MODERN BIOLOGY

FOR SECONDARY SCHOOLS

revised edition

revised edition

MODERN BIOLOGY FOR SECONDARY SCHOOLS

Sarojini T. Ramalingam B. Sc. (Hons.), Ph.D.
Sheila Pereira B. Sc. (Hons.)
Charles T. Pereira B. Sc.

FEP INTERNATIONAL PRIVATE LIMITED
Accra · Bangkok · Hong Kong · Karachi · Kingston · Lagos · London · Manila
Maseru · Mbabane · Nairobi · Petaling Jaya · Port-of-Spain · Singapore · Sydney

23456789S7654321098

The publishers wish to thank Miss Justina Fletcher for her help and contributions towards the new sections included in the book.

Printed and bound by
FEP International Private Limited, Jurong, Singapore.

PREFACE

Modern Biology (Revised Edition) provides a complete and detailed coverage of all the topics in the Biology syllabus for 'O' Level. It gives the student a firm understanding of the morphology and basic life processes of a wide variety of organisms, how they have adapted to their environments, their interdependence and their relationship with Man.

This edition is a thorough revision of the highly successful original text. It expands and brings up to date information on such topics as reproduction, inheritance and molecular genetics, and incorporates several new chapters on practical ecology, crop cultivation and poultry farming, in keeping with the modern activity-oriented approach to Biology. It also includes important new studies on invertebrate phylla — molluscs, annelids, crustaceans, arachnids and myriapods — to complete the picture of evolutionary development.

The book explains rather than merely describes data. It synthesizes and integrates information, organizing material under topics into chapters and sections which are logically arranged and, to a large extent, complete in themselves. An important feature of the book is the generous use of accurate and detailed diagrams and illustrations to aid in quick comprehension and arouse student interest. Emphasis is given to experimental work, much of which can be performed without using expensive and sophisticated instruments, and to exercises for investigation and recapitulation. Throughout the book the language is clear and concise, with technical terminology limited to the essential, to make studying and reading easier.

CONTENTS

1. LIVING THINGS

The study of living things, or **organisms**, is termed **Biology**. The word 'Biology' has been derived from two root words — 'bios' (meaning 'life') and 'logy' or 'logos' (meaning 'the study of'). Living organisms include both plants and animals. The study of plants is **Botany** while that of animals is **Zoology**. These are the two big branches of Biology.

CHARACTERISTICS OF LIVING ORGANISMS

Living organisms are quite distinct from **non-living things** and are characterized by the ability to carry out the following functions which are also known as 'life processes':

(*a*) **Nutrition**
Living organisms such as trees and animals **feed** on a variety of substances while non-living things like tables and books have no such function.

(*b*) **Respiration**
Living organisms breathe, or **respire**, in order to obtain energy for all their activities. The oxygen taken in by a living organism is used to oxidize food in order to provide energy. Non-living things do not respire.

(*c*) **Excretion**
The activities that go on in the bodies of living organisms give rise to waste products which are either stored away or **excreted** by special means. Non-living things cannot get rid of their waste products, if any are formed at all.

(*d*) **Locomotion**
In order to carry out all their activities, living organisms are able to **move** about. Plants generally show only growth movements in certain parts of their bodies. Most animals can move from place to place. In contrast, non-living things do not move at all unless some outside force is applied to them.

(*e*) **Reproduction**
Living organisms are able to **reproduce** new offspring which resemble themselves. Non-living things do not possess this ability.

(*f*) **Growth**
Living organisms are able to transform the food they take in into living material. As a result, they increase in size and weight, or **grow**. Non-living things do not possess the ability to form new living material.

(*g*) **Response**
Living organisms are sensitive to external stimuli and **respond** to them. They are said to possess **sensitivity** or **irritability**. Non-living things do not show this characteristic.

DIFFERENCES BETWEEN PLANTS AND ANIMALS

The main differences between plants and animals may be summarized as follows:

(*a*) **Nutrition**
All green plants are able to prepare their own food from simple liquids, gases and solar energy with the help of a green pigment, **chlorophyll**, present mostly in their leaves and sometimes in their stems. Animals, on the other hand, are unable to prepare their own food as they do not possess this pigment. They, therefore, are ultimately dependent on plants for their food. The nutrition of green plants is described as **holophytic** or **autotrophic**, while that of animals is **holozoic** or **heterotrophic**.

