

The State of Eritrea
Ministry of Education

Biology

for

Grade 9

Textbook

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Introduction

Dear Learners, welcome to **Grade 9 Biology**.

By the end of Grade 9, you are expected to be able to describe cells as the basic structural units of life, the specialized parts of cells and the properties of viruses and bacteria; explain the application of taxonomy; describe metabolic processes and energy transfer in living organisms; and explain the importance of the adaptations of plants and animals to their environment.

This Biology Textbook has four units each of which is structured to incorporate the following sections:

Let us discuss: In this section questions are asked to stimulate, brainstorm and encourage you to express your ideas, relate the different units and sub-units with each other and to enhance your understanding of the lessons to follow.

Activities: This section is included to help the learners with practical work, individually or in groups, with a strict follow-up from the teacher and with the necessary precautions. Biology as a branch of science is built from ideas obtained from laboratory investigations. Learners are reminded to read the procedures (wherever applicable) carefully and to ask their teachers to check their work and give them the necessary conclusions that reflect the activities .

Exercises: This section is given at the end of most sub-units with the intention that these exercises help the learners to revise the main contents of the sub-unit before they proceed to a new topic. This section will also help the teacher to monitor the progress of the learners and plan the next lesson accordingly.

Summary: This section is very essential to grasp the main points of the sub-unit and to give them a chance to compare the notes they prepared during the lesson.

Key Terms/Phrases: This section contains a list of words and phrases at the end of each unit. This list is given to underline the main terms the learners should understand and describe, and in the process develop their science vocabulary.

Review Questions: This section contains various questions that are given at the end of each unit as a way of assessing how much the learners understood the units covered.

This Biology Textbook is prepared based on the secondary level syllabus of the Ministry of Education. All efforts have been put into making the Textbooks activity-oriented and practical, so that the teaching-learning process will be learner-centred and more interactive.

The Textbook is written in simple English so that the students can easily understand it. Moreover, motivation and encouragement by parents/guardians is very important in bringing about a positive change in the learners and to enhance learning. It is also recommended that parents visit the school frequently to discuss the overall progress of their children with the teacher.

This Textbook is accompanied by a Teacher's Guide, which complements it.

All comments and suggestions that can contribute to the improvement of the quality of the Textbook are most welcome.

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UNIT 1

The Cell

Expected Learning Outcomes

By the end of this unit, you are expected to:

- explain what biology is and identify its branches
- describe the basic units of life that carry on various processes
- describe the basic structure of bacteria and viruses

1.1 Introduction to Biology

Let us discuss

1. What is science?
2. What are the three branches of science? Explain each of them.
3. Imagine an ant on a rock. What is the main difference between the ant and the rock?
4. Why is it important to study biology?

1.1.1 What is Biology?

The word “biology” is derived from two Greek words: “*bios*” meaning “life” and “*logos*” meaning “study of”. Biology is therefore the branch of science that deals with the study of life or living things.

All living things are often called **organisms**. An organism is a living entity consisting of one cell such as bacteria or several cells like animals, plants and fungi. The common characteristics of all living organisms are:

Order and Organization: All living organisms have an orderly structure and behavioral complexity. To maintain this order, the living organism requires energy and materials from the environment. There is also a hierarchy of life that ranges from small to large. Living organisms are made up of one or more cells.

Metabolism: This is the sum total of all the chemical reactions that take place within an organism. Organized chemical steps deal with the break down and build up of food molecules, making energy available for the necessary processes.

Transmission of Heredity: Living organisms have units of inheritance called **genes**. These genes are transmitted from parents to offspring. Genes control and determine the shape (form) and size range, as well as chemical and behavioral characteristics of living organisms. A human infant, for example, normally has a human structure due to the inherited genes.

Growth and Development: An organism grows in weight, length, height or width by taking in nutrients. Development is an orderly sequence of change in shape and function over the lifespan of an organism. Every living organism has a definite period of life, such as birth, growth, maturity, senility and death.

Responsiveness: Organisms sense and respond to stimuli such as light, water or pain. For example animals move away from something that causes pain. Plant shoots usually grow towards a light stimulus and roots grow towards a water stimulus. Appropriate responses are key to survival.

Movement: Most living things usually move from one place to another for food, shelter, water, and mating. For example a tree shows growth movements.

Reproduction: All organisms give rise to others of the same type. Most plants are formed from seeds. In many animals, the young are born alive or are hatched from eggs.

Adaptations: Living organisms acquire inheritable specific structures and behaviours that enable them to survive in a particular environment.

The aim of biology is to explain the living world in terms of scientific principles.

1.1.2 Branches of Biology

The study of biology can be divided into different branches. See Table 1.1.

Branch of biology	Definition
Morphology	the study of the general form of an organism
Physiology	the study of the normal functions of the various parts of an organism or the organism as a whole
Geneticv	the study of heredity and variation in organisms
Cytology	the study of the formation, structure, and function of cells
Ecology	the study of the interactions of organisms and their environment
Botany	the study of plants
Zoology	the study of animals
Taxonomy	the study of classification of organisms
Microbiology	the study of micro-organisms
Parasitology	the study of parasites and parasitism
Embryology	the study of the early development of organisms
Evolution	the study of how organisms originated

Table 1.1 Some branches of biology and their definitions

Biology often overlaps with other sciences such as biochemistry and biogeography.

In studying biology, one acquires very useful knowledge that can be used in many ways. Some of these are listed below:

1. To solve **environmental problems** such as a shortage of food, poor health services or pollution.
2. To enter into **careers** like medicine, agriculture, public health, etc.
3. To develop the **scientific skills** such as observation, identifying, recording, classifying, measuring, analyzing and evaluating. Such skills are also useful in everyday life.

Activity 1.1

- Walk in groups of five or six around your school campus.
- Observe the area using some of your senses.
- List some living- and non-living things in your exercise books, in column form as indicated below.

Living things

1. _____
2. _____
3. _____
4. _____
5. _____

Non-living things

1. _____
2. _____
3. _____
4. _____
5. _____

1. Look at your list of living things. How did you determine that these things are alive?
2. Look at your list of nonliving things. How did you determine that these things are not alive?
3. List three professional occupations that require the study of biology.

1.1.3 The Microscope

To study small living organisms or cells we use a magnifying lens. A magnifying lens is an instrument used to enlarge objects (living organisms). These types of lenses include a microscope and a hand lens.

Hand Lens: One of the common magnifying instruments used in biology is the hand lens. It is made up of a biconvex lens mounted onto a frame and has a handle. The magnifying power of the lens is usually marked on the frame of the lens. This magnification number indicates how much larger the image will be compared with the object.

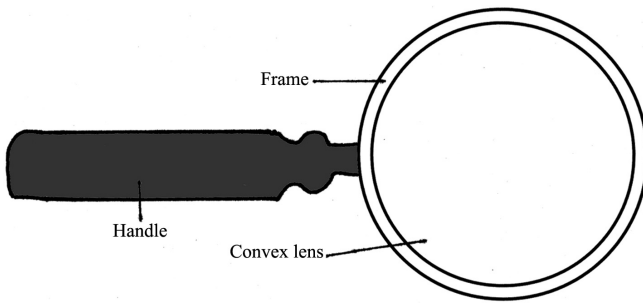


Figure 1.1 A hand lens

A hand lens is always held close to the eye, while the object is brought into focus to get an enlarged view. A hand lens is used to make a quick identification of small plants and animals. It is more closely related to microscopes because it is designated to provide relatively high magnification of a smaller area rather than a low magnification of a larger area. However, a hand lens cannot magnify cells enough for us to see them as a microscope does.

Activity 1.2

- a. Use a hand lens to look closely at the tip of a pen.
 - b. Hold the lens close to the eye.
 - c. Allow light to fall on the tip of the pen.
 - d. Keep the hand lens still and move the pen slowly towards the lens until you can see the tip of the pen clearly.
 - e. Keep both eyes open.
1. What did you observe?
 2. What is the magnifying power of your hand lens?

Microscope: A microscope is an instrument that is designed to make objects visible that are otherwise too difficult or too small to be seen with the naked eye. The microscope is one of the most important instruments in biology. It magnifies extremely small organisms and structures.

There are two types of microscopes. These are the light microscope and the electron microscope.

A. The Light Microscope

The commonly used microscope in schools is the light microscope. It is called a light microscope because it uses light (visible light) as a source of illumination to see the specimen on the stage. A light microscope has two lenses to magnify or enlarge the specimen. These are the **eyepiece** and the **objective lens**. The eyepiece is a lens attached to the top of the body tube through which we view the object. The objective lens is the lens attached to the nosepiece of the microscope.

There are usually three objective lenses of different magnifications and lengths in a light microscope. These objective lenses are attached to the nosepiece of the microscope. The shortest objective lens has the lowest magnification and is called a low power objective lens. The longest objective has the highest magnification and is called a high power objective lens. To change the magnification the objective lenses can be rotated into position by turning the nosepiece. It is therefore important to know the parts of a microscope and how to use and care for it (see Figure 1.2 and Table 1.2).

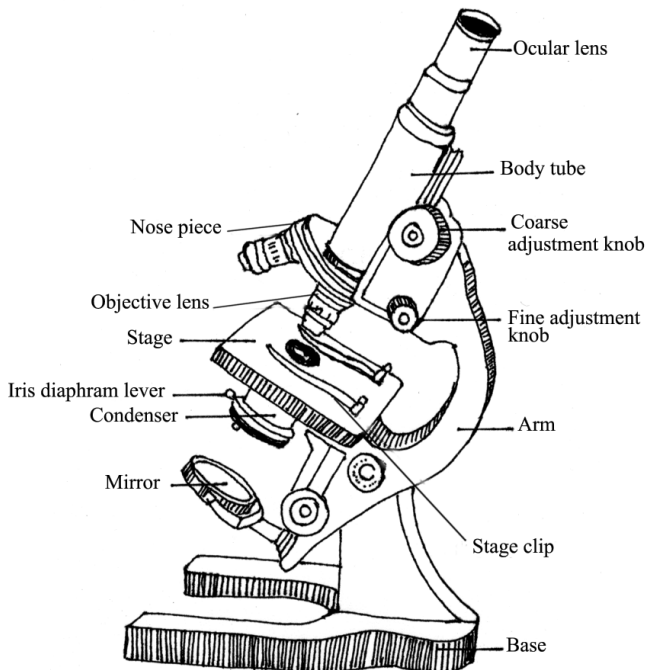


Figure 1.2 The light microscope

Parts of a microscope	Function
Arm	Supports the body tube and stage
Coarse adjustment knob (screw)	Rapidly brings image into focus
Fine adjustment knob	Stowly brings image into focus
Iris diaphragm level	Controls the amount of light passing on the specimen
Light source/mirror	Illuminates the specimen
Objective lens	Brings image into focus and magnifies it
Ocular lens (eye piece)	Magnifies the image
Nosepiece	Rotates the objectives into position
Stage clip	Holds the slide
Stage	Holds a specimen or a slide which contains an object

Table 1.2 Parts of the light microscope and their function**Activity 1.3**

- Look at the microscope that you have in your school.
 - Observe the objective lenses of the microscope.
 - Identify the functions of each part of the microscope.
 - Look closely at the numbers written on the ocular lens and on the objective lenses.
- How many objective lenses does the microscope have?
 - What do the numbers on the lenses indicate?
 - How do you calculate the magnification of a given object or specimen?

B. The Electron Microscope

An electron microscope is a type of microscope that has a much higher magnifying power than the light microscope. It uses a beam of electrons as a source of illumination for the specimen to be seen. An electron microscope examines smaller structures such as viruses or the internal structures of cells. Electron microscopes began to be widely used for research in the 1950s. An electron microscope helps to identify organelles like ribosomes, chromosomes or chloroplasts. It is a more expensive and more complex instrument than the light microscope.

Rules for the care of the microscope

1. Always carry the microscope with two hands: one hand on the arm and the other under the base.
2. Clean the lenses and the stage with tissue paper before positioning the slide.
3. Never examine a slide without a cover slip.
4. Always begin an examination of a slide on low power, never on high power.
5. Always remove the slide after use, and put the low power objective back in place.
6. Always cover the microscope before it is put away, to prevent the accumulation of dust on the lenses.
7. Make sure that the microscope is put back in the box after use.

Rules for the use of the microscope

1. Place the microscope away from the edge of the table and rotate the objective to bring it in line with the body tube until a faint “click” is heard.
2. Look through the eyepiece lens and adjust the mirror to the source of light.
3. Put the low power objective lens in place. Place the slide to be studied, with a cover slip, on the stage with the help of the clips. The slide, the stage and the lens should be absolutely clean.
4. Centre the objective over the light source. Turn the coarse focusing knob to move the stage away from the objective lens.
5. Looking from the side, move the coarse adjustment knob until the low power objective is close to the cover slip of the slide.
6. Now look through the ocular lens and focus upward using the coarse adjustment until a clear image appears.
7. Turn the fine adjustment knob back and forth slowly to sharpen the image.

8. After examining the object under low power, switch to higher power magnification. Then, using the fine adjustment knob, focus the object upwards (never downwards) to improve the image.
9. Never use the coarse adjustment knob during high magnification. Switch back to low power before removing the slide.

Table 1.3 Rules for the care and use of a microscope

How to Prepare a Wet Mount

Your school may have some permanent slides; however, you can make temporary slides by preparing a **wet mount** of very small organisms or cells. Follow the steps below to prepare a wet mount.

- a. Place a drop of water on a microscope slide containing a given specimen.
- b. Using a scalpel, support the cover slip from one side.
- c. Place the cover slip on the slide using a scalpel, avoiding trapping air bubbles.
- d. If required, add a dye (stain) to it from one side using an eyedropper.
- e. Remove the excess stain or excess water with absorbent filter paper, from the opposite side. Then place the slide on the stage of the microscope. Observe it through the eyepiece and adjust to focus the specimen. See Figure 1.3.

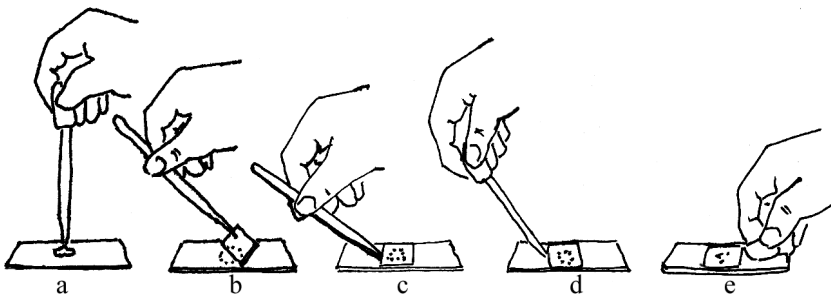


Figure 1.3 How to prepare a wet mount

Activity 1.4

- a. Cut a letter “e” from any newspaper.
- b. Put the letter on the microscope slide.
- c. Look through the eyepiece and adjust the mirror to allow a good source of light.
- d. Move the fine adjustment knob until the slide comes into focus.
- e. Focus the slide under low magnification and then change to a higher magnification.

What did you see? Why?

The Magnifying Power of a Microscope

The magnifying power of each lens is written on its case. For example the label 10X means the lens magnifies an object 10 times its actual size. The magnifying power of the microscope is the power of the ocular lens multiplied by the power of the objective lens being used.

Exercise 1.1

1. A child might argue that a car is alive. After all, it takes water and gasoline, it moves, and even responds to certain types of stimuli. How would you explain that a car is a non-living thing?
2. Distinguish between growth and development.
3. Compare and contrast a hand lens with a light microscope in relation to the study of cells.

Summary

Biology is the study of living organisms. Living organisms have several features that distinguish them from objects which are not alive. They reproduce, respire, grow, move, respond, metabolize, adapt, evolve and are organized. The field of biology is divided into different branches, such as ecology, genetics, zoology, microbiology and morphology.

In biology we study many organisms or cells that are different in shape and are too small to be seen with the naked eye, unless one uses magnifying instruments. The most common ones include the hand lens, light microscope, and electron microscope, and they vary in their magnifying powers. Although all these instruments are capable of magnifying small objects, the electron microscope has a much higher magnifying power than the hand lens and the light microscope.

1.2 What is a Cell?

Let us discuss

1. How would you describe a cell?
2. Is there any living organism without a cell?
3. How are cells organized into an organism?

1.2.1 Cell Theory

A **cell** is the basic unit of life. All living things are made up of a cell or cells. A cell is the structural and functional unit of all organisms. Cells vary in size, shape, and function. Most cells cannot be seen with the unaided eye. Cells can be seen using a microscope. The smallest cells are bacteria and the biggest cells are birds' eggs. The longest cells are muscle and nerve cells.

Because cells are so small, no one observed them until microscopes were invented. In 1665, **Robert Hook** discovered cells. He used a microscope he designed to examine very thin sections of cork and saw that each section was made up of tiny box-like structures that he called cells. Living cells were observed first in the mid-seventeenth century by the Dutch naturalist **Antonie van Leeuwenhoek**. He called the tiny organisms that he observed "*animacules*", meaning "little animals". In 1838, a botanist called **Matthias Schleiden** made a careful study of plant tissues. He stated that "all plants are aggregates of fully individualized, independent, separate beings, namely the cells themselves." In 1839, **Theoder Schwann** reported that all animal tissues also consist of individual cells. In 1849, cell division

was seen and described for the first time. In the early twentieth century, certain chemicals were developed that stained different structures of the cell with a variety of colours so that they could be seen easily. Based on these and other relevant findings, the cell theory was formulated.

Cell Theory states:

1. the cell is the unit of structure and function of all living organisms.
2. cells come from pre-existing cells.
3. non-living matter within living things is the product of cell activity e.g. hair, nails.

The organization of each living thing emerges from pools of simple building blocks, in the presence of an energy source and DNA instructions. The non-living matter found in cells, such as the biomolecules that make up a living cell, is the product of cell activities.

A single cell can by itself form an entire living organism. Organisms consisting of only a single cell are called **unicellular** for example bacteria. All the animals and plants you see in your surroundings are made up of many cells and are called **multicellular**. Multicellular organisms contain hundreds, thousands, or even trillions of cells.

Activity 1.5

1. What are the three basic parts of a cell?
2. Draw and label the three parts.

1.2.2 The Cell Structure

All cells have several basic features in common. Regardless of their size and shape, all cells have three basic structures. These three basic structures are the **cell membrane** (plasma membrane), the **cytoplasm**, and the **nucleus**. Each cell is a collection of living

matter enclosed by a barrier that separates the cell from its surroundings. They are all bound by a cell membrane.

The cell membrane regulates the movement of molecules into and out of the cytoplasm. The cytoplasm is the fluid region between the nucleus and the cell membrane. It is the site of thousands of chemical reactions. A nucleus is a membrane-bound structure where deoxyribonucleic acid (DNA) is housed within thread-like structures called **chromosomes**. All cells have genes made of DNA as their hereditary material.

A. Animal Cell Organelles

In addition to the three basic structures of the cell, animal cells have **organelles**. Organelles are small bodies found in the cell, each with a specific structure and function.

i. Mitochondria

These are elongated organelles that carry out cellular respirations in cells. They harvest chemical energy from food and hence are considered the “power house” of a cell.

ii. Endoplasmic Reticulum (ER)

This is a network of interconnected tubules. It can be smooth or rough. The smooth endoplasmic reticulum lacks attached ribosomes. One of the most important functions of this organelle is the synthesis of lipids. The name “rough endoplasmic reticulum” denotes the presence of ribosomes attached to it. The ribosomes attached to endoplasmic reticulum synthesize proteins, which are used to make components of a membrane. The other major function of the rough ER is to modify proteins secreted by the cell before they are transported to other organelles.

iii. Golgi Apparatus

This is an organelle consisting of membrane-bound sacks that modify the products of the ER and then transport them to other organelles or to the cell surface.

iv. Centrioles

These are barrel-shaped organelles found only in animal cells. Centrioles help to assemble the microtubules, which are long, hollow cylinders that influence cell shape and movement of the chromosomes during cell division.

v. Lysosomes

Lysosomes are organelles found only in animal cells. They are sacs of enzymes that function in digestion and recycling within the cell.

vi. Ribosomes

These are tiny structures that synthesize proteins according to the instructions received from the genes. Ribosomes are not bound by a membrane and are found in all types of cells.

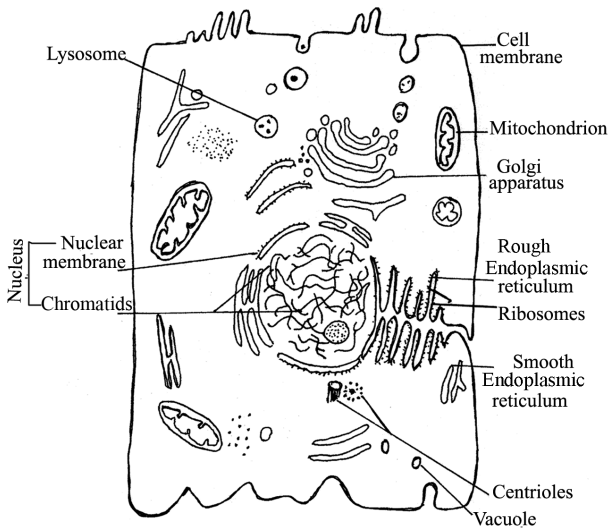


Figure 1.4 A typical animal cell

Activity 1.6

- a. Gently scrap the inside of your cheek with the broad end of a sterilized toothpick.
- b. Add the scrapings to a drop of water prepared on the glass slide, and gently spread it out.
- c. Add a few drops of methylene blue and cover the specimen using a cover slip. Use filter paper to absorb excess water from under the slide cover.
- d. Place your slide under the microscope and examine. First use the low power objective of your microscope to examine the cells. Thereafter use the high power objective and observe the slide again.

What did you observe? Draw and label a few cells.

B. Plant Cell Organelles

Almost all of the membrane bounded organelles appearing in animal cells are also present in plant cells. There are few exceptions. A plant cell has some structures that an animal cell lacks. These are:

i. Cell Wall

A plant cell has a rigid, rather thick cell wall. It protects the cells and helps maintain their shape. The cell wall of plants is chemically different from the cell wall of bacteria. A plant cell wall contains polysaccharide **cellulose**.

ii. Plastids

There are different types of plastids, such as chloroplasts, chromoplasts and leucoplasts. Chloroplasts are the organelles where photosynthesis occurs.

iii. Central vacuoleS

This is a compartment that stores water and a variety of chemicals. These chemicals, dissolved in water, make up the cell sap.

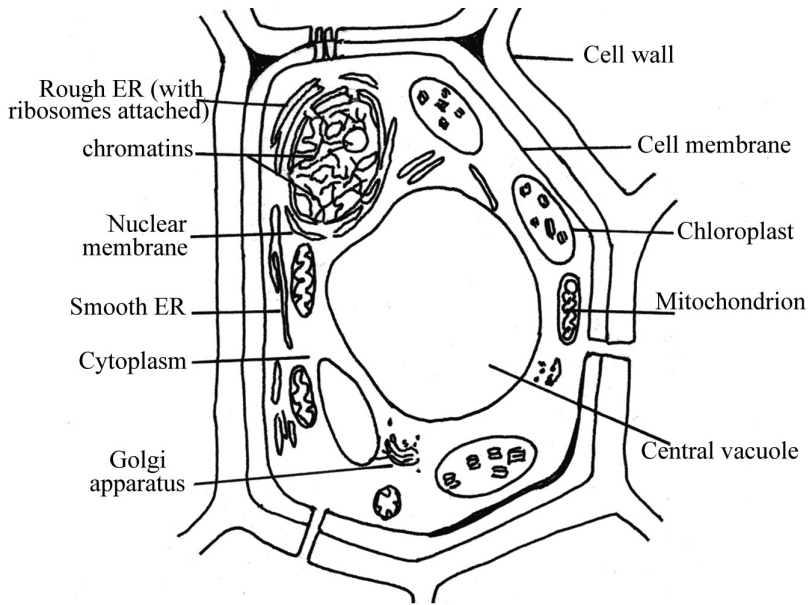


Figure 1.5 A typical plant cell

Activity 1.7

- Cut a small piece of an onion bulb, and use forceps to peel a piece of thin skin from the inside. Do not let it dry.
- Put one or two drops of water onto the centre of a clean glass slide.
- Place the piece of thin onion skin on the slide and spread it flat. The size of the specimen should not exceed the size of the cover slip.
- Gently lower a cover slip onto it.
- Use filter paper or blotting paper to clean the slide.
- Using a pipette, take a small amount of iodine solution.
- Carefully place some iodine solution next to the edge of the cover slip. The iodine solution will seep underneath the cover slip. To help it do this, place a small piece of filter paper next to the opposite side of the cover slip, which will soak up some of the liquid.
- Look at the slide under the low power of the microscope.

1. Draw and label a few cells.
2. What common structures have you observed between the onion cells and the cheek cells?
3. Name two structures which you can see in the onion cells, but not in the cheek cells?

Activity 1.8

Refer to Figure 1.4 and Figure 1.5.

1. What are the organelles found in both animal and plant cells?
2. Which organelle produces energy in a cell?

1.2.3 Prokaryotic and Eukaryotic Cells

There are two kinds of structurally different cells: they are **prokaryotic** and **eukaryotic** cells. Both animals and plants have eukaryotic types of cells. Eukaryotic cells are much more complex and in general larger than prokaryotic cells. Prokaryotic cells are those cells found in bacteria. The most obvious difference between eukaryotic and prokaryotic cells is the presence of a true nucleus and membrane-bound organelles in the cytoplasm of eukaryotic cells.

A prokaryotic cell lacks a true nucleus. The DNA of a prokaryotic cell is coiled into a **nucleoid** region that is not surrounded by a membrane. The differences between prokaryotic and eukaryotic cells are summarized in Table 1.4 below.

Eukaryotic cells	Prokaryotic cells
Have nucleus bound by a nuclear membrane	Nucleus not bound by a nuclear membrane
Have endoplasmic reticulum	Do not have endoplasmic reticulum
Have Golgi apparatus	Do not have Golgi apparatus
Have mitochondria	Do not have mitochondria
Have membrane-bound organelles	Do not have membrane-bound organelles

Table 1.4 Differences between eukaryotic and prokaryotic cells

Exercise 1.2

1. List three structures found in plant cells but not in animal cells.
2. What is the function of the following organelles?
A. mitochondria C. ribosome
B. chloroplast D. lysosome
3. How is the nucleoid region of a prokaryotic cell different from the nucleus of a eukaryotic cell?
4. Give at least five examples each of unicellular and multicellular organisms.
5. Name the structures that are found in animal cells but not in plant cells.

Summary

A cell is the smallest unit that can carry out all the processes of life. Every living thing, from the smallest bacterium floating in a drop of water, to the largest organism, such as the elephant, is made up of one or more cells. Cells arise only by division of a previously existing cell. A complete living thing that consists of only one cell is called a unicellular organism. A living thing consisting of more than one cell is called a multicellular organism. Although all living things are composed of cells, not all cells are alike. Even cells within the same organism may show enormous diversity in size and shape. A cell has different organelles that play important roles in the various functions of the cell. There are two kinds of structurally different cells: prokaryotic and eukaryotic cells.

1.3 Cell Processes

Let us discuss

1. What is the structure of the cell that regulates the movement of materials into and out of it?
2. What is homeostasis?
3. What is respiration? What is the difference between the two types of respiration?

1.3.1 Permeability

Among the cell's most important activities is its interaction with the environment. This give and take process never stops as long as the cell is alive. Without this process life cannot persist. For

all cells, the cell membrane controls the movement of molecules into and out of the cell. It acts like a “gate”. The cell membrane takes up substances the cell needs such as oxygen and glucose, and disposes of the cell’s wastes such as carbon dioxide and excess water. The cell membrane exhibits **selective permeability**. It allows some substances to cross and inhibits others. Hence, the cell membrane is said to be partially permeable (semi-permeable). The key to how a membrane functions is its structure.

1.3.2 The Transportation of Molecules

All living organisms need to transport useful materials into the cells and remove waste materials from the cells in order to carry out their life activities. There are different types of transport mechanisms used by living organisms.

Diffusion is the movement of particles from a high concentration to a low concentration until they are spread out evenly. Particles move from an area of higher concentration to an area of lower concentration through a semi-permeable membrane or through the air. There is a tendency for particles of any kind to spread out evenly in an available space. Diffusion requires no energy. It results from the random motion of particles.

Because a cell does not required energy when molecules diffuse across the membrane, the diffusion of a substance across a biological membrane is called **passive transport**. Passive transport is extremely important to all cells. In our lungs for example the exchange of oxygen and carbon dioxide between the lungs and blood cells is done by passive diffusion. Diffusion helps to distribute the necessary materials to cells equally. **Active transport** is a type of transport whereby molecules are transported into and out of the cell with the help of energy.

Activity 1.9

- a. Take a glass tube.
- b. Stick a red litmus paper at one end of the glass tube and close the end with a stopper.

- c. Place a cotton ball soaked in ammonia solution at the other end and close both ends with a stopper.
- d. Observe and note your results.

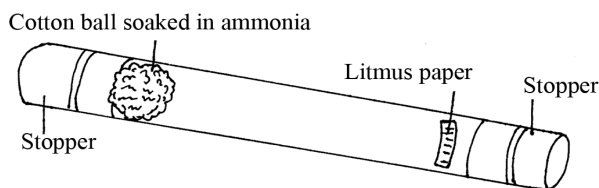


Figure 1.6

1. What happened to the red litmus paper?
2. What is the significance of diffusion in living things?

Activity 1.10

Imagine that some sort of gas (or a perfume) escapes from one corner of the laboratory. After some time, the whole classroom will smell the gas/perfume.

