

PREFACE

Grade 10 Biology guides students and encourages them to study fundamental life science dealing with microorganisms, plants and animals including humans. Students will learn that Biology deals with the study of all living organisms that live or have ever lived on the earth.

Each chapter in this book begins with learning outcomes and ends with chapter concept map. The learning outcomes of the chapters are more or less in sequence and are explained in straight forward language. Photographs and full-colour illustrations are provided to support the text, with annotations to elaborate the context and functions. Review questions at the end of each chapter will definitely aid students to review and assess their ability of attaining knowledge. Scientific terms in Biology are explained thoroughly in this text. Most of the terms are given in the glossary. References are also provided for further reading to gain more knowledge.

Studying this book will result in students gaining much knowledge on Biology and able to do critical thinking, reasoning and analyzing logically. It is hoped that students will be able to participate successfully in 21st century learning based on the skills through the 5 C's:

Collaboration – in lessons, students will be learning to work in groups, share ideas with their classmates and find out the solutions together

Communication – students will develop verbal and non-verbal communication skills in group works

Critical thinking and Problem solving – students will be given interesting problems to solve – finding and explaining solutions, looking for errors

Creativity and Innovation – thinking ‘outside the box’ is an important 21st century skill. Students will be encouraged to explore new ideas and solve problems in new ways

Citizenship – students will join the school community and develop fairness and conflict resolution skills.

The contents in the textbook include Chapter 1: Introduction to Biology, Chapter 2: Cell Structure and Organization, Chapter 3: Support and Locomotion, Chapter 4: A Body System to Sustain Life and Chapter 5: Continuation of Life.

After the completion of Grade 10, students will be able to describe the context in this text conceptually, explain the importance of life processes, discuss the inheritance of new generations and be able to carry out all types of experiments skillfully in the laboratory.

CHAPTER 1 INTRODUCTION TO BIOLOGY

Learning Outcomes

It is expected that students will

- explain how the study of biology is important in daily life
- identify the common characteristics of living things
- know how living things are classified into three domains and six kingdoms

1.1 THE STUDY OF BIOLOGY

Biology is the study of living things. A large variety of living things exists on the land, in the water and in the air. Living things (organisms) include plants, animals including humans and other organisms. Thus, biology deals with the study of all organisms that live or have ever lived on the earth.

1.1.1 The Importance of Biology in Everyday Life

Biology is very fundamental and important science dealing with bacteria, protista, fungi, plants and animals including humans. Their structures and functions are associated with one another in their respective environments. To a great extent, we owe our daily high standard of living to biological advances in two areas: food production and disease control.

Plant and animal breeders have modified organisms to yield greater amounts of food than did older varieties. The improvements in the plants, along with better farming practices, have greatly increased food production.

Biological research has also improved food production by developing controls for the disease organisms, pests and weeds that reduce yields. Biologists must understand the nature of these harmful organisms to develop effective control methods.

1.1.2 The Different Fields of Study in Biology

The main branches of biology are:

Botany	: study of plants
Zoology	: study of animals
Microbiology	: study of microscopic organisms

Some other branches of biology are:

Morphology	: study of forms and structures of organisms
Anatomy	: study of gross internal structures
Histology	: study of microscopic structures of tissues
Cytology	: study of cells
Physiology	: study of living processes or functions of the various parts of organisms
Embryology	: study of early development of organisms
Palaeontology	: study of fossils (the remains of organisms that lived millions of years ago; now preserved in rocks)

Taxonomy	: study of classification of organisms
Ecology	: study of the relationships of organisms to their environments
Biodiversity	: study of varieties among living organisms
Evolution	: study of the origin and change in forms of organisms over time
Genetics	: study of heredity and variations
Mycology	: study of fungi
Protistology	: study of protists
Phycology	: study of algae
Virology	: study of viruses
Bacteriology	: study of bacteria
Molecular Biology	: study of molecules in organisms
Biotechnology	: study of utilization of living organisms in industrial processes
Bioinformatics	: study of information technology to interpret molecular biology data

1.1.3 Characteristics of Living Things

The main characteristics of living things are their cellular structure, metabolism, growth, movement, irritability, reproduction and adaptability.

Cellular structure

All living things consist of the living substance called protoplasm which forms the basis of cells. These cells contain DNA (deoxyribonucleic acid) molecules that carry biological information. Cells of plants and animals are organized into tissues and tissues are in turn organized into organs and systems. These structures are responsible for carrying out the various life processes.

Metabolism

Metabolism is the sum of the various processes that give the organism's life. The two aspects of metabolism are anabolism and catabolism. The food material is made into a part of the organism in the process of anabolism. The food material, when broken down, releases energy and results in the formation of waste products. This process is termed as catabolism. The important metabolic processes that take place in organisms involve the utilization of food. This includes nutrition, respiration and excretion.

Growth

The growth of an organism is seen as an increase in size and weight resulting from the use of food to further develop structures in the organism.

Movement

All living things show some kinds of movement. This is more obvious in animals since they have organs of movement or locomotion. Movements in plants mainly take place inside the cells although some results from a stimulus such as light.

Irritability

Living things respond to stimulus. The stimulus can be any changes in the environment (light, sound, touch, temperature, etc.) which brings about a reaction in an organism due to a sensitivity to the stimulus.

Reproduction

Reproduction is the production of a new generation of offspring. The two types of reproduction are asexual reproduction and sexual reproduction. In asexual reproduction, the new individual may be produced by a part of the old one. There is only one parent organism needed for asexual reproduction.

Sexual reproduction produces a new individual as a result of the fusion of two parental sex cells. These two cells come, one from each individual of the same species. The cells are fused to form a single new organism.

Adaptability

Living organisms are able to adjust and adapt themselves to changes in their external and internal environments. Adaptability increases the chances of species surviving and can result in the formation of a new species. For instance, a change of seasons or a shortage of food may cause certain birds to migrate to another place where the conditions are more favourable. A plant may grow very straight and upright to stand above plants around it. This enables this plant or plant species to get enough sunlight to survive and even to dominate the environment.

1.2 TAXONOMY

The science of classification of organisms is taxonomy. This is the general name for groups or categories within a classification system.

1.2.1 Diversity of Organisms

There are vast numbers of living things in the world. The word 'biodiversity' is a short form of 'biological diversity' which means that the abundance of different types of species.

Scientists are not aware just how many different types of organisms exist in nature. It is because, previously unknown species are being discovered all the time.

1.2.2 Taxonomy in the Study of Biology

Classification is essential to biology because there are too many different living things to sort out and compare unless they are organized into manageable categories. With an effective classification system in use, it is easier to organize the ideas about organisms and make generalizations.

The scheme of classification has to be flexible, allowing newly discovered living organisms to be added into the scheme where they fit best. As living and extinct species are related, fossils should also be considered in this scheme.

The process of classification involves:

- giving every organism an agreed name
- placing the organism into a group based on the common characteristics it shares with others in the group.

1.2.3 The Importance of Taxonomy

By taxonomy, it is much easier to learn biology as there are millions of known and unknown organisms. Taxonomy can be used to examine the evolutionary history of organisms and the relationships between organisms.

1.2.4 Taxonomic Hierarchy

Biological classification schemes are the invention of biologists, based upon the best available evidence at that time. In classification, the aim is to use as many characteristics as possible in placing similar organisms together. Just as similar **species** are grouped together into the same **genus** (*plural* genera).

Similar genera are grouped together into **families**. This approach is extended from families to **orders**, then **classes**, **phyla** or **divisions** and **kingdoms**. This is the hierarchical scheme of classification, each successive group containing more and more different kinds of organisms. When a classification of a species is written, it starts with the kingdom followed by other taxonomic ranks of division or phylum, class, order, family, genus and species.

For examples,

Kingdom	: Plantae	Kingdom	: Animalia
Division	: Magnoliophyta	Phylum	: Chordata
Class	: Monocotyledons	Class	: Mammalia
Order	: Cyperales	Order	: Primates
Family	: Poaceae	Family	: Hominidae
Genus	: <i>Oryza</i>	Genus	: <i>Homo</i>
Species	: <i>O. sativa</i>	Species	: <i>H. sapiens</i>

1.2.5 Classification of Plants and Animals

Everyone must be able to identify objects and to relate their observations to other people. Most people are familiar with some of the common forms of plants and animals. However, since there are so many different kinds of plants as well as animals, the word 'plant' or 'animal' is not sufficient for identification.

Linnaeus (1707-1778), a Swedish naturalist, studied and gave scientific names to thousands of plants and animals. He introduced the **Binomial System of Nomenclature** in the year 1753. Each plant and animal is given a two-word name by this system. The first name is the **genus** and the second is the **species**. The name of the genus is always started with a capital letter and the name of the species is started with a small letter. These two names constitute the scientific name of the organism. For example, the scientific name of human is *Homo sapiens* and that of paddy plant is *Oryza sativa*.

1.3 KINGDOMS

A **Kingdom** is a subdivision of a **Domain**. The living things are classified and placed in one of the six kingdoms. The three domains - **Bacteria**, **Archaea** and **Eukarya** diverged early in the history of life. Subsequently, many new kinds of organisms have evolved. Each of these kingdoms has its own set of characteristics.

1.3.1 Kingdoms of Living Things

Organisms are divided into six kingdoms. There are two kingdoms within the domains **Archaea** and **Bacteria**, namely kingdoms **Archaeobacteria** and **Eubacteria**. Their differences are based primarily on the metabolism and genetic composition of the organisms. Within the domain **Eukarya**, there are four kingdoms: **Protista**, **Fungi**, **Plantae** and **Animalia** (Table 1.1 and Figure 1.1).

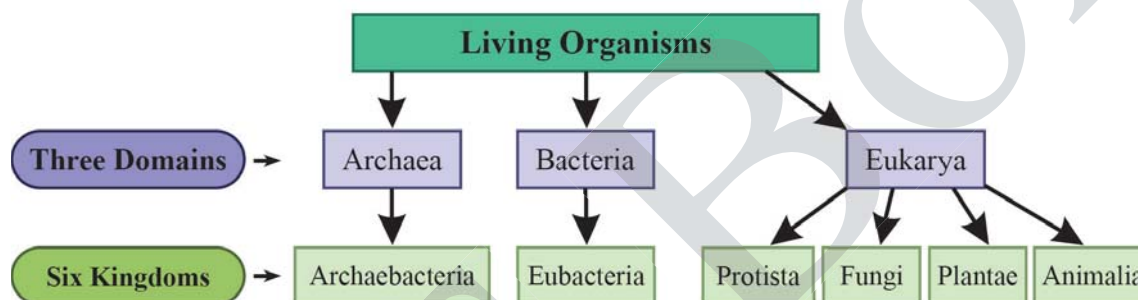


Figure 1.1 Relationship between three domains and six kingdoms of classification

Table 1.1 Characteristics of six kingdoms




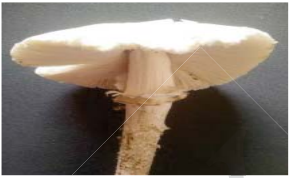


Kingdoms	Characteristics	Examples	Diagrams
Archaeobacteria	<ul style="list-style-type: none"> - Primitive - Live in extreme environment - Prokaryote - Unicellular - Obligate anaerobic 	Thermophiles Methanogens	 <p>Thermophiles</p>
Eubacteria	<ul style="list-style-type: none"> - Prokaryote - Unicellular - Autotrophs or heterotrophs - Asexual reproduction by fission 	Bacteria Cyanobacteria	 <p>Bacteria</p>
Protista	<ul style="list-style-type: none"> - Eukaryote - Unicellular - Autotrophs or heterotrophs - Asexual or sexual reproduction 	<i>Amoeba</i> <i>Euglena</i> Slime mold <i>Paramecium</i>	 <p><i>Paramecium</i></p>

Table 1.1 Characteristics of six kingdoms (continued)

Kingdoms	Characteristics	Examples	Diagrams
Fungi	<ul style="list-style-type: none"> - Eukaryote - Unicellular or multicellular - Heterotrophs - Asexual or sexual reproduction 	Yeast <i>Rhizopus</i> Mushroom	 Mushroom
Plantae	<ul style="list-style-type: none"> - Eukaryote - Multicellular - Autotrophs - Vegetative, asexual or sexual reproduction 	Algae Liverworts Mosses Ferns Conifers Angiosperms	 Angiosperm
Animalia	<ul style="list-style-type: none"> - Eukaryote - Multicellular - Heterotrophs - Asexual or sexual reproduction 	Earthworms Insects Fish Birds Mammals	 Mammal

Viruses

Viruses are not included in the six kingdoms of living organisms. Viruses, although not considered as living organisms, cause common diseases such as colds and influenza (Figure 1.2) and also more serious ones such as AIDS (Acquired Immune Deficiency Syndrome).

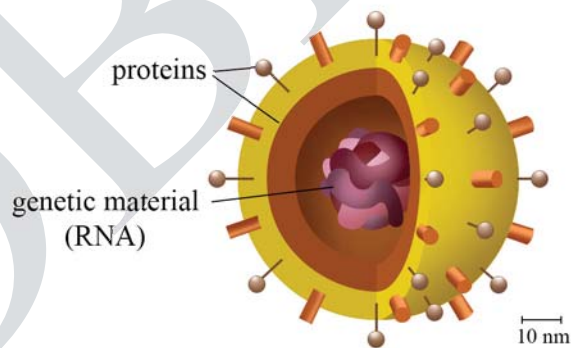


Figure 1.2 An influenza virus

Characteristics of viruses

1. Viruses are not generally considered to be alive.
2. They are very small (20-400 nm) non-cellular particles.
3. Each virus particle contains DNA or RNA covered by a protein coat.

4. They are parasites and causing diseases in plants and animals.
5. Virus in infected cells can make copies of themselves for reinfection in other host cells.
6. Viruses cannot move, feed, excrete, show sensitivity or grow and can reproduce only in the living host cells.
7. Virus cannot survive outside the host cells.

1.3.2 Kingdom Protista

The term protist means “any eukaryotic organism that is not a plant, animal or fungus”. About 60,000 protist species have been described. They are the most diverse of the four kingdoms in the domain Eukarya. The kingdom Protista contains unicellular and colonial groups.

Characteristics of protista

1. They live in water, but a few species live in moist area. Some can even live in the human intestine.
2. Nucleus and other organelles are present.
3. Movement is often by flagella, cilia or pseudopodia.
4. Contractile vacuole helps the cell remove excess water.
5. They reproduce asexually by fission, budding or fragmentation.
6. Most protists can be divided into three main groups based on their characteristics:
 - a. **Plant-like protists** – contain chlorophyll in chloroplasts and make their own food (autotrophs) (e.g., *Euglena*).
 - b. **Animal-like protists** – no chlorophyll, feed on other organisms (heterotrophs) and can move from place to place (e.g., *Amoeba*).
 - c. **Fungus-like protists** – no chlorophyll, feed on dead organic matter (heterotrophs) and lack chitin in their cell walls (e.g., slime mold, water mold).

The protists include six general groups according to the characteristics (Table 1.2).

Table 1.2 Divisions/Phyla of protists

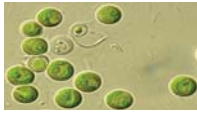

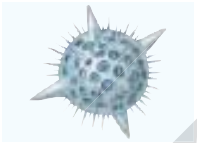


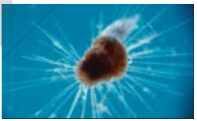
Divisions/Phyla	Characteristics	Examples
AUTOTROPHIC PROTISTS		
Chlorophyta	- Photosynthetic, unicellular, without flagella, contains chlorophylls	 <i>Chlorella</i>
Euglenophyta	- Some photosynthetic, others heterotrophic, unicellular, contains chlorophylls or none	 <i>Euglena</i>

Table 1.2 Divisions/Phyla of protists (continued)

Divisions/Phyla	Characteristics	Examples
HETEROTROPHIC PROTISTS		
Chrysophyta	- Unicellular, manufactures the carbohydrate chrysolaminarin, unique double shells of silica, contains chlorophylls	 <i>Diatom</i>
Rhizopoda	- Movement by pseudopodia, lack chromatophores (pigment containing cells), possess a single nucleus, asexual reproduction by binary fission	 <i>Amoeba</i>
Actinopoda	- Glassy skeletons, needle-like pseudopods	 <i>Actinosphaerium</i>
Foraminifera	- Rigid shells, move by protoplasmic streaming	 <i>Podia</i>

1.3.3 Kingdom Fungi

Characteristics of fungi

1. A collection of hyphae, thin thread-like filaments form the mycelia.
 2. Chlorophyll is absent and unable to carry out photosynthesis.
 3. They grow as parasites on other organisms or as saprophytes on decaying organic matter in the soil and water.
 4. Cell wall of hypha is made up of chitin.
 5. They reproduce in a variety of ways: vegetatively, asexually or sexually.
- The fungi are subdivided into five divisions (Table 1.3).

Table 1.3 Divisions of fungi

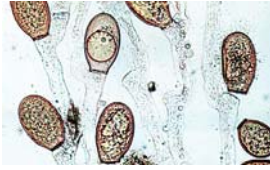

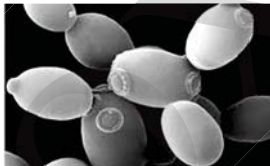


Divisions	Characteristics	Examples
Chytridiomycota	- The simplest and most primitive form - Coenocytic hyphae (no septum) - Unicellular or multicellular - Sexual or asexual reproduction	 <i>Chytrids</i>

Table 1.3 Divisions of fungi (continued)

Divisions	Characteristics	Examples
Zygomycota	<ul style="list-style-type: none"> - Conjugated fungi - Aseptate hyphae with many nuclei (coenocytic) - Formation of zygospore in sexual reproduction 	 <p style="text-align: center;"><i>Rhizopus</i></p>
Ascomycota	<ul style="list-style-type: none"> - Sac fungi - Hypha is septate and branched except in yeast (unicellular). - Mostly reproduce by budding 	 <p style="text-align: center;">Yeast</p>
Basidiomycota	<ul style="list-style-type: none"> - Club fungi - Unicellular or multicellular - Sexual or asexual reproduction - Club-shaped fruiting bodies (basidia) present 	 <p style="text-align: center;">Mushroom</p>
Deuteromycota	<ul style="list-style-type: none"> - Imperfect fungi - Septate hyphae - Strictly asexual reproduction by means of conidia 	 <p style="text-align: center;"><i>Penicillium</i></p>

1.3.4 Kingdom Plantae

Characteristics of plantae

1. Plants are eukaryotic and chlorophyll containing organisms.
2. They obtain their energy from sun through photosynthesis.
3. Cell wall of plant is composed of cellulose.
4. Plants reproduce by vegetative, asexual and sexual methods.
5. In life cycle of plants, interchanges occur from the embryo and are supported by other tissues.
6. They lack motility.

The plantae are subdivided into five divisions (Table 1.4).

Table 1.4 Divisions of plantae

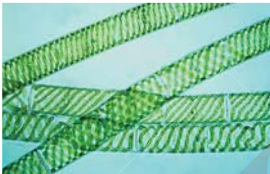







Divisions	Characteristics	Examples
Thallophyta	<ul style="list-style-type: none"> - Plant body is simple (thallus). - Grow in water, on damp soil, on wet rocks and on tree trunks - Vascular system absent - Reproduce by means of asexual or sexual - No embryo formation 	 <p><i>Spirogyra</i></p>
Bryophyta	<ul style="list-style-type: none"> - Most primitive land plants - Grow on damp and shaded soil - Thallus dorsiventral with thread-like rhizoids - No vascular system - Have parenchymatous tissue - Sporophyte upright, foliose type - Life cycle of bryophytes shows two distinct generations (gametophytic and sporophytic generations). - Those two generations regularly alternate with each other in a single life cycle, is called alternation of generations. 	 <p>Liverworts (<i>Riccia</i>)</p>  <p>Hornworts (<i>Anthoceros</i>)</p>  <p>Mosses (<i>Funaria</i>)</p>
Pteridophyta	<ul style="list-style-type: none"> - More advanced than bryophytes - Grow chiefly in shaded moist places - Differentiated into rhizome, rachis and pinna - A well-developed vascular system - Reproduction by spores - Life cycle shows distinct alternation of generations. 	 <p>Ferns (<i>Adiantum</i>)</p>
Gymnospermae	<ul style="list-style-type: none"> - Woody, non-flowering plants - Seed-bearing vascular plants - Seeds are not enclosed in a fruit. - Seeds develop either on the surface of scale or leaf-like appendages known as sporophylls. 	 <p>Coniferous trees (Pine)</p>

Table 1.4 Divisions of plantae (continued)

Divisions	Characteristics	Examples
Angiospermae	<ul style="list-style-type: none"> - Flowering vascular plants - The plants with roots, stems and leaves - Widely distributed on the earth's surface - Reproduce by means of flowers, fruits and seeds - Seeds are produced inside the ovary of the flower. - Seed with one cotyledon (monocots) - Seed with two cotyledons (dicots) 	 <p>Monocots (Maize)</p>  <p>Dicots (Mango)</p>

1.3.5 Kingdom Animalia

Animals are multicellular and heterotrophic organisms. Animals are divided into two main groups: those that do not have a backbone (vertebral column) are grouped as invertebrates and those that have a backbone are grouped as vertebrates. Invertebrates make up more than 95 percent of all animal species alive today (Table 1.5 and 1.6).

Table 1.5 Major phyla of invertebrates


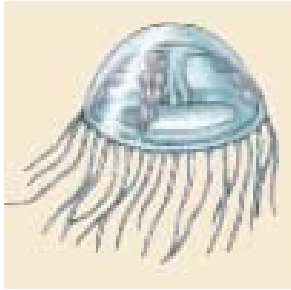
Phyla	Characteristics	Examples
Porifera	<ul style="list-style-type: none"> - Asymmetrical - Pore-filter feeders - Not motile (sessile) - Consists of two cell layers only; ectoderm and endoderm with mesoglea (non-cellular layer) between them (e.g., sponges) 	 <p>Sponge</p>
Cnidaria	<ul style="list-style-type: none"> - Radial symmetry - Two cell layers only; ectoderm and endoderm with mesoglea between them - Body plan is with sessile polyp (vase-shaped) or motile medusa (inverted bowl-shaped). - Gastrovascular cavity present - All have stinging cells (e.g., corals, jellyfish) 	 <p>Jellyfish</p>

Table 1.5 Major phyla of invertebrates (continued)







Phyla	Characteristics	Examples
Platyhelminthes	<ul style="list-style-type: none"> - Bilateral symmetry - Cephalization with head and brain - Three distinct cell layers (ectoderm, mesoderm and endoderm) - Acoelomate (no body cavity) - Incomplete digestive system (one opening) - Some are parasitic and others free living (e.g., tapeworm, flatworm) 	 <p>Tapeworm</p>
Nematoda	<ul style="list-style-type: none"> - Bilateral symmetry - Cephalization with head and brain - Three distinct cell layers (ectoderm, mesoderm and endoderm) - Pseudocoelomate - Complete digestive system with separate mouth and anus (2 openings) - Many are parasitic (e.g., roundworms) 	 <p>Roundworm</p>
Annelida	<ul style="list-style-type: none"> - Bilateral symmetry and segmented - Cephalization with head and brain - Three distinct cell layers (ectoderm, mesoderm and endoderm) - True coelom present, coelomate (e.g., earthworms, leeches) 	 <p>Earthworm</p>
Mollusca	<ul style="list-style-type: none"> - Bilateral symmetry - Three distinct cell layers (ectoderm, mesoderm and endoderm) - Have soft body with or without shell (e.g., snails, slugs, clams, mussels, scallops, oysters, octopuses, squids) 	 <p>Snail</p>

Table 1.5 Major phyla of invertebrates (continued)

Phyla	Characteristics	Examples
Arthropoda	<ul style="list-style-type: none"> - Bilateral symmetry with jointed appendages - Three distinct cell layers (ectoderm, mesoderm and endoderm) - Exoskeleton present (e.g., insects, spiders and scorpions, shellfishes (crustaceans), centipedes (one pair of leg per segment), millipedes (two pairs of leg per segment)) 	 <p style="text-align: center;">Insect</p>
Echinodermata	<ul style="list-style-type: none"> - Bilateral symmetry in embryo and radial symmetry in adult - Three distinct cell layers (ectoderm, mesoderm and endoderm) - Water vascular system present - Tube feet present on arms (e.g., starfishes, sea urchins, sea cucumbers) 	 <p style="text-align: center;">Starfish</p>

Phylum Chordata (Vertebrata)

All the chordates have bilateral symmetry with three cell layers (ectoderm, mesoderm and endoderm) and dorsal hollow nerve cord. In addition, they all have notochord, pharyngeal gill slits and tail in embryo or in adults. The body of most of the vertebrates is divided into head, trunk and tail (Table 1.6).

