

STRUCTURAL ORGANISATION IN ANIMALS

ANIMAL TISSUES

A group of cells having *same origin, structure and function* are called the **tissues**. Animal tissues are 4 types:

(i) Epithelial (ii) Connective (iii) Muscular (iv) Neural

I. EPITHELIAL TISSUE (EPITHELIUM)

- It has a **free surface** that faces **body fluid** or **outside environment**.
- **Covers** or **lines** body or body parts.
- Compactly packed cells with **little intercellular matrix**.
- Epithelial tissues are 2 types: **Simple** and **Compound**.

1. Simple epithelium

It is composed of a **single layer of cells**. It lines body cavities, ducts and tubes. Based on **structural modification of cells**, simple epithelium is 3 types:

o Squamous epithelium:

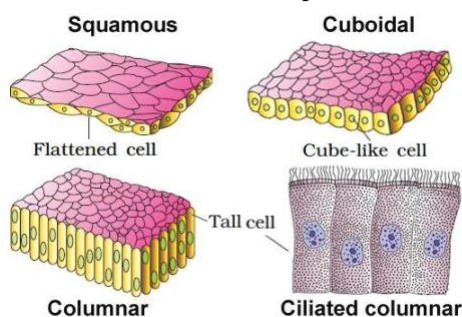
- Thin layer of flattened cells with irregular boundaries.
- Found in the walls of blood vessels and lung alveoli.
- **Functions:** Form a diffusion boundary.

o Cuboidal (cubical) epithelium:

- Composed of cube-like cells.
- Found in ducts of glands and tubular parts of nephrons.
- **Functions:** Secretion and absorption.
- The epithelium of **proximal convoluted tubule (PCT)** of nephron in the kidney has **microvilli**.

o Columnar epithelium:

- Composed of tall and slender cells.
- Their nuclei are located at the base.
- Free surface may have microvilli.
- Found in the lining of stomach and intestine.
- **Functions:** Secretion and absorption.



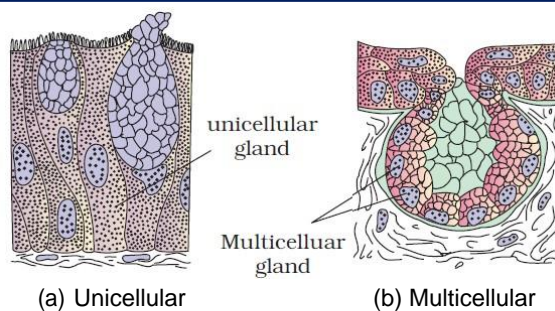
Modification of columnar or cuboidal cells

• Ciliated epithelium:

- Cells bearing **cilia** on their free surface.
- Present in the inner surface of hollow organs like **bronchioles** and **fallopian tubes**.
- **Functions:** To move particles or mucus in a specific direction over the epithelium.

• Glandular epithelium: For secretion. They are 2 types:

- **Unicellular:** Consists of isolated glandular cells. E.g. Goblet cells of the alimentary canal.
- **Multicellular:** Contains cluster of cells. E.g. salivary glands.

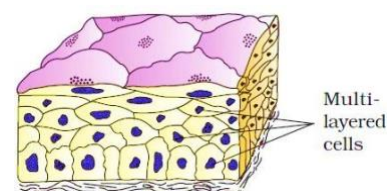


Based on mode of pouring of secretions, glands are 2 types:

- **Exocrine glands:** Here, secretions are released through **ducts (tubes)**. Exocrine glands secrete **mucus, saliva, earwax, oil, milk, digestive enzymes** etc.
- **Endocrine glands:** Ductless. They produce **hormones**.

2. Compound epithelium

- Made up of more than one layer (**multi-layered**) of cells.
- Limited role in secretion & absorption.
- They cover dry surface of **skin**, moist surface of **buccal cavity, pharynx, inner lining of ducts of salivary glands and pancreatic ducts**.
- **Function:** Protect against chemical & mechanical stresses.



Cell junctions: The junctions that provide structural and functional links between adjacent cells. They are found in epithelium and other tissues. They are 3 types:

- Tight junctions:** Help to stop substances from leaking across a tissue.
- Adhering junctions:** Perform cementing to keep neighbouring cells together.
- Gap junctions:** Facilitate communication b/w adjoining cells by connecting the cytoplasm for rapid transfer of ions, small molecules and sometimes big molecules.

II. CONNECTIVE TISSUE

- It links and supports other tissues/organs.
- They are most abundant in complex animals.
- All connective tissues except blood have **fibroblast** cells. They secrete structural fibrous proteins called **collagen & elastin**. They give strength, elasticity & flexibility to tissue.
- The cells also secrete modified polysaccharides (**matrix**), which accumulate between cells and fibres.
- Types of connective tissues: **Loose, Dense & Specialised**.

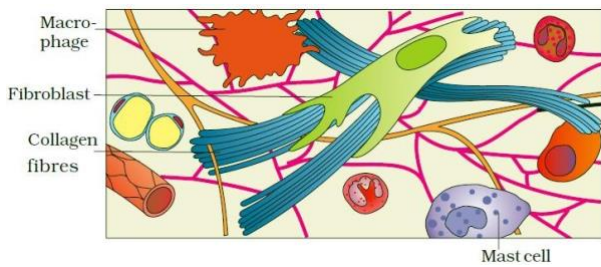
1. Loose Connective Tissues

In this, cells (**fibroblasts, macrophages, mast cells etc.**) and fibres are loosely arranged in a semi-fluid matrix.

It is 2 types: Areolar & Adipose.

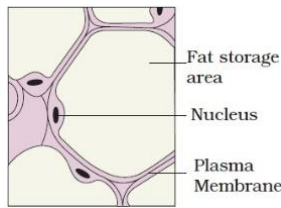
o Areolar tissue:

- Present beneath the skin.
- It serves as a support framework for epithelium.



o Adipose tissue:

- Seen mainly under skin.
- Its cells (**adipocytes**) store fats.
- Excess nutrients which are converted into fats are stored in this tissue.