1. Why do you think that the whole classroom smells the gas?
2. How did the molecules of the gas move from one side of the laboratory to the other?

Activity 1.11

- a. Pour an equal amount of water into two beakers.
- b. Label the beakers **A** and **B**. Beaker A will be the experimental group and beaker B will serve as the control.
- c. Add a drop of ink to one side of beaker A.
- d. Observe the result of the experiment and record the data correctly.

1. What happened to the ink in the beaker?
2. Compare the two beakers and report your findings.

Osmosis is the movement of water molecules from a region of high water concentration (weaker solution) to a region of low water concentration (a stronger solution) through a semi-permeable membrane. Osmosis is the movement of water across a membrane. It is the passive transport by which water moves through a selectively permeable membrane in response to a concentration difference i.e. from a high concentration to a low concentration. The movement of water will continue until the concentration of water inside and outside the cell becomes equal.

The cytoplasm of a cell contains molecules, such as sugars and amino acids, dissolved in water. The mixture of these substances and water is called an **aqueous solution**. Water, the most common of the molecules in the mixture, is the **solvent**, and the substances dissolved in the water are **solutes**. The concentration of water and of solutes dissolved in the solutions, both inside the cell and out (the environment of the cell), determine the movement of water and hence the process of osmosis. Based on their solute concentrations there are different types of solutions. A **hypertonic solution** is a solution with a higher solute concentration. A **hypotonic solution** is a solution with a lower solute concentration. An **isotonic solution** is a solution that has an equal solute concentration with the solutions inside the cell.

Condition	Environment solution is	Cell solution is	Water will move
If solute concentration in the environment is lower than in the cell	Hypotonic	Hypertonic	Into the cell
If solute concentration in the environment is higher than in the cell	Hypertonic	Hypotonic	Out of the cell
If solute concentration in the environment is equal to that in the cell	Isotonic	Isotonic	Water will move in and out of the cell at equal rate

Table 1.5 The movement of water in osmosis

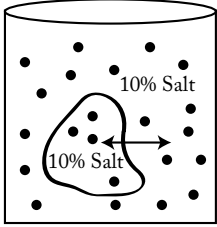
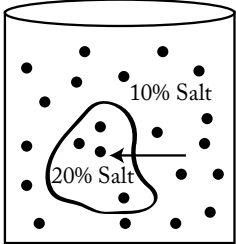
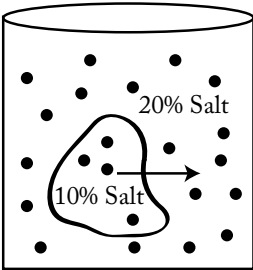
<p>A</p> <p>Solution is Isotonic</p>  <p>10% Salt</p> <p>10% Salt</p> <p>Water goes in both directions</p> <p>● Water molecules</p>	<p>In this case, the concentration of solute (salt) is equal on both sides (inside and outside the cell). Water will move back and forth but won't have any result on the overall amount of water on either side</p>
<p>B</p> <p>Solution is Hypotonic</p>  <p>10% Salt</p> <p>20% Salt</p> <p>Water moves into the cell</p> <p>● Water molecules</p>	<p>In this case there are less solute (salt) molecules outside the cell. Water will move into the cell. The cell will gain water and grow larger. In plant cells, the central vacuoles will fill and the plant will become turgid (stiff and rigid); the cell wall keeps the plant cell from bursting. In animal cells, the cell may be in danger of bursting</p>
<p>C</p> <p>Solution is Hypertonic</p>  <p>20% Salt</p> <p>10% Salt</p> <p>Water moves out of the cell</p> <p>● Water molecules</p>	<p>In this case, there are more solute (salt) molecules outside the cell. Water will move out of the cell. In plant cells, the central vacuole loses water and leads to plasmolysis (the shrinkage of the cell membrane from the cell wall), causing wilting. In animal cells, the cells also shrink and collapse. In both cases, the cell may die</p>

Table 1.6 Types of solutions (a. isotonic; b. hypotonic, c. hypertonic) and the effect of osmosis in living cells

When a cell is immersed in a hypertonic solution, water moves out of the cell towards the higher concentration of solutes, causing the cell to shrivel or shrink (a plasmolysed cell). This condition is known as **plasmolysis**. In a plant cell, the cell membrane shrinks and separates from the cell wall. In an animal cell, the cell shrinks and collapses, as there is no cell wall. When a cell is immersed in a hypotonic solution, the concentration of solutes inside the cell is higher than outside, so water moves into the cell. As water passes (diffuses) into the cell by osmosis, pressure is built up within the cell. This pressure is known as **turgor pressure**. As a result the cell swells becoming turgid, and eventually bursts in case of animal cells. In the case of plant cells, the cell will be turgid but will not burst due to the presence of the cell wall. When a cell is immersed in an isotonic solution, there will be an equal movement of water into or out of the cell; the concentration of solutes is equal both inside and outside the cell.

In small one-celled organisms diffusion alone is sufficient to transport materials into and out of the cells because the entire body surface is in contact with the surroundings. However, in large organisms having millions of cells, most of the cells are away from the body surface; that is, they are not in immediate contact with the surroundings. In this case, diffusion alone is not an effective way of transporting materials. Large organisms need other forms of transport to move materials quickly into, around and out of the body.

For example the transport of food, oxygen, and waste materials in large animals is carried away by the circulatory system. The system consists of a pumping heart, a system of tubes called blood vessels and a liquid medium called blood. The transport system in flowering plants is made up of two types of tubes: the xylem and phloem.

Activity 1.12

- Take a glass tube and close one end with a selectively permeable membrane (as shown in Figure 1.7).
- Add a 3% salt solution to the glass tube.
- Immerse the tube in a beaker containing distilled water.
- Leave the set-up for some time and observe.

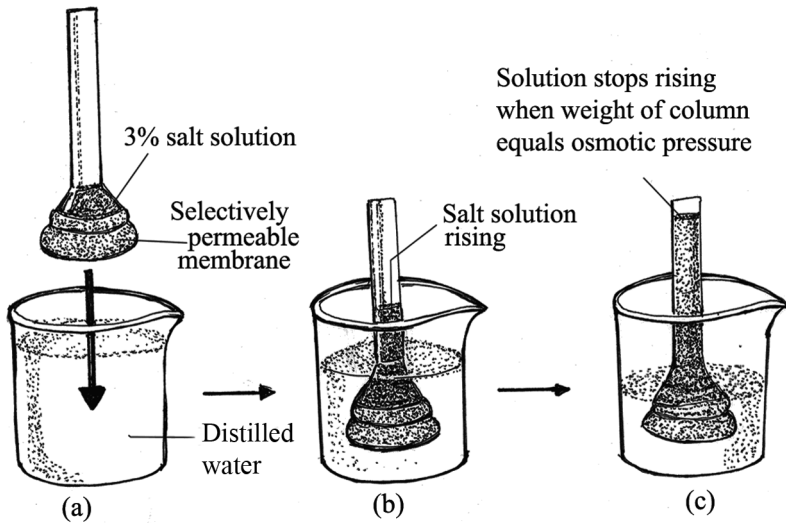
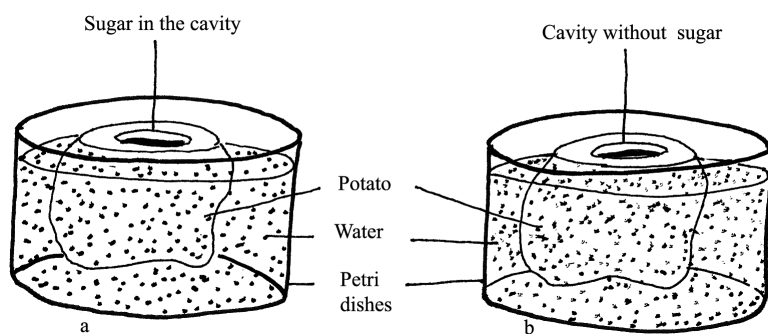


Figure 1.7

- What happened to the distilled water in the beaker?
- What happened to the salt solution in the glass tube?

Activity 1.13

- Peel the skin of a potato and cut it into two halves.
- Make a cavity in each potato with the help of a blade or knife and label them A and B.
- Place a small quantity of sugar inside the cavity of potato A and leave potato B as it is.
- Keep each potato on two separate Petri dishes and add water until the potatoes are partially immersed. See Figure 1.8.
- Leave for three hours and observe.

**Figure 1.8**

- In which potato cavity did you see more water? Why?
- What is the significance of osmosis in living things?
- What is the difference and similarity of osmosis and diffusion?

1.3.3 Homeostasis

Homeostasis is the maintenance of a constant internal environment of a cell. This process of keeping a constant internal environment provides the best conditions for the efficient functioning of cells. In order to remain alive, cells must maintain a biological balance with their immediate environment. Cells undergo homeostasis by controlling and regulating what passes in and out of them. Depending on the requirements, a cell allows

solutes and other necessary materials to enter and removes waste products. The exchange of oxygen and carbon dioxide is an example of homeostasis. The cell takes oxygen for respiration and removes carbon dioxide as a byproduct. Though cells can exist within a range of environmental states, there is a limit to how much they can adjust to. Homeostasis is dynamic and is affected by environmental changes.

1.3.4 Respiration

All living things require energy to survive. Whether they are unicellular or multicellular, all organisms need energy to undergo cellular activities. Cells are constantly active in building, repairing, growing and reproducing activities, which require energy. **Respiration** is the process by which energy is released from food to living cells. This takes place inside the cell, therefore it is also referred to as **cellular respiration**. In general there are two types of respiration:

A. Aerobic Respiration

This is the release of a large amount of energy as a result of the breakdown of food in the presence of oxygen.

B. Anaerobic Respiration

This is the release of a small amount of energy from the breakdown of food in the absence of oxygen.

During aerobic respiration, sugar is combined with oxygen and energy is released. Carbon dioxide and water are formed as byproducts and are removed from the cell. This aerobic respiration takes place inside the mitochondria of eukaryotic cells. In the case of prokaryotic cells, since there are no mitochondria, aerobic respiration occurs in the extension of the cell membrane.

1.3.5 Excretion

Chemical reactions constantly take place inside living cells. The sum total of all chemical reactions carried out by the cell is called metabolic reactions or **metabolism**. Metabolism is divided

into two, namely **anabolism** and **catabolism**. Those reactions that produce or build up complex compounds from simpler compounds with the expenditure of energy are called anabolic reactions or anabolism. Those reactions that break down complex molecules into simpler molecules, and in the process produce energy, are called catabolic reactions or catabolism.

During metabolism, living cells use water, oxygen and digested food. In the process of using these substances, the living cells produce harmful byproducts. The byproducts of metabolism are considered waste products because they are unwanted by the cells and need to be removed. The process of removing metabolic waste products from the body is called excretion.

Carbon dioxide and water, produced from cellular respiration, and nitrogenous compounds, produced from the break down of proteins, are the main waste products that the body must eliminate. The lungs excrete most of the carbon dioxide and some of the water through respiration. Carbon dioxide is a gas that forms an acid when dissolved in water. This acid slows down many enzyme reactions. Excess water in the body will cause cells to swell and burst.

The most common nitrogenous waste is ammonia, which is toxic to the cell. The body is protected from ammonia poisoning by the liver, which removes ammonia from the blood and converts it to a less harmful substance called **urea**. Urea is a less poisonous substance that prevents enzyme reactions from taking place. Urea enters the bloodstream and is removed by the kidneys in the form of urine. Finally, urine flows from the kidneys into the urinary system for storage and is eventually eliminated from the body.

Exercise 1.3

1. What does “selectively permeable” mean?
2. How does the cell membrane help maintain homeostasis?
3. What is the difference between active and passive transport?
4. How is the body protected from ammonia poisoning?

Summary

All living organisms, be they unicellular or multicellular, need to transport useful materials into the cell and remove waste materials from the cell. The cell membrane plays an important role in the transportation of materials. It exhibits selective permeability. The cell membrane allows some substances to cross more easily than others. Both diffusion and osmosis are types of passive transport because no energy is required for the molecules to move into or out of the cell.

1.4 Bacteria

Let us discuss

1. What is the first thing that comes to the mind when the word “bacteria” is mentioned?
2. Are bacteria prokaryotes or eukaryotes? Why?

1.4.1 The Structures and Forms of Bacteria

A. The Structures of Bacteria

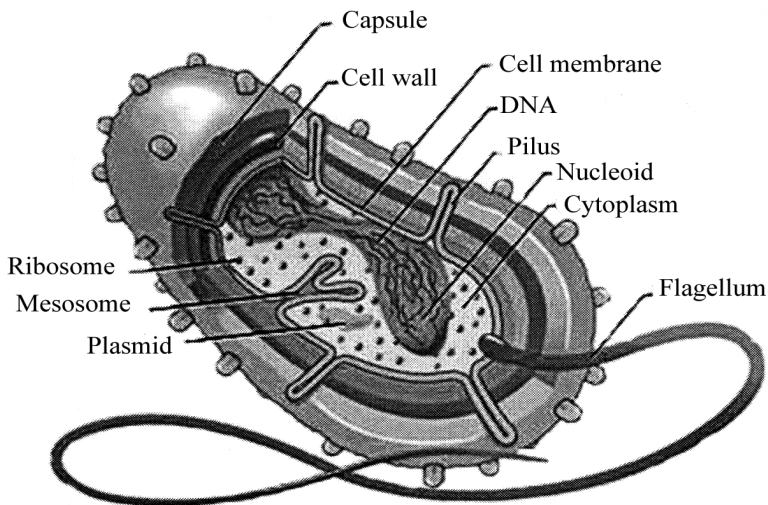


Figure 1.9 A typical bacterial cell

i. Cell Wall

Most bacteria possess relatively rigid, protective outer cell walls that give the cells their characteristic shape. The cell wall is composed of proteins and carbohydrates called the **peptidoglycan** layer. The possession of peptidoglycan layer makes the cell wall of bacteria different from the cell wall of plants (remember, the cell wall of plants is made up of cellulose).

Not all bacteria possess cell walls. Some bacteria have a polysaccharide layer, called a **capsule**, which surrounds the cell membrane. The capsule protects the cell from the host's immune defenses, and serves as a means of attachment to the cell surfaces of the host during infection. Most bacteria with this structure are called parasites and they live in the tissues of plants and animals.

ii. Flagella and Pili

Bacterial cells may also have structures like flagella on their surfaces. **Flagella** are long, slender protein structures that are anchored in the cell membrane; they extend through the cell wall and help the bacteria to swim. In addition to flagella, some bacteria may also have structures called **pili**. Pili are short, fine, hair-like appendages that are thinner than flagella and may serve as a means of attachment to solid surfaces.

iii. Cell Membrane

Like all other cells, bacterial cells also have a cell membrane. The bacterial cell membrane serves in regulating the passage of molecules into and out of the cell.

iv. Cytoplasm

The cell membrane encloses a space called the cytoplasm. Different proteins, including enzymes and thousands of ribosomes, are found suspended in the cytoplasm.

Bacterial cells, like all prokaryotic cells, do not have a nucleus; instead they have a dense area called the **nucleoid**. This nucleoid region contains a single chromosome consisting largely of a circular strand of deoxyribonucleic acid (DNA).

Bacterial cell structure	Function
Cell wall	Gives shape to bacteria Provides protection for the cell
Capsule	Gives resistance to the host's immune system Serves as attachment site to the surfaces of host cells or tissues
Flagella	Serve as locomotory structures
Cell membrane	Physical boundary of bacterial cells Serves as transport for nutrients and wastes Location of many metabolic processes
Cytoplasm	Fluid part of bacterial cell that houses proteins, enzymes and other substances
Ribosomes	Cytoplasmic structures that synthesize proteins
Nucleoid	Region that contains genetic material

Table 1.7 The main structures of a bacterial cell and their functions**Activity 1.14**

Complete the table below by indicating the presence or absence of the following structures and organelles in bacterial, animal and plant cells.

Structure/Organelle	Bacterial cell	Animal cell	Plant cell
Flagella			
Pili			
Cell wall			
Cell membrane			
Cytoplasm			
Mitochondria			
Endoplasmic reticulum			

Golgi bodies			
Plastids			
Vacuoles			
Ribosomes			
Nucleus			

Table 1.8

B. Forms of Bacteria

Bacterial species have a characteristic cell shape that is maintained by a rigid cell wall. Bacterial cells are found in a variety of different shapes. Depending upon the species, the three most common shapes of bacterial cells include cocci, bacilli and spirilla.

i. Cocci

Bacterial cells with **cocci** (singular: coccus) are rounded or roughly spherical cells. They can exist as individual cells and as special arrangements that are frequently useful in bacterial identification. **Diplococci** (singular: diplococcus) arise when cocci divide and remain together to form pairs of cells. Long chains of cocci result when cells remain attached to each other after repeated divisions in one line to form **streptococci** (singular: streptococcus). When bacterial cells divide randomly in many lines to form irregular grape-like clumps, they form **staphylococci** (singular: staphylococcus).

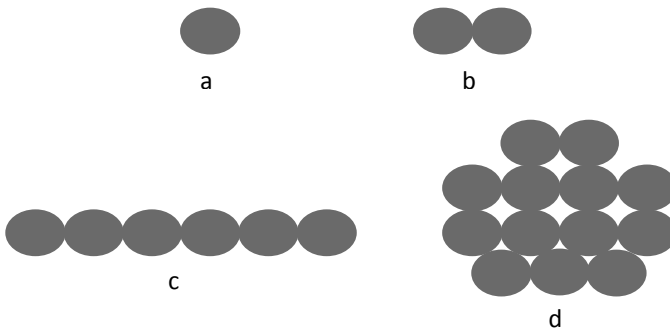


Figure 1.10 Cocci forms of bacteria: a. Coccus, b. Diplococcus, c. Streptococcus, d. Staphylococcus

ii. Bacilli

Bacilli (singular: bacillus) are rod-shaped bacterial cells. Many rods occur singly. However, some rods may remain together after division to form pairs of bacterial cells called **diplobacilli** (singular: diplobacillus) or chains of cells called **streptobacilli** (singular: streptobacillus).

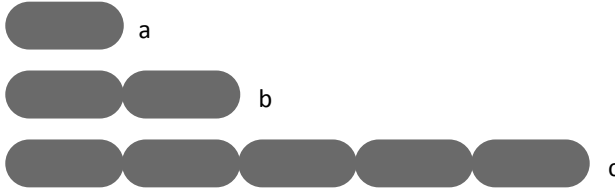


Figure 1.11 Bacillus forms of bacteria:
a. Bacillus, b. Diplobacillus, c. Streptobacillus

iii. Spirilla

Many bacteria also assume another form of bacterial cells, called **spirilla** (singular: spirillum) if rigid and **spirochetes** if flexible. These shapes are formed when long rod-shaped bacteria are twisted into spiral forms.



Figure 1.12 Spiral forms of bacteria

In addition to the above three forms, some bacteria may also characteristically form long **filaments** that may branch to produce a network.

Activity 1.15

Use a microscope to observe permanent slides that represent the three different bacterial forms and colonies or filaments. Follow the rules for the use and handling of a microscope given in Table 1.3 on page 10.

1. Draw what you have observed.
2. Report your findings.

1.4.2 The Economic Importance of Bacteria

Although considered structurally simple, bacteria are extremely diverse in terms of their metabolic processes and are found almost everywhere on earth in vast numbers. Humans and all other organisms depend on bacteria in many ways. Life on the earth would not exist without many of these bacteria.

Bacteria in general can be categorized as useful or harmful. Beneficial bacteria are involved in such diverse processes as digestion in animals, nitrogen fixation in the roots of certain legumes, the decomposition of animal and plant remains, and sewage disposal systems. Pathogenic bacteria, on the other hand, can cause severe and often fatal diseases in humans, animals and plants.

A. Useful Bacteria

The following are useful contributions of bacteria:

i. Decomposition of Waste Materials

The greatest, most significant role in which bacteria are involved is the decomposition of waste materials. Without these bacteria, the remains of dead organisms and plants would not decay and the waste would accumulate so rapidly that it would soon interfere with our daily lives and the lives of future generations. Bacteria enrich the soil by returning the minerals produced from the process of decomposition to the soil, making it useful once again for plants and animals. During this natural recycling process,

bacteria also release carbon dioxide into the air. Carbon dioxide is an essential substance for the growth of plants and consequently for the survival of all living things.

ii. Nitrogen Fixation

Some bacteria are involved in increasing soil fertility through the process of nitrogen fixation. This process is important in supplying the soil with the nitrogen plants need for growth.

iii. Secretion of Important Enzymes

Some bacteria that live in the gut of cattle, horses and other plant-eating animals (herbivorous animals) secrete an enzyme that aids in the digestion of the cellulose contents of plant cell walls (cellulose is the major source of energy for these animals).

iv. Fermentation Processes

Bacteria are exploited by humans in a number of beneficial ways. Many bacteria produce chemical changes that are part of the natural process called fermentation. **Fermentation** is used for the manufacture of fermented foods and beverages such as yogurt and cheese. The process of fermentation is also important in the industrial manufacturing of solvents like liquor and other alcoholic products (e.g. beer, wine, etc.).

v. Production of Vaccines and Antibiotics

Bacteria are very important in the production of vaccines and antibiotics. Today, humans receive vaccinations for bacterial diseases such as tuberculosis, diphtheria and tetanus. Some bacteria may also secrete antibiotics (drugs useful in fighting bacterial diseases).

vi. Secretion of Human Enzymes

Escherichia coli that live in the human large intestine synthesize vitamin B and release it for human use. Similarly, *Clostridium butylicum* is used for the commercial preparation of riboflavin (vitamin B₂).

B. Harmful Bacteria

Some bacteria are harmful and act either as disease-causing agents (pathogens) both in plants and animals (including humans), or may play a role in food spoilage and tooth decay. Bacteria may also produce deadly toxins and substances that are responsible for body odour.

Different methods have been invented and used by humans to prevent the damage caused by bacteria. Food preservation methods for example are among the methods used to prevent food spoilage caused by certain bacteria.

Activity 1.16

Go to the library or use the internet and write about the following:

1. How bacteria cause food spoilage.
2. Describe at least eight methods of food preservation

i. Human Diseases Caused by Bacteria

Some of the human diseases caused by bacteria are gonorrhea, syphilis, tetanus, pneumonia and tuberculosis.

1. Gonorrhoea

Gonorrhea is one of the sexually transmitted diseases (STDs) caused by a bacteria called *Neisseria gonorrhea*. Gonorrhoea spreads through sexual intercourse with an infected person, and during childbirth of an infected mother.

Gonorrhoeal symptoms usually appear between one and 14 days after exposure and are different for males and females. Gonorrhoea can be treated using different antibiotics. However, since gonorrhoea may be asymptomatic in many instances, prevention is the best option.

2. Syphilis

Syphilis is another example of an STD caused by the bacterium known as *Treponema pallidum*. It has often been called “the great imitator” because so many of the signs and symptoms are similar to other diseases.

Syphilis is passed from one person to another through direct contact with syphilis sores. Transmission of the bacteria occurs during sexual contact or from infected pregnant women to the babies they are carrying.

There is an incubation period of nine days to three months between being infected by syphilis and showing the first signs and symptoms of the disease. Syphilis progresses through three stages, namely primary, secondary and tertiary syphilis. Each stage has characteristic signs and symptoms.

Even though syphilis is treatable, if it goes unnoticed it may lead to different complications. Therefore, the best way to prevent syphilis is to abstain from having sex with an infected person or to stick with only one partner and practise safe sex.

ii. Animal Diseases Caused by Bacteria

Some of the animal diseases caused by bacteria are salmonellosis, anthrax and tuberculosis.

1. Salmonellosis

Salmonellosis is a disease caused by *Salmonella* bacteria, characterized by septicemia and severe diarrhoea. In its many forms, it is one of the major diseases of wild and domestic mammals, birds and reptiles, as well as humans. *Salmonella* bacteria usually enter the body through the mouth, most commonly along with food or water contaminated by infected faeces. Transmission may also occur through direct contact with an infected animal. In addition, *Salmonella* bacteria can be spread by contact with objects, such as bowls and cutting boards, that have been contaminated by infected animal products e.g. eggs, meat. If not treated immediately, *Salmonella* may cause severe infection and death.

2. Anthrax

Anthrax is one of the oldest and most destructive diseases recorded in history. Caused by the bacterium *Bacillus anthracis*, anthrax can affect almost all warm-blooded animals, including humans. Typical symptoms of anthrax include restlessness, exhaustion, loss of appetite, fever and rapid breathing. Animals can get the disease from contaminated soil, feed or water. It can also spread when the skin is penetrated by insect bites or by objects contaminated with anthrax spores.

3. Tuberculosis

Tuberculosis (TB) is a chronic disease of animals and humans. Tuberculosis is caused by bacteria called *Mycobacterium tuberculosis*. The disease is transmitted by inhalation of droplets from an infected animal's cough or sneeze, or by a wound infection. Symptoms include fever and weakness.

iii. Plant Diseases Caused by Bacteria

Plants also suffer from bacterial infections. Some bacteria infect the leaves and this reduces a plant's ability to produce food. Some bacteria grow in either the xylem or phloem tissues of plants and may reduce or completely stop the transport of water and nutrients. Some of the plant diseases caused by bacteria include wilt, leaf spot, soft rot, as well as fire blight. *Agrobacterium* species even have the ability to form tumor-like overgrowths (in plants they infect), called **crown gall**.

1. Wilt

Wilt is a disease that attacks corn, onions and tomatoes. This bacterial disease causes the leaves of the plant to wilt and drop before they should. The bacteria remain dormant in the seed for several months before the seed starts to germinate. Once the bacteria start to multiply and increase in number, they block the water-conducting tissue (xylem) of the plant. This decreases or stops the movement of water to various parts of the plant.

2. Ring Rot

Ring rot is a very infectious and destructive disease. It is a common plant disease in tubers (like potatoes). The leaves of

an infected plant become pale yellow at first, with progressive yellowing after a few days. As the disease progresses the leaves curl upwards and wilt, subsequently resulting in the death of the plant.

3. Leaf Spot

Leaf spot is another example of a bacterial disease in plants that primarily affects the leaves. Spots on the leaves are the main symptoms of the disease. Severely infected leaves fall from the plant followed by the death of the plant. This disease also infects the stems.

Bacteria that cause plant diseases are spread in many ways. They can be splashed about by rains or carried by the wind, birds, or insects. Many of the bacteria that infect plants are vectored by sucking insects such as leafhoppers. People can unknowingly spread bacterial diseases by pruning infected plants. Water facilitates the entry of bacteria carried on pruning tools into the pruning cuts. Propagation with bacteria-infected plant material is a major way pathogenic bacteria are moved over great distances.

However, no matter how the bacterial pathogens are disseminated, they require a wound or natural opening, such as stomata, to get inside a plant host. Once inside a plant, bacterial diseases are difficult to control. Therefore emphasis should be on preventing the spread of bacteria rather than on curing the plant. Some of the preventive measures for controlling bacterial plant pathogens include:

1. Using bacteria-resistant plant varieties.
2. Using bacteria-free seed or propagation materials.
3. Good sanitation, particularly disinfecting pruning tools.
4. Cultural practises that either eliminate or reduce sources of bacterial contamination, such as crop rotation to reduce over-wintering.
5. The prevention of surface wounds that permit the entrance of bacteria into inner tissues.
6. Insect control to help eliminate vectors or the reduction of feeding wounds that can provide points of entry.

Exercise 1.4

1. What are the five major structures found in all bacteria? Draw a simple diagram of a bacterial cell, labeling all five structures.
2. Distinguish between the three major shapes of bacteria and draw a diagram for each.
3. How are bacteria disseminated from plant to plant?
4. What is the requirement for bacterial infection to occur in plants?

Summary

Bacteria are microscopic, single-celled prokaryotic organisms without a defined nucleus. They contain structures like the nucleoid, cytoplasm and cell membrane, which usually are surrounded by a cell wall and a resistant covering called a capsule. Bacterial cells can be rod-shaped, spherical or spiral-shaped. They occur singly or in colonies of cells. Most bacteria are motile (capable of movement) and have whip-like flagella that propel them through fluids.

There are both beneficial and harmful bacteria. Beneficial bacteria are involved in such diverse processes as digestion in animals, nitrogen fixation in the roots of certain legumes, the decomposition of animal and plant remains and sewage disposal systems. Harmful bacteria, on the other hand, cause severe and often fatal diseases in humans, animals and plants.

1.5 Viruses

Let us discuss

1. What are viruses?
2. Are viruses useful or harmful? Why?

1.5.1 The Structures of Viruses

Most viruses are much smaller than bacteria. They can be seen only by using an electron microscope. The complete assembly of an infectious particle is known as a virion. A **virion** is a **nucleic acid** (DNA or RNA not both) core surrounded by a protein coat or **capsid**. In addition to the nucleocapsid core, certain plant and animal viruses and bacteriophages (viruses that infect bacteria) are surrounded by a thin membranous **envelope**. The viral envelope is made up of protein, lipids and carbohydrates. Lipids provide flexibility to the shape of these viruses.

Activity 1.17

Study the different diagrams of viruses provided in Figure 1.13 (a and b) and answer the following questions.

1. Identify as many structures as possible from the diagrams.
2. Report your findings to the class for discussion.

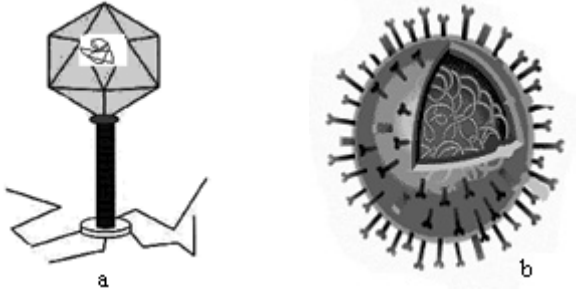


Figure 1.13 Viruses

Bacteriophages exist in many different sizes and shapes. As illustrated in Figure 1.14, a bacteriophage structure has two parts: a head, which contains the nucleic acid and a tail, which consists of fibres extending from its distal end.

