UNIT II

Chapter 4

Organ and Organ Systems in Animals

Chapter Outline

A function to each organ and each organ to its own function is seen in all animals.

Learning Objectives:

- *Understands and appreciates the morphology of the earthworm, cockroach and frog.*
- *Recognises the functions of different organ systems.*
- *Appreciates the differences in the structural organization of the earthworm, cockroach and frog.*

Introduction

From microbes to the blue whale, organisms occur in different sizes and shapes with a well organized organ and organ systems. The basic tissues (chapter-3) organize to form an organ which in turn associates to form organ systems in multicellular organisms. Such an organization is essential for efficient and better coordinated activities of millions of cells constituting an organism. You are being introduced to understand the morphology and anatomy of three organisms placed at different evolutionary levels to show their organization and functions. Morphology refers to the study of form or externally visible features. The word anatomy is used for the study of internal organs in the animals. This chapter deals with the morphology and anatomy of invertebrates represented by the earthworm and cockroach and the vertebrates represented by the frog.

4.1 Earthworm - *Lampito mauritii*

Classification

Phylum	:	Annelida
Class	:	Oligochaeta
Order	:	Haplotaxida
Genus	:	*Lampito*
Species	:	*mauritii*

Earthworm is a terrestrial invertebrate that inhabits the upper layers of the moist soil, rich in decaying organic matter. It is nocturnal and during the day it lives in burrows made

by burrowing and swallowing the soil. In gardens, they can be traced by their faecal deposits known as worm castings on the soil surface. Earthworms are considered as **"Friends of Farmers".** The common Indian earthworms are *Lampito mauritii (*Syn. *Megascolex mauritii), Perioynx excavatus* and *Metaphire posthuma (*Syn. *Pheretima posthuma).* Earthworms are also conveniently classified based on their ecological strategies as **epigeics, anecics** and **endogeics** (Figure 4.1). Epigeics (Greek for "up on the earth") are surface dwellers, eg. *Perionyx excavatus* and *Eudrilus eugeniae.* Anecics (Greek for "outer layer of the earth") are found in upper layers of the soil, eg. *Lampito mauritii, Lumbricus terrestris.* Endogeics (Greek for "within the earth") are found in deeper layers of the soil eg. *Octochaetona thurstoni.*

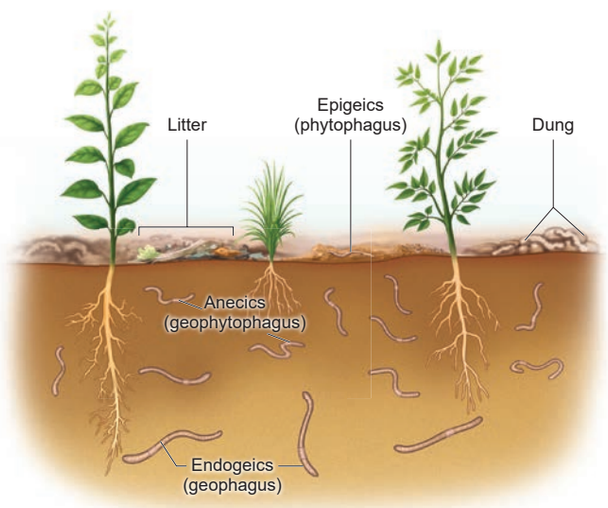


Figure 4.1 Earthworm classification based on ecological strategies

Morphology

Lampito mauritii is commonly found in Tamil Nadu. It has a long and cylindrical narrow body which is bilaterally symmetrical. *L. mauritii* is 80 to 210 mm in length with a diameter of 3.5 – 5 mm, and is light brown in colour, with purplish tinge at the anterior end. This colour of the earthworm is mainly due to the presence of porphyrin pigment. The body of the earthworm is encircled by a large number of grooves which divides it into a number of compartments called **segments** or **metameres** (Figure 4.2). *L. mauritii* consists of about 165 – 190 segments. The dorsal surface of the body is marked by a dark mid dorsal line (dorsal blood vessel) along the longitudinal axis of the body. The ventral surface is distinguished by the presence of genital openings. The mouth is found in the centre of the first segment of the body, called the **peristomium**. Overhanging the mouth is a small flap called the upper lip or **prostomium**. The last segment has the anus called the **pygidium.** In mature worms, segments 14 to 17 may be found swollen with a glandular thickening of the skin called the **clitellum**. This helps in the formation of the cocoon. Due to the presence of clitellum, the body of an earthworm is divided into pre clitellar region (1^{st} – 13^{th} segments), clitellar region (14^{th} – 17^{th} segments) and the post – clitellar region (after the 17^{th} segment). In all the segments of the body except the first, last and clitellum, there is a ring of chitinous body setae. This body setae arises from a setigerous sac of the skin and it is curved as **S** – shaped. Setae can be protruded or retracted and their principal role is in locomotion.

The external apertures are the mouth, anus, dorsal pores, spermathecal openings, genital openings and nephridiopores. The dorsal pores are present from the 10^{th} segment onwards. The coelomic fluid communicates to the exterior through these pores and keeps the body

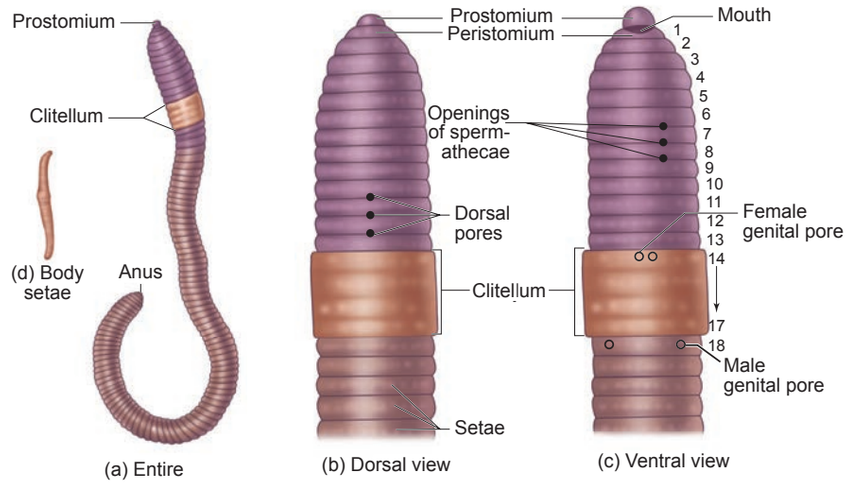


Figure 4.2 *Lampito mauritii*

surface moist and free from harmful microorganisms. Spermathecal openings are three pairs of small ventrolateral apertures lying intersegmentally between the grooves of the segments 6/7, 7/8 and 8/9. A pair of female genital apertures lie on the ventral side in the 14th segment and a pair of male genital apertures are situated latero-ventrally in the 18th segment. Nephridiopores are numerous and found throughout the body of the earthworm except a few anterior segments, through which the metabolic wastes are eliminated.

Table 4.1: Morphological and anatomical differences between *Lampito mauritii* and *Metaphire posthuma*

S.No	Characters	*Lampito mauritii*	*Metaphire posthuma*
1.	**Shape and size**	Cylindrical 80 mm – 210 mm in length 3.5mm - 5.0 mm in width	Cylindrical 115 – 130 mm in length 5 mm in width
2.	**Colouration**	Light Brown	Dark Brown
3.	**Segmentation**	165 – 190 Segments	About 140 Segments
4.	**Clitellum**	14th – 17th Segments (4)	14th – 16th Segments (3)
5.	**Spermathecal opening**	Three pairs 6/7, 7/8 and 8/9	Four pairs 5/6, 6/7, 7/8 and 8/9
6.	**Pharynx**	3rd – 4th segment	Runs up to 4th Segment
7.	**Oesophagus**	5th segment	8th segment
8.	**Gizzard**	6th segment	8th – 9th segment
9.	**Intestine**	7th segment to anus	15th segment to anus
10.	**Intestinal caeca**	Absent	Present in 26th segment
11.	**Lateral hearts**	8 pairs from 6th to 13th segments	3 pairs from 7th to 9th segments
12.	**Pharyngeal nephridia**	5th - 9th segment	4th – 6th segment
13.	**Micronephridia**	14th to last segment	7th to last segment
14.	**Meganephridia**	19th to last segment	15th to last segment
15.	**Male genital pore**	18th segment	18th segment
16.	**Female genital pore**	14th segment	14th segment

Anatomy

The body wall of the earthworm is very moist, thin, soft, skinny, elastic and consists of the cuticle, epidermis, muscles and coelomic epithelium. The epidermis consists of supporting cells, gland cells, basal cells and sensory cells. A spacious body cavity called the **coelom** is seen between the alimentary canal and the body wall. The coelom contains the coelomic fluid and serves as a **hydrostatic skeleton,** in which the coelomocytes are known to play a major role in regeneration, immunity and wound healing. The coelomic fluid of the earthworm is milky and alkaline, which consists of granulocytes or eleocytes, amoebocytes, mucocytes and leucocytes.

Digestive system

The digestive system of the earthworm consists of the alimentary canal and the digestive glands. The alimentary canal runs as a straight tube throughout the length of the body from the mouth to anus (Figure 4. 3).

The **mouth** opens into the **buccal cavity** which occupies the 1st and 2nd segments. The buccal cavity leads into a thick **muscular pharynx**, which occupies the 3rd and 4th segments and is surrounded by the pharyngeal glands. A small narrow tube, **oesophagus** lies in the 5th segment and continues into a muscular **gizzard** in the 6th segment. The gizzard helps in the grinding of soil particles and decaying leaves. **Intestine** starts from the 7th segment and continues till the last segment. The dorsal wall of the intestine is folded into the cavity as the **typhlosole**. This fold contains blood vessels and increases the absorptive area of the intestine. The inner epithelium consists