Table 1.6 Major groups of vertebrates






Groups	Characteristics	Examples
Fish	<ul style="list-style-type: none"> - Vertebrates with scaly skin, except a few are scaleless - Live in water - Have gills - Have fins for swimming - Poikilothermic (e.g., bony and cartilaginous fish) 	 <p style="text-align: center;">Fish</p>

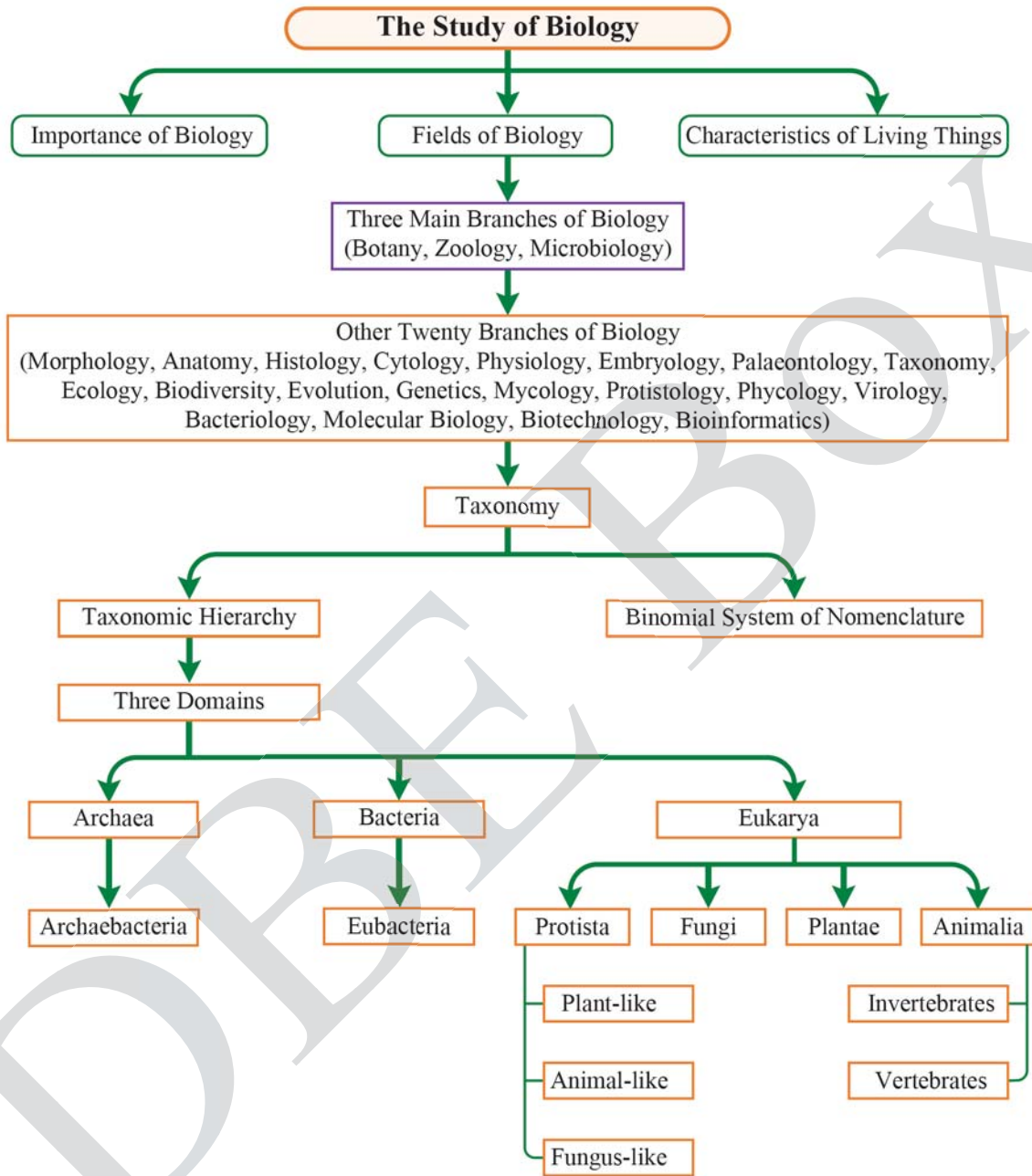
Table 1.6 Major groups of vertebrates (continued)

Groups	Characteristics	Examples
Amphibians	<ul style="list-style-type: none"> - Vertebrates with moist, scaleless skin - Larva has gills and adult has lungs. - Poikilothermic - Eggs laid in water, larva (tadpole) lives in water which metamorphoses into adult. - Adult often lives on land (e.g., frogs, newts and salamanders). 	 <p>Frog</p>
Reptiles	<ul style="list-style-type: none"> - Vertebrates with scaly skin, some limbless - Lungs present - Poikilothermic - Lay eggs with shells (e.g., lizards, snakes, turtles) 	 <p>Snake</p>
Birds	<ul style="list-style-type: none"> - Vertebrates with feathers and beak - Forelimbs have become wings for flight. - Lungs present - Homoiothermic - Lay eggs with hard shells (e.g., birds) 	 <p>Bird</p>
Mammals	<ul style="list-style-type: none"> - Vertebrates with hair - Have different types of teeth (incisors, canines, premolars and molars) - Have lungs and diaphragm - Homoiothermic - Have a placenta and young feed on milk from mammary glands (e.g., cats, dogs, humans) 	 <p>Wild cat</p>

Review questions

1. What are the main branches of biology?
2. State the different fields of biology and their definitions.
3. Explain the term taxonomy in your own words.
4. Define the term biodiversity.
5. Why are living organisms grouped into domains, kingdoms and lower category hierarchies?
6. Briefly explain what is meant by the Binomial System of Nomenclature.
7. Write down the names of the three domains and the six kingdoms.
8. Distinguish eubacteria from archaeobacteria citing major differences and similarities.
9. Explain how living things have been separated into six kingdoms.
10. Explain why Protists could be considered as animals.
11. Explain why Protista are classified separately from Animalia.
12. Can heterotrophic Protists be placed under a single phylum? Explain your reasoning.
13. State the characteristics of Fungi.
14. What are the characteristics of Bryophyta with examples?
15. Describe the nature of flowering plants.
16. Describe the characteristics that allow nematodes to be distinguished from platyhelminth worms.
17. Where can you find metamorphosis among the vertebrates? Give examples.

Concept map



CHAPTER 2

CELL STRUCTURE AND ORGANIZATION

Learning Outcomes

It is expected that students will

- distinguish between the prokaryotic and eukaryotic cells by reviewing their common characteristics, roles and functions
- examine cellular components and describe their characteristics and functions
- study how cells are organized into tissues, organs and organ systems

2.1 CELLS AS THE BUILDING BLOCKS OF LIFE

All living organisms are composed of basic functional units called cells. The simplest organisms are made up of the single cells which perform all the functions of life. The complex organisms are composed of millions of cells. In multicellular (many-celled) organisms, there may be hundreds of different types of cells with different structures. They are specialized to carry out particular functions in plants or animals.

Cells are made up of a number of different subunits called organelles. These subunits are often of a particular size but all are microscopically small. So that a microscope with a high magnification and resolution is needed to observe cells and their subunits.

2.1.1 The Cell Theory

The basic principles of the cell theory are:

1. Cells are the building blocks or basic structures in all living things.
2. Cells are the smallest units of living things, they are the basic units of organization of all organisms.
3. All cells are derived from other cells (pre-existing cells) by means of division.
4. Cells contain a blueprint (i.e. information) outlining their growth, development and function.
5. Within cells, there are sites and structures where the chemical reactions of life occur (metabolism).

2.1.2 Prokaryotic and Eukaryotic Cells

Both types of cells are bounded by the plasma membrane which is semipermeable. Inside the cells is a semifluid jelly-like substance called cytoplasm, in which cellular organelles are suspended. All cells contain chromosomes which carry genes in the form of DNA. All cells have ribosomes, tiny organelles that make proteins according to instructions from the genes.

The cells of bacteria and archaea are prokaryotic (Figure 2.1) while those of protists, fungi, plants and animals are eukaryotic (Figure 2.2 and 2.3). Prokaryotic cells evolved before eukaryotic cells and they lack a true nucleus. A membrane bounds the nuclear materials of a true nucleus. Eukaryotic cell possesses a true nucleus. Prokaryotic cell possesses nuclear materials but lacks a nuclear membrane. Prokaryotic cells are 0.1 - 5.0 μm in diameter while eukaryotic cells are typically 10 - 100 μm in diameter.

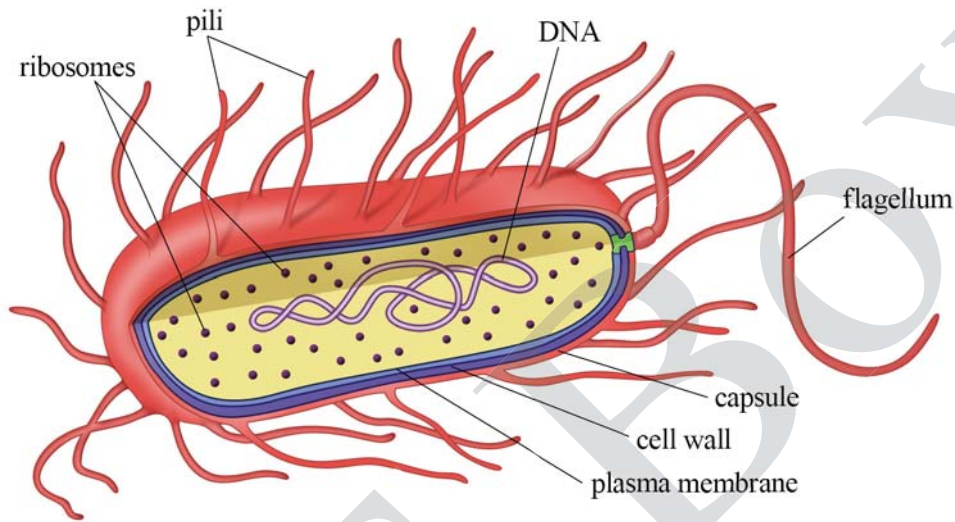


Figure 2.1 Prokaryotic cell: a rod-shaped bacterium

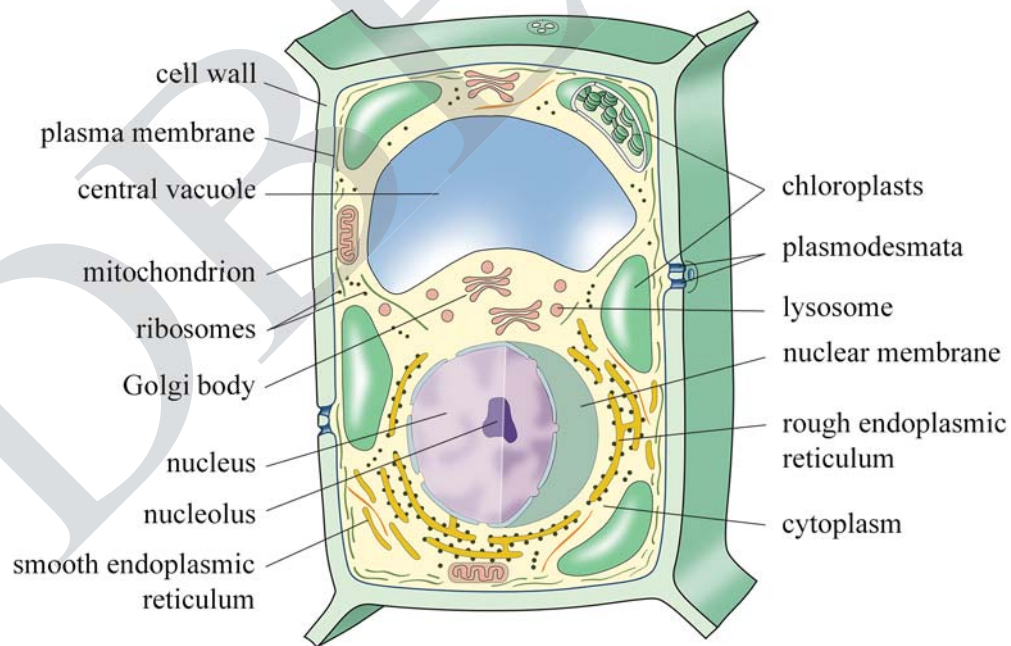


Figure 2.2 Eukaryotic cell: a plant cell

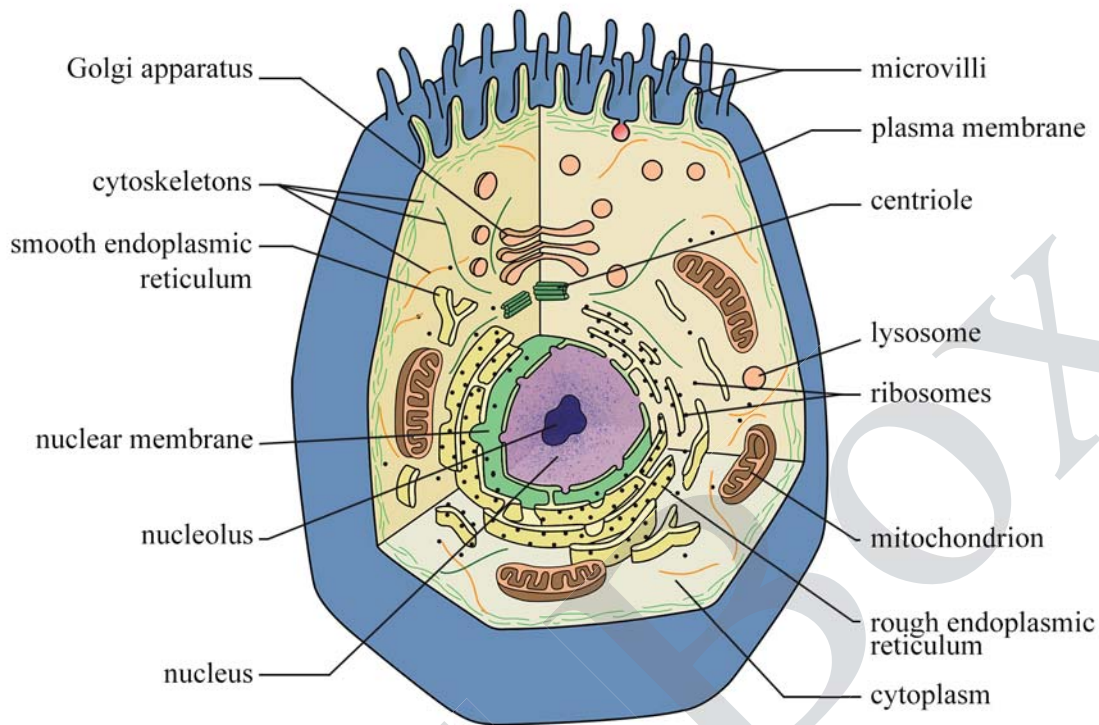


Figure 2.3 Eukaryotic cell: an animal cell

The major difference between prokaryotic and eukaryotic cells is the location of their DNA. In a eukaryotic cell, most of DNA is in the nucleus, which is bounded by a double membrane. In a prokaryotic cell, the DNA is concentrated in a region that is not membrane bound called the nucleoid, which is part of cytoplasm. The DNA of prokaryotic cell is circular and contains only nucleic acid with no proteins while that of eukaryotic cells is linear and made up of nucleic acid and the proteins called **histones**.

Membrane bounded organelles are present in eukaryotic cell, whereas membrane bounded organelles are not present in prokaryotic cell. In eukaryotes, cell walls are absent except in plants and fungi. In prokaryotes, cell walls are present (Table 2.1).

Table 2.1 Comparison between the structure of prokaryotic and eukaryotic cells

Prokaryotic cell	Eukaryotic cell
- Average diameter is 0.1 - 5 μm .	- Average diameter is 10 - 100 μm .
- Single copy DNA present and it is circular and contains only nucleic acid with no proteins.	- Multiple copies DNA present - They are linear and made up of nucleic acid and proteins.
- DNA is located in the cytoplasm.	- DNA is located in the nucleus, chloroplasts and mitochondria.
- Nucleus absent	- Nucleus present
- Ribosomes are about 20 nm in size.	- Ribosomes are about 25 nm in size.
- No membrane bounded organelles	- Membrane bounded organelles present
- Cell wall present which is made up of murein, a peptidoglycan	- Cell wall present in plants and fungi only - In plants, it is made up of cellulose or lignin while in fungi, it is made up of chitin. Cell wall absent in animal cell.

2.2 EUKARYOTIC CELL STRUCTURE

Plant and animal cells have common features which include a **plasma membrane** (cell membrane), a **nucleus** and **cytoplasm**. Not all the ultrastructures of a cell are seen with a light microscope.

2.2.1 Differences in Cell Structure

Cells of different organisms and even cells within the same organisms are very diverse in terms of shape, size, internal organization and function. One theme that occurs repeatedly throughout biology is that form follows function. In other words, a cell's function influences its physical features. The diversity in cell shape and structure reflects the different functions of cells.

2.2.2 Cell Components

Most plant and animal cells contain certain parts such as the nucleus, cytoplasm and cell membrane. But other cell components may be present or absent in plant and animal cells (Table 2.2).

Table 2.2 Summarized account of the components found in plant and animal cells

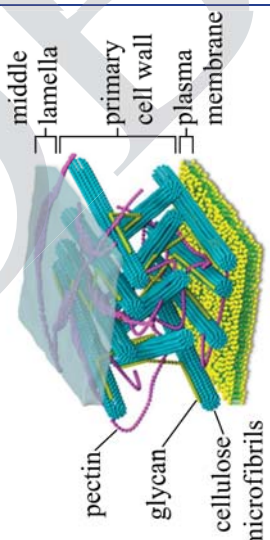
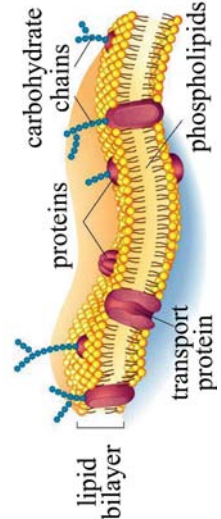
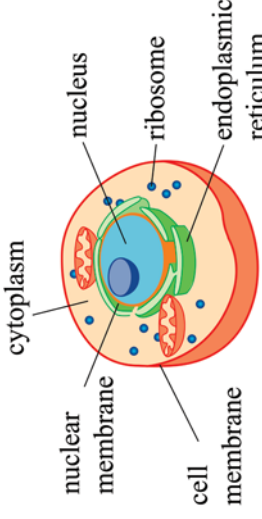
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
<p>Cell wall</p> 	<ul style="list-style-type: none"> - Outside the cell membrane 	<ul style="list-style-type: none"> - A structural layer surrounding some types of cells, just outside the cell membrane 	<ul style="list-style-type: none"> - Give the cell strength and structure, and to filter molecules that pass in and out of the cell 	Present	Absent
<p>Cell membrane (Plasma membrane)</p> 	<ul style="list-style-type: none"> - Around the cytoplasm 	<ul style="list-style-type: none"> - Phospholipid bilayer with proteins attached to or embedded in it 	<ul style="list-style-type: none"> - Surround the cell - Act as partially permeable membrane 	Present	Present
<p>Cytoplasm</p> 	<ul style="list-style-type: none"> - Outside of the nucleus and within the cell membrane 	<ul style="list-style-type: none"> - Jelly like structure, in which organelles are embedded 	<ul style="list-style-type: none"> - Act as a site for chemical reactions to take place - Hold the organelles 	Present	Present

Table 2.2 Summarized account of the components found in plant and animal cells (continued)

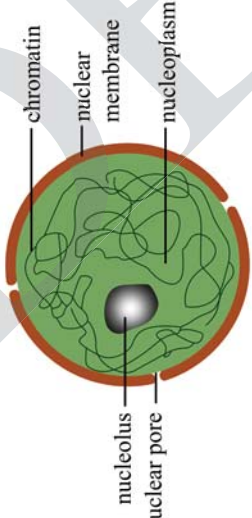
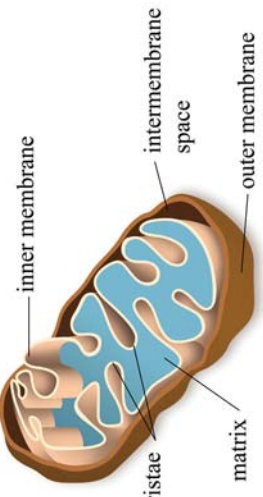
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
<p>Nucleus</p>  <p>chromatin nucleolus nuclear pore nuclear membrane nucleoplasm</p>	<p>- Inside the cytoplasm</p>	<p>- A circular (or) oval structure</p>	<p>- Control the cell's activities</p>	<p>Present</p>	<p>Present</p>
<p>Mitochondrion</p>  <p>cristae matrix inner membrane intermembrane space outer membrane</p>	<p>- Inside the cytoplasm</p>	<p>- Rod (or) spherical shape</p>	<p>- Aerobic respiration - Acts as a site for synthesis of lipids - Generate ATP as energy molecules</p>	<p>Present</p>	<p>Present</p>

Table 2.2 Summarized account of the components found in plant and animal cells (continued)

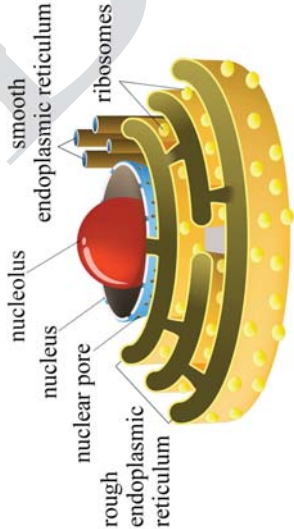
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
Endoplasmic reticulum (ER) (Smooth ER, Rough ER) 	<ul style="list-style-type: none"> - Inside the cytoplasm 	<ul style="list-style-type: none"> - A network of tubules and flattened sacs - Smooth ER; its outer surface lacks ribosomes - Rough ER is studded with ribosomes on the outer surface of its membrane 	<ul style="list-style-type: none"> - Continuous with the outer membrane of the nuclear envelope - Smooth ER: synthesis of lipids, metabolism of carbohydrates, calcium storage, detoxification of drugs and poisons - Rough ER: aids in synthesis of secretory and other proteins on bound ribosomes; adds carbohydrates to proteins to make glycoproteins; produces new membrane 	Present	Present

Table 2.2 Summarized account of the components found in plant and animal cells (continued)

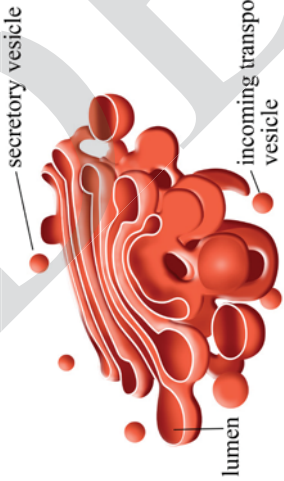
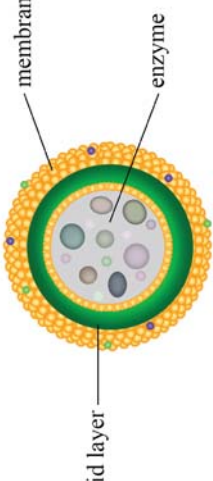
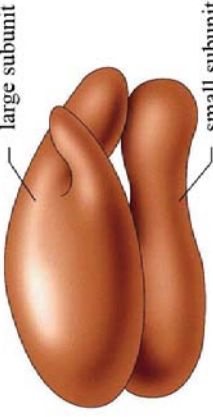
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
<p>Golgi apparatus</p> 	<ul style="list-style-type: none"> - Located very near the rough endoplasmic reticulum and hence near the nucleus 	<ul style="list-style-type: none"> - A stack of flattened sacs 	<ul style="list-style-type: none"> - Collect, process and sorts molecules - Convert sugars into cell wall components - Make lysosomes 	Present	Present
<p>Lysosome</p> 	<ul style="list-style-type: none"> - Inside the cytoplasm 	<ul style="list-style-type: none"> - Spherical sacs - Surrounded by a single membrane and having no internal structure 	<ul style="list-style-type: none"> - Breakdown (digestion) the unwanted structures such as old organelles or even whole cells 	Present	Present
<p>Ribosome</p> 	<ul style="list-style-type: none"> - Some are attached to rough endoplasmic reticulum - Some are free in cytoplasm 	<ul style="list-style-type: none"> - Tiny organelle - Has two subunits 	<ul style="list-style-type: none"> - Protein synthesis 	Present	Present

Table 2.2 Summarized account of the components found in plant and animal cells (continued)


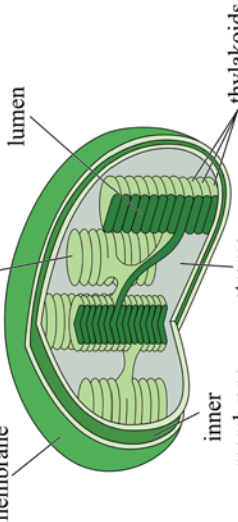
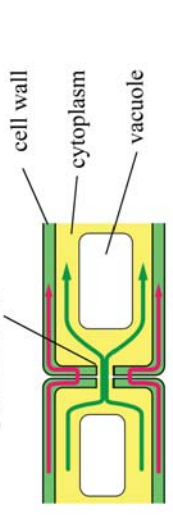
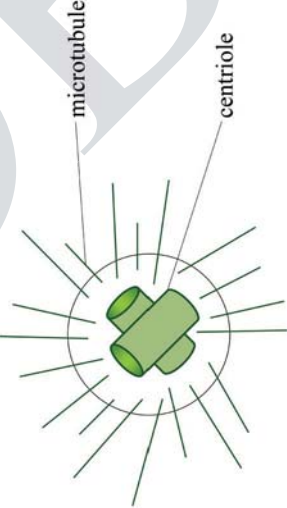
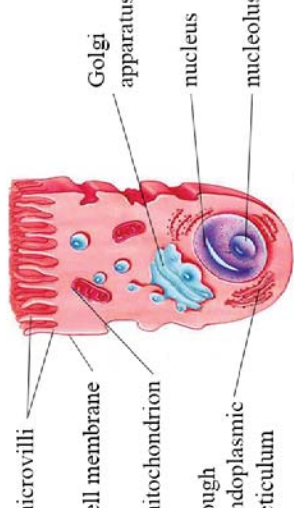
Names of components	Locations	Structures	Functions	Plant cell	Animal cell
<p>Vacuole</p> 	<ul style="list-style-type: none"> - Inside a cell 	<ul style="list-style-type: none"> - A fluid-filled space enclosed by a membrane 	<ul style="list-style-type: none"> - Control exchange between the vacuole and the cytoplasm, regulate the osmotic properties of cells 	Present	Present
<p>Chloroplast</p> 	<ul style="list-style-type: none"> - Present in the leaves 	<ul style="list-style-type: none"> - Large organelle 	<ul style="list-style-type: none"> - Photosynthesis - Generate chemical energy as glucose molecules 	Present	Absent
<p>Plasmodesmata</p> 	<ul style="list-style-type: none"> - Only in plant and algal cells 	<ul style="list-style-type: none"> - Fine strands of cytoplasm - Pass through pore-like structures 	<ul style="list-style-type: none"> - Connects the internal chemical environment of adjacent cells - Allows water and small solutes to pass freely from cell to cell 	Present	Absent

Table 2.2 Summarized account of the components found in plant and animal cells (continued)

Names of components	Locations	Structures	Functions	Plant cell	Animal cell
<p>Centrosome and centrioles</p> 	<ul style="list-style-type: none"> - Near the nucleus 	<ul style="list-style-type: none"> - Within the centrosome is a pair of centrioles - Each composed of nine sets of triplet microtubules arranged in a ring 	<ul style="list-style-type: none"> - Grow spindle microtubules for nuclear division 	Absent	Present
<p>Microvilli</p> 	<ul style="list-style-type: none"> - Located on cell surface 	<ul style="list-style-type: none"> - Finger-like extensions 	<ul style="list-style-type: none"> - Absorption (in the gut), reabsorption (in the kidney) 	Absent	Present

2.2.3 Cell Organization

Atoms are organized into molecules, molecules into organelles and organelles into cells. Cells are divided into several compartments called organelles, each with a characteristic structure, biochemical composition and function. The cell must possess enough information to specify which molecules are to be associated in a specific compartment. It is ensured to route the appropriate groups of molecules to their compartments. According to the cell theory, all living things are composed of one or more cells as unicellular and multicellular organisms.

