Crash Course for NEET

ZOOLOGY

Study Package-1

Aakash
Medical | IIT-JEE | Foundations
(Divisions of Aakash Educational Services Limited)

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Preface

Dear NEET Aspirant,

This book has been written specifically for the students who get themselves enrolled for the crash course for medical entrance exams. which is a limited days programme. It is meant for the quick brush-up of all the important topics. All the chapters have been written by the experienced faculties who have been preparing the students for qualifying various medical entrance exams. Each chapter covers all the important and must do topics and has been written in such a way that the student can grasp the contents easily.

After the theory portion in the study package, Try Yourself have been given to make the student practice the questions similar to those asked in entrance exams. The sequence of the questions has been kept same as the sequence of theory part so that a student can solve questions as per his/her coverage of theory part. The questions asked in previous AIPMT/NEET exam have also been included. This will help the students to assess the difficulty level in the actual medical entrance exams. We have also added a sample paper of 45 questions covering the entire content of this study package.

As the days are limited, the students should never miss a single class and must cover the syllabus in tandem with the coverage in the classroom. Once the topic is finished, you must do all the questions of same topic given in the form of Try Yourself. If there is any doubt, you can get it clarified from the faculties.

Finally, you are advised to remain focused on your target and must work hard and complete all the necessary work sincerely in a planned manner. You must stay away from all distractions including the mobile phone. All other things can wait but time never waits for anyone. So gear up your preparations to realise your dream of joining the most prestigious and respected profession.

Wishing you a brighter career!

J. C. CHAUDHRY
Managing Director

Analysis of NEET–2019

Subject-wise Report

Subject-wise Difficulty Level

S. No.	SUBJECT	EASY	MEDIUM	DIFFICULT	REMARKS
1	PHYSICS	18	25	2	Medium
2	CHEMISTRY	17	22	6	Medium
3	BOTANY	21	13	14	Easy
4	ZOOLOGY	9	25	8	Medium

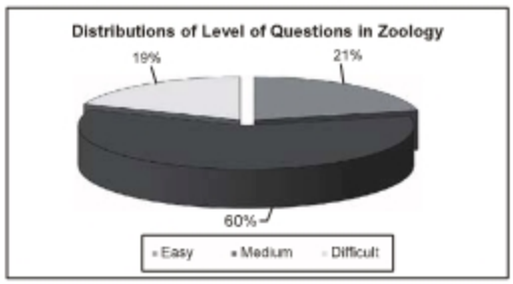
Topic-wise Credits & Difficulty Level

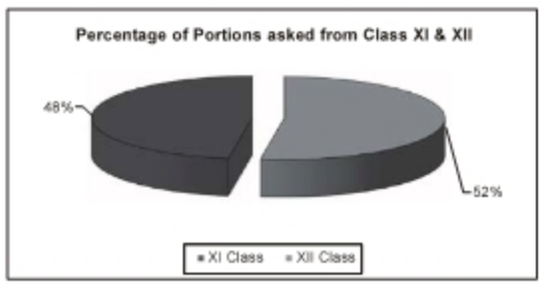
ZOOLOGY

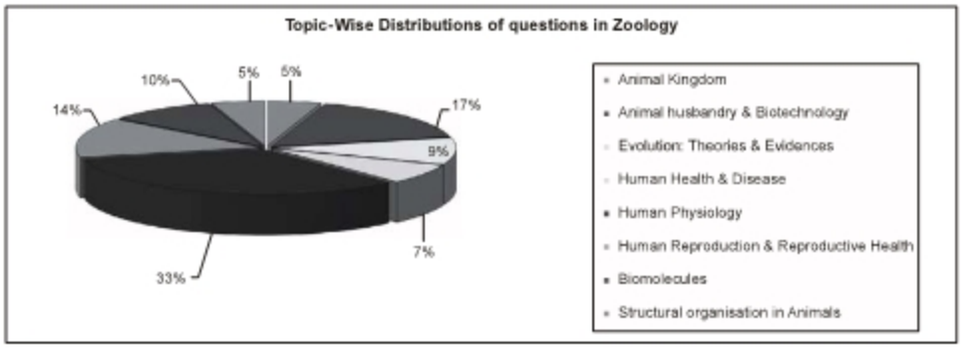
ANALYSIS OF ZOOLOGY PORTION OF NEET 2019

	XI	XII	XII	XII	XI	XII	XI	XI	
	Animal Kingdom	Animal husbandry & Biotechnology	Evolution: Theories & Evidences	Human Health and Disease	Human Physiology	Human Reproduction & Reproductive Health	Biomolecules	Structural organisation in Animals	Total
Easy	0	2	1	1	2	1	1	1	9
Medium	2	4	3	2	6	5	2	1	25
Difficult	0	1	0	0	6	0	1	0	8
Total	2	7	4	3	14	6	4	2	42

XI Class	22	XII Class	20







Contents

Chapter 1

Animal Kingdom

Sub-topics *Salient Features and Classification of Animals - Non-chordates up to Phyla Level and Chordate up to Classes Level (Three to Five Salient Features and at least Two Examples)*

Multicellular eukaryotic organisms with holozoic mode of nutrition are called metazoans. Based on complexity of organisation, metazoans are divided into two sub-kingdoms, *Parazoa* and *Eumetazoa*.

Parazoa includes the sponges, in which the cells are loosely aggregated and do not form tissues or organs.

Eumetazoa includes the rest of the animals in which cells are organised into structural and functional units called tissues, organs and organ systems.

BASIS OF CLASSIFICATION

Levels of Organisation

Though all members of Animalia are multicellular, all of them do not exhibit the same pattern of organisation of cells. For example, in sponges, the cells are arranged as loose cell aggregates, *i.e.*, they exhibit **cellular level** of organisation. Division of labour (activities) occurs among the cells. In coelenterates, the arrangement of cells is more complex. Here the cells performing the same function are arranged into tissues, hence is called **tissue level** of organisation. A still higher level of organisation, *i.e.*, **organ level** is exhibited by members of Platyhelminthes and other higher phyla where tissues are grouped together to form organs, each specialised for a particular function. In animals like Annelids, Arthropods, Molluscs, Echinoderms and Chordates, organs have associated to form functional systems, each system concerned with a specific physiological function. This pattern is called **organ system** level of organisation. Organ systems in different groups of animals exhibit various patterns of complexities. For example, the digestive system in Platyhelminthes has only a single opening to the outside of the body that serves as both mouth and anus, and is hence called incomplete. A complete digestive system has two openings, mouth and anus. Similarly, the circulatory system may be of two types

(i) **Open type** in which the blood is pumped out of the heart and the cells and tissues are directly bathed in it.

(ii) **Closed type** in which the blood is circulated through a series of vessels of varying diameters (arteries, veins and capillaries).

Symmetry

(a) The animals with radial symmetry are called *Radiata*. Body can be divided into equal parts by any plane passing through the centre from top to bottom. *e.g.*, cnidarians (sea anemone, jellyfish and corals), ctenophores (comb jellies), adult echinoderm

(b) The animals with bilateral symmetry are called *Bilateria*. The body can be divided into equal right and left halves in only one plane. *e.g.*, platyhelminthes, nemathelminthes, annelida, arthropoda, mollusca, chordata.

Germ Layers

In **Diploblastic animals,** the body cells are arranged in two embryonic layers, an outer ectoderm and an inner endoderm with an intervening mesoglea *e.g.*, coelentrata.

If the body of animals is made up of three germ layers *i.e.*, ectoderm, mesoderm and endoderm, they are called **triploblastic animals.**

Body Plan

Cell aggregate type of body plan is present in sponges.

Blind sac type of body plan is present in coelenterates and platyhelminthes, the alimentary canal has only one opening.

Tube-within tube type of body plan is present in **nemathelminthes, annelids, arthropods, molluscs, echinoderms and chordates**. The digestive system is a continuous tube with an opening at each end.

Two ways to a 'Tube-within-a-tube' Body Plan : Tube-within-a-tube body plan has been achieved in two different ways on two evolutionary lines. In one, called the **protostomic line**, the first opening to develop in the embryonic digestive tube is the mouth; the anus develops later. This is seen in the **annelids, molluscs and arthropods**. In other, the **deuterostomic line,** the anus develops first and the mouth is formed later. This occurs in the **echinoderms** and **chordates** (including the vertebrates). We are thus evolutionarily closer to the echinoderms (starfish) than to insects or molluscs.

Body Symmetry, Feeding and Brain Formation : For **sessile** animals, radial symmetry is advantageous as it allows food to be gathered from all sides. They may develop appendages all around the mouth to capture and push prey into it. Their sensory and nerve coordination system surrounds the mouth. We see this in coelenterates.

Bilateral symmetry arose when animals on the ocean floor became mobile. A crawling animal is most likely to encounter food with the end that goes first. So the mouth developed at this end. With the mouth, all sensory organs and a coordinating brain also developed at the front end. These organs helped in sensing food. So we see how the head cephalization enclosing the brain, became associated with the mouth end.

Body Cavity or Coelom

(a) The animals in which coelom is absent are called **acoelomates**, *e.g.*, flatworms. In flatworms the space between ectoderm and endoderm is filled with parenchyma.

(b) **Pseudocoelom :** The body cavity is not completely lined with mesoderm. Instead, the mesoderm is present as scattered pouches in between the ectoderm and endoderm. Such a body cavity is called pseudocoelom *e.g.* roundworms.

(c) **Eucoelom :** The true coelom is a body cavity which arises as a cavity in embryonic mesoderm. In this case, the mesoderm of the embryo provides a cellular lining, called coelomic epithelium or peritoneum, to the cavity. The coelom is filled with coelomic fluid secreted by the peritoneum. True coelom is found in annelids, arthropods, molluscs, echinoderms and chordates. True coelom is of two types:

(i) **Schizocoelom :** It develops as a split in mesoderm. It is found in annelids, arthropods and molluscs.

(ii) **Enterocoelom :** The mesoderm arises from the wall of the embryonic gut or enteron as hollow outgrowths or enterocoelomic pouches. It occurs in echinoderms, hemichordates and chordates.

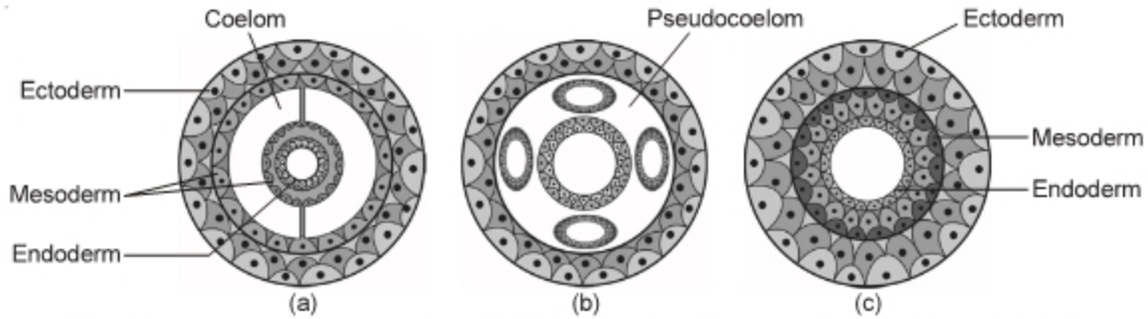


Fig. : Diagrammatic sectional view of (a) Coelomate, (b) Pseudocoelomate, (c) Acoelomate

Segmentation

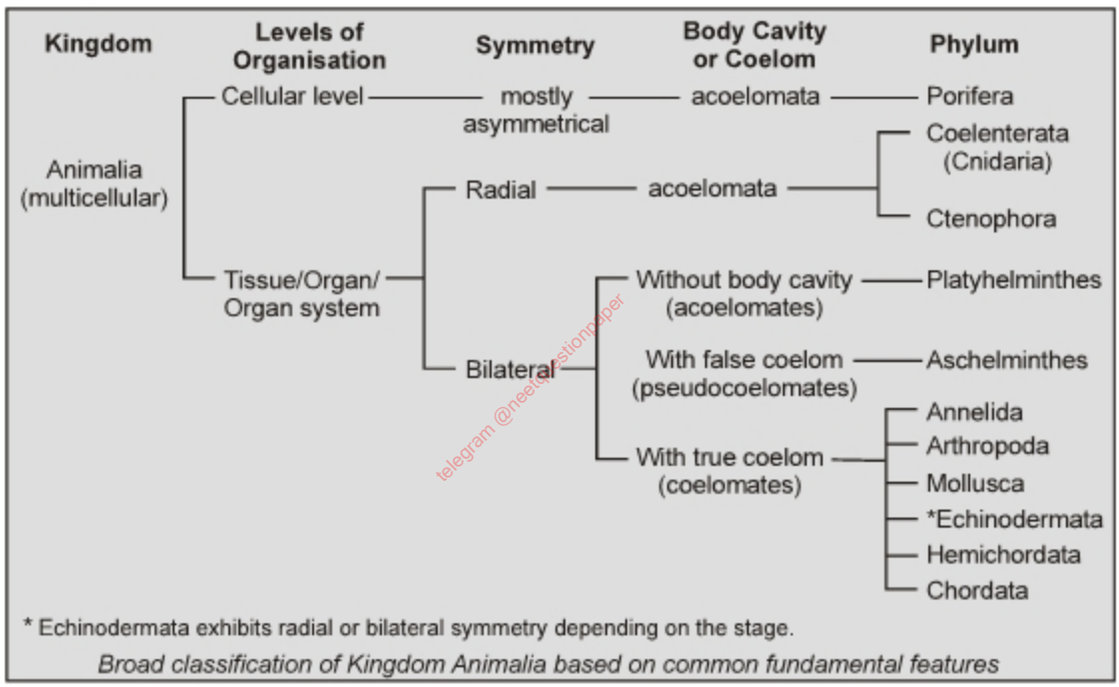
In some animals like annelids, arthropods and chordates, the body is externally and internally divided into segments with a serial repetition of at least some organs. For example, in earthworm, the body shows this pattern called metameric segmentation and the phenomenon is known as metamerism.

Notochord

Notochord is a mesodermally derived rod-like structure formed on the dorsal side during embryonic development in some animals. Animals with notochord are called chordates and those animals which do not form this structure are called non-chordates, *e.g.*, porifera to echinoderms.

CLASSIFICATION OF ANIMALS

The broad classification of Animalia based on common fundamental features as mentioned in the preceding sections is given below :



* Echinodermata exhibits radial or bilateral symmetry depending on the stage.

Broad classification of Kingdom Animalia based on common fundamental features

PHYLUM-PORIFERA (Sub-kingdom Parazoa)

Most poriferans are marine and remain attached to rocks (sessile). A few live in fresh water *e.g.*, *Spongilla*. **This is the only phylum in animal kingdom without any nerve cell. These have cellular level of organisation**, mostly asymmetrical.

1. **Body wall :** The body wall of a common sponge consists of following layers :

   (a) **Pinacoderm (dermal layer) :** It is outer cellular layer which consists of (i) flattened **Pinacocytes** and (ii) oval **porocytes**.

   (b) **Choanoderm (gastral layer) :** It is inner cellular layer which consists of highly specialized flagellated cells called **choanocytes** (**collar cells**). They are the characteristic cells of this phylum.

   (c) **Mesohyl layer (mesenchyme) :** It is a noncellular layer found between pinacoderm and choanoderm. It has fine dispersed spongin fibres and numerous spicules. It also contains **amoebocytes** (amoeba-like cells) of both pinacoderm and choanoderm.

- **Archaeocytes :** These cells are modified amoebocytes. They may be converted into other types of cells and are hence called undifferentiated **"totipotent"** cells.

The central body cavity of a sponge is called **spongocoel** or **paragastric cavity**.

The characterstics cell of sponges is choanocyte/collar cell which lines the spongocoel and canals.

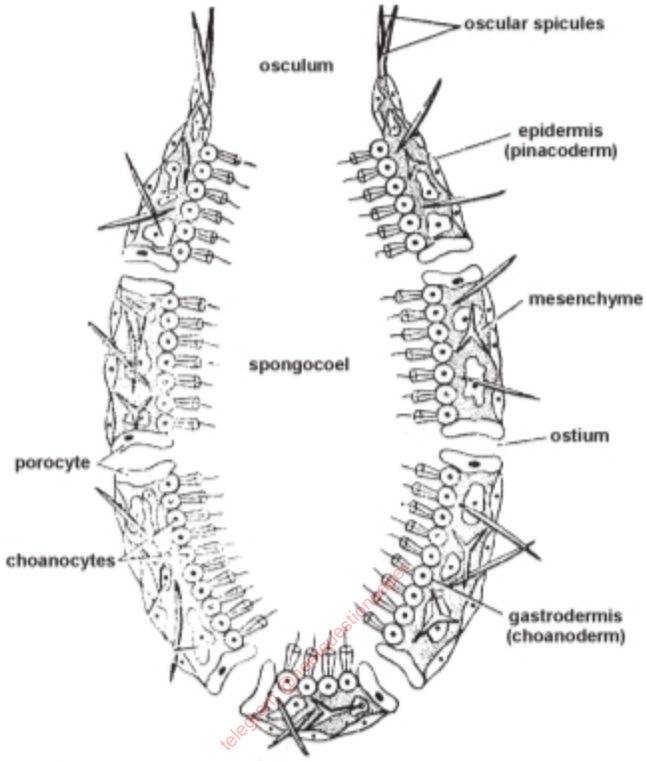


Fig. : Most Primitive Sponge (*Leucosolenia*)

2. **Canal system :** The body of a sponge is organized in such a manner as to form a complex system of pores and canals called canal system.

   Functions of water canal system / Water transport system : The continuous water current flowing through canal system is very important for the life of a sponge. It brings in food and oxygen and carries away carbon dioxide, nitrogenous wastes and reproductive bodies. Thus the canal system helps the sponge in nutrition, respiration, excretion and reproduction.

3. **Skeleton :** Almost all sponges possess an internal skeleton. It may consist of calcareous or siliceous **spicules** or fine **spongin fibres** or both and is located in the mesohyl layer.

4. **Digestion :** It is **intracellular** and occurs in food vacuoles as in protozoans.

5. **Circulation :** Distribution of food from the ingesting cells to others is brought about by wandering amoebocytes of mesohyl layer.

6. **Respiration :** Exchange of gases occurs by diffusion through the plasma membranes of the cells as in protozoans.

7. **Excretion :** Removal of metabolic wastes also occurs by diffusion through the plasma membranes of the cells as in protozoans. Ammonia is chief excretory waste.

8. **Reproduction:** Both asexual and sexual reproduction occur in sponges. Asexual reproduction occurs by **budding** and **gemmules**.

   In fresh water sponges and a few marine sponges, **gemmules** (internal buds) are formed. Each gemmule has a mass of **archaeocytes** surrounded by protective covering to tide over seasonal drought or adverse environmental conditions. Gemmule formation is often called **internal budding**. Sponges have a great power of **regeneration**. Most forms are hermaphrodite. Sperms leave one sponge and enter another with water current to fertilize the ova (eggs) *in situ*. Thus, fertilization is internal.

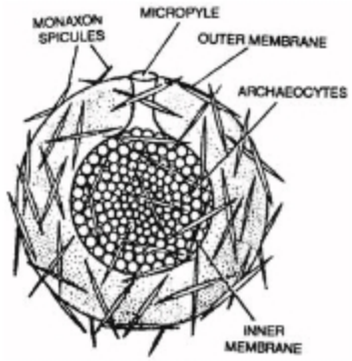


Fig. : Gemmule

9. **Development.** Development is **indirect** and includes free swimming larvae, **amphiblastula** (in *Sycon*) or **parenchymula** (in *Leucosolenia*) for dispersal of the species.

10. The skeleton of bath sponge *Euspongia* is made up of spongin fibres only. A sponge harmful to oyster industry is *Cliona* (boring sponge). *Euplectella* is venus flower basket. *Proterospongia* is a connecting link between protozoa and porifera.

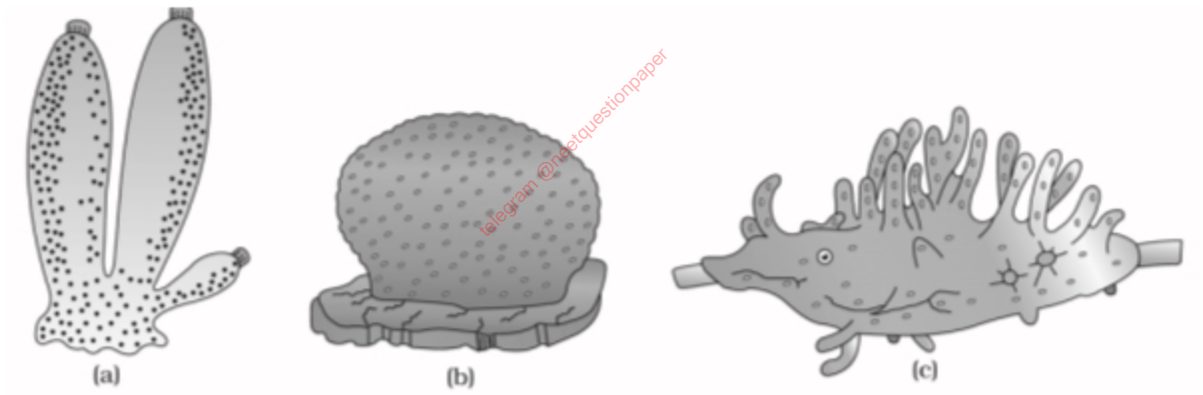


Fig. : Examples of *Porifera* : (a) *Sycon* (Scypha) (b) *Euspongia* (Bath sponge) (c) *Spongilla* (fresh water sponge)

PHYLUM-CNIDARIA (Coelenterata)

Aquatic, mostly marine, sessile or free-swimming, diploblastic, radially symmetrical animals. The name cnidaria is derived from the cnidoblasts or cnidocytes.

1. Phylum Cnidaria (old name is Coelenterata and hence these animals are (also known as coelenterates) includes about 9,000 species, mostly marine. The famous *Hydra* is a fresh water form.

2. **Cnidarians exhibit a blind sac body plan and are radially symmetric**. They are more advanced than sponges in having true tissues. They are, however, **acoelomate**; their body wall consists of only two cell layers, the ectoderm and endoderm, separated by a jelly-like **mesoglea**. These animals are therefore **diploblastic**, *i.e.,* arising from two embryonic cell layers.

3. The ectoderm and endoderm are specialised for different functions. Most ectodermal cells are contractile and possess muscle fibres within them. Some transmit stimuli and are connected to form a **nerve net**,

a primitive form of nervous system. The muscle and nerve cells allow the animal to coordinate its body movements, particularly the tentacles around the mouth for capturing the prey. **Stinging cells or cnidoblasts,** mainly in the ectoderm of the tentacles and body, discharge stinging organs called **nematocysts.** Nematocysts are usually triggered by contact and inject poison and paralyse the prey. They are unique to cnidarians and are the characteristic cells of this phylum.

4. Endodermal cells, lining the blind sac or **gastrovascular** cavity, are specialised for secreting digestive enzymes. These enzymes partly digest the food by **extracellular** digestion, which is then both absorbed (as solution) and ingested (as small particles) by the endoderm **for intracellular digestion**. Gastrovascular cavity is with a single opening, mouth on hypostome. Due to their ability to digest food extracellularly, cnidarians can manage to prey on larger organisms than those the sponges can feed. Undigested matter is egested from the mouth.

Hydra feeds only on those **substances** which **contain glutathione.**

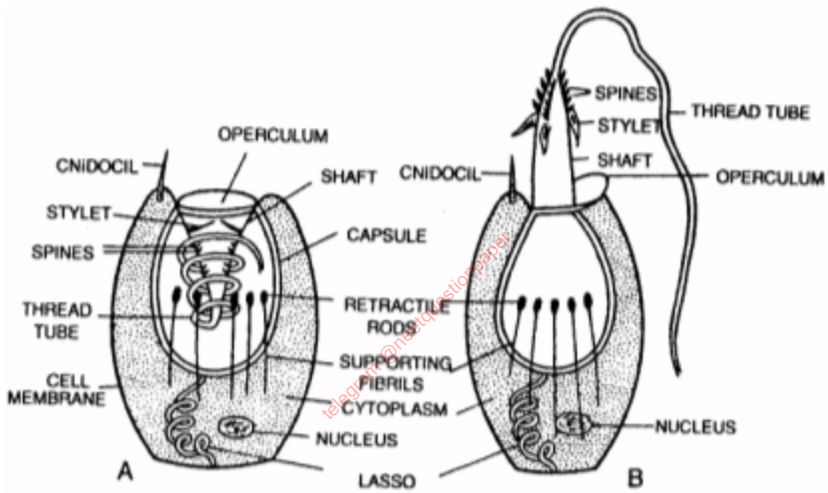


Fig. : Cnidoblasts. A. Undischarged; B. Discharged

5. **Types of Cnidoblasts :**

Penetrant are largest nematocysts containing hypnotoxin to paralyze the prey.

Desmoneme are smallest and their thread tube coils around the prey

Large and **small glutinants** secrete sticky substance, to help in locomotion.

6. **Metagenesis** – Alternation of generation between sexual and asexual forms i.e. medusa and polyp, respectively.

Cnidarians exhibit two basic body forms, the polyp and medusa. **Polyp** is sessile and the body is hydra-like; *i.e.,* a cylindrical stalk with mouth and tentacles facing upwards. **Medusa** is a free-floating or swimming structure like the jelly fish. It is like a bell or an umbrella with mouth and tentacles facing downwards. The medusa can be regarded as an upside-down polyp with reduced stalk which can swim. In many cnidarians, polyps give rise to medusae by vegetative budding and medusae form polyps by sexual reproduction. During which medusae liberate gametes into water. Following fertilization, the zygote forms a ciliated larva called **Planula**, which swims, settles and grows into a sessile polyp. Many like *Obelia* pass through an alternation between these two forms or stages *i.e.*, ***metagenesis***.

Some cnidarians, like *Hydra*, do not have a medusa stage. *Hydra* has no **larval** form and therefore, no metagenesis

7. **Metagenesis** should not be confused with alternation of generation found in plants where alternation of haploid and diploid forms occurs.

8. **Interstitial cells in the body wall of coelenterates are totipotent.**

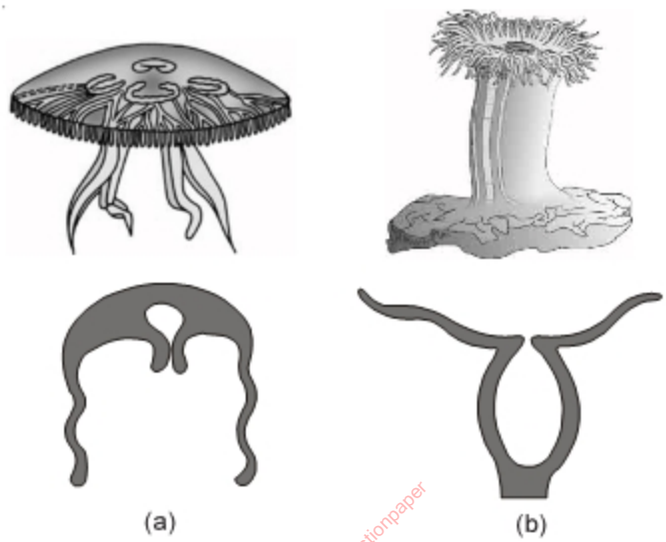


Fig. : Examples of Coelenterata indicating outline of their body form :
(a) *Aurelia* (Medusa) (b) *Adamsia* (Polyp)

Examples : *Physalia* (Portuguese man of war), *Adamsia* (Sea anemone), *Pennatula* (Sea pen), *Gorgonia* (Sea fan), *Meandrina* (Brain coral)

PHYLUM-CTENOPHORA

1. They are radially symmetrical, diploblastic and devoid of cnidoblasts. Polyp phase is absent. These are commonly called **Sea walnuts** or **Comb jellies** and are exclusively marine with tissue level of organisation.

2. Tentacles may be present or absent. When present, the number of tentacles is two. They are solid and possess adhesive cells called **colloblasts** (lasso cells).

3. Digestion is both extracellular and intracellular.

4. **Bioluminescence** is well marked in ctenophores.

5. The animals move with cilia, which are arranged in the form of eight median ciliated comb plates.

6. They reproduce only by sexual means. Sexes are not separate. Fertilisation is external. Development is indirect and an immature ciliated stage called '**cydippid larva**' is found in these forms.

Examples : *Cestum* (Venus girdle), *Beroe*, *Ctenoplana*, *Hormiphora*, *Pleurobrachia*.

Fig. : Examples of Ctenophora *(Pleurobrachia)*

PHYLUM-PLATYHELMINTHES (Flat worms)

1. They are triploblastic animals exhibiting bilateral symmetry with organ grade organisation. They have dorso-ventrally flattened body. They are acoelomate and parenchyma cells originating from mesoderm fill up the cavities of the body. Alimentary canal is incomplete having mouth opening but no anus. Hooks and suckers present in the parasitic forms.
2. Tapeworms **lack the alimentary canal** as they absorb nutrients from the host directly through their body surface.
3. **Excretory system** consists of peculiar **flame cells** (**solenocytes**) which are meant for excretion and osmoregulation. Ammonia is chief excretory waste.
4. **Nervous system** is **ladder-like**. It consists of the brain/cerebral ganglia and two main longitudinal nerve cords joined at intervals by transverse commissures.
5. **Reproductive system :** These animals are generally hermaphrodite and the reproductive organs are well developed. Fertilization is always internal. Anatomy of the body encourages cross fertilization rather than self fertilization. Asexual reproduction by **transverse binary fission** occurs in some flat worms.
6. **Development :** Life cycle is complicated in most flat worms with one or more larval stages.
7. **Regeneration** is well marked in some flat worms like *Planaria* (*Dugesia*).

Examples : *Taenia* (Tapeworm), *Fasciola* (Liver fluke), *Schistosoma* (Blood fluke)

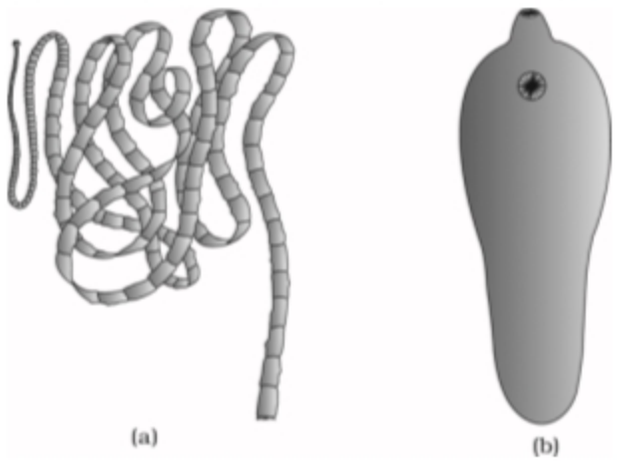


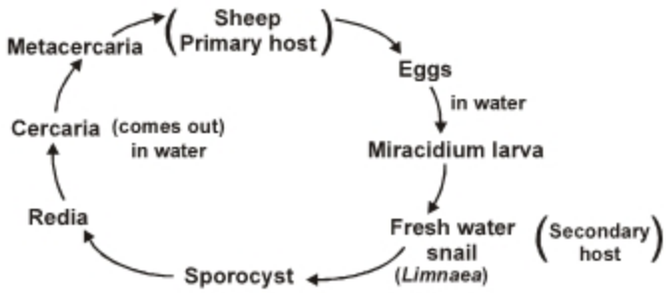
Fig. : Examples of Platyhelminthes : (a) Tape worm (b) Liver fluke

Fasciola – The Liver fluke

Habitat. Adult *Fasciola hepatica* is found in the liver and bile duct of sheep and goat which are its **primary hosts**. The **secondary** or **intermediate host** is a pond snail (a mollusc) of genus *Limnaea* or genus *Planorbis*.

Some important characteristics : Anterior end of the body is in the form of a conical projection, called the **head lobe** at the tip of which **oral-sucker** having mouth is present. There are two muscular suckers - an **oral sucker** enclosing mouth and a **ventral sucker** or **acetabulum** without an aperture. The suckers are organs for attachment although anterior sucker also helps in taking the food. There are three permanent apertures on the body – **mouth**, **common genital pore** and **excretory pore**.

The different stages in the life cycle of *Fasciola hepatica* are in the following sequence :



Infective stage for the secondary host (snail) is *Miracidium* larva and for the primary host (sheep) is *Metacercaria*.

PHYLUM-NEMATHELMINTHES OR ASCHELMINTHES

1. The phylum includes bilaterally symmetrical, triploblastic and **pseudocoelomate** animals with organ system grade of organisation. They may be free living, aquatic, terrestrial or parasitic on plants and animals.
2. They have tube-within tube type of body plan evolved along **Protostomic** evolutionary line. Alimentary canal is complete with a well developed muscular pharynx.
3. Excretory cell is a large, giant H-shaped cell called Renette cell.
4. Sexes are separate (Dioecious).
5. Fertilisation is internal and development may be direct or indirect.

   Examples : *Ascaris*, *Wuchereria*, *Enterobius*, *Trichuris*. *Rhabditis* is a free living round worm.

Ascaris – The round worm

1. *Ascaris* infection is common in children than in adults.
2. Epidermis of *Ascaris* is syncytial.
3. *Ascaris* is the most common endoparasite in small intestine of man.
4. The body is elongated, unsegmented and cylindrical with tapering ends.
5. Sexes are separate with **sexual dimorphism**.
6. Male is smaller than female with curved tail has two **pineal setae (copulatory organs)** and **cloaca.**
7. Posterior end of the body in female is straight.
8. *Ascaris* is **monogenetic** *i.e.,* no intermediate host. Only one host *i.e.*, human is required for completion of life cycle.
9. Life cycle of *Ascaris* involves four moults – first occurs in soil, second and third occurs in lung alveoli and last or fourth moult in intestine of human.

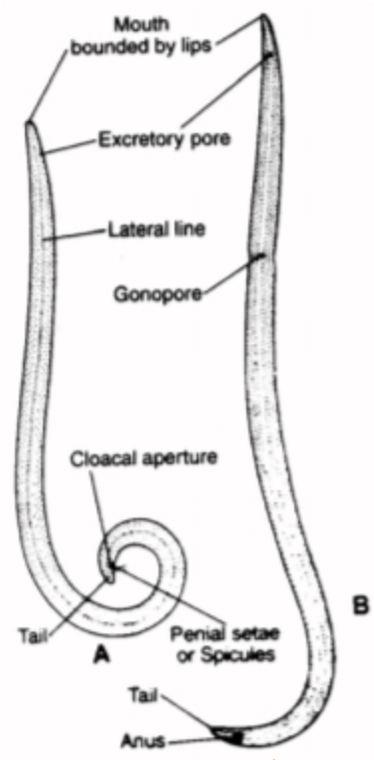


Fig. : Morphology of *Ascaris* : A. Male, **B.** Female

10. The larva is called **rhabditoid** or **rhabditiform** for its close resemblance with *Rhabditis*.

Other Nematode Parasites :

a. ***Ancylostoma duodenale* (Hookworm of man) –** enters directly by penetrating through skin and causes ancylostomiasis.

b. ***Wuchereria bancrofti* (Filarial worm)** – causes filariasis and involves female *Culex* as the vector of it.

c. ***Enterobius vermicularis* (Pinworm) –** Causes anal itching (Oxyuriasis/Enterobiasis) and is most common in children.

Phylum : ANNELIDA

1. This phylum includes over 9,000 species of **metamerically segmented** animals with a true coelom called **Schizocoelom**.
2. Annelids are triploblastic and bilaterally symmetrical animals with organ system grade of organisation.
3. The body wall of annelids have both longitudinal and circular muscles. These contract alternately against the fluid filled segments during locomotion.
4. They may be aquatic (marine and fresh water) or terrestrial, free living and sometime parasitic. Aquatic annelids like ***Nereis*** possess lateral appendages parapodia which help in swimming and also help in gaseous exchange.
5. A closed circulatory system is present. Blood of earthworm is red with haemoglobin dissolved in plasma.
6. Nephridia help in osmoregulation and excretion. In earthworm, chloragogen cells help in excretion.
7. Neural system consists of paired ganglia connected by lateral nerves to a double ventral nerve cord.

8. Trochophore larva is present in *Nereis*.
9. *Nereis* is dioecious but earthworm and leeches are monoecious.
10. Reproduction is sexual

Examples : *Nereis*, *Pheretima* (Earthworm), *Hirudinaria* (Blood sucking leech)

Earthworm and its close relatives derive nourishment from decaying fallen leaves and soil organic matter.

Hirudinaria secrete anticoagulant, hirudin from salivary glands.

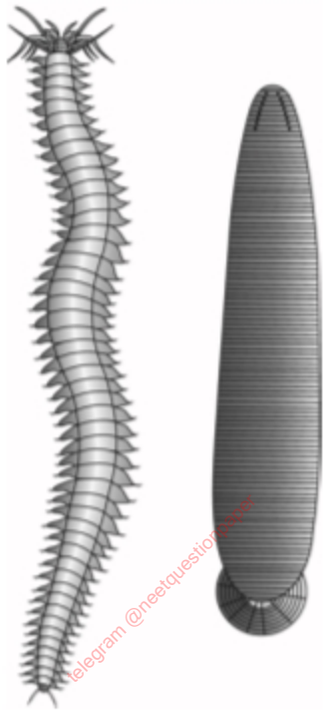


Fig. : Examples of Annelida : (a) *Nereis* (b) *Hirudinaria*

Phylum : ARTHROPODA

1. It is the largest phylum in the animal kingdom, including over 900,000 species. **The largest class is insecta with 750,000 species**.
2. They are triploblastic, coelomate and bilaterally symmetrical animals.
3. The body is covered by chitinous cuticle which forms the exoskeleton.
4. They have a segmented body, each segment generally bearing a pair of jointed appendages covered by a jointed exoskeleton.
5. The body is divided into head, thorax and abdomen, in some cases the head and thorax are fused to form cephalothorax, while in others, thorax and abdomen are fused to form trunk.
6. In insects, the thoracic segments have legs and wings, the abdomen has no legs in insects.
7. Respiratory organs are **gills, book gills, book lungs or tracheal system**. Book lungs are found in spider and scorpion. Book gills are found in *Limulus*.
8. Excretion takes place through **green glands or malpighian tubules** since nephridia are absent.
9. Sensory organs like eyes are compound in nature. In honey bees, butterflies and moths, gustatory receptors are present on their feet. Statocysts or balance organs are present.

10. The heart is dorsal and circulatory system is open.
11. Central nervous system consists of paired pre-oral ganglia connected by commissures to a solid ventral nerve cord.
12. In land arthropods, fertilization is always internal and in aquatic arthropod fertilization is usually external.
13. Arthropods are oviparous. In some like the scorpions, the eggs hatch within the female body. They bring forth the young ones alive. They are viviparous.
14. Life cycle generally involves metamorphosis. Larvae and adults may show a different feeding habit and occupy different habitats.

Examples : *Economically important insects-Apis* (Honey bee), *Bombyx* (Silkworm), *Laccifer* (Lac insect).

Vectors : Mosquito (*Anopheles, Culex, Aedes*), TseTse fly, Sand fly

Gregarious pest : *Locusta* (Locust)

Living fossil : *Limulus* (King crab)

Wingless insect : *Lepisma* (Silver fish / Book worm)

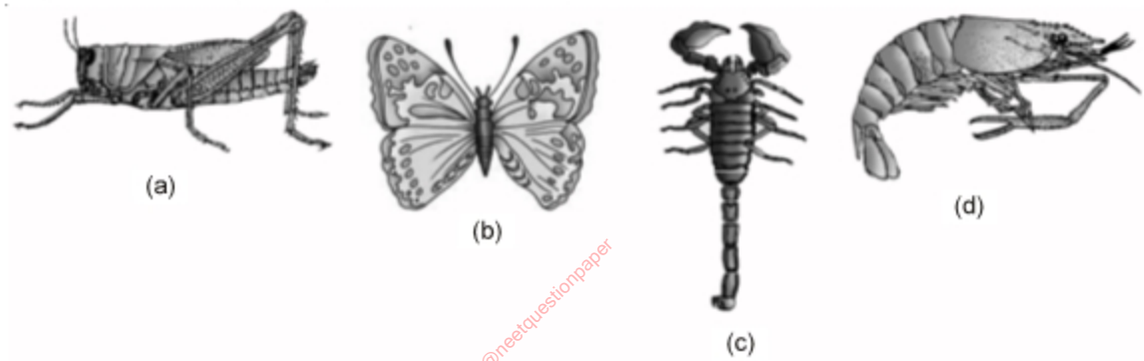


Fig. : Examples of Arthropoda : (a) Locust (b) Butterfly (c) Scorpion (d) Prawn

Phylum : MOLLUSCA

1. Phylum mollusca is the **second largest** phylum in animal kingdom.
2. Molluscs are triploblastic, bilaterally symmetrical, schizocoelic and unsegmented animals. The only segmented mollusc is *Neopilina*.
3. Most molluscs secrete a **shell** of calcium carbonate that protects and supports their soft tissues.
4. The body is organised into three general regions : **head, foot** and **visceral hump.**
5. The visceral hump contains digestive tract and other visceral organs.
6. The body is covered by a skin fold called mantle which secretes the shell.
7. Molluscs typically employ a file like rasping organ called **radula** which is armed with rows of **chitinous teeth.**
8. The radula protrudes out from mouth and is worked back and forth to rasp the food into fine particles.
9. Circulatory system is mainly of **open type** / some reduced sinuses are present.
10. **Respiration is by gills or pulmonary sac or both; may also occur through body surface.**
11. Excretion is by paired **Organs of Bojanus**. Another excretory organ called **Keber's organ (Pericardial gland** is present in *Unio*. It pours the waste into pericardium from where the waste is carried to organ of Bojanus.
12. Sense organs include eyes, statocysts and osphradia (a chemoreceptor to test chemical nature of water).
13. Reproduction is sexual. Organisms may be dioecious or monoecious.

14. Fertilization is generally external, development is either direct or through free larval forms like trochophore, veliger (in *Pila*), glochidium (in *Unio*). Glochidium larva is an ectoparasite on fishes.

    Example : *Pila* (Apple snail), *Pinctada* (Pearl oyster), *Sepia* (Cuttle fish), *Loligo* (squid), *Octopus* (Devil fish), *Aplysia* (sea hare), *Dentalium* (Tusk shell), *Chaetopleura* (Chiton).

Fig. : Pila

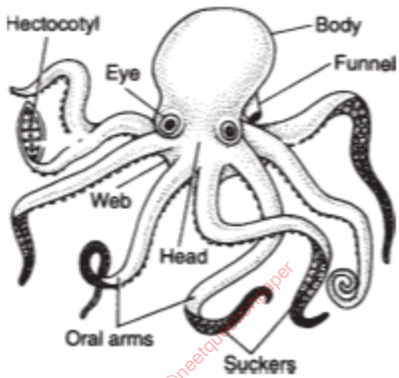


Fig. : *Octopus*

Phylum : ECHINODERMATA (Spiny bodied)

1. **They are exclusively marine and there are no parasitic forms.**

   Three characters make the echinoderms closer to chordates :

   (i) They have tube within tube type of body plan which has evolved along **deuterostomic evolutionary** line.

   (ii) They possess a true coelom called **enterocoelom**.

   (iii) They have **mesodermal endoskeleton** made of calcareous plates or ossicles.

2. The symmetry is bilateral in larvae but pentamerous radial in adults.

3. **Ambulacral System (Water Vascular System) is the characteristic feature of phylum echinodermata.** A perforated plate called **madreporite** is present in this system. The pores of madreporite allow water into the system. **Tube feet of this system help in locomotion**. Water vascular system is of coelomic origin which helps in locomotion, capture and transport of food and respiration.

4. The water vascular system starts with madreporite, a sieve like structure present on the aboral surface. From the madreporite starts a stone canal or madreporic canal which opens into a **ring canal.**

   From each angle of ring canal arises a **radial canal** which runs throughout the length of the arm on oral surface.

   From each radial canal arise **lateral canals** on either side which end in tube feet.

5. **Haemal** and **Perihaemal Systems :** Instead of blood vascular system, there are present haemal and perihaemal systems which are of coelomic origin. Thus the so called circulatory system is open type and includes haemal and perihaemal rings. The blood is often without a respiratory pigment. There is no heart.

6. Specialized excretory organs are absent. Nitrogenous wastes are diffused out *via* gills or dermal branchia. Ammonia is chief excretory matter.

7. Fertilisation is usually external.

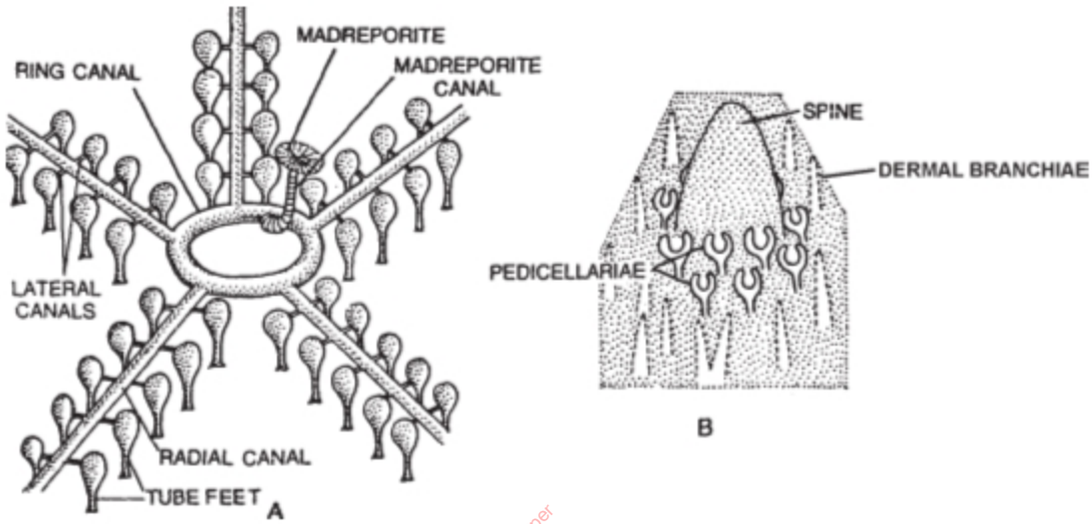


Fig. : A. Water vascular system of star fish; B. Pedicellariae and spine

8. **Development :** The development is indirect and includes a ciliated, bilaterally symmetrical larva that undergoes metamorphosis to change into a radially symmetrical adult. Bipinnaria and **brachiolaria** larvae are present in the development of star fish. The echinoderms resemble chordates in early embryonic development. It shows that echinoderms are closer to chordates. Dipleura larva is the common ancestral larval form of echinoderms, hemichordates and chordates.

   Examples : *Asterias* (Star fish), *Echinus* (Sea urchin), *Antedon* (Sea lily), *Cucumaria* (Sea cucumber), *Ophiura* (Brittle star).

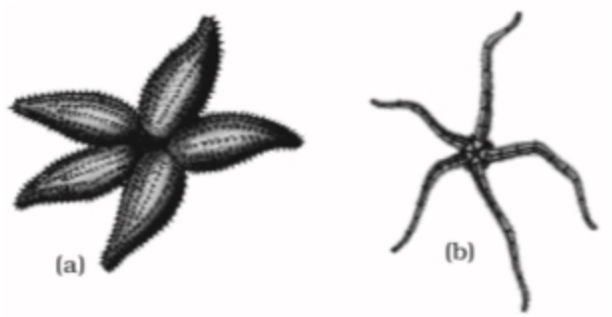


Fig. : Examples of Echinodermata : (a) *Asterias* (b) *Ophiura*

Phylum : HEMICHORDATA / STOMOCHORDATA

Hemichordata was earlier considered as a sub-phylum under phylum chordata. But now it is placed as a separate phylum under non-chordata. Due to the absence of true notochord in **hemichordata,** many taxonomists do not consider these animals as **chordates**. **Hemichordata have a rudimentary structure in the collar region called stomochord, a structure similar to notochord.**

1. In hemichordata or stomochordata, true notochord is absent. Gill slits are present but they are dorsal in position.
2. **Stomochord** is a hollow outgrowth arising from the roof of the buccal cavity and is also called **'buccal diverticulum'**. It is present in the proboscis.
3. This phylum consists of a small group of worm like marine animals with organ system level of organisation. They are bilaterally symmetrical, triploblastic and coelomate animals.
4. The body is cylindrical and is composed of an anterior **proboscis**, a **collar** and a long **trunk**.
5. Circulatory system is of open type.
6. Excretory organ is proboscis gland.
7. Respiration is through gills.
8. Sexes are separate. Fertilization is external.
9. Development is mostly indirect through a free swimming **tornaria larva**.

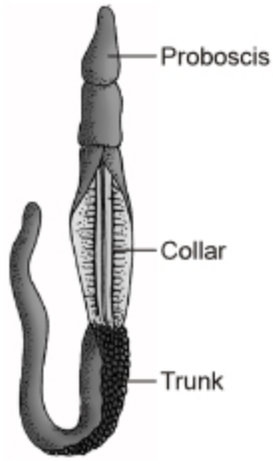


Fig. : *Balanoglossus*

Examples : *Balanoglossus* (acorn or tongue worm), *Glossobalanus*, *Saccoglossus*.

Phylum : CHORDATA

The most important characteristics of **phylum chordata** are the presence of

1. A notochord either throughout life or during early embryonic development.
2. Dorsal hollow nerve cord.
3. Paired pharyngeal gill slits.
4. Post-anal tail.

Table : Comparison of Chordates and Non-chordates

S.No.	Chordates	Non-chordates
1.	Notochord present	Notochord absent
2.	Central nervous system is dorsal, hollow and single	Central nervous system is ventral, solid and double
3.	Pharynx perforated by gill slits	Gill slits are absent.
4.	Heart is ventral	Heart is dorsal (if present)
5.	A post-anal part (tail) is present	Post-anal tail is absent

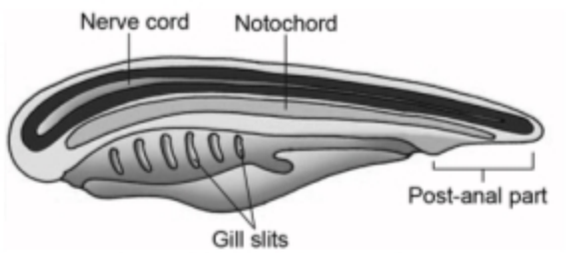
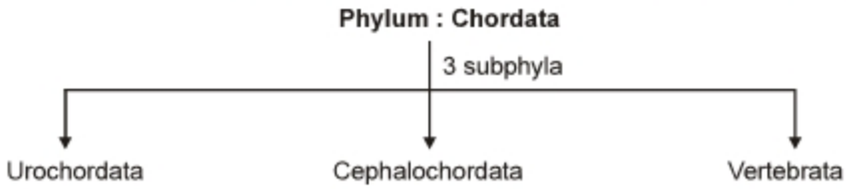


Fig. : Chordata characteristics

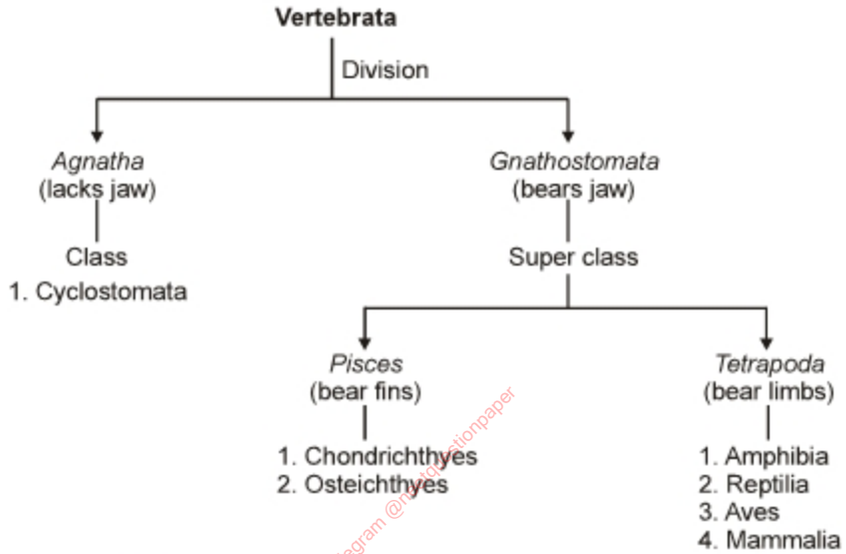
Phylum Chordata is divided into three subphyla :

Urochordata or *Tunicata*, *Cephalochordata* and *Vertebrata*

Sub-phyla *Urochordata* and *Cephalochordata* often referred to as *protochordates* and are exlusively marine.



The sub-phylum vertebrata is further divided as follows :



Sub-phylum : Urochordata

(i) This sub-phylum is also called **Tunicata** because the adult body is enclosed within a leathery **test** or **tunic** formed of a cellulose-like organic substance, **tunicin**.

(ii) Notochord is present only in the tail of the larva (hence named urochordata) and disappears in the adult.

(iii) The larva (ascidian tadpole) undergoes **retrogressive metamorphosis**, *i.e.*, change from better developed larva to less developed adult,

Examples : *Herdmania* (Sea Squirt), *Ascidia, Salpa, Doliolum.*

Fig. : *Ascidia*

Sub-phylum : Cephalochordata

(i) The notochord extends upto anterior end of the body, hence this sub-phylum is named cephalochordata

(ii) The notochord persists throughout life.

(iii) Pharyngeal gill slits are more numerous and are better developed.

(iv) The tail is present throughout life.

Examples : *Branchiostoma* (Amphioxus) has both ends pointed like lance, hence commonly called **lancelet**.

Sub-phylum : Vertebrata or Craniata

(i) These are advanced chordates that have **cranium** (brain box) around brain.

(ii) Notochord is present only in the embryonic stages, it is replaced by **vertebral column** (back bone) in the adults.

(iii) Vertebrates have ventral muscular heart with two/three/four chambers, kidneys for excretion and osmoregulation and paired appendages which may be fins or limbs.

All vertebrates are chordates but all chordates are not vertebrates.

Section Agnatha (The Jawless Vertebrates)

They are most primitive of all craniates. The mouth does not possess jaws, hence named Agnatha. Notochord persists throughout life. Vertebral column is represented only by small imperfect neural arches over the notochord. They do not have paired appendages. They have a single dorsal nostril. Internal ear has one or two semi-circular canals. They are cold blooded. Agnatha has a single existing class named **cyclostomata**.

Class : CYCLOSTOMATA

1. All living members of the class Cyclostomata are ectoparasites on some fishes.
2. They have an elongated body bearing 6-15 pairs of **gill slits** for respiration.
3. Cyclostomes have a sucking and circular mouth without jaws.
4. Their body is devoid of scales and paired fins.
5. Cranium and vertebral column are cartilaginous.
6. Circulation is of closed type.
7. Cyclostomes are marine but migrate for spawning to fresh water. After spawning, within a few days, they die. Their larvae (Ammocoete larva) after metamorphosis, return to the ocean.

Examples : *Petromyzon* (Lamprey) and *Myxine* (Hagfish).

Gnathostomata (The Jawed Vertebrates) : It includes advanced vertebrates. Embryonic notochord is usually replaced in adult by a vertebral column. Paired fins or limbs are present. Mouth has jaws hence it is named gnathostomata. Paired nostrils are present. Internal ear has three semicircular canals.

Gnathostomata is divided into two super classes : **Pisces** and **Tetrapoda**.

Super-class Pisces : It includes **true fishes**. All are aquatic. The body bears fins. Respiration occurs typically by gills. They are cold blooded. Each eye has a well developed nictitating membrane.

Pisces and Amphibia are called **Anamniotes** (without amnion – an extra embryonic membrane). Reptilia, aves and mammalia are known as **Amniotes** (with amnion).

Fig. : A jawless vertebrate - Petromyzon

Fig. : Examples of Cartilaginous fishes : (a) *Scoliodon* (b) *Pristis*

Class : CHONDRICHTHYES – The Cartilaginous Fishes

1. The fishes of this class are marine and bear cartilaginous endoskeleton. They are cold blooded (ectothermic or poikilothermal).
2. The exoskeleton consists of **placoid scales** which are dermal in origin and are homologous to teeth. Teeth are modified placoid scales which are backwardly directed.
3. Except in ***Chimaera***, the gills are not covered by operculum (gill cover).
4. Jaws are well developed. Mouth is **ventrally** placed. A spiral valve called **scroll valve** is usually present in the intestine. The digestive tract leads into **cloaca**.
5. **External nares** are present on the ventral side of the head. The internal nares are lacking.
6. Paired fins are broad. The caudal fin is mostly heterocercal.
7. Heart is two chambered (one auricle and one ventricle). It also has well developed **sinus venosus** and **conus arteriosus**. There is a well developed renal portal system.
8. Kidneys are mesonephric. Urea is chief nitrogenous waste.
9. There are 10 pairs of cranial nerves.
10. Lateral line system is well developed consisting of neuromast organs (rheoreceptors)
11. Lung or air bladder is absent in these fishes due to which they have to swim continuously or will sink in water.
12. They have cloaca. Male usually has pelvic **claspers** which are used in copulation. The fertilization is internal and many of them are viviparous.

Examples : *Scoliodon* (Indian shark), *Torpedo* (Electric ray), *Trygon* (Sting ray) and *Chimaera* (Rabbit fish), *Rhinobatus* (Guitar fish), *Pristis* (Saw fish), *Sphyrna* (Hammer headed shark), *Carcharodon* (Great white shark).

Class : OSTEICHTHYES – The Bony Fishes

1. It includes both marine and freshwater fishes.
2. The endoskeleton is cartilaginous in the embryonic stage, but in the adult forms, it is replaced by bones. They are ectothermic (cold blooded).
3. Caudal fins usually **homocercal**.
4. The exoskeleton, if present comprises of **cycloid, ctenoid** or **ganoid scales**. Scales are mesodermal in origin.
5. The mouth is terminal. Digestive tract leads into an **anus**. **Cloaca is absent in bony fishes.**

(a) (b)

Fig. : Examples of Bony fishes : (a) *Hippocampus* (b) *Catla*

6. External nares lie on the dorsal surface of the snout. In lung fishes, internal nares are also present.
7. A **swim bladder or air bladder** is usually present. It facilitates floating and may function as a respiratory organ.
8. Gills are 4 pairs and covered by an **operculum**.
9. The heart is 2-chambered and has sinus venosus and conus arteriosus. Lung fishes have three chambered heart (Two auricles and one ventricle). They also have well developed renal portal system.
10. Kidneys are mesonephric. Ammonia is chief nitrogenous waste.
11. 10 pairs of cranial nerves are present.
12. Lateral line system is well developed.
13. Fertilization is generally external and are mostly oviparous and development is direct.
14. Bony fishes occur in all sort of waters – fresh, marine, brackish.

Examples :

Marine – *Exocoetus* (Flying Fish) can glide in air.

Hippocampus (Sea Horse) the male has a brood pouch.

Freshwater – *Labeo* (Rohu), *Catla* (Katla), *Clarias* (Magur)

Aquarium – *Betta* (Fighting fish), *Pterophyllum* (Angel fish)

Gambusia is a predator of mosquito larvae.

Latimeria (*Coelacanth*)

It is a "living fossil". *Latimeria* is believed to be the oldest amongst living fishes. It's a connecting link between fishes and amphibians. **Though it is grouped in crossopterygii, it respires by gills.**

Class : AMPHIBIA – The Vertebrates with Dual life

(Gk. *Amphi* = two or both; *bios* = life)

1. **They are poikilothermal (cold blooded) animals.**
2. They are **amphibious** in nature, *viz.*, they can live on land as well as in water.
3. The skin may be either smooth or rough having cutaneous glands to keep it moist.
4. **They are usually without scales,** but if present, these are hidden beneath the skin (*e.g.* Caecilians).
5. Body is divided into head and trunk. Tail may be present in some.
6. Two pairs of limbs are used for locomotion.
7. The gills are present at least in larval stage; some adult forms also carry them in addition to lungs (*e.g., Necturus*).
8. Skull is **dicondylic**, *i.e.*, with two occipital condyles for articulation with vertebral column.
9. Alimentary canal, urinary and reproductive tracts open into a common chamber called cloaca.
10. The respiratory organs are lungs, buccopharyngeal cavity, skin and gills.

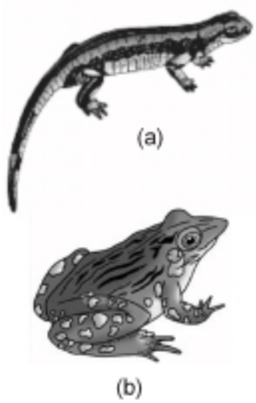


Fig. : Examples of Amphibia :
(a) *Salamandra*
(b) *Rana*

11. The heart is three chambered, having two auricles and one ventricle. In the heart, there are also present sinus venosus and truncus arteriosus. Erythrocytes are oval and nucleated. Both hepatic portal and renal portal systems are well developed.
12. Kidneys are mesonephric. Urinary bladder is present in frog. All larvae and tailed amphibians (*e.g.*, Salamanders) are ammonotelic. Frogs and toads are ureotelic.
13. Ear consists of middle and internal ear. **Tympanum** (outer membrane) covers the middle ear which has a single ear ossicle called **Columella Auris**.
14. Ten pairs of cranial nerves are present.
15. Lateral line system is found during their development (larval stages).
16. They return to water for breeding. Males lack copulatory organs. Metamorphosis usually occurs. A fish like stage, **tadpole,** is seen.
17. They occur only in fresh water and moist land. **Amphibians are not found in sea.**

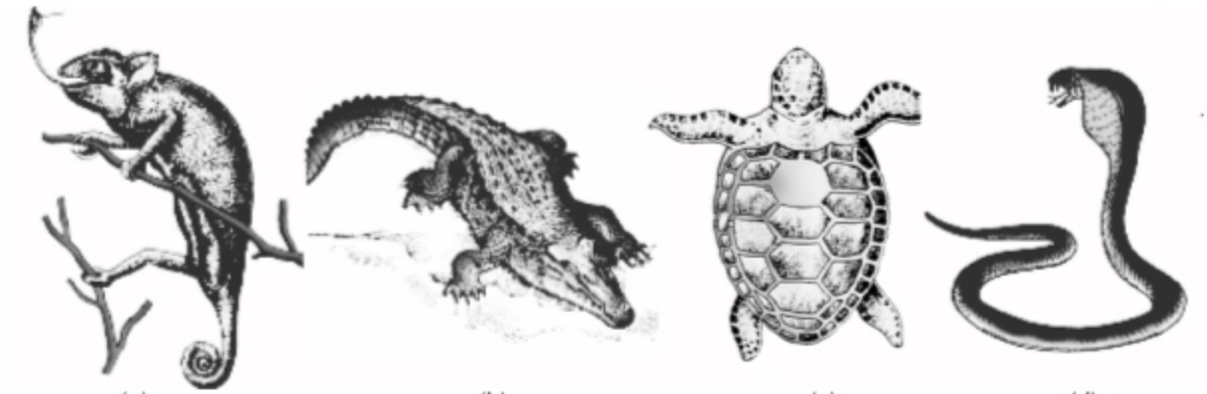
    Example : *Bufo* (Toad), *Rana* (Frog), *Hyla* (Tree frog), *Salamandra* (Salamander), *Ichthyophis* (Limbless amphibia).

Class – REPTILIA

General Characteristics :

1. Reptiles are readily distinguished by their dry horny scales or scutes covered skin. Snakes and lizards shed their scales as 'skin cast'. Scales prevent loss of body water and so reptiles do not require a moist environment like amphibians.
2. Respiration is only through lungs, which is improved by the development of ribs.
3. **Two features make reptiles truly land animals**. One is the development of internal fertilization. The other is presence of a special membrane in the yolk filled egg called **'Amnion'**. The amnion encloses the embryo and provides it with a watery environment during development. It is generally held that the development of reptilian egg, with the provision of amnion, was a decisive event in the conquest of land by vertebrates.
4. Limbs are two pairs and pentadactyl. Digits with horny claws, but limbs are absent in few lizards and all snakes.
5. Mouth is terminal bearing conical teeth-**pleurodont** in lizards and snakes and **thecodont** in crocodiles. Teeth are absent and replaced by horny beaks in turtles.
6. Endoskeleton bony, skull is monocondylic (with one occipital condyle).
7. Heart is usually 3-chambered or partially 4-chambered as interventricular septum is incomplete. It is completely 4-chambered in crocodiles.
8. Two systemic arches are present.
9. Erythrocytes are oval and nucleated.
10. Kidneys are **metanephric**. Excretion is uricotelic.
11. Cranial nerves are 12 pairs.
12. **Jacobson's organ** (vomeronasal organ) is an additional olfactory organ in the roof of buccal cavity, well developed in snakes and lizards.
13. They do not have external ear. Tympanum represents ear.
14. Sexes separate. Male is usually with a muscular copulatory organ.
15. Fertilization internal and are oviparous.
16. Reptiles are cold blooded or **poikilothermic animals**.

    Example : *Chelone* (Turtle), *Testudo* (Tortoise), *Chameleon* (Tree lizard), *Calotes* (Garden lizards), *Crocodilus* (Crocodile), *Alligator* (Alligator), *Hemidactylus* (Wall lizard), Poisonous snake - *Naja* (Cobra), *Bungarus* (Krait), *Vipera* (Viper). Only poisonous lizard in world is *Heloderma*. *Python* (Ajgar) is a non-poisonous snake.



(a) (b) (c) (d)

Fig. : Reptiles : (a) *Chameleon* (b) *Crocodilus* (c) *Chelone* (d) *Naja*

Class – AVES

1. Birds are **feathered bipeds**, air breathing, truly flying warm blooded vertebrates (other being bats from Class Mammalia).
2. Jaw bones are prolonged into toothless **beak** or bill.
3. Limbs are two pairs. Forelimbs are modified as wings for flying. Hindlimbs or legs are large, each foot usually bears four clawed toes modified for walking, swimming or clasping tree branches.
4. Exoskeleton consists of feathers, scales (on hind limbs only) and claws which are all epidermal derivatives.
5. **Skin is without glands. Only cutaneous gland is uropygial or preen gland at the base of the tail.** Feathers of birds are water proof due to oily secretions of preen gland but absent in flightless birds and parrot.
6. The largest and most powerful flight muscle is **pectoralis major**.
7. Bones are pneumatic or hollow and have no marrow.
8. Skull is **monocondylic** like reptiles.
9. A **synsacrum** is formed by fusion of posterior thoracic, lumbar, sacral and anterior caudal vertebrae.
10. The last three or four tail vertebrae are fused to form a **pygostyle.**
11. Sternum is large, usually with a vertical, midventral **keel** for attachment of flight muscles.
12. Ribs possess posteriorly directed **uncinate processes.**
13. **Both clavicles and a single interclavicle fuse to form a V-shaped bone called furcula or wishbone or merry-thought bone.**
14. Oesophagus is dilated into a crop for quick feeding and storage.
15. Crop secretes **'pigeon milk'** during breeding season.
16. Stomach is divided into a glandular **proventriculus** and a muscular **gizzard.**

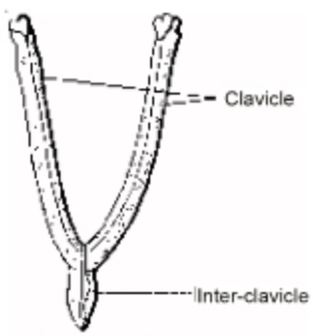


Fig. : Furcula

17. Respiration with compact, spongy, nondistensible lungs which are continuous with thin walled **air sacs**. Air sacs reduce body weight.

18. Larynx is without vocal cords.
19. A sound box or **syrinx** produces voice, It lies at or near the junction of trachea and bronchi.
20. Heart is completely four-chambered (also in mammals).
21. Sinus venosus is absent.
22. Only **right aortic** (systemic) arch persists in the adults.
23. Renal portal system is vestigial.
24. Erythrocytes are minute, oval and nucleated.
25. Blood of the birds may be called the **richest blood** in animal kingdom as they have more RBCs per cubic mm of blood than any other animal.
26. Kidneys are **metanephric** and three-lobed. Ureters open into cloaca as urinary bladder is absent. Excretion is uricotelic.
27. Cranial nerves are 12 pairs.
28. Olfactory organs are poorly developed. Middle ear contains a single ossicle.
29. Eyes possess nictitating membrane. **Pecten** is a comb-like structure found in the eyes near blindspot. Pecten helps in the nutrition of eyeball.
30. Pecten is found in all birds except Kiwi.
31. Sexes are separate. Some birds show sexual dimorphism (*e.g.*, Parrot and Peacock). Fertilisation is internal.
32. **Females are oviparous with only a single (left) functional ovary and oviduct (Mullerian duct).**
33. Feathers are found only in birds. They are made of a hard and indigestible protein **keratin** and Quill feather is largest feather.

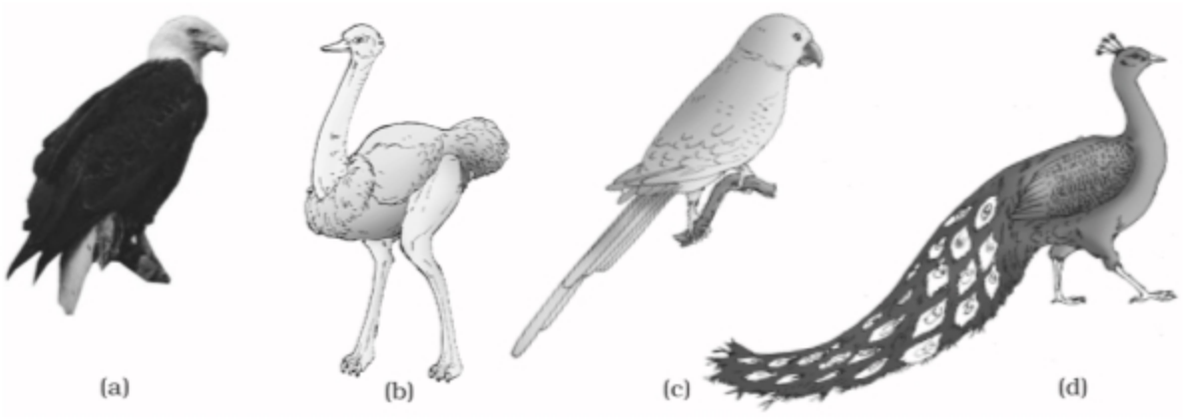


Fig. : Some Birds : (a) *Neophron* (b) *Struthio* (c) *Psittacula* (d) *Pavo*

Examples : *Corvus* (Crow), *Columba* (Pigeon), *Psittacula* (Parrot), *Struthio* (Ostrich : It is largest living bird), *Pavo* (Peacock), *Aptenodytes* (Penguin), *Neophron* (Vulture).

Class – MAMMALIA

They are terrestrial warm-blooded (endothermous) or homeothermal animals *i.e.*, their body temperature remains constant in spite of the changes in the temperature of the environment.

1. The skin is covered with epidermal **hair** which act as insulating layer and allow high body temperature to be maintained. The hair may be partly lost as a secondary adaptation. In some aquatic mammals where hair is negligible, there is a subcutaneous layer of fat blubber which provides insulation to the body and makes the warm-blooded conditions possible.

2. The skin has two kinds of glands : **sudorific glands** which produce sweat – evaporation of which controls the body temperature; and **sebaceous glands** which produce an oily secretion which makes their hair water-resistant.

3. Modified sweat glands form **mammary glands** which produce milk in the females for nourishment of the young for some time after birth. Because they possess **mammae** (breasts) and mammary glands, they are called mammals.

4. There is an external ear or **pinna** with an external auditory meatus. This is in addition to middle and internal ear.

5. In higher mammals, the anus is separated from the urinogenital aperture; consequently, urinary and genital ducts have no connection with the digestive tube.

6. In males, testes have come to lie outside the body cavity in scrotal sacs (except in elephants, aquatic and prototherian mammals)

7. Teeth are embedded in sockets of the jaw bone and are said to be **thecodont**. There are only two sets of teeth in lifetime, one deciduous or milk set and another **permanent** set. This condition is known as **diphyodont**. There are four different types of teeth, hence mammals are **heterodont**. The tusk of elephants are incisors.

8. A muscular **diaphragm** divides the coelom into thoracic and abdominal cavity; the thoracic part has a **pericardial cavity** containing the heart and two **pleural cavities** containing the lungs, the remaining viscera lie in the abdominal cavity.

9. The heart is 4-chambered with two auricles and two ventricles so that pure blood lies in the left half and impure blood in the right half. This condition is also found in birds.

10. Only the left aortic arch is present.

11. Erythrocytes are round, biconcave and non-nucleated (except in camel where they are oval).

12. Cerebral hemispheres and cerebellum are large-sized and highly developed with great increase in the cortex. The two cerebral hemispheres are joined by a transverse band of nerve fibres called **corpus callosum**. There are four solid optic lobes called **corpora quadrigemina**, in the mid brain.

13. The middle ear has three **ear ossicles** called malleus, incus and stapes; the internal ear has a spirally coiled **cochlea** as an efficient organ of hearing.