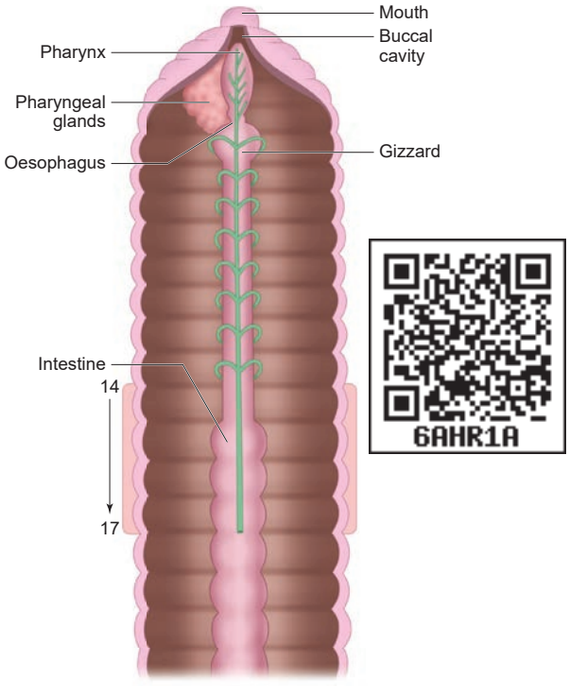


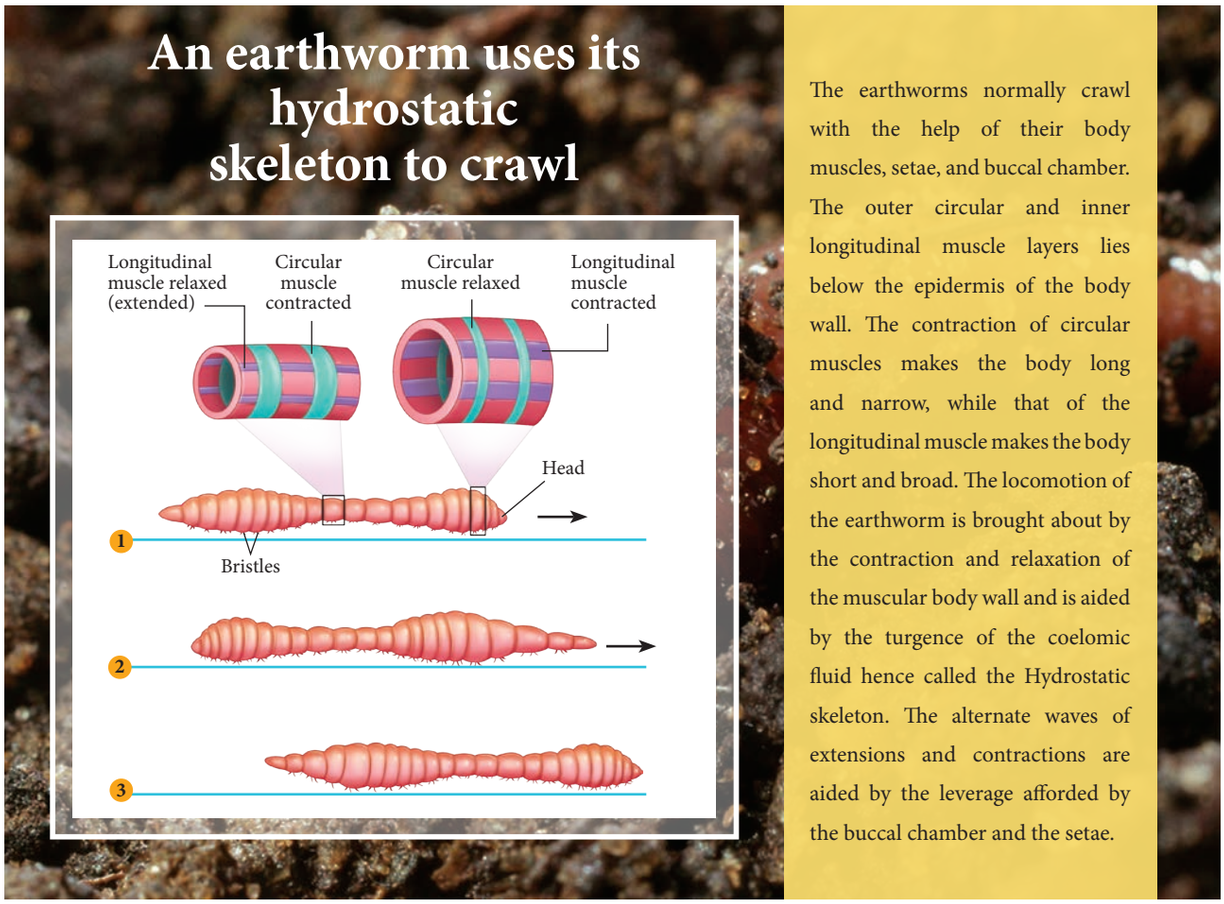
Figure 4.3 *Lampito mauritii* – Digestive System

of columnar cells and glandular cells. The alimentary canal opens to the exterior through the anus.

The ingested organic rich soil passes through the digestive tract where digestive enzymes breakdown complex food into smaller absorbable units. The simpler molecules are absorbed through the intestinal membrane and are utilized. The undigested particles along with earth are passed out through the anus, as **worm castings** or **vermicasts**. The pharyngeal

Intestinal Caeca

In *Metaphire posthuma*, the 26th segment has a pair of short conical out growths called intestinal caecae. It is extended anteriorly up to the 22nd segment. These are digestive glands and secrete an amylolytic enzyme for the digestion of starch. Intestinal caecae are not present in many species of earthworms such as the *Lampito mauritii*.



or salivary gland cells and the glandular cells of the intestine are supposed to be the digestive glands which secrete digestive enzymes for digestion of food.

Respiratory System

The earthworm has no special respiratory organs like lungs or gills. Respiration takes place through the body wall. The outer surface of the skin is richly supplied with blood capillaries which aid in the diffusion of gases. Oxygen diffuses through the skin into the blood while carbon dioxide from the blood diffuses out. The skin is kept moist by mucous and coelomic fluid and facilitates exchange of gases.

Circulatory system

Lampito mauritii exhibits a closed type of blood vascular system consisting of blood vessels, capillaries and lateral hearts (Figure 4.4). Two median longitudinal vessels run above and below the alimentary canal as dorsal and ventral vessels of the earthworm. There are paired valves in the dorsal vessels which prevent the backward flow of the blood. The ventral vessel has no valves and is non contractile, allowing the backward flow of blood. In the anterior part of the body the dorsal vessel is connected with the ventral vessel by eight pairs of **commissural vessels** or the **lateral hearts** lying in the 6^{th} to 13^{th} segments. These vessels run on either side of the alimentary canal and pump blood from the dorsal vessel to the ventral vessel. The dorsal vessel receives blood from various organs in the body. The ventral vessel supplies blood to the various organs. Blood glands are present in the

anterior segments of the earthworm. They produce blood cells and haemoglobin which is dissolved in the plasma and gives red colour to the blood.

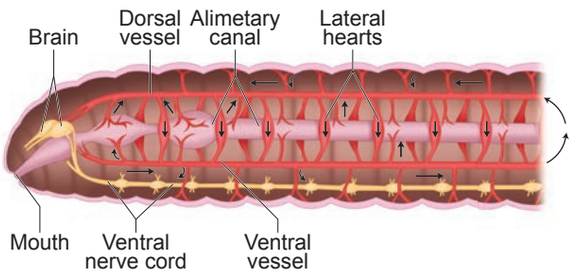


Figure 4.4 *Lampito mauritii*: Circulatory system and Nervous System

Nervous System

The bilobed mass of nervous tissue called supra - pharyngeal ganglia, lies on the dorsal wall of the pharynx in the 3rd segment, is referred as the "brain". The ganglion found below the pharynx in the 4th segment is called the sub-pharyngeal ganglion (Figure. 4.4). The brain and the sub - pharyngeal ganglia are connected by a pair of circum-pharyngeal connectives. They run one on each side of the pharynx. Thus a nerve ring is formed around the anterior region of the alimentary canal. The double ventral nerve cord runs backward from the sub - pharyngeal ganglion. The brain along with other nerves in the ring integrates sensory inputs and command muscular responses of the body.

The earthworm's receptors are stimulated by a group of slender columnar cells connected with nerves. The **Photoreceptors** (sense of light) are found on the dorsal surface of the body. **Gustatory** (sense of taste) and **olfactory receptors** (sense of smell) are found in the buccal cavity**. Tactile receptors** (sense of touch), **chemoreceptors** (detect chemical changes) and **thermoreceptors** (changes in temperature) are present in the prostomium and the body wall.

How do the earthworm's sense activity in their habitat without eyes, ears or a nose?

Excretory System

Excretion is the process of elimination of metabolic waste products from the body. In earthworm, excretion is effected by segmentally arranged, minute coiled, paired tubules called nephridia. There are three types of nephridia; (i) **pharyngeal** or

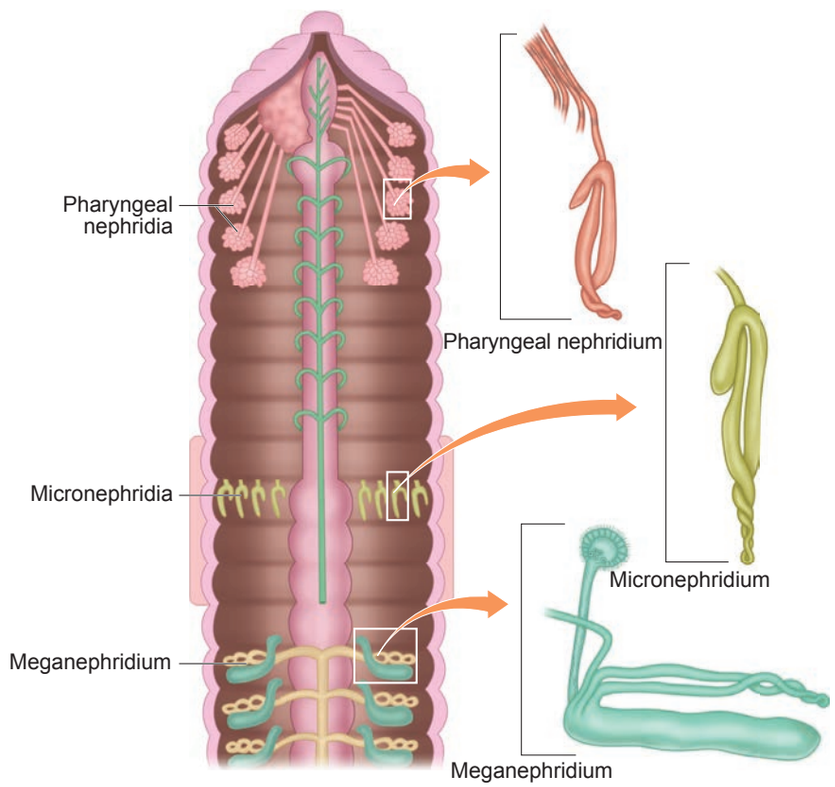


Figure: 4.5 *Lampito mauritii* – Types of Nephridia

tufted nephridia – present as paired tufts in the 5th - 9th segments (ii) **Micronephridia** or **Integumentary nephridia** – attached to the lining of the body wall from the14th segment to the last which open on the body surface (iii) **Meganephridia** or **septal nephridia** – present as pair on both sides of intersegmental septa of the 19th segment to the last and open into intestine (Figure 4. 5). The meganephridium has an internal funnel like opening called the nephrostome, which is fully ciliated**.** The nephrostome is in the preceding segment and the rest of the tube is in the succeeding segment. This tube consists of three distinct divisions, the ciliated, the glandular and the muscular region. The waste material collected through the ciliated funnel is pushed into the muscular part of nephridium by the ciliated region. The glandular part extracts the waste from the blood and finally the wastes exit out through the nephridiopore.