In unicellular organisms, the single cell performs all life functions independently. In multicellular organisms, various levels of organization are present. They are made up of more than one type of cells and have specialized cells that are grouped together to carry out specialized functions. Individual cells may perform specific functions and also work together for the survival of the entire organism. The cells become dependent on one another. There are five levels of organization in multicellular organisms: cells, tissues, organs, organ systems and organisms.

Cells are the simplest level of organization. Specialized cells show division of labour by being grouped into tissues; the tissues may be further grouped into organs and the organs into systems. Each tissue, organ or system has a particular function and a structure appropriate to that function.

Tissues

A **tissue** is a group of cells with similar structures, working together to perform a particular function. In each tissue, the cells are alike, with the same characteristics of size, form and arrangement. They are specialized or differentiated both structurally and physiologically to perform some particular functions.

(A) Plant tissues

Plant tissues deal with the study of internal structure of various parts of the plant like root, stem and leaf. All these parts are made up of different kinds of tissues. The cells of a tissue generally have a common origin. In the higher plants, tissues show a division of labour and form three basic tissue systems in plants (Figure 2.4).

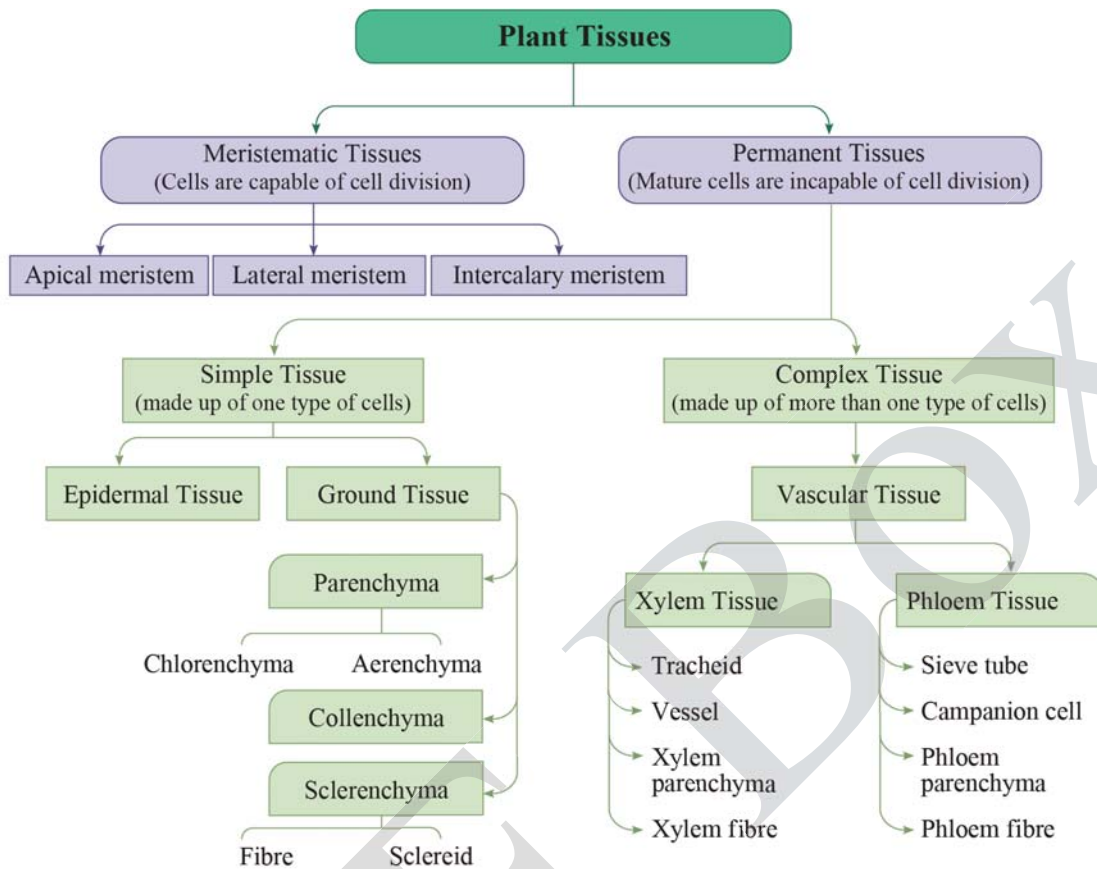


Figure 2.4 Types of tissue system in plant

Level of organization in plants

The plant body of most vascular plants is constructed from millions of tiny cells. They have characteristic shapes and functions and are grouped together to form tissues. Various types of tissues are grouped together into a structural and functional unit called an organ. The organs that perform major activity together are formed as a system.

Organs

1. Plant organs include roots, stems, leaves and flowers which consist of tissues.
2. There are less organs in plants as compared to animals.

Organ systems

1. The plant body consists of two main systems:
 - (a) The root system (underground part) - is composed of main roots and branches. These organs are formed as the absorptive system; absorb water and mineral salts from the soil.

- (b) The shoot system (above ground part) - is composed of stems, leaves, buds, flowers and fruits. The stem acts as a support system and the flower performs as a reproductive system.

Root system and shoot system work together as a plant.

(B) Animal tissues

Animal tissues can be classified into four basic groups: (1) **epithelial or covering** (2) **connective or supporting** (3) **muscle or contractile** and (4) **nervous**. Each tissue type is assembled from individual cells that determine the structure and the function of the tissue. The structure and integrity of a tissue depend on the structure and organization of the cytoskeleton within the cells, the type and organization of the extracellular matrix (ECM) surrounding the cell and the junctions holding cells together (Figure 2.5).

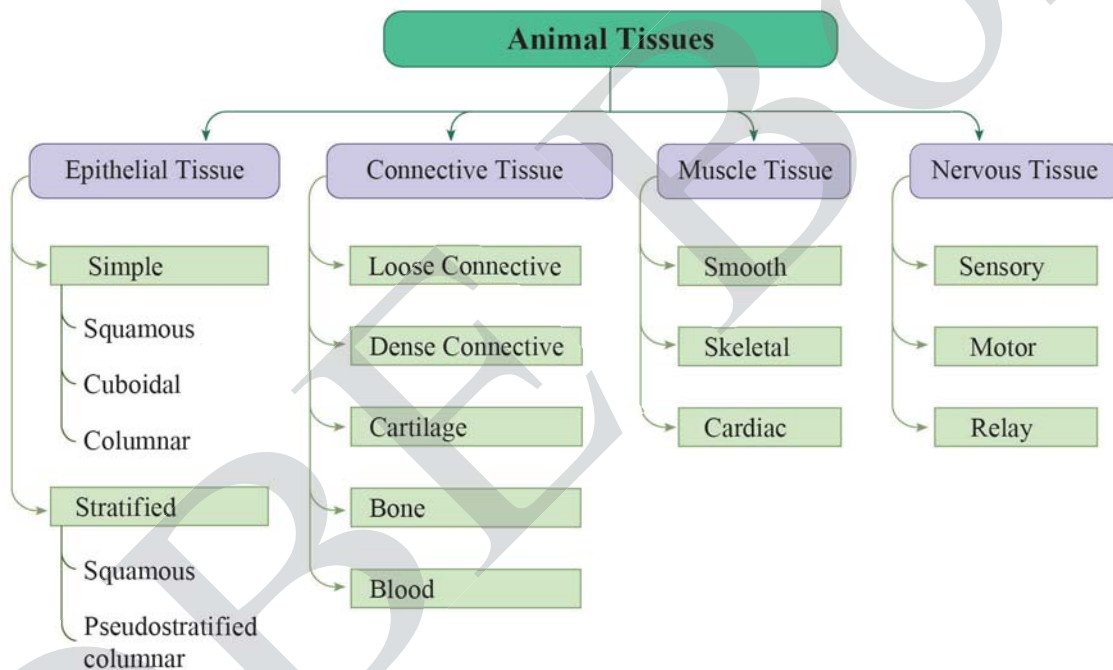


Figure 2.5 Types of tissue system in animal

Organs

Organs are body structures composed of several different types of tissues that form a structural and functional unit. One example is the heart which contains cardiac muscle, connective tissue and epithelial tissue and is laced with nerve tissue that helps to regulate the heartbeat.

Organ systems

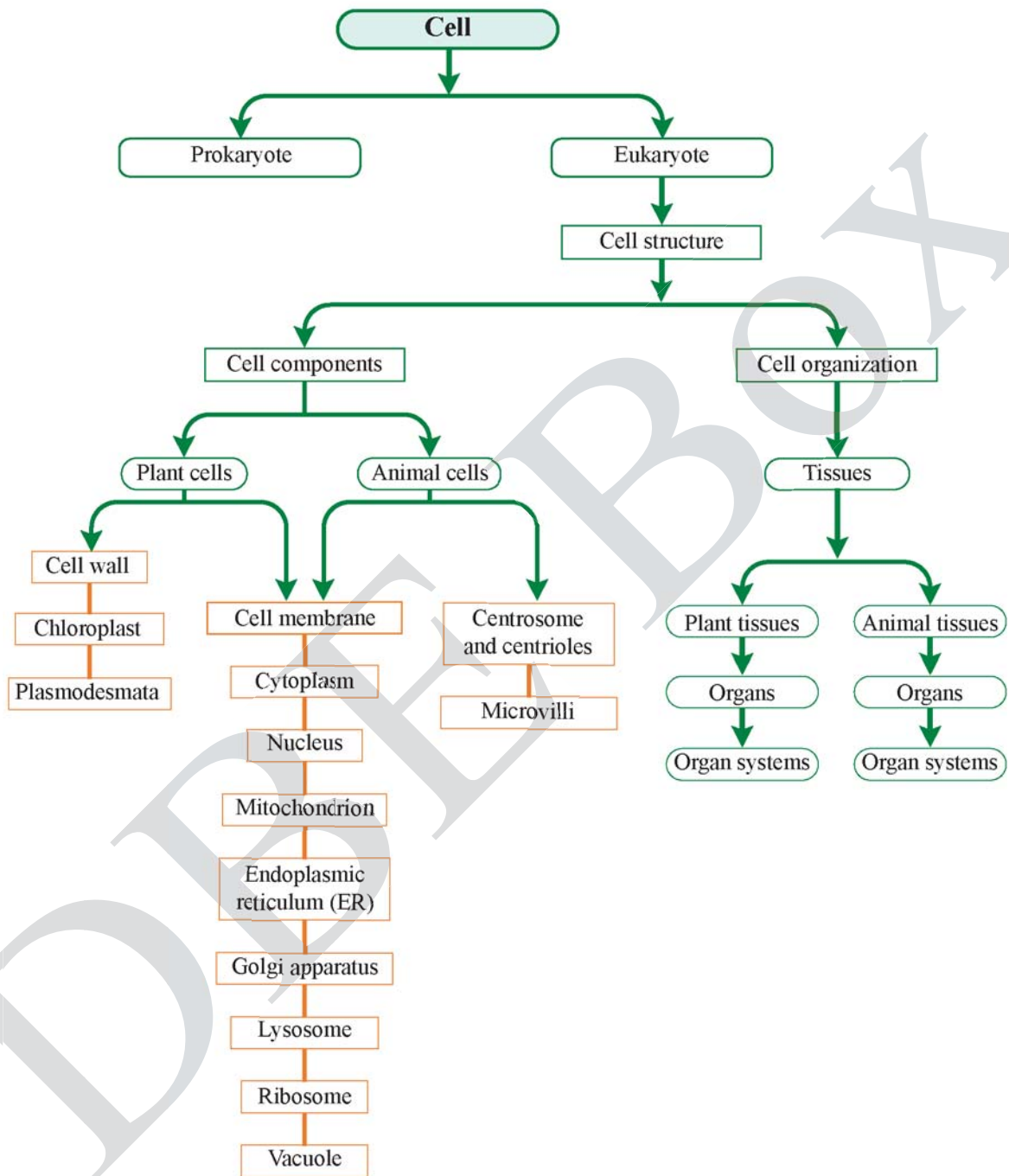
An organ system is a group of organs that function together to carry out the major activities of the body. For example the seven main systems in the human body are given below.

- (1) Digestive system - the digestive system is composed of the digestive tract, liver, gall bladder and pancreas. These organs cooperate in the digestion of food and the absorption of digested products into the body
- (2) Gas exchange system - including the lungs which exchange oxygen and carbon dioxide
- (3) Circulatory system - including the heart and blood vessels which transport materials around the body
- (4) Excretory system - including the kidneys which filter toxic waste materials from the blood
- (5) Nervous system - consisting of the brain, spinal cord and nerves which coordinate the body's actions
- (6) Endocrine system - glands secreting hormones which act as chemical messengers
- (7) Reproductive system - producing male and female gametes, respectively and allowing the development of the embryo

Review questions

1. Define the basic principles of cell theory.
2. What are the features that are common to cells in all living things?
3. State the differences of DNA between prokaryote and eukaryote.
4. Compare and contrast the structures of cells with and without a nuclear membrane.
5. What are the functions of plant cell wall?
6. Energy is essential in cells. Which organelles of a cell generate energy to support cell activities?
7. Mention the levels of cell organization in multicellular organism such as human being.
8. Which components of the cell control the cell activities?
9. Define the terms tissue, organ and system.
10. Differentiate plant tissues with a relevant flow chart.
11. Identify the basic tissue groups found in animals.
12. Which organ systems are responsible for
 - (a) gaseous exchange
 - (b) filtering toxic waste materials
 - (c) coordination of the body's actions

Concept map



CHAPTER 3 SUPPORT AND LOCOMOTION

Learning Outcomes

It is expected that students will

- identify the different types of support and locomotion systems in living organisms and can describe each function
- investigate the importance of maintaining a healthy musculoskeletal system

3.1 SUPPORT SYSTEMS

The support system is very important to all living things such as plants, animals and humans.

Plants do not have skeletons like animals but they use their turgidity of cells within packing tissue and the strongly constructed conducting tissue for support.

In humans and other animals, the main body support is provided by the internal skeletal system of bones in association with cartilage and the muscular system. In some animals, the skeleton is external as in insects and prawns. In all animals and humans, the skeleton supports body weight, maintains body shape, protects soft organs inside the body, provides place for muscle attachment and enables movement.

3.1.1 Support Systems in Aquatic Plants

Aquatic plants cannot stay upright on land because of their stems which are soft and non-woody. But aquatic plants can stay upright in water because their weights are supported by the buoyancy of water. Some aquatic plants have many air sacs in their leaves and stems that make them light so that they can float on water. Some aquatic plants have tiny leaves to ensure that they are not disrupted by the flow of water, e.g., *Hydrilla*. Aquatic plants may be distinguished into three groups: (1) submerged plants (2) floating plants and (3) emergent plants.

(1) Submerged plants

They are rooted in the bottom of a water course and the leaves remain submerged below the surface of the water. Numerous air sacs inside the leaves and stems keep the plant floating close to the surface to obtain maximum sunlight. e.g., *Vallisneria* (Nga-shint-myet) (Figure 3.1)



Figure 3.1 *Vallisneria*

(2) Floating plants

(a) Free floating plants

These plants float freely on the water surface. In free floating plants, the petioles are swollen and spongy, consisting of numerous air spaces. The presence of these air spaces makes the plants lighter and enables them to float on water. e.g., water hyacinth (Beda) (Figure 3.2)



Figure 3.2 Water hyacinth

(b) Submerged floating plants

These plants anchor to the bottom of the pond by roots but their leaves and flowers float on the water surface. The aerenchyma tissues (spongy and air spaces) in the stems and leaves make the plants float on the surface of the water. e.g., water lily (Kya) (Figure 3.3)



Figure 3.3 Water lily

(c) Trailing floating plants

These plants have long and horizontal stems (stolon). These stems are hollow and can float easily. e.g., buffalo spinach (Kana-hpaw) (Figure 3.4)



Figure 3.4 Buffalo spinach

(3) Emergent plants

The plant consists of tufts of basal leaves which rise from the spreading rhizomes. The leaves are erect, sword-shaped, flat and have parallel veins. e.g., sweet flag (Linn-nay) (Figure 3.5)



Figure 3.5 Sweet flag

3.1.2 Support Systems in Terrestrial Plants

The plant has various methods and systems for support to maintain its shape and for its protection. The types of support are physiological and structural. The physiological support is a temporary support because it depends on the presence of water in the plant cells. There is no support if the water in the plant cells is lost.

(a) The physiological support

Physiological support affects the cell itself as a whole. The water enters the vacuole of the cell by osmosis. An internal pressure is built up inside the cell vacuole, called turgor pressure. The pressure pushes the plasma membrane against the cell wall, causing the cell to swell. The cell becomes turgid to get the support (Figure 3.6).

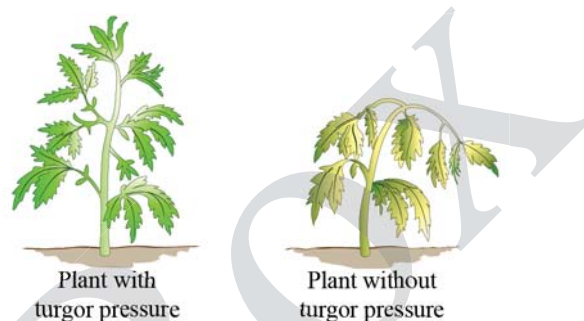


Figure 3.6 The physiological support

(b) The structural support

The structural support is a permanent support. Various structural support systems include woody plants: trees and shrubs, non-woody plants: herbaceous plants and climbers.

Support in woody plants

Support in woody plants has specialized tissue to give them support. The tissue has cellulose cell wall, having lignification for added strength. Tissues with such walls are sclerenchyma tissues, e.g., xylems, vessels and tracheids (Figure 3.7).

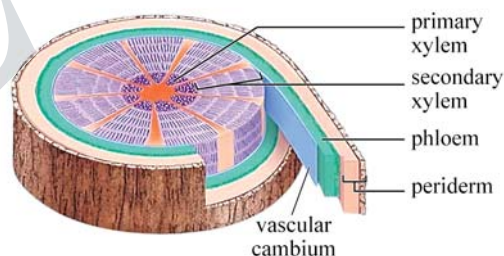


Figure 3.7 Woody stem

Support in non-woody plants

Support in non-woody plants (herbaceous and climbers) depends on the turgidity of their cells such as parenchyma, collenchyma and other supportive tissues to give support. Climbers have modifications for climbing up a support in order to obtain sunlight (Figure 3.8).

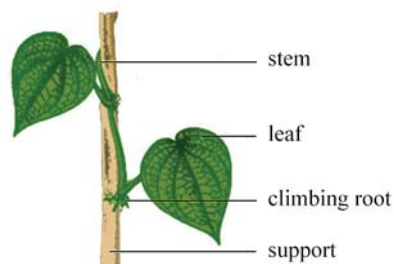


Figure 3.8 Climbing roots of betel

(c) Special support structures

Prop roots

Roots which grow down from the stem or branches into the ground for support. e.g., banyan tree (Nyaung-pin), maize (Pyauung) (Figure 3.9)



Figure 3.9 Prop roots

Tendrils

Curly string-like structures modified from the stems and leaves curl and twine around the parts of other plants or objects to help the plant to climb. e.g., cucumber (Tha-khwar), bittergourd (Kyet-hin-khar) (Figure 3.10)



Figure 3.10 Tendrils

Thorns

Sharp modified branches that cannot be easily removed. Thorns act as hooks to hold onto the support. e.g., bougainvillea (Setku-pan), rattan (Kyein) (Figure 3.11)



Figure 3.11 Thorns

Prickles

An outgrowth of the epidermis can be easily removed from the stem. e.g., rose (Hnin-si) (Figure 3.12)



Figure 3.12 Prickles

Buttress roots

The thick support roots grow from the stem above the ground. These roots hold the tree firmly to the ground, giving it extra support. e.g., durian (Duyin), casuarina (Pinle-kavee) (Figure 3.13)



Figure 3.13 Buttress roots

Clasping roots

Roots grip onto other plants or structures to get support. e.g., betel (Kun), pepper (Nga-yoke-kaung) (Figure 3.14)



Figure 3.14 Clasping roots

3.1.3 Support Systems in Animals

Skeletons serve as main support systems for animals. Zoologists commonly recognize three types of skeletal systems in animals: **hydrostatic skeleton**, **exoskeleton** and **endoskeleton**.

(a) **Hydrostatic skeletons** are found primarily in soft-bodied terrestrial invertebrates, such as earthworms and slugs and soft-bodied aquatic invertebrates such as jellyfish and squids. Fluid-filled body cavities in **coelom** give support by means of hydrostatic pressure on the body wall (Figure 3.15 a).

(b) An **exoskeleton** is a rigid, hard case that surrounds the body. Arthropods such as crustaceans and insects have exoskeletons made of the polysaccharide **chitin** (Figure 3.15 b). A chitinous exoskeleton resists bending and thus acts as the skeletal framework of the body; it also provides attachment sites for the muscles which lie inside the exoskeletal casing. But in order to grow, the animal must periodically **molt**, shedding the exoskeleton. A slightly larger new exoskeleton will be formed.

(c) **Endoskeletons** found in vertebrates, sponges and echinoderms are rigid internal skeletons that form the body's frame work and offer surfaces for muscle attachment for movement and locomotion. Vertebrates such as fish, frogs, snakes, birds and mammals including humans have internal **bones** forming an endoskeleton. Echinoderms such as sea urchins and sand dollars have **endoskeletons** of ossicles made of calcium carbonate. This calcium compound is different from that in bone which is based mainly on calcium phosphate (Figure 3.15 c).

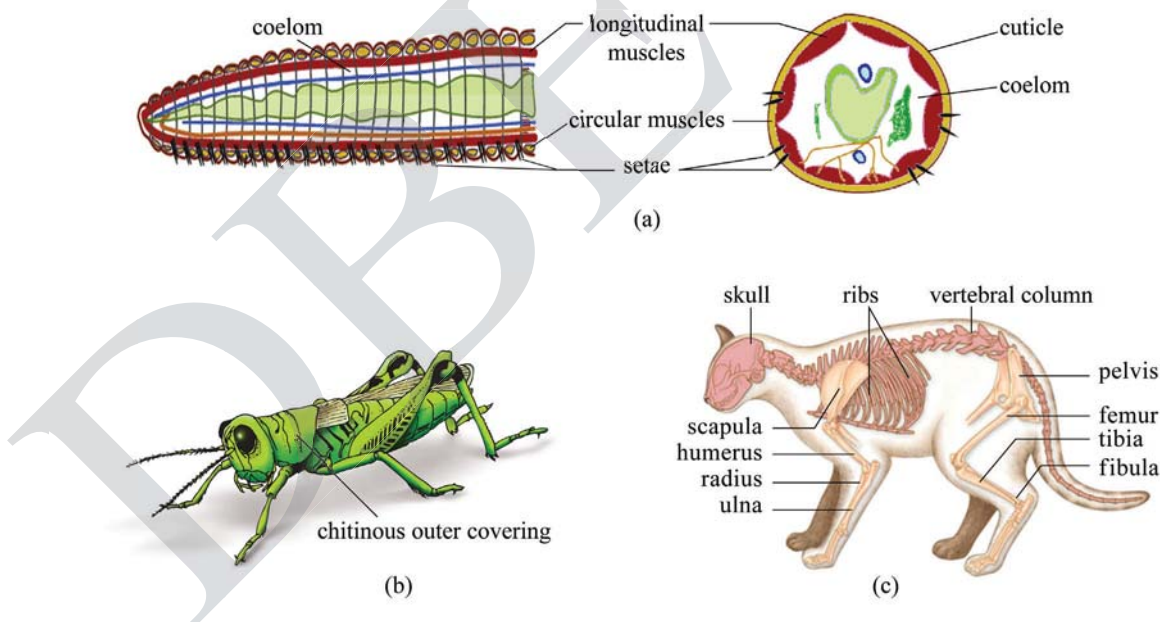


Figure 3.15 Skeletal systems of animals (a) Hydrostatic skeleton of earthworm
(b) Exoskeleton of grasshopper (c) Endoskeleton of cat

3.1.4 Support System in Humans

The human skeleton has about 206 bones which can be categorized as part of either the **axial** or **appendicular** skeleton. The bones of the skeleton provide sites for muscle attachment, making movement possible particularly with jointed appendages.

The human endoskeletal system has many functions that contribute to homeostasis. The rigid endoskeleton supports the body. (1) The skeleton protects vital **internal** organs such as the brain, spinal cord, heart and lungs. (2) The bones of the skeleton provide sites for muscle attachment, making movement possible particularly with **jointed appendages**. (3) The skeleton serves as an important storage reservoir for ions such as calcium and phosphorus. (4) The skeleton produces blood cells within the **red bone marrow** of the skull, ribs, sternum, pelvis and long bones.

Axial skeleton

The axial skeleton is made up of the **bones** found in the trunk and head of the body. The bones of the axial skeleton support the weight of the body and protect the internal tissues. The axial skeleton includes the 27 bones in the **skull**, the 33 bones that form the **spine**, the 12 pairs of **ribs** and the **breast-bone** (sternum), the flat bone in the front of the chest that connects the ribs. Mandible or lower jaw bone is attached flexibly to the skull.

The bones of the axial skeleton cover most of the body's vital organs. **Vertebrae** are serially arranged bones of the spine that surround the spinal cord; there are cartilage discs between the vertebrae. Ligaments, holding the vertebrae together, permit a degree of movement in the spine. The bones of the **skull** are rigid and protect the brain but the lower jaw can move strongly in eating and speaking. The **ribs** and **sternum** protect the heart and lungs. Flexible tissues and muscles connecting the ribs allow the chest to expand and contract during breathing. Flexible tissues in the spine connecting vertebrae allow people to bend, turn and look behind.

Appendicular skeleton

The appendicular skeleton is the part of endoskeleton that is adapted to allow the body to move. It includes the bones in the **limbs** that extend from the trunk of the body such as legs, feet, arms and hands.

The appendicular skeleton also includes two sets of bones, called **girdles** that connect limbs to the axial skeleton of the body. The girdles attach the bones of the arms and legs to the body loosely enough that these limbs have a wide range of motion (Figure 3.16).

