 12.17. What do you infer? Classification follows a step-by-step order, starting from very broad groups, and moving towards smaller and more specific ones. At each lower level, organisms share more common features. Every lower group is a part of the group above it.

Kingdom → Phylum → Class → Order → Family → Genus → Species

This arrangement works like an address. Just as a house address helps us locate a place exactly, classification helps scientists identify, compare and study organisms accurately, and understand how they are related.



Tiger	
Kingdom	*Animalia*
Phylum	*Chordata*
Sub-phylum	*Vertebrata*
Class	*Mammalia*
Order	*Carnivora*
Family	*Felidae*
Genus	*Panthera*
Species	*P. tigris*

Pea	
Kingdom	*Plantae*
Phylum	*Magnoliophyta*
Class	*Magnoliopsida*
Order	*Fabales*
Family	*Fabaceae*
Genus	*Pisum*
Species	*P. sativum*

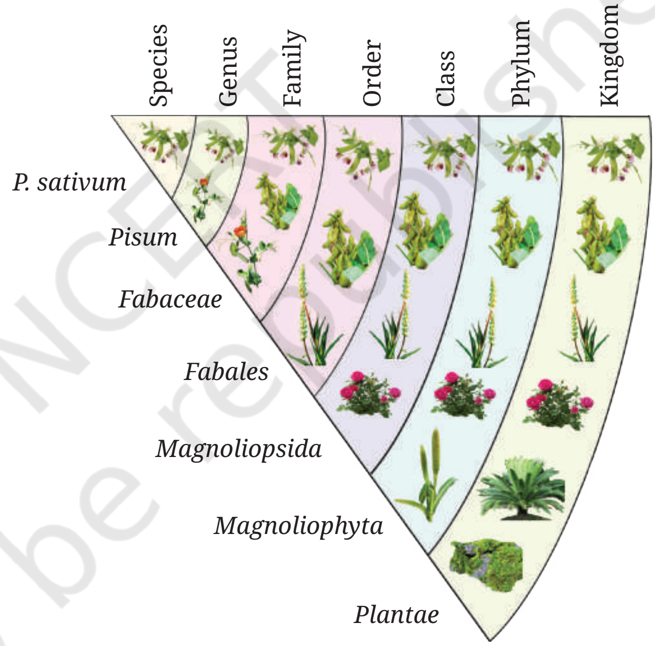


Fig. 12.17: Pyramids showing levels, from kingdom at the top to species at the base, with the examples of a tiger and a pea plant

12.8 Scientific Naming — The Binomial System

A tiger is called *bagh* in Hindi, or *puli* in Tamil, tiger in English and *tigre* in French. If people from different regions discuss this animal, confusion may arise. To avoid this, scientists use a universal system of naming living organisms called binomial nomenclature. This system was introduced by Carolus Linnaeus in the 18th century. According to this, every organism has a scientific name with two parts, written in Latin or a Latinised form (Table 12.3).

Fig. 12.18: Example illustrating a scientific name

Table 12.3: Scientific names of organisms in the binomial system of nomenclature

S. No.	Common name	Scientific Name
1.	Tiger	*Panthera tigris*
2.	Mango	*Mangifera indica*

The first word, *Panthera* or *Mangifera*, is the name of the genus and the second, *tigris* or *indica*, is the name of the species. A genus groups closely related species that share common features, in this case, *Panthera tigris* (tiger) and *Panthera leo* (lion) under the genus *Panthera*—the roaring cats (possessing the ability to roar), have similar skull structure, and so on. The species name indicates a group of organisms that consists of similar individuals capable of interbreeding and producing offsprings. Together, the genus and species name form a unique scientific name used worldwide.

Rules for writing the scientific names

1. The name has two parts— genus and species.
2. The genus name begins with a capital letter and comes first, followed by the species name, which is written in small letters (lower case).
3. The scientific name is written in italics when printed, or underlined when handwritten (Fig. 12.18).

Ready to Go Beyond

The five kingdom classification offered a more comprehensive way to group organisms compared to the previous systems, but it still could not fully explain the diversity of life. Latest advances in genetic research aided in modifying this classification. With advances in microscopes and genetic studies, scientists began to compare organisms at the DNA level. As you have studied in Chapter 2, every living cell contains genetic material (DNA), which carries the instructions for its growth and function. Organisms with similar DNA are considered to have a common ancestry. Based on the genetic data, Carl Woese (1977) proposed the three domain system (Fig. 12.19)—

Next Level Up

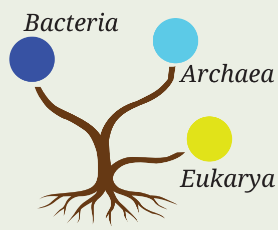


Fig. 12.19: Three domains of life

- Bacteria
- Archaea
- Eukarya

This system showed that microscopic life forms are far more diverse than previously believed.