Besides nephridia, special cells on the coelomic wall of the intestine, called chloragogen cells are present. They extract the nitrogenous waste from the blood of the intestinal wall, into the body cavity to be sent out through the nephridia.

Reproductive System

Earthworms are hermaphrodites or monoecious i.e. male and female reproductive organs are found in the same individual (Figure 4. 6). Self fertilization is avoided because two sex organs mature at different times, which means the sperm develops earlier than the production of ova **(Protandrous).** Thus cross fertilization takes place.

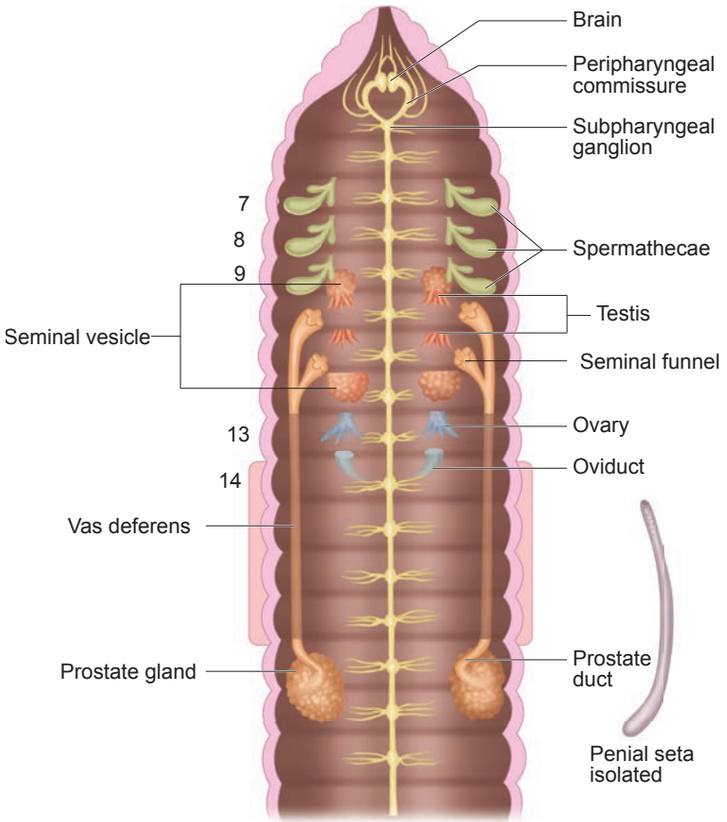


Figure: 4. 6 *Lampito mauritii*: Reproductive System.

In the male reproductive system, two pairs of testes are present in the 10th and 11th segments. The testes give rise to the **germ cells** or **spermatogonia**, which develops into spermatozoa in the two pairs of seminal vesicles. Two pairs of seminal funnels called **ciliary rosettes** are situated in the same segments as the testes. The ciliated funnels of the same side are connected to a long tube called vas deferens. The **vasa deferentia** run upto the 18th segment where they open to the exterior through the **male genital aperture**. The male genital aperture contains two pairs of **penial setae** for copulation. A pair of prostate glands lies in the 18th – 19th segments. The secretion of the prostate gland serves to cement the spermatozoa into bundles known as **spermatophores**.

The female reproductive system consists of a pair of **ovaries** lying in the 13th segment. Each ovary has finger like projections which contain ova in linear series. Ovarian funnels are present beneath the ovaries which continue into the **oviducts**. They open as a pair of genital apertures on the ventral side of the 14th segment. **Spermathecae** or **seminal receptacles** are three pairs lying in segments 7th, 8th and 9th, opening to the exterior on the ventral side between 6th & 7th, 7th & 8th and 8th & 9th segments. They receive spermatozoa from the partner and store during copulation.

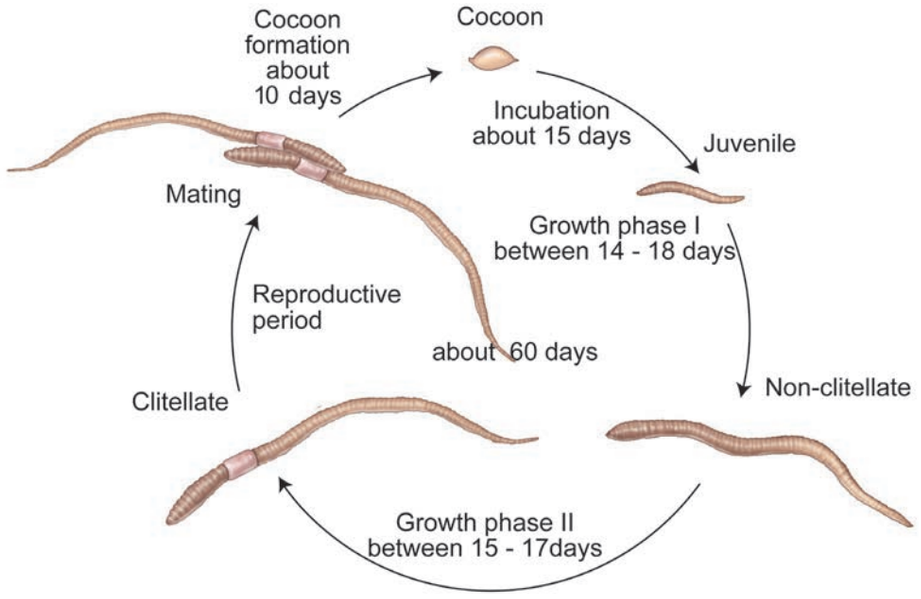


Figure 4.7 Life cycle of *Lampito mauritii*

Regeneration

Earthworms have most of their important organ in the first 20 segments. If earthworm gets cut after the 20th segment, the anterior half can regenerate, while the posterior half shall disintegrate after some time.

A mutual exchange of sperms occurs between two worms during mating. One worm has to find another worm and they mate juxtaposing opposite gonadal openings, exchanging the sperms. Mature egg cells in the nutritive fluid are deposited in the cocoons produced by the gland cells of the clitellum which also collects the partner's sperms from the spermthecae. Fertilization and development occurs within the cocoons, which are deposited in the soil. After about 2 – 3 weeks, each cocoon produces baby earthworms. Development is direct and no larva is formed during development.

Life cycle

Lampito mauritii begins its life cycle, from the fertilized eggs. The eggs are held in a protective cocoon. These cocoons have an incubation period of about 14- 18 days after which they hatch to release **juveniles** (Figure 4.7). The juveniles undergo changes into **non-clitellate** forms in phase – I after about 15 days, which then develops a clitellum, called the **clitellate** at the end of the growth phase – II taking 15 - 17 days to complete. During the reproductive stage, earthworms copulate, and later shed their cocoons in the soil after about 10 days. The life cycle of *Lampito mauritii* takes about 60 days to complete.

4.2 Cockroach - *Periplaneta americana*

Classification

Phylum	:	Arthropoda
Class	:	Insecta
Order	:	Orthoptera
Genus	:	*Periplaneta*
Species	:	*americana*

Cockroach is a typical cosmopolitan insect and exhibits all the fundamental characteristics of Class Insecta. Generally cockroaches are reddish brown or black bodied with a light brown margin in the first thoracic segment. They are omnivores, nocturnal, living in damp and warm places and are quite common in kitchens, hotels, bakeries, restaurants, warehouse, sewage and public places. *Periplaneta* is a cursorial (swift runner) animal. It is dioecious and oviparous and exhibits parental care. They carry with them harmful germs of various bacterial diseases like cholera, diarrhoea, tuberculosis, and typhoid and hence are known as "**Vectors**".

Morphology

The adult cockroaches are about 2 to 4 cm in length and about 1cm in width. The body of the cockroach is compressed dorso-ventrally, bilaterally symmetrical, segmented and is divisible into three distinct regions – head, thorax and abdomen. The entire body is covered by a hard, brown coloured, chitinous exoskeleton. In each segment, exoskeleton has hardened plates called **sclerites**, which are joined together by a delicate and elastic **articular membrane** or **arthrodial membrane**. The sclerites of the dorsal side are called **tergites**, those on the ventral side are called **sternites** and those of lateral sides are called **pleurites**.

The head of cockroach is small, triangular lies at right angle to the longitudinal body **axis**. the mouth parts are directed downwards so it is **hypognathous.** It is formed by the fusion of six segments and shows great mobility in all directions due to a flexible neck (Figure 4.8). The head capsule bears a pair of large, sessile, and reniform **compound eyes**, a pair of

The cockroaches are ancient and most basic among all groups of insects, dating back to the carboniferous period, about 320 million years ago.

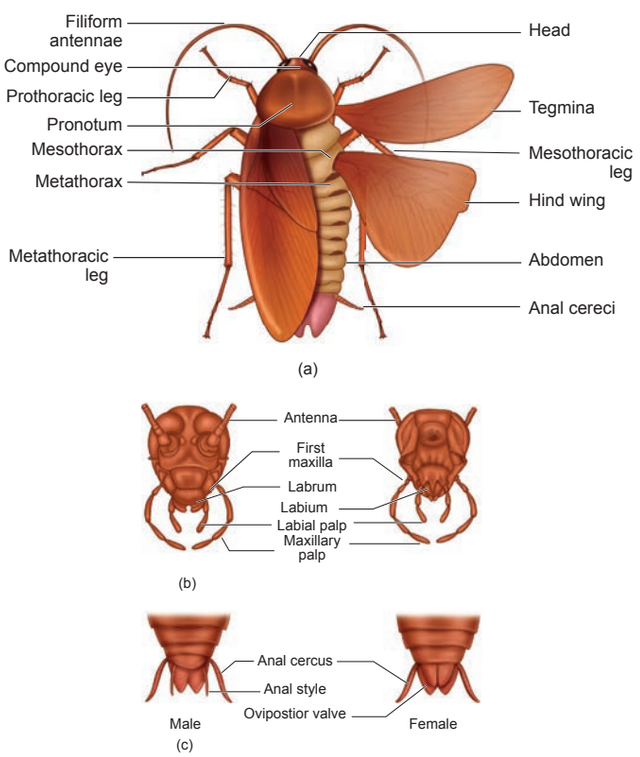


Figure 4.8 *Periplaneta americana:* (a) External features (b) Head dorsal and ventral view (c) Male and Female ventral view of posterior segment of abdomen

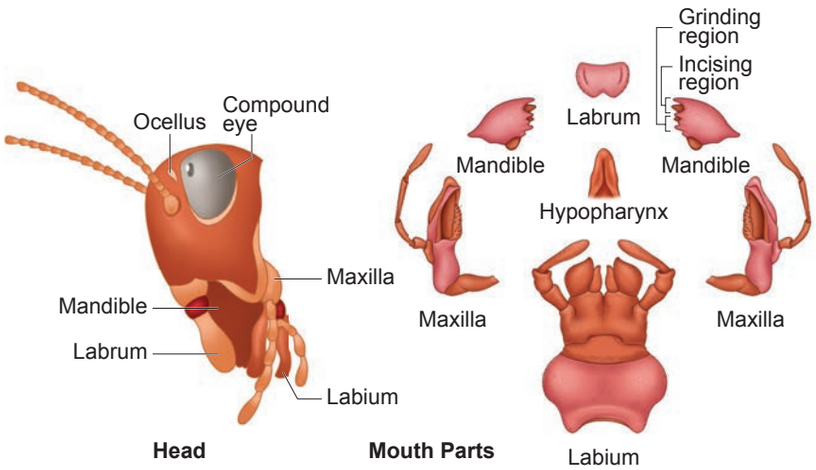


Figure 4.9 *Periplaneta americana*

antennae and appendages around the mouth. Antennae have sensory receptors that help in monitoring the environment. The appendages form the mouth parts which are of biting and chewing type (**Mandibulate** or **Orthopterus type**).