14. The neck generally has seven cervical vertebrae.

15. Fertilisation is internal and are viviparous with few exception. Development is direct.

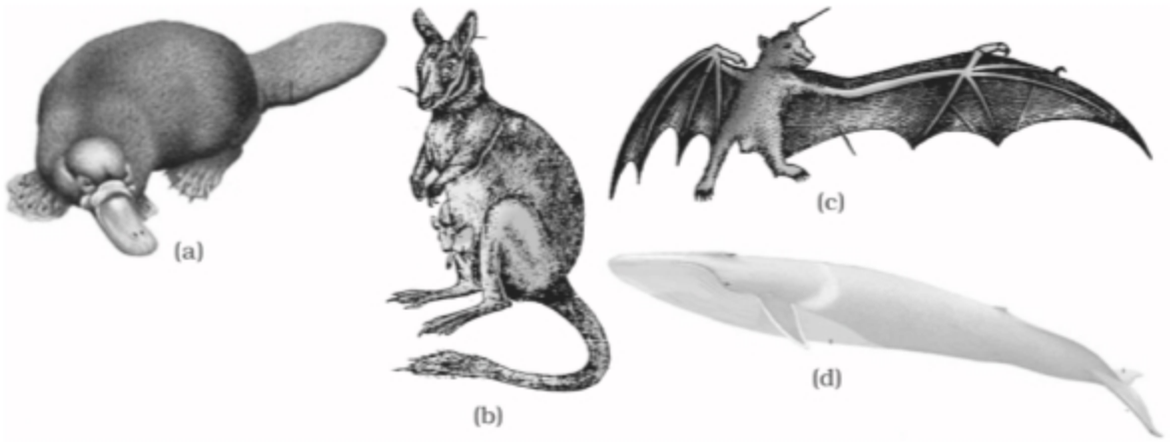


Fig. : Some Mammals : (a) *Ornithorhynchus* (b) *Macropus* (c) *Pteropus* (d) *Balaenoptera*

Examples : Oviparous-*Ornithorhynchus* (Platypus); Viviparous-*Macropus* (Kangaroo), *Pteropus* (Flying fox), *Camelus* (Camel), *Macaca*(Monkey), *Rattus* (Rat), *Canis* (Dog), *Felis* (Cat), *Elephas* (Elephant), *Equus* (Horse), *Delphinus* (Common dolphin), *Balaenoptera* (Blue whale), *Panthera tigris* (Tiger), *Panthera leo* (Lion).

The salient distinguishing features of all phyla under animal kingdom is comprehensively given in the Table.

Table : Salient Features of Different Phyla in the Animal Kingdom

Phylum	Level of Organisation	Symmetry	Coelom	Segmentation	Digestive System	Circulatory System	Respiratory System	Distinctive Features
Porifera	Cellular	Many	Absent	Absent	Absent	Absent	Absent	Body with pores and canals in walls.
Coelenterata (Cnidaria)	Tissue	Radial	Absent	Absent	Incomplete	Absent	Absent	Cnidoblasts present.
Ctenophora	Tissue	Radial	Absent	Absent	Incomplete	Absent	Absent	Comb plates for locomotion.
Platyhelminthes	Organ & Organ-system	Bilateral	Absent	Absent	Incomplete	Absent	Absent	Flat body, suckers.
Aschelminthes	Organ-system	Bilateral	Pseudo-coelomate	Absent	Complete	Absent	Absent	Often wormshaped, elongated.
Annelida	Organ-system	Bilateral	Coelomate	Present	Complete	Present	Present	Body segmentation like rings.
Arthropoda	Organ-system	Bilateral	Coelomate	Present	Complete	Present	Present	Exoskeleton of cuticle, jointed appendages.
Mollusca	Organ-system	Bilateral	Coelomate	Absent	Complete	Present	Present	External skeleton shell usually present.
Echinodermata	Organ-system	Radial	Coelomate	Absent	Complete	Present	Present	Water vascular system, radial symmetry.
Hemichordata	Organ-system	Bilateral	Coelomate	Absent	Complete	Present	Present	Worm-like with proboscis, collar and trunk.
Chordata	Organ-system	Bilateral	Coelomate	Present	Complete	Present	Present	Notochord, dorsal hollow nerve cord, gill slits with limbs or fins.

❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. Animals which are triploblastic, have tube within tube type of body plan and in which embryonic blastopore forms anus (deuterostomia) are
   (1) Annelids (2) Molluscs
   (3) Platyhelminthes (4) Echinoderms
2. Echinoderms and chordates have
   (1) Pseudocoel (2) Shizocoelom
   (3) Enterocoelom (4) Haemocoel
3. True segmentation (metamerism) occurred for the first time in
   (1) Platyhelminthes (2) Aschelminthes
   (3) Annelids (4) Arthropods
4. Metameric segmentation is the characteristic of
   (1) Platyhelminthes and Arthropoda
   (2) Echinodermata and Annelida
   (3) Annelida and Arthropoda
   (4) Mollusca and Chordata
5. Sponges, in which the cells are loosely aggregated and do not form tissues or organs, are grouped under which sub-kingdom?
   (1) Metazoa (2) Eumetazoa
   (3) Parazoa (4) Bilateria
6. Which of the following is not an example of porifera?
   (1) *Sycon* (2) *Euspongia*
   (3) *Spongilla* (4) *Adamsia*
7. Find out **incorrect** statement related to phylum *Porifera*
   (1) Members of this phylum are commonly known as sponges
   (2) They are generally marine and mostly asymmetrical animals
   (3) These are primitive multicellular animals and have tissue level of organisation
   (4) Sponges have a water transport or canal system
8. Water transport or canal system in sponges is helpful in
   (1) Food gathering
   (2) Respiratory exchange
   (3) Removal of waste
   (4) All of these
9. In phylum porifera digestion is
   (1) Extracellular
   (2) Intracellular
   (3) First extracellular then intracellular
   (4) First intracellular then extracellular
10. In sponges fertilisation and development is
    (1) External and direct respectively
    (2) Internal and direct respectively
    (3) Internal and indirect respectively
    (4) External and indirect respectively
11. *Euspongia* is also known as
    (1) *Sycon* (2) Fresh water sponge
    (3) *Scypha* (4) Bath sponge
12. In sponges water enters through_____ into a central cavity; _____
    (1) Osculum and spongocoel respectively
    (2) Ostia and osculum respectively
    (3) Osculum and ostia respectively
    (4) Ostia and spongocoel respectively
13. Sponges are exclusively
    (1) Present in marine water
    (2) Asymmetrical animals
    (3) Primitive multicellular animals
    (4) All of these

14. The most important characteristic of phylum porifera is
(1) They are acellular
(2) They possess blind sac type of body plan
(3) They possess canal system and choanocytes
(4) They possess water vascular system

15. Which of the following cells is totipotent and is responsible for regenerative capacity in sponges?
(1) Pinacocyte (2) Thesocyte
(3) Archaeocyte (4) Scleroblast

16. The skeleton of bath sponge, *Euspongia*, is made of
(1) Spongin fibres
(2) Siliceous spicules
(3) Calcareous spicules
(4) Spongin fibres and siliceous spicules

17. A sponge harmful to oyster industry is
(1) *Spongilla* (2) *Euspongia*
(3) *Hyalonema* (4) *Cliona*

18. 'Venus Flower Basket' is
(1) *Leucosolenia* (2) *Euplectella*
(3) *Euspongia* (4) *Sycon*

19. *Proterospongia* is a connecting link between
(1) Protozoa and porifera
(2) Porifera and coelenterata
(3) Protozoa and annelida
(4) Porifera and annelida

20. Larva of *Leucosolenia* is
(1) Parenchymula (2) Amphiblastula
(3) Planula (4) Trochophore

21. Most of the sponges are marine and remain attached to rocks (sessile). The fresh water sponge is
(1) *Sycon* (2) *Spongilla*
(3) *Cliona* (4) *Euplectella*

22. Which is the only phylum in the animal kingdom without any nerve cell?
(1) Porifera (2) Coelenterata
(3) Annelida (4) Eumetazoa

23. Cnidoblasts are used for
(1) Anchorage (2) Defence
(3) Capturing the prey (4) All of these

24. *Hydra* and *Obelia* are
(1) Diploblastic with blind sac body plan, radial symmetry and are acoelomate
(2) Diploblastic with bilateral symmetry and are acoelomate
(3) Triploblastic with radial symmetry and are coelomate
(4) Triploblastic with bilateral symmetry and are coelomate

25. The most important characteristic of phylum cnidaria is
(1) Cnidoblasts (2) Choanocytes
(3) Thesocytes (4) Archaeocytes

26. Digestion in *Hydra* is
(1) Extracellular
(2) Intracellular
(3) Extracellular and intracellular
(4) Holozoic

27. Metagenesis is found in
(1) *Physalia* (Portuguese man of war)
(2) *Hydra*
(3) *Obelia*
(4) Both (1) & (3)

28. Which of the following statements is incorrect about metagenesis?
(1) Alternation of asexual and sexual phases in the life cycle of *Obelia* is called metagenesis
(2) Metagenesis is similar to alternation of generations as found in plants
(3) Both medusa and polyp are diploid
(4) Medusa is the sexual phase and polyp is the asexual phase

29. The hypnotoxin is produced by
(1) Penetrant (2) Volvent
(3) Large glutinant (4) Small glutinant

30. Sea anemone is a/an
(1) Cnidarian (2) Protozoan
(3) Platyhelminth (4) Aschelminth

31. Which animal has been placed in wrong habitat?
(1) *Hydra vulgaris* – sea water
(2) *Hydra gangetica* – fresh water
(3) *Obelia* – sea water
(4) *Physalia* – sea water

32. Find out incorrect one related to phylum ctenophora
(1) Commonly known as sea walnuts
(2) Exclusively marine
(3) Triploblastic organism
(4) Tissue level of organisation

33. Which type of reproduction takes place in animal like *Ctenoplana*?
(1) Asexual (2) Sexual
(3) Budding (4) Both (1) and (3)

34. How many ciliated comb plates are found in ctenophorans?
(1) 4 (2) 6
(3) 8 (4) 10

35. Which of the following belongs to phylum ctenophora?
(1) *Hormiphora* (2) *Ctenoplana*
(3) *Beroe* (4) All of these

36. An animal which is triploblastic and acoelomate is
(1) *Ascaris* (2) *Periplaneta*
(3) *Planaria* (4) *Sycon*

37. Animals possessing pseudocoelom are
(1) Flat worms (2) Round worms
(3) Annelids (4) Molluscs

38. Flatworms are
(1) Bilaterally symmetrical
(2) Triploblastic
(3) Acoelomate animals
(4) All of these

39. In phylum platyhelminthes specialised cells called flame cells help in
(1) Osmoregulation (2) Circulation
(3) Excretion (4) Both (1) & (3)

40. Which of the following animals is known as pork tapeworm?
(1) *Taenia solium* (2) *Echinococcus*
(3) *Taenia saginata* (4) *Schistosoma*

41. Which of the following are triploblastic acoelomates with a blind sac type of body plan and where parenchymal cells originating from mesoderm fill up the cavities of the body?
(1) Cnidarians (2) Platyhelminthes
(3) Annelids (4) Arthropods

42. In platyhelminthes, the excretory organs are
(1) Nephridia (2) Nephrons
(3) Flame cells (4) Archaeocytes

43. Which of the following stages in the life history of liver fluke infects the sheep?
(1) Miracidium (2) Redia
(3) Cercaria (4) Metacercaria

44. The correct sequence of various larvae in life history of liver fluke is
(1) Miracidium, sporocyst, cercaria, redia, metacercaria
(2) Miracidium, sporocyst, redia, cercaria, metacercaria
(3) Sporocyst, redia, miracidium, cercaria, metacercaria
(4) Cercaria, sporocyst, redia, miracidium, metacercaria

45. *Schistosoma* is known as
(1) Blood fluke (2) Chinese liver fluke
(3) Dog tapeworm (4) Lung fluke

46. Ladder like nervous system is present in
(1) Cnidaria (2) Platyhelminthes
(3) Annelida (4) Arthropoda

47. Alimentary canal is absent in
(1) *Planaria* (2) Tapeworm
(3) Blood fluke (4) Liver fluke

48. Which of the following animals has/have blind sac body plan?
(1) Sponges (2) Cnidarians
(3) Platyhelminthes (4) Both (2) & (3)

49. *Ancylostoma* is also known as
(1) Filaria worm (2) Hook worm
(3) Liver fluke (4) Lung worm

50. Nemathelminthes are
(1) Round worms
(2) Bilaterally symmetrical
(3) Triploblastic
(4) All of these

51. All of the following statements are correct about *Ascaris*, but one is wrong. Which one is wrong?
(1) It is dioecious
(2) Fertilisation is internal
(3) It is a digenetic parasite
(4) Female is longer than male, with straight tail

52. All of the following animals are examples of metamerically segmented animals except
(1) *Nereis* (2) *Pheretima*
(3) *Ascaris* (4) *Hirudinaria*

53. A free living roundworm is
(1) *Enterobius* (2) *Rhabditis*
(3) *Dracunculus* (4) *Trichinella*

54. Male *Ascaris* differs from female in having
(1) Lips (2) Amphids
(3) Pineal spicules (4) Tail

55. The epidermis of *Ascaris* is
(1) Unicellular (2) Syncytial
(3) Columnar (4) Cuboidal

56. Filariasis is caused by
(1) *Wuchereria* (2) *Ancylostoma*
(3) *Trichinella* (4) *Enterobius*

57. Annelids possess
(1) Cell aggregate plan (2) Blind sac plan
(3) Tube within tube plan (4) Pseudocoelom

58. In phylum annelida the structure related to excretion and osmoregulation are
(1) Flame cells (2) Nephridia
(3) Parapodia (4) Setae

59. Which of the following annelid is dioecious?
(1) *Nereis* (2) *Pheretima*
(3) Earthworm (4) *Hirudinaria*

60. The larva related to phylum annelida is
(1) Cysticercus (2) Hexacanth
(3) Trochophore (4) Planula

61. Leech belongs to the phylum
(1) Cnidaria (2) Platyhelminthes
(3) Annelida (4) Ctenophora

62. *Hirudinaria* is
(1) Monoecious (2) Dioecious
(3) Unisexual (4) Both (2) & (3)

63. Parapodia for locomotion are found in one of the following
(1) Earthworm (2) *Hirudinaria*
(3) *Nereis* (4) *Polygordius*

64. In earthworm, the function of chloragogen cells is
(1) Excretion (2) Reproduction
(3) Digestion (4) Regeneration

65. Which of the following is earthworm?
(1) *Nereis* (2) *Hirudinaria*
(3) *Pheretima* (4) *Aphrodite*

66. *Nephridia* help in
(1) Excretion (2) Osmoregulation
(3) Haematopoiesis (4) Both (1) & (2)

67. Blood of *Pheretima* is
(1) Blue with haemocyanin in corpuscles
(2) Blue with haemocyanin in plasma
(3) Red with haemocyanin in corpuscles
(4) Red with haemoglobin in plasma

68. The unit of compound eye in arthropods is
(1) Rhabdome (2) Ospharidium
(3) Ocellus (4) Ommatidium

69. The feature not related to phylum arthropoda is
(1) Organ-system level of organisation
(2) Bilaterally symmetrical
(3) Segmented
(4) Acoelomate animals

70. The respiratory organ found in arthropods are
(1) Gills (2) Book lungs
(3) Tracheal system (4) All of these

71. All of the following are excretory structures found in arthropods, except
(1) Malpighian tubules (2) Green glands
(3) Coxal glands (4) Keber's organ

72. All of the following arthropods act as vector except
(1) *Anopheles* (2) *Culex*
(3) *Aedes* (4) *Locusta*

73. Find out incorrect match
(1) *Apis* – Honey bee
(2) *Limulus* – King crab
(3) *Locusta* – Gregarious pest
(4) *Bombyx* – Lac insect

74. Fertilisation in terrestrial arthropods is
(1) Internal
(2) External
(3) Fertilisation does not take place
(4) Both (1) & (2)

75. Respiratory organ of spider is
(1) Gills
(2) Book gills
(3) Tracheal system
(4) Book lungs

76. Which of the following is viviparous?
(1) Cockroach (2) Spider
(3) Scorpion (4) Silkworm

77. Which of the following is represented by the largest number of species?
(1) Insecta (2) Protozoa
(3) Mammalia (4) Aves

78. The largest phylum is
(1) Arthropoda (2) Mollusca
(3) Annelida (4) Chordata

79. Which of the following is not an economically important insect?
(1) *Apis* (2) *Bombyx*
(3) *Laccifer* (4) *Limulus*

80. Which of the following has an open circulatory system?
(1) *Pheretima* (2) *Periplaneta*
(3) *Nereis* (4) *Octopus*

81. Which type of respiratory organs are present in spiders and scorpions?
(1) Book lungs (2) Gills
(3) Gill pouch (4) Lungs

82. Which of the following animal is commonly known as tusk shell?
(1) *Pila* (2) *Sepia*
(3) *Octopus* (4) *Dentalium*

83. In molluscs mouth contains a file-like rasping organ for feeding, called
(1) Macula (2) Crista
(3) Radula (4) Cupula

84. Find out incorrect match
(1) *Chaetopleura* – Chiton
(2) *Octopus* – Devil fish
(3) *Aplysia* – Pearl oyster
(4) *Loligo* – Squid

85. Respiration in mollusca takes place by
(1) Body surface (2) Gills or ctenidia
(3) Pulmonary sac (4) All of these

86. A fold of dorsal body wall which covers the visceral mass in molluscs is
(1) Operculum (2) Mantle
(3) Shell (4) None of these

87. The only segmented mollusc is
(1) *Neopilina* (2) *Teredo*
(3) *Nautilus* (4) *Chiton*

88. Pearls are produced by
(1) *Mytilus* (2) *Doris*
(3) *Pecten* (4) *Pinctada*

89. Second largest phylum is
(1) Arthropoda (2) Annelida
(3) Mollusca (4) Echinodermata

90. Organ of Bojanus is found in
(1) Annelida (2) Mollusca
(3) Arthropoda (4) Echinodermata

91. *Octopus* is commonly called
(1) Cuttle fish (2) Devil fish
(3) Hag fish (4) Silver fish

92. Radula of molluscs is a part of _____ system.
(1) Circulatory (2) Nervous
(3) Digestive (4) Respiratory

93. In which of the following groups of animals, larvae are bilaterally symmetrical and the adult are radially symmetrical?
(1) Molluscs (2) Cnidarians
(3) Echinoderms (4) Platyhelminthes

94. Which of the following statements is **incorrect** w.r.t. echinoderms?
(1) The most distinctive feature of echinoderms is the presence of water vascular system which is a part of the coelom
(2) The main function of water vascular system is locomotion and capture of food
(3) Echinoderms have no proper excretory system
(4) They have well developed circulatory system

95. Echinoderms are closely related to chordates due to
(1) Tube within tube type of body plan developed along deuterostomic evolutionary line
(2) They have enterocoelom
(3) They have mesodermal endoskeleton
(4) All of these

96. Which phylum includes exclusively marine organisms without any parasitic forms?
(1) Porifera (2) Cnidaria
(3) Mollusca (4) Echinodermata

97. Excretory organ in hemichordate is
(1) Proboscis gland (2) Neural gland
(3) Malpighian tubules (4) Organ of Bojanus

98. Which of the following is the common ancestral larva of echinoderms, hemichordates and chordates?
(1) Trochophore (2) Dipleura
(3) Pluteus (4) Nauplius

99. The body is divided into proboscis, collar and trunk in
(1) *Ophiura* (2) *Balanoglossus*
(3) *Dentalium* (4) *Branchiostoma*

100. In which of the following phylum stomochord is present instead of true notochord?
(1) Chordata (2) Hemichordata
(3) Protochordata (4) Urochordata

101. Tornaria is the larva of
(1) *Balanoglossus* (2) *Salpa*
(3) *Doliolum* (4) *Herdmania*

102. Retrogressive metamorphosis occurs in
(1) *Balanoglossus*
(2) *Amphioxus*
(3) Ascidian tadpole larva of *Herdmania*
(4) *Glossobalanus*

103. Which of the following group of characters is present in all chordates in some or other stage of their life?
(1) Mammary glands, hairs and gill slits
(2) Notochord, gill slits and dorsal tubular nervous system
(3) Notochord, scales and dorsal tubular nervous system
(4) Gill slits, vertebral column and notochord

104. Blood vascular system in hemichordata is
(1) Open (2) Reduced
(3) Closed (4) Absent

105. Which of the following is a matching set of phylum and its three examples?
(1) Cnidaria – *Bonellia, Physalia, Aurelia*
(2) Platyhelminthes – *Planaria, Schistosoma, Enterobius*
(3) Mollusca – *Loligo, Teredo, Octopus*
(4) Porifera – *Spongilla, Euplectella, Pennatula*

106. Mark wrong one w.r.t. *Petromyzon* (*Lamprey*)
(1) Ectoparasite on fishes
(2) Anadromous
(3) Indirect development
(4) Presence of scales and paired fins

107. Fishes are characterised by
(1) Two chambered heart
(2) Venous heart
(3) Single circulation
(4) All of the above

108. In which of the following fish electric organs are present which are modified musculature between eye and nostrils?
(1) *Torpedo* (electric ray)
(2) *Scoliodon* (dog fish)
(3) *Trygon* (sting ray)
(4) *Pristis* (saw fish)

109. Gill slits in chondrichthyes are
(1) Uncovered
(2) Covered by operculum
(3) Absent
(4) Connected to air bladder

110. Scales in cartilaginous fishes are
(1) Cycloid (2) Ctenoid
(3) Placoid (4) Leptoid

111. Which of the following is viviparous and bring forth its young alive?
(1) *Hippocampus* (2) Shark (*Scoliodon*)
(3) *Anabas* (4) *Trygon*

112. Heterocercal tail and placoid scales are found in which one of the following?
(1) Rohu (2) *Neoceratodus*
(3) *Scoliodon* (4) *Anguilla*

113. *Gambusia* is a
(1) Pest on fishes
(2) Pathogenic fish
(3) Parasitic fish
(4) Predator of mosquito larvae

114. Which of the following fish does not belong to class osteichthyes?
(1) *Hippocampus* (2) *Labeo*
(3) *Torpedo* (4) *Exocoetus*

115. Which of the following fish can glide in air?
(1) *Exocoetus* (2) *Anabas*
(3) *Echeneis* (4) *Labeo*

116. In which fish male shows parental care and has a brood pouch?
(1) *Anabas* (2) *Labeo*
(3) *Hippocampus* (4) *Synaptura*

117. Which of the following is absent in cartilaginous fish which makes them to swim constantly?
(1) Air bladder (2) Operculum
(3) Gills (4) Caudal fin

118. In fishes, the lateral line receptors are neuromast organs. These are
(1) Olfactoreceptors (2) Gustatoreceptors
(3) Rheoreceptors (4) Chemoreceptors

119. Which of the following is a fish?
(1) Sea cucumber (2) Sea horse
(3) Sea hare (4) Sea pen

120. *Ichthyophis* is a/an
(1) Amphibian (2) Reptile
(3) Bird (4) Fish

121. Which of the following is tree frog?
(1) *Rana tigrina* (2) *Hyla*
(3) *Bufo* (4) *Alytes*

122. One of the following is a limbless amphibian
(1) *Salamandra* (2) *Ichthyophis*
(3) *Necturus* (4) *Hyla*

123. Heart in amphibians is
(1) Two chambered (2) Three chambered
(3) Four chambered (4) Absent

124. External ear in amphibians is represented by
(1) Operculum
(2) Tympanum
(3) Scale
(4) Columella auris

125. The reptile having four chambered heart is
(1) *Neophron* (2) *Pavo*
(3) *Crocodilus* (4) *Chelone*

126. Reptiles are
(1) Poikilotherms (2) Endotherms
(3) Ectotherms (4) Both (1) & (3)

127. Find the incorrect match.
(1) *Testudo* – Tortoise
(2) *Crocodilus* – Crocodile
(3) *Naja* – Cobra
(4) *Calotes* – Tree lizard

128. The success of reptiles as true land animals was due to
(1) Development of internal fertilization
(2) Presence of amnion, an extra-embryonic membrane which encloses the embryo and provides watery environment during its development
(3) Respiration only through lungs which is improved by the development of ribs
(4) All of these

129. Which of the following are poikilothermal animals with single occipital condyle and twelve pairs of cranial nerves?
(1) Aves (2) Reptiles
(3) Mammals (4) Amphibia

130. Which is the only poisonous lizard of the world?
(1) *Ophiosaurus* (2) *Varanus*
(3) *Heloderma* (4) *Draco*

131. Which of the following is a non-poisonous snake?
(1) Cobra (*Naja naja*) (2) Ajgar (*Python*)
(3) Krait (*Bungarus*) (4) Viper (*Vipera russelli*)

132. Lateral line sense organs do not occur in
(1) Cartilaginous fishes (2) Bony fishes
(3) Amphibian larva (4) Reptiles

133. The bones of bird are called pneumatic bones because
(1) They are fully ossified
(2) Maximum bones are fused together
(3) Have air cavities
(4) Have bone marrow in the cavity

134. Additional chamber which are known as crop and gizzard in birds are the part of
(1) Digestive tract (2) Respiratory tract
(3) Reproductive tract (4) All of these

135. The first warm blooded vertebrates with four chambered heart are
(1) Reptiles (2) Aves
(3) Mammals (4) Amphibians

136. In which of the following animal air sacs are connected to lungs to supplement respiration?
(1) *Corvus* (2) *Alligator*
(3) *Macaca* (4) *Salamandra*

137. Feathers of the birds are waterproof due to the oily secretions of
(1) Cutaneous gland (2) Preen gland
(3) Sudorific gland (4) None of these

138. The largest living bird is
(1) *Struthio* (Ostrich)
(2) *Aptenodytes* (Penguin)
(3) *Phonicopterus* (Flamingo)
(4) *Aepyornis* (Giant elephant bird)

139. Which of the following statements is **incorrect** w.r.t. birds?
(1) The two clavicles and one interclavicle form a Y-shaped bone called furcula
(2) The eyes of birds are peculiar due to presence of pecten
(3) Carinatae or flying birds have sternum with keel
(4) In birds, the left ovary and oviduct is atrophied

140. The most unique mammalian characteristic is
(1) Mammary glands
(2) Presence of hair
(3) Presence of placenta
(4) Having external ear

141. Which of the following has three chambered heart?
(1) *Columba* (2) *Macropus*
(3) *Vipera* (4) *Scoliodon*

142. External ear or pinnae are present in
(1) *Pteropus* (2) *Bufo*
(3) *Bangarus* (4) *Corvus*

143. Blue whale is
(1) *Balaenoptera* (2) *Delphinus*
(3) *Canis* (4) *Felis*

144. An oviparous mammal is
(1) *Ornithorhynchus* (2) *Equus*
(3) *Panthera* (4) *Elephas*

145. Which of the following animals has a diaphragm between the thorax and abdomen?
(1) Frog (2) Lizard
(3) Pigeon (4) Whale

146. The tusks of elephants are
(1) Incisors (2) Canines
(3) Molars (4) Premolars

147. Which of the following groups of animals are homeothermal, have a single occipital condyle, twelve pairs of cranial nerves, pneumatic bones and four chambered heart?
(1) Amphibia (2) Aves
(3) Reptilia (4) Mammalia

SECTION - B

Previous Years Questions

1. In which one of the following, the genus name, its two characters and its phylum are **not** correctly matched, whereas the remaining three are correct?

[AIPMT 2012]

	Genus Name		Two Characters	Phylum
(1)	*Sycon*	(a) (b)	Pore bearing Canal System	Porifera
(2)	*Periplaneta*	(a) (b)	Jointed Appendages Chitinous Exoskeleton	Arthropoda
(3)	*Pila*	(a) (b)	Body segmented Mouth with Radula	Mollusca
(4)	*Asterias*	(a) (b)	Spiny skinned Water vascular System	Echinoder-mata

2. Which one of the following pairs of animals are similar to each other pertaining to the feature stated against them? **[AIPMT 2012]**

(1) *Pteropus and Ornithorhyncus* – Viviparity

(2) Garden lizard and Crocodile – Three chambered heart

(3) *Ascaris* and *Ancylostoma* – Metameric segmentation

(4) Sea horse and Flying fish – Cold blooded (poikilothermal)

3. Which one of the following categories of animals, is correctly described with no single exception in it? **[AIPMT 2012]**

(1) All reptiles possess scales, have a three chambered heart and are cold blooded (poikilothermal)

(2) All bony fishes have four pairs of gills and an operculum on each side

(3) All sponges are marine and have collared cells

(4) All mammals are viviparous and possess diaphragm for breathing

4. Which one of the following characteristics is common both in humans and adult frogs?

[AIPMT 2012]

(1) Four-chambered heart

(2) Internal fertilisation

(3) Nucleated RBCs

(4) Ureotelic mode of excretion

5. *Pheretima* and its close relatives derive nourishment from **[AIPMT 2012]**

(1) Soil insects

(2) Small pieces of fresh fallen leaves of maize etc

(3) Sugarcane roots

(4) Decaying fallen leaves and soil organic matter

6. Compared to those of humans, the erythrocytes in frog are **[AIPMT 2012]**

(1) Very much smaller and fewer

(2) Nucleated and without haemoglobin

(3) Without nucleus but with haemoglobin

(4) Nucleated and with haemoglobin

7. Which group of animals belong to the same phylum? **[NEET 2013]**

(1) Earthworm, Pinworm, Tapeworm

(2) Prawn, Scorpion, *Locusta*

(3) Sponge, Sea anemone, Starfish

(4) Malarial parasite, *Amoeba,* Mosquito

8. Match the name of the animal (Column I) with one characteristics (Column II) and the phylum/class (Column III) to which it belongs. **[NEET 2013]**

	Column I	Column II	Column III
(1)	*Ichthyophis*	Terrestrial	Reptilia
(2)	*Limulus*	Body covered by chitinous exoskeleton	Pisces
(3)	*Adamsia*	Radially symmetrical	Porifera
(4)	*Petromyzon*	Ectoparasite	Cyclostomata

9. Which of the following are correctly matched with respect to their taxonomic classification? **[NEET 2013]**

(1) Centipede, millipede, spider, scorpion – Insecta

(2) House fly, butterfly, tsetsefly, silverfish – Insecta

(3) Spiny anteater, sea urchin, sea cucumber – Echinodermata

(4) Flying fish, cuttlefish, silverfish, – Pisces

10. One of the representatives of Phylum Arthropoda is **[NEET 2013]**

(1) Silverfish (2) Pufferfish

(3) Flying fish (4) Cuttlefish

11. Select the Taxon mentioned that represents both marine and fresh water species **[AIPMT 2014]**

(1) Echinoderms (2) Ctenophora

(3) Cephalochordata (4) Cnidaria

12. Which one of the following living organisms completely *lacks* a cell wall? **[AIPMT 2014]**

(1) Cyanobacteria (2) Sea - fan (*Gorgonia*)

(3) *Saccharomyces* (4) Blue - green algae

13. *Planaria* possess high capacity of **[AIPMT 2014]**

(1) Metamorphosis

(2) Regeneration

(3) Alternation of generation

(4) Bioluminescence

14. A marine cartilaginous fish that can produce electric current is **[AIPMT 2014]**

(1) *Pristis* (2) *Torpedo*

(3) *Trygon* (4) *Scolidon*

15. Which of the following characteristics is mainly responsible for diversification of insects on land? **[AIPMT-2015]**

(1) Eyes (2) Segmentation

(3) Bilateral symmetry (4) Exoskeleton

16. Which of the following endoparasites of humans does show viviparity? **[AIPMT-2015]**

(1) *Ascaris lumbricoides*

(2) *Ancylostoma duodenale*

(3) *Enterobius vermicularis*

(4) *Trichinella spiralis*

17. Which of the following represents the **correct** combination without any exception? **[AIPMT-2015]**

	Characteristics	Class
(1)	Body covered with feathers; skin moist and glandular; fore-limbs form wings; lungs with air sacs	Aves
(2)	Mammary gland; hair on body; pinnae, two pairs of limbs	Mammalia
(3)	Mouth ventral; gills without operculum; skin with placoid scales; persistent notochord	Chondrichthyes
(4)	Sucking and circular mouth; jaws absent, integument without scales; paired appendages	Cyclostomata

18. Which of the following animals **is not** viviparous? **[AIPMT-2015]**

(1) Whale (2) Flying fox (Bat)

(3) Elephant (4) Platypus

19. Metagenesis refers to: **[Re-AIPMT-2015]**

(1) Presence of a segmented body and parthenogenetic mode of reproduction

(2) Presence of different morphic forms

(3) Alternation of generation between asexual and sexual phases of an organism

(4) Occurrence of a drastic change in form during post-embryonic development

20. Body having meshwork of cells, internal cavities lined with food filtering flagellated cells and indirect development are the characteristics of phylum: **[Re-AIPMT-2015]**

(1) Protozoa (2) Coelenterata

(3) Porifera (4) Mollusca

21. A jawless fish, which lays eggs in fresh water and whose ammocoetes larvae after metamorphosis return to the ocean is : **[Re-AIPMT-2015]**

(1) Petromyzon (2) Eptatretus

(3) Myxine (4) Neomyxine

22. Which of the following features is not present in the Phylum-Arthropoda? **[NEET-2016]**

(1) Jointed appendages

(2) Chitinous exoskeleton

(3) Metameric segmentation

(4) Parapodia

23. Which of the following characteristic features always holds true for the corresponding group of animals?
[NEET-2016]

(1)	3-chambered heart with one incompletely divided ventricle	Reptilia
(2)	Cartilaginous endoskeleton	Chondrichthyes
(3)	Viviparous	Mammalia
(4)	Possess a mouth with an upper and a lower jaw	Chordata

24. Which one of the following characteristics is **not** shared by birds and mammals? **[NEET-2016]**
(1) Warm blooded nature
(2) Ossified endoskeleton
(3) Breathing using lungs
(4) Viviparity

25. Match **Column-I** with **Column-II** for housefly classification and select the correct option using the codes given below:

	Column-I		**Column-II**
a.	Family	(i)	Diptera
b.	Order	(ii)	Arthropoda
c.	Class	(iii)	Muscidae
d.	Phylum	(iv)	Insecta

[NEET (Phase-2) 2016]

Codes:
(1) a(iii), b(i), c(iv), d(ii) (2) a(iii), b(ii), c(iv), d(i)
(3) a(iv), b(iii), c(ii), d(i) (4) a(iv), b(ii), c(i), d(iii)

26. Choose the **correct** statement.
[NEET (Phase-2) 2016]
(1) All mammals are viviparous
(2) All cyclostomes do not possess jaws and paired fins
(3) All reptiles have a three-chambered heart
(4) All pisces have gills covered by an operculum

27. In case of poriferans the spongocoel is lined with flagellated cells called **[NEET-2017]**
(1) Ostia (2) Oscula
(3) Choanocytes (4) Mesenchymal cells

28. An important characteristic that Hemichordates share with Chordates is **[NEET-2017]**
(1) Absence of notochord
(2) Ventral tubular nerve cord
(3) Pharynx with gill slits
(4) Pharynx without gill slits

29. Which among these is the correct combination of aquatic mammals? **[NEET-2017]**
(1) Seals, Dolphins, Sharks
(2) Dolphins, Seals, Trygon
(3) Whales, Dolphins Seals
(4) Trygon, Whales, Seals

30. Which of the following represents order of 'Horse'?
[NEET-2017]
(1) Equidae (2) Perissodactyla
(3) Caballus (4) Ferus

31. Which one of these animals is not a homeotherm?
[NEET 2018]
(1) *Camelus* (2) *Chelone*
(3) *Macropus* (4) *Psittacula*

32. Identify the vertebrate group of animals characterized by crop and gizzard in its digestive system **[NEET 2018]**
(1) Aves (2) Reptilia
(3) Amphibia (4) Osteichthyes

33. Which of the following animals does not undergo metamorphosis? **[NEET 2018]**
(1) Moth (2) Tunicate
(3) Earthworm (4) Starfish

34. Consider following features
(a) Organ system level of organisation
(b) Bilateral symmetry
(c) True coelomates with segmentation of body
Select the **correct** option of animal groups which possess all the above characteristics
[NEET-2019]
(1) Annelida, Arthropoda and Chordata
(2) Annelida, Arthropoda and Mollusca
(3) Arthropoda, Mollusca and Chordata
(4) Annelida, Mollusca and Chordata

35. Match the following organisms with their respective characteristics :

(a)	*Pila*	(i)	Flame cells
(b)	*Bombyx*	(ii)	Comb plates
(c)	*Pleurobrachia*	(iii)	Radula
(d)	*Taenia*	(iv)	Malpighian tubules

Select the **correct** option from the following :

[NEET-2019]

	(a)	**(b)**	**(c)**	**(d)**
(1)	(iii)	(ii)	(i)	(iv)
(2)	(iii)	(iv)	(ii)	(i)
(3)	(ii)	(iv)	(iii)	(i)
(4)	(iii)	(ii)	(iv)	(i)

36. Match the following genera with their respective phylum : **[NEET-2019 (Odisha)]**

(a)	*Ophiura*	(i)	Mollusca
(b)	*Physalia*	(ii)	Platyhelminthes
(c)	*Pinctada*	(iii)	Echinodermata
(d)	*Planaria*	(iv)	Coelenterata

Select the correct option :

(1) (a)-(iii), (b)-(iv), (c)-(ii), (d)-(i)

(2) (a)-(iv), (b)-(i), (c)-(iii), (d)-(ii)

(3) (a)-(iii), (b)-(iv), (c)-(i), (d)-(ii)

(4) (a)-(i), (b)-(iii), (c)-(iv), (d)-(ii)

37. Which of the following animals are true coelomates with bilateral symmetry? **[NEET-2019 (Odisha)]**

(1) Annelids (2) Adult Echinoderms

(3) Aschelminthes (4) Platyhelminthes

❑ ❑ ❑

Chapter 2

Structural Organization in Animals

Sub-topics *Animal Tissues; Morphology, Anatomy and Functions of Different Systems (Digestive, Circulatory, Respiratory, Nervous and Reproductive) of an Insect (Cockroach)*

Animal Tissues

In multicellular animals, a group of similar cells along with intercellular substances perform a specific function. Such an organisation is called tissue. The structure of the cells vary according to their function. Therefore, the tissues are different and are categorised into 4 types : (1) Epithelial, (2) Connective, (3) Muscular, (4) Neural.

EPITHELIAL TISSUE

Cells of the epithelium are very close to each other, separated by very thin films of extracellular material. Neighbouring cells are held together by cell junctions. The epithelial tissue rests on a non-cellular **Basement membrane** which separates it from the underlying connecting tissue.

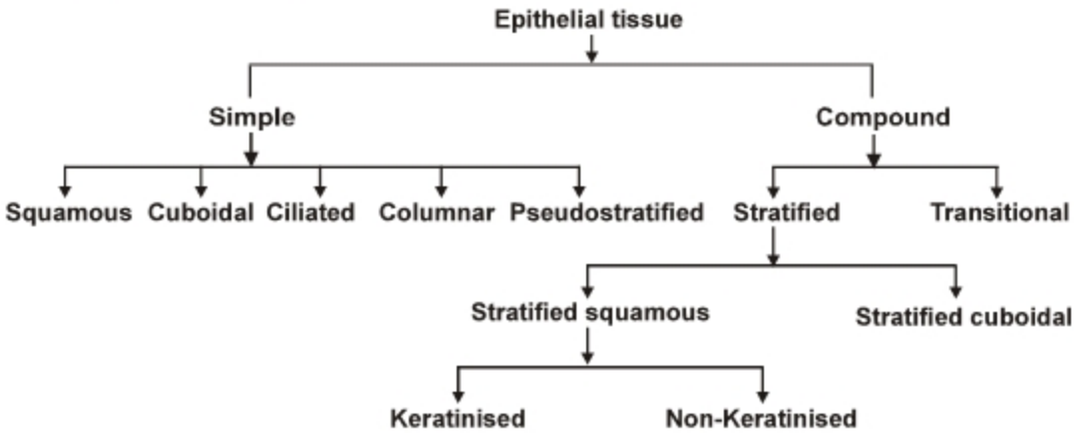
The basement membrane is made of two layers

(i) Upper thin layer called basal lamina made of glycoproteins and mucopolysaccharides secreted by epithelial cells.

(ii) Lower thick fibrous layer called reticular lamina, made of reticular fibres and collagen fibres which are the part of underlying connective tissue.

Blood vessels are absent in the epithelial tissue. Materials are exchanged between epithelial cells and blood vessels of the connective tissues by diffusion across the basement membrane.

Classification of Epithelial Tissues



Simple Epithelium

It is formed of a single layer of cells resting on the basement membrane. Simple epithelium occurs mainly on secretory and absorptive surfaces.

(i) **Squamous Epithelium** consists of a layer of thin, flat, scale-like cells with prominent nuclei. The cells have irregular boundaries that fit closely into those of neighbouring cells. **It forms the inner lining of lung alveoli and blood vessels.**

(ii) **Cuboidal Epithelium** has cells which are polygonal in outline, but appear cuboidal in vertical section. It lines small salivary and pancreatic ducts and thyroid vesicles. The cells participate in secretion, excretion and absorption. The cells of cuboidal epithelium in absorptive surfaces often bear **microvilli** on their free surfaces. This gives a brush-like appearance to their free border. They are, therefore, called **Brush-Bordered Cuboidal Epithelial Cells** *e.g.*, in **proximal tubules of kidneys**. Microvilli greatly increase the absorptive area of the free surface of the cell and thereby enhance absorption.

(iii) **Columnar Epithelium** is characterised by the presence of tall cells shaped like polygonal columns. The nucleus is usually located at the base of the cells. Columnar epithelium covers the inner surface of intestine, stomach and gall bladder. It also occurs in gastric and intestinal glands. Its function is secretion or absorption. The intestinal mucosa is lined by **Brush-Bordered Columnar Epithelium** which is highly absorptive.

(iv) **Ciliated Epithelium** consists of columnar or cuboidal cells bearing cilia on their free surfaces. The function of the cilia is to move particles, free cells or mucus in a specific direction over the epithelial surface. Ciliated epithelium lines the inner surfaces of some hollow organs such as **fallopian tubes**, **bronchioles** and small bronchi. Ciliated columnar epithelium lining the ventricles of brain and spinal canal is called **ependyma**. Cilia are of two types : (i) Kinocilia are motile cilia with (9 + 2) microtubular organisation, (ii) Stereocilia are immotile cilia where basal granule and (9 + 2) microtubular organisation is absent. Stereocilia are found in some parts of the male reproductive tracts such as the epididymis and Vas deferens.

(v) **Pseudostratified Epithelium** covers the inner linings of trachea and large bronchi. Although made up of a single layer of columnar cells, it appears two-layered because some cells are shorter than the others and have their nuclei at a different level. The shorter cells lack cilia and secrete mucus which traps particles on the epithelial surface. The longer cells are ciliated. The ciliary movements propel the mucus and the trapped particles towards the larynx.

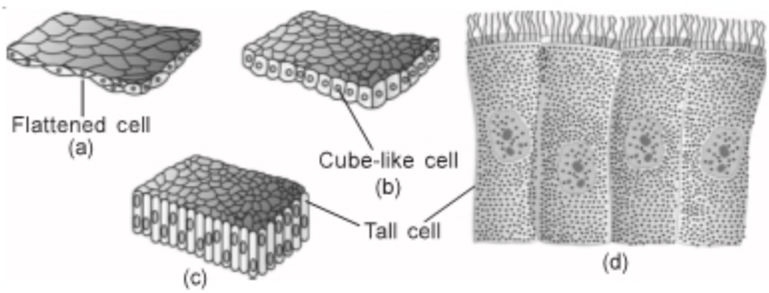


Fig. : Simple epithelium: (a) Squamous (b) Cuboidal (c) Columnar (d) Columnar cells bearing cilia

Compound Epithelium

It consists of more than one layer of cells. Only the cells of the deepest layer rest on the basement membrane. Being multilayered, compound epithelia have little role in secretion or absorption but they provide protection to underlying tissues against mechanical, chemical, thermal or osmotic stress. Compound epithelia may be stratified or transitional.

Stratified Epithelium has many layers of epithelial cells. The deepest layer is formed of cuboidal cells. But the morphology of the superficial layers varies in the different kinds of stratified epithelia. In stratified cuboidal epithelium the superficial cells are cuboidal. It lines the inner surfaces of larger salivary and pancreatic ducts. **Stratified non-keratinised Squamous Epithelium covers moist surfaces such as those of buccal cavity, pharynx and oesophagus**. It has several superficial layers of living squamous cells and deeper layers of interlinked polygonal

cells. **Stratified Keratinised Squamous Epithelium** covers the dry surface of skin. It has many superficial layers of horny, scale-like remains of dead squamous cells and several deeper layers of living polygonal cells. Heavy deposits of the insoluble protein keratin in the dead superficial cells make the epithelium impervious to water and highly resistant to mechanical abrasions. In contrast, non-keratinised stratified epithelia cannot prevent water loss and afford only moderate protection against abrasions.

Transitional Epithelium is much thinner and more stretchable than the stratified epithelium. It has a single layer of cuboidal cells at the base, 2-3 middle layers of large polygonal or pear-shaped cells and a superficial layer of large, broad, rectangular or oval cells. **It lines the inner surface of the urinary bladder and ureter.** It allows considerable expansion of these organs to accommodate urine because stretching considerably flattens and broadens the cells of superficial and middle layers.

Histologists have identified two more types of epithelia which cannot be included in any of the former types of covering epithelia. One is **neuroepithelial cells** of epithelial origin. **These cells are specialised for sensory functions (*e.g.*, cells of taste bud).** The other is **myoepithelial cells**, which are branched cells that contain muscle proteins such as myosin and actin. These are specialised for contraction for the release of secretion from sweat glands, mammary glands and salivary glands.

Glandular Epithelia

The cells of glandular epithelia are generally columnar or cuboidal. The glandular epithelium can be classified into two types : **unicellular**, consisting of isolated glandular cells (*e.g.*, goblet cell of alimentary canal), and **multicellular**, consisting of cluster of cells. A gland, with a single unbranched duct is called a **simple gland**. The secretory part of the gland consists of epithelial cells arranged in the form of tubes (tubules) or sacs (acini, alveoli) or a combination of both. The duct is also made of epithelial cells. Tubular glands, found in the human intestine, are an example of simple glands. A gland with a branched system of ducts is called a **compound gland**. In these glands, the secretory tubule or acinus may be coiled or branched and opens into the single duct of the gland. Compound glands are present in the pancreas and sub-mandibular salivary glands.

Endocrine glands pour their secretion into blood as they lack ducts while **Exocrine glands** have a secretory portion which contains the cells for secretion, and **ducts** which transport their secretions to the respective sites of action, *e.g.*, salivary glands, tear glands, gastric glands and intestinal glands. When a gland performs as both exocrine and endocrine parts, it is called a **mixed or composite or heterocrine gland** (*e.g.*, pancreas).

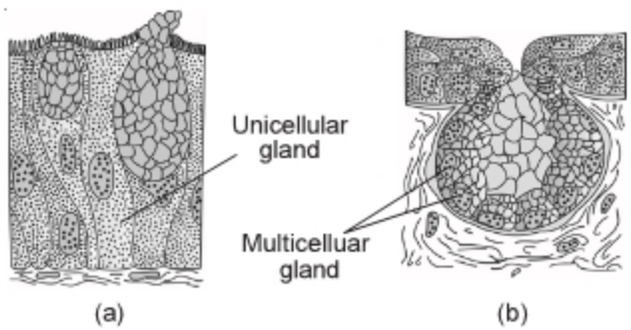
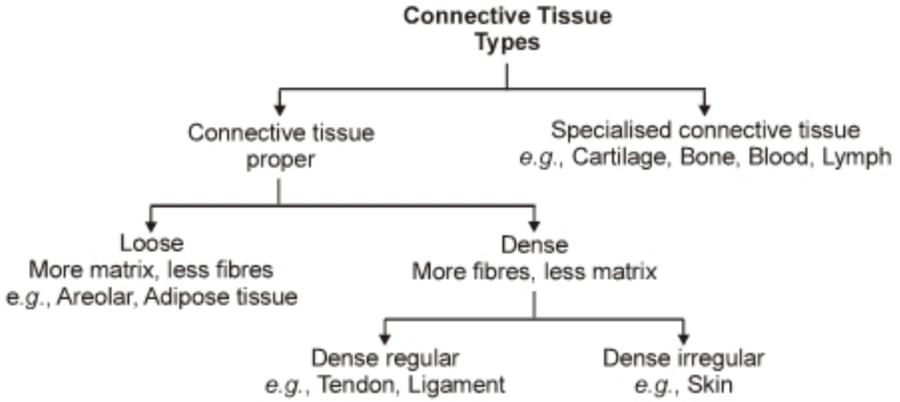


Fig. : Glandular epithelium : (a) Unicellular (b) Multicellular

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

CONNECTIVE TISSUE

Connective tissue is widely distributed and most abundant. This tissue is involved in linking or provides support to other tissues/organs. It includes bone, cartilage, adipose tissue and blood. The cells of connective tissues secrete fibres except in blood.



Loose Connective Tissue

Areolar Tissue

It occurs beneath the epithelia of many hollow visceral organs, skin and on the walls of arteries and veins. The areolar tissue contains four types of cells: fibroblasts, macrophages, mast cells and plasma cells. **Fibroblasts are the principal cells of this tissue**. They are irregulary-shaped flat cells with long protoplasmic processes. Fibroblasts synthesise two kinds of proteins-collagen and elastin. **They secrete the major amount of matrix.**

Macrophages / Histiocytes / Clasmocytes are phagocytic in nature.

Mast cells / Mastocytes are irregularly ovoid cells and contain basophilic granules. These granules contain:

(i) **Histamine :** Inflammatory substance vasodilator produced during allergic reactions.

(ii) **Heparin :** Natural anti-coagulant.

(iii) **Serotonin :** Vasoconstrictor.

Plasma cells / cart wheel cells synthesize antibodies.

The areolar tissue joins different tissues, forms the packing between them and helps to keep the organs in place and in normal shape.

Adipose Tissue

Adipose tissue is a located beneath the skin, around kidneys and in mesenteries and bone marrow. Besides fibroblasts, macrophages, collagen fibres and elastic fibres, the adipose tissue also contains large, spherical or oval cells called **Fat Cells** or **Adipocytes**. The cytoplasm and organelles in adipocytes are pressed by fat into a narrow annular layer just beneath the plasma membrane. The adipose tissue synthesises, stores and metabolises fat.

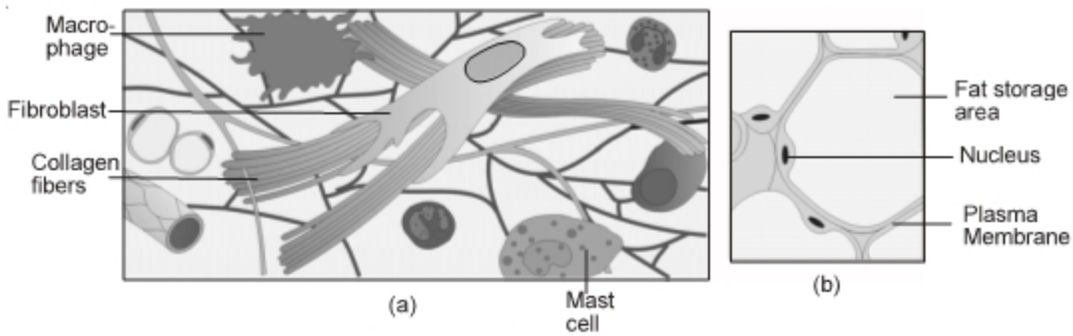


Fig. : Loose connective tissue : (a) Areolar tissue (b) Adipose tissue

Dense Connective Tissue

Fibres and fibroblasts are compactly packed. The orientation of fibres can be regular or irregular.

Dense Regular Tissue

It is a very dense, strong and fibrous connective tissue with thick parallel bundles of collagen fibres. A few flat, elongated cells lie in single row in between the fibre bundles. *e.g.*, **Tendons** which attach skeletal muscles to bones. **Ligaments** attach one bone to another.

Dense Irregular Tissue

Its ground substance is densely crowded with collagen fibres running in different directions and some elastic fibres. A few elongated flat cells lie between the fibres. This tissue is present in skin.

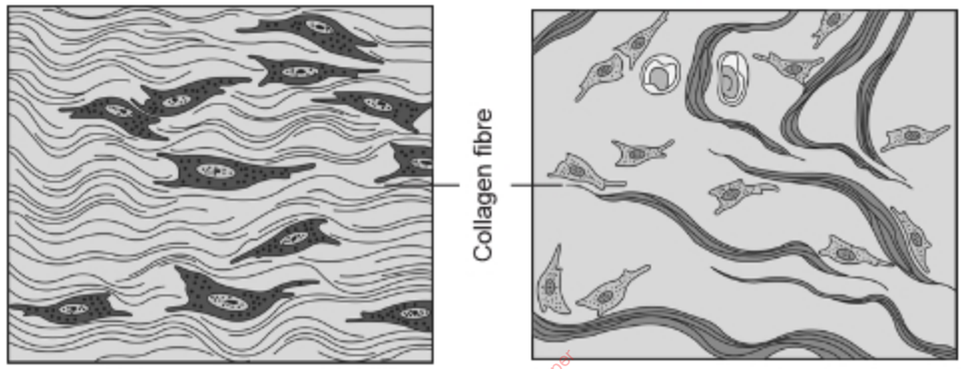


Fig. : Dense connective tissue : (a) Dense regular (b) Dense irregular

Cartilage

Cartilage is solid, pliable and resists compression. **Chondrocytes** are large, bluntly angular cartilage cells. They occur in clusters of 2 to 3 cells in small spaces (lacunae) scattered in the martix. Most of the cartilages in vertebrate embryos are replaced by bones in adults.

In **Hyaline Cartilage**, the matrix looks apparently fibre-less and glass-like (hyaline). It occurs in the larynx, nasal septum, tracheal rings and ribs. It gives these structures a definite but pliable form.

White Fibrocartilage has thick dense bundles of collagen fibres between rows of chondrocytes in lacunae. It occurs in joints between vertebrae. Its collagen fibres make such joints strong but less elastic and only slightly movable. In the centre of the intervertebral disc, a soft area is present called nucleus pulposus, it is supposed to be remnant of notochord.

Elastic Cartilage contains a dense network of elastic fibres between scattered chondrocytes. It forms the eustachian tube, epiglottis nose tip and pinna of ear. The elastic fibres make these organs considerably elastic and pliable.

Calcified Cartilage : Initially, it is like hyaline cartilage but later on it gets hardened like bone due to deposition of calcium salts. It occurs in suprascapula of pectoral girdle and pubis of pelvic girdle in frog.

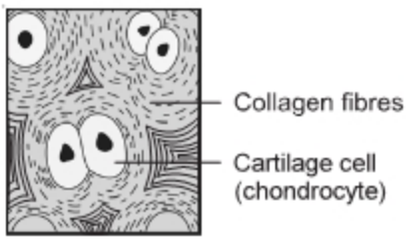


Fig. : Cartilage

BONE

(i) It is a solid, rigid connective tissue. The matrix of the bone has deposition of apatite salts of calcium and phosphorus.

(ii) 60-70% of bone is made up of inorganic matter and 30-40% is made up of organic matter.

(iii) If the bone is put in HCl, it becomes decalcified, soft and flexible. However, nothing happens to the bone if it is put in KOH.

(iv) **Osteoblasts are bone forming cells which secrete ossein protein.**

(v) Osteocytes are metabolically inactive cells present in lacunae.

(vi) Flat irregular spaces called **Lacunae** occur in the solid matrix of bones. Each lacuna lodges a flat bone cell or **Osteocyte**. A bone cell has an irregular shape and long cytoplasmic processes. These processes extend into minute canals (**Canaliculi**) radiating from each lacuna.

Limb bones such as long bones of legs serve weight bearing functions.

(vii) **Compact Bone** forms the dense outer layers of all bones. It is composed of many parallel, longitudinal, column-like structures called **Haversian Systems**, cemented to each other. In each Haversian system, several concentric layers of **Lamellae** (bony matrix) encircle a longitudinal central canal, **Haversian Canal**. Haversian canals in centre of Haversian systems are connected to each other by **Volksman canals**. Haversian canals carry blood vessels and nerves. Lacuane containing osteocytes occur in the layer between two lamellae. Compact bone has yellow bone marrow.

(viii) **Spongy Bone** occurs in the deeper central parts of bones. It carries no concentric organisations like the Haversian systems. It consists of a network of many fine irregular bony plates or **Trabeculae**. Each trabecula consists of many irregularly arranged lamellae with lacunae between them. It has red bone marrow.

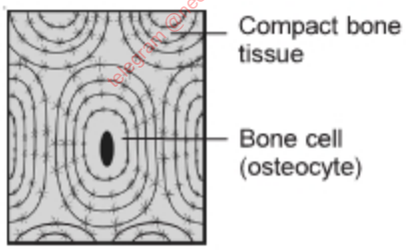


Fig. : Bone

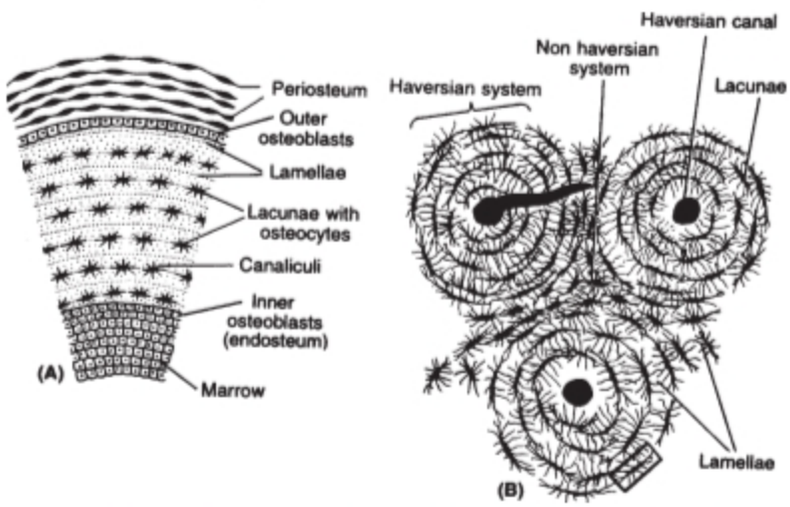


Fig. : (A) T.S. of amphibian bone, **(B)** T.S. of mammalian bone

BLOOD

Blood is a fluid connective tissue. Its cells are quite distinct from other connective tissue cells both in structure and functions. The extracellular material in blood is a fluid devoid of fibres. (Fluids outside the cells are generally called **Extracellular Fluids** or ECF). Blood has been discussed in the chapter **Body Fluids and Circulation.**

MUSCLE TISSUE

Muscles cause movements of limbs and internal organs and also locomotion of the organism. Cells of muscle tissue can shorten forcefully and again return to the relaxed state. This specialised property is called **Contractility**. It is based on the organised arrangement of some protein filaments in the cytoplasm of a muscle cell. The cell shortens or relaxes according to the relative positions of different intracellular filaments. Whenever adequately stimulated, muscle cells respond by contracting. This property of the muscle tissue is responsible for the various movements in an animal. Muscle cells are usually called **Muscle Fibres** because they are thin and elongated. In higher animals, some muscles remain associated with the skeleton but many others form walls of visceral organs, blood vessels and heart. Muscle tissue may be classified into striated, non-striated and cardiac muscles according to their structure, location and functions.

Striated / Skeletal / Voluntary muscles are attached to bones by tendons such as biceps. A voluntary muscle is composed of long bundles of striated muscle fibres. Each fibre is a long, unbranched, cylindrical cell. It shows transverse striations in the form of regular alternate dark (A) **anisotropic** and light (I) **isotropic** bands. At the centre of the I band is a fine, dense, dark Z band or Z-line. The plasma membrane covering the fibre is called **Sarcolemma**. The cytoplasm inside the fibre is called **Sarcoplasm**. The sarcoplasm contains many long, thin, unbranched, cross-striated cylindrical structures called **Myofibrils**. They are arranged along the long axis of the fibre. Dark (A) bands of neighbouring myofibrils are located side by side, so also are their light I bands. This gives cross-striated appearance to the entire muscle fibre also. The portion of A-band where actin filaments are absent is called H-zone.

Muscle is rich in proteins. Most of these proteins occur as two types of filaments arranged longitudinally in myofibrils. The thick filaments are made of the protein **Myosin**. Myosin filaments are located inside A bands. Thin filaments are more numerous. They are composed of the protein **Actin**. From a fine, dense, dark Z band at the centre of each I band, actin filaments extend through the I band and encroach between myosin filaments upto a considerable distance into the A band.

Each segment of the myofibril from one Z band to the next functions as a contractile unit and is called a **Sarcomere**.

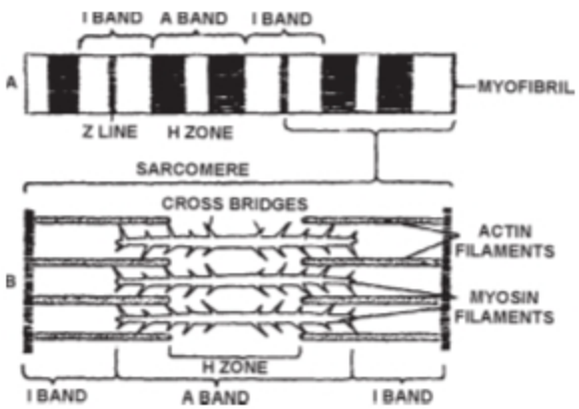


Fig. : Structure of Sarcomere

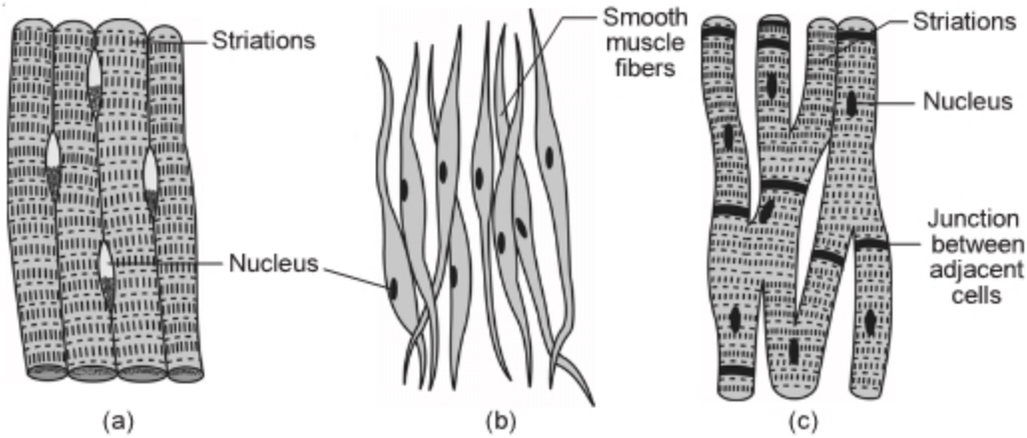


Fig. : Muscle tissue : (a) Skeletal (striated) muscle tissue (b) Smooth muscle tissue (c) Cardiac muscle tissue

Non-Striated or Smooth muscle fibres do not show cross-striations, instead, they look smooth. Smooth muscles cannot be moved voluntarily. So they are also called **Involuntary Muscles**. Functionally, smooth muscles are of two types : **Single-Unit Smooth Muscles** are composed of muscle fibres closely joined together. All their fibres contract together as a single unit. They may contract automatically and rhythmically. Such smooth muscles occur on the walls of hollow visceral organs such as the urinary bladder and the gastrointestinal tract. **Multi-Unit Smooth Muscles** are composed of more independent muscle fibres, not so closely joined together. Individual fibres of such smooth muscles contract as separate units. These occur at hair roots (Erector pili muscles) and on the walls of large blood vessels.

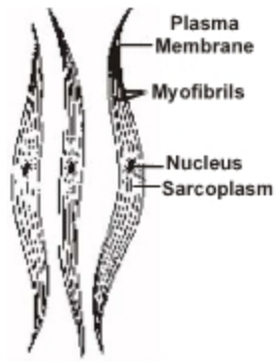


Fig. : Nonstriated muscle fibres

Smooth muscle fibres are elongated spindle-shaped cells. They are packed parallel to each other in branching bundles. Each fibre contains a single, spindle shaped nucleus at its thick central part. The smooth muscle fibre is generally shorter than a striated muscle fibre. Mitochondria and other organelles are less extensive and protein filaments are not regularly arranged to give rise to striations.

Cardiac muscles occur exclusively in the heart. They possess considerable automatic rhythmicity and generate their own wave of excitation. The excitation can also pass directly from fibre to fibre in the cardiac muscles. It is not under voluntary control. They show cross-striations but striations are much fainter than those of striated muscles.

Cardiac muscle cells are short cylindrical cells joined end to end to form rows. They possess abundant cytoplasm (sarcoplasm) with myofibrils and numerous mitochondria and glycogen granules. This is because they need a large amount of energy. Faint but regular alternate dark and light bands gives rise to cross-striations in the cardiac muscle fibres and indicate regular and alternate arrangements of thin and thick filaments in the fibre. Sarcomeres are also present. Cardiac muscle cells frequently branch to form junctions with neighbouring cells. Where two cardiac muscle cells meet end to end, dense zig-zig junction is formed between them. It is called an **Intercalated Disc**.

NEURAL TISSUE

Ordinary connective tissue is absent from central nervous system, the neurons are held together by supportive cells called **Neuroglial Cells**. Nerve tissue is made of neurons and neuroglial cells.

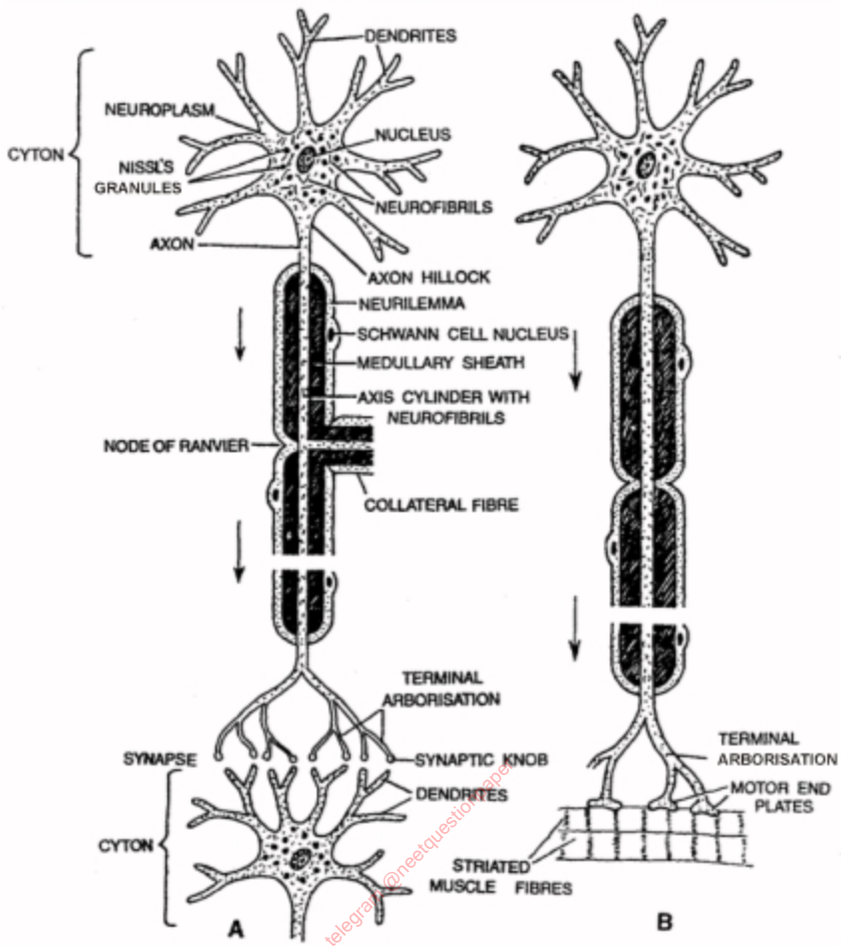


Fig. : Neurons and medullated nerve fibres. A, showing collateral fibre and synapse. B, showing motor neuron and striated muscle fibres

A **Neuron** has a large cell body with two or more, thin protoplasmic processes extending from it. One of the processes called the **Axon** is long and conducts nerve impulses away from the cell body. It ends in a number of small branches on muscle fibres, gland cells or other neurons. The remaining one or more processes conduct nerve impulses towards the cell body and are called **Dendrites** or **Dendrons**. The axon terminals may form inter-communicating junctions, called **Synapses**, with dendrite terminals, cell bodies or even axons of other neurons. Nerve impulses pass between neurons through the synapses with the help of chemicals such as acetycholine which are termed **Neurotransmitters**.

The cell body of a neuron is called the **Soma**. It has various shapes. Both the soma and the processes are covered by plasma membrane. The soma contains abundant granular cytoplasm and a large nucleus. To serve the high energy needs for impulse conduction, neurons have many mitochondria. Light microscopy shows many small, conical, angular or rhomboidal and highly basophilic structures in the cytoplasm of soma and dendrites, called **Nissl Bodies.** These are however, **absent** in the axon and axon hillock. Nissl's bodies are made of ribosomes, ER and m-RNA.

Each myelinated nerve fibre shows constrictions at regular intervals called **Nodes of Ranvier**, which result from interruptions in the myelin sheath at some places. Nodes of Ranvier have neurilemma but lack myelin sheath.

Some nerve fibres are not covered by myelin sheath. They are called **Non-Myelinated Nerve Fibres**. They do not possess nodes of Ranvier, Myelinated fibres are generally thicker than non-myelinated ones.

Arrival of disturbance at neuron's endings or output zone triggers events that may cause stimulation or inhibition of adjacent neuron and other cells.

Neuroglial Cells / Glial cells

Glial cell make up more than one half the volume of neural tissue in our body. They are undifferentiated cells with no Nissl's granules. Their different types are

(i) **Astrocytes / Macrocytes :** They are large in size with a number of protoplasmic processes. They form maximum number of glial cells. They help in repair of nerve tissue and form blood brain barrier.

(ii) **Oligodendrocytes :** They are with few protoplasmic processes and form myelin sheath in CNS. There is no neurilemma in the central nervous system. In the absence of Schwann cells, myelin is formed here by the spiral wrapping of nerve fibre by processes of Oligodendrocytes.

(iii) **Microglial cells - (mesodermal in origin) :** They are smallest in size with few cytoplasmic processes and help in phagocytosis.

Periplaneta americana (Cockroach)

Cockroaches are brown or black bodied animals that are included in class Insecta of Phylum Arthropoda. Bright yellow, red and green coloured cockroaches have also been reported in tropical regions. Their size ranges from ¼ inches to 3 inches (0.6–7.6 cm) and have long antenna, legs and flat extension of the upper body wall that conceals head. They are nocturnal omnivores that live in damp places throughout the world. They have become residents of human homes and thus are serious pests and vectors of several diseases.

MORPHOLOGY

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

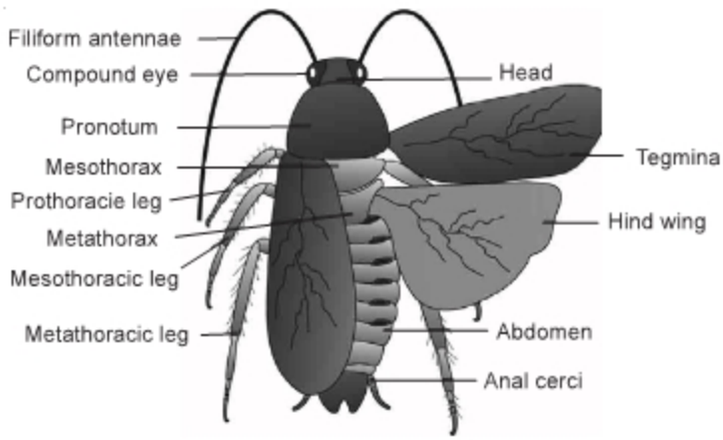


Fig. : External features of cockroach

Head

1. It is small and triangular. Its narrow end is bent downwards in **hypognathous position** *i.e.*, at an angle of 90° from the long axis of the body and is formed by fusion of **six** segments. A pair of thread like antennae arise from membranous sockets lying in front of eyes.
2. On each lateral side, it bears a large and blackish **compound eye.**
3. At the base of each antenna, on the inner side, a small rounded and light coloured area called **fenestra** or **ocellar spot,** representing simple eye is present.
4. All sclerites of the head are fused, forming a strong head capsule, exhibiting only faint lines of fusion.
5. Endoskeleton of head is called **tentorium.**

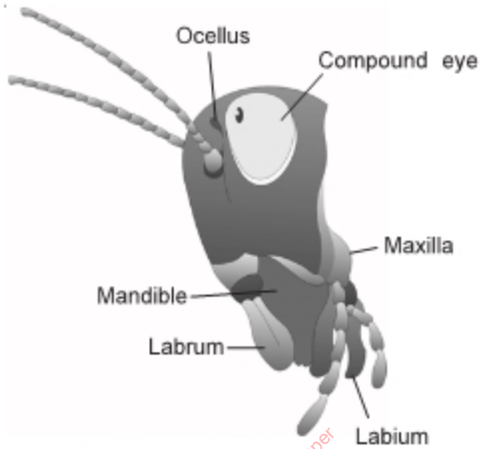


Fig. : Parts of head region

Mouth Parts

Anteriorly, the head bears the mouth which is provided with **appendages** collectively called mouth parts which are used in chewing, cutting and swallowing food. The mouth parts consist of a pair of **mandibles** and **maxillae, labium** (forming the lower lip) and a **labrum** (forming upper lip). Within the cavity enclosed by mouthparts, there is a median flexible lobe called **hypopharynx** which acts like a **tongue.**

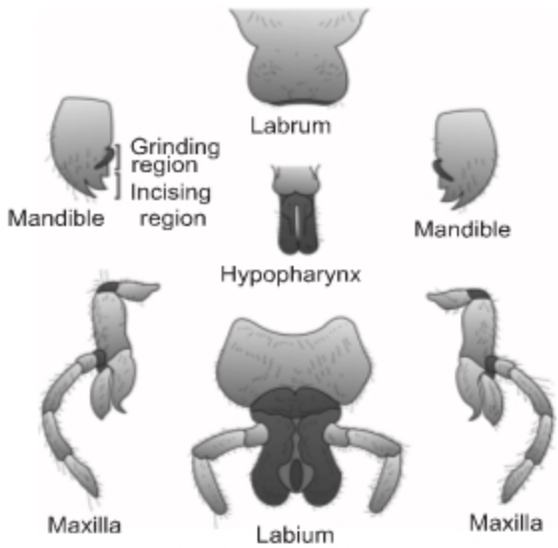


Fig. : Mouth parts of Cockroach

Thorax consists of 3 segments – the prothorax, mesothorax and metathorax. Each thoracic segment bears a pair of walking legs. A pair of wings arise from mesothorax which are thick and leathery and are called **Elytra** or **Tegmina.** Another pair of membranous wings, used in flying arises from metathorax. (In housefly and mosquitoes, the metathoracic wings are reduced to **halters** for balancing the body during flight).