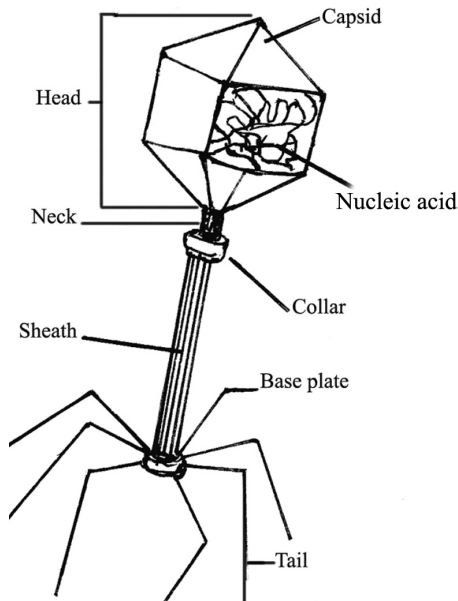


Figure 1.14 A bacteriophage structure

Head: All phages contain a head structure which can vary in size and shape. The head is composed of a capsid and nucleic acid. The capsid is made up of many different proteins and serves as a protective covering for the nucleic acid inside.

Tail: Many bacteriophages have a tail attached to their head. The tail is a hollow tube through which the nucleic acid passes during infection. The size of the tail varies among bacteriophages and in the more complex bacteriophages, the tail is surrounded by a **contractile sheath**, which contracts during infection of the bacterium. At the end of the tail, some bacteriophages may also have a **base plate**, with one or more **tail fibres** attached to it.

Activity 1.18

Go to the library and prepare a list of facts that may help you in debating “whether or not viruses are alive”.

In your discussion, address the following questions.

1. Are viruses truly living organisms? Why?
2. Do viruses fulfil the most basic characteristics of life?

1.5.2 Comparison with Cells

The nature of viruses is ambiguous whether they are living organisms or non-living matter. Viruses do not have a nucleus, cytoplasm, or cell membranes, which are characteristics of living cells.

Even though viruses do have their own nucleic acid, they are not capable of metabolism as are other living things. They have no mechanisms for generating their own metabolic energy and neither are they capable of replicating themselves unless they are inside host cells. Therefore, outside host cells viruses are considered to be non-living particles.

In order to multiply, a virus needs to invade a living host cell and take over its metabolic machinery. A virus inserts its genetic material into its host only after establishing contact with the

surface of the host cell. Once inside the host, some viruses may remain dormant for long periods, causing no obvious change in their host cells. The virus stays in this dormant stage until there is change in the host cell, which then leads to the formation of new viruses. New viruses are then assembled and burst out of the host cell (i.e. killing the cell) to infect other cells.

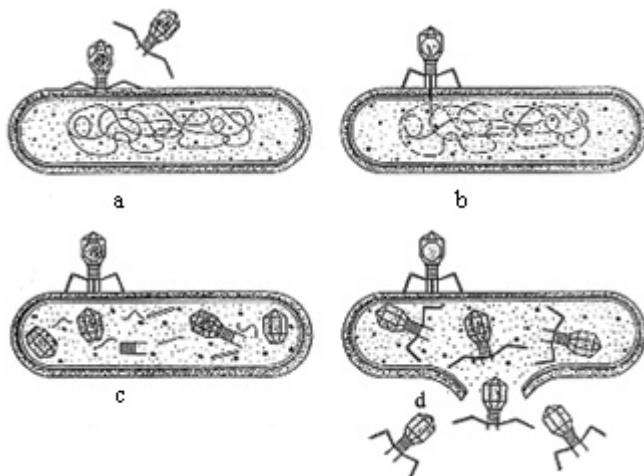


Figure 1.15 The lytic phase of a phage: a. Attachment to cell surface, b. The nucleic acid of the phage penetrates, c. Maturation of the phage, d. The phage is assembled and bursts out of the cell for further infection of other cells

1.5.3 Diseases Caused by Viruses

Let us discuss

1. Why are viruses considered to be obligate intracellular parasites?
2. Are viruses useful or harmful?
3. Do you think antibiotics are effective against viral infections?

A. Viral Diseases in Humans

Viruses cause a number of diseases in humans. Smallpox, the common cold, chickenpox, influenza, shingles, herpes, polio, rabies, Ebola and HIV/AIDS are some of the examples of viral diseases in humans.

i. HIV/AIDS

Acquired Immuno Deficiency Syndrome (AIDS) is a disease that develops when people are infected with the Human Immunodeficiency Virus (HIV). It is now a pandemic (occurring throughout the world) with prevalence more in less-developed countries.

Human Immunodeficiency Virus is dangerous because it specifically attacks the white blood cells, which normally are used to fight the virus itself. Once HIV kills sufficient white blood cells, the infection slowly progresses to AIDS. As the infection develops, a person who has been infected with HIV is likely to become vulnerable to other **opportunistic diseases**. These are illnesses that do not normally occur or, if they do occur, are not normally serious. They are called opportunistic because they take advantage of the weakened immune system.

Human Immunodeficiency Virus is found in the blood, the semen and vaginal fluids of an infected person and in the breast milk of an infected woman. Transmission occurs when a sufficient quantity of these fluids get into another person's bloodstream or by passing through the delicate mucous membranes. There are various ways a person can become infected with HIV.

Activity 1.19

1. What are the methods by which HIV can be transmitted from person to person?
2. What are the ways by which HIV cannot be transmitted from person to person?

The symptoms of AIDS are primarily the result of conditions that do not normally develop in individuals who are not infected. Most of the symptoms are caused by an infections of bacteria, viruses and parasites that are normally controlled by the white blood cells which have been destroyed by the HIV infection.

In humans, the HIV virus goes through a long **latent period**, during which the host does not show any symptoms, and hence is called **asymptomatic**. During this time the symptoms of the HIV infection do not manifest themselves as AIDS. People who carry the HIV virus but remain asymptomatic for many years appear physically healthy and have a high probability of transmitting the virus to others.

Currently there is no vaccine, or safe and fully effective cure for the HIV infection. The medicines available in clinics (the retroviral drugs) are useful in prolonging the life of an infected person. The only way to stop or slow the spread of the virus is through prevention.

ii. Influenza

Influenza, commonly referred to as the flu, is an infectious disease caused by influenza viruses. Influenza is a viral infection that affects mainly the nose, throat, bronchi and lungs. Even though flu is often confused with other influenza-like illnesses, such as the common cold, it is a much more severe disease than the latter.

Flu can be identified easily by its sudden onset of a high fever and extreme fatigue. Most infected people recover within one to two weeks without requiring medical treatment. However, in the very young, the elderly, and those with other serious medical conditions, infection can lead to pneumonia, which can be fatal.

Transmission

Influenza can be spread in three main ways:

1. Inhaling aerosols produced by infected people during coughing, sneezing and spitting.
2. By direct transmission when an infected person sneezes mucus into the eyes, nose or mouth of another person.
3. Through hand-to-mouth transmission from either contaminated surfaces or direct personal contact, such as a handshake, bank notes, door knobs, light switches and other household items.

Symptoms

Influenza infection is characterized by the sudden onset of high fever (38-39°C) associated with chilly sensations one to two days after infection. Symptoms of influenza include:

1. Headache and fatigue
2. Body aches: muscles, joints and throat
3. Sore throat
4. Irritated watering eyes
5. Non-productive cough
6. Reddened eyes, skin (especially the face), mouth, throat and nose
7. Diarrhoea and abdominal pain in children

Treatment

Antiviral medication can be effective if given early. Some strains of influenza can show resistance to the standard antiviral drugs. Infected people are usually advised to get plenty of rest, drink ample fluids, avoid using alcohol and tobacco and, if necessary, take medications to relieve the fever and muscle aches associated with the flu.

Prevention

Good personal health and hygiene habits, like hand washing, avoiding the habit of spitting, covering the nose and mouth when sneezing or coughing, wearing a face mask when caring for the sick, and vaccination are some of the preventive methods against influenza, especially during pandemics.

B. Viral Diseases in Animals

Viruses cause diseases in animals, which include rabies and foot-and-mouth disease.

i. Rabies

Rabies is a viral disease of mammals. It is a significant killer of livestock and is also fatal to humans if the post-exposure preventive method (prophylaxis) is not administered prior to the onset of severe symptoms.

Transmission

The disease is transmitted to domestic animals and humans through exposure to infected saliva. Dogs are still the main carriers of rabies.

Symptoms

The first symptoms of rabies are flu-like, including fever, headache and fatigue, and then progress to involve the respiratory, gastrointestinal and/or central nervous systems. In the critical stage, signs of hyperactivity or paralysis dominate, followed by coma and death, usually due to respiratory failure.

Treatment

Immediate wound cleansing and immunization after contact with a suspect-animal can prevent the onset of the disease. When humans are exposed to such animals, attempts to identify, capture or humanely dispose of the animal involved should be undertaken immediately. Post-exposure treatment should start right away and only be stopped if the animal remains healthy after 10 days. Post-exposure prophylaxis is highly successful in preventing the disease if administered promptly, generally within 10 days of infection.

Prevention

Safe and effective vaccines are available to prevent rabies in animals and in humans before and after suspected exposure. The most cost-effective strategy for preventing rabies in people is by eliminating rabies in dogs through animal vaccinations.

ii. Foot-and-mouth Disease

Another example of an animal disease caused by viruses is foot-and-mouth disease. Foot-and-mouth disease is caused by a virus, which is found in the saliva of cattle, pigs and other hoofed animals.

The disease is highly contagious and spreads through direct contact with an infected animal. It may also spread through contaminated milk or meat. Typical symptoms include blisters that

appear on the mouth and feet, and animals may become lame as hooves degenerate.

C. Viral Diseases in Plants

Some of the viral diseases in plants include mosaic diseases and potato leaf roll.

1. Mosaic Diseases

Many viruses produce mosaic-like symptoms in plants. Mosaic-like symptoms are characterized by intermingled patches of normal and light green or yellowish colours on the leaves of infected plants. Tobacco mosaic damages the leaves, flowers and fruits, and causes stunting of the tobacco plant by blocking the food transport system. The virus almost never kills plants but lowers the quality and quantity of the crop, particularly if the infected plant is young.

Plants like potatoes, wheat, etc. are also attacked by mosaic diseases. Insects often play an important role in the transfer of the virus from one plant to another.

2. Potato Leaf Roll

This type of viral disease of potato plants (also common in tomatoes) causes the leaves to roll up and become brittle. This reduces the photosynthetic process in potato tubers and makes them light in weight. The virus is transmitted from plant to plant by insects that feed by sucking; once inside the plant, disease spreads throughout the plant.

Plant viruses cannot be directly controlled by chemical application. Therefore the major means of control depends on the type of the disease, which includes:

1. Chemical or biological control of the vector i.e. the organism that transmits the disease, which is often an insect.
2. Growing crop varieties that are resistant to viral infections.
3. Using plant material that is free of plant viruses.

Exercise 1.5

1. List and describe the structural components of viruses.
2. Write down some characteristics that viruses share with living organisms and explain why viruses do not fit our usual definition of life.
3. List at least three differences between bacteria and viruses.

Summary

Viruses are non-cellular particles with a range of variable sizes and shapes. They are small, infectious elements and contain only one kind of nucleic acid, either DNA or RNA, as their genetic material, which is protected by a capsid. Some viruses may have other structures like an envelope and additional appendages.

Viruses replicate only in living cells and cause diseases to humans, animals and plants in the process. Viruses cause many infections in humans and also result in economic damage by affecting numerous animals and plants. Preventive measures against viruses are more commonly taken as there are no effective drugs available to date that can be used against many viruses.

Key Terms/Phrases

Active transport	Microscope
Anabolism	Multicellular organism
Bacteriophages	Nucleus
Capsule	Objective lens
Catabolism	Organelles
Cell	Organisms
Cell membrane	Osmosis
Cytoplasm	Passive transport
Diffusion	Plasmolysis
Eukaryotes	Prokaryotes
Hypertonic solution	Selective permeability
Hypotonic solution	Solutes
Isotonic solution	Solvents
Latent period	Unicellular organism
Lytic phase	Vector
Lysogenic phase	Virion
Metabolism	Wet mount

Review Questions

Part I. Choose the correct answer

1. Botany is:
 - A. the study of plants.
 - B. the study of animals.
 - C. the study of all living organisms.
 - D. the study of heredity.

2. To find the magnification of any specimen under a microscope, we must:
 - A. add the magnification of the eyepiece and that of the objective lens.
 - B. multiply the magnification of the eyepiece by the magnification of the objective lens.
 - C. divide the magnification of the objective lens by that of the eyepiece.
 - D. subtract the magnification of the objective lens from that of the eyepiece.

3. All living things except viruses are composed of one or more:
 - A. proteins.
 - B. cells.
 - C. carbohydrates.
 - D. lipids.

4. Living organisms give rise to others of the same type. This is an example of:
 - A. respiration.
 - B. development.
 - C. reproduction.
 - D. evolution.

5. Waste products are produced by:
 - A. metabolic reactions.
 - B. homoeostasis.
 - C. adaptation.
 - D. evolution.

6. What makes the endoplasmic reticulum (ER) look rough?
 - A. the presence of vacuoles.
 - B. the presence of mitochondria.
 - C. the presence of ribosomes.
 - D. the presence of DNA molecules.

7. What clue would tell you whether a cell is prokaryotic or eukaryotic? The presence or absence of:
A. a cell membrane. C. a cell wall.
B. a nucleus. D. a cytoplasm.
8. The protein factories of a cell are the:
A. Golgi apparatus. C. ribosomes.
B. lysosomes. D. mitochondria.
9. Which structure of the cell is responsible for regulating the movement of materials into and out of the cell?
A. nucleus. C. cell wall.
B. plasma membrane. D. ribosome.
10. Which of the following substances are not used during metabolism?
A. water. C. digested food.
B. oxygen. D. carbon dioxide.
11. Urea is changed into urine in the:
A. liver. C. kidneys.
B. lungs. D. bladder.
12. Which of the following characteristics of viruses is different from the rest?
A. they are made up of many specialized cells.
B. they contain genetic material.
C. they reproduce by mitosis.
D. they contain chlorophyll.
13. Rod-shaped bacteria are called:
A. bacilli. C. cocci.
B. streptococci. D. Spirilla.
14. Which of the following are characteristics of bacterial cells?
A. Bacterial cells are prokaryotes.
B. Bacterial cells have a cell wall.
C. Bacterial cells have a ring of double-stranded DNA
D. All of the above.

15. The basic structure of a virus contains:
- A. a nucleus.
 - B. a cell wall.
 - C. an envelope.
 - D. a nucleocapsid core.
16. Which of the following is necessary for a virus to reproduce?
- A. a living host cell.
 - B. a nutrient.
 - C. a high body temperature.
 - D. sunlight, water and food.
17. Which of the following diseases has NOT been reduced or eliminated by vaccines?
- A. smallpox.
 - B. HIV/AIDS.
 - C. polio.
 - D. measles.
18. When the HIV virus weakens the immune system:
- A. people with AIDS are more vulnerable to other diseases.
 - B. the AIDS virus is spread very easily.
 - C. people with AIDS are immune to all other diseases.
 - D. all of the above.
19. The first stage of _____ is characterized by the appearance of a chancre.
- A. gonorrhoea.
 - B. influenza.
 - C. syphilis.
 - D. HIV/AIDS.
20. Which of the following is characteristic of a virus shared with living things?
- A. they are made up of many specialized cells.
 - B. they contain genetic material.
 - C. they reproduce by mitosis.
 - D. they contain chlorophyll.

Part II. Fill in the blanks

1. _____ is an instrument that is designed to magnify objects that are too difficult to be seen with the naked eye.
 2. The organelle responsible for cellular respiration in eukaryotic cells is _____.
 3. The DNA inside the cell is found within a thread-like structure is called _____.
 4. _____ is a process by which energy is released from food to living cells.
-

5. The movement of water across a semi-permeable membrane is called _____.
6. The term “biology” literally means _____.
7. A physical feature that enhances an organism’s ability to survive in its environment is called _____.
8. _____ is the ratio of the apparent size of an object as seen through a microscope (image size) to the real size of the object (object size).
9. The disease caused by _____ is sometimes called the silent STD.

Part III. Match the following

Column A

1. fine adjustment knob
2. illuminator
3. diaphragm
4. revolving nosepiece
5. Robert Hook
6. centrioles
7. cellulose

Column B

- a. provides light
- b. moves objective lenses
- c. focuses on detail
- d. controls the amount of light
- e. discovered cells
- f. found only in plant cells
- g. found only in animal cells
- h. observed in living cells

Part IV. Give short answers

1. What characteristics do all organisms have in common?
2. How can the study of biology help one to understand the environment?
3. What is the similarity between a hand lens and a light microscope?
4. Distinguish between microbiology and taxonomy.
5. What are the functions of the smooth ER?
6. What makes one’s understanding of the cell clear?
7. Which organelle undergoes photosynthesis?
8. What is the role of the kidneys in the excretion of nitrogenous wastes?
9. What is the effect of the presence of excess water in the body?
10. Why is the nature of viruses ambiguous i.e. whether they are living or non-living organisms?

UNIT 2

Taxonomy

Expected Learning Outcomes

By the end of this unit, you are expected to:

- develop a model of a hierarchical classification system using taxonomic nomenclature

2.1 The Importance of Classification

Let us discuss

1. Why is classification important to humans?
2. Why is there a need for classification in biology?
3. How can one sort out plants and animals commonly found in the school compound?

From early times humans have found it convenient to classify plants and animals according to their usage, habit or size. For example plants can be classified according to their use as edible, poisonous or medicinal plants. According to their characteristics plants can be divided into herbs, shrubs, and trees. Similarly, animals are also classified as insects, birds, fishes, etc. Placing these into groups makes it easier for us to understand them. The branch of biology that deals with the naming and classification of organisms is called **taxonomy**. A biologist who specializes in this field of study is called a **taxonomist**.

The classification used by biologists is mainly based on a careful and detailed examination of the structure of organisms. Taxonomists classify organisms according to the **similarities** and **differences** of the structures examined. Organisms that are alike are grouped together and those that are different are put in another group. There are millions of already identified organisms and many new kinds are being discovered all the time. The total number of organisms, living and fossil, is so vast that taxonomists devised a system of classifying (naming and arranging) organisms into groups.

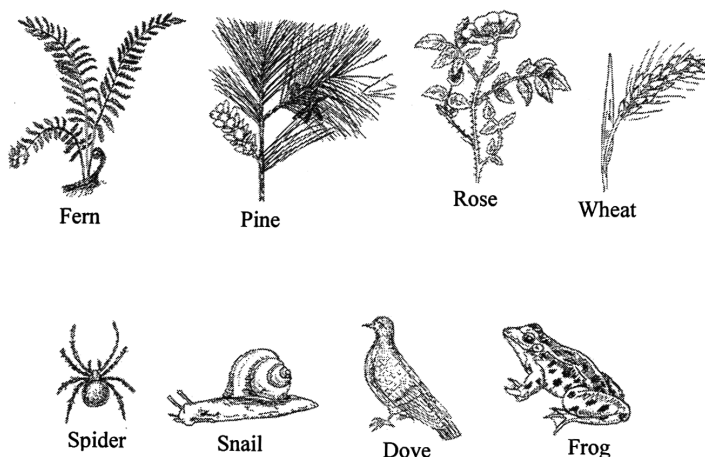
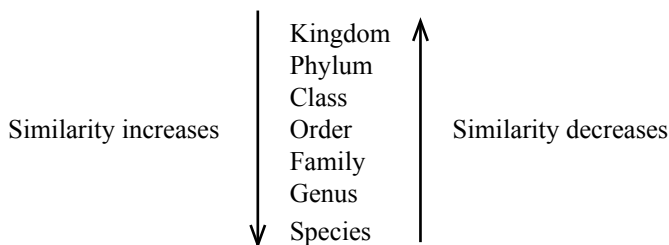


Figure 2.1 Different types of plants and animals.

More than 200 years ago, a Swedish botanist named **Carl Linnaeus** developed a classification system in which every organism then known to science was assigned to a series of increasingly more general groups. This arrangement was based on the degree of structural similarity among various organisms. In the biological system of classification, a group is called a **taxon**. Since the time of Linnaeus, the biological system of classification has been conceived as a hierarchy with specified levels or ranks. There are seven different levels or ranks into which living things are arranged into groups.



Kingdom: This is the highest level of classification. Living things are divided into five kingdoms, known as monera, protista, fungi, plantae, and animalia.

Phylum: Each kingdom is subdivided into a number of **phyla** (singular: **phylum**). Studying the main characteristics of an organism will identify its phylum. For example in the animal kingdom, if an animal has a backbone it is assigned into the phylum chordata (vertebrates).

Class: This is a smaller division of a phylum and looks at differences at this level. For example the phylum chordata contains several classes, which include fishes, amphibians, reptiles, birds and mammals.

Order: Each class is subdivided into orders. This is a further subdivision, looking at even smaller differences. For example the class of insects is divided into orders mainly according to the type of wings. All insects with two wings belong to the order diptera for example house flies.

Family: Each order contains several families. Members of the same family will show even more similarities. Frogs and toads belong to the same order but to two separate families.

Genus: Each family is further divided into several genera (singular: genus). At this level the organisms are very similar. Some of them may be capable of interbreeding but the offspring may not be fertile e.g. the mule.

Species: This is the lowest rank of classification. Members of the same species are very similar although there are differences for example the colour of flowers. Members of the same species are capable of interbreeding. A genus usually contains several species sharing many similar features. For example the genus *Felis* is made up of 10 or more species, including the lion, tiger, leopard, cheetah, domestic cat, and others.

The following table shows the hierarchical classification of a mushroom, maize and humans.

Category	Mushroom	Maize	Humans
Kingdom	Fungi	Plantae	Animalia
Phylum	Basidiomycota	Angiospermae	Chordata
Class	Hymenomycetes	Monocotyledon	Mammalia
Order	Agaricales	Commelinales	Primate
Family	Agaricaceae	Poaceae	Hominidae
Genus	<i>Agaricus</i>	<i>Zea</i>	<i>Homo</i>
Species	<i>bisporus</i>	<i>mays</i>	<i>sapiens</i>

Table 2.1 Classification of a mushroom, maize and humans

Linnaeus also devised a way to name each type of organism – this system is known as **binomial nomenclature** (binomial means two names). Linnaeus’s system of naming organisms assigns each species a two-word name e.g. *Homo sapiens* (humans), *Felis domestica* (domestic cat), *Zea mays* (maize). This is known as the scientific name of the organism. The first of the two names is the genus name and the second, the species name. It is conventional to write the first letter of the genus with capital and the species name with a small letter. The scientific name is always underlined, the genus and species names separately when hand-written or italicized when typed. The genus name can also be abbreviated for example *A. tortilis* for *Acacia tortilis* if it appears for the second time in a text.

Taxonomists use Latin when naming organisms and they avoid common names because they are not universal, as different people use different languages and common names throughout the world. If the name used is not Latin, it needs to be Latinised. For example *Aloe massawana* is the name given to the aloe species that was first identified near Massawa.

In short, the rules for naming organisms include the following:

1. Every organism can have only one scientific name.
2. The scientific name of an organism has two parts: the **genus** and **species** names.
3. The genus name starts with a capital letter and the species name with a small letter.
4. Both genus and species names ought to be printed in italics e.g. *Felis leo* or underlined separately for genus and species when hand-written e.g. Felis leo.

Activity 2.1

- a. Using the Textbook or any biology books in the library, write down the common names of any six plants and animals.
- b. Record the scientific name of each plant and animal.
- c. Classify the listed plants and animals into two or three groups using any classification criteria.

Exercise 2.1

1. The smallest unit of classification of organisms is:
A. phylum. C. species.
B. class. D. kingdom.
2. The category “class” is subdivided into:
A. species. C. families.
B. phyla. D. orders.
3. The scientific name of an organism has two parts; these are:
A. phylum and species. C. family and genus.
B. class and genus. D. genus and species.
4. Which of the following scientific names is correct?
A. Homo sapiens. C. homo sapiens.
B. Homo Sapiens. D. Homo sapiens.
5. List the rules for writing a scientific name.
6. Why do taxonomists use Latin for naming organisms?

Summary

In biology, organisms are classified into groups according to their similarities and differences in structure. The system of classification that we use today in biology was first developed by Carl Linnaeus, the “father” of modern taxonomy. He classified organisms into a hierarchy of taxonomic ranks that include the kingdom, phylum, class, order, family, genus and species. He also introduced the system of naming organisms, the binomial nomenclature.

2.2 Specimen Identification and Keys

Let us discuss

1. How does one identify plants found in the school compound as herbs, shrubs or trees?
2. How are animals around your school compound identified as vertebrates or invertebrates?

Most books that enable us to find out about the names of organisms make use of what is called a “key”. Such a key consists of a series of questions, which, when answered, lead one to name the specimen. In identifying organisms different types of keys are used by taxonomists, of which the **dichotomous key** is familiar in botanical and zoological works. The dichotomous key consists of a series of mutually exclusive couplets (pairs of statements). At each couplet a decision has to be taken to follow one lead or the other. Each statement of a pair will lead the reader to a taxon or to a further couplet. At each step the number of possible taxa with which the unknown specimen can be identified is successively reduced until there is only one possibility.

It is possible to construct a dichotomous key in the following way:

- a. First list the main features of the organisms, looking for those which make each one unique from the others.
- b. Arrange these features together in pairs.
- c. Read and look at the pair of descriptions; either the name of the organism or the number of the next group of descriptions will be found.

- d. Continue in this way until the name of each organism is established.

In order to produce a simple key for the animals shown below, that is, a goat, donkey, cow, bat, fish and hyena, make a series of pairs of statements like the ones below.

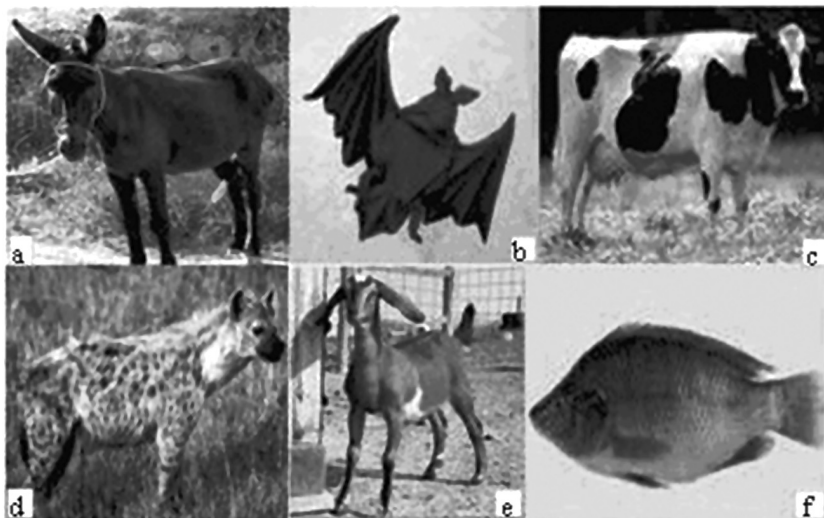


Figure 2.2

Pairs of statements

1. aquatic, breathe with gills
terrestrial, breath with lungs
2. wings present
wings absent
3. the animal is flesh eating, carnivore
the animal is plant eating, herbivore
4. hoof undivided
hoof divided
5. height more than 1.5 m
height less than 0.5 m

Animal

- fish (F)
go to no. 2
bat (B)
go to no. 3
hyena (D)
go to no. 4
donkey (A)
go to no. 5
cow (C)
goat (E)

If the above dichotomous key is read carefully, there is a “yes” or “no” answer to successive questions. If the statement is changed to a question form then part of the key would look like this:

1. Is the animal aquatic and breathes with gills?
Yes. Then the animal is a fish.
No, it is terrestrial and breathes with lungs. Go to no. 2.
2. Are wings present?
Yes. Then the animal is a bat.
No, wings are absent. Go to no. 3.
3. Is the animal flesh eating?
Yes. Then the animal is a hyena.
No, the animal is plant eating. Go to no. 4, and so on.

Activity 2.2

Practice constructing a dichotomous key for the organisms illustrated below.

Use the following features: shell, wing and legs (number).

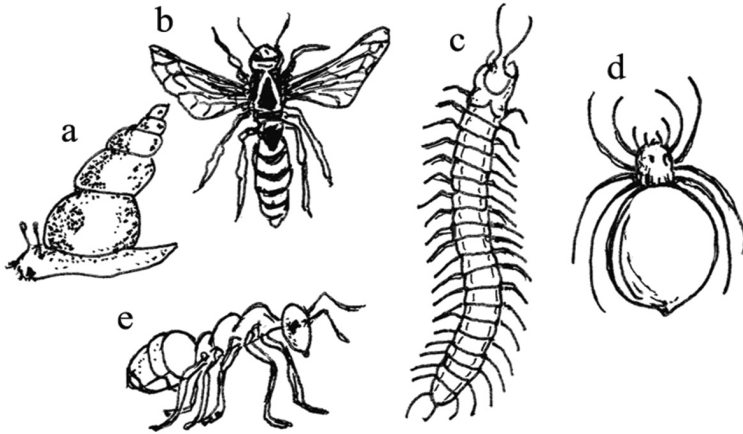


Figure 2.3

2.3 The Five-Kingdom Classification

Let us discuss

1. What are the main differences between prokaryotic and eukaryotic cells?
2. How do organisms differ in their mode of nutrition?
3. How do organisms differ in their cellular organization?