The mouth parts consist of a **labrum** (upper lip), a pair of **mandibles**, a pair of **maxillae**, a **labium** (lower lip) and a **hypopharynx** (tongue) or **lingua** (Figure 4.9).

The thorax consists of three segments – **Prothorax**, **Mesothorax** and **Metathorax**. The prothoracic segment is the largest. The head is connected with thorax by a short extension of the prothorax called as the **neck** or **cervicum**. Each thoracic segment bears a pair of walking legs. Due to the presence of three pairs of walking legs it is also called **hexapoda** (hexa-six, poda-feet) All the three pairs of walking legs are similar and each leg consists of five segments – **coxa** (large), **trochanter** (small), **femur** (long and broad), **tibia** (long and thick) and **tarsus**. The last segment of the leg - tarsus has five movable joints or **podomeres** or **tarsomeres**. Cockroach has two pairs of wings, the first pair arises from mesothorax and protects the hind wings when at rest, and is called **elytra** or **tegmina**. The second pair of wings arises from the metathorax and are used in flight. The abdomen in both male and female consists of 10 segments. Each segment is covered by the dorsal tergum, the ventral sternum and between them a narrow membranous pleuron on each side. In females, the 7th sternum is boat shaped and together with the 8th and 9th sterna forms a **brood** or **genital pouch** whose anterior parts contains female gonopore, spermathecal pores, collaterial glands and posterior parts constitutes the oothecal chamber in which the cocoons are formed. In males, the genital pouch lies at the hind end of the abdomen bound dorsally by 9th and 10th terga and ventrally by the 9th sternum. It contains the dorsal anus and ventral male genital pore. In both the sexes, genital apertures are surrounded by sclerites called **gonapophysis**. Male bears a pair of short and slender **anal styles** in the 9th sternum which are absent in the female. In both sexes, the 10th segment bears a pair of jointed filamentous structures called **anal cerci** and bears a sense organ that is receptive to vibrations in air and land. The 7th sternum of male has a pair of large and oval apical lobes or gynovalvular plates which form a keel like structure which distinguishes the male from the female.

One of the fastest moving land insects is the cockroach. They can move as fast as 5.4 Km per hour.

Table 4.2: Differences between male and female cockroach

S. No	Character	Male cockroach	Female cockroach
1.	Abdomen	Long and narrow	Short and broad
2.	Segments	In the abdomen, nine segments are visible	In the abdomen, seven segments are visible
3.	Anal styles	Present	Absent
4.	Terga	7th tergum covers 8th tergum	7th tergum covers 8th and 9th terga
5.	Brood pouch	Absent	Present
6.	Antenna	Longer in length	Shorter in length
7.	Wings	Extends beyond the tip of abdomen	Extends up to the end of abdomen

Anatomy

Digestive system

The digestive system of cockroach consists of the alimentary canal and digestive glands. The alimentary canal is present in the body cavity and is divided into three regions: foregut, midgut and hindgut (Figure 4.10). The foregut includes pre-oral cavity, mouth, pharynx and oesophagus. This in turn opens into a sac like structure called the **crop** which is used for storing food. The crop is followed by the **gizzard** or **proventriculus** which has an outer layer of thick circular muscles and thick inner cuticle forming six highly chitinous plates called **"teeth"**. Gizzard helps in the grinding of the food particles. The midgut is a short and narrow tube behind the gizzard and is glandular in nature. At the junctional region of the gizzard are eight fingers like tubular blind processes called the **hepatic caecae** or **enteric caecae.** The hindgut is marked by the presence of 100 – 150 yellow coloured thin filamentous **malpighian** tubules which are helpful in removal of the excretory products from the haemolymph. The hindgut is broader than the midgut and is differentiated into ileum, colon, and rectum. The rectum opens out through the anus.

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Digestive glands of cockroach consist of the salivary glands, the glandular cells and hepatic caecae. A pair of salivary glands is found on either side of the crop in the thorax. The glandular cells of the midgut and hepatic or gastric caecae produce digestive juices.

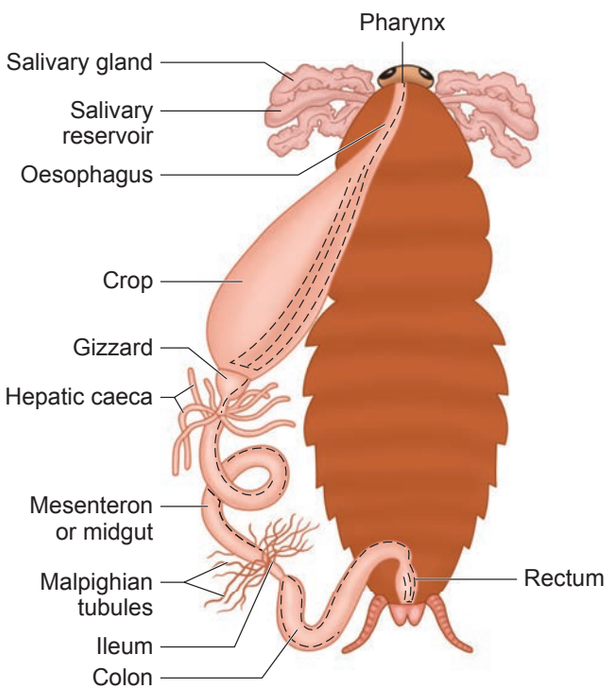


Figure 4.10 *Periplaneta americana*: Digestive system

Respiratory system

The respiratory system of cockroach is well developed compared with other terrestrial insects (Figure 4.11). Branched tubes known as **trachea** open through 10 pairs of small holes called **spiracles** or **stigmata,** present on the lateral side of the body. Terminal branches of tracheal tubes are called **tracheoles** which carry oxygen to the entire body. The spiracles open and close by valves regulated by **sphincter** or **spiracular muscles**. Each tracheole is filled with a watery fluid through which exchange of gases takes place. During high muscular activity, a part of the fluid is drawn into the tissues to enable more oxygen intake and rapid diffusion. The passage of air in the tracheal system is:

SPIRACLES → TRACHEA → TISSUES → TRACHEOLES

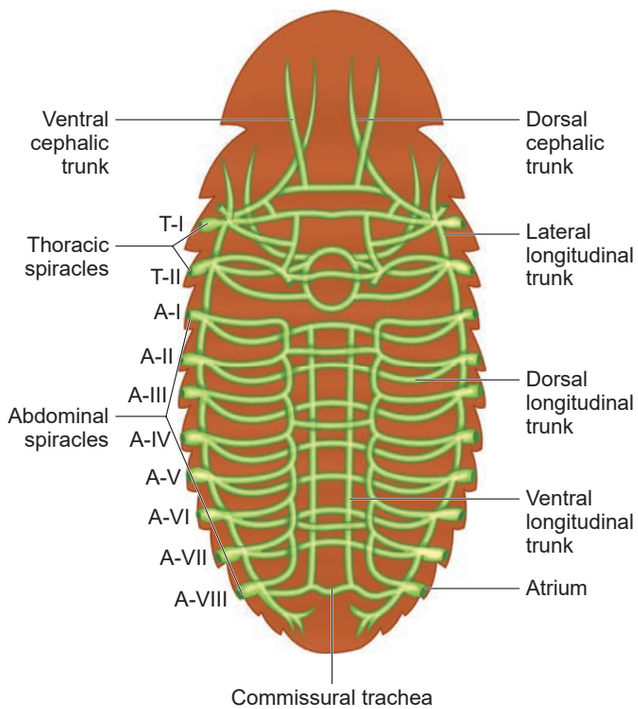


Figure 4.11 *Periplaneta americana*: Tracheal system in dorsal view

Respiratory system of cockroach is formed of spiracles and tracheal interconnections. Why is it said to be more efficient than that of earthworm? Why inspiration of cockroach is said to be a passive process while it is an active process in man?

Circulatory system

Periplaneta has an open type of circulatory system (Figure 4.12) Blood vessels are poorly developed and opens into the haemocoel in which the blood or haemolymph flows freely. Visceral organs located in the haemocoel are bathed in blood. The haemolymph is colourless and consists of plasma and haemocytes which are 'phagocytic' in nature. Heart is an elongated tube with muscular wall lying mid dorsally beneath the thorax. The heart consists of 13 chambers with ostia on either side. The blood from the sinuses enters the heart through the **ostia** and is pumped anteriorly to sinuses again. The triangular muscles that are responsible for blood circulation in the cockroach are called **alary muscles** (13 pairs). One pair of these muscles is found in each segment on either side of the heart. In cockroach, there is an accessory **pulsatile vesicle** at the base of each antenna which also pumps blood.

Cockroaches survive without a head

A cockroach can live for about a week without its head. Due to their open circulatory system, and the fact that they breathe through little holes on each of their body segments, since they are not dependent on the mouth or head to breathe. The cockroach dies later due to starvation

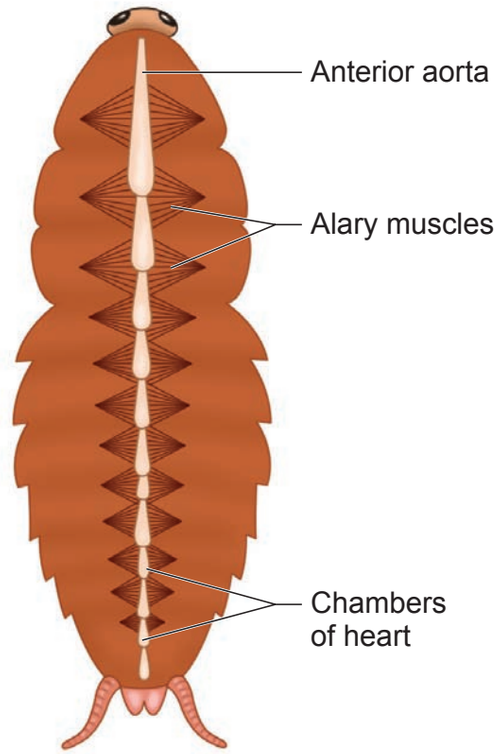


Figure 4.12 *Periplaneta americana*: Circulatory system

A **cockroach** can hold its breath for 45 minutes, and can even survive being submerged under water for half an hour. They hold their breath often to help regulate loss of water.