Abdomen

Abdomen in both males and females consists of 10 segments. A typical abdominal segment has a dorsal **tergum**, ventral **sternum** and between them a narrow membranous **pleuron** on each side which bears **spiracles**. In females, the sclerites of 8th and 9th are overlapped by corresponding sclerites of the 7th segment. The seventh sternum is boat shaped and together with eighth and ninth sterna forms **a brood** or **genital pouch**. In males only 8th is overlapped by the 7th segment. The tenth segment bears a pair of 15 jointed filamentous structures called as **anal cerci**. Ventral to these in the males, the 9th segment bears a pair of short, thread like **anal styles** which are absent in females. Between one sclerite and the other, there is a flexible **arthrodial membrane**.

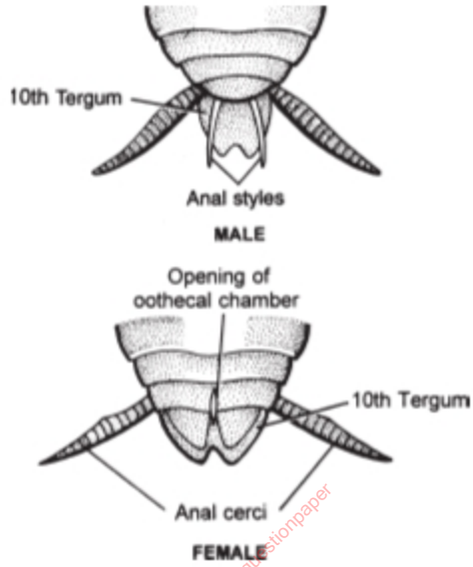


Fig. : Hind part of abdomen (dorsal view)

ANATOMY

Digestive System

1. The alimentary canal is long and somewhat coiled, divisible into three main parts namely foregut, midgut and hindgut.
2. Foregut (**stomodaeum**) is differentiated into five parts: buccal chamber, pharynx, oesophagus, crop and gizzard.
3. **Gizzard** or proventriculus is muscular and internally provided with six cuticular teeth which crush the food.
4. A stomodaeal valve is present between gizzard and mesenteron.
5. Midgut (**mesenteron** or **ventriculus**) is short, tubular portion lined with glandular endoderm.
6. At anterior end of mesenteron, there are 6–8 blind glandular hepatic caecae which secrete digestive enzymes.
7. Internally mesenteron is not lined by cuticle but is covered by a very thin and transparent **peritrophic membrane** formed of chitin and proteins.

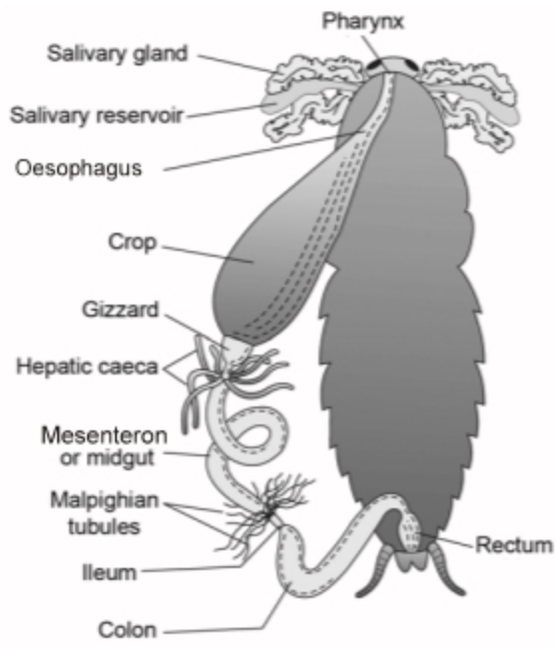


Fig. : Alimentary canal of cockroach

8. Peritrophic membrane is secreted by gizzard. It serves to protect the wall of midgut from abrasion due to friction of food particles.
9. Peritrophic membrane is permeable to **digested food** and **enzymes** in the mesenteron.
10. Hindgut (**proctodaeum**) comprises **ileum, colon and rectum**. Foregut and hindgut, both are lined with cuticle. At the junction of midgut and hindgut, 100 - 150 yellow coloured thin filamentous malpighian tubules are present.
11. The wall of rectum is provided with six **rectal papillae.** They help in the absorption of water and salts.
12. Cockroach is **omnivorous** *i.e.*, feeds on all sorts of organic debris and food.
13. The digestive enzymes of saliva are mainly zymase and amylase.
14. Most of the nutrients of food are digested in the mesenteron.
15. Absorption of digested food takes place in **mesenteron.**

Circulatory system

1. Blood vascular system of cockroach is an open type.
2. Blood vessels are poorly developed and open into space (haemocoel). Visceral organs located in the haemocoel are bathed in blood (haemolymph).
3. The haemolymph is composed of colourless plasma and haemocytes.
4. Heart of cockroach consists of elongated muscular tube lying along mid dorsal line of thorax and abdomen. It is differentiated into funnel shaped chambers (13 in number : 3 thoracic and 10 abdominal) with ostia on either side.
5. Blood from sinuses enter heart through ostia and is pumped anteriorly to sinuses again.

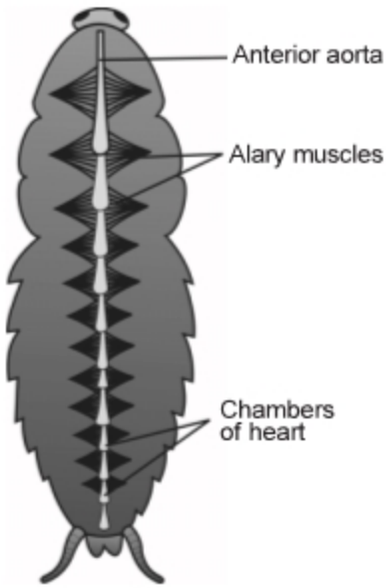


Fig. : Open circulatory system of cockroach

Respiratory system

1. The respiratory system consists of a network of trachea, that open through 10 pairs of small holes called spiracles present on the lateral side of the body.
2. Thin branching tubes (tracheal tubes subdivided into tracheoles) carry oxygen from the air to all the parts.
3. The opening of spiracles is regulated by sphincters. Exchange of gases take place at the tracheoles by diffusion.

Excretory system

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

Nervous system

1. The nervous system of cockroach consists of a series of fused, segmentally arranged ganglia joined by paired longitudinal connectives on the ventral side.
2. **Three ganglia** lie in the thorax, and **six** in the abdomen.
3. The nervous system of cockroach is spread throughout the body.
4. The head holds a bit of a nervous system while the rest is situated along the ventral (belly-side) part of its body.
5. If the head of a cockroach is cut off, it will still live for as long as one week.
6. In the head region, the **brain** is represented by supra-oesophageal ganglion which supplies nerves to antennae and compound eyes.

Sense organs

1. In cockroach, the sense organs are **antennae**, **eyes**, **maxillary palps**, **labial palps**, **anal cerci** etc.
2. The compound eyes are situated at the dorsal surface of the head. Each eye consists of about 2000 hexagonal ommatidia (sing.: *ommatidium*). With the help of several ommatidia, a cockroach can receive several images of an object. This kind of vision is known as mosaic vision with **more sensitivity but less resolution**, being common during night (hence called **nocturnal vision**).

Male Reproductive System

1. In cockroach, sexes are separate. (dioecious)
2. Testes of male cockroach are located in the 4^{th}, 5^{th} and 6^{th} abdominal segments. From each testis arises a thin vas deferens which opens into ejaculatory duct through seminal vesicle.
3. **Mushroom gland** (present in 6^{th}-7^{th} abdominal segments) consists of two types of tubules, the (i) long, slender tubules called **utriculi majores** or **peripheral tubules** and (ii) short tubules, the **utriculi breviores,** making up the major part of the gland.
4. Small **seminal vesicles** are also found associated with mushroom gland.

5. All sperms of a seminal vesicle are glued together into a large bundle called **spermatophore.**
6. Spermatophore has three layered wall : inner layer is secreted by **utriculi majores**; middle layer is secreted by **ejaculatory duct** and the outer layer is secreted by **phallic gland**
7. There are present three asymmetrical, chitinous structures called male **gonapophyses** or **phallomeres.** They are right phallomere, left phallomere (largest) and ventral phallomere (smallest).

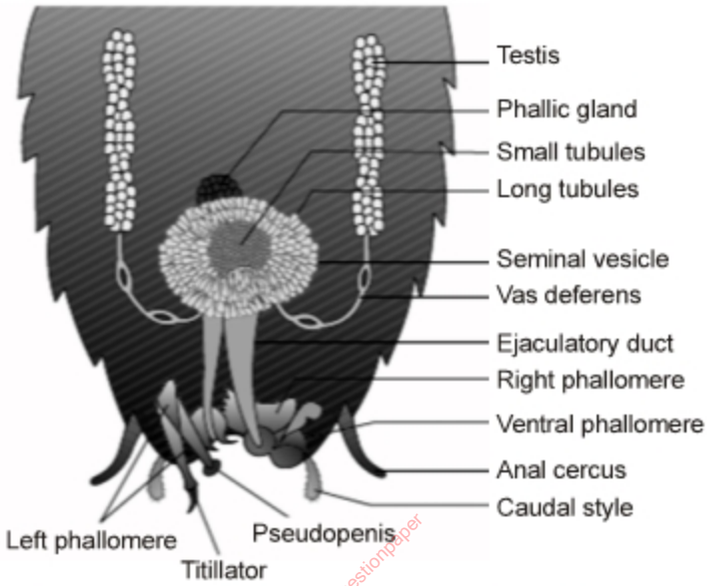


Fig: *Periplaneta americana* : Male reproductive system

Female Reproductive System

1. Female reproductive organs consist of (one pair) ovaries, (one pair) oviducts, vagina (common oviduct), genital chamber, spermathecae (one pair), collaterial glands (one pair) and female gonapophysis (ovipositor processes).
2. Ovaries of cockroach are located in the abdominal segments 2 to 6.
3. Each ovary consists of eight ovarioles
4. Two oviducts from each side open into a common oviduct or vagina which open into genital chamber by female genital pore.
5. A pair of spermathecae (left larger, pyriform sac) is present near female genital pore in 6^{th} segment.
6. A pair of **collaterial glands** also open in genital chamber.
7. **Genital pouch** or **gynatrium** is divisible into a **genital chamber** in front and **oothecal chamber** behind.
8. Female external genitalia consists of 3 pairs of chitinous processes hanging from the roof of oothecal chamber into its cavity.
9. On an average, females produce 9–10 oothecae. Each ootheca contains 14–16 fertilized eggs.
10. Ootheca of cockroach is formed of a protein secreted by collaterial glands.
11. Ootheca is a dark reddish to blackish brown capsule about 3/8 inch (8 mm) long.

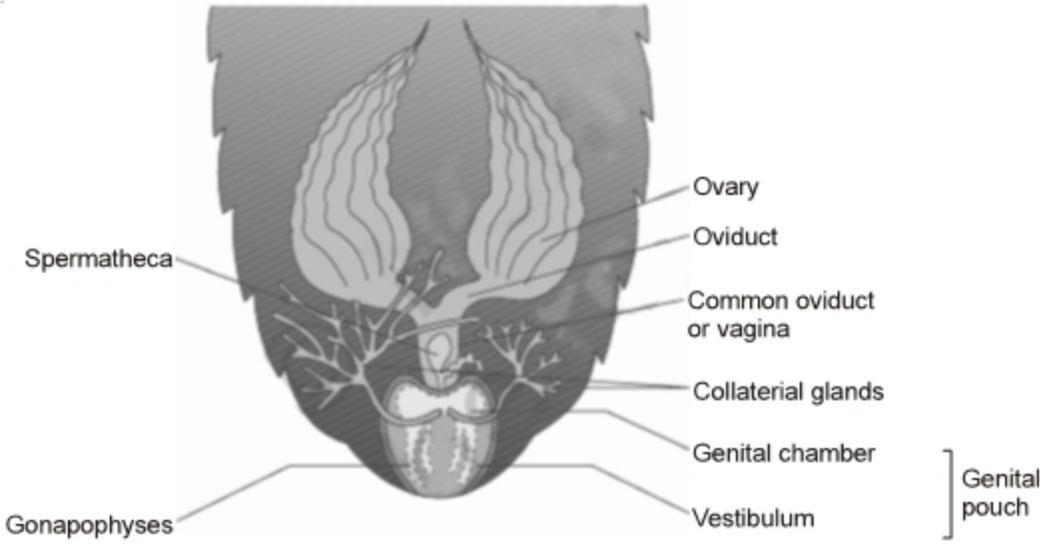


Fig. : *Periplaneta americana :* Female Reproductive System

Development

1. The development of *P. americana* is **paurometabolous** which means there is development through nymphal stage. **Nymph** of cockroach emerges out from ootheca.
2. A nymph resembles the adult in general structure but lacks the wings and mature reproductive organs.
3. **Instar** is a stage in the development of insect (larval instar, nymphal instar).
4. Period between two moults in insects is termed **stadium**.
5. In *Periplaneta americana*, nymph grows by moulting about 13 times to reach the adult form. *Blatta orientalis* moults 6 times. The next to last nymphal stage has wing pads but only adult cockroaches have wings.
6. Metamorphosis is regulated by two hormones, ecdysone secreted by prothoracic glands and juvenile hormone secreted by corpora allata.

Comparison of *Periplaneta* and *Blatta*

Periplaneta americana	*Blatta orientalis*
1. **Size -** larger	Smaller
2. **Colour -** shiny brown	Dark brown
3. **Wings** well developed	In female, the tegmina are very short : hind wings are absent
4. **Pronotum** narrower	Pronotum broader
5. **Saliva** without invertase	Saliva with invertase
6. **Chromosome number :** Male 2n = 33 Female 2n	Chromosome number : Male 2n = 47 ~~8~~ 34Female 2n

❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. Epithelial tissues lie on the basement membrane which is made of
   (1) Basal lamina composed of muco-polysaccharides and glycoproteins secreted by epithelial cells
   (2) Fibrous lamina composed of collagen or reticular fibres of underlying connective tissue
   (3) Both (1) & (2)
   (4) Cells and hence, is a cellular layer
2. Simple epithelium is not effective in
   (1) Nutrition
   (2) Excretion
   (3) Secretion
   (4) Protecting the underlying tissues
3. Brush bordered cuboidal epithelium is present in
   (1) Intestine
   (2) Proximal convoluted tubule
   (3) Stomach
   (4) Gall bladder
4. Which of the following epithelia forms the inner lining of lung alveoli, blood vessels and peritoneum of body cavity?
   (1) Cuboidal (2) Squamous
   (3) Columnar (4) Ciliated columnar
5. All the statements about stereocilia are correct, **except**
   (1) They are non-motile
   (2) These are found in epididymis and vas deferens
   (3) They have 9+2 ultrastructure
   (4) The basal granule is absent
6. Ciliated columnar epithelium called ependyma is present in the lining of
   (1) Fallopian tubes (2) Ventricles of brain
   (3) Nasal passages (4) Branchioles
7. Which of the following epithelium covers the inner linings of trachea, large bronchi and helps to synthesize mucus?
   (1) Ciliated columnar
   (2) Pseudo-stratified epithelium
   (3) Compound epithelium
   (4) Cuboidal epithelium
8. Stratified squamous non-keratinized epithelium is present in the lining of
   (1) Buccal cavity, oesophagus, cornea of eye
   (2) Skin, hair, horn, nail
   (3) Small pancreatic ducts, thyroid follicles and ovary
   (4) Intestine, stomach and gall bladder
9. Which of the following epithelium is much thinner and more stretchable than the stratified epithelium and covers the inner surface of urinary bladder and ureter?
   (1) Transitional
   (2) Compound
   (3) Simple
   (4) Stratified
10. Which of the following cells are specialised for sensory functions, *e.g.*, cells of taste bud?
    (1) Myoepithelial
    (2) Neuroepithelial
    (3) Cuboidal
    (4) Cornified
11. Which of the following match is **incorrect**?
    (1) Exocrine – Sebaceous
    (2) Endocrine – Thyroid
    (3) Exocrine – Mammary gland
    (4) Endocrine – Sweat gland

12. Which of the following tissues is present in maximum amount, joins different tissues together, forms the packing material between them and helps to keep the organs in place and in normal shape?
    (1) Areolar
    (2) Adipose
    (3) Tendon
    (4) Ligament

13. Which of the following are principal cells of areolar connective tissue and secrete maximum amount of matrix?
    (1) Macrophages
    (2) Mast cells
    (3) Fibroblasts
    (4) Histiocytes

14. Which of the following tissues is present at the joints between skull bones and makes them immovable?
    (1) Cartilage
    (2) White fibrous connective tissue
    (3) Ligament
    (4) Areolar tissue

15. Which of the following tissues connects bones at joints and enables us to move and rotate our neck, limbs and fingers comfortably?
    (1) Tendon
    (2) Hyaline cartilage
    (3) Ligament
    (4) White fibrous cartilage

16. All the following statements are correct, **except**
    (1) Hyaline cartilage lacks fibres and is present in sternum, hyoid and ribs
    (2) White fibrous cartilage is the strongest cartilage and is present in the intervertebral disc
    (3) Elastic cartilage is present in the tip of nose and ear pinna
    (4) Calcified cartilage is not present in the pubis of pelvic girdle of frog

17. Bone forming cells which secrete ossein protein are called
    (1) Chondroblasts
    (2) Chondrocytes
    (3) Osteoblasts
    (4) Osteocytes

18. Which of the following character will not be applicable to a decalcified bone?
    (1) Bone becomes soft and flexible
    (2) Only organic matter present
    (3) Inorganic matter present
    (4) Bone has been treated with dilute HCl

19. Which of the following is **incorrect** w.r.t. cartilage?
    (1) Matrix is solid and pliable
    (2) Chondrocytes are present in lacuna
    (3) Growth of cartilage is bidirectional
    (4) Cartilage is *Avascular*

20. The bone of a mammal contains Haversian canals which are interconnected by transverse canals known as
    (1) Canaliculi
    (2) Volksman canal
    (3) Trabeculae
    (4) Bidder's canal

21. Spongy or cancellous bone is present in vertebrae, ribs, skull and epiphysis of long bones. They have
    (1) Haversian canals
    (2) Trabeculae
    (3) Red bone marrow
    (4) Both (2) & (3)

22. Cardiac muscles are
    (1) Striated, voluntary with syncytial condition
    (2) Unstriated, involuntary, uninucleated
    (3) Striated, involuntary with intercalated discs
    (4) Involuntary and unstriated

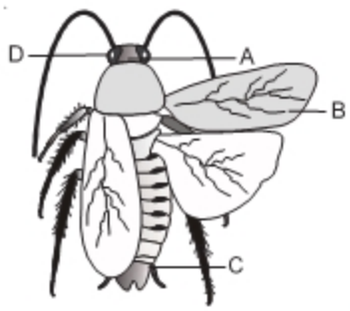
23. Erector pili muscles are
    (1) Voluntary, multiunit
    (2) Involuntary, multiunit
    (3) Involuntary, single unit
    (4) Voluntary, single unit

24. Nissl's granules are made of
(1) Ribosomes and RNA
(2) DNA and protein
(3) Ribosomes and DNA
(4) RNA, DNA and protein

25. In central nervous system, the myelin sheath around the nerve fibre is formed by wrapping of
(1) Neurilemma
(2) Schwann cells
(3) Oligodendrocytes
(4) Neurolemmocytes

26. The body of cockroach is segmented and is divisible into
(1) Head and trunk
(2) Head, thorax and abdomen
(3) Cephalothorax and abdomen
(4) More than one option is correct

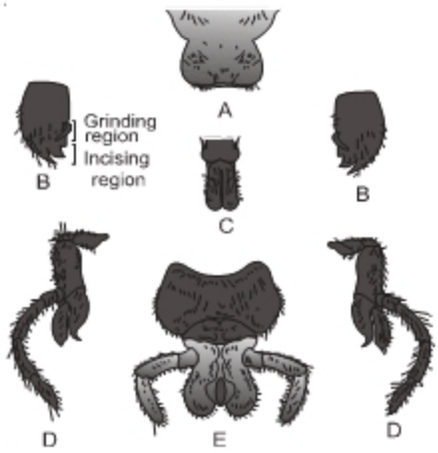
27. Given below is the diagram of cockroach exhibiting its external features with certain labelled parts A, B, C, & D. Each labelled part is provided with certain description in the statements given. Which of the following statement is **correct**?



a. Part A is head which is triangular in shape and is formed by the fusion of six segments
b. Part B is mesothoracic wings called Tegmina and are effectively used in flight
c. Part C is anal styles which are only found in male cockroaches
d. Part D is compound eye situated at the ventral surface of the head and consists of about 2000 hexagonal ommatidia

(1) a only
(2) a, c & d only
(3) a, b & d only
(4) a & d only

28. Following figure shows mouth parts of cockroach which are labelled as A, B, C, D & E. In which one of the following options all the parts are **correctly** labelled?



Options

(1) A - Labium B - Mandible C - Hypopharynx D - Maxilla E - Labrum
(2) A - Labrum B - Maxilla C - Hypopharynx D - Mandible E - Labium
(3) A - Labrum B - Mandible C - Hypopharynx D - Maxilla E - Labium
(4) A - Hypopharynx B - Mandible C - Maxilla D - Labrum E - Labium

29. Male cockroach can be distinguished from female externally by
(1) Anal styles in male, shorter antennae, and wings shorter than abdomen
(2) Anal cerci in female
(3) Anal style and long antennae in male and wings are longer than the length of abdomen
(4) Anal cerci in male

30. In cockroach, fore wings are called as
(1) Mesothoracic wings (2) Tegmina
(3) Metathoracic wings (4) Both (1) & (2)

31. The correct order of podomeres in the walking leg of cockroach is
(1) Coxa → trochanter → femur → tibia → tarsus
(2) Coxa → femur → trochanter → tibia → tarsus
(3) Coxa → tibia → trochanter → femur → tarsus
(4) Coxa → tarsus → tibia → trochanter → femur

32. Which portion of alimentary canal of cockroach is not internally lined by cuticle?
(1) Crop (2) Gizzard
(3) Mesenteron (4) Hind gut

33. Which of the following is absent in blood of cockroach?
(1) Plasma
(2) Blood cells/Haemocytes
(3) Nutrient
(4) Respiratory pigment

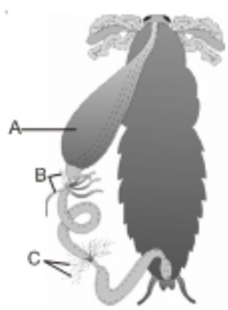
34. Which of the following is **not** found in haemolymph of cockroach?
(1) Haemocytes (2) Plasma
(3) Water (4) Haemoglobin

35. Which of the following statement w.r.t. cockroach is **incorrect**?
(1) It has 13 chambered tubular heart
(2) Blood from sinuses enters heart through ostia
(3) Sac like structure crop present in alimentary canal helps in grinding food
(4) Network of trachea present for respiration opening outside through 10 pairs of spiracles

36. Alary muscles are involved in
(1) Circulation in *Periplaneta americana*
(2) Reproduction in *Periplaneta americana*
(3) Mouth parts of *Periplaneta americana*
(4) Respiration in *Periplaneta americana*

37. Which of the following is **incorrect** w.r.t. cockroach?
(1) Malpighian tubule is present between midgut and hindgut
(2) 6^{th} sternum is boat shaped in female forms brood pouch along with 7^{th} and 8^{th} sternum
(3) Hind wings are membranous and used to fly
(4) Hepatic caecae is present at the junction of foregut and midgut

38. Label the following diagram of digestive system of cockroach



(1) A – Crop
B – Malpighian tubules
C – Hepatic caecae
(2) A – Hepatic caecae
B – Crop
C – Malpighian tubules
(3) A – Crop
B – Hepatic caecae
C – Malpighian tubules
(4) A – Malpighian tubules
B – Crop
C – Hepatic caecae

39. Cockroach is
(1) Uricotelic
(2) Ureotelic
(3) Ammonotelic
(4) Both (2) & (3)

40. In cockroach, malpighian tubules help in removal of excretory product from
(1) Foregut
(2) Haemolymph
(3) Midgut
(4) Hindgut

41. Each compound eye of cockroach consists of about _____ hexagonal ommatidia
(1) 500 (2) 1000
(3) 1500 (4) 2000

42. Cockroach is
(1) Diurnal and herbivorous
(2) Nocturnal and herbivorous
(3) Diurnal and carnivorous
(4) Noctural and omnivorous

43. Which of the following is an **incorrect** match w.r.t respective segments in the body of cockroach and the associated structures contained in these segments?
(1) 4^{th} – 6^{th} abdominal segments – A pair of testes in male
(2) 2^{nd} – 6^{th} abdominal segments – A pair of ovaries in female
(3) 6^{th} abdominal segment – A pair of spermatheca in male
(4) 6^{th} – 7^{th} abdominal segments – Mushroom gland in male

44. In cockroach which of the following gland form oothecal covering?

(1) Phallic gland (2) Conglobate gland

(3) Collaterial gland (4) Utricular gland

45. Find the **incorrect** statement w.r.t. reproductive system in cockroach (*Periplaneta americana*)

(1) On an average, female *Periplaneta* produce 9–10 ootheca, each containing 14–16 eggs

(2) The development of *P. americana* is paurometabolous, meaning there is development through nymphal stage

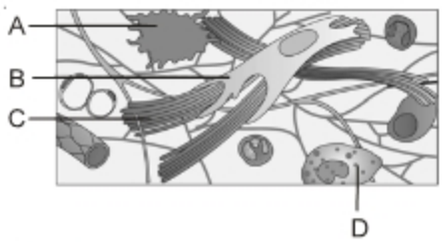
(3) The nymph grows by moulting about 9 times to reach the adult form

(4) The next to last nymphal stage has wing pads but only adult cockroaches have wings

SECTION - B

Previous Years Questions

1. Given below is the diagrammatic sketch of a certain type of connective tissue. Identify the parts labelled A, B, C and D and select the right option about them. **[AIPMT 2012]**



Options :

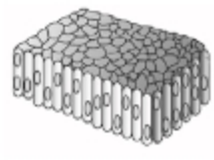
	Part-A	Part-B	Part-C	Part-D
(1)	Macro-phage	Fibroblast	Collagen fibres	Mast cells
(2)	Mast cell	Macro-Phage	Fibroblast	Collagen fibres
(3)	Macro-phage	Collagen fibres	Fibroblast	Mast cell
(4)	Mast cell	Collagen fibres	Fibroblast	Macro-phage

2. The supportive skeletal structures in the human external ears and in the nose tip are examples of **[AIPMT 2012]**

(1) Ligament (2) Areolar tissue

(3) Bone (4) Cartilage

3. The four sketches (A, B, C and D) are given below, represent four different types of animal tissues. Which one of these is correctly identified in the options given, along with its correct location and function? **[AIPMT 2012]**

(A) 

(B) 

(C) 

(D) 

		Tissue	Location	Function
(1)	(B)	Glandular epithelium	Intestine	Secretion
(2)	(C)	Collagen fibres	Cartilage	Attach skeletal muscles to bones
(3)	(D)	Smooth muscle tissue	Heart	Heart contraction
(4)	(A)	Columnar epithelium	Nephron	Secretion and absorption

4. Select the **correct** statement from the ones given below with respect to *Periplaneta americana*

[AIPMT 2012]

(1) There are 16 very long Malpighian tubules present at the junctions of midgut and hindgut

(2) Grinding of food is carried out only by the mouth parts

(3) Nervous system located dorsally, consists of segmentally arranged ganglia joined by a pair of longitudinal connectives

(4) Males bear a pair of short thread like anal styles

5. What external changes are visible after the last moult of a cockroach nymph? **[NEET 2013]**
   (1) Anal cerci develop
   (2) Both fore wings and hind wings develop
   (3) Labium develops
   (4) Mandibles become harder

6. The terga, sterna and pleura of cockroach body are joined by **[AIPMT-2015]**
   (1) Cartilage (2) Cementing glue
   (3) Muscular tissue (4) Arthrodial membrane

7. The function of the gap junction is to : **[Re-AIPMT-2015]**
   (1) Stop substance from leaking across a tissue
   (2) Performing cementing to keep neighbouring cells together
   (3) Facilitate communication between adjoining cells by connecting the cytoplasm for rapid transfer of ions, small molecules and some large molecules
   (4) Separate two cells from each other

8. Which type of tissue **correctly** matches with its location? **[NEET-2016]**

	Tissue	Location
(1)	Cuboidal epithelium	Lining of stomach
(2)	Smooth muscle	Wall of intestine
(3)	Areolar tissue	Tendons
(4)	Transitional epithelium	Tip of nose

9. Which of the following features is not present in *Periplaneta americana*? **[NEET-2016]**
   (1) Metamerically segmented body
   (2) Schizocoelom as body cavity
   (3) Indeterminate and radial cleavage during embryonic development
   (4) Exoskeleton composed of N-acetylglucosamine

10. In male cockroaches, sperms are stored in which part of the reproductive system? **[NEET (Phase-2) 2016]**
    (1) Seminal vesicles (2) Mushroom glands
    (3) Testes (4) Vas deferens

11. Smooth muscles are **[NEET (Phase-2) 2016]**
    (1) Involuntary, fusiform, non-striated
    (2) Voluntary, multinucleate, cylindrical
    (3) Involuntary, cylindrical, striated
    (4) Voluntary, spindle-shaped, uninucleate

12. Select the **correct** route for the passage of sperms in male frogs **[NEET 2017]**
    (1) Testes → Bidder's canal → Kidney → Vasa efferentia → Urinogenital duct → Cloaca
    (2) Testes → Vasa efferentia → Kidney → Seminal Vesicle → Urinogenital duct → Cloaca
    (3) Testes → Vasa efferentia → Bidder's canal → Ureter → Cloaca
    (4) Testes → Vasa efferentia → Kidney → Bidder's canal → Urinogenital duct → Cloaca

13. Frog's heart when taken out of the body continues to beat for some time.
    Select the best option from the following statements
    (a) Frog is a poikilotherm
    (b) Frog does not have any coronary circulation
    (c) Heart is "myogenic" in nature
    (d) Heart is autoexcitable
    Options **[NEET 2017]**
    (1) Only (c) (2) Only (d)
    (3) (a) & (b) (4) (c) & (d)

14. Which of the following features is used to identify a male cockroach from a female cockroach? **[NEET 2018]**
    (1) Forewings with darker tegmina
    (2) Presence of caudal styles
    (3) Presence of a boat shaped sternum on the 9^{th} abdominal segment
    (4) Presence of anal cerci

15. Nissl bodies are mainly composed of **[NEET 2018]**
    (1) Nucleic acids and SER
    (2) DNA and RNA
    (3) Proteins and lipids
    (4) Free ribosomes and RER

16. Select the correct sequence of organs in the alimentary canal of cockroach starting from mouth **[NEET-2019]**
    (1) Pharynx → Oesophagus → Crop → Gizzard → Ileum → Colon → Rectum
    (2) Pharynx → Oesophagus → Gizzard → Crop → Ileum → Colon → Rectum
    (3) Pharynx → Oesophagus → Gizzard → Ileum → Crop → Colon → Rectum
    (4) Pharynx → Oesophagus → Ileum → Crop → Gizzard → Colon → Rectum

17. The ciliated epithelial cells are required to move particles or mucus in a specific direction. In humans, these cells are mainly present in

[NEET-2019]

(1) Bile duct and Bronchioles

(2) Fallopian tubes and Pancreatic duct

(3) Eustachian tube and Salivary duct

(4) Bronchioles and Fallopian tubes

18. Match the following cell structure with its characteristic feature :

(a)	Tight junctions	(i)	Cement neighbouring cells together to form sheet
(b)	Adhering junctions	(ii)	Transmit information through chemical to another cells
(c)	Gap junctions	(iii)	Establish a barrier to prevent leakage of fluid across epithelial cells
(d)	Synaptic junctions	(iv)	Cytoplasmic channels to facilitate communication between adjacent cells

Select correct option from the following :

[NEET-2019 (Odisha)]

(1) (a)-(iv), (b)-(iii), (c)-(i), (d)-(ii)

(2) (a)-(ii), (b)-(iv), (c)-(i), (d)-(iii)

(3) (a)-(iv), (b)-(ii), (c)-(i), (d)-(iii)

(4) (a)-(iii), (b)-(i), (c)-(iv), (d)-(ii)

19. Which of the following statements is INCORRECT? **[NEET-2019 (Odisha)]**

(1) Female cockroach possesses sixteen ovarioles in the ovaries.

(2) Cockroaches exhibit mosaic vision with less sensitivity and more resolution.

(3) A mushroom-shaped gland is present in the 6^{th}-7^{th} abdominal segments of male cockroach.

(4) A pair of spermatheca is present in the 6^{th} segment of female cockroach

❑ ❑ ❑

Chapter 3

Biomolecules

Sub-topics *Biomolecules - Structure and Function of Proteins, Amino acids, Polysaccharides, Carbohydrates, Lipids, Nucleic Acids; Enzymes - Types, properties, mode of action*

There is a wide diversity in living organisms in our biosphere. Are all the living organisms made up of the same chemicals *i.e.*, elements and compounds? If we perform an analysis on a plant tissue, animal tissue or a microbial paste, we obtain a list of elements like carbon, hydrogen, oxygen and several others and their respective content per unit mass of a living tissue. If the same analysis is performed on a piece of earth's crust (non-living matter), we obtain a similar result. All the elements present in the sample of earth's crust are also present in a sample of living tissue. But the relative abundance of carbon and hydrogen with respect to other chemicals is higher in any living organism than in earth's crust.

Biochemistry is the science dealing with chemicals and physico-chemical reactions found in living organisms and their life processes. The term biochemistry was first introduced by **Neuberg**. It is concerned with the chemical nature and chemical behaviour of living matter. Protoplasm is a complex mixture of both organic and inorganic compounds. Molecules found in the protoplasm of cells are called **biomolecules**.

A Comparison of Elements Present in Non-living and Living matter

Element	% weight of Earth's crust	% weight of Human Body
Hydrogen (H)	0.14	0.5
Carbon (C)	0.03	18.5
Oxygen (O)	46.6	65.0
Nitrogen (N)	Very little	3.3
Sulphur (S)	0.03	0.3
Sodium (Na)	2.8	0.2
Calcium (Ca)	3.6	1.5
Magnesium (Mg)	2.1	0.1
Silicon (Si)	27.7	Negligible

The collection of various types of molecules in a cell is called the **cellular pool**. It consists of various types of biomolecules such as : (a) water (b) inorganic materials (c) organic compounds. The small molecules of low molecular weight, simple molecular conformations and higher solubilities are called **micromolecules.** These include minerals, water, amino acids, simple sugars and nucleotides.

The various minerals found in cells have many uses. Mitochondria are rich in **manganese**. **Molybdenum** is necessary for fixation of nitrogen catalysed by the enzyme nitrogenase. **Copper** occurs in cytochrome oxidase.

Magnesium is essential for a large number of enzymes, particularly those utilising ATP. **Ca and Mg decrease the excitability of nerves and muscles.**

(i) **Sodium** and **potassium** are responsible for the maintenance of extracellular and intracellular fluids through the osmotic effects of their concentration. These two ions are also responsible for the maintenance of membrane potential and transmission of electrical impulses in the nerve cells. **Both in cells and in extracellular fluids, diabasic phosphate (HPO_4^{2-}) and monobasic phosphate ($H_2PO_4^-$) act as acid-base buffers to maintain the H^+ ion concentration.**

(ii) **The most abundant element in cell/living matter is oxygen.** O > C > N > H

(iii) **Fe^{++} and Cu^{++}** are found in cytochromes.

(iv) The concentration of the cations inside the cell is **$K^+ > Na^+ > Ca^{++}$**.

How to analyse Chemical Composition?

In order to study the various biomolecules found in living tissues (a vegetable or a piece of liver etc.), the tissue is **ground** in **trichloroacetic acid** (Cl_3CCOOH) using pestle and mortar. The resultant slurry is strained through cheese cloth or cotton and we obtain two fractions. The filtrate is called **acid soluble pool** while the retentate is called **acid insoluble fraction**. The acid soluble pool represents roughly the cytoplasmic composition. The macro molecules from cytoplasm and organelles become the acid - insoluble fraction. Chemicals present in both the fractions are further separated by various analytical techniques and identified.

Average Composition of Cells

Components	% of the total cellular mass
Water	70 – 90
Proteins	10 – 15
Carbohydrates	3
Lipids	2
Nucleic Acids	5 – 7
Ions	1

The **acid soluble pool** contains chemicals called **biomicromolecules** as they have small molecular mass of 18-800 daltons approximately. The **acid insoluble fraction** contains chemicals with large molecular mass of more than 800 daltons, they are biomacromolecules. **Biomacromolcules** are large size, high molecular weight, complex molecules that are formed by condensation of biomicromolecules. **Their molecular mass is in the range of ten thousand daltons and above**. Biomacromolecules are of three types-proteins, nucleic acids and polysaccharides. Though **lipids** have a molecular mass similar to that of micromolecules *i.e.* less than 800 Da, but they do not appear in the acid soluble pool due to their **non-polar nature**. All biomacromolecules are polymers except lipids. **Polymers** are formed by process of union of repeating subunits, each subunit being called **monomer**. Monomers are simple small sized low molecular weight molecules which cannot be hydrolysed further into smaller subunits. Polymers occur in the form of threads. They are folded to form three-dimensional shapes required for their functioning.

A list of Representative Inorganic Constituents of Living Tissues

Components	Formula
Sodium	Na^+
Potassium	K^+
Calcium	Ca^{++}
Magnesium	Mg^{++}
Water	H_2O
Compounds	NaCl, $CaCO_3$, PO_4^{3-}, SO_4^{2-}

Primary and Secondary Metabolites

The most exciting aspect of chemistry deals with isolating thousands of compounds, small and big, from living organisms, determining their structure and if possible, synthesising them.

If one were to make a list of biomolecules, such a list would have thousands of organic compounds including amino acids, sugars, etc. We can call these biomolecules, 'metabolites'. In animal tissues, one notices the presence of all such categories of compounds *e.g.*, **proteins, carbohydrates, fats, aminoacids, nucleic acids. These are called primary metabolites**. However, when one analyses plant, fungal and microbial cells, one would see thousands of compounds other than these primary metabolites, *e.g.*, alkaloids, flavonoids, rubber, essential oils, antibiotics, coloured pigments, scents, gums, spices etc. These are called **secondary metabolites**. While primary metabolites have identifiable functions and play known roles in normal physiological processes, many **secondary metabolites** are useful to 'human welfare' (*e.g.*, rubber, drugs, spices, scents and pigments). Some secondary metabolites have ecological importance.

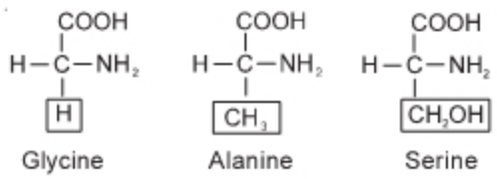
Some Secondary Metabolites	
Pigments	Carotenoids, Anthocyanins etc.
Alkaloids	Morphine, Codeine etc.
Terpenoids	Monoterpenes, Diterpenes etc.
Essential oils	Lemon grass oil, etc.
Toxins	Abrin, Ricin
Lectins	Concanavalin A
Polymeric Substances	Rubber, Gums, Cellulose
Drugs	Vinblastin, Curcumin, etc.

All the macromolecules **except lipids** are formed by the process of polymerisation, a process in which repeating sub-units termed monomers are bound into chains of different lengths (Polymers) *e.g.*, **Raffinose** is trisaccharide formed by polymerisation of glucose, fructose and galactose.

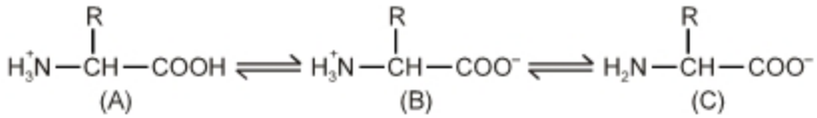
AMINO ACIDS

Amino acids are substituted methane and made of carbon, hydrogen, oxygen, nitrogen and in some cases also sulphur. A free amino group is basic while a free carboxyl group is acidic. Lysine and arginine are **Basic Amino acids** because they carry two amine groups and one carboxyl group. Glutamic acid (glutamate) and aspartic acid (aspartate) contain one amine and two carboxyl groups each and are classified as **Acidic Amino Acids**. Alanine, glycine, valine and phenylalanine are **Neutral Amino Acids** as these contain one amine and one carboxyl group. Similarly there are Aromatic amino acid (tyrosine, phenylalanine, tryptophan).

Amino Acids which occur in Proteins : Glycine, alanine, serine, cysteine, aspartic acid, glutamic acid, asparagine, glutamine, methionine, threonine, valine, leucine, isoleucine, lysine, histidine, arginine, phenylalanine, tyrosine, tryptophan and proline.



Amino acids



(B) is called **Zwitterionic form**

PROTEINS

The sequence of amino acids in the polypeptide chains give the protein its **Primary Structure**. The primary structure, albeit very important as it determines the specificity of protein, does not make a protein functional. To be functional, the protein must have a particular 3-dimensional structure (conformation). A functional protein contains one or more polypeptide chains. The sequence of amino acids in the chain determine, where the chain will bend or fold and where the various lengths will be attracted to each other.

Through the formation of hydrogen bonds peptide chain assumes a **Secondary Structure**. When a chain is arranged like a coil, it is called an α-Helix. When two or more chains are joined together by intermolecular hydrogen bonds, the structure is called the **Pleated Sheet**. Helical structure is found in keratin of hair and pleated structure in silk fibres.

In a large protein like enzyme, the molecule undergoes further folding and **coiling to attain functional conformation**. This is termed as the **Tertiary Structure**. The coils and folds of the protein molecule are so arranged as to hide non-polar amino acid side chains inside and expose the polar side chains. The 3-dimensional conformation of a protein brings distant amino acid side chains closer. The active sites of proteins such as enzymes are thus formed. The conformation of proteins is easily changed by pH, temperature and chemical substances and hence the function of proteins is labile and subject to regulation.

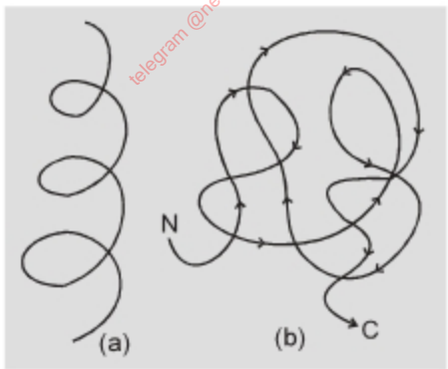


Fig. : Cartoon showing : (a) A secondary structure and
(b) A tertiary structure of proteins

In aqueous media, proteins carry both cationic and anionic groups on the same molecule. The ionic state of the protein depends on the pH of the medium. A protein, rich in basic amino acids like lysine and arginine exists as a cation and behaves as a base **(Basic Protein)** at the physiological pH of 7.4 *e.g.*, histones of nucleoproteins. Similarly, a protein with acidic amino acids exists as an anion and behaves as an acid **(Acidic Proteins)** *e.g.* most blood proteins.

Some proteins are an assembly of more than one polypeptide or subunits. The manner in which these individual folded polypeptides or subunits are arranged with respect to each other (*e.g.*, linear string of spheres, spheres arranged one upon each other in the form of a cube or plate etc.) is the architecture of a protein otherwise called the **quaternary structure** of a protein. Adult haemoglobin consists of 4 subunits. Two of these are identical to each other. Hence, two subunits of α type and two subunits of β-type together

constitute the human haemoglobin (Hb).

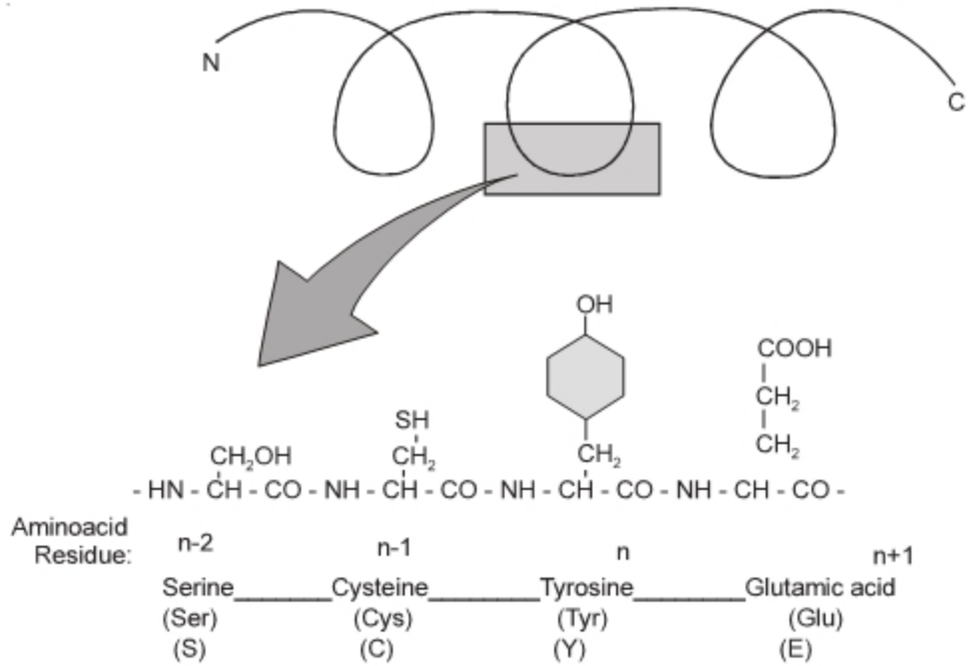


Fig. : Primary structure of a portion of a hypothetical protein. N and C refer to the two termini of every protein. Single letter codes and three letter abbreviations for amino acids are also indicated.

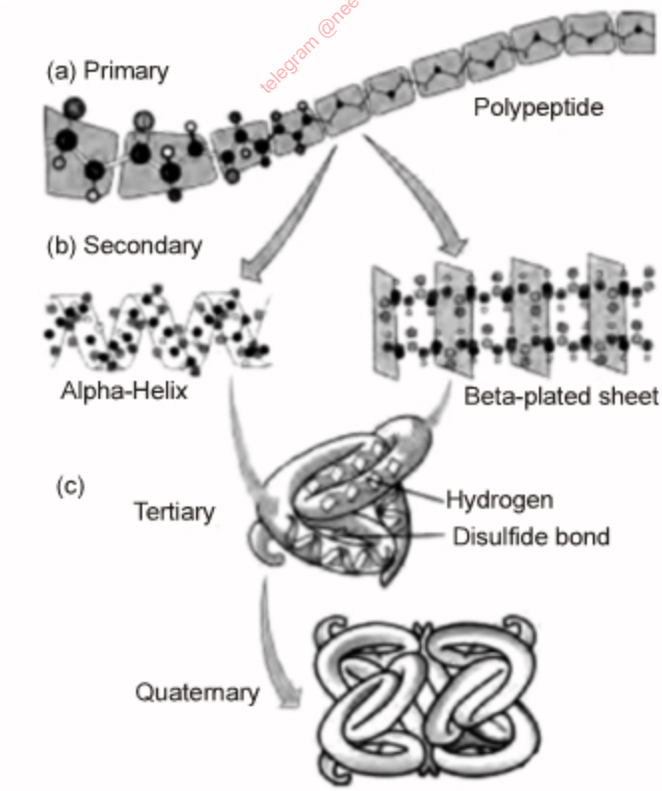


Fig : Various levels of protein structure

Some Proteins and their functions

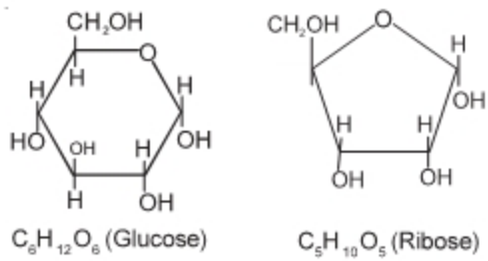
Protein	Functions
Collagen	Intercellular ground substance
Trypsin	Enzyme
Insulin	Hormone
Antibody	Fights infectious agents
Receptor	Sensory reception (smell, taste, hormone, etc.)
GLUT-4	Enables glucose transport into cells

Collagen is the most abundant protein in animal world. RuBisCo is the most abundant protein in whole biosphere.

CARBOHYDRATES

Carbohydrates are so called because in most of them, the proportion of hydrogen and oxygen is the same as in water (H_2O) and the general formula is written as $C_nH_{2n}O_n$. Carbohydrates also possess more than one alcoholic (OH) group.

Carbohydrates are known as saccharides or compounds containing sugar. The simplest carbohydrates are the simple sugars or **monosaccharides**, many of which have the general formula $C_nH_{2n}O_n$. These cannot be hydrolysed into still smaller carbohydrates. **Monosaccharides are composed of 3 to 7 carbon atoms.** They are classified according to the number of carbon atoms, as trioses ($C_3H_6O_3$), tetroses ($C_4H_8O_4$), pentoses($C_5H_{10}O_5$), hexoses ($C_6H_{12}O_6$) and heptoses ($C_7H_{14}O_7$) in that order. Hexoses and pentoses exist in both open chain and ring forms. Glucose, fructose and galactose are hexoses. They are all white, crystalline, sweet-tasting substances, extremely soluble in water. Ribose is a pentose and glyceraldehyde and dihydroxyacetone are trioses. These compounds have very important roles to play in the metabolism of cells as you will learn later. Glucose is the most important sugar occurring in animals. **Fructose is the commonest form of sugar in fruits**. Deoxyribose which occurs in deoxyribonucleic acid (DNA) is a pentose.



$C_6H_{12}O_6$ (Glucose) $C_5H_{10}O_5$ (Ribose)

Sugars (Carbohydrates)

Monosaccharides have two important chemical properties. Sugars having a free *aldehyde* or *ketone* group can reduce Cu^{++} to Cu^{+}. These are called *reducing sugars*. This property is the basis for Benedict's test and Fehling's test to detect the presence of glucose in urine. The aldehyde or ketone group of monosaccharide can react and bind with an alcoholic group of another organic compound to join the two compounds together. This bond is called the **glycosidic bond**. This bond can be hydrolysed to give the original compounds.

Monosaccharides by joining together through glycosidic bonds give rise to **compound carbohydrates**. The latter can be hydrolysed into the component monosaccharides by water or enzyme. Compound carbohydrates can be classified into two major groups, **oligosaccharides** made of a few molecules of monosaccharides (2 to 10) and polysaccharides composed of hundreds of simple sugar molecules (more than 10).

Disaccharides are composed of two monosaccharides. A molecule of sucrose is formed from a molecule of glucose and one of fructose. **Sucrose** or cane sugar does not reduce Cu^{++} to Cu^{+} (non-reducing). It is also the storage product of photosynthesis in sugarcane and sugarbeet. **Lactose** or milk sugar is found in human milk and cow's milk. It is formed of one molecule of glucose and one of galactose. **Maltose** or malt sugar is formed from two molecules of glucose during germination of starchy seeds. Maltose and lactose are reducing disaccharides. **Fructose is the sweetest among naturally occurring sugars.**

POLYSACCHARIDES

Food-Storage Polysaccharides : Starch forms helical secondary structure. In fact starch can hold I_2 molecules in helical portion. The starch-I_2 is blue in colour. Starch is found abundantly in rice, wheat and other cereal grains, legumes, potato, tapioca and bananas. It is formed during photosynthesis and serves as an energy-storing material. Glycogen found in liver and muscles stores energy in mammals. Storing carbohydrates in the form of polysaccharides has two advantages. During their formation many molecules of water are removed from monosaccharides. This helps in condensing the bulk to be stored. Unlike small carbohydrates, polysaccharides are relatively easy to store. When necessary polysaccharides are broken down by enzymes for the release of energy. In a polysaccharide chain the right end is called reducing end and the left end is called non reducing end.

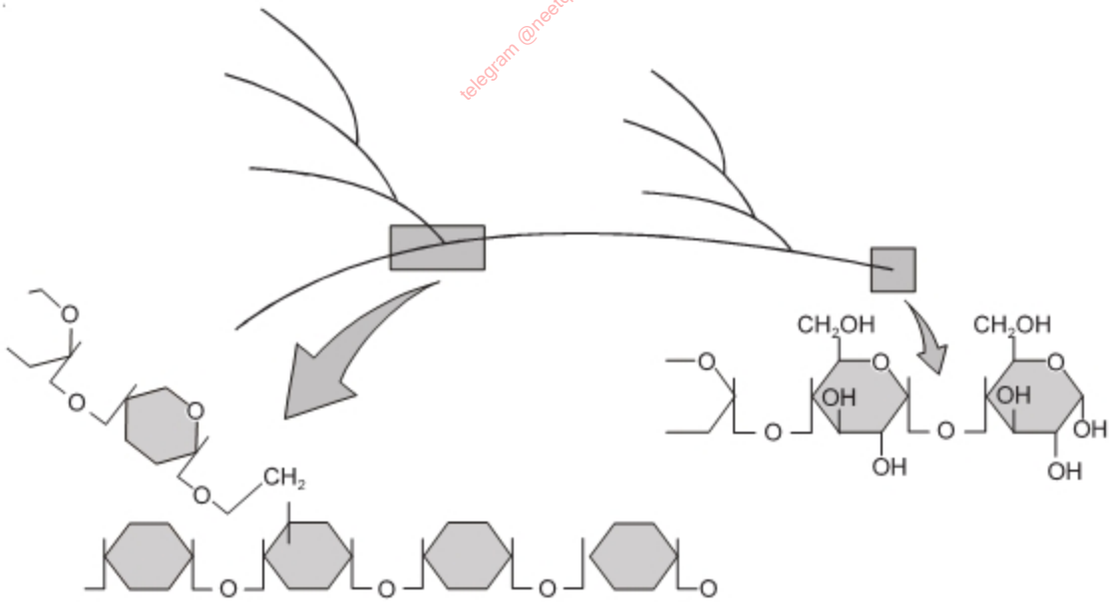


Fig. : Diagrammatic representation of a portion of Glycogen

Structural Polysaccharides : Cellulose is produced by plants and is used for building cell walls. **Cellulose is the most abundant organic compound in the biosphere**. Wood and cotton contain large quantities of cellulose. **Chitin** is a **polysaccharide found in the exoskeletons** of insects, crabs and prawns. Chitin is similar to cellulose in many ways except that its basic unit is not glucose but a similar molecule that contains nitrogen (N-acetylglucosamine). Exoskeleton of arthropods have chitin which is a homopolymer.

Cellulose (Hexosan polysaccharide) : Cellulose is the main structural unbranched homopolysaccharide of plants. One molecule of cellulose has about 6000 glucose residues. Cotton fibres contain the largest amount (90 percent) of cellulose among natural materials. Wood contains 25 to 50 percent cellulose, the rest being hemicellulose or lignin. Fibres of cotton, linen and jute are used for textile and ropes. Cellulose is unbranched homopolysaccharide of β-glucose. Cellulose does not contain complex helices and hence cannot hold I_2. Plant cell wall are made of cellulose. Paper made from plant pulp is cellulose.

Inulin : It is a polymer of fructose.

LIPIDS

They are compounds made of carbon, hydrogen and oxygen. The number of oxygen atoms in a lipid molecule is always lesser than the number of carbon atoms. Sometimes, small amounts of phosphorus, nitrogen and sulphur are also present. Lipids are insoluble in water, but soluble in non-polar solvents like chloroform and benzene.

$CH_3(CH_2)_{16}COOH$

Stearic acid

$CH_3(CH_2)_7CH = CH(CH_2)_7COOH$

Oleic acid

Saturated and unsaturated fatty acids

Fatty acids are organic acids with a hydrocarbon chain in which carbon varies from 1 to 19 ending in a carboxyl group (COOH). Fatty acids are called **saturated** if they do not have any double bonds between the carbons of the molecular chain *e.g.*, palmitic acid (16 C) and stearic acid (18 C) including carboxyl group. **Unsaturated Fatty acids** have one or more double bonds between the carbons of the chain. The 18 C unsaturated fatty acids oleic, linoleic and linolenic acids have 1, 2 and 3 double bonds respectively. The unsaturated fatty acids have lower melting points than saturated fatty acids. In lipids, fatty acids usually exist in the form of esters. Just as acids and bases react to form salts, organic acids react with alcohols to form esters.

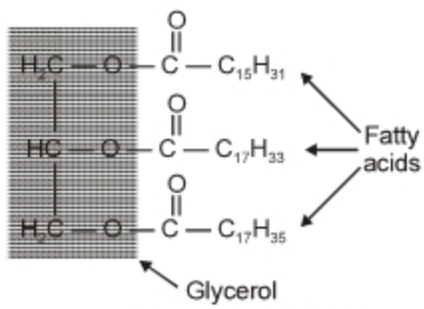


Fig. : A triglyceride fat

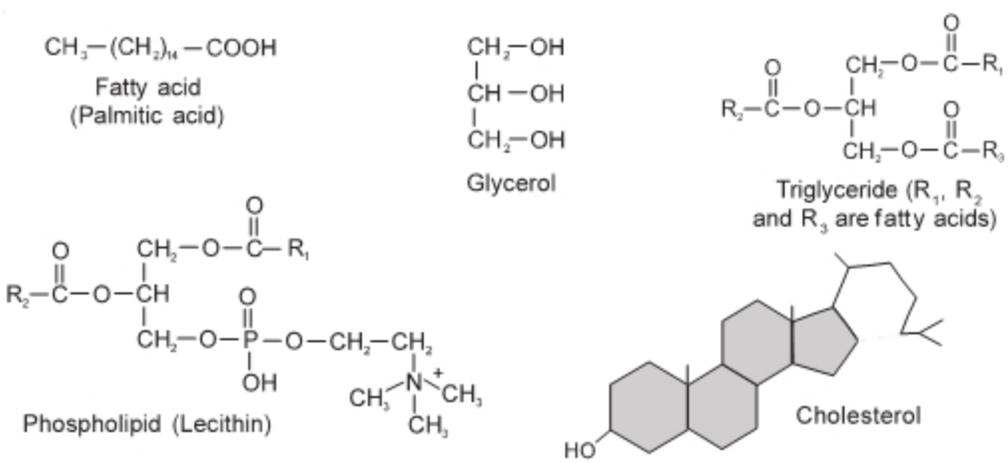


Fig. : Fats and oils (lipids)

Fats are esters of fatty acids with glycerol (glycerine). Each molecule of glycerol can react with three molecules of fatty acids. Depending on the number of fatty acids that are attached to the glycerol molecule, the esters are called mono-, di- or tri- glycerides. Fats that are generally liquid at room temperature are called **Oils**. Oils are rich in unsaturated fatty acids and consequently have low melting points (*e.g.*, **gingelly oil**). In hydrogenation, the unsaturated acids become saturated and the oil becomes a solid fat ("Vanaspati" and margarine).

There are other types of lipids occurring in the cell. The most common among them are the **phospholipids**. These lipids contain not only a fatty acid and an alcohol but also a phosphate group. Hence the name phospholipid. Some phospholipids also have a nitrogenous compound such as choline attached to them. Phospholipid molecules carry both hydrophilic (water-attracting) polar groups and hydrophobic (water-repellant) nonpolar groups. The hydrocarbon chains of the fatty acids are the **Non-Polar Tails** of the molecule. The phosphate and the nitrogenous/non-nitrogenous groups form the **polar Head-Group** of the molecule. Many phospholipid molecules may arrange themselves in a double-layered membrane **(Lipid Bilayer)** in aqueous media. These have one or more simple sugars. Some tissue especially the neural tissue have lipids with more complex structures.

Functions of Lipids

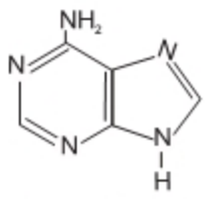
Fats are storage products in plants as well as animals. In oil-seeds such as groundnut, mustard, coconut and castor, the fat is stored by the plants to provide nourishment for the embryo during germination. Oil extracted from these seeds is used for cooking and other purposes. In animals, the fat droplets are found in the **Adipocytes**. Fat are the most highly concentrated source of energy for man. They are oxidised for energy when necessary. Fat deposited beneath the skin and around the internal organs minimises loss of body heat and also act as cushions to absorb mechanical impacts.

Phospholipids, glycolipids and sterols serve mainly as structural lipids. They are important components of membranes. Cholesterol is the most important sterol in animals. It forms a part of the animal cell membrane and is also used in the synthesis of **steroid hormones**, **vitamin D** and **bile salts**.

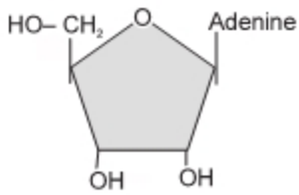
NUCLEOTIDES

This is a group of small complex molecules forming a part of the information transfer system in cells. They are basic units of nucleic acids. They also participate in energy transfer systems.

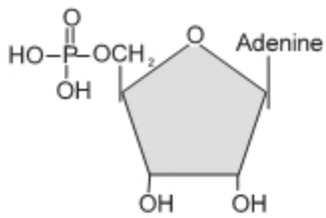
Nucleotides contain carbon, hydrogen, oxygen, nitrogen and phosphorus. Each nucleotide is made up of a cyclic nitrogenous base, a pentose and one to three phosphate groups. The nitrogenous bases occurring in nucleotides are either purines or a pyrimidines. Major purines are adenine and guanine. Thymine, uracil and cytosine are pyrimidines. The sugar pentose is either ribose or deoxyribose. The nucleotides are thus called **Ribonucleotides** or **Deoxyribonucleotides**. Examples of ribonucleotides and deoxyribonucleotides are adenylic acid (AMP) and deoxyadenylic acid (d AMP) respectively. Ribonucleotides are the basic units of ribonucleic acids (RNA) and deoxyribonucleotides are the basic units of deoxyribonucleic acids (DNA).



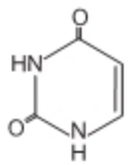
Adenine (Purine)



Adenosine

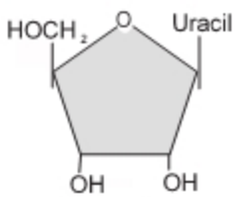


Adenylic acid



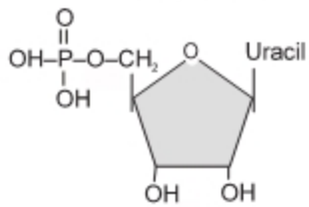
Uracil (Pyrimidine)

Nitrogen bases



Uridine

Nucleosides

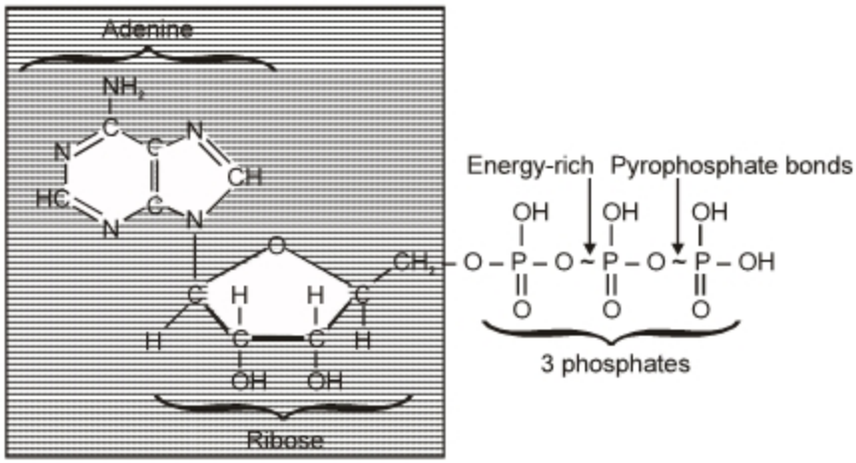


Uridylic acid

Nucleotide

Nucleotides are mono-, di- or tri-phosphates of nucleosides. *e.g.*, adenylic acid or adenosine monophosphate (AMP), adenosine disphosphate (ADP) and adenosine triphosphate (ATP) are all adenine nucleotides. Nucleotides with more than one phosphate group are called higher nucleotides, *i.e.*, ATP and ADP. Likewise, other purines and pyrimidines can also form higher nucleotides.

Higher nucleotides of purines and pyrimidines occur in the free state *e.g.*, ATP and ADP. Their second and third phosphate bonds can release about 8 kcal or more of free energy per mol on hydrolysis. This far exceeds the energy released on hydrolysis of most other covalent bonds. So, these phosphate bonds of the higher nucleotides are called **High-Energy Bonds**.



Functions of Nucleotides

Purine and pyrimidine nucleotides polymerise to form nucleic acids. Higher purine and pyrimidine nucleotides, particularly ATP, store energy in their high-energy phosphate bonds. They are formed during photosynthesis and respiration. Hydrolysis of the phosphate bonds of ATP releases their bond energy for driving energy-dependent reactions and processes. Nicotinamide and riboflavin nucleotides act as coenzymes of oxidising enzymes.

NUCLEIC ACIDS

Nucleic acids are giant molecules having a variety of functions. There are two major types as **Deoxyribonucleic Acid** or DNA and **Ribonucleic Acid** or RNA DNA is found mainly in the nucleus but also occurs in chloroplasts and mitochondria. It is the genetic material and contains all the information needed for the development and existence of an organism.

Nucleic acids are linear polymers of purine and pyrimidine nucleotides. The nucleotides are linked serially by phosphate groups, each linking the $C^{5'}$ (5′ – C) and the $C^{3'}$ (3′ – C) of the pentoses of the successive nucleotides. The DNA molecule consists of two chains of nucleotides whereas RNA consists of a single chain. The nucleotides of DNA contain the bases adenine (A), thymine (T), guanine (G) and cytosine (C), while RNA contains A, G, C and uracil (U) instead of T. Backbone of the nucleic acid is uniformly made up of alternating pentose and phosphate groups. The pentose in DNA is deoxyribose ($C_5H_{10}O_4$) and that in RNA is ribose ($C_5H_{10}O_5$). In the double stranded DNA, the bases of the opposite strands pair in a specific relationship by means of hydrogen bonds. A always pairs with T and G always pairs with C. This complementarity is known as the **Base-Pairing Rule**.

The two strands of DNA are coiled around common axis forming a double helix, like a spiral staircase with the sugar-phosphate units along the railing and the hydrogen-bonded base pairs as the steps. This is known as the **Watson and Crick Model of DNA**. Sugar and phosphates form the backbone of DNA molecules in the model.

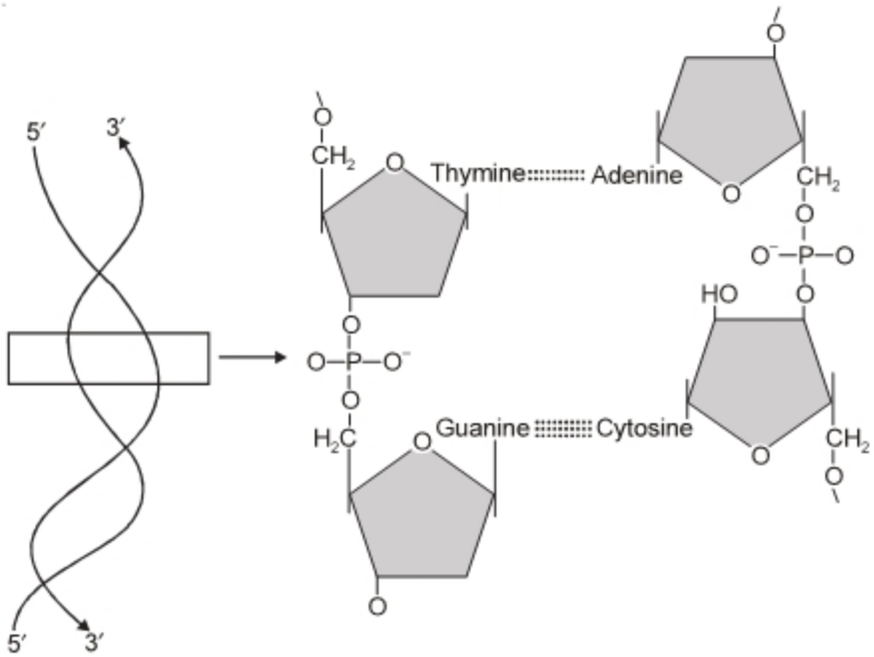


Fig. : Diagram indicating secondary structure of DNA

Dynamic State of Body Constituents - Concept of Metabolism

A simple bacterial cell, a protozoan, a plant or an animal, contain thousands of organic compounds. All these biomolecules have a **turn over**. This means that they are constantly being changed into some other biomolecules and also made from some other biomolecules. This breaking and making is through chemical reactions constantly occuring in living organisms. Together all these chemical reactions are called **metabolism**. Each of the metabolic reactions results in the transformation of biomolecules. *e.g.*, removal of CO_2 from amino acids making an amino acid into an amine, removal of amino group in a nucleotide base; hydrolysis of a glycosidic bond in a disaccharide, etc. Majority of these metabolic reactions do not occur in isolation but are always linked to some other reactions or metabolites are converted into each other in a series of linked reactions called metabolic pathways. Flow of metabolites through metabolic pathway has a definite rate and direction and is called the dynamic state of body constituents. Another feature of these metabolic reactions is that every chemical reaction is a **catalysed reaction**. There is no uncatalysed metabolic conversion in living systems. The catalysts which hasten the rate of a given metabolic conversation are also proteins. These proteins with catalytic power are named **enzymes**.

Metabolic basis of Life

Metabolic pathways can lead to breakdown of complex structure into a simpler structure or lead a simpler structure to from a complex structure. The former cases are called degradation pathways or catabolic pathways. The latter constitute biosynthetic and hence are called anabolic pathways. Anabolic pathways, as expected, consume energy. Assembly of a protein from amino acids requires energy input. On the other hand, catabolic pathways lead to the release of energy. For example, when glucose is degraded to lactic acid in our skeletal muscle, energy is liberated. Living organisms have learnt to trap this energy liberated during degradation and store it in the form of chemical bonds. As and when needed, this bond energy is utilised for biosynthetic, osmotic and mechanical work that we perform. The most important form of energy currency in living systems is the bond energy in a chemical called **adenosine triphosphate (ATP)**.

The Living State

The tens and thousands of chemical compounds occur in a living organism, otherwise called metabolites, or biomolecules and are present at concentrations characteristic of each of them. For example, the blood

concentration of glucose in a normal healthy individual is 4.5–5.0 mM, while that of hormones would be nanograms/mL. The most important fact of biological systems is that all living organisms exist in a steady-state characterised by concentrations of each of these biomolecules. These biomolecules are in a metabolic flux. Any chemical or physical process moves spontaneously to equilibrium. The steady state is a non-equilibirium state. As living organisms work continuously, they cannot afford to reach equilibrium. **Hence, the living state is a non-equilibrium steady-state to be able to perform work**; living process is a constant effort to prevent falling into equilibrium. This is achieved by energy input. Metabolism provides a mechanism for the production of energy. Hence, the living state and metabolism are synonymous. Without metabolism there cannot be a living state.

Enzymes

Term enzyme was coined by **Kuhne**. All enzymes are proteinaceous in nature (Sumner, 1926) with the exception of recently discovered RNA enzymes. The two RNA enzymes are **Ribozyme** (Cech *et al.*, 1981, for removing introns) and **Ribonuclease-P** (Altman *et al.*, 1983, for separating t-RNAs from hnRNA). Enzymes can be simple or conjugate enzymes. **Simple Enzymes** are made of only proteins. *e.g.*, pepsin, trypsin, steapsin. **Conjugate Enzymes** are formed of **two** parts.