(*b*) **Respiration**
Both animals and plants respire throughout the day and night by taking in oxygen and giving out carbon dioxide. During the daytime, however, most plant cells simultaneously take in carbon dioxide and give out oxygen. This accompanies the process of food preparation which does not occur at night.

(*c*) **Excretion**
Waste products in plants are not removed but stored away in certain cells as harmless substances until the plants die. On the other hand, in animals the waste products are removed by special excretory systems.

(*d*) **Locomotion**
Most plants are fixed to the soil and are, therefore, unable to move about. A few unicellular water plants, however, show active movement. Most animals, are free to move about from place to place in search of food and shelter or to escape from their enemies.

(*e*) **Growth**
Growth in plants is said to be **indefinite** as plants do not have a fixed number of organs such as roots, stems, flowers, fruits and leaves. In animals, however, growth is **definite** as animals have a fixed number of organs such as eyes, ears, hearts and limbs.

(*f*) **Growth Regions**
In plants maximum growth occurs mainly at the tips of the roots and shoots. This is described as **apical** growth. In animals growth occurs equally in all parts of the body. This is **intercalary** growth.

(*g*) **Response**
Plants react slowly to external stimuli such as heat, light, gravity and touch while animals react quickly.

THE IMPORTANCE OF LIVING ORGANISMS

Living organisms, i.e. plants and animals, play a very important part in one another's lives. Animals depend on plants and on one another for food and survival. Man, being a superior living organism with the most highly developed brain, is able to utilize both plants and animals for his food. Some plants, such as cereals and vegetables, are used directly as food for Man while others are used to feed his animals such as cattle, sheep and birds. These animals in turn become Man's food. Because of this and a number of other reasons, human beings are considered the highest, or most advanced, of all animals. They influence and control many aspects of Nature.

Special attention has to be paid to the growing of plants important in Agriculture. This requires a study of the habit of each type of plant, the type of soil and food materials required for a healthy crop, the best season for reaping and replanting the crop and the control of pests such as insects and rodents. These and other factors have to be considered if the maximum yield of a crop is desired. Therefore, a detailed study of a crop plant becomes very important and necessary. In order to control the multiplication of the pests of a particular crop and to eliminate them, one has to study the life cycles and habits of these pests, and the type of damage each pest causes. Only then can control measures be implemented.

Similarly, in Dairy Farming, Poultry Farming and Animal Husbandry, the study of the structure, behaviour and habits of the animals, as well as the factors influencing reproduction have to be known before one can establish a successful industry.

Therefore, it may be realized now that the study of plants and animals should not be merely a mechanical observation of their structure and mode of life. The emphasis should be on the interrelationships of plants and animals and their economic value to Man. Greater emphasis should be laid on the discovering of potential resources that

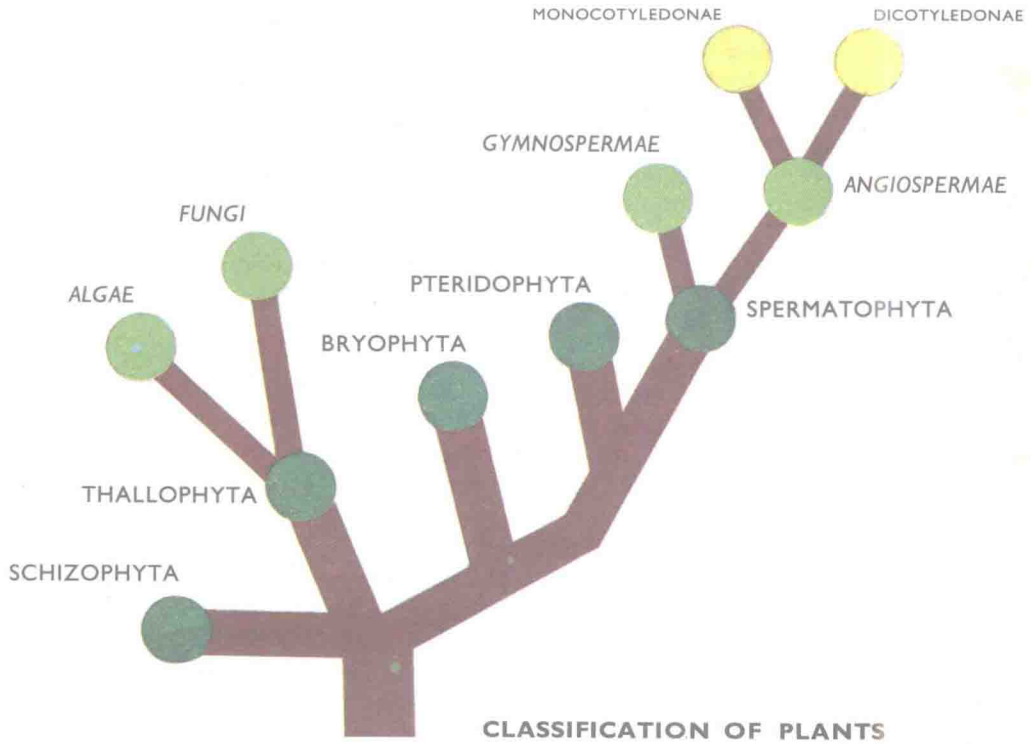
can be derived from various plants and animals, and the methods of making use of such potentialities to the maximum.