Nervous system

The nervous system of cockroach consists of a **nerve ring** and a **ganglionated double ventral nerve cord**, **sub-oesophageal ganglion**, **circum–oesophageal connectives** and **double ventral nerve cord (Figure 4.13)**. The nerve ring is present around the oesophagus in the head capsule and is formed by the supra-oesophagial ganglion called the **'brain'**, The brain is mainly a sensory and an endocrine centre and lies above the oesophagus. Sub-oesophageal ganglion is the motor centre that controls the movements of the mouth parts, legs and wings. It lies below the oesophagus and formed by the fusion of the paired gangalia of mandibular, maxillary and labial segments of the head. A pair of circum–oesophageal connectives is present around the oesophagus, connecting the supra-oesophageal ganglia with the sub-oesophageal ganglion. The double ventral nerve cord is solid, ganglionated and arises from the sub-oesophageal ganglion and extends up to the 7th abdominal segment. Three thoracic ganglia are present, one in each thoracic segment and six abdominal ganglia in the abdomen.

In cockroach, the sense organs are antennae, compound eyes, labrum, maxillary palps, labial palps and anal cerci. The receptor for touch (thigmo receptors) is located in the antenna, maxillary palps and cerci. The receptor for smell (olfactory receptors) is found on the antennae. The receptor for taste (gustatory receptors) is found on the palps of maxilla and labium.

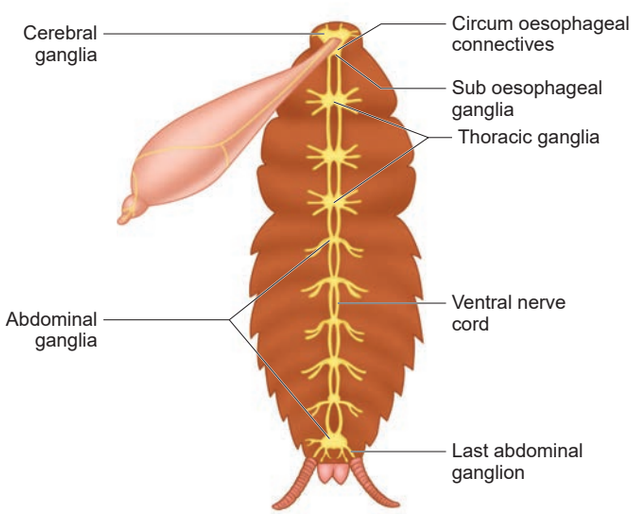


Figure 4.13 *Periplaneta americana*: Nervous system

Thermoreceptors are found on the first four tarsal segments on the legs. The receptor chordotonal is found on the anal cerci which respond to air or earth borne vibrations. The photoreceptors of the cockroach consists of a pair of compound eyes at the dorsal surface of the head. Each eye is formed of about 2000 simple eyes called the **ommatidia** (singular: *ommatidium*), through which the cockroach can receive several images of an object. This kind of vision is known as mosaic vision with more sensitivity but less resolution.

Arthropod eyes are called compound eyes because they are made up of repeating units, the ommatidia, each of which functions as a separate visual receptor.

What is the difference between compound eyes and simple eyes?

Why is mosaic vision with less resolution seen in cockroaches?

Excretory system

The Malpighian tubules are the main excretory organs of cockroach which help in eliminating the nitrogenous wastes from the body in the form of uric acid. Cockroach excretes uric acid, so it is **uricotelic**. In addition, fat body, nephrocytes, cuticle, and urecose glands are also excretory in function.

The malpighian tubules are thin, long, filamentous, yellow coloured structures attached at the junction of midgut and hindgut. These are about 100-150 in number and are present in 6-9 bundles. Each tubule is lined by glandular and ciliated cells and the waste is excreted out through the hindgut. The glandular cells of the malpighian tubules absorb water, salts, and nitrogenous wastes from the haemolymph and transfer them into the lumen of the tubules. The cells of the tubules reabsorb water and certain inorganic salts. By the contraction of the tubules nitrogenous waste is pushed into the ileum, where more water is reabsorbed. It moves into the rectum and almost solid uric acid is excreted along with the faecal matter.

Marcello Malpighi – described these tubules and called them vasa varicose. Meckel later called them Malpighian tubules.

Reproductive system

Cockroach is dioecious or unisexual. They have well developed reproductive organs. The male reproductive system consists of a **pair of testes, vasa deferentia**, **an ejaculatory duct**, **utricular gland**, **phallic gland** and the external genitalia. A pair of three lobed testes lies on the lateral side of the 4th and 6th abdominal segments. From each testis arises a thin vas deferens, which opens into the ejaculatory duct through the seminal vesicles. The ejaculatory duct is an elongated duct which opens out by the male gonopore lying ventral to the anus. A **utricular** or **mushroom shaped gland** is a large accessory reproductive gland, which opens into the anterior part of the ejaculatory duct. The seminal vesicles are present on the ventral surface of the ejaculatory duct. These sacs store the sperms in the form of bundles called **spermatophores**. The duct of **phallic** or **conglobate gland** also opens near the gonopore, whose function is uncertain. Surrounding the male genital opening are few chitinous and asymmetrical structures called **phallomeres or gonapophyses** which help in copulation.

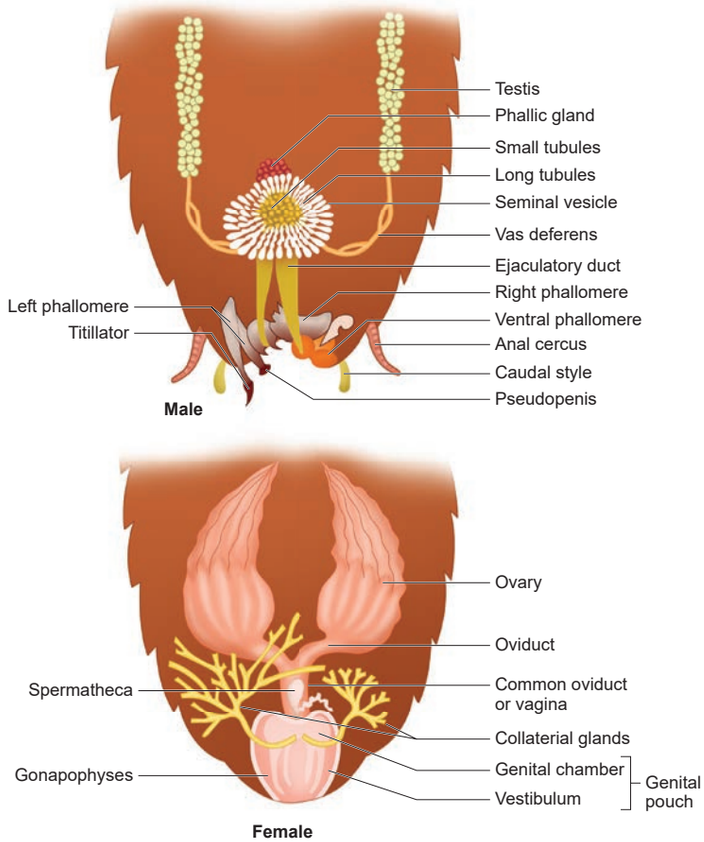


Figure 4.14 *Periplaneta americana reproductive system*

The female reproductive system of cockroach consists of a **pair of ovaries**, **vagina, genital pouch**, **collaterial glands**, **spermathecae** and the external genitalia. A pair of ovaries lies laterally in the 2nd and 6th abdominal segment. Each ovary is formed of a group of eight ovarian tubules or ovarioles, containing a chain of developing ova. The lateral oviducts of each ovary unite into a broad median common oviduct known as vagina, which opens into the genital chamber. The vertical opening of the vagina is the female genital pore. A pair of spermathecae is present in the 6th segment, which opens by a median aperture in the dorsal wall of the genital pouch. During copulation, the ova descend to the genital chamber, where they are fertilized by the sperms. A pair of white and branched **collaterial glands** present behind the ovaries forms a hard egg case called **Ootheca** around the eggs. Genital pouch is formed by the 7th, 8th and 9th abdominal sterna. The genital pouch has two chambers, a genital chamber into which the vagina opens and an oothecal chamber where oothecae are formed. Three pairs of plate like chitinous structures called gonapophyses are present around the female genital aperture. These gonapophyses guide the ova into the ootheca as ovipositors. (Figure 4. 14).

Ootheca is a dark reddish to blackish brown capsule about 12mm long which contains nearly 16 fertilized eggs and dropped or glued to a suitable surface, usually in crack or crevice of high relative humidity near a food source. On an average, each female cockroach produces nearly 15 – 40 oothecae in its life span of about one to two years. The embryonic development occurs in the ootheca, which takes nearly 5 – 13 weeks. The development of cockroach is gradual through **nymphal stages (paurometabolus)**. The nymph resembles the adult and undergoes moulting. The nymph grows by moulting or ecdysis about 13 times to reach the adult form.

Many species of cockroaches are wild. About 30 cockroach species out of 4,600 are associated with human habitats. About four species are well known as pests. They destroy food and contaminate with their offensive odour. The mere presence of cockroaches is a sign of unhygienic condition and they are also known to be carriers of a number of bacterial diseases. The cockroach allergen can cause asthma to sensitive people.

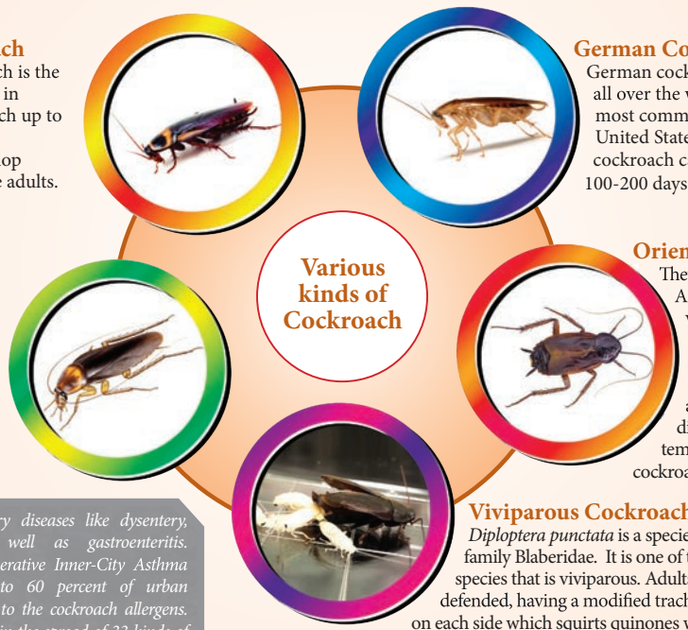
COCKROACHES

Cockroaches have been around since the time of dinosaurs!

American Cockroach
The American Cockroach is the largest cockroach found in houses. Females can hatch up to 150 offspring per year. Cockroaches don't develop wings until they become adults.