Threads of Curiosity

Why do classification systems keep changing? Does that indicate how science works? Yes, science evolves and progresses as we learn new things. For example, Aristotle's system worked for his time, but with new tools (like microscopes) and technological advancements (like staining techniques), scientists discovered microorganisms. These discoveries helped us understand the natural world better. Accordingly, the biological classification changed. The biological classification (and science) thus, is an ongoing process of reasoning and change.

12.9 Fossils as Evidence

When we talk of diversity changing over time, what evidence do we have? Fossils are preserved remains of plants and animals found in layers of rocks, sand and mud. Generally, older layers contain simpler organisms, while newer layers show more complex forms. From giant dinosaurs to early humans and ancient plants, some important fossils have been discovered in India. Fossils act as natural records that help us understand how life has changed over millions of years.

12.10 Biodiversity Under Threat

Each species, large or small, plays an important role in nature. Plants produce food and oxygen, animals pollinate flowers and disperse seeds, and microorganisms recycle nutrients. Human activities, such as pollution, deforestation, the overuse of resources and climate change are reducing biodiversity. When one species disappears, others that depend on it may also decline in number and eventually also, disappear.

Meet a Scientist

Birbal Sahni was an eminent scientist who studied fossil plants. He founded the Birbal Sahni Institute of Palaeosciences (BSIP) in Lucknow, which continues his work on ancient plants and past environments even to this day. His studies helped link present-day plants with their ancestors and showed that life on the Earth has a long, connected history. His work continues to inspire young scientists to explore how fossils reveal the story of our planet.

Pause and Ponder

7. Does the term 'biodiversity' relate only to the variety of organisms, or does it encompass other elements?
8. If you find a new organism in a pond, what features will you observe to classify it and why?
9. Why do genetic studies provide deep information about living beings?
10. How can changes in climate affect the biodiversity?

Threads of Curiosity

When scientists discover a new organism, they compare it with the already known species. Sometimes, the species name reflects their place of discovery, or honours a scientist. The Purple Frog (*Nasikabatrachus sahyadrensis*) from Kerala has a species name after the Sahyadri Hills (Fig. 12.20).

The Purple Frog lives underground for most of the year and comes out only during the monsoon to breed. It belongs to an ancient family of frogs as understood from fossils. Its discovery in 2003 helped scientists understand ancient amphibian groups and highlighted the need for biodiversity conservation in the Western Ghats.

Fig. 12.20: A purple frog resting on wet soil

Bridging Science and Society

Floating grasslands, locally known as *phumdis* are classified as one of the unique habitats in the world. It is located in the Loktak lake of the Keibul Lamjo National Park, in Manipur, India. These floating beds of soil have a variety of rooted vegetation growing with rich organic matter in it. Its thickness varies from a few centimetres to two metres. The habitat supports an association of unique vegetation and is home to an endangered variety of *Sangai*, the dancing deer, endemic to Manipur. The deer spends considerable time on *phumdis* restricted to this small area. This deer species was declared extinct in 1951. In 1953 the deer species was rediscovered, with the efforts of naturalists based on their unique characteristics of having hooves and elongated patterns. These characteristics of the deer species helped in their identification. Recently, the *phumdis* are degenerating and the *Sangai* deer is listed in the IUCN Red Data list. Habitat loss will significantly affect the *Sangai* population. Efforts for the conservation of *phumdis* and the *Sangai* deer are currently in progress. Provide your suggestions to save habitat and the *Sangai* deer.

At a Glance

- Life on the Earth exists in many forms, from simple bacteria to complex animals.
- Scientists classify organisms based on the cell structure, number of cells, mode of nutrition and the organism's ecological role.
- Whittaker's five kingdom classification system — Monera, Protista, Fungi, Plantae and Animalia — is a simple and useful system to understand diversity.
- Kingdom Plantae is further divided into five classes — Thallophyta, Bryophyta, Pteridophyta, Gymnosperm and Angiosperm.
- Kingdom Animalia is divided into non-chordata (invertebrates) and chordata (vertebrates) on the basis of formation of notochord. Non-chordata (Invertebrates) has been divided into phyla — Porifera, Cnidaria, Platyhelminthes, Nematoda, Annelida, Arthropoda, Mollusca, Echinodermata.
- Protochordates show a transition from invertebrates to vertebrates as they possess notochord atleast once in their life. Vertebrates are further divided into groups — fish, amphibians, reptiles, birds and mammals.
- Classification is not just about naming organisms. It helps us understand the relationships among organisms, trace the history of life on the Earth and conserve the biodiversity.