THE CLASSIFICATION OF LIVING ORGANISMS

Living organisms are classified into two main groups, namely, **Plants** and **Animals**.

PLANTS

All plants are not alike and are, therefore, subdivided into groups. These groups include minute unicellular and simple multicellular plants known as **bacteria** and **algae**, plants without chlorophyll known as **fungi** (e.g. moulds and mushrooms), and other simple and complex plants. The main groups of plants are, therefore, as follows:



CLASSIFICATION OF PLANTS

A. **Schizophyta**, i.e. bacteria.
These are unicellular non-green plants. They lack a definite nucleus and reproduce by simple asexual cell division known as **binary fission**. Bacteria do not display any form of sexual reproduction.

B. **Thallophyta**
Thallophytes are plants which have a simple body structure and lack definite organs like roots, stems and leaves. They reproduce both asexually and sexually. Sexual reproduction occurs by means of very simple sex cells, or **gametes**. Thallophytes are divided into algae and fungi.

(*a*) ALGAE, e.g. *Chlamydomonas*, *Ulva*, *Volvox*, *Fucus*, *Spirogyra*.
There are green, blue-green, red, brown and golden algae. Many green algae and most blue-green and golden algae are unicellular. Other members of these groups may be organized into filamentous or colonial forms. Red and brown algae are multicellular. Though some brown algae are very

large (e.g. the seaweeds), the body, which is known as a **thallus**, is not differentiated into stems, roots and leaves. Most algae are aquatic.

(*b*) FUNGI, e.g. *Mucor, Rhizopus, Penicillium*, mushrooms, bracket fungi.
Fungi are simple, multicellular non-green plants which are either parasitic or saprophytic in habit. They consist of strands which can form a loose mesh (as in the moulds), or which can be tightly bound together to form the various types of mushrooms, toadstools, puff-balls and bracket fungi.

C. **Bryophyta**, i.e. mosses and liverworts.
These are multicellular, non-flowering and non-vascular plants which have no true roots, stems and leaves but have structures resembling these. They reproduce asexually by means of spore formation and sexually by gamete formation. Many bryophytes have spore capsules to hold their spores. Bryophytes are found in moist places.

D. **Pteridophyta**, i.e. ferns.
These are non-flowering vascular plants which have structures resembling roots, stems and leaves but do not produce flowers, fruits or seeds. They reproduce by special gametes and spores. Ferns are mostly terrestrial, while some grow in moist places and a few are aquatic.

E. **Spermatophyta**
These are the green seed-producing vascular plants. They are divided into **gymnosperms** and **angiosperms**.

(*a*) GYMNOSPERMS, i.e. conifers.
Gymnosperms are non-flowering, seed-producing vascular plants which have true roots and stems. The leaves of most gymnosperms are fine needle-like structures or tiny scale-like structures. The seeds of these plants are borne in seed-boxes called **cones**.

(*b*) ANGIOSPERMS, i.e. flowering plants.
These are green vascular plants whose seeds arise from flowers bearing ovaries and ovules. They have true roots, stems and leaves. The angiosperms consist of **monocotyledons** and **dicotyledons**.