(i) A protein part called **apoenzyme**, and

(ii) A non-protein part named **co-factor**.

The complete conjugate enzyme consisting of an apoenzyme and a co-factor is called **holo-enzyme**.

Three kinds of cofactors may be identified :

(i) **Prosthetic Group :**

These are organic compounds which are tightly bound to apoenzyme (protein part).

For example, in peroxidase and catalase, which catalyze the breakdown of hydrogen peroxide to water and oxygen, haem is the prosthetic group and it is a part of the active site of the enzyme.

(ii) **Coenzyme :**

These are organic compounds but their association with the apoenzyme is only transient. The essential chemical components of many coenzymes are vitamins *e.g.*, coenzyme nicotinamide adenine dinucleotide (NAD) and NADP contains the vitamin niacin.

(iii) **Metal ions :**

A number of enzymes require metal ions for their activity.

For example, Zinc is a cofactor for the proteolytic enzyme carboxypeptidase.

How do enzymes bring about high rates of chemical conversions?

The chemical which is converted into a product is called a 'substrate'. Hence enzymes, *i.e.*, proteins with three dimensional structures including an 'active site', convert a substrate (S) into a product (P). Symbolically, this can be depicted as :

$$[S] \rightarrow [P]$$

The substrate 'S' has to bind the enzyme at its 'active site' within a given cleft or pocket. The substrate has to diffuse towards the 'active site'. There is thus, an obligatory formation of an 'ES' complex. E stands for enzyme. This complex formation is a **transient phenomenon**. During the state where substrate is bound to the enzyme active site, a new structure of the substrate called transition state structure is formed. Very soon, after the expected bond breaking/making is completed, the product is released from the active site. In other words, the structure of substrate gets transformed into the structure of product(s). The pathway of this transformation must go through the so-called transition state structure. There could be many more 'altered

structural states' between the stable substrate and the product. Implicit in this statement is the fact that all other intermediate structural states are unstable. Stability is something related to energy status of the molecule or the structure.

The 'S' has to go through a much higher energy state or transition state. The difference in average energy content of 'S' from that of this transition state is called 'activation energy'. Enzymes eventually bring down this energy barrier making the transition of 'S' to 'P' more easy.

Activation energy is the energy needed to start a biochemical reaction. Activation energy increases the kinetic energy of the system and brings about forceful collisions between the reactants.

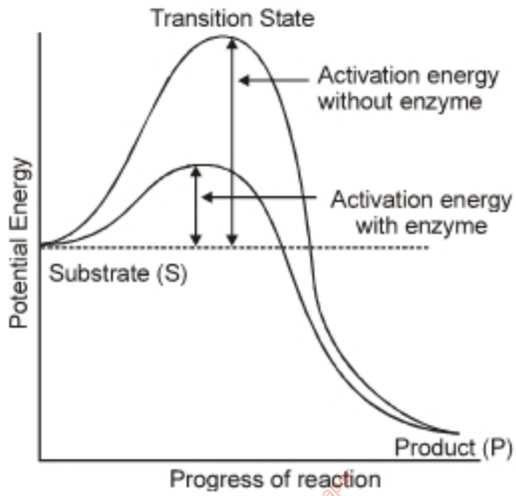


Fig. : Concept of activation energy

Enzyme lowers the activation energy thus increases the rate of reaction.

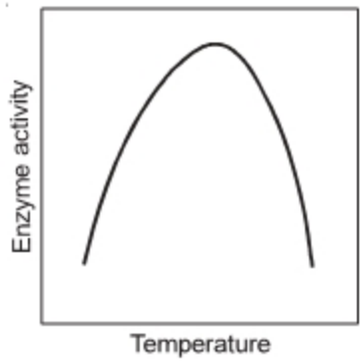
Each enzyme (E) has a substrate (S) binding site in its molecule so that a highly reactive enzyme-substrate complex (ES) is produced. This complex is short-lived and dissociates into its product(s) P and the unchanged enzyme with an intermediate formation of the enzyme-product complex (EP).

The formation of the ES complex is essential for catalysis.

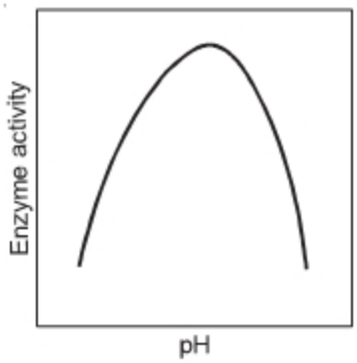
$$E + S \rightleftharpoons ES \longrightarrow EP \longrightarrow E + P$$

Factors affecting enzyme activity

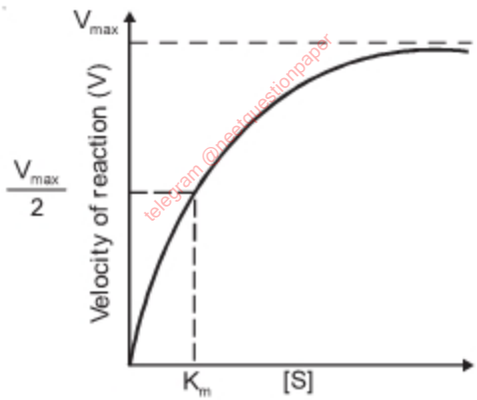
1. **Optimum Temperature :** Enzymes generally work over a narrow range of temperatures. Usually they correspond to the body temperature of the organism. For instance human enzymes work at the normal body temperature of 37°C. Each enzyme shows its highest activity at a particular temperature that is called its optimum temperature. Activity declines both above and below the optimum temperature.



2. **Optimum pH :** Each enzyme shows its highest activity at a specific pH that is called its optimum pH. Activity declines both above and below the optimum pH. Most intracellular enzymes function best around neutral pH. Some digestive enzymes have their optima in the acidic or alkaline range. *e.g.,* the protein digesting enzyme pepsin found in the stomach has an optimum pH of 2.0 Another protein digesting enzyme, trypsin, found in the duodenum functions best at an alkaline pH of 8.0



3. **Substrate concentration :** When substrate concentration is increased, the rate of enzymatic reaction also increase first. When the reaction rate becomes maximum (V_{max}), no further increase is possible by adding substrate molecules as there are no free enzyme molecule to bind with the additional substrate molecule.



Classification of Enzymes

Enzymes were variously named in the past. Enzymes such as ptyalin (salivary amylase), pepsin and trypsin give no indication of their action. Other enzymes such as amylase, sucrase, protease and lipase were named after the substrates on which they act *i.e.*, amylose (starch), sucrose, protein and lipids respectively. Still others were named according to the source from which they were obtained *e.g.*, papain from papaya, bromelain from pineapple (which belongs to the family Bromeliaceae). Some enzymes like DNA polymerase indicate their specific action *e.g.*, polymerisation.

The name of each enzyme ends with an -**ase** and consists of two parts. The first part indicates its substrates and the second the reaction catalysed. *e.g.*, glutamate pyruvate transaminase transfers an amino group from the substrate glutamate to another substrate pyruvate. However, arbitrary names like ptyalin and trypsin still continue to be used because of their familiarity.

Enzymes are grouped into six major classes :

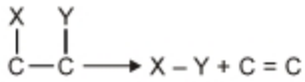
Class 1. Oxidoreductases : These catalyse oxidation or reduction of their substrates and act by removing or adding electrons (and/or H^+) from or to substrates *e.g.*, cytochrome oxidase (oxidises cytochrome).

$$S_{reduced} + S'_{oxidised} \rightarrow S_{oxidised} + S'_{reduced}$$

Class 2. **Transferases :** These transfer specific groups from one substrate to another. The chemical group transferred in the process is not in a free state, *e.g.*, glutamate pyruvate transaminase.

Class 3. **Hydrolases :** These break down large molecules into smaller ones by the addition of water (hydrolysis) and catalyse breaking of specific covalent bonds. Most digestive enzymes belong to this category *e.g.*, amylase which hydrolyses starch.

Class 4. **Lyases :** These catalyse the cleavage of specific covalent bonds and removal of groups without hydrolysis *e.g.*, histidine decarboxylase cleaves C – C bond in histidine to form carbon dioxide and histamine.



Class 5. **Isomerases :** These catalyse the rearrangement of molecular structures to form isomers *e.g.*, phosphohexose isomerase changes glucose-6-phosphate to fructose-6-phosphate (both are hexose phosphates).

Class 6. **Ligases :** These catalyse covalent bonding between two substrates to form a large molecule. The energy for the reaction is derived from the hydrolysis of ATP. Pyruvate carboxylase combines pyruvate and carbon dioxide to form oxaloacetate at the expense of ATP.

Mode of Enzyme Action

1. **Lock and key Hypothesis** was put forward by Emil Fischer in 1894.
2. **Induced Fit Theory** was proposed by Koshland in 1959. According to this theory, the active site of the enzyme contains two groups, buttressing and catalytic. The buttressing group is meant for supporting the substrate and the catalytic group for converting it to product.

Inhibition of Enzyme Action

Competitive Inhibition : The action of an enzyme may be reduced or inhibited in the presence of a substance that closely resembles the substrate in molecular structure. Such an inhibitor is called **Competitive Inhibitor** of that enzyme. Due to its close structural similarity with the substrate, the inhibitor competes with the latter for the substrate-binding site of the enzyme. Consequently, the enzyme cannot catalyse the change of the substrate. As a result, the rate of enzyme action declines, *e.g.*, the inhibition of succinate dehydrogenase by malonate which closely resembles succinate in structure. This may be compared to a lock jammed by a key similar to the original key. **Such competitive inhibitors are often used in the control of bacteria. For instance, sulpha drugs are competitive inhibitors of folic acid synthesis in bacteria as they substitute for and compete with para-amino benzoic acid, thus preventing the next step of synthesis.**

Competitive inhibitor of an enzyme increase K_m without affecting V_{max}.

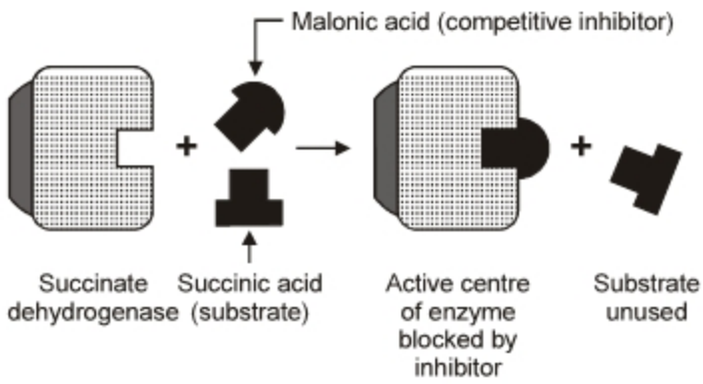


Fig. : Competitive inhibition of enzyme action

Non-competitive Inhibition : Cyanide kills an animal by inhibiting cytochrome oxidase, a mitochondrial enzyme, essential for cellular respiration. This is an example of non-competitive inhibition of an enzyme. Here, the inhibitor (cyanide) has no structural similarity with the substrate (cytochrome c) and does not bind to the substrate-binding site but at some other site of the enzyme. Thus, in non-competitive inhibition, substrate binding may take place but no products are formed.

Non-competitive inhibitor of an enzyme decrease V_{max} without affecting K_m.

Allosteric Modulation or Feedback Inhibition : The activities of some enzymes, particularly those which form a part of a chain of reactions (metabolic pathway), are regulated internally. Some specific low molecular weight substances, such as the product(s) of another enzyme further down the chain act as inhibitor. Such modulator substances bind to a specific site of the enzyme different from its substrate-binding site. This binding increases or decreases the enzyme action. Such enzymes are called **Allosteric Enzymes**, *e.g.*, hexokinase (changes glucose to glucose-6-phosphate in glycolysis). Decline in the enzyme activity by allosteric effect of the product is called **Feedback Inhibition** *e.g.*, allosteric inhibition of hexokinase by glucose-6-phosphate.

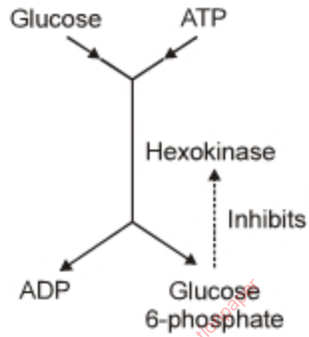


Fig. : Feedback/allosteric inhibition

Enzyme phosphofructokinase is activated by ADP and inhibited by ATP.

Another example is inhibition of **threonine deaminase** by **isoleucine**. Amino acid isoleucine is formed in bacterium *Escherichia coli* in a 5-step reaction from threonine. When isoleucine accumulates beyond a **threshold level,** its further production stops.

❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. All the macromolecules are results of the process of polymerisation, a process in which repeating subunits termed **monomers** are bound into chains of different lengths. All macromolecules are polymers, **except**
   (1) Nucleic acids (2) Carbohydrates
   (3) Lipids (4) Proteins
2. Which of the following are basic aminoacids?
   (1) Glycine and Alanine
   (2) Lysine and Arginine
   (3) Glutamic acid and Aspartic acid
   (4) Histidine and Proline
3. On losing the carboxyl group as carbon dioxide amino acids form biologically active
   (1) Glucose
   (2) Amines such as histamine
   (3) Alcohol
   (4) Nitrogenous-base
4. β-pleated structure of proteins is present in silk fibres, the protein of these fibres is
   (1) Fibroin (2) Collagen
   (3) Rayon (4) Keratin
5. Keratin of hair has
   (1) Tertiary structure of protein
   (2) α-helical structure of protein
   (3) β-pleated structure of protein
   (4) Primary structure of protein
6. Most of the blood proteins in our body are
   (1) Basic (2) Acidic
   (3) Neutral (4) Basic and Neutral
7. Casein of milk is a
   (1) Glycoprotein (2) Phosphoprotein
   (3) Chromoprotein (4) Metaloprotein
8. Lactose has two monosaccharide units. These are
   (1) Glucose and maltose
   (2) Glucose and galactose
   (3) Glucose and sucrose
   (4) Fructose and galactose
9. A monosaccharide is a simple polyhydroxy aldehyde or ketone molecules which cannot be further hydrolysed into smaller units. The number of carbon atoms in monosaccharides vary from
   (1) 2-8 carbons (2) 2-7 carbons
   (3) 3-6 carbons (4) 3-7 carbons
10. The sweetest of all naturally occurring sugars is
    (1) Glucose (2) Fructose
    (3) Mannose (4) Galactose
11. Which of the following is not a reducing sugar?
    (1) Glucose (2) Lactose
    (3) Maltose (4) Sucrose
12. Which of the following will yield only glucose on hydrolysis?
    (1) Sucrose (2) Lactose
    (3) Maltose (4) Raffinose
13. Storing carbohydrates in the form of polysaccharides has which of the following advantages
    (1) During their formation many molecules of water are removed from monosaccharide (dehydration synthesis), condensing the bulk to be store
    (2) When necessary, polysaccharides are broken down by enzymes for the release of energy
    (3) Unlike small carbohydrates, polysaccharides are relatively easy to store
    (4) All of these
14. The most abundant organic compound in biosphere is
    (1) Lignin (2) Cellulose
    (3) Pectin (4) Hemi-cellulose

15. The largest amount (90%) of cellulose amongst the natural materials is present in
(1) Wood (2) Cotton fibres
(3) Rayon (4) Roughage

16. Glycosidic linkage at place of branching in starch and glycogen has
(1) α -1, 4 linkage (2) α -1, 6 linkage
(3) β -1, 4 linkage (4) β -1, 6 linkage

17. Monomer unit of chitin is
(1) N-acetyl glucosamine
(2) Mannitol
(3) Glucoronic acid
(4) Ascorbic acid

18. Cellulose is
(1) Heptopolysaccharide
(2) Heteropolysaccharide, branched
(3) Hexosan polysaccharide, unbranched
(4) Pentosan polysaccharide, branched

19. Chitin is the second most abundant organic substance in the biosphere and is present in the exoskeleton of insects and crustaceans. It is a
(1) Protein
(2) Polysaccharide and the basic unit is N-acetylglucosamine
(3) Protein and $CaCO_3$ deposits occur in it
(4) Lipid

20. Which of the following is essential fatty acid with two double bonds in chain?
(1) Linoleic (2) Linolenic
(3) Arachidonic (4) Stearic

21. Lecithin is a
(1) Fatty acid
(2) Phospholipid with choline attached to phosphate group
(3) Chloesterol
(4) Fat

22. The backbone of a nucleic acid strand is made of
(1) Base and phosphate
(2) Sugar and phosphate
(3) Sugar and base
(4) Sugar, base and phosphate

23. Which of following is not present in DNA?
(1) Cytosine (2) Adenine
(3) Guanine (4) Thiamine

24. Nucleotides take part in
(1) Information transfer system
(2) Energy transfer system
(3) Formation of NAD and FAD which act as co-enzymes of oxidising enzymes
(4) All of these

25. A nucleotide is made of
(1) Sugar and phosphate only
(2) Nitrogenous base and sugar only
(3) Nitrogenase base, sugar and phosphate
(4) Phosphate and Nitrogenous-base only

26. Nucleoside on hydrolysis will not yield
(1) Sugar
(2) Phosphoric acid
(3) Nitrogenous base
(4) Sugar and nitrogenous base

27. The term enzyme was coined by
(1) Kuhne (2) Buchner
(3) De Duve (4) Boveri

28. All of the following enzymes are proteins, **except**
(1) Trypsin
(2) Pepsin
(3) Steapin
(4) Ribozyme and Ribonuclease-p

29. The non-protein organic factor firmly attached to apoenzyme is called
(1) Metal ion (2) Co-enzyme
(3) Prosthetic group (4) Activator

30. Lock and key hypothesis was put forward by
(1) Emil Fischer (2) Koshland
(3) Buchner (4) Kuhne

31. A specific low molecular weight substance such as the product of another enzyme in the chain reaction which binds with a specific site of the enzyme different from its substrate binding site is called
(1) Competitive inhibitor
(2) Non-competitive inhibitor
(3) Irreversible inhibitor
(4) Allosteric modulator

32. Sulpha drugs control bacterial pathogens by
(1) Non-competitive inhibition
(2) Allosteric modulation
(3) Acting as competitive inhibitors of folic acid synthesis in bacteria
(4) Controlling the bacterial pathogens by feedback inhibition

33. Cyanide kills an animal by
(1) Killing the brain cells
(2) Acting as competitive inhibitor of enzyme cytochrome oxidase
(3) Inhibiting cytochrome oxidase, a mitochondrial enzyme essential for cellular respiration by non-competitive inhibition
(4) Killing the cardiac muscles

34. All are the examples of feed back inhibition, **except**
(1) Inhibition of succinic dehydrogenase by malonate
(2) Inhibition of hexokinase by glucose-6-phosphate
(3) Inhibition of phosphofructokinase by ATP
(4) Inhibition of threonine deaminase by isoleucine in bacteria

35. Which of the following groups of enzymes catalyses the cleavage of specific covalent bonds and removal of groups without hydrolysis?
(1) Oxidoreductases (2) Hydrolases
(3) Lyases (4) Isomerases

36. Alcohol dehydrogenase enzyme also exists in its isoenzymes. The number of isoenzyme forms of alcohol dehydrogenase in maize are
(1) 16 (2) 4
(3) 100 (4) 5

37. All enzymes of human body have
(1) Same pH and temperature optima
(2) Same pH but different temperature optima
(3) Different pH but same temperature optima
(4) Different pH and different temperature optima

38. A competitive inhibitor of an enzyme
(1) Increases K_m without affecting V_{max}
(2) Decreases K_m without affecting V_{max}
(3) Increases V_{max} without affecting K_m
(4) Decreases both V_{max} and K_m

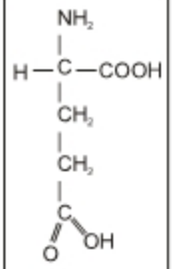
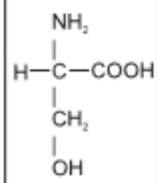
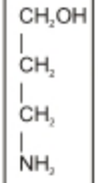
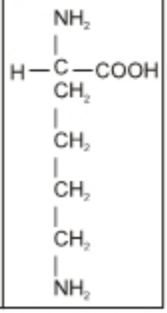
39. A non-competitive inhibitor of an enzyme
(1) Increases V_{max} without affecting K_m
(2) Decreases V_{max} without affecting K_m
(3) Decreases both V_{max} and K_m
(4) Increases both V_{max} and K_m

40. An organic substance bound lightly to an enzyme and which is essential for its activity is called
(1) Holoenzyme (2) Apoenzyme
(3) Isoenzyme (4) Coenzyme

SECTION - B

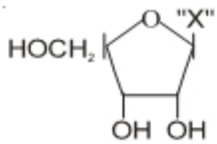
Previous Years Questions

1. Which one out of A - D given below correctly represents the structural formula of the basic amino acid?

A	B	C	D
			

Options : **[AIPMT 2012]**
(1) A (2) B
(3) C (4) D

2. Given below is the diagrammatic representation of one of the categories of small molecular weight organic compounds in the living tissues. Identify the **category** shown and the one blank **component** "X' in it **[AIPMT 2012]**



	Category	**Component**
(1)	Nucleotide	Adenine
(2)	Nucleoside	Uracil
(3)	Cholesterol	Guanin
(4)	Amino acid	NH_2

3. Which one is the **most** abundant protein in the animal world? **[AIPMT 2012]**
(1) Collagen (2) Insulin
(3) Trypsin (4) Haemoglobin

4. For its activity, carboxypeptidase requires **[AIPMT 2012]**
(1) Zinc (2) Iron
(3) Niacin (4) Copper

5. Which one of the following biomolecules is **correctly** characterised? **[AIPMT 2012]**
(1) Lecithin - a phosphorylated glyceride found in cell membrane
(2) Palmitic acid - an unsaturated fatty acid with 18 carbon atoms
(3) Adenylic acid - adenosine with a glucose phosphate molecule
(4) Alanine amino acid - Contains an amino group and an acidic group anywhere in the molecule

6. A phosphoglyceride is always made up of **[NEET 2013]**
   (1) Only an unsaturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached
   (2) A saturated or unsaturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached
   (3) A saturated or unsaturated fatty acid esterified to a phosphate group which is also attached to a glycerol molecule
   (4) Only a saturated fatty acid esterified to a glycerol molecule to which a phosphate group is also attached

7. The essential chemical components of many coenzymes are **[NEET 2013]**
   (1) Nucleic acids
   (2) Carbohydrates
   (3) Vitamins
   (4) Proteins

8. Transition state structure of the substrate formed during an enzymatic reaction is **[NEET 2013]**
   (1) Permanent but unstable
   (2) Transient and unstable
   (3) Permanent and stable
   (4) Transient but stable

9. The most abundant intracellular cation is **[NEET 2013]**
   (1) Ca^{++} (2) H^{+}
   (3) K^{+} (4) Na^{+}

10. Macro molecule chitin is **[NEET 2013]**
   (1) Phosphorus containing polysaccharide
   (2) Sulphur containing polysaccharide
   (3) Simple polysaccharide
   (4) Nitrogen containing polysaccharide

11. Select the option which is not correct with respect to enzyme action **[AIPMT 2014]**
   (1) Substrate binds with enzyme at its active site
   (2) Addition of lot of succinate does not reverse the inhibition of succinic dehydrogenase by malonate
   (3) A non-competitive inhibitor binds the enzyme at a site distinct from that which binds the substrate
   (4) Malonate is a competitive inhibitor of succinic dehydrogenase

12. Which one of the following is a non-reducing carbohydrate? **[AIPMT 2014]**
   (1) Maltose (2) Sucrose
   (3) Lactose (4) Ribose 5-phosphate

13. In sea urchin DNA, which is double stranded 17% of the bases were shown to be cytosine. The percentages of the other three bases expected to be present in this DNA are **[AIPMT-2015]**
   (1) G 8.5%, A 50%, T 24.5%
   (2) G 34%, A 24.5%, T 24.5%
   (3) G 17%, A 16.5%, T 32.5%
   (4) G 17%, A 33%, T 33%

14. Which one of the following statements is **incorrect**? **[AIPMT-2015]**
   (1) The presence of the competitive inhibitor decreases the K_m of the enzyme for the substrate
   (2) A competitive inhibitor reacts reversibly with the enzyme to form an enzyme-inhibitor complex
   (3) In competitive inhibition, the inhibitor molecule is not chemically changed by the enzyme
   (4) The competitive inhibitor does not affect the rate of breakdown of the enzyme-substrate complex

15. Which of the following biomolecules does have a phosphodiester bond? **[Re-AIPMT-2015]**
   (1) Nucleic acids in a nucleotide
   (2) Fatty acids in a diglyceride
   (3) Monosaccharides in a polysaccharide
   (4) Amino acids in a polypeptide

16. The chitinous exoskeleton of arthropods is formed by the polymerisation of : **[Re-AIPMT-2015]**
   (1) Lipoglycans
   (2) Keratin sulphate and chondroitin sulphate
   (3) D-glucosamine
   (4) N-acetyl glucosamine

17. A typical fat molecule is made up of **[NEET-2016]**
   (1) Three glycerol and three fatty acid molecules
   (2) Three glycerol molecules and one fatty acid molecule
   (3) One glycerol and three fatty acid molecules
   (4) One glycerol and one fatty acid molecule

18. Which one of the following statements is wrong? **[NEET-2016]**
   (1) Glycine is a sulphur containing amino acid
   (2) Sucrose is a disaccharide
   (3) Cellulose is a polysaccharide
   (4) Uracil is a pyrimidine

19. A non-proteinaceous enzyme is **[NEET (Phase-2) 2016]**

(1) Lysozyme (2) Ribozyme

(3) Ligase (4) Deoxyribonuclease

20. Which of the following is the least likely to be involved in stabilizing the three-dimensional folding of most proteins? **[NEET (Phase-2) 2016]**

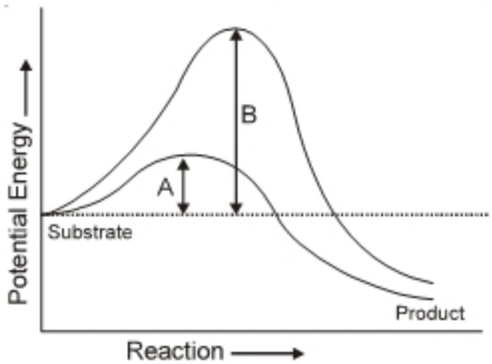
(1) Hydrogen bonds

(2) Electrostatic interaction

(3) Hydrophobic interaction

(4) Ester bonds

21. Which of the following describes the given graph **correctly**? **[NEET (Phase-2) 2016]**



(1) Endothermic reaction with energy A in presence of enzyme and B in absence of enzyme

(2) Exothermic reaction with energy A in presence of enzyme and B in absence of enzyme

(3) Endothermic reaction with energy A in absence of enzyme and B in presence of enzyme

(4) Exothermic reaction with energy A in absence of enzyme and B in presence of enzyme

22. Which of the following are not polymeric? **[NEET-2017]**

(1) Nucleic acids (2) Proteins

(3) Polysaccharides (4) Lipids

23. Which one of the following statements is **correct**, with reference to enzymes? **[NEET-2017]**

(1) Apoenzyme = Holoenzyme + Coenzyme

(2) Holoenzyme = Apoenzyme + Coenzyme

(3) Coenzyme = Apoenzyme + Holoenzyme

(4) Holoenzyme = Coenzyme + Cofactor

24. The two functional groups characteristic of sugars are **[NEET-2018]**

(1) Carbonyl and phosphate

(2) Carbonyl and methyl

(3) Hydroxyl and methyl

(4) Carbonyl and hydroxyl

25. Concanavalin A is **[NEET-2019]**

(1) an alkaloid (2) an essential oil

(3) a lectin (4) a pigment

26. Consider the following statement :

(A) Coenzyme or metal ion that is tightly bound to enzyme protein is called prosthetic group.

(B) A complete catalytic active enzyme with its bound prosthetic group is called apoenzyme.

Select the correct option. **[NEET-2019]**

(1) Both (A) and (B) are true.

(2) (A) is true but (B) is false.

(3) Both (A) and (B) are false.

(4) (A) is false but (B) is true.

27. Purines found both in DNA and RNA are **[NEET-2019]**

(1) Adenine and thymine

(2) Adenine and guanine

(3) Guanine and cytosine

(4) Cytosine and thymine

28. Prosthetic groups differ from co-enzymes in that- **[NEET-2019 (Odisha)]**

(1) They can serve as co-factors in a number of enzyme - catalyzed reactions

(2) They require metal ions for their activity

(3) They (prosthetic groups) are tightly bound to apoenzymes

(4) Their association with apoenzymes is transient

29. "Ramachandran plot" is used to confirm the structure of **[NEET-2019 (Odisha)]**

(1) DNA (2) RNA

(3) Proteins (4) Triacylglycerides

30. Which of the following organic compounds is the main constituent of Lecithin? **[NEET-2019 (Odisha)]**

(1) Phosphoprotein (2) Arachidonic acid

(3) Phospholipid (4) Cholesterol

❑ ❑ ❑

Chapter 4

Digestion and Absorption

Sub-topics *Alimentary Canal and Digestive Glands; Role of Digestive Enzymes and Gastrointestinal Hormones; Peristalsis, Digestion, Absorption and Assimilation of Proteins, Carbohydrates and Fats; Calorific Value of Proteins, Carbohydrates and Fats; Egestion; Nutritional and Digestive Disorders – PEM, Indigestion, Constipation, Vomiting, Jaundice, Diarrhoea*

DIGESTIVE SYSTEM

The human digestive system consist of the alimentary canal and the associated glands.

Alimentary Canal

Alimentary canal starts from an anterior opening, the mouth which leads into buccal cavity or oral cavity.

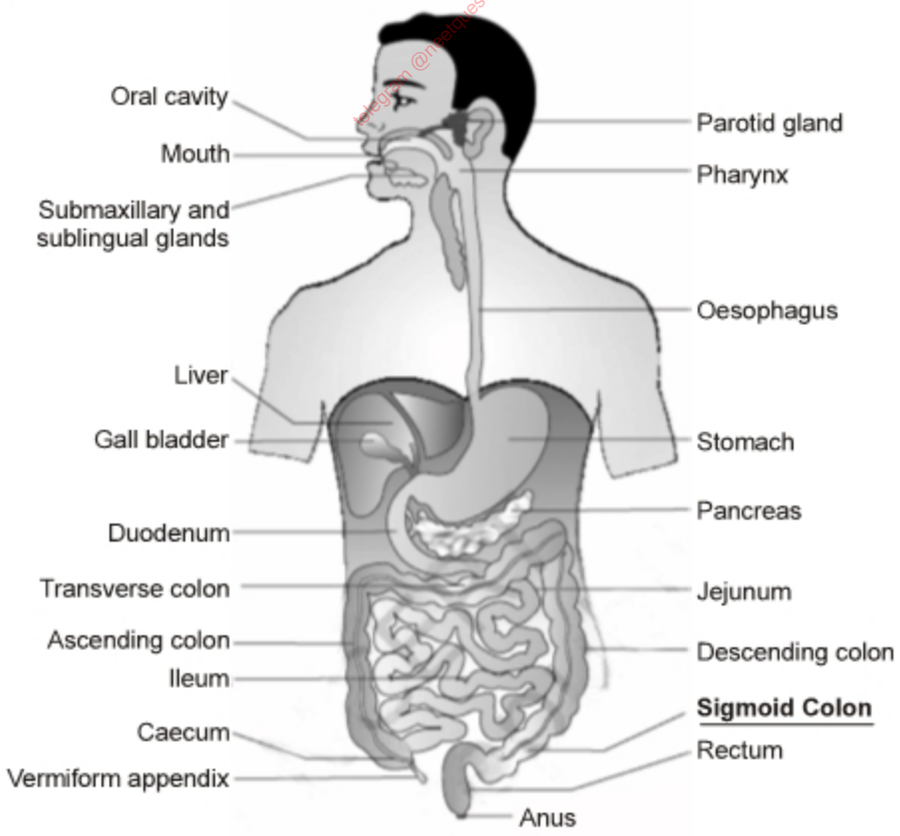


Fig. : The Digestive System

Buccal Cavity : The space between lips and teeth is called **vestibule**. The roof of buccal cavity is palate consisting of hard palate (maxilla, premaxilla and palatine bones) and soft palate. Hard palate epithelium has thick transverse folds called **palatine rugae**. Terminal part of soft palate hangs in the throat as **uvula**. On sides of uvula, tonsils are present which are made of lymphatic tissue. The floor of buccal cavity is occupied by a muscular tongue attached at base by a fold called lingual **frenulum**. On the tongue, various pepillae are present :

(i) Filiform papillae : Most abundant and have no taste buds.

(ii) Fungiform papillae : Appear as red dots on tongue and contain taste buds for sweet, sour or salty taste.

(iii) Foliate papillae : Not developed in humans.

(iv) Circumvallate papillae : Largest and knob like contain taste buds for bitter taste.

The different areas of tongue are demarcated on basis of taste they percieve as follows :

Tip	–	Sweet
Tips and sides	–	Salt
Sides	–	Sour
Base	–	Bitter

Sweat glands of dogs are present on tongue and panting of dogs facilitates thermo-regulation.

There are no taste buds for chillies on tongue; the burning sensation is due to the stimulation of pain receptors.

Structure of human tooth

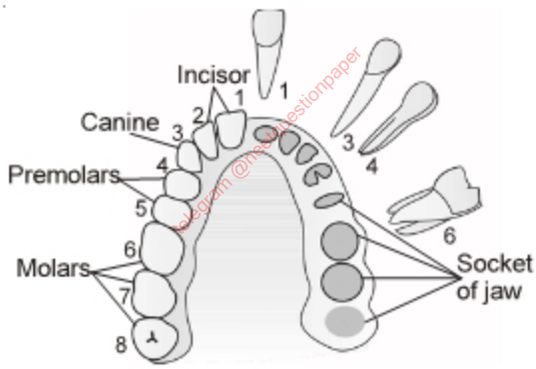


Fig. : Arrangement of different types of teeth in the jaws on one side and the sockets on the other side

The portion of tooth that is exposed forms **crown**. The crown is covered with enamel. Enamel is the hardest substance in vertebrate body. **Enamel is ectodermal in origin and is produced by ameloblasts**. Enamel consists primarily of calcium phosphate and calcium carbonate. The element that hardens the tooth enamel is **fluorine**. Bulk of the teeth in mammals is made of **dentine**. **Dentine is the part of tooth between enamel and pulp. It is mesodermal in origin, produced by odontoblasts**. Dental caries or tooth decay involves a gradual demineralization (softening) of enamel and dentine.

In most mammals, only two sets of teeth arise in life time(diphyodont). Different types of teeth in mammals are incisors, canines, premolars and molars **(Heterodont)**. Incisor teeth are meant for biting and cutting. Molars are used for grinding the hard food. In mammals, teeth have well developed roots implanted in deep bony sockets called **alveoli** or **theca** (**Thecodont**). A natural space between two types of teeth is referred to as **diastema**.

In rabbit which lacks canines, diastema is present between the incisors and premolars on each side. In many carnivore mammals such as dogs, last upper premolar and first lower molar teeth (**carnassials**) are specially large and used for shearing the flesh. **Tusks** of **walrus** are modified **canines**. Fangs are specialized teeth attached to maxillary bones in poisonous snakes. When a functional fang is lost or damaged, it is replaced by one of the reserve fangs. Toothed whale is a mammal with **homodont** dentition.

Dentition in Man

Total number of teeth in an adult human is 32. Dental formula of an adult man is 2123/2123. Upper jaw and lower jaw have equal number of teeth, *i.e.*, 16 each. Milk dentition formula of a baby is $\frac{2102}{2102}$ (premolars are absent). In man, 20 teeth are diphyodont, *i.e.*, grow twice in life. Teeth not present in milk dentition are premolars and last molars. **In man, 12 teeth are monophyodont, *i.e.*, grow once in life**. Monophyodont teeth in man are premolars and last molars.

Pharynx :

Pharynx is a common passage for swallowing food and breathing. **Gullet** is the aperture which leads into the oesophagus. **Glottis** is the aperture which leads in to larynx and trachea. **Epiglottis** is the structure which prevents entry of food into wind pipe(trachea) during swallowing in mammals. Epiglottis is absent in frogs.

Oesophagus :

Oesophagus is involved in **deglutition** (swallowing). In man, oesophagus is about 10 inches long and does not secrete any digestive enzyme. Oesophagus secretes mucus and transports food to the stomach.

Stomach

It is a J-shaped bag like structure that has three portions cardiac, fundic and pyloric. The oesophagus is a thin, long tube which extends posteriorly passing through the neck, thorax and diaphragm and ends in the stomach. A muscular sphincter (gastro-oesophageal) regulates the opening of oesophagus into the stomach. The stomach, located in the upper left portion of the abdominal cavity, has four major parts – a **cardiac** portion into which the oesophagus opens, a **fundic** region, body and a **pyloric** portion which opens into the first part of small intestine.

Gastric mucosa contains gastric glands (simple branched tubular), which are made of following types of cells:

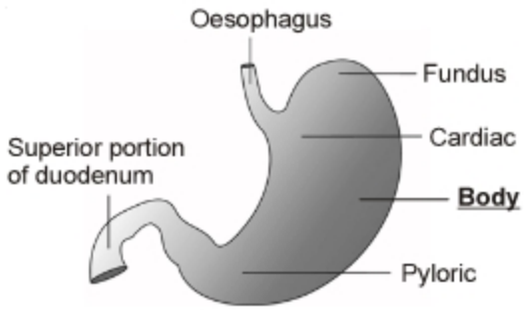


Fig. : Anatomical regions of human stomach

1. **Peptic/Zymogen/Chief cells** present at the base : they secrete protease enzymes in inactive/precursor forms; pepsinogen and prorennin.
2. **Parietal/Oxyntic cells** present along the sides : they secrete **HCl** and a protein factor called **Castle's Intrinsic** Factor. This factor helps in absorption of vitamin B_{12}. So, if gastro-ectomy is done, the person will suffer from pernicious anaemia; iron deficiency anaemia can also occur because the conversion of ferric *i.e.*, (Fe^{3+}) to ferrous (*i.e.*, Fe^{2+}) form occurs in presence of HCl. $\underset{\text{(Dietary iron)}}{Fe^{3+}} \xrightarrow{HCl} \underset{\text{Ferrous}}{Fe^{2+}}$. Iron is absorbed in ferrous state

Small Intestine

Small intestine is distinguishable into three regions, a **'C' shaped duodenum**, a long coiled middle portion jejunum and a highly coiled ileum. The opening of the stomach into the duodenum is guarded by the pyloric sphincter. Ileum opens into the large intestine.

In the entire small intestine, the mucous membrane is thrown into folds called *Plicae circulares* or folds of Kerkring.

These folds are prominent in the jejunum. In the entire small intestine, diffused patches of lymphoid tissues are also present and are called **GALT (Gut Associated Lymphoid Tissue)**. In Ileum, these patches get aggregated to form **Peyer's patches** (also called abdominal tonsils).

Intestinal glands

They are of two types :

(i) **Crypts of Lieberkuhn :** They are simple tubular glands which occur throughout the small intestinal mucosa and secrete both enzymes and mucous.

Cells of Crypts of Lieberkuhn are (1) **Paneth cells** Present at the base and secrete enzymes. (2) **Goblet** cells-secrete mucous (3) **Argentaffin cells** - secrete 5-hydroxy tryptamine (5HT) that increases intestinal movements.

(ii) **Brunner's gland :** They are present in the sub-mucosa of duodenum only and secrete mucous.

The distal end of small intestine in rabbit is swollen to form a sac like structure called **sacculus rotundus**.

Large intestine

Large intestine consists of caecum, colon and rectum. Caecum is a small blind sac which hosts some symbiotic micro-organisms. A narrow finger-like tubular projection, the vermiform appendix which is a vestigial organ, arises from the caecum. The caecum opens into the colon. The colon is divided into three parts – an ascending, a transverse and a descending part. The descending part opens into the rectum which opens out through the anus.

First part of large intestine is caecum and it opens into colon. The serosa surrounding the colon has fat storage areas called **Epiploic Appendages**.

In the colon, there are 3 longitudinal bands of smooth muscle fibres called **Taeniae coli**. They contract to form pocket like structures called **haustra.** Enlarged rectal veins lead to **Haemorrhoids** or piles.

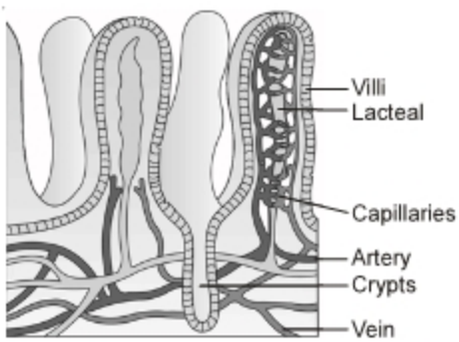


Fig. : A section of small intestinal mucosa showing villi

Histology of Human Gut

The outermost layer of the gut is a fibrous coat, called **the Serosa/mesothelium/visceral peritoneum.**

Inner to serosa is **muscularis externa,** which is formed of an outer **layer of longitudinal smooth muscles and** an inner layer of **circular smooth muscle. (In stomach, inner to the circular muscle layer is a layer of oblique muscles).**

Between circular and longitudinal muscle layers, a motor plexus called **Myenteric** (**Auerbach's Plexus**) is present. This controls peristaltic movements in the gastro intestinal tract (GIT); and is supplied with both Parasympathetic and Sympathetic fibres.

Inner to muscularis externa is **sub-mucosa** which is loose connective tissue layer with blood and lymph vessels and nerve supply

Submucosal plexus is Meissner's plexus. It is a sensory plexus and controls exocrine and endocrine secretions of GIT. This is also supplied with both **Sympathetic and Parasympathetic fibres.** Inner to submucosa **is mucosa.**

Mucosa is made of an innermost layer of epithelium, middle Lamina propria and external muscularis mucosa in contact with the submucosa.

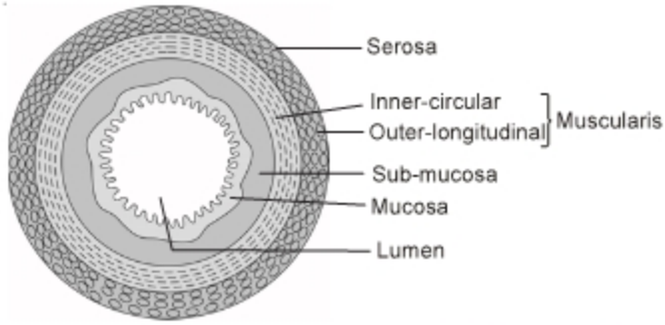


Fig. : Diagrammatic representation of transverse section of gut

DIGESTIVE GLANDS

Digestive gland associated with the alimentary canal include Salivary glands, Liver, Pancreas.

Salivary Glands :- These glands are situated just outside the buccal cavity and secrete saliva into the buccal cavity.

1. In man, 3 pairs of salivary glands are present. **Infraorbital glands** are absent.

Gland type and weight	Location	Route of the secretory duct	Histology	Percentage out of total salivary secretion (1500 ml/day)	Source of parasym-pathetic nerve supply
1. **Parotid**; 20-30 gm each, largest	In front of the ears	Its secretion passes via **Stensen's duct** which opens opposite to the second molar tooth in the vestibule	Contains purely serous cells	25%	IX nerve
2. **Submandi-bular** or **submaxillary;** 8-10 gm each	Medial to the mandible in submaxillary triangle	Its duct *i.e.*, **Wharton's duct** opens on floor of the buccal cavity along the sides of the frenulum linguae	Mixed *i.e.*, contains both serous and mucous cells in the ratio of 4 : 1	70%	VII nerve
3. **Sublingual** 2-3 gm each, smallest	Subadjacent to mucosa of floor of the buccal cavity	Its secretions are discharged by 5-15 small ducts **(ducts of Rivinus)** into the sublingual part of the buccal cavity	Mixed but mainly mucous cells. Serous cells: mucous cells :: 1:4	5%	VII nerve

2. The parotid glands are compound tubulo-acinar glands, whereas the submandibular and sublingual are compound acinar glands. Their collective secretion is called saliva.
3. **Mumps is a viral disease caused by paramyxovirus, causing painful inflammation of parotid glands.**
4. Salivary glands are absent in frogs.

Liver

Liver is the largest gland of the body weighing about 1.2 to 1.5 kg in an adult human. It is situated in the abdominal cavity, just below the diaphragm and has two lobes. The hepatic lobules are the structural and functional units of liver containing hepatocytes arranged in the form of cords. Liver secretes bile which is alkaline, yellowish green fluid. It has no enzymes, but help in emulsification of fats due to presence of bile salt which are

1. **Na/K Taurocholate**
2. **Na/K Glycocholate**

The two lobes of liver are subdivided into a number of lobules, pentagonal or hexagonal in shape. It has polyhedral hepatic cells arranged in the manner of cords. In mammals, each lobules is externally surrounded by a thin connective tissue sheath called **Glisson's capsule**. Sinusoids are blood filled spaces between the hepatic cords. They are enlarged capillaries lined with endothelium. They also contain **Kupffer cells** (macrophages of liver). At each corner of the lobule, Portal triad is present which contains a branch of **1.** Hepatic artery and Lymph vessels **2.** Hepatic portal vein **3.** Bile ductules. From liver, right and left hepatic ducts arise which join to form common hepatic duct this joins with the **cystic duct** (from gall bladder) to form a common bile duct (or **Ductus Choledochus**). It has **Sphincter of Boyden**, which allows the filling of gall bladder. Common bile duct unites with the main pancreatic duct *i.e.*, duct of Wirsung to form Hepatopancreatic duct that opens through hepatopancreatic ampulla into duodenum. Its opening is controlled by **sphincter of Oddi**.

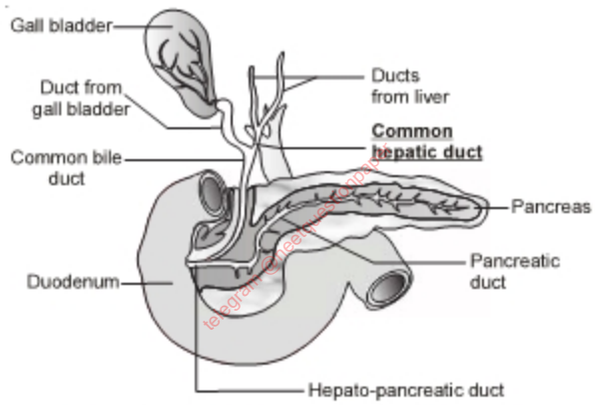


Fig. : The duct systems of liver, gall bladder and pancreas

Pancreas

The pancreas is a compound (both exocrine and endocrine) elongated organ situated between the limbs of the 'U' shaped duodenum. The exocrine portion secretes an alkaline pancreatic juice containing enzymes and the endocrine portion secretes hormones, insulin and glucagon.

DIGESTION OF FOOD

Digestion of food is carried out mechanically as well as chemically. Digestion starts in the buccal cavity. It involves mechanical breakdown with the grinding action of teeth. Tongue and teeth help in masticating the food with the help of saliva. Saliva contains the enzyme salivary amylase or ptyalin, lysozyme and various electrolytes like Na^+, K^+, Cl^-, HCO_3^-. Salivary amylase acts upon starch to convert it into disaccharides-maltose.

$$\text{Starch} \xrightarrow[\text{pH 6.8}]{\text{Salivary amylase}} \text{Maltose}$$

Lysozyme is an antibacterial enzyme. Cl^- are involved in the activity of salivary amylase.

Mucus in saliva is responsible for binding the food particles to form food bolus. The food bolus is then swallowed into the pharynx and then oesophagus by swallowing or deglutition.

Then the food reaches stomach with the relaxation of gastro-oesophageal sphincter.

Gastric glands of gastric mucosa release gastric juice and contains HCl, Pepsinogen, Prorennin.

Pepsinogen $\xrightarrow{HCl/Pepsin}$ Pepsin

Prorennin $\xrightarrow{HCl/Pepsin}$ Rennin

Coagulation of Milk

Casein $\xrightarrow{Rennin}$ Paracasein

Paracasein + Calcium $\longrightarrow$ Calcium Paracaseinate (Solid Curd) + Liquid whey

Calcium Paracaseinate $\xrightarrow{Pepsin}$ Peptones + Calcium

Protein + Water $\xrightarrow{Pepsin}$ Peptones + Peptides

Fat + Water $\xrightarrow[\text{activated at pH = 2.0}]{\text{Lingual lipase}}$ Fatty acids + Glycerol

Lingual lipase and **rennin** occur only in infants. In adults, casein of milk can be changed into calcium paracaseinate by pepsin. At times, the acidic contents of stomach enter oesophagus causing a burning sensation, that tends to rise towards the neck. It is called **heart burn** or **pyrosis**. Food mixed with gastric juices is called chyme.

Food in Duodenum. As soon as chyme enters duodenum, it meets the secretions of Brunner's glands. Sodium bicarbonate of their secretion and of bile and pancreas neutralises acid present in the chyme and the alkaline contents are now called 'chyle'.

Bile salts, sodium **taurocholate** and sodium **glycocholate**, act on fats of the food and break them into fine droplets. The process is called **emulsification**. Emulsification provides large surface area for the lipase to act.

Role of Pancreatic Juice in Digestion of Proteins, Carbohydrates and Fats :

Proenzymes of pancreatic juice are **trypsinogen**, **chymotrypsinogen and procarboxypeptidase**. Enterokinase or enteropeptidase of intestinal juice acts on proenzyme trypsinogen and changes it to active enzyme trypsin. Trypsin also has catalytic activity. It changes chymotrypsinogen and procarboxypeptidase into active enzymes, chymotrypsin and carboxypeptidase respectively.

Trypsinogen $\xrightarrow{Enterokinase/Trypsin}$ Trypsin
Chymotrypsinogen $\xrightarrow{Trypsin}$ Chymotrypsin
} Endopeptidases

Procarboxypeptidase $\xrightarrow{Trypsin}$ Carboxypeptidase } **Carboxypeptidase is an exopeptidase acting on 'C' terminal end of peptide chain**

Trypsin acts on proteins and peptones forming peptides.

Proteins + Peptones + Water $\xrightarrow{Trypsin}$ Peptides.

Coagulation of milk can be caused by Chymotrypsin in alkaline medium

Chymotrypsin acts on casein of milk and changes it into paracaseinate. The same is further acted upon by trypsin or chymotrypsin to form peptides.

Casein $\xrightarrow{Chymotrypsin}$ Paracaseinate

Paracaseinate + Ca^{+2} $\longrightarrow$ Calcium paracaseinate

Calcium paracaseinate $\xrightarrow{Chymotrypsin/Trypsin}$ Peptides + Calcium

Peptides + Water $\xrightarrow{Carboxypeptidase}$ Dipeptides + Amino acids

The other three active enzymes of pancreatic juice are pancreatic lipase, pancreatic amylase and nucleases. **Pancreatic lipase or steapsin hydrolyses fats into fatty acids and glycerol.**

DIGESTION OF CARBOHYDRATES

Pancreatic amylase **(amylopsin)** hydrolyses glycogen, starch and dextrins into limit dextrins, maltose and isomaltose.

Starch + Water $\xrightarrow{\text{Pancreatic amylase or amylopsin}}$ Limit Dextrins + Maltose + Isomaltose.

Digestion of Fats

Fat + Water $\xrightarrow{\text{Pancreatic lipase or steapsin}}$ Diglycerides + Monoglycerides + Fatty acids + Glycerol

Digestion of Nucleic Acids

Nucleases of pancreas are of two types : DNAase and RNAase. They hydrolyse the polynucleotides into nucleotides.

DNA + Water $\xrightarrow{\text{DNAase}}$ Deoxyribonucleotides

RNA + Water $\xrightarrow{\text{RNAase}}$ Ribonucleotides

Role of Intestinal Juice in Digestion

As the food passes into jejunum, it meets intestinal juice or **succus entericus**. Succus entericus contains enterokinase or enteropeptidase, aminopeptidase, dipeptidases, maltase, isomaltase, sucrase, lactase, lipase, nucleotidases and nucleosidases. Enterokinase converts trypsinogen into trypsin.

Maltase, isomaltase, sucrase and **lactase** hydrolyse different types of disaccharides.

Maltose + Water $\xrightarrow{\text{Maltase}}$ Glucose + Glucose

Isomaltose + Water $\xrightarrow{\text{Isomaltase}}$ Glucose + Glucose

Sucrose + Water $\xrightarrow{\text{Sucrase/Invertase}}$ Glucose + Fructose

Lactose + Water $\xrightarrow{\text{Lactase}}$ Glucose + Galatose

Lactase is, however, absent in the intestinal juice of most adults resulting in non digestion of lactose. As lactose or milk sugar cannot be digested, the adults develop **lactose intolerance**. It is characterised by formation of excessive gases causing (flatulence) and acids due to bacterial fermentation of lactose. Such persons should not take milk or milk preparations. They can, however, take curd or yoghurt where lactose has been metabolised by bacteria.

Galactosemia : It is a metabolic and genetic disorder due to the deficiency of enzyme uridyl transferase. Galactose is absorbed at fast rate from the intestinal cells and immediately converted into glucose with the help of **enzyme uridyl transferase**, if this enzyme is absent, galactose will accumulate in the blood and can lead to mental retardation.

Aminopeptidases act on peptides forming dipeptides and amino acids. Dipeptides are hydrolysed by dipeptidases to produce amino acids.

Peptides + Water $\xrightarrow{\text{Aminopeptidase}}$ Dipeptides + Amino Acids

Dipeptides + Water $\xrightarrow{\text{Dipeptidase}}$ Amino Acids

DIGESTION OF NUCLEIC ACIDS

Nucleotidases hydrolyse nucleotides while nucleosidases hydrolyse nucleosides

Nucleotides $\xrightarrow{\text{Nucleotidases}}$ Nucleosides + H_3PO_4

Nucleosides $\xrightarrow{\text{Nucleosidases}}$ Nitrogen Bases + Pentose sugars

Depending on the nature of nucleotides and nucleosides, they are acted upon by different types of nucleotidases (Deoxyribonucleotidase and Ribonucleotidase) and nucleosidases (Deoxyribonucleosidase and Ribonucleosidase) Food gets converted to a liquid emulsion due to completion of digestion of most of the nutrients.

Role of Some Major Gastrointestinal Peptide Hormones in Digestion

Hormone	Source Secretion	Stimulus for Release	Target/Action
Gastrin	Pyloric stomach	Vagus nerve activity; peptides and proteins in stomach	Secretory cells and muscles of stomach; secretion of HCl and stimulation of gastric motility.
Cholecystokinin (CCK)	Upper small intestine (Duodenum)	Food (fatty chyme and amino acids) in duodenum	Gall bladder; contraction of gall bladder (bile release), secretion of pancreatic enzymes
Secretin	Intestinal wall (Duodenum)	Food and strong acid in stomach and intestine	Pancreas, secretory cells and muscles of stomach; secretion of water and bicarbonate ($NaHCO_3$); inhibition of gastric motility
Gastric Inhibitory Peptide (GIP)/ Enterogasterone	Upper small intestine (Duodenum)	Monosaccharides and fats (fatty chyme) in duodenum	Gastric mucosa and muscles; inhibition of gastric secretion and motility (slowing food passage)

ABSORPTION OF DIGESTED PRODUCTS

Absorption is the process by which the end products of digestion pass through the intestinal mucosa into the blood or lymph. It is carried out by passive, active or facilitated transport mechanisms. Small amounts of monosacharides like glucose, amino acids and some of electrolytes like chloride ions are generally absorbed by **simple diffusion**. The passage of these substances into the blood depends upon the concentration gradients. **However, some of the substances like glucose and some amino acids are absorbed with the help of the carrier proteins. This mechanism is called the facilitated transport.**

Transport of water depends upon the osmotic gradient. **Active transport** occurs against the concentration gradient and hence requires energy. Various nutrients like amino acids, monosaccharides like glucose, electrolytes like Na^+ are absorbed into the blood by this mechanism.

The products of fats such as fat soluble but water-insoluble monoglycerides, fatty acids and glycerol are first incorporated into water soluble droplets called **Micelles**. (A combination of fatty acids, monoglycerides and bile salts.) Monoglycerides, cholesterol and fatty acids from the micelles enter the mucosal cells by diffusion. Within the absorptive cells, they are reconstructed to form triglycerides. The triglycerides are combined with phospholipids and cholesterol and released into the lymph to form protein-coated water soluble fat globules called **chylomicrons**. Like this, 95% or more of ingested fat is absorbed.

Absorption of substances takes place in different parts of the alimentary canal, like mouth, stomach, small intestine and large intestine. However, maximum absorption occurs in the small intestine. A summary of absorption (sites of absorption and substances absorbed) is given in table.

The Summary of Absorption in Different Parts of Digestive System

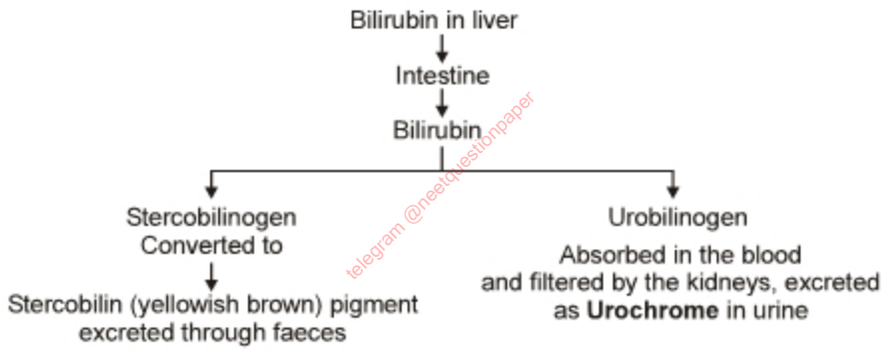
Mouth	Stomach	Small Intestine	Large Intestine
Certain drugs coming in contact with the mucosa of mouth and lower side of the tongue are absorbed into the blood capillaries lining them.	Absorption of water, simple sugars, and alcohol etc. takes place.	Principal organ for absorption of nutrients. The digestion is completed here and the final products of digestion such as glucose, fructose, fatty acids, glycerol and amino acids are absorbed through the mucosa into the blood stream and lymph.	Absorption of water, some minerals and drugs takes place.

The absorbed substances finally reach the tissues which utilise them for their activities. This process is called assimilation.

Defaecation :-

The digestive wastes, solidified into coherent faeces in the rectum initiate a neural reflex causing an urge or desire for its removal. The egestion of faeces to the outside through the anal opening (defaecation) is a voluntary process and is carried out by a mass peristaltic movement.

Fate of bile pigment :-



Skatole is 3-methyl indole, and foul smell of faeces is due to skatole.

Meconium : Dark green mucilagenous material in the intestine of a full term foetus. Small quantities of meconium are continuously formed in the gastro-intestinal tract and excreted from the anus into the amniotic fluid. Meconium is composed partly of residue from swallowed amniotic fluid and partly of mucus and other residues of excretory products from the intestinal mucosa and glands.

TYPES OF NUTRIENTS

1. Carbohydrates, lipids and proteins are **macronutrients** or **proximate principles of food** because these constitute the energy sources for the production of heat and occurence of different organic functions. Minerals, vitamins and water are **micronutrients** or **protective principles of food** because although these do not provide energy, yet their deficiencies are related to specific diseases and abnormalities in body.

2. **Energy Yielding Nutrients :** Carbohydrates are used primarily as sources of chemical energy, to be either metabolised immediately as glucose or stored as glycogen.

CALORIFIC VALUE OF PROTEIN, CARBOHYDRATE AND FAT
(Boxed item – Not for evaluation)
The energy requirements of animals, and the energy content of food, are expressed in terms of measure of heat energy because heat is the ultimate form of all energies. This is often measured to as calorie (cal) or joule (J), which is the amount of heat energy required to raise

the temperature of 1 g of water by 1 °C. Since this value is tiny amount of energy, physiologists commonly use kilocalorie (kcal) or kilo joule (kJ). One kilo calorie is the amount of energy required to raise the temperature of 1 kg of water by 1 °C. Nutritionists, traditionally refer to kcal as the Calorie or Joule (always capitalised). The amount of heat liberated from complete combustion of 1 g food in a bomb calorimeter (a closed metal chamber filled with O_2) is its gross calorific or gross energy value. The actual amount of energy combustion of 1 g of food is the physiologic value of food. Gross calorific values of carbohydrates, proteins and fats are 4.1 kcal/g, 5.65 kcal/g and 9.45 kcal/g, respectively, whereas their physiologic values are 4.0 kcal/g, 4.0 kcal/g and 9.0 kcal/g, respectively.

3. Energy required per day by a moderately active person is 2800 kcal for adult male and 2200 kcal for adult female.
4. When catabolism exceeds anabolism, first carbohydrates are consumed, then internal food reserves (fats in adipose tissue) are consumed and then, finally, the energy is obtained at the expense of body proteins.

DISORDERS OF DIGESTIVE SYSTEM

The inflammation of the intestinal tract is the most common ailment due to bacterial or viral infections. The infections are also caused by the parasites of the intestine like tape worm, round worm, thread worm, hook worm, pin worm, etc.

1. Protein Energy Malnutrition (PEM) :

PEM Dietary deficiencies of proteins and total food calories are widespread in many underdeveloped countries of South and South-east Asia, South America, and West and Central Africa. Protein-energy malnutrition (PEM) may affect large sections of the population during drought, famine and political turmoil. This happened in Bangladesh during the liberation war and in Ethiopia during the severe drought in mid-eighties. PEM affects infants and children to produce Marasmus and Kwashiorkar. Marasmus is produced by a simultaneous deficiency of proteins and calories. It is found in infants less than a year in age, if mother's milk is replaced too early by other foods which are poor in both proteins and caloric value. This often happens if the mother has second pregnancy or childbirth when the older infant is still too young. In Marasmus, protein deficiency impairs growth and replacement of tissue proteins; extreme emaciation of the body and thinning of limbs results, the skin becomes dry, thin and wrinkled. Growth rate and body weight decline considerably. Even growth and development of brain and mental faculties are impaired. Kwashiorkar is produced by protein deficiency unaccompanied by calorie deficiency. It results from the replacement of mother's milk by a high calorielow protein diet in a child more than one year in age. Like marasmus, kwashiorkor shows wasting of muscles, thinning of limbs, failure of growth and brain development. But unlike marasmus, some fat is still left under the skin; moreover, extensive oedema and swelling of body parts are seen.

PEM is of two types : Kwashiorkor and Marasmus

Deficient nutrient	Name of deficiency	Deficiency symptoms
Protein (PEM)	**Kwashiorkor :** Usually observed in children in the age group of 1-5 years.	Wasted muscles, thin limbs, retarded growth of body and brain, swelling of legs due to retention of water (oedema), reddish hair, pot belly and diarrhoea.
Protein and calorie (PEM)	**Marasmus :** It usually affects infants below the age of one year.	Impaired growth and replacement of tissue proteins, thin limbs and prominent ribs (emaciated body), dry, wrinkled and thin skin, diarrhoea.

The child suffering from PEM can recover if adequate quantities of protein and carbohydrate rich food are given.

2. **Indigestion :** In this condition, the food is not properly digested leading to a feeling of fullness. The causes of indigestion are inadequate enzyme secretion, anxiety, food poisoning, over eating, and spicy food.
3. **Constipation :** In constipation, the faeces are retained within the **colon** as the bowel movements occur irregularly.
4. **Vomiting :** It is the ejection of stomach contents through the mouth. This reflex action is controlled by the vomit centre in the medulla. A feeling of nausea precedes vomiting.
5. **Jaundice :** The liver is affected, skin and eyes turn yellow due to the deposit of bile pigments.
6. **Diarrhoea :** The abnormal frequency of bowel movement and increased liquidity of the faecal discharge is known as diarrhoea. It reduces the absorption of food.
7. **Haemorrhoids :** Enlargement of rectal veins due to frequent constipation.

❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. Lingual frenulum is
   (1) Adenoid present on pharyngeal wall
   (2) Tonsil found on lateral walls of soft palate
   (3) V-shaped sulcus dividing tongue into pharyngeal and oral parts
   (4) Fold attaching the tongue with the floor of oral cavity

2. Smallest and most numerous papillae on tongue are
   (1) Circum vallate papillae
   (2) Fungiform papillae
   (3) Filiform papillae
   (4) Foliate papillae

3. Which of the following is not true for human dentition?
   (1) Thecodont (2) Heterodont
   (3) Diphydont (4) Secodont

4. Which of the following is ectodermal in origin and is secreted by ameloblasts?
   (1) Dentine (2) Enamel
   (3) Cementum (4) Ivory

5. Dental formula of an adult human is
   (1) $\frac{3143}{3143}\times 2$ (2) $\frac{2123}{2123}\times 2$
   (3) $\frac{2033}{1023}\times 2$ (4) $\frac{1003}{1003}\times 2$

6. Upper molars have
   (1) One root (2) Three roots
   (3) Four roots (4) Two roots

7. The number of teeth which appear once in the life of human are
   (1) 4 (2) 12
   (3) 20 (4) 28

8. Oesophagus opens into _____ part of stomach
   (1) Cardiac (2) Fundus
   (3) Body (4) Pyloric

9. Gastric glands are
   (1) Simple tubular
   (2) Simple coiled tubular
   (3) Simple branched tubular
   (4) Compound tubular

10. Oxyntic cells of the stomach epithelium secrete
    (1) Hydrochloric acid, Intrinsic Factor and large quantity of pepsinogen
    (2) Mainly mucous, some pepsinogen and the hormone gastrin
    (3) Only mucous
    (4) Only hydrochloric acid and Intrinsic factor

11. HCl of gastric juice is produced by
    (1) Chief cells (2) Oxyntic cells
    (3) Goblet cells (4) Columnar cells

12. Paneth cells are found in
    (1) Crypts of Lieberkuhn (2) Peyer's patches
    (3) Islets of Langerhans (4) Gastric glands

13. Which of the following is the correct sequence of layers in the alimentary canal starting from outwards to inwards?
    (1) Serosa, Muscularis mucosa, Muscularis externa, Lamina propria, Epithelium
    (2) Muscularis mucosa, Muscularis externa, Lamina propria, Epithelium, Serosa
    (3) Serosa, Muscularis externa, Submucosa, Muscularis mucosa, Lamina propria, Epithelium
    (4) Epithelium, Lamina propria, Muscularis mucosa, Muscularis externa, Serosa

14. Meissner's or Remak Plexus is present
(1) Between longitudinal and circular muscles in muscularis externa
(2) In sub-mucosa
(3) In muscularis mucosa
(4) Between circular and oblique muscles in muscularis externa

15. Mumps disease is related to inflammation of
(1) Infra-orbital glands
(2) Sub-maxillary gland
(3) Sub-lingual glands
(4) Parotid glands

16. Bile can be prevented to pass into duodenum by
(1) Pyloric valve (2) Sphincter of Boyden
(3) Sphincter of Oddi (4) Cardiac sphincter

17. Trypsinogen is activated by an enzyme
(1) Enterokinase (2) Enterogastrone
(3) Enterocrinin (4) Aminopeptidase

18. An exopeptidase that cleaves the peptide bond at N-terminal end is
(1) Carboxypeptidase (2) Aminopeptidase
(3) Trypsin (4) Enterokinase

19. Galactosemia in children can be avoided by
(1) Giving them more milk
(2) Giving them milk free diet
(3) Giving them milk fortified with vitamins
(4) Giving them more proteinous diet

20. Inhibition of gastric and stimulation of gastric, pancreatic and bile secretions are respectively controlled by hormones
(1) Gastrin, secretin, enterokinin and cholecystokinin
(2) Enterogastrone, gastrin, pancreozymin and cholecystokinin
(3) Gastrin, enterogastrone, cholecystokinin and pancreozymin
(4) Secretin, enterogastrone, secretin and enterokinin

21. Which of the following is the largest gland of the human body?
(1) Parotid gland (2) Pancreas
(3) Liver (4) Gastric gland

22. Which one of the following does **not** belong to exopeptidases?
(1) Aminopeptidase (2) Carboxypeptidase
(3) Pepsin (4) Both (1) & (2)

23. The yellowish brown colour of the faeces is due to
(1) Urochrome (2) Stercobilin
(3) Meconium (4) Skatole

24. Haemorrhoids are
(1) Small pouches of colon
(2) Enlarged rectal veins
(3) Outgrowths of anal canal
(4) Longitudinal folds of rectum

25. Carbohydrates, lipids and proteins are
(1) Macronutrients or proximate principles of food
(2) Micronutrients or protective principles of food
(3) Macronutrients or protective principles of food
(4) Protective principles

26. The physiologic fuel values of carbohydrates, proteins and fats are
(1) 4.1 kcal/g, 5.65 kcal/g, 9.45 kcal/g respectively
(2) 4.0 kcal/g, 4.0 kcal/g, 9.0 kcal/g respectively
(3) 5.65 kcal/g, 4.0 kcal/g and 9.45 kcal/g respectively
(4) 9.45 kcal/g, 5.65 kcal/g, and 9.0 kcal/g respectively

27. A moderately active man needs everyday
(1) 2700 kcal (2) 2800 kcal
(3) 4000 kcal (4) 2200 kcal

28. During prolonged fasting
(1) First carbohydrates are used up and then fat and in the end, proteins are metabolised
(2) First lipids are used up, then proteins and finally carbohydrates
(3) First fats are used up, then carbohydrates and then the proteins are metabolised
(4) First enzymes are used up and then minerals are absorbed

29. In the invertebrates, which one of the following enzyme is absent?
(1) Pepsin (2) Trypsin
(3) Lipase (4) Amylase

30. Which of the following is accessory organ/structure in human digestive system?

(1) Colon (2) Ileum

(3) Tongue (4) Stomach

SECTION - B

Previous Years Questions

1. Anxiety and eating spicy food together in an otherwise normal human, may lead to **[AIPMT 2012]**

(1) Diarrhoea (2) Vomiting

(3) Indigestion (4) Jaundice

2. Where do certain symbiotic microorganisms normally occur in human body? **[AIPMT 2012]**

(1) Caecum

(2) Oral lining and tongue surface

(3) Vermiform appendix and rectum

(4) Duodenum

3. Select the **correct** match of the digested products in humans given in **column I** with their absorption site and mechanism in **column II** **[NEET 2013]**

	Column I	**Column II**
(1)	Fructose, Na^+	Small intestine passive absorption
(2)	Glycerol, fatty acids	Duodenum, move as chylomicrons
(3)	Cholesterol, maltose	Large intestine, active absorption
(4)	Glycine, glucose	Small intestine, active absorption

4. The initial step in the digestion of milk in humans is carried out by? **[AIPMT 2014]**

(1) Lipase

(2) Trypsin

(3) Rennin

(4) Pepsin

5. Fructose is absorbed into the blood through mucosa cells of intestine by the process called **[AIPMT 2014]**

(1) Active transport

(2) Facilitated transport

(3) Simple diffusion

(4) Co-transport mechanism

6. Which of the following statements is **not correct**? **[AIPMT-2015]**

(1) Acini are present in the pancreas and secrete carboxypeptidase

(2) Brunner's glands are present in the submucosa of stomach and secrete pepsinogen

(3) Goblet cells are present in the mucosa of intestine and secrete mucus

(4) Oxyntic cells are present in the mucosa of stomach and secrete HCl

7. Gastric juice of infants contains **[AIPMT-2015]**

(1) Amylase, rennin, pepsinogen

(2) Maltase, pepsinogen, rennin

(3) Nuclease, pepsinogen, lipase

(4) Pepsinogen, lipase, rennin

8. The primarzy dentition in human differs from permanent dentition in not having one of the following type of teeth **[Re-AIPMT-2015]**

(1) Incisors (2) Canine

(3) Premolars (4) Molars

9. The enzyme that is **not** present in succus entericus is **[Re-AIPMT-2015]**

(1) Lipase (2) Maltase

(3) Nucleases (4) Nucleosidase

10. Which of the following guards the opening of hepatopancreatic duct into the duodenum? **[NEET-2016]**

(1) Sphincter of Oddi

(2) Semilunar valve

(3) Ileocaecal valve

(4) Pyloric sphincter

11. In the stomach, gastric acid is secreted by the **[NEET-2016]**

(1) Acidic cells

(2) Gastrin secreting cells

(3) Parietal cells

(4) Peptic cells

12. Which hormones do stimulate the production of pancreatic juice and bicarbonate? **[NEET (Phase-2) 2016]**

(1) Angiotensin and epinephrine

(2) Gastrin and insulin

(3) Cholecystokinin and secretin

(4) Insulin and glucagon

13. Which cells of 'Crypts of Lieberkuhn' secrete antibacterial lysozyme? **[NEET-2017]**

(1) Argentaffin cells

(2) Paneth cells

(3) Zymogen cells

(4) Kupffer cells

14. Lungs are made up of air-filled sacs the alveoli. They do not collapse even after forceful expiration, because of **[NEET-2017]**

(1) Residual Volume

(2) Inspiratory Reserve Volume

(3) Tidal Volume

(4) Expiratory Reserve Volume

15. A baby boy aged two years is admitted to play school and passes through a dental check-up. The dentist observed that the boy had twenty teeth. Which teeth were absent? **[NEET-2017]**

(1) Incisors (2) Canines

(3) Pre-molars (4) Molars

16. Which of the following options best represents the enzyme composition of pancreatic juice? **[NEET-2017]**

(1) Amylase, peptidase, trypsinogen, rennin

(2) Amylase, pepsin, trypsinogen, maltase

(3) Peptidase, amylase, pepsin, rennin

(4) Lipase, amylase, trypsinogen, procarboxy-peptidase

17. Which of the following gastric cells indirectly help in erythropoiesis? **[NEET-2018]**

(1) Goblet cells (2) Mucous cells

(3) Chief cells (4) Parietal cells

18. Which of the following terms describe human dentition? **[NEET-2018]**

(1) Pleurodont, Monophyodont, Homodont

(2) Thecodont, Diphyodont, Heterodont

(3) Thecodont, Diphyodont, Homodont

(4) Pleurodont, Diphyodont, Heterodont

19. Match the following structures with their respective location in organs

(a) Crypts of Lieberkuhn (i) Pancreas

(b) Glisson's Capsule (ii) Duodenum

(c) Islets of Langerhans (iii) Small intestine

(d) Brunner's Glands (iv) Liver

Select the correct option from the following **[NEET-2019]**

	(a)	(b)	(c)	(d)
(1)	(iii)	(i)	(ii)	(iv)
(2)	(ii)	(iv)	(i)	(iii)
(3)	(iii)	(iv)	(i)	(ii)
(4)	(iii)	(ii)	(i)	(iv)

20. Identify the cells whose secretion protects the lining of gastro-intestinal tract from various enzymes. **[NEET-2019]**

(1) Chief Cells (2) Goblet Cells

(3) Oxyntic Cells (4) Duodenal Cells

21. Which of the following glucose transporters is insulin-dependent? **[NEET-2019]**

(1) GLUT I (2) GLUT II

(3) GLUT III (4) GLUT IV

22. Match the items given in Column-I with those in Column-II and choose the correct option.

Column-I	**Column-II**
(a) Rennin	(i) Vitamin B_{12}
(b) Enterokinase	(ii) Facilitated transport
(c) Oxyntic cells	(iii) Milk proteins
(d) Fructose	(iv) Trypsinogen

[NEET-2019 (Odisha)]

(1) (a)-(iii), (b)-(iv), (c)-(i), (d)-(ii)

(2) (a)-(iii), (b)-(iv), (c)-(ii), (d)-(i)

(3) (a)-(iv), (b)-(iii), (c)-(i), (d)-(ii)

(4) (a)-(iv), (b)-(iii), (c)-(ii), (d)-(i)

23. Kwashiorkor disease is due to - **[NEET-2019 (Odisha)]**

(1) protein deficiency not accompanied by calorie deficiency

(2) simultaneous deficiency of proteins and fats

(3) simultaneous deficiency of proteins and calories

(4) deficiency of carbohydrates

❑ ❑ ❑

Chapter 5
Breathing and Respiration

Sub-topics *Respiratory Organs in Animals (Recall only); Respiratory System in Humans; Mechanism of Breathing and its Regulation in Humans - Exchange of Gases, Transport of Gases and Regulation of Respiration, Respiratory Volumes; Disorders related to Respiration - Asthma, Emphysema, Occupational Respiratory Disorders*

Respiratory Organs in Animals

Whether between cells and the extracellular fluid or between the animal and the surrounding medium, gases are exchanged by the physical process of diffusion. A gas diffuses across a membrane from the side where its partial pressure is higher to the side where its partial pressure is lower. But its diffusion is independent of the partial pressure of any other gas mixed with it.