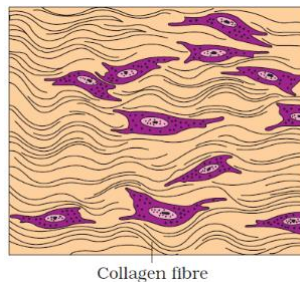


2. Dense Connective Tissues

In this, fibres and fibroblasts are compactly packed. 2 types:

o Dense regular connective tissues:

- Show regular pattern of fibres.
- Collagen fibres are present in rows between many parallel bundles of fibres.
- E.g. tendons & ligaments.



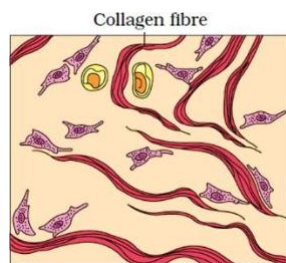
i. Tendons: Attach muscles to bones.

ii. Ligaments: Attach one bone to another.

o Dense irregular connective tissues:

Irregular pattern of fibres.

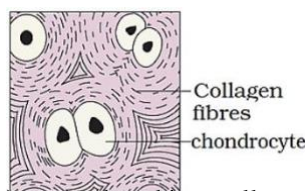
- Fibroblasts & fibres (mostly collagen) are oriented differently.
- This tissue is present in skin.



3. Specialized Connective Tissues

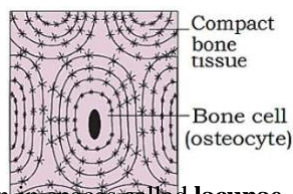
o Cartilage:

- o In this, intercellular material (matrix) is solid and pliable (due to **chondroitin salts**) and resists compression.
- o Cartilage cells (**chondrocytes**) are enclosed in small cavities within the matrix secreted by them.
- o Most of the cartilages in vertebrate embryos are replaced by bones in adults.
- o Cartilage is present in the **tip of nose, outer ear, joints in the vertebral column, limbs and hands in adults.**



o Bone:

- o It has hard and non-pliable matrix rich in **calcium salts** and **collagen fibres** which give bone its strength.
- o Bone cells (**osteocytes**) are seen in spaces called **lacunae**.



o Functions:

- It provides structural frame to the body.
- Support and protect softer tissues and organs.

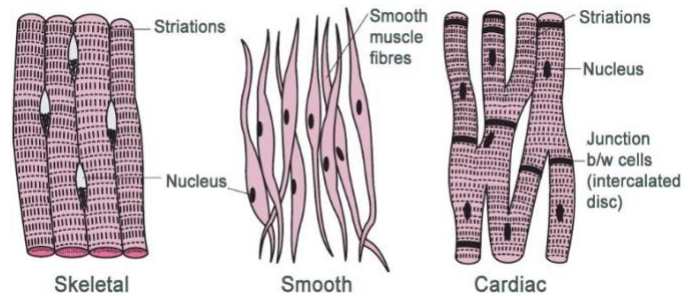
- Limb bones serve weight-bearing functions.
- Take part in locomotion and movements.
- Blood cells are produced in bone marrow.

o Blood:

- o A fluid connective tissue containing **plasma, red blood cells (RBC), white blood cells (WBC)** and **platelets**.
- o Helps in the circulation of various substances.

III. MUSCLE TISSUE

- The tissues made of many **muscle fibres (muscle cells)**.
- Muscle fibres are composed of numerous fine **myofibrils**.
- Muscle fibres can contract (shorten) and relax (lengthen).
- Muscles take part in locomotion and movements.
- Muscles are 3 types: **skeletal, smooth** and **cardiac**.



1. Skeletal (striated or voluntary) muscle

- They are attached to bones. E.g. **Biceps**.
- Striations are present in muscle fibres.
- Muscle fibres are bundled together in a parallel fashion.
- A sheath of tough connective tissue encloses several bundles of muscle fibres.

2. Smooth (non-striated or visceral) muscle

- **Involuntary** and **fusiform** (Fibres taper at both ends).
- No striations.
- Cell junctions hold them together and they are bundled together in a connective tissue sheath.
- They are seen in the wall of internal organs such as the **blood vessels, stomach and intestine.**

3. Cardiac muscle

- **Involuntary** muscle seen only in the **heart**.
- Cell junctions fuse the plasma membranes of cardiac muscle cells and make them stick together.
- Communication (gap) junctions (**intercalated discs**) at some fusion points allow cells to contract as a unit, i.e., when a cell receives signal to contract, other cells also contract.

IV. NEURAL TISSUE

- Made up of neurons (unit of neural system).
- Responsible for **control** and **co-ordination** of the body.
- **Neurons** are excitable cells. They carry impulses.
- Neurons are protected and supported by **neuroglial cells**.
- Neuroglia make up more than half the volume of neural tissue.

ORGAN AND ORGAN SYSTEM

- **Cells → tissues → organs → organ systems.**
- This organization is essential for better coordinated activities of cells.
- An organ is made of one or more type of tissues. E.g. Heart has epithelial, connective, muscular & neural tissues.