Taxonomy has changed as technology enables biologists to discover more complex details of cellular and molecular structures. The initial two-kingdom that classified all organisms as **plants** or **animals** expanded to a three-kingdom system, recognizing **fungi** as a separate kingdom. Fungi used to be treated as plants, for possessing a cell wall, but the chemical nature of a plant cell wall and that of fungi is different. A plant cell wall is made up of **cellulose** while that of fungi comprises **chitin**. Further, fungi lack chlorophyll and hence are organisms that grow on and derive their nourishment from dead or decaying organic matter. Then a four-kingdom classification scheme was suggested, acknowledging the significant difference between prokaryotes and eukaryotes. The prokaryotic organisms such as bacteria are treated as a separate kingdom: **monera**. Currently scientists recognize five kingdoms. Many of the simple organisms that used to be classified under the plant or animal kingdom were separated to form the kingdom **protista**. The five-kingdom system was first suggested by R. H. Whittaker in 1969 and is now widely used by biologists. Remember that this is not the only system, but it is the most accepted one.

The main features of the five kingdoms can be summarized as follows:

- Monera:* Simple, single-celled prokaryotes, chemosynthetic or photosynthetic autotrophs, some are parasites e.g. bacteria, cyanobacteria. An autotroph is an organism that produces complex organic compounds from simple inorganic molecules.
- Protista:* Simple eukaryotic organisms, mostly unicellular but sometimes joined together; some make their own food, others feed on other organisms e.g. protozoa, algae, slime moulds.
- Fungi:* Mostly multicellular eukaryotes, saprophytes that absorb food, with a cell wall of chitin e.g. yeast, mould, mushroom.

Plantae: Complex multicellular eukaryotes, photosynthetic autotrophs containing chlorophyll, with cell walls made of cellulose e.g. mosses, ferns and fern allies, seed plants.

Animalia: Complex multicellular eukaryotes without a cell wall, heterotrophs that ingest food e.g. sponges to vertebrates. Heterotrophs are organisms that cannot synthesize their own food and are dependent on complex organic substances for nutrition.

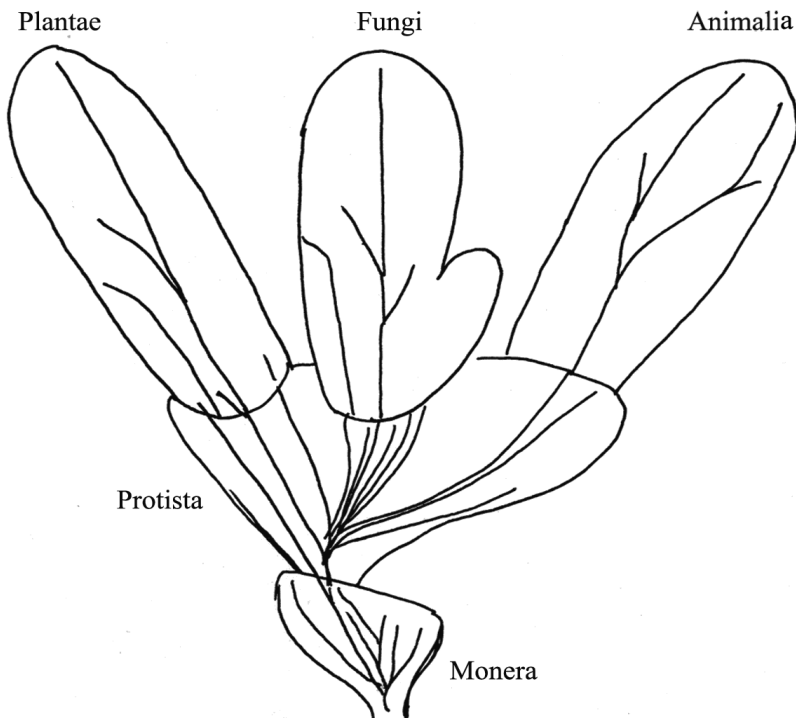


Figure 2.4 The five kingdoms according to Whittaker

Activity 2.3

Draw the following table in your exercise book and compare the five kingdoms with the following characteristics: cell type, cellular organization, cell wall and mode of nutrition.

Kingdom	Cell type	Cellular organization	Cell wall	Mode of nutrition
Monera				
Protista				
Fungi				
Plantae				
Animalia				

Table 2.2**2.3.1 Kingdom Monera****Let us discuss**

1. What are monerans?
2. What are the common forms of bacteria?
3. Are all bacteria harmful? Why?

All members of the kingdom monera are prokaryotic and unicellular. The kingdom includes organisms like bacteria and cyanobacteria (formerly known as blue-green algae).

A. Bacteria

Bacteria are simple and most abundant microorganisms. They exist at every place where life is possible, including hot springs, deep ocean beds, air, water, soil, and on surfaces of objects, as well as in the bodies of animals and plants. They are adapted to live in a wide variety of environments.

i. Mode of Nutrition

The means whereby an organism assimilates its food is called nutrition. Bacteria, like all other living organisms, need a constant supply of food in order to continue to live. There are two modes of nutrition observed in bacteria, namely **heterotrophic** and **autotrophic**.

Most bacteria do not produce their own food and are, therefore, **heterotrophic**. Heterotrophic bacteria can be **saprophytic** i.e. consume waste products and dead organic matter, or **parasitic**, which derive food from their host. **Autotrophic** bacteria, on the other hand, are bacteria that are capable of manufacturing their own food and can be either **photoautotrophic** or **chemoautotrophic** bacteria depending on their energy source.

Photoautotrophic bacteria absorb light energy for the process of photosynthesis while chemoautotrophic bacteria use inorganic substances (chemical energy) such as ammonia, hydrogen sulphide or hydrogen gas to prepare their own food.

Activity 2.4

How would one classify bacteria based on their utilization of:

1. oxygen
2. sunlight
3. ability to metabolize inorganic compounds
4. organic compounds

ii. Mode of Reproduction

Bacteria reproduce by asexual reproduction. Asexual reproduction in bacteria occurs by means of cell division, called **binary fission**. The division begins when the cell starts to elongate; chromosomes duplicate and the cytoplasm divides into two to produce two daughter cells. The two daughter cells then grow and start to divide again into two each, in 20-30 minutes. Thus, a bacterium doubles in number every 20-30 minutes. Bacteria do not reproduce by sexual reproduction. However, some bacteria, like *Escherichia coli*, transfer their genetic material from one organism to another through a primitive means of sexual reproduction called **conjugation**.

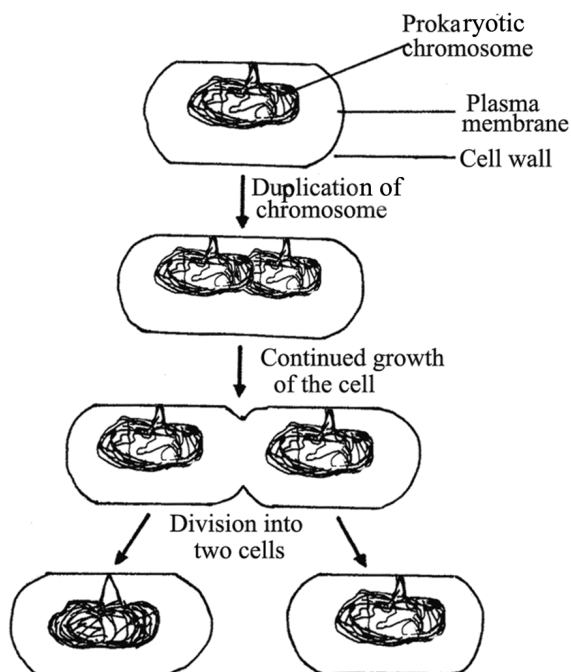


Figure 2.5 Binary fission in bacteria

B. Cyanobacteria

Cyanobacteria are found in almost every life-supporting environment. They occur in fresh water and marine environments and in damp soils (where they produce some of the compounds responsible for “earthy” odours). Cyanobacteria acquire their name from the bluish pigment they contain. However, not all cyanobacteria are blue-green in colour; other common forms include red, pink, yellow, brown and black. The Red Sea periodically becomes red when the species bearing red pigment is abundant.

Cyanobacteria are single rod-shaped or spherical cells that occur in clusters to form colonies or long filamentous chains. The individual cells are relatively larger than other bacterial cells. Cyanobacteria lack flagella.

i. Mode of Nutrition

Cynobacteria are autotrophic and contain chlorophyll to carry out photosynthesis. Cyanobacteria, like green plants, release oxygen during photosynthesis. It is believed that cyanobacteria were responsible for the first appearance of significant amounts of oxygen on the earth. Besides their ability to photosynthesize, cyanobacteria can also fix atmospheric nitrogen into nitrates or ammonia in the soil.

ii. Mode of Reproduction

Cyanobacteria reproduce by asexual reproduction. This is done by simple cell division or **fragmentation**. During fragmentation, cyanobacteria break into fragments that form separate organisms. No sexual reproduction occurs in cyanobacteria.

Exercise 2.3.1

1. Describe the process of binary fission in bacteria.
2. What is the difference between chemosynthetic and photosynthetic bacteria?
3. Explain the process of fragmentation by giving specific examples.

Summary

The kingdom monera includes most organisms with a prokaryotic cell organization. The two groups of organisms that represent the kingdom monera are bacteria and cyanobacteria. Although considered structurally simple, they are diverse from a metabolic standpoint and are found almost everywhere in the world in vast numbers. Based on carbon and energy sources for growth, two major nutritional types of monera are observed. Monera reproduce mainly by asexual means.

2.3.2 Kingdom Protista

Let us discuss

1. What is the simplest type of cellular organization in organisms?
2. What is the difference between autotrophic and heterotrophic mode of nutrition?

Kingdom protista includes many simple eukaryotes. Some members of protista are unicellular, others are colonial, and yet others are multicellular. They all need a water-based environment, which can be fresh water, marine water or damp soil. All are aerobic and have mitochondria for cellular respiration. Some have chloroplasts and can photosynthesize. Most of them reproduce or grow by binary fission and conjugation. Many can form **cysts** (an outer covering) in adverse conditions. Protista can be divided into three major categories, based on their mode of nutrition. These are:

- A. Animal-like Protista or **Protozoa**
- B. Plant-like Protista or **Algae**
- C. Fungus-like Protista or **Slime Moulds**

A. Animal-like Protista or Protozoa

These protists are heterotrophs and ingest their food in solid form. They are holozoic. Some have mouth-like structures with which to capture prey, while others use pseudopodia to move and to engulf their prey. Typical prey includes bacteria and other small one-celled organisms. Protists possess different types of locomotory structures, such as pseudopodia, cilia, and flagella. According to the locomotory structure they possess, they are divided into four phyla, which are sarcodina, ciliophora, mastigophora and sporozoa.

i. Sarcodina

Sarcodina move using false feet known as **pseudopodia** (singular: pseudopodium). A pseudopodium is formed when cytoplasm flows and causes an outgrowth which elongates as more cytoplasmic fluid flows into it. The genus *Amoeba* has many species of various sizes and shapes. They live in fresh water, marine water, and muddy soils. Some species of *Amoeba* are free living e.g. *Amoeba proteus*. There are also many commensals and parasitic kinds of amoeba. *Entamoeba histolytica* is a parasitic form that causes amoebic dysentery in humans. *Entamoeba* is spread by drinking contaminated water and eating uncooked vegetables.

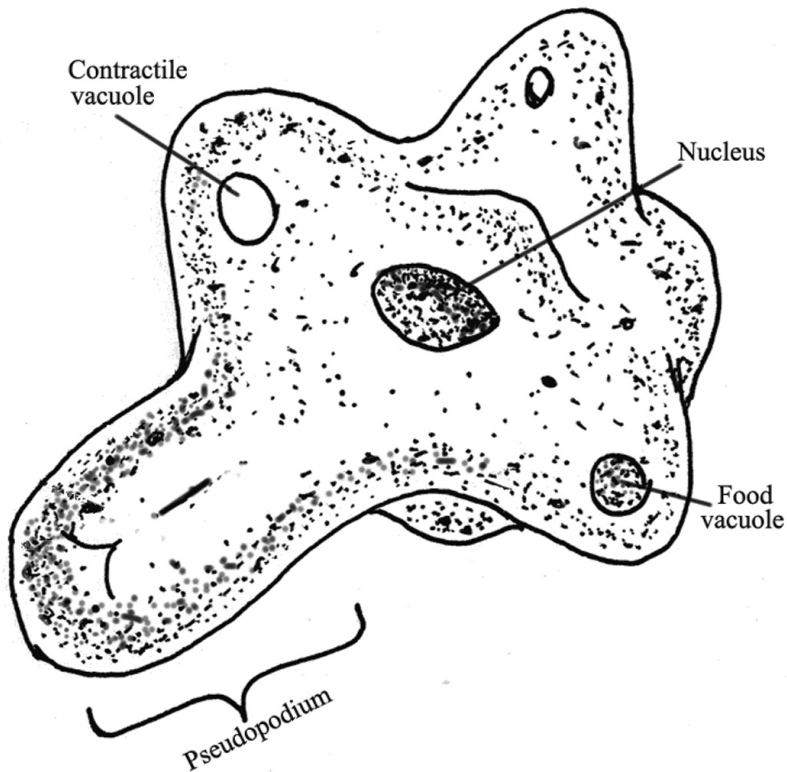


Figure 2.6 The structure of Amoeba

ii. Ciliophora

Ciliophora use cilia for movement. They have probably the most complex structure and organization of all cells for example *Paramecium*. *Paramecium* is a fresh-water organism. The whole surface of the organism is covered by regular rows of cilia. On one side the oral groove leads to the mouth pore, which is the external opening of the gullet. In the protoplasm there are two nuclei lying next to one another. The smaller nucleus is called a **micronucleus** and the larger one, a **meganucleus** or **macronucleus**. *Paramecium* has two **contractile vacuoles**, one near the front and the other near the back. The main function of the contractile vacuole is to remove excess water from the cytoplasm. *Paramecium* usually reproduces by the asexual method of binary fission. It also uses a form of sexual reproduction called conjugation, in which the contents of the micronuclei are exchanged between the two individuals involved.

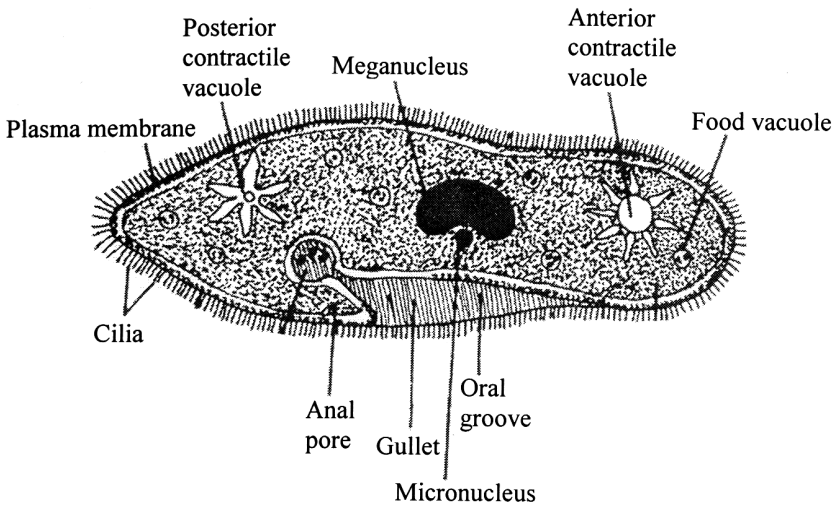


Figure 2.7 The structure of paramecium

iii. Mastigophora

Flagella (singular: flagellum) are the characteristic features of mastigophora. A flagellum is a whip-like structure that provides a means of locomotion in this group e.g. *Trypanosoma*.

Trypanosoma is a parasitic flagellate that causes African sleeping sickness (trypanosomiasis). It is spread by the bite of a tsetse fly. It can cause immense damage to cattle farms as well as to humans. Symptoms include irregular fever, general swelling, and skin eruptions. It eventually leads to a headache and convulsions, and coma and death. At an early stage the parasites are found in blood, but later on in the nervous system only.

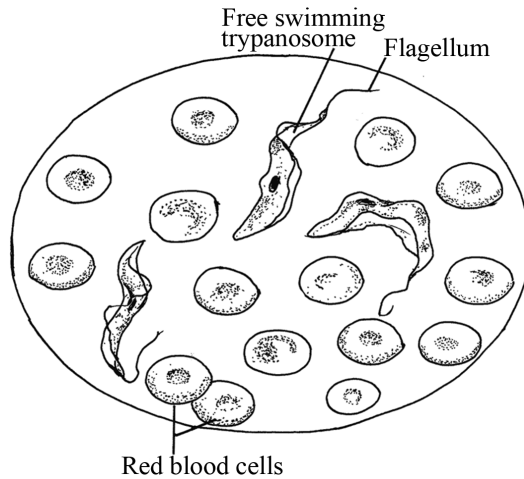


Figure 2.8 Trypanosoma in the blood

iv. Sporozoa

Members of this group are almost all parasites. They are spore-forming protists without a locomotory structure. Many live in one of two alternate hosts. The most familiar example of a sporozoan parasite is *Plasmodium*, which causes malaria in humans. The parasite is transmitted to humans by the female anopheles mosquito. Four species of *Plasmodium* are known to cause malaria. These are *P. vivax*, *P. falciparum*, *P. ovale* and *P. malariae*. The first two are common in Eritrea. The chief symptoms of malaria include chills and fever at regular intervals, along with excessive sweating. *P. vivax* produces an infection known as **benign** (mild) malaria, where the symptoms recur every 48 hours. **Malignant** (harmful) malaria is caused by *P. falciparum*, with the symptoms recurring every 36 to 48 hours.

B. Plant-like Protista or Algae

These protists are autotrophic and are plant-like in their mode of nutrition. They contain a variety of photosynthetic pigments and stored carbohydrates. The protists in this group may be unicellular or multicellular. They are classified into groups using the cell structure, number of flagella, reproductive mechanism and life cycle characteristics. Frequently they are grouped into several different phyla (more than six). The phyla may also be categorized as simple algae or complex algae.

i. Simple Algae

Members of this group are all simple, unicellular organisms. This group of simple algae includes the following phyla: **chrysophyta** (diatoms), **euglenophyta** (euglenoides) and **pyrrophyta** (dinoflagellates). In all water bodies, minute photosynthetic cells and tiny animals occur as suspended **plankton** (free-floating aquatic micro-organisms). The unicellular algae constitute the **phytoplankton**, the photosynthetic constituent of the plankton. As such, they are the primary source of food for aquatic animals. The tiny animals in plankton are known as **zooplankton**.

Among the simple algae, *Euglena* is a common genus that is often used for laboratory studies in biology. *Euglena* is found in the muddy waters of slow-moving streams, stagnant pools and ditches, which are contaminated with the urine and faeces of domestic animals.

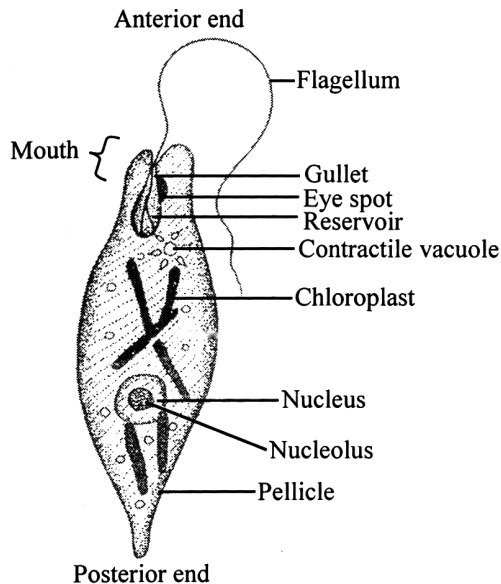


Figure 2.9 The structure of euglena

Euglena has a definite shape and is very small compared to amoeba. It has a whip-like structure called a **flagellum** at its anterior end. The flagellum is attached at the base of the flask-shaped opening known as the **reservoir**. Near this reservoir is

found a **contractile vacuole**. The anterior end contains a funnel-like **mouth**. This leads to a short tubular **cell-gullet**. Euglena has numerous chloroplasts. It lacks a cell wall but the body shape is maintained by a thin flexible covering or membrane called the **pellicle**. Euglena has a light-sensitive “**eyespot**” or **stigma** near the anterior end. Euglena reacts positively to light by swimming towards a source of favourable intensity. On the other hand, Euglena avoids direct sunlight and will move away from it.

In normal conditions euglena reproduces asexually by binary fission while under unfavourable conditions a cyst forms. During encystment the nucleus divides and is followed by cell division. When favourable conditions return the cyst breaks and two daughter cells are released.

ii. Complex Algae

These protists are also known as sea weeds. They include three phyla of algae that are wholly or partly multicellular. These are **rhodophyta** (red algae), **phaeophyta** (brown algae) and **chlorophyta** (green algae). These are the algae that form masses along the coasts and at times float free in the open sea.

The green algae are the most diverse, both in form and life history. There are different forms of green algae, such as unicellular, filamentous, colonial and multicellular algae. Various species of green algae may be found in a variety of environments including marine water, fresh water and damp soil. Common examples of green algae include *Chlamydomonas*, *Spirogyra*, *Volvox* and *Ulva*. *Chlamydomonas* is a unicellular biflagellate green alga. Each cell has a single large chloroplast that contains a red pigment called stigma or eyespot. At the anterior end of the cell there are two contractile vacuoles, which collect excess water and discharge it from the cell.

Chlamydomonas reproduce both sexually and asexually. During asexual reproduction the nucleus divides to produce up to 16 daughter cells within the parent cell wall. Sexual reproduction involves the fusion of individuals belonging to different mating

types or gametes. Two gametes fuse completely, forming a zygote. A thick cell wall forms around the zygote and then undergoes a period of dormancy. At the end of the dormant period the nucleus divides to produce four cells which develop flagella and cell walls.

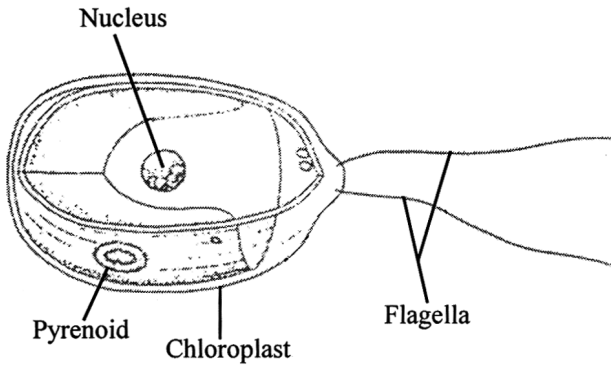


Figure 2.10 The structure of *Chlamydomonas*, a unicellular alga

Spirogyra is a filamentous, green alga. The species is common in slow-moving water, ponds and ditches. It is seen as a mass of hair-like, dark-green filaments. Each cell of the filament is independent and contains a spiral chloroplast with pyrenoids. The

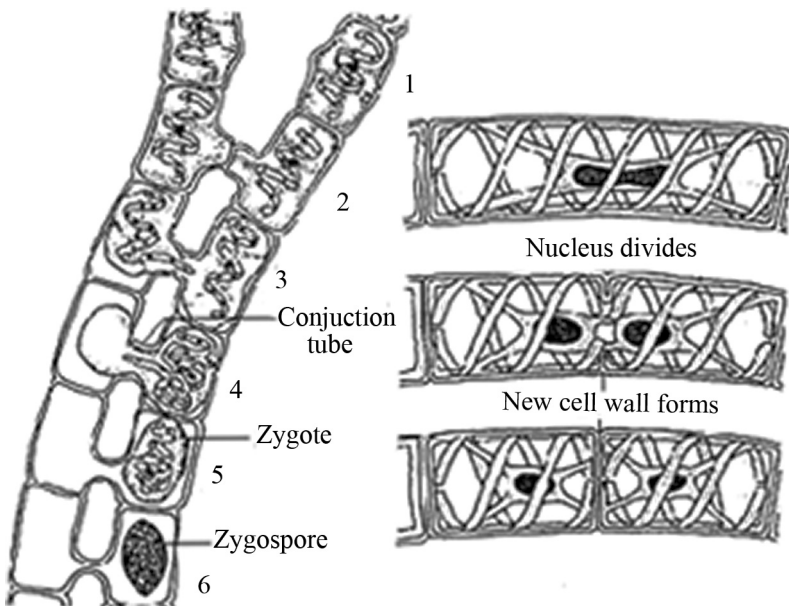


Figure 2.11 The structure of *Spirogyra* and conjugation

sugar which is manufactured by the cell is stored in the pyrenoids in the form of starch. *Spirogyra* reproduces in two ways. The first method is by simple cell division known as fission. During unfavourable conditions *Spirogyra* reproduce by a process known as **conjugation**. During conjugation, the contents of one cell pass through a canal and merges with the contents of the opposite cell. This results in the fusion of the two nuclei to form a zygote. This fusion is called fertilization. The zygote then develops a protective thick coating and becomes a **zygospore**. Under favourable conditions the zygospore will grow into a new filament.

Volvox is colonial and often contains darker green, daughter colonies. Each cell possesses two flagella, enabling the colony to be mobile. There is an intercellular matrix holding the colony of cells together.

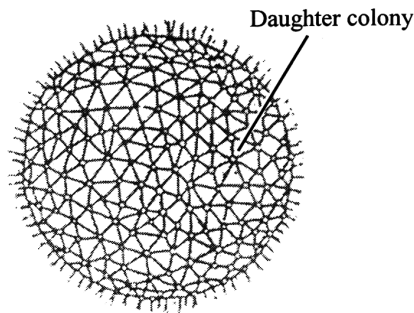


Figure 2.12 The structure of a *Volvox* a colonial algae

Activity 2.5

- Collect water samples from a shallow pond that has green slime threads and take them back to the laboratory.
 - Pour water into a white bowl or flat dish.
 - With a dropper, place a drop of pond water on a glass slide.
 - Put a cover-glass on the drop and examine under a microscope.
- What can you see?
 - Make a drawing of what you have observed.

Ulva or sea lettuce is truly multicellular, with a division of labour among the various cells. The “body” is two cells thick, and there is a specially-modified “holdfast” to anchor the organism to the ocean floor.

C. Fungus-like Protists or Slime Moulds

Slime moulds are fungus-like in their mode of nutrition in that they absorb nutrients from their environment. The structural organization of slime moulds is unusual in that it can be acellular or cellular. In acellular forms the slime mould is without individual cells, having one nucleus each. The structure is a giant, multinucleate mass of cytoplasm. The cellular slime mould resembles a mass of amoebae that have aggregated to form a single colony. The individual cells usually referred to as amoebae are normally free-living individuals. They feed on bacteria and other micro-organisms. They assemble when the food supply runs short and move collectively as a “slug” or **pseudoplasmodium**. The slug differentiates into a fruiting body that produces numerous spores. Spores are released and eventually produce amoebae, completing the life cycle.

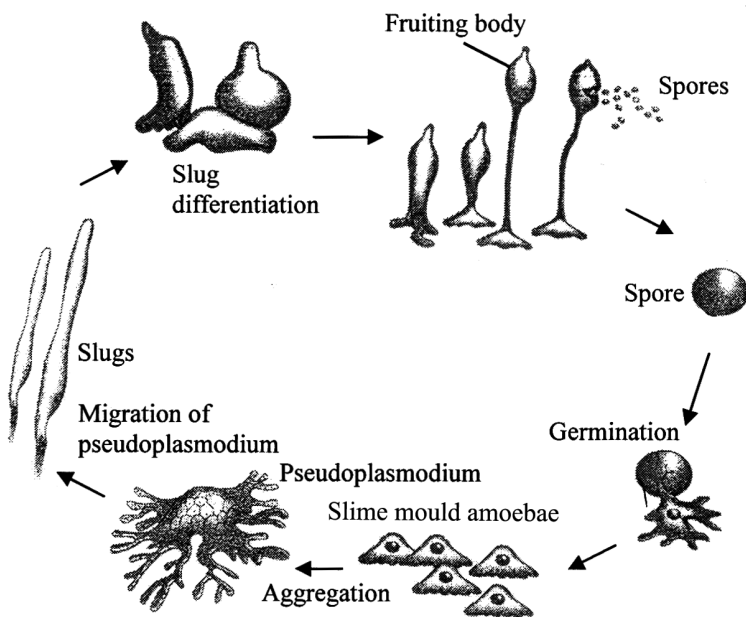


Figure 2.13 The life cycle of cellular slime mould

Exercise 2.3.2

1. What feature would enable you to identify protista as
 - a. plant-like protists
 - b. animal-like protists
 - c. fungi-like protists
2. What type of protist is *Paramecium*? What are its distinguishing characteristics?
3. How does *Trypanasoma* affect humans?

Summary

Protists are diverse group of eukaryotic organisms. Unicellular forms are the most prevalent but many groups include filamentous, colonial and multicellular forms. The majority is aquatic and has flagella or cilia. Protists have a wide range of methods to obtain nutrition, including photosynthesis, parasitism, predation and absorption. Protists can be grouped into three major categories based on their mode of nutrition: plant-like protists (algae), animal-like protists (protozoa) and fungi-like protists (slime moulds).

2.3.3 Kingdom Fungi

Let us discuss

1. How can you differentiate *Spirogyra* from bread mould?
2. How do saprophytes obtain food?

Fungi are filamentous eukaryotes with a saprophytic mode of nutrition. Some fungi are unicellular, while most filamentous mushrooms consist of a great many filaments packed tightly together. Fungal filaments are known as **hyphae** and a mass of hyphae is called a **mycelium** (plural: mycelia). Some species of fungi have their hyphae divided into individual cells, while others have hyphae that are multinucleate tubes without individual cells. Fungi are very important in the environment as **decomposers**.