(i) *Monocotyledons*, e.g. lilies, palms, grasses, orchids.
Monocotyledons are plants whose seeds have one seed leaf each. The vascular bundles of the stem are scattered, the petals are arranged in groups of three or multiples of three and the leaves have veins running parallel to one another. Most monocotyledons have a fibrous root system.

(ii) *Dicotyledons*, e.g. *Hibiscus*, balsam, daisy.
Dicotyledons are plants whose seeds have two seed leaves each. The vascular bundles of the stems and roots are arranged regularly, the petals are arranged mostly in groups of four or five and the leaves have veins arranged in a branched network. Most dicotyledons have a tap root system.

ANIMALS

Animals are also divided into groups based on their similarities and differences. For instance, a bird is very different from an earthworm. The differences cause these animals to be placed into two different groups.

Animals are classified into two main groups, namely, **Invertebrata** (the **invertebrates**) and **Vertebrata** (the **vertebrates**). Invertebrates are animals which lack vertebral columns or backbones, while vertebrates possess this structure as well as internal skeletons.

1. *INVERTEBRATA*
This enormous group is further subdivided into the following main groups:

A. **Protozoa**, e.g. *Amoeba*, *Plasmodium*, *Paramecium*.
These are unicellular animals, most of which live in water or as parasites on other animals.

B. **Coelenterata**, e.g. *Hydra*, jellyfish, corals, sea anemones.
These are simple multicellular aquatic animals. The soft jelly-like body of a coelenterate is radially symmetrical with a central mouth surrounded by tentacles.

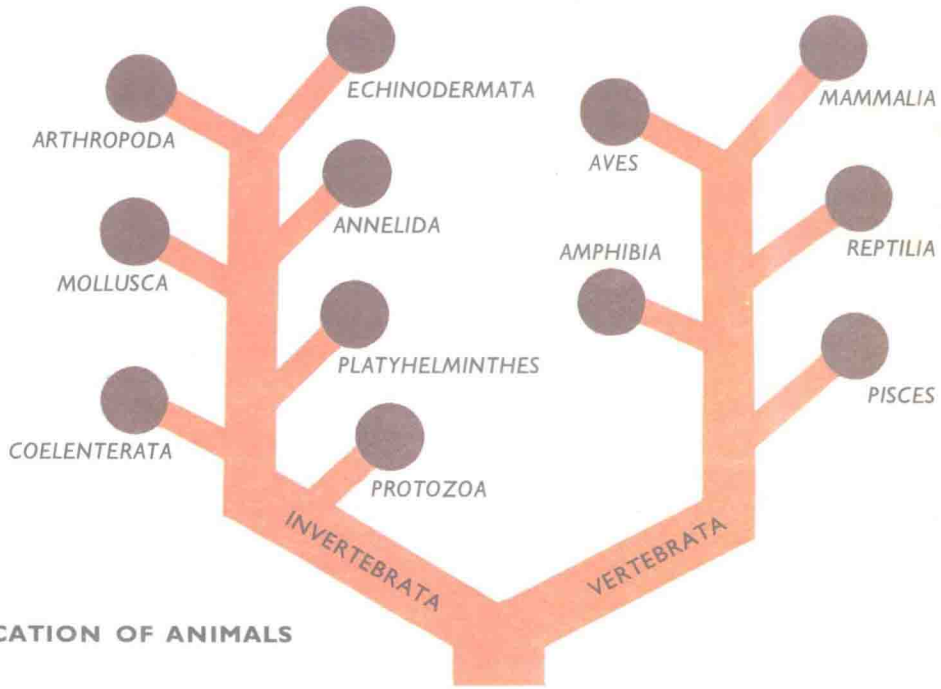
C. **Platyhelminthes**, e.g. tapeworms, liver-flukes, planarians.
These are flatworms existing mostly as parasites in Man and other animals. The gut of a flatworm has only one opening which serves for the entrance of food and the exit of wastes.

D. **Mollusca**, e.g. snails, mussels, squids, cuttlefish.
These are soft-bodied animals, many of which possess external shells. Some, however, have internal shells. The gut of a mollusc has two external openings. In most molluscs, a fleshy, muscular ventral foot is present. In some molluscs the foot is modified into tentacles (e.g. squids).

E **Annelida**, e.g. earthworms, leeches.
These are the true worms, which are segmented or 'ringed'. The body of an annelid is tubular and has two openings, one at either end of it.