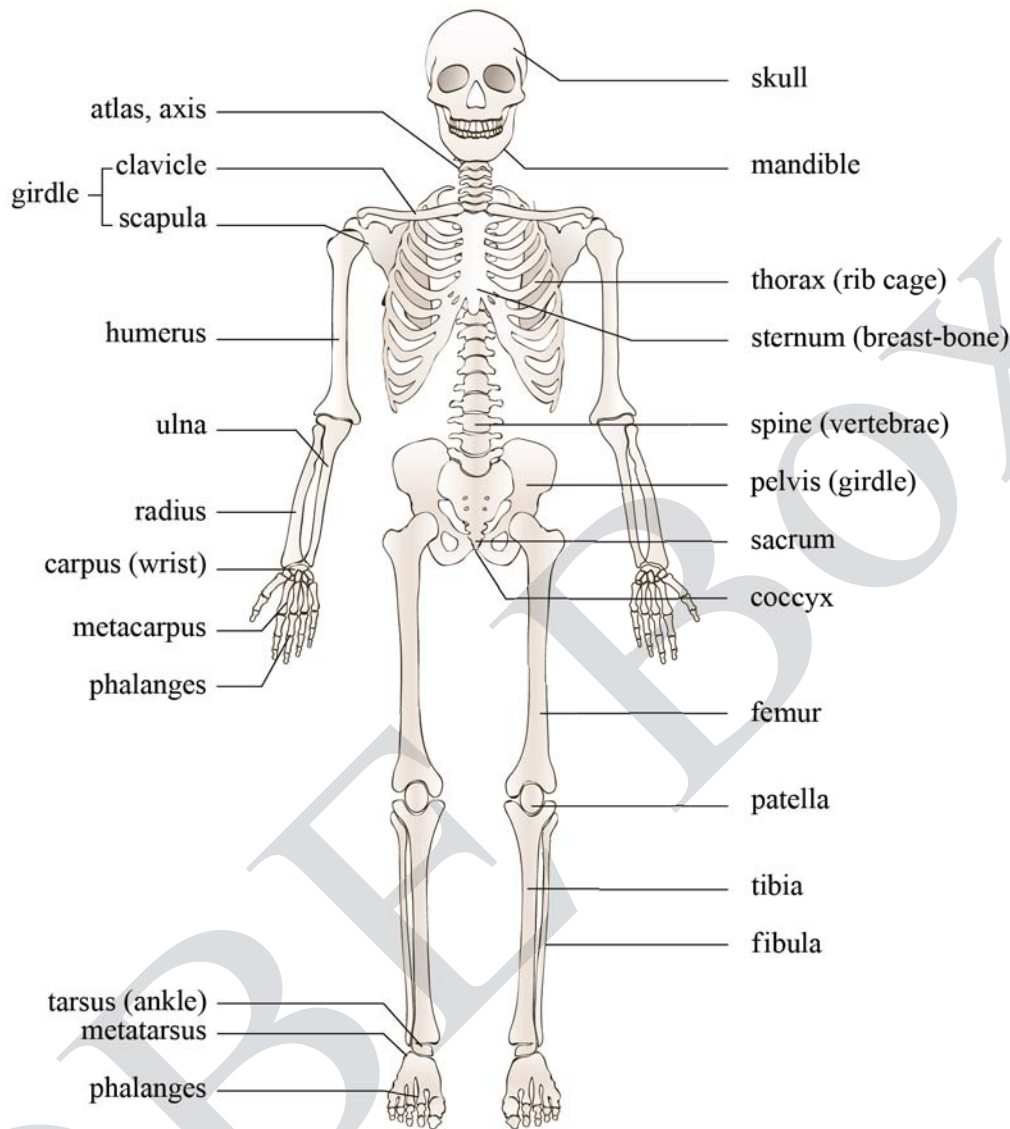


Figure 3.16 The human skeletal system

Bone

Bone tissue consists of a dense and hard organic matrix deposits of minerals (mainly calcium phosphate and some calcium carbonate) in between the bone cells. These cells remain alive and secrete the matrix throughout life. Most bones have a large cavity called marrow cavity in the centre. The marrow cavity may contain yellow marrow which is mainly fat or red marrow where blood cells are produced. **Haversian canals** running through the matrix of the bone consist of blood vessels and nerves for oxygen supply and control of the bone cells (Figure 3.17).

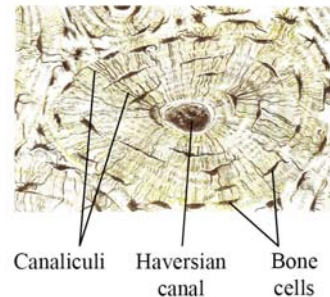


Figure 3.17 Microscopic structure of bone

Cartilage

If the two bones were in contact with one another, they would rub together every time they moved and eventually, the ends of the bones would wear down. But the ends of the bones are protected from wear by cartilage.

Cartilage is a flexible connective tissue that is found between the bones. It cushions the bones and allows for smooth movements. The cartilage found in the chest holds neighboring ribs together into one strong but flexible rib cage.

Joints

A joint is the place where two bones meet. Different types of joints allow for different amounts of bone movement. **Fibrous joints** are made of the same dense material that bone is made of and they act like a tough glue that connects the bones and holds them in place. **Cartilaginous joints** allow partial movement. In these joints, cartilage physically holds bone together.

Other joints called **synovial joints** are cushioned with cartilage and held together by a capsule of ligaments. A **ligament** is a long, flexible band of connective tissue that connects two bones across a joint. Synovial joints allow great degree of movement between bones. There are several different types of synovial joint which are listed below (Table 3.1).

Table 3.1 List of types of synovial joint in humans



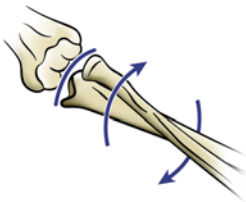

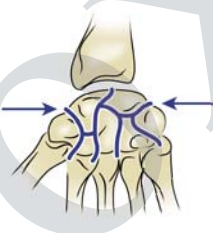
Joint types	Movements	Examples	Illustrations
Hinge joint	- Flexion, extension	- Elbow joint (shown), knee joint	
Ball and socket joint	- Flexion, extension, adduction, circumduction	- Shoulder joint (shown), hip joint	
Pivot joint	- Rotation	- Skull and atlas-axis and proximal radioulnar joint (shown)	

Table 3.1 List of types of synovial joint in humans (continued)

Joint types	Movements	Examples	Illustrations
Saddle joint	- Flexion, extension, adduction, circumduction	- Base of thumb and carpals (shown)	
Gliding joint	- One surface moves over another surface	- Between tarsal bones of ankle, between carpal bones (shown) of wrist	

The importance of maintaining a healthy musculoskeletal system

The healthy musculoskeletal system allows for normal physical activities such as walking, running, jumping and other activities. Abnormal **joints** and **muscles** result in osteoarthritis in which damaged ends of **bones** rub against each other, causing joint pain and stiffness or the bones may become **brittle** and are more prone to fracture.

To maintain the musculoskeletal system the followings could be done.

(a) Stay active

Physical activities and exercises are necessary to maintain healthy joints between bones. These can also strengthen muscles that hold the joints.

(b) Do not overextend the joints

Some movements can cause injuries. Rapid direction changes and twisting can lead to joint damage involving cartilages and ligaments.

(c) Eat healthy food

Health of bones, joints and muscles can be supported by healthy food. Dark green vegetables, olive oil, citrus fruits, fish and poultry have nutrients for bone and muscle development. Vitamins C, K and A, iron, calcium, phosphorus and magnesium are good for joints. Proteins play a critical role in muscle and cartilage repair.

(d) Reduce weight and stay fit by exercising

Reducing body weight by exercising regularly reduces joint pain, improve joint health and keeps muscle strong.

3.2 MOVEMENT IN PLANTS

The plants are fixed at a place with their roots in the ground. Although they cannot move from one place to another by their bodies but they can move with their parts. These movements are caused due to response of plants to external stimuli such as light, water, gravity, chemicals, etc. Plants show two types of movements.

1. Growth-dependent movements called the tropic movements (towards or away from a stimulus) and
2. Non-growth dependent movements called the nastic movements (not dependent on the direction of stimulus)

3.2.1 Tropic Movements

The movement of a plant in the direction of stimulus is known as tropic movement. Plant may either show a positive or negative movement as a response to a stimulus. If the movement is towards the direction of stimuli, it is known as positive tropism. If the movement is away from the stimuli, it is known as negative tropism. Tropic movements in plants can be classified into six types. These are:

- | | |
|------------------|-----------------------|
| (a) Phototropism | (d) Chemotropism |
| (b) Geotropism | (e) Thigmotropism and |
| (c) Hydrotropism | (f) Thermotropism |

(a) Phototropism

Plants are very sensitive to light. The movement of plants in response to light is known as phototropism. The shoot system of a plant shows positively phototropic whereas the root is negatively phototropic (Figure 3.18).

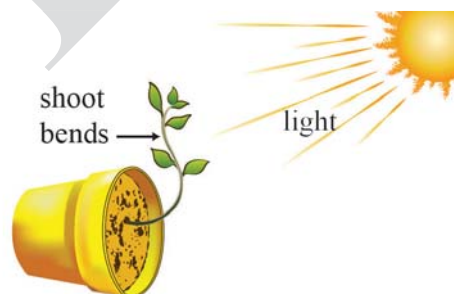


Figure 3.18 Phototropism

(b) Geotropism

The movement of a plant part towards the soil in response to earth's gravity is known as geotropism. In geotropism, the shoot is negatively geotropic and the root is positively geotropic (Figure 3.19).



Figure 3.19 Geotropism

(c) Hydrotropism

The movement of the plant towards the water is known as hydrotropism. The stimulus here is water. Roots are positively hydrotropic (Figure 3.20).

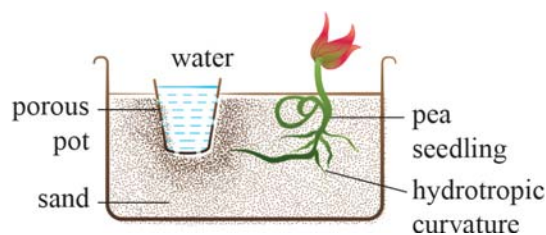


Figure 3.20 Hydrotropism

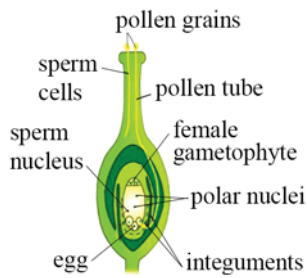


Figure 3.21 Chemotropism

(d) Chemotropism

The movement of plants in response to a chemical stimulus is known as chemotropism. An example of this type of movement is the growth of pollen tube towards ovule during fertilization due to secretion of a sugary chemical in the ovary (Figure 3.21).

(e) Thigmotropism

The directional movement in plants in response to touch is known as thigmotropism. e.g., the plant tendrils climb around any support which they touch (Figure 3.22).

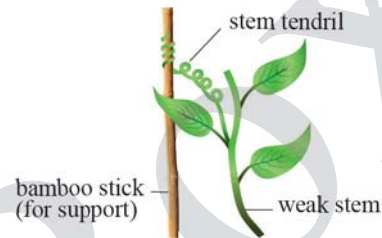


Figure 3.22 Thigmotropism

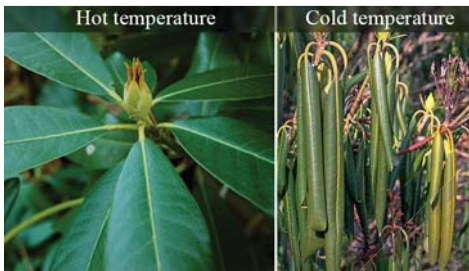


Figure 3.23 Thermotropism

(f) Thermotropism

Thermotropism is the movement of plant or their parts in response to changes in the external stimulus of temperature (Figure 3.23).

3.2.2 Nastic Movements

Nastic movements in plants are not directional movements. They are not dependent on the direction of the stimulus. For example, the leaves of 'touch me not' (*Mimosa*, Hti-ka-yone), fold up immediately when touched. These kinds of changes occur due to the changes in the amount of water in the leaves. Depending on the quantity of water, they either swell up or shrink (Figure 3.24). In other example, pitcher plant (*Nepenthes*, Ye-ta-gaung), the closing of the lid of insectivorous plant occurs due to the catchment of the insects (Figure 3.25).

Figure 3.24 *Mimosa*Figure 3.25 *Nepenthes*

3.3 MOVEMENT AND LOCOMOTION IN ANIMALS AND HUMANS

The ability to move in animals is made possible by the combination of a semi rigid skeletal system with joints that act as hinges and a muscular system attached that can pull on this skeleton. Muscular action produces a change in body shape, which places a force on different parts of the outside environment, for example, when a horse runs, its feet contact the ground, the force they exert moves its body forward rapidly. In a similar way, when a bird takes off into flight, its wings exert force on the air and a swimming fish movements push against the water. The nature of the muscular and skeletal systems allows movement in animals.

3.3.1 Movement and Locomotion in Various Simple Animals

Locomotion in earthworm

In these animals a fluid-filled central body cavity or coelom is encompassed by two sets of muscles in the body wall: **circular muscles** that are repeated in segments and run the length of the body and **longitudinal muscles** that oppose the action of the circular muscles. Short and bristle like structures called **setae** are on the underside of a worm's body.

Muscles act on the fluid in the body's central space which represents the **hydrostatic skeleton**.

This locomotion process proceeds as waves of circular-muscle contraction that are followed by waves of longitudinal muscle contraction which pass backward.

Steps in earthworm locomotion are:

1. In the anterior end, circular muscles contract and longitudinal muscles relax. Setae lose contact with ground.
2. The front end of the body extends forward.
3. Next, the circular muscles contract; the longitudinal muscles relax. Anterior of the body swells and setae anchor the ground.
4. Body region behind the anterior end is pulled forward. Setae prevent slipping backward of the front end (Figure 3.26).

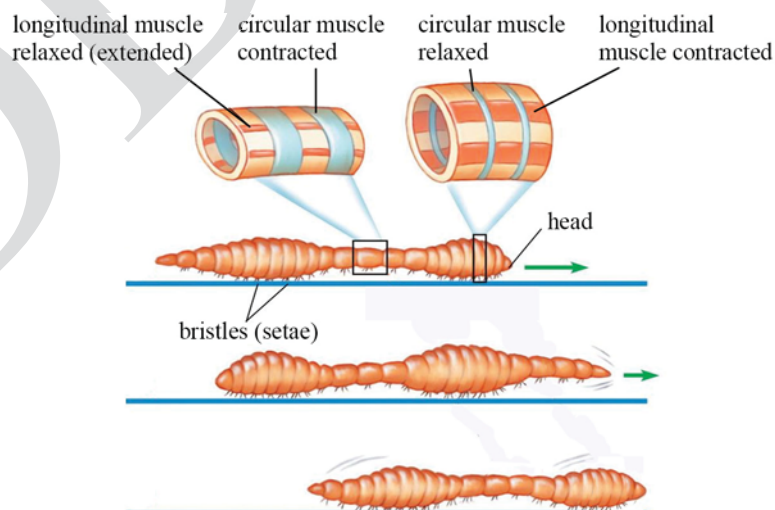


Figure 3.26 Locomotion in earthworm

Locomotion in grasshopper

Jumping

The **flexor** and **extensor** (antagonistic) muscles are attached to the internal surface of the exoskeleton. Flexor muscles bend a joint. Extensor muscles straighten it. The rear legs of a grasshopper are long and muscular and are adapted for **hopping** or **jumping**. When the flexor muscle contracts, the lower leg (tibia) is pulled towards the body. The hind leg is folded in a Z shape and ready for a jump. When the extensor muscle contracts, the leg jerks backwards, propelling the grasshopper forward and up (Figure 3.27 a).

Flight

The movement (raising and lowering) of the wings, in flight of the grasshopper, is achieved by the alternate contraction of **extensor** muscles (elevators) and **flexor** muscles (depressors) located inside the exoskeleton of the thorax (Figure 3.27 b).

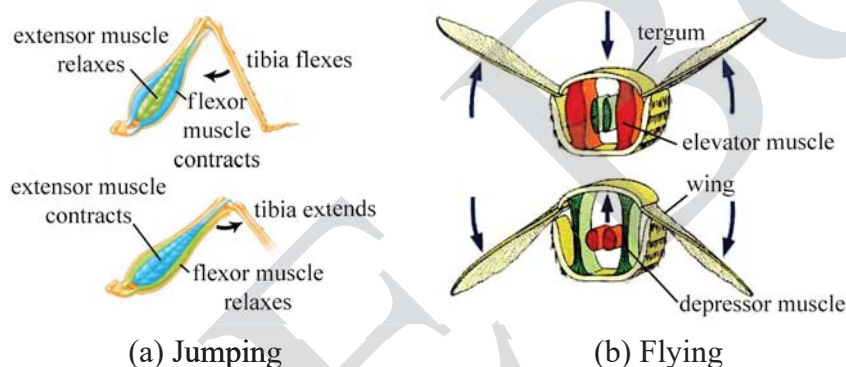


Figure 3.27 Muscles in jumping and flight of grasshopper

3.3.2 Movement and Locomotion in Various Complex Animals and Humans

Antagonist and agonist skeletal muscles often occur in pairs, called **antagonistic pairs**. As one muscle contracts, the other relaxes causing movement or locomotion at different types of bony joints.

Locomotion in fish

Fish have a **streamlined body shape** for **swimming** in water to reduce friction. Fish moves forward as a result of the contraction and relaxation of (antagonistic) muscles called **myotomes** on either side of the body and the tail or **caudal fin** propels the fish. The function of **fins** in fish is to **balance the body** in an upright position in water. **Pectoral** fins are used to steer the fish. **Pelvic** fins are used to balance the fish and prevent the body from diving or rolling (Figure 3.28).

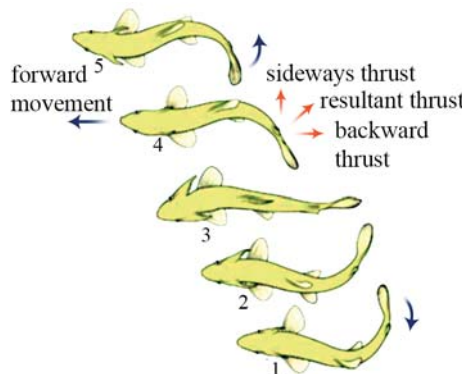


Figure 3.28 Swimming in fish

Locomotion in frog

The frog's powerful hind legs are adapted for both **swimming** and **leaping**. The strong **extensor** muscles of the thigh contract, extending the limb and thrusting the foot against the ground or against the water. The thrust is transmitted through the body of the frog by the **pelvic girdle** and the spine so that the whole animal is pushed forward. **Flexor** muscles of the thigh contract to pull or flex the leg for the next extension (Figure 3.29).

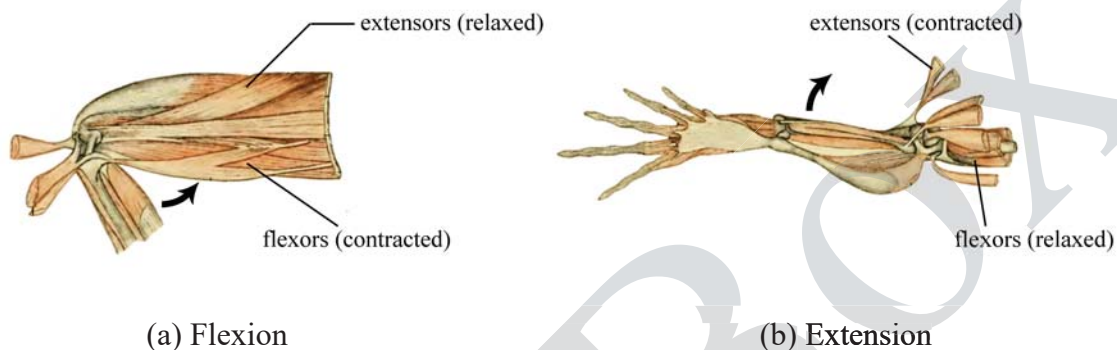


Figure 3.29 Rear legs propel a frog in swimming and leaping

Locomotion in bird

Most birds have approximately 175 different muscles, mainly controlling the wings, skin and legs. During flight, a bird moves its wings in weak **upstrokes** and strong **downstrokes** to get lifted and fly in the air.

The antagonistic muscle pair of **pectoral** and **supracoracoideus** forms the major flight muscles. Both muscles are attached to the breast bone (sternum) but the pectoral muscles contract to cause downstroke of the humerus bone of the wings while the supracoracoideus causes the upstroke of the wings, providing **lift**.

In addition, circular movement of the wings, forward and then backward, during each downstroke, provides **thrust** that moves the bird forward through the air (Figure 3.30).

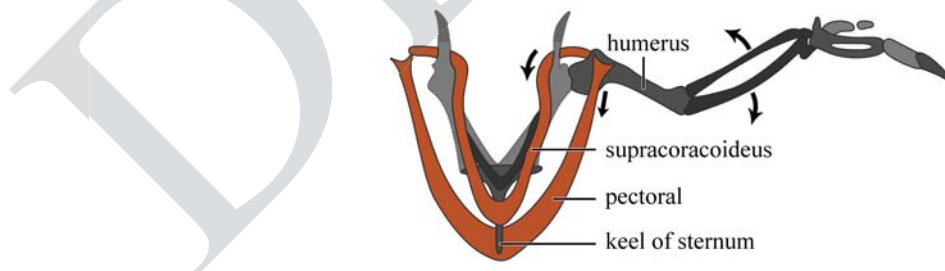


Figure 3.30 Muscles of wing flapping in flight of bird

Locomotion in humans

There are about 650 skeletal muscles in the human body. Most of these muscles function in “antagonistic pairs” for locomotion and movement in humans.

The antagonistic muscle pairs carry out many types of movements. Some of which are as follows:

Flexion and extension

One prominent example pair of muscles is **biceps brachii** and **triceps brachii** in the upper arm. Contraction of biceps brachii **flexes** or pulls the forearm towards the upper arm. When the triceps brachii is relaxed, **flexion** happens at the hinge joint at the elbow.

But when the biceps relaxes and the triceps contracts, the forearm is pulled away from upper arm. The locomotion is termed **extension** (Figure 3.31 a).

Another example pair of muscles is the **hamstring** and **quadriceps** muscles in the thigh of the legs. Contraction of the hamstring and relaxing of the quadriceps **flex** the leg at the knee. Next, the leg is **extended** at the knee by contraction of the quadriceps and relaxing of the hamstring muscles (Figure 3.31 b).

The working muscle is termed **agonist** and the resting muscle is the **antagonist**.

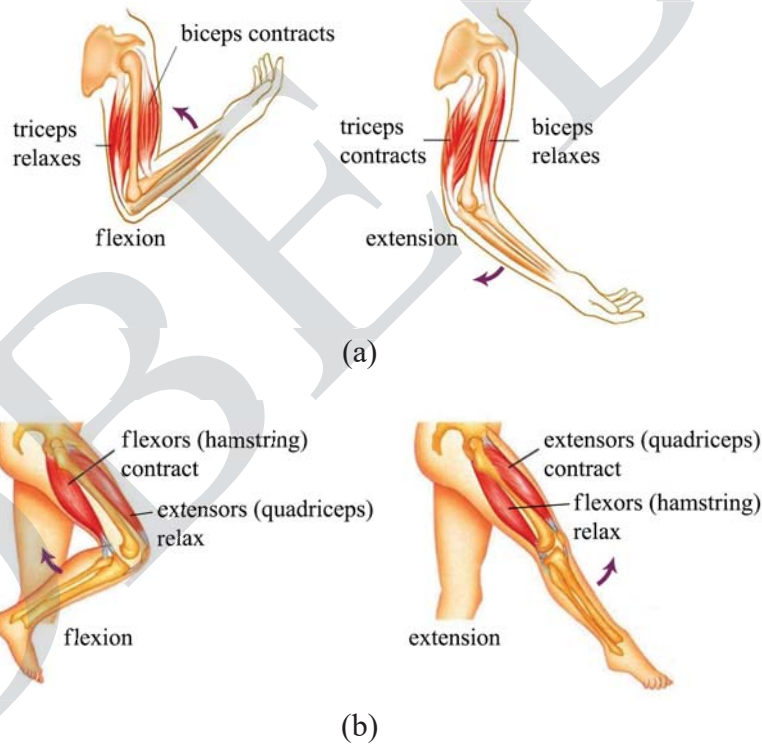
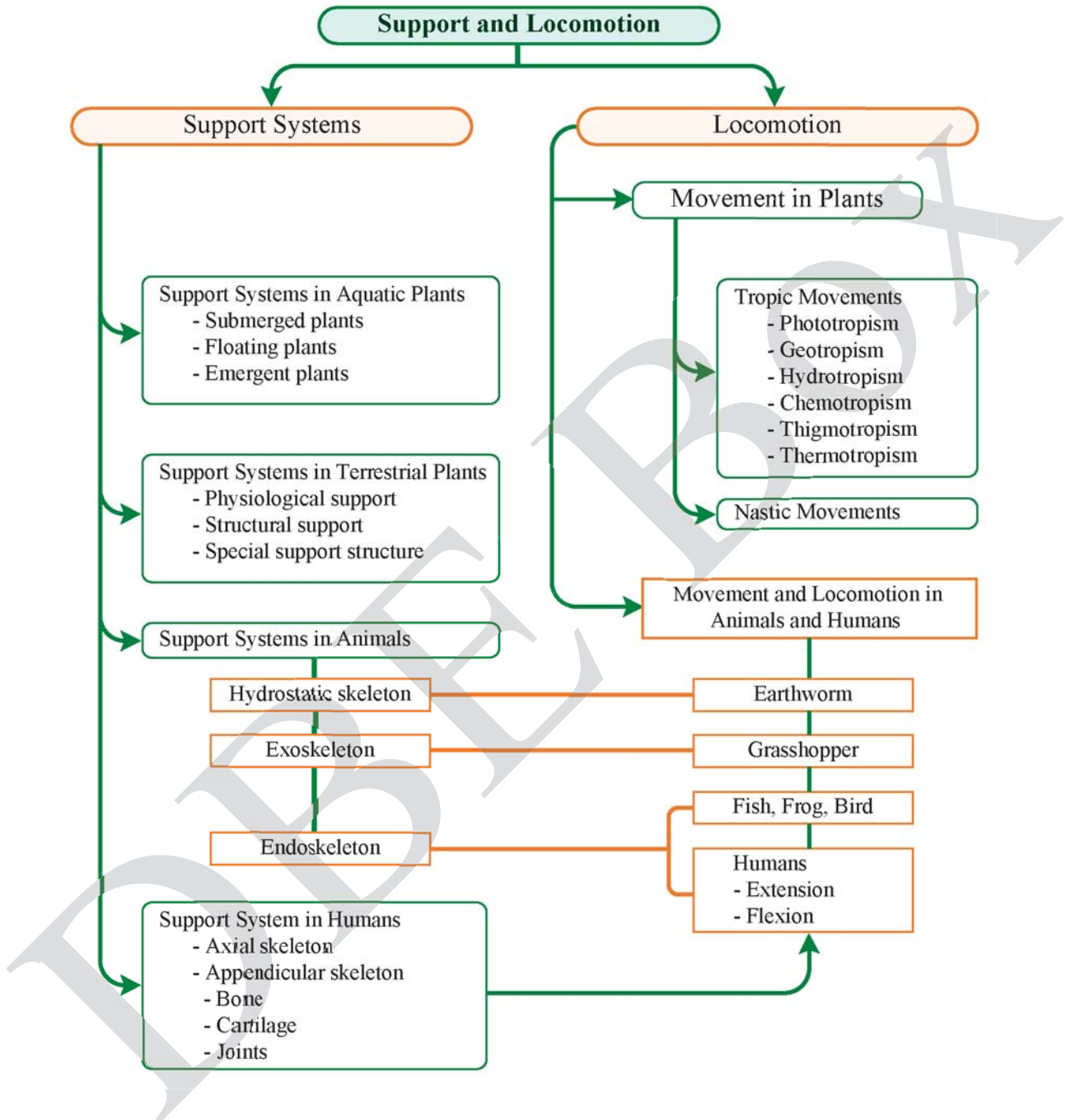


Figure 3.31 The arrangement and functions of skeletal muscles in an antagonistic pair (a) in the arm (b) in the leg of humans

Review questions

1. Distinguish the types of aquatic plants and describe the characteristics of one which grows below the surface of the water.
2. Why can floating plants exist above the surface of the water?
3. Describe the physiological support in plants.
4. State the structural support of plants and its effect.
5. Clarify the types of special support structures found in terrestrial plants and state their functions.
6. How does the exoskeleton differ from the endoskeleton?
7. "Skeletal systems can vary in different animals". Substantiate this statement.
8. How do human endoskeletal system support the body?
9. Different movements occur at joints between bones. Explain them with examples.
10. Why is it important to maintain a healthy musculoskeletal system?
11. Differentiate between tropic and nastic movements in plants.
12. Define the term tropism and mention its types.
13. Mention the differences between phototropism and geotropism in plants.
14. How do *Mimosa* and *Nepenthes* response to touch?
15. What is the significance of tropic movements in plants? Explain any two types of tropic movements with fully labeled diagrams.
16. How are movement and support maintained in an animal lacking an exoskeleton or endoskeleton?
17. Explain how insects are able to jump and fly.
18. Discuss how fish achieve locomotion and stability in swimming.
19. How are amphibians able to move both in water and on land?
20. Describe the mechanisms of flight in birds.
21. Briefly explain the movement and locomotion of arms and legs in humans.

