Chapter 33

Morphology & Anatomy of Animals

EARTHWORM (*Pheretima posthuma*)

- The **common Indian earthworm**, *Pheretima posthuma* **belongs to class oligochaete of the phylum annelida**.
- The generic name *Pheretima* was first used by **Kinbery** in 1867.
- The anatomy of *Pheretima* has been worked out by late Professor **K.N. Bahl (1926)**.
- *Pheretima posthuma* is a terrestrial earthworm lives in **damp soil** & burrows (fussorial) and is nocturnal.
- **Brown colour of the body** is due to a pigment called **porphyrin**, present in the circular muscles of body wall. Porphyrin **protects the animal from ultraviolet rays**.
- **Moisture is essential** for the **survival of earthworm**.
- *Pheretima* **has no specialized respiratory organs**.
- The **moist skin acts as a respiratory organ**. The respiration in earthworm is called **cutaneous respiration**.
- Skin of earthworm is kept moist by **mucous**, **coelomic fluid** & **moisture of soil**. Mucous serves not only in respiratory exchange but it also lubricates the worm body & easy passage through the burrow. The mucous covered skin help in binding soil particles together & prevents the walls of burrow from collapsing.
- In *Pheretima*, **epidermal receptors** are present all over the body. They are of two types – **tangoreceptors** (sense of touch) and **chemoreceptors** (sense of chemical stimuli).
- In *Pheretima*, **buccal receptors** are found in the buccal cavity. They are of two types – **gustatory receptors** (organs of taste) and **olfactory receptors** (organs to detect smell).
- If the **skin is dry,** respiration cannot take place and the **earthworm dies by suffocation**.
- During rainy season it comes out of their burrows for respiration & to escape from endosmosis.
- Earthworm **lacks** a **distinct head** and **sense organs like eyes, cirri & tentacles**.

Earthworm **do not have special sense organ**. Yet they show behaviour to all kinds of stimuli. This is mainly due to presence of receptors cells for taste, touch & apparently vibration all over the body surface. There is a concentration of sensory cells at the anterior end of prostomium. Because of these receptors they feel the vibrations of animals moving nearby.

- **1st segment** (or **peristomium**) has a **ventral mouth** with a dorsal lobe or **prostomium** & the **last segment has anus**.
- Earthworm has **great power of regeneration**.
- **Clitellum** (or cingulum) is a glandular organ used for the **formation of cocoon**.
- Clitellum completely and permanently **surrounds the segments 14th to 16th** in the form of a girdle like thick band of glandular tissue.
- Due to presence of clitellum, the body is distinguished into *periclitellar*, **clitellar** and **post clitellar regions**.
- **Setae** or **chaetae (made by chitin)** are S-shaped structures occur in median whorls (perichaetine

Table : Number of segment with the structures located on it in earthworm

No. of segments	Structures located
1st segment (Peristomium)	Mouth
6th, 7th, 8th, 9th	Spermathecae
14th to 16th	Clitellum
14th	One female genital opening
18th	A pair of male genital opening
4th	Pharynx
5th – 7th	Oesophagus
8th	Gizzard
15th – last	Intestine
17th and 19th	Genital papillae
15th – last	Septal nephridia
3rd – last	Integumentary nephridia
4th, 5th, 6th	Pharyngeal nephridia or branched nephridia
10th, 11th	Testes, testis sacs
13th	Ovary
17th, 19th	Accessory glands
16th – 21st	Prostate gland
11th, 12th	Seminal vesicles
26th – 95th	Typhlosole
7th, 9th	Lateral hearts
12th, 13th	Lateral oesophageal hearts
10th, 11th	Anterior loops
5/6, 6/7, 7/8, 8/9	Spermathecal opening
4th, 5th, 6th	Blood glands

arrangement = arrangement of numerous setae in a ring) **in all except first (peristomium), last & clitellar segments**.

- Setae **helps in locomotion by anchoring structure**s.
- In *Pheretima*, **four pairs of spermathecal openings** are present on the **inter segmental grooves of 5/6, 6/7, 7/8 and 8/9 segments**, one pair in each groove.
- In *Pheretima*, single **female genital opening** is present on the mid ventral side of the **14th segment** and one pair of **male genital openings** are seen on the ventral side of the **18th segment**.
- In *Pheretima*, close to the male genital pores, two pairs of **genital papillae** are present ventrally, one pair in the **17th segment** and the other pair in the **19th segment**. They **act as suckers** for attachment during copulation.
- **Accessory glands** of **17th and 19th segments** open to the exterior on genital papillae in *Pheretima*.
- The **body wall** of *Pheretima* is **derived from ectoderm and somatic mesoderm**.
- Body wall of *Pheretima* shows **circular** and **longitudinal muscles**.
- The **muscles of body wall** of *Pheretima* **help in locomotion in association with setae.**
- The outer coelomic epithelium of body wall is made by **squamous epithelium**.
- **Body cavity** is a true coelom **(schizocoel)**, containing milky white alkaline coelomic fluid.
- Septa divide coelom into chambers.
- Coelomic fluid contains corpuscles of following types– **phagocytes** (largest, more numerous, amoeboid corpuscles), **mucocytes, circular nucleated cells** and **chloragogen cells**.
- Coelomic fluid **serves as a hydraulic skeleton during locomotion**.
- Septal wall is **absent in the first four segments** and also **between 9th and 10th segments**.
- The **speed of progression** of *Pheretima* is **25 cm per minute.**
- The **muscles of alimentary canal** of *Pheretima* **helps in peristalsis**.
- Earthworm has a straight alimentary canal, representing a **tube in tube plan**.
- Pharyngeal glands with **some chromophil cells** are present on the roof of the pharynx. They **produce mucin and proteolytic enzymes (protease)**.
- **Gizzard** (present in the 8th segment) is a thick walled, highly muscular and lined internally by cuticle for grinding.
- In *Pheretima*, glandular cells of stomach contains calciferous gland which secrete calcium oxalate and **neutralizes the humic acid of the food**.
- In *Pheretima*, the dorsal wall of intestine shows **typhlosole**. Typhlosole is the **largest villus for increasing absorptive area**.
- In *Pheretima* the **intestine is divisible into 3 parts** based on the presence of typhlosole –
  - **Pre-typhlosolar region** from **15th to 26th segments.**
  - **Typhlosolar region** extends from **27th segment to 23rd or 25th segment in front of anus.**
  - **Post-typhlosolar region** occupies the **last 23rd or 25th segment.**

- In *Pheretima*, the intestine shows a pair of **intestinal caecae** in **the 26th segment**. They **extend upto 22nd or 23rd segment**. They secrete **amylase enzyme**.
- Earthworms are **omnivorous**.
- The food of *Pheretima* consists of dead and decaying organic matter mixed in the soil.
- In *Pheretima*, undigested food with soil is sent out through anus in the form of **worm castings or faecal pellets**.
- The **digestion is extracellular** in earthworm.
- **Blood vascular system** of earthworm is a **closed type** consisting of blood vessels and capillaries.
- Blood is **red in colour due to presence of haemoglobin which is dissolved in blood plasma**.
- In *Pheretima*, there are **three main blood vessels- dorsal blood vessel**, **ventral blood vessel** and **subneural blood vessel**.
- **Dorsal blood vessel** is the **largest blood vessel** extending from one end of the body to the other end. It has thick, muscular walls with valves. It **drives the blood in forward direction**.
- In the intestinal region *i.e.*, **behind 14th segment**, **dorsal vessel acts as a collecting vessel**.
- The dorsal blood vessel **acts as a distributing vessel** in the **first 13th segments**.
- The **ventral blood vessel** extends from one end of the body to the other end. It is **non-muscular** and **non-valvular vessel**.
- Ventral blood vessel is **the chief distributing vessel**, in which blood flows from anterior to posterior end.
- **Sub-neural blood vessel** is present beneath the ventral nerve cord. It extends from 14th segment to the posterior end. It is a **collecting vessel**.
- **Supraoesophageal blood vessel** is a short thin walled collecting vessel lying mid dorsally above the stomach and confined to **segments 9 to 13**.
- On the lateral sides of the alimentary canal from **1st to 13th segments** a pair of **lateral oesophageal blood vessel is seen.**
- A pair of large, thick, muscular and rhythmically contractile vertical vessels, called **hearts**, are **present in each of the segments 7, 9, 12 and 13**.
- **Lateral hearts** that are **present in 7th and 9th segments**, connect dorsal blood vessel with ventral blood vessel.
- Above the alimentary canal in **4th, 5th and 6th segments**, 3 pairs of globular structures called **blood glands** are present. Blood gland **produce haemoglobin** and **blood cells**.
- **Lymph glands**, present on both sides of dorsal blood vessel from segment 26th and those behind it, are supposed to produce certain phagocytic cells.
- In *Pheretima*, there are **three types of nephridia** (ectodermal in origin) according to their location – pharyngeal nephridia, integumentary nephridia and septal nephridia.
- The **pharyngeal nephridia** are **present in 4th, 5th and 6th segments** (one pair in each). Nephrostome and nephridiopore are **absent** in pharyngeal nephridia.
- Pharyngeal nephridia open in the anterior part of alimentary canal *i.e.* buccal cavity and pharynx thus are also called **enteronephric**.
- Pharyngeal nephridia of *Pheretima* are called **peptonephridia** (4th and 5th groups open into pharynx, 6th group opens into buccal cavity).
- **Integumentary nephridia** are microscopic V-shaped. They are small and have **no nephrostome** and are **exonephric type**.
- In the clitellar region each segment has 2000 to 2500 micronephridia. They are called **forest of nephridia**.
- **Septal nephridia** are the **largest nephridia** and the **only nephridia with nephrostome** (a ciliated funnel communicating with the coelom).
- The septal nephridia are open to **enteronephric nephridia**. They perform both **excretion** and **osmoregulation**.
- Earthworms are mainly **ureotelic (excrete urea)**.
- **Chlorogogen cells** (or **yellow cells**) are star shaped, small sized cells. They perform excretion by removing excretory products from coelomic fluid. It is bright yellow or orange colour cells derived from splanchnic peritoneum which explains its position and distribution on the surface.
- **Chlorogogen cells** are **analogous to liver of vertebrates** because of the connection with storage and synthesis of glycogen & fat, deamination & urea formation.
- Earthworm has a **well developed nervous system**, it has a brain but no head.
- The **nervous system includes a nerve ring** around pharynx in 3rd and 4th segments.
- **Brain hormone** produced by supra-pharyngeal ganglia brings **regeneration of the posterior segments**.
- Neurons in earthworm are– **motor**, **sensory** and