German Cockroach
German cockroaches can be found all over the world. They are the most common cockroach in the United States. Each German cockroach can live about 100-200 days.

Brown-banded Cockroach
The wings of male cockroaches are larger than the female's wings. Brown-banded cockroaches often hide their eggs in or under furniture. They usually live for 5-6½ months.



Oriental Cockroach
They are actually from Africa. They are large and very dark compared to other cockroaches. They usually travel through sewer pipes and drains. They prefer dirty places and cooler temperatures than other cockroaches.

Viviparous Cockroach
Diploptera punctata is a species of cockroach in the family Blaberidae. It is one of the few cockroach species that is viviparous. Adults are chemically defended, having a modified tracheal gland and spiracle on each side which squirts quinones which can poison or discourage a predator.

Facts

- *Cockroaches are known to carry diseases like dysentery, typhoid and poliomyelitis, as well as gastroenteritis.*
- *According to The National Cooperative Inner-City Asthma Study (NCICAS) – 23 percent to 60 percent of urban residents with asthma are sensitive to the cockroach allergens.*
- *Cockroaches have been implicated in the spread of 33 kinds of bacteria, including E. coli and Salmonella species, six parasitic worms and more than seven other types of human pathogens.*

Diploptera punctata, a viviparous cockroach, produces a nutritionally dense crystalline "milk" to feed their live-born young. It is found in Myanmar, China, Fiji, Hawaii, and India. Scientists think Cockroach milk could be the super food of the future.

4.3 Frog - Rana hexadactyla

About 360 million years ago, amphibians were the first vertebrates to live on land. Amphibians are diverse, widespread, and abundant group since the early diversification. There are about 4,500 species of amphibians. Frog is an amphibian and hence placed in the class Amphibia [Greek. *Amphi* - Both, *bios* – life]. The largest order, with more than 3,900 species, is Anura, which includes the **frogs** and **toads**. *Rana hexadactyla* is placed in the order Anura. Frogs live in fresh water ponds, streams and in moist places. They feed on small animals like insects, worms, small fishes, slugs, snails, etc. During its early development a frog is fully aquatic and breathes like a fish with gills. It is **poikilothermic**, i.e., their body temperature varies with the varying environmental temperature.

Morphology of Frog

Classification

Phylum	:	Chordata
Class	:	Amphibia
Order	:	Anura
Genus	:	*Rana*
Species	:	*hexadactyla*

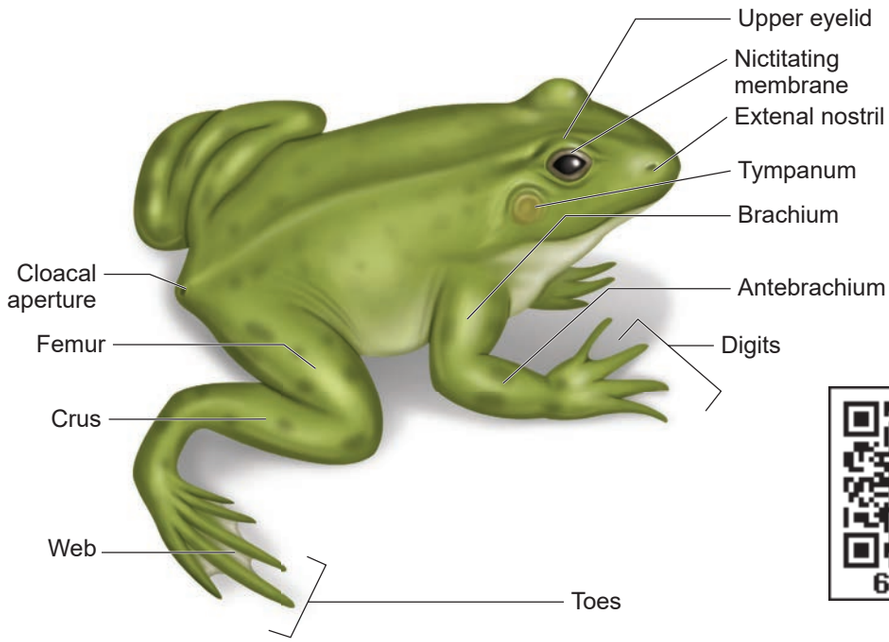


Figure 4.15 *Rana hexadactyla* - External morphology

Table 4.3: Differences between a Frog and Toad

Characters	 Frog	 Toad
Family	Ranidae	Bufonidae
Body shape	Slender	More Bulky
Legs	Longer	Shorter
Webbed feet	present	Absent
Skin	Smooth and moist skin	Dry skin covered with wart like glands.
Teeth	Maxillary and vomerine teeth.	Teeth absent.
Egg formation	Lays eggs in clusters.	Lays eggs in strings.

The body of a frog is **streamlined** to help in swimming. It is dorso-ventrally flattened and is divisible into head and trunk. Body is covered by a smooth, slimy skin loosely attached to the body wall. The skin is dark green on the dorsal side and pale ventrally. The head is almost triangular in shape and has an apex which forms the snout. The mouth is at the anterior end and can open widely.

Order - Anura (Frogs and Toads)

Frogs and toads have bodies specially designed for jumping with greatly elongated hind limbs. Frogs can live in water (aquatic), on land (terrestrial), or on trees (arboreal). Parental care is seen in few species.

External nostrils are present on the dorsal surface of the snout, one on each side of the median line (Figure 4.15). Eyes are large and project above the general surface of the body. They lie behind the external nostrils and are protected by a thin movable lower eyelid, thick immovable upper eyelid and a third transparent eyelid called **nictitating membrane**. This membrane protects the eye when the frog is under water. A pair of **tympanic membranes** forms the ear drum behind the eyes on either side. Frogs have no external ears, neck and tail are absent. Trunk bears a pair of fore limbs and a pair of hind limbs. At the posterior end of the dorsal side, between the hind limbs is the **cloacal aperature**. This is the common opening for the digestive, excretory and reproductive systems.

Fore limbs are short, stumpy, and helps to bear the weight of the body. They are also helpful for the landing of the frog after leaping. Each forelimb consists of an upper arm, fore arm and a hand. Hand bears four digits. **Hind limbs** are large, long and consist of thigh, shank and foot. Foot bears five long webbed toes and one small spot called the sixth toe. These are adaptations for leaping and swimming. When the animal is at rest, the hind limbs are kept folded in the form of letter **'Z'**. **Sexual dimorphism** is exhibited clearly during the breeding season. The male frog has a pair of **vocal sacs** and a copulatory or **nuptial pad** on the ventral side of the first digit of each forelimb (Figure 4.16). Vocal sacs assist in amplifying the croaking sound of frog. Vocal sacs and nuptial pads are absent in the female frogs.

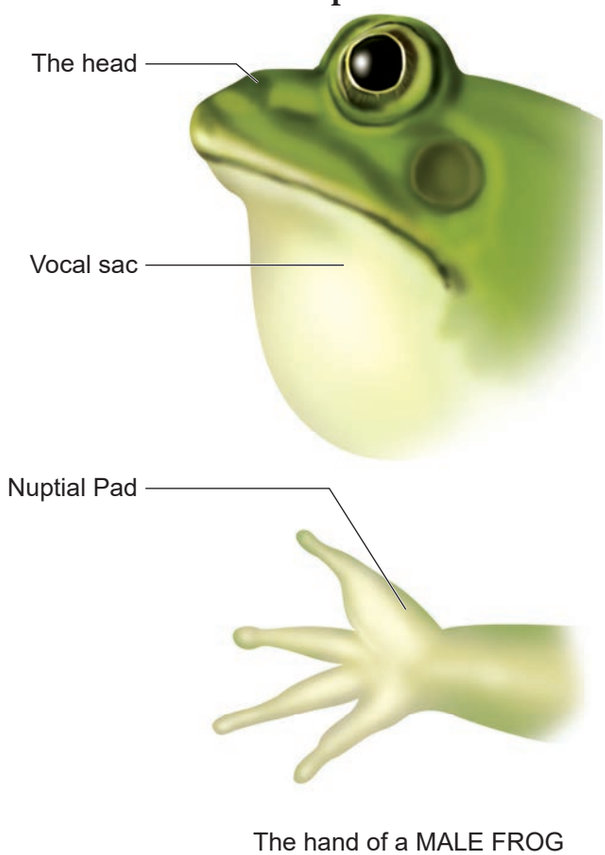


Figure 4.16 Male *Rana hexadactyla* with vocal sacs and nuptial pad

Why three chambered heart of frog is not as efficient has the four chambered heart of birds and mammals?

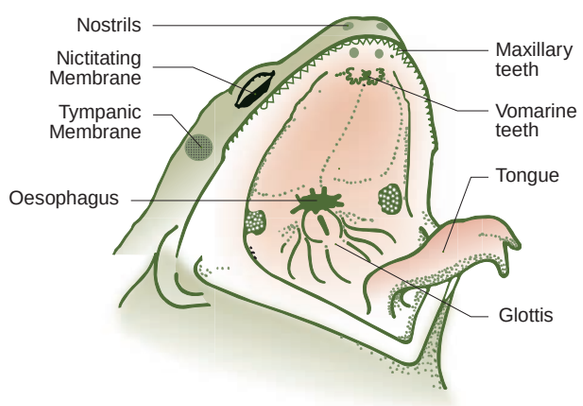


Figure 4.17 The Buccal Cavity of *Rana hexadactyla*

Anatomy

The Digestive System

The **alimentary canal** consists of the buccal cavity, pharynx, oesophagus, duodenum, ileum and the rectum which leads to the cloaca and opens outside by the cloacal aperture. The wide mouth opens into the buccal cavity. On the floor of the **buccal cavity** lies a large **muscular sticky tongue**. The tongue is attached in front and free behind. The free edge is forked. When the frog sights an insect it flicks out its tongue and the insect gets glued to the sticky tongue. The tongue is immediately withdrawn and the mouth closes. A row of small and pointed **maxillary teeth** is found on the inner region of the upper jaw (Figure. 4.17) In addition **vomerine teeth** are also present as two groups, one on each side of the internal nostrils. The lower jaw is devoid of teeth. The mouth opens into the buccal cavity that leads to the **oesophagus** through the **pharynx**. Oesophagus is a short tube that opens into the stomach and continues as the intestine, rectum and finally opens outside by the cloaca (Figure 4. 18). **Liver** secretes bile which is stored in the gall bladder. **Pancreas**, a digestive gland produces pancreatic juice containing digestive enzymes.

Food is captured by the bifid tongue. Digestion of food takes place by the action of **Hydrochloric acid** and **gastric juices** secreted from the walls of the stomach. Partially digested food called chyme is passed from the stomach to the first part of the intestine, the duodenum. The duodenum receives bile from the gall bladder and pancreatic juices from the pancreas through a common bile duct. **Bile** emulsifies fat and **pancreatic juices** digest carbohydrates, proteins and lipids. 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 the **cloaca.**

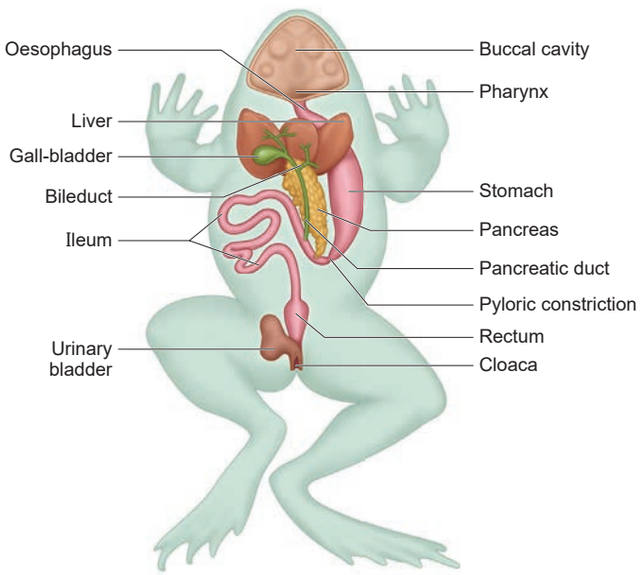


Figure: 4.18 Digestive System of *Rana hexadactyla*

Anus: The opening at the lower end of the alimentary canal in mammals through which solid waste leaves the body.

Cloaca: The common chamber into which the intestinal, urinary and genital tracts open. It is present in birds, reptiles, amphibians, elasmobranch fishes and monotremes. The cloaca has an opening for expelling its contents from the body and in females it serves as the depository for sperm.

Respiratory System

Frog respires 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 gets, exchanged through the skin by diffusion. On land, the buccal cavity, skin and lungs act as the respiratory organs. In **buccal respiration** on land, the mouth remains permanently closed while the nostrils remain open. The floor of the buccal cavity is alternately raised and lowered, so air is drawn into and expelled out of the buccal cavity repeatedly through the open nostrils. 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 the lungs. During **aestivation** and **hibernation** gaseous exchange takes place through skin.

The Blood-Vascular System

Blood vascular system consists of a **heart** with three chambers, **blood vessels** and **blood**. Heart is covered by a double-walled membrane called **pericardium**. There are two thin walled anterior chambers called auricles (Atria) and a single thick walled posterior chamber called ventricle. **Sinus venosus** is a large, thin walled, triangular chamber, which is present on the **dorsal side** of the heart. **Truncus arteriosus** is a thick walled and cylindrical structure which is obliquely placed on the **ventral surface** of the heart. It arises from the ventricle and divides into right and left **aortic trunk,** which is further divided into **three aortic arches** namely carotid, systemic and pulmo-cutaneous. The **Carotid** trunk supplies blood to the anterior region of the body. The **Systemic trunk** of each side is joined posteriorly to form the **dorsal aorta.** They supply blood to the posterior part of the body. **Pulmo-cutaneous trunk** supplies blood to the lungs and skin. Sinus venosus receives the deoxygenated blood from the body parts by two anterior precaval veins and one post caval vein. It delivers the blood to the right auricle; at the same time left auricle receives oxygenated blood through the pulmonary vein. Renal portal and hepatic portal systems are seen in frog (Figure. 4. 19 and 4. 20).

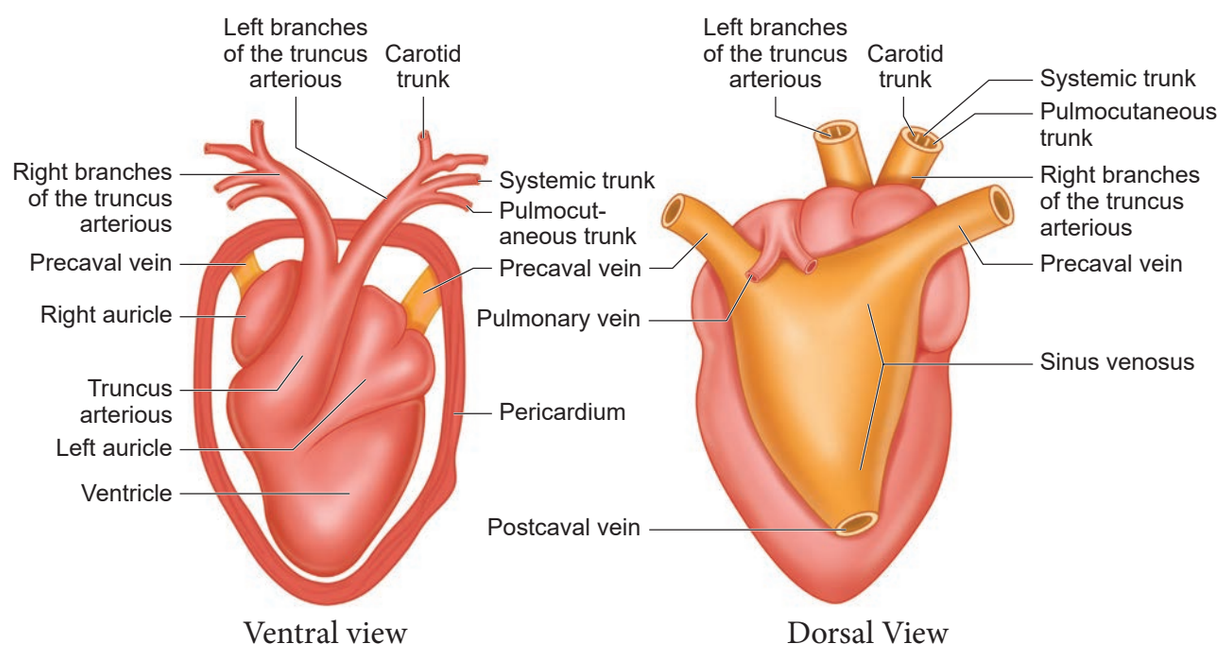


Figure 4.19 *Rana hexadactyla* - Structure of Heart

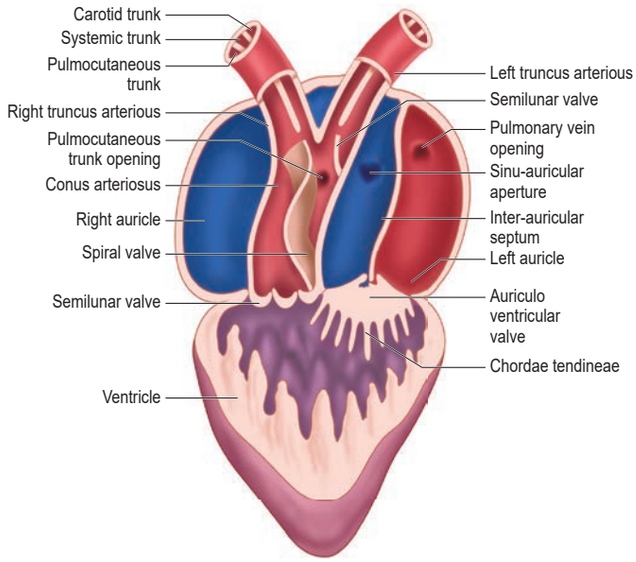


Figure 4.20 *Rana hexadactyla - Internal Structure of Heart*

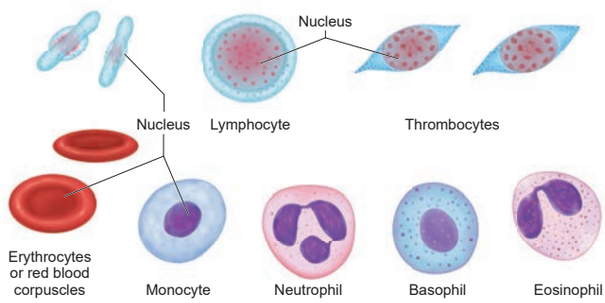


Figure 4.21 *Rana hexadactyla* – Blood cells

The **blood** consists of **plasma** [60%] and blood **cells** [40 %] includes red blood cells, white blood cells, and platelets. RBCs are loaded with red pigment, nucleated and oval in shape. Leucocytes are nucleated, and circular in shape (Figure 4.21).

The Nervous System

The Nervous system is divided into the Central Nervous System [CNS], the Peripheral Nervous System [PNS] and the Autonomous Nervous System [ANS]. **Peripheral Nervous System** consists of 10 pairs of **cranial nerves** and 10 pairs of **spinal nerves**. **Autonomic Nervous System** is divided into **sympathetic** and **parasympathetic** nervous system. They control involuntary functions of **visceral organs**. CNS consists of the Brain and Spinal cord. Brain is situated in the cranial cavity and covered by two meninges called piamater and duramater. The brain is divided into forebrain, midbrain and hindbrain. Fore brain (Prosencephalon) is the anterior most and largest part consisting of a pair of **olfactory lobes** and **cerebral hemisphere** (as Telencephalon) and a **diencephalon**. Anterior part of the olfactory lobes is narrow and free but is fused posteriorly. The **olfactory lobes** contain a small cavity called **olfactory ventricle**. The mid brain (Mesencephalon) includes two large, oval **optic lobes** and has cavities called **optic ventricles**. The hind brain (Rhombencephalon) consists of the **cerebellum** and **medulla oblongata**. Cerebellum is a narrow, thin transverse band followed by **medulla oblongata.** The medulla oblongata passes out through the **foramen magnum** and continues as **spinal cord,** which is enclosed in the vertebral column (Figure 4.22).

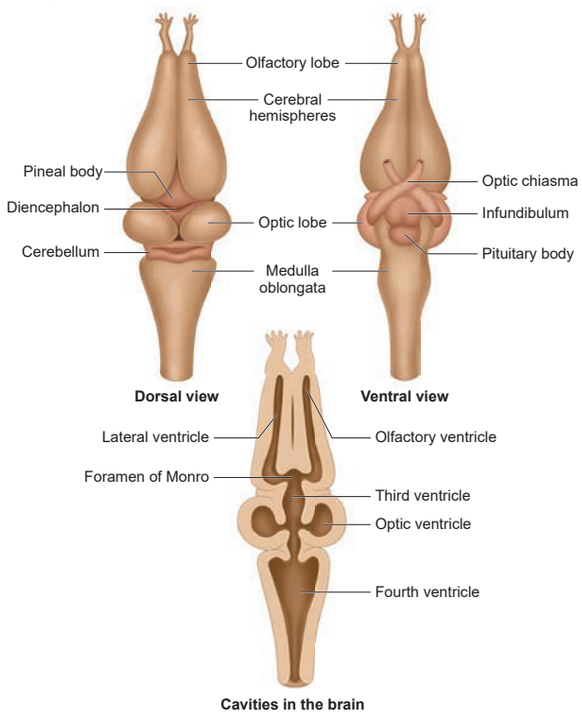


Figure: 4.22 *Rana hexadactyla* – Brain dorsal and ventral view

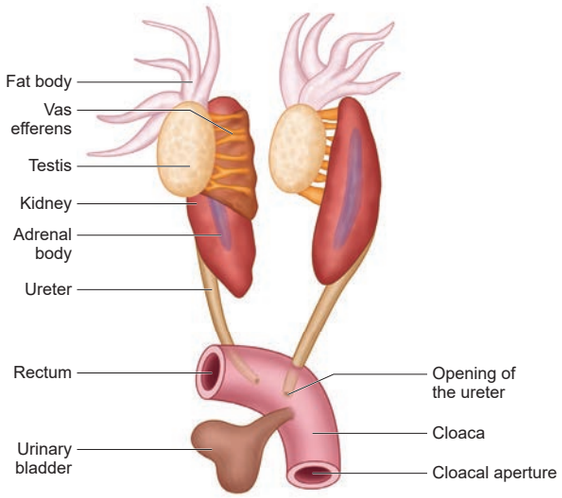


Figure 4.23 *Rana hexadactyla* - Male Urinogenital System

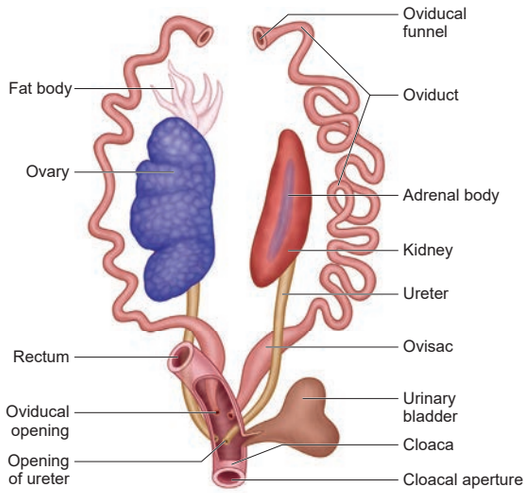


Figure 4.24 *Rana hexadactyla* - Female Urinogenital System

Excretory system

Elimination of **nitrogenous waste** and salt and water balance are performed by a well developed excretory system. It consists of a pair of kidneys, ureters, urinary bladder and cloaca. Kidneys are dark red, long, flat organs situated on either sides of the vertebral column in the body cavity. Kidneys are **Mesonephric.** Several nephrons are found in each kidney. They separate nitrogenous waste from the blood and excrete urea, so frogs are called **ureotelic** organisms. A pair of ureters emerges from the kidneys and opens into the cloaca. A thin walled unpaired **urinary bladder** is present ventral to the **rectum** and opens into the **cloaca.**

Reproductive system

The **male** frog has a pair of testes which are attached to the kidney and the dorsal body wall by folds of peritonium called mesorchium. Vasa efferentia arise from each **testis**. They enter the kidneys on both side and open into the bidder's canal. Finally, it communicates with the urinogenital duct that comes out of kidneys and opens into the cloaca (Figure 4.23).

Female reproductive system (Figure 4.24) consists of paired **ovaries,** attached to the kidneys, and dorsal body wall by folds of peritoneum called mesovarium. There is a pair of coiled **oviducts** lying on the sides of the kidney. Each oviduct opens into the body-cavity at the anterior end by a funnel like opening called ostia. Unlike the male frog, the female frog has separate genital ducts distinct from ureters. Posteriorly the oviducts dilated to form **ovisacs** before they open into cloaca. Ovisacs store the eggs temporarily before they are sent out through the cloaca. Fertilization is external.

Within few days of fertilization, the **eggs** hatch into **tadpoles**. A newly hatched tadpole lives off the yolk stored in its body. It gradually grows larger and develops three pairs of gills. The tadpole grows and **metamorphosis** into an air – breathing carnivorous adult frog (Figure 4.25). Legs grow from the body, and the tail and gills disappear. The mouth broadens, developing teeth and jaws, and the lungs become functional.

Economic importance of Frog

- Frog is an important animal in the **food chain**; it helps to maintain our ecosystem. So '**frogs should be protected'.**
- Frog are beneficial to man, since they feed on insects and helps in reducing insect pest population.
- Frogs are used in traditional medicine for controlling **blood pressure** and for its **anti aging** properties.
- In USA, Japan, China and North East of India, frogs are **consumed** as delicious food as they have high nutritive value.

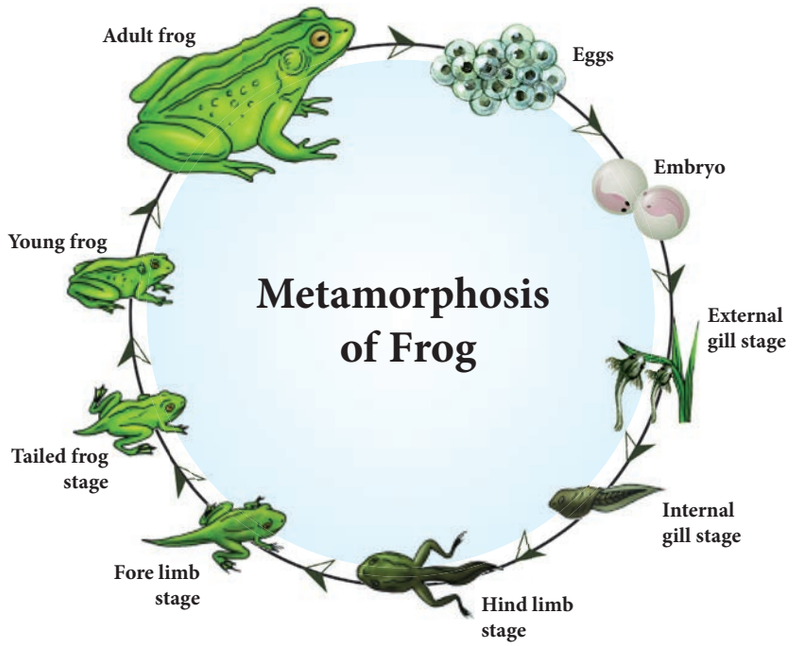


Figure 4.25 *Rana hexadactyla* - Metamorphosis

Summary

Earthworm, Cockroach and Frog show characteristic features in body organization. *Lampito mauritii* (earthworm) is commonly found in Tamil Nadu, its body is covered by cuticle. It has a long and cylindrical narrow body which is bilaterally symmetrical. All segments of its body are alike except the 14 to 17 segments, which are thick and dark and glandular, forming the clitellum. This helps in the formation of cocoons. A ring of S-shaped chitinous setae is found in each segment. These setae help in locomotion. Earthworm's development is direct and no larva is formed during development.

Cockroach is a typical cosmopolitan insect and exhibits all the fundamental characteristics of class Insecta. The body of the cockroach is compressed dorso-ventrally, bilaterally symmetrical, segmented and divisible into three distinct regions – head, thorax and Abdomen. The photoreceptor organ of the cockroach consists of a pair of compound eyes with mosaic vision. Segments bear jointed appendages. There are three throacic segments of each bearing a pair of walking legs. Two pairs of wings are present, one pair each on 2nd and 3rd segment. There are ten segments in abdomen. Fertilization is internal. The development of cockroach is gradual through nymphal stages (paurometabolus).

Frogs are cold blooded vertebrates – Poikilotherms. Skin is smooth and moist, Red blood corpuscles are nucleated. Eggs are laid in water. The larvae pass through an aquatic stage before metamorphosing into adult.

Evaluation

1. The clitellum is a distinct part in the body of earthworm *Lampito mauritii*, it is found in?

   47YJ7U

   a. Segments 13 - 14
   b. Segments 14 - 17
   c. Segments 12 - 13
   d. Segments 14 - 16

2. Sexually, earthworms are
   a. Sexes are separate
   b. Hermaphroditic but not self - fertilizing
   c. Hermaphroditic and self – fertilizing
   d. Parthenogenic

3. State whether the statement is true or false

   To sustain themselves, earthworms must guide their way through the soil using their powerful muscles. They gather nutrients by ingesting organic matter and soil, absorbing what they need into their bodies. State wheather the statement is true or false: The two ends of the earthworm can equally ingest soil.

   a. True b. False

4. The head region of Cockroach _____ pairs of _____ and _____ shaped eyes occur.
   a. One pair, sessile compound and kidney shaped
   b. Two pairs, stalked compound and round shaped
   c. Many pairs, sessile simple and kidney shaped
   d. Many pairs, stalked compound and kidney shaped

5. The location and numbers of malpighian tubules in *Periplaneta*.
   a. At the junction of midgut and hindgut, about 150.
   b. At the junction of foregut and midgut, about 150.
   c. Surrounding gizzard, eight.
   d. At the junction of colon and rectum, eight.

6. The type of vision in Cockroach is _____
   a. Three dimensional
   b. Two dimensional
   c. Mosaic
   d. Cockroach do not have vision

7. How many abdominal segments are present in male and female Cockroaches?

   a. 10, 10 b. 9, 10
   c. 8, 10 d. 9, 9

8. Which of the following have an open circulatory system?

   a. Frog b. Earthworm
   c. Pigeon d. Cockroach

9. Buccopharyngeal respiration in frog
   a. is increased when nostrils are closed
   b. Stops when there is pulmonary respiration
   c. is increased when it is catching fly
   d. stops when mouth is opened.

10. Kidney of frog is
    a. Archinephros
    b. Pronephros
    c. Mesonephros
    d. Metanephros

11. Presence of gills in the tadpole of frog indicates that
    a. fishes were amphibious in the past
    b. fishes evolved from frog -like ancestors
    c. frogs will have gills in future
    d. frogs evolved from gilled ancestor
12. Choose the wrong statement among the following:
    a. In earthworm, a pair of male genital pore is present.
    b. Setae help in locomotion of earthworms.
    c. Muscular layer in the body wall of earthworm is made up of circular muscles and longitudinal muscles.
    d. Typhlosole is part of the intestine of earthworm.
13. Which of the following are the sense organs of Cockroach?
    a. Antennae, compound eyes, maxillary palps, anal cerci
    b. Antennae, compound eye, maxillary palps and tegmina
    c. Antennae, ommatidia, maxillary palps, sternumv and anal style
    d. Antennae, eyes, maxillary palps, tarsus of walking legs and coxa
14. What characteristics are used to identify the earthworms?
15. What are earthworm casts?
16. How do earthworms breathe?
17. Why do you call cockroach a pest?
18. Comment on the functions of alary muscles?
19. Name the visual units of the compound eyes of cockroach.
20. How does the male frog attracts the female for mating?
21. Write the types of respiration seen in frog.
22. Differentiate between peristomium and prostomium in earthworm.
23. Give the location of clitellum and spermathecal openings in *Lampito mauritii.*
24. Differentiate between tergum and a sternum.
25. Head of cockroach is called hypognathous. Why?
26. What are the components of blood in frog?
27. Draw a neat labeled diagram of the digestive system of frog.
28. Explain the male reproductive system of frog.
29. Explain the female reproductive system of frog.
30. Differentiate between male and female cockroach?

Concept Map