Concept map



CHAPTER 4

A BODY SYSTEM TO SUSTAIN LIFE

Learning Outcomes

It is expected that students will

- state that chlorophyll traps light energy and converts it into chemical energy for the formation of carbohydrates
- determine the types of nutrients, including macronutrients and micronutrients which are important for living things and why they are important
- explain the importance of a healthy diet and maintaining a healthy digestive system
- identify and describe the structure and mechanisms involved in the digestive system of humans including the formations of the teeth
- understand the diseases that cause malfunction of the digestive system

4.1 NUTRITION

Nutrition is the process of taking food by an organism and utilization of food for energy. This is a vital process which helps living things to obtain their energy from various sources. Nutrients are the substances which provide nutrition and consists of carbohydrates, proteins, fats, vitamins and minerals. These essential components of food are called nutrients. Mode of nutrition varies from one species to another for their important life processes. There are two types of nutrition, autotrophic and heterotrophic nutritions.

(1) Autotrophic nutrition (able to make its own food)

In autotrophic nutrition, the organisms make or synthesize their own food from the simple inorganic materials. Plants are autophytes and they have an autotrophic mode of nutrition. There are two types of autotrophic nutritions.

- (a) **Photosynthetic** plants use energy from the sun to make their own food.
e.g., all green plants
- (b) **Chemosynthetic** organism consumes simple nonliving chemical nutrients such as hydrogen sulphide (H_2S), sulphur (S) and iron (Fe) to make their own food.
e.g., autotrophic bacteria

(2) Heterotrophic nutrition (unable to make its own food)

Heterotrophic nutrition is that mode of nutrition in which an organism cannot make or synthesize its own food from simple inorganic materials. Animals depend on other organisms for their food. Hence they have a heterotrophic mode of nutrition. There are three main types of heterotrophic nutrition.

- (a) **Holozoic nutrition** - the organisms feed by ingesting solid organic matter which is then digested and absorbed into their bodies.
e.g., humans, animals and insectivorous plants
- (b) **Saprophytic nutrition** - feeding on dead and decaying matter. Include bacteria and fungi which digest the food externally before the nutrients are absorbed.
e.g., many bacteria and fungi

- (c) **Parasitic nutrition** - the parasite obtains nutrients by living on or in the body of the host. e.g., dodder, fleas, lice and tapeworms

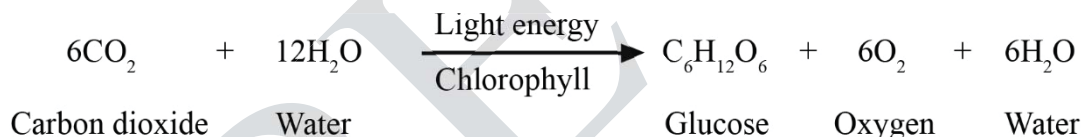
4.1.1 Plant Nutrition

Green plants synthesize their own food by the process of photosynthesis. In the process, they make their own food from CO_2 and H_2O by using sunlight in the presence of chlorophyll. The process of photosynthesis can be represented as:

1. The process of photosynthesis takes place in the green leaves of a plant.
2. The food is prepared by the green leaves of a plant in the form of a simple sugar called glucose.
3. The extra glucose is changed into starch that temporarily stored in the leaves of the plant.
4. Green plants convert energy of sunlight into chemical energy by making carbohydrate.

Photosynthesis

Photosynthesis is a metabolic reaction occurring in plants in which light energy converts raw materials into carbohydrates such as glucose which can be stored in cells and used as an energy source via respiration. Photosynthesis occurs in the chloroplasts of plant cells. Chloroplasts contain chlorophyll that transfers light energy into chemical energy. The whole process of photosynthesis can be shown by following equation:



The photosynthesis takes place in the following four steps:

1. Absorption of sunlight energy by chlorophyll.
2. Conversion of light energy into chemical energy.
3. Splitting of water into hydrogen and oxygen by light energy.
4. Reduction of carbon dioxide by hydrogen to form glucose by the use of chemical energy.

Chlorophyll

Chlorophyll is a pigment that absorbs light of particular wavelengths (mainly blue and red). Chlorophyll in green plants is spread on stacks of membrane in the chloroplast.

Chloroplast

The site of photosynthesis in a cell of the leaf is chloroplast which contains chlorophyll. Chloroplasts are present in the photosynthetic cells (mesophyll cells) of green leaves of plants. These cells contain more chlorophyll than other plant cells.

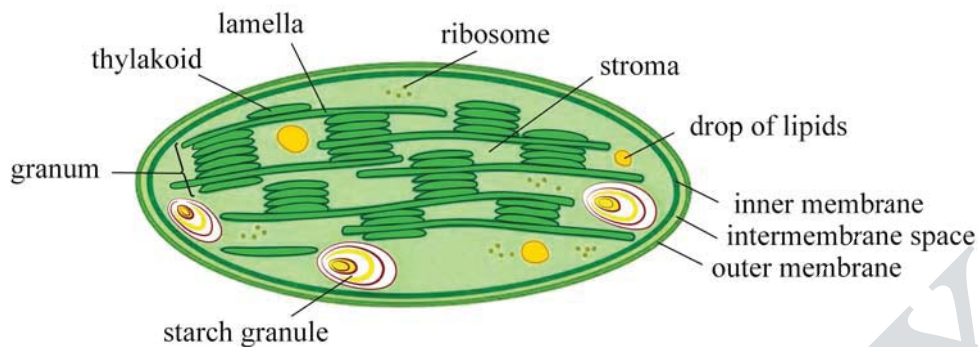


Figure 4.1 Structure of chloroplast

Experiment to demonstrate that starch is formed during photosynthesis

The experiments on photosynthesis depend on the fact that green leaves make starch as food and starch gives a blue-black colour with iodine solution.

A leaf can be tested for starch in the following steps:

1. The variegated leaf is boiled in water for a minute. This kills the protoplasm by destroying the enzymes and hence prevents further chemical changes. It also makes the cells more permeable to iodine solution.
2. Then, the leaf is boiled in methylated spirit to remove the chlorophyll. This turns into a white leaf and makes colour changes easier to see.
3. The leaf becomes brittle because of boiling in spirit. However, it can be softened by dipping into boiling water. It is then spread out in a petri-dish or on a glazed tile.
4. Iodine solution is placed on the leaf. If starch is present, the leaf turns blue-black. If there is no starch, the leaf is stained brown by iodine.

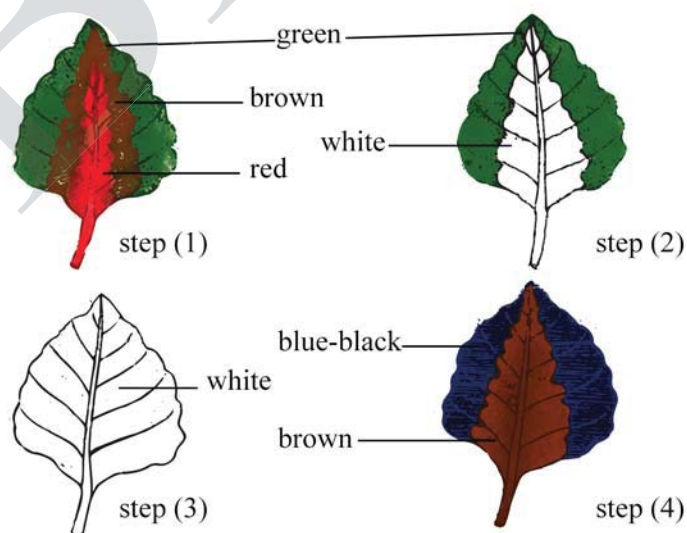


Figure 4.2 Starch test with variegated leaf

Factors affecting photosynthesis

Intensity of light, concentration of carbon dioxide in the air, temperature and water are the important external factors that influence photosynthesis. Internal factors include chlorophyll content and the accumulation of the products of photosynthesis.

Intake of substances required for photosynthesis

Plants get the materials required for photosynthesis from their environment.

Table 4.1 Intake of substances required for photosynthesis

Material	Method of intake by green plant	Next stage
Light	- Light is absorbed by chlorophyll in chloroplasts of plant cells, mainly in the leaves.	- Light energy is changed into chemical energy.
Water	- Water is absorbed by the roots and travels up the xylem from the root to the stem and then into the leaves.	- Water is split to provide hydrogen atoms. Oxygen is released.
Carbon dioxide	- Carbon dioxide diffuses from the atmosphere into the leaves through the stomata.	- Carbon dioxide combines with the hydrogen from water. Through a series of reactions, glucose is formed and is stored temporarily in the leaf as starch.

4.1.2 Types of Nutrients

Types of Nutrient in Plants

Plants require a number of inorganic nutrients. Plants require essential elements such as C, H and O which are derived from the atmosphere and the other elements are supplied from the soil or by fertilizer.

The plant nutrients can be divided into two groups:

1. **Macronutrients:** carbon (C), oxygen (O), hydrogen (H), nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg) and sulphur (S)
2. **Micronutrients:** boron (B), iron (Fe), chlorine (Cl), manganese (Mn), zinc (Zn), copper (Cu), molybdenum (Mo) and nickel (Ni)

The plants need large amounts of the macronutrients and trace amounts of the micronutrients. The functions of the macronutrients in plant are described in the following table.

Table 4.2 Macronutrients for plants

Nutrients	Functions	Effects of deficiency
Carbon (C)	- Part of carbohydrates, proteins and fats have a role to play in the general metabolisms of plant	- Affects the normal growth and development of plants
Hydrogen (H)		
Oxygen (O)		

Table 4.2 Macronutrients for plants (continued)

Nutrients	Functions	Effects of deficiency
Nitrogen (N)	<ul style="list-style-type: none"> - Components of nucleic acids, amino acids and proteins - Affects shoot-root growth, density, colour, disease resistance and stress tolerance 	- Chlorosis or yellowing of leaves, stunting of plants, dormancy of lateral buds and late flowering
Phosphorus (P)	<ul style="list-style-type: none"> - Components of nucleic acids and adenosine triphosphate - Affects rate of seedling development, maturation and root growth 	- Purple or red spots on leaves, dark green leaves, premature falling of leaves
Potassium (K)	<ul style="list-style-type: none"> - Activates enzymes and starch synthesis. Important in maintaining turgor pressure in plants - Affects drought tolerance and disease resistance 	- Chlorosis, scorched leaf tips, shorter internodes, loss of apical dominance, stunted growth and premature death of plants
Calcium (Ca)	- Formation of cell wall, maintenance of membrane structure, permeability and importance in cell division	- Stunted growth, necrosis of young meristematic regions
Magnesium (Mg)	- Important component of chlorophyll and activates many enzymes	- Chlorosis of older leaves with necrotic or purple spots and premature leaf abscission
Sulphur (S)	- Present in certain amino acids, proteins, membrane and coenzymes	- Chlorosis of younger leaves, stunted growth, accumulation of anthocyanin, terminal buds develop prematurely

Types of nutrients in animals

Nutrients are the substances that are required for the nourishment of animals. Nutrients are of two types:

1. **Macronutrients** are needed in relatively large amounts. The macronutrients are carbohydrates, fats, proteins, fibres and water. Macronutrients that provide energy include carbohydrates, fats and proteins derived from plants and animals. Macronutrients that do not provide energy include fibres and water. Water is essential for metabolism.
2. **Micronutrients** are needed in small quantities. The micronutrients are represented by vitamins and minerals. **Vitamins** are needed for a large number of cellular and extracellular chemical reactions. Vitamins are essential for energy production,

immune system function, blood clotting and other body functions. Some important vitamins are vitamin A, vitamin B complex, vitamin C, vitamin D and vitamin E. **Minerals** are used in chemical reactions as well as in structural components of cells and tissues. Minerals play an important role in growth, bone and muscle health and other processes. Some important minerals are calcium, iodine, iron, magnesium and potassium.

Table 4.3 Macronutrients for humans

Types of nutrient	Food sources	Functions	Effects of deficiency
Carbohydrates	- Rice, bread, beans, milk, popcorn, potatoes, cookies, spaghetti and soft drinks	- Give the body energy - The best source of fuel for the body	- Nausea, dizziness, constipation, lethargy, bad breath, loss of appetite, excessive breakdown of proteins
Proteins	- Meat, fish, eggs, poultry, dairy products, legumes, nuts and seeds	- Provide energy - Help to build, maintain and repair body tissues - Involve in the interaction of several organs - Help to regulate cell growth	- Confusion, slow wound healing, food cravings, fatigue, muscle weakness, thin hair, weak nails, weight loss, swelling of the gut
Fats	- Butter, animal fats, eggs, milk, chocolate, avocados, fish oil and vegetable oil	- Provide energy - Cushion organs - Carry vitamins - Act as an insulator and provide taste	- Dry, scaly, dull skin - Dry, brittle hairs - Hunger
Fibres	- Cereals, whole grain bread - Fruits such as apples, berries, pears, melons, oranges, bananas - Vegetables such as peas, beans, potatoes with skin - Nuts and seeds	- Lower cholesterol and stabilize blood glucose level - Help to prevent constipation - Help the stomach feel fuller	- Leads to risk of heart disease, constipation, diabetes, bowel cancer

Table 4.3 Macronutrients for humans (continued)

Types of nutrient	Food sources	Functions	Effects of deficiency
Water	- Drinking water, hot and cold drinks, succulent fruits and vegetables	- Lubricates the joints, boosts skin health and beauty - Cushions the brain, spinal cord and other sensitive tissue - Regulates body temperature - Flushes body waste - Helps to maintain blood pressure	- Dry skin, dry or sticky mouth and tongue, constipation, thirst and hunger, tiredness, headache, dark urine and kidney failure

4.1.3 A Healthy Diet

Characteristics of a healthy diet

- (1) **Balanced diets** contain carbohydrates, lipids, proteins, minerals and vitamins along with dietary fibres and water. These substances must be in the right amount and in the correct proportions to keep healthy.
- (2) **Balanced calories** with physical activity or energy output.
- (3) **To manage weight**, consume more fruits, vegetables, whole grains, fat-free or low-fat dairy products, seafood which can reduce risks of constipation and heart disease.
- (4) **Consume lower sodium**, saturated fats, trans fats, cholesterol, added sugars, refined grains to prevent diabetes and cardiovascular diseases.
- (5) **Nutritious diet** includes a selection of healthy food groups: i.e. grains, vegetables, fruits, dairy products and proteins. Consider variety, balance, proportionality and moderation.
- (6) **Healthy eating** means eating a variety of foods that give the nutrients needed to maintain health, feel good and have energy. Essential nutrients are carbohydrates, proteins, fats, vitamins, minerals, omega-3 fatty acids, fibres and water.
- (7) **Portion size** is a **recommended serving size** which is the amount of each food that a person should eat during a meal or snack.
- (8) **Healthiest diet** in the world is perhaps the Mediterranean Diet which includes abundance of fruits, vegetables, whole grains, legumes, nuts, olive oil, fish and poultry as lean sources of proteins.
- (9) Drinking enough **water** is important for health. Water is important for food digestion, waste elimination and all other body functions and metabolic activities.

4.2 DIGESTIVE SYSTEMS

Single-celled organisms (as well as sponges) digest their food **intracellularly**. They lack a digestive tract. Other animals digest their food **extracellularly** within a digestive cavity. In this case, the digestive enzymes are continuously released into the digestive cavity. In coelenterates (such as *Hydra*), the digestive cavity called a **gastrovascular cavity** has only one opening that serves as both mouth and anus (Figure 4.3).

Specialization occurs when the **digestive tract** or **alimentary canal** has a separate mouth and anus, so that transport of food is **one-way**. The most primitive digestive tract is seen in nematodes (roundworms) where it is simply a tubular gut lined by an epithelial membrane. Earthworms have a digestive tract specialized in different regions for the ingestion, storage, digestion and absorption of food. All higher animal groups including all vertebrates show similar specializations (Figure 4.4).

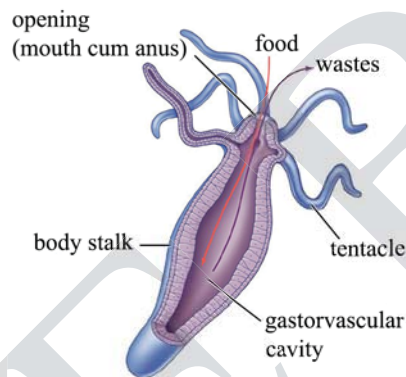


Figure 4.3 Gastrovascular cavity of *Hydra*, a coelenterate

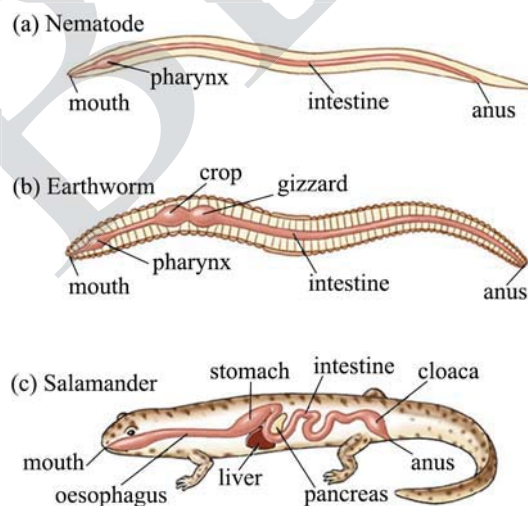


Figure 4.4 One-way digestive tract of (a) nematode (b) earthworm and (c) salamander

4.2.1 Structure of the Human Digestive System

Regions of the alimentary canal and their functions

The **alimentary canal (digestive tract)**, starting with a mouth and ending with an anus, is a tube running through the body. Food digested in the alimentary canal are absorbed and the indigestible residues are expelled (egested) (Table 4.4 and Figure 4.5).

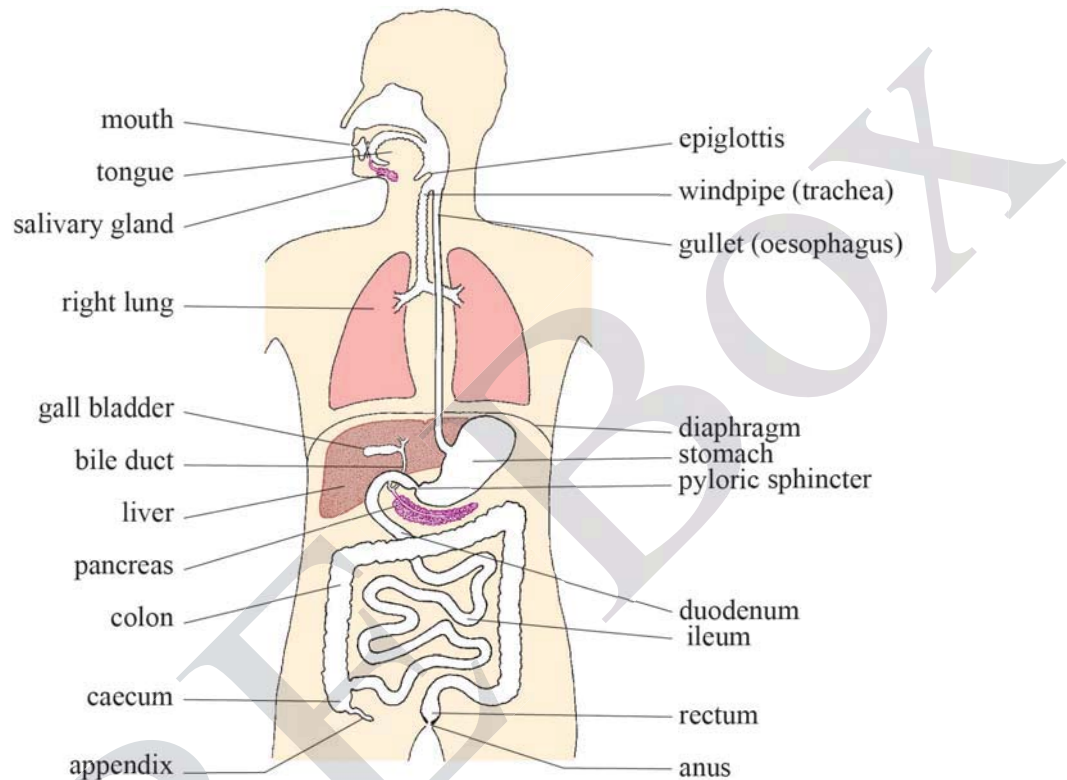


Figure 4.5 Generalized diagram of the alimentary canal in human

Two muscle layers, longitudinal and circular, cover the alimentary canal. The inside of the alimentary canal is lined with layers of cells forming an **epithelium** (Figure 4.6). There are also cells in the lining that produce **mucus**. Mucus is a slimy liquid that lubricates the lining of the canal and protects it from wear and tear and from attack by the **digestive enzymes**. Some of the digestive enzymes are produced by cells in the lining of the alimentary canal. Among the **accessory organs** (salivary glands, pancreas, liver and gall bladder) the **salivary glands** and **pancreas** produce other digestive enzymes. The **liver** produces **bile** (not enzyme) into the gall bladder and duodenum. The alimentary canal has many blood vessels in villi of its walls, close to the lining. They absorb the digested food from the alimentary canal.

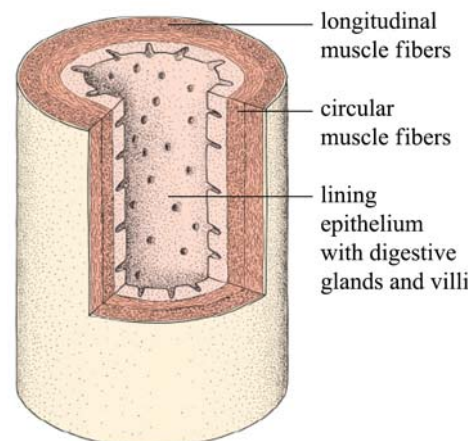


Figure 4.6 The general structure of the alimentary canal

Table 4.4 Functions of main parts of the human digestive system

Parts	Functions
Mouth	- Ingestion of food; mechanical digestion by teeth; chemical digestion of starch by amylase; formation of a bolus food for swallowing aided by the tongue
Oesophagus (gullet)	- Transfers food from the mouth to the stomach, by peristalsis
Stomach	- Produces hydrochloric acid which kills bacteria and provides optimum pH for the enzymes pepsin to be activated; also produces gastric juice which contains pepsinogen (inactivated); when pepsinogen encounters with hydrochloric acid, it becomes active pepsin; pepsin digest proteins into peptides (chemical digestion); physical digestion takes place by churning to mix food thoroughly with enzymes forming chyme.
Duodenum	- First part of the small intestine; receives pancreatic juice from pancreas for chemical digestion of starch, proteins and fats; receives bile to emulsify fats into tiny fat droplets (a form of physical digestion); neutralizes acid chyme from the stomach to have optimum pH for the enzymes; secretes maltase which converts maltose into glucose; secretes peptidase which converts peptides into amino acids
Ileum	- Second part of the small intestine; enzymes in the epithelial lining carry out chemical digestion of maltose and peptides; very long and has villi to increase surface area for absorption of digested food molecules
Colon	- First part of the large intestine; absorption of water from undigested food; absorption of bile salts to pass back to the liver
Rectum	- Second part of the large intestine; stores faeces
Anus	- Egestion of faeces
Associated glands	Functions
Salivary glands	- Saliva contains amylase which digests starch into maltose; saliva lubricates food and makes small pieces stick together
Liver	- Makes bile, containing salts to emulsify fats into tiny fat droplets; assimilation of digested food such as glucose converts into glycogen; deamination of excess amino acids
Gall bladder	- Stores bile (which is made in liver); secretes bile into the duodenum via the bile duct

Table 4.4 Functions of main parts of the human digestive system (continued)

Associated glands	Functions
Pancreas	- Secretes pancreatic juice into the duodenum via pancreatic duct; pancreatic juice contains enzymes amylase, trypsinogen and lipase; amylase converts starch into maltose; trypsinogen is inactive; after having optimum pH, it becomes an active form of trypsin which converts proteins into peptide; lipase converts tiny fat droplets into glycerol and fatty acids

4.2.2 The Process of Digestion


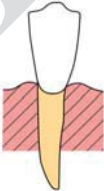
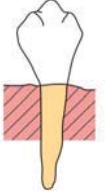

Digestion is the process by which the large complex molecules in food are broken down into smaller molecules that can be used by the body. It consists of mechanical digestion and chemical digestion.