Revise, Reflect, Refine

1. Meena and Hari observed an animal in their garden. Hari called it an insect while Meena said it was an earthworm. Choose the correct option which confirms that it is an insect.
   (i) Bilateral symmetrical body
   (ii) Body with jointed legs
   (iii) Cylindrical body
   (iv) Body with little segmentation
2. Sponges represent one of the simplest animal body plans. Their bodies lack true tissues and organs. Which feature of sponge cells supports its classification under the animal kingdom?
   (i) Absence of mitochondria
   (ii) Ability to photosynthesise
   (iii) Presence of a cell membrane
   (iv) Presence of a cell wall
3. Observe two different animals in your immediate environment. What features help you distinguish between them? How do these features help place them into different groups?
4. How would a scientist justify choosing cellular organisation as a more fundamental characteristic for the basis of classification rather than the presence of xylem and phloem?
5. You find an unlabelled slide of a single-celled organism that has a well-defined nucleus and multiple cilia. Which group would it most likely belong to? Give reasons.
6. How does the diversity of organisms contribute to the balance and stability of an ecosystem?
7. If all unicellular organisms were grouped into a single kingdom, what problems would arise?
8. Viruses were studied in earlier classes. Why are they not placed in any of the five kingdoms? Give reasons.
9. If you were asked to revise the five kingdom classification, would you create a separate category for viruses or keep them outside the system? Justify your answer and explain what this indicates about the evolving nature of scientific classification.
10. Viruses contain genetic material like living organisms but lack cellular organisation. Which features prevent them from fitting into the five kingdom system? What does this tell us about the limitations of classification systems?
11. Both pteridophytes and bryophytes lack flowers and seeds, yet they are placed in different groups. Explain this classification using their key features.

12. In the classification hierarchy, which group — class or genus — has fewer members but more features in common? Explain your answer.
13. A scientist discovers a new organism with the characteristic features of locomotion and autotrophic nutrition. Which character(s) would help the scientist identify the organism belonging to Protista according to the five kingdom classification?
14. A researcher identified a unicellular eukaryotic organism as fungi. What identification key would you suggest according to the five kingdom classification to keep a unicellular organism in the Kingdom Fungi?
15. During a long-term ecological study, students examined organisms collected from three different environments — a freshwater pond, damp soil near decaying logs and the digestive tract of animals. Instead of naming organisms directly, scientists recorded only structural, cellular and nutritional features as given in the table below.

Organisms	Key Observations
P	Microscopic; no true nucleus; rigid cell covering; survives high salinity and temperature
Q	Multicellular; filamentous body; cell wall present; no chlorophyll; grows on dead organic matter
R	Unicellular; true nucleus; contractile vacuole present; moves using flagella; shows photosynthesis in light but heterotrophic in the absence of light
S	Multicellular; well-differentiated tissues; backbone present; aquatic respiration during early life stage
T	Acellular; contains genetic material; remains inactive outside a host cell

The students realised that some organisms fit neatly into Whittaker's five kingdom classification, while others challenged the very basis of this classification.

Based on the case study, answer the following questions —

(i) Identify one organism that clearly belongs to the Kingdom Fungi. State one observation that supports your answer.
(ii) Which organism would be placed in the Kingdom Monera? Mention one characteristic that justifies this placement.
(iii) Organisms R and Q are both eukaryotic, yet they are placed in different kingdoms. Analyse the criteria that separate them.
(iv) Explain why organism S cannot be classified using the mode of nutrition alone.
(v) Organism T does not fit into any of the five kingdoms. Which fundamental characteristic used in classification does it lack and what does this reveal about the limitations of classification systems?

(vi) If classification were based only on habitat, which organisms might be incorrectly grouped together? Explain the scientific consequences of such a classification.

(vii) Imagine scientists discover a new organism that is multicellular, eukaryotic, lacks chlorophyll and absorbs nutrients from a host externally. Should it be placed under fungi or animalia? Justify your reasoning using classification criteria.

The Journey Beyond

- Visit a nearby park or a water body. Observe the water body and its surroundings. Identify ten organisms and classify them into kingdoms.
- Interview a gardener or a forest worker. Ask them how they identify species. Compare the traditional scientific methods of identification.
- If you were studying the Pakke Tiger Reserve or any other bird sanctuary of your choice, how would you organise the information about the bird species?
- Conduct a survey in a forest area near a village, identify edible and poisonous mushrooms with the help of indigenous knowledge of community resource person(s).
- Collect and study the postal stamps of India and the world released over time on diversified flora and fauna. Based on your learning, make your own criteria and classify them. Organise a philately (collection of postage stamps) exhibition in your school and showcase your work in this exhibition.
- Investigate an extinct species and analyse how its disappearance impacted the organisms that depend on it, and how this affected the ecological balance of the ecosystem.
- Study the diversity of farm animals used in different types of farming practices in various parts of the country.

The Quest Continues...

What knowledge do you think scientists would come up with further and how would it affect the classification system?