Fungi reproduce both asexually and sexually by spore formation. Fungal spores are non-motile and are disseminated by wind or water. Fungi usually reproduce by asexual spores. However, under adverse conditions (such as a lack of food and water), many fungi

also use sexual reproduction. Fungi are classified according to what type of sexual reproduction they use.

Activity 2.6

- a. Keep a piece of bread previously soaked in water and leave it for two to three days in a drawer or dark cupboard.
- b. Take out the bread and examine it with a hand lens.
 1. What do you observe?
 2. Describe and draw the structures you observed.

A. Zygomycota

The typical members of this group are filamentous and grow in cottony masses; filaments lack cross walls between adjacent cells. In this group of fungi, sexual reproduction is by conjugation and produces a **zygosporangium** (containing zygospores). The zygosporangium can remain dormant in unfavourable conditions, releasing spores when the environment is suitable. *Rhizopus*, often called black bread mould consists of tubular, multinucleate hyphae differentiated into prostrate branches, absorptive rhizoids, and erect **sporangiophores**. The blackness of the walls of the numerous spores is responsible for the colour of the mature fungus. If the spores fall on suitable substrate, they will germinate and produce mature spore-bearing mycelia within 72 hours under favourable conditions.

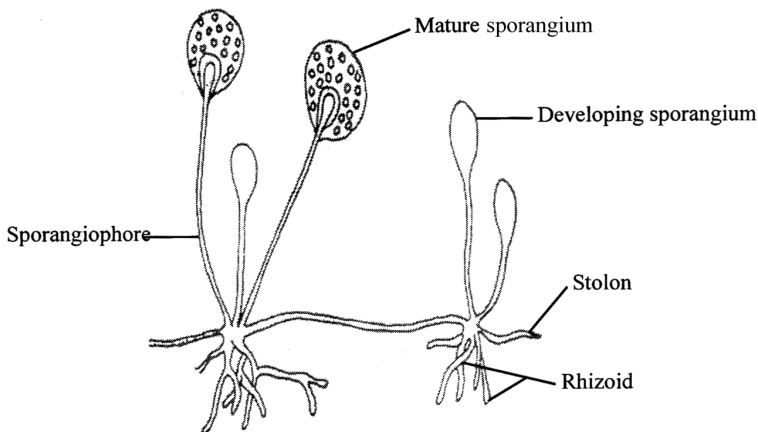


Figure 2.14 *Rhizopus*, black bread mould, showing growth

B. Ascomycota: Sac Fungi

Fungi in this group primarily reproduce asexually by forming chains of spores called **conidia** (singular: conidium). In sexual reproduction, ascomycotes produce spores in a little sac called an **ascus** (plural: asci). In many species, rows of these sacs are born in a cup-like structure called an **ascocarp**. This contains a number of asci, each of which contains eight **ascospores**.

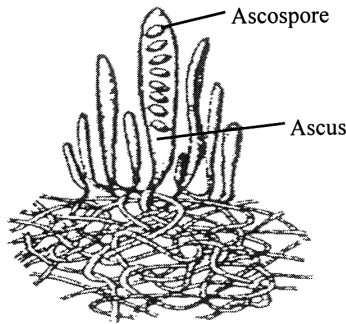


Figure 2.15 Ascomycota, showing asci and ascospores

Among the simplest ascomycota are the yeasts. These are one celled microscopic organisms, which are important in food preparation e.g. bread. Yeasts are extremely important commercially in the production of alcoholic beverages e.g. beer, wine, etc. In a suitable environment, yeasts multiply rapidly by unequal partitioning known as **budding**. As conditions become unfavourable for rapid growth and budding, a yeast cell may undergo two nuclear divisions, forming four nuclei. Each nucleus is surrounded by cytoplasm and a cell wall. We call these four cells ascospores and the yeast that formed them an ascus. In the ascospore stage yeasts are dormant; they can resist desiccating and unfavourable temperatures. It is these dormant cells that are sold commercially as “active yeast”. Under favourable conditions the ascospores germinate and form active yeast cells.

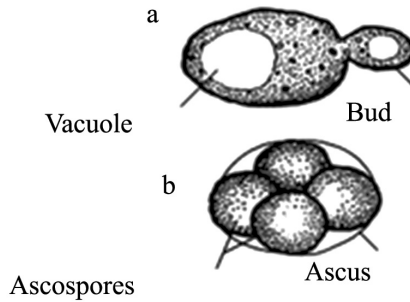


Figure 2.16 Methods of reproduction in yeast:

a. Budding, b. Ascus (containing ascospores)

C. Basidiomycota: Club Fungi

The most familiar fungi – mushrooms, bracket fungi and puffballs– are basidiomycetes. They produce spores on a club-shaped structure called a **basidium** (plural: basidia). Often the mycelium of mushrooms starts in one place (wherever the initial spore landed) and spreads outward from there in a circle. Around the edge of the circle, specialized, densely-packed hyphae form fruiting structures, each of which is called a **basidiocarp** (or mushroom). The gills of mushrooms are lined with basidia, each bearing four **basidiospores**.

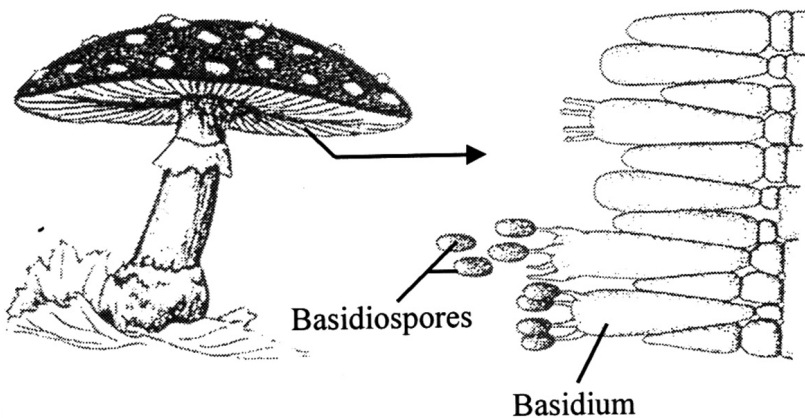


Figure 2.17 Basidiomycota: section of a gill from the underside of a mushroom cup

D. Deuteromycota: Imperfect Fungi

This is a general category of fungi in which sexual reproduction is unknown, hence the name “imperfect fungi”. Some fungi may actually have no sexual phase, but others probably have one that has not yet been discovered. When the means of sexual reproduction is ascertained, the fungus can be removed from the imperfect fungi and assigned to the appropriate phylum, either to ascomycota or basidiomycota.

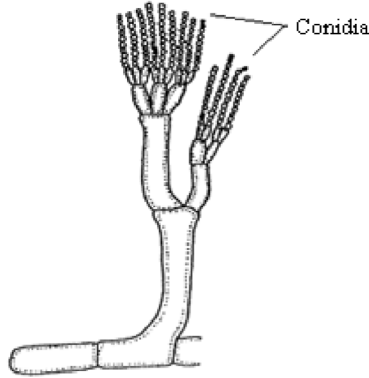


Figure 2.18 Deutromycota

Lichens

Lichens are an association of fungus and green algae. The fungus and alga live in a symbiotic relationship called **mutualism**, in which both benefit from the association. The fungus holds water to keep the alga moist, “digests” the rock substrate and

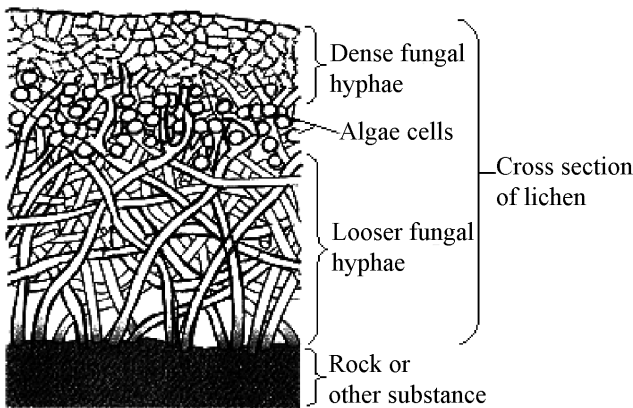


Figure 2.19 The structure of a lichen

makes minerals available for both to use, and generally serves as protection for the alga. The alga, which possesses chlorophyll, produces organic food for both by the process of photosynthesis.

The Economic Importance of Fungi

A number of fungi are commercially important: yeast and all the various edible mushrooms are fungi. Various strains of yeast are used for making beer, wine, and bread. The antibiotic penicillin is produced from a fungus called *Penicillium notatum*.

Conversely, a number of fungi are pathogenic and adversely affect humans. *Candida albicans* causes a disease of the mouth and throat called **thrush**. Another group of fungi the **dermatophytes**, infect the skin of humans causing ringworm, athlete's foot and other fungal diseases.

Fungus-induced plant diseases cause tremendous economic losses in agriculture for example **blight fungus**, **rust fungus** and **downy mildew**. Blight fungus belongs to zygomycota and causes diseases in potatoes and tomatoes. Rust fungus belongs to the basidiomycota group. There are more than 250 rust fungi that attack crop cereals, such as wheat, barley, and oats. **Wheat rust** is one of the well known diseases of plant parasites and causes serious problem for farmers.

Exercise 2.3.3

1. List the common characteristics of fungi and give a distinguishing characteristic features of:
 - A. zygomycota
 - B. ascomycota
 - C. basidiomycota
2. How do fungal pathogens affect the way people live?
3. Describe the fungal and algal association in lichens.

Summary

Fungi are filamentous eukaryotes that form non-motile spores, both sexually and asexually. A fungal mycelium grows as hyphae. Fungi are food absorbers, secreting enzymes that digest their food externally. They are saprophytes (feeding on dead

organisms), parasites (feeding on living host cells), or partners in a mutually beneficial association (lichens). Fungi can be classified into four phyla: zygomycota, ascomycota, basidiomycota and deuteromycota. Fungi are economically important to humans.

2.3.4 Kingdom Plantae

Let us discuss

1. What is meant by multicellular organization and differentiation?
2. What are the different organs found in plants?
3. How do plants differ from complex algae?

Members of the kingdom plantae are multicellular eukaryotes that have cell walls made of cellulose. They have cells specialized to form tissues and organs. They are photosynthetic organisms that have adapted to life on land. They possess different photosynthetic pigments that include chlorophyll and carotenoids. Plants store their food in the form of starch.

The life cycle of plants is a complex **alternation of generations**. In the life cycle, the **sporophyte** generation alternates with the **gametophyte** generation. The spore-bearing plant is known as the sporophyte. The gamete-producing plant is known as the gametophyte. When a sporophyte plant matures, it produces spores that grow into a gametophyte plant. When the gametophyte plant matures it produces sexual cells, called **gametes**. The union of two gametes results in a **zygote**, which grows into a sporophyte plant.

Plants are classified by the presence or absence of vessels and seeds. There are four main groups of plants: these are bryophytes, pteridophytes, gymnosperms and angiosperms.

A. Bryophyta

Bryophytes include mosses and liverworts. These are the first land plants, but live in very damp, shady places. Bryophytes lack the specialized vascular cells for conducting nutrients and water within the plant body. They must rely on cell-to-cell movement

for internal transport, therefore, they must remain small in size. Bryophytes have root-like rhizoids and leaf-like structures, but these are not true roots or leaves because they have no vascular system. The dominant generation in the life cycle is the gametophyte. The sporophyte is dependent on the gametophyte for nutrition. In bryophytes, sexual reproduction requires water for sperm to swim to the ova.

Activity 2.7

- Collect moss plants from shaded damp places (near a pond, stream or well).
- Examine a moss shoot with a lens and look for the detailed structure of the plant.
- Draw the structures of the plant you have observed.

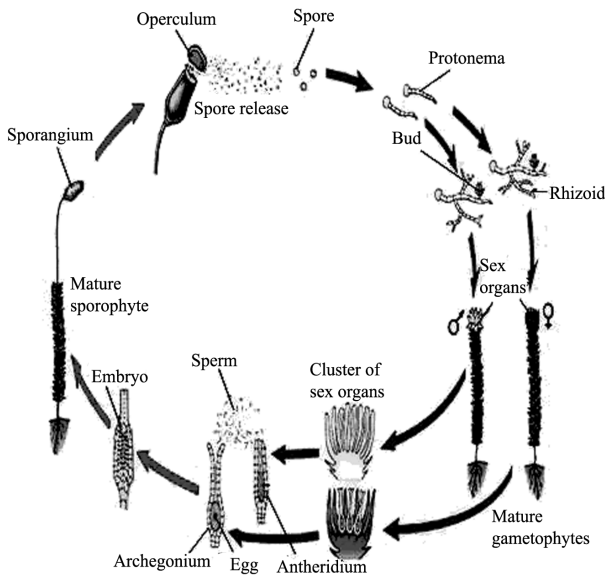


Figure 2.20 The life cycle of a moss plant

B. Pteridophyta

These are seedless vascular plants and include ferns, club mosses, and horse tails. They have true roots, stems and leaves. They have an underground stem called a **rhizome**. The fern leaves are called

fronds, which arise from buds on the rhizome. The dominant phase is the sporophyte generation. The gametophyte plant is an independent, tiny heart-shaped structure called a **prothallus**. The sporophyte phase of the life cycle is much larger than the gametophyte but the gametophyte develops separately from the sporophyte and does not depend on it for nutrition.

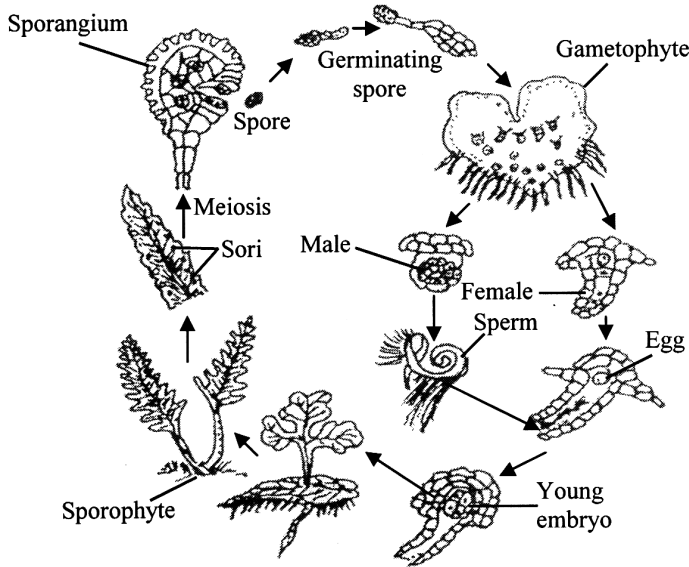


Figure 2.21 The life cycle of a fern

Activity 2.8

- Sketch a diagram of any fern frond found in the locality.
- Examine the underside of the leaf.
 - What did you observe?
 - Describe the shape of the leaf.

C. Gymnosperms

Gymnosperms are also known as naked-seed plants. They differ from pteridophytes in two key characteristics in having seeds and no independent gametophyte generation. Gametophytes become even more reduced in size, often staying within the parent sporophyte plant. In gymnosperms, the seeds are produced on the surface of **cones**, thus the name naked-seed plants.

Gymnosperms include conifers, ginkgos, cycads and gnetophytes. Conifers are the largest group in the gymnosperms. An example of a conifer is the pine tree. A pine tree produces two kinds of cones: **staminate cones** and **ovulate cones**. The staminate cones are small (less than 3 cm) while the ovulate cones are large and easily visible. The ovulate cone is composed of many scales and on the surface of each scale are two seeds.

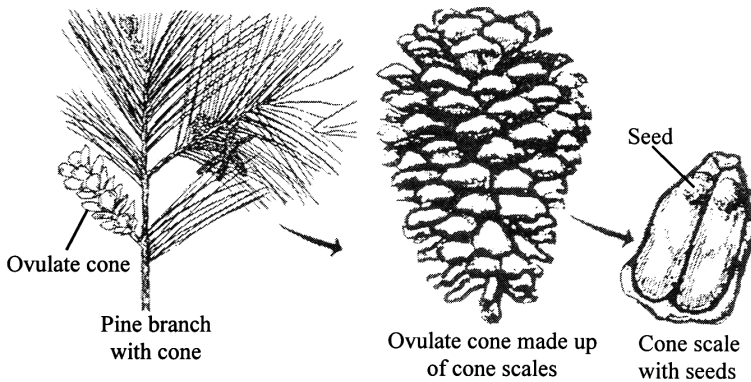


Figure 2.22 Cone: The reproductive structure of a pine tree

D. Angiosperms

Angiosperms, like other plants, exhibit an alternation of a gametophyte and sporophyte generation. In angiosperms, the gametophyte is reduced to a few cells lying within the tissues of the sporophyte **flower**. The common name for this group is the “**flowering plants**”. Angiosperms are so named because the seeds are enclosed within a fruit. The seed development takes place within a structure at the base of the flower, called the **ovary**. The ovary gives the ovules more protection than the gymnosperm cone scale. The wall of the ovary eventually matures into fruit that surrounds the seeds. Flowering plants are the most diverse plant group, with more than 250000 species. Angiosperms are divided into two main classes: **monocotyledons** (the “monocots”) and **dicotyledons** (the “dicots”). These two classes can be distinguished in a number of ways, including differences between the seeds, leaves, flowers, roots and vascular bundles. Monocots have one cotyledon or seed leaf (e.g. “*taff*”, sorghum, wheat, maize), while dicots possess two cotyledons or seed leaves (e.g. beans, groundnuts, chickpeas).

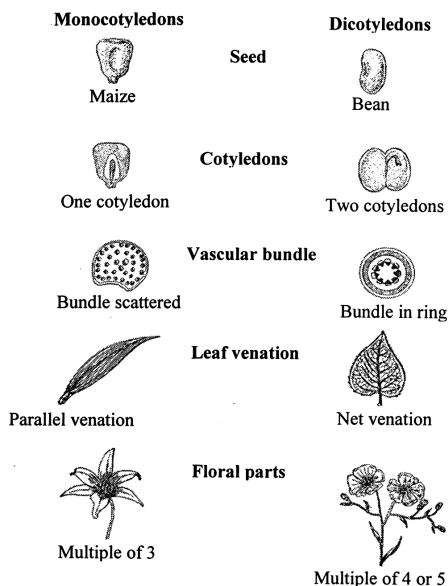


Figure 2.23 A comparison of monocots and dicots

Activity 2.9

- A. Collect different types of leaves and examine their shape and structure. Identify each leaf as a monocot or a dicot.
- B.
- Soak seeds of beans, peas, maize and barley in water for three days.
 - Examine the cotyledons by removing the seed coat.
 - Identify each type of seed as monocot or a dicot.

Exercise 2.3.4

- Describe the life cycle of plants.
- What are the general characteristics of pteridophytes?
- Compare the characteristics of monocots and dicots.

Summary

Green plants are photosynthetic organisms that have adapted to life on land. They are multicellular; and have cells specialized to form tissues and organs. In their life cycle, plants show an

alternation of generation in which the sporophyte generation alternates with the gametophyte generation. Plants are classified into one of four phyla: bryophytes, pteridophytes, gymnosperms or angiosperms (flowering plants). Angiosperms are the largest and most diverse group and can be categorized into two major groups: monocotyledons and dicotyledons.

2.3.5 Kingdom Animalia

Let us discuss

1. What are the common characteristics shared by animals?
2. How are animals different from plants?

Body Organization and Symmetry

All animals are composed of eukaryotic cells. A fundamental aspect of the organization of an animal body is the body shape, form, and manner in which the body parts are arranged.

A structure that allows an animal to be divided into parts of an equal shape and size, and a similar position to the line of division is called **symmetry**. Symmetry is used to describe the arrangement of body structures with reference to the body axis.

The most primitive animals are **asymmetrical** (animals with no pattern of symmetry). The bodies of these animals cannot be split into similar halves. On the other hand, animals that can be bisected or split along at least one plane so that it results into two similar halves, are described as **symmetrical**. There are two basic forms of symmetry: **radial** and **bilateral** symmetry.

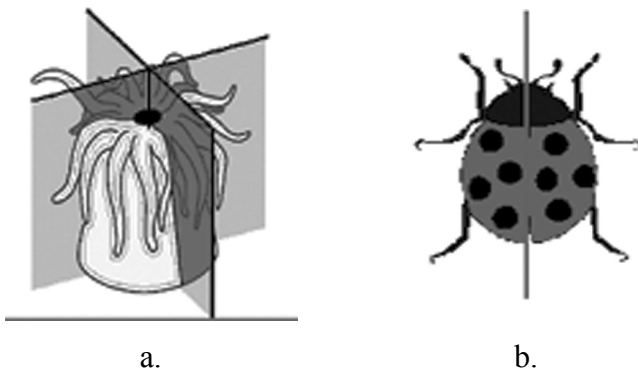


Figure 2.24 Symmetry in animals:
a. Radial symmetry, b. Bilateral symmetry

The body parts of a radially symmetrical animal are arranged around a central axis so that each part extends from the centre. The animal can be cut along the axis in more than one plane to produce identical halves. Animals that exhibit radial symmetry are usually **sessile** (immobile). Radial symmetry allows them to reach out in all directions.

Mode of Nutrition

Animals are heterotrophs. They do not possess chlorophyll and therefore cannot produce their own food. They survive by feeding on other animals or plants, or both. Animals move from place to place in search of food. Locomotion is, therefore, an important characteristic of nearly all animals.

Mode of Reproduction

Most animals undergo some form of sexual reproduction. They have a few specialized reproductive cells. During fertilization, these reproductive cells fuse to form a **zygote**, which develops into a new individual.

Some animals are also capable of asexual reproduction, which may take place through **regeneration**, **parthenogenesis** or **budding**. Regeneration is the regrowth of lost tissue or a body part in an adult organism. Parthenogenesis occurs when an unfertilized mature egg cell is spontaneously activated and develops into a new organism. Animals (like hydra) also rely on a budding form of asexual reproduction, where the animal develops an outgrowth, which, when detached from the parent, becomes a new individual.

Generally, animals are broadly classified as **invertebrates** or **vertebrates**, even though they vary greatly in size, shape, movement, method of food capture, habitat, etc.

Activity 2.10

Name nine animals from your surroundings and answer the following questions:

1. How do these animals differ from each other?
2. Which of these animals are beneficial to humans?

A. Invertebrates

Invertebrates are animals without backbones. This group includes poriferans, cnidarians, platyhelminthes, nematodes, annelids, mollusks, arthropods and echinoderms.

i. Porifera

Members of the phylum porifera are commonly called sponges. Sponges are usually found at seas with few species that live in fresh water. Sponges are the simplest of all animals. They have an asymmetric body and their cells are differentiated (cells with specialized functions), yet they do not have tissues. They do not have the three germ layers. The cells of a sponge are arranged into an inner and an outer layer, with amoeboid cells crawling within a gelatinous layer that separates the two layers (ectoderm and mesoderm). Amoeboid cells secrete hard mineral, needle-like structures called **spicules** or **spongin** (if the material is made up of protein) or both.

Sponges are **sessile** (immobile) porous filter feeders. The inner layer is composed of flagellated collar cells (**choanocytes**). The flagella beat to move water in through the **pores** and out through the **osculum**. Food is trapped by the collar cells and is digested within the cell (**intracellular digestion**) or passed to the amoeboid cells for digestion.

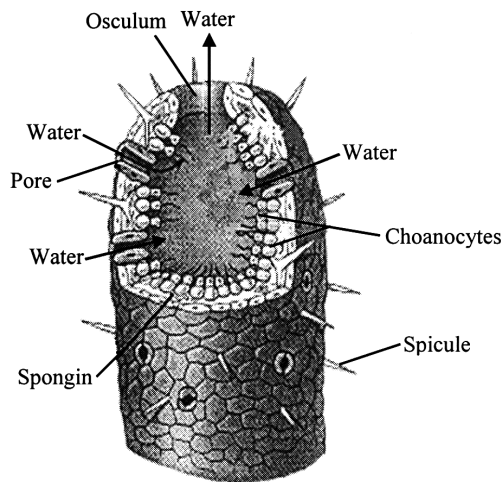


Figure 2.25 Body parts of a sponge

Asexual reproduction in sponges is by fragmentation. Small fragments break off the sponge body, settle on a substrate and develop into new sponges. Most sponges also show sequential **hermaphroditism**; they function as one sex for a period and then change to the other sex in another period to carry out sexual reproduction. Sequential hermaphroditism prevents **self-fertilization** and encourages **cross-fertilization**.

ii. Cnidarians

The phylum cnidaria, also called coelentrates, includes animals like jellyfishes, hydras, sea anemones and corals. Most cnidarians are marine species, except hydra, which live in freshwater.

Cnidarians have a simple, radially symmetrical body plan. They have two tissue layers, the outer and the inner layers. These layers are separated by gelatinous material. The bodies of cnidarians contain long structures called **tentacles** that can be moved to capture prey. The tentacles contain stinging structures called **nematocysts**, which are discharged to either trap or sting prey. Cnidarians have a hollow digestive tract with a single opening, which serves as both the mouth and anus.

The two body forms found among the cnidarians are the **polyp** and **medusa**. The polyp is attached and has the tentacles and mouth directed upward. The medusa is free-floating and has the mouth and tentacles on the ventral surface. It resembles an upside-down polyp. Some species have both a polyp and a medusa in their life cycle, while others have one of the two forms as a dominant stage.

Members of this group can reproduce by budding, an asexual process in which small polyps form on a parent polyp and then break off. Sexual reproduction also occurs and produces a larval form called a **planula** (plural: planulae). The planula is motile and capable of swimming to a new location. Planulae settle and develop into polyps.

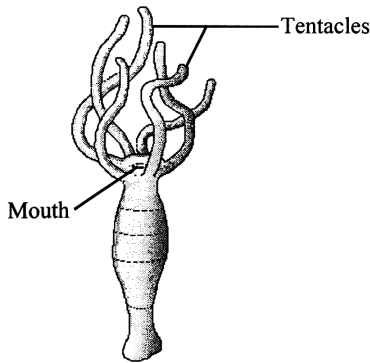


Figure 2.26 Hydra

iii. Platyhelminthes

Animals that belong to this phylum include planaria, flukes, and tapeworms. These animals have a flat body (hence, the common name, flatworms), with simple bilateral symmetry and **cephalization**. Cephalization is the development of the anterior (front) end of an organism into a definite head. Platyhelminthes have a definite head at the anterior end of the body and they possess organs. Some flatworms have a digestive gut with only one opening (therefore, an incomplete digestive system). The mode of nutrition in flatworms is one of two types.

1. Free-living flatworms: These occur in a wide variety of marine and fresh water habitats (for example planaria), as well as moist places on land. Free-living flatworms are carnivores and scavengers, and eat various small animals and organic debris.

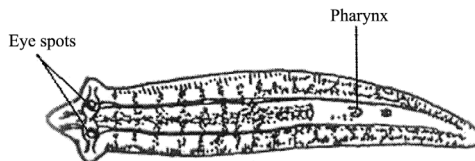


Figure 2.27 Planaria

2. Parasitic flatworms: Two classes of parasitic flatworms live within the bodies of other animals: **flukes** and **tapeworms**. Both groups of worms have outer body coverings resistant to the digestive enzymes and immune defenses produced by their hosts.

Flukes are parasites that usually live within vertebrate hosts, especially in the gut, liver, lungs, bladder or blood vessels. Those living on the body surface feed by sucking cells, tissue juices, or blood. The vast majority of the internal parasites have complex life cycles.

Tapeworms are intestinal parasites of vertebrates. They feed entirely on soluble nutrients provided by their hosts because they have no digestive tract of their own. The body consists of an anterior **scolex** solely for attachment to the host's gut and a string of units called **proglottids**, each of which possesses both male and female organs. Tapeworms are consequently hermaphrodites.

The reproductive systems of flatworms are complex. Most flatworms are **hermaphrodites**, with each individual containing both male and female sexual structures. Even though they are hermaphrodites, they usually practice **cross-fertilization**. In many species, fertilization is internal. Flatworms are also capable of asexually reproducing by **transverse fission** followed by **regeneration**. In some groups of flatworms, when a single individual is divided into two or more parts, each part can regenerate an entirely new flatworm.

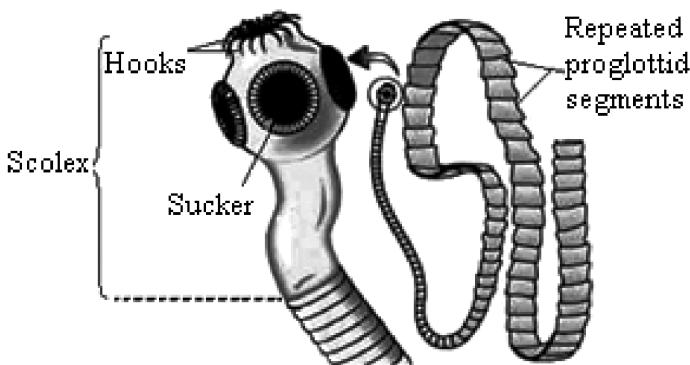


Figure 2.28 A tapeworm

iv. Nematodes

Nematodes, like ascaris and hookworms, are also known as roundworms because of their cylindrical bodies. They are bilateral, unsegmented worms and possess a slender, tapered body covered with a tough, flexible covering called a **cuticle**. This

cuticle is molted when the round worms grow. Nematodes lack flagella or cilia for movement. They have a complete digestive system with a separate mouth and anus.

Members of the phylum include free-living scavengers, which live in soil; many are successful parasites of animals and plants, including hookworms and ascaris.