adjustor (association neurons).

- **Photoreceptors** of *Pheretima* contain a L-shaped lens called **phaosome** or **optic organelle** (made up of a hyaline substance). It **cannot form an image**.
- Photoreceptors enable worms to judge the intensity & duration of light. **Photoreceptors restricted to dorsal surface, are more numerous on prostomium and peristomium**.
- *Pheretima* are monoecious or **hermaphrodite organism**.
- In earthworm **cross fertilization takes place** instead of self fertilization. This is due to **protandrous condition** (where testes mature earlier than ovaries).
- In *Pheretima*, the **spermathecae** (or **receptacula seminales**) **show one diverticulum and a big ampulla**. **Diverticulum** stores sperms and **ampulla** gives nourishment to the stored sperms.
- **Copulation** takes place for **one hour** between two mature earthworms in the **night time**.
- **Fertilization** is **external** and **occurs in cocoon**.
- **Cleavage** is **holoblastic and unequal** and **development is direct** without any free larval stage.
- Earthworms are **friends of farmers** because they enrich the soil by nephridial excretion, that increases the fertility of soil.
- Earthworms found in South India are *Megascolex, Lampito, Octochaetus, Drawida, Eutyphaeus* etc.
- *Drawida grandis* is the **largest earthworm in India**.
- **Largest earthworm in world** is *Megascoloides australis*.
- **Megascolex** is abundantly found in Andhra Pradesh.
- *Pheretima* and *Eutyphaeus* are found in North India. *Pheretima posthuma* is also found in Kerala state.
- *Lumbricus terrestris* is an European earthworm, **not found in India**.
- *Allolobophora* is found in hilly regions of North India.

COCKROACH (*Periplaneta americana*)

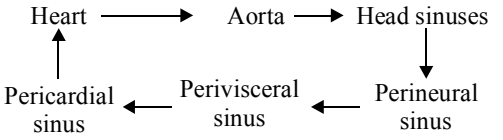
- Cockroaches belong to the class **insecta of phylum arthropoda**.
- Class insecta is the **largest in the animal kingdom**, as there are more species of insects (about 80,000) than all other species of animals combined.
- **Four species of cockroaches** found in India are– *Blattella germanica* (the German or croton cockroach); *Blatta orientalis* (the Oriental or Indian cockroach); *Periplanata americana* (the American cockroach or ship cockroach); and *Periplaneta australasiae* (the Australian cockroach).
- Cockroaches are **nocturnal** (active in night), **cursorial** (fast runners) and **omnivorous** and **scavangerous** in diet.
- *Blatta orientalis* is black in colour and it is commonly known as **black beetle**.
- *Periplaneta americana* is the **largest and most common species**.
- The wings are **well developed in both sexes** of *Periplaneta americana* and extend beyond the body.
- The wings are **reduced in male** and **vestigial in female** *Blatta orientalis*.
- Body is covered with non-living, brown coloured, hard jointed and chitinous exoskeleton of sclerites which are formed by thin, flexible **arthrodial** or **articular membranes** to allow movements.
- The dorsal sclerite of the exoskeleton of cockroach is called **tergum** or **tergite**, ventral sclerite is **sternum** or **sternite** and two lateral sclerites are called **pleura** or **pleurites**.
- Body of cockroach is distinctly divided into **head**, **thorax** and **abdomen**.
- The part of head between and behind the eyes is **epicranium (vertex)**.
- The front of head capsule is made up of three unpaired flattened sclerites called **frons, clypeus** and **labrum**.
- Head bears a **pair of long antennae**, a **pair of ocelli or fenestrae** (simple eyes) and a **pair of compound eyes**.
- The **thorax** of cockroach consists of three segments – **prothorax, mesothorax** and **metathorax**.
- Thorax **bears three pairs of jointed appendages** (**walking legs**) and **two pairs of wings** on mesothorax and metathorax.
- **Abdomen** is the **largest and broadest part** consisting of **ten segments (11 segments in embryo) without appendages**.
- The 11th somite of embryo is represented in adult by **podical plates**.
- Abdomen is **long & narrow in male** but is **short and broad in female.**
- **8 pairs of tracheal openings or spiracles** are **present** on lateral pleura of **first 8 abdominal segments**.

- **Main appendages** of cockroach are **antennae and mouthparts** (on head); **legs and wings** (on thorax) and **external genitala** (on abdomen).
- The **antenna** is made of many segments called **podomeres**. The **first segment is scape** (largest), **second pedicel** and **rest many jointed flagellum**.
- Antenna is a **thigmoreceptor sensitive to touch** and **smell**.
- Mouthparts of cockroaches are **mandibulate type** or **cutting and chewing type**.
- Mouthparts consists of **labrum** (upper lip), **labium** (lower lip), **maxillae** (segmented and resemble to a leg), **mandibles** and **hypopharynx** (tongue).
- The **main structures** and **well developed part of mastication (chewing)** are **mandibles** which are short with teeth.
- The **mandibles work as jaws** and are **used for crushing and cutting the food materials**.
- Each **leg of cockroach** (used for walking, running and climbing) is **made up of 5 segments (or) podomeres**. They are **coxa, trochanter, femur, tibia** and **tarsus**.
- Tarsus is subdivided into five tarsomeres. The last tarsomere is called **pretarsus** forming the claws and bearing an adhesive **arolium** or **pulvillus**.
- Similar but smaller adhesive pads called **plantula** are located at each joint of the tarsus.
- The **most swollen segment in the leg** of cockroach is **coxa**.
- **Tibia** is the **largest podomere** in the leg of cockroach. The bristles on tibia are called **tibial spurs**.
- **Mesothoracic wings or forewings** are thick leathery and opaque wings. They are **not used in flight** but **protective in function**.
- **Metathoracic or hindwings** are broad, thin and membraneous wings which are **used in flight.**
- **Anal cerci** and **anal styles** are the **external genitalia** which are **involved in sexual dimorphism**, **mating** and **deposition of eggs**.
- **Anal cerci**, a pair of many jointed structures are **present on the tergite of 10th segment in both sexes**.
- **Anal styles**, a pair of small, spine-like unjointed structures are **present on sternite of the segment in males only**.
- **Body wall of cockroach** is made up of **two layers** - outer **cuticle** and **inner hypodermis**.
- **Cuticle** is invaginated forming endoskeletal elements like **tentorium** in head and **apodemes** in thorax. They **provide sites for attachment of muscles**.
- Cuticle is **principally made of chitin**, a horny proteinous substance, chemically an amino-polysaccharide, insoluble in water and resistant to most solvents.
- The cuticle has **three distinct layers**: outer primary cuticle or **epicuticle**, middle thick **exocuticle** and inner thick **endocuticle**. All three are secreted by hypodermis.
- Exo- and endocuticle together constitute the so called **'procuticle'**.
- Exo- and endocuticle **contain chitin**, a structural polysaccharide, basic unit being **N-acetyl glucosamine**.
- **Melanin** pigment is **found only in exocuticle**.
- **Hypodermis** is a single layered epithelium. Some of its cells are modified into large oval **trichogen cells** concerned with secretion of movable bristles on the body of cockroach.
- Besides secreting cuticle, hypodermis resorbs endocuticle before each moult or ecdysis.
- The **alimentary canal** is long and divisible into three main parts namely **foregut, midgut** and **hindgut**.
- **Foregut** (**stomodaeum**) is differentiated into five parts: **buccal chamber, pharynx, oesophagus, crop** and **gizzard**.
- **Crop or ingluvius** occupies the entire thoracic and some abdominal part and **stores the food.**
- **Gizzard** is adapted for grinding the food into a pulp. The **main part of gizzard** is called **armarium** [anterior part with **teeth** (which masticate the food) and **pulvillii** (whose bristles form a strainer which allow only fine food particles to pass through)].
- **Stomodeal valve** is posterior narrow and tubular part of gizzard which projects into the midgut to prevent backflow of food.
- From the junction of midgut and gizzards arises seven to eight finger like structures called **hepatic caecae**.
- **Midgut** (**mesenteron or ventriculus**) is short, tubular lined with glandular endoderm.
- Midgut **forms the true stomach** serving mainly for digestion and absorption.
- Internally mesenteron is not lined by cuticle but it is **covered by a very thin and transparent**

peritrophic membrane formed of chitin and proteins.