For efficient gas exchange, the membrane separating the body fluid from the surrounding medium should be extensive, thin, highly vascular and easily permeable to oxygen and carbon dioxide. To fulfil these requirements, complex respiratory systems have evolved in many multicellular organisms. Indeed, a major evolutionary change in vertebrates has been a progressive increase in the surface area of the membrane through which respiratory exchanges take place.

In unicellular organisms such as aerobic bacteria and protistans (*e.g.*, *Amoeba*), respiratory gases diffuse between the surrounding medium and the cell across the plasma membrane. Even in some multicellular animals such as *Hydra*, gases are exchanged by diffusion between individual cells and the surrounding water.

In some marine annelids such as *Nereis*, respiratory gases are exchanged between blood and sea-water mainly through the integument over appendages called parapodia. These are hollow and highly vascular appendages on lateral sides of most body segments. The integument over parapodia is particularly thin and permeable to gases.

- Book lungs are respiratory organs of scorpion and spider.
- Respiration through gills (branchial respiration) in fishes and tadpole of frog.
- Amphibians such as frog respire by means of
  - (i) Cutaneous respiration through moist skin,
  - (ii) Buccopharyngeal respiration, and
  - (iii) Pulmonary respiration through lungs
- During hibernation (winter sleep), frog respires with the help of moist skin only.
- In frog, skin serves as an accessory organ of respiration.
- Amphibians, reptiles, birds and mammals respire through lungs.
- Whether aquatic or terrestrial, all mammals use atmospheric air for respiration.
- Respiratory system is derived from **endoderm**.

RESPIRATORY SYSTEM IN HUMANS

The respiratory system in human starts from external nares and involves nasal cavity, pharynx, larynx, trachea, bronchi, bronchioles and alveoli. External nares open into nasal chamber having 3 parts vestibular, respiratory, olfactory. **The nasal chamber open into pharynx the portion which is common passage for food and air. Pharynx opens through larynx region into the trachea**. Epiglottis is the structure that prevents the entry of food into respiratory tract during swallowing.

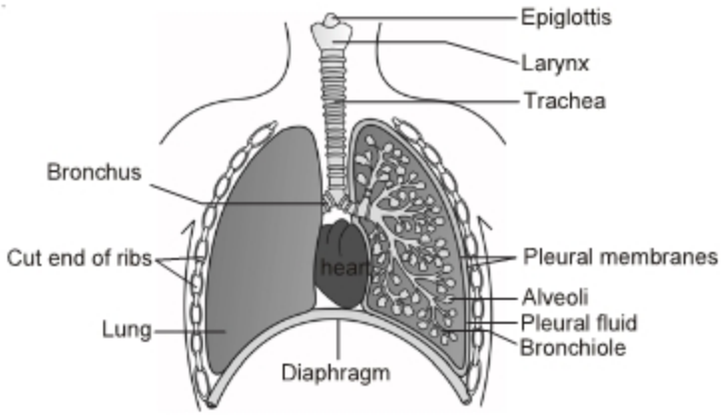


Fig. : Diagrammatic view of human respiratory system
(Sectional view ofthe left lung is also shown)

Larynx

Skeleton of Larynx is made of cartilages, 3 of which are paired and **3 are unpaired.** Paired cartilages are Arytenoid, Corniculate or Cartilage of Santorini and Cuneiform. Unpaired cartilages are : Thyroid, Cricoid and Epiglottis. **In man, the midventral portion of the thyroid cartilage forms a prominent protuberance and is called 'Adam's apple'. Cricoid is a ring like cartilage of larynx**. A small nodule-like **cartilage of Santorini** is attached to the anterior tip of each **Arytenoid cartilage, which themselves are pyramidal shaped**. **Larynx** contains vocal cords, the sound producing elastic fibres. Air forced out of lungs during expiration may vibrate vocal cords and columns of air are set in to produce sounds. In women and children, the vocal cords (1.7 cm long) are usually short and hence the voice is high pitched. In men, the vocal cords (2.3 cm long) are usually thicker and longer (caused by the male sex hormone) and voice is correspondingly low pitched.

Trachea

The trachea is a tube about 10 cm long in man, supported by C-shaped incomplete (dorsally) rings of hyaline cartilage in its walls. The trachea branches into two bronchi, one into each lung at the level of 5^{th} thoracic vertebra and these branch within the lungs into many smaller bronchioles. Even when there is no air in it, trachea does not collapse due to the presence of C-shaped narrow **hyaline cartilaginous** rings. Trachea is lined with a **pseudostratified ciliated columnar epithelium**.

Lungs

Coverings of the lungs are called **pleural membranes**. Each lung is enclosed in two membranes called pleurae. The outer covering is adhered to chest wall and diaphragm and is called **parietal pleura**. The inner covering which closely covers the lung is called **visceral pleura**. **Accumulation of fluid between the pleura is called pleurisy. In man, the left lung has two lobes, superior lobe and inferior lobe while the right lung has three lobes, superior lobe, middle lobe and inferior lobe**. The terminal bronchioles are subdivided in lungs into a number of respiratory bronchioles further leading into **alveolar ducts**. Alveolar ducts divide and expand into a number of alveolar sacs (air sacs). The alveoli of lungs provide a large surface (like villi of intestine in mammals) for gaseous exchange. **The number of alveoli in the human lungs has been estimated to be**

approximately 300 million, spanning a surface area of nearly 100 m^2. In adult man, the surface area of skin is around 1.6 m^2 only. The alveoli are covered with **Surfactant** to reduce the surface tension. Surfactant is lecithin, phospholipid. It is a mixture of protein-lipid complexes made mainly of **Dipalmitoyl Phosphatidyl Choline** (DPPC) lipid. It is produced by epithelial cells called pneumocytes type II lining the alveoli. Deficiency of surfactant can lead to **Atelectasis**, collapsing of alveoli.

Diaphragm

Diaphragm is characteristic of mammals. It is highly muscular and fibrous partition, elevated towards thorax like a dome. The most important function of diaphragm of mammals is to aid in respiration. Puncturing of diaphragm results in stoppage of breathing and is fatal. The term '**phrenic**' is associated with diaphragm (*e.g.*, phrenic muscles, arteries or veins).

MECHANISM OF BREATHING

In general, a man respires about 12-14 times in a minute. A person with fever may breathe faster than normal. This is due to high temperature of the body. Smaller the animal, higher is its respiratory rate. The main muscles of respiration in normal quiet breathing are **Muscles of diaphragm** (Phrenic muscle). Larynx does not contribute to breathing movements. The muscles of ribs (intercostal) and diaphragm (phrenic) are responsible for intake and output of air from lungs. **Inspiration** in man is an active process, it is the result of muscle contraction. During **inspiration** in humans, the **diaphragm** and **external intercostal muscles contract**. This moves the lateral thoracic walls outward and upward. During inspiration the diaphragm is flattened and that contributes to increased volume of thoracic cavity. **Expiration** in man is a passive process, it is the result of muscle relaxation. But in cockroach, it is an active process brought about by contraction of tergo-sternal muscles. During expiration in humans, the diaphragm and external intercostal muscles relax simultaneously. This moves the lateral thoracic walls inward and downward. Diaphragm is dome shaped or arched and that reduces the volume of thoracic cavity. In **forceful expiration, internal intercostal muscles** and some abdominal muscles contract to reduce the volume of thorax further. Breathing rate is lowest while we are snoring. **Asthma** is a respiratory disease caused due to spasm in bronchial muscles in which expiration becomes difficult.

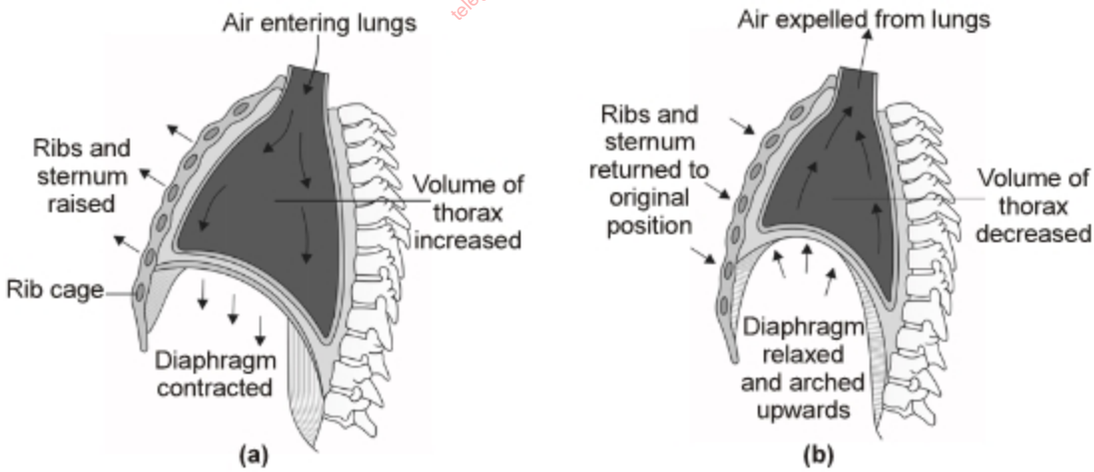


Fig. : Mechanism of breathing showing : (a) inspiration (b) Expiration

Respiratory Volumes and Capacities

1. **Tidal volume :** The air that normally goes in and out of lungs during breathing (500 ml). The air normally inspired and expired during one breath is called the tidal volume *i.e.* a healthy man can inspire or expire approximately 6000 to 8000 ml of air per minute.
2. **Dead air space :** A part of the inspired air is left in the trachea and bronchial tree (about 150 ml) where no gaseous exchange occurs. This part is called dead space volume.

3. **Minute volume :** The amount of air moved in and out of the lungs during one minute. It is equal to the tidal volume times the number of breaths per minute (500 ml × 12 = 6000 ml).
4. **Inspiratory reserve volume :** This is also called **complemental air**. The amount of air we can inspire besides the tidal volume by deepest possible inspiration This averages 2500 ml to 3000 ml.
5. **Expiratory reserve volume :** This is also called **supplemental air**. The amount of air we can expire besides the tidal volume by most forceful expiration. This averages 1000 ml to 1100 ml.
6. **Residual volume :** The volume of air that remains in the lungs after the most forceful expiration. This averages 1100 ml to 1200 ml.
7. **Inspiratory capacity :** Total amount of air that can be inhaled forcefully into the lungs after a normal expiration. This includes TV + IRV.
8. **FRC (Functional residual capacity) :** When a person breathes normally, then, the amount of air which remains in the lungs after a normal expiration is called FRC. This includes ERV + RV.
9. **Vital capacity :** The capacity of lungs to expire maximum volume of air after a forceful inspiration. *i.e.*, the largest quantity of air that can be expired after a maximal inspiratory effort. **Vital capacity** is equal to the sum of the tidal, complemental and supplemental air or it is the maximum volume of air a person can breathe in after a forced expiration.

$$VC = TV + ERV + IRV$$

10. **Total lung capacity : TLC** is the sum of the vital capacity (VC) and residual volume (RV), *i.e.*, TLC = VC + RV. It is the total volume of air accommodated in the lungs at the end of forced inspiration.

EXCHANGE OF GASES

Alveoli are the primary sites of exchange of gases. Exchange of gases also occur between blood and tissues. O_2 and CO_2 are exchanged in these sites by simple diffusion mainly based on pressure/concentration gradient. Solubility of the gases as well as the thickness of the membranes involved in diffusion are also some important factors that can affect the rate of diffusion.

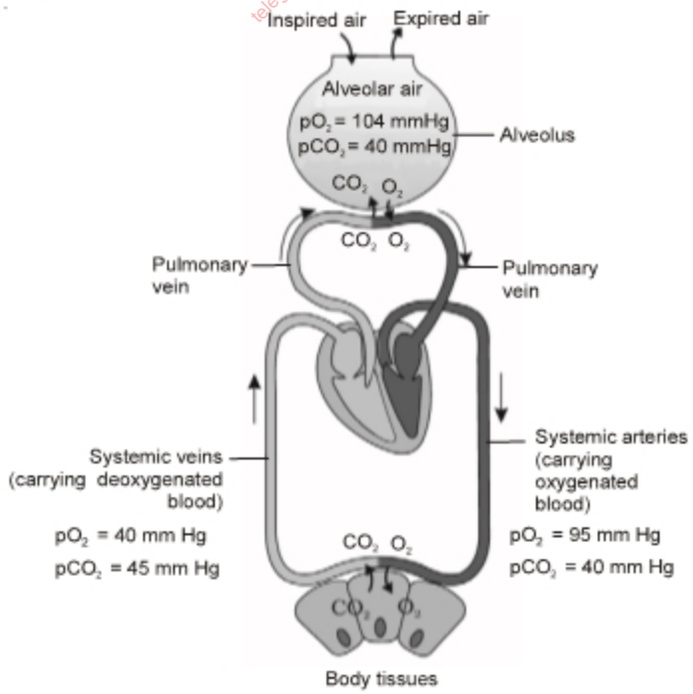


Fig. : Diagrammatic representation of exchange of gases at the alveolus and the body tissues with blood and transport of oxygen and carbon dioxide

As the solubility of CO_2 is 20-25 times higher than that of O_2, the amount of CO_2 that can diffuse through the diffusion membrane per unit difference in partial pressure is much higher compared to that of O_2. The **diffusion membrane** is made up of three major layers namely, the thin squamous epithelium of alveoli, the endothelium of alveolar capillaries and the basement substance in between them. However, its total thickness is much less than a millimeter.

Partial Pressures (in mm Hg) of Oxygen and Carbon dioxide at Different Parts Involved in Diffusion in Comparison to those in Atmosphere

Respiratory Gas	Atmospheric Air	Alveoli	Blood (Deoxygenated)	Blood (Oxygenated)	Tissues
O_2	159	104	40	95	40
CO_2	0.3	40	45	40	45

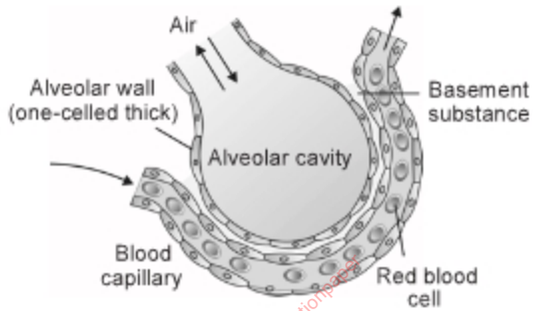


Fig. : A diagram of a section of an alveolus with a pulmonary capillary

Transport of Gases

Blood is responsible for the transport of O_2 and CO_2. Plasma and RBCs both are involved in the transport of gases.

Transport of Oxygen

100 ml or 1 dl of our blood carries about **19.4 ml or 20 ml of oxygen.** Out of this 19.4 ml or 20 ml, 5 ml or 4.6 ml diffuses from the arterial blood into the tissues. So, the venous blood still has 14.4 ml O_2 *i.e.*, it is still 75% saturated with oxygen. Our tissues are able to get only 25% of O_2. 1 gm of haemoglobin can transport 1.34 ml of oxygen. Most of the oxygen is carried in chemical combination with haemoglobin and some in the form of dissolved gas in plasma. 1 molecule of haemoglobin can transport 4 molecules of oxygen. **Oxygen haemoglobin dissociation curve is S-shaped Sigmoid shaped.** It represents percentage saturation of haemoglobin at different partial pressures of oxygen.

pO_2 (in mm Hg)	% saturation of Haemoglobin
20	30%
40	75%
95	97%

Oxygen Myoglobin dissociation curve is rectangular hyperbolic.

The binding of oxygen with haemoglobin is primarily related to partial pressure of O_2. Partial pressure of CO_2, hydrogen ion concentration and temperature are the other factors which can interfere with binding.

Factors affecting oxygen haemoglobin dissociation curve :

1. **Concentration of CO_2 or pCO_2** If we increase the concentration of CO_2 with constant temperature and pH, the O_2 dissociation curve moves towards right, it indicates the dissociation of HbO_2 into Hb + O_2. The phenomenon is called **Bohr's effect** *i.e.*, loading of CO_2 on Hb will cause unloading of oxygen.
2. **Decrease in pH :** the curve will shift towards right.
3. **Increase in temperature :** The curve will shift towards right.

P_{50} → Partial pressure of oxygen at which Hb is 50% saturated with O_2.

pO_2 of 26-30 mm Hg, Hb is 50% saturated. Affinity of Hb for $O_2 \propto \frac{1}{P_{50}}$ value.

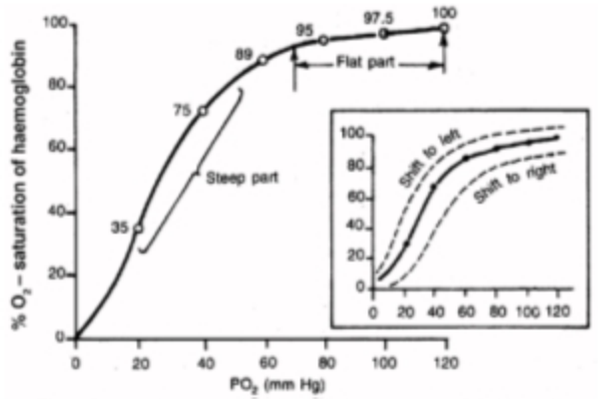
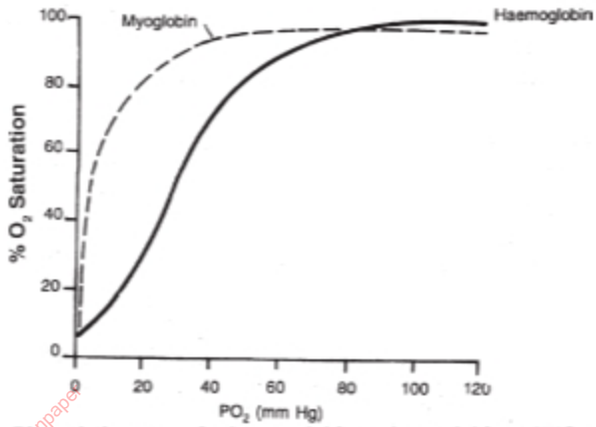


Fig. : Oxygen-haemoglobin dissociation curve at pCO_2 40 mmHg pH 7.4 and temperature 37°C; & factors affecting it (inset)



Dissociation curve for haemoglobin and myoglobin at 37°C; pCO_2 40 mmHg and pH 7.4

Foetal Haemoglobin (HbF – $\alpha_2\gamma_2$)

(i) Its structure is same as that of Hb of adults (HbA), except that the β-globin chains are replaced by γ-chains. γ-chains also contain 146 amino-acid residues but have 37 amino-acid residues that differ from those in the β-chains.

(ii) HbF has greater affinity for oxygen because it has less affinity for 2, 3 DPG (diphosphoglycerate), therefore, it can bind to much larger volume of oxygen than HbA at low oxygen pressure. This facilitates the movement of oxygen from maternal to foetal circulation. HbF is 60% saturated at 20 mmHg of O_2 whereas HbA is only 30-35% saturated at this pressure.

(iii) Myoglobin does not show Bohr effect. As a result, even at pO_2 of 40 mmHg, it is 95% saturated with O_2 and only when pO_2 falls below 5 mmHg, it becomes < 60% saturated. Therefore, myoglobin acts as a temporary O_2 storehouse in the muscles.

Transport of CO_2

CO_2 is transported in the blood in three forms :

1. Dissolved as such in plasma (7%).
2. In the form of HCO_3^- in plasma and RBC (70%).
3. Along with Hb (20-25%).

CO_2 combines with NH_2 group of globin protein in deoxy Hb to form Carbamino-haemoglobin.

1. Carbondioxide transported in Plasma

$$CO_2 + H_2O \rightarrow H_2CO_3$$

(In plasma, carbonic anhydrase is present in small amount but it is present in large amount inside RBCs).

$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$

$HCO_3^- + Na^+ \rightarrow NaHCO_3$

$H^+ + NH_3 \rightarrow NH_4^+$ (less toxic)

or H^+ + Plasma proteins $\rightarrow$ Proteinic acid

2. Transportation inside RBC

$$CO_2 + H_2O \xrightarrow[Zn^{++}]{\text{Carbonic anhydrase}} H_2CO_3$$

$H_2CO_3 \rightleftharpoons H^+ + HCO_3^-$

H^+ ions immediately occupy the position of oxygen in deoxyhaemoglobin.

70% of HCO_3^- ions formed inside RBCs will diffuse out but the H^+ ions cannot move out. As the HCO_3^- diffuse out in the plasma, same number of chloride ions will move in to maintain the ionic balance. This inward movement of chloride ions to maintain ionic balance is called **chloride shift** or **Hamburger effect**.

Cl^- in RBC will combine with K^+, *i.e.*,

$K^+ + Cl^- \rightarrow KCl$

HCO_3^- which diffuses into plasma will combine with Na^+ as $Na^+ + HCO_3^- \rightarrow NaHCO_3$.

HCO_3^- left inside RBC will combine with K^+ as $K^+ + HCO_3^- \rightarrow KHCO_3$.

Oxyhaemoglobin is a weak acid, it remains associated with K^+ to form $KHbO_2$.

$$KHbO_2 \rightleftharpoons \underset{\text{deoxy Hb}}{KHb} + O_2$$

$$H^+ + HCO_3^- + KHb \rightleftharpoons \underset{\text{Haemoglobinic acid}}{H \cdot Hb} + KHCO_3$$

At the surface of the lungs, opposite reactions take place.

REGULATION OF RESPIRATION

Respiration has both nervous and chemical control.

Nervous regulation of Respiration : It involves

1. Medulla oblongata
2. Pons varolii

Medulla oblongata has Inspiratory centre in the dorsal part and Expiratory centre in its ventral part.

Inspiratory centre has motor inspiratory neurons. They send the impulses through phrenic nerves to the diaphragm which has main inspiratory muscles.

Expiratory centre has both expiratory and inspiratory neurons. During normal breathing, they remain inactive as expiration is a passive process. They are activated only at the time of forceful expiration.

In Pons varoli, pneumotaxic centre is located dorsally in the upper pons. It controls the switch off point of inspiration. *i.e.*, it stimulates expiratory centre and inhibits the inspiratory centre. If the signal is strong, inspiration will last 0.5 seconds and lungs are partially filled but if the signal is weak, the inspiration will be of 5 seconds and lungs are completely filled. Apneustic centre stimulates inspiration.

Chemical Regulation of Respiration

The chemical regulatory mechanism adjusts ventilation in such a way that the alveolar pCO_2 is kept constant at normal value of 40 mmHg. It also maintains the tension of O_2, CO_2 and H^+ of blood. *e.g.*, a fall in arterial pO_2 or pH or rise in arterial pCO_2 **stimulates the respiratory centre to increase rate and depth of respiration.** Body O_2 supply increases and CO_2 is breathed out, restoring the normal arterial pO_2, pH and pCO_2.

These changes are mediated via **respiratory chemoreceptors** *i.e.*, receptor cells in the carotid and aortic bodies called peripheral chemoreceptors and receptor cells in medulla called medullary (or Central) chemoreceptors that are sensitive to changes in the blood chemistry and initiate impulses that stimulate respiratory centres.

Medullary (Central Chemoreceptors) : These receptors are located on the ventral surface of the medulla near the respiratory centre but are seperate from it. They get stimulated by the H^+ concentration of cerebro-spinal fluid and brain interstitial fluid as this parallels with the increase in arterial pCO_2. **They also increase the rate and depth of respiration in response to increase in arterial pCO_2.**

The role of oxygen in the regulation of respiratory rhythm is insignificant.

DISORDERS OF RESPIRATORY SYSTEM

1. **Asthma** is a difficulty in breathing causing wheezing due to inflammation of bronchi and bronchioles.
2. **Emphysema** is a chronic disorder in which alveolar walls are damaged due to which respiratory surface is decreased. One of the major cause is cigarette smoking.
3. **Occupational Respiratory Disorders :** In certain industries, especially those involving grinding or stone-breaking, so much dust is produced that the defense mechanism of the body cannot fully cope with the situation. Long exposure can give rise to inflammation leading to fibrosis (proliferation of fibrous tissues) in upper part of lungs, thus causing serious lung damage. Workers in such industries should wear protective masks.
4. **Hypoxia :** When arterial pO_2 decreases.
5. **Decompression Sickness :** The pressure of water rises progressively with the depth in the sea. When a diver descends to great depths, his body is subjected to high pressure by the surrounding sea water. This tends to collapse his lungs unless he breathes compressed air under high pressure. But breathing of air at high pressure increases the partial pressures of gases in alveoli. **As nitrogen forms about 79 percent of the air, the rise in alveolar nitrogen tension affects the body most**. While at the depth, much nitrogen diffuses and dissolves in the blood and body fats. This makes the diver lose his strength and work capacity, and feel drowsy. But more severe symptoms develop if he is lifted rapidly to sea surface **(decompression sickness)**. With the rapid fall in pressure, nitrogen is evolved from his body fluids and forms gas bubbles in the blood and tissues. Nitrogen bubbles may block pulmonary vessels producing serious shortness of breath. Itchings and local pain result from bubbles in peripheral nerves. Dizziness, paralysis and mental derangement may be caused by bubbles in the vessels of brain and spinal cord. To avoid decompression sickness, the diver should ascend very slowly to the sea surface, nitrogen will then be diffused out very slowly and will be effectively removed without forming bubbles.
6. **Mountain Sickness :** When a person living on plains ascends and stays on a mountain above 8000 ft. from sea level, he develops certain symptoms in 8-24 hours. These symptoms include breathlessness, headache, dizziness, irritability, nausea, vomiting, mental fatigue and a bluish tinge on the skin, nails and lips. This is known as **Mountain Sickness**.

   You know that the barometric pressure falls progressively with the rise in altitude. Simultaneously, pO_2 falls proportionately in the atmospheric air. This lowers the alveolar pO_2 and consequently reduces the diffusion of oxygen from the alveolar air to the blood. So, oxygenation of blood is decreased progressively with the rise in altitude. The reduction in oxygenation of blood produces symptoms of mountain sickness.

7. **Asphyxia :** It is produced by occlusion of airways. It results in lack of O_2 due to hypercapnia (excess of CO_2).

8. **Carbon Monoxide poisoning :** If a person sleeps in a closed room with a lamp burning, the absence of sufficient amount of oxygen causes an incomplete combustion of carbon and produces carbon monoxide in the room. As the person inhales **carbon monoxide**, it diffuses from the alveolar air to the blood and binds to **hemoglobin** forming **carboxyhemoglobin**. The latter is a relatively stable compound and cannot bind any oxygen. So, the amount of **hemoglobin available for oxygen transport is reduced**. The resulting deficiency of oxygen causes headache, dizziness, nausea and even death. Carbon monoxide combines with hemoglobin at the same point as does oxygen and therefore can displace oxygen from the hemoglobin. It binds to hemoglobin 250 times faster than oxygen.

   It shifts the oxygen hemoglobin dissociation curve towards the left and decreases the availability of O_2.

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Try Yourself

SECTION - A

Objective Type Questions

1. Adam's apple is another name for
   (1) Sound box in birds (2) Sound box in man
   (3) Epiglottis (4) Thyroid cartilage
2. Ring like cartilage of larynx is
   (1) Thyroid cartilage (2) Arytenoid cartilage
   (3) Cricoid cartilage (4) Cartilage of Santorini
3. Which is the wrong statement?
   (1) Left lung has two lobes and right lung has three lobes
   (2) Left lung has three lobes and right lung has two lobes
   (3) In the lungs, each alveolar duct opens into a blind chamber, the infundibulum or alveoli
   (4) Pleurisy is a painful condition which results if the pleura becomes inflated due to over production of fluid between them
4. Number of alveoli in the human lungs is about
   (1) 300 millions (2) 100 millions
   (3) 1-2 million (4) 100,00-150,000
5. Ribs move outwards during respiration due to contraction of
   (1) Intercostal muscles (2) Petrohyal muscles
   (3) Pharyngeal muscles (4) None of these
6. Tidal volume is
   (1) The volume of air taken in or out in one normal inspiration/expiration
   (2) Volume of air taken out by forced inspiration after normal inspiration
   (3) Volume of air taken out by forced expiration after normal expiration
   (4) Volume of air that remains in lungs even after maximum expiration
7. Air forcibly inhaled after normal inspiration is called
   (1) Tidal volume (2) Supplemental air
   (3) Inspiratory capacity (4) Complemental air
8. Total lung capacity is
   (1) TV + IRV
   (2) TV + IRV + ERV + RV
   (3) IRV + ERV + RV
   (4) TV + RV + ERV
9. When a person breathes normally, then the amount of air which remains in the lung after normal expiration is
   (1) RV (2) ERV
   (3) ERV + RV (4) TV + ERV
10. Which of the following pulmonary air volumes **cannot** be measured with the help of a spirometer?
    (1) Expiratory Reserve Volume
    (2) Inspiratory Reserve Volume
    (3) Residual Volume
    (4) Minute Volume
11. Partial pressure of O_2 in the inspired and expired air is respectively
    (1) 158 and 116 mm Hg (2) 158 and 40 mm Hg
    (3) 100 and 95 mm Hg (4) 40 and 95 mm Hg
12. One haemoglobin molecule carries a maximum of
    (1) 1 molecule of O_2 (2) 2 molecules of O_2
    (3) 3 molecules of O_2 (4) 4 molecules of O_2
13. 100 ml of oxygenated blood carries
    (1) 14-15 ml of O_2 (2) 19-20 ml of O_2
    (3) 1.34 ml of O_2 (4) None of these
14. In which condition, oxygen dissociation curve of haemoglobin shifts to right of the normal curve according to Bohr's effect?
    (1) Decrease in CO_2 concentration
    (2) Rise in P_{50} with an increase in CO_2 concentration
    (3) Decrease in pH
    (4) Both (2) & (3)

15. Oxygen Hb dissociation curve in mammals is
(1) J-shaped (2) Sigmoid shaped
(3) T-shaped (4) L-shaped

16. Percentage amount of CO_2 carried or transported by Hb is
(1) 10% (2) 80%
(3) 70% (4) 23%

17. Carbon dioxide combines with haemoglobin
(1) 25 times more readily than oxygen
(2) 125 times more readily than oxygen
(3) 250 times more readily than oxygen
(4) 205 times more readily than oxygen

18. When the CO_2 concentration in the blood increases, breathing becomes
(1) Shallower and slow
(2) There is no effect on breathing
(3) Slow and deep
(4) Faster and deeper

19. Which of the following is the switch off point of inspiration?
(1) Apneustic centre
(2) Pneumotaxic centre
(3) Respiratory centre of medulla
(4) Cerebrum

20. Which of the following disorder is related to cigarette smoking in which alveolar walls are damaged?
(1) Asthma (2) Emphysema
(3) Atelectasis (4) Bend's disease

21. When the oxygen supply to the tissues is inadequate, the condition is called
(1) Hypoxia (2) Asphyxia
(3) Pleurisy (4) Anoxia

22. Asphyxia occurs due to
(1) Rise in CO_2 level (2) Fall in CO_2 level
(3) Rise in O_2 level (4) Fall in O_2 level

23. When a person living on plains ascends and stays on a mountain above 8000 ft from sea level, he develops the symptoms of headache, nausea dizziness and bluish tinge on skin. This is known as
(1) Hypoxia
(2) Mountain Sickness
(3) Dyspnoea
(4) Cheyne-Stoke Syndrome

24. As a diver breathing 80% N_2 ascends from a dive, the elevated alveolar pN_2 falls. If the ascent is rapid, bubbles of N_2 form in tissues and blood, causing the symptoms of
(1) Decompression sickness, Dysbarism
(2) Bends or Caisson's disease
(3) Cystic fibrosus
(4) Both (1) & (2)

25. Atelectasis is due to
(1) Lack of surfactant (2) Hydrothorax
(3) Pneumothorax (4) All of these

26. Which of the following statements is **incorrect**?
(1) The residual air in lungs slightly decreases the efficiency of respiration in mammals
(2) The presence of non-respiratory air sacs increases the efficiency of respiration in birds
(3) In insects, the circulating body fluids serve to distribute oxygen to the tissues
(4) The principle of countercurrent flow facilitates efficient respiration in gills of fishes

27. People living at sea-level have around 5 million RBC per cubic millimeter of their blood whereas those living at an altitude of 5,400 ft have around 8 million. This is because at high altitude
(1) People get pollution free air to breathe and more oxygen is available
(2) Atmospheric O_2 level is less and hence more RBCs are needed to carry the required amount of O_2 to survive higher altitudes
(3) There are more UV radiations which enhance RBC production
(4) People eat more nutritive food, therefore more RBCs are found

28. Which of the following mammalian cells is **not** capable of metabolising glucose to carbon-dioxide aerobically?
(1) Red blood cells
(2) White blood cells
(3) Unstriated muscle cells
(4) Liver cells

29. Trachea divides at the level of
(1) 2nd thoracic vertebra
(2) 5th thoracic vertebra
(3) 5th cervical vertebra
(4) 4th cervical vertebra

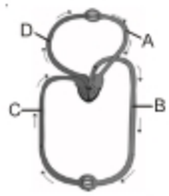
30. If a person sleeps in a closed room with a lamp burning, he suffers with headache, dizziness nausea and even death due to carbon monoxide poisoning. In carbon monoxide poisoning there is
(1) Increase in carboxyhaemoglobin
(2) Decrease in oxygen availability
(3) Increase in carbamino-haemoglobin
(4) Both (1) & (2)

SECTION - B

Previous Years Questions

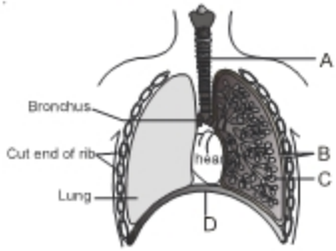
1. Which one of the following is the **correct** statement for respiration in humans? **[AIPMT 2012]**
(1) Workers in grinding and stone-breaking industries may suffer from lung fibrosis
(2) About 90% of carbon dioxide (CO_2) is carried by haemoglobin as carbaminohaemoglobin
(3) Cigarette smoking may lead to inflammation of bronchi
(4) Neural signals from pneumotoxic centre in pons region of brain can increase the duration of inspiration

2. Figure shows schematic plan of blood circulation in humans with labels A to D. Identify the label and give its function/s. **[NEET 2013]**



(1) B – Pulmonary artery – takes blood from heart to lungs, PO_2 = 90 mm Hg
(2) C – Vena Cava – takes blood from body parts to right auricle, PCO_2 = 45 mm Hg
(3) D – Dorsal aorta – takes blood from heart to body parts, PO_2 = 95 mm Hg
(4) A – Pulmonary vein – takes impure blood from body parts, PO_2 = 60 mm Hg

3. The figure shows a diagrammatic view of human respiratory system with labels A, B, C and D. Select the option which gives correct identification and main function and/or characteristic. **[NEET 2013]**



(1) B-pleural membrane - surround ribs on both sides to provide cushion against rubbing
(2) C-Alveoli - thin walled vascular bag like structures for exchange of gases
(3) D-Lower end of lungs - diaphragm pulls it down during inspiration
(4) A - trachea - long tube supported by complete cartilaginous rings for conducting inspired air

4. Approximately seventy percent of carbon-dioxide absorbed by the blood will be transported to the lungs **[AIPMT 2014]**
(1) As bicarbonate ions
(2) In the form of dissolved gas molecules
(3) By binding to R.B.C.
(4) As carbamino-haemoglobin

5. When you hold your breath, which of the following gas changes in blood would first lead to the urge to breathe? **[AIPMT-2015]**
(1) Rising CO_2 and falling O_2 concentration
(2) Falling O_2 concentration
(3) Rising CO_2 concentration
(4) Falling CO_2 concentration

6. Name the pulmonary disease in which alveolar surface area involved in gas exchange is drastically reduced due to damage in the alveolar walls. **[Re-AIPMT-2015]**
(1) Asthma (2) Pleurisy
(3) Emphysema (4) Pneumonia

7. Name the chronic respiratory disorder caused mainly by cigarette smoking **[NEET-2016]**
(1) Respiratory alkalosis
(2) Emphysema
(3) Asthma
(4) Respiratory acidosis

8. Reduction in pH of blood will **[NEET-2016]**
(1) Release bicarbonate ions by the liver
(2) Reduce the rate of heart beat
(3) Reduce the blood supply to the brain
(4) Decrease the affinity of hemoglobin with oxygen

9. Asthma may be attributed to **[NEET-2016]**
(1) Accumulation of fluid in the lungs
(2) Bacterial infection of the lungs
(3) Allergic reaction of the mast cells in the lungs
(4) Inflammation of the trachea

10. It is much easier for a small animal to run uphill than for a large animal, because **[NEET 2016]**
    (1) The efficiency of muscles in large animals is less than in the small animals
    (2) It is easier to carry a small body weight
    (3) Smaller animals have a higher metabolic rate
    (4) Small animals have a lower O_2 requirement

11. The partial pressure of oxygen in the alveoli of the lungs is **[NEET (Phase-2) 2016]**
    (1) Equal to that in the blood
    (2) More than that in the blood
    (3) Less than that in the blood
    (4) Less than that of carbon dioxide

12. Lungs do not collapse between breaths and some air always remains in the lungs which can never be expelled because **[NEET (Phase-2) 2016]**
    (1) There is a negative pressure in the lungs
    (2) There is a negative intrapleural pressure pulling at the lung walls
    (3) There is a positive intrapleural pressure
    (4) Pressure in the lungs is higher than the atmospheric pressure

13. Which of the following options correctly represents the lung conditions in asthma and emphysema, respectively? **[NEET-2018]**
    (1) Increased respiratory surface; Inflammation of bronchioles
    (2) Increased number of bronchioles; Increased respiratory surface
    (3) Inflammation of bronchioles; Decreased respiratory surface
    (4) Decreased respiratory surface; Inflammation of bronchioles

14. Match the items given in Column I with those in Column II and select the correct option given below: **[NEET-2018]**

	Column I	Column II
a.	Tidal volume	i. 2500 – 3000 mL
b.	Inspiratory Reserve volume	ii. 1100 – 1200 mL
c.	Expiratory Reserve volume	iii. 500 – 550 mL
d.	Residual volume	iv. 1000 – 1100 mL

	a	b	c	d
(1)	i	iv	ii	iii
(2)	iii	i	iv	ii
(3)	iii	ii	i	iv
(4)	iv	iii	ii	i

15. Which of the following is an occupational respiratory disorder? **[NEET-2018]**
    (1) Botulism
    (2) Silicosis
    (3) Anthracis
    (4) Emphysema

16. Tidal Volume and Expiratory Reserve Volume of an athlete is 500 mL and 1000 mL, respectively. What will be his Expiratory Capacity if the Residual Volume is 1200 mL? **[NEET-2019]**
    (1) 1500 mL
    (2) 1700 mL
    (3) 2200 mL
    (4) 2700 mL

17. Select the correct statement. **[NEET-2019 (Odisha)]**
    (1) Expiration is initiated due to contraction of diaphragm.
    (2) Expiration occurs due to external intercostal muscles.
    (3) Intrapulmonary pressure is lower than the atmospheric pressure during inspiration.
    (4) Inspiration occurs when atmospheric pressure is less than intrapulmonary pressure.

18. The maximum volume of air a person can breathe in after a forced expiration is known as : **[NEET-2019 (Odisha)]**
    (1) Total Lung Capacity
    (2) Expiratory Capacity
    (3) Vital Capacity
    (4) Inspiratory Capacity

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Chapter 6

Body Fluids and Circulation

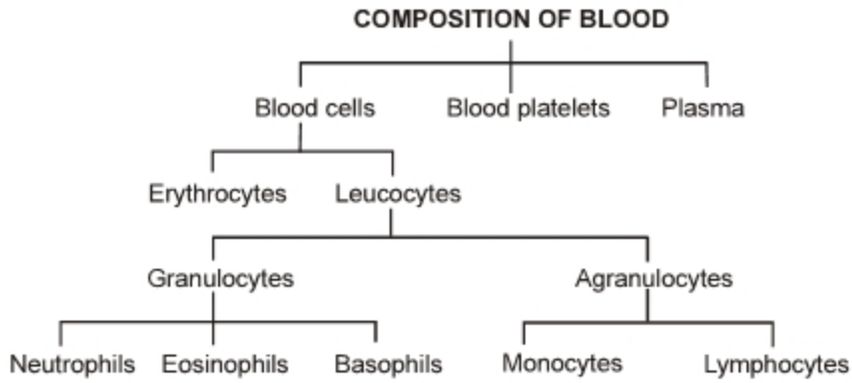
Sub-topics *Composition of Blood, Blood Groups, Coagulation of Blood; Composition of Lymph and its Function; Human Circulatory System - Structure of Human Heart and Blood Vessels; Cardiac Cycle, Cardiac Output, ECG, Double Circulation; Regulation of Cardiac Activity; Disorders of Circulatory System - Hypertension, Coronary Artery Disease, Angina Pectoris, Heart Failure*

Blood

Blood is a fluid connective tissue. Its cells are quite distinct from other connective tissue cells both in structure and functions. The extracellular material in blood is a fluid devoid of fibres. Fluids outside the cells are generally called **Extracellular Fluids** (ECF). Blood is heavier than water.

The extracellular material in blood is a straw-coloured, slightly alkaline (pH = 7.4) aqueous fluid called **plasma.**

Constituents, having characteristic forms, float in the plasma. They are collectively called the **Formed Elements** of blood. They include the blood cells and blood platelets. Blood cells are of two types-**Erythrocytes** and **Leucocytes**. Blood circulates within blood vessels in higher animals. But other extracellular fluids such as cerebrospinal fluid, interstitial fluid, lymph and aqueous humour occur outside blood vessels.



Plasma

Plasma contains plasma proteins viz. **serum albumin, serum globulins prothrombins** and **fibrinogens**. Tissue cells may utilise plasma proteins for forming their cellular proteins. Additionally, albumin and globulins retain water in blood plasma by their osmotic effects. A fall in plasma proteins leads to movement of excessive volumes of water from blood to tissues. Albumins and globulins also transport many substances such as thyroxine and Fe^{3+} in combination with them. One class of globulins, called immunoglobulins, act as **Antibodies**. Plasma proteins also maintain the blood pH by neutralising strong acids and bases. Thus, they act as **Acid-Base Buffers**.

Composition of Plasma. Plasma forms 55-60% by volume of blood.

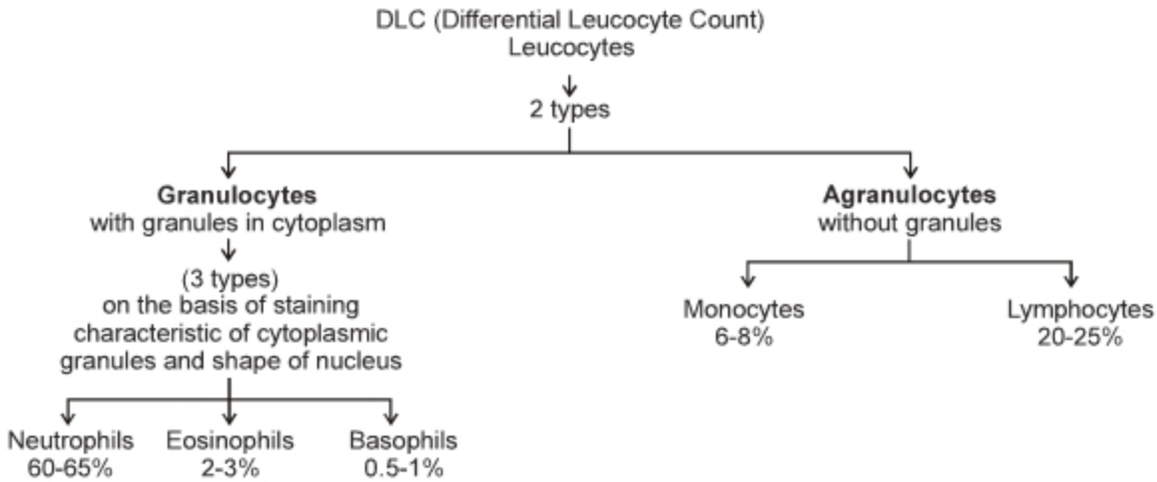
1. **Water—**Water alone forms about 90% to 92% of the plasma. Solids form about 8% of the plasma.
2. **Plasma proteins—**They constitute about 7 to 8% of plasma.
3. Various inorganic/organic components like mineral salts, nutrients, dissolved gases form the remaining part.

Functions of Blood plasma—These can be summarised as under (i) transport, (ii) retention of fluid in blood, (iii) maintenance of blood pH, (iv) body immunity, (v) prevention of blood loss, (vi) conducting heat to skin for dissipation and (vii) uniform distribution of heat all over the body.

Formed Elements

(i) **Erythrocytes :** Erythrocytes (red blood corpuscles or RBC) are the most numerous of the formed elements of blood. Their most important characteristic feature is the presence of hemoglobin, the oxygen carrying pigment. The total number of erythrocytes per microlitre (1 μl = 1mm^3 = 10^{-6}) of blood is known as the **Total Count of RBC**. It averages 5 millions and 4.5 millions in adult man and adult woman respectively. A healthy person has 12-16 gm of haemoglobin per 100 ml of blood which takes part in transport of gases. RBC have an average life span of 120 days. Dead RBCs are filtered out by Spleen (Graveyard of RBCs). The total count would be low **in anaemia** and after profuse bleeding. On the contrary, the abnormal rise in the total count of RBC is called **Polycythemia**. **Anaemia is caused due to the deficiency of folic acid, vitamin B_{12} and haemoglobin.**

(ii) **Leucocytes :** Leucocytes (white blood corpuscles or WBC) are devoid of hemoglobin and are consequently colourless. Leucocytes are nucleated blood cells. They are of two major classes : granulocytes (with cytoplasmic granules) and agranulocytes (without granules). **Granulocytes** are of three types, *viz.* **neutrophils**, **eosinophils** and **basophils**, each with lobed nucleus. **Agranulocytes** are of two types, *viz.* **lymphocytes** and **monocytes**. Neutrophils and monocytes protect the body against microbes by phagocytosing them. B-lymphocyte secrete antibodies in the blood to destroy microbes and their toxins. The number of leucocytes per microlitre (1 μl = 1 mm^3 = 10^{-6}) of blood is called the **Total Count of WBC**. It is 6000–8000/mm^3 of blood normally. **It may rise abnormally in acute infections (*e.g.*, pneumonia),** inflammations (*e.g.* appendicitis) and **malignancies (*e.g.*, leukemia).** In some conditions such as folic acid deficiency, the total count falls abnormally (leukopenia). The total count of WBCs is also of diagnostic value in many diseases. **The process by which monocytes and neutrophils squeeze out through thin capillary walls is *Diapedesis*.**



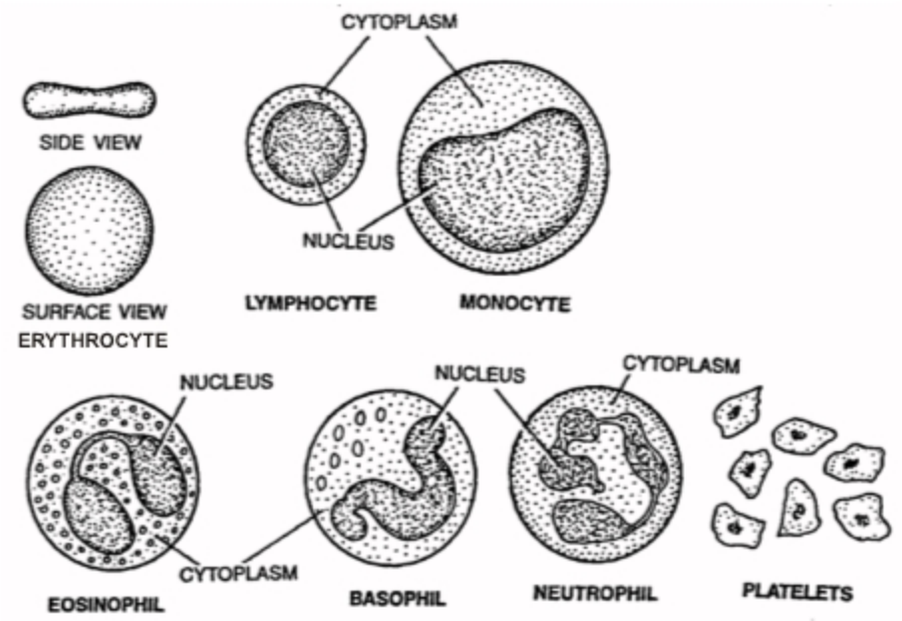


Table : Differences between different types of Leucocytes

Character	Lymphocytes	Monocytes	Eosinophils (Acidophils)	Basophils	Neutrophils
Number/ Percentage	20-25%	6-8%	2-3%	0.5-1%	60-65%
Granules in cytoplasm	Absent	Absent	Coarse	Coarse	Fine
Staining of cytoplasm	Basophilic	Basophilic	Eosinophilic	Basophilic	Neutrophilic
Nucleus	Rounded	**Bean-shaped**/ Kidney shaped	Bilobed	S-shaped 3-lobed	Multilobed
Site of Formation	Lymph nodes spleen, thymus tonsils, Peyer's patches Bone marrow	Bone marrow	Bone marrow	Bone marrow	Bone marrow
Life span	Few days or even years	10–20 hours in the blood and in tissue, months or even years	4-8 hours in blood and 4 to 5 days in tissue	4-8 hours in blood and 4 to 5 days in tissue	4-8 hours in blood and 4 to 5 days in tissue
Function	Provide Immunity	Phagocytic	Important role in immunity, antiallergic reactions and parasitic infection	Secretion of heparin, histamine and serotonin	Phagocytic

(iii) **Blood platelets :** Also called thrombocytes. Blood platelets are non-nucleated, round or oval, biconvex disc-like bodies. They are 2-3 micrometres in diameter and their number normally varies from 0.15 to 0.35 million/mm^3 or 1,50,000 - 3,50,000 platelets/mm^3. They bud off from the cytoplasm of very large **Megakaryocytes** of the bone marrow. Their normal life-span is about a week. When a blood vessel is injured, platelets get clumped at the site of injury and release certain chemicals called **Platelet Factors**. These promote blood coagulation. **Thrombocytopenia** is decrease in platelet count and **Purpura** is a group of bleeding diseases due to thrombocytopenia.

Blood group

Agglutination is due to the interaction of antigens and antibodies. There are two kinds of antigens that are named A and B. There are also two kinds of antibodies which are called a and b. The antigen A and antibody a are incompatible (antagonistic) and cause self clumping and cannot exist together. Similarly, the antigen B and antibody b are incompatible and cause self clumping and cannot exist together. Thus, A and b can exist together and B and a can exist together. The corpuscle factors A and B can occur together if their antagonistic plasma factors a and b are not present. The plasma factors a and b can occur together if their antagonistic corpuscle factors A and B are absent.

Blood Group	Antigens on RBCs	Antibodies in Plasma	Donor's Group
A	A	anti-B	A, O
B	B	anti-A	B, O
AB	A, B	nil	AB, A, B, O
O	nil	anti-A, B	O

Rh grouping

Another antigen, the Rh antigen, similar to one present in Rhesus monkeys (hence Rh), is also observed on the surface of RBCs of majority (nearly 80 per cent) of humans. Such individuals are called **Rh Positive** (Rh+ve) and those in whom this antigen is absent are called **Rh negative** (Rh-ve). An Rh-ve person, if exposed to Rh+ve blood, will form specific antibodies against the Rh antigens. Therefore, Rh group should also be matched before transfusions. A special case of Rh incompatibility (mismatching) has been observed between the **Rh-ve blood of a pregnant mother** with **Rh+ve blood of the foetus**. Rh antigens of the foetus do not get exposed to the Rh-ve blood of the mother in the first pregnancy as the two bloods are well separated by the placenta. However, during the delivery of the first child, there is a possibility of exposure of the maternal blood to small amounts of the Rh+ve blood from the foetus. In such cases, the mother starts preparing antibodies against Rh antigen in her blood. In case of her subsequent pregnancies, the Rh antibodies from the mother (Rh-ve) can leak into the blood of the foetus (Rh + ve) and destroy the foetal RBCs. This could be fatal to the foetus or could cause severe anaemia and jaundice to the baby. This condition is called **erythroblastosis foetalis**. This can be avoided by administering **anti-Rh antibodies** to the mother immediately after the delivery of the first child.

Blood Coagulation

When blood oozes out of a cut, it sets into gel within a few minutes. This is called **coagulation**. Coagulation is brought about by hydrolysis of soluble fibrinogen of plasma to insoluble fibrin. This is catalysed by an enzyme called thrombin. Fibrin precipitates as a network of fibres. This network traps many blood cells, particularly RBCs, to form a red solid mass called the **Blood clot**. The clot seals the wound in the vessel to stop the bleeding. The straw coloured fluid left after clotting of blood, is called **Serum**. The serum cannot be coagulated as it lacks fibrinogen.

Thrombin occurs in normal blood as an inactive globulin called **Prothrombin**. It must be activated to thrombin before blood coagulation can occur. In case of injury to a blood vessel, coagulation promoting substances called **Thromboplastins** are released into the blood from clumped platelets and damaged tissues. Thromboplastins help in the formation of the enzyme **Prothrombinase**. This enzyme hydrolyses prothrombin to thrombin to initiate coagulation. **Ca^{2+} ions** are essential for both activation and action of thrombin.

Blood normally contains an anticoagulant, **Heparin** which prevents activation of prothrombin, Heparin is released from mast cell granules. Blood also contains **Antithrombin** which inhibits any thrombin formed accidentally.

Blood drawn from a blood vessel can be kept **uncoagulated** by adding a pinch of **oxalate (sodium or potassium oxalate)** to it. Oxalate precipitates Ca^{2+} and consequently prevents coagulation. Chilling of blood also delays coagulation because lesser temperature depresses the action of coagulation promoting enzymes.

Lymph

As the blood passes through the capillaries in tissues, some water along with many small water-soluble substances move out into the spaces between the cells of tissues leaving the larger proteins and most of the formed elements in the blood vessels. This fluid released out is called the interstitial fluid or tissue fluid. It has the same mineral distribution as that in plasma. Exchange of nutrients, gases, etc., between the blood and the cells always occur through this fluid. An elaborate network of vessels called the lymphatic system collects this fluid and drains it back to the major veins. The fluid present in the lymphatic system is called the lymph. Lymph is a colourless fluid containing specialised lymphocytes which are responsible for the immune responses of the body. Lymph is also an important carrier for nutrients, hormones, etc. Fats are absorbed through lymph in the lacteals present in the intestinal villi.

Circulatory Pathways

Circulatory pattern is of two types :

1. **Open circulatory system :** Blood flows through vessels which open into tissue spaces or membrane lined sinuses, hence comes directly in contact with tissue *e.g.*, arthropods, non-cephalopod molluscs and tunicates.
2. **Closed circulatory system :** Blood flows in a closed circuit through heart, vessels and finely branched capillaries, without coming in direct contact with body tissues or body cavity. It is more advantageous as the flow of fluid can be more precisely regulated.

Circulatory system consists of a heart (pumping organ), arteries and arterioles (carry blood away from heart), and venules (bring blood back to heart) and capillaries (connecting arterioles and venules). Circulation is of two types :

1. **Single Circulation :** When blood flows through heart only once during its course of circulation *e.g.* invertebrates and fish.
2. **Double Circulation :** When blood flows through heart twice during its course of circulation *e.g.* amphibians, reptiles, birds and mammals.

   In amphibians and reptiles, the left atrium receives oxygenated blood from the gills/lungs/skin and the right atrium gets deoxygenated blood from other body parts. However, they get mixed up in the single ventricle which pumps out mixed blood (incomplete double circulation). In birds and mammals, oxygenated and deoxygenated blood received by the left and right atria, respectively passes onto the ventricles of the same sides. The ventricles pump it out without any mixing up *i.e.* two separate circulatory pathway are present in these organisms, hence, these have complete double circulation.

HUMAN CIRCULATORY SYSTEM

Heart

Heart is the mesodermal derived organ situated in the **thoracic cavity**, in mediastinal space. Its covering is called **pericardium** which is double walled - outer parietal pericardium and inner visceral pericardium. In between these two is present pericardial cavity filled with pericardial fluid. Wall of heart is made up of 3 layers. Outermost is **epicardium** (visceral pericardium), middle **myocardium** (consisting of cardiac muscles) and innermost lining is **endocardium**. Cardiac muscle is syncytium in functional terms because of intercalated discs.

Atrium is divided by an interatrial septum into right and left atria. On this septum a depression **fossa ovalis** is present which is remnant of embryonic **foramen ovale**, an aperture present between right and left atria. Three large veins (superior vena cava, inferior vena cava and coronary sinus) pour blood in the right atrium by separate pores. **Eustachian valve** guards the opening of inferior vena cava. A **coronary** or **thebesian valve** is present at the opening of coronary sinus. Four pulmonary veins, two from each lung, bring oxygenated blood into left atrium. The openings of pulmonary veins are without any valve as their openings are oblique, which prevents back flow of blood. Ventricle is also divided by an interventricular septum.

Atria open into ventricles by separate atrio-ventricular apertures. In the right side is present **tricuspid valve** and in the left side is present **bicuspid** or **mitral valve**. The cuspid valves are connected below to the walls of ventricles by **chordae tendinae** which terminate on the papillary muscles. Right ventricle receives the deoxygenated blood from the right atrium and pumps it into pulmonary trunk arising from it. Pulmonary trunk bifurcates to form right and left pulmonary arteries which supply deoxygenated blood to the lungs of the respective side. Left ventricle receives oxygenated blood from the left atrium and sends it into ascending aorta which puts blood into the coronary arteries and the systemic circulation of the body. Origin of pulmonary trunk and ascending aorta is guarded by a set of three semilunar valves in each. This is to prevent the back flow of blood.

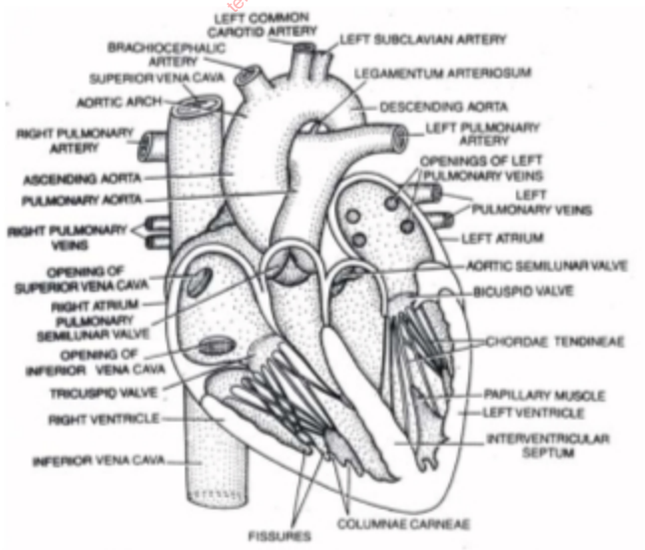


Fig. : Internal Structure of Human heart

The inner surface of ventricle has a number of irregular muscular ridges called **trabeculae carnae** or **columnae carneae** with **papillary muscles** also present. These are inserted at ventricular wall at one end and continued at the other end with collagenous cords called **chordae tendinae**. These prevent collapse of AV valves into atrium during ventricular contraction.

Left ventricle has the **thickest muscles** because it pumps the blood to the whole body.

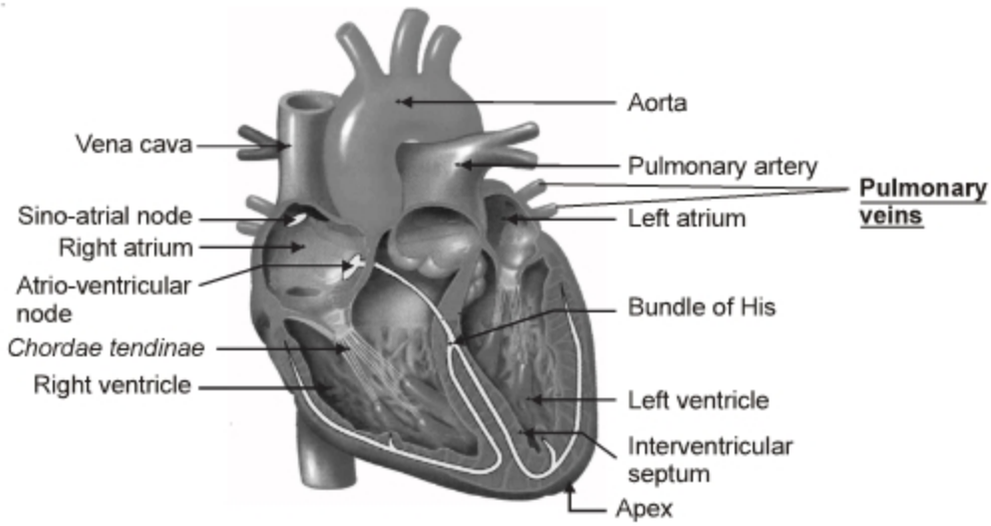


Fig. : Internal structure of human heart

Neurogenic and Myogenic Heart

1. **In neurogenic heart, contractions are initiated by nerve ganglia situated in the vicinity of heart *i.e.*, the heartbeat originates by nervous stimulation. *e.g.* cockroach.**
2. **Myogenic heart** has contractions initiated by a special node of modified heart muscles called **sino-atrial node (SA node).** *e.g.*, the hearts of vertebrates, tunicates and molluscs.
3. If the nerve supply of the vertebrate heart is cut off or even if heart is removed from the body, it continues to beat.

Conducting System

1. Mammals have two contraction nodes namely **SA node (sino-atrial node)** and **AV node (atrio-ventricular node).**
2. The muscle fibres of SA node possess the highest rhythmicity among all cardiac muscle fibres and hence can initiate excitatory waves at the highest rate.
3. So, cardiac impulses normally originate from the SA node. It can generate the maximum number of action potential *i.e.*, 70–75 min^{-1} and is responsible for intiating and maintaining the rhythmic contractile activity of the heart. Therefore, it is called the **pacemaker of heart**.
4. Other parts of the conducting system in mammals are **AV node**, the **AV bundle (also called bundle of His),** the bundle branches and specialized cardiac muscle fibres called **Purkinje fibres**.
5. When the cardiac impulses are spread over the atria to reach AV-node, these run along the AV node, the AV bundle, its branches and Purkinje fibres to reach the ventricular muscle fibres.
6. SA node is located in the right atrial wall below the opening of the superior vena cava.
7. SA node initiates each cardiac cycle and thereby sets the basic pace of the heartbeat, hence its name pacemaker.
8. AV node is situated at the posterior right border of the interatrial septum.
9. SA node initiates impulse at the rate of 72 times per minute.
10. So, in a normal resting man, the rate of heart beat is 72/minute.
11. One heart beat (cardiac cycle) lasts 0.8 second. $\left(\frac{60\,s}{72\text{ cycles}}\right)$

Cardiac Cycle

During each heart beat, the chambers of the heart contract and relax in a definite and a cyclic manner called the Cardiac Cycle.

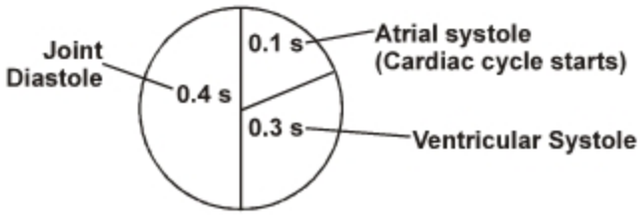


Fig. : Cardiac Cycle

Atrial Systole : New cardiac cycle starts with atrial systole. AV valves open. Blood from auricles enters the ventricles. Back flow to the pulmonary veins is prevented by the oblique openings of pulmonary veins and the compression of openings of other veins in systole.

Ventricular Systole - During ventricular systole**, the pressure in the ventricles is more than auricles. This will cause the closure of AV valves which is heard as 1st heart sound Lub. (Both Tricuspid and Mitral valves close) This sound is of longer duration (0.16 s), louder and low pitched.**

During early Ventricular Systole, AV valves close, semilunar valves are already closed. So, ventricles are contracting but these is no change in their volume. This is called **isovolumetric or isometric contraction**. As the pressure in ventricles increases, semilunar valves will open and the blood enters the great arteries.

Ventricular Diastole : During ventricular diastole, the pressure in ventricles is less than arteries. To prevent the back flow of blood, semilunar valves will close producing second heart sound, Dub. It is of shorter duration (0.1 s), less loud and high pitched. The AV valves are however still closed, so during early diastole, the ventricles relax as closed chambers, There is no change in their volume. This phase is called as **isovolumetric relaxation.**

HS_1 — Lub

HS_2 — Dup

The cardiac cycle ends with **Joint Diastole (0.4 s)** During this phase, the atria and ventricles are relaxed. Blood from great veins is poured into atria. From atria, the blood enters into ventricles (AV valves are open). 2/3rd filling of the ventricles occurs during joint diastole.

1/3rd filling is done during auricular systole. During joint diastole, there is a rapid filling stage followed by a slow filling stage called **Diastasis**.

Cardiac Output : It is the volume of blood pumped by the heart per minute. In one heart beat, the heart pumps out 70 ml of blood, called **stroke volume**.

Cardiac output = Stroke volume × Heart beat rate *i.e.*, 70 ml × 72/min ≈ 5040 ml ≈ 5 L/min.

The cardiac output rises during exercise. In very severe exercise, it may rise to even 20 litres per minute, about four to fivefold the normal resting value of about 5 litres per minutes. The rise in cardiac output helps the body in exercise by enhancing manifolds the supply of nutrients and oxygen to the contracting muscles.

$$\text{Cardiac Index} = \frac{\text{Cardiac output}}{\text{Surface area of the body}}$$

$$= \frac{5 \text{ L/minute}}{1.6 \text{ m}^2} = 3.1 \text{ L/min/m}^2$$

Frank Starling law of Heart : Force of contraction of cardiac muscle fibres is directly proportional to length of cardiac muscle fibres.

Distribution of blood to different parts

1. 10% to heart muscles (500 ml)
2. 15% to brain (750 ml)
3. 20% to kidneys (1000) ml
4. 25% to digestive system (1250 ml)
5. 30% to other organs

Leaky Valves — Defective Valves

The valves will not open and close properly. So, proper heart sounds will not be produced and the heart is said to be murmuring. The instrument used to hear heart sounds is **stethoscope** (PCG = Phonocardiogram).

Electrocardiogram (ECG) : ECG is the graphical representation of electrical activity of heart muscles. To obtain a standard ECG, a patient is connected to the machine with three electrical leads on limbs (one to each wrist and one to the left ankle).

A normal electrocardiogram is composed of a P-wave, a QRS complex and a T-wave.

1. **P-wave –** It is a small upward wave that indicates depolarization of atria *i.e.*, spreading of impulse from SA node throughout atria.
2. **PQ wave –** Auricular contraction
3. **Q-wave** is a small downward deflection.
4. **PQ or PR interval** the time is between the start of P-wave and start of Q-wave. It is the time taken by the impulse to travel through atria, AV node and rest of conducting system. The normal PQ interval is 0.16 s. It lengthens during arteriosclerotic heart disease.
5. **QR wave –** Depolarisation of AV node

   RS wave – Depolarisation of Bundle of His and Purkinje fibres

   QRS wave – Depolarisation of ventricles. By counting QRS complexes that occur in a given time period, one can determine the heart beat rate of an individual.

   ST-Wave – Ventricular contraction, which initiates the ventricular relaxation. The contraction starts shortly after Q and marks the beginning of the systole.

   ST interval is the time between the end of S-wave and end of T-wave. The duration is 0.32 s.

   ST interval is the representation of the time between the end of spread of impulse through ventricles and their repolarisation.

   ST segment is between the end of 'S' and start of T-waves. **ST segment is elevated above baseline in acute myocardial infarction and depressed when heart muscles receive insufficient O_2.**

   T-wave represents ventricular repolarisation. **The end of T-wave marks the end of systole.** When the heart muscles receive insufficient O_2, the T-wave is flattened.

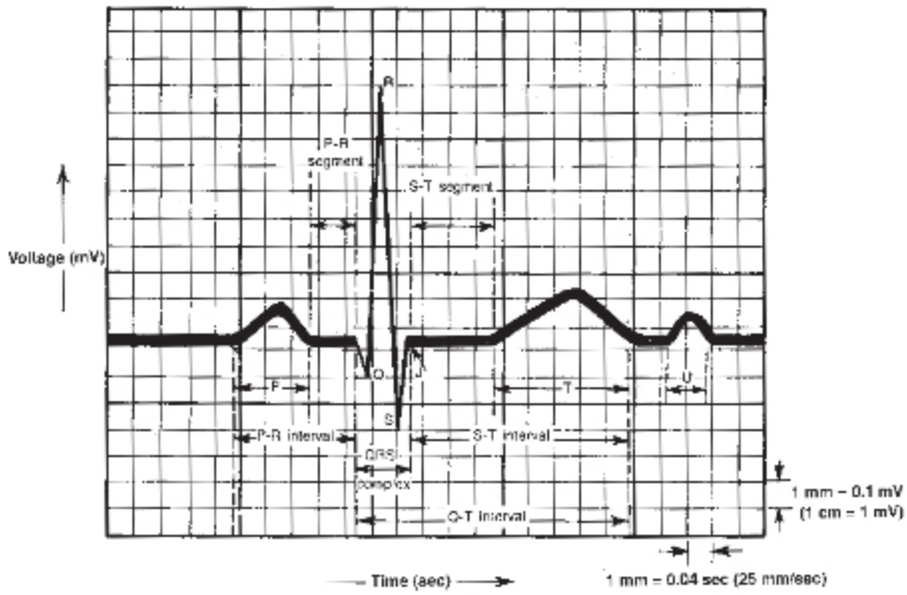


Fig. : Normal Electrocardiogram (ECG)

A patient is hooked up to a monitoring machine that shows voltage traces on a screen and makes the sound ".....pip .....pip .....pip .....peeeeeee" as the patient goes into cardiac arrest.