MORPHOLOGY & ANATOMY OF COCKROACH

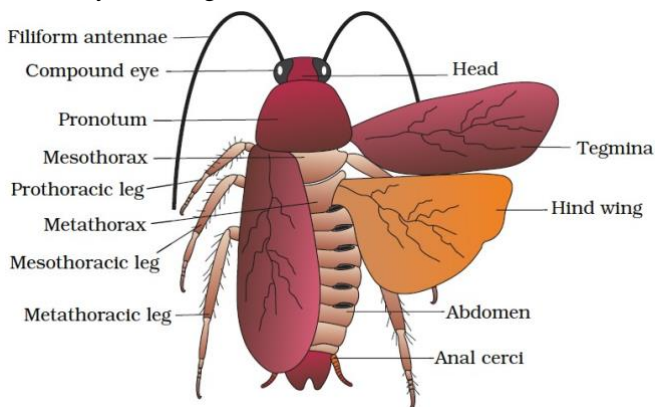
- **Morphology:** Study of external features of organisms.
- **Anatomy:** Study of morphology of internal organs.
- **Cockroach (*Periplaneta americana*)** are nocturnal, omnivores and live in damp places.
- **Colour:** Brown or black. Bright yellow, red & green coloured cockroaches are also seen in tropical regions.
- **Size:** ¼ inches to 3 inches (0.6-7.6 cm).

Systematic position

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

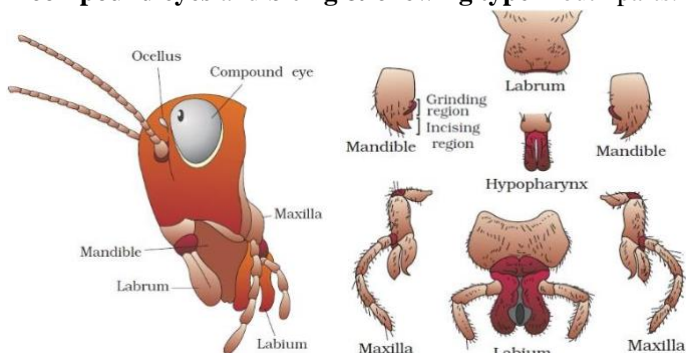
MORPHOLOGY OF COCKROACH

- The adults are about **34-53 mm** long.
- Body is covered by a hard brown **chitinous exoskeleton**.
- In each segment, exoskeleton has hardened plates called **sclerites (dorsal tergites & ventral sternites)**. They are joined to each other by a thin and flexible **articular membrane (arthrodial membrane)**.
- The body has 3 regions – **head, thorax and abdomen**.



Head

- Triangular head is formed by 6 fused segments.
- It shows great mobility in all directions due to flexible neck.
- Head bears a pair of thread-like **antennae**, a pair of **compound eyes** and **biting & chewing type** mouth parts.



- **Mouthparts:** a **labrum** (upper lip), **2 mandibles**, **2 maxillae**, **hypopharynx** (tongue) & a **labium** (lower lip).

Thorax

- It has 3 parts: **prothorax, mesothorax & metathorax**.
- The head is connected to thorax by a **neck** (short extension of the prothorax).
- Each thoracic segment bears a pair of walking legs.
- 2 pairs of wings: **Forewings (2)** and **Hind wings (2)**.

- **Forewings (mesothoracic) or tegmina:** Opaque, dark and leathery and cover the hind wings when at rest.
- **Hind wings (metathoracic):** Transparent, membranous and are used in flight.

Abdomen

- It consists of **10 segments**.
- In females, 7th (boat shaped), 8th & 9th sterna form a **brood (genital) pouch**. It contains female **gonopore**, **spermathecal pores & collateral glands**.
- In males, genital pouch lies at the hind end of abdomen bounded dorsally by 9th & 10th terga and ventrally by the 9th sternum. It contains **dorsal anus**, **ventral male genital pore (gonopore)** and **gonapophysis**.
- In both sexes, 10th segment bears a pair of jointed **anal cerci**. Males bear a pair of short, threadlike **anal styles**.

Differences between male & female cockroaches

Male	Female
i. Larger size	Smaller
ii. Wings extend beyond the tip of the abdomen.	Wings do not extend beyond the tip of abdomen.
iii. Narrow abdomen	Broad abdomen
iv. Anal styles present	Absent
v. Brood pouch absent	Present

ANATOMY OF COCKROACH

Digestive system

Alimentary canal has 3 parts: **foregut, mid gut & hindgut**.

- **Foregut:** It is lined by **cuticle**. It includes

Mouth → **pharynx** → **oesophagus** → **crop** (to store food) → **gizzard (proventriculus)**.

Gizzard helps in grinding the food. It

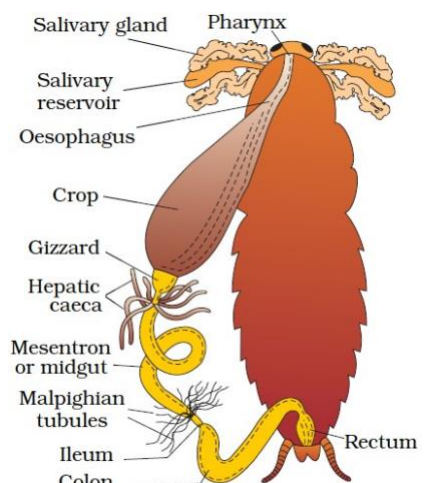
has an outer layer of thick circular muscles and thick inner cuticle forming **6 chitinous plates (teeth)**.

- **Mid gut (Mesenteron):** It is not lined by cuticle. 6-8 tubules (**hepatic or gastric caecae**) are seen at the junction of foregut & mid gut. They secrete digestive juice. At the junction of mid gut & hindgut, there are **100-150** yellow coloured thin filamentous **Malpighian tubules**.

- **Hindgut:** It is broader than mid gut and lined internally by cuticle. Hindgut includes **ileum, colon & rectum**. Rectum opens out through anus.

Circulatory system

- Blood vascular system: **open type**.
- Blood vessels are poorly developed and open into space (**haemocoel**).