Nematodes reproduce by sexual means and both sexes are usually found in separate individuals. Their development is simple and the adult roundworms usually have very few cells.



Figure 2.29 Representative nematodes:

a. Roundworm, b. *Trichinella*, c. Hookworm

v. Molluscs

Molluscs include snails, slugs and clams. Molluscs have a body with distinct bilateral symmetry. They have a distinct head at the anterior part of their body. The body is soft and usually protected by a hard shell made of calcium carbonate. The body of molluscs contain three parts:

Foot: A muscular structure used for movement.

Visceral mass: This contains most of the internal organs.

Mantle: A fold of tissue that hangs over the visceral mass and, in some molluscs, secretes the shell.

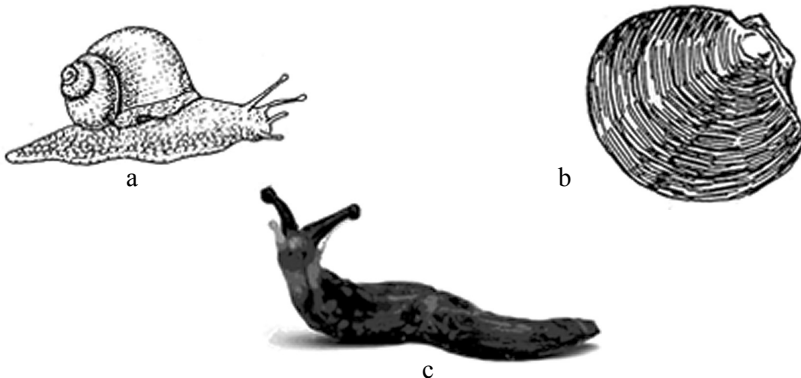


Figure 2.30 Representative molluscs: a. Snail, b. Clam, c. Slug

Many have a toothed structure called a **radula**, which is used for digging holes in rocks and removing algae from rocks. Most molluscs have well-developed digestive, excretory and nervous systems. They possess an open circulatory system, which consists of a three-chambered heart.

Most molluscs have distinct male and female individuals, which undergo sexual reproduction, with few hermaphroditic molluscs that usually undergo cross-fertilization.

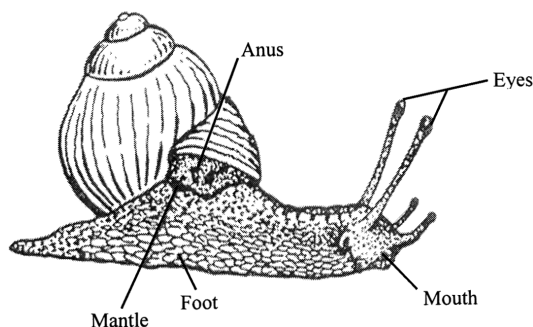


Figure 2.31 A mollusc's body parts

vi. Annelids

Annelids are segmented worms, such as earthworms and leeches. Annelids are bilaterally symmetrical worms. They have a series of ring-like segments running the length of the body. Internally, the segments are separated by structures called **septa**. Annelids have a closed circulatory system. Each segment has its own circulatory, excretory, nervous, muscular and respiratory system. In most annelids, each segment possesses **setae** that help for locomotion i.e. anchor the worms on surfaces during movement. Annelids have a complete digestive system. Most annelids are hermaphrodites and reproduce by sexual reproduction.

a. Earthworms

Earthworms are land-dwelling and aquatic scavengers that burrow in moist soil, mud and silt. They feed largely on decomposing plant material and may also use organic matter that is part of the soil they swallow as they burrow. Their habit of ingesting dirt particles while scavenging for organic matter makes them valuable contributors to the fertility and aeration of the soil.

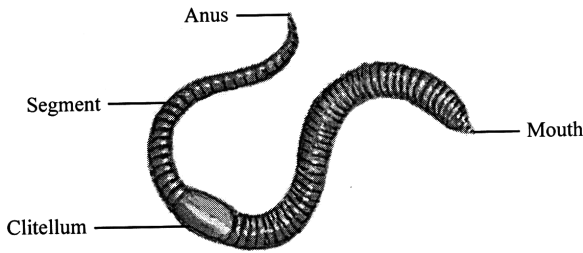


Figure 2.32 An earthworm

b. Leeches

Leeches are found in fresh water, seas and moist regions of the tropics. They are predators of invertebrates or parasites of vertebrates. They have no setae. Some leeches and earthworms have an organ called the **clitellum**. A clitellum is a structure that secretes a sticky substance, which is used to form an egg sac (cocoon) in which the eggs are deposited.



Figure 2.33 A leech

c. Polychaetes

Polychaetes include wandering or tube-dwelling marine worms with tentacles and numerous setae. They can be herbivores, carnivores or filter feeders.



Figure 2.34 Nereis, a polychaete

vii. Arthropods

This phylum is the largest phylum in the animal kingdom. It includes animals like insects, spiders, scorpions, crabs, millipedes, centipedes, mites, ticks, etc. The word “arthropod” comes from two Greek words: “*arthron*” means “joint” and “*pod*” means “leg” (appendage). Arthropods are therefore animals with **jointed appendages** and a body covered by an **exoskeleton**. Because of these two characteristics, arthropods are the most successful animals to live in wide variety of environments.

Arthropods use their jointed appendages, such as legs for walking, antennae to sense the environment, and mouthparts for feeding. Arthropods can move from place to place using a number of different methods. They can walk, crawl, climb, hop, fly, glide or swim.

The exoskeleton of arthropods is made up of chitin and protein. This protects the organs, gives support for the body and allows for efficient locomotion. Since the exoskeleton cannot expand, it must be shed periodically to allow the organism to grow.

Arthropods have a complex internal design, with ganglia for a brain and an organ-like structure that acts as a heart. They have a complete digestive and excretory system. They also have well-developed sensory organs, that include antennae, eyes and in some cases internal ears. Respiration occurs through the body surface, gills, trachea and/or book lungs. Oxygen is carried in an open circulatory system, where blood is pumped by the heart to blood vessels that open into the body space around every organ and tissue. After bathing the organs, the blood returns to the heart.

Based on the number of legs, arthropods are divided into four groups: arachnids, crustaceans, myriapods and insects.

a. Arachnids

Arachnids include animals like spiders, ticks, mites and scorpions. Arachnids have four pairs of appendages. They lack antennae and mandibles (pair of jaws). The body of an arachnid is divided into the **cephalothorax** (when the head is fused to the thorax) and **abdomen**.

Arachnids live on land and some are exo-parasites (parasites that live on the external body surfaces of an animal), like ticks and mites.

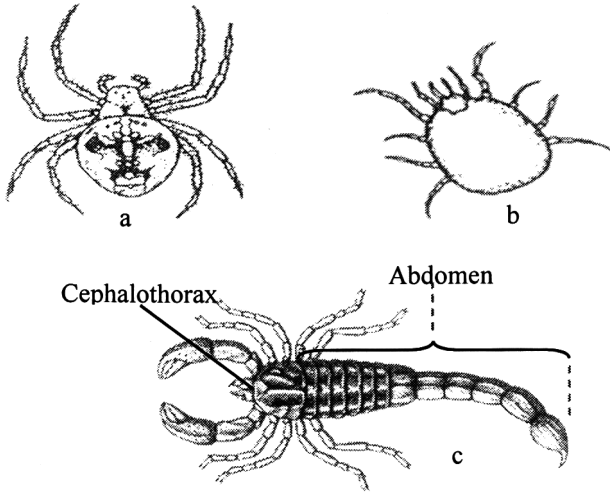


Figure 2.35 Arachnid representatives: a. Spider, b. Mite, c. Scorpion

Activity 2.11

Collect a spider

1. Examine the body structures, body divisions and number of appendages.
2. Draw the main structures of the animal.

b. Crustaceans

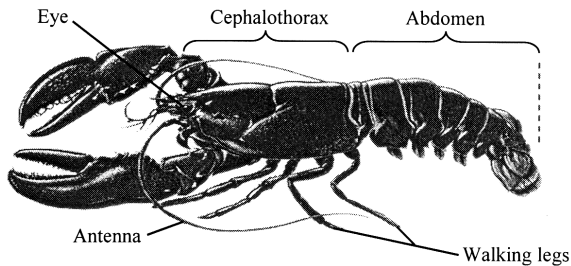


Figure 2.36 A lobster

Members of this group include the lobster, shrimp, crab and crayfish. Most crustaceans are aquatic, with a few species living in moist places on land. The body of a crustacean is divided into the cephalothorax and abdomen. Their body is covered by a shield-like cover and they have two pairs of antennae, mandibles and many legs. Crustaceans can be predators, herbivores, scavengers or parasites.

c. Myriapods

Myriapods include millipedes and centipedes. The body parts of myriapods consist of a head region followed by numerous segments that are more or less similar and nearly all of which bear paired appendages. Each segment in centipedes has one pair of legs, while millipedes have two pairs.

Centipedes are carnivorous and feed mainly on insects. The appendages of the first trunk (region behind the head) are modified into a pair of poison fangs. The poison is often quite toxic to humans. In contrast, most millipedes are herbivorous, feeding mainly on decaying vegetation.

In both centipedes and millipedes, fertilization is internal and takes place by direct transfer of sperm. The sexes are separate and all species lay eggs.

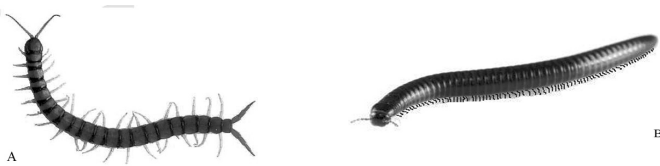


Figure 2.37 a. A centipede, b. A millipede

d. Insects

Insects include crickets, ants, wasps, bees, grasshoppers, beetles, moths, dragonflies, butterflies and flies. Insects are the most successful invertebrates on land. A tracheal system for respiration, a cuticle that minimizes the evaporation of water, the development of wings and the capacity for flight are the key characteristics that have led to their success on land. Winged insects disperse

themselves rapidly, move into areas where food may be abundant, snatch or capture prey or other insects in midair, and escape from predators.

Insects are very diverse because of their varied feeding habits. In the less specialized insects, such as the grasshopper, the mouthparts are used for handling and masticating food. In the more specialized groups, the mouthparts are often modified into sucking, piercing and slicing.

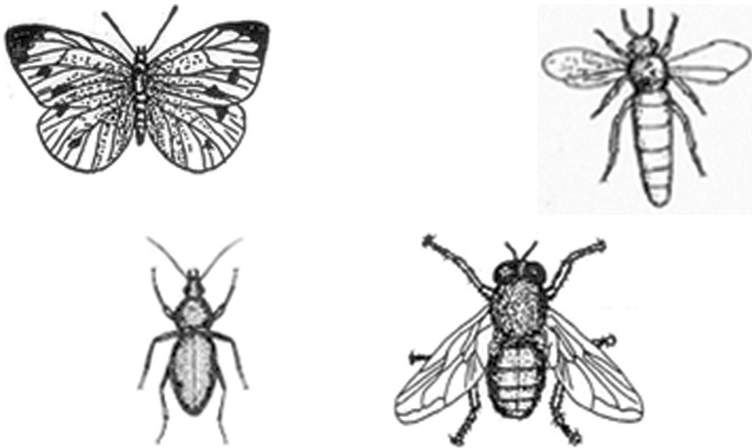


Figure 2.38 Representative insects

The body of an insect has three distinct parts: the head, thorax and abdomen. The **head** contains one pair of antennae or feelers, the eyes and the mouth. The **thorax** is the middle part and is segmented into three. Each segment bears one pair of legs. It also bears one or two pairs of wings. Some insects have no wings for example ants, fleas and lice. The thorax also contains the main muscles so that the insect can run, fly, swim or walk. The **abdomen** is the third segment in an insect's body and contains the stomach and reproductive organs. Some insects also have a stinger at the tip of their abdomen. Insects have no lungs, but possess small openings on their bodies called **spiracles**, which are used for gaseous exchange.

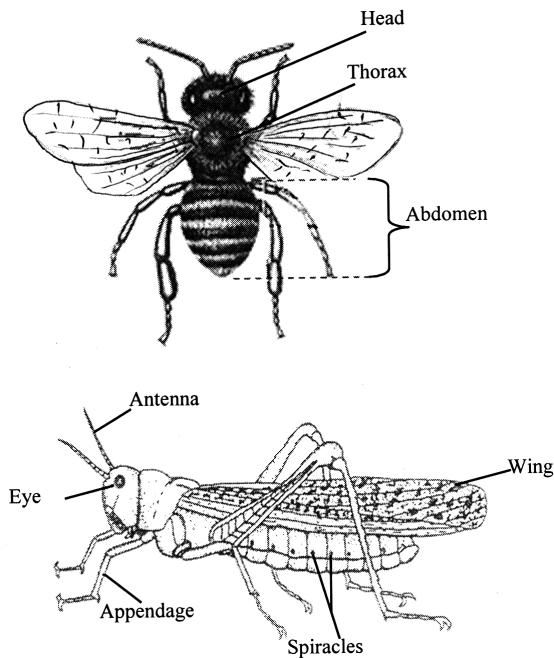


Figure 2.39 The body parts of insects

Activity 2.12

- a. Collect three to five specimens of insects from your locality or school.
- b. Examine (using a hand lens if needed) the body parts of the insects.
- c. Copy and complete the table below.

Common name	features			
	Body parts	Number of legs	Number of antenna	Number of wings

Table 2.3

Insects have separate sexes and reproduce sexually, during which the female lays fertilized eggs. Most insects go through a life cycle, in which young, growing insects change not only in size but often with a marked change in form, a phenomenon known as **metamorphosis**. There are two principal kinds of metamorphosis in insects: **complete** metamorphosis and **incomplete** metamorphosis. Insects, like grasshoppers, undergo incomplete metamorphosis. Insects with this type of life cycle go through only three changes: egg, nymphs (immature stages) and adult. Other insects, like the butterfly and house fly, undergo complete metamorphosis, in which their life cycle includes the stages of an egg, larva, pupa and adult.

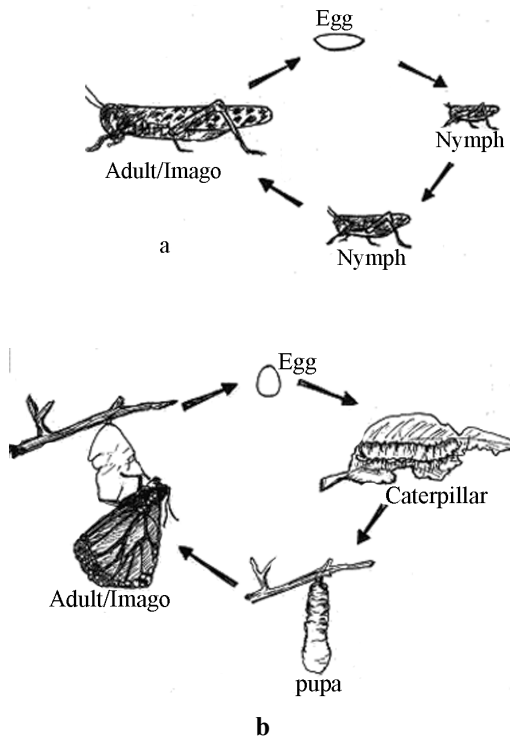


Figure 2.40 The life cycle of a. A grasshopper (incomplete metamorphosis),
b. A butterfly (complete metamorphosis)

viii. Echinoderms

The term “echinoderm” is derived from two Greek words: “*echinos*” means “spiny” and “*derma*” refers to “skin”.

Echinoderms are radially symmetrical and exclusively marine animals. This phylum includes the common starfishes, sea urchins, sea cucumbers and so forth.

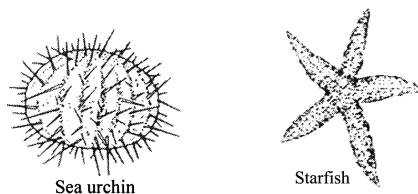


Figure: 2.41 Representatives of echinoderms

Echinoderms have diverse body forms, including soft, cylindrical, spiny, multi-armed and feathery structures. Despite their external differences, all possess a unique **water vascular system** that is used in feeding, locomotion, respiration and sensory perception. All the internal and external parts of echinoderms radiate outwards from the centre. Echinoderms lack a head, eyes and brain.

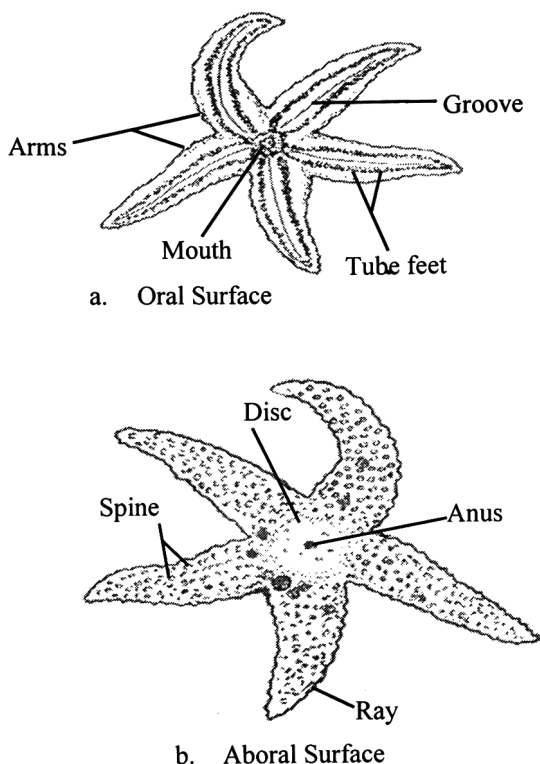


Figure 2.42 Star fish: a. Oral surface b. Aboral surface

Reproduction in echinoderms is by both asexual and sexual processes. A single starfish arm containing just a small portion of the central disk region will slowly regenerate the rest of the creature. Sexual reproduction involves typical seasonal breeding in which mature eggs are released directly into the ocean. Fertilization is usually external. Most echinoderms develop through one or more free-swimming larval stages and gradually develop into adult.

B. Vertebrates

Vertebrates are animals having a true, usually bony, **endoskeleton**, with a backbone encasing the spinal column and a skull encasing a brain. Vertebrates include fishes, amphibians, reptiles, birds and mammals.

i. Fishes

Fishes are aquatic animals. They are the most diverse vertebrate group and include animals like common fishes, sharks, skates and rays. Fishes swim with the help of fins. Swimming is less energy consuming for fishes because their body is stream lined and lubricated. Many fishes are covered with scales and they breathe through **gills**.

Most modern fishes are predators or scavengers. Fishes have a complete digestive system and a closed circulatory system with a two-chambered heart. Fishes are animals with a variable body temperature, known as **poikilothermic** (cold-blooded animals). The body temperature of a poikilothermic animal varies with the temperature of its surroundings.

Most fishes reproduce by producing a large number of eggs and releasing them into the water. The males generally release their sperm into the water, containing the eggs. Union of the sperm and egg cells take place outside the body (external fertilization). Sharks, unlike other fishes, use internal fertilization.

There are two groups of fishes based on the type of endoskeleton they possess. These are chondrichthyes and osteichthyes.

a. Chondrichthyes or cartilaginous fishes are a group with a cartilaginous endoskeleton. This group includes sharks and rays. The cartilaginous fishes have a mouth with a true jaw, two pairs of fins, skin covered with tooth-like scales and five pairs of slit-like openings on each side of the head.

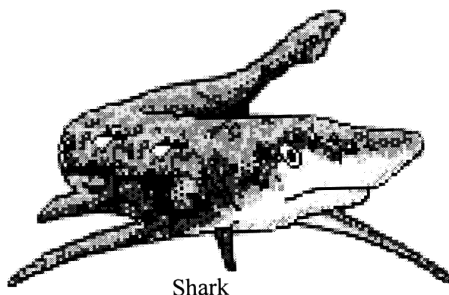
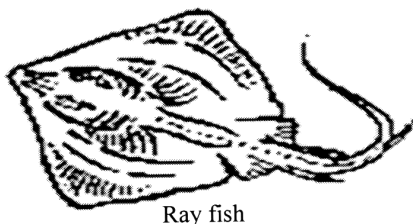


Figure 2.43 Representative fishes: chondrichthyes

b. Osteichthyes or bony fishes are fishes with an endoskeleton made up of bone. This group includes a large variety of freshwater and marine fishes, among which are sturgeons, eels and sea horses. Most bony fishes are covered with overlapping scales. These fishes have a two-chambered heart, a mouth with a jaw, covered gills and usually possess a **swim bladder**. The swim bladder is a gas-filled, bag-like structure that gives bony fishes buoyancy in water.

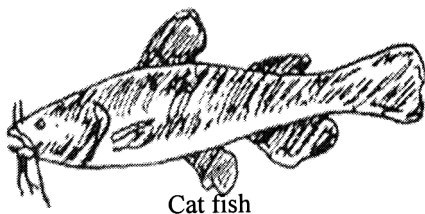
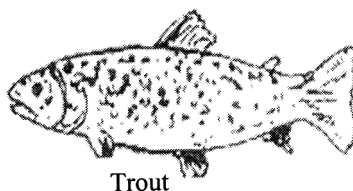


Figure 2.44 Representative fishes: osteichthyes

ii. Amphibians

Amphibians are animals with two pairs of legs. These were the first vertebrates to walk on land. They either move back and forth between water and land or pass one stage of their lives in water and the other on land. Amphibians include animals such as salamanders, frogs and toads.

Most amphibians are carnivorous, while their larvae are herbivorous. A true tongue is first seen in amphibians. Amphibians respire through their moist, non-scaly skin or using lungs. They have a three-chambered heart and, like fishes, are **poikilothermic**.

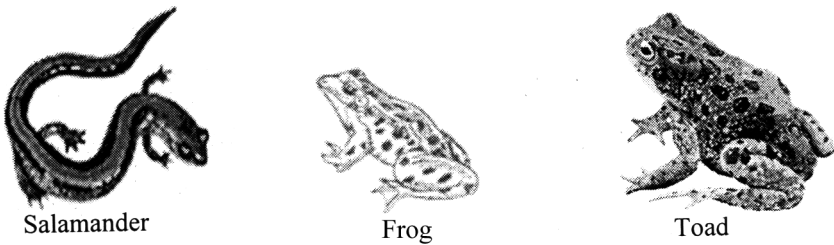


Figure 2.45 Representative amphibians

Activity 2.13

Go to the library and write a report about the skin of amphibians, placing emphasis on the frog's skin.

Most frogs and toads return to water to reproduce, laying their eggs directly in water. Eggs are fertilized externally and hatch into swimming larval forms, called **tadpoles**. Tadpoles undergo a series of gradual changes in form, through a process called **metamorphosis**.

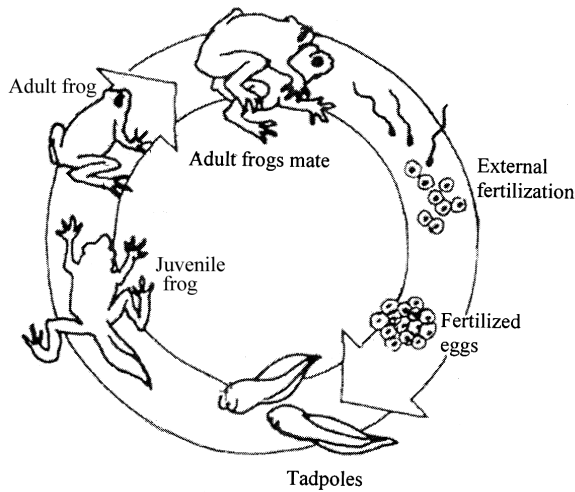


Figure 2.46 The life cycle of a frog

iii. Reptiles

All reptiles except snakes possess two pairs of limbs, with claws on their feet. A reptile's legs do not give full support to the body. They also possess a dry, waterproof skin covered with scales to help them live in dry environments. Some reptiles, like sea turtles and others, live in water. Animals such as snakes, lizards, turtles, tortoises, alligators and crocodiles are examples of reptiles.

Reptiles regularly shed the outer layer of their skin as they grow. Even in reptiles that are not growing, the scales become dull and worn over time and must be periodically replaced by a new, healthy layer. In the shedding process, a new layer develops below the surface of the old one, which gradually separates in preparation for being shed or sloughed off.

Reptiles breathe through their lungs. Reptiles, like fishes and amphibians, are poikilothermic. They have a heart that is not completely four-chambered (except for crocodiles, which have a four-chambered heart). Most young reptiles hatch from shelled eggs after internal fertilization.

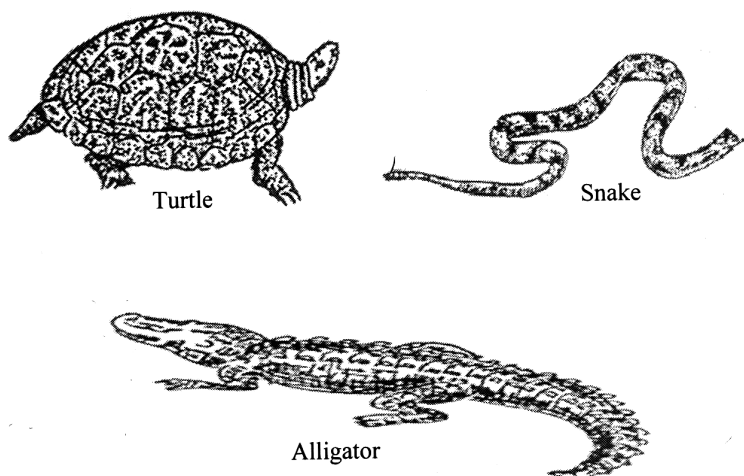


Figure 2.47 Representative reptiles

iv. Birds

There are thousands of different kinds of birds. They vary in size from the tiny humming bird to the large ostrich. Birds have four limbs, but the two forelimbs are modified as wings. Feathers are one of the prominent features of a bird's anatomy and they are unique to birds. Feathers perform a number of functions.

- a. Feathers provide insulation; this is very important in a warm-blooded animal (the body temperature of most birds is maintained at around 40°C).
- b. Feathers protect birds from ultra violet (UV) rays.
- c. Feathers play a role in incubation and waterproofing.
- d. Feathers aid in flying.
- e. Feathers provide different appearances for birds.
- f. Feathers supply the bird with colours, allowing for camouflage, and secondary sexual characteristics and breeding display.

Birds cannot prevent their feathers from wearing out. However, they have a mechanism of replacing worn-out feathers. This process of replacement is termed molting.

Other distinguishing features of birds include the presence of scales on their legs, a definite four-chambered heart, hollow bones (which aid in flying) and the absence of teeth.

Activity 2.14

A. Go to the library and write a report on the following points:

1. Describe the main structures of a bird's feather.
2. Write a report on the types of feathers found on birds by giving detailed information on their description and function.

B. Collect any bird's feather from your surroundings and try to identify the type of the feather.

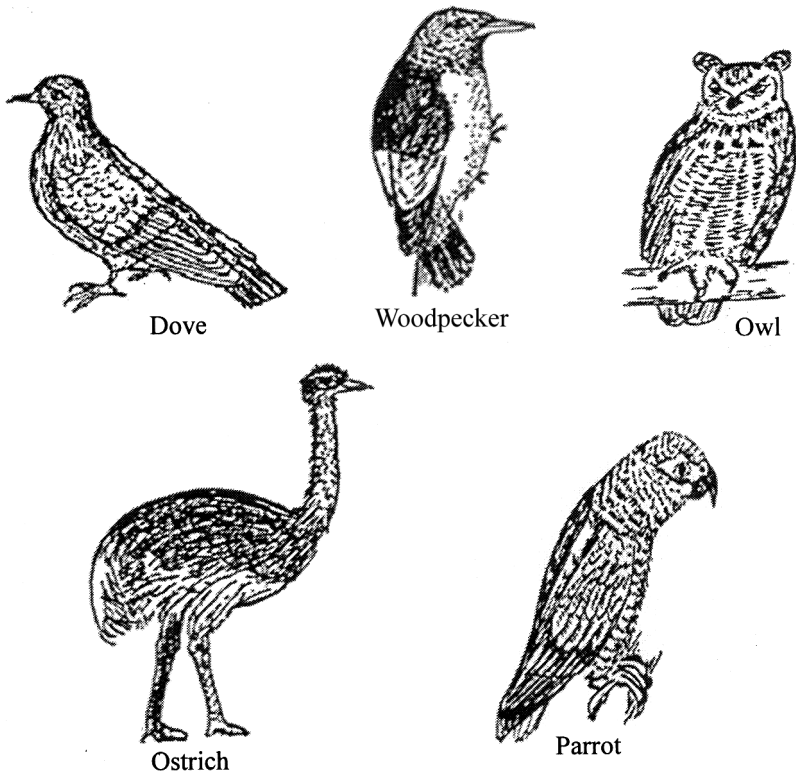


Figure 2.48 Representative birds

Birds are able to maintain a constant body temperature in a changing environment, therefore, they are called **homoeothermic**

(warm-blooded) animals. Birds breathe faster than mammals and their bodies are warmer.

Each bird species has special adaptations that help them to survive in their particular environment. The presence of many types of beaks and feet are some of the adaptations observed in birds.

Type of bird	Type of food eaten	Special use of beak
 Finch	Seeds	Crack seeds
 Hawk	Animal flesh	Cut and tear flesh
 Swallow	Insects	Catch insects
 Duck	Small animals in water	Strain food out of water

Table 2.4 Adaptations of birds' beaks for feeding

The feet of birds are specialized in different ways. For example a woodpecker's feet (Figure 2.49a) are adapted for climbing, a duck's feet (Figure 2.49b) for swimming and a pigeon's feet (Figure 2.49c) for perching.