Double Circulation

As mentioned earlier, the blood pumped by the right ventricle enters the pulmonary artery, whereas the left ventricle pumps blood into the aorta. The deoxygenated blood pumped into the pulmonary artery is passed onto the lungs from where the oxygenated blood is carried by the pulmonary veins into the left atrium. This pathway constitutes the **pulmonary circulation**. The oxygenated blood entering the aorta is carried by a network of arteries, arterioles and capillaries to the tissues from where the deoxygenated blood is collected by a system of venules, veins and vena cava and emptied into the right atrium. This is the **systemic circulation**. The systemic circulation provides nutrients, O_2 and other essential substances to the tissues and takes CO_2 and other harmful substances away for elimination. A unique vascular connection exists between the digestive tract and liver called **hepatic portal system**. The hepatic portal vein carries blood from intestine to the liver before it is delivered to the systemic circulation. A special coronary system of blood vessels is present in our body exclusively for the circulation of blood to and from the cardiac musculature.

Regulation of Cardiac Activity

Normal activities of the heart are regulated intrinsically, *i.e.*, auto regulated by specialised muscles (nodal tissue), hence the heart is called myogenic. A special neural centre in the medulla oblangata can moderate the cardiac function through autonomic nervous system (ANS). Neural signals through the sympathetic nerves (part of ANS) can increase the rate of heart beat, the strength of ventricular contraction and thereby the cardiac output. On the other hand, parasympathetic neural signals (another component of ANS) decrease the rate of heart beat, speed of conduction of action potential and thereby the cardiac output. This happens because these nerves release chemicals (hormones) when stimulated. Adrenal medullary hormones can also increase the cardiac output.

(i) High levels of **potassium** and **sodium** ions decrease heart rate and strength of contraction.

(ii) An excess of **calcium ions** increases heart rate.

(iii) Increased body temperature during fever increases heart rate.

(iv) Strong emotions such as **fear, anger** and **anxiety** increase heart rate, resulting in increased blood pressure.

(v) Mental states such as **depression** and **grief** decrease heart rate.

(vi) The heart beat is somewhat faster in females.

(vii) The heart beat is fastest at birth, moderately fast in youth, average in adulthood and above average in old age.

(viii) Decrease in heart rate is **Bradycardia** and increase in heart rate is **Tachycardia**.

Blood Vessels

The blood flows strictly by a fixed route through **Blood Vessels**—the arteries and veins. Basically, each artery and vein consists of three layers: an inner lining of squamous endothelium, the **tunica intima**, a middle layer of smooth muscle and elastic fibres, the tunica media, and an external layer of fibrous connective tissue with collagen fibres, the **tunica externa**. The tunica media is comparatively thin in the veins.

The wall of blood vessels is typically made of three layers:

(i) Tunica externa : Loose connective tissue containing scattered collagen and elastic fibres, lymph vessel and nerve fibres.

(ii) Tunica media : Circular smooth muscle fibres and elastic fibres.

(iii) Tunica interna : A single layered endothelium of squamous cells.

Arteries

Arteries carry blood away from heart. They are stronger and thicker than veins.

Arteries consist of tunica externa, tunica media (thickest layer which maintains elasticity and contractility) and tunica interna.

Artery is thick-walled in which blood flows under high pressure.

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.

Arterioles

Arterioles are small arteries that deliver blood to capillaries.

Arterioles also have smooth muscles in their walls.

Contraction and relaxation of these muscles alter the diameters of arterioles and thereby respectively decrease and increase the blood flow through them.

Capillaries

Capillary has no muscular wall. Its wall is made of a single layer of flat **endothelial cells** only and is consequently very permeable to water and small solutes but not to proteins and other macromolecules.

The diameter of lumen of capillaries is from 7.5 μm to 75 μm.

Only about 5 to 7% of the total volume of blood is contained in the capillaries.

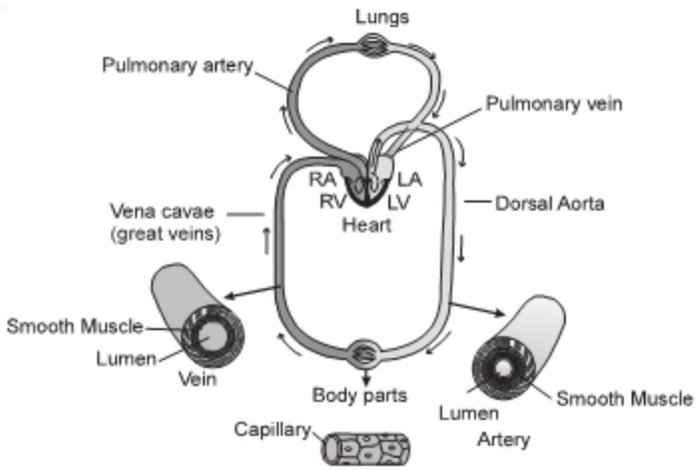


Fig. : Schematic plan of blood circulation in human

Veins

Veins have less elastic tissue and smooth muscles than arteries.

One major difference between an artery and vein is that the vein has a **thin muscular wall**.

Veins contain valves to prevent backflow of blood, as blood flows in them under low pressure.

Weak valves can lead to varicose veins or **haemorrhoids** (Leakage of blood out of veins)

All veins carry deoxygenated blood except **pulmonary veins**. Pulmonary veins carry oxygenated blood from lungs back to the heart.

Walls of veins are collapsible (noncollapsible in arteries).

Lumen of veins is wider and of arteries is narrower.

Most veins are located close to skin (superficial) while arteries are deep seated.

Vasa Vasorum

Small blood vessels which supply blood to walls of thick bloods vessels are called **'vasa vasorum'**.

Blood Pressure

1. Blood pressure means the lateral pressure on the **arterial walls.**
2. The instrument used to measure blood pressure is **sphygmomanometer**.
3. Blood pressure is usually measured from the **left brachial artery**.
4. Normal systolic BP in a healthy adult man is 120 mm Hg.
5. Normal diastolic BP in a healthy adult man is 80 mm Hg.
6. The average blood pressure is expressed as 120/80 mm Hg.
7. **Pulse pressure** is the difference between systolic and diastolic pressure. It averages 40 mm Hg and provides information about the condition of arteries.
8. The normal ratio of **systolic** pressure to **diastolic** pressure to **pulse** pressure is about 3 : 2 : 1.
9. **Hypertension** is the high blood pressure starting from 140/90 mm of Hg and may damage brain, kidneys and heart.

Portal Systems

1. Blood circulation that starts and ends in capillaries is called **portal circulation**.
2. Frog has both **renal portal system** and **hepatic portal system**.
3. Renal portal system is absent in mammals, hepatic portal system is present.
4. Hepatic portal system starts from **digestive system** and ends in liver.
5. **Hypophysial portal system :** Blood from **hypothalamus** is collected by hypophysial portal vein which pours in the **anterior pituitary**.

Some Important Blood Vessels of body

Arteries	Supply to	Veins	Drain from
Pulmonary	Lungs	Jugular	Head
Coronary	Wall of heart		
Subclavian	Forelimbs	Lingual	Tongue
Carotid	Brain (Head)	Femoral	Hindlimbs
Phrenic	**Diaphragm**	Sciatic	Hindlimbs
Hepatic	**Liver**	Hepatic	Liver
Lienogastric	Stomach, Spleen	Hepatic portal	Digestive system
Renal	**Kidneys**	Vesicular	Urinary bladder
Iliac	**Hindlimbs**	Caudal	Tail

DISORDERS OF CIRCULATORY SYSTEM

1. **Coronary artery disease (CAD) :** Coronary artery disease, often referred to as **atherosclerosis**, affects the vessels that supply blood to the heart muscles. It is caused by deposits of calcium, fat, cholesterol and fibrous tissues in coronary arteries which makes the lumen of arteries narrower.
2. **Angina** is also called 'angina pectoris'. A symptom of acute chest pain appears when not enough oxygen is reaching the heart muscles. Angina can occur in men and women of any age but is more common among the middle-aged and elderly. It occurs due to conditions that affect the blood flow.
3. **Heart failure :** Heart failure means the state of heart when it is not pumping blood effectively enough to meet the needs of the body. It is sometimes called congestive heart failure because congestion of the lungs is one of the main symptoms of this disease.
4. **Cardiac arrest** when the heart stops beating.
5. **Heart attack** when the heart muscles are suddenly damaged by an inadequate blood supply.
6. **Atherosclerosis :** It refers to the deposition of lipids (specially cholesterol) on the walls lining the lumen of large and medium sized arteries. Such a deposit is called **atheromatous** or **atherosclerotic plaque**. Its formation starts with the deposition of minute cholesterol particles/crystals in the **tunica interna** and smooth muscles. Gradually, these plaques grow due to proliferation of the fibres and small muscles around them. This results in reduction of the lumen size of the artery and consequently, the flow of blood is also reduced. In extreme circumstances, these plaques may completely block the artery. The proliferation of smooth muscles occurs because these plaques provide a rough surface to the platelets to adhere to, causing the release of **platelet derived growth factor** (PDGF). Such plaques, if formed in the coronary artery, reduce the blood supply to the heart or may stop the supply due to complete blockage. This may result in **heart attack** or **stroke**.
7. **Arteriosclerosis :** In arteriosclerosis, calcium salts precipitate with cholesterol of the formed or forming plaques. This calcification of the plaques ultimately makes the wall of the arteries stiff and rigid and is referred to as the **'hardening of arteries'.** Such affected artery loses the property of distension and its walls may rupture. The blood leaking from the ruptured wall may clot and block the pathway of blood flow. Such a thrombosis or clot formation in the coronary artery may lead to a heart attack and even death.
8. **Coronary thrombosis :** Formation of blood clot in coronary artery can lead to mycocardial infarction. Streptokinase is used to dissolve blood clot.

Artificial Pacemaker

During the pumping action of the heart, the atria and the ventricles contract rhythmically. The impulse of this wave of contraction begins every time from the SA node present in the wall of right atrium. Thus, it can be said that SA node generates the heartbeat, and hence, is the **natural pacemaker** of the heart. Sometimes, the components of the impulse conduction system are disrupted, **causing irregularities in the heart rhythm** like failure of receiving the atrial impulse by ventricles or completely independent contraction of the atria and the ventricles. Such patients are provided with an artificial electronic device which regularly sends off small amounts of electrical charge for maintaining the rhythmicity of the heart. **This device is known as artificial pacemaker** and is implanted subcutaneously in the upper thoracic region having a connection with the heart. In the patients having symptoms of **ventricular escape** (**Stokes - Adams syndrome**) in which the atrial impulses suddenly fail to be transmitted to the ventricles, a condition which may last for a few seconds to even few hours, **the artificial pacemaker is connected to the right ventricle** for controlling its rhythm. The artificial pacemaker consists of a pulse-generator cell (solid state lithium cell) to produce electrical impulses, lead in the form of a wire to transmit the impulses to heart and an electrode which is connected to that portion of heart where impulse is to be transmitted.

LYMPHATIC SYSTEM

It comprises of lymph, lymphatic capillaries, lymphatic vessels, lymphatic ducts and lymphatic nodes.

1. **Lymphatic capillaries :** They lie close to the blood capillaries but end blindly. They have extremely thin walls. They are composed of a single layer of endothelial cells.

2. **Lymphatic vessels :** The lymphatic capillaries unite to form larger lymphatic vessels. They are composed of an outer coat of fibrous tissue, middle coat of muscular tissue and an inner lining of endothelial cells. The lymphatic vessels have numerous valves. The lymph vessels of intestinal regions absorb the digested fats. They are milky in appearance and are called lacteals (lactos : milk).

3. **Thoracic duct :** The lymphatic vessel of left side begins at the **cisterna chyli**, present at the level of (anterior to) the first and second lumbar vertebrae. It discharges its lymph into the **left subclavian vein**.

4. **Right lymphatic duct :** The lymphatic vessels of the right side of the thorax, head and neck unite to form the **right lymphatic duct.** It discharges its lymph into the **right subclavian vein**.

5. **Lymphatic nodes :** The lymphatic vessels bear lymph nodes at intervals and are abundant in the neck, armpit and groin. The lymph is filtered through lymph nodes which contain phagocytic white blood corpuscles and macrophages which eat harmful microorganisms and foreign particles from the lymph. Lymph nodes also add lymphocytes and antibodies.

   Lymph Movement : The lymph flows slowly and moves from lymphatic vessels, lymphatic ducts to the venous system. Blocking of lymph flow causes oedema.

   Lymphoid Organs : The organs which secrete lymph are called lymphoid organs. Besides the lymph nodes, tonsils, thymus gland, Peyer's patches, liver and spleen are the other lymphoid organs that secrete lymph.

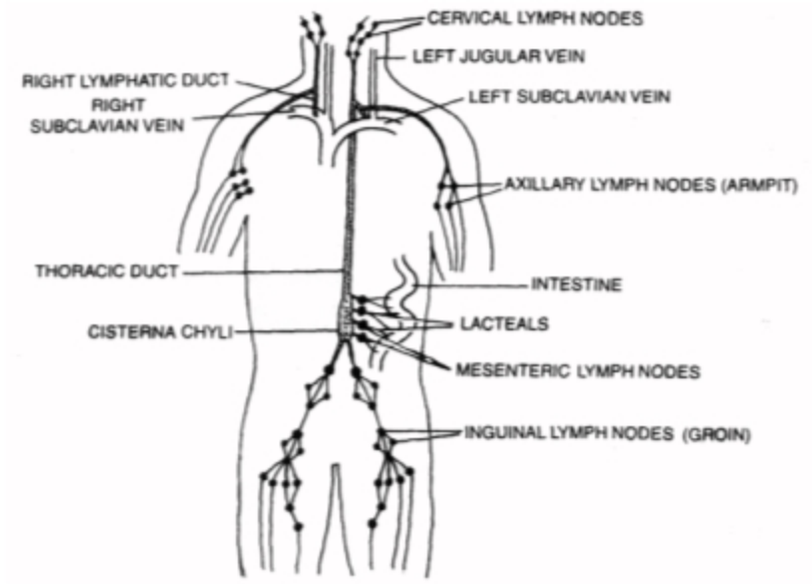


Fig. : Human Lymphatic system

Functions of Lymph

1. Lymph acts as a "middle man" which transports various proteins, hormones, etc., to the body cells and brings carbon dioxide and other metabolic wastes, from the body cells and finally pours the same into the venous system.
2. Lymph nodes produce lymphocytes. Lymph takes lymphocytes and antibodies from the lymph nodes to the blood.
3. It absorbs and transports fat and fat soluble vitamins from the intestine. Lymph capillaries present in the intestinal villi are called **lacteals** which are associated with absorption and transportation of fat and fat soluble vitamins.
4. It brings plasma protein macromolecules synthesized in the liver cells and hormones produced in the endocrine glands to the blood. These molecules can not pass into the narrow blood capillaries but can diffuse into the lymphatic capillaries.
5. Lymph maintains the volume of the blood. As soon as the volume of the blood reduces in the blood vascular system, the lymph rushes from the lymphatic system to the blood vascular system.

❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. RBCs of mammals are
   (1) Non-nucleated, biconcave and circular
   (2) Nucleated, biconvex, oval
   (3) Non-nucleated, biconvex, oval
   (4) Non-nucleated, biconvex and circular
2. Which of the following statements is **incorrect**?
   (1) Increase in RBC count is called polycythemia
   (2) Decrease in leucocyte count is called leucopenia
   (3) Decrease in thrombocyte count is called thrombocytopenia
   (4) Purpura is a group of bleeding disorders due to increase in platelet count
3. Old RBCs are destroyed in 'tissue macrophage system'. In the breakdown of haemoglobin, bilirubin is formed from
   (1) Globin part
   (2) Porphyrin
   (3) Mainly from globin and a part from heme
   (4) Iron part
4. Which of the following cells has kidney shaped nucleus?
   (1) Neutrophils (2) Monocytes
   (3) Lymphocytes (4) Eosinophils
5. Cardiac muscles are
   (1) Striated, voluntary with syncytial condition
   (2) Unstriated, involuntary, uninucleated
   (3) Striated, involuntary with intercalated discs
   (4) Unstriated, voluntary
6. Single circulation of blood is found in
   (1) Fish (2) Frog
   (3) Man (4) Lizard
7. Systemic heart refers to
   (1) The two ventricles together in humans
   (2) The heart that contracts under stimulation from nervous system
   (3) Left atrium and left ventricle in higher vertebrates
   (4) Entire heart in lower vertebrates
8. The middle thick layer of cardiac muscle fibres around heart is known as
   (1) Pericardium (2) Epicardium
   (3) Endocardium (4) Myocardium
9. The aperture between right atrium and right ventricle is guarded by a one way valve called the
   (1) Semilunar valve
   (2) Tricuspid valve
   (3) Bicuspid valve
   (4) Valve of inferior vena cava
10. An oval depression present in the inter-atrial septum of our heart is
    (1) Foramen ovale (2) Fossa ovalis
    (3) Coronary sulcus (4) Septum primum
11. Opening of coronary sinus is guarded by
    (1) Thebasian valve (2) Eustachian valve
    (3) Semilunar valve (4) Bicuspid valve
12. The inner walls of the ventricles have low muscular ridges called
    (1) Endocardium (2) Epicardium
    (3) Columnae carnae (4) None of these
13. Tendons of papillary muscles which are attached to the wall of ventricles are called
    (1) Myocardium (2) Myonemes
    (3) Chordae tendinae (4) AV valves

14. Pulmonary artery in mammalian embryo communicates with systemic aorta by a thin vessel called Ductus - Arteriosus which later closes and remains in adult as
    (1) Fossa ovalis
    (2) Ligamentum arteriosum
    (3) Duct of Botallo
    (4) Carotico-pulmonary aperture

15. Myogenic heart is **not** found in one of the following
    (1) *Octopus* (2) Frog
    (3) Fish (4) Cockroach

16. One of the following lies in the wall of right atrium
    (1) Purkinje fibres (2) bundle of His
    (3) SA node (4) AV node

17. A cardiac cycle involves the sequence
    (1) Joint diastole-ventricular systole-auricular systole
    (2) Auricular systole-ventricular systole-complete cardiac diastole
    (3) Auricular systole-joint diastole-ventricular systole
    (4) Auricular systole-ventricular diastole-joint diastole

18. The heart sound 'lubb' is produced due to
    (1) Closure of AV valves
    (2) Closure of semilunar valves
    (3) Opening of AV valves
    (4) Opening of semilunar valves

19. Second heart sound is
    (1) 'Lubb' at the beginning of ventricular systole
    (2) 'Lubb' at the end of atrial systole
    (3) 'Dup' at the beginning of ventricular diastole
    (4) 'Dup' at the beginning of ventricular systole

20. The duration of atrial systole is
    (1) 0.5 seconds (2) 0.3 seconds
    (3) 0.1 seconds (4) 0.8 seconds

21. The pause between the end of second heart sound (Dup) and the beginning of the first sound (Lubb) of next cardiac cycle is
    (1) 0.3s and coincides with ventricular systole
    (2) 0.5s and coincides with ventricular diastole
    (3) 0.4s and coincides with joint diastole
    (4) 0.1s auricular systole

22. The murmuring in heart takes place due to
    (1) Coronary thrombosis
    (2) Defective leaky valves
    (3) Arterial pulse
    (4) Poorly developed atrium

23. The cardiac output per minute per square meter of the body surface is known as
    (1) Stroke volume index (2) Minute volume
    (3) Cardiac index (4) Systolic discharge

24. If in the ECG of a person, S-T segment is elevated, it indicates
    (1) Acute myocardial infarction
    (2) Ventricular depolarisation
    (3) That heart muscle are receiving insufficient oxygen
    (4) Ventricular failure

25. The end of T wave marks
    (1) Start of systole
    (2) End of ventricular systole
    (3) Ventricular depolarisation
    (4) Atrial depolarisation

26. If a person is suffering with fever, heart beat rate increases. Then the duration of cardiac cycle will
    (1) Remain the same (2) Increase
    (3) Decrease (4) Be irregular

27. Decrease in heart beat rate is called
    (1) Tachycardia (2) Bradycardia
    (3) Tachypnoea (4) Bradykinins

28. For a healthy resting adult person, the systolic/diastolic blood pressures in capillaries are
    (1) 120/80 mm Hg (2) 30/10 mm Hg
    (3) 10/0 mm Hg (4) 160/120 mm Hg

29. Pulse pressure is
    (1) Temporarily elevated pressure during systole and normally averages about 120 mmHg
    (2) The pressure maintained in the arteries during diastole although no blood is pumped into them
    (3) The difference between the systolic pressure and diastolic pressures, it averages about 40 mmHg in a normal person
    (4) Same as heart beat rate

30. The difference in the thickness of the walls of arteries and veins is mainly because of
(1) Tunica externa (2) Tunica media
(3) Tunica interna (4) Endothelium only

31. Hepatic portal system is present in
(1) Fishes, Amphibians and Reptiles
(2) Reptiles and Birds
(3) All mammals
(4) All vertebrates

32. Which of the following cells plays an important role in the growth of atheromatous plaque due to proliferation of the fibres and smooth muscles fibres?
(1) Macrophages (2) Natural killer cells
(3) Lymphocytes (4) Platelets

33. An artificial pacemaker is implanted subcutaneously and connected to the heart in patients
(1) Having 90% blockage of the three main coronary arteries
(2) Having high blood pressure
(3) Having irregularity in heart rhythm
(4) Suffering from arteriosclerosis

34. In ventricular escape (Stokes-Adams syndrome), the electrode of artificial pacemaker is connected to
(1) Left ventricle (2) AV node
(3) Right ventricle (4) SA node

35. Which lymph vessel picks up the lymph from lower body parts, left side of head and opens near the junction of left internal Jugular and subclavian vein?
(1) Cisterna chyli (2) Thoracic duct
(3) Lymphatic duct (4) Inguinal nodes

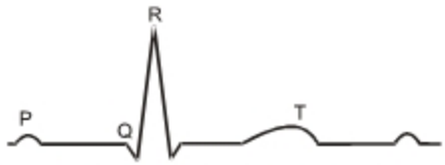
SECTION - B

Previous Years Questions

1. A patient brought to a hospital with myocardial infarction is normally immediately given **[AIPMT 2012]**
(1) Cyclosporin–A (2) Statins
(3) Penicillin (4) Streptokinase

2. Which one of the following human organs is often called the "graveyard" of RBCs? **[AIPMT 2012]**
(1) Gall bladder (2) Kidney
(3) Spleen (4) Liver

3. The diagram given here is the standard ECG of a normal person. The P-wave represents the **[NEET 2013]**



(1) Initiation of the ventricular contraction
(2) Beginning of the systole
(3) End of systole
(4) Contraction of both the atria

4. Person with blood group AB is considered as universal recipient because he has **[AIPMT 2014]**
(1) Both A and B antigens on RBC but no antibodies in the plasma
(2) Both A and B antibodies in the plasma
(3) No antigen on RBC and no antibody in the plasma
(4) Both A and B antigens in the plasma but no antibodies

5. How do parasympathetic neural signals affect the working of the heart? **[AIPMT 2014]**
(1) Reduce both heart rate and cardiac output
(2) Heart rate is increased without affecting the cardiac output
(3) Both heart rate and cardiac output increase
(4) Heart rate decreases but cardiac output increases

6. Which one of the following is **correct**? **[AIPMT-2015]**
(1) Blood = Plasma + RBC + WBC + Platelets
(2) Plasma = Blood – Lymphocytes
(3) Serum = Blood + Fibrinogen
(4) Lymph = Plasma + RBC + WBC

7. Blood pressure in the mammalian aorta is maximum during **[AIPMT-2015]**
(1) Diastole of the right atrium
(2) Systole of the left atrium
(3) Diastole of the right ventricle
(4) Systole of the left ventricle

8. Erythropoiesis starts in **[AIPMT-2015]**
(1) Red bone marrow (2) Kidney
(3) Liver (4) Spleen

9. A man with blood group 'A' marries a woman with blood group 'B'. What are all the possible blood groups of their offsprings? **[AIPMT-2015]**
(1) O only (2) A and B only
(3) A, B and AB only (4) A, B, AB and O

10. Blood pressure in the pulmonary artery is **[NEET 2016]**

(1) Less than that in the venae cavae
(2) Same as that in the aorta
(3) More than that in the carotid
(4) More than that in the pulmonary vein

11. Name the blood cells, whose reduction in number can cause clotting disorder, leading to excessive loss of blood from the body. **[NEET (Phase-2) 2016]**

(1) Erythrocytes (2) Leucocytes
(3) Neutrophils (4) Thrombocytes

12. Serum differs from blood in **[NEET (Phase-2) 2016]**

(1) Lacking globulins
(2) Lacking albumins
(3) Lacking clotting factors
(4) Lacking antibodies

13. The hepatic portal vein drains blood to liver from **[NEET-2017]**

(1) Heart (2) Stomach
(3) Kidneys (4) Intestine

14. Adult human RBCs are enucleate. Which of the following statement(s) is/are most appropriate explanation for this feature?

(a) They do not need to reproduce.
(b) They are somatic cells.
(c) They do not metabolize.
(d) All their internal space is available for oxygen transport. **[NEET-2017]**

(1) Only (d) (2) Only (a)
(3) (a), (c) & (d) (4) (b) & (c)

15. Match the items given in Column I with those in Column II and select the correct option given below : **[NEET-2018]**

	Column I		Column II
a.	Tricuspid valve	i.	Between left atrium and left ventricle
b.	Bicuspid valve	ii.	Between right ventricle and pulmonary artery
c.	Semilunar valve	iii.	Between right atrium and right ventricle

	a	b	c
(1)	i	ii	iii
(2)	i	iii	ii
(3)	iii	i	ii
(4)	ii	i	iii

16. Match the items given in Column I with those in Column II and select the correct option given below : **[NEET-2018]**

	Column I		Column II
a.	Fibrinogen	(i)	Osmotic balance
b.	Globulin	(ii)	Blood clotting
c.	Albumin	(iii)	Defence mechanism

	a	b	c
(1)	(i)	(iii)	(ii)
(2)	(i)	(ii)	(iii)
(3)	(iii)	(ii)	(i)
(4)	(ii)	(iii)	(i)

17. Match the **Column-I** with **Column-II**

	Column-I		Column-II
(a)	P - wave	(i)	Depolarisation of ventricles
(b)	QRS complex	(ii)	Repolarisation of ventricles
(c)	T - wave	(iii)	Coronary ischemia
(d)	Reduction in the size of T-wave	(iv)	Depolarisation of atria
		(v)	Repolarisation of atria

Select the **correct** option. **[NEET-2019]**

	(a)	(b)	(c)	(d)
(1)	(iv)	(i)	(ii)	(iii)
(2)	(iv)	(i)	(ii)	(v)
(3)	(ii)	(i)	(v)	(iii)
(4)	(ii)	(iii)	(v)	(iv)

18. What would be the heart rate of a person if the cardiac output is 5 L, blood volume in the ventricles at the end of diastole is 100 mL and at the end of ventricular systole is 50 mL? **[NEET-2019]**

(1) 50 beats per minute
(2) 75 beats per minute
(3) 100 beats per minute
(4) 125 beats per minute

19. All the components of the nodal tissue are autoexcitable. Why does the SA node act as the normal pacemaker? **[NEET-2019 (Odisha)]**

(1) SA node has the highest rate of depolarisation.

(2) SA node has the lowest rate of depolarisation.

(3) SA node is the only component to generate the threshold potential.

(4) Only SA node can convey the action potential to the other components.

20. A specialised nodal tissue embedded in the lower corner of the right atrium, close to Atrio-ventricular septum, delays the spreading of impulses to heart apex for about 0.1 sec. This delay allows **[NEET-2019 (Odisha)]**

(1) the atria to empty completely.

(2) blood to enter aorta.

(3) the ventricles to empty completely.

(4) blood to enter pulmonary arteries.

❑ ❑ ❑

Chapter 7

Excretory Products and their Elimination

Sub-topics *Modes of Excretion - Ammonotelism, Ureotelism, Uricotelism; Human Excretory System - Structure and Function; Urine Formation, Osmoregulation; Regulation of Kidney Function - Renin-angiotensin, Atrial Natriuretic Factor, ADH and Diabetes Insipidus; Role of other Organs in Excretion; Disorders; Uraemia, Renal Failure, Renal Calculi, Nephritis; Dialysis and Artificial Kidney*

EXCRETION

Excretion is removal of metabolic wastes from the body. It is different from removal of undigested food that is called defaecation or egestion. Carbondioxide and water are metabolic wastes of carbohydrate and fat metabolism.

Mode of Excretion

1. **Ammonotelic :** Excretory product is mainly ammonia. Ammonia molecules being readily soluble in water, easily cross the membrane barriers. In soft bodied invertebrates, ammonia diffuses out across whole body surface while in fishes as NH_4^+ or ammonium ions across gill epithelium, *e.g.*, *Amoeba*, aquatic invertebrates such as, sponges, *Hydra*, cray fish, starfish, vertebrates such as tadpole larva of frog, bony fish.
2. **Ureotelic :** Excretory product is mainly urea. Urea can be tolerated in much more concentrated form because it is 100,000 times less toxic than ammonia. However, entire amount of urea produced is not excreted out but a part is retained in kidney and is involved in osmoregulation. *e.g.*, cartilaginous fish, amphibians and mammals.
3. **Uricotelic :** Excretory product is mainly uric acid. Uric acid can be passed out almost in the form of a precipitate since it is almost insoluble in water. This leads to minimum loss of water. Uricotelism is very important for land vertebrates laying shelled eggs. If the embryo within the shelled egg had produced ammonia or urea, that would have accumulated to toxic level. However this problem is solved by being uricotelic, as uric acid being almost insoluble, gets precipitated and remain with the shell only. This problem is not faced by fishes or amphibians by having shell-less eggs (Ammonia or urea can diffuse out) or mammals (as urea carried away by maternal blood at placenta). *e.g.*, reptiles, birds, cockroach.

Other Metabolic wastes

4. **Xanthines :** It is metabolic waste of nucleotide metabolism, e.g. spiders and penguins.
5. **Guanines :** It is a metabolic waste of nucleotide metabolism, e.g. spiders and penguins.
6. **Trimethylamine oxide :** It is found in marine bony fish.

7. **Ornithuric acid :** It is a specialised product in birds.

8. **Hippuric acid :** It is a specialised product in mammals. It is produced from benzoic acid.

9. **Creatinine :** It is produced from creatine phosphate present in muscles. Increased level of creatinine is indicative of kidney damage.

Excretory organs in animals :

	Animal groups	Main excretory structure
1.	Porifera and cnidaria	Plasma-membrane of each cell
2.	Platyhelminthes (*Planaria*, *Fasciola*, *Taenia*)	Protonephridia or flame cells
3.	Aschelminthes (Round worms)	H-shaped renette cells
4.	Annelids (*Nereis*, *Pheretima*, *Hirudinaria*)	Nephridia
5.	Arthropods	
	(i) Insects, centipedes and millipedes	Malpighian tubules
	(ii) Crustaceans (*e.g., Prawn*)	Antennary or green glands
	(iii) Scorpions and spiders	Coxal glands
6.	Molluscs (*e.g., Unio*)	Keber's organs and organs of Bojanus
7.	Echinodermates (*e.g., Astereas*)	No specialised excretory organ
8.	Hemichordates (*e.g., Balanoglossus*)	Proboscis gland
9.	Urochordates	Neural gland
10.	Cephalochordates	Solenocytes
11.	Vertebrates	1 pair of kidneys

Urea Synthesis (The Ornithine Cycle) is the biochemical aspect of excretion. Also called **Krebs-Henseleit** cycle, it occurs in liver and includes :

(i) Formation of carbamoyl phosphate by the combination of ammonia, CO_2 and ATP.

(ii) Carbamoyl phosphate combines with ornithine to form citrulline.

(iii) Citrulline joins aspartic acid and changes to argininosuccinic acid.

(iv) The latter breaks into fumaric acid and arginine.

(v) With the help of enzyme arginase, arginine is hydrolysed to urea and ornithine (which is thus, regenerated and re-used in the cycle).

(vi) Maximum urea is present in hepatic vein while minimum amount of urea is in renal vein

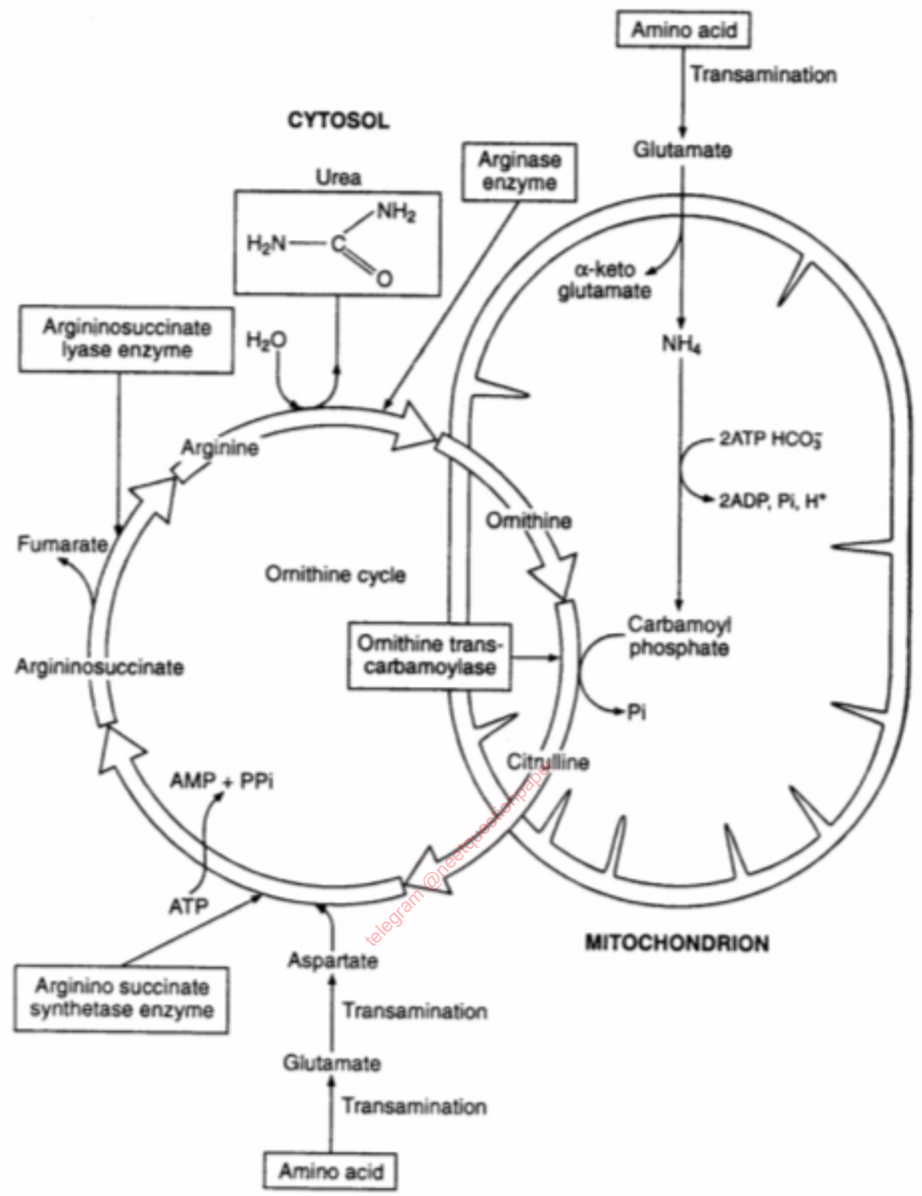


Fig. : Urea Cycle

Human Excretory System

It consists of a pair of kidneys, a pair of ureters, a urinary bladder and a urethra. Kidneys in human are **metanephric**, located near the posterior wall of the abdominal cavity, one on either side of 12^{th} thoracic to 3^{rd} lumbar vertebrae. The kidneys are covered with peritoneum only on the ventral surface, so are called as **retroperitoneal** (behind the peritoneum). Each kidney of an adult human measures 10–12 cm in length, 5–7 cm in width, 2–3 cm in thickness with an average weight of 120–170 g. The right kidney is slightly lower than the left because of the large area occupied by the liver on right side.

On the concave median margin of the kidneys, there is a longitudinal opening called the **hilum (hilus renalis)** through which renal artery and nerves enter and renal vein and ureters leave the kidneys. A longitudinal section through a kidney shows that the hilum leads to an extensive flat, funnel-shaped space called the **pelvis**. The pelvis is almost completely surrounded by the kidney tissue, which is arranged in an outer functional layer called the **renal cortex** and an inner functional layer called **the renal medulla**. Conical pyramid-shaped masses of the renal medulla project into the renal pelvis and are called **medullary pyramids** or **renal pyramids**.

Columns of cortex between the medullary pyramids are called as **Columns of Bertini.** Pyramids contain the functional units of the mammalian kidney, called **nephrons**.

Each kidney has approx. one million nephrons or uriniferous tubules. Each nephron consist of 2 parts :

1. Glomerulus
2. Renal tubule

The glomerulus is a network of capillaries formed from the renal arteriole which originates from the renal artery and is involved in the filtration of blood. Blood from the glomerulus is drained out by an efferent arteriole.

Renal tubule has the following parts :

(i) Bowman's capsule : It is double layered cup like structure. The outer layer is parietal layer and inner layer is visceral layer. Visceral layer has specialised podocytes which are special pedicel bearing cells forming the slit membrane. Bowman's capsule along with glomerulus is called Malpighian corpuscle or renal body.

(ii) Proximal convoluted tubule : It forms a highly coiled structure and is lined by simple cuboidal epithelium having brush bordered surface with abundant mitochondria.

(iii) Henle's loop : It is hairpin shaped part of tubule which has a descending and an ascending limb.

(iv) Distal convoluted tubule : It is also a highly coiled tubular region.

The DCTs of many nephrons open into collecting duct which converge and open into the renal pelvis through medullary pyramids in the calyces.

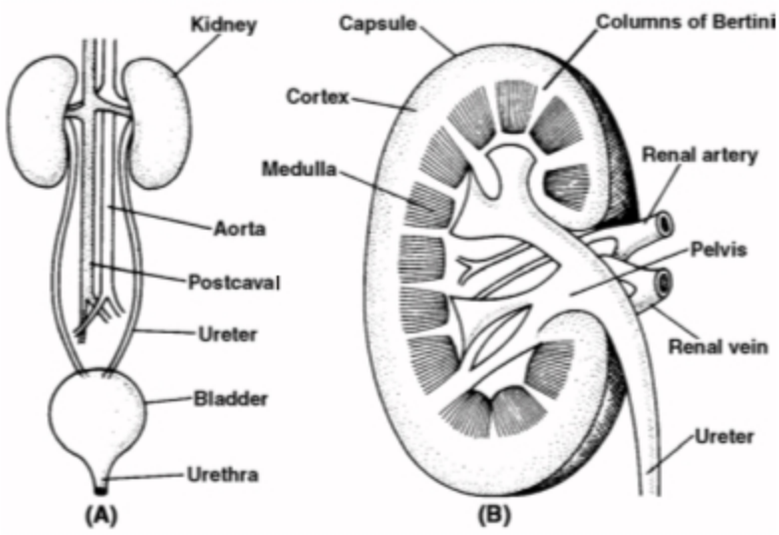


Fig. : (A) Urinary system of man, (B) Internal structure of kidney

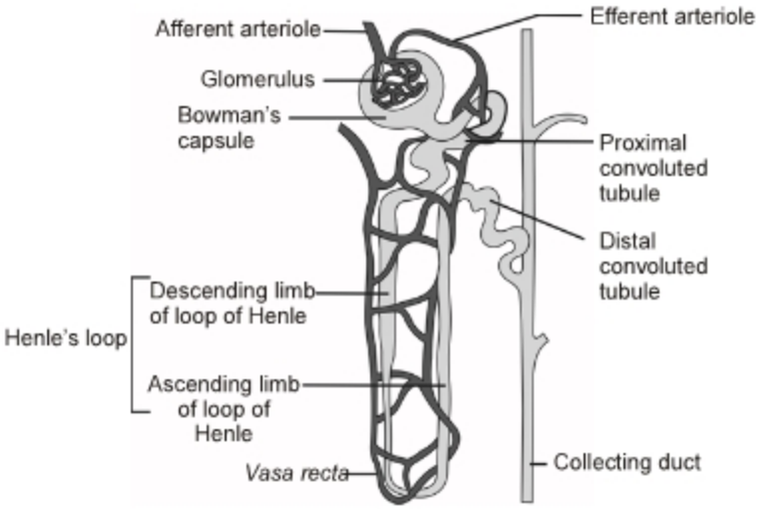


Fig. : A diagrammatic representation of a nephron showing blood vessels, duct and tubule

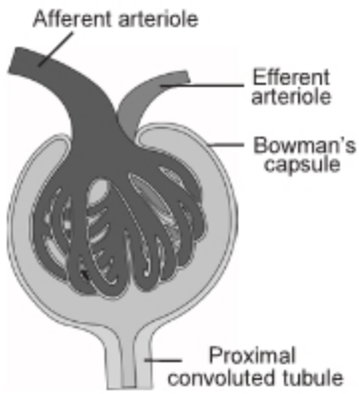


Fig. : Malpighian body (renal corpuscle)

Nephrons are of two types

	Cortical Nephrons	Juxtamedullary Nephrons
1.	85-86%	14-15%
2.	Small in size	Larger
3.	Glomeruli in outer cortex and relatively short loop of Henle that extends upto a short distance into into medulla.	Glomeruli at the junction of cortex and medulla and long loop of Henle that extend deep medulla.
4.	Lack Vasa rectae (blood capillaries around loop of Henle)	Vasa rectae present

The efferent arteriole appearing from glomerulus forms a fine capillary network around renal tubule called peritubular capillaries.

Juxta glomerular Apparatus

Just before the afferent arteriole divides to form glomerulus, its muscle cells are modified as myoepitheloid cells. They are highly vascular with more mitochondria, ribosomes and golgi bodies. These cells are called JG cells and secrete **Renin** and **Erythropoietin**. Renin is a proteolytic enzyme. JG cells of afferent arterioles and macula densa cells of DCT (acting as chemoreceptors) together consitute the JGA (Juxta glomerular apparatus)

Urine Formation

It includes

1. Glomerular Filtration
2. Tubular Reabsorption and
3. Tubular Secretion

1. **Glomerular Filtration :** On an average, 1000-1200 ml of blood is filtered by the kidney per minute. For filtration to take place, some net filtration pressure is required. Net filtration pressure is the difference between glomerular hydrostatic pressure and the sum of osmotic pressure of plasma proteins in the efferent arteriole and fluid already present in the capsule.

(a) Glomerular hydrostatic pressure (GHP) = 60 mmHg

(b) The proteins in efferent arteriole exert an osmotic pressure of 30 mmHg. (BCOP)

(c) Fluid already present in capsule exerts pressure of 20 mmHg. (CHP)

Net filtration pressure = GHP – (BCOP + CHP)

= 60 – (30 + 20) = 10 mmHg

GHP — Glomerular hydrostatic pressure

BCOP — Blood colloidal osmotic pressure

CHP — Capsular hydrostatic pressure

Podocytes are simple squamous epithelial cells **lining inner wall of Bowman's capsule**. From these cells, foot like processes called pedicles arise, they interdigitate between the endothelial cells forming filtration slits of 25 nm, which help in ultra filtration.

Glomerular filtration rate (GFR) is the amount of filtrate formed per minute of kidneys **i.e. 125 ml/min** or **180 L/day**.

Renal plasma Flow (RPF) is the total amount of plasma flowing to kidneys per minute (600–700 ml/m)

So, FF (Filtration fraction) in% $= \frac{GFR}{RPF} \times 100 \approx 18\%$

2. **Tubular Reabsorption**

A comparison of the volume of the filtrate formed per day (180 litres per day) with that of urine released (1.5 litres), suggest that nearly 99 percent of the filtrate has to be reabsorbed by the renal tubules. This process is called reabsorption.

In **PCT**, (proximal convoluted tubule) all glucose, amino acids, 70% Na^+, 75% K and Vitamin C are absorbed by active transport. Cl^- are absorbed by diffusion. 75% of H_2O is absorbed by osmosis.

Glomerular filtrate is isotonic to blood plasma and also lacks plasma proteins and it remains so after passing through PCT.

Absorption of water in PCT is **obligatory** (depends on absorption of other solutes)

Loop of Henle : Minimum reabsorption takes place. In the descending limb of loop of Henle, 5% H_2O is absorbed due to high concentration of medullary interstitial fluid maintained by vasa rectae. Filtrate is now hypertonic to plasma.

Ascending limb of loop of Henle, however, is impermeable to water. Rest of 25% K^+ ions are reabsorbed here Cl^- are also reabsorbed, so Na^+ ions follow them by electrostatic forces of attraction. So, filtrate may become isotonic again. The reabsorption of water in distal convoluted tubule (DCT) depends on the release of ADH (anti diuretic hormone). If ADH is released from posterior pituitary, DCT becomes more permeable to water and filtrate becomes hypertonic. This reabsorption of water in DCT is **facultative**. DCT also functions in K^+ and Na^+ homeostasis. Na^+ are reabsorbed in blood (peritubular capillaries) in exchange of K^+ ions which are secreted in the filtrate. ($Na^+ – K^+$ pump mechanism). It also helps to regulate pH by the reabsorption of HCO_3^-.

3. **Tubular Secretion**

The tubular cells secrete substances like H^+, K^+ and ammonia into the filtrate which helps in pH control and maintains level of ions.

Along with PCT and DCT, collecting duct also plays a role in the maintenance of pH and ionic balance of blood by the selective secretion of H^+ and K^+ ions.

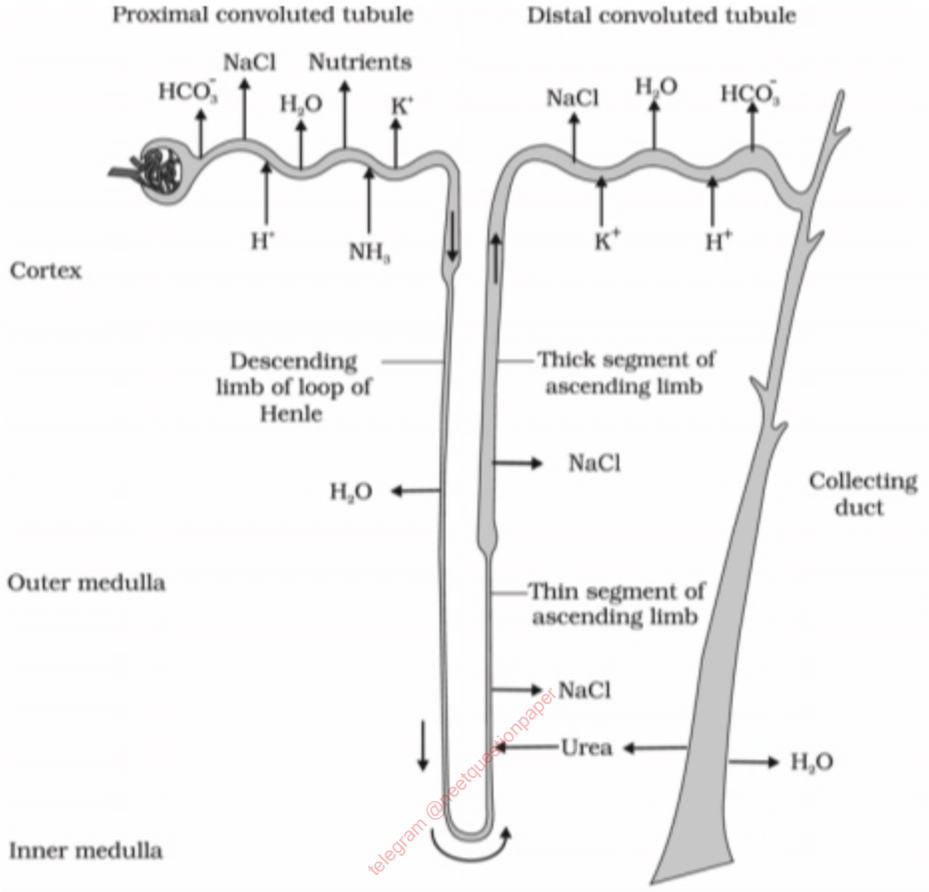


Fig. : Reabsorption and tubular secretion of major substances at different parts of the nephron (Arrows indicate direction of movement of materials)

H^+ secretion is a process in whose exchange HCO_3^- are reabsorbed from the tubule. The process of H^+ ions secretion and bicarbonate ion reabsorption occurs throughout the tubule except in the descending limb of loop of Henle. H^+ ions secretion makes the urine more acidic. The secretion of H^+ ions is an active process and is coupled with the absorption of Na^+ and HCO_3^-.

Function of the Tubules

Proximal Convoluted Tubule (PCT) : PCT is lined by simple cuboidal brush border epithelium which increases the surface area for reabsorption. Nearly all of the essential nutrients, and 70-80 per cent of electrolytes and water are reabsorbed by this segment. PCT also helps to maintain the pH and ionic balance of the body fluids by selective secretion of hydrogen ions, ammonia and potassium ions into the filtrate and by absorption of HCO_3^- from it.

Henle's Loop : **Reabsorption in its ascending limb is minimum**. However, this region plays a significant role in the maintenance of high osmolarity of medullary interstitial fluid. The descending limb of loop of Henle is permeable to water but almost impermeable to electrolytes. This concentrates the filtrate as it moves down. The ascending limb is impermeable to water but allows transport of electrolytes actively or passively. Therefore, as the concentrated filtrate pass upward, it gets diluted due to the passage of electrolytes to the medullary fluid.

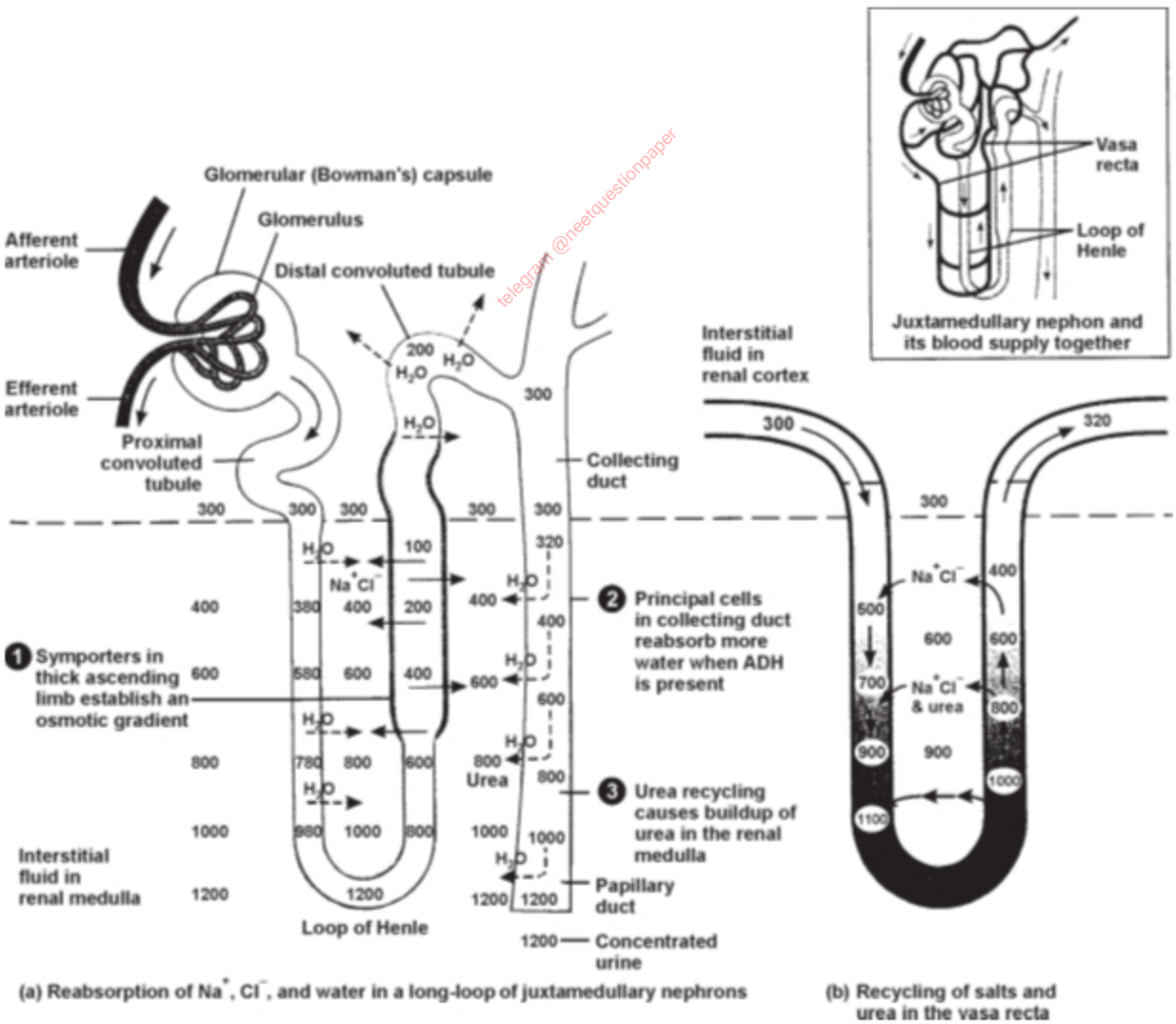
Distal Convoluted Tubule (DCT) : Conditional reabsorption of Na^+ and water takes place in this segment. DCT is also capable of reabsorption of HCO_3^- and selective secretion of hydrogen and potassium ions and NH_3 to maintain the pH and sodium-potassium balance in blood.

Collecting Duct : This long duct extends from the cortex of the kidney to the inner parts of the medulla. Large amounts of water could be reabsorbed from this region to produce a concentrated urine. This segment allows passage of small amounts of urea into the medullary interstitium to keep up the osmolarity. It also plays a role in the maintenance of pH and ionic balance of blood by the selective secretion of H^+ and K^+ ions.

Mechanism of concentration of the filtrate

Counter-current system : It is a mechanism to retain water in the body and occurs in the vasa rectae and loop of Henle. The blood flows in opposite directions in the two limbs of each vasa rectae; and even the glomerular filtrate moves in opposite directions in the limbs of loop of Henle. These counter-current systems significantly contribute to concentrate urine in the mammalian kidney. It is the cyclic movement of Na^+, Cl^- from the ascending limb of loop of Henle to the descending limb of vasa rectae via the medullary interstitial fluid. This is responsible for 5% reabsorption of water in the descending limb of Henle's loop, making the filtrate hypertonic. Due to this, concentration of Na^+ and Cl^- in renal medulla is higher as compared to renal cortex. The interstitial fluid of the kidney increases in osmolarity from about 300 to 1200 mol mL^{-1} from the cortex to the inner medulla, concentrating the urine.

Urine concentration occurs in long-loop of juxtamedullary nephrons. The presence of symporters in the thick ascending limb of the loop of Henle causes a simultaneous reabsorbption of a sodium ion (Na^+), a potassium ion (K^+) and two chloride ions ($2Cl^-$) into the interstitial fluid of the renal medulla. Also, this portion of the nephron is relatively impermeable to water and urea.



(a) Reabsorption of Na^+, Cl^-, and water in a long-loop of juxtamedullary nephrons

(b) Recycling of salts and urea in the vasa recta

REGULATION OF KIDNEY FUNCTION

The functioning of the kidney is efficiently monitored and regulated by hormonal feedback and regulated by hormonal feedback mechanisms involving the hypothalamus, JGA and to a certain extent, the heart.

1. Osmoreceptors

Osmoreceptors in the body are activated by changes in blood volume, body fluid volume and ionic concentration. An excessive loss of fluid from the body can activate these receptors which stimulate the hypothalamus to release ADH or vasopressin from the neurohypophysis. ADH facilitates water reabsorption from latter parts of the tubule, thereby preventing diuresis. An increase in body fluid volume can switch off the osmoreceptors and suppress the ADH release to complete the feedback. ADH can also affect the kidney function by its constrictory effects on blood vessels. This causes an increase in blood pressure. An increase in blood pressure can increase the glomerular blood flow and thereby the GFR.

2. Renin Angiotensin Aldosterone System (RAAS)

The JGA responds to

1. Decrease in B.P. and
2. Decrease in blood volume in the afferent arteriole of glomerulus and releases enzyme Renin into the blood.

$$\underset{\text{(inactive plasma protein)}}{\text{Angiotensinogen}} \xrightarrow{\text{Renin}} \text{Angiotensin - I} \xrightarrow{\text{ACE}} \text{Angiotensin - II}$$

ACE – Angiotensin converting enzyme (in lungs)

Angiotensin II is a peptide which works as a hormone. It increases the BP by causing the arterioles to constrict. It also contributes to an increase in the blood volume.

1. By signalling the PCT to absorb more NaCl and H_2O and
2. By stimulating the release of aldosterone from adrenal cortex.

Aldosterone signals the DCT to absorb more Na^+ and H_2O.

3. Atrial Natriuretic Factor (ANF) :

It opposes RAAS. The wall of atria release ANF in response to high B.P. and blood volume. ANF inhibits the release of Renin.

The other important **intrinsic mechanism** that provides autoregulation to glomerular filtration rate is

Myogenic Mechanism : An increase in blood pressure will tend to stretch the walls of arteriole. The wall of afferent arteriole however responds to the stretch by contraction, the diameter is reduced, increasing the resistance to flow. Thus, this mechanism reduces blood flow to the glomerulus in case of increase in B.P.

ADH and Diabetes Insipidus

Deficiency of ADH results in excessive loss of water or increased urinary output. This condition is called Diabetes insipidus. Other symptoms are excessive thirst and dehydration.

Threshold substances

High threshold substances are those which are excreted in the urine only when their blood concentration is considerably high *e.g.*, glucose and amino acids. **Renal threshold of a substance is its highest concentration in the blood upto which it is totally reabsorbed from the glomerular filtrate**. If its blood concentration exceeds the renal threshold, so much of it is filtered in the glomerular filtrate and it can no longer be totally reabsorbed; consequently, it appears in the urine. For example, glucose is a high threshold substance its renal threshold is as high as 180 mg per 100 ml of plasma; it is totally reabsorbed and does not appear in the urine so long as its blood level does not exceed 180 mg/100 ml. But when its blood level exceeds 180 mg/100 ml, some of the filtered glucose is left unabsorbed in the renal tubules and consequently appears in the urine.

MICTURITION

Voiding or expulsion of urine stored in the urinary bladder is called micturition. Urinary bladder gets gradually filled up with the urine. Though the capacity of urinary bladder is about 800 ml, but as the volume is around 500 ml, its wall gets stretched. Urine formed by nephrons is ultimately carried to the urinary bladder where it is stored till a voluntary signal which is initiated by the stretching of urinary bladder as it gets fill with urine. Stretch receptors generate nerve impulse that is carried by sensory neuron to brain producing the sensation of fullness. This initiates the autonomic reflex (parasympathetic involving sacral spinal nerves) resulting in contraction of detrusor muscles of urinary bladder and inhibition of motor impulse of voluntary, striated external sphincter, making it relaxed; and urine comes out.

Micturition can be initiated voluntarily also by contracting the abdominal muscle which applies pressure over urinary bladder, activating the stretch receptors.

The process of release of urine is called micturition and the neural mechanism causing it is called micturition reflex. An adult human excretes, on an average, 1–1.5 litres of urine in 24 hours, **25–30 g** of urea is excreted with it.

Role of other Organs in Excretion

Other than the kidneys, lungs, liver and skin also help in the elimination of excretory wastes.

1. **Lungs :** Our lungs remove large amounts of CO_2 (**approximately 200 ml/min**) and also significant quantities of water every day.
2. **Liver :** Liver, the largest gland in our body, secretes bile-containing substances like bilirubin, biliverdin, cholesterol, degraded steroid hormones, vitamins and drugs. Most of these substances ultimately pass out alongwith digestive wastes.
3. **Skin :** The sweat and sebaceous glands in the skin can eliminate certain substances through their secretions. Sweat produced by the sweat glands is a watery fluid containing NaCl, small amounts of urea, lactic acid, etc. Though the primary function of sweat is to facilitate a cooling effect on the body surface, it also helps in the removal of some of the wastes mentioned above. Sebaceous glands eliminate certain substances like sterols, hydrocarbons and waxes through sebum. This secretion provides a protective oily covering for the skin. Small amounts of nitrogenous wastes could be eliminated through saliva too. Some nitrogenous waste is also eliminated through saliva.

Disorders of the excretory system

Malfunctioning of kidneys can lead to accumulation of urea in blood, a condition called **uremia** which is highly harmful and may lead to kidney failure. In such patients, urea can be removed by a process called **haemodialysis**. This method is a boon for thousands of uremic patients all over the world.

1. **Uremia :** Higher concentration of urea in blood.
2. **Renal failure :** Renal or kidney failure is a life threatening situation and can occur due to acute or chronic infections, long standing diabetes, untreated high blood pressure or auto immunity. It results in accumulation of urea and H^+ in the blood. In complete renal failure, only two treatment option remain dialysis or kidney transplant.
3. **Renal calculi :** Stones or insoluble masses of crystallised salts (oxalates, etc.) formed within the kidney.
4. **Nephritis:** Inflammation of nephron and may involve glomerulus or the Bowman's capsule - Glomerulonephritis.
5. **Haemoglobinuria :** Presence of haemoglobin in urine.
6. **Albuminuria :** Presence of albumin in urine; usually occurs in nephritis (inflammation of glomerulus)
7. **Haematuria :** Presence of blood or blood cells in the urine.

ARTIFICIAL KIDNEY

When the kidneys are completely damaged and do not function, the patient often receives **haemodialysis** (treatment with an artificial kidney). **During the process of haemodialysis the blood drained from a convenient artery is pumped into a dialysing unit called artificial kidney.** Haemodialysis is the separation of certain substances from blood by use of a selectively permeable membrane. The pores in the membrane allow some substances to pass through, however, prevent others. The patient is connected to the machine by a tube attached to an artery often the radial artery. Blood from the artery is pumped into a tube that runs through the dialyzer. The dialyzer is filled with dialysis fluid which contains the same quantities of electrolytes and nutrients as normal plasma but contains no waste products. The **cellophane tube** (a tube bounded by thin membrane) is kept in the dialysis fluid. The pores in the cellophane tube do not allow the movement of blood cells and proteins from the blood into the dialysis fluid, but are large enough to allow smaller molecules to diffuse into the fluid. Molecules of waste substances such as urea, ammonia and waste diffuse into the dialysis fluid. Diffusion of other substances such as glucose, amino acids and electrolysis is prevented by the presence of these substances in the dialysis fluid in the same concentration as in the normal plasma. Now the blood is returned to the patient body through a vein usually the **radial vein.**

When the blood is taken out, it is cooled to 0°C, mixed with anticoagulant and then pumped into artificial kidney. The blood coming out of the artificial kidney is warmed to body temperature, mixed with antiheparin, and returned to vein.

KIDNEY TRANSPLANTATION

When both the kidneys are completely damaged, kidney transplantation is done. The world's first successful organ transplant was kidney transplantation which was undertaken by David Hume and Joseph Kelly at the Peter Bent Brigham Hospital in Boston in 1954. The recipient was Richard Heerick who lived for a further eight years. The first kidney transplant in India was performed on Dec. 1, 1971 at the Christian Medical College, Vellore (Tamil Nadu) on a 35 year old patient named Shanmughan.

Most patients need to be dialysed before transplantation to avoid fluid overload and hyperkalaemia after the operation. Antibiotics and immunosuppressive drugs are given before the operation. Postoperative care is very essential.

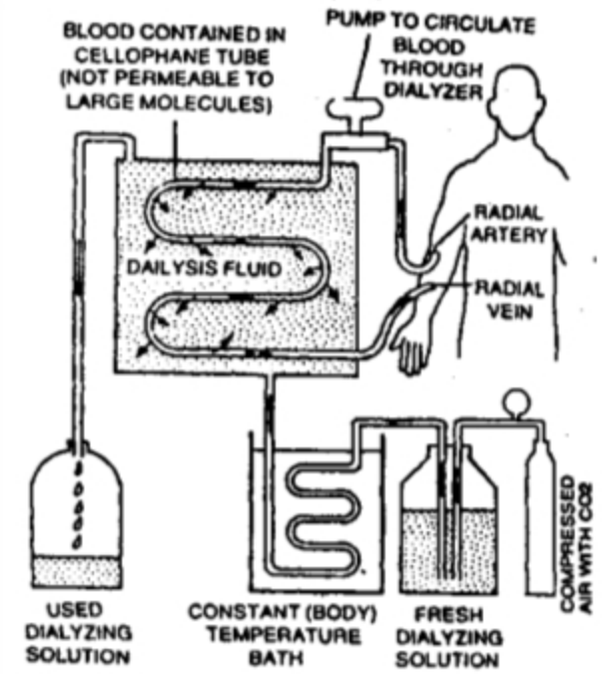


Fig. : A Schematic diagram to show the working of an artificial kidney

Osmoconformers and Osmoregulators

The regulation of solute movement, and hence water movement, which follows solutes by osmosis, is known as osmoregulation.

Osmoconformers are the animals that do not actively control the osmotic conditions of their body fluids. They rather change the osmolarity of body fluids according to the osmolarity of the ambient medium. All marine invertebrates and some freshwater invertebrates are strictly osmoconformers. Hagfish is a vertebrate osmoconformer. Osmoconformers show an excellent ability to tolerate a wide range of cellular osmotic environments.

Osmoregulators, on the other hand, are the animals that maintain a constant internal osmolarity, different from the surrounding medium which they inhabit. Many aquatic invertebrates are strict or limited osmoregulators. Most vertebrates are strict osmoregulators, *i.e.*, they maintain the composition of the body fluids within a narrow osmotic range. **The notable exception, however, are the hagfish (*Myxine*, a marine cyclostome) and elasmobranchs (sharks and rays).**

Osmoregulators must either eliminate excess water if they live in a hypotonic medium or continuously take in water to compensate for water loss if they are in hypertonic medium. Therefore, osmoregulators have to spend energy to move solutes in or out and maintain constant osmotic gradients by manipulating solute concentrations in their body fluids.

Water and Solute Regulation in Freshwater Organisms : Osmolarity of freshwater is generally much less than 50 mosm L^{-1} while the freshwater vertebrates have blood osmolarities in the range of 200 to 300 mosm L^{-1}. The body fluids of freshwater animals are hence generally hypertonic to their surrounding environment and they suffer from endosmosis.

Protozoa (*Amoeba, Paramecium*) have contractile vacuoles that pump out excess water from the cell.

***Amoeba* removes the nitrogenous waste in the form of NH_3, through the plasma membrane.**

Animals excrets large amounts of dilute urine to rid of excess water and do not drink water.

Water and Solute Regulation in Marine Environment : Sea water usually has an osmolarity of about 1000 mosm L^{-1}. Osmolarity of human blood in about 300 mosm L^{-1}. The osmoregulatory problems in marine water are opposite to those in freshwater environment. Marine bony fish have the body fluids which are hypotonic to seawater, and thereby, they tend to lose water from the body through permeable surfaces (gill membranes, oral and anal membranes). To compensate for the water loss, marine bony fish drink seawater. However, drinking seawater results in a gain of excess salts. The **ionocytes** or **chloride cells** of the gill membranes of marine bony fish help to **eliminate excess monovalent ions** from the body fluid to the seawater. Excess divalent ions are removed along with faecal matter.

In general, the body fluids of marine invertebrates, ascidians and the hagfish are isosmotic to seawater. Osmolarity of the body fluids is raised by accumulating certain organic substances (Osmolytes) in the body. Retention of osmolytes in body fluids reduces the osmoregulatory challenges. The best known examples of such organic osmolytes are urea and trimethylamine oxide (TMAO). Body fluids of sharks and coelacanths are slightly hyperosmotic to seawater due to retention of urea and TMAO while hypoionic to seawater as they maintain far lower concentration of inorganic ions in the body fluids.

Water and Solute Regulation in Terrestrial Environment

1. Humans die if they lose around 12 percent of the body water. Therefore, water loss must be compensated by drinking and eating moist food.

2. Desert mammals are well adapted to minimise water loss. **Kangaroo rats,** for example lose so little water that they can recover 90 percent of the loss by using metabolic water (water derived from different cellular metabolic processes). The **nasal countercurrent mechanism for conserving respiratory moisture is also important**.

3. **Camels :** When water is not available, the camels do not produce urine but store urea in tissues and solely depend on metabolic water. When water is available, they rehydrate themselves by drinking up to 80 litres of water in 10 minutes.