Mechanical digestion includes: chewing in the mouth and churning in the stomach. **Chemical digestion** involves enzymes. These are proteins that function as **biological catalysts**.

Mechanical digestion

The process of mechanical digestion mainly occurs in the mouth by means of the teeth, through a process called **mastication** or grinding of food into smaller pieces. Humans are omnivores (organisms that eat animal and plant materials). Thus, although humans have different teeth termed incisors, canines, premolars and molars (Table 4.5 and Figure 4.7), they do not show such big variations in size and shape as, e.g., teeth of a wolf, a carnivore.

Table 4.5 Summary of types of human teeth and their functions

Types	Incisor (i)	Canine (c)	Premolar (pm)	Molar (m)
Diagrams				
Positions in mouth	front	either side of incisors	behind canines	back, behind premolars
Descriptions	chisel-shaped (sharp edge)	more pointed than incisors	have two points (cusps); have one or two roots	have four or five cusps; have two or three roots
Functions	biting off pieces of food	similar function to incisors	tearing and grinding food into small pieces	chewing and grinding food into smaller pieces

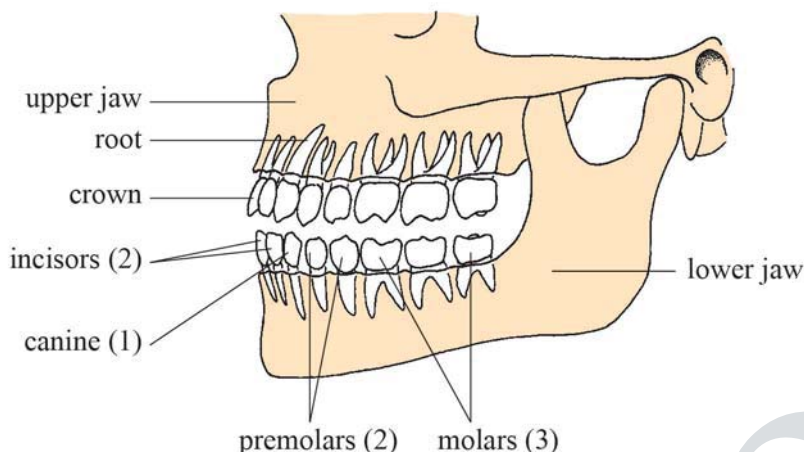


Figure 4.7 Human jaws and teeth (left side view)

Dental formula in humans

The dental formula expresses the arrangement of teeth in each half of the upper jaw and the lower jaw. The entire formula is multiplied by two to express the total number of teeth.

The dental formula for permanent teeth in humans is: $i \frac{2}{2} c \frac{1}{1} pm \frac{2}{2} m \frac{3}{3} = 32$

Each half of the upper jaw and the lower jaw has 2 incisors (i), 1 canine (c), 2 premolars (pm), and 3 molars (m) respectively. An adult human has a total of 32 permanent teeth.

Comparison of the teeth of mammals based on different diets

Table 4.6 Comparison of the teeth of mammals based on different diets

Diets	Omnivores	Carnivores	Herbivores
Examples	Man	Dog	Rabbit
Dental formulae	$i \frac{2}{2} c \frac{1}{1} pm \frac{2}{2} m \frac{3}{3} = 32$	$i \frac{3}{3} c \frac{1}{1} pm \frac{4}{4} m \frac{2}{3} = 42$	$i \frac{2}{1} c \frac{0}{0} pm \frac{3}{2} m \frac{3}{3} = 28$
Food sources	Plants and animals	Animals	Plants

Chemical digestion

Digestion is mainly a chemical process and consists of breaking down large molecules of food into small molecules. The small molecules can be absorbed by the blood vessels of the epithelium of the alimentary canal.

Some food such as **glucose** in fruit juice, for example, could pass through the walls of the alimentary canal and enter the blood vessels without digestion. Most food, however, is solid and cannot get into blood vessels. Digestion is the process by which solid food is dissolved to make a solution which is soluble.

The chemicals that dissolve or digest the food are digestive **enzymes**. All the solid starch in carbohydrate foods such as bread and potatoes are digested into **glucose** which

is soluble in water. The solid proteins in meat, eggs and beans are digested to soluble substances called **amino acids**. Fats are digested into two soluble products called **glycerol** and **fatty acids**.

Use of digested food

The products of digestion such as glucose, fats and amino acids are carried around the body in the blood. The uptake and use of food is called **assimilation**. During respiration, glucose is oxidized to form carbon dioxide, water and energy to drive **cellular metabolism**. Fats are built into cell membrane and other cell structures. Amino acids in the cells are built up with the aid of enzymes into proteins which will become enzymes, **hormones** and other cellular structures.

4.3 A HEALTHY DIGESTIVE SYSTEM

4.3.1 Identifying a Healthy Digestive System

- (1) The organs of the gut should almost always be moving driven by muscles in its thin walls. These muscles consist of an outer longitudinal layer and an inner circular layer. The coordinated contractions of these muscle layers push food and fluids along the gut, in a process called peristalsis.
- (2) Digestive enzymes from glands, in the mucosa or lining of the mouth, stomach and small intestine, help in the digestion of food.
- (3) Juices, secreted by the salivary glands, liver and pancreas, help make food dissolve in water so that nutrients can be passed easily into the blood stream.
- (4) Teeth should be healthy, to cut and grind solid food, into digestible smaller pieces, before swallowing the food into stomach through the gullet or oesophagus.
- (5) The swallowed food must be directed to enter the oesophagus and be prevented from entering the windpipe or trachea to the lungs. A cartilage flap called epiglottis must be functioning to close the windpipe during swallowing.
- (6) The colon must move normally to expel the faeces (egestion) easily and regularly.
- (7) The digestive tract and accessory organs such as liver, pancreas and gall bladder should be free of infection, ulcers and abnormal growth.
- (8) The pH of gastric juice should be acidic in the stomach but alkaline in the small intestine.

4.3.2 A Malfunctioning Digestive System

The digestive tract is made up of the mouth, oesophagus, stomach, small and large intestines and rectum, with liver, gall bladder and pancreas as accessory organs.

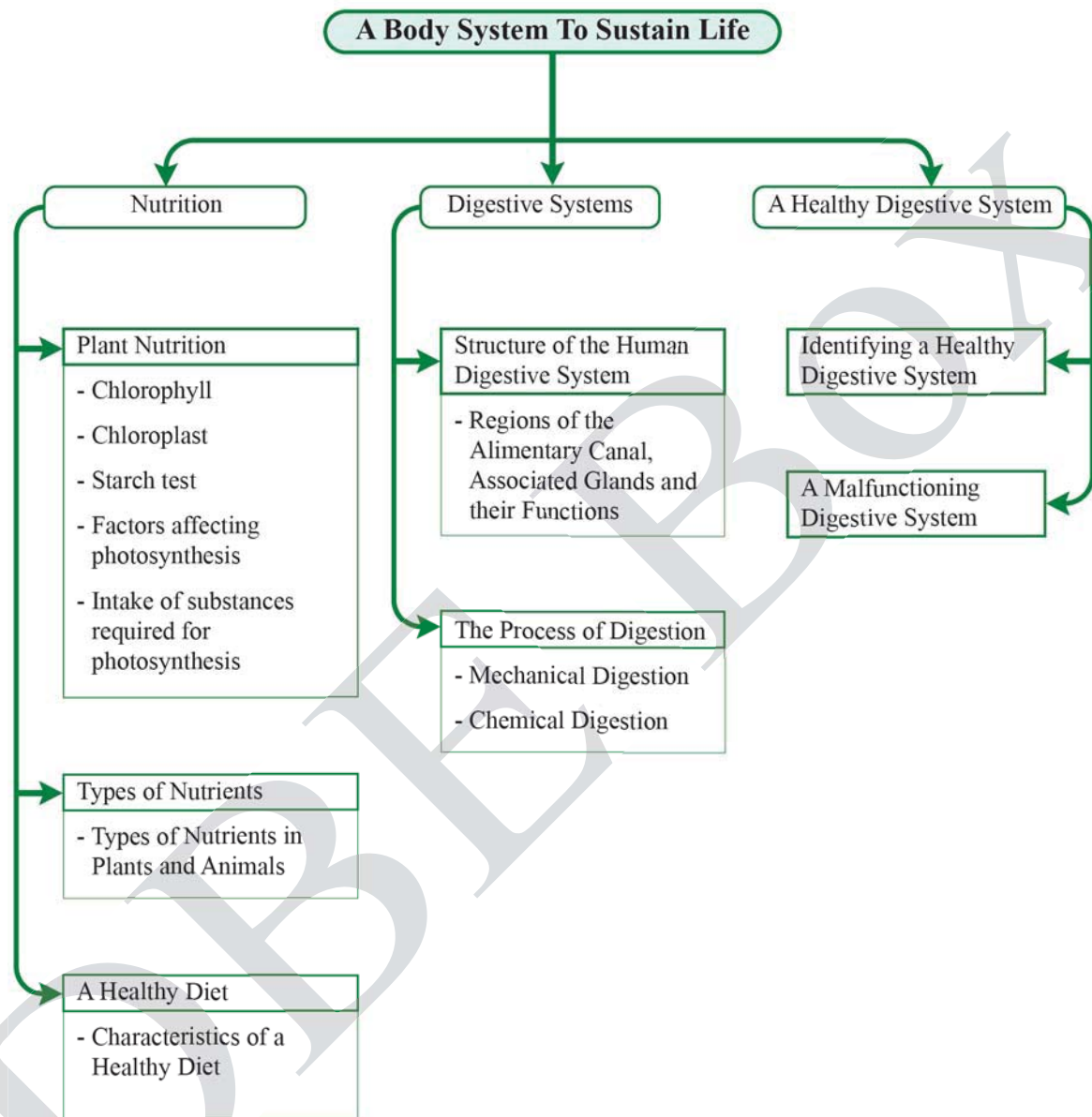
Many **symptoms** can signal problems with the digestive tract. These include abdominal pain, blood in the stool, bloating, constipation, diarrhea, heartburn, incontinence, nausea and vomiting and difficulty in swallowing. The symptoms indicate the occurrence of some common **diseases** in the digestive system.

Some examples of common diseases in human gut and teeth include: (1) constipation (2) appendicitis (3) gall stones (4) stomach ulcers (5) gastrointestinal infections (6) hepatitis (7) polyps and colon cancer and (8) tooth decay (dental caries).

Review questions

1. Mention the raw materials of photosynthesis and its equation.
2. How would you demonstrate that starch is formed during photosynthesis?
3. Write briefly on the intake of substances required for photosynthesis.
4. Give the functions of macronutrients in plants.
5. Tabulate the food sources of carbohydrates and proteins and the effects of their deficiency.
6. Which macronutrients prevent constipation? Mention their functions, food sources and effects of deficiency.
7. Describe the nutrients that the animals need to sustain life.
8. What micronutrients are essential for human?
9. What are the macronutrients? How important are they in a human diet?
10. What will happen to the human body if the diet is not balanced? Focus on nutrient deficiencies.
11. Describe the structures and functions of teeth in human.
12. Why are foods needed to be digested?
13. Where do chemical digestion and absorption of food occur in the human digestive tract?
14. Enumerate the factors which maintain a healthy digestive system.
15. Explain some of the common symptoms and diseases of malfunctioning digestive system.

Concept map



CHAPTER 5 CONTINUATION OF LIFE

Learning Outcomes

It is expected that students will

- explain the types of reproduction in plants and animals
- describe the formation and role of gametes
- explain how chromosomes behave during reproduction
- identify the steps in the processes of mitosis and meiosis and compare the two processes
- explain the role of chromosomes and genes in the inheritance of characteristics and on the continuation of life

5.1 REPRODUCTION

The production of new organisms from the existing organisms of the same species is called reproduction. Reproduction is essential for survival of species on earth. The process of reproduction ensures continuation of life on earth.

5.1.1 Reproduction in Fungi and Plants

Two main types of reproduction found in fungi and plants are asexual and sexual reproductions.

Asexual reproduction in cyanobacteria, fungi and plants

A new individual produced from a single parent without involving the sex cell (gamete) is called asexual reproduction. Asexual reproduction may occur through binary or multiple fission, budding, fragmentation, spore formation and vegetative propagation.

Fission

When the parent organism reaches its maximum growth, it splits to form two new organisms. e.g., Cyanobacteria, etc. (Figure 5.1)

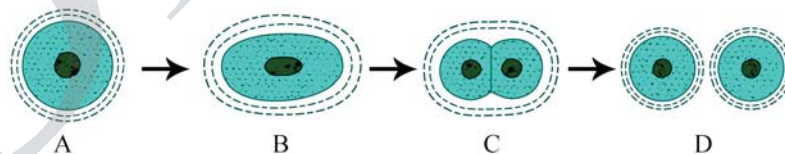


Figure 5.1 Asexual reproduction in Cyanobacteria by binary fission

Budding

In budding, a small part of a body of the parent organism grows out as a bud which then detaches and becomes a new organism. e.g., Yeast (Figure 5.2)

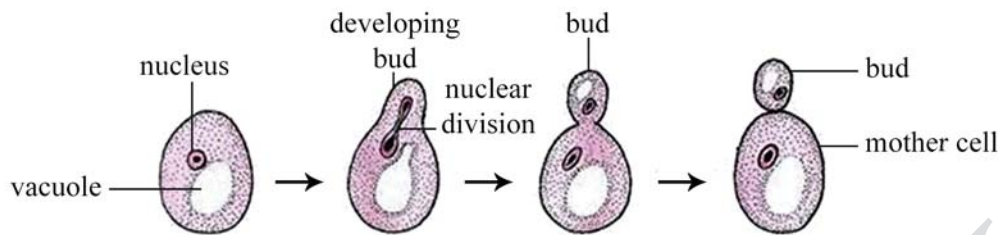


Figure 5.2 Asexual reproduction in yeast by budding

Fragmentation

The breaking up of the body of simple multicellular organism into two or more fragments, each fragment subsequently grows to form a new complete organism.

e.g., *Spirogyra* (a green filamentous alga) (Figure 5.3)

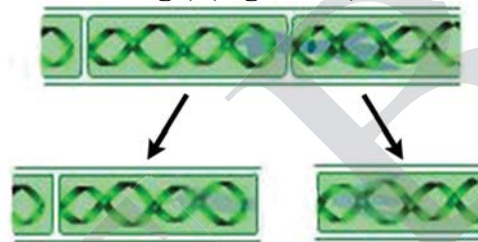


Figure 5.3 Asexual reproduction in *Spirogyra* by fragmentation

Spore formation

The parent plant produces many microscopic reproductive units called spores inside the spore sac. When the spore sac (sporangium) bursts, then the spores spread into air. When these spores stand on food or soil, under favorable condition they germinate and produce the new plants. e.g., Fern (Figure 5.4)



Figure 5.4 Asexual reproduction in Fern by spores

Vegetative propagation

In vegetative propagation, new plants are obtained from the parts of old plants such as stems, leaves or roots without the help of any reproductive organ. The green grass grows in the field after rain from the dry, old stem of the grass plant by the method of vegetative propagation.

Similarly, *Bryophyllum* plants can be reproduced by vegetative propagation by its leaves; gingers grow from the nodes of rhizomes, potato grows from the bud or eye of the tuber (Figure 5.5, 5.6 and 5.7).

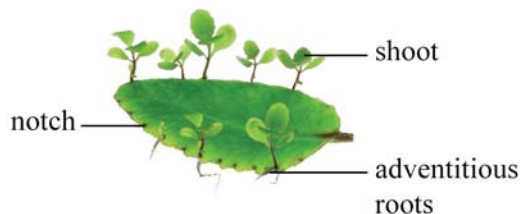


Figure 5.5 Vegetative propagation of *Bryophyllum* by leaves

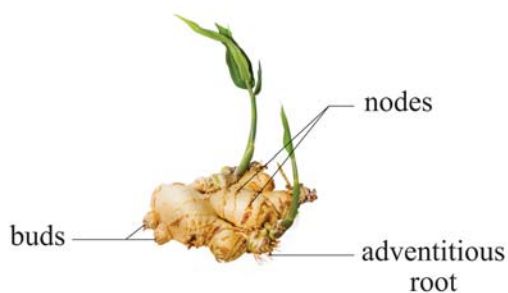


Figure 5.6 Vegetative propagation of ginger by rhizome



Figure 5.7 Vegetative propagation of potato by tuber

Artificial methods of vegetative propagation

The process of growing many plants from one plant by man-made method is called artificial method of vegetative propagation.

1. **Cutting:** A small part of root, stem, or leaves from a plant which is cut with a sharp knife is called cutting. A cut piece of the plant necessary to have some buds on it. e.g., rose, sugarcane, cactus (Figure 5.8).
2. **Layering:** It is a type of vegetative multiplication in which shoot of parent plant is allowed to develop roots while it is intact with the plant. After the development of enough roots, the shoot is detached from the parent plant to plant in the medium to lead an independent life. In layering, rooted branch is called a **layer**. e.g., rubber, croton (Figure 5.9).
3. **Grafting:** The cut stems of two different plants (one with roots and the other without roots) are joined together to grow as single plant is called grafting. The new plant has the characteristics of both plants. The cut stem having roots is called **stock** and the cut stem of another plant without roots is called **scion**. e.g., apple, mango, avocado (Figure 5.10).
4. **Budding:** Budding is a form of grafting most often used commercially. In this procedure, just the axillary buds are grafted onto the stem of another plant. e.g., rose, avocado, plum, citrus (Figure 5.11).

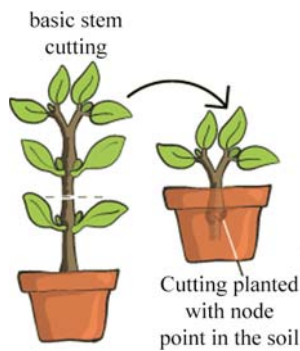


Figure 5.8
Vegetative propagation by cutting



Figure 5.9
Vegetative propagation by layering



Figure 5.10
Vegetative propagation by grafting



Figure 5.11
Vegetative propagation by budding

Micropropagation (Tissue Culture)

The new plants are produced from a small piece of the plant tissue (e.g., branch tip, root tip, leaf portion) in growing medium (agar medium).

Sexual reproduction in plants

The production of new plant from two parent plants by the use of sex cells (gametes) is called sexual reproduction. In plants, the sex organs are carried within the flowers.

Female gamete

Fertilization takes place inside the ovary inside which is the female gamete. One or many ovules are found attached to the inner wall of the ovary by means of funicles.

The body of the ovule is termed as the nucellus and one or two layers of integuments cover it. A pore, left uncovered, at the tip of the ovule, is the micropyle. Embedded in the nucellus is a large oval-shaped embryo sac, containing eight nuclei. Three of these are situated at the micropylar end. The biggest is called the egg cell or the female gamete. The other two are the synergids. At the opposite end are three nuclei, known as the antipodal cells. At the centre of the embryo sac are two polar nuclei (Figure 5.12).

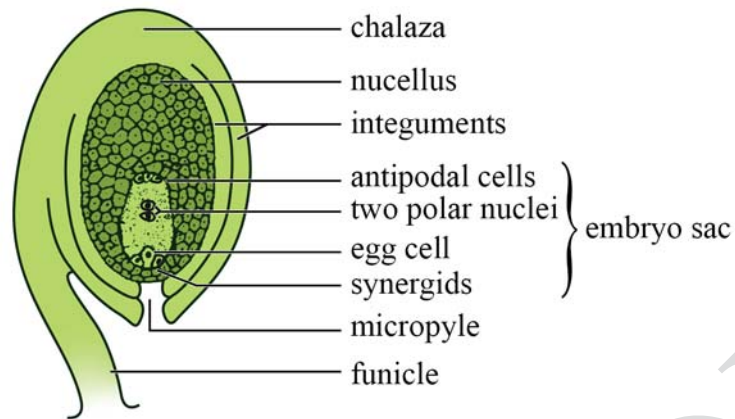


Figure 5.12 L.S. of ovule

Male gamete

The formation of male gamete takes place inside the pollen, a more or less rounded structure. It is uninucleate and possesses a two-layered wall. The inner wall or the intine is soft and thin. The outer wall or the exine is tough and often provided with spinous outgrowth. Some weak spots called germ pores may be present in the exine.

At the time of pollination, the stigma is viscous with a sticky substance containing sugar and other compounds. This substance stimulates the pollen grains to germinate.

Just before pollination, the nucleus of the pollen divides into two, the tube nucleus and the generative nucleus. On pollination, the pollen begins to germinate and the intine protrudes through the germ pore of the exine and elongates to form a pollen tube. The tube nucleus, carried along with the generative nucleus at the tip of the pollen tube controls the growth of the pollen tube.

The pollen tube penetrates the stigma and grows down the style until it finally reaches the ovule. By that time, the generative nucleus has already divided into two male gametes (Figure 5.13).

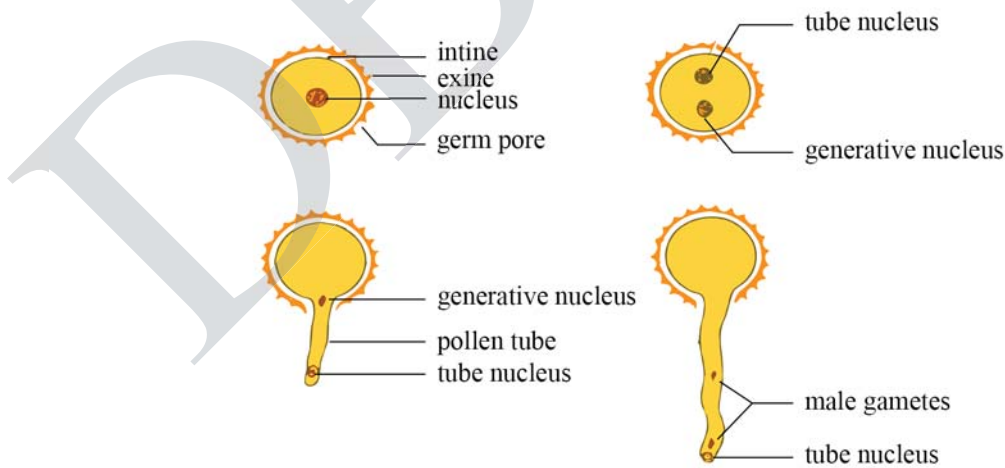


Figure 5.13 Germinating pollen grain

Fertilization

The pollen tube enters the ovule through the micropyle and it passes through the nucellus to approach the embryo sac. Then the tip of the pollen tube dissolves and the two male gametes are set free into the embryo sac. The tube nucleus disintegrates eventually.

One of the two male gametes fuses with the female gamete or egg cell, resulting in the fertilized egg or oospore. This process is termed as “fertilization”. The two polar nuclei fuse to form the definitive or secondary nucleus. This in turn fuses with the second male gamete to form the primary endosperm nucleus.

The fusion of three nuclei, i.e. the two polar nuclei and the male gamete is therefore termed as “triple fusion”. One male gamete fuses with the egg cell and the other with the two polar nuclei and that is why this process of fertilization and triple fusion are together known as “double fertilization”.

During the process of fertilization, the synergids direct the male gamete towards the egg cell and the polar nuclei. They then disintegrate. The antipodal cells disappear before fertilization (Figure 5.14).

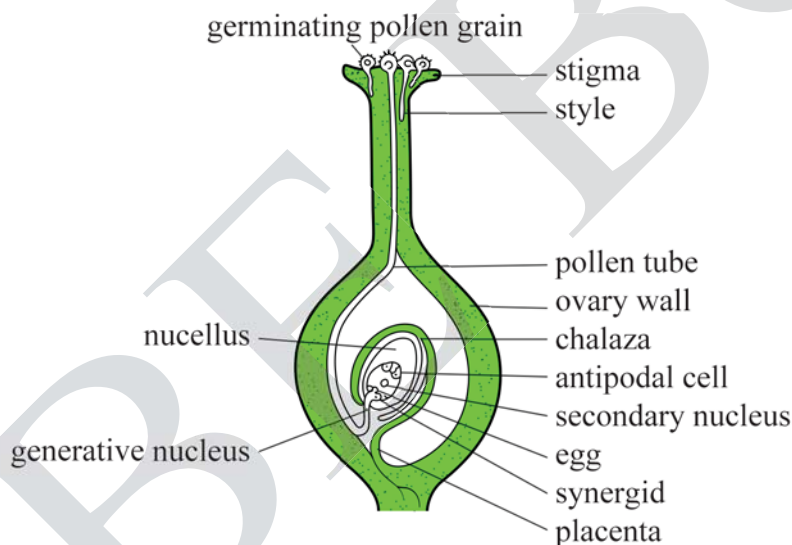


Figure 5.14 L.S. of the ovule showing the process of fertilization

Changes after fertilization

After fertilization, the stigma, style, stamens and petals wither and fall off. The sepals may fall off in some plants, in others they may persist until the formation of the fruits. The ovules develop into seeds and the ovary as a whole changes to form a fruit. The embryo sac enlarges and the fertilized egg grows and gives rise to an embryo. At the same time, the primary endosperm nucleus divides repeatedly to form the endosperm which stores food material for the growing embryo. The integuments become the seed coats.

5.1.2 Reproduction in Animals

Two types of reproduction, asexual and sexual, are found among the animals. Asexual means ‘without sex’ and this method of reproduction does not involve gametes (sex cells). In sexual reproduction, gametes from male and female combine to form an embryo which then grows into a young organism.

Asexual reproduction in animals

Some species of invertebrate animals are able to reproduce asexually by fission, fragmentation, budding or parthenogenesis. Some protists such as *Amoeba* reproduce by fission whereas sponges and some echinoderms reproduce by fragmentation. In some insects such as bees reproduce by parthenogenesis. *Hydra* is a small animal, 5-10 mm long, which lives in ponds attached to pondweed. *Hydra* has an asexual method of reproduction called **budding**. But *Hydra* can also reproduce sexually by gametes (Figure 5.15).