- **Peritrophic membrane** is **secreted by stomodeal valve of gizzard** and serves to **protect the wall of midgut from abrasion due to friction of food particles**.
- **Hindgut (proctodaeum)** comprises ileum, colon and rectum.
- Most of the nutrients of food are digested in the crop.
- **Digestive glands** includes one pair of salivary gland, each is formed of two parts - sac like **resorvoir** or (**receptacle**) and a bipartite **glandular part**.
- The **digestive enzymes** of **saliva** are mainly **zymase** and **amylase**.
- Digestion is **intercellular** in cockroach.
- **Absorption of digested food** takes place in **mesenteron**.
- **Circulatory system** of cockroach is **open** or **lacunar type**. The **blood flows through haemocoelic system**.
- Haemocoel is divided into a dorsal **pericardial sinus** (containing heart), a middle **perivisceral sinus** (containing the gut) and a ventral **perineural sinus** (containing the nerve cord) by two perforated diaphragms.
- **Heart** is longitudinally **beaded with 13 chambers perforated by ostia having valves**.
- The **blood circulation is maintained** by 13 pairs of wing-shaped involuntary **alary muscles**.
- **Heart** of cockroach is **neurogenic** (myogenic in frog, rabbit and man).
- In addition to the main heart there are present very small **accessory heart** or **pulsatile vesicles** one at the base of each antenna located in the head, to pump the blood from the head sinuses to the antenna.
- The **blood** of cockroach is **colourless due to the lack of respiratory pigment**. It consists of colourless plasma and corpuscles called haemocytes.
- **Pacemakers are absent** in the cockroach heart.
- In cockroach, oxygen is carried to individual cell without participation of blood.
- All body tissues **receives oxygen directly**.
- The **rate of heart beat** in *Periplaneta* is **49/min**.
- Blood circulartion in cockroach is **completed in 5-6 minutes.**

The pathways follow as



- **Respiratory system** of cockroach consists of **tracheal system** (containing tracheae, tracheoles and spiracles).
- The tracheal system open outside by ten pairs of **spiracles** or **stigmata** (two pairs thoracic and eight pairs of abdominal). The spiracles are with valves.
- The **trachea** is lined with spiral thickening of cuticle called **intima** or **taenidia** which prevents the tracheal tubes from collapsing (trachea of rabbit is also noncollapsible).
- **Ventilation of tracheal system** is by alternate contraction and relaxation of abdominal muscles (tergo-sternal muscles).
- Respiratory movements **depend on the activity of insects and temperature**, greater the muscular activity the more vigorous is the pumping in and out of air.
- Respiratory movement are **coordinated and regulated by nerve centres in thoracic ganglia** which are stimulated by low O_2 and higher CO_2 concentrations in tissue fluids.

  Tracheal systems of respiration is also found in centipedes, millipedes, ticks and *Peripatus*.
- **Excretory organs** of cockroach are **malpighian tubules** [long, very fine unbranched yellow coloured blind tubules attached at the junction of midgut and hindgut (ileum)], **fatbody cells**; **uricose glands** and **cuticle**.
- Malpighian tubules **absorb excretory substances from haemolymph and fat bodies and pass into the proctodaeum**.
- Fat body of cockroach contains mainly four types of cells, *viz*., **trophocytes, mycetocytes, oenocytes** and **urate cells**.
- The **trophocytes** are most numerous **containing reserve food in the form of fats, glycogen and proteins**.
- **Mycetocytes** contain symbiotic bacteria which help in synthesis of some amino acids, vitamins and of glycogen from glucose.
- **Oenoctyes** are supposed to help intermediary metabolism at times of ecdysis. **It secretes wax**

which covers the cuticle of cockroach.

- **Urate cells** absorb nitrogenous waste products from haemolymph and synthesize uric acid from these for storage **(storage excretion)**.
- The **fat body of cockroach** is functionally **analogous to liver of vertebrates**.
- **Uricose gland** are long, blind tubules present at the periphery of mushroom gland in the male cockroach.
- These tubules **store uric acid** and discharge it over the spermatophore during copulation.
- Uricose gland **serves as storage excretory organs between matings** and as **active excretory organs during copulation**.
- **Excretory products** of cockroach are **uric acid (hence uricotelic)** and **urates of sodium and potassium**, so they are **uricotelic**.
- The **nitrogeneous waste** which are deposited **beneath the cuticle are eliminated by the body during moulting** (**ecdysis**).
- **Nephrocytes** are large colourless ovoid binucleate cells attached to diaphragm in the body cavity. These are arranged on the lateral sides of heart hence also called **pericardial cells,** which probably regulates the pulsation of the heart and also help in excretion.
- Cockroach has a **well developed nervous system** with central, peripheral and sympathetic system.
- Central nervous system consists of **cerebral or supraoesophageal ganglion** (brain), **suboesophageal ganglion, paired circumoesophageal connectives** and **double ventral nerve cord** (with three thoracic and six abdominal compound segmental ganglia.)
- The **total number of ganglia in ventral nerve cord** of cockroach is **nine**.
- **Sense organs** in cockroach are – **photoreceptors** (compound and simple eye), **thigmoreceptors** (antennae), **chemoreceptors** (on maxillary and labial palps, labuim and hypopharynx) and **auditory receptors** on anal cerci.
- Each **compound eye** of cockroach is composed of about **2000 visual units** called **ommatidia**.
- Each **ommatidium** is composed of a **cuticular lens**, two **corneagen cells**, a **crystalline cone** surrounded by four cone cells, a **rhabdome** surrounded by seven reticular cells and a **basement membrane**.
- There are **two types of vision in insects – mosaic vision** (or **apposition image**) during day time and **superposition** (or **dull image**) in dim light.
- But in cockroach, **pigment sheath of ommatidia is noncontractile** so capable of **only mosaic vision** even during night.
- In cockroach, **sexes are separate**, so **dioecious**.
- **Male organs** consists of **testes**, **vasa deferentia**, **ejaculatory duct**, **mushroom or utricular gland, phallic or conglobate gland** and **male gonaphophysis**.
- **Testes** of cockroach are **located in the abdominal segments 4, 5 and 6**.
- **Mushroom gland** consists of two types of tubules- the long slender tubules, the **utriculi majores** or **peripheral tubules**; and short tubules, the **utriculi breviores**, making up of the **major part** of the gland.
- All sperms of a seminal vesicle are glued together into a large bundle called **spermatophore**.
- Spermatophore has three-layered wall: inner layer secreted by **utriculi majores**; middle layer secreted by **ejaculatory duct** and outer layer secreted by **phallic gland**.
- There are three asymmetrical chitinous structures called male **gonapophyses** or **phallomeres**. These are right phallomere, left phallomere (**largest**) and ventral phallomere (**smallest**).
- **Female organs** consist of **ovaries, oviducts, vagina, genital chamber, spermathecae, collaterial glands** and **female gonapophysis** (**ovipositor processes**).
- **Copulatory organ** of cockroach is **pseudopenis**.
- **Copulation** in cockroach **occur at night**.
- Each ovary (located in the abdominal segments 2 to 6) of cockroach consists of **eight ovarioles**.
- The egg of cockroach is **centrolecithal type, yolk being in the centre**.
- Nymph of cockroach **emerge out from ootheca**.
- Nymph of cockroach **undergoes 13 moults to reach the adult form.**
- **Ootheca** or egg case (**formed of a protein secreted by collaterial gland**) of **cockroach contains sixteen fertilized eggs**.
- **Metamorphosis** in cockroach is **incomplete or paurometabolous type**.
- **Instar** is a stage in the development of insect (larval instar, nymphal instar).
- Period between two moults in insects is termed as **stadium**.