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Try Yourself

SECTION - A

Objective Type Questions

1. In amoeba, NH_3 is excreted through
   (1) Food vacuole (2) Contractile vacuole
   (3) Plasma membrane (4) All of these
2. Trimethylamine is excreted by
   (1) Fresh water fish (2) Marine teleosts
   (3) Amphibians (4) Molluscs
3. One of the following can retain a large amount of urea in the blood and tissue fluid. Choose the correct option
   (1) Mammals including man
   (2) Toad, Frog, Prawn
   (3) Sharks, Electric ray, Sting ray
   (4) Alligators, Terrapins, Turtles
4. Ornithine cycle removes two waste products from blood in liver which are
   (1) Urea and carbondioxide
   (2) Carbondioxide and ammonia
   (3) Ammonia and urea
   (4) Ammonia and uric acid
5. The kidneys resemble contractile vacuoles of protozoans in
   (1) Expelling out excess water
   (2) Expelling out excess glucose
   (3) Expelling out urea and uric acid
   (4) Expelling out salts
6. The position of kidneys in human is
   (1) Inter-peritoneal (2) Retroperitoneal
   (3) Intraperitoneal (4) None of these
7. Columns of Bertini in the kidneys of mammals are formed as extensions of
   (1) Medulla in cortex (2) Cortex in medulla
   (3) Medulla in pelvis (4) Pelvis in ureter
8. Ducts of Bellini are formed by joining together of
   (1) Collecting ducts
   (2) Peritubular capillaries
   (3) Medullary pyramids
   (4) Calyces of the pelvis
9. Which of the following is **not** a correct statement for Juxtamedullary nephrons?
   (1) They have long loops of Henle placed deep into the medulla and are associated with vasa rectae
   (2) Their glomeruli are placed close to inner margin of cortex
   (3) They are less in number (about 14-15 percent of the nephrons)
   (4) They lack vasa rectae
10. Mark the **incorrect** statement
    (1) The JGA responds to increase in blood pressure or blood volume in the afferent arteriole of glomerulus
    (2) Renin converts angiotensinogen to a peptide angiotensin
    (3) Angiotensin-II increases blood pressure by causing arterioles to constrict
    (4) The walls of the atria release ANF in response to an increase in blood volume and pressure and opposes RAAS
11. Glomerulus and its surrounding Bowman's capsule together form the specialised structure called
    (1) Malpighian tubule (2) Rete mirabilia
    (3) Malpighian corpuscle (4) Green gland
12. Podocytes occur in the wall of
    (1) Neck region of nephrons
    (2) Glomerular capillaries
    (3) Outer wall of Bowman's capsule
    (4) Inner wall of Bowman's capsule

13. Which of the following is correct?
(1) GHP = EFP – CHP
(2) BCOP = GHP – CHP
(3) CHP = EFP + GHP
(4) EFP = GHP – (BCOP + CHP)

14. Total pressure which tends to move the fluid in glomerulus in reverse direction is
(1) –30 mm Hg
(2) –50 mm Hg
(3) –75 mm Hg
(4) –10 mm Hg

15. The glomerular filtration rate in a normal adult human being is
(1) 125 ml per minute
(2) 180 litres per day
(3) Both (1) & (2)
(4) 100 ml per minute

16. Most of the glucose, amino acids, Na^+, K^+ are reabsorbed by active transport in
(1) PCT (2) DCT
(3) Henle's loop (4) Collecting tubules

17. Which one of the following is impermeable to water?
(1) PCT
(2) DCT
(3) Descending limb of Henle's loop
(4) Ascending limb of Henle's loop

18. The reabsorption of water in the distal convoluted tubule is called
(1) Obligatory reabsorption
(2) Facultative reabsorption
(3) Autoregulation
(4) Filtration fraction

19. If the diameter of afferent renal arteriole is decreased and that of efferent renal arteriole is increased, ultrafiltration will
(1) Be faster
(2) Be slower
(3) Not take place
(4) Take place at the same speed

20. Concentration of sodium and chloride ions is lowest
(1) Near the cortex
(2) Deep in medulla
(3) In the interstitial fluid
(4) In the middle of Henle's loop

21. Diuresis is the condition in which
(1) The volume of urine excreted increases
(2) The volume of urine excreted decreases
(3) The kidneys fails to excrete urine
(4) All of these can occur

22. The release of ADH is triggered when the osmoreceptors in the hypothalamus detect a/an
(1) Decrease in osmolarity of the blood below the set point of 300 mosmL^{-1}
(2) Increase in osmolarity of blood above a set point of 300 mosmL^{-1}
(3) Increase in blood volume
(4) Constant osmolarity

23. Which of the following are intrinsic mechanisms to control auto-regulation of glomerular filtration rate?
(1) Myogenic mechanism
(2) Juxta glomerular apparatus
(3) Neural control
(4) Both (1) & (2)

24. If Henle's loop were to be absent from mammalian nephron, which of the following is to be expected?
(1) There will be no urine formation
(2) There will be hardly any change in the quality and quantity of urine formed
(3) The urine will become more concentrated
(4) The urine will become more dilute

25. Reabsorption of Na^+ is controlled by
(1) Vasopressin or ADH (2) Aldosterone
(3) Renin (4) Rennin

26. The yellow colour of urine is due to
(1) Uric acid (2) Urea
(3) Urochrome (4) Melanin

27. The presence of blood cells in urine is called
(1) Hemoglobinuria (2) Albuminuria
(3) Haematuria (4) Uraemia

28. Glucose will appear in the urine of a diabetic person only when
    (1) The concentration of glucose in blood is 150 mg/100 ml
    (2) When the concentration of glucose in blood exceeds 180 mg/100 ml
    (3) When the concentration of glucose in blood exceeds the renal threshold of glucose
    (4) Both (2) & (3)
29. A fresh water fish carries out osmoregulation by
    (1) Continuously taking in water and eliminating excess of salts
    (2) Eliminating excess of water and taking up salts from the environment
    (3) Taking both water and salt from the environment
    (4) Eliminating both salt and water into the environment
30. Hag fish (*Myxine*) a marine cyclostome and elasmobranchs (sharks and rays) are
    (1) Osmoregulators
    (2) Osmoconformers
    (3) The animals that do not actively control the osmotic conditions of their body fluids. They rather change the osmolarity of the body fluids according to the ambient medium
    (4) Both (2) & (3) are correct

SECTION - B

Previous Years Questions

1. The maximum amount of electrolytes and water (70 - 80 percent) from the glomerular filtrate is reabsorbed in which part of the nephron? **[AIPMT 2012]**
    (1) Proximal convoluted tubule
    (2) Descending limb of loop of Henle
    (3) Ascending limb of loop of Henle
    (4) Distal convoluted tubule
2. A fall in glomerular filtration rate (GFR) activates **[AIPMT 2012]**
    (1) Juxta glomerular cells to release renin
    (2) Adrenal cortex to release aldosterone
    (3) Adrenal medulla to release adrenaline
    (4) Posterior pituitary to release vasopressin
3. Which one of the following options gives the **correct** categorisation of six animals according to the type of nitrogenous wastes (A, B, C) they give out? **[AIPMT 2012]**

	A AMMONO TELIC	B UREOTELIC	C URICOTELIC
(1)	Pigeon, Humans	Aquatic Amphibia, Lizards	Cockroach, Frog
(2)	Frog, Lizards	Aquatic Amphibia, Humans	Cockroach, Pigeon
(3)	Aquatic Amphibia	Frog, Humans	Pigeon, Lizards, Cockroach
(4)	Aquatic Amphibia	Cockroach, Humans	Frog, Pigeon, Lizards

4. Which of the following causes an increase in sodium reabsorption in the distal convoluted tubule? **[AIPMT 2014]**
    (1) Increase in aldosterone levels
    (2) Increase in antidiuretic hormone levels
    (3) Decrease in aldosterone levels
    (4) Decrease in antidiuretic hormone levels
5. Human urine is usually acidic because **[Re-AIPMT-2015]**
    (1) Hydrogen ions are actively secreted into the filtrate
    (2) The sodium transporter exchanges one hydrogen ion for each sodium ion, in peritubular capillaries
    (3) Excreted plasma proteins are acidic
    (4) Potassium and sodium exchange generates acidity
6. Removal of proximal convoluted tubule from the nephron will result in **[AIPMT-2015]**
    (1) No urine formation
    (2) More diluted urine
    (3) More concentrated urine
    (4) No change in quality and quantity of urine
7. Which of the following does **not** favour the formation of large quantities of dilute urine? **[AIPMT-2015]**
    (1) Atrial-natriuretic factor
    (2) Alcohol
    (3) Caffeine
    (4) Renin

8. In mammals, which blood vessel would normally carry largest amount of urea? **[NEET 2016]**
   (1) Hepatic Portal Vein
   (2) Renal Vein
   (3) Dorsal Aorta
   (4) Hepatic Vein

9. The part of nephron involved in active reabsorption of sodium is **[NEET (Phase-2) 2016]**
   (1) Distal convoluted tubule
   (2) Proximal convoluted tubule
   (3) Bowman's capsule
   (4) Descending limb of Henle's loop

10. A decrease in blood pressure/volume will not cause the release of **[NEET-2017]**
    (1) Renin
    (2) Atrial Natriuretic Factor
    (3) Aldosterone
    (4) ADH

11. Which of the following statements is correct? **[NEET-2017]**
    (1) The ascending limb of loop of Henle is impermeable to water
    (2) The descending limb of loop of Henle is impermeable to water
    (3) The ascending limb of loop of Henle is permeable to water
    (4) The descending limb of loop of Henle is permeable to electrolytes

12. Match the items given in Column I with those in Column II and select the correct option given below : **[NEET 2018]**

	Column I		**Column II**
a.	Glycosuria	i.	Accumulation of uric acid in joints
b.	Gout	ii.	Mass of crystallised salts within the kidney
c.	Renal calculi	iii.	Inflammation in glomeruli
d.	Glomerular nephritis	iv.	Presence of glucose in urine

	a	b	c	d
(1)	ii	iii	i	iv
(2)	i	ii	iii	iv
(3)	iii	ii	iv	i
(4)	iv	i	ii	iii

13. Match the items given in Column I with those in Column II and select the correct option given below: **[NEET 2018]**

	Column I (Function)		**Column II (Part of Excretory system)**
a.	Ultrafiltration	i.	Henle's loop
b.	Concentration of urine	ii.	Ureter
c.	Transport of urine	iii.	Urinary bladder
d.	Storage of urine	iv.	Malpighian corpuscle
		v.	Proximal convoluted tubule

	a	b	c	d
(1)	v	iv	i	ii
(2)	iv	i	ii	iii
(3)	iv	v	ii	iii
(4)	v	iv	i	iii

14. Which of the following factors is responsible for the formation of concentrated urine? **[NEET-2019]**
    (1) Low levels of antidiuretic hormone
    (2) Maintaining hyperosmolarity towards inner medullary interstitium in the kidneys.
    (3) Secretion of erythropoietin by Juxtaglomerular complex
    (4) Hydrostatic pressure during glomerular filtration

15. Use of an artificial kidney during hemodialysis may result in :
    (a) Nitrogenous waste build-up in the body
    (b) Non-elimination of excess potassium ions
    (c) Reduced absorption of calcium ions from gastro-intestinal tract
    (d) Reduced RBC production

    Which of the following options is the most **appropriate**? **[NEET-2019]**
    (1) (a) and (b) are correct
    (2) (b) and (c) are correct
    (3) (c) and (d) are correct
    (4) (a) and (d) are correct

16. Match the following parts of a nephron with their function :

(a)	Descending limb of Henle's loop	(i)	Reabsorption of salts only
(b)	Proximal convoluted tubule	(ii)	Reabsorption of water only
(c)	Ascending limb of Henle's loop	(iii)	Conditional reabsorption of sodium ions and water
(d)	Distal convoluted tubule	(iv)	Reabsorption of ions, water and organic nutrients

Select the correct option from the following :

[NEET-2019 (Odisha)]

(1) (a)-(iv), (b)-(i), (c)-(iii), (d)-(ii)

(2) (a)-(i), (b)-(iii), (c)-(ii), (d)-(iv)

(3) (a)-(ii), (b)-(iv), (c)-(i), (d)-(iii)

(4) (a)-(i), (b)-(iv), (c)-(ii), (d)-(iii)

17. Match the items in Column-I with those in Column-II

	Column-I		**Column-II**
(a)	Podocytes	(i)	Crystallised oxalates
(b)	Protonephridia	(ii)	Annelids
(c)	Nephridia	(iii)	Amphioxus
(d)	Renal calculi	(iv)	Filtration slits

Select the correct option from the following :

[NEET-2019 (Odisha)]

(1) (a)-(iv), (b)-(ii), (c)-(iii), (d)-(i)

(2) (a)-(iii), (b)-(iv), (c)-(ii), (d)-(i)

(3) (a)-(iii), (b)-(ii), (c)-(iv), (d)-(i)

(4) (a)-(iv), (b)-(iii), (c)-(ii), (d)-(i)

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Chapter 8

Locomotion and Movement

Sub-topics *Types of Movement - Ciliary, Flagellar, Muscular; Skeletal Muscle - Contractile Proteins and Muscle Contraction; Skeletal System and its Functions; Joints; Disorders of Muscular and Skeletal System - Myasthenia Gravis, Tetany, Muscular Dystrophy, Arthritis, Osteoporosis, Gout*

TYPES OF MOVEMENT

Movements can be of two types : Non-muscular and muscular.

Non-muscular movements can be by pseudopodia/cilia/flagella.

Some specialised cells in our body like macrophages and leucocytes in blood exhibit amoeboid movement. It is effected by pseudopodia formed by the streaming of protoplasm (as in *Amoeba*). Cytoskeletal elements like microfilaments are also involved in amoeboid movement.

You have studied that the cilia and flagella are the outgrowths of the cell membrane. **Flagellar movement** helps in the swimming of spermatozoa, maintenance of water current in the canal system of sponges and in locomotion of Protozoans like Euglena.

Ciliary movement occurs in those internal tubular organs which are lined by ciliated epithelium. The coordinated movements of cilia in the trachea help us in removing dust particles and some of the foreign substances inhaled alongwith the atmospheric air. Passage of ova through the female reproductive tract is also facilitated by the ciliary movement. Sperms move in the female genital tract by their flagellar movement.

Movement of our limbs, jaws, tongue, etc, requires muscular movement. The contractile property of muscles are effectively used for locomotion and other movements by human beings and majority of multicellular organisms. Locomotion requires a perfect coordinated activity of muscular, skeletal and neural systems. In this chapter, you will learn about the types of muscles, their structure, mechanism of their contraction and important aspects of the skeletal system.

Muscle

Muscle is a specialised contractile tissue of mesodermal origin. About 40-50 percent of the body weight of a human adult is contributed by muscles. They have special properties like excitability, contractility, extensibility and elasticity. Muscles have been classified using different criteria, namely location, appearance and nature of regulation of their activities. Based on their location, three types of muscles are identified : (i) Skeletal (ii) Visceral and (iii) Cardiac.

Skeletal or striped muscles are closely associated with the skeletal components of the body. They have a striped appearance under the microscope and hence are called **striated muscles**. As their activities are under the voluntary control of the nervous system, they are known as voluntary muscles too. They are primarily involved in locomotory actions and changes of body postures.

Visceral muscles are located in the inner walls of hollow visceral organs of the body like the alimentary canal, reproductive tract, etc. They do not exhibit any striation and are smooth in appearance. Hence, they are called **smooth muscles (nonstriated muscle)**. Their activities are not under the voluntary control of the nervous system and are therefore known as involuntary muscles. They assist, for example, in the transportation of food through the digestive tract and gametes through the genital tract.

As the name suggests, Cardiac muscles are the muscles of heart. Many cardiac muscle cells assemble in a branching pattern to form a cardiac muscle.

Structure of a skeletal muscle fibre

The muscle fibre is composed of smaller unit called 'myofibrils'. Each myofibril is formed of units called **sarcomeres**. The myofibril is composed of contractile proteins **actin** and **myosin**. The thin actin protein is present in **light band** or **isotropic band** or **I-band** as well as dark band whereas thick myosin protein is present only in **dark band** or **anisotropic band** or **A-band**. The thick filaments lie parallel to one another and thin filaments are present in an orderly array between the thick filaments. In the centre of the I-band, there is a band of dense amorphous material, the **Z-line** (Line of Krause). The structure between two Z-lines of the muscle fibre is termed *sarcomere*. In the middle of the A-band is another zone which takes a light stain and is known as the **'H' band** or **'H zone**.

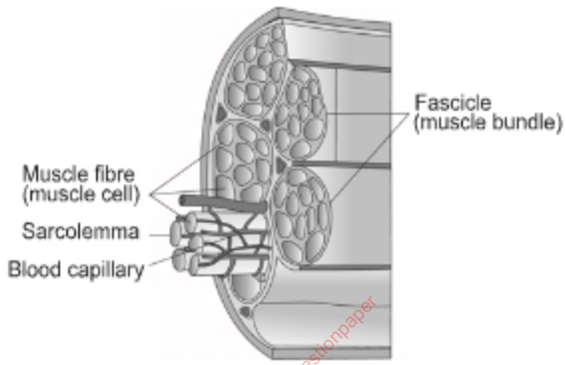


Fig. : Diagrammatic cross sectional view of a muscle showing muscle bundles and muscle fibres

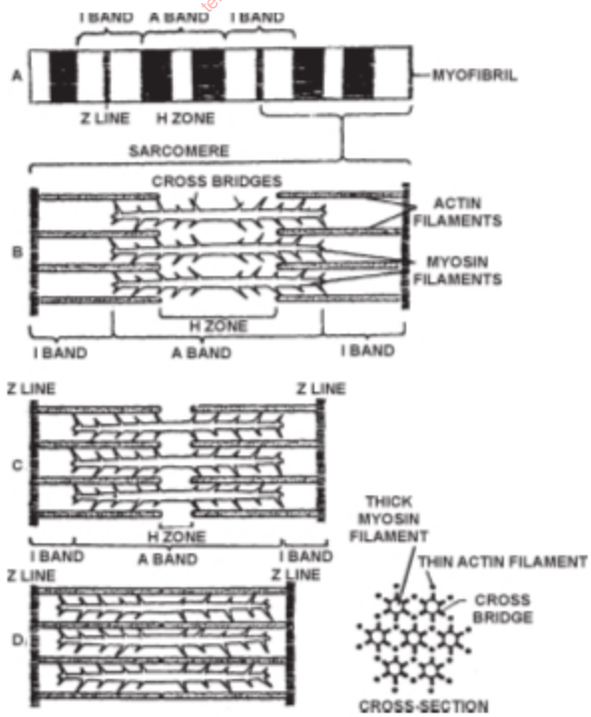


Fig. : Sliding filament theory of the mechanism of muscle contraction

Structure of Contractile Proteins

Each actin (thin) filament is made of two 'F' (filamentous) actins helically wound to each other. Each 'F' actin is a polymer of monomeric 'G' (Globular) actins. Two filaments of another protein, tropomyosin also run close to the 'F' actins throughout its length. A complex protein Troponin is distributed at regular intervals on the tropomyosin. In the resting state a subunit of troponin masks the active binding sites for myosin on the actin filaments.

Each myosin (thick) filament is also a polymerised protein. Many monomeric proteins called Meromyosins constitute one thick filament. Each meromyosin has two important parts, a globular head with a short arm and a tail, the former being called the heavy meromyosin (HMM) and the latter, the light meromyosin (LMM). The HMM component, *i.e.*, the head and short arm projects outwards at regular distance and angle from each other from the surface of a polymerised myosin filament and is known as cross arm. The globular head is an active ATPase enzyme and has binding sites for ATP and active sites for actin.

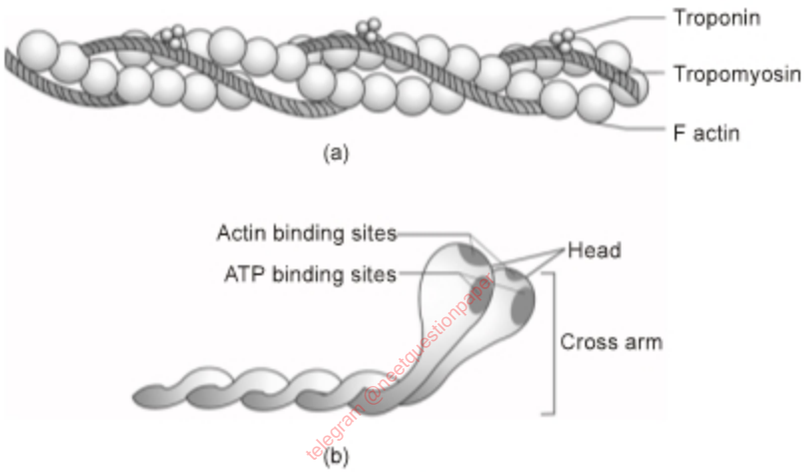


Fig. : (a) An actin (thin) filament (b) Myosin monomer (Meromyosin)

All-or-none Principle

It states that a muscle fibre either contracts fully or does not contract at all. The law is applicable to all muscle fibres, cardiac, smooth and striated. It is also applicable to nerve fibres but is not applicable to a complete muscle or nerve.

Mechanism of Muscle Contraction

The most accepted theory of muscle contraction is sliding filament theory given by Huxley and Huxley. The actin filaments slide over the myosin filament by the formation of cross-bridges and during these slidings the I-bands get reduced while the A-bands remain of the same length. The lengths of actin and myosin filaments also remains unchanged.

Acetylcholine released at the neuromuscular junction stimulates the muscle fibre contraction by stimulating the release of Ca^{2+} from the sarcoplasmic reticulum to the interior of the fibre. Ca^{2+} are required for muscle contraction.

When a muscle fibre is relaxed, troponin-tropomyosin complex blocks the myosin binding sites of actin.

Tropomyosin is a fibrous protein which blocks myosin binding sites in actin proteins. Attached to tropomyosin is troponin which has 3 subunits :

1. TpT – Tropomyosin binding Troponin
2. TpC – Calcium binding Troponin
3. TpI – inhibitory troponin which blocks the myosin binding site of actin protein.

In smooth muscle fibres, calcium binding protein is Calmodulin

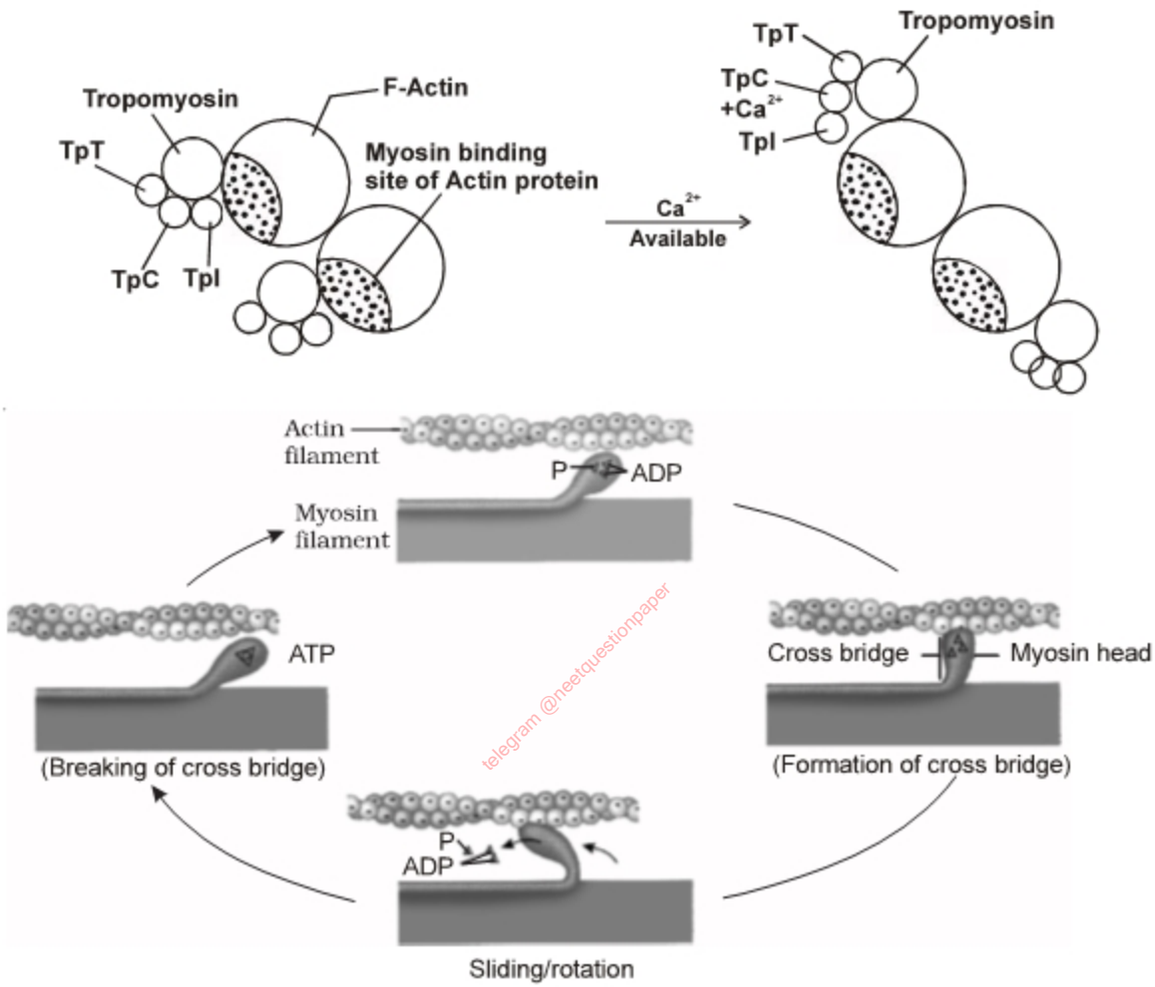


Fig. : Stages in cross bridge formation, rotation of head and breaking of cross bridge

When Ca^{2+} are available, they bind with TpC, this causes the shifting of Tropomyosin-Troponin complex. Now actins can attach and slide over myosin.

The immediate source of energy for muscle contraction is ATP.

$$ATP + H_2O \xrightarrow[Mg^{2+}]{\text{Myosin ATPase}} ADP + Pi + \text{Energy}$$

Mg^{++} dependent ATPase activity is present in myosin head.

When we are doing light exercise, the energy comes from aerobic breakdown of glycogen.

During strenous exercise, energy comes from anaerobic breakdown of glycogen. This will lead to accumulation of lactic acid, causing pain, fatigue and rigidity in the muscles called Rigor. (**Rigor mortis—after death, rigidity in muscles**). As the supply of ATP decreases, there is another high energy compound called creatine phosphate abbreviated **(CP)** and called (phosphagen) in muscle fibres.

$$CP + ADP \rightarrow ATP + C$$

Rigor is stiffening/rigidity of muscles due to lack of ATP/CP, actins are bound to myosin but are unable to slide back.

Tetanus : Sustained contraction of a muscle fibre due to application of succession of stimuli. This can happen due to increase in availability of Ca^{2+}.

Red Skeletal Muscle Fibres : Thin, dark coloured striated fibres which are rich in myoglobin (red coloured oxygen storing pigment) and have abundant **mitochondria**. Amount of sarcoplasmic reticulum is low. These fibres are also called aerobic muscle fibres. They can undergo sustained contraction over a long period without getting fatigued; *e.g.,* the extensor muscles of human back, the flight muscles of certain birds like **kites** which sail in air over a long period.

White Skeletal Muscle Fibres : These fibres are much thicker and of light colour due to lesser amount of myoglobin. Number of mitochondria is also low. Amount of sarcoplasmic reticulum is high. These fibres depend on anaerobic process of energy. They are meant for fast and strenous physical activity over a short duration as they get tired soon; *e.g.,* the flight muscles of fast flying birds such as sparrows.

SKELETAL SYSTEM

1. The total number of bones in adult humans is 206.
2. The **axial skeleton** of adult man consists of 80 bones. It includes skull, vertebral column, ribs and sternum.
3. The **appendicular skeleton** of adult man consists of 126 bones. It includes fore and hindlimbs, pectoral and pelvic girdles.
4. The number of bones in the skull of man is 29 (cranial bones 8, facial bones 14 and ear ossicles 3 × 2 = 6 and 1 Hyoid). Hyoid is a U-shaped bone present at the base of buccal cavity. The skull region articulates with superior region of vertebral column with the help of two occipital condyles (dicondylic skull). The skull bones are jointed by **sutures**. The unossified areas in the skull at the time of birth are called **fontanells**.
5. **The only movable bone in the skull of man is mandible**.
6. Looked at from the side, the vertebral column presents four antero-posterior curves : the *cervical curve* in the neck which is convex forwards, the *thoracic curve* which is convex backwards, the *lumbar curve* that convex forwards, and the *pelvic curve* which is convex backwards.
7. The vertebral column of man consists of 33 embryonic vertebrae. These include 7 cervical, 12 thoracic, 5 lumbar, 5 sacral and 4 coccygeal vertebrae. All 5 sacral vertebrae fuse to form 1 sacrum and all 4 coccygeal vertebrae fuse to form 1 coccyx.
8. Adult human vertebral formula is $C_7T_{12}L_5\ S_{(5)}C_{(4)}$ hence, the number of vertebrae in the adult vertebral column is only 26. Heaviest vertebrae are lumbar vertebrae.

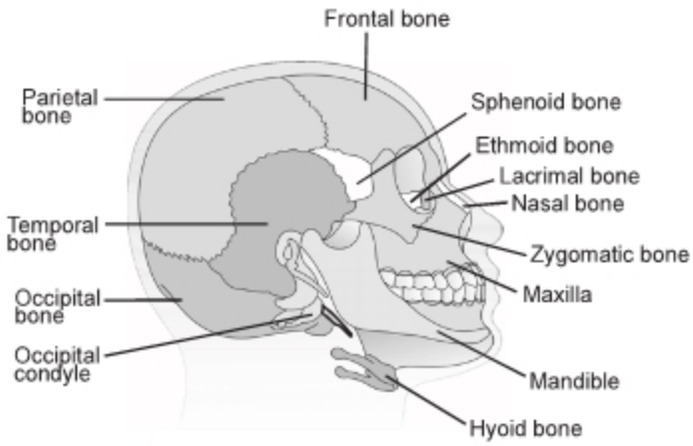


Fig. : Diagrammatic view of human skull

9. In our body, there are seven cervical vertebrae. Out of these, 1, 2, 7 are atypical and 3, 4, 5, 6 are typical. In the transverse processes of cervical vertebrae **except seventh, vertebroarterial canal** or **foramen transversarium** is present for the passage of vertebral arteries.
10. The characteristic feature of second cervical vertebra *i.e.*, **Axis** is the presence of a knob-like process called **odontoid process**. This process fits into the fossa of **Atlas** vertebra to form a **pivot joint** which allows only rotational movements.

    Vertebra prominens is the large neural spine of seventh cervical vertebra.
11. Usually, there are 12 pairs of ribs. Each rib is flat bone connected dorsally to vertebral column and has two articulation surfaces on its dorsal end hence called bicephalic ribs.

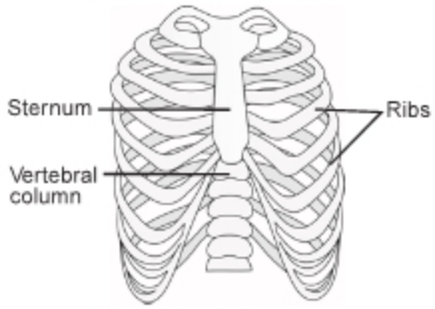


Fig. : Ribs and rib cage

12. The first seven pairs of ribs are known as **'true ribs'**, the only ones to reach the sternum on ventral side directly (vertebro sternal ribs)

AXIAL SKELETON			APPENDICULAR SKELETON		
Cranium } **Skull**		8	**Pectoral girdle**		
Face }		14	Clavicle		2
Hyoid		1	Scapula		2
Ear ossicles	3 × 2	6	**Forelimbs**		
Vertebral column		26	Humerus		2
Sternum		1	Ulna		2
Ribs	12 × 2	24	Radius		2
		80	Carpals	8 × 2	16
Cranial Bones			Metacarpals	5 × 2	10
Frontal		1	Phalanges	14 × 2	28
Parietals		2			60
Temporals		2	**Pelvic girdle**		
Occipital		1	Coxal, hip or pelvic		2
Sphenoid		1	**Hindlimbs**		
Ethmoid		1	Femur		2
		8	Tibia		2
Facial Bones			Fibula		2
Nasals		2	Patella		2
Maxillae		2	Tarsals	7 × 2	14
Zygomatic bones		2	Metatarsals	5 × 2	10
Mandible		1	Phalanges	14 × 2	28
Lacrimal bones		2			60
Palatines		2			
Inferior nasal conchae		2			
Vomer		1			
		14			
Vertebral Column					
Cervical	7				
Thoracic	12				
Lumbar	5				
Sacrum	1	(5)			
Coccyx	1	(4)			
	26	(33)			

Total number of bones in adult human
80 + 2 + 2 + 60 + 2 + 60 = 206

Digital formula of both limbs 2, 3, 3, 3, 3

13. Pairs 8, 9 and 10 are **'false ribs'** or vertebro-chondral and are attached indirectly to sternum by means of cartilages with sternal part of the 7th rib.
14. Last two pairs (11 and 12) fall far short of the sternum and are known as **'floating ribs'** or vertebral ribs.
15. 'Gorilla ribs' are the extra floating ribs, if any.
16. Sternum or breast bone (flat bone) of man consists of three portions: manubrium, body and xiphoid process.
17. The sternum is a favoured site for obtaining samples of hemopoietic (blood forming) tissues during diagnosis of suspected blood diseases.

The two posteriorly convex curves, thoracic and pelvic, are called **primary curves** as they persist from the total backward convexity of the column which is C-shaped at birth with the head bent downwards on to the chest and the pelvic girdle tilted upwards towards the body.

The two anteriorly convex curves are called **secondary curves** – the cervical curve is developed when the infant raises its head to look around and investigate his surroundings, and the lumbar curve forms when he crawls and learns to stand and walk and keep himself erect.

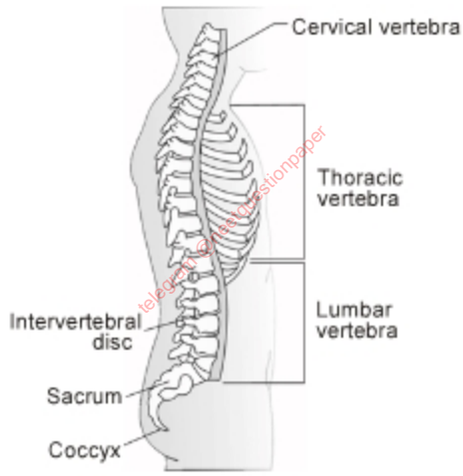


Fig. : Vertebral column (right lateral view)

The Joints of the Vertebral Column : These are cartilaginous joints formed by pads of fibro-cartilages placed between each successive vertebrae, strengthened by ligaments running in front and behind the vertebral bodies throughout the entire length of the column. Masses of muscles on each side aid in the stability of the spine.

***The Intervertebral Discs* are thick pads of fibro-cartilage between the bodies of the movable vertebrae.**

APPENDICULAR SKELETON

The Skeleton of the Upper Limbs and Pectoral Girdles

The skeleton of the upper limbs is attached to the skeleton of the trunk by means of the ***shoulder (pectoral) girdles***, which consists of the ***clavicle*** and ***scapula.***

Below this, 30 bones form the skeleton of arm, forearm and hand. Each fore limb and hind limb has 30 bones each. Bones of forelimbs are

Humerus - 1

Ulna and Radius - 1 each

Carpal bones - 8

Metacarpals - 5

Bones as phalanges in digits - 14

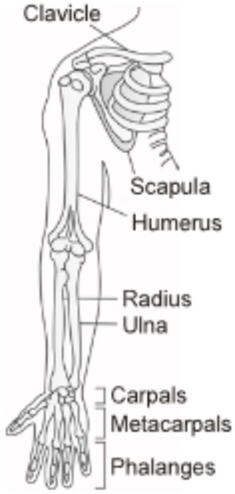


Fig. : Right pectoral girdle and upper arm (frontal view)

The **Clavicle** or collar bone is a long curved bone forming the anterior part of the shoulder girdle.

Scapula : The scapula forms the posterior part of the shoulder girdle and lies at the back of the thorax superficially to the ribs. It is a triangular, flat bone situated in dorsal part of thorax between the 2nd and 7th ribs.

Scapula has acromian process which articulates with clavicle. Below acromian process there is a depression called **the *glenoid cavity*** which is a shallow cavity directed outwards to receive the head of the humerus in the formation of the shoulder joint (humero-scapular joint).

Humerus : The humerus is a long bone, the longest bone of the upper limb. It presents a shaft and two extremities. A rough tubercle on the lateral aspect of the shaft, just above the middle, is called the *deltoid tuberosity*. It receives the insertion of the deltoid muscle. So, characteristic feature of humerus is **Deltoid ridge**.

Ulna : The ulna is a long bone having a shaft and two extremities. **It is the medial bone of the forearm and is longer than the radius. The head of the ulna is at the lower end.**

Radius : The radius is the lateral bone of the forearm. It is a long bone with a shaft and two extremities. It is shorter than the ulna. Radius is towards the thumb.

Bones of Wrist and Hand

The bones of the hand are arranged in groups. ***Carpals*** or the bones which enter into the formation of the wrist are short bones. The carpals are eight bones, arranged in two rows of four bones each. The ***metacarpals*** form the skeleton of the palm of the hand so called palm bones and are long bones. The *phalanges*, or bones of the fingers, are long bones.

The Pelvic Girdle or Body Pelvis

The pelvic girdle is the connection between the trunk and lower extremities. This girdle is formed by part of the axial skeleton – the ***sacrum*** and ***coccyx*** being wedged between the two ***innominate (coxal) bones.*** The male pelvis is longer and narrower than the female pelvis.

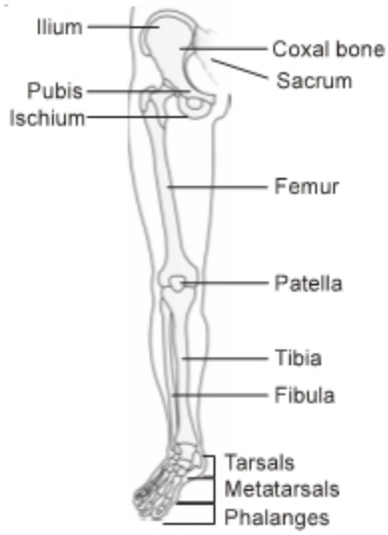


Fig. : Right pelvic girdle and lower limb bones (frontal view)

Each coxal bone is formed by fusion of 3 bones : ilium, ischium and pubis.

The Acetabulum is a deep, cup-shaped cavity formed at the point of union of the three bones; the *pubis* forms the front part, the *ilium* the upper part, and the *ischium* the back part. The acetabulum articulates with the head of femur in formation of the hip joint.

Femur : It is the longest bone in the body. It articulates with the acetabulum in the formation of **hip joint and from here, the bone inclines medially to the knee where it articulates with the tibia. It is a long bone with a shaft and two extremities.** Hip joint is a ball and socket joint.

Patella : The patella is a *sesamoid bone* developed in the tendon of the quadriceps extensor muscle. The anterior surface of the bone is rough. The posterior surface is smooth and articulates with the patellar surface of the lower extremity of the femur. This articulating surface is divided by a line into two facets.

Tibia : The lower extremity of tibia enters into the formation of the ankle joint.

Fibula : The fibula is the lateral bone of the leg. It is a long bone with a shaft and two extremities.

Bones of the Foot

The Tarsal Bones : There are seven bones collectively known as the *tarsus*. They are short bones, made of cancellous bone tissue with a covering of compact tissue. These bones support the weight of the body while standing.

Metatarsals are 5 and phalanges are 14 in number.

Joints

1. Joints are the point of contact between bones, or between bones and cartilages. Force generated by the muscles is used to carry out movement through joints, where the joint acts as a **fulcrum**.
2. Three main types of joints are
   (i) Immovable joints or fibrous joints (Synarthroses)
   (ii) Imperfectly movable joints or cartilaginous joints (Amphiarthroses) and
   (iii) Perfectly movable joints or synovial joints (Diarthroses)

Immovable Joints/fibrous Joints : No joint cavity and no movements possible. These joints include :

1. **Sutures :** Found between skull bones, Sutures are fixed or fibrous joints where, articulating bones are held together by white fibrous tissues.
2. **Gomphoses :** Joint between the roots of teeth and sockets of jaw bones.

Imperfectly Movable Joints : With or without joint cavities, permit a small amount of movement. Fibrocartilage is present between the bones, so these joints are also called **cartilaginous joints**. *e.g.,* between vertebrae of vertebral column (Intervertebral joint), pubic symphysis.

Synovial joints are of the following types :

(a) Ball and socket joint : The 'head' of one bone fitting in the 'socket' of the other and allowing free movement in all planes; *e.g.*, **shoulder joint** and **hip joint**.

In the scapula, there is **glenoid cavity** which articulates with the head of the humerus , forming ball and socket joint.

Each half of the pelvic girdle consists of **ilium**, **ischium** and **pubis**. At the point of fusion of the three bones, a cavity is present called **acetabulum** that articulates with the head of femur, forming ball and socket joint.

(b) Hinge joint : The perfect joint which allows the movements only in a single plane; *e.g.,* **elbow joint** and **knee joint**.

(c) Pivotal joint (Rotary joints) : One of the two bones is fixed in its place and bears a peg like process over which rotates the other bone; *e.g.,* **atlas** (first cervical vertebra) along with the skull rotating over the odontoid process of **axis** (second cervical vertebra) in mammals.

(d) Saddle joint : Similar to ball and socket joint but both the ball and the socket are poorly developed and movements are comparatively less free, *e.g.* the joint between **metacarpal of the thumb** and the **carpals**.

(e) Gliding joint : The joint which permits **sliding** of the articulating bones on each other; *e.g.,* joints between **radio ulna** and **carpals**, and joints between the **zygapophyses** of successive vertebrae, between carpals and also joint between sternum and clavicles.

One end of the clavicle articulates with the **acromian** process of scapula and the other end articulates with of sternum by gliding joint.

(f) Ellipsoid or **condyloid joint :** These joints allow the movements in two directions, *i.e.,* side to side and back and forth; *e.g.,* between the metacarpals and the phalanges.

Types of Bones

1. **Cartilaginous** or **replacing bones :** These bones are formed by the replacement of an existing cartilage by bone. These are also called **endochondrial bones**, *e.g.,* humerus, femur.
2. **Investing** or **dermal or membranous bones :** These bones develop in the dermis of the skin as thin plates and get invested over original cartilages *e.g.,* Frontal, nasals, vomer, parietals of the skull.
3. **Sesamoid bones :** These bones are formed by ossification of tendons at the joints *e.g.,* patella (Knee cap).
4. **Visceral bones :** These bones are detached from the skeleton and come to lie in visceral organs. *e.g.*, In the heart of some ungulates (ruminates), bones develop in the connective tissue of the cardiac skeleton as Os cordis.

Disorders of muscular and skeletal system

1. **Myasthenia gravis :** Auto immune disorder affecting neuromuscular junctions leading to fatigue, weakening and paralysis of skeletal muscle.
2. **Muscular dystrophy :** Progressive degeneration of skeletal muscles, mostly a genetic disorder.
3. **Tetany :** Rapid spasms (wild contractions) in muscles due to low Ca^{++} in body fluids.
4. **Arthritis :** It is the inflammation of the joints. It can be of several types such as rheumatoid arthritis, osteoarthritis and gouty arthritis.
   (a) **Rheumatoid arthritis :** It is diagnosed by the presence of rheumatoid factor (a type of immunoglobulin, I_gM). It's the primary symptom is inflammation of synovial membranes. If it is left untreated, the membrane thickens and synovial fluid increases, exerting pressure that causes pain. The membrane then starts secreting abnormal granules, called **pannus**, which after accumulating on the surface of the articular hyaline cartilage, cause its erosion. As a result, the fibrous tissues are attached to the bones and they become ossified, making the joints immovable. Its treatment concentrates on reduction of pain and inflammation by heat treatment and physiotherapy and in extreme cases, replacement of the damaged joints.
   (b) **Osteoarthritis :** It is a degenerative joint disease characterised by degeneration of articular cartilage and proliferation of bones. Usually affected joints are of spine, knees and hands.
   (c) **Gouty arthritis or gout :** It is caused either due to excessive formation of uric acid, or inability to excrete it. Uric acid gets deposited in joints as monosodium salt.
5. **Osteoporosis :** Age-related disorder characterised by decreased bone mass and increased chances of fractures. Decreased levels of estrogen is a common cause.

Points to Remember :

1. **Arthrology :** Study of joints.
2. **Sella turcica :** Depression in the sphenoid of the skull that lodges the pituitary body.
3. **Strongest muscle :** Masseters.
4. **Largest muscle :** Gluteus maximus.
5. **Sharpey's fibres :** Calcified bundles of white and yellow fibres perforating through and holding periosteal bone lamellae.
6. **Longest bone in human body :** Femur.
7. **Longest bone in frog :** Tibio fibula.
8. **Largest foramen :** Foramen magnum.
9. **Electromyography :** Graphic recording of electric currents produced by an active muscle, as during muscle twitch. EMG is electromyogram.
10. **Urostyle :** Bone of frog.
11. **Pygostyle :** Bone supporting the oil glands in birds, mid-dorsally located in the posterior part.
12. **Furcula/wishbone :** Y shaped bone in birds.
13. **Uncinate processes :** Small bony projections running from one rib to another in birds. Providing a uniform surface during flight.
14. **Lordosis :** When spine becomes straight and loses its flexion curves.
15. **Slip disc :** Displacement of vertebrae from their normal position due to displacement or degeneration of a part of intervertebral disc.

16. **Chevron bones :** Y shaped bones found in snakes and lizards.
17. **Monocondylic skull :** Birds, reptiles and pisces.
18. **Dicondylic skull :** Mammals and amphibians.
19. **Motor unit :** A single nerve fibre with its supply to muscle fibres (as many as it covers).
20. **Treppe** or **staircase phenomenon :** The repeated stimulus of a single muscle fibre in such a manner that the kymograph records a staircase like graph.

❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. Which of the following is the functional unit of muscle fibre?
   (1) Fasciculus (2) Sarcomere
   (3) Myofibril (4) Myosin
2. Consider the following
   a. Actin b. Myosin
   c. Tropomyosin d. Troponin
   The regulatory proteins for contraction are
   (1) a, b, c, d (2) a, b
   (3) c, d (4) a, c, d
3. The part of myofibril between two successive membrane of Krause, which functions as a contractile unit is termed as
   (1) Sarcosome
   (2) Sarcomere
   (3) Sarcoplasmic reticulum
   (4) Sarcoplasm
4. Consider the following
   a. Head of myosin b. Tail of myosin
   c. Tropomyosin d. Troponin
   Which of the above possesses ATPase activity?
   (1) Only a (2) a, b
   (3) a, b, c (4) a, b, c, d
5. Consider the following
   a. Z lines move apart
   b. Sarcomere shortens
   c. A band shortens
   d. I band remains same sized
   e. H-zone disappears
   Which of the above occur during muscle contraction?
   (1) a, b, c, d, e (2) b, d, e
   (3) b, c, e (4) b, e
6. All or None Law is applicable to all, **except**
   (1) Nerve fibres (2) Entire muscle
   (3) Striated muscle fibres (4) Smooth muscle fibres
7. According to sliding filament theory proposed by A.F. Huxley and H.E. Huxley in 1954 regarding contraction of muscles, one of the following events does not occur during contraction of muscle fibre
   (1) Z lines come closer
   (2) Length of A bands remains constant
   (3) H zone shortens and becomes narrower
   (4) Width of I band remains constant
8. Which of the following is called a phosphagen?
   (1) cAMP (2) AMP
   (3) CP (4) GMP
9. Which of the following statements is true during muscle contraction of striated muscle?
   (1) Sarcolemma becomes permeable to Ca^{2+} ions
   (2) Sarcolemma becomes permeable to Na^{+} ions
   (3) Sarcolemma becomes impermeable to Na^{+} ions
   (4) Ca^{2+} is pumped back into the sarcoplasmic reticulum
10. Contraction of smooth muscles is initiated by binding of calcium to
    (1) Troponin (2) Tropomyosin
    (3) Myosin (4) Calmodulin
11. The muscle fatigue occurs due to accumulation of
    (1) CO_2 (2) Lactic acid
    (3) Creatine phosphate (4) Myosin ATPase
12. Rigor mortis is due to
    (1) Abundance of CP
    (2) Abundance of ATP
    (3) Lack of ATP
    (4) Succession of stimuli
13. Which of the following ions are essential for muscular contraction?
    (1) Na^{+}, Ca^{++} (2) Mg^{++}, Ca^{++}
    (3) Mg^{++}, K^{+} (4) K^{+}, Na^{+}
14. The total number of muscles in the body of a man is
    (1) 409 (2) 439
    (3) 539 (4) 639

15. One of the following is not included in axial skeleton
(1) Skull (2) Back bone
(3) Sternum (4) Girdles

16. Cranium is made of
(1) 8 bones (2) 14 bones
(3) 22 bones (4) 206 bones

17. Only movable bone of skull is
(1) Mandible (2) Vomer
(3) Maxilla (4) Palatine

18. Vertebral formula of man is
(1) $C_7\ T_{12}\ L_5\ S_{(5)}\ C_{(3-4)}$ (2) $C_7\ T_{12}\ L_5\ S_4\ C_5$
(3) $C_7\ T_{12}\ L_4\ S_4\ C_5$ (4) $C_{12}\ T_5\ L_5\ S_5\ C_4$

19. Axis vertebra of a mammal differs from atlas in
(1) Absence of centrum
(2) Presence of vertebroarterial canal
(3) Presence of central canal
(4) Presence of odontoid process

20. Cervical vertebrae can be identified from other vertebrae on the basis of
(1) Odontoid processes
(2) Transverse processes
(3) Amphiplatyan centrum
(4) Vertebro-arterial canals

21. Vertebra prominents is
(1) 1st thoracic vertebra (2) 1st lumbar vertebra
(3) 7th cervical vertebra (4) 1st cervical vertebra

22. Smallest bone of body is
(1) Incus (2) Femur
(3) Stapes (4) Malleus

23. The heaviest and largest vertebrae are
(1) Thoracic (2) Lumbar
(3) Cervical (4) None of these

24. In birds the vertebrae in the neck region are
(1) Amphiplatyan (2) Heterocoelous
(3) Opisthocoelous (4) Amphicoelous

25. Deltoid ridge is found in which of the following bones?
(1) Radius (2) Tibia
(3) Femur (4) Humerus

26. Cup shaped structure of pelvic girdle, the acetabulum in man is formed by
(1) Ilium, ischium and pubis
(2) Ileum, ischium and pubis
(3) Ilium and ischium
(4) Ilium and condyloid

27. Bone formed by the ossification of tendon is called
(1) Sesamoid
(2) Cartilage or replacing bone
(3) Investing or dermal bone
(4) All of these

28. Find the **incorrect** match
(1) Clavicle – Collar bone
(2) Scapula – Triangular bone
(3) Sternum – Long slender bone with two curvature
(4) Patella – Knee cap

29. The joint between atlas and axis vertebra is an example of
(1) Saddle joint
(2) Immovable joint
(3) Slightly movable joint
(4) Pivot joint

30. Hinge joint is present between
(1) Humerus and Radio-ulna
(2) Femur and Pelvic girdle
(3) Femur and Acetabulum
(4) Humerus and Pectoral girdle

31. The type of joint between metacarpals and phalanges of the fingers is
(1) Hinge (2) Ellipsoid
(3) Cartilagenous (4) Gliding

32. An autoimmune disorder affecting neuromuscular junction leading to fatigue, weakening and paralysis of skeletal muscle is
(1) Tetany (2) Myasthenia gravis
(3) Muscular dystrophy (4) Gout

33. Decreased level of estrogen is a common cause for
(1) Rheumatoid arthritis
(2) Osteoporosis
(3) Osteoarthritis
(4) Osteomalacia

34. What would happen to the joint if the ligaments holding the articulating bones together are cut?
(1) Freely movable (2) Unstable
(3) Slightly movable (4) Fixed

35. Rapid spasm in muscles due to low Ca^{2+} in body fluid is called
(1) Muscle fatigue (2) Muscle tetanus
(3) Muscle tetany (4) Muscle dystrophy

SECTION - B

Previous Years Questions

1. Select the **correct** statement regarding the specific disorder of muscular or skeletal system : **[AIPMT 2012]**
   (1) *Myasthenia gravis* - Auto immune disosrder which inhibits sliding of myosin filaments
   (2) *Gout* - inflammation of joints due to extra deposition of calcium
   (3) *Muscular dystrophy* - age related shortening of muscles
   (4) *Osteoporosis* - decrease in bone mass and higher chances of fractures with advancing age

2. The characteristics and an example of a synovial joint in humans is **[NEET 2013]**

	Characteristics	Examples
(1)	Fluid filled between two joints, provides cushion	Skull bones
(2)	Fluid filled synovial cavity between two bones	Joint between atlas and axis
(3)	Lymph filled between two bones, limited movement	Gliding joint between carpals
(4)	Fluid cartilage between two bones, limited movements	Knee joints

3. Select the correct statement with respect to locomotion in humans. **[NEET 2013]**
   (1) Accumulation of uric acid crystals in joints causes their inflammation
   (2) The vertebral column has 10 thoracic vertebrae
   (3) The joint between adjacent vertebrae is a fibrous joint
   (4) A decreased level of progesterone causes osteoporosis in old people

4. The H-zone in the skeletal muscle fibre is due to **[NEET 2013]**
   (1) The central gap between myosin filaments in the A-band
   (2) The central gap between actin filaments extending through myosin filaments in the A-band
   (3) Extension of myosin filaments in the central portion of the A-band
   (4) The absence of myofibrils in the central portion of A-band

5. Select the **correct** matching of the type of the joint with the example in human skeletal system. **[AIPMT 2014]**

	Type of joint		Example
(1)	Cartilaginous joint	-	between frontal and parietal
(2)	Pivot joint	-	between third and fourth cervical vertebrae
(3)	Hinge joint	-	between humerus and pectoral girdle
(4)	Gliding joint	-	between carpals

6. Stimulation of a muscle fiber by a motor neuron occurs at **[AIPMT 2014]**
   (1) The neuromuscular junction
   (2) The transverse tubules
   (3) The myofibril
   (4) The sacroplasmic reticulum

7. Which of the following is not a function of the skeletal system? **[Re-AIPMT-2015]**
   (1) Locomotion
   (2) Production of erythrocytes
   (3) Storage of minerals
   (4) Production of body heat

8. Which of the following joints would allow no movement? **[Re-AIPMT-2015]**
   (1) Ball and Socket joint (2) Fibrous joint
   (3) Cartilaginous joint (4) Synovial joint

9. Sliding filament theory can be best explained as **[AIPMT-2015]**
   (1) When myofilaments slide pass each other, Myosin filaments shorten while Actin filaments do not shorten
   (2) When myofilaments slide pass each other Actin filaments shorten, while Myosin filament do not shorten
   (3) Actin and Myosin filaments shorten and slide pass each other
   (4) Actin and Myosin filaments do not shorten but rather slide pass each other

10. Glenoid cavity articulates **[AIPMT-2015]**
    (1) Humerus with scapula
    (2) Clavicle with acromion
    (3) Scapula with acromion
    (4) Clavicle with scapula

11. Lack of relaxation between successive stimuli in sustained muscle contraction is known as **[NEET-2016]**

(1) Tonus (2) Spasm
(3) Fatigue (4) Tetanus

12. Name the ion responsible for unmasking of active sites for myosin for cross-bridge activity during muscle contraction. **[NEET (Phase-2) 2016]**

(1) Calcium (2) Magnesium
(3) Sodium (4) Potassium

13. Osteoporosis, an age-related disease of skeletal system, may occur due to **[NEET (Phase-2) 2016]**

(1) Immune disorder affecting neuromuscular junction leading to fatigue
(2) High concentration of Ca^{++} and Na^{+}
(3) Decreased level of estrogen
(4) Accumulation of uric acid leading to inflammation of joints

14. The pivot joint between atlas and axis is a type of **[NEET-2017]**

(1) Fibrous joint (2) Cartilaginous joint
(3) Synovial joint (4) Saddle joint

15. Out of 'X' pairs of ribs in humans only 'Y' pairs are true ribs. Select the option that correctly represents values of X and Y and provides their explanation **[NEET-2017]**

(1) X = 12, Y = 7 — True ribs are attached dorsally to vertebral column and ventrally to the sternum
(2) X = 12, Y = 5 — True ribs are attached dorsally to vertebral column and sternum on the two ends
(3) X = 24, Y = 7 — True ribs are dorsally attached to vertebral column but are free on ventral side
(4) X = 24, Y = 12 — True ribs are dorsally attached to vertebral column but are free on ventral side

16. Calcium is important in skeletal muscle contraction because it **[NEET 2018]**

(1) Detaches the myosin head from the actin filament.
(2) Activates the myosin ATPase by binding to it.
(3) Binds to troponin to remove the masking of active sites on actin for myosin.
(4) Prevents the formation of bonds between the myosin cross bridges and the actin filament.

17. Which of the following muscular disorders is inherited? **[NEET-2019]**

(1) Tetany (2) Muscular dystrophy
(3) Myasthenia gravis (4) Botulism

18. Select the **correct** option. **[NEET-2019]**

(1) 8^{th}, 9^{th} and 10^{th} pairs of ribs articulate directly with the sternum.
(2) 11^{th} and 12^{th} pairs of ribs are connected to the sternum with the help of hyaline cartilage.
(3) Each rib is a flat thin bone and all the ribs are connected dorsally to the thoracic vertebrae and ventrally to the sternum.
(4) There are seven pairs of vertebrosternal, three pairs of vertebrochondral and two pairs of vertebral ribs.

19. Match the following joints with the bones involved:

(a) Gliding joint	(i) Between carpal and metacarpal of thumb
(b) Hinge joint	(ii) Between Atlas and Axis
(c) Pivot joint	(iii) Between the Carpals
(d) Saddle joint	(iv) Between Humerus and Ulna

Select the correct option from the following : **[NEET-2019 (Odisha)]**

(1) (a)-(i), (b)-(iii), c-(ii), (d)-(iv)
(2) (a)-(iii), (b)-(iv), c-(ii), (d)-(i)
(3) (a)-(iv), (b)-(i), c-(ii), (d)-(iii)
(4) (a)-(iv), (b)-(ii), c-(iii), (d)-(i)

20. Which of the following diseases is an autoimmune disorder ? **[NEET-2019 (Odisha)]**

(1) Gout (2) Myasthenia gravis
(3) Arthritis (4) Osteoporosis

❑ ❑ ❑

Chapter 9

Neural Control and Coordination

Sub-topics *Neuron and Nerves; Nervous System in Humans Central Nervous System, Peripheral Nervous System and Visceral Nervous System; Generation and Conduction of Nerve Impulse; Reflex Action; Sense Organs; Elementary Structure and Function of Eye and Ear*

Neural System

The human nervous system consists of two contrasting functional subsystems, the central nervous system and the peripheral nervous system. Together, **brain** and **spinal cord** make the **central nervous system (CNS)**. It is the site of information processing. The **peripheral nervous system (PNS)** includes all the nerve pathways of the body outside the brain and spinal cord. **Visceral nervous system is the part of the peripheral nervous system that comprises the whole complex of nerves, fibres, ganglia, and plexuses by which impulses travel from the central nervous system to the viscera and from the viscera to the central nervous system.** These pathways are divided into two groups: the **sensory or** afferent pathways which transmit information **to the CNS**, and the **motor** or **efferent** pathways, which transmit commands from the CNS. The motor pathways, in turn, are partitioned into **somatic (voluntary) nervous system** which relays commands to skeletal muscles, and **autonomic (involuntary) nervous system (ANS)** that relay commands to the glands and other involuntary muscles of the body. If the neurons are clustered into groups within the CNS, there are called **nuclei** and if these clusters are in the PNS, these are called **ganglia**. Within the CNS, the bundles of nerve fibres are called **tracts** whereas in the PNS they are called **nerves**.

The autonomic neural system is further classified into **sympathetic neural system** and **parasympathetic neural system**.

A typical nerve has a tough outer covering, the **epineurium**. Inside are the long fibres or axons of individual nerve cells, gathered into bundles called **fascicles**, wrapped in the **perineurium**. Each nerve has its own supply of small blood vessels and its each nerve fibre is individually also covered by a tough endoneurium.

Neuron as Structural and Functional unit of Neural System

Nerve cells or **neurons** are the functional units of nervous system. These include **multipolar nerve cells** with many short dendrites and one long axon (*e.g.*, pyramidal cells in cerebral cortex), **bipolar nerve cells** with one axon and dendrite (*e.g.*, bipolar neurons in the retina of eye), **unipolar** (cell body with one axon only *e.g.*, embryo) and **pseudounipolar nerve cells** with the cell body on a side-branch of the main axon (*e.g.*, cells of dorsal root ganglion of spinal cord).

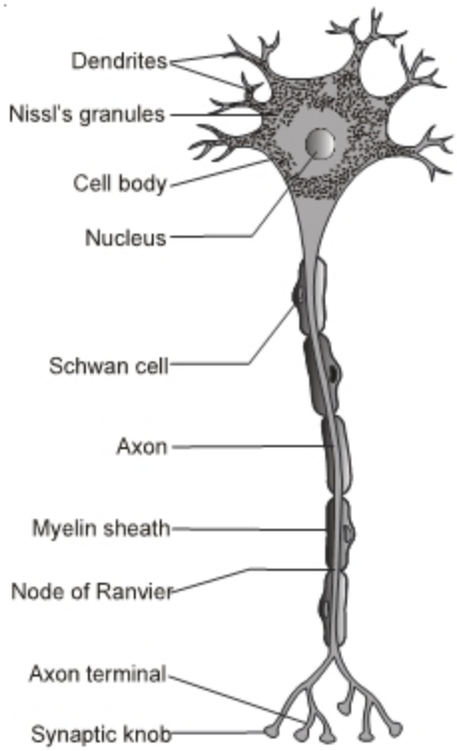


Fig. : Structure of a neuron

Surrounding neurons are special companion cells known as **glial** cells (*Gk : glue*). The glial cells perform many house-keeping functions, provide nutritional support to neurons and consume waste products. They also insulate, or separate each neuron from the others.

In the PNS, **Schwann cells**, a type of glial cell, wrap around the axons of neurons, thereby covering the axon with concentric layers of insulating membranes.

Generation and Conduction of Nerve Impulse

1. When a nerve fibre is at rest, the outer surface is positively charged and inner surface is negatively charged. On the outer surface, more Na^+ ions are present and on inner surface more K^+. If we connect the two ends of a neuron to dual beam cathode ray oscilloscope, we get the potential difference of –70 mV, called **resting potential** and the membrane is polarised. When the neuron is at rest; both Na^+ and K^+ voltage gated channels are closed and the polarisation of the membrane is maintained by the ion channels and Sodium-Potassium pump. At rest, the membrane has poor permeability for Na^+ ions.

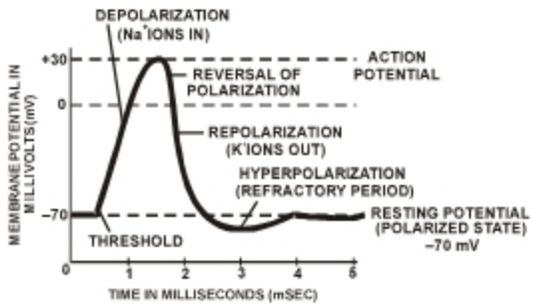


Fig. : Record of potential changes during a nerve impulse

2. When a threshold stimulus is applied at a site on the neuronal membrane, the voltage gated Na^+ channels open up, allowing Na^+ ions to enter the neuron. This entry wipes out the membrane's polarisation. **This causes the neuron's interior to develop a positive charge relative to its exterior**. The membrane is depolarised and the **action potential** of +30 mV is obtained.
3. Next, the voltage gated Na^+ channels close and the voltage gated K^+ channels suddenly open, allowing the K^+ ions to leave the neuron. **So, repolarisation starts with exit of K^+ and the closure of Na^+ gates. The exit of K^+ quickly restores the resting potential.**

$Na^+ - K^+$ pump restores a normal high concentration of Na^+ outside and K^+ inside.

The recovery period is $\frac{1}{1000}$ th of a second. In a myelinated nerve fibre, the impulse jumps from one node of Ranvier to the other, this is called **saltatory conduction** of impulse.

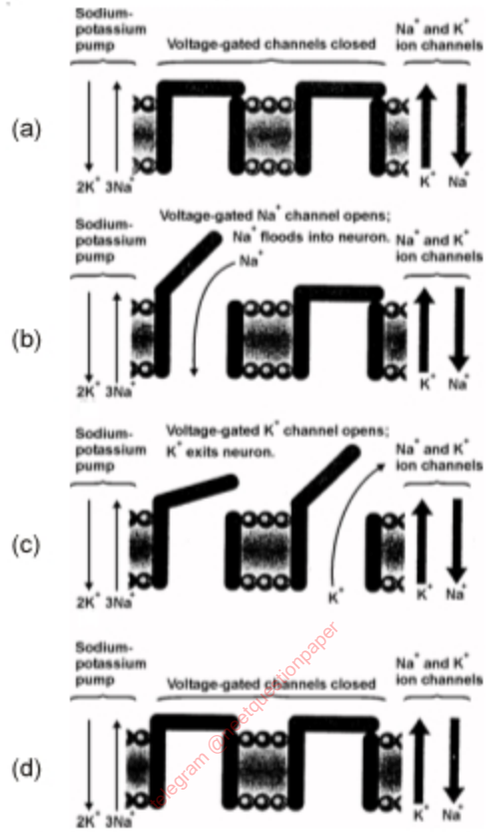


Fig. : The action potential, step by step

Transmission of Impulse

Nerve signals traverse from neurons to neurons all around the body. These associations of neurons are called **synapses**. In a synapse, there is a narrow intercellular gap, 10 to 20 nanometers across, separating the axon tip and the target cell. This gap is called a **synaptic cleft**. The number of synapses is usually very large, providing a large surface area for the transfer of information. For instance, over 1000 synapses may be found on the dendrites and the cell body of a motor neuron in the spinal cord.

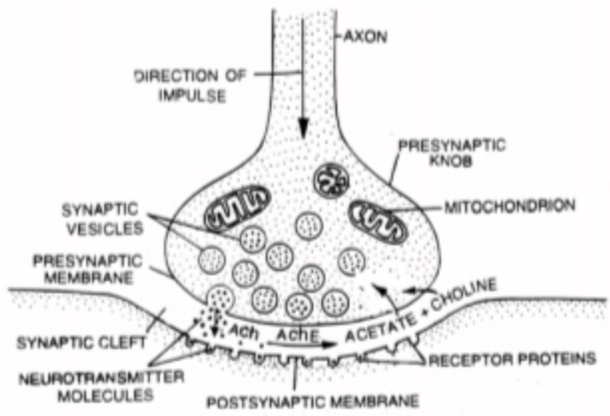


Fig. : Transmission of Nerve impulse at a synapse

There are mainly two types of synapses :

(i) Electrical, and (ii) Chemical, depending on the nature of transfer of information across the synapse. In **electrical synapses** which are specialised for rapid signal transmission, the cells are separated by a gap, the synaptic cleft, of only 0.2 nm, so that an action potential arriving at the presynaptic side of cleft, can sufficiently depolarise the postsynaptic membrane to directly trigger its action potential. However, 10-20 nm gap of most synapses is too great a distance for such direct electrical coupling. **Chemical synapses**, the most common type of synapses, consist of a bulbous expansion of a nerve terminal called **synaptic knob**, lying in close proximity to the membrane of a dendrite. The cytoplasm of the synaptic knob contains numerous tiny, round sacs called **synaptic vesicles**. Each vesicle has a diameter of approximately 50 nm and contains as many as 10,000 molecules of a neurotransmitter substance responsible for the transmission of nerve impulse across the synapse.

The membrane of the synaptic knob on the axon side, thickened as a result of cytoplasmic condensation, is called **presynaptic membrane**. When a wave of depolarisation reaches the presynaptic membrane, voltage-gated calcium channels, concentrated at the synapse open. Because they are 10,000 times more concentrated outside cells, Ca^{2+} ions then diffuse into the axon terminal from the surrounding fluid. The Ca^{2+} ions, in some way, stimulate synaptic vesicles in the terminal to move to the terminal membrane, fuse with it and then rupture thereby causing release of neurotransmitter chemicals from vesicles at the tip by exocytosis into the cleft. These neurotransmitters rapidly pass to the other side of the gap. They then combine with specific **receptor molecules** on the membrane of the target cell which is called the **postsynaptic membrane**. By doing so, they cause a second electrical current, passing on the signal. To end the signal, the synaptic bulb reabsorb some neurotransmitters and enzymes in the synaptic cleft neutralise others.

The enzyme acetylcholinesterase is released from the post synaptic membrane and acts as

Acetylcholine $\xrightarrow{AchE}$ Choline + Acetate.

Choline and Acetate will enter back into the pre-synaptic membrane for resynthesis of neurotransmitter.

As the chemicals stored in the synaptic vesicles help to transmit nerve impulses across the synapses, they are called **NEUROTRANSMITTERS**. A neuron is called **ADRENERGIC** or **CHOLINERGIC** accordingly as it releases noradrenaline or acetylcholine as neurotransmitter at its axon terminals.

One Way Conduction of Impulse : Nerve impulses are always transmitted across a synapse from the axon terminals of one neuron to the dendrite/cell body of the next neuron but never in the reverse direction. Since the neurotransmitter is present only in the axon terminals and not in the dendrites or cell body, it cannot be released from the dendrite or cell body even if the impulse reaches there. So, the impulse can never be transmitted from the dendrite or cell body of the next neuron to the axon of the preceding neuron across the synapse. This **explains the one-way conduction**. You may compare this to the relay race where the baton has to be transferred always from the first runner to the second because the former carries the baton.

Synaptic Delay : Just as a change of baton slows the relay run temporarily, there is delay in the transmission of the nerve impulses at each synapse. This interval, called the **SYNAPTIC DELAY** results from the time taken in releasing the neurotransmitter and in stimulating the next neuron by it.

The axon of a neuron may form synapses with several neurons; so, the nerve impulse from a neuron may diverge to several neurons at the synapse. Again, the axons of several neurons may synapse with a single neuron; this causes the impulses from all those axons to converge to a single neuron at the synapse.

Synaptic Fatigue : On repeated transmission of nerve impulses through a synapse, there occurs a temporary suspension of impulse transmission at the synapse. This is called **SYNAPTIC FATIGUE**. It results from an exhaustion of the neurotransmitter in the synaptic vesicles of the axon terminals. After some time, the neurotransmitter accumulates again in the synaptic vesicles and the synapse regains its ability to transmit impulses.

Central Nervous System

The structures of the CNS arises from its embryological components. **Prosencephalon** (fore brain) becomes the thalamus and hypothalamus **(diencephalon)**, cerebral cortex, corpus striatum, hippocampus and amygdala **(telencephalon)**. **Mesencephalon** (mid brain) becomes midbrain. **Rhombencephalon** (hind brain) develops into the medulla **(myelencephalon)** and the pons and cerebellum **(metencephalon)**.

Human brain : The first thing to notice in the human brain after removing skull is that it is covered by tough tissues known as **meninges**. Surrounding the brain, the cranial meninges are continuous with spinal meninges and have the same basic structure and bear the same names. The outer meninx is **dura mater**. The durameter is a thick double layer of fibrous tissue which resists the movement of the brain that may stretch and break the blood vessels. The middle layer is called the **arachnoid** (*Gk. : spider's web*). The inner layer which is highly vascular and is the one close to the brain is called **pia mater** (*L. soft mother*). It is a moderately tough membrane of connective tissue fibres that clings to the surface of the brain.

The human brain is made of about 100 billion neurons. The cerebral cortex contains roughly 10% of all neurons and is made of six layers of neurons. Such a cortex is called Neocortex. If the layers of neurons are less than six, such cortex is called as Allocortex.

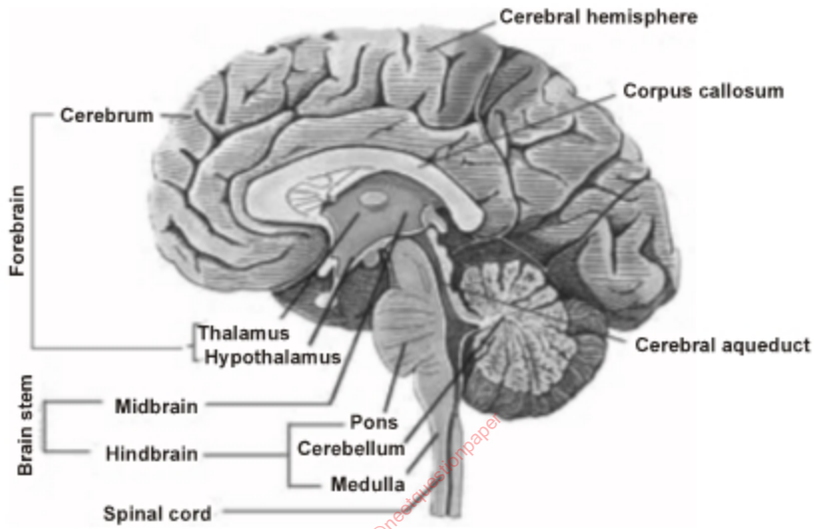


Fig. : Diagram showing sagital section of the human brain

Forebrain

The forebrain consists of cerebrum, thalamus and hypothalamus. Cerebrum forms the major part of the human brain. A deep cleft divides the cerebrum longitudinally into two halves, which are termed as the left and right cerebral hemispheres. The hemispheres are connected by a tract of nerve fibres called **corpus callosum**. The layer of cells which covers the cerebral hemisphere is called cerebral cortex and is thrown into prominent folds. The cerebral cortex is referred to as the grey matter due to its greyish appearance. The neuron cell bodies are concentrated here giving the colour. The cerebral cortex contains motor areas, sensory areas and large regions that are neither clearly sensory nor motor in function. These regions called as the association areas are responsible for complex functions like intersensory associations, memory and communication. Fibres of the tracts are covered with the myelin sheath, which constitute the inner part of cerebral hemisphere. They give an opaque white appearance to the layer and, hence, is called the white matter. The cerebrum wraps around a structure called **thalamus**, which is a major coordinating centre for sensory and motor signaling. Another very important part of the brain called hypothalamus lies at the base of the thalamus. The hypothalamus contains a number of centres which control body temperature, urge for eating and drinking. It also contains several groups of neurosecretory cells, which secrete hormones called hypothalamic hormones. The inner parts of cerebral hemispheres and a group of associated deep structures like amygdala, hippocampus, etc., form a complex structure called the limbic lobe or limbic system. Along with the hypothalamus, it is involved in the regulation of sexual behaviour, expression of emotional reactions (*e.g.*, excitement, pleasure, rage and fear), and motivation.

Basal ganglia is a collection of sub-cortical nuclei (neurons) in forebrain. They are present at the base of cortex. The largest nucleus in them is ***Corpus striatum***. It regulates **planning** and execution of stereotyped movements.

Limbic System : It is the most advanced part of the primate brain which encircles the corpus callosum and the brainstem like a belt. It is like a wish bone, ring like or fork like having links with the cerebrum above and the brain stem below.

It consists of limbic lobes and related sub-cortical nuclei.

Limbic lobes – Cingulate gyrus, Hippocampal gyrus.

Sub-cortical nuclei – Amygdala, hypothalamus.

It is phylogenetically the oldest part of cerebral cortex (Allocortex).

Amygdala : Attached to the interior tips of both forks, is almond shaped structure called amygdala. It is like a defense castle, controlling the moods, especially anger and rage. Certain parts are also concerned with remembering fear.

The **hippocampus** functions as a kind of index for recall of an event with its associated memory. Hippocampus converts information from short-term memory to long-term memory.

Mid brain : The midbrain has one pair optic lobes divided by a transverse sulcus/fissure. This way, the midbrain contains four little lobes, the **corpora quadrigemina**. Its principal structures are **superior colliculi** and **inferior colliculi**. The superior colliculi control and coordinate the visual reflexes.

The inferior pair of colliculi receive impulses from ears and muscles of the head and control auditory reflexes.

Hindbrain : Hind brain comprises pons, cerebellum and medulla.

Like cerebrum, the **cerebellum** has its gray matter on the outside, comprising of three layers of cells and fibres. The middle layer contains characteristically large flask-shaped **Purkinje cells**. Appearing tree like, these cells rank amongst the most complex of all neurons.

Pons consists of fibre tracts that interconnect different regions of the brain.

Medulla contains centres which control respiration, cardiovascular reflexes and gastric secretion.

Brainstem : It is made of Pons Varolii, Medulla, Midbrain and Diencephalon. (Diencephalon may or may not be included; but cerebellum and cerebrum are never a part). **Brain stem forms the connections between the brain and spinal cord. Three major regions make up the brain stem; midbrain, pons and medulla oblongata.**

Ventricles of Brain

They are central CSF-filled cavities in brain, lined by ependymal cells.

1st ventricle is **Rhinocoel.** It is absent in humans. Its present in frog and rabbits in their olfactory lobes.

↓ It communicates with

2nd Ventricle (**Paracoel**/Lateral ventricles). They are present in the cerebral hemispheres. Both communicate with IIIrd ventricle through foramen of **Monro/Interventricular foramen**.

↓

3rd Ventricle **(Diocoel)**. It is present inside Diencephalon(floor of fore brain). It communicates with the IVth ventricle through **Iter or Aqueduct of Sylvius**.

↓

4th ventricle **(Metacoel)** is present in medulla oblongata and

↓ Communicates with

Spinal Canal **(Myelocoel)** or **central canal.**

In the roof of metacoel, three Foramina are present. Two lateral foramina called **Foramina of Luschka** and 1 median foramen called **Foramen of Magendie**. They enable the CSF secreted by **choroid plexus** to escape above piamater into sub arachnoid space.

Spinal cord has grey matter in centre and white matter in periphery.

Reflex Action and Reflex Arc

1. **Monosynaptic reflex/Simple reflex :** It involves a single sensory and a single motor nerve fibre. Interneuron will be absent. *e.g.*, Knee jerkreflex, Biceps jerkreflex (Tendon jerk).
2. **Polysynaptic reflex :** There are two or more than two synapses. It involves one (or more) sensory nerve fibres and more than one motor nerve fibres. Polysynaptic reflexes are more common in human body. All our visceral reflexes are polysynaptic reflexes. Interneurons are present.

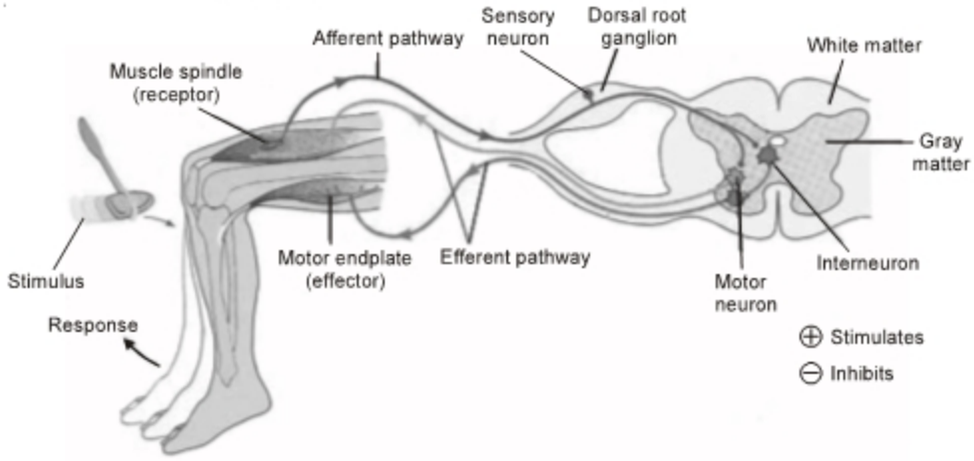


Fig. : Reflex Arc

Peripheral Nervous System

Cranial Nerves

No.	Name	Fibres	Organs Innervated	Functions
Ist	**Olfactory**	Sensory	Olfactory mucosa in nose	Smell
IInd	**Optic**	Sensory	Retina of eye	Vision
IIIrd	**Occulomotor**	Motor	Eyeball muscles, ciliary muscles, tear glands	Eyeball movement
IVth	**Trochlear/pathetic**	Motor	Eyeball muscles	Eyeball movement
Vth	**Trigeminal** Dentist's nerve, largest cranial nerve	Mixed	Skin, oral mucosa, muscles of head, face, mouth	Cutaneous sensation, muscle movements
VIth	**Abducens**	Motor	Eyeball muscles	Eyeball movement
VIIth	**Facial**	Mixed	Taste buds, salivary glands, facial and neck muscles	Taste, salivation, muscles movements, tear secretion
VIIIth	**Auditory**	Sensory	Internal ear	Hearing, equilibrium
IXth	**Glossopharyngeal**	Mixed	Pharynx, tongue, salivary glands	Taste, salivation, swallowing
Xth	**Vagus** longest cranial nerve with maximum branches	Mixed	Pharynx, respiratory tract, heart, pancreas, alimentary canal, blood vessels	Gastric and pancreatic secretion, cardiac rate slowing, gastrointestinal movements, respiratory reflexes, vasomotor reflexes, visceral reflexes
XIth	**Spinal accessory**	Motor	Neck and shoulder muscles, thoracic and abdominal viscera	Muscle movements, visceral reflexes
XIIth	**Hypoglossal**	Motor	Tongue muscles	Tongue movements

Autonomic Nervous System

The autonomic nervous system is composed of two types of neurons, myelinated preganglionic neurons, which leave the ventral roots of the segmental nerves before synapsing with several unmyelinated neurons leading to the effectors. With one exception, all sympathetic preganglionic axons enter the **autonomic ganglia** which are bulbous structures containing the cell bodies of many neurons of the sympathetic chain, but not all of them synapse there. The exception is the medulla of the adrenal gland. The cell bodies of sympathetic postganglionic (motor) neurons are situated in ganglia close to the spinal cord. Each **sympathetic ganglion** is connected to the spinal cord by a **white ramus communicans** and to the spinal nerve by a **gray ramus communicans.**

The **neurotransmitter within the ganglion** is **acetylcholine for both sympathetic and parasympathetic nerves**. However, the neurotransmitter between the terminal autonomic axon and the target organ is different in the two antagonistic autonomic nervous systems. In the parasympathetic system, the neurotransmitter at the terminal synapse is acetylcholine, just as it is in the ganglion. However, in the sympathetic system, the neurotransmitter at the terminal synapse is either **adrenaline** or **noradrenaline**, both of which have an effect opposite to that of acetylcholine. The sympathetic postganglionic neuron that terminates on the sweat glands however uses **acetylcholine** an exceptional feature.

Functions of autonomic nervous system

Organ Innervated	Function of Sympathetic Nervous System (Thoracico- Lumbar outflow)	Function of Parasympathetic Nervous System (Cranio-sacral outflow)
Heart	**Accelerates heart beat rate**	**Slows heart beat rate**
Arteries	Constricts arteries and raises blood pressure	Dilates arteries and lowers blood pressure
Digestive tract	Slows peristalsis, decreases activity of digestive glands	Speeds peristalsis, increases activity of digestive glands
Salivary glands	**Inhibits secretion**	**Stimulates secretion**
Gall Bladder	Relaxes	Contracts
Gastric glands	Inhibits secretion	Stimulates secretion
Pancreas	Inhibits secretion	Promotes secretion
Intestinal glands	Inhibits secretion	Stimulates secretion
Liver	Promotes sugar release; decreases bile production	Promotes glycogen formation; increases bile production
Urinary bladder	Relaxes bladder	Constricts bladder
Muscles in bronchi	**Dilates respiratory passages, making breathing easier**	**Constricts respiratory passages**
Muscles of iris	Dilates pupil	Constricts pupil
Muscles attached to hair	Causes erection of hair	No effect
Sweat glands	Increases secretion	No effect

Sense Organs In Humans

We smell things by our nose, taste by tongue, hear by ear and see objects by eyes. The nose contains mucus-coated receptors which are specialised for receiving the sense of smell and called olfactory receptors. These are made up of olfactory epithelium that consists of three kinds of cells. The neurons of the olfactory epithelium extend from the outside environment directly into a pair of broad bean-sized organs, called olfactory bulb, which are extensions of the brain's limbic system.

Both nose and tongue detect dissolved chemicals. The chemical senses of gustation (taste) and olfactory (smell) are functionally similar and interrelated. The tongue detects tastes through taste buds, containing gustatory receptors. With each taste of food or sip of drink, the brain integrates the differential input from the taste buds and a complex flavour is perceived.

Sensory Reception and Processing

Have you ever thought how do you feel the climatic changes in the environment? How do you see an object and its colour? How do you hear a sound? The sensory organs detect all types of changes in the environment and send appropriate signals to the CNS, where all the inputs are processed and analysed. Signals are then sent to different parts/centres of the brain. This is how you can sense changes in the environment.

EYE

Our paired eyes are located in sockets of the skull called **orbits**. A brief account of structure and functions of the human eye is given in the following sections.

Parts of an eye

The adult human eye ball is nearly a spherical structure. The wall of the eye ball is composed of three layers as in figure. The external layer is composed of a dense connective tissue and is called the **sclera**. The anterior portion of this layer is called the **cornea**. The middle layer, **choroid**, contains many blood vessels and looks bluish in colour. The choroid layer is thin over the posterior two-thirds of the eye ball, but it becomes thick in the anterior part to form the **ciliary body**. The ciliary body itself continues forward to form a pigmented and opaque structure called the **iris** which is the visible coloured portion of the eye. The eye ball contains a transparent crystalline **lens** which is held in place by ligaments attached to the ciliary body. In front of the lens, the aperture surrounded by the iris is called the **pupil**. The diameter of the pupil is regulated by the muscle fibres of iris.

The inner layer is the **retina** and it contains three layers of cells – from inside to outside – ganglion cells, bipolar cells and photoreceptor cells.

In the retina (nervous layer), the ratio of receptor neurons to bipolar cells to ganglion cells is 1 : 1 : 1 in the fovea. **Fovea** is the point where **visual acuity is greatest**. Outside the fovea, however, processing of visual information can also occur in the retina because several receptor cells synapse with a single bipolar cell, and several bipolar cells synapse with a single ganglion cell. Besides this convergence, **horizontal** and **Amacrine cells** enable lateral transfer. Horizontal cells connect receptor cells to each other. **Amacrine** cells connect ganglion cells to one another.

Ora Serrata : The anterior margin of the optic part of retina forms a wavy line called the ora serrata. Beyond ora serrata, retina continues forwards as a thin, non-nervous insensitive layer that covers the ciliary body and iris.

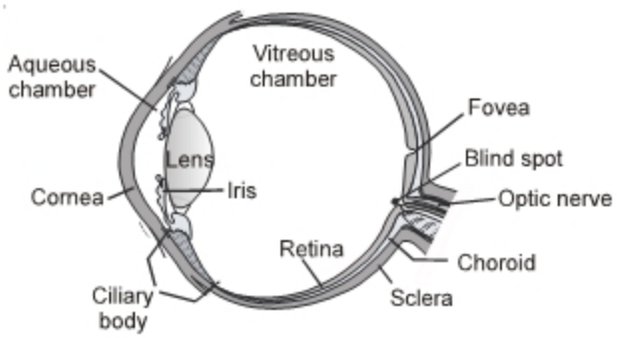


Fig. : Diagram showing parts of an eye

There are two types of photoreceptor cells, namely, **rods** and **cones**. These cells contain the light-sensitive proteins called the photopigments. The daylight (photopic) vision and colour vision are functions of cones and the twilight (scotopic) vision is the function of the rods. The rods contain a purplish-red protein called the rhodopsin or visual purple, which contains a derivative of Vitamin A. In the human eye, there are three types of cones which possess their own characteristic photopigments that respond to red, green and blue lights. The sensations of different colours are produced by various combinations of these cones and their photopigments. When these cones are stimulated equally, a sensation of white light is produced. The **optic nerves** leave the eye and the retinal blood vessels enter it at a point medial to and slightly above the posterior pole of the eye ball. Photoreceptor cells are not present in that region and hence it is called the **blind spot**. At the posterior pole of the eye lateral to the blind spot, there is a yellowish pigmented spot called macula lutea with a central pit called the **fovea**. The fovea is a thinned-out portion of the retina where only the cones are densely packed. It is the point where the visual acuity (resolution) is the greatest.

The space between the cornea and the lens is called the **aqueous chamber** and contains a thin watery fluid called aqueous humor. The space between the lens and the retina is called the **vitreous chamber** and is filled with a transparent gel called vitreous humor.

Mechanism of Vision

The light rays in visible wavelength focussed on the retina through the cornea and lens generate potentials (impulses) in rods and cones. As mentioned earlier, the photosensitive compounds (photopigments) in the human eyes is composed of **opsin** (a protein) and **retinal** (an aldehyde of vitamin A). Light induces dissociation of the retinal from opsin resulting in changes in the structure of the opsin. This causes membrane permeability changes. As a result, potential differences are generated in the photoreceptor cells. This produces a signal that generates action potentials in the ganglion cells through the bipolar cells. These action potentials (impulses) are transmitted by the optic nerves to the **visual cortex** area of the brain, where the neural impulses are analysed and the image formed on the retina is recognised based on earlier memory and experience.

Accommodation

1. The process by which the curvature of the lens is increased or decreased to focus is called accommodation. Accommodation is an active process, requiring muscular effort and can therefore be tiring.
2. **To focus the near objects, the circular ciliary muscles will contract. The ciliary body will move inwards and forwards; the suspensory ligaments will slacken/loosen, the radius of curvature of the lens will decrease, its focal length will decrease, *i.e.*, it becomes thicker, round up and the refraction of rays increases.** The size of the pupil also decreases increasing the depth of focus of the eye.
3. When the ciliary muscles are relaxed, parallel light rays striking the optically normal (emmetropic) eye are brought to focus on the retina. Our resting eye is focused for distant objects (more than 6m). When the ciliary muscles are relaxed, the ciliary body will move backwards, suspensory ligaments tighten, radius of curvature of lens increases, *i.e.*, focal length increases.

Disorders

1. **Myopia (short-sightedness) :** In this defect, the eyeball elongates antero-posteriorly, so that the image is formed in front of retina. Concave lenses are used to diverge the rays and locus the image on retina.
2. **Hypermetropia (long-sightedness) :** In this defect, the eyeball shortens antero-posteriorly, so that the image is formed behind the retina, Convex lenses are used to converge the image on the retina.
3. **Cataract :** Lens becomes opaque. It is caused by the denaturation of lens proteins due to various causes. Modern treatment of cataract comprises introduction of an artificial lens surgically into the eye. Diabetes mellitus may cause cataract even at an early age.

4. **Astigmatism** results from the differences in curvature between different meridians of the cornea. Light rays passing through different meridians of the cornea suffer different degrees of refraction and are consequently focused at different points, blurring the image. It can be corrected by using cylindrical lenses.
5. **Glaucoma (Kalamotia), Intra-ocular pressure is increased due to blockage in canal of Schlemn.**
6. **Presbyopia** is old age sightedness, generally occurs after the age of 40 when the lens looses its elasticity and ability to focus on near objects. When a person is in water, no refraction occurs at cornea because refractive index of water and cornea becomes the same, thus producing blurred vision.

Glands of eyes :

(i) Embedded in each tarsal plate of the eyelids is a row of elongated modified sebaceous glands known as **Meibomian glands**. Their oily secretion helps to keep the eyelids from adhering to each other.

(ii) **Harderian Glands :** They are absent in man and rabbit. They are modified sebaceous glands and produce an oily secretion for lubricating the nictitating membrane.

EAR

The primary function of the ear is balancing and hearing. Human ear can hear vibrations ranging from 20 to 20,000 cycles/sec. Anatomically, the ear can be divided into three major sections called the outer ear, the middle ear and the inner ear. The external ear funnels sound waves to the external auditory meatus, which leads them inwards to the tympanic membrane (eardrum).

The middle ear is an air filled cavity in the temporal bone that opens via Eustachian tube into the nasopharynx. The tube is usually closed, but during swallowing, chewing and yawning it opens, keeping the air pressure on the two sides equalised. The three auditory ossicles, the **malleus, incus** and **stapes** are located in middle ear. The manubrium (handle of malleus) is attached to the tympanic membrane. The footplate of stapes is attached by angular ligament to wall of **oval window,** the **fenestra ovalis**. An Eustachian tube connects the middle ear cavity with the pharynx.

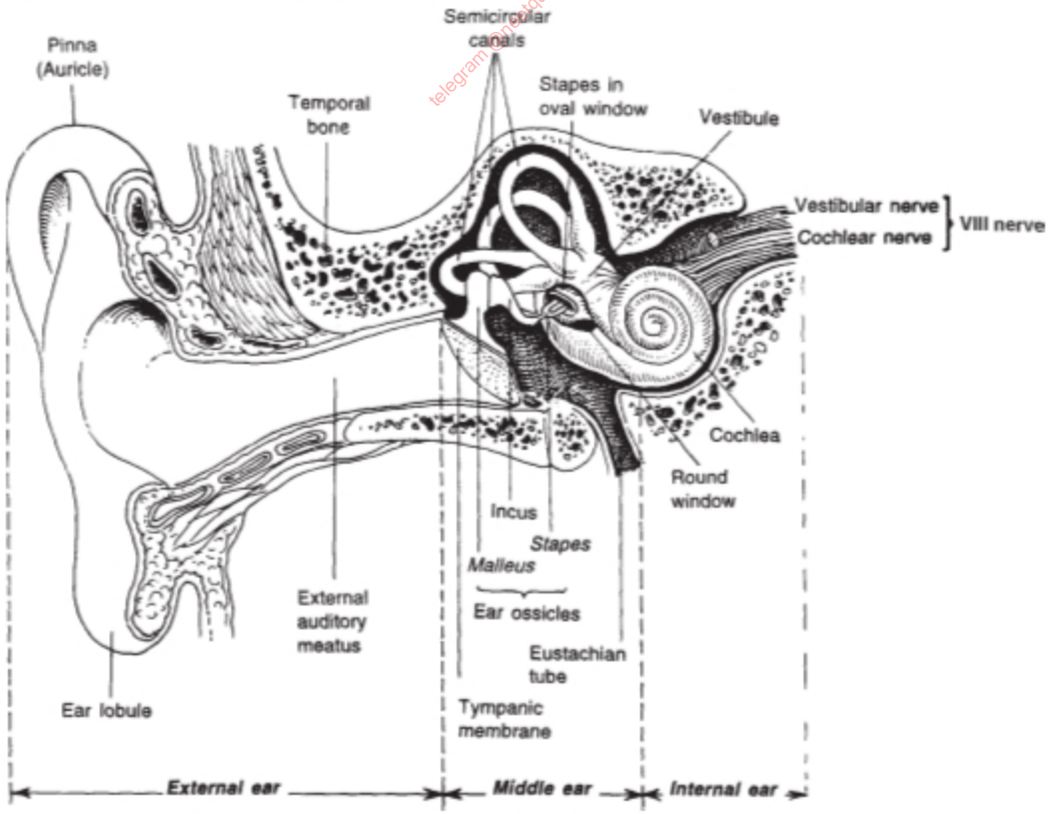


Fig. : Structure of the ear

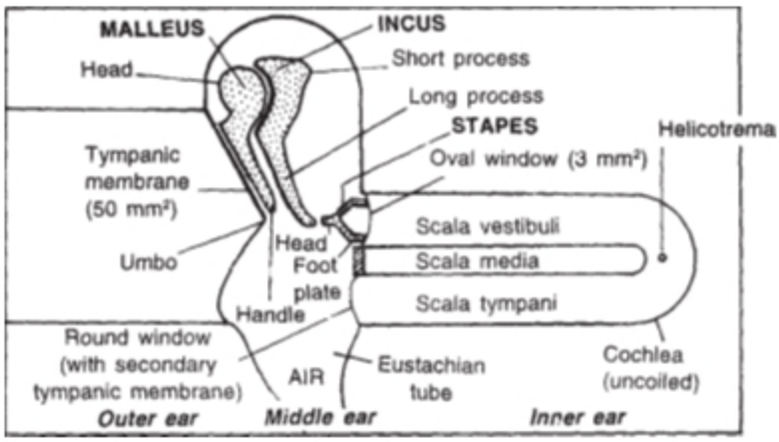


Fig. : Arrangement of ear (auditory) ossicles in the middle ear and scalae in the cochlea (inner ear)

Inner ear (labyrinth) is made of bony labyrinth and membranous labyrinth. The membranous labyrinth is filled with **Endolymph** while bony labyrinth contains **Perilymph**.

Cochlea portion of the labyrinth is a coiled tube which, in humans, is 35 mm long and makes $2\frac{3}{4}$ turns. Throughout the length, the **Basilar membrane** and **Reissner's membrane** divide it into 3 chambers. The upper scala vestibuli and lower scala tympani contain perilymph and communicate with each other at the apex of cochlea by a small opening, **helicotrema**. The scala tympani ends at the round window, **fenestra rotunda**, a foramen in the median wall of middle ear. **Scala media** contains endolymph. **Basilar membrane** is present in the floor of scala media and **Reissner's membrane** is present in its roof. Located on the basilar membrane is **organ of corti**, that contains sensory hair cells. Covering the rows of hair cells, is a thin elastic membrane called **tectorial membrane**. The sensory hair cells are supplied with cochlear branch of auditory nerve and are concerned with hearing.

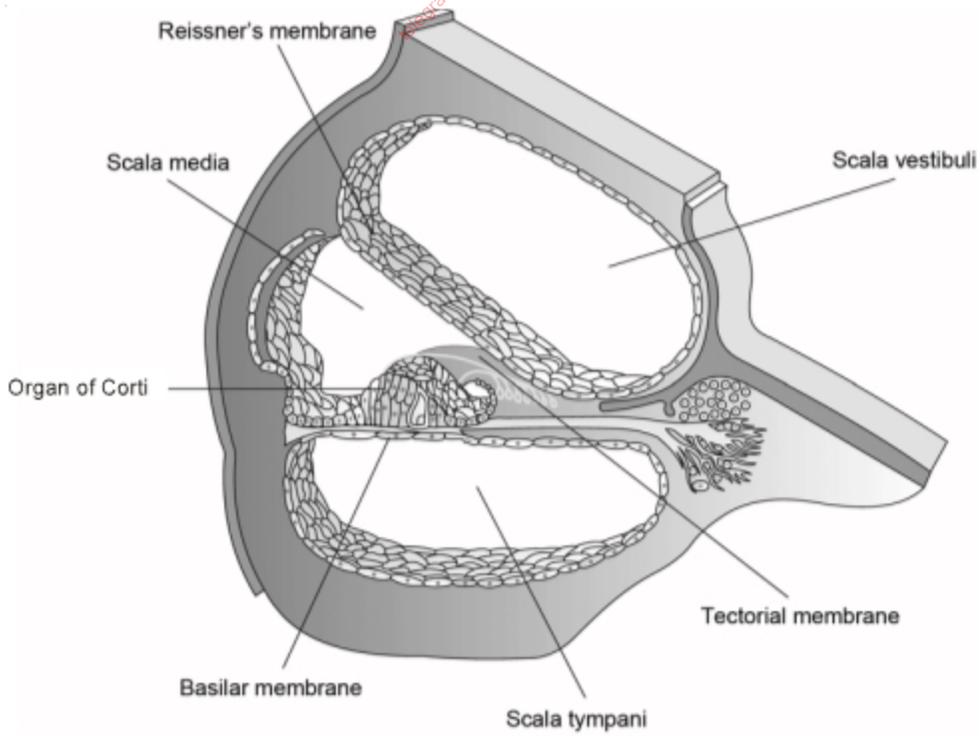


Fig. : Diagrammatic representation of the sectional view of cochlea

The internal ear also contains a complex system called **Vestibular apparatus** located above the cochlea. The vestibular apparatus is composed of

Semicircular canals : Semicircular canals lie perpendicular to each other, oriented in 3 planes of space. A receptor structure, the **crista ampullaris** is located in the expanded end (ampulla) of each semicircular canal. They are concerned with dynamic equilibrium.

Otolith organ : It consists saccule and utriculus. Utricle and saccule lie within each membranous labyrinth. On the floor of utricle, there is **otolithic organ** (macula). Another macula is located in the wall of saccule. Both **maculae** are concerned with static equilibrium.

Mechanism of Hearing

How does ear convert sound waves into neural impulses, which are sensed and processed by the brain enabling us to recognise a sound? The external ear receives sound waves and directs them to the ear drum. The ear drum vibrates in response to the sound waves and these vibrations are transmitted through the ear ossicles (malleus, incus and stapes) to the oval window. The vibrations are passed through the oval window onto the fluid of the cochlea, where they generate waves in the lymphs. The waves in the lymphs induce a ripple in the basilar membrane. These movements of the basilar membrane bend the hair cells, pressing them against the tectorial membrane. As a result, nerve impulses are generated in the associated afferent neurons. These impulses are transmitted by the afferent fibres via auditory nerves to the auditory cortex of the brain, where the impulses are analysed and the sound is recognised.

Olfactory and Gustatory receptors

The **nose** contains mucus-coated receptors which are specialised for receiving the sense of smell and called **olfactory receptors**. These are made up of olfactory epithelium that consists of three kinds of cells and Bowman's gland. The neurons of the olfactory epithelium extend from the outside environment directly into a pair of broad bean-sized organs, called **olfactory bulb**, which are extensions of the brain's limbic system.

Both nose and tongue detect dissolved chemicals. The chemical senses of gustation (taste) and olfactory (smell) are functionally similar and interrelated. The tongue detects tastes through **taste buds**, containing **gustatory receptors**. With each taste of food or sip of drink, the brain integrates the differential input from the taste buds and a complex flavour is perceived.

Receptors

These are structures at the ends of the sensory nerve fibres for collecting information. Some receptors are specialised cells near the termination of nerve fibres, *e.g.*, rod and cone cells in the retina. Some other receptors are specially modified terminals of the nerve fibre itself, *e.g.*, Pacinian corpuscles in the skin. But even nerve terminals showing no apparent specialised form or structure may serve as receptors in many cases; they are called **FREE NERVE ENDINGS** and are plentiful in the skin.

Types of Receptors

Receptors can be classified according to their location or the kinds of stimuli they can receive.

(A) Classification of Receptors according to their location

(i) **Exteroreceptors** are usually located near the surface of the body and detect changes in the surroundings. Receptors for touch, heat, cold, light and sound are examples of exteroreceptors. Free nerve endings in the skin that detect pain are also exteroreceptors.

(ii) **Proprioreceptors** are located in the muscles, tendons, and joints. They detect changes in the position of limbs and changes in muscle length and tension.

(iii) **Visceroreceptors** (enteroreceptors) are located within the organs of the body other than muscles, tendons, and joints. They detect pain, the degree of stretching of blood vessel walls, movements in the digestive tract and similar sensations. Pain receptors **(nociceptors)** are found in nearly every tissue of the body. We usually are conscious of the activities of exteroreceptors, but many of the impulses from proprioreceptors and visceroreceptors are relayed to the cerebellum, brainstem and other parts of the central nervous system besides the cerebral cortex.

(B) Classification of Receptors according to the type of Stimuli they receive

1. **Mechanoreceptors :** Respond to mechanical changes or stimuli. They are of following types :
   - (i) **Tangoreceptors :** Respond to touch and pressure *e.g.*, **Merkel's discs, Meissner's corpuscles** and root hair plexus respond to touch. **Pacinian corpuscles** respond to strong pressure.
   - (ii) **Algesireceptors :** Respond to pain *e.g.*, free nerve endings.
   - (iii) **Proprioreceptors :** Respond to stimuli originating within the body itself, especially respond to position or stretch. Within skeletal muscles, are a number of proprioreceptors called **muscle spindles**. Muscle spindles are found in the muscles of mammals, amphibians, crustaceans and insects.
   - (iv) **Statoreceptors :** Respond to acceleration and gravity *e.g.*, hair cells in cristae and maculae of internal ear (membranous labyrinth).
   - (v) **Phonoreceptors :** Respond to air borne sound waves *e.g.*, Organ of Corti of internal ear (membranous labyrinth).
   - (vi) **Rheoreceptors :** Respond to pressure waves and currents in water *e.g.*, Neuromast organ in the lateral line sense organs of fish and tadpole larva of frog.
2. **Thermoreceptors :** Respond to temperature. They are of two types :
   - (i) **Caloreceptors :** Respond to heat *e.g.*, Ruffini's corpuscles.
   - (ii) **Frigidoreceptors :** Respond to cold *e.g.*, Krause's bulbs.
3. **Chemoreceptors :** Respond to chemicals. They are of two types :
   - (i) **Gustatoreceptors :** Respond to taste *e.g.*, Taste buds.
   - (ii) **Olfactoreceptors :** Respond to smell *e.g.*, olfactory epithelium.
4. **Electroreceptors (Galvanoreceptors) :** Respond to electric currents in surrounding water *e.g.*, organs in skin of some fish like *Torpedo*.
5. **Photoreceptors :** Respond to light *e.g.*, Rods and Cones of retina of vertebrate eyes and ommatidia of compound eyes in arthropods.

❑ ❑ ❑

Try Yourself

SECTION - A

Objective Type Questions

1. A neuron is depolarised when it acquires
   (1) A negative charge in the intracellular fluid and a positive charge outside
   (2) A positive charge in the intracellular fluid and a negative charge outside
   (3) A positive charge on both sides
   (4) A negative charge on both sides
2. Synaptic delay results from
   (1) Exhaustion of the neurotransmitter in the synaptic vesicles of the axon
   (2) The time taken in releasing the neurotransmitter and in stimulating the next neuron
   (3) The time taken for the resynthesis of the neurotransmitter in the synaptic vesicles
   (4) The divergence of nerve impulse from a neuron to several neurons at the synapse because the axon of a neuron may form synapse with several neurons
3. During the conduction of nerve impulse, repolarisation starts with the
   (1) Influx of K^+ ions
   (2) Efflux of K^+ ions and closure of Na^+ gates
   (3) Efflux of Na^+ ions, opening of Na^+ gates
   (4) Influx of Na^+
4. One way conduction of the nerve impulse is due to
   (1) Neurotransmitter being present only in the axon terminals and not in dendrites of cell body
   (2) Nerve fibre being insulated by a medullary sheath
   (3) Neurotransmitters being released by dendrites and not by the axon
   (4) Sodium potassium pump operating only at the cyton
5. Highly vascular and closely investing protective coat around brain is known as
   (1) Arachnoid mater
   (2) Pia mater
   (3) Dura mater
   (4) Sub-arachnoid space
6. You have two types of brains in petri dish. Which structure helps you distinguish the brain of a mammal?
   (1) Cerebellum
   (2) Cerebrum
   (3) Optic lobes
   (4) Corpus callosum
7. Telencephalon includes
   (1) Thalamus and hypothalamus
   (2) Cerebral cortex, corpus striatum, hippocampus and amygdala
   (3) Mid brain
   (4) Medulla, pons and cerebellum
8. Cerebral cortex (Neocortex) is made of how many layers and of how many neurons?
   (1) Less than six layers, 100 billion neurons
   (2) Six layers, 100 billion neurons
   (3) Six layers and 10 billion neurons
   (4) Three layers and 10 billion neurons
9. Basal ganglia is a collection of subcortical nuclei in the forebrain at the base of the cortex. Primary function of one of the basal ganglia, corpus striatum, is
   (1) Sensory integration
   (2) Short term memory
   (3) Planning voluntary stereotyped movements
   (4) Neuroendocrine control

10. Which part of the brain does not initiate movements but modulates or reorganises motor commands?
    (1) Cerebrum
    (2) Cerebellum
    (3) Amygdala
    (4) Inferior colliculi

11. Which part of the brain is like a defense castle controlling moods and plays an important role in emotional behaviour such as aggression and remembering fear?
    (1) Hippocampus (2) Amygdala
    (3) Limbic system (4) Thalamus

12. Which part of the brain stem controls and co-ordinates the movements of the head and eyes to fix and focus on an object?
    (1) Superior colliculi
    (2) Inferior colliculi
    (3) Pons
    (4) Medulla oblongata

13. Which structure forms the cerebrospinal fluid?
    (1) Cerebrum
    (2) Choroid plexus
    (3) Duramater
    (4) Sub arachnoid space

14. Thermoregulatory centre in the body of man is in
    (1) Skin (2) Diencephalon
    (3) Hypothalamus (4) Pituitary

15. Brain stem consists of
    (1) Medulla oblongata and Pons varolii only
    (2) Pons, Diencephalon, Mid brain, Cerebrum
    (3) Medulla, Pons, Mid brain, Diencephalon
    (4) Medulla, Pons, Mid brain, Cerebellum

16. Foramen of Monro connects
    (1) Diocoel with metacoel
    (2) Diocoel with paracoel
    (3) Optocoel with diocoel
    (4) Rhinocoel with paracoel

17. Aqueduct of Sylvius connects the
    (1) Paracoel with 3rd ventricle
    (2) Paracoel with 4th ventricle
    (3) Paracoel with metacoel
    (4) Diocoel with metacoel

18. Which of the following cranial nerve is called Dentist's nerve and reacts to messages of pain. It also protects us by warning about harmful chemicals in air?
    (1) Trigeminal (V) (2) Facial (VII)
    (3) Olfactory (I) (4) Vagus (X)

19. Which structure has gray matter in centre and white matter in periphery?
    (1) Meninges (2) Spinal cord
    (3) Brain (4) Spinal nerves

20. Thoracico-lumbar outflow is
    (1) ANS
    (2) Sympathetic nervous system
    (3) Parasympathetic nervous system
    (4) All of these

21. Parasympathetic nervous system
    (1) Dilates pupil of eye
    (2) Accelerates heart beat
    (3) Stimulates secretion of saliva
    (4) Dilates bronchioles

22. The neuro transmitter released from presynaptic autonomic fibres is
    (1) Nor-epinephrine for sympathetic ganglia
    (2) Acetylcholine for both sympathetic and parasympathetic ganglia
    (3) Serotonin
    (4) Glycine

23. The part of an eye which acts like a diaphragm of a photographic camera is
    (1) Pupil (2) Iris
    (3) Lens (4) Cornea

24. Cone cells contain
    (1) Rhodopsin or visual purple pigment
    (2) Iodopsin or visual violet pigment
    (3) Both (1) & (2)
    (4) Bipolar neurons

25. The visual purple is concerned with vision in
(1) Bright light (2) Dim light
(3) Moderate light (4) Complete darkness

26. Processing of visual information before it leaves retina is the function of
(1) Amacrine cells (2) Eccrine cells
(3) Apocrine cells (4) Holocrine cells

27. Macula lutea is a part of
(1) Optic nerve (2) Sclerotic layer
(3) Choroid (4) Retina

28. Ora serrata is / refers to
(1) Oral cavity of protochordates
(2) A part of utriculus of ear
(3) Gland present in oral cavity of frog
(4) The junction between the neurosensory retina and ciliary body of choroid layer

29. The secretion of Harderian gland is
(1) Watery (2) Acidic
(3) Oily (4) Alkaline

30. In mammalian eye, the power of accommodation is controlled by changing thickness of the lens. This is governed by
(1) Cornea (2) Pupil
(3) Iris (4) Ciliary body

31. The blind spot is the region where
(1) Image is formed
(2) Cones are numerous
(3) The optic nerve leaves the eye ball
(4) Image is formed during darkness

32. Visual accommodation for near objects involves
(1) Increased tension in the lens ligaments
(2) An increase in the radius of curvature of the lens
(3) Relaxation of the sphincter muscles of the iris
(4) Contraction of the ciliary muscles

33. When eye ball becomes shorter than normal, it results in an eye defect known as
(1) Myopia (2) Hypermetropia
(3) Cataract (4) Presbyopia

34. Astigmatism is corrected by the use of
(1) Convex lens (2) Concave lens
(3) Cylindrical lens (4) Surgery

35. One of the following glands are present on edges of eyelids of human and produce a greasy substance for frictionless blinking
(1) Lacrimal gland (2) Harderian gland
(3) Meibomian gland (4) Ceruminous gland

36. Short sightedness or myopic vision is corrected by wearing
(1) Convex lens (2) Concave lens
(3) Convex mirror (4) Concave mirror

37. Glaucoma is due to
(1) Elongation of the eye ball
(2) Shortening of the eye ball
(3) Increase in intraocular pressure
(4) Improper drainage of the vitreous humor into the canal of schlemn

38. A tube which communicates the pharynx with tympanic cavity and equalises the pressure of air on the two sides of the tympanic membrane is known as
(1) Eustachian tube (2) Fallopian tube
(3) Blind tube (4) All of these

39. Correct sequence of ear ossicles starting from tympanic membrane is
(1) Malleus-Incus-Stapes
(2) Stapes-Malleus-Incus
(3) Malleus-Stapes-Incus
(4) Incus-Stapes-Malleus

40. One of the following is stirrup shaped bone
(1) Incus (2) Malleus
(3) Stapes (4) Hyoid

41. Upper aperture which puts tympanic cavity in communication with a narrow space around the internal ear is known as
(1) Fenestra ovalis (2) Fenestra rotundus
(3) Fossa ovalis (4) Foraman ovale

42. The membranous labyrinth is concerned with
(1) Hearing (2) Equilibrium
(3) Both (1) & (2) (4) Visual reception

43. The membranous labyrinth contains a fluid called
(1) Perilymph (2) Haemolymph
(3) Lymph (4) Endolymph

44. Which part of internal ear receives sound waves in man?
(1) Cochlea
(2) Lagena and utriculus
(3) Ampullae and utriculus
(4) All of these

45. The floor of scala media is formed by
(1) Reissner's membrane (2) Basillar membrane
(3) Tectorial membrane (4) Organ of corti

46. Loudness of sound is discriminated by
(1) Intensity of movement of basilar fibres of cochlea and rate of nerve impulses reaching the auditory cortex
(2) Vibration of semicircular canals
(3) Vibration of endolymphatic sac
(4) Vibration of tympanic bulla

47. The range of audible sound frequency in case of man is
(1) 16-200,000 cycles/s (2) 160-20,000 cycles/s
(3) 20-20,000 cycles/s (4) 1600-20,000 cycles/s

48. At the time of flight, the pain in the ear is due to
(1) Sound of engine
(2) Difference in pressure between the middle ear and outer ear
(3) Difference in pressure between the middle and inner ear
(4) Destruction of ear drum

49. Which of the following receptors are specially modified terminals of nerve fibre themselves and act as strong pressure receptors?
(1) Meissner's corpuscles
(2) Pacinian corpuscles
(3) Merkel's disc
(4) Proprioreceptor

50. Bowman's glands are found in
(1) Olfactory epithelium
(2) External auditory canal
(3) Cortical nephrons only
(4) Juxta medullary nephrons

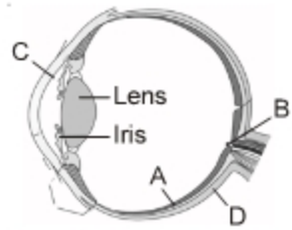
SECTION - B

Previous Years Questions

1. The human hind brain comprises three parts, one of which is **[AIPMT 2012]**
(1) Cerebellum (2) Hypothalamus
(3) Spinal cord (4) Corpus callosum

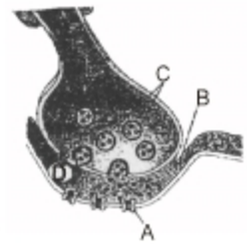
2. Which part of the human ear plays no role in hearing as such but is otherwise very much required? **[AIPMT 2012]**
(1) Vestibular apparatus (2) Ear ossicles
(3) Eustachian tube (4) Organ of Corti

3. Parts A, B, C and D of the human eye are shown in the diagram. Select the option which gives **correct** identification along with its functions/ characteristics **[NEET 2013]**



(1) B – Blind spot – has only a few rods and cones.
(2) C – Aqueous chamber – reflects the light which does not pass through the lens.
(3) D – Choroid – its anterior part forms ciliary body.
(4) A – Retina – contains photo receptors – rods and cones.

4. A diagram showing axon terminal and synapse is given. Identify correctly at least two of A-D



[NEET 2013]

(1) B - Synaptic connection
D - K^+
(2) A - Neurotransmitter
B - Synaptic cleft
(3) C - Neurotransmitter
D - Ca^{++}
(4) A - Receptor
C - Synaptic vesicles

5. Injury localized to the hypothalamus would most likely disrupt **[AIPMT 2014]**
(1) Short term memory
(2) Co-ordination during locomotion
(3) Executive function, such as decision making
(4) Regulation of body temperature

6. Which one of the following statements is **not correct?** **[AIPMT 2014]**
(1) Retinal is the light absorbing portion of visual photo pigments
(2) In retina the rods have the photopigment rhodopsin while cones have three different photopigments
(3) Retinal is a derivative of vitamin C
(4) Rhodopsin is the purplish red protein present in rods only

7. In mammalian eye, the 'fovea' is the center of the visual field, where **[Re-AIPMT-2015]**
   (1) More rods than cones are found
   (2) High density of cones occur, but has no rods
   (3) The optic nerve leaves the eye
   (4) Only rods are present

8. Destruction of the anterior horn cells of the spinal cord would result in loss of **[Re-AIPMT-2015]**
   (1) Integrating impulses
   (2) Sensory impulses
   (3) Voluntary motor impulses
   (4) Commissural impulses

9. A gymnast is able to balance his body upside down even in the total darkness because of **[AIPMT-2015]**
   (1) Organ of corti (2) Cochlea
   (3) Vestibular apparatus (4) Tectorial membrane

10. Which of the following regions of the brain is **incorrectly** paired with its function? **[AIPMT-2015]**
   (1) Cerebrum-calculation and contemplation
   (2) Medulla oblongata-homeostatic control
   (3) Cerebellum-language comprehension
   (4) Corpus callosum-communication between the left and the right cerebral cortices

11. Photosensitive compound in human eye is made up of **[NEET-2016]**
   (1) Transducin and Retinene
   (2) Guanosine and Retinol
   (3) Opsin and Retinal
   (4) Opsin and Retinol

12. Choose the **correct** statement. **[NEET (Phase-2) 2016]**
   (1) Nociceptors respond to changes in pressure
   (2) Meissner's corpuscles are thermoreceptors
   (3) Photoreceptors in the human eye are depolarised during darkness and become hyperpolarized in response to the light stimulus
   (4) Receptors do not produce graded potentials

13. Myelin sheath is produced by **[NEET-2017]**
   (1) Schwann Cells and Oligodendrocytes
   (2) Astrocytes and Schwann Cells
   (3) Oligodendrocytes and Osteoclasts
   (4) Osteoclasts and Astrocytes

14. Receptor sites for neurotransmitters are present on **[NEET-2017]**
   (1) Membranes of synaptic vesicles
   (2) Pre-synaptic membrane
   (3) Tips of axons
   (4) Post-synaptic membrane

15. Good vision depends on adequate intake of carotene rich food. Select the best option from the following statements **[NEET-2017]**
   (a) Vitamin A derivatives are formed from carotene.
   (b) The photopigments are embedded in the membrane discs of the inner segment.
   (c) Retinal is a derivative of vitamin A.
   (d) Retinal is a light absorbing part of all the visual photopigments.
   (1) (a) & (b)
   (2) (a), (c) & (d)
   (3) (a) & (c)
   (4) (b), (c) & (d)

16. The transparent lens in the human eye is held in its place by **[NEET 2018]**
   (1) Smooth muscles attached to the iris
   (2) Ligaments attached to the iris
   (3) Ligaments attached to the ciliary body
   (4) Smooth muscles attached to the ciliary body

17. Which of the following structures or regions is incorrectly paired with its functions? **[NEET 2018]**
   (1) Hypothalamus : production of releasing hormones and regulation of temperature, hunger and thirst.
   (2) Limbic system : consists of fibre tracts that interconnect different regions of brain; controls movement.
   (3) Medulla oblongata : controls respiration and cardiovascular reflexes.
   (4) Corpus callosum : band of fibers connecting left and right cerebral hemispheres.

18. Which part of the brain is responsible for thermoregulation? **[NEET-2019]**

(1) Cerebrum

(2) Hypothalamus

(3) Corpus callosum

(4) Medulla oblongata

19. Which of the following statements is **correct**?

[NEET-2019]

(1) Cornea is an external, transparent and protective proteinacious covering of the eye-ball.

(2) Cornea consists of dense connective tissue of elastin and can repair itself.

(3) Cornea is convex, transparent layer which is highly vascularised.

(4) Cornea consists of dense matrix of collagen and is the most sensitive portion the eye.

20. Which of the following statements is **not** correct?

[NEET-2019 (Odisha)]

(1) In the knee-jerk reflex, stimulus is the stretching of muscle and response is its contraction

(2) An action potential in an axon does not move backward because the segment behind is in a refractory phase

(3) Depolarisation of hair cells of cochlea results in the opening of the mechanically gated potassium-ion channels

(4) Rods are very sensitive and contribute to daylight vision

21. Which of the following receptors are specifically responsible for maintenance of balance of body and posture? **[NEET-2019 (Odisha)]**

(1) Crista ampullaris and macula

(2) Basilar membrane and otoliths

(3) Hair cells and organ of corti

(4) Tectorial membrane and macula

❑ ❑ ❑

Chapter 10

Chemical Coordination and Regulation

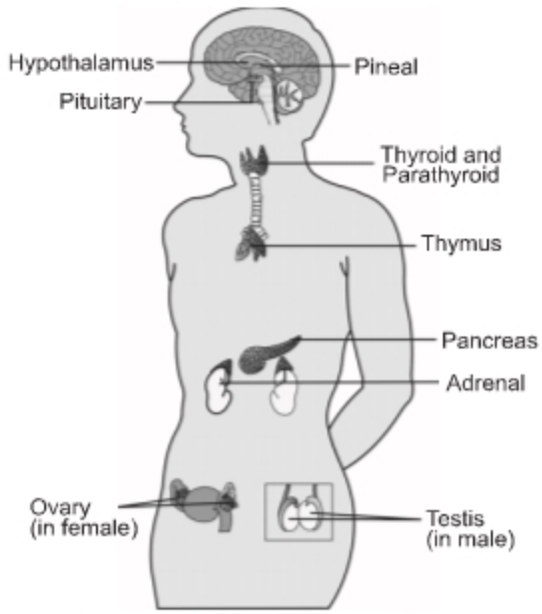
Sub-topics *Endocrine Glands and Hormones; Human Endocrine System - Hypothalamus, Pituitary, Pineal, Thyroid, Parathyroid, Adrenal, Pancreas, Gonads; Mechanism of Hormone Action (Elementary Idea); Role of Hormones as Messengers and Regulators, Hypo-and Hyperactivity and related Disorders (Common Disorders e.g. Dwarfism, Acromegaly, Cretinism, Goitre, Exopthalmic Goitre, Diabetes, Addison's Disease)*

Endocrine Glands and Hormones

Endocrine glands lack ducts and are hence, called ductless glands. Their secretions are called hormones. The classical definition of hormone is that of a chemical produced by endocrine glands, released into blood and transported to a distantly located target organ. The current scientific definition is as follows: **Hormones are non-nutrient chemicals which act as intercellular messengers and are produced in trace amounts.** The new definition covers a number of new molecules in addition to the hormones secreted by the organised endocrine glands. Invertebrates possess very simple endocrine systems with few hormones whereas a large number of chemicals act as hormones and provide coordination in the vertebrates. The human endocrine system is described here.

Human Endocrine System

Consists of glands and their hormones (primary messengers).



Location of endocrine glands

Hypothalamus

Hormones originating in the hypothalamic neurons, pass through their axons and are released from their nerve endings. These hormones reach the pituitary gland through a portal circulatory system and regulate the functions of the anterior pituitary. The posterior pituitary is under the direct neural regulation of the hypothalamus.

Releasing or Inhibiting Hormones of Hypothalamus, their Roles and Specific Hormones they control

Releasing or Inhibiting Hormone / factor from hypothalamus	**Control and Regulation of Specific Hormone Secretion from anterior pituitary**
Thyrotropin releasing hormone (TRH)	Stimulates thyrotropin (TSH) release
Growth hormone releasing hormone (GHRH)	Stimulates growth hormone release
Growth hormone inhibiting hormone (GHIH) or **Somatostatin**	Inhibits growth hormone release
Gonadotropin releasing hormone (GnRH)	Stimulates release of follicle stimulating hormone and luteinising hormone (Gonadotropins)
Prolactin releasing hormone (PRH)	Stimulates prolactin (PRL) release
Prolactin inhibiting hormone (PIH)	Inhibits prolactin release
Adrenocorticotropic hormone releasing hormone (CRH)	Stimulates adrenocorticotropin release
Melanocyte stimulating hormone releasing hormone (MRH)	Stimulates melanocyte stimulating hormone (MSH) release
Melanocyte stimulating hormone inhibiting hormone (MIH)	Inhibits melanocyte stimulating hormone release

Pituitary gland : The pituitary is a pinkish pea-sized gland, about 1.3 cm in diameter, weighing only 0.5 g, attached to the hypothalamus via a stalk called **infundibulum**. Pituitary gland is lodged in a depression of sphenoid bone called **sella turcica**. This complex organ of human body is the source of chemicals that play a key role in many functions. The pituitary gland has anatomically two and functionally three separate lobes initially.

1. The much larger **anterior lobe/adenohypophysis/Pars distalis** produces a cluster of hormones.
2. The smaller **posterior lobe/neurohypophysis/Pars nervosa** stores two hormones synthesized by hypothalamic neurons. A third region, called the **intermediate lobe** or **pars intermedia**, atrophies during foetal development and is smaller in adults.

Complete destruction of anterior lobe of pituitary causes **Simmond's disease**. The anterior lobe of the pituitary is connected to the hypothalamus by **portal blood vessels**. Through these vessels pass a group of regulating hormones, which are produced in the hypothalamus. These **releasing** or **inhibiting hormones** (factor) regulate the anterior lobe of the pituitary to initiate the production or suppression of specific hormones from it.

For each releasing hormone secreted by the hypothalamus, there is a corresponding hormone synthesised by the anterior lobe of the pituitary. When the pituitary receives a releasing hormone from the hypothalamus, it responds by stimulating cells in it to secrete the pituitary hormones. Five principal types of anterior pituitary cells have been identified. These secrete seven major hormones.

Prolactin is unique among the pituitary hormones as it is under predominantly inhibitory control from hypothalamus. The controlling agent is neurotransmitter dopamine produced by tubero-infundibular neurons.

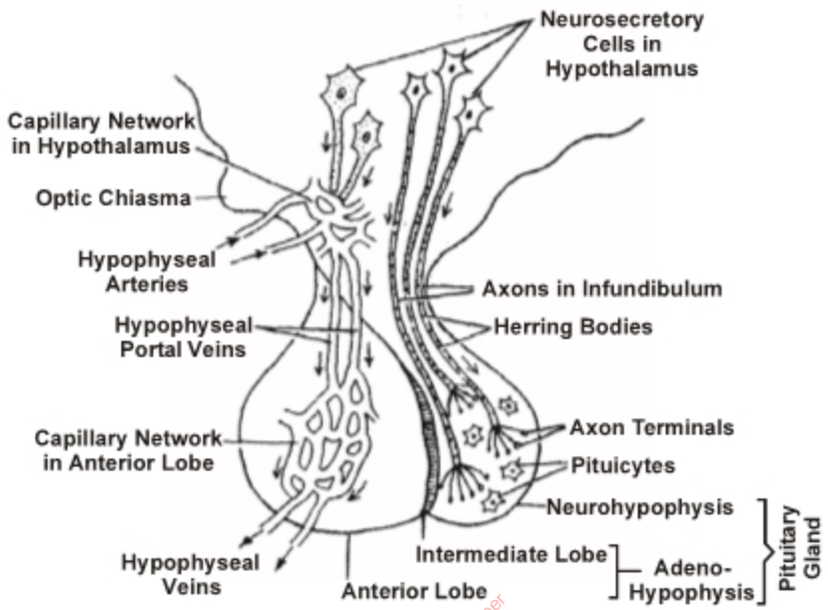


Fig. : Neurosecretory cells (Neurons) of hypothalamus discharging their neurohormones into hypophysial portal veins and into neurohypophysis (posterior lobe) of pituitary gland

Hormones of Pituitary Gland and their Actions on Target Organs

Part of Pituitary	Principal Cell Type	Hormones	Principal Actions	Target Organs
Adeno-hypophysis	**Somatotroph**	Human growth hormone (hGH)	Growth of body cells, specially of bones of limbs, stimulates protein synthesis and inhibits protein breakdown and hydrolysis of fats, retards use of blood glucose for ATP production	General body It is the only hormone produced by anterior lobe of pituitary which does not stimulate any other endocrine gland
	Thyrotroph	Thyroid stimulating hormone (TSH)	Controls secretion of thyroid hormones	Thyroid gland
	Corticotroph	Adrenocorti-cotropic hormone (ACTH)	Controls secretion of adrenal cortex hormones	Adrenal cortex
		Melanocyte stimulating hormone (MSH)	Stimulates cutaneous pigmentation by dispersion of melanin granules	Melano-cytes in skin

Part of Pituitary	Principal Cell Type	Hormones	Principal Actions	Target Organs
	Lactotroph	Prolactin (PRL)	Stimulates milk production and secretion, participates in control of reproduction, osmoregulation, growth and metabolism	Mammary glands
	Gonadotroph	Follicle stimulating hormone (FSH)	In males, stimulates spermatogenesis. In females, stimulates growth of ovarian follicles	Gonads
		Interstitial cell stimulating hormone (ICSH)	In males, secretion of testosterone	Gonads
		Luteinising hormone (LH)	In females together with FSH, it triggers ovulation, stimulates conversion of broken ovarian follicles into corpus luteum	Gonads
Neuro-hypophysis	**No hormones synthesised here. Its hormones are synthesised in hypothalamus**	Oxytocin (OT)	Stimulates contraction of uterine muscles during birth; initiates **ejection of milk**	Mammary glands, uterus
		Antidiuretic hormone (ADH) or Vasopressin	Stimulates reabsorption of water in DCT and reduction of urine secretion; stimulates constriction of blood vessels and thus increases blood pressure	Kidneys and blood vessels

Excess secretion of growth hormone in adults especially in middle age can result in severe disfigurement (especially of the face) called Acromegaly, which may lead to serious complications and premature death if unchecked. The disease is hard to diagnose in the early stages and often goes undetected for many years, until changes in external features become noticeable. Low secretion of GH results in early life leads to stunted growth in **Pituitary dwarfism**.

Anti Diuretic Hormone (ADH) : When a person feels thirsty or there is dehydration, it results in increase in osmolarity of the blood above a physiological set point *i.e.*, 300 mosmL^{-1}. The osmoreceptors in the hypothalamus detect the resultant increase in blood solute concentration. This triggers the release of ADH. As a result, water passes out of the descending limb of loop of Henle in the surrounding tissue. ADH also increases the uptake of water by DCT. Combined action of drinking water, with increased uptake, there is decrease in the osmolarity of the blood. This suppresses the secretion of ADH by feedback inhibition. **An impairment affecting synthesis or release of ADH results in a diminished ability of the kidney to conserve water leading to water loss and dehydration. This condition is known as diabetes insipidus.**

Oxytocin : Oxytocin stimulates the rhythmic contractions of uterine smooth muscles during parturition (child birth). It also stimulates milk ejection from lactating breast in response to a suckling infant by triggering contraction of myoepithelial cells in the ducts of mammary glands. Even sight and sound of a baby can cause a nursing mother to secrete this hormone.

Pineal Gland : The endocrine gland attached to the roof of third ventricle in the rear portion of the brain is known as the pineal gland, named for its resemblance to a pine cone. It is variable in size and weighs about 150 mg but is richly vascularised and secretes several hormones, including **melatonin**. In humans, it has no light-sensitive cells, like lower vertebrates, where pineal gland is eye-like and responds to light. Pineal gland functions as a biological clock and as a neurosecretory transducer interconverting neural information. More melatonin is produced during darkness. Its formation is interrupted when light enters the eyes and stimulates the retinal neurons, which transmit impulses to the hypothalamus and finally to the pineal gland. The result is inhibition of melatonin secretion. In this way, the release of melatonin is governed by the diurnal dark-light cycle. Melatonin maintains the normal rhythms of sleep wake cycle, body temperature and influences metabolism, pigmentation, menstrual cycle as well as our defence capability.

Thyroid Gland

Thyroid is butterfly-shaped gland that lies below larynx. The right and left lateral lobes lie on either sides of trachea. Connecting the lobes is a mass of tissue, the **isthmus**. Thyroid gland consists of microscopic spherical sacs called **thyroid follicles**. These follicles are filled with colloid, a fluid composed of the

glycoprotein thyroglobulin. The walls of each follicle consists of cuboidal epithelium. Under the influence of TSH, the follicular cells synthesise the hormone thyroxine.

(1) **Thyroxine**, which is also called T_4 (tetraiodothyronine) because it contains four atoms of iodine, and

(2) **Triiodothyronine** or T_3, which contains three atoms of iodine. T_3 is more active and several times more potent than T_4 but is secreted in smaller amounts. T_4 is converted to T_3 by removal of one iodine. Because T_4 and T_3 have virtually identical effects on the target cells, they are usually considered together under the designation **thyroid hormones** or TH. **Thyroid is the only endocrine gland in which the follicles (secretory units) store their secretory product in large quantity.** T_3 and T_4 both are synthesised by attaching iodine to amino acid **tyrosine** by enzymatic action, stored for some time and then secreted into the blood.

(3) The parafollicular cells of thyroid produce **calcitonin** or thyrocalcitonin (TCT) which regulates calcium homeostasis. It is a non-iodised hormone.

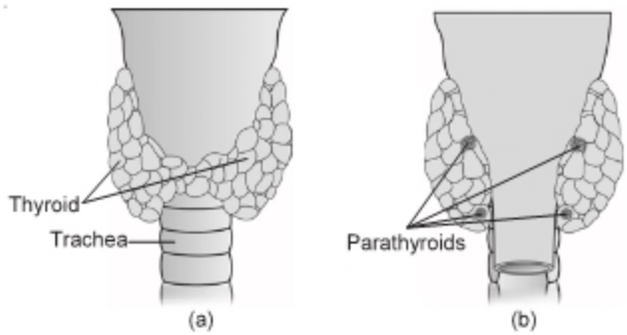


Fig. : Diagrammatic view of the position of Thyroid and Parathyroids (a) Ventral side (b) Dorsal side

Functions of Thyroxines

(a) It regulates metabolic rate.
(b) It maintains normal body temperature and is called calorigenic hormone.
(c) It helps in metamorphosis in frog.
(d) It regulates the development of mental faculties.
(e) It enhances some actions of neurotransmitters like adrenaline and noradrenaline.
(f) Stimulates erythropoiesis

Disorders Resulting from Malfunctioning of Thyroid Gland

Hypothyroidism	Hyperthyroidism
It can result from (i) Primary failure of thyroid gland itself (ii) Secondary failure due to hyposecretion of TRH, TSH or both; or (iii) An inadequate dietary supply of iodine. The symptoms include reduction in overall metabolic activity and poor tolerance to cold (Simple Goitre). **Cretinism (in children)** It is characterised by dwarfism because the skeleton fails to grow and mature. Patients are severely mentally retarded as the brain also fails to develop fully. Other clinical features include, deaf-mutism , dry skin, potbelly, pigeon-like chest, thick tongue, prolonged neonatal jaundice, lethargy, respiratory problems and constipation. **Myxoedema (in adults)** The cardinal symptom of this disorder is edema (accumulation of interstitial fluid) that causes the facial tissues to swell and look puffy.	**Grave's disease (exopthalamic goitre)** It is an autoimmune disorder in which the person produces antibodies that mimic the action of TSH but are not regulated by normal negative feedback controls. These patients have a peculiar edema behind the eyes called exopthalamos which causes the eyes to protrude. This disorder, like myxoedema, also occurs more often in females. **Exopthalmic goitre is a form of hyperthyroidism, characterised by enlargement of the thyroid gland, protrusion of the eyeballs, increased basal metabolic rate and weight loss, also called Grave's disease.**

If young tadpoles are **administered thyroxine**, they metamorphose into frogs **prematurely** before their body growth is complete. They are thus changed into tiny frogs. On the other hand, feeding of antithyroid substances like thiourea to tadpoles delays their metamorphosis. As they continue to grow without metamorphosis, they become giant tadpoles. Mexican axolotls are amphibians which ordinarily exist and even reproduce in the aquatic larval forms without metamorphosing into the adult forms, because they are born with deficiency of thyroid hormones. But on administration of thyroid hormones, they metamorphose into the terrestrial adult forms.

Hashimoto's disease is an autoimmune disease of thyroid gland in which antibodies are produced against cells of the gland.

Parathyroid Glands

These are four small glands situated very close to the thyroid. They secrete a hormone called **Parathormone (PTH)**. The secretion of PTH is under the feedback control of blood calcium levels. A fall in blood calcium stimulates the gland to secrete parathormone while a rise in the same inhibits parathormone secretion from them.

Parathormone increases the concentration of calcium ions in the blood plasma because it mobilises more calcium from the bones to the plasma and reduces urinary elimination of calcium. It is secreted whenever the plasma Ca^{2+} concentration falls and restores the Ca^{2+} concentration to normal. On the other hand, it increases phosphate elimination in the urine and consequently lowers the phosphate concentration of the plasma. Thus, parathormone regulates the metabolism and homeostasis of both calcium and phosphorus.

Disorders Resulting from Malfunctioning of Parathyroid Glands

Hypoparathyroidism	Hyperparathyroidism
Accidental damage to the parathyroids or their blood supply during thyroidectomy surgery causes **hyposecretion** of PTH.	A tumour usually in the parathyroids causes **hypersecretion** of PTH.
Because of deficiency of Ca^{2+}, neurons and muscle fibres become depolarised without the usual threshold stimulus. Consequently, nerve and muscle action potentials arise spontaneously, leading to muscle twitches, spasms and convulsions. This condition is called **hypocalcemic or parathyroid tetany.**	Because of demineralisation, the bones become deformed and get easily fractured. If untreated, this condition may lead to **osteitis fibrosa cystica**, so named because the areas of the destroyed bone tissue are replaced by cavities that are filled with fibrous tissues.

Metabolism of calcium and phosphorus is also regulated by another hormone called **CALCITONIN**. It is secreted by parafollicular cells situated outside the follicles in the thyroid gland. Its secretion is also under the feedback control of the plasma Ca^{2+} concentration. But unlike parathormone, calcitonin is secreted when the concentration of Ca^{2+} rises in the blood plasma. Calcitonin then lowers the concentrations of both calcium and phosphate ions in the plasma by reducing their mobilisation from bones. Thus, it restores the normal concentration of these ions in the blood. The plasma calcium level is very effectively maintained by a balance between the activities of parathormone and calcitonin.

Another hormone **Calcitriol** is released by kidneys when plasma Ca^{2+} is low. This hormone enhances Ca^{2+} absorption from the intestine.

Thymus

It is a soft bilobed structure where the two lobes lie side by side and joined in the middle by connective tissue. It is pyramidal in children with maximum size reaching at about 15 years of age. Its size is reduced somewhat later due to decrease in its lymphoid content. The weight at birth is 15 - 20 g in children remaining at that level thereafter. It is deep red in young age becoming thinner and greyer with age and later yellow due to infiltration of adipose tissue. Thymus is covered on the outside by a capsule of loose connective tissue which also penetrates the interior of gland forming septa and irregular lobules. There is an outer **cortex** of densely packed **thymocytes** (or T-lymphocyte lineage) and inner **medulla** having connective tissue with fewer lymphoid cells. Balls of flattened

epithelial cell called **Hassal's corpuscles** occur here and there in the medulla. Thymocytes also occur alongwith some B-lymphocytes. Hormones produced by the thymus gland are called **thymosins**. Thymosins are released in the bloodstream has a stimulating effect on the entire immune system. It promotes proliferation and maturation of T-lymphocytes. It is also called "the throne of immunity", or training school of T-lymphocytes.

In addition, thymosins also promote production of antibodies.

Adrenal Gland

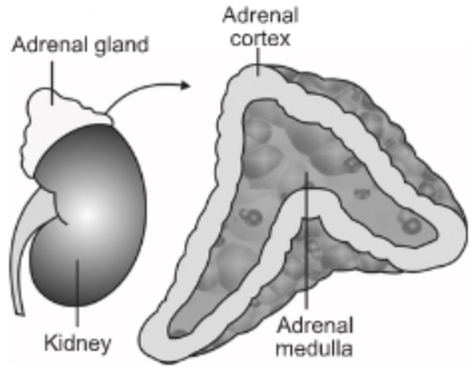


Fig. : Diagrammatic representation of : (a) Adrenal gland on kidney (b) Section showing two parts of adrenal gland

Adrenals are two conical pyramid-shaped glands, one immediately above each kidney. Each adrenal comprises of an outer portion called **adrenal cortex** and a central portion called **adrenal medulla**. The cortex and medulla secrete different hormones and are regulated in different ways.

Adrenal Cortex : This part of adrenal glands is vitally important for life and its destruction or removal kills the animal. It secretes a number of steroid hormones which are broadly classified into three groups viz. glucocorticoids, mineralocorticoids and sex corticoids.

Adrenal cortex is divided into three layers :

(1) Outermost Zona Glomerulosa : It secretes mineralocorticoids.

(2) Middle Zona Fasciculata : It secretes glucocorticoids.

(3) Innermost Zona Reticulata : It secretes sex corticoids.

Zona Fasciculata and Zona Reticulata are under the control of **ACTH** from anterior lobe of pituitary.

(i) **Mineralocorticoids** are secreted from the outermost cellular layer of the adrenal cortex. **Aldosterone** is the principal mineralocorticoid in man, other mammals and birds. Mineralocorticoids regulate the metabolism of sodium and potassium. Their secretion is stimulated by a fall in plasma Na^+ concentration, a rise in plasma K^+ concentration or a fall in circulating volume of blood. Aldosterone reduces the elimination of Na^+ in the urine, sweat, saliva or bile by enhancing the active reabsorption of this ion from these fluids. It also increases the elimination of K^+ in these fluids in exchange of the reabsorbed Na^+. By retaining more Na^+ in the blood, it increases the reabsorption of water from the urine by osmotic effects of Na^+. Hence, it increases the volume of blood and other extracellular fluids.

(ii) **Glucocorticoids** such as **Cortisol** are secreted from the middle cellular layer of the adrenal cortex. They regulate the metabolism of carbohydrates, fats and proteins. You may recall that the anterior pituitary hormone called corticotropin stimulates glucocorticoid secretion. Glucocorticoids, on the other hand, exert a feedback inhibitory effect on corticotropin secretion. Glucocorticoids are secreted during allergic reactions and produce anti-inflammatory reactions and suppress the immune response. Cortisol stimulates the RBC production.

(iii) **Sex corticoids** are secreted also from both the middle and the inner layers of the adrenal cortex. Their secretion is believed to be stimulated by corticotropin of anterior pituitary. They include steroids which might stimulate the development of external sexual characterstics of the male such as the male pattern of distribution of body hair. Examples of sex corticoids are **Androstenedione** and **Dehydroepiandrosterone (DHEA)**.

Disorders :

(i) Under production of hormones due to destruction of adrenal cortex by diseases like tuberculosis alters carbohydrate metabolism causing acute weakness and fatigue leading to a disease called **Addison's disease** characterized by the deficiency of both glucocorticoids and mineralocorticoids. Symptoms include acute weakness and fatigue, a bronzelike pigmentation of skin, low blood sugar, low plasma Na^+, high plasma K^+, increased urinary Na^+, nausea, vomiting and diarrhoea.

(ii) A tumour of the adrenal cortex may secrete too much cortisol to produce **Cushing's syndrome**. High blood sugar, appearance of sugar in the urine, obesity, wasting of limb muscles, rise in plasma Na^+, fall in plasma K^+, rise in blood volume and high blood pressure are observed in the patient.

(iii) Excessive secretion of aldosterone from an adrenal cortical tumour causes **Aldosteronism/Conn's disease.** This disease is characterised by a high plasma Na^+, low plasma K^+, rise in blood volume and high blood pressure.

(iv) An excessive secretion of sex corticoids produces the male-type external sexual characteristics such as beard, moustaches and hoarse voice in women. The disease is called **Adrenal Virilism**.

Adrenal medulla : This part of adrenal glands helps the body to combat stress or emergency conditions. But it is not vital for survival and may be removed without causing death. Adrenal medulla secretes two hormones, viz. **adrenaline** and **noradrenaline**. The proportion of the two hormones varies from species to species; in man, much more adrenaline is secreted than noradrenaline. **The secretion of these hormones is stimulated when nerve impulses reach the adrenal medulla through sympathetic nerve fibres.** These hormones act on organs and tissues supplied by sympathetic fibres and produce effects like those of sympathetic stimulation. Noradrenaline is also released at sympathetic nerve terminals to transmit nerve impulses from them to smooth muscles and glands. Both sympathetic nerves and adrenal medulla are stimulated in physical stress like fall in blood pressure or blood sugar, pain, cold or injury; both are also stimulated in emotional stress such as anger, fear and grief. All these indicate that the adrenal medulla and the sympathetic nervous system function as a closely integrated system; this may be called **sympathetico-adrenal system** and is an instance of close coordination between nerves and hormones.

Actions of adrenaline and noradrenaline are not identical in many tissues. Adrenaline dilates (widens) arterioles in the skeletal muscles but constricts (narrows) those in the skin and abdominal viscera; noradrenaline constricts arterioles in general to increase the total peripheral resistance against the flow of blood. Adrenaline increases both rate and force of heart beats, noradrenaline has little effect on the heart. Both increase arterial blood pressure, the former by enhancing the cardiac output and the latter by raising the peripheral resistance. Adrenaline relaxes the smooth muscles of gastrointestinal tract, urinary bladder and bronchioles, but constricts the sphincters of gastrointestinal tract and bladder; noradrenaline has no action on the bronchiolar muscles and only weak actions on the other smooth muscles. Adrenaline increases blood sugar and blood lactic acid levels; noradrenaline has very little effect on them. Both hormones increase heat production, metabolic rate and body temperature. Their coordinated action helps the body respond to stress. This is why adrenal medulla is sometimes called the gland for 'fight, fright and flight.'

Pancreas

The pancreas comprises both exocrine and endocrine parts. The endocrine part consists of small masses of hormone secreting cells called **Islets of Langerhans**. There are about 1 to 2 million Islet of Langerhans in a normal human pancreas representing only 1 to 2 percent of the pancreatic tissue. The two main cells in the Islet of Langerhans are called α-cells and β-cells. The α-cells secrete a hormone called glucagon, while the β-cells secrete insulin.

Insulin and **Glucagon** are the hormones secreted by pancreatic islets. A rise in blood glucose level stimulates both the synthesis and secretion of insulin. A rise in blood amino-acids may also increase insulin secretion. The functions of insulin are :

(i) Insulin acts mainly on hepatocytes and adipocytes

(ii) Insulin increases the utilisation of glucose in tissues and facilitates the storage of glucose as glycogen in muscles and liver (Glycogenesis). By these actions, insulin lowers the blood sugar level (hypoglycemia).

(iii) Insulin increases the synthesis of fat in the adipose tissues from fatty acids as well as glucose.

(iv) It also reduces the breakdown and oxidation of fat.

(v) Insulin promotes protein synthesis in tissues from amino acids.

(vi) It reduces catabolism of proteins in the body. So, insulin is an anabolic hormone.

Glucagon acts mainly on liver cells and stimulates glycogenolysis resulting in an increased blood sugar (hyperglycemia).

Failure of insulin secretion causes **Diabetes Mellitus**. In this disease, blood sugar is abnormally high (hyperglycemia) and exceeds the renal threshold for glucose. Consequently, glucose appears in the urine. The utilisation of glucose is decreased; instead, catabolism of fats and proteins are enhanced. **Increased oxidation of fats produces ketone bodies such as acetoacetate and acetone (ketonuria)**. Also the blood cholesterol level rises. The osmotic effect of glucose in the urine considerably increases the volume of urine. Thirst is enhanced due to urinary loss of water. Injuries take a long time to heal and may turn into gangrenes. In extreme cases, the patient suffers from coma and may die. Administration of insulin reduces the blood sugar and checks other symptoms of diabetes.

Hyperglycaemia	Hypoglycaemia
It results from **hyposecretion** of insulin. Symptoms include : high blood glucose level; breakdown of muscle tissue; loss of weight; tiredness	It results from **hypersecretion** of insulin. Symptoms include : low blood glucose level; hunger; sweating; Irritability; double vision

Diabetes mellitus may be caused by underactivity of β cells in islets of Langerhans that results in reduced secretion of insulin. Such a condition is called **insulin-dependent diabetes mellitus (IDDM)**. Diabetes mellitus is, however different from diabetes insipidus as discussed in table below

Diabetes Mellitus	Diabetes Insipidus
It results from hyposecretion of **insulin.**	It results from hyposecretion of **ADH.**
Symptoms include :	Symptoms include :
excessive urine production;	excretion of large amounts of urine;
excessive thirst;	thirst;
excessive eating	dehydration

Endocrine Functions of Gonads : The gonads, viz. testes in males and ovaries in females are **mixed/heterocrine** glands. They produce both reproductive cells (gametes) and secrete hormones which control reproductive organs. These hormones are collectively called sex hormones.

Testis

Male Sex Hormone : Testes secrete the male sex hormone **Testosterone**. The endocrine part of testes consists of groups of cells located in the connective tissue around the sperm-producing (seminiferous) tubules. These cells are called **Interstitial Cells or Leydig Cells**. The luteinizing hormone (LH) of anterior pituitary stimulates the interstitial cells to secrete testosterone; this is why LH is also known as **Interstitial Cell Stimulating Hormone (ICSH)**. When the blood level of testosterone rises above normal, it exerts a feedback inhibitory effect on the anterior pituitary to stop further **ICSH** secretion. This normally prevents the oversecretion of testosterone.

Functions : Testosterone stimulates the growth and development of **male secondary sex organs** such as the prostate, seminal vesicles and penis. It also stimulates and maintains their normal functions in reproduction. These organs are called secondary sex organs because they participate and help in reproduction but do not produce gametes. Testosterone stimulates the development of the external male sexual characters such as beards, moustaches and low-pitched male voice in humans and combs and wattles in male cocks. It also maintains these external characters. It also stimulates the formation of sperms in the testes. Testosterone promotes the growth of many body tissues including bones and muscles; this explains the body growth at puberty and a higher stature of the male body than the female body. The hormones which stimulate the development of male sexual characters are called **Androgens**. They include testosterone and some