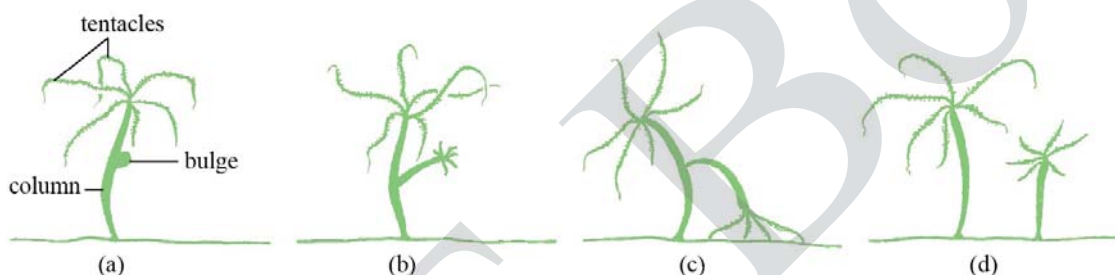


Figure 5.15 Asexual reproduction by budding in *Hydra* (a) a group of cells on the column starts dividing rapidly and produces a bulge (b) the bulge grows and develops tentacles (c) the daughter *Hydra* pulls itself off the parent and (d) the daughter becomes an independent animal

Sexual reproduction in animals

Sexual reproduction involves the production of sex cells. These sex cells are called **gametes** and they are made in reproductive organs called testes (in male) and ovaries (in female). The process of cell division that produces the gametes is called **meiosis**. In sexual reproduction, the male and female gametes come together and fuse (**fertilization**), i.e. their cytoplasm and nuclei join together to form a single cell called a **zygote**. The zygote or embryo then grows into a new individual (Figure 5.16).

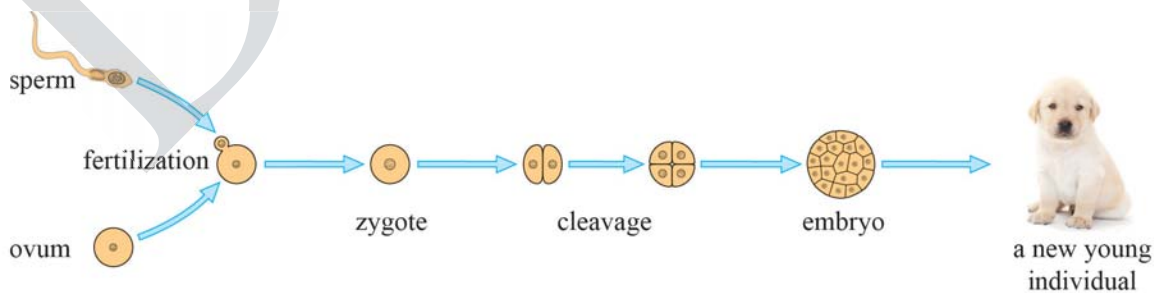


Figure 5.16 Fertilization and development of embryo and young in sexual reproduction of an animal

Sexual reproduction in humans

In humans, like in other mammals, an ovum from a female (a woman) is fertilized by a sperm from a male (a man), after sexual intercourse. This produces an embryo in the woman's uterus. After 270 days of conception which is about nine months, an embryo grows into a foetus and then a baby is born.

Female

The female reproductive organs and parts are shown in Figure 5.17 and Table 5.1.

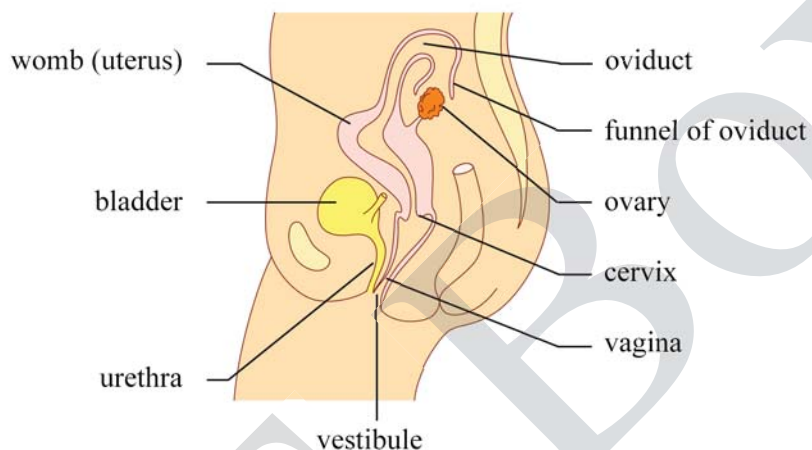


Figure 5.17 The female reproductive system in human (side view)

Table 5.1 Functions of parts of the female reproductive system in humans

Parts	Functions
Ovary	- Contains follicles in which ova (eggs) are produced
Funnel of oviduct	- Directs an ovum (egg) from the ovary into the oviduct
Oviduct	- Carries an ovum to the uterus, with propulsion provided by tiny cilia in the wall; also the site of fertilization
Uterus	- Where the foetus develops
Cervix	- A ring of muscle, separating the vagina from the uterus
Vagina	- Receives the male penis during sexual intercourse; sperm are deposited here: serves also as a birth canal
Urethra	- Carries urine from the bladder
Vestibule	- Area guarding the urethral and vaginal openings

Male

The male reproductive organs and parts are shown in Figure 5.18 and Table 5.2.

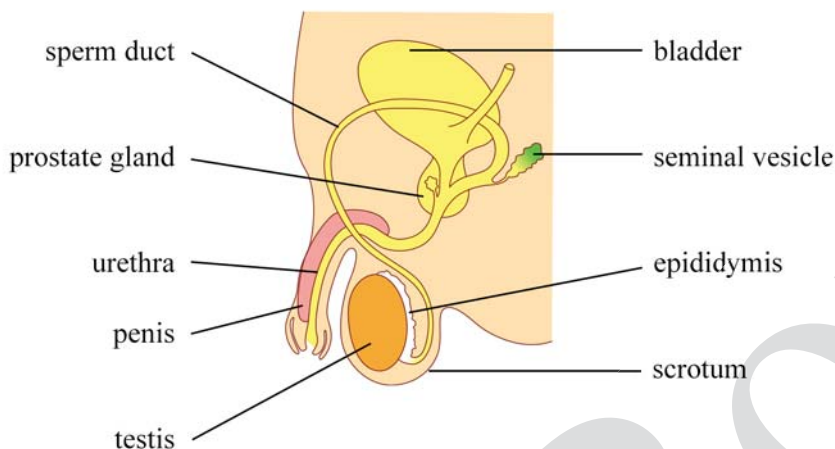


Figure 5.18 The male reproductive system in human (side view)

Table 5.2 Functions of parts of the male reproductive system in humans

Parts	Functions
Testis	- Male gonad that produces sperm
Epididymis	- A mass of tubes in which sperm are stored
Sperm duct	- Muscular tube that links the testis to the urethra to allow the passage of semen containing sperm
Seminal vesicle	- Adds fluid and nutrients to sperm to form semen
Prostate gland	- Adds fluid and nutrients to sperm to form semen
Scrotum	- A sac that holds the testes outside the body, keeping them cooler than the body temperature
Urethra	- Passes semen containing sperm through the penis; also carries urine from the bladder
Penis	- Can become firm, to insert into the vagina of the female during sexual intercourse to transfer sperm

Fertilization

Immediately after **mating** or **copulation** (sexual intercourse), the sperm swim up the uterus through the mucus lining to the oviducts (**fallopian tubes**). If there is an egg, one of the sperm may fuse with it to form a **zygote**. The process in which an egg unites with a sperm is termed as **fertilization**.

Implantation

The zygote divides continuously into a ball of cells called **embryo**. The embryo moves towards the uterus, becomes attached to the wall and is surrounded by the uterus lining. This process is termed **implantation**.

Gestation period

The period between fertilization and birth is called **gestation period** and it takes about nine months in humans. During this period, the following new structures are developed to keep the embryo alive and healthy.

Placenta - has numerous finger-like villi made up partly of embryonic tissue and partly of uterine wall (maternal tissue). The villi consist of maternal and embryonic **blood capillary** systems which are very closely associated, allowing easy diffusion of oxygen, nutrients and antibodies to the embryo and metabolic wastes from the embryo. The placenta also secretes **hormones**.

Umbilical cord - connects the embryo's body to the placenta. The two umbilical arteries and one umbilical vein are the first embryonic structures to develop. The arteries carry deoxygenated blood and excretory wastes from the embryo to the placenta. The vein carries oxygenated blood and dissolved nutrients from the placenta to the embryo.

Amnion - a sac-like membrane around the embryo, filled with a watery fluid called amniotic fluid.

Amniotic fluid - allows the embryo freedom of movement during growth and cushions it against knocks and mechanical injury (Figure 5.19).

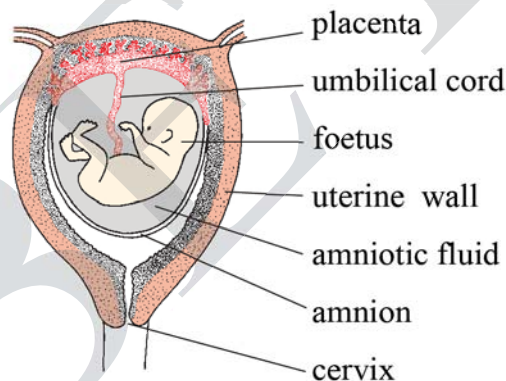


Figure 5.19 Developing foetus in human uterus

Birth

The embryo eventually develops into a **foetus**, with recognizable human features. At the end of gestation period, the muscular uterine walls begin to contract. This is termed as **labour**. The amnion bursts and the amniotic fluid is discharged. The cervix opens, and the foetus now called a baby, passes through the vagina, then out of the mother's body. This is termed birth.

Lactation and maternal care

Lactation is the process of producing milk in the mother's breasts, for feeding the baby. Breastfeeding is one of the maternal care activities.

Menstrual cycle

Ovulation occurs once in about every 28 days in woman. If the egg is not fertilized within 36 hours, it dies and the uterus lining breaks down slowly. The dead egg together with the uterus lining, mucus and some blood are discharged through the vagina. This period of bleeding is termed as **menstruation**. Ovulation does not occur during pregnancy. Therefore, menstruation ceases once a woman is pregnant until after the baby is born.

5.2 INHERITANCE

Inheritance is the transmission of genetic information from generation to generation. Plants and animals inherited certain characteristics such as plant height, fruit colour, seed shape, skin colour and eye colour. The inheritance of such characteristics is called **heredity**. Heredity is the passing of traits from parent to offspring. The branch of biology that studies how heredity works is **genetics**.

5.2.1 Nature of Chromosomes, Genes and DNA

Chromosome

Chromosome is an organized package of DNA found in nucleus of the cell.

Structure of chromosome

Each **chromosome** is made up of DNA and proteins. It can be seen at the time of cell division. Each chromosome has certain characteristics when it is ready to divide. It becomes two chromatids, joined at one point called a **centromere**. Each chromatid is a string of genes, coding for the person's characteristics. The other chromatid carries the same genes in the same order. Genes are segments of DNA (Figure 5.20).

A human body (somatic) cell nucleus contains 23 pairs of chromosomes. These are difficult to distinguish in the nucleus, so biologists separated and arranged them by sizes and appearances. This arrangement is called a **karyotype** (Figure 5.21).

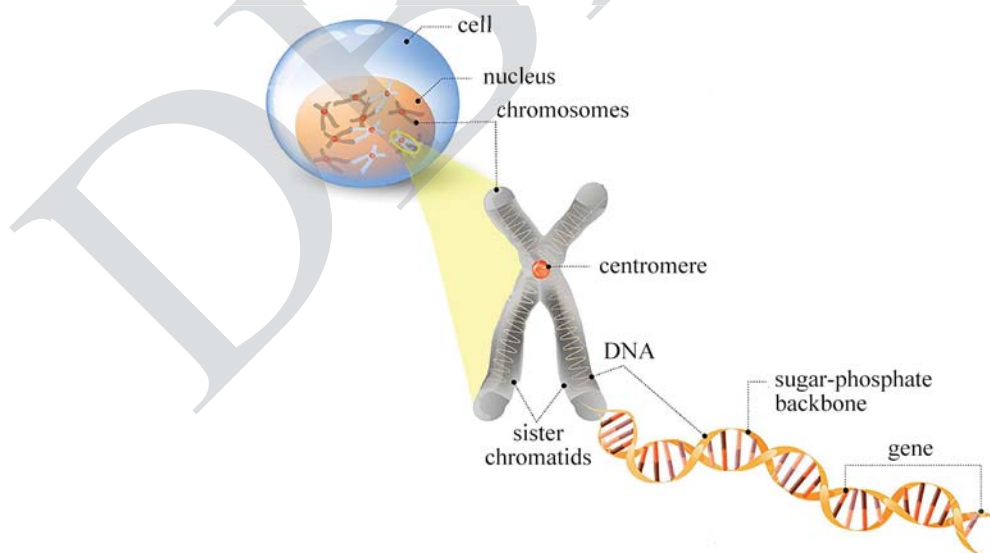


Figure 5.20 Nature of chromosomes, genes and DNA

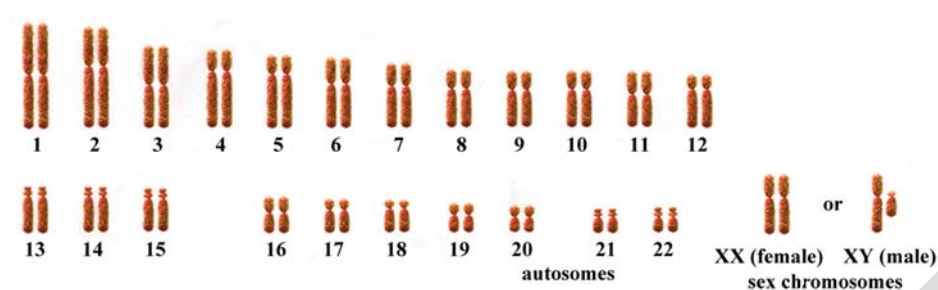


Figure 5.21 Human karyotype

Number of chromosomes

There is a **fixed number** of chromosomes in each cell of the same species. In human body cells, each contains 46 chromosomes, mouse cell contains 40, wheat contains 42 and garden pea contains 14. The number of chromosomes in a species is the **same** in all of its body cells. There are 46 chromosomes in each of liver cells, in every nerve cell, skin cell and so on in humans. The chromosomes are always in pairs, called **homologous chromosomes** such as two long ones, two short ones and two medium ones because one of each pair comes from the male gamete and one from the female gamete. In humans, there are 46 chromosomes in each cell which are inherited as 23 chromosomes from the mother and another 23 from the father.

Genes

The **gene** is the basic physical and functional unit of heredity. It is a length of **DNA** which consists of a **specific sequence** of nucleotides at a given position on a given chromosome that codes for a specific protein.

Gene locus

Each gene occupies a specific position on a chromosome called the gene locus.

Allele

One of the alternative forms of a gene. In a diploid cell, there are usually two alleles occupying the same **gene locus** of a pair of homologous chromosomes.

Deoxyribonucleic acid (DNA)

DNA is the chemical substance found in the chromosomes of the nucleus of a cell. DNA is the basis of inheritance in all organisms.

Structure of DNA

A molecule of DNA is made from two strands of nucleotides. Each nucleotide contains a nitrogenous base which is either adenine (A) or thymine (T) or cytosine (C) or guanine (G), a sugar molecule and a phosphate group (Figure 5.22).

In the two strands of DNA, nucleotides with adenine are always paired to opposite nucleotides with thymine and nucleotides with guanine to that of cytosine. Adenine and thymine are **complementary** bases, as are also cytosine and guanine. Complementary bases always bind with each other. They are always fixed pair. This is known as base-pairing rule. DNA can **replicate** itself, so replication is able to pass genetic information from one generation to the next as a **genetic code** (Figure 5.23).

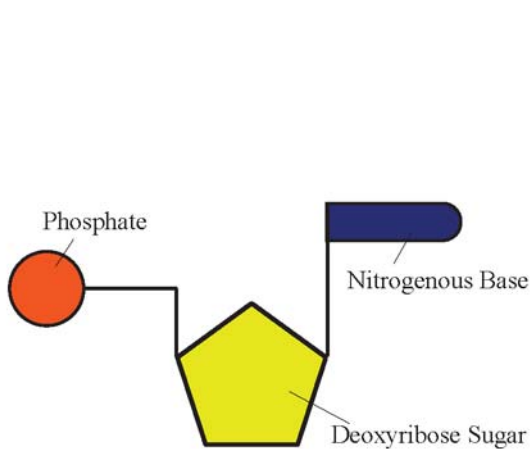


Figure. 5.22 A nucleotide of DNA

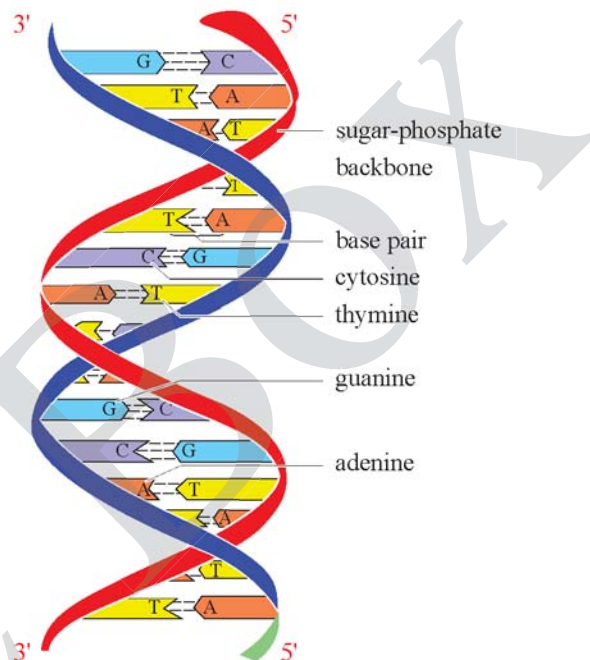


Figure 5.23 The structure of DNA

5.2.2 Cellular Reproduction

Cellular reproduction is a process by which cells duplicate their contents and then divides to produce two similar cells. It is essential to growth and development of cells.

Cell division

Every living cell is formed from a pre-existing cell by the process of cell division. Cell division consists of four stages, **prophase**, **metaphase**, **anaphase** and **telophase**. The cell cycle includes an additional stage termed interphase. Cell division in eukaryotes is the process by which a parent cell divides into two or more daughter cells. In eukaryotes, there are two distinct types of cell division; a vegetative cell division where each daughter cell is genetically identical to the parent cell i.e., same number of chromosomes (**mitosis**) and a reproductive cell division where the number of chromosomes in the daughter cell is reduced by half to produce haploid gametes (**meiosis**).

Types of cell division

Two different types of cell division in eukaryotes are mitosis and meiosis.

Mitosis

Mitosis is a process that creates a nearly exact copy of the parental cells. The mitotic cell division involves mitosis and cytokinesis. Mitosis is the division of the nucleus and results into two identical daughter nuclei. Cytokinesis is the division of the cytoplasm into two cells. After mitosis and cytokinesis, two diploid daughter cells which are genetically identical to the diploid parent cells (Figure 5.24).

Meiosis

Meiosis is a different form of cellular reproduction that leads to germ cells or sex cells. It consists of two stages: Meiosis I and Meiosis II. Meiosis I is the first cell division, results into two haploid cells and meiosis II is the second cell division, results into four haploid cells. This type of cell division is called reduction division because they contain half the number of chromosomes of the diploid parent cells (Figure 5.25).

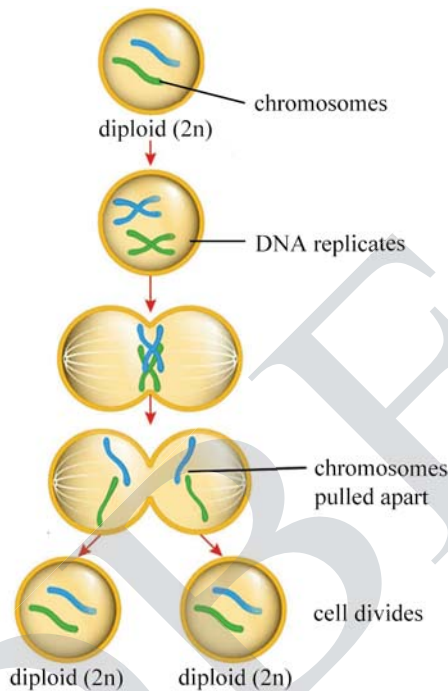


Figure 5.24 Mitosis

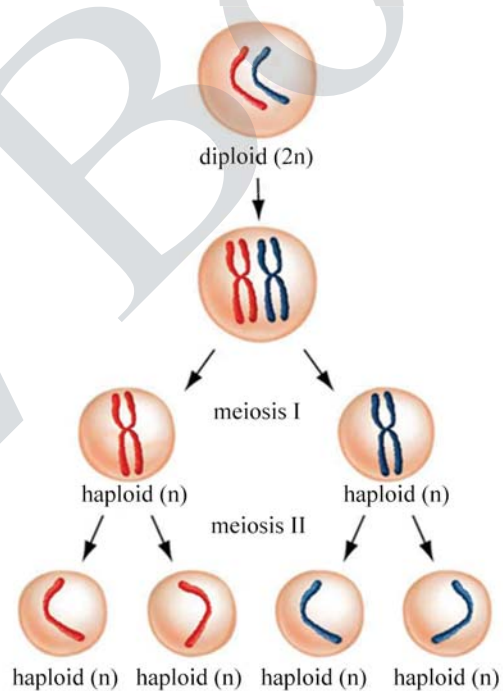


Figure 5.25 Meiosis

Importance of mitosis

Mitosis produces two daughter cells with the same identical genetic components (chromosomes) as the parent cell. Mitosis is important to regulate the cell growth, development and repair in multicellular organisms.

Importance of meiosis

Meiotic cell division produces four haploid sex cells from existing diploid cell and therefore it creates genetic variation. Meiosis is nature's way of keeping the chromosome number constant from generation to generation.

Table 5.3 Mitosis versus meiosis

Facts	Mitosis	Meiosis
Type of reproduction	- Asexual	- Sexual
Occurs in	- All eukaryotes	- Humans, animals, plants, fungi
Genetically	- Identical to parent cell	- Different from parent cell
Function	- Cellular reproduction, general growth, repair of the body and clone production	- Genetic diversity through sexual reproduction
Chromosome number	- Remain the same as in parent cell	- Reduce by half of parent cell
Creates	- New cells other than sex cells	- Sex cells only: female egg cells or male sperm cells

5.2.3 The Role of Cellular Reproduction in Multicellular Organisms

In multicellular organisms, the cellular reproduction (cell division) is important for the following purposes.

1. Growth – The cells in meristematic tissues of multicellular plants divide throughout life for growth in length and girth, while growth in animal cells increases in number by mitotic cell division.
2. Healing of wounds – In both plants and animals, cells divide to heal the wounds. It is an occasional event by mitosis.
3. Reproduction – Sex cells of both plants and animals divide meiotically during the reproductive age.
4. Stem cells – In animals, after mitotic cell division, some cells become specialized but some become stem cells which are able to divide for continuous growth of the animals. But specialized cells cease to divide.

5.2.4 The Role of Chromosomes and Genes in Inheritance

Heredity is the transfer or passing of characteristics genetically from the parents to the offspring.

The genetic information is carried within chromosomes. The chromosomes are found in the nucleus of a cell. Long coiled molecules of DNA make up chromosomes. The genes are contained in the DNA. They are the units of heredity and are responsible for inheritance. Information for the expression of characteristics is contained in genes. Different traits are formed by different genes. The gene carries the genetic code for a particular characteristic. e.g., the height of a person or the facial features such as nose or jawline are all controlled by different genes.

The inheritance of characteristics in an organism is contributed equally by the mother and father. The mother and father provide equal amounts of genetic material to their offspring. Therefore, each trait has two factors, one that comes from the mother and the other that comes from the father.

Most of the genes have more than two variations, they are called alleles. e.g., there are two alleles for the height gene, one is short and one is tall. The offspring may inherit the same alleles from both parents or two different alleles from them. When the offspring inherits two different alleles then it interacts in a particular way. There is a dominant trait and a recessive trait.

The dominant trait comes from an allele of the gene that decides the trait in the presence of the other recessive allele of the identical gene. The trait that does not get to express itself is called the recessive trait.

Genetics

Genetics is the study of heredity and variations of inherited characteristics, and the way that characters are passed on from one generation to the next.

Character

A distinctive inherited feature of an organism

Trait

Different variations of a character

Variation

Variation is the differences in characters between the individuals of the same species.

Dominant trait

The trait is expressed in an organism, suppressing the recessive trait. The dominant trait is denoted using capital letters.

Recessive trait

The trait stays suppressed or cannot be expressed in the presence of the dominant trait. The recessive trait is denoted using small letters.

Dominant allele

An allele carries the dominant trait and is expressed in the phenotype of the organism. For example, the dominant trait tall is represented by **T**.

Recessive allele

An allele carries the recessive trait and is only expressed as the phenotype of the organism in the absence of the dominant allele. For example, the recessive trait short or dwarf is represented by **t**.

Genotype

The genetic constituents of an organism, i.e., the different alleles of different traits present in a gene. That is **TT** or **Tt** for tall genotypes, **tt** for short or dwarf genotype.

Phenotype

The observable characteristics of an organism are determined by the specific genotype. That is whether the plant is tall, short, with white flowers or red ones, etc.

Homozygote

An individual contains only one allele of the allelic pair. Alleles that form the homozygous allelic pair are the same (e.g., **TT**). A homozygote produces only one kind of gamete.

Heterozygote

An individual contains one of each member of the allelic pair. Alleles that form the heterozygous allelic pair are different (e.g., **Tt**). A heterozygote produces different kinds of gamete.

Pure breeding plants

Those plants when self-fertilized, produce identical offspring generation after generation.

Pure line animals

Mating sexually between the homozygous individuals (male and female) produces individuals of pure line with same genetic identity for many generations.