- *Periplaneta americana* has **11 nymphal instars in female** and **12 nymphal instars in male**. *Blatta orientalis* moults 6 times.
- Gonapophyses **acts as external genitalia** & **help in copulation.**
- **Metamorphosis is regulated** by two hormones, **ecdysone** (secreted by prothoracic glands) and **juvenile hormone** or **neotinin** (secreted by corpora allata).

FROG (*Rana tigrina*)

- Frog, belongs to amphibia class of vertebrate, is a cold blooded or poikilothermic anamniote.
- Frog is **selected for type study** due to being non poisonous, easy to procure, less expensive, kept alive in captivity for a long time very easily and its internal anatomy can be seen by simply opening its body cavity.
- Frog is an **amphibious animal** *i.e.,* it lives in fresh water and on terrestrial environment.
- Because of possessing amphibious mode of life frog has streamlined body, the characteristic of the aquatic animals assisting in swimming in water.
- The body of the frog is divided into **head** and **trunk**, the true neck and tail of tadpole being absent.
- Because frogs have eyes and nostrils on the top of their head, they can see and breathe while the rest of the body is under water.
- Frogs have smooth skin and long legs to help them leap.
- **Skin** of frog **consists of two types of glands**: **mucous** and **poison glands.**
- Both glands are the **derivative of epidermis** but lying in the dermis.
- The **mucous glands** secretes a colourless watery fluid (mucous) that keeps the skin moist, glistening and sticky, whereas the **poison gland** secrete a mild poison for protecting the animal from the enemies.
- Skin of frog forms a **chief respiratory organ** as its moist surface brings about an exchange of respiratory gases in between the body of the animal and the environment.
- Being devoid of sweat glands, **skin of frog acts as an excretory organ** as the shedding of stratum corneum helps in removing the excretory wastes.
- Skin of frog larva produces certain enzymes (called **hatching enzymes**) which dissolves the egg membrane and help in hatching.
- **Exoskeleton is absent** is frog.
- Frog's endoskeleton is made by bones and cartilage. But in **tadpole larva** the **entire skeleton is cartilaginous**.
- The **skull** of frog is **dicondylic** and consists of the following regions - cranium, olfactory capsule, auditory capsules, orbits, upper jaw, lower jaw and hyoid apparatus.
- The skull of frog is **platybasic** *i.e.,* an inter-orbital septum is absent and cranium extends beyonds orbits.
- **Cranium is made by 6 bones** and divisible into 3 regions - **occipital region, fronto-parietal region** and **ethmoid region.**
- **Occipital region** is formed by two irregular exoccipital bones (replacing bones) which are present on either side of the foramen magnum.
- The **roof of the cranium is constituted by two fronto-parietals** fusing in the middle line forming compound bones (In tadpole stage **these two bones are distinct**).
- The **floor of the cranium** is covered by a median dagger shaped or inverted T-shaped bone called **parasphenoid.**
- **Sphenethmoid**, a ring shaped girdle bone **surrounds the anterior part of the cranium** and is **divisible into an anterior ethmoidal portion** and **a posterior sphenoidal portion**.
- **Auditory capsule** consists of **pro-otic bone** (saddle shaped cartilage bone) in the anterior face, **columnella auris** (derived from hyomandibular) and **stapedial plate** (cartilage) in the middle ear.
- Auditory capsules **communicates by fenestra ovalis.**
- **Fenestra ovalis** is the opening of pro-otic bone in which the columnella auris fits in.
- **Olfactory capsule** consists of ethmoidal portion of sphenethmoid, paired nasal, vomers and septomaxillaries.
- **Nasals** are large triangular bones covering the roof of olfactory capsules.
- **Vomers** form the floor of the olfactory capsules, bearing about seven vomerine teeth in the posterior margin of each bone.
- **Septomaxillaries** are a pair of small irregular bones bounding external nares. Each consists of a basal plate, small limb and a large limb.
- **Upper jaw** consists of **premaxilla** (anterior most bone of upper jaw with four to five teeth), **maxilla**

(side bone of upper jaw with four to five teeth) and **quadratojugals** (coma shaped, small slender bone of posterior outer margin of upper jaw).

- **Quadrate cartilage** is found at angle of jaw. **It is attached to lower jaw through autostylic suspensorium**.
- **Three pairs of suspensoria bones** connecting upper jaw with cranium are : **palatines, pterygoids** and **squamosals.**
- **Lower jaw** consists of **mento-meckelian** (found at the tip of lower jaw), **dentary** (outer surface of anterior half of jaw), **angulo-splenial** (3 pair of bones, at the inner surface and lower edge of the jaw) and **Meckel's cartilage** (found at the articular surface).
- **Teeth** are **entirely absent in the lower jaw** of frog.
- **Hyoid apparatus** lies in the floor of buccopharyngeal cavity and **provides attachment and support to the tongue**.
- Hyoid apparatus consists of **body** (a cartilaginous plate), **alar processes** (also called anterior process 'wing like'), **posterior processes** (present in posterior lateral margin), **anterior cornua** (two long processes articulating with auditory capsule) and **posterior cornua** (two short processes, replacing bones).
- Frog has total **ten vertebrae** including **urostyle**.
- **First vertebra** is called **atlas** with reduced centrum and without pre-zygapophyses and transverse processes.
- **2nd to 7th vertebra have same structure**, called **typical vertebrae**, characterized by **procoelous** condition, **centrum concave in front and convex behind**.
- **8th vertebra** is **amphicoelous** as the centrum is biconcave.
- **9th vertebra** is **acoelous** as the centrum is convex on both the sides.
- 9th vertebra is also called **sacral**, its transverse processes are backwardly directed and articulated with ilium of pelvic girdle (**sacroiliac joint**).
- **Urostyle** is the **10th vertebra**, as long as remaining vertebral column.
- Urostyle has dorsal keel or crest or ridge.
- Spinal cord in frog extends up to the anterior part of urostyle.
- **Ribs are absent in frog**, so sternum (also called breast bone) articulates directly with the pectoral girdle.
- Sternum of frog has **four parts** : **episternum** (anterior flattened circular cartilage), **omosternum** (inverted 'Y' shaped cartilage bone articulated with clavicles), **mesosternum** (rod-like cartilage bone articulated with epicoracoids), **xiphisternum** (terminal circular cartilage).
- **Vertebral column terminates** by **urostyle** in frog, **coccyx** in man and **pygostyle** in bird.
- Each half of **pectoral girdle** consists of **suprascapula** (a calcified cartilage), **scapula, coracoid, precoracoid, epicoracoid** and **paraglenoid cartilage.**
- **Clavicle** is a slender rod, separated from the coracoid by a wide gap called coracoid foramen.
- In between the coracoid and clavicle a big space is present. It is called **coracoid fenestra** or **coracoid fontanella.**
- In frog the **pelvic girdle** is V-shaped and composed of two similar halves called **os-innominatum.**
- Each *os-innominatum* is **composed of 3 bones-ilium** (greatly elongated and forms the major part), **pubis** (smallest, triangular calcified cartilage) and **ischium.**
- The **bones of forelimbs** includes **humerus**, **radio ulna** and **the bones of hand**.
- There are **four digits in forelimbs** and **five digits in hindlimb**.
- The bones of hindlimbs includes **femur, tibiofibula, astragalus, calcaneum** and **bones of foot.**
- **Tibio fibula** is the **longest bone** in frog.
- Tibio fibula **forms knee joint** with femur.
- Digital formula of forelimb and hindlimb are **0, 2, 2, 3, 3** and **2, 2, 3, 4, 3** respectively.
- The **digestive system** of frog shows two parts– food catching organ, the **alimentary canal** and the **digestive glands**.
- **Alimentary canal** consists of mouth, buccopharyngeal cavity, oesophagus, stomach, duodenum, ileum, rectum, and anus which opens out by cloaca.
- **Digestive glands** include **liver**, **pancreas** and the **glands of gut wall**.
- **Salivary glands are not present in frog**.
- The **buccopharyngeal cavity** is bounded by upper and lower jaws. At the floor of the cavity, there is a sticky tongue. It is useful to catch the prey.
- The **teeth** are **pleurodont, homodont** and **polyphydont** type. There are also a pair of

vomerine teeth. Teeth are useful only to avoid the escape of the prey.