F. **Arthropoda**, e.g. insects, prawns, crabs, spiders.
These are segmented animals with jointed legs. Most arthropods have hard, jointed external skeletons. By numbers, this group makes up more than three-quarters of the total number of living animals.

G. **Echinodermata**, e.g. starfishes, sea urchins, brittle stars, sea cucumbers.
These are marine animals which possess bilateral symmetry in the larval stage and five-rayed radial symmetry in the adult stage. The majority of them have calcareous exoskeletons and locomotory organs called **tube feet**.



CLASSIFICATION OF ANIMALS

2. *VERTEBRATA*

The members of this group show great diversity and can be placed in the following subdivisions:

A. **Pisces**, e.g. shark, ray-fish, angel fish, guppy, mackerel.

All types of fishes are included in this group. There are cartilaginous as well as bony fishes. Fishes are cold-blooded animals and are characterized by fins, scales and gills for breathing. Almost all fishes are entirely aquatic in habit.

B. **Amphibia**, e.g. frogs, toads, newts, salamanders.

These are cold-blooded vertebrates, most of which spend part of their lives in water and the other part on land. In the first stage, they breathe with gills and are known as **tadpoles**. In the second stage, the terrestrial amphibians breathe with lungs while the aquatic ones remain gill-breathers. Amphibians can also breathe with their skin, which is usually soft and moist for this purpose. Terrestrial amphibians always return to the water to lay their eggs.

C. **Reptilia**, e.g. lizards, snakes, turtles.

These are cold-blooded animals which are characterized by a dry skin covered with scales or bony plates. They are lung-breathers and are found both in water and on land. Aquatic reptiles always return to the land to lay their soft-shelled eggs.

D. **Aves**, e.g. pigeon, magpie, kiwi, ostrich.

This group includes the flying as well as the flightless birds. They are warm-blooded animals which are characterized by a pair of wings, a body covered with feathers, a mouth modified into a beak and the absence of teeth. All birds lay hard-shelled eggs.

E. **Mammalia**, e.g. rat, horse, bear, elephant, Man.

Mammals are warm-blooded animals, most of which have a glandular skin bearing hair or fur. Most female mammals have **mammary glands** which produce the milk necessary to nourish their young. The vast majority of mammals give birth to their young but some primitive forms (namely, the **monotremes**) are egg-layers.

WHAT LIVING ORGANISMS ARE MADE UP OF

CELLS

In an earlier part of this chapter, it was pointed out that there are unicellular plants and animals. The multicellular plants and animals are made up of large numbers of such unicellular structures or units, called **cells**. Therefore, it may be said that a cell is a 'single unit' of a living organism. Since plants and animals differ from one another, the cells that compose the body of a plant or an animal must also be different from each other in certain respects.

Plant Cells

Plant cells are of different types and sizes. Most plant cells have regular outlines and fixed shapes. They may be rectangular, polygonal or cylindrical in shape.

A typical plant cell taken from the surface of a leaf would clearly show the various parts which most plant cells are composed of. There is a distinct **cell wall** composed of non-living material and divided into two layers, namely, the **primary wall** and the **secondary wall**. These two layers are made up of different types of substances such as **lignin**, **pectin**, **tannin** and **cellulose**. The most important of all these substances is the carbohydrate cellulose which is found in all plant cells. The cell wall is generally thick and rigid and does not change its shape. However, in some plant cells it is thin and flexible. In all plants, the cell wall is permeable. In between adjacent cells lies a very thin layer of cementing material known as the **middle lamella**. This also is permeable.