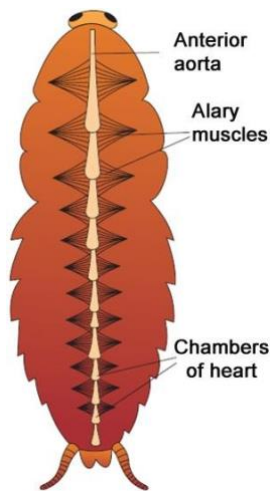
- Visceral organs located in the haemocoel are bathed in blood (**haemolymph**).

- **Haemolymph**= colourless plasma + haemocytes.

- **Heart** consists of elongated muscular tube lying along mid dorsal line of thorax and abdomen.

- It has funnel-shaped chambers with **ostia** on either side.

- Blood from sinuses enter heart through ostia and is pumped anteriorly to sinuses again.



Respiratory system

- It consists of a network of **trachea** that open through **10 pairs** of small holes called **spiracles** present on the lateral side of the body.

- The thin branches of **tracheal tubes** are called **tracheoles**. They carry oxygen from the air to all parts.

- The opening of the spiracles is regulated by **sphincters**.

- Gas exchange takes place at the tracheoles by **diffusion**.

Excretory system

- **Uricotelic**. Excretory organ is **Malpighian tubules**.

- Each tubule is lined by glandular and ciliated cells. They absorb nitrogenous wastes and convert them into **uric acid** which is excreted out through the hindgut.

- **Fat body, nephrocytes & urecose glands** also help in excretion.

Nervous system

- It consists of segmentally arranged **ganglia** joined by paired longitudinal connectives on the ventral side.

- 3 ganglia lie in the thorax and 6 in the abdomen.

- The head holds only a bit of nervous system. Remaining part is situated along the ventral part of the body. So, if the head of cockroach is cut off, it will still live for one week.

- The **supra-oesophageal ganglion** (brain) supplies nerves to antennae and compound eyes.

- **Sense organs: Antennae, eyes, maxillary palps, labial palps, anal cerci etc.**

- Sensory receptors of antennae monitor the environment.

- Each compound eye consists of about **2000 hexagonal ommatidia**. Using these, a cockroach can receive several images of an object. This is called **mosaic vision**. It has more sensitivity but less resolution, being common during night (hence called **nocturnal vision**).

Reproductive system

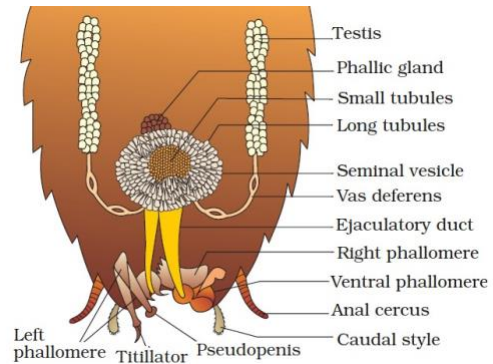
Cockroaches are **dioecious**.

Male reproductive system:

It consists of a pair of **testes, seminal vesicles, accessory glands & external genitalia**.

▪ **Testes:** Lie laterally in the **4th-6th abdominal segments**.

Each **testis** → a thin **vas deferens** → **seminal vesicle** → **ejaculatory duct** → **male gonopore**.

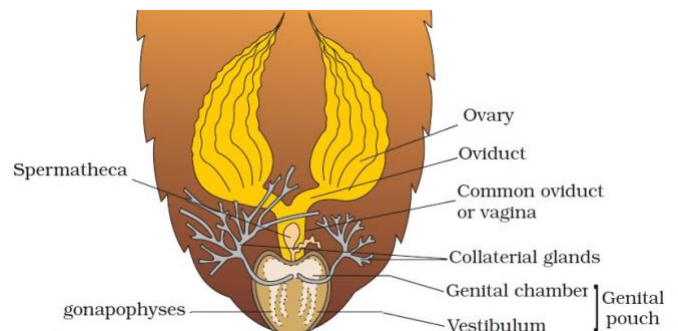


▪ **Seminal vesicles:** To store sperms. Sperms are glued together to form bundles called **spermatophores**. They are discharged during copulation.

▪ **Accessory glands:** Include a **mushroom gland** (in **6th-7th abdominal segments**) and **phallic gland**. Their secretions nourish the sperms.

▪ **External genitalia (male gonapophysis or phallomeres):** Chitinous asymmetrical structures, surrounding the **male gonopore**.

Female reproductive system:



▪ It consists of **2 large ovaries, oviducts, spermatheca, genital chamber, Collateral glands etc.**

▪ **Ovaries** lie laterally in the **2nd – 6th abdominal segments**. Each ovary is formed of **8 ovarian tubules (ovarioles)**, containing a chain of developing ova.

▪ **Oviducts** of each ovary unite into a single **median oviduct (vagina)** which opens into the **genital chamber**.

▪ A pair of **spermatheca** is present in the **6th segment** which opens into the **genital chamber**.

▪ Sperms are transferred through spermatophores. Their fertilised eggs are encased in **oothecae**.

▪ **Ootheca** is dark reddish to blackish brown capsule, 8 mm long. Females lay **9-10 oothecae**, each contain **14-16 eggs**.

- Development of *P. americana* is **paurometabolous**, (development through **nymphal stage**).

- **Nymphs** look like adults. They moult **13 times** to reach the adult form. The next to last nymphal stage has **wing pads**. Only adult cockroaches have wings.

ECONOMIC IMPORTANCE OF COCKROACH

They are pests because they destroy food and contaminate it with their smelly excreta. They also transmit bacterial diseases like **cholera, typhoid, tuberculosis** etc.

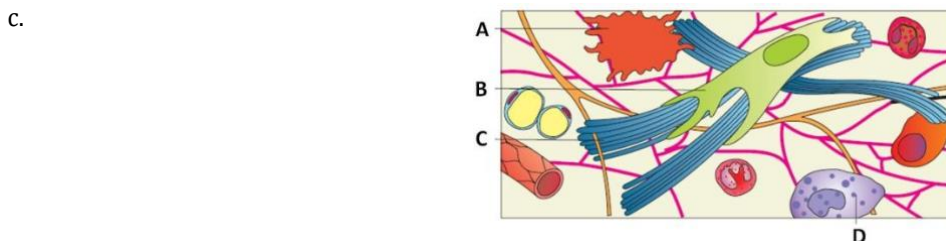
MODEL QUESTIONS

1. Find the relationship between first two words and suggest a suitable word in the fourth position.

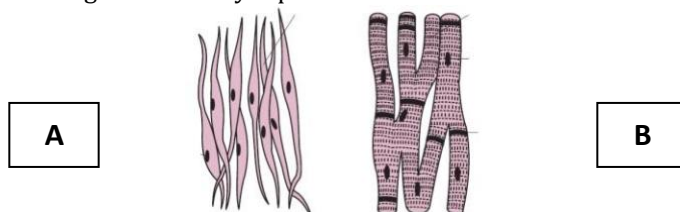
a. Squamous epithelium: lining of blood vessels	Cuboidal epithelium:
b. Cartilage: chondrocytes	Bone:
c. Frog: Kidney	Cockroach:
2. Odd man out. Justify your answer.

a. Areolar tissue, blood, neuron, tendon	Mushroom gland, Ommatidium, Ootheca, Oviducts
b. Maxilla, Mandible, Labrum, Antennae	d. Exocrine, Endocrine, Salivary gland, Ligament
3. Identify the following tissues and write down their location.

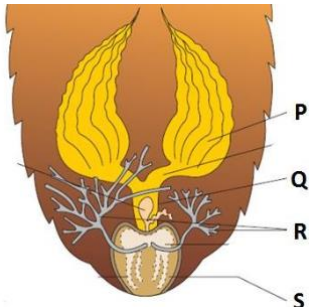
a. Tissue which store fat	c. Tissue that connects muscle and bone
b. Tissue that conducts impulses	d. Tissue that serves as supporting frame of body
4. Identify the following tissue and label A, B, C & D.



5. Two types of muscle tissues are diagrammatically represented.



- a. Identify muscle tissues A and B. Mention their location.
 - b. Find out any two differences between them.
6. Prepare a flowchart using the following terms.
Crop, Pharynx, Ileum, Mouth, Oesophagus, Mesenteron, Anus, Gizzard, Colon
 7. Observe the diagram given below:



- a. Identify the figure.
- b. Label the parts P, Q, R and S.

8. Analyse the following statements. Find out the wrong statements and rewrite them correctly.
 - a. In cockroach, hepatic or gastric caecae act as the digestive glands.
 - b. Mushroom gland and phallic gland are concerned with female reproductive system of cockroach.
 - c. Antennae, eyes, maxillary palps, labial palps etc. are the sensory organs of cockroach.
 - d. Anal cerci are the structures present only male cockroach and used to identify the sex of cockroach.

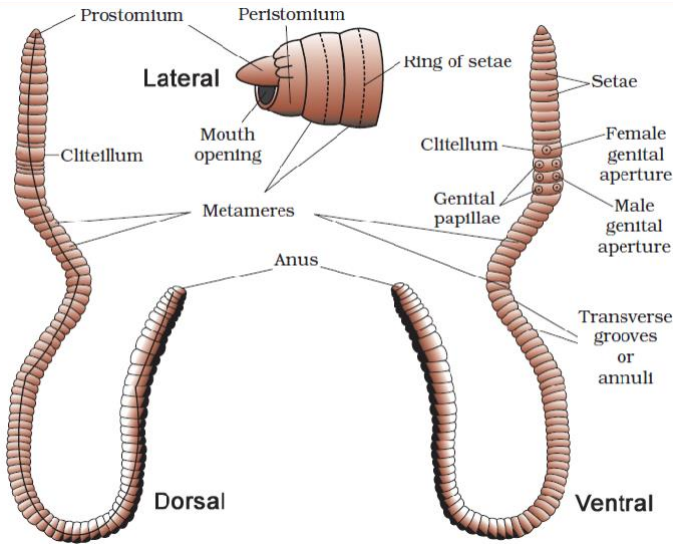
MORPHOLOGY & ANATOMY OF EARTHWORM

Systematic position

Phylum : Annelida
 Class : Oligochaeta
 Genus : *Pheretima*
 Species : *posthuma*

- Earthworm is a reddish-brown terrestrial invertebrate that inhabits the upper layer of moist soil.
- During day time, they live in burrows made by boring and swallowing the soil.
- Common Indian earthworms: *Pheretima* and *Lumbricus*.

MORPHOLOGY OF EARTHWORM



- Earthworms have long segmented cylindrical body.
- Number of **segments (metameres)**: about **100-120**.
- **Dorsal surface** has a **dark median mid dorsal line (dorsal blood vessel)** along the longitudinal axis of the body.
- First segment (**peristomium or buccal segment**) bears the mouth. A lobe called **prostomium** covers the mouth.
- Prostomium is sensory in function and is used to force open cracks in the soil into which the earthworm may crawl.
- In a mature worm, segments **14-16** are covered by a dark band of glandular tissue called **clitellum**.
- Body has 3 regions: **preclitellar, clitellar & postclitellar**.
- **4 pairs of spermathecal apertures** are found on ventro-lateral sides of **intersegmental grooves (5th-9th segments)**.
- A single **female genital pore** is present in the mid-ventral line of **14th segment**.
- A pair of **male genital pores** is present on the ventro - lateral sides of the **18th segment**.
- Many minute **nephridiopores** open on the body surface.
- All segments except the first, last and clitellum bear S-shaped **setae**, embedded in the epidermal pits. Setae can be extended or retracted. Their function is locomotion.