Figure 2.49 Adaptations of birds' feet

Activity 2.15

Match the following birds' beaks to the type of food the bird eats:

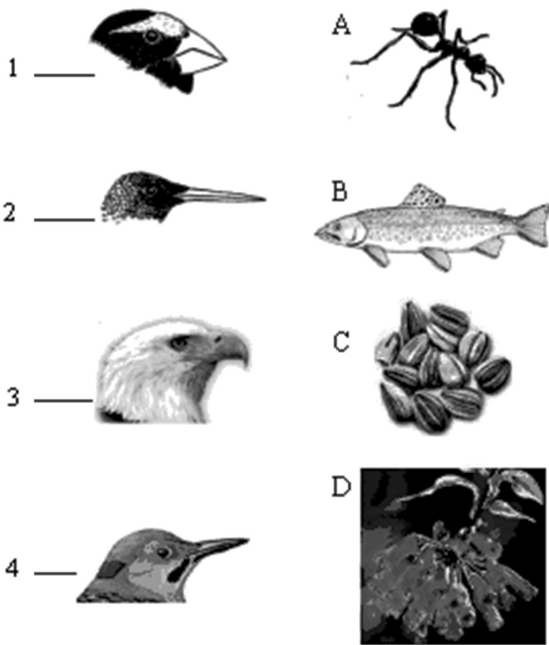


Figure 2.50

v. Mammals

Let us discuss

1. List about 10 domestic mammals from your locality.
2. Categorize the animals in the list according to their general characteristics.
3. List the main features that are common to each category.

Mammals are characterized by having body hair, external ears and an ability to nourish their young with milk that females produce in their mammary glands. Mammals possess specialized teeth that match their particular eating habits. It is usually possible to determine a mammal's diet simply by examining its teeth. Mammals can be categorized as carnivores, herbivores, omnivores or insectivores according to their mode of nutrition.

- a. Carnivores** are those mammals that eat only meat. For example a lion, wolf, tiger, dog and cat is carnivorous.
- b. Herbivores** are mammals, like a cow, elephant, giraffe and horse, which eat plants.
- c. Omnivores** are mammals like humans and pigs that eat both plants and meat.
- d. Insectivores** are a small group of mammals that are insect-eaters. For example anteaters are insectivorous.

Mammals are **homoeothermic**, a crucial adaptation that has allowed mammals to be active at any time of the day or night and to colonize harsh environments. Characteristics of mammals include efficient breathing mechanisms, aided by the **diaphragm** (a muscular structure, the contraction and relaxation of which contributes to breathing), efficient blood circulation provided by four-chambered heart, and presence of sweat glands.

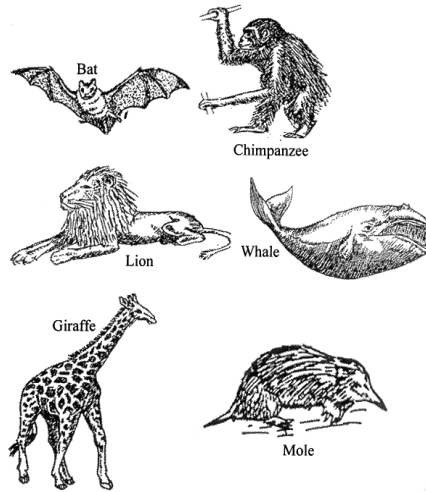
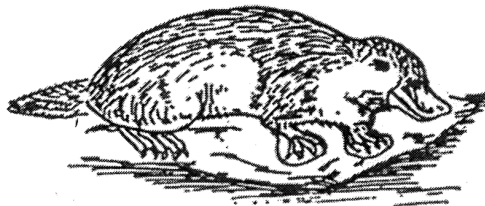


Figure 2.51 Representative mammals

Mammals are divided into two main groups depending on how they are born and the way in which their young are nourished. These are **aplacental** mammals, such as monotremes and marsupials, and **placental** mammals, which includes most mammals.

Monotremes are egg-laying mammals. Newly hatched monotremes immediately start to feed on their mother's milk. The platypus (or duckbill) and spiny anteater are examples of living members of monotremes.



Egg-laying Duckbill (platypus)

Figure 2.52 Representative monotreme

Marsupials are another group of mammals sometimes known as pouched mammals. These mammals develop a placenta to nourish their young for a short period (about eight to 12 days after

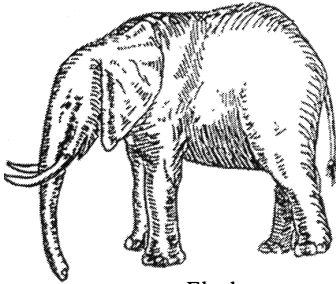
fertilization). The marsupial embryo then leaves the placenta and continues its development in the marsupial pouch. Marsupials include animals such as the kangaroo.



Pouched Kangaroo

Figure 2.53 Representative marsupial

Conversely, **placental mammals** are mammals that produce a true placenta that nourishes the embryo throughout its entire development. This group includes mammals like shrews, dogs, whales, dolphins humans.



Elephant



Shrew

Figure 2.54 Representative placental mammals

Activity 2.16

- A. List the features that distinguish humans as mammals.
- B. Name any mammal in the locality.
 1. What distinguishes this animal as a mammal?
 2. What features do you and the mammal have in common?
 3. In what ways are you and the mammal different?

Exercise 2.3.5

1. How do vertebrates differ from the other chordates?
2. Explain why reptiles were some of the first vertebrates to fully adapt to terrestrial habitats.
3. Differentiate between internal and external fertilization.

Summary

Animals are multicellular organisms with tissues arranged into organs and organ systems. Animals respire aerobically and are heterotrophic in their mode of nutrition. Reproduction in animals is usually sexual, but in some cases asexual, or both. Most animals are motile during at least part of their life cycle. Animals without backbones are called invertebrates and include animals like sponges, cnidarians, platyhelminthes, nematodes, molluscs, annelids, arthropods and echinoderms; those with backbones, called vertebrates, include fishes, amphibians, reptiles, birds and mammals.

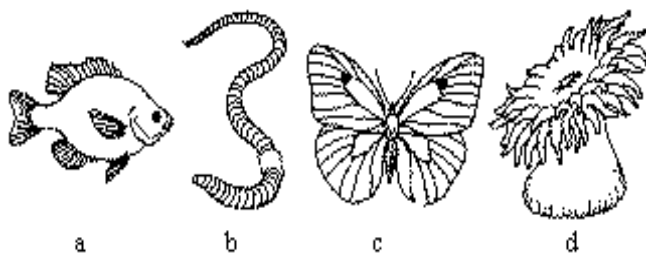
Key Terms/Phrases

Autotroph	Mycellium
Closed circulatory system	Parthenogenesis
Fron	Prothallus
Gametophyte	Plankton
Habitat	Spore
Hermaphrodite	Sporophyte
Heterotroph	Taxon (order or phylum)
Hypha (plural: hyphae)	Taxonomy
Metamorphosis	Zygote

Review Questions

Part I. Choose the correct answer

1. Which of the following has a radial symmetry?
 - A. flatworm.
 - B. annelid.
 - C. chordate
 - D. cnidarian

**Figure 2.55**

2. Refer to Figure 2.55 above. Which two organisms in the diagram have segmented body plans?
A. organisms "a" and "c" C. organisms "a" and "d"
B. organisms "b" and "d" D. organisms "b" and "c"
3. The clitellum of an earthworm:
A. contains the heart.
B. is associated with reproduction.
C. acts as a primitive respiratory system.
D. is necessary for movement.
4. Members of the class osteichthyes:
A. have skeletons made of bone.
B. include rays and skates.
C. do not have jaws.
D. all of the above.
5. The scientific name of any organism consists of two parts namely:
A. class and genus. C. phylum and class.
B. class and order. D. genus and species.
6. Diatoms and euglena belong to the kingdom:
A. protista. C. animalia.
B. fungi. D. plantae.
7. In mosses, spores are produced inside the:
A. thallus. C. sori.
B. capsule. D. gemme.
8. Which of the following features are used in the classification of vascular plants?
A. the presence and absence of seed.
B. the type of vascular bundle.
C. the type of leaves.
D. the type of sporangia.

9. Nitrifying bacteria are examples of:
 - A. photoautotrophs.
 - B. chemoautotrophs.
 - C. chemoheterotrophs.
 - D. photoheterotrophs.
10. Cell division in bacteria takes place mainly by:
 - A. fragmentation.
 - B. binary fission.
 - C. conjugation.
 - D. sporulation.
11. Organisms that obtain their energy by oxidizing inorganic chemical sources are called:
 - A. heterotrophs.
 - B. decomposers.
 - C. chemoautotrophs.
 - D. photoautotrophs.
12. Bacteria are responsible for:
 - A. introducing oxygen into the atmosphere.
 - B. recycling minerals within the ecosystem.
 - C. causing deadly diseases.
 - D. all of the above.

Part II. Fill in the blanks

1. A plant cell wall is made up of _____ and that of fungi is made up of _____.
2. The two modes of nutrition observed in bacteria are _____ and _____.
3. _____ were responsible for the first appearance of significant amounts of oxygen on earth.
4. _____ is a parasitic flagellate that causes African sleeping sickness.
5. _____ are examples of unicellular biflagellate green alga.
6. Fungi are very important in the environment as _____.
7. The fungus and alga in lichen live in a symbiotic relationship called _____.
8. During alternation of generations a _____ alternates with the _____ generation.
9. Angiosperms are divided into two main classes called _____ and _____.
10. Some animals are capable of asexual reproduction, which may take place through _____, _____ and _____.
11. The phenomenon by which most sponges function as one sex for one period and change to the other in another period is called _____.

12. The two body forms found among the cnidarians are _____ and _____.
13. _____ is a structure found in an earthworm that secretes a sticky substance used to form an egg sac.
14. Most insects go through a life cycle, in which the growing young changes not only in size but also often with marked change in appearance. This phenomenon is known as _____.
15. Fishes are animals with a variable body temperature, and are known as _____.

Part III. Match the following

Column A

1. chemoautotrophic prokaryotes
2. cyanobacteria
3. parasitic bacteria
4. saprophytic bacteria

Column B

- a. decomposers
- b. give off O_2
- c. change NH_3 to NO_2
- d. disease-causing organism
- e. photosynthesis

Part IV. Give short answers

1. List three differences between fungi and plants.
2. Describe at least three ways in which bacteria can obtain nutrients.
3. What is the difference between aerobic and anaerobic bacteria?
4. Taking spiders and insects as examples, explain why certain groups of arthropods have become so successful in terrestrial habitats.
5. Why are amphibians usually found near water?
6. How do animals get their nutrition?
7. What is the organism that causes malaria? Describe the life cycle of the organism.

UNIT 3

Metabolic Processes and Energy Transfers in Living Organisms

Expected Learning Outcomes

By the end of this unit, you are expected to:

- list the major types of biomolecules
- explain the role of enzymes in food molecules
- explain the flow of energy in photosynthesis and respiration
- analyze the flow of matter and energy through different trophic levels and the physical environment

3.1 Biomolecules

Let us discuss

1. What are the food types that you eat daily?
2. What are the basic classes of food substances?
3. Why are food substances important to living organisms?
4. What is a plant cell wall made of?

Biomolecules are the building blocks of cells. These include carbohydrates, lipids, proteins and nucleic acids. Biomolecules have different functions in living organisms.

3.1.1 Carbohydrates

Carbohydrates are the most abundant organic compounds in living organisms. They are made up of atoms like carbon (C), hydrogen (H) and oxygen (O). A carbohydrate (e.g. $C_6H_{12}O_6$) has about twice as many hydrogen atoms as carbon or oxygen atoms. Based on the sugar units they contain, carbohydrates are classified as monosaccharides, disaccharides or polysaccharides. Carbohydrates are mainly found in plants such as potatoes, rice and wheat.

A. Monosaccharides

Monosaccharides are single sugar containing molecules. They are the basic units of carbohydrates (“*mono*” means “single” and “*saccharide*” means “sugar”). Monosaccharides are **glucose**, **fructose** and **galactose**. Most cells use glucose as their major energy source for life activities. Glucose is found in grapes and bananas. Fructose is a sugar found in fruits, like oranges, whereas galactose is a sugar found in milk. Monosaccharides are soluble in water and they have a sweet taste.

Activity 3.1

- a. Put glucose powder into a test tube.
 - b. Add some water and shake it well.
 - c. Add some blue Benedict’s solution to the glucose solution.
 - d. Boil it in a water bath.
-
1. What change did you see?
 2. Summarize your results in a table form as indicated below

Observation	Result

B. Disaccharides

If two single sugar molecules join together, a larger molecule called a **disaccharide** (“*di*” means “two”) or double sugar is formed. Disaccharides include **sucrose** or table sugar, **maltose** and **lactose**. Sucrose is the common sugar that is used in foods and drinks. It is found mainly in plants, like sugar cane. Lactose is present in milk. Maltose is used as a source of energy by seedlings for growth.

Disaccharides can be split into two single sugars with the help of enzymes for easy absorption into the cells. Like monosaccharides, disaccharides are soluble in water and have a sweet taste.

Activity 3.2

A.

- a. Place a small spoon-ful of sucrose powder in a test tube.
- b. Add some water and shake it well.
- c. Add Benedict's solution to the sugar solution.

What change did you see?

B.

- a. Put a small spoon-ful of sucrose powder into a test tube. Add some water and shake well.
- b. Add dilute hydrochloric acid to the solution. Boil it for about one minute.
- c. Add sodium hydroxide to the sugar solution. Then add a small quantity of Benedict's solution to the sugar solution.
- d. Boil it in a water bath.

1. What change was observed?
2. Why was hydrochloric acid added to the sugar solution?
3. Why was sodium hydroxide added to the sugar solution?
4. Summarize your results in a table form as indicated below.

Observation	Result

C. Polysaccharides

If many single sugars are joined together, a very large molecule called a **polysaccharide** (“poly” means “many”) is formed. These single sugars can be of the same or different kinds. The most common polysaccharides are **starch**, **cellulose** and **glycogen**. These polysaccharides can be broken into their monosaccharide forms with the help of different enzymes. Polysaccharides are stored as starch in plants and as glycogen in animals. Most polysaccharides are insoluble in water and they do not have sweet taste.

Activity 3.3

- a. Place a small piece of bread on a plate or white tile.
 - b. Add one or two drops of iodine solution to the bread.
1. What change did you observe? Why?
 2. Summarize the results in a table form as indicated below.

Observation	Result

Carbohydrates are the main energy sources for living organisms. In addition, carbohydrates help humans to keep them healthy. If we eat too much carbohydrates, we become fat or **obese** (or overweight), because excess carbohydrates are converted to fats and stored in the body. In contrast, if we eat too little carbohydrates, we become weak, will not grow well, and even develop a disease known as **marasmus**.

3.1.2 Lipids

Let us discuss

1. Distinguish between fats and oils?
2. From where can we obtain fats and oils?

The word **lipid** comes from the Greek word “*lipos*”, meaning “fat” or “lard” (fat of pork/a pig). Like carbohydrates, lipids are large molecules made up of carbon, hydrogen and oxygen. The most common lipids are fats, oils and waxes. Lipids are found in animals and plants e.g. butter and groundnut oil. A fat molecule is made up of three **fatty acid molecules** joined to one molecule of **glycerol**. A lipid can be broken down into its three fatty acid molecules and one glycerol molecule, with the help of an enzyme known as lipase.

Lipids are classified as saturated or unsaturated fats according to the number of hydrogen atoms present in their fatty acid molecules. Saturated fats are animal fats and are solid at room temperature. Unsaturated fats are plant oils and are liquid at room temperature. Lipids are insoluble in water but are soluble in alcohol.

Lipids function mainly as an energy reservoir in the bodies of living organisms. A gram of fat contains twice as much energy as a gram of carbohydrate or protein. Lipids also form a protective layer around internal organs. For example organs like the heart and kidneys are surrounded by a thick layer of fat. Fat stored under the skin also acts as a protector against the loss of body heat, especially in animals that live in very cold environment.

Activity 3.4

- a. Rub a piece of an oily or fatty food on a piece of paper.
 - b. Leave the paper in direct sunlight for a few minutes.
 - c. Look through the paper toward the sunlight.
-
1. What do you observe?
 2. Summarize your results in a table form as given below.

Observation	Result

3.1.3 Proteins

All proteins contain carbon, hydrogen, oxygen and nitrogen (N). In addition, some proteins contain sulphur (S) and phosphorus (P).

Protein molecules are made up of long chains of smaller molecules joined end to end. These smaller molecules are called **amino acids**. There are 20 different amino acids and any of these can be combined in different ways to make thousands of different kinds of proteins.

Amino acids are classified as essential or non-essential amino acids. **Essential amino acids** are those which cannot be synthesized by the body. Therefore, they must be obtained from the diet. **Non-essential amino acids** are those that the body can synthesize from other amino acids or nutrients present in food. For example humans are able to make 12 of the 20 amino acids. Nevertheless, most amino acids are obtained from the food that we consume.

In general, proteins are not soluble in water. However, some proteins such as haemoglobin (the red pigment of blood) are soluble. Proteins are essential to the structures and activities of living cells. Proteins in the food we eat are mainly used for growth, the repair of damaged parts of the body, to replace worn-out cells and as antibodies for fighting disease.

If we eat too little protein our muscles will become poorly developed, resulting in general weakness. Deficiency of protein in children develops a disease known as **kwashiorkor**.

Activity 3.5

- Place a small quantity of cooked egg white into a test tube.
 - Add a little dilute nitric acid.
 - Gently heat the test tube.
 - Remove the acid by pouring a small amount of water into the test tube.
- What change did you observe?
 - What does this indicate?
 - Summarize your results in table form as indicated below.

Observation	Result

The Role of Enzymes in Metabolic Processes

Enzymes are proteins which act as **biological catalysts**. Catalysts are substances that speed up the rate of chemical reactions (metabolic reactions) in living organisms without changing themselves. Enzymes are required only in small amounts to catalyze the conversion of large food molecules to smaller molecules as well as to synthesize large molecules from smaller ones.

Enzymes are also present in plants. For example in germinating seeds, enzymes digest the stored food for the growth of seedling, as well as other purposes.

Catalase is an enzyme present in almost all living tissues of plants and animals. Catalase breaks down hydrogen peroxide, a poisonous substance produced during cellular metabolism, into water and oxygen, which are non-toxic substances. Hydrogen peroxide is a highly toxic (poisonous) chemical substance and must be broken down immediately so as to remove its toxicity.

Activity 3.6

- a. Measure 10 ml of hydrogen peroxide into each of the two test tubes prepared for this purpose.
 - b. Cut two small pieces of raw potato of equal size.
 - c. Cook one of the pieces in boiling water for about five minutes. Remove and allow it to cool.
 - d. Add the boiled piece of potato to one tube and the raw piece to the other.
 - e. After three to five minutes, light a wooden splint and gently put the glowing splint into each test tube.
-
1. What did you observe?
 2. Record the results from the two test tubes and explain them fully.
 3. What can be concluded from this experiment?

3.1.4 Nucleic Acids

Nucleic acids are thread-like, large molecules that contain carbon, hydrogen, oxygen, nitrogen and phosphorus. They are called nucleic acids because they were first discovered in the nuclei of cells.

Nucleic acids are found in all living cells and viruses. There are two kinds of nucleic acids; these are **deoxyribonucleic acid** (DNA) and **ribonucleic acid** (RNA). The two nucleic acids (DNA and RNA) vary in some of their structural components and in their functions. Each of them is named after the sugar molecule it contains. Deoxyribonucleic acid contains **deoxyribose** and ribonucleic acid contains **ribose**.

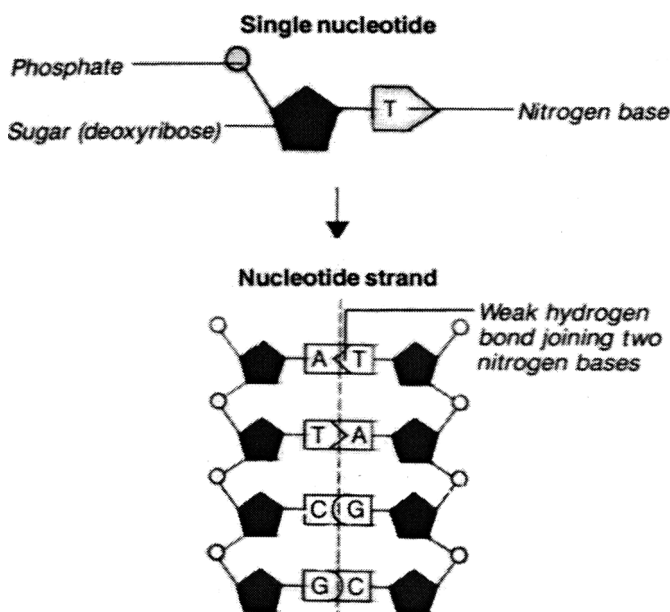


Figure 3.1 A chain of DNA nucleotide with paired nitrogenous bases

The structure of DNA was described by James Watson and Francis Crick in 1953. Deoxyribonucleic acid is a long molecule made up of two strands of materials, which are twisted into a shape called a **double helix**. The double helix looks like a ladder that has been twisted into a spiral staircase. It is made up of two long chains of small molecules called **nucleotides**. Each type of a nucleotide

possesses a deoxyribose sugar, a phosphate molecule and a nitrogenous base. There are four types of nitrogen bases in DNA. These are adenine (A), cytosine (C), guanine (G) and thymine (T). See Figure 3.1.

Deoxyribonucleic acid (DNA) is found in chromosomes. It is a physical carrier of genetic information from generation to generation.

Ribonucleic acid (RNA) is a linear, straight-chain nucleic acid formed by a single strand of nucleotides. The four nitrogenous bases are adenine, cytosine, guanine and uracil (U). It plays an important role in the synthesis of proteins.

Activity 3.7

- a. Use a cardboard box to cut out the shapes that represent the different parts of DNA.
- b. Make different shapes for the sugar, the phosphate molecule and the four different nitrogen bases.
- c. Use different colour pencils for the different parts.
- d. Connect the parts of the molecule together with glue or sticky tape.
- e. Describe the DNA model that you have constructed

Exercise 3.1

1. Which form of carbohydrate is soluble in water?
A. glucose. B. starch. C. glycogen. D. cellulose.
2. The primary function of a carbohydrate is to provide:
A. energy. B. growth. C. oxygen. D. minerals.
3. What is the basic unit of a protein?
A. fatty acid. B. polypeptide. C. amino acid. D. enzyme.
4. If a food gives a blue-black colour upon the addition of iodine, what does it indicate?
A. the presence of carbohydrates in the food.
B. the presence of starch in the food.
C. the presence of protein in the food.
D. the presence of lipids in the food.

5. How are carbohydrates and lipids related and how do they differ from each other?
6. Compare and contrast cellulose, starch and glycogen.
7. How do disaccharides break down into their small components?

Summary

Biomolecules consist of carbohydrates, proteins, lipids and nucleic acids. They are mainly made up of three elements: carbon, hydrogen and oxygen. Carbohydrates are important structurally and functionally to all living cells. These biomolecules make up the chief constituents of the food we eat every day. These large molecules are broken down into simple molecules inside the cell with the help of different enzymes, which provide us with energy. The released energy is used for various body processes. Enzymes are proteins that act as catalysts, remaining unchanged by the reactions. Nucleic acids include DNA and RNA. They are critical molecules because they control basic life processes such as the synthesis of proteins and enzymes.

3.2 The Energy Flow in Photosynthesis and Cellular Respiration

Let us discuss

1. What is energy?
2. Why do living organisms need energy?
3. Where do animal cells get their energy from?
4. What is photosynthesis?

A. Photosynthesis

Photosynthesis is a chemical process that takes place in plants to make food. It literally means synthesizing sugar molecules using light energy (“*photo*” means “light” and “*synthesis*” is to “assemble” or “produce”). Green plants use solar energy to make biomolecules. Most plants have a green substance, called **chlorophyll**, found inside the chloroplasts of plant cells. Chlorophyll absorbs the light energy needed for photosynthesis. Carbon dioxide and water are the two raw materials required for

photosynthesis. Plants get carbon dioxide from the air, whereas water is absorbed from the soil by their root hairs. Photosynthesis occurs in two reactions, called a **light reaction** and a **dark reaction**.

i. Light Reaction (light-dependent reaction)

Trapping the energy from the sun in the chloroplast is the first stage of photosynthesis. This light energy is converted into chemical energy and stored as food. See Figure 3.2.

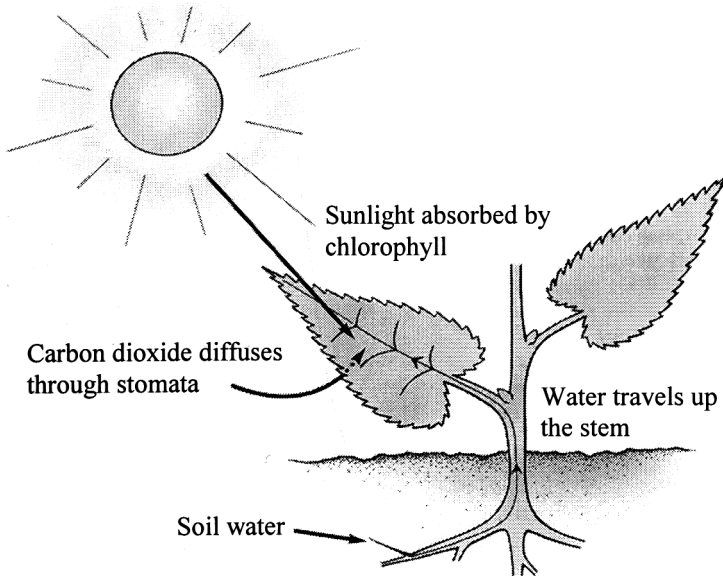
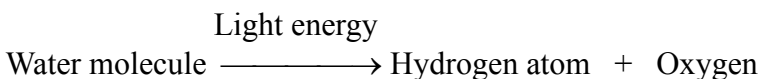


Figure 3.2 How the raw materials of photosynthesis reach the leaf

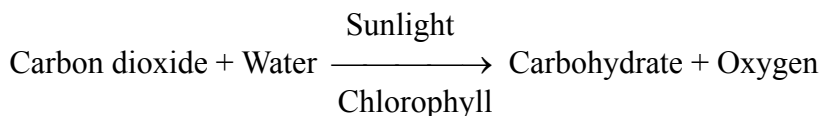
Most chloroplasts are found in the cells of the leaves. A leaf is a factory for making food. Energy from sunlight hits the water molecule and dissociates it into hydrogen and oxygen gases.



The hydrogen atom is used in the dark reaction and oxygen diffuses out of the leaf to the atmosphere as a byproduct.

ii. Dark Reaction

The dark reaction includes a series of reactions that form simple sugars using carbon dioxide, hydrogen from water and energy released from the light reaction. The dark reaction occurs whether light is present or not. The first product of photosynthesis is glucose which is converted to starch and stored in plant cells. The overall process of photosynthesis can be summarized in a word equation:



The balanced chemical equation for photosynthesis is:

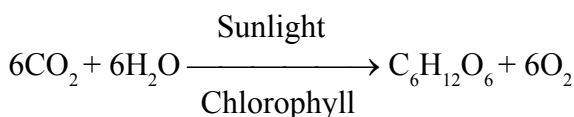
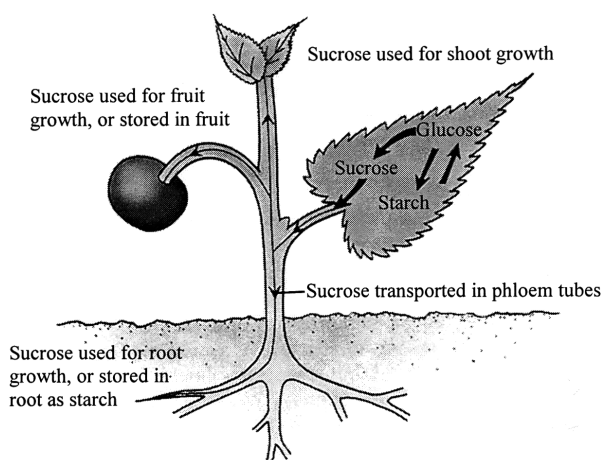


Figure 3.3 The products of photosynthesis

Activity 3.8

- Take a leaf from a healthy plant and keep it in a dark cupboard to destarch it for at least 24 hours.
- Put the leaf into boiling water in a water bath. Leave it for about 30 seconds.
- Remove the leaf and place it in a tube of alcohol kept in a water bath.
- Set up the experiment as shown in Figure 3.4 below

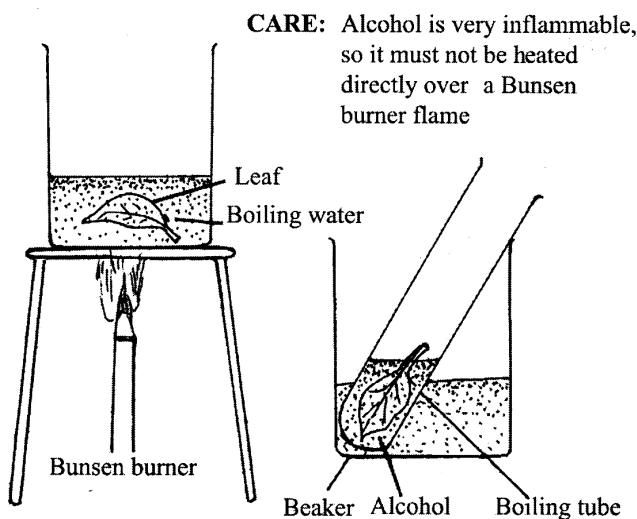


Figure 3.4

- Remove the leaf from the alcohol and place it in water to soften it.
 - Place the leaf on a white tile and add iodine solution to it.
- Why did you put the leaf into alcohol?
 - Why was the leaf put into boiling water?
 - Was starch present in the leaf? Why?
 - Why did we immerse the leaf in water after removing it from the alcohol?
 - What is the purpose of removing chlorophyll in this experiment?
 - What can you conclude from this experiment? Explain why.