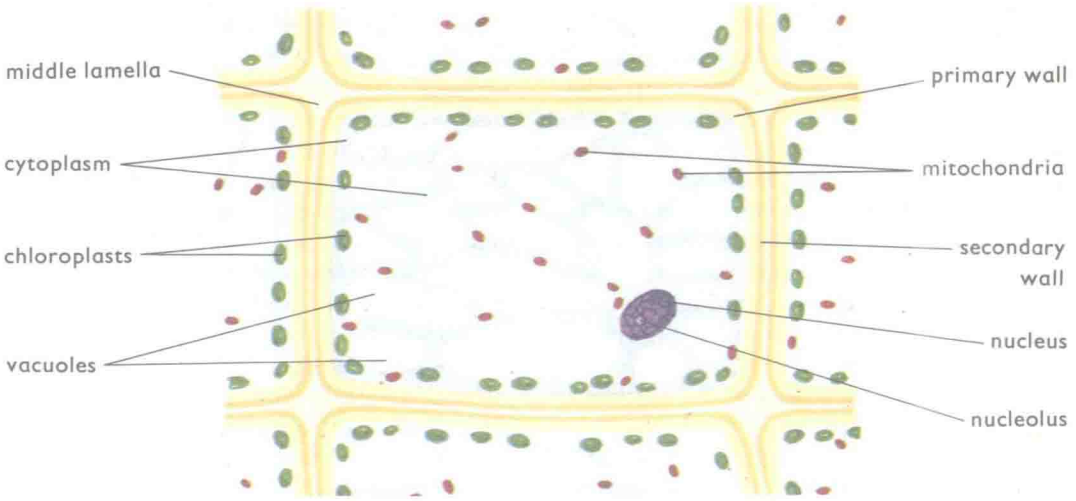


Fig. 1.1 A plant cell

Enclosed by this non-living cell wall is the living material known as **protoplasm**. The outer surface of the protoplasm is thicker than the rest of it and is called the **plasma membrane** or the **plasmalemma**. It is semi-permeable. Protoplasm is semi-fluid in nature and in a living cell is in continuous motion. When you view the tip of a thin leaf of a water plant under a microscope you will be able to notice this protoplasmic movement. The protoplasm in a cell is composed of two parts, namely, the **cytoplasm** and the **nucleus**. The cytoplasm occupies a large part of the space within the cell wall. The nucleus may be situated at the centre or periphery of the cell.

There are open spaces called **vacuoles** in the cytoplasm. In a young cell the cytoplasm is dense and there may be several tiny vacuoles. As the cell grows older, all these vacuoles finally join up to form a large central vacuole. The vacuoles are filled with a fluid known as **cell sap**. This fluid consists of a high percentage of water with sugars and some mineral salts dissolved in it.

Cytoplasm is colloidal in nature and consists of solutions of many different types of proteins. Sometimes reserve food substances such as starch or sugar may be present in the cytoplasm in addition to these proteins.

Embedded in the cytoplasm are little ovoid organelles known as **plastids**. Most of these plastids are green in colour and are known as **chloroplasts**. They contain chlorophyll and their presence gives rise to the green colour of leaves and stems. Chloroplasts are essential for the manufacture of carbohydrates. Some plants, however, have leaves which are red and yellow in colour. This is due to the presence of coloured plastids (known as **chromoplasts**) in the cytoplasm. Chromoplasts contain red and yellow pigments in them, e.g. **carotene** and **xanthophyll**.

Also embedded in the cytoplasm are tiny organelles called **mitochondria** which may be elongated, round or oblong in shape. They are intimately connected with the respiration of the cell. There are also minute granular **microsomes** which are essential for the formation of proteins. Besides, they play an important role in cell metabolism.

The nucleus is generally spherical or ovoid in shape. It is denser than the cytoplasm and is very prominent. It is enclosed in a thin membrane, the **nuclear membrane** or **neurilemma**, and contains a few long, coiled thread-like structures called **chromosomes**. Besides the chromosomes, the nucleus also contains a small, dense, spherical structure called the **nucleolus**. This contains **nucleoproteins**.

Each chromosome bears numerous tiny structures arranged in a neat row along its length. These structures are known as **genes**. Each gene contains the information for the expression of a particular characteristic such as the height of a plant, the colour of a flower or the shape of a fruit. Genes are believed to be the units of inheritance; that is, the characteristics of the parent plant are passed on to the young seedlings through the genes which are contained in the seeds of the parent plant. It may, therefore, be said that the genes on a chromosome are the carriers of parental characteristics.

The cytoplasm and the nucleus contain two special type of acids known as **deoxyribonucleic acid** (DNA) and **ribonucleic acid** (RNA). These substances consist of sugars, phosphates and certain types of nitrogenous bases.