- **Oesophagous** is **very short due to absence of neck**.
- The **food taken by frog** includes proteins, fats, carbohydrates, vitamins and mineral salts.
- Frog is **carnivorous** in its feeding habit and feeds on small insects, spiders and earthworm which are caught by throwing out the extensible sticky mucous coated tongue.
- Digestion starts in the stomach by the action of gastric juice. Food is completely digested in the intestine by the action of pancreatic juice and succus entericus.
- The end products of digestion are aminoacids from proteins, glucose from carbohydrates, fatty acids and glycerol from fats.
- Digested food is absorbed by villi of intestine and undigested food is sent out through cloaca.
- Frog respire by means of **cutaneous respiration** (skin), **buccopharyngeal respiration** (buccopharyngeal cavity), and **pulmonary respiration** (lungs).
- In frog, **diaphragm is absent** and is **not related with respiration**.
- Contraction of **sternohyal muscle** during breathing **lowers floor of oral cavity**.
- Contraction of **petrohyal muscle** during breathing **raises the floor of buccal cavity**.
- **Epithelial lining of the alveoli** of frog's lung **facing lung cavity is columnar and ciliated**.
- During pulmonary respiration of frog, **mouth remain closed**.
- In frog, glottis is controlled by muscles of **arytenoid cartilages**.
- The **lungs** of frogs are **not only the organs of respiration** but also an **hydrostatic organ** as they enable frog to float in water when they are inflated.
- In frog **cutaneous respiration takes place always**, therefore frog dies if the skin dries up as the cutaneous respiration is impaired.
- During severe cold winter frog will go for **winter sleep** or **hibernation.**
- During winter sleep lung breathing is stopped, while skin breathing continues which suffice the need of oxygen.
- During severe summer frog will go for **summer sleep or aestivation.**
- In this state it performs minimal metabolic activities, minimal cutaneous respiration and excrete uric acid.
- The **spring and rainy seasons** are the **periods of great activity for the frogs**.
- The **circulatory system** of frog shows **blood vascular system** and **lymphatic system**.
- The **life span of RBC** in frog is **100 days.**
- The heart of frog is **three chambered with two auricles and one ventricle**. It is enclosed in double walled pericardium. Two additional chambers are also present, these are **- sinus venosus** and **truncus arteriorus**.
- The **circulation can be described as incomplete double circulation**. The blood is pumped to various parts of the body by arteries which constitute the arterial system. Various veins of the venous system collect the blood and bring it to the heart.
- The **portal system** is **well developed** with both hepatic and renal portal systems.
- The **hepatic portal system** has much significance by taking the end products of digestion first to the liver.
- The **renal portal system** is significant by taking the impure blood to the kidney where it is filtered even before it reaches the heart.
- The **lymphatic system** is closely associated with blood vascular system.
- The lymphatic system consists of **lymph capillaries**, **lymph vessels**, **lymph hearts** and **lymph sinuses**.
- A colourless fluid called **lymph** flows through the lymphatic system.
- Lymph **acts as middle man** between vascular system and tissue fluids.
- **Spleen** is the **largest lymphatic gland**.
- At the base of the internal carotid artery of frog carotid labyrinth is present. It **work as chemo- and baroreceptor.**
- The sequence of heart contraction in frog are sinuous venousus, auricles and ventricles.
- The frog has a **highly developed nervous system**. It consists of **brain, a spinal cord** and **nerves**.
- Frog has **ten pairs of cranial nerves** arises from brain (olfactory, optic, oculomotor, trochlear, trigeminal, abducens, facial, auditory, glossopharyngeal, vagus) and **10 pairs of spinal nerve**.
- Frog shows **monocular visions** as the two eyes are situated far away from each other over the head and their images also do not coincide.

- Frog eye has **no power of accommodation**.
- **Harderian gland** present at the inner angle of the eye, produces oily secretion, which lubricate the eye ball and nictitating membrane.
- The **external ear is absent** in frog. Both ear drums or tympanic membrane are exposed. These is **only bone in the frog's middle ear**.
- In frog the **excretory system and reproductive system are intimately associated**. So these two systems are together referred as **urinogenital system**.
- The **excretory system** consists of a pair of kidneys, a pair of ureters, the urinary bladder and cloaca.
- Each kidney consists of a large number of excretory units called uriniferous tubules or nephrons.
- The nephron is divisible into two parts namely the **malpighian capsule** and **nephric tubule**.
- The malpighian capsule is the **filtration unit of excretory system** and the nephric tubule is **useful for secretion and selective reabsorption**.
- The **main excretory product** in frog is **urea**.
- The urea along with some unnecessary salts and water is collected into the urinary bladder in the form of urine. It will be stored there for some time and is sent out through cloaca. So frog is described as **ureotelic animal**.
- **Excretory product of tadpole larva** is **ammonia**.
- Kidneys are **pronephros** in tadpoles and **mesonephric in adult frog**.
- Frog shows **sexual dimorphism**. Male frog shows **vocal sacs** and **nuptial pads**.
- **Vocal sacs** are present at the junction of two jaws on the ventral side of the head.
- Vocal sacs are **resonators of the sounds and produce croaking sound**.
- **Amplexusory pads** or **nuptial pads** are **present on the index finger of the forelimb**.
- These pads **help male animal to clasp the female firmly during copulation**.
- The forelimbs of frogs are short and hindlimbs of frogs are long. Long hind limbs help in **leaping**.
- Neck is absent in frog as an aquatic adaptation.
- The posterior end of trunk of frog show cloacal aperture.
- In frog testis is attached to the kidney by **mesorchium** (peritoneal layer).
- In adult male toad **bidder's organ** is present. If testes are removed bidder's organ will become ovary.
- The **mass of sperms** liberated by male frog is called **milt**.
- The **mass of eggs liberated by female frog** is called **spawn**.
- In frog **fertilization is external**.
- Zygote undergoes cleavage and develops into morula and blastula. **The cleavage is holoblastic and unequal**.
- The blastula changes into gastrula by **epiboly**, **modified invagination** and **involution**.
- The gastrula has three germ layers which further differentiate and give rise to various organs.
- The **life history of frog includes** three stages - **egg, larva and adult**.
- The **tadpole undergoes metamorphosis** to become the adult. The **metamorphosis is complete**. Finally the aquatic gill breathing, herbivorous, fish like tadpole transforms into an amphibious, lung breathing, carnivorous adult frog.
- **Thyroxine controls the metamorphosis** in frog.
- The **tail of tadpole** is the **locomotory organ**.
- During metamorphosis the tail is absorbed by **auto-phagocytosis.**

RABBIT (*Oryctolagus cuniculus*)

- *Oryctolagus cuniculus* or the rabbit is a **fossorial, nocturnal**, **herbivorous**, and **polygamous animal**.
- Rabbit is **crepuscular**(that is coming out of burrows for feeding in twilight chiefly at dawn or dusk), **timid**, **can be domesticated**.
- Its body is **pointed anteriorly** and **broad posteriorly** which is covered with fur and hairs.
- The rabbit are **gregarious** in habit *i.e.* they live in groups and even several families consisting of hundred of rabbits may live in one burrow.
- The body is divided into **head, neck, trunk** (which is **divided into thorax and abdomen**) and **tail**.
- **Head** is large, pear shaped, distinct and anterior pointed blunt snout has a terminal, transverse slit like **mouth**, which is divided into left and right equal halves due to a vertical cleft, which continues upto the nostrils. Such divided lips are known as **hare lip**.
- Due to hare lip **front incisors are exposed**.
- From the sides of upper lip thick tactile hairs or **vibrissae** or **whiskers** project outward.
- **Vibrissae** are stiff, long and sensory in function because they have nerve ending at their base.