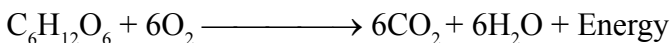
B. Respiration

Respiration (cellular respiration) is a process by which cells produce energy. Respiration occurs all the time in the cells of living organisms. There are two types of cellular respiration: **aerobic respiration** and **anaerobic respiration**.

i. Aerobic Respiration

The breakdown of food substances such as glucose in the presence of oxygen in a series of reactions controlled by enzymes is called **aerobic respiration**. This happens inside the mitochondria of cells. The process of aerobic respiration of glucose can be summarized by the following chemical reaction:

Glucose + Oxygen $\longrightarrow$ Carbon dioxide + Water + Energy



This reaction releases energy, carbon dioxide and water. The energy is stored in a chemical compound called **adenosine triphosphate (ATP)**. It is an immediate source of energy for all life processes. Each glucose molecule can be used to make 38 ATP molecules. When ATP is broken down, energy is released and may be used for various activities such as the transport of substances across the cell membrane, cell division, the growth and manufacture of organic compounds and the absorption of mineral nutrients by active transport.

Activity 3.9

Set up your apparatus as follows:

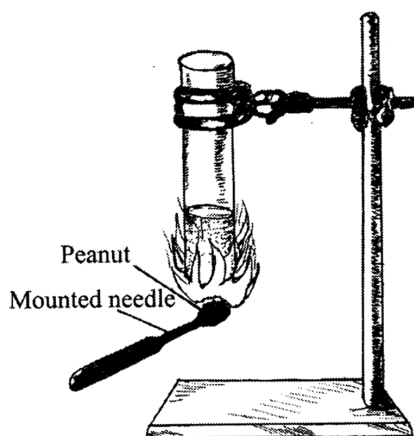


Figure 3.5

- Measure the temperature of the water in the test tube and record it.
 - Pierce the peanut at one end and mount it on a needle.
 - Light or burn the peanut by holding it in a flame.
 - Hold the burning peanut under the test tube of water until it stops burning.
 - Immediately measure the temperature of the water again and record it.
-
- Is there any difference between the two temperature measures? Why?
 - What type of chemical reaction was occurring as the peanut was burning?
 - How can you relate this activity to anaerobic respiration?

ii. Anaerobic Respiration

Oxygen is usually needed for the respiration process to release ATP but sometimes it can be formed without oxygen. The process of releasing energy without oxygen is called **anaerobic respiration** (“an” means “without”). Anaerobic respiration is

common in many bacteria and yeast cells. These organisms can live without any oxygen. Anaerobic respiration can take place both in micro-organisms and sometimes in animal cells.

The process of anaerobic respiration in some bacteria and yeast is called **fermentation**. People have been using yeast for thousands of years to make alcohol. Yeasts are used for baking bread and making alcoholic beverages such as wine, beer, “*mies*” or “*suwa*”. Fermentation is used to breakdown glucose in the absence of oxygen to release energy, ethanol (a type of alcohol) and carbon dioxide. This process is called **alcohol fermentation**. The alcohol fermentation of glucose can be summarized as follows:

Glucose $\longrightarrow$ Alcohol + Carbon dioxide + Energy (2ATP)

Anaerobic respiration also occurs in human cells. You have probably experienced a burning feeling in the legs or had muscle pain while running. This indicates the switching of the muscle from aerobic respiration to anaerobic respiration for a short time.

Normally our muscle cells are supplied with sufficient amounts of oxygen for aerobic respiration. However, during intense exercise, the oxygen supplied may not be enough. To provide the energy needed for these activities, the muscle cells respire anaerobically.

During aerobic respiration, animal cells break down glucose to make a substance called **lactic acid**. This process is called **lactic acid fermentation**. The accumulation of lactic acid results in muscle fatigue and a burning sensation; this prevents the muscles from working properly. Anaerobic respiration in animals can be represented by the following equation:

Glucose $\longrightarrow$ Lactic acid + Energy (2ATP)

In anaerobic respiration, glucose is not completely broken down, and only a small amount of energy is released for use in the cells. Aerobic respiration is, therefore, far more efficient than anaerobic respiration in terms of energy production. The cells store the lactic

acid until oxygen becomes available to further break it down:

Lactic acid + Oxygen $\longrightarrow$ Carbon dioxide + Water

Certainly, the products of cellular respiration play an important role in the process of photosynthesis.

Activity 3.10

Copy and complete the table below.

Event	Aerobic respiration	Anaerobic respiration
Where does it occur?		
How many molecules of ATP are produced?		
Is oxygen needed?		
What products are formed in: a. human muscle cells b. yeast cells		

Exercise 3.2

- ATP is:
A. an immediate energy source. B. an energy carrier.
C. produced by all organisms. D. all of the above.
- A large amount of energy is released by the breakdown of glucose during:
A. anaerobic respiration. B. aerobic respiration.
C. lactic acid fermentation. D. alcohol fermentation.
- The process of photosynthesis takes place in:
A. the nucleus. B. the mitochondria.
C. the chloroplasts. D. the chromosomes.
- One of the functions of a yeast cell is to produce
A. milk. B. alcohol. C. lipids. D. proteins.

During _____ (5) _____ green plants convert the _____ (6) _____ of the sun into the _____ (7) _____ within the food. Some of the energy in food is transferred to other living organisms when they _____ (8) _____ on plants.

9. Explain the similarities and differences between aerobic respiration and anaerobic respiration.
10. Explain the importance of photosynthesis in living organisms.

Summary

All living cells need energy, which is obtained from food. Plants are producers that manufacture their own food from carbon dioxide and water, using sunlight. They convert solar energy into chemical energy through photosynthesis, releasing oxygen as a byproduct into the air. Photosynthesis occurs in two stages: the light reaction and the dark reaction that occur in the chloroplast of a plant cell. Respiration is the process by which food substances are chemically broken down into living cells to release energy. Carbon dioxide and water are produced as byproducts. There are two types of respiration, namely aerobic and anaerobic. Some organisms like yeast and bacteria produce energy (ATP) without using oxygen. These organisms break down glucose in the absence of oxygen into alcohol, carbon dioxide and energy. During rigorous exercise, human muscles change from aerobic respiration to anaerobic respiration, to get enough energy for the body processes. Photosynthesis and respiration both deal with energy conversion. Photosynthesis converts light energy to chemical energy, while respiration converts energy stored in food to another form of energy which can be utilized by cells.

3.3 The Flow of Matter and Energy through Different Trophic Levels

Let us discuss

1. What are autotrophs, heterotrophs and decomposers?
2. Explain how energy is transferred from green plants to animals.

All living organisms need energy for various body activities such as growth, movement and reproduction. We eat plants and meat to get energy. For example plants use non-living sources such as light, water and air (CO_2) to make food. Food provides them with chemical energy. Some of the chemical energy is used by plants for different activities and the rest is stored. This stored energy is transferred to other living organisms, including animals, when they feed on plants.

All living organisms in an ecosystem need energy in order to stay alive. They get energy from food, using respiration. All the energy in an ecosystem comes from the sun. Some of the energy in sunlight is captured by green plants and is used to make food such as glucose, starch, fats and proteins. When a plant needs energy, it breaks down some of this food by respiration and energy is released.

Animals get their food and energy by eating plants or by eating other animals. Living organisms are classified as **autotrophs** and **heterotrophs**, based on how they obtain their food.

There are three trophic (feeding) levels. These are producers, consumers and decomposers.

A. Producers are also called **autotrophs**, which means that they are **self-feeders**. Plants are said to have autotrophic nutrition because they produce their own food. The energy trapped from the sun by green plants is transferred from one organism to another. However, some energy is lost as it is utilized by the organism itself in various processes.

B. Consumers are organisms that are not able to make their own food from inorganic materials. They are called **heterotrophs**, which are different **feeders**. They have to eat plants or other animals to obtain their own energy. All animals are consumers.

C. Decomposers feed on the dead bodies or waste of animals and plants, to release energy through **decomposition**. Some

bacteria and fungi are the main decomposers. Decomposers are also called **saprotrophs**, because they can neither make their food using photosynthesis nor eat solid food. “*Sapro*” means “dead” or “decaying” and “*troph*” means “feeder”. Saprophytes are organisms which feed on dead organisms.

The organic matter returns to the environment after their death and decay. The organic matter is recycled but the energy utilized only once.

Exercise 3.3

1. To make carbohydrates, plants use carbon dioxide and:
A. chlorophyll. B. ATP. C. water. D. minerals.
2. The first product of photosynthesis is:
A. glucose. B. starch. C. fat. D. protein.
3. A hyena is:
A. an autotroph. B. a decomposer.
C. a producer. D. a heterotroph.
4. Plants are autotrophs and humans are:
A. autotrophs. B. heterotrophs.
C. saprotrophs. D. decomposers.
5. Aerobic respiration takes place in the:
A. chromosome. B. chloroplast.
C. chlorophyll. D. mitochondria.
6. What does the term “trophic level” mean?
7. To which group does each of the following organisms belong?
Cow, bean, “taff”, maize, goat, lion, and fungus.
8. Distinguish between producers and consumers.

Summary

Living organisms are classified into three different trophic levels based on how they obtain their energy. These include the producers, consumers and decomposers. Plants are autotrophs or self-feeders in that they can produce their own food. All animals are heterotrophs and they depend on plants or other animals to get their energy. In living organisms, energy flows from one trophic level to the next, but some energy is lost as heat at each level. Energy is not recycled but all plants and animals play an

important role in the flow of energy and the recycling of materials in nature, which is used over and over again.

Key Terms/Phrases

Adenosine triphosphate (ATP)	Disaccharide
Amino acid	DNA
Aerobic respiration	Aerobic respiration
Anaerobic respiration	Anaerobic respiration
Autotrophs	Lipid
Carbohydrates	Monosaccharide
Chlorophyll	PigmentChloroplast
Chloroplast	Producer
Consumer	Protein
Decomposers	Respiration

Review Questions

Part I. Choose the correct answer

- One of the following lipids is not found in animals:
A. lard. B. butter.
C. olive oil. D. margarine.
- The end-product of light reaction in photosynthesis is:
A. energy, carbohydrates and water.
B. carbon dioxide, carbohydrates and water.
C. energy, oxygen and hydrogen.
D. both a and b are correct.
- In which part of the following cell bodies does photosynthesis take place?
A. the nucleus. B. the mitochondria.
C. the chloroplast. D. the cytoplasm.
- Which of the following is not a function of a carbohydrate?
A. the conservation of water.
B. a structural component of living organisms.

1. Plants absorb water and minerals through their _____.
2. All organisms get their energy directly or indirectly from the _____.
3. The sugar present in DNA is called _____, whereas that in RNA is called _____.
4. _____ is the byproduct of photosynthesis.
5. Amino acids are classified into _____ and _____.
6. Complete the table on the characteristics of DNA and RNA.

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Part III. Match the following

Column A

1. primary producers
2. consumers
3. decomposers

Column B

- a. herbivores, carnivores, omnivores, parasites
- b. break down dead bodies of other organisms
- c. decomposers
photoautotrophs
- d. recycling substances

Part IV. Give short answers

1. Do you think respiration is the same as breathing? Why?
2. What are the raw materials needed for photosynthesis?
3. Distinguish between photosynthesis and respiration.
4. If you mix oil and water, what will happen? Why?
5. Why do animals need fats in their diet?
6. What are the main functions of proteins in living organisms?
7. Why is photosynthesis important to animals?
8. Write the overall equation for the process of photosynthesis.

UNIT 4

Plants, Animals and the Environment

Expected Learning Outcomes

By the end of this unit, you are expected to:

- evaluate the significance of structural and physiological adaptations of plants and animals to their environment

4.1 What is Adaptation?

Let us discuss

1. Do all plants and animals in your surroundings have the same structures (such as leaves, stems, legs, skin, etc.)?
2. Are these structures of the same colour, type and size? Explain why.

Living organisms are characterized by the changes they make to live in the environmental conditions around them. The changes can be morphological (change in structure and form) or physiological (internal and functional change), and is called **adaptation**. Adaptation is the modification in structure or function that increases the fitness of an organism in a stressful environment. Adaptation is hereditary and thus passed from one generation to the next.

Adaptation mechanisms of living organisms to various environmental stress factors are generally classified as **avoidance**, **tolerance** and **escape** mechanisms. Avoidance mechanisms enable the organism to reduce the impact or effect of the stress. Tolerance mechanisms enable the organism to live under the stressful conditions with minimal effect. Escape mechanisms enable the organism to escape from the stressful circumstances.

The Importance of Adaptation

Adaptation occurs as a result of an increase in those genes that allow individuals in a population to better survive and reproduce

in a changing environment. The environment is always changing. Over a long period of time, plants and animals have accumulated very important mechanisms. These accumulated mechanisms enable them to live in a given environment. Adaptation is a means of survival and without it species might become extinct.

Exercise 4.1

1. Explain what adaptation is.
2. What are the benefits of adaptation to the organisms that have it?

4.2 Adaptations of Plants to their Environment

Plants differ from one another in their leaf structure, stem type, height or shape. Such differences arise because plants have, over time, developed different adaptations that enable them to survive in different environmental conditions. These environmental conditions include temperature, water, salinity, growth, etc.

4.2.1 Adaptations of Plants to Temperature

Activity 4.1

1. What functions of plants are affected by high temperatures or when there is excessive heat?
2. What features of plants allow them to live in hot conditions?
3. What plant functions do you think are affected by cold temperatures and what do plants do to resist it?

Temperature is a very important environmental factor that affects plant functions and growth. It can affect many plant functions such as photosynthesis, metabolism, respiration, and distribution of organic materials inside the plant.

A. Adaptations of Plants to Low Temperatures

At low temperatures, plants develop adaptations that allow them to reduce their exposure to the cold environment. For example,

temperate woody perennials (e.g. deciduous trees) shed their leaves to prevent water loss by transpiration. **Transpiration** is the loss of water from plants through the small openings called stomata in the leaves and stems. The low temperature limits soil water uptake. Coniferous trees have needle-like leaves and thick cuticles to prevent or reduce the amount of snow that can accumulate on the trees during the winter season. Many annual plants have short growing periods to enable them adapt to low temperatures. Many plants that grow in low temperatures remain inactive during the cold season. They pass the cold season as dormant plant parts (such as rhizomes, bulbs, etc.) or as seeds. Plants like strawberries shorten their internodes and reduce their size during the cold season.

B. Adaptations of Plants to High Temperatures

Plants that live in warm conditions show various structural and physiological modifications. At high temperatures, plants suffer from water loss due to high transpiration rates. Thus they develop features that reduce their leaf surfaces. Many plants have thin leaves to reduce the part of the leaf exposed to the sun e.g. grasses. Other plants have shiny leaves that reflect much of the incident light. This prevents the plant from overheating. Some plants have many openings in the surface of their leaves and stems, called **stomata**, to allow them to lose heat and thus cool.

Succulent plants such as *Opuntia* (“Beles”) have their leaves modified to spines to reduce loss of water by transpiration (see Figure 4.1). The photosynthetic function of the leaves in this case is taken over by the stem which is also modified to store water. In addition, many plants, including *Opuntia* have few stomata and a waxy covering on the outer surface in order to reduce water loss. The outer covering, called a **cuticle**, is important to reduce water loss through transpiration and evaporation. Pine trees have sunken stomata that create an atmosphere of high humidity on the leaves to reduce transpiration.

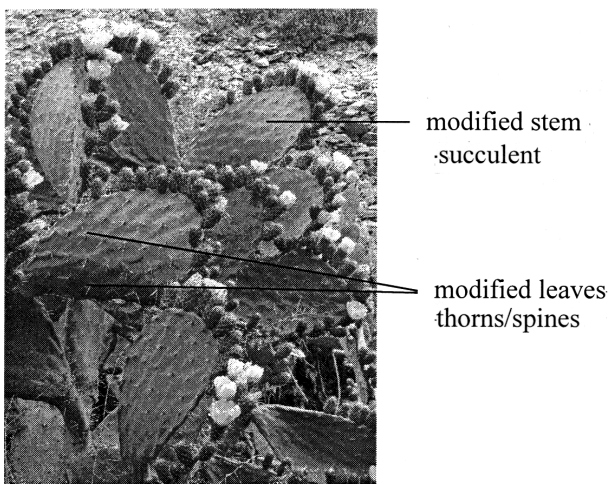


Figure 4.1 Opuntia “beles” showing leaf and stem adaptations

4.2.2 Adaptations of Plants to Water

Water is essential for any plant life. Plants are classified into three major categories according to their adaptations to water conditions. These are **xerophytes**, **hydrophytes** and **mesophytes**. The majority of plant species live in optimal environments with regard to water availability.

A. Mesophytes

Mesophytes are plants that live under normal water conditions or in intermediate water availability e.g. many crop species. In order to live in such conditions, they have various morphological and physiological modifications. Mesophytes usually have a well developed root system, their leaves are flat and their stomata do not have protective features.

B. Hydrophytes

Hydrophytes are plants that live in excessive water conditions or in places where water is abundant. These plants have reduced supporting and conducting tissues. Instead they may have air chambers and passages filled with air/gases to enable them grow in wet conditions and float. Such plants can live in water submerged or half submerged. **Emergent plants** are plants rooted

to the soil in water but their stems and leaves extending above the water surface e.g. reedmace (“*seti*”). **Floating** plants have their roots inside the water but have leaves that float at the water surface e.g. water lily. These plants have buoyant leaves that are often filled with air sacs. **Submergent plants** are plants that live totally under water e.g. *Elodea*.

C. Xerophytes

Xerophytes are plants that live in dry conditions and can tolerate water scarcity. These plants are essentially desert plants and show the following adaptations which help them to minimize water loss.

- | | |
|-----------------------------|----------------------|
| a. thick layer of epidermis | e. hairs on stomata |
| b. extensive root system | f. sunken stomata |
| c. water storage tissues | g. rolling leaves |
| d. heavy wax or cuticle | h. reduced leaf area |

Plants that live in the desert have developed many other adaptive strategies that include **succulence**, a change in their physiological and biochemical functions, and drought avoidance. These mechanisms are very effective types of adaptations for survival in dry conditions. Succulent plants store water in fleshy leaves, stems or roots. Good examples of succulents are *Aloe* (see Figure 4.2), *Crassula* (see Figure 4.3) and many *Euphorbia* plants (e.g. cacti; singular: cactus). Several other adaptations are essential for the water-storing habit to be effective. A succulent plant must be able to absorb large quantities of water in short periods. Desert rains are often light and brief, and the soil dries up rapidly under an intense sun. To cope with these conditions, nearly all succulents have extensive, shallow root systems.



Figure 4.2 *Aloe* species



Figure 4.3 *Crassula*, succulent plant

Adaptations of desert plants are not limited to structural features. Many of them have distinctive biochemical or physiological characteristics. Plants need CO_2 for the process of photosynthesis, which is obtained from the air through the stomata. However, whenever plants open their stomata they tend to lose water too. Many plants that live in the deserts have evolved a unique system of storing CO_2 . These plants close their stomata during the day to minimize water loss. At night, temperatures are lower and humidity is high, so transpirational water loss is low. Carbon dioxide is absorbed at night and is stored for daytime use. During the day, when light energy is available, the stomata close and the CO_2 is released to be used for photosynthesis.

Annual plants escape unfavourable conditions such as dry climate as seeds. They mature in a single season and then die after using all of their energy to produce seeds for continued survival.

Activity 4.2

- a. Observe different plants in your surroundings.
 - b. Bring different leaves and classify them as normal, succulent and modified.
-
1. How many types of plants did you observe?
 2. Which types of plant adaptation mechanisms were you able to identify in the plants?

4.2.3 Adaptations of Plants to Salt

Plants such as mangroves, that cover a great part of the seashores in Massawa and the coastal areas, are salt-tolerant plants. They have developed unique adaptations that allow them to live in harsh saline environments where other plants would not survive. There is typically little oxygen in the muddy soil that mangroves grow in. Therefore, they developed root structures that allow them to obtain oxygen directly from the air. These aerial roots rise from the soil into the air above the water at low tide. Mangroves also have small openings (lenticels) in their bark that allow oxygen to diffuse into the plant and down into its underground roots.

Plants that have developed adaptations to saline environments are called **halophytes**. Many salt-tolerant plants have developed salt glands, salt-filtering root, or salt-excreting leaves or branches in order to prevent the build up of high salt concentrations. Mangroves for example almost completely eliminate salt and, when squeezed, their leaves consist of almost pure water.

4.2.4 Adaptations of Plants to Air

Air plants (also called **epiphytes**) grow or cling upon other plants or other structures such as electricity poles for support. They produce their own food and are therefore not parasites. They are not connected to the soil and thus derive their nutrients from the air or from debris (waste) falling on them. These plants have an unusual leaf structure that creates a reservoir in which to store water when it rains, to use at other times. In this reservoir, the

leaves and other organic matter decompose to release nutrients to the plants.

Activity 4.3

Copy the table given below into your exercise book.

S. No	Plant	Adaptation	Effect

Table 4.1

1. Name a plant or request a list of plant names from your teacher and discuss the kind of adaptations you have observed in the plant.
2. What effects do the adaptations have on the plant's life?
3. Fill the table with as many plants as possible.

Exercise 4.2

1. What are the three types of plants, classified according to their adaptations to water?
2. What is the advantage of succulence in desert plants?
3. Name some plant modifications that help plants reduce water loss in warm conditions.

Summary

Plants are classified into mesophytes, hydrophytes and xerophytes, according to the adaptations they have developed in response to water conditions. They also show various adaptation mechanisms such as leaf rolling, leaf shedding, the presence of a cuticle, and modified leaves, roots and other plant parts in response to different temperatures.

4.3 Adaptations of Animals to their Environment

Let us discuss

1. Is there any difference between animals living in lowlands and those living in highlands?
2. Why do you think a camel has large and flat feet?
3. Why do you think birds have different beak shapes?

Many animals are adapted to different environmental conditions. Animal adaptations can be physical or behavioural. **Physical** adaptations are changes that occur in a structure or part of a body of an organism. For example the polar bear's thick fur gives it warmth in cold temperatures. A giraffe's long neck enables it to feed on high leaves and vegetation (see Figure 4.4). Lizards have excellent vision and use their tongues to "taste" the environment. **Behavioural** adaptations are changes in the behaviour of animals. For example some lizards, when attacked by predators, pretend to be dead to avoid further injury.

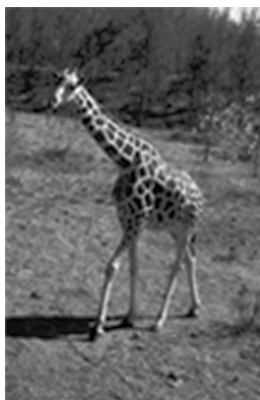


Figure 4.4 An example of physical adaptation

Organisms maintain a constant internal environment through a process called **homeostasis**. Homeostasis provides optimum conditions for the body to function. Temperature regulation in animals is one form of homeostasis. An organism has an optimal temperature range within which it maintains a fairly constant internal temperature. There are different physiological and anatomical modifications that help animals to regulate their body temperature.

4.3.1 Adaptations of Animals to Low Temperatures

Activity 4.4

1. Why do you think animals living in cold regions develop thick fur?
2. The ear size of goats living in cold regions is smaller than that of goats living in warm regions. Explain the advantage of having smaller ear size in cold regions?

Adaptations of animals to low temperatures include:

1. **Hormonal changes:** In cold weather hormonal changes tend to boost the metabolic rate. For example in birds and mammals an increase in metabolic rate increases their heat production.
2. **Good appetite:** Small animals in cold regions usually eat more food to increase heat production.
3. **Moving around more or shivering:** The contraction of skeletal muscles when animals move around or shiver produces heat as metabolic byproduct.
4. **Insulation:** A major thermoregulatory adaptation in mammals and birds is insulation. Mammals develop hair (often called fur), or have fat deposits in their bodies. Birds grow feathers. Most land mammals and birds react to the cold by raising their fur or feathers. This action traps a layer of air next to the warm skin, improving insulation. Aquatic mammals are insulated by a thick layer of fat.
5. **Hibernation:** This is a type of long-term metabolic rate reduction in cold weather. When food supplies are low and the environmental temperature is too low, some organisms are able to reduce their metabolic rates to save energy.
6. **Basking in the sun:** Some animals, such as desert lizards, lie in the sun when it is cold.
7. **Small body projections:** Some animals, such as the Arctic fox, have short ears to minimize heat loss from their body.

4.3.2. Adaptations of Animals to High Temperatures

Activity 4.5

1. What is the advantage of having large ears for animals living in warm regions?
2. Why do dogs pant (breathe heavily) during hot weather?

Animal adaptations to high temperature include:

1. **Large ears:** Large mammals living in warm regions, such as the elephant and hippopotamus, have large ears, which provide a large surface area for heat loss.
2. **Absence of fat layer:** Some animals, like the camel, have long, thin legs and no layer of fat under the skin as a means to regulate their body temperature.
3. **Evaporative cooling:** Panting, sweating, or spreading saliva on the body surfaces helps animals lose heat from their bodies.
4. **Water fanning:** Honey bees cool their hive during hot weather by transporting water into it and fanning it with their wings.
5. **Hiding:** Animals hide themselves in damp areas or burrows when the weather is warm e.g. desert lizards.
6. **Bathing:** Many animals seek relief from the heat by bathing in water.
7. **Aestivation:** In regions where the day-time temperature is very high and the water supply is very scarce, some animals tolerate (endure) the period of high temperature by aestivation. They become dormant until favourable conditions return. Their slow metabolism and inactivity allows them to survive long periods of high temperatures with limited water supplies.
8. **Obtaining water from food and chemical reactions:** Some animals of warm regions obtain water from their food and chemical reactions within their body e.g. insects and reptiles.
9. **Nocturnal behaviour:** There are many animals that become active and feed during the night, becoming inactive during the day e.g. bats.

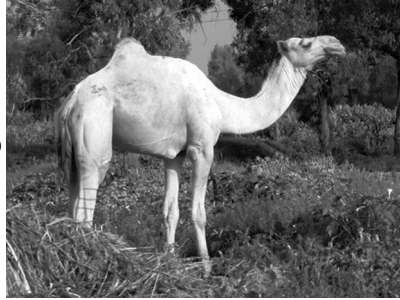
Activity 4.6

Look at the following figures of animals.

Which animal do you think is better adapted to higher temperature conditions? Why



a



b



c



d

Figure 4.5

Exercise 4.3

1. How do hormonal changes help animals to adapt to low temperatures?
2. What is the advantage of not having a fat layer under the skin when living in hot regions?
3. What is hibernation?
4. Most animals living in hot regions are active during the night rather than the day. Can you explain why?

Summary

Animals, like plants, must adapt to their environment if they are to survive. Animals are able to adjust their internal conditions

according to the environment in which they live. The mechanism that enables an organism to adapt to its environment is called homeostasis, which involves temperature regulation. There are different mechanisms by which animals are adapted to cool or warm temperature conditions. Some of the regulatory mechanisms may require physiological and anatomical modifications. Adaptations allow both plants and animals to be better suited to their living conditions and are the means to their survival.

Key Terms/Phrases

Adaptations	Hydrophytes
Aestivation	Insulation
Epiphytes	Mesophytes
Halophytes	Succulence
Hibernation	Xerophytes
Homeostasis	

Review Questions

Part I. Choose the correct answer

1. An adaptation mechanism of living organisms that enables them to not be exposed to stressful conditions is:
A. avoidance. C. escape.
B. tolerance. D. A and B.
2. Plants that live in excessive water conditions are called:
A. mesophytes. C. xerophytes.
B. hydrophytes. D. epiphytes.
3. Which of the following plants is well adapted to living in a salt-water environment?
A. grass. C. "beles".
B. water lily. D. mangrove.
4. A type of animal adaptation to high temperatures, by which the animal becomes dormant until favourable conditions return is:

- A. nocturnal behaviour. C. aestivation.
B. hiding. D. hibernation.

5. Which of the following animals is better adapted to cool environments?

- A. camel. C. Arctic fox.
B. lizard. D. bat.

Part II. Fill in the blanks

- _____ are plants that have needle-like leaves and a thick cuticle to prevent or reduce the accumulation of snow during the winter season.
- _____ is an example of plants that have modified their leaves to spines to reduce loss of water by transpiration.
- Plants that live totally under water are called _____ plants.
- A process in living organisms, by which the organisms maintain a constant internal environment, is called _____.

Part III. Match the following

Column A

Column B

- | | |
|----------------|---------------------------------------|
| 1. tolerance | a. long-term metabolic rate reduction |
| 2. mesophytes | b. active during the night |
| 3. xerophytes | c. heavy, wax coating or cuticle |
| 4. nocturnal | d. many crop species |
| 5. hibernation | e. live in stressful conditions |
| | f. not facing stressful condition, |

Part IV. Give short answers

- Plants that live in cold temperatures shed their leaves. What is the advantage of this?
- What are the characteristic features of nocturnal animals?
- How do honey bees cool their hive during the weather?
- Go to the library and read about the changing environment and the ecology of many areas in the world. Identify the kind of adaptations that are helping the plants and animals that live in that area. You may focus on one animal or plant and report on the adaptations that the organism has.
- Why did dinosaurs become extinct? Explain in terms of adaptation.