Animal Cells

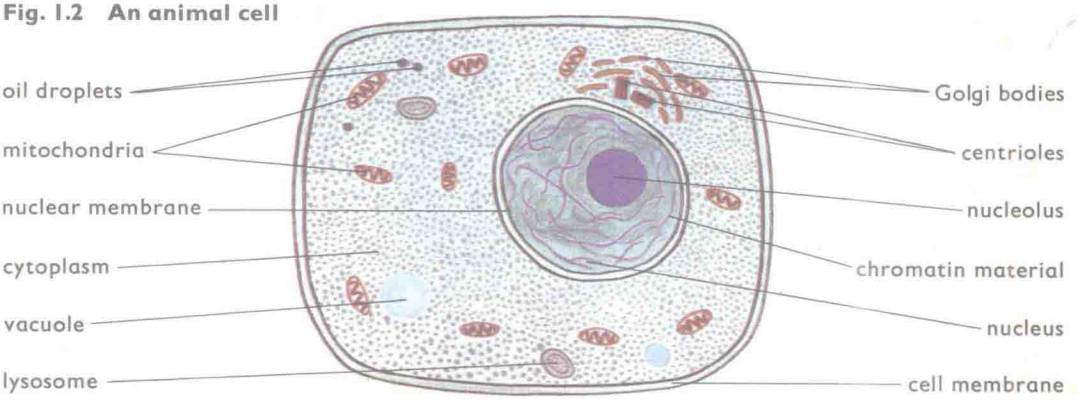
Animal cells, like plant cells, are of different shapes and sizes. They may be spherical, rectangular, cuboidal, spindle-shaped or irregular. In general, an animal cell is much smaller than a plant cell. It does not have a thick, rigid cell wall as in the case of a plant cell. The outer wall, or **cell membrane**, is rather thin and delicate and is not made up of cellulose but of lipids and proteins. Owing to the delicate and flexible nature of the cell membrane, the shape of an animal cell can change and does so in certain cases.

Within the thin cell membrane lies the protoplasm which is made up of the **cytoplasm** and the **nucleus**. The cytoplasm is semi-fluid in nature and as in a plant cell, contains dissolved proteins and sugars. Most animal cells have no plastids; if pigments are present, they occur in the form of **granules** scattered throughout the cytoplasm. Unlike the plant cell, there are no large vacuoles in the cytoplasm. However, there may be a few tiny **vacuoles** as well as little **oil droplets** containing fat or oil. Rod-like, granular or filamentous **mitochondria** which help in the oxidation of food substances are also present. The cytoplasm also contains **microsomes** which help in the manufacture of proteins and **lysosomes** which are the sites of the enzymes concerned with the breakdown of large molecules. Coiled thread-like **Golgi bodies** are also present near the nucleus. The nucleus contains the same structures as those found in a plant cell, but the number of chromosomes and types of genes as well as the characteristics which the genes carry are different.

Cell Division

Both plant and animal cells grow to a maximum size after which each cell divides into two equal cells. The division starts first with the nucleus and passes on to the cytoplasm so as to produce two new identical cells with an equal number of chromosomes. This type of cell division is known as **mitosis**. Another type of cell division occurs prior to sexual reproduction. This is known as **meiosis.**

Fig. 1.2 An animal cell



TISSUES, ORGANS AND SYSTEMS

Cells that are similar in structure and function are generally grouped together to form a **tissue**. For instance, all the cells that manufacture food in plants are green in colour and have the same structure and appearance as one another. In leaves they are grouped to form the major photosynthesizing tissue in plants known as the **mesophyll**.

Similarly, two or more different types of tissues may lie adjacent to each other and consequently, form an **organ**. Tissues for protection (the epidermis), manufacture of food (the mesophyll), conduction of water (the xylem) and conduction of prepared food (the phloem) all lie adjacent to one another in the leaf which is, therefore, an organ. Similarly, the branch, another plant organ, contains various tissues.

Organs such as leaves, branches, flowers and fruits together form a **system** — the shoot system. Similarly, the epidermal cells of a root and their root hairs, the supporting cells of the cortex, and the conducting cells of the xylem and the phloem together form an organ — the root. Several such roots make up the root system. Different systems such as the shoot and root systems form a living **organism**, which in this case is a plant.