Patterns of inheritance

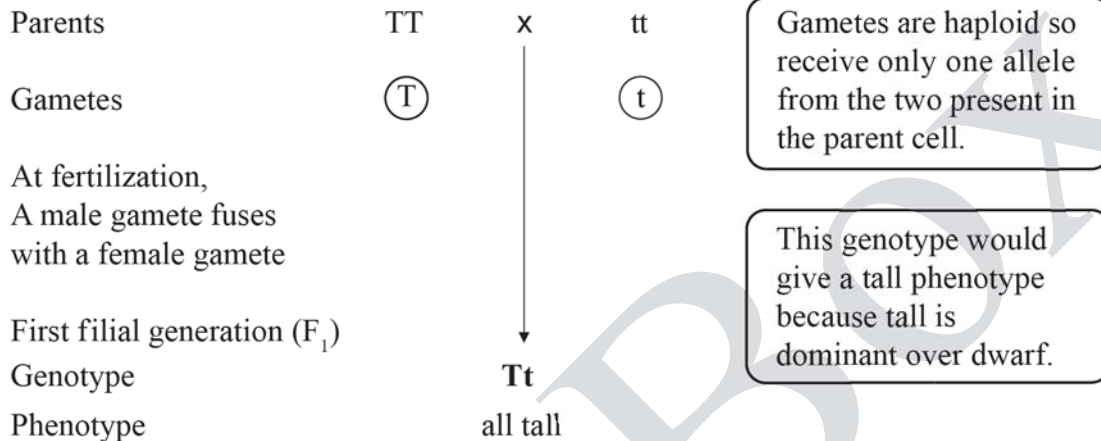
The breeding experiments are carried out to study the inheritance of characteristics in sexually reproducing plants and animals. There is a general pattern for describing the results of experiments. At fertilization, male gamete fuses with female gamete to produce offspring or progeny. In writing the stages of a cross, chromosomes and genes are replaced by using **symbols** that should be identified at the start of a **cross**.

For example: Monohybrid crosses

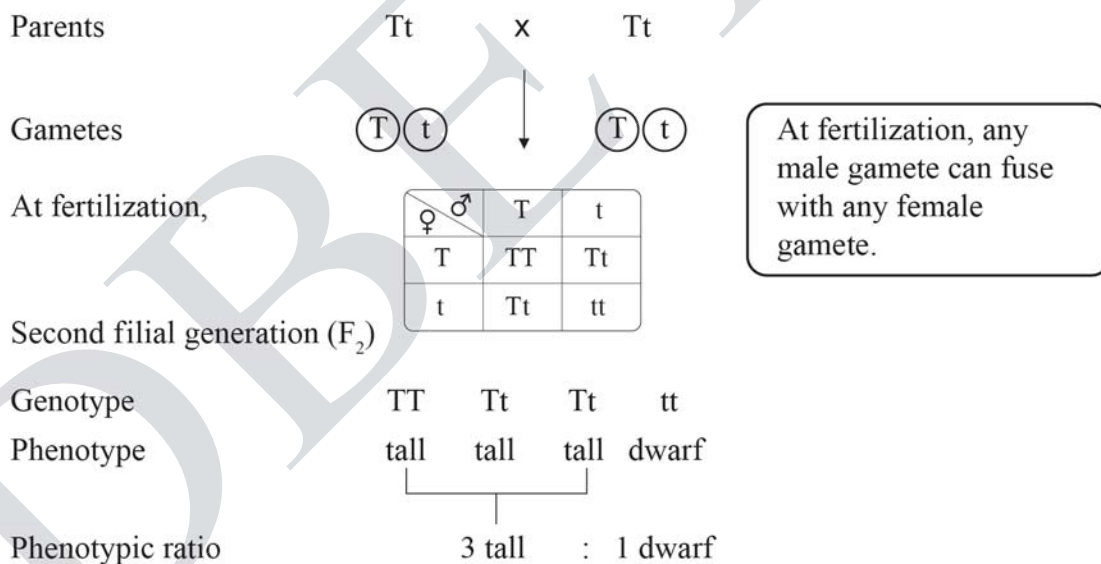
Let **T** = tall allele and **t** = dwarf or short allele for height

The capital letter is used for dominant allele and small letter is used for recessive allele. Tall **T** and dwarf **t** are alleles for pea plant height.

- A cross between a homozygous tall (**TT**) and a homozygous dwarf (**tt**) parents



- A cross between a heterozygous tall (**Tt**) and a heterozygous tall (**Tt**) parents from F_1

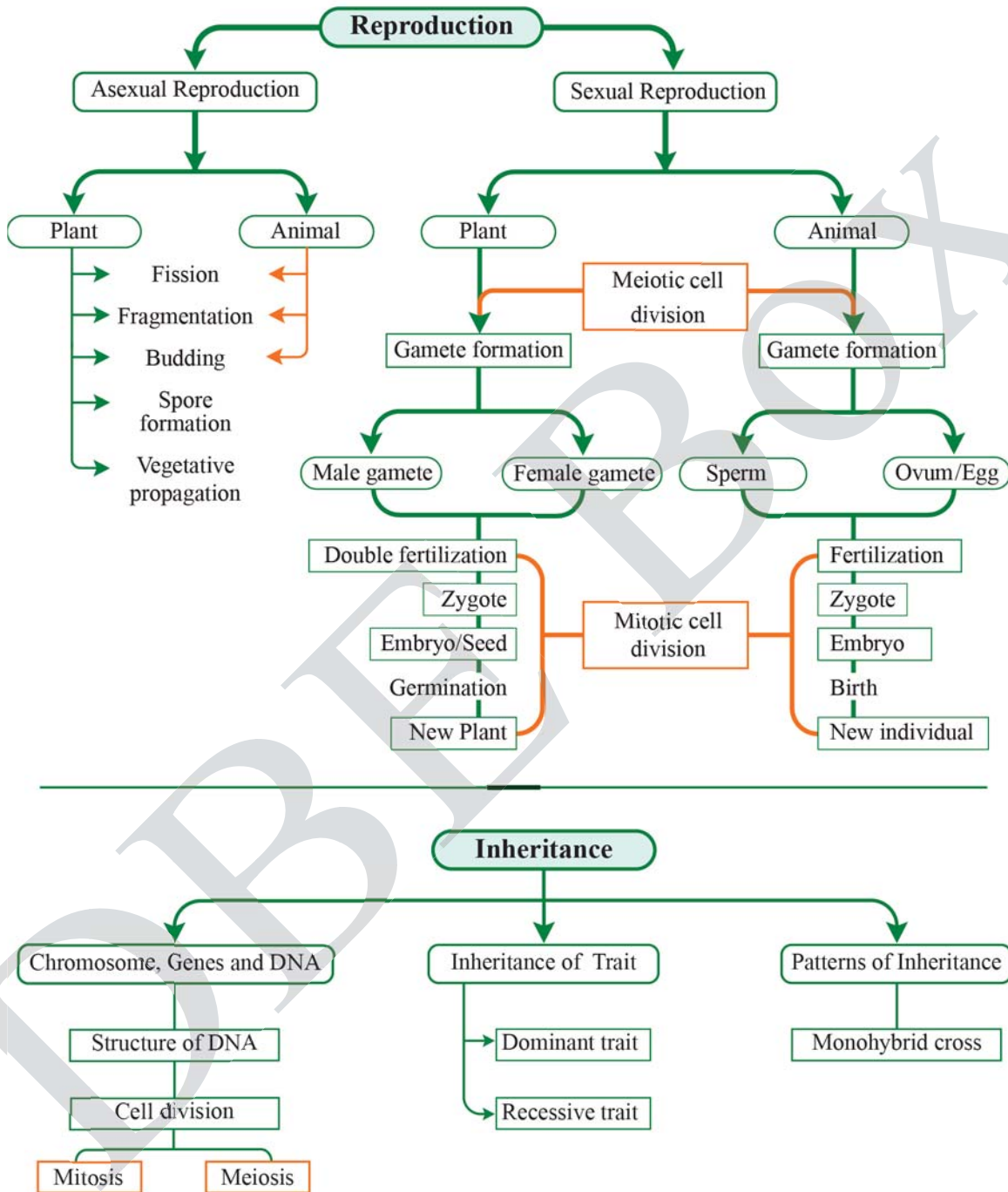


These results are possibilities (chances). In the second cross, the offspring may be in the 3:1 ratio but each fertilization is random so that the ratio may vary. In theory, a cross between two heterozygous parents should produce offspring in the ratio of 3:1 (3 dominants: 1 recessive). This result can be restated as the probability of any offspring showing dominant height (tall) is 3/4 or 75% and recessive (dwarf) is 1/4 or 25%.

Review questions

1. Enumerate the types of asexual reproduction in plants and explain any two with appropriate diagrams.
2. Define the term vegetative propagation with examples.
3. Explain how the bud grafting is carried out in plants with a suitable diagram.
4. What happens to the pollen grain before and after pollination?
5. Describe the process after pollination in plants.
6. Name the different types of reproduction in animals.
7. State the parts and functions of female reproductive system in human.
8. Describe the parts with related functions in male reproductive system of human.
9. How many chromosomes would be in the nucleus of
 - (a) human muscle cell
 - (b) a mouse kidney cell
 - (c) human skin cell
 - (d) human sperm cell?
10. How many chromosomes would be present in
 - (a) a mouse sperm cell
 - (b) a mouse ovum?
11. What is the basic unit of heredity?
12. What are the components of a nucleotide?
13. Name the nitrogenous bases in DNA.
14. DNA exists as a double helix. Name the base pairs that hold the double helix together.
15. How many stages are involved in mitosis?
16. Compare the meiotic and mitotic cell divisions with diagrams.
17. Compare the significance of mitosis versus meiosis.
18. In pea plants, there are two different heights: tall or dwarf. This characteristic is controlled by one pair of genes. Tall is dominant over dwarf. Choose the suitable letters for the gene pair.

Concept map



GLOSSARY

A

adenosine triphosphate (ATP) A nucleotide consisting of adenine, ribose sugar, and three phosphate groups; ATP is the energy currency of cellular metabolism in all organisms.

aerobic respiration Glucose and oxygen are converted to carbon dioxide and water, producing on average 38 ATP molecules per oxidized glucose molecule.

alimentary canal Pertaining to food or the digestive tract.

anaphase The third stage of cell division, between metaphase and telophase during which the chromosomes move away from one another to opposite poles of the spindle.

anus The terminal opening of the gut; the solid residues of digestion are eliminated through the anus.

atom The smallest unit of an element that contains all the characteristics of that element. Atoms are the building blocks of matter.

B

binary fission Asexual reproduction by division of one cell or body into two equal or nearly equal parts.

C

caecum In vertebrates, a blind pouch at the beginning of the large intestine.

calories Calories are a measurement of energy. One calorie is equivalent to 4.18 kJ.

carbohydrate Any of various neutral compounds of carbon, hydrogen, and oxygen (such as sugars, starches, and celluloses) most of which are formed by green plants and which constitute a major class of animal foods.

cardiac muscle The specialized striated muscle tissue of the heart.

cartilage A connective tissue in skeletons of vertebrates.

cell cycle The repeating sequence of growth and division through which cells pass each generation.

cell wall The rigid, outermost layer of the cells of plants, some protists, and most bacteria; the cell wall surrounds the plasma membrane.

cellulose The chief constituent of the cell wall in all green plants, some algae, and a few other organisms.

centriole A self-replicating, small, fibrous, cylindrical-shaped organelle, typically located

in the cytoplasm near the nucleus in cells of most animals. It is involved in the process of nuclear division.

centromere A visible point of constriction on a chromosome that contains repeated DNA sequences that bind specific protein.

centrosome Material present in the cytoplasm of all eukaryotic cells and important during cell division; also called microtubule-organizing center.

chaetae Bristles of chitin on each body segment that help anchor annelid worms during locomotion.

chalaza The region of an ovule that is opposite the micropyle, where the integuments and nucellus are joined.

chemical digestion Enzymatic breakdown of food

chitin A tough, resistant, nitrogen-containing polysaccharide that forms the cell walls of certain fungi, the exoskeleton of arthropods, and the epidermal cuticle of other surface structures of certain other invertebrates.

chlorophyll A green photosynthetic pigment found in plants, algae and cyanobacteria.

chloroplast A cell-like organelle present in algae and plants that contains chlorophyll (and usually other pigments) and carries out photosynthesis.

chlorosis An abnormal condition of plants in which the green parts lose their color or turn yellow as a result of a lack of chlorophyll production due to disease, lack of light, etc.

cholesterol A sterol which is made by the body and is found naturally in animal products such as meat, eggs, poultry and dairy foods.

chromatid One of the two daughter strands of a duplicated chromosome that is joined by a single centromere.

chromatin A complex of DNA and protein found in eukaryotic cells.

chromosome A threadlike structure of nucleic acids and protein found in the nucleus of most living cells, carrying genetic information in the form of genes.

class A taxonomic category between phyla and orders. A class contains one or more orders, and belongs to a particular phylum.

coelom In animals, a fluid-filled body cavity that develops entirely within the mesoderm.

complementary Describes genetic information in which each nucleotide base has a complementary partner with which it forms a base-pair.

constipation A condition of prolonged gastrointestinal transit time, making the stool hard, dry and difficult to pass

cotyledon The leaf of the embryo of a seed-bearing plant, after germination it becomes the first leaves of the seedling.

cuboidal epithelial Cuboidal epithelia are epithelial cells having a cube-like shape; that is, their width is approximately equal to their height.

cuticle The noncellular, hardened or membranous protective covering of many invertebrates, such as the transparent membrane that covers annelids.

cytokinesis Division of the cytoplasm of a cell after nuclear division.

cytoplasm The material within a cell, excluding the nucleus; the protoplasm.

cytoskeleton A network of protein microfilaments and microtubules within the cytoplasm of a eukaryotic cell that maintains the shape of the cell, anchors its organelles, and is involved in animal cell motility.

D

deoxyribonucleic acid (DNA) The genetic material of all organisms; composed of two complementary chains of nucleotides wound in a double helix.

detoxification The process of removing harmful chemicals from something.

diploid Having two sets of chromosomes ($2n$); in animals, twice the number characteristic of gametes; in plants, the chromosome number characteristic of the sporophyte generation; in contrast to haploid (n).

domain (1) A distinct modular region of a protein that serves a particular function in the action of the protein, such as a regulatory domain or a DNA-binding domain. (2) In taxonomy, the level higher than kingdom. The three domains currently recognized are Bacteria, Archaea, and Eukarya.

domain archaea In the three-domain system of taxonomy, the group that contains only the Archaea, a highly diverse group of unicellular prokaryotes.

domain bacteria In the three-domain system of taxonomy, the group that contains only the Bacteria, a vast group of unicellular prokaryotes.

domain eukarya In the three-domain system of taxonomy, the group that contains eukaryotic

organisms including protists, fungi, plants, and animals.

double fertilization The fusion of the egg and sperm (resulting in a $2n$ fertilized egg, the zygote) and the simultaneous fusion of the second male gamete with the polar nuclei (resulting in a primary endosperm nucleus, which is often triploid, $3n$); a unique characteristic of all angiosperms.

duodenum In vertebrates, the upper portion of the small intestine.

E

embryo Stage of a multicellular organism that develops from a zygote before it becomes free-living; in seed plants, the embryo is part of the seed.

endoplasmic reticulum (ER) Internal membrane system that forms a netlike array of channels and interconnections within the cytoplasm of eukaryotic cells. The ER is divided into rough (RER) and smooth (SER) compartments.

energy level A discrete level, or quantum, of energy that an electron in an atom possesses. To change energy levels, an electron must absorb or release energy.

enzymes Protein molecules which act as catalysts to speed up chemical reactions. Enzymes in the digestive process aid the breakdown of food into nutrients which can then be absorbed by the body.

epidermal tissue A single layer of cells that covers the leaves, flowers, roots and stems of plants. It forms a boundary between the plant and the external environment.

epithelium In animals, a type of tissue that covers an exposed surface or lines a tube or cavity.

eukaryote A cell characterized by membrane bounded organelles, most notably the nucleus, and one that possesses chromosomes whose DNA is associated with proteins; an organism composed of such cells.

exoskeleton An external skeleton, as in arthropods.

F

family A taxonomic grouping of similar species above the level of genus.

fertilization The fusion of two haploid gamete nuclei to form a diploid zygote nucleus.

first filial (F_1) generation The offspring resulting from a cross between a parental generation (P).

G

gamete A haploid reproductive cell.

gastrovascular cavity The primary organ of digestion and circulation in two major animal **phyla**: the *Cnidaria* (including jellyfish and corals) and *Platyhelminthes* (flatworms).

genetic code The biochemical basis of heredity consisting of codons in DNA and RNA that determine the specific amino acid sequence in proteins and appear to be uniform for nearly all known forms of life.

glycoprotein Protein molecule modified within the Golgi complex by having a short sugar chain (polysaccharide) attached.

glycosylation (Biochemistry) The process by which sugars are chemically attached to proteins to form glycoproteins.

Golgi apparatus (Golgi body) A collection of flattened stacks of membranes in the cytoplasm of eukaryotic cells; functions in collection, packaging, and distribution of molecules synthesized in the cell.

H

haemoglobin A globular protein in vertebrate red blood cells and in the plasma of many invertebrates that carries oxygen and carbon dioxide.

haploid Having only one set of chromosomes (n), in contrast to diploid ($2n$).

histone A small protein with high proportion of positively charged amino acid that binds to the negatively charged DNA and plays a key role in its chromatin structure

hydrolytic enzyme A catalyst that acts like a hydrolase.

I

integument An integument is a protective cell layer surrounding the ovule.

interphase The period between two mitotic or meiotic divisions in which a cell grows and its DNA replicates.

L

lesion A lesion is any damage or abnormal change in the tissue of an organism, usually caused by disease or trauma.

lignin A highly branched polymer that makes plant cell walls more rigid; an important component of wood.

lipid bilayer The structure of a cellular membrane, in which two layers of phospholipids spontaneously align so that the hydrophilic

head groups are exposed to water, while the hydrophobic fatty acid tails are pointed toward the center of the membrane.

locus The position on a chromosome where a gene is located.

lysosome A membrane-bounded vesicle containing digestive enzymes that is produced by the Golgi apparatus in eukaryotic cells.

M

meiosis I The first round of cell division in meiosis; it is referred to as a “reduction division” because homologous chromosomes separate, and the daughter cells have only the haploid number of chromosomes.

meiosis II The second round of division in meiosis, during which the two haploid cells from meiosis I undergo a mitosis-like division without DNA replication to produce four haploid daughter cells.

metabolic processes Processes that take place in the cells and tissues during which energy is released and carbon dioxide is produced and absorbed by the blood to be transported to the lungs.

metaphase The stage of mitosis or meiosis during which microtubules become organized into a spindle and the chromosomes come to lie in the spindle’s equatorial plane.

microtubule In eukaryotic cells, a long, hollow protein cylinder, composed of the protein tubulin; these influence cell shape, move the chromosomes in cell division, and provide the functional internal structure of cilia and flagella.

microvillus Cytoplasmic projection from epithelial cells; microvilli greatly increase the surface area of the small intestine.

mitochondrion The organelle called the powerhouse of the cell.

mitosis Somatic cell division; nuclear division in which the duplicated chromosomes separate to form two genetically identical daughter nuclei.

murein Any of several polymers containing sugars and amino acids which help to make up the cell walls of certain bacteria.

N

necrosis The death of a plant cell or group of cells while the rest of the plant is still alive, particularly when the dead tissue becomes dark in colour.

nervous tissue Tissue composed of neurons.

notochord In chordates, a dorsal rod of cartilage that runs the length of the body and forms the primitive axial skeleton in the embryos of all chordates.

nucellus The nucellus is part of the inner structure of ovule, forming a layer of diploid (sporophytic) cells immediately inside the integuments.

nuclear energy The energy released when the smallest particles (called atoms) of a substance break apart or fuse together; also known as atomic energy.

nuclear membrane The double-layered membrane enclosing the nucleus of a cell. Also called nuclear envelope.

nuclear pore Each nuclear pore is a large complex of proteins that allows small molecules and ions to freely pass, or diffuse, into or out of the nucleus.

nucleic acid A nucleotide polymer; chief types are deoxyribonucleic acid (DNA), which is double stranded, and ribonucleic acid (RNA), which is typically single-stranded.

nucleolus The nucleolus is the largest structure in the nucleus of eukaryotic cells.

nucleoplasm The nucleoplasm is a type of protoplasm, and is enveloped by the nuclear envelope.

nucleotide A single unit of nucleic acid, composed of a phosphate, a 5-carbon sugar (either ribose or deoxyribose), and a purine or a pyrimidine.

O

order A category of classification above the level of family and below that of class.

organ A body structure composed of several different tissues grouped in a structural and functional unit.

organelle Specialized part of a cell; literally, a small cytoplasmic organ.

ovary (1) In animals, the organ in which eggs are produced. (2) In flowering plants, the enlarged basal portion of a carpel that contains the ovule(s); the ovary matures to become the fruit.

P

parthenogenesis Plants or animals developed from seed or ovum without fertilization by pollen or spermatozoan.

pharynx A muscular structure lying posterior to the mouth in many animals; aids in propelling food into the digestive tract.

phenotype The realized expression of the genotype; the physical appearance or functional expression of a trait.

phloem In vascular plants, a food-conducting tissue basically composed of sieve elements, various kinds of parenchyma cells, fibers, and sclereids.

phospholipid Molecules that constitute the inner bilayer of biological membranes, having a polar, hydrophilic head and a nonpolar, hydrophobic tail.

phototropism In plants, a growth response to a light stimulus.

phylogeny The evolutionary history of an organism, including which species are closely related and in what order related species evolved; often represented in the form of an evolutionary tree.

phylum A major category, between kingdom and class, of taxonomic classifications.

pigment A molecule that absorbs light.

placenta In flowering plants, the part of the ovary wall to which the ovules or seeds are attached.

plankton Generally tiny, passively floating or weakly motile aquatic plants and animals.

plasma membrane The membrane surrounding the cytoplasm of a cell; consists of a single phospholipid bilayer with embedded proteins.

plumule The epicotyl of a plant with its two young leaves.

pollen tube A tube formed after germination of the pollen grain; carries the male gametes into the ovule.

pollination The transfer of pollen from an anther to a stigma.

polyp A typically sessile, cylindrical body form found in cnidarian animals, such as hydras.

prophase The phase of cell division that begins when the condensed chromosomes become visible and ends when the nuclear envelope breaks down. The assembly of the spindle takes place during prophase.

protein A chain of amino acids joined by peptide bonds.

R

radial symmetry A type of structural symmetry with a circular plan, such that dividing the body or structure through the midpoint in any direction yields two identical sections.

radicle The part of the plant embryo that develops into the root.

rhizome In vascular plants, a more or less horizontal underground stem; may be enlarged for storage or may function in vegetative reproduction.

S

second filial (F₂) generation The offspring resulting from a cross between members of the first filial (F₁) generation.

semipermeable Allowing some substances to pass; permeable to smaller molecules but not to larger ones, as a membrane in osmosis.

seta In an annelid, bristles of chitin that help anchor the worm during locomotion or when it is in its burrow.

somatic cell Any of the cells of a multicellular organism except those that are destined to form gametes (germ-line cells).

spore A haploid reproductive cell, usually unicellular, capable of developing into an adult without fusion with another cell.

stoma In plants, a minute opening bordered by guard cells in the epidermis of leaves and stems; water passes out of a plant mainly through the stomata.

stroma In chloroplasts, the semiliquid substance that surrounds the thylakoid system and that contains the enzymes needed to assemble organic molecules from CO₂.

synergids Part of the egg apparatus and are thought to help the pollen nucleus reach the egg cell for fertilization.

T

telophase The phase of cell division during which the spindle breaks down, the nuclear envelope of each daughter cell forms, and the chromosomes uncoil and become diffuse.

thallus A type of body found among plants and fungi that is not differentiated into roots, stems, or leaves.

tropism Response to an external stimulus.

turgor pressure The internal pressure inside a plant cell, resulting from osmotic intake of water, that presses its cell membrane tightly against the cell wall, making the cell rigid. Also known as *hydrostatic pressure*.

V

vacuole A membrane-bound organelle which is present in all plant and fungal cells and some protist, animal and bacterial cells.

variegated Having a pattern of different colors or marks.

vascular tissue The conducting tissue in the plant and consists of xylem (water conduction) and phloem (food conduction) tissue.

vitamin An organic substance that cannot be synthesized by a particular organism but is required in small amounts for normal metabolic function.

X

xylem In vascular plants, a specialized tissue, composed primarily of elongate, thick-walled conducting cells, which transports water and solutes through the plant body.

Z

zygote The diploid (2n) cell resulting from the fusion of male and female gametes (fertilization).

REFERENCES

- Bradfield P. and S. Potter. 2017. **Edexcel International GCSE (9-1) Biology**. Student Book. United Kingdom.
- Campbell, N. A., L. A. Urry, M. L. Cain, S. A. Wassermans, P. V. Minorsky and J. B. Reece. 2018. **Biology A Global Approach (Eleventh Edition)**. Pearson Company, England.
- Damon A., R. McGonegal, P. Tosto and W. Ward. 2014. **Higher Level Biology (Second Edition)**. Supporting Every Learner Across the IB Continuum. Pearson Education Limited.
- Jones, M. and G. Jones. 2010. **Cambridge IGCSE Biology Coursebook (Second Edition)**. Cambridge University, United Kingdom.
- Jones M., R. Fosbery, J. Gregory and D. Taylor. 2014. **Cambridge International AS and A Level Biology Coursebook (Fourth Edition)**. United Kingdom.
- Leong, W., 2008. **O' Level Classified Science Biology**. Singapore Asian Publications (S) Pte Ltd.
- Raven P. H. and G. B. Johnson. 2002. **Biology (Sixth Edition)**. New York.
- Reece J. B., L. A. Urry, M. L. Cain, S. A. Wassermans, P. V. Minorsky and R. B. Jackson. 2011. **Campbell Biology (Ninth Edition)**. United States of America.
- Richard, Y.K., 2015. **STPM Text, Biology**. Term 1. Kuan Press Sdn. Bhd.
- Richard, Y.K., 2015. **STPM Text, Biology**. Term 2. Herald Printers Sdn. Bhd.
- White, P.J. and P.H. Brown. 2010. **Plant nutrition for sustainable development and global health**. *Annals of botany*, 105(7), 1073-1080. doi:10.1093/aob/mcq 085
- Basic Education Curriculum, Syllabus and Textbook Committee. 2018-2019. **BIOLOGY Grade 9**. The Government of the Republic of the Union of Myanmar, Ministry of Education.
- Basic Education Curriculum, Syllabus and Textbook Committee. 2018-2019. **BIOLOGY Grade 10**. The Government of the Republic of the Union of Myanmar, Ministry of Education.