ANATOMY OF EARTHWORM

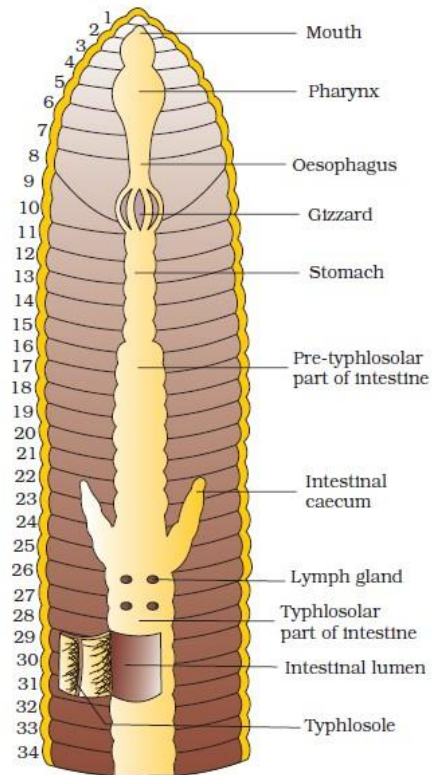
Body wall

It is composed of

- Outermost thin **non-cellular cuticle**.

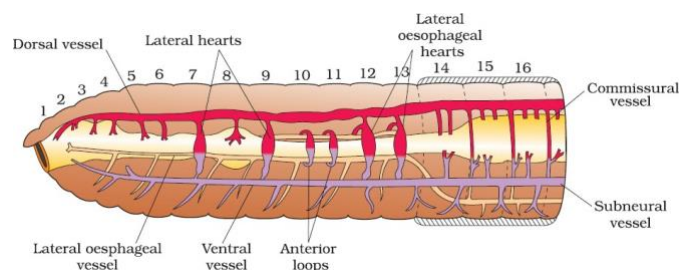
- **Epidermis**: Made up of a single layer of columnar epithelial cells which contain secretory gland cells.
- **Two muscle layers (circular and longitudinal)**.
- An innermost **coelomic epithelium**.

Digestive system



- The straight **alimentary canal** extends from first to last segment of the body. It has
- **Mouth** → **buccal cavity (1-3 segments)** → **muscular pharynx (4th segment)** → **oesophagus (5-7 segments)** → **muscular gizzard (8-9 segments)** → **stomach (9-14 segments)** → **Intestine (15th segment to last)** → **anus**.
- Gizzard helps to grind soil particles, decaying leaves, etc.
- **Calciferous glands**, present in the stomach, neutralise the **humic acid** present in humus.
- A pair of short and conical **intestinal caecae** project from the intestine on the **26th segment**.
- The intestinal part between **26-35 segments** has an internal median fold of dorsal wall called **typhlosole**. It increases area of absorption.
- The organic rich soil is digested in the digestive tract by digestive enzymes. Digested nutrients are absorbed through intestinal membranes. Their faecal deposits are known as **worm castings**.

Circulatory system (blood vascular system)

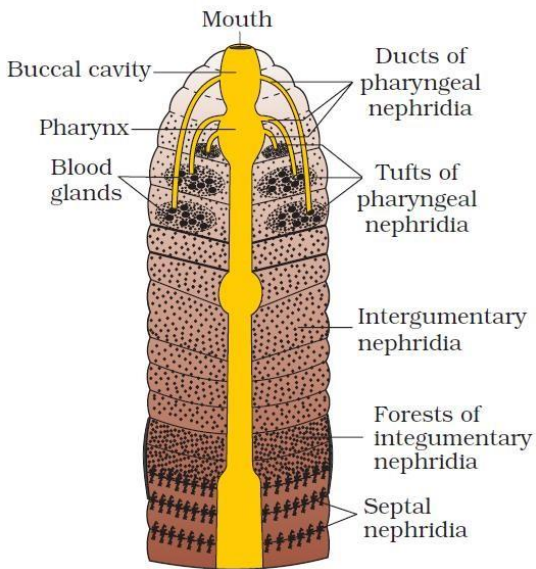


- Circulatory system is **closed type** (blood flows through heart and blood vessels).
- Consists of **blood vessels, capillaries** and **heart**.
- Contractions keep blood circulating in one direction.
- **Blood glands** are present on the **4th, 5th & 6th segments**. They produce **phagocytic blood cells** and **haemoglobin** which is dissolved in blood plasma.

Respiratory system

- No specialized system.
- Gas exchange occurs through moist body surface into the blood stream.

Excretory system



Excretory organs are segmentally arranged tubules called **nephridia**. They are 3 types:

- Septal nephridia:** Found on both sides of intersegmental septa (segment 15 to last) that open into intestine.
- Integumentary nephridia:** Attached to lining of body wall (segment 3 to last). They open on body surface.
- Pharyngeal nephridia:** Present in the **4th, 5th & 6th segments** in the form of paired tufts.

Funnel-shaped part of nephridium collects excess fluid from coelom. The funnel connects with a tubular part of nephridium which delivers the wastes into digestive tube.

Nervous system

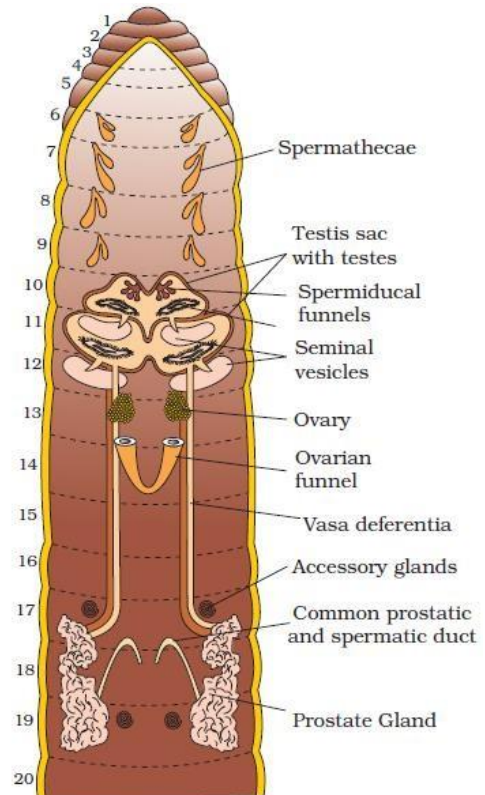
- Includes segmentally arranged **ganglia** on the ventral paired and fused **nerve cord**.
- The nerve cord in the anterior region (**3rd & 4th segments**) divides and encircles the pharynx and joins the **cerebral ganglia** dorsally to form a **nerve ring**.
- The nerve ring with cerebral ganglia represents the brain.
- **Sensory system:** Includes
 - Light and touch sensitive **receptor cells**. No eyes.
 - **Chemoreceptors (taste receptors):** React to chemical stimuli.

Reproductive system

Earthworm is **hermaphrodite**.

Male reproductive organs:

- **Testes:** 2 pairs. Enclosed in **testis sacs** in **10th & 11th segments**. The sperms from testes shed into testis sacs. From where, they enter **seminal vesicles** for maturation. Mature sperms move back into testis sacs and enter **spermiducal funnels** which are connected to **vasa deferentia (spermatic ducts)**. The vasa deferentia run up to **18th segment** where they join the **prostatic duct**. The **common prostate** and **spermatic duct** open to the exterior by a pair of **male genital pores** on the ventro-lateral side of the **18th segment**.
- **Accessory glands:** 2 pairs. Found in the **17th & 19th segments** (one pair in each segment).



Female reproductive organs:

- **Spermathecae:** 4 pairs. Located in **6th-9th segments** (one pair in each segment). They receive and store spermatozoa during copulation.
- **Paired ovaries:** Attached at the inter-segmental septum of the **12th and 13th segments**.
- **Ovarian funnels:** Present beneath the ovaries which continue into **oviduct**, join together and open on ventral side as single median female genital pore on **14th segment**.
- During mating, two worms exchange sperms each other. They mate juxtaposing opposite gonadal openings exchanging **spermatophores** (packets of sperms).
- Mature sperm, ova and nutritive fluid are deposited in **cocoons** produced by gland cells of clitellum. Cocoon with fertilized ova slips off and deposit in the soil. After 3 weeks, cocoon produces 2 to 20 baby worms (no larva).

ECONOMIC IMPORTANCE

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

MORPHOLOGY & ANATOMY OF FROG

Systematic position

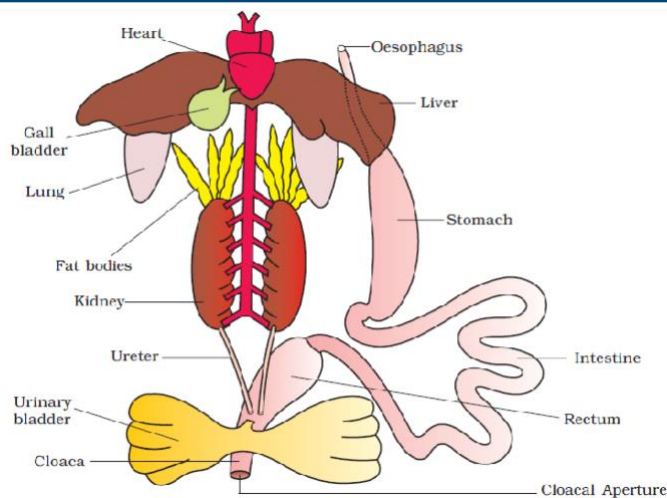
Phylum	: Chordata
Class	: Amphibia
Genus	: <i>Rana</i>
Species	: <i>tigrina</i>

- *Rana tigrina* is the most common species in India.
- They are **poikilotherms (cold blooded)**.
- They can change colour to hide them from their enemies (**camouflage**). This protective coloration is called **mimicry**.
- During summer and winter, they undergo **aestivation (summer sleep)** and **hibernation (winter sleep)** respectively to protect them from extreme heat and cold.

MORPHOLOGY OF FROG

- Body is divisible into **head & trunk**. Neck and tail absent.
- Skin is moist, smooth and slippery due to the mucus.
- Colour of dorsal side is olive green with dark irregular spots and ventral side is pale yellow.
- The frog never drinks water but absorb it through the skin.
- A **mouth**, paired **nostrils** and bulged **eyes** (covered by nictitating membrane) are present.
- On either side of eyes have a membranous **tympanum (ear)**.
- The **forelimbs (4 digits)** and **hind limbs (5 digits)** help in **swimming, walking, leaping and burrowing**. The hind limbs are larger and muscular than fore limbs.
- Feet have webbed digits that help in swimming.
- Frogs exhibit **sexual dimorphism**. Male frogs have sound producing **vocal sac** and also a **copulatory (nuptial) pad** on the first digit of fore limbs which are absent in female frogs.

ANATOMY OF FROG



Digestive system

- Consists of **alimentary canal** and **digestive glands**.
- The alimentary canal is short because frogs are carnivores and hence the length of intestine is reduced.
- **Mouth** → **buccal cavity** → **pharynx** → **oesophagus** → **stomach** → **intestine** → **rectum** → **cloaca**.
- Liver secretes **bile** that is stored in **gall bladder**. **Pancreas** produces **pancreatic juice** containing digestive enzymes.
- Food is captured by the bilobed tongue.

- **Digestion**: Gastric juice and HCl secreted from gastric wall digest the food. Partially digested food (**chyme**) is passed from stomach to the **duodenum**. Duodenum receives **bile** and **pancreatic juices** through a **common bile duct**. Bile emulsifies fat. Pancreatic juice digests carbohydrates and proteins. Digestion completes in the intestine.
- Finger-like **villi** and **microvilli** in intestine absorb digested food. The undigested solid waste moves into the **rectum** and passes out through **cloaca**.

Respiratory system

- **Skin** acts as aquatic respiratory organ (**cutaneous respiration**). Dissolved oxygen in the water is exchanged through the skin by diffusion. During aestivation and hibernation respiration takes place through skin.
- On land, the **buccal cavity, skin** and **lungs (pulmonary respiration)** act as the respiratory organs.
- The lungs are a pair of elongated, pink coloured sac-like structures present in the thorax. Air enters through the nostrils into the buccal cavity and then to lungs.

Circulatory system

- **Closed type**. Includes **Blood vascular system (heart, blood vessels & blood)** and **lymphatic system (lymph, lymph channels & lymph nodes)**.
- Heart is **3-chambered**, (**two atria** and **one ventricle**) and is covered by a membrane called **pericardium**.
- A triangular structure called **sinus venosus** joins the right atrium. It receives blood through major veins (**vena cava**).
- The ventricle opens into a sac-like **conus arteriosus** on the ventral side of the heart.
- The blood pumped from the muscular heart is carried to all parts of the body by the **arteries (arterial system)**.
- The **veins** collect blood from different parts of body to the heart and form the **venous system**.
- **Hepatic portal system** (venous connection between liver and intestine) and **renal portal system** (between kidney and lower parts of the body) are present in frogs.
- Blood contains **plasma** and **cells (RBC, WBC & platelets)**. RBCs are nucleated and contain haemoglobin.
- Blood transports nutrients, gases and water to tissues.

Excretory system

- Includes **kidneys (2), ureters (2), cloaca & urinary bladder**.
- **Kidneys** are dark red and bean-shaped. Found posteriorly in the body cavity on both sides of vertebral column. Each kidney is formed of **uriniferous tubules (nephrons)**.
- 2 ureters emerge from the kidneys. In male frogs, the ureters act as **urinogenital duct** which opens into cloaca. In females, ureters & oviduct open separately in cloaca.
- The thin-walled **urinary bladder** is present ventral to the rectum which also opens in the cloaca.
- The frog is a **ureotelic** animal (excretes urea). Nitrogenous wastes are carried by blood into the kidney where it is separated and excreted.

Control and co-ordination

Endocrine system

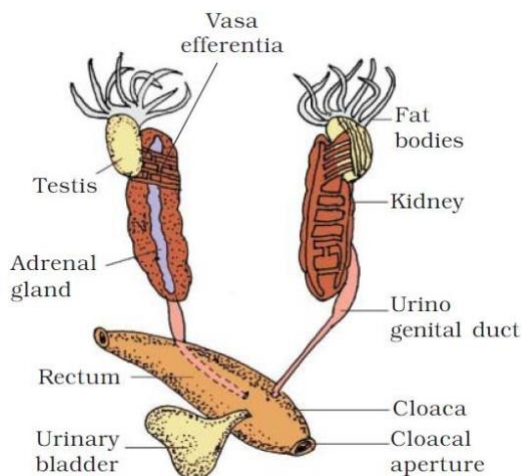
- The **endocrine glands** secrete **hormones**.
- Endocrine glands: **pituitary, thyroid, parathyroid, thymus, pineal body, pancreatic islets, adrenals & gonads**.

Nervous system

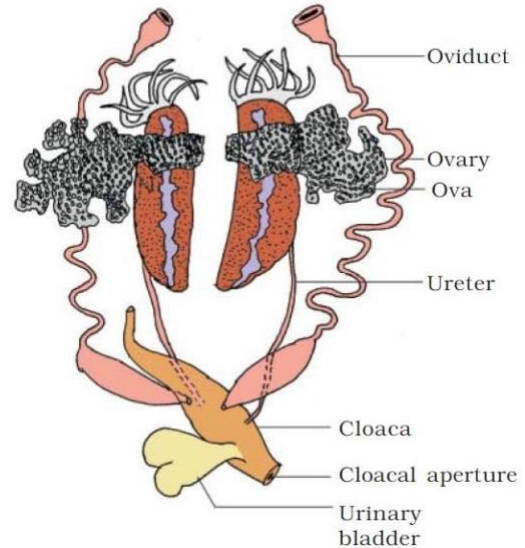
It includes

- **Central nervous system (brain & spinal cord),**
- **Peripheral nervous system (cranial & spinal nerves)**
- **Autonomic nervous system (sympathetic & parasympathetic).**
- There are 10 pairs of **cranial nerves** arising from brain.
- Brain is enclosed in a bony **brain box (cranium)**.
- The brain is divided into
 - **Fore-brain:** Includes **olfactory lobes, paired cerebral hemispheres** and **unpaired diencephalon**.
 - **Mid-brain:** Includes a pair of **optic lobes**.
 - **Hind-brain:** Includes **cerebellum & medulla oblongata**.
- **Medulla oblongata** passes out through the **foramen magnum** and continues into **spinal cord**, which is enclosed in the vertebral column.
- Sense organs include organs of
 - **Sensory papillae:** For touch
 - **Taste buds:** For taste
 - **Nasal epithelium:** For smell
 - **Simple eyes:** For vision. Paired and situated in orbit
 - **Tympanum with internal ears:** For hearing and balancing (equilibrium).

Reproductive system



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



- The female reproductive organs include a pair of **ovaries**. The ovaries are situated near kidneys and there is no functional connection with kidneys.
- A pair of oviduct arising from the ovaries opens into the cloaca separately.
- A mature female can lay **2500 to 3000 ova** at a time.
- Fertilisation is external and takes place in water.
- Development involves a larval stage called **tadpole**.
- Tadpole undergoes metamorphosis to form the adult.

ECONOMIC IMPORTANCE

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