- **Nictitating membrane** is present in the inner corner of the eye, which is movable and used for cleaning cornea.
- Just above the mouth, large, oblique slit like, olfactory **nostrils** are present which is **respiratory in nature.**
- Ear opening is surrounded by movable pinna. Tympanic membrane is sunken at the base of external auditory meatus.
- Vocal sacs are **absent**.
- **Neck** is short, flexible and well demarcated from head and trunk.
- **Trunk** is differentiated into **anterior thorax** and posterior **abdomen** which is covered with hairs.
- Paired forelimb and hind limbs are present. Forelimb bears **5 clawed digit adapted for digging the burrow**. Hind limb **bears 4 clawed digit**, which is **adapted for walking and leaping**.
- On the ventral side between thorax and abdomen 4-5 pairs of teeths or nipples are present which are functional in female only.
- Separate anus and urinogenital opening present at the hind end.
- Short, bushy, curved upward tail is present. Tail is **used for giving warning, signals, when danger approaches** and **as balancer during leaping**.
- A female reaches maturity at the age of **6 months** only and average **life span to about 8 years**.
- At the time of birth the young are blind, deaf, naked (hairless) and helpless. They are fed on milk by mother who shows parental care.
- They show **coprophagy** or **rejection**, by eating their soft night doppings without mastication, so the same food passes twice through gut to provide maximum nourishment.
- **Skin** of rabbit is made of **epidermis** and **dermis.**
- **Epidermis** is highly stratified. Stratum corneum is composed of hard, scale-like, dead, fully, keratinized flattened cells.
- The complex epidermis is primarily made of two zones–the deep **malpighian layer** and the superficial **cornified layer**.
- **Malpighian layer** is further divided into **stratum germinativum**, **stratum spinosum** (also called **prickle cell layer**), **stratum granulosum** and **stratum lucidum**.
- The outermost cells on the skin surface are **thin dead and fully keratinized.**
- **Stratum granulosum** contains basophilic and refractile **keratohyaline** granules.
- In **stratum lucidum**, keratohyaline granules are dissolved and transformed into **eleidin** which makes cells semitransparent, shiny and waterproof.
- In **stratum corneum**, eleidin is replaced by **keratin,** a scleroprotein which is insoluble in water.
- When keratin is synthesized in a cell, the cell is said to be keratinized or cornified and it dies.
- The cells of stratum corneum are **non-living, flattened**, **keratinized without nuclei.**
- Presence of dead dry cornified cells of stratum corneum helps to **prevent evaporation of water from its surface**.
- **Dermis** is thickest, consists of connective tissue fibres, unstriped muscles, blood capillaries, nerves, fat cells, tactile receptors and pigment cells.
- Deeper part of the dermis is composed by subdermal **adipose tissue** or **panniculus adiposes**.
- It is concerned with **storage of fat.**
- Pigment granules are present in the hairs. **Pigment cells found** in the **basal layer of epidermis.**
- Skin is **highly glandular** due to presence of sweat glands, sebaceous glands, mammary glands and scent glands, but **mucous gland is absent**.
- Skin or integument **serves a variety of important functions** like it gives shape, protection, defence, homoiothermy (maintenance of a fairly constant body temperature), synthesis of vitamin D, excretion, secretion, sexual selection etc.
- The **skull** of rabbit consists of two main regions– **posterior cranial region** and **anterior facial region**.
- Three segments of cranium are : **occipital segment, parietal segment** and **frontal segment**.
- There are **four bones in occipital segment** surrounding foramen magnum: **supraoccipital** (1), **exoccipitals** (2) and **basioccipital** (1).
- The skull of rabbit is **dicondylic with two occipital condyles**.
- There are **five bones in parietal segment**. They are **parietals** (2) in the roof, **alisphenoids** (2) in sides and **basisphenoid** (1) in the floor.
- A depression called **"sella turcica"** is on the basisphenoid **to lodge pituitary gland.**
- There are **five bones in frontal segment**. They are **frontals** (2) in the roof, **orbitosphenoids** (2) in sides

and **presphenoid** (1) in the floor.

- An **ethmoid bone** (cribriform plate) perforated with many small holes closes the cranial cavity in front.
- Auditory capsule consists of **periotic bone** and **tympanic bulla**.
- **Periotic** is a compound bone formed by the fusion of **pro-otic**, **epiotic** and **opisthotic**.
- Periotic is **located between squamosal and occipital ring**.
- **Tympanic bulla** is a flask-shaped bone applied to outside of periotic between the basisphenoid and squamosal.
- Tympanic bulla encloses tympanic cavity or middle ear containing tympanic membrane and a chain of the 3 ear ossicles, which from outside are **malleus, incus** and **stapes**.
- **Stapes** is the **smallest bone in the body**.
- Ear ossicles are **concerned with hearing.**
- Periotic consists of **two parts** : an internal hard bony **petrous part** enclosing internal ear, and a posterior light and **porous mastoid part**.
- **Orbits** are situated on the sides of frontal segment of the cranial region.
- The skull of rabbit is **tropibasic**, *i.e.*, an inter-orbital septum is present.
- The front wall of each eye orbit contains a small bone called **lachrymal** having a notch for tear duct.
- **Facial region** consists of **bones of olfactory capsule** and **jaws**.
- **Olfactory capsule** consists of **nasals** in the roof, **vomer** in the floor (median formed by the fusion of two), **premaxillae** and **maxillae** at the sides.
- **Mesethmoid** or **internal septum** separates two nasal chambers.
- Each olfactory or nasal chamber encloses an irregular mass of **turbinal** or **scroll bone**.
- Scroll bones help in **increasing the sensory surface of olfactory chamber**.
- The **upper jaw** consists of the following bones: premaxilla, maxilla, palatine, pterygoid, squamosal and jugal.
- Each ramus of lower jaw is made up of a single **dentary**.
- Dentary has a conspicuous **condyle**, **coronoid process** and **angular process**.
- Teeth in each dentary are **incisor (1), premolars (2)** and **molars (3)**.
- The **jaw suspensorium** in rabbit is **craniostylic** *i.e.*, lower jaw articulates with upper jaw by squamosal.
- Main part of the body of **hyoid apparatus** located beneath and supporting root of tongue, is called **basihyal**.
- Vertebrae of mammals are **acoelous** or **amphiplatyan**.
- Total number of vertebrae in rabbit varies from **45 to 47**.
- The vertebral column in divisible into **five regions**, namely– **cervical, thoracic, lumbar, sacral** and **caudal**.
- Vertebral formula of rabbit is $\mathbf{C_7T_{12\text{-}13}L_{6\text{-}7}S_4Cd_{16}}$.
- The first cervical vertebra is **atlas**. **Centrum** is **absent**. It is articulated to skull through occipital condyle, **zygapophyses** are **absent**. **Odontoid fossa** are **present**.
- Second cervical is the **axis**. It has **odontoid process**.
- All cervical vertebrae except 7th possess **vertebrarterial canals** for the passage of cervical blood vessels and nerves.
- In **between the centra**, there are **intervertebral discs of fibrocartilage**.
- The central portion of the vertebral disc is called **nucleus pulposus** which represents the remnant of notochord in the adult.
- Sternum of rabbit consists of **seven sternebrae**, and a **xiphoid cartilage**.
- Sternum is composed of **seven rod-like pieces**.
- The **first piece** is called **pre–sternum** or **manubrium**.
- Remaining five sternebrae constitute **mesosternum** (**gladiolus**).
- This is followed by rod-like last sternebra **metasternum**. Metasternum terminates in an expanded plate of cartilage, the **xiphisternal cartilage** or **xiphoid cartilage**.
- There are **12 or 13 pairs of thoracic ribs** present in a rabbit.
- **Three types of ribs** in rabbit are : **true ribs** (1st to 6th pair); **false ribs** [7, 8 and 9th pair (3 pairs)]; and **floating ribs** [10, 11 and 12th pairs (3 pairs), not attached to sternum].
- Vertebral rib is **bicephalous** (with two heads). It is articulated to thoracic vertebra by tuberculum to transverse process and by capitulum to centrum.
- **Pectoral girdle** of rabbit consists of two bones, a membranous bone called **clavicle** and a large replacing bone called **shoulder blade** or **scapula-coracoid**.

- Dorsal or vertebral edge of scapula is made of a thin strip of cartilage, the **suprascapula**.
- A **glenoid cavity** for articulation of head of humerus is present at the tip of scapula and coracoid process. Clavicle is articulated with **acromian process.**
- **Pelvic girdle** of rabbit is **W-shaped**. Each half consists of four bones namely **ilium, ischium, pubis** and **cotyloid**.
- A **small cotyloid bone** is present on the inner side of acetabulum between ilium and ischium.