Fig. 1.3 Plant tissue — epidermis

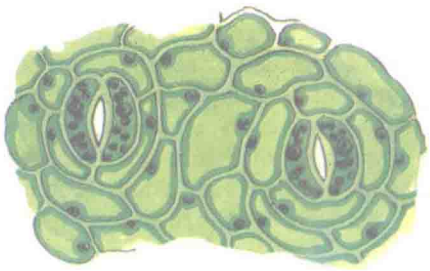
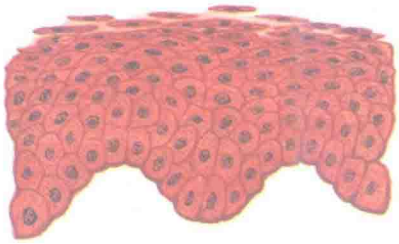


Fig. 1.4 Animal tissue — epithelial layer



In animals, as in plants, cells of similar shape, size and function are grouped together to form tissues. Some examples of tissues in the human body are muscular, epithelial, connective, nervous and skeletal tissues.

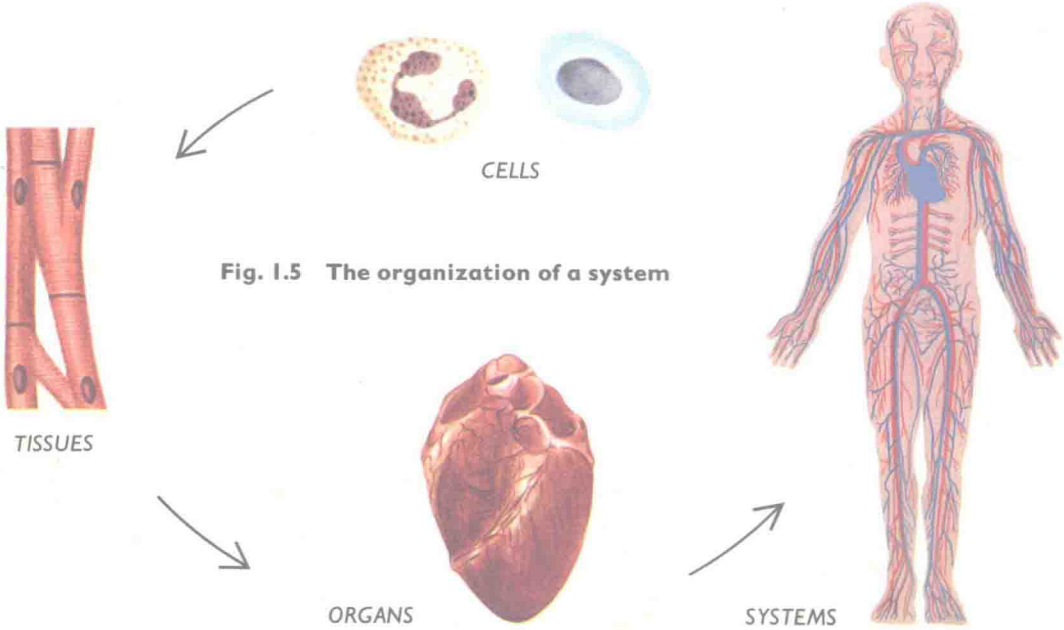


Fig. 1.5 The organization of a system

In an animal also, a few types of tissues form an organ. For example, muscular, skeletal, nervous, fatty (adipose), epidermal and connective tissues combine to form the fore and hind limbs which are organs. Similarly, epithelial, muscular, connective and other types of tissues form the different organs in the alimentary canal. The mouth, gullet, stomach, intestines, liver and pancreas are organs concerned with feeding and the digestion of food. All these organs combine to form a system known as the digestive system.

There are a number of systems in the body of an animal. Some of these are the circulatory, nervous, locomotory, excretory and respiratory systems. All these systems work together to form a complete organism.

EXERCISES

1. What are the differences between living and non-living things?
2. Summarize in a tabular form the differences between a plant and an animal.
3. Classify the following animals and plants according to the classification that is given in this chapter.
   (*a*) cow, snake, shark, parrot and starfish.
   (*b*) maize, flame of the forest, bird's nest fern, mushroom and pine tree.
4. Discuss the characteristics which are used in subdividing:
   (*a*) Thallophyta into fungi and algae,
   (*b*) Spermatophyta into gymnosperms and angiosperms,
   (*c*) Angiosperms into monocotyledons and dicotyledons and
   (*d*) Animals into invertebrates and vertebrates.
5. Draw a typical plant and a typical animal cell. Discuss the similarities and differences between them.
6. Write short notes on the following:
   (*a*) a tissue
   (*b*) mitosis
   (*c*) chromosomes
   (*d*) an organ
   (*e*) a system
   (*f*) nucleolus