

**Figure 6.11** Different stages of the secondary growth in a typical dicot root

Secondary growth also occurs in stems and roots of gymnosperms. However, secondary growth does not occur in monocotyledons.

### SUMMARY

Anatomically, a plant is made of different kinds of tissues. The plant tissues are broadly classified into meristematic (apical, lateral and intercalary) and permanent (simple and complex). Assimilation of food and its storage, transportation of water, minerals and photosynthates, and mechanical support are the main functions of tissues. There are three types of tissue systems – epidermal, ground and vascular. The epidermal tissue systems are made of epidermal cells, stomata and the epidermal appendages. The ground tissue system forms the main bulk of the plant. It is divided into three zones – cortex, pericycle and pith. The vascular tissue system is formed by the xylem and phloem. On the basis of presence of cambium, location of xylem and phloem, the vascular bundles are of different types. The vascular bundles form the conducting tissue and translocate water, minerals and food material.

Monocotyledonous and dicotyledonous plants show marked variation in their internal structures. They differ in type, number and location of vascular bundles. The secondary growth occurs in most of the dicotyledonous roots and stems and it increases the girth (diameter) of the organs by the activity of the vascular cambium and the cork cambium. The wood is actually a secondary xylem. There are different types of wood on the basis of their composition and time of production.

### EXERCISES

1. State the location and function of different types of meristems.
2. Cork cambium forms tissues that form the cork. Do you agree with this statement? Explain.
3. Explain the process of secondary growth in the stems of woody angiosperms with the help of schematic diagrams. What is its significance?
4. Draw illustrations to bring out the anatomical difference between
  - (a) Monocot root and Dicot root
  - (b) Monocot stem and Dicot stem
5. Cut a transverse section of young stem of a plant from your school garden and observe it under the microscope. How would you ascertain whether it is a monocot stem or a dicot stem? Give reasons.
6. The transverse section of a plant material shows the following anatomical features - (a) the vascular bundles are conjoint, scattered and surrounded by a sclerenchymatous bundle sheaths. (b) phloem parenchyma is absent. What will you identify it as?
7. Why are xylem and phloem called complex tissues?
8. What is stomatal apparatus? Explain the structure of stomata with a labelled diagram.
9. Name the three basic tissue systems in the flowering plants. Give the tissue names under each system.
10. How is the study of plant anatomy useful to us?
11. What is periderm? How does periderm formation take place in the dicot stems?
12. Describe the internal structure of a dorsiventral leaf with the help of labelled diagrams.

# CHAPTER 7

## STRUCTURAL ORGANISATION IN ANIMALS

7.1 Animal Tissues

7.2 Organ and Organ System

7.3 Earthworm

7.4 Cockroach

7.5 Frogs

In the preceding chapters you came across a large variety of organisms, both unicellular and multicellular, of the animal kingdom. In unicellular organisms, all functions like digestion, respiration and reproduction are performed by a single cell. In the complex body of multicellular animals the same basic functions are carried out by different groups of cells in a well organised manner. The body of a simple organism like *Hydra* is made of different types of cells and the number of cells in each type can be in thousands. The human body is composed of billions of cells to perform various functions. How do these cells in the body work together? In multicellular animals, a group of similar cells alongwith intercellular substances perform a specific function. Such an organisation is called **tissue**.

You may be surprised to know that all complex animals consist of only four basic types of tissues. These tissues are organised in specific proportion and pattern to form an organ like stomach, lung, heart and kidney. When two or more organs perform a common function by their physical and/or chemical interaction, they together form organ system, e.g., digestive system, respiratory system, etc. Cells, tissues, organs and organ systems split up the work in a way that exhibits division of labour and contribute to the survival of the body as a whole.

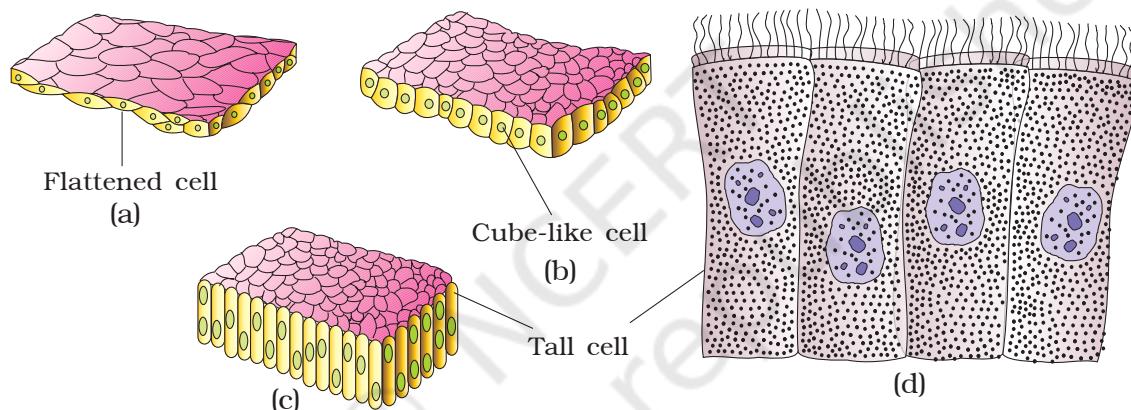
### 7.1 ANIMAL TISSUES

The structure of the cells vary according to their function. Therefore, the tissues are different and are broadly classified into four types : (i) Epithelial, (ii) Connective, (iii) Muscular and (iv) Neural.

### 7.1.1 Epithelial Tissue

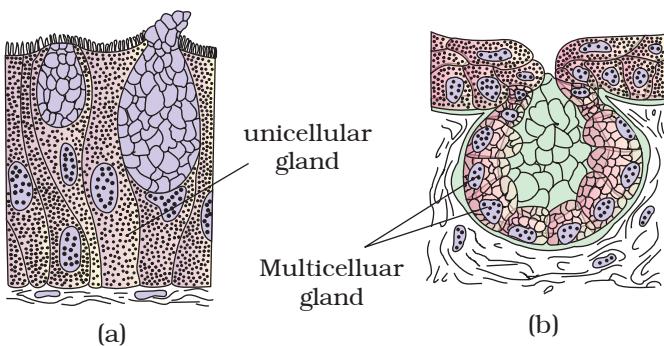
We commonly refer to an epithelial tissue as epithelium (pl.: epithelia). This tissue has a free surface, which faces either a body fluid or the outside environment and thus provides a covering or a lining for some part of the body. The cells are compactly packed with little intercellular matrix. There are two types of epithelial tissues namely **simple epithelium** and **compound epithelium**. Simple epithelium is composed of a single layer of cells and functions as a lining for body cavities, ducts, and tubes. The compound epithelium consists of two or more cell layers and has protective function as it does in our skin.

On the basis of structural modification of the cells, simple epithelium is further divided into three types. These are (i) Squamous, (ii) Cuboidal, (iii) Columnar (Figure 7.1).

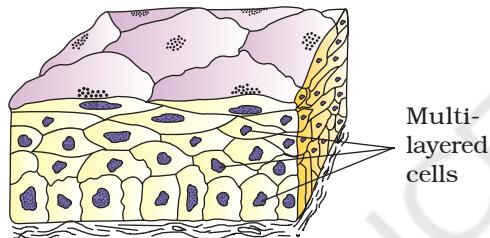


**Figure 7.1** Simple epithelium: (a) Squamous (b) Cuboidal (c) Columnar  
(d) Columnar cells bearing cilia

The **squamous epithelium** is made of a single thin layer of flattened cells with irregular boundaries. They are found in the walls of blood vessels and air sacs of lungs and are involved in functions like forming a diffusion boundary. The **cuboidal epithelium** is composed of a single layer of cube-like cells. This is commonly found in ducts of glands and tubular parts of nephrons in kidneys and its main functions are secretion and absorption. The epithelium of proximal convoluted tubule (PCT) of nephron in the kidney has microvilli. The **columnar epithelium** is composed of a single layer of tall and slender cells. Their nuclei are located at the base. Free surface may have microvilli. They are found in the lining of stomach and intestine and help in secretion and absorption. If the columnar or cuboidal cells bear cilia on their free surface they are called **ciliated epithelium** (Figure 7.1d). Their function is to move particles or mucus in a specific direction over the epithelium. They are mainly present in the inner surface of hollow organs like bronchioles and fallopian tubes.



**Figure 7.2** Glandular epithelium : (a) Unicellular  
(b) Multicellular



**Figure 7.3** Compound epithelium

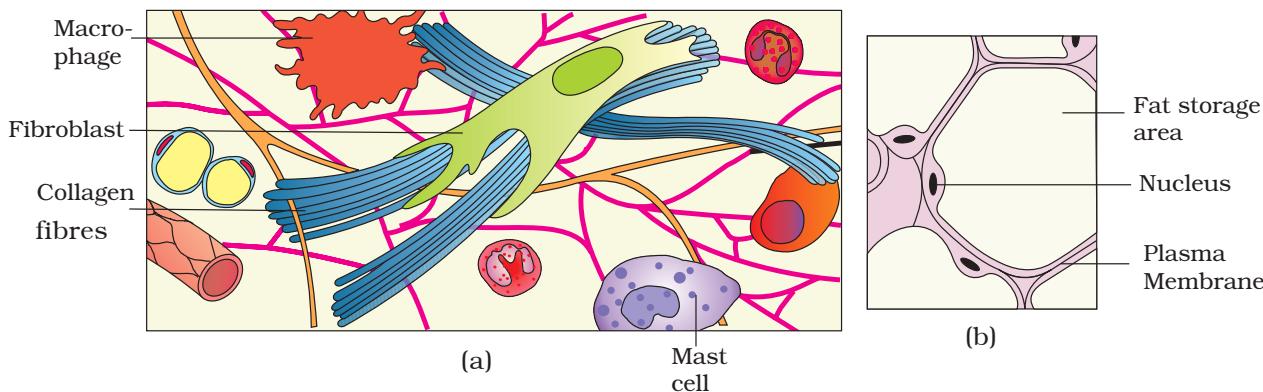
Some of the columnar or cuboidal cells get specialised for secretion and are called **glandular epithelium** (Figure 7.2). They are mainly of two types: unicellular, consisting of isolated glandular cells (goblet cells of the alimentary canal), and multicellular, consisting of cluster of cells (salivary gland). On the basis of the mode of pouring of their secretions, glands are divided into two categories namely **exocrine** and **endocrine** glands. Exocrine glands secrete mucus, saliva, earwax, oil, milk, digestive enzymes and other cell products. These products are released through ducts or tubes. In contrast, endocrine glands do not have ducts. Their products called hormones are secreted directly into the fluid bathing the gland.

**Compound epithelium** is made of more than one layer (multi-layered) of cells and thus has a limited role in secretion and absorption (Figure 7.3). Their main function is to provide protection against chemical and mechanical stresses. They cover the dry surface of the skin, the moist surface of buccal cavity, pharynx, inner lining of ducts of salivary glands and of pancreatic ducts.

All cells in epithelium are held together with little intercellular material. In nearly all animal tissues, specialised junctions provide both structural and functional links between its individual cells. Three types of cell junctions are found in the epithelium and other tissues. These are called as tight, adhering and gap junctions. **Tight junctions** help to stop substances from leaking across a tissue. **Adhering junctions** perform cementing to keep neighbouring cells together. **Gap junctions** facilitate the cells to communicate with each other by connecting the cytoplasm of adjoining cells, for rapid transfer of ions, small molecules and sometimes big molecules.

### 7.1.2 Connective Tissue

Connective tissues are most abundant and widely distributed in the body of complex animals. They are named connective tissues because of their special function of linking and supporting other tissues/organs of the body. They range from soft connective tissues to specialised types, which

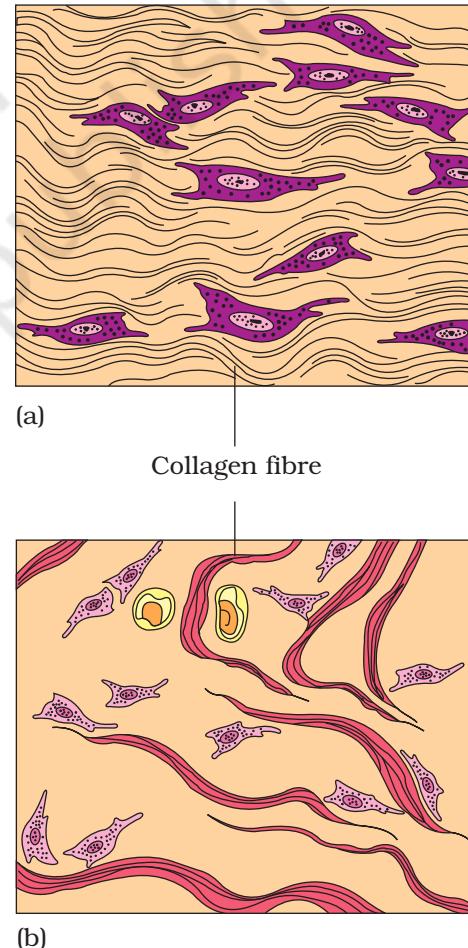


**Figure 7.4** Loose connective tissue : (a) Areolar tissue (b) Adipose tissue

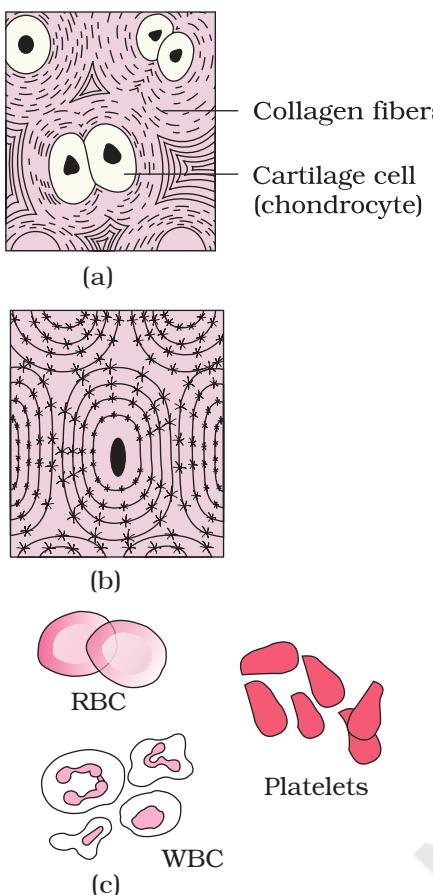
include cartilage, bone, adipose, and blood. In all connective tissues except blood, the cells secrete fibres of structural proteins called collagen or elastin. The fibres provide strength, elasticity and flexibility to the tissue. These cells also secrete modified polysaccharides, which accumulate between cells and fibres and act as matrix (ground substance). Connective tissues are classified into three types: (i) Loose connective tissue, (ii) Dense connective tissue and (iii) Specialised connective tissue.