Cotyloid bone (acetabular bone) is **not found in the pelvic girdle of frog.**

- In rabbit, a ninth carpal may be present called **pisciform, sesamoid bone.**
- In rabbit, there are **five digits** in forelimb and **four digits** in hindlimb.
- Digital formula of **forelimb** is **2, 3, 3, 3, 3.**
- Digital formula of **hindlimb** is **0, 3, 3, 3, 3.**
- Rabbit has **no hallux**.
- **Femur** is the **longest** and **stoutest bone** of the body in a mammal. Proximally it bears a **head, greater trochanter, lesser trochanter** and **third trochanter**.
- The proximal end of tibia bears a small sharp ridge called **cnemial crest**.
- Proximal part of humerus bears a slight **deltoid ridge** and distally it bears a pulley like **trochlea**.
- Above trochlea are present **supratrochlear foramen** and **olecranon fossa.**
- The **digestive system** of rabbit consists of **alimentary canal** and **digestive glands.**
- The various parts of alimentary canal are **mouth, vestibule, buccal cavity, pharynx, oesophagous, stomach, small intestine, caecum, large intestine** and **anus**.
- **Dental formula** of a rabbit is **2033/1023**.
- Total number of teeth in rabbit is **28**.
- Number of teeth in upper jaw of rabbit is **16** and **12** in the lower jaw.
- Rabbit has no **canine teeth**, it is **herbivorous**.
- In rabbit, teeth are **heterodont, diphyodont** and **thecodont**.
- The **mouth** of the rabbit is a transverse slit-like terminal aperture situated at the snout.
- The mouth opens into a large spacious **buccal cavity** between the jaws.
- The **tongue** in its dorsal surface bears numerous papillae containing taste buds.
- The buccal cavity merges behind into a short, narrow chamber, the **pharynx**.
- A soft palate divides the pharynx into **3 parts** as **nasopharynx** lies dorsal to the soft palate, the **oropharynx** below the soft palate, and both communicate behind with the **laryngopharynx**.
- The floor of laryngopharynx carries a median verticle slit, the **glottis** leading into the **larynx**.
- Larynx is guarded by a bilobed thin cartilaginous flap or tissue, the **epiglottis**.
- The laryngopharynx leads posteriorly into the oesophagus through a wide aperture, the **gullet**.
- **Oesophagous** is a long narrow, elastic and muscular tube. Its inner wall has several longitudinal folds.
- The **stomach** is differentiated into **three regions**: a broad **cardiac region** into which oesophagus opens, a narrow **pyloric region** which leads into the duodenum and the third part is situated in between cardiac and pyloric regions called **fundic region**.
- Small intestine following stomach made of three parts– **duodenum, jejunum** and **ileum**.
- Large intestine consists of two regions– **colon** and **rectum**.
- At the junction of ileum and colon a wide about 50 cm long, thin walled tube, the **caecum** is present.
- **Rectum** opens outside through anus, situated at the base of tail and guarded by **anal spincter**.
- Rectum of rabbit is the narrow terminal part with the faecal pellets present inside which gives it a **beaded appearance**.
- Distally caecum terminates in a small, about 15 cm long narrow thick walled blind tube, the **vermiform appendix**.
- The caecum is very **large** and **spacious in herbivores** such as rabbit, horse and ass.
- Caecum of rabbit is thin wall tube with peculiar external spiral constriction, which marks the presence of an internal spiral valve.
- **Digestion of cellulose** in rabbit takes place in caecum (stomach in ruminants).
- The various **salivary gland** of rabbit are **parotid gland** (situated at the base of pinna), **submandibular gland** (situated on the inner side of the angles of lower jaw); **sublingual glands** (situated below the tongue) and **infra–orbital glands** (situated below the orbit).
- **Liver of rabbit** is partly **divided into 5 lobes** : three

lobes on left side are a small **spigelian, left lateral** and **left central**, while two lobes on the right side are **caudate** and **right central** or **cystic**.

- The cellulose in the diet of rabbit remains undigested, for which it passes in the caecum. Thus the digestion of cellulose occurs in the caecum which is well developed in rabbit and herbivorous mammals.
- Cellulose decomposing bacteria and protozoans are **found in the caecum**, where it is decomposed to soluble sugars.
- Rabbit feeds on night excreta (**coprophagy**) which is moist and soft for the digestion of remaining cellulose.
- **Respiratory system** of rabbit consists of nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles and alveoli.
- A cartilaginous partition called **mesethmoid** separates the right and left nasal passage or respiratory passage.
- The respiratory passage is lined by richly vascularized, ciliated, mucous secreting epithelium.
- Respiratory passage performs the function of warming the air before entering into trachea and lungs; filtering air etc.
- **Lungs** are the **sole respiratory surface** in rabbit and are **without central cavities**.
- Lung is divided into **two lobes**-right and left lung.
- **Right lung** is divided into **four lobes** while **left lung** into **two lobes**.
- The **larynx or voice-box** is the **sound producing organ** of rabbit which is a modified anterior part of the trachea.
- The larynx leads into the trachea which is a long tube **supported by a series of incomplete rings of elastic cartilage**.
- The larynx is supported be **four cartilages**.
- The largest shield-shaped and most anterior is the **thyroid cartilage** which supports the larynx ventrally and is incomplete dorsally. Just a bit posterior to it is a ring-like **cricoid cartilage** which is broad on the dorsal side but narrow ventrally.
- A pair of **arytenoid cartilages** are situated at the anterior end of the dorsal side of the cricoid.
- There is also a pair of small nodules the **cartilages of Santorini**.
- Rabbit **does not produce audible sound.**
- **Trachea** is **lined with a pseudostratified ciliated epithelium** and **helps in pushing mucous out.**
- Even there is no air in trachea, it **does not collapse due to presence of C-shaped narrow cartilaginous rings.**
- Larynx of rabbit **acts as a valve for controlling the movement of air and organ for producing low pitched sound.**
- The **mechanism of breathing** consists of intake of fresh air into the lungs **(inspiration)** and elimination of respired air from the lungs **(expiration)**.
- **Inspiration** is an **active process** during which firstly the **external intercostal muscles** contract dragging the ribs forwards and downwards and the sternum is moved downwards.
- **Gaseous exchange takes place in the alveoli** where inspired air comes in contact with the blood capillaries.
- Oxygen from the air diffuses in the blood and CO_2 from the blood diffuses out in the air through the thin alveolar wall.
- **Expiration** is more or less a passive action during which internal intercostal muscles contract, thereby the ribs and sternum attain their normal position.
- Ribs, intercostal muscles and diaphragm are **helpful in pulmonary respiration.**
- The respiratory pigment **haemoglobin,** present in RBC of rabbit, plays a pivotal part in the transport of O_2 from blood to tissue and of CO_2 from tissue to blood.
- **Scroll like bones** are present in the cavity of nasal passage which are called **turbinals**.
- There are three such structures called **naso-turbinals, ethmo-turbinals** and **maxillo-turbinals**.
- In rabbit, there is **no sexual difference pertaining to ventilation movements** in male and female as observed in human.
- **Blood vascular system** of rabbit is of **closed type**.
- The **blood vascular system** of rabbit consists of a circulatory media called the **blood**, channels through which the circulatory media flows called **blood-vessels** and a central pumping organ, the **heart** which pumps the circulatory media in the blood vessels.
- The **lymph hearts are not found in rabbit**, therefore the lymph flows in the lymph vessels with the help of body muscles.
- Mature RBC of rabbit are **biconcave, enucleate, contain haemoglobin** and **contain antigens on their plasmalemma.**

- RBC have a **short life**.
- Fragile, weak, senescent and abnormal RBC are phagocytised by **spleen cells** which is aptly called the **'grave yard' of RBC.**
- **WBC** are **nucleated**, fewer in number as compared to RBC, **devoid of pigment and are motile** (by pseudopodia).
- **Heart** of rabbit is **4-chambered** and is enclosed by a double walled **pericardium**.
- The **pericardial cavity** present between the outer parietal and inner visceral pericardium is filled with **pericardial fluid** and **protects the heart from external shocks, lubricates it to facilitate smooth systolic and diastolic movement.**
- The **heart muscles** (=cardiac muscles) are **striated** but **involuntary**. They consists of outer **epicardium**, middle **myocardium** and inner **endocardium**.
- Rabbit **does not have sinus venosus** which is incorporated in the wall of right auricle. The **truncus arteriosus is also absent**.
- The two aorta–the pulmonary and systemic **arise directly and separately from the ventricle.**
- The **eustachian valve** is present between the openings of 2 pre-cavals and **thebesian valve** (form a crescentic fold) bounds the opening of left pre-caval.
- The **ventricles** are **thick-walled and muscular** as compared to atria.
- The left ventricle is **larger and more muscular than the right ventricle.** This difference is due to the fact that left ventricle pumps blood to all parts of the body while the right provides the propulsive force to drive the blood only to lungs.
- The longitudinal ridges present on the surface of ventricle is called **columnae carnae** which extends into the ventricular cavity.
- **Papillary muscles** are conical muscular projections on the walls of ventricles.
- The opening between the right auricle and right ventricle is guarded by **tricuspid** (tri = 3, cusp = flaps) **valve**, while the one between left auricle and left ventricle is guarded by **bicuspid or mitral valve**.
- The rate of heart beat in rabbit is **210/min**. Each heart beat consists of a contraction (systole) and relaxation (diastole).
- The systole **creates the necessary pressure to push the blood**, while diastole **facilitates refilling**.
- In rabbit the oxygenated and deoxygenated blood flows *via* different channels (circuits). The blood during its complete circulation passes through heart twice and hence this is called **double circulation**.
- The **blood vessels** in rabbit is a system of closed channels through which blood flows.
- The wall of blood vessel is typically made of three layers: **tunica externa; tunica media;** and **tunica interna.**
- Arteries carry blood **away from heart**. They are **stronger** and **thicker than veins.**
- The **largest artery** in the body is **aorta.**
- Both pulmonary artery and renal artery have a **thick muscular coat as compared to the respective veins.**
- **Capillaries** are the **smallest blood vessels** in the body.
- Capillary has **no muscular wall**. Its wall is made of a single layer of flat **endothelial cells** and is consequently very **permeable to water and small solutes**, but **not to proteins and other macromolecules**.
- One **major difference between an artery and vein** is that vein has a **thin muscular wall**.
- Veins **contain valves to prevent backflow of blood.**
- Weak valves can lead to **varicose veins or haemorrhoids.**
- All veins **carry deoxygenated blood except pulmonary veins**. Pulmonary veins carry pure blood from lungs back to heart.
- Renal portal sysem is **absent in mammals**, only **hepatic portal system is present.**
- **Nervous system** of rabbit consists of **central nervous system** (brain and spinal cord); **peripheral nervous system** (cranial and spinal nerves) and **autonomic nervous system** (sympathetic and parasympathetic nervous system).
- **Brain** lies in the cranial cavity of the skull surrounded by **3 meninges: duramater** (outer), **arachnoid** (middle) and **piamater** (inner).
- The brain of rabbit can be divided into three regions: (a) the **fore-brain** (or **prosencephalon**), (b) the **mid-brain** (or **mesencephalon)**, and (c) the **hind-brain** (or **rhombencephalon)**.
- Fore brain consists of **olfactory lobes**, **cerebral hemispheres** and **diencephalon**.
- **Olfactory lobes** are **responsible for controlling the organs of smell.**