**Loose connective tissue** has cells and fibres loosely arranged in a semi-fluid ground substance, for example, **areolar tissue** present beneath the skin (Figure 7.4). Often it serves as a support framework for epithelium. It contains fibroblasts (cells that produce and secrete fibres), macrophages and mast cells. **Adipose tissue** is another type of loose connective tissue located mainly beneath the skin. The cells of this tissue are specialised to store fats. The excess of nutrients which are not used immediately are converted into fats and are stored in this tissue.

Fibres and fibroblasts are compactly packed in the **dense connective tissues**. Orientation of fibres show a regular or irregular pattern and are called **dense regular** and **dense irregular tissues**. In the dense regular connective tissues, the collagen fibres are present in rows between many parallel bundles of fibres. Tendons, which attach skeletal muscles to bones and ligaments which attach one bone to another are examples of this tissue. Dense irregular connective tissue has fibroblasts and many fibres (mostly collagen) that are oriented differently (Figure 7.5). This tissue is present in the skin. Cartilage,



**Figure 7.5** Dense connective tissue:  
 (a) Dense regular  
 (b) Dense irregular



**Figure 7.6** Specialised connective tissues : (a) Cartilage  
(b) Bone (c) Blood

bones and blood are various types of **specialised connective tissues**.

The intercellular material of **cartilage** is solid and pliable and resists compression. Cells of this tissue (chondrocytes) are enclosed in small cavities within the matrix secreted by them (Figure 7.6a). Most of the cartilages in vertebrate embryos are replaced by bones in adults. Cartilage is present in the tip of nose, outer ear joints, between adjacent bones of the vertebral column, limbs and hands in adults.

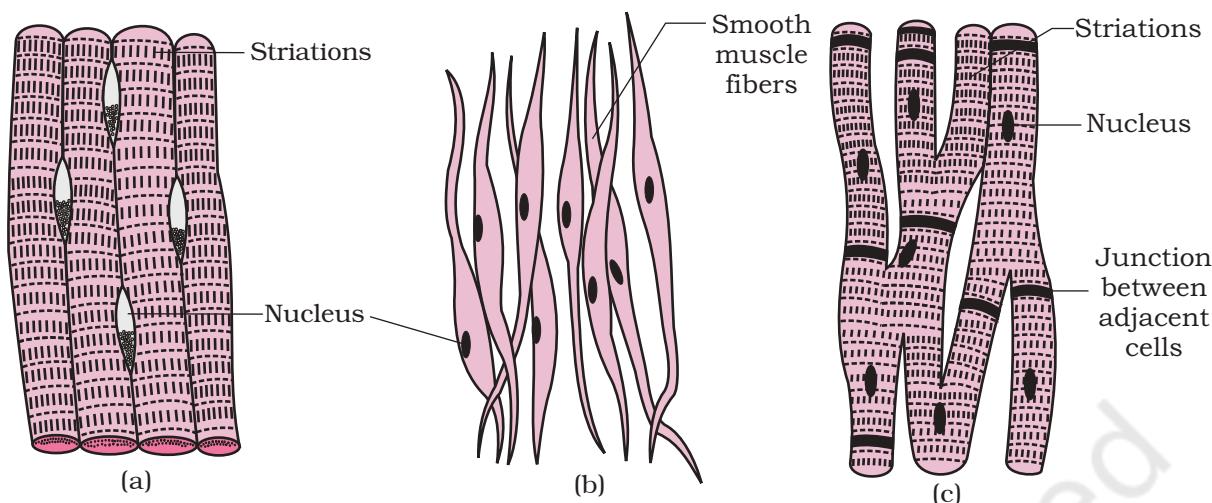
**Bones** have a hard and non-pliable ground substance rich in calcium salts and collagen fibres which give bone its strength (Figure 7.6b). It is the main tissue that provides structural frame to the body. Bones support and protect softer tissues and organs. The bone cells (osteocytes) are present in the spaces called lacunae. Limb bones, such as the long bones of the legs, serve weight-bearing functions. They also interact with skeletal muscles attached to them to bring about movements. The bone marrow in some bones is the site of production of blood cells.

**Blood** is a fluid connective tissue containing plasma, red blood cells (RBC), white blood cells (WBC) and platelets (Figure 7.6c). It is the main circulating fluid that helps in the transport of various substances. You will learn more about blood in Chapters 17 and 18.

### 7.1.3 Muscle Tissue

Each muscle is made of many long, cylindrical fibres arranged in parallel arrays. These fibres are composed of numerous fine fibrils, called myofibrils. Muscle fibres contract (shorten) in response to stimulation, then relax (lengthen) and return to their uncontracted state in a coordinated fashion. Their action moves the body to adjust to the changes in the environment and to maintain the positions of the various parts of the body. In general, muscles play an active role in all the movements of the body. Muscles are of three types, skeletal, smooth, and cardiac.

**Skeletal muscle** tissue is closely attached to skeletal bones. In a typical muscle such as the biceps, striated (striped) skeletal muscle fibres are bundled together in a parallel fashion (Figure 7.7a). A sheath of tough connective tissue encloses several bundles of muscle fibres (You will learn more about this in Chapter 20).



**Figure 7.7** Muscle tissue : (a) Skeletal (striated) muscle tissue (b) Smooth muscle tissue  
(c) Cardiac muscle tissue

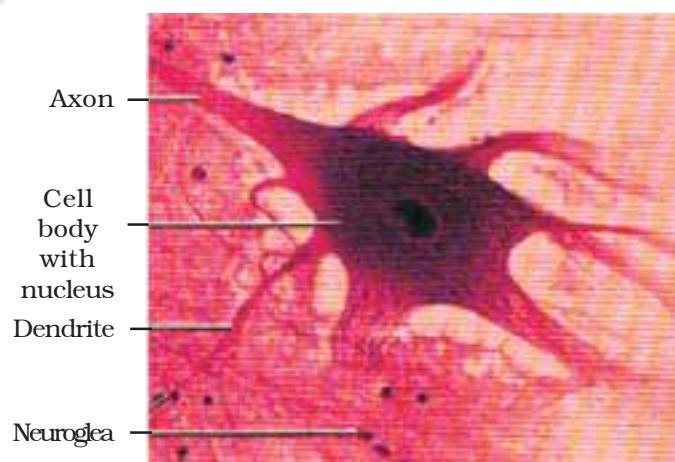
The **smooth muscle** fibres taper at both ends (fusiform) and do not show striations (Figure 7.7b). Cell junctions hold them together and they are bundled together in a connective tissue sheath. The wall of internal organs such as the blood vessels, stomach and intestine contains this type of muscle tissue. Smooth muscles are ‘involuntary’ as their functioning cannot be directly controlled. We usually are not able to make it contract merely by thinking about it as we can do with skeletal muscles.

**Cardiac muscle tissue** is a contractile tissue present only in the heart. Cell junctions fuse the plasma membranes of cardiac muscle cells and make them stick together (Figure 7.7c). Communication junctions (intercalated discs) at some fusion points allow the cells to contract as a unit, i.e., when one cell receives a signal to contract, its neighbours are also stimulated to contract.

#### 7.1.4 Neural Tissue

Neural tissue exerts the greatest control over the body's responsiveness to changing conditions. Neurons, the unit of neural system are excitable cells (Figure 7.8). The neuroglial cell which constitute the rest of the neural system protect and support neurons. Neuroglia make up more than one-half the volume of neural tissue in our body.

When a neuron is suitably stimulated, an electrical disturbance is generated which swiftly travels along its plasma



**Figure 7.8** Neural tissue (Neuron with neuroglia)

membrane. Arrival of the disturbance at the neuron's endings, or output zone, triggers events that may cause stimulation or inhibition of adjacent neurons and other cells (You will study the details in Chapter 21).

## 7.2 ORGAN AND ORGAN SYSTEM

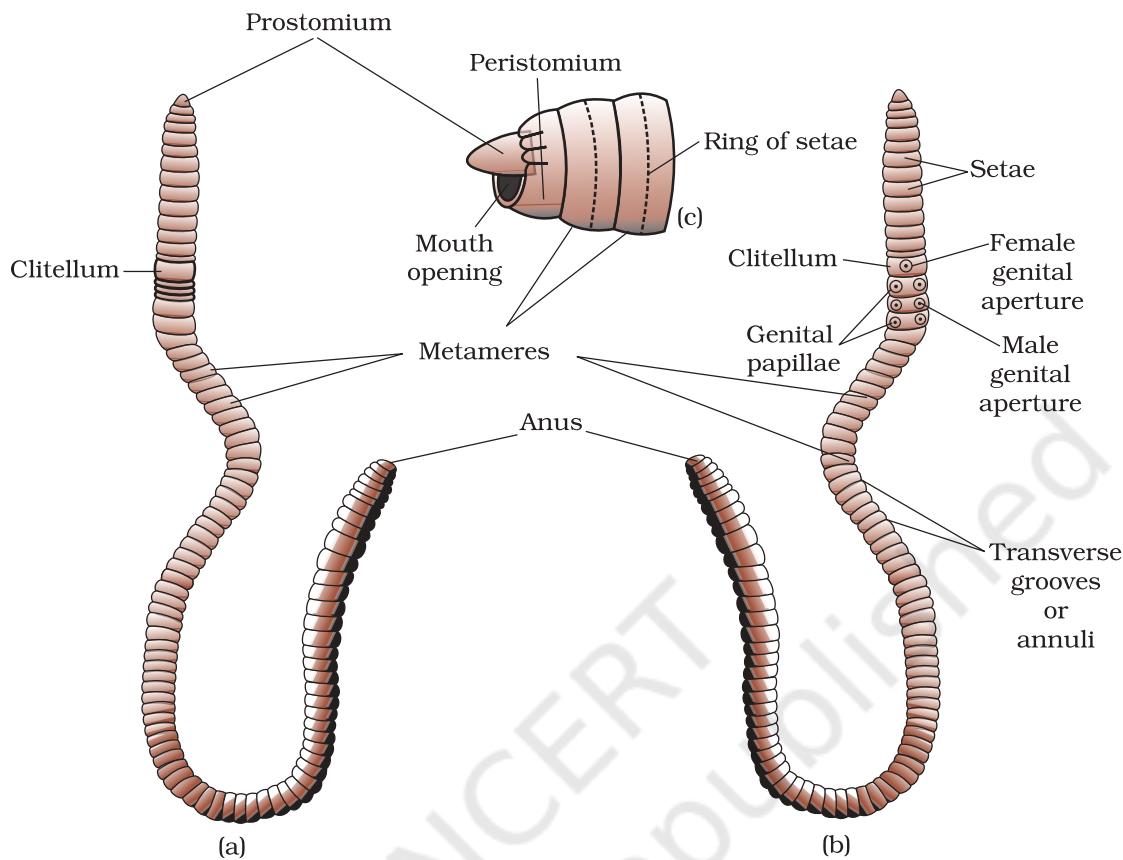
The basic tissues mentioned above organise to form organs which in turn associate to form organ systems in the multicellular organisms. Such an organisation is essential for more efficient and better coordinated activities of millions of cells constituting an organism. Each organ in our body is made of one or more type of tissues. For example, our heart consists of all the four types of tissues, i.e., epithelial, connective, muscular and neural. We also notice, after some careful study that the complexity in organ and organ systems displays certain discernable trend. This discernable trend is called evolutionary trend (You will study the details in class XII). You are being introduced to morphology and anatomy of three organisms at different evolutionary levels to show their organisation and functioning. Morphology refers to study of form or externally visible features. In the case of plants or microbes, the term morphology precisely means only this. In case of animals this refers to the external appearance of the organs or parts of the body. The word anatomy conventionally is used for the study of morphology of internal organs in the animals. You will learn the morphology and anatomy of earthworm, cockroach and frog representing invertebrates and vertebrates.

## 7.3 EARTHWORM

Earthworm is a reddish brown terrestrial invertebrate that inhabits the upper layer of the moist soil. During day time, they live in burrows made by boring and swallowing the soil. In the gardens, they can be traced by their faecal deposits known as worm castings. The common Indian earthworms are *Pheretima* and *Lumbricus*.

### 7.3.1 Morphology

Earthworms have long cylindrical body. The body is divided into more than hundred short segments which are similar (metameres about 100-120 in number). The dorsal surface of the body is marked by a dark median mid dorsal line (dorsal blood vessel) along the longitudinal axis of the body. The ventral surface is distinguished by the presence of genital openings (pores). Anterior end consists of the mouth and the prostomium, a lobe which serves as a covering for the mouth and as a wedge to force open cracks in the soil into which the earthworm may crawl. The prostomium is sensory in function. The first body segment is called the peristomium (buccal segment) which contains the mouth. In a mature worm, segments



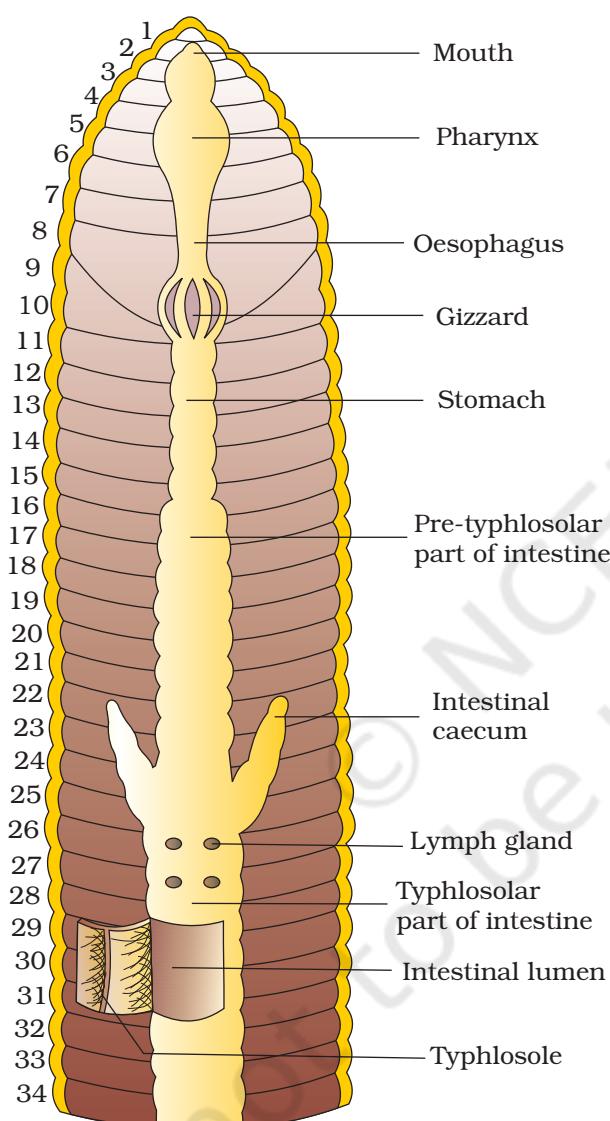
**Figure 7.9** Body of earthworm : (a) dorsal view (b) ventral view (c) lateral view showing mouth opening

14–16 are covered by a prominent dark band of glandular tissue called **clitellum**. Thus the body is divisible into three prominent regions – preclitellar, clitellar and postclitellar segments (Figure 7.9).

Four pairs of spermathecal apertures are situated on the ventro-lateral sides of the intersegmental grooves, i.e., 5<sup>th</sup>–9<sup>th</sup> segments. A single female genital pore is present in the mid-ventral line of 14<sup>th</sup> segment. A pair of male genital pores are present on the ventro-lateral sides of the 18<sup>th</sup> segment. Numerous minute pores called nephridiopores open on the surface of the body. In each body segment, except the first, last and clitellum, there are rows of S-shaped **setae**, embedded in the epidermal pits in the middle of each segment. Setae can be extended or retracted. Their principal role is in locomotion.

### 7.3.2 Anatomy

The body wall of the earthworm is covered externally by a thin non-cellular cuticle below which is the epidermis, two muscle layers (circular and longitudinal) and an innermost coelomic epithelium. The epidermis is made

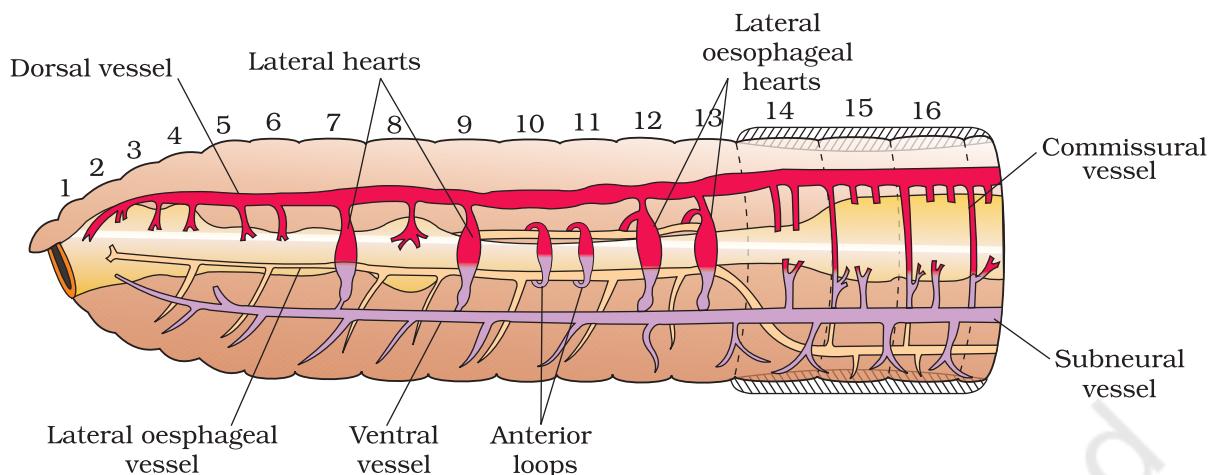


**Figure 7.10** Alimentary canal of earthworm

up of a single layer of columnar epithelial cells which contain secretory gland cells.

The alimentary canal is a straight tube and runs between first to last segment of the body. (Figure 7.10). A terminal mouth opens into the buccal cavity (1-3 segments) which leads into muscular pharynx. A small narrow tube, oesophagus (5-7 segments), continues into a muscular gizzard (8-9 segments). It helps in grinding the soil particles and decaying leaves, etc. The stomach extends from 9-14 segments. The food of the earthworm is decaying leaves and organic matter mixed with soil. Calciferous glands, present in the stomach, neutralise the humic acid present in humus. Intestine starts from the 15<sup>th</sup> segment onwards and continues till the last segment. A pair of short and conical intestinal caecae project from the intestine on the 26<sup>th</sup> segment. The characteristic feature of the intestine after 26<sup>th</sup> segment except the last 23<sup>rd</sup>-25<sup>th</sup> segments is the presence of internal median fold of dorsal wall called **typhlosole**. This increases the effective area of absorption in the intestine. The alimentary canal opens to the exterior by a small rounded aperture called anus. The ingested organic rich soil passes through the digestive tract where digestive enzymes breakdown complex food into smaller absorbable units. These simpler molecules are absorbed through intestinal membranes and are utilised.

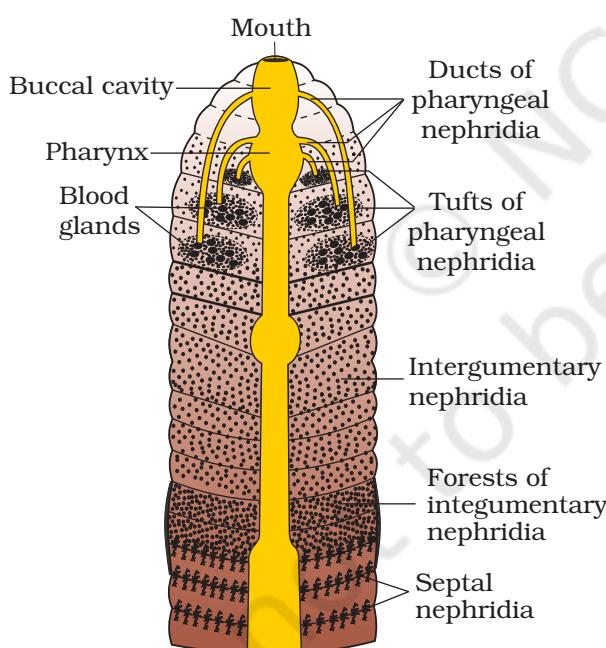
*Pheretima* exhibits a closed type of blood vascular system, consisting of blood vessels, capillaries and heart. (Figure 7.11). Due to closed circulatory system, blood is confined to the heart and blood vessels. Contractions keep blood circulating in one direction. Smaller blood vessels supply the gut, nerve cord, and the body wall. Blood glands are present on the 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> segments. They produce blood cells and haemoglobin which is dissolved in blood plasma. Blood cells are phagocytic in nature. Earthworms lack specialised breathing devices. Respiratory exchange occurs through moist body surface into their blood stream.



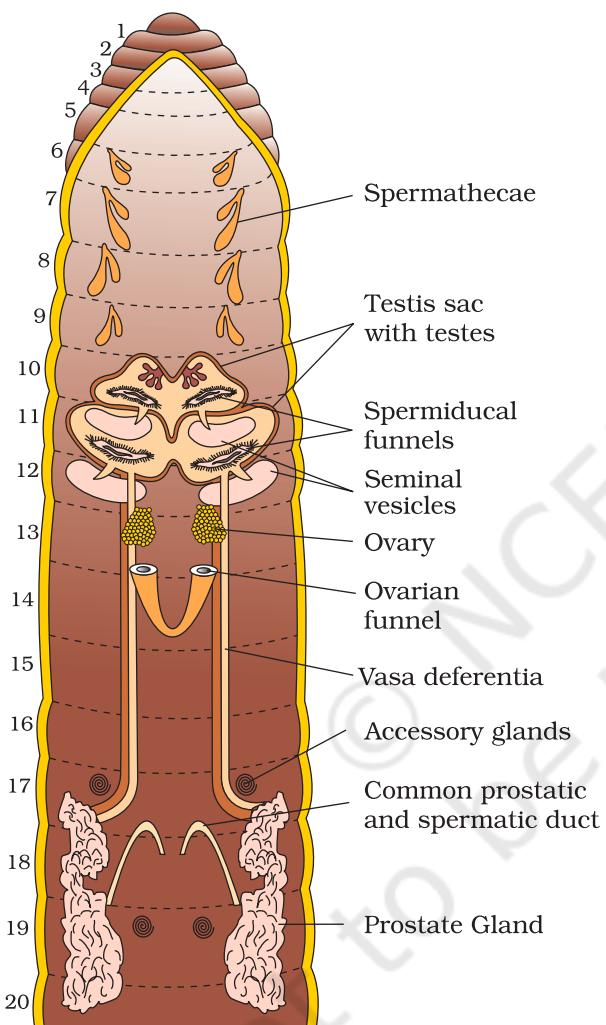
**Figure 7.11** Closed circulatory system

The excretory organs occur as segmentally arranged coiled tubules called nephridia (sing.: *nephridium*). They are of three types: (i) septal nephridia, present on both the sides of intersegmental septa of segment 15 to the last that open into intestine, (ii) integumentary nephridia, attached to lining of the body wall of segment 3 to the last that open on the body surface and (iii) pharyngeal nephridia, present as three paired tufts in the 4<sup>th</sup>, 5<sup>th</sup> and 6<sup>th</sup> segments (Figure 7.12). These different types of nephridia are basically similar in structure. Nephridia regulate the volume and composition of the body fluids. A nephridium starts out as a funnel that collects excess fluid from coelomic chamber. The funnel connects with a tubular part of the nephridium which delivers the wastes through a pore to the surface in the body wall into the digestive tube.

Nervous system is basically represented by ganglia arranged segmentwise on the ventral paired nerve cord. The nerve cord in the anterior region (3<sup>rd</sup> and 4<sup>th</sup> segments) bifurcates, laterally encircling the pharynx and joins the cerebral ganglia dorsally to form a nerve ring. The cerebral ganglia alongwith other nerves in the ring integrate sensory input as well as command muscular responses of the body.



**Figure 7.12** Nephridial system in earthworm



**Figure 7.13** Reproductive system of earthworm

Sensory system does not have eyes but does possess light and touch sensitive organs (receptor cells) to distinguish the light intensities and to feel the vibrations in the ground. Worms have specialised chemoreceptors (taste receptors) which react to chemical stimuli. These sense organs are located on the anterior part of the worm.

Earthworm is hermaphrodite (bisexual), i.e., testes and ovaries are present in the same individual (Figure 7.13). There are two pairs of testes present in the 10<sup>th</sup> and 11<sup>th</sup> segments. Their vasa deferentia run up to the 18<sup>th</sup> segment where they join the prostatic duct. Two pairs of accessory glands are present one pair each in the 17<sup>th</sup> and 19<sup>th</sup> segments. The common prostate and spermatic duct (*vasa deferentia*) opens to the exterior by a pair of male genital pores on the ventro-lateral side of the 18<sup>th</sup> segment. Four pairs of spermathecae are located in 6<sup>th</sup>-9<sup>th</sup> segments (one pair in each segment). They receive and store spermatozoa during copulation. One pair of ovaries is attached at the inter-segmental septum of the 12<sup>th</sup> and 13<sup>th</sup> segments. Ovarian funnels are present beneath the ovaries which continue into oviduct, join together and open on the ventral side as a single median female genital pore on the 14<sup>th</sup> segment.

A mutual exchange of sperm occurs between two worms during mating. One worm has to find another worm and they mate juxtaposing opposite gonadal openings exchanging packets of sperms called spermatophores. Mature sperm and egg cells and nutritive fluid are deposited in cocoons produced by the gland cells of clitellum. Fertilisation and development occur within the cocoons which are deposited in soil. The ova (eggs) are fertilised by the sperm cells within the cocoon which then slips off the worm and is deposited in or on the soil. The cocoon holds the worm embryos. After about 3 weeks, each cocoon produces two to twenty baby worms with an average of four. Development of earthworms is direct, i.e., there is no larva formed.

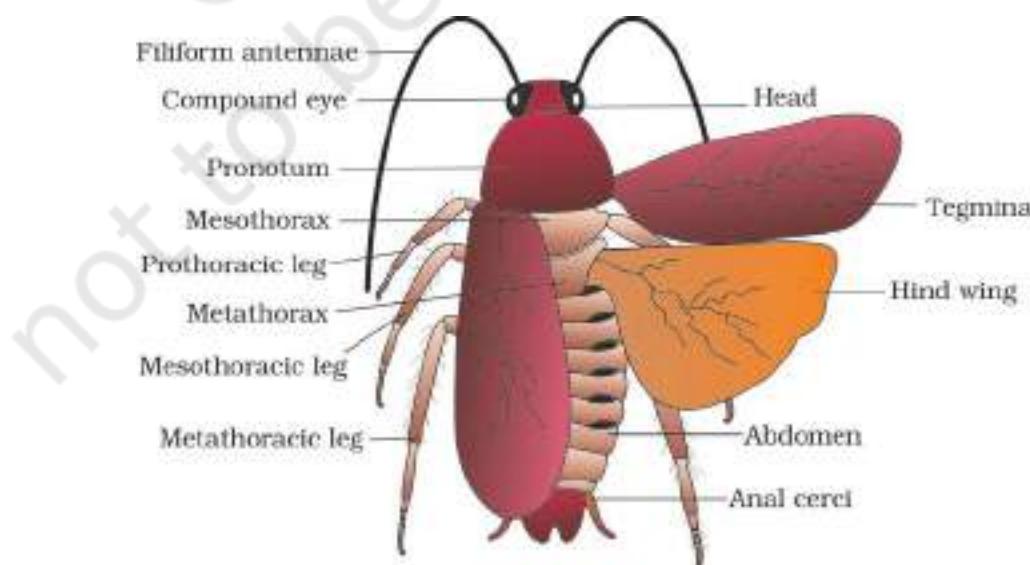
Earthworms are known as 'friends of farmers' because they make burrows in the soil and make it porous which helps in respiration and penetration of the developing plant roots. The process of increasing fertility of soil by the earthworms is called vermicomposting. They are also used as bait in game fishing.

## 7.4 COCKROACH

Cockroaches are brown or black bodied animals that are included in class Insecta of Phylum Arthropoda. Bright yellow, red and green coloured cockroaches have also been reported in tropical regions. Their size ranges from 1 to 3 inches (0.6-7.6 cm) and have long antenna, legs and flat extension of the upper body wall that conceals head. They are nocturnal omnivores that live in damp places throughout the world. They have become residents of human homes and thus are serious pests and vectors of several diseases.

### 7.4.1 Morphology

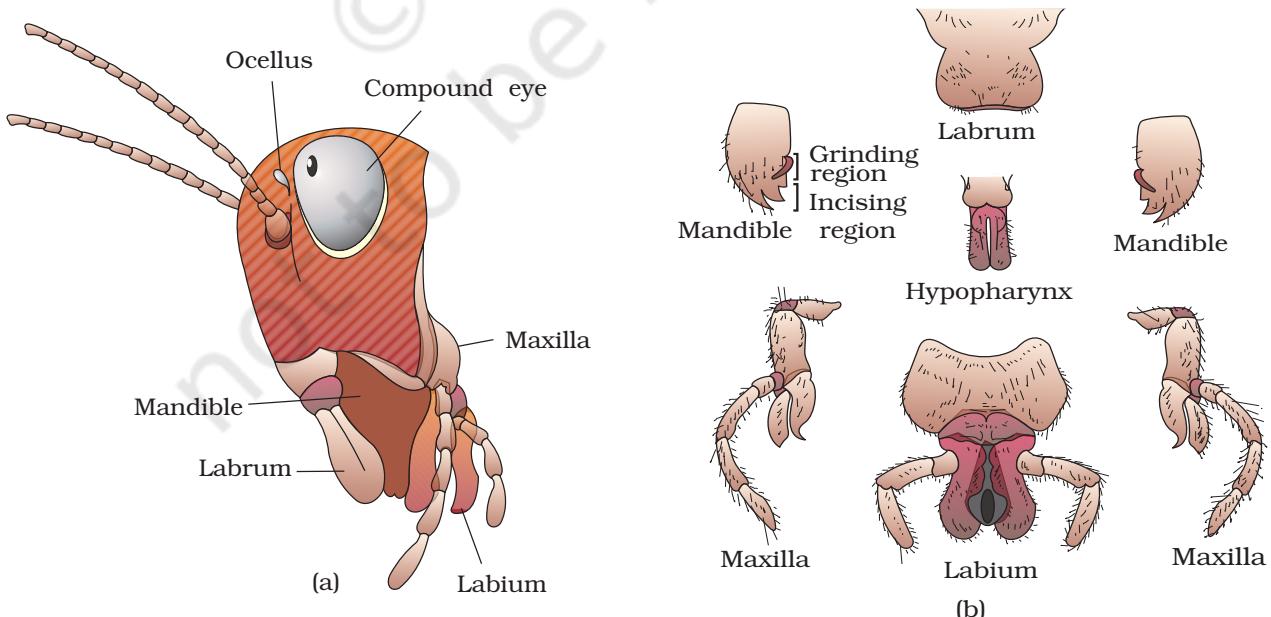
The adults of the common species of cockroach, *Periplaneta americana* are about 34-53 mm long with wings that extend beyond the tip of the abdomen in males. The body of the cockroach is segmented and divisible into three distinct regions – head, thorax and abdomen (Figure 7.14). The entire body is covered by a hard chitinous exoskeleton (brown in colour). In each segment, exoskeleton has hardened plates called sclerites (tergites dorsally and sternites ventrally) that are joined to each other by a thin and flexible articular membrane (arthrodial membrane).



**Figure 7.14** External features of cockroach

Head is triangular in shape and lies anteriorly at right angles to the longitudinal body axis. It is formed by the fusion of six segments and shows great mobility in all directions due to flexible neck (Figure 7.15). The head capsule bears a pair of compound eyes. A pair of thread like antennae arise from membranous sockets lying in front of eyes. Antennae have sensory receptors that help in monitoring the environment. Anterior end of the head bears appendages forming biting and chewing type of mouth parts. The mouthparts consisting of a labrum (upper lip), a pair of mandibles, a pair of maxillae and a labium (lower lip). A median flexible lobe, acting as tongue (hypopharynx), lies within the cavity enclosed by the mouthparts (Figure 7.15b). Thorax consists of three parts – prothorax, mesothorax and metathorax. The head is connected with thorax by a short extension of the prothorax known as the neck. Each thoracic segment bears a pair of walking legs. The first pair of wings arises from mesothorax and the second pair from metathorax. Forewings (mesothoracic) called tegmina are opaque dark and leathery and cover the hind wings when at rest. The hind wings are transparent, membranous and are used in flight.

The abdomen in both males and females consists of 10 segments. In females, the 7<sup>th</sup> sternum is boat shaped and together with the 8<sup>th</sup> and 9<sup>th</sup> sterna forms a brood or genital pouch whose anterior part contains female gonopore, spermathecal pores and collateral glands. In males, genital pouch or chamber lies at the hind end of abdomen bounded dorsally by 9<sup>th</sup> and 10<sup>th</sup> terga and ventrally by the 9<sup>th</sup> sternum. It contains dorsal anus, ventral male genital pore and gonapophysis. Males bear a pair of short, thread-like anal styles which are absent in females. In both sexes, the 10<sup>th</sup> segment bears a pair of jointed filamentous structures called anal cerci.



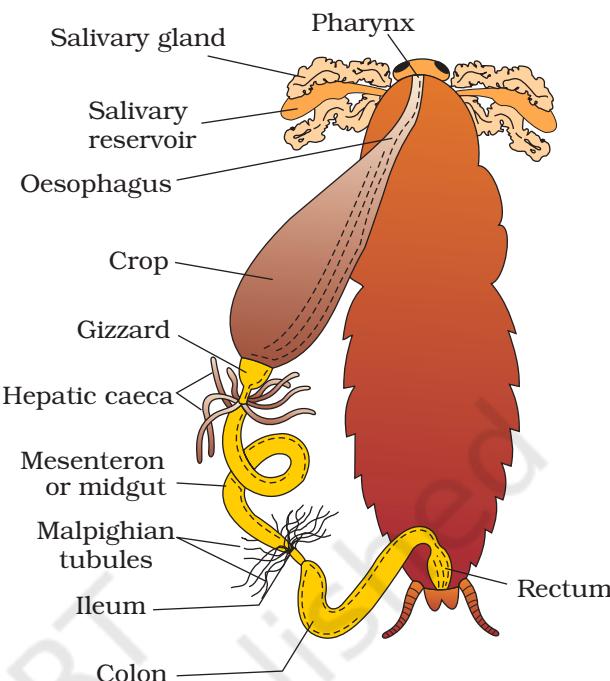
**Figure 7.15** Head region of cockroach : (a) parts of head region (b) mouth parts

### 7.4.2 Anatomy

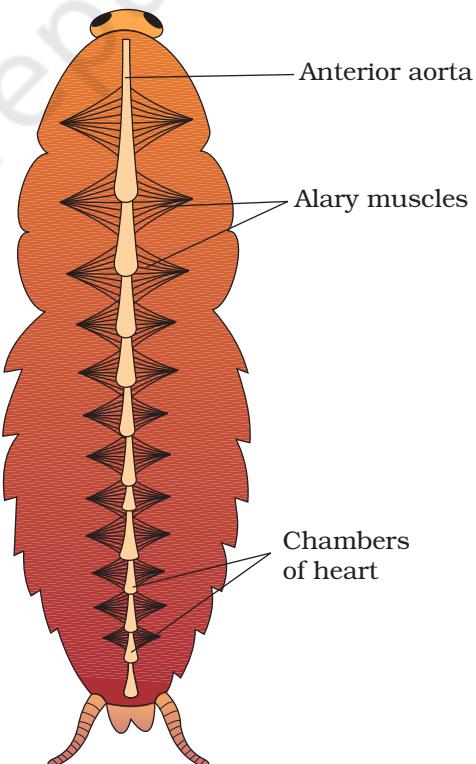
The alimentary canal present in the body cavity is divided into three regions: foregut, midgut and hindgut (Figure 7.16). The mouth opens into a short tubular pharynx, leading to a narrow tubular passage called oesophagus. This in turn opens into a sac like structure called crop used for storing of food. The crop is followed by gizzard or proventriculus. It has an outer layer of thick circular muscles and thick inner cuticle forming six highly chitinous plate called teeth. Gizzard helps in grinding the food particles. The entire foregut is lined by cuticle. A ring of 6-8 blind tubules called hepatic or gastric caecae is present at the junction of foregut and midgut, which secrete digestive juice. At the junction of midgut and hindgut is present another ring of 100-150 yellow coloured thin filamentous **Malpighian tubules**. They help in removal of excretory products from haemolymph. The hindgut is broader than midgut and is differentiated into ileum, colon and rectum. The rectum opens out through anus.

Blood vascular system of cockroach is an open type (Figure 7.17). Blood vessels are poorly developed and open into space (haemocoel). Visceral organs located in the haemocoel are bathed in blood (haemolymph). The haemolymph is composed of colourless plasma and haemocytes. Heart of cockroach consists of elongated muscular tube lying along mid dorsal line of thorax and abdomen. It is differentiated into funnel shaped chambers with ostia on either side. Blood from sinuses enter heart through ostia and is pumped anteriorly to sinuses again.

The respiratory system consists of a network of trachea, that open through 10 pairs of small holes called spiracles present on the lateral side of the body. Thin branching tubes (tracheal tubes subdivided into tracheoles) carry oxygen from the air to all the parts. The



**Figure 7.16** Alimentary canal of cockroach



**Figure 7.17** Open circulatory system of cockroach

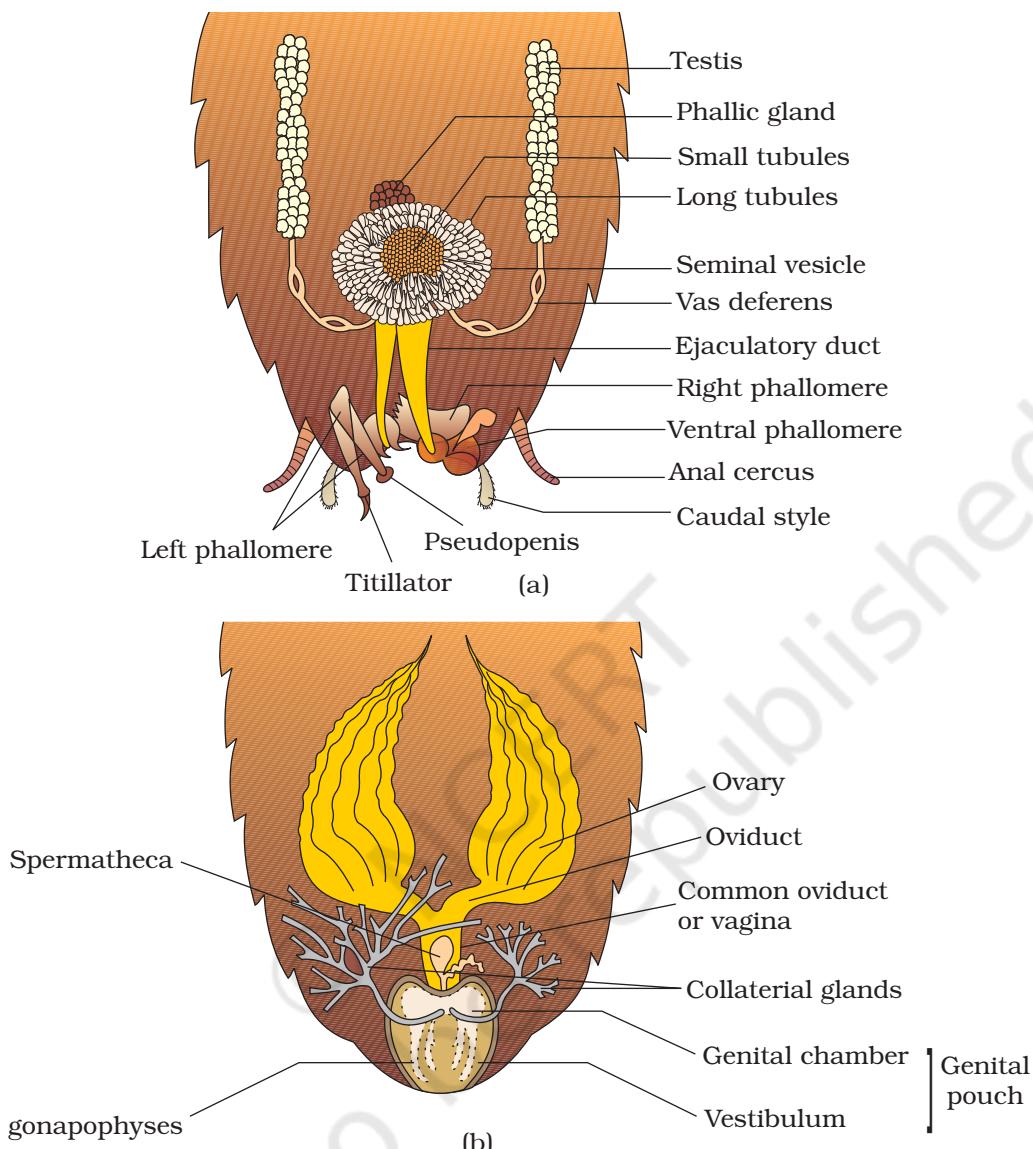
opening of the spiracles is regulated by the sphincters. Exchange of gases take place at the tracheoles by diffusion.

Excretion is performed by Malpighian tubules. Each tubule is lined by glandular and ciliated cells. They absorb nitrogenous waste products and convert them into uric acid which is excreted out through the hindgut. Therefore, this insect is called **uricotelic**. In addition, the fat body, nephrocytes and urecose glands also help in excretion.

The nervous system of cockroach consists of a series of fused, segmentally arranged ganglia joined by paired longitudinal connectives on the ventral side. Three ganglia lie in the thorax, and six in the abdomen. The nervous system of cockroach is spread throughout the body. The head holds a bit of a nervous system while the rest is situated along the ventral (belly-side) part of its body. So, now you understand that if the head of a cockroach is cut off, it will still live for as long as one week. In the head region, the brain is represented by supra-oesophageal ganglion which supplies nerves to antennae and compound eyes. In cockroach, the sense organs are antennae, eyes, maxillary palps, labial palps, anal cerci, etc. The compound eyes are situated at the dorsal surface of the head. Each eye consists of about 2000 hexagonal ommatidia (sing.: *ommatidium*). With the help of several ommatidia, a cockroach can receive several images of an object. This kind of vision is known as mosaic vision with more sensitivity but less resolution, being common during night (hence called nocturnal vision).

Cockroaches are dioecious and both sexes have well developed reproductive organs (Figure 7.18). Male reproductive system consists of a pair of testes one lying on each lateral side in the 4<sup>th</sup>-6<sup>th</sup> abdominal segments. From each testis arises a thin vas deferens, which opens into ejaculatory duct through seminal vesicle. The ejaculatory duct opens into male gonopore situated ventral to anus. A characteristic mushroom-shaped gland is present in the 6<sup>th</sup>-7<sup>th</sup> abdominal segments which functions as an accessory reproductive gland. The external genitalia are represented by male gonapophysis or phallomere (chitinous asymmetrical structures, surrounding the male gonopore). The sperms are stored in the seminal vesicles and are glued together in the form of bundles called spermatophores which are discharged during copulation. The female reproductive sysystem consists of two large ovaries, lying laterally in the 2<sup>nd</sup> – 6<sup>th</sup> abdominal segments. Each ovary is formed of a group of eight ovarian tubules or ovarioles, containing a chain of developing ova. Oviducts of each ovary unite into a single median oviduct (also called vagina) which opens into the genital chamber. A pair of spermatheca is present in the 6<sup>th</sup> segment which opens into the genital chamber.

Sperms are transferred through spermatophores. Their fertilised eggs are encased in capsules called oothecae. Ootheca is a dark reddish to blackish brown capsule, about 3/8" (8 mm) long. They are dropped or



**Figure 7.18** Reproductive system of cockroach : (a) male (b) female

glued to a suitable surface, usually in a crack or crevice of high relative humidity near a food source. On an average, females produce 9-10 oothecae, each containing 14-16 eggs. The development of *P. americana* is paurometabolous, meaning there is development through nymphal stage. The nymphs look very much like adults. The nymph grows by moulting about 13 times to reach the adult form. The next to last nymphal stage has wing pads but only adult cockroaches have wings.

Many species of cockroaches are wild and are of no economic importance. A few species thrive in and around human habitat. They are pests because they destroy food and contaminate it with their smelly excreta. They can transmit a variety of bacterial diseases by contaminating food material.

## 7.5 FROGS

Frogs can live both on land and in freshwater and belong to class Amphibia of phylum Chordata. The most common species of frog found in India is *Rana tigrina*.

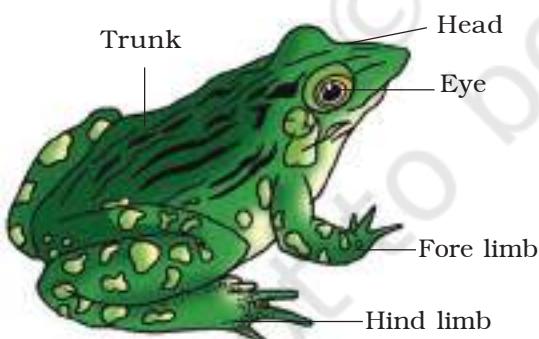
They do not have constant body temperature i.e., their body temperature varies with the temperature of the environment. Such animals are called cold blooded or poikilotherms. You might have also noticed changes in the colour of the frogs while they are in grasses and on dry land. They have the ability to change the colour to hide them from their enemies (camouflage). This protective coloration is called mimicry. You may also know that the frogs are not seen during peak summer and winter. During this period they take shelter in deep burrows to protect them from extreme heat and cold. This is called as summer sleep (aestivation) and winter sleep (hibernation).

### 7.5.1 Morphology

Have you ever touched the skin of frog? The skin is smooth and slippery due to the presence of mucus. The skin is always maintained in a moist condition. The colour of dorsal side of body is generally olive green with dark irregular spots. On the ventral side the skin is uniformly pale yellow. The frog never drinks water but absorb it through the skin.

Body of a frog is divisible into head and trunk (Figure 7.19). A neck and tail are absent. Above the mouth, a pair of nostrils is present. Eyes are bulged and covered by a nictitating membrane that protects them

while in water. On either side of eyes a membranous tympanum (ear) receives sound signals. The forelimbs and hind limbs help in swimming, walking, leaping and burrowing. The hind limbs end in five digits and they are larger and muscular than fore limbs that end in four digits. Feet have webbed digits that help in swimming. Frogs exhibit sexual dimorphism. Male frogs can be distinguished by the presence of sound producing vocal sacs and also a copulatory pad on the first digit of the fore limbs which are absent in female frogs.

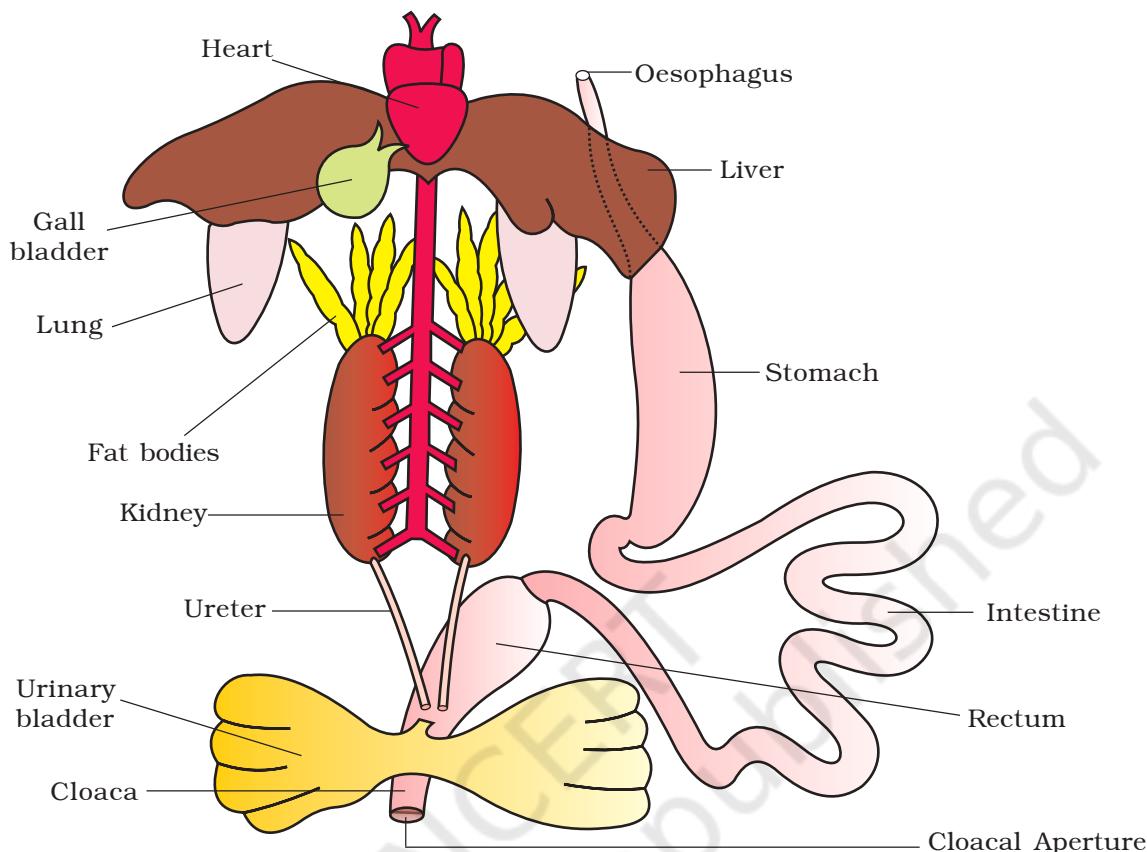


**Figure 7.19** External features of frog

### 7.5.2 Anatomy

The body cavity of frogs accommodate different organ systems such as digestive, circulatory, respiratory, nervous, excretory and reproductive systems with well developed structures and functions (Figure 7.20).

The digestive system consists of alimentary canal and digestive glands. The alimentary canal is short because frogs are carnivores and hence the length of intestine is reduced. The mouth opens into the buccal cavity



**Figure 7.20** Diagrammatic representation of internal organs of frog showing complete digestive system

that leads to the oesophagus through pharynx. Oesophagus is a short tube that opens into the stomach which in turn continues as the intestine, rectum and finally opens outside by the cloaca. Liver secretes bile that is stored in the gall bladder. Pancreas, a digestive gland produces pancreatic juice containing digestive enzymes. Food is captured by the bilobed tongue. Digestion of food takes place by the action of HCl and gastric juices secreted from the walls of the stomach. Partially digested food called chyme is passed from stomach to the first part of the intestine, the duodenum. The duodenum receives bile from gall bladder and pancreatic juices from the pancreas through a common bile duct. Bile emulsifies fat and pancreatic juices digest carbohydrates and proteins. Final digestion takes place in the intestine. Digested food is absorbed by the numerous finger-like folds in the inner wall of intestine called villi and microvilli. The undigested solid waste moves into the rectum and passes out through cloaca.

Frogs respire on land and in the water by two different methods. In water, skin acts as aquatic respiratory organ (cutaneous respiration). Dissolved oxygen in the water is exchanged through the skin by diffusion.

On land, the buccal cavity, skin and lungs act as the respiratory organs. The respiration by lungs is called pulmonary respiration. The lungs are a pair of elongated, pink coloured sac-like structures present in the upper part of the trunk region (thorax). Air enters through the nostrils into the buccal cavity and then to lungs. During aestivation and hibernation gaseous exchange takes place through skin.

The vascular system of frog is well-developed closed type. Frogs have a lymphatic system also. The blood vascular system involves heart, blood vessels and blood. The lymphatic system consists of lymph, lymph channels and lymph nodes. Heart is a muscular structure situated in the upper part of the body cavity. It has three chambers, two atria and one ventricle and is covered by a membrane called pericardium. A triangular structure called sinus venosus joins the right atrium. It receives blood through the major veins called vena cava. The ventricle opens into a sac-like conus arteriosus on the ventral side of the heart. The blood from the heart is carried to all parts of the body by the arteries (arterial system). The veins collect blood from different parts of body to the heart and form the venous system. Special venous connection between liver and intestine as well as the kidney and lower parts of the body are present in frogs. The former is called hepatic portal system and the latter is called renal portal system. The blood is composed of plasma and cells. The blood cells are RBC (red blood cells) or erythrocytes, WBC (white blood cells) or leucocytes and platelets. RBC's are nucleated and contain red coloured pigment namely haemoglobin. The lymph is different from blood. It lacks few proteins and RBCs. The blood carries nutrients, gases and water to the respective sites during the circulation. The circulation of blood is achieved by the pumping action of the muscular heart.

The elimination of nitrogenous wastes is carried out by a well developed excretory system. The excretory system consists of a pair of kidneys, ureters, cloaca and urinary bladder. These are compact, dark red and bean like structures situated a little posteriorly in the body cavity on both sides of vertebral column. Each kidney is composed of several structural and functional units called uriniferous tubules or nephrons. Two ureters emerge from the kidneys in the male frogs. The ureters act as urinogenital duct which opens into the cloaca. In females the ureters and oviduct open separately in the cloaca. The thin-walled urinary bladder is present ventral to the rectum which also opens in the cloaca. The frog excretes urea and thus is a **ureotelic** animal. Excretory wastes are carried by blood into the kidney where it is separated and excreted.

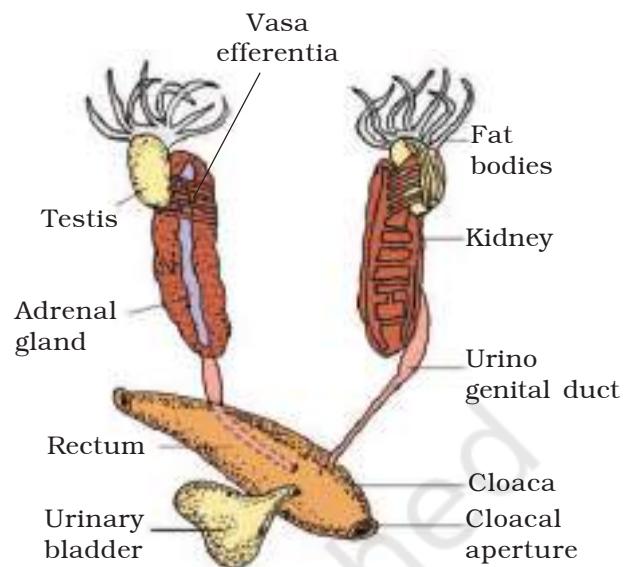
The system for control and coordination is highly evolved in the frog. It includes both neural system and endocrine glands. The chemical coordination of various organs of the body is achieved by hormones which are secreted by the endocrine glands. The prominent endocrine glands found in frog are pituitary, thyroid, parathyroid, thymus, pineal body, pancreatic islets, adrenals and gonads. The nervous system is organised

into a central nervous system (brain and spinal cord), a peripheral nervous system (cranial and spinal nerves) and an autonomic nervous system (sympathetic and parasympathetic). There are ten pairs of cranial nerves arising from the brain. Brain is enclosed in a bony structure called brain box (cranium). The brain is divided into fore-brain, mid-brain and hind-brain. Forebrain includes olfactory lobes, paired cerebral hemispheres and unpaired diencephalon. The midbrain is characterised by a pair of optic lobes. Hind-brain consists of cerebellum and medulla oblongata. The medulla oblongata passes out through the foramen magnum and continues into spinal cord, which is enclosed in the vertebral column.

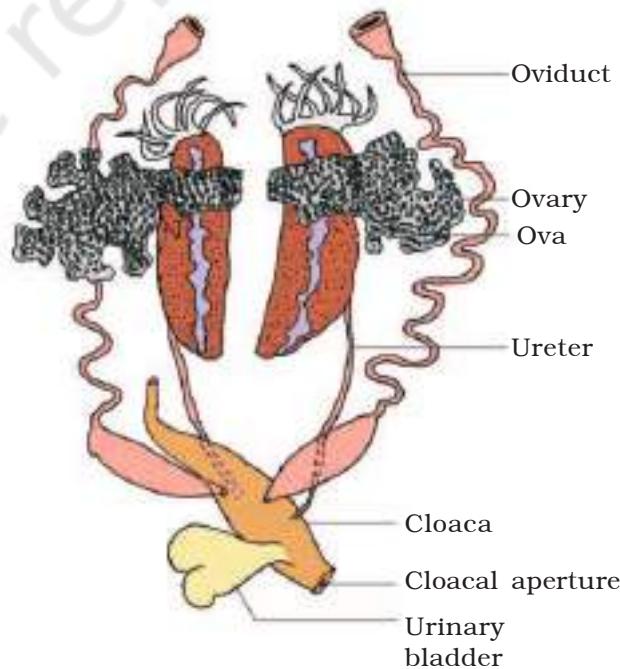
Frog has different types of sense organs, namely organs of touch (sensory papillae), taste (taste buds), smell (nasal epithelium), vision (eyes) and hearing (tympanum with internal ears). Out of these, eyes and internal ears are well-organised structures and the rest are cellular aggregations around nerve endings. Eyes in a frog are a pair of spherical structures situated in the orbit in skull. These are simple eyes (possessing only one unit). External ear is absent in frogs and only tympanum can be seen externally. The ear is an organ of hearing as well as balancing (equilibrium).

Frogs have well organised male and female reproductive systems. Male reproductive organs consist of a pair of yellowish ovoid testes (Figure 7.21), which are found adhered to the upper part of kidneys by a double fold of peritoneum called mesorchium. Vasa efferentia are 10-12 in number that arise from testes. They enter the kidneys on their side and open into Bidder's canal. Finally it communicates with the urinogenital duct that comes out of the kidneys and opens into the cloaca. The cloaca is a small, median chamber that is used to pass faecal matter, urine and sperms to the exterior.

The female reproductive organs include a pair of ovaries (Figure 7.22). The ovaries are situated near kidneys and there is no functional connection with kidneys. A pair of oviduct arising



**Figure 7.21** Male reproductive system



**Figure 7.22** Female reproductive system

from the ovaries opens into the cloaca separately. A mature female can lay 2500 to 3000 ova at a time. Fertilisation is external and takes place in water. Development involves a larval stage called tadpole. Tadpole undergoes metamorphosis to form the adult.

Frogs are beneficial for mankind because they eat insects and protect the crop. Frogs maintain ecological balance because these serve as an important link of food chain and food web in the ecosystem. In some countries the muscular legs of frog are used as food by man.

### SUMMARY

Cells, tissues, organs and organ systems split up the work in a way that ensures the survival of the body as a whole and exhibit division of labour. A tissue is defined as group of cells along with intercellular substances performing one or more functions in the body. Epithelia are sheet like tissues lining the body's surface and its cavities, ducts and tubes. Epithelia have one free surface facing a body fluid or the outside environment. Their cells are structurally and functionally connected at junctions.

Diverse types of connective tissues bind together, support, strengthen, protect, and insulate other tissue in the body. Soft connective tissues consist of protein fibres as well as a variety of cells arranged in a ground substance. Cartilage, bone, blood, and adipose tissue are specialised connective tissues. Cartilage and bone are both structural materials. Blood is a fluid tissue with transport functions. Adipose tissue is a reservoir of stored energy. Muscle tissue, which can contract (shorten) in response to stimulation, helps in movement of the body and specific body parts. Skeletal muscle is the muscle tissue attached to bones. Smooth muscle is a component of internal organs. Cardiac muscle makes up the contractile walls of the heart. Connective tissue covers all three types of tissues. Nervous tissue exerts greatest control over the response of body. Neurons are the basic units of nervous tissue.

Earthworm, Cockroach and Frog show characteristic features in body organisation. In *Pheretima posthuma* (earthworm), the body is covered by cuticle. All segments of its body are alike except the 14<sup>th</sup>, 15<sup>th</sup> and 16<sup>th</sup> segment, which are thick and dark and glandular, forming clitellum. A ring of S-shaped chitinous setae is found in each segment. These setae help in locomotion. On the ventral side spermathecal openings are present in between the grooves of 5 and 6, 6 and 7, 7 and 8 and 8 and 9 segments. Female genital pores are present on 14<sup>th</sup> segment and male genital pores on 18<sup>th</sup> segment. The alimentary canal is a narrow tube made of mouth, buccal cavity, pharynx, gizzard, stomach, intestine and anus. The blood vascular system is of closed type with heart and valves. Nervous system is represented by ventral nerve cord. Earthworm is hermaphrodite. Two pairs of

testes occur in the 10<sup>th</sup> and 11<sup>th</sup> segment, respectively. A pair of ovaries are present on 12 and 13<sup>th</sup> intersegmental septum. It is a protandrous animal with cross-fertilisation. Fertilisation and development take place in cocoon secreted by the glands of clitellum.

The body of Cockroach (*Periplaneta americana*) is covered by chitinous exoskeleton. It is divided into head, thorax and abdomen. Segments bear jointed appendages. There are three segments of thorax, each bearing a pair of walking legs. Two pairs of wings are present, one pair each on 2<sup>nd</sup> and 3<sup>rd</sup> segment. There are ten segments in abdomen. Alimentary canal is well developed with a mouth surrounded by mouth parts, a pharynx, oesophagus, crop, gizzard, midgut, hindgut and anus. Hepatic caecae are present at the junction of foregut and midgut. Malpighian tubules are present at the junction of midgut and hindgut and help in excretion. A pair of salivary gland is present near crop. The blood vascular system is of open type. Respiration takes place by network of tracheae. Trachea opens outside with spiracles. Nervous system is represented by segmentally arranged ganglia and ventral nerve cord. A pair of testes is present in 4<sup>th</sup>-6<sup>th</sup> segments and ovaries in 2<sup>nd</sup>-6<sup>th</sup> segments. Fertilisation is internal. Female produces 9-10 ootheca bearing developing embryos. After rupturing of single ootheca sixteen young ones, called nymphs come out.

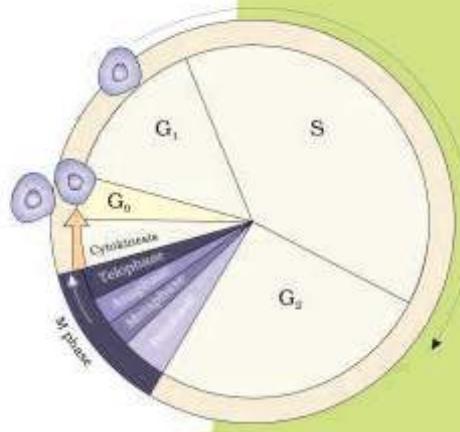
The Indian bullfrog, *Rana tigrina*, is the common frog found in India. Body is covered by skin. Mucous glands are present in the skin which is highly vascularised and helps in respiration in water and on land. Body is divisible into head and trunk. A muscular tongue is present, which is bilobed at the tip and is used in capturing the prey. The alimentary canal consists of oesophagous, stomach, intestine and rectum, which open into the cloaca. The main digestive glands are liver and pancreas. It can respire in water through skin and through lungs on land. Circulatory system is closed with single circulation. RBCs are nucleated. Nervous system is organised into central, peripheral and autonomic. The organs of urinogenital system are kidneys and urinogenital ducts, which open into the cloaca. The male reproductive organ is a pair of testes. The female reproductive organ is a pair of ovaries. A female lays 2500-3000 ova at a time. The fertilisation and development are external. The eggs hatch into tadpoles, which metamorphose into frogs.

### EXERCISES

1. Answer in one word or one line.
  - (i) Give the common name of *Periplaneta americana*.
  - (ii) How many spermathecae are found in earthworm?
  - (iii) What is the position of ovaries in cockroach?
  - (iv) How many segments are present in the abdomen of cockroach?
  - (v) Where do you find Malpighian tubules?

2. Answer the following:
  - (i) What is the function of nephridia?
  - (ii) How many types of nephridia are found in earthworm based on their location?
3. Draw a labelled diagram of the reproductive organs of an earthworm.
4. Draw a labelled diagram of alimentary canal of a cockroach.
5. Distinguish between the followings
  - (a) Prostomium and peristomium
  - (b) Septal nephridium and pharyngeal nephridium
6. What are the cellular components of blood?
7. What are the following and where do you find them in animal body.
  - (a) Chondrocytes
  - (b) Axons
  - (c) Ciliated epithelium
8. Describe various types of epithelial tissues with the help of labelled diagrams.
9. Distinguish between
  - (a) Simple epithelium and compound epithelium
  - (b) Cardiac muscle and striated muscle
  - (c) Dense regular and dense irregular connective tissues
  - (d) Adipose and blood tissue
  - (e) Simple gland and compound gland
10. Mark the odd one in each series:
  - (a) Areolar tissue; blood; neuron; tendon
  - (b) RBC; WBC; platelets; cartilage
  - (c) Exocrine; endocrine; salivary gland; ligament
  - (d) Maxilla; mandible; labrum; antennae
  - (e) Protonema; mesothorax; metathorax; coxa
11. Match the terms in column I with those in column II:
 

<b>Column I</b>	<b>Column II</b>
(a) Compound epithelium	(i) Alimentary canal
(b) Compound eye	(ii) Cockroach
(c) Septal nephridia	(iii) Skin
(d) Open circulatory system	(iv) Mosaic vision
(e) Typhlosole	(v) Earthworm
(f) Osteocytes	(vi) Phallomere
(g) Genitalia	(vii) Bone
12. Mention briefly about the circulatory system of earthworm
13. Draw a neat diagram of digestive system of frog.
14. Mention the function of the following
  - (a) Ureters in frog
  - (b) Malpighian tubules
  - (c) Body wall in earthworm



# UNIT 3

## CELL: STRUCTURE AND FUNCTIONS

### **Chapter 8**

Cell: The Unit of Life

### **Chapter 9**

Biomolecules

### **Chapter 10**

Cell Cycle and  
Cell Division

Biology is the study of living organisms. The detailed description of their form and appearance only brought out their diversity. It is the cell theory that emphasised the unity underlying this diversity of forms, i.e., the cellular organisation of all life forms. A description of cell structure and cell growth by division is given in the chapters comprising this unit. Cell theory also created a sense of mystery around living phenomena, i.e., physiological and behavioural processes. This mystery was the requirement of integrity of cellular organisation for living phenomena to be demonstrated or observed. In studying and understanding the physiological and behavioural processes, one can take a physico-chemical approach and use cell-free systems to investigate. This approach enables us to describe the various processes in molecular terms. The approach is established by analysis of living tissues for elements and compounds. It will tell us what types of organic compounds are present in living organisms. In the next stage, one can ask the question: What are these compounds doing inside a cell? And, in what way they carry out gross physiological processes like digestion, excretion, memory, defense, recognition, etc. In other words we answer the question, what is the molecular basis of all physiological processes? It can also explain the abnormal processes that occur during any diseased condition. This physico-chemical approach to study and understand living organisms is called 'Reductionist Biology'. The concepts and techniques of physics and chemistry are applied to understand biology. In Chapter 9 of this unit, a brief description of biomolecules is provided.



**G.N. Ramachandran**  
(1922 – 2001)

G.N. RAMACHANDRAN, an outstanding figure in the field of protein structure, was the founder of the 'Madras school' of conformational analysis of biopolymers. His discovery of the triple helical structure of collagen published in *Nature* in 1954 and his analysis of the allowed conformations of proteins through the use of the 'Ramachandran plot' rank among the most outstanding contributions in structural biology. He was born on October 8, 1922, in a small town, not far from Cochin on the southwestern coast of India. His father was a professor of mathematics at a local college and thus had considerable influence in shaping Ramachandran's interest in mathematics. After completing his school years, Ramachandran graduated in 1942 as the top-ranking student in the B.Sc. (Honors) Physics course of the University of Madras. He received a Ph.D. from Cambridge University in 1949. While at Cambridge, Ramachandran met Linus Pauling and was deeply influenced by his publications on models of the  $\alpha$ -helix and  $\beta$ -sheet structures that directed his attention to solving the structure of collagen. He passed away at the age of 78, on April 7, 2001.

# CHAPTER 8

## CELL: THE UNIT OF LIFE

[8.1 What is a Cell?](#)

[8.2 Cell Theory](#)

[8.3 An Overview of Cell](#)

[8.4 Prokaryotic Cells](#)

[8.5 Eukaryotic Cells](#)

When you look around, you see both living and non-living things. You must have wondered and asked yourself – ‘what is it that makes an organism living, or what is it that an inanimate thing does not have which a living thing has’? The answer to this is the presence of the basic unit of life – the cell in all living organisms.

All organisms are composed of cells. Some are composed of a single cell and are called unicellular organisms while others, like us, composed of many cells, are called multicellular organisms.

### 8.1 WHAT IS A CELL?

Unicellular organisms are capable of (i) independent existence and (ii) performing the essential functions of life. Anything less than a complete structure of a cell does not ensure independent living. Hence, cell is the fundamental structural and functional unit of all living organisms.

Anton Von Leeuwenhoek first saw and described a live cell. Robert Brown later discovered the nucleus. The invention of the microscope and its improvement leading to the electron microscope revealed all the structural details of the cell.

### 8.2 CELL THEORY

In 1838, Matthias Schleiden, a German botanist, examined a large number of plants and observed that all plants are composed of different kinds of cells which form the tissues of the plant. At about the same time, Theodore

Schwann (1839), a British Zoologist, studied different types of animal cells and reported that cells had a thin outer layer which is today known as the 'plasma membrane'. He also concluded, based on his studies on plant tissues, that the presence of cell wall is a unique character of the plant cells. On the basis of this, Schwann proposed the hypothesis that the bodies of animals and plants are composed of cells and products of cells.

Schleiden and Schwann together formulated the cell theory. This theory however, did not explain as to how new cells were formed. Rudolf Virchow (1855) first explained that cells divided and new cells are formed from pre-existing cells (*Omnis cellula-e cellula*). He modified the hypothesis of Schleiden and Schwann to give the cell theory a final shape. Cell theory as understood today is:

- (i) all living organisms are composed of cells and products of cells.
- (ii) all cells arise from pre-existing cells.

### 8.3 AN OVERVIEW OF CELL

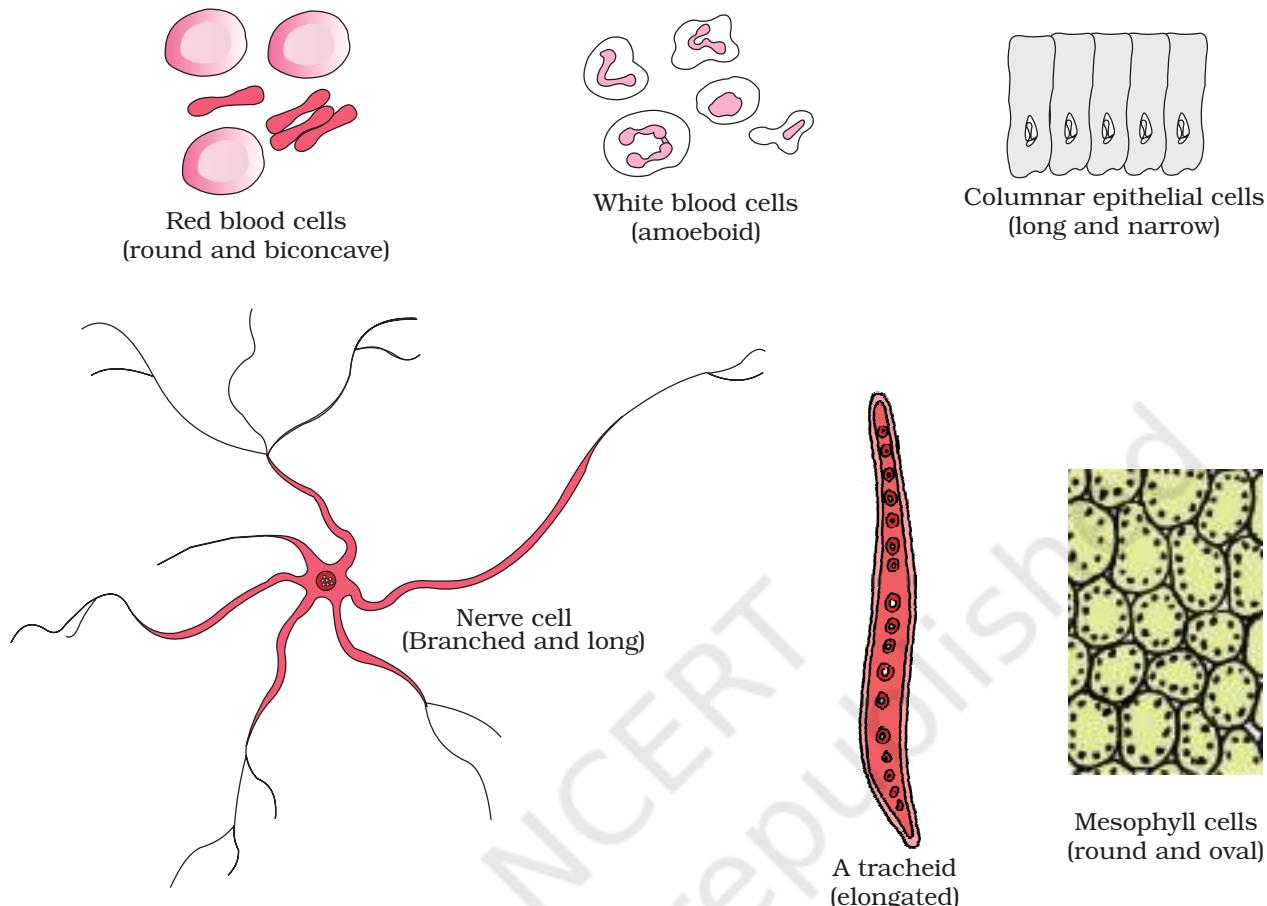
You have earlier observed cells in an onion peel and/or human cheek cells under the microscope. Let us recollect their structure. The onion cell which is a typical plant cell, has a distinct cell wall as its outer boundary and just within it is the cell membrane. The cells of the human cheek have an outer membrane as the delimiting structure of the cell. Inside each cell is a dense membrane bound structure called nucleus. This nucleus contains the chromosomes which in turn contain the genetic material, DNA. Cells that have membrane bound nuclei are called eukaryotic whereas cells that lack a membrane bound nucleus are prokaryotic. In both prokaryotic and eukaryotic cells, a semi-fluid matrix called cytoplasm occupies the volume of the cell. The cytoplasm is the main arena of cellular activities in both the plant and animal cells. Various chemical reactions occur in it to keep the cell in the 'living state'.

Besides the nucleus, the eukaryotic cells have other membrane bound distinct structures called **organelles** like the endoplasmic reticulum (ER), the golgi complex, lysosomes, mitochondria, microbodies and vacuoles. The prokaryotic cells lack such membrane bound organelles.

Ribosomes are non-membrane bound organelles found in all cells – both eukaryotic as well as prokaryotic. Within the cell, ribosomes are found not only in the cytoplasm but also within the two organelles – chloroplasts (in plants) and mitochondria and on rough ER.

Animal cells contain another non-membrane bound organelle called centriole which helps in cell division.

Cells differ greatly in size, shape and activities (Figure 8.1). For example, Mycoplasmas, the smallest cells, are only 0.3  $\mu\text{m}$  in length while bacteria



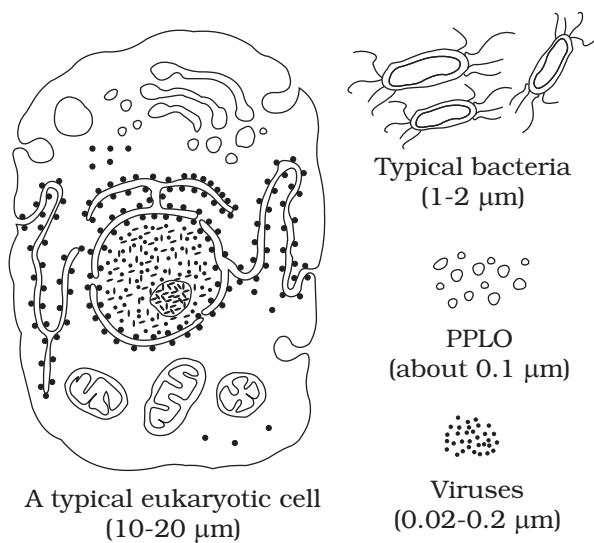
**Figure 8.1** Diagram showing different shapes of the cells

could be 3 to 5  $\mu\text{m}$ . The largest isolated single cell is the egg of an ostrich. Among multicellular organisms, human red blood cells are about 7.0  $\mu\text{m}$  in diameter. Nerve cells are some of the longest cells. Cells also vary greatly in their shape. They may be disc-like, polygonal, columnar, cuboid, thread like, or even irregular. The shape of the cell may vary with the function they perform.

#### 8.4 PROKARYOTIC CELLS

The prokaryotic cells are represented by bacteria, blue-green algae, mycoplasma and PPLO (Pleuro Pneumonia Like Organisms). They are generally smaller and multiply more rapidly than the eukaryotic cells (Figure 8.2). They may vary greatly in shape and size. The four basic shapes of bacteria are bacillus (rod like), coccus (spherical), vibrio (comma shaped) and spirillum (spiral).

The organisation of the prokaryotic cell is fundamentally similar even though prokaryotes exhibit a wide variety of shapes and functions. All



**Figure 8.2** Diagram showing comparison of eukaryotic cell with other organisms

prokaryotes have a cell wall surrounding the cell membrane except in mycoplasma. The fluid matrix filling the cell is the cytoplasm. There is no well-defined nucleus. The genetic material is basically naked, not enveloped by a nuclear membrane. In addition to the genomic DNA (the single chromosome/circular DNA), many bacteria have small circular DNA outside the genomic DNA. These smaller DNA are called plasmids. The plasmid DNA confers certain unique phenotypic characters to such bacteria. One such character is resistance to antibiotics. In higher classes you will learn that this plasmid DNA is used to monitor bacterial transformation with foreign DNA. Nuclear membrane is found in eukaryotes. No organelles, like the ones in eukaryotes, are found in prokaryotic cells except for ribosomes. Prokaryotes have something unique in the form of inclusions. A specialised

differentiated form of cell membrane called mesosome is the characteristic of prokaryotes. They are essentially infoldings of cell membrane.

#### 8.4.1 Cell Envelope and its Modifications

Most prokaryotic cells, particularly the bacterial cells, have a chemically complex cell envelope. The cell envelope consists of a tightly bound three layered structure i.e., the outermost glycocalyx followed by the cell wall and then the plasma membrane. Although each layer of the envelope performs distinct function, they act together as a single protective unit. Bacteria can be classified into two groups on the basis of the differences in the cell envelopes and the manner in which they respond to the staining procedure developed by Gram viz., those that take up the gram stain are **Gram positive** and the others that do not are called **Gram negative** bacteria.

Glycocalyx differs in composition and thickness among different bacteria. It could be a loose sheath called the **slime layer** in some, while in others it may be thick and tough, called the **capsule**. The **cell wall** determines the shape of the cell and provides a strong structural support to prevent the bacterium from bursting or collapsing.

The plasma membrane is semi-permeable in nature and interacts with the outside world. This membrane is similar structurally to that of the eukaryotes.

A special membranous structure is the **mesosome** which is formed by the extensions of plasma membrane into the cell. These extensions are in the **form of vesicles, tubules and lamellae**. They help in cell wall

formation, DNA replication and distribution to daughter cells. They also help in respiration, secretion processes, to increase the surface area of the plasma membrane and enzymatic content. In some prokaryotes like cyanobacteria, there are other membranous extensions into the cytoplasm called chromatophores which contain pigments.

Bacterial cells may be motile or non-motile. If motile, they have thin filamentous extensions from their cell wall called flagella. Bacteria show a range in the number and arrangement of flagella. Bacterial flagellum is composed of three parts – **filament, hook and basal body**. The filament is the longest portion and extends from the cell surface to the outside.

Besides flagella, Pili and Fimbriae are also surface structures of the bacteria but do not play a role in motility. The **pili** are elongated tubular structures made of a special protein. The **fimbriae** are small bristle like fibres sprouting out of the cell. In some bacteria, they are known to help attach the bacteria to rocks in streams and also to the host tissues.

#### 8.4.2 Ribosomes and Inclusion Bodies

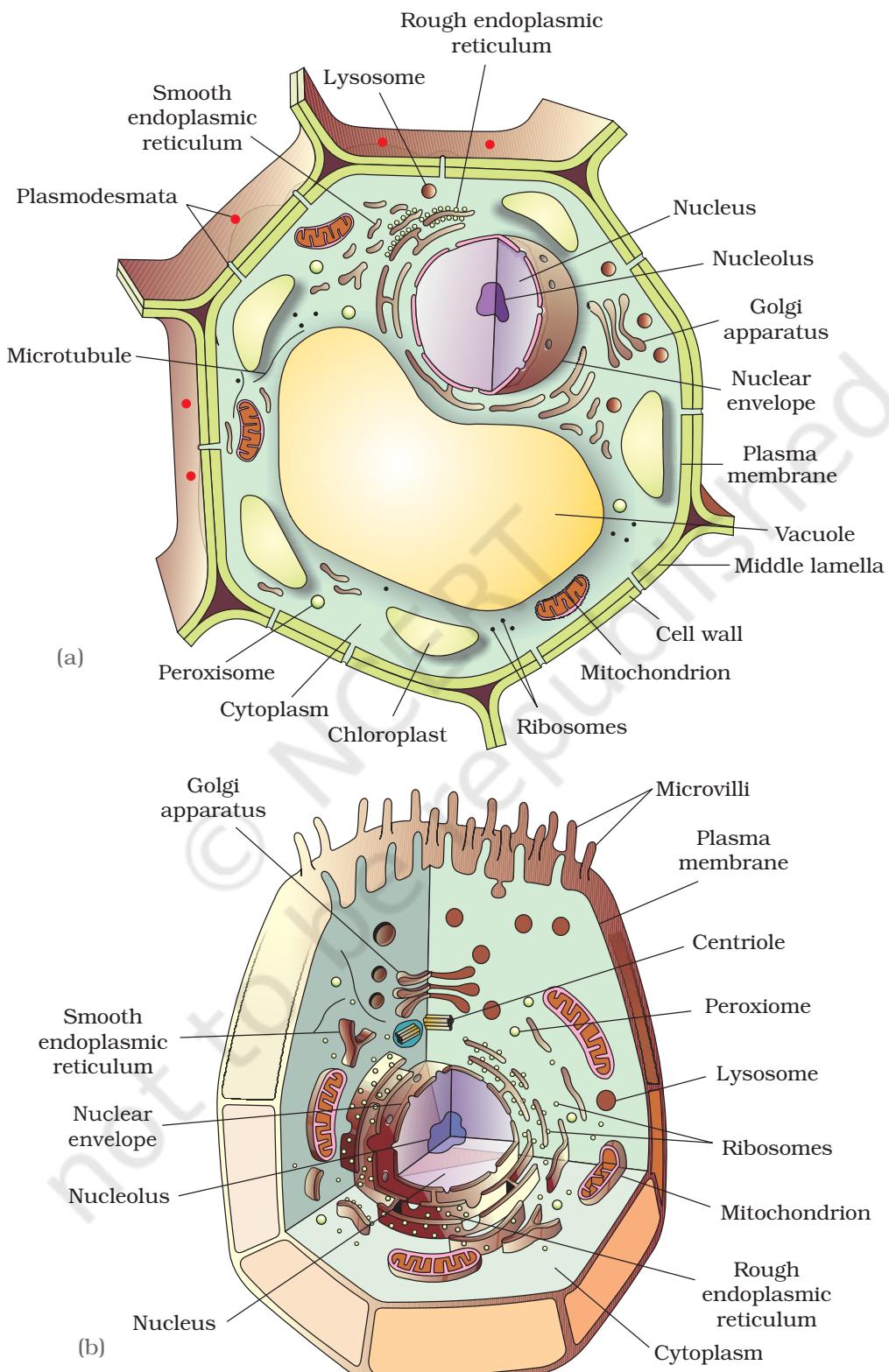
In prokaryotes, ribosomes are associated with the plasma membrane of the cell. They are about 15 nm by 20 nm in size and are made of two subunits - 50S and 30S units which when present together form 70S prokaryotic ribosomes. Ribosomes are the site of protein synthesis. Several ribosomes may attach to a single mRNA and form a chain called **polyribosomes** or **polysome**. The ribosomes of a polysome translate the mRNA into proteins.

**Inclusion bodies:** Reserve material in prokaryotic cells are stored in the cytoplasm in the form of inclusion bodies. These are not bound by any membrane system and lie free in the cytoplasm, e.g., phosphate granules, cyanophycean granules and glycogen granules. Gas vacuoles are found in blue green and purple and green photosynthetic bacteria.

### 8.5 EUKARYOTIC CELLS

The eukaryotes include all the protists, plants, animals and fungi. In eukaryotic cells there is an extensive compartmentalisation of cytoplasm through the presence of membrane bound organelles. Eukaryotic cells possess an organised nucleus with a nuclear envelope. In addition, eukaryotic cells have a variety of complex locomotory and cytoskeletal structures. Their genetic material is organised into chromosomes.

All eukaryotic cells are not identical. Plant and animal cells are different as the former possess cell walls, plastids and a large central vacuole which are absent in animal cells. On the other hand, animal cells have centrioles which are absent in almost all plant cells (Figure 8.3).



**Figure 8.3** Diagram showing : (a) Plant cell (b) Animal cell

Let us now look at individual cell organelles to understand their structure and functions.

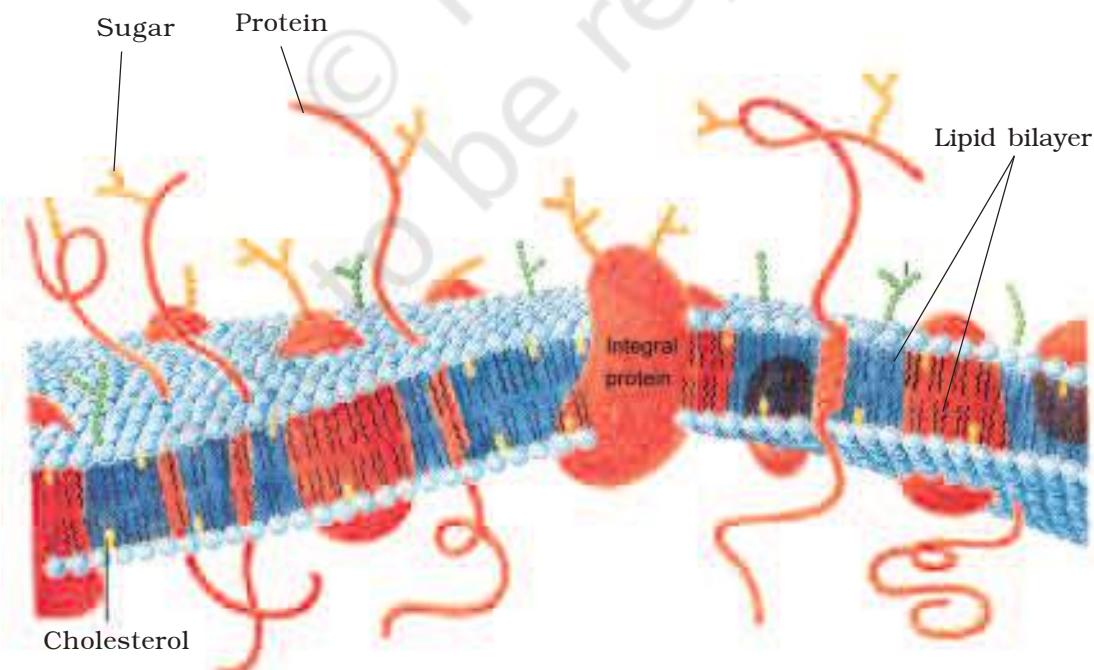
### 8.5.1 Cell Membrane

The detailed structure of the membrane was studied only after the advent of the electron microscope in the 1950s. Meanwhile, chemical studies on the cell membrane, especially in human red blood cells (RBCs), enabled the scientists to deduce the possible structure of plasma membrane.

These studies showed that the cell membrane is composed of lipids that are arranged in a bilayer. Also, the lipids are arranged within the membrane with the polar head towards the outer sides and the hydrophobic tails towards the inner part. This ensures that the nonpolar tail of saturated hydrocarbons is protected from the aqueous environment (Figure 8.4). The lipid component of the membrane mainly consists of phosphoglycerides.

Later, biochemical investigation clearly revealed that the cell membranes also possess protein and carbohydrate. The ratio of protein and lipid varies considerably in different cell types. In human beings, the membrane of the erythrocyte has approximately 52 per cent protein and 40 per cent lipids.

Depending on the ease of extraction, membrane proteins can be classified as integral or peripheral. Peripheral proteins lie on the surface of membrane while the integral proteins are partially or totally buried in the membrane.



**Figure 8.4** Fluid mosaic model of plasma membrane

An improved model of the structure of cell membrane was proposed by Singer and Nicolson (1972) widely accepted as **fluid mosaic model** (Figure 8.4). According to this, the quasi-fluid nature of lipid enables lateral movement of proteins within the overall bilayer. This ability to move within the membrane is measured as its fluidity.

The fluid nature of the membrane is also important from the point of view of functions like cell growth, formation of intercellular junctions, secretion, endocytosis, cell division etc.

One of the most important functions of the plasma membrane is the transport of the molecules across it. The membrane is selectively permeable to some molecules present on either side of it. Many molecules can move briefly across the membrane without any requirement of energy and this is called the **passive transport**. Neutral solutes may move across the membrane by the process of simple diffusion along the concentration gradient, i.e., from higher concentration to the lower. Water may also move across this membrane from higher to lower concentration. Movement of water by diffusion is called **osmosis**. As the polar molecules cannot pass through the nonpolar lipid bilayer, they require a carrier protein of the membrane to facilitate their transport across the membrane. A few ions or molecules are transported across the membrane against their concentration gradient, i.e., from lower to the higher concentration. Such a transport is an energy dependent process, in which ATP is utilised and is called **active transport**, e.g.,  $\text{Na}^+/\text{K}^+$  Pump.

### 8.5.2 Cell Wall

As you may recall, a non-living rigid structure called the cell wall forms an outer covering for the plasma membrane of fungi and plants. Cell wall not only gives shape to the cell and protects the cell from mechanical damage and infection, it also helps in cell-to-cell interaction and provides barrier to undesirable macromolecules. Algae have cell wall, made of cellulose, galactans, mannans and minerals like calcium carbonate, while in other plants it consists of cellulose, hemicellulose, pectins and proteins. The cell wall of a young plant cell, the **primary wall** is capable of growth, which gradually diminishes as the cell matures and the secondary wall is formed on the inner (towards membrane) side of the cell.

The middle lamella is a layer mainly of calcium pectate which holds or glues the different neighbouring cells together. The cell wall and middle lamellae may be traversed by plasmodesmata which connect the cytoplasm of neighbouring cells.

### 8.5.3 Endomembrane System

While each of the membranous organelles is distinct in terms of its structure and function, many of these are considered together as an

endomembrane system because their functions are coordinated. The endomembrane system include endoplasmic reticulum (ER), golgi complex, lysosomes and vacuoles. Since the functions of the mitochondria, chloroplast and peroxisomes are not coordinated with the above components, these are not considered as part of the endomembrane system.

#### 8.5.3.1 The Endoplasmic Reticulum (ER)

Electron microscopic studies of eukaryotic cells reveal the presence of a network or reticulum of tiny tubular structures scattered in the cytoplasm that is called the endoplasmic reticulum (ER) (Figure 8.5). Hence, ER divides the intracellular space into two distinct compartments, i.e., luminal (inside ER) and extra luminal (cytoplasm) compartments.

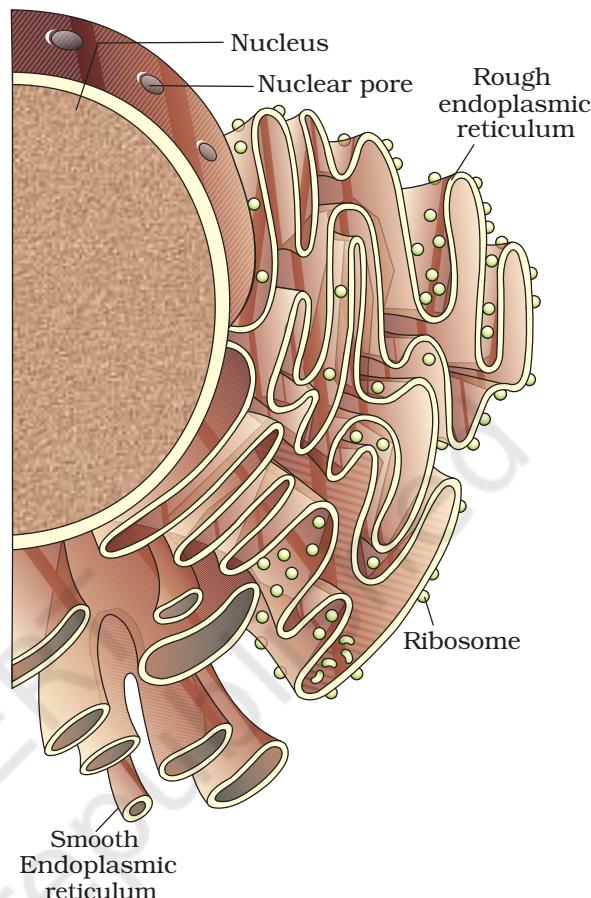
The ER often shows ribosomes attached to their outer surface. The endoplasmic reticulum bearing ribosomes on their surface is called rough endoplasmic reticulum (RER). In the absence of ribosomes they appear smooth and are called smooth endoplasmic reticulum (SER).

RER is frequently observed in the cells actively involved in protein synthesis and secretion. They are extensive and continuous with the outer membrane of the nucleus.

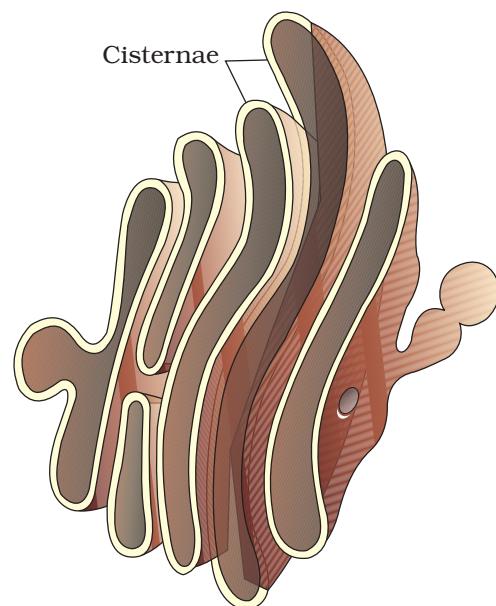
The smooth endoplasmic reticulum is the major site for synthesis of lipid. In animal cells lipid-like steroid hormones are synthesised in SER.

#### 8.5.3.2 Golgi apparatus

Camillo Golgi (1898) first observed densely stained reticular structures near the nucleus. These were later named Golgi bodies after him. They consist of many flat, disc-shaped sacs or cisternae of  $0.5\mu\text{m}$  to  $1.0\mu\text{m}$  diameter (Figure 8.6). These are stacked parallel to each other. Varied number of cisternae are present in a Golgi complex. The Golgi cisternae are concentrically arranged near the nucleus with distinct convex *cis* or the forming face and concave *trans* or the maturing face.



**Figure 8.5** Endoplasmic reticulum



**Figure 8.6** Golgi apparatus