- The **cerebral hemispheres** (or **telencephalon**) are **well developed** and form about **2/3 of the whole brain**.
- **Corpus callosum** is a thick whitish band of semicircular nerve fibres interconnecting two cerebral hemispheres (found only in mammals).
- **Genu** is a small front part and **splenium** is the posterior part of corpus callosum.
- **Corpus striatum** is found in the floor of cerebrum.
- **Diencephalon** is a small and narrow posterior part of the forebrain.
- Diencephalon is dorsally overlapped by cerebral hemispheres except for **epiphysis or pineal body**.
- **Corpus albicans** is the **swollen part of pituitary stalk.**
- **Midbrain** of rabbit **consists of four optic lobes** (= **corpora quadrigemina**).
- Optic lobes are solid and **optocoels are absent**.
- **Crura cerebri** or **cerebral peduncles** are two thick fibrous white matter tracts on the ventral and lateral regions of midbrain.
- **Hindbrain** includes **cerebellum and medulla oblongata**.
- **Cerebellum** has five lobes namely a median **vermis**, **two laterals** and two **flocculi**.
- The anterior ventral part of cerebellum forms **pons varolii**.
- **Arbor vitae** is a branched tree-like structure composed of white matter, seen in the section of cerebellum.
- Cavity in olfactory lobe is known as **rhinocoel.**
- **Ventricles I and II** are called as **paracoels** or **lateral ventricles**.
- **Ventricle IV** is the **metacoel**.
- **Foramen of Monro** connects lateral ventricles with diocoel.
- Cavity of midbrain called **iter** or **aqueduct of Sylvius communicates diocoel with fourth ventricle of hindbrain.**
- **Optocoels** are **present in frog** but **absent in rabbit.**
- **Formamen of Magendie** is the aperture present in the roof of fourth ventricle or metacoel.
- **Foramina of Luschka** are present on the lateral wall of metacoel.
- Foramen of Magendie and foramina of Luschka "three holes" **permit cerebrospinal fluid to flow out** into the subarachnoid space from metacoel.
- The medulla oblongata **exits from the skull *via* foramen magnum** and becomes spinal cord which extends to the trunk region of the rabbit.
- Spinal cord in rabbit **extends upto 4th lumbar vertebra.**
- **Filum terminale** is the terminal non-nervous part (made of only piamater) of spinal cord in the lumbar region.
- **Cauda equina** (horse-tail) is the tail-like collection of roots of spinal nerves at the posterior end of spinal cord.
- In spinal cord, **white matter** is found outside the **gray matter** (reverse in brain).
- Internally the spinal cord consists of a **neurocoel** which is continuous with the metacoel of brain.
- Neurocoel is lined by **ependymal epithelium** and **filled with cerebrospinal fluid.**
- Rabbit has **12 pairs of cranial nerves** just like all other amniote vertebrates (anamniotes have 10 pairs).
- These nerves are of 3 **types** (a) **sensory,** e.g. olfactory, optic, auditory (b) **motor,** e.g. oculmotor and (c) **mixed** *i.e.* have both sensory and motor fibres.
- **Spinal nerves** of rabbit **arise from spinal cord** (in pairs) and **exit *via* intervertebral foramen** between the vertebra.
- Each spinal nerve arises from a dorsal root (sensory) and a ventral root (motor).
- The **spinal nerves** in rabbit are **37 pairs** which can be divided into five zones, *viz.,* **8 pairs cervical**, **12 pairs thoracic**, **7 pairs lumbar**, **4 pairs sacral** and **6 pairs caudal nerves**.
- The autonomic nervous system in mainly **responsible for controlling the involuntary activities of the body.**
- The sympathetic and parasympathetic nervous systems **work independently but opposite to one another.**
- Thus each visceral organ is supplied by a **sympathetic fibre** which **stimulates** the organ to start the function and a **parasympathetic fibre** which inhibits and stops the function.
- Sympathetic preganglionic motor fibres in **rabbit** occur only in its **thoracic** and anterior 3 pairs of **lumbar spinal nerves.**
- Total number of sympathetic ganglia in rabbit is **18 pairs.**
- Sympathetic nervous system **increases defence system of body against adverse conditions.** It is **active in stress condition, pain, fear and anger.**

- Parasympathetic provides **relaxation, comfort, pleasure at the time of rest.** It helps in the **restoration and conservation of energy.**
- The **hypothalamus** controls and integrates the autonomic nervous system.
- Sympathetic is **accelerator** by release of **adrenaline**.
- Parasympathetic is **inhibitor** by release of **acetylcholine**.
- Rabbit, like all other mammals has a wide variety of sensory organs which perceive diverse stimuli. The type of receptors are–
  - **Tactile** (touch) or **thigmoreceptor** [sensitive to touch (cutaneous)];
  - **Pressure receptor, baroreceptors** (Meissner's corpuscles);
  - **Olfactory sensilla** [in nasal epithelium (Jacobson's organ)];
  - **Gustatory sense organs** (taste buds present on tongue);
  - **Sensilla of common chemical sense** (detect deleterious chemicals and when stimulated give avoidance reaction);
  - **Proprioceptor** (present in stomach);
  - **Pain receptors** (present in skin).
- In rabbit all cutaneous receptors are naked. Vibroreceptors of rabbit are naked nerve ending present upon the follicles of vibrissae.
- The nictitating membrane in rabbit is a **vestigeal structure** and is called **plica semilunaris.**
- Rabbit exhibit **ureotelic excretion** *i.e.* its principal nitrogenous waste is **urea**.
- The **urinary** or **excretory** and the genital or **reproductive systems** are closely associated with each other, therefore, these systems are considered together and collectively known as **urinogenital system.**
- The excretory system consists of paired **kidney**; paired **ureter** (which open independently into the urinary bladder); **urethra**; and **urinogenital aperture** (which **acts as common passage for urine and sperm** in male and is present on the ventral aspect of glans penis. In female the **urethra opens into the vulva**).
- **Kidney** of rabbit is bean shaped, **metanephric**, measure 25 mm in length, dark pink in color.
- The right kidney is **usually larger than the left**.
- Both kidney are **convex on the outside** and **concave on the inner side.**
- A notch-like structure called **hilus** in present through which renal artery, nerves; lymphatic channels enter the substance of the kidney, and the renal vein and ureter exit.
- **Afferent arteriole** carries blood to glomerulus while **efferent arteriole** collects blood from it.
- The diameter of afferent arteriole is **much more than that of efferent arteriole.**
- In nephron Henle's loop is present **to concentrate the urine**.
- Rabbit manifests **sexual dimorphism.**
- **Male reproductive system** consists of **testis** [(= cytogenous gland), scrotal, and site of spermatogenesis and androgenesis]; **epididymis** (tripartite); **vas deferens**; **urethra**; **penis** and associated male genital glands includes **prostate gland** (major contributor of seminal fluid); **seminal vesicles** (= uterus masculinus); **Cowper's gland** (=bulbo-urethral gland); **perineal gland; rectal glands.**
- In rabbit, the testes are migratory *i.e.* present in scrotum **during breeding season** but are pulled up in abdominal cavity in the **non-breeding state.**
- Testicular sperm of rabbit transit *via* rete testis and vasa efferentia into epididymis.
- **Female reproductive system** of rabbit consists of **ovaries**, **fallopian or uterine tubes, vagina, urethra**, **vestibule**, **vulva**, accessory reproductive glands (include bartholin's, rectal and perineal glands.
- **Uterus** is **bicornuate** in rabbit.
- Rabbits are **polyestrous mammals**.
- The **ovulation** is of the **reflex (induced) type** and mating is pre-requisite for it.
- Fertilization of ovum is **internal** and occur **in the upper part of oviduct.**
- Rabbit has well **developed endocrine system** with **pituitary** as **master gland**.

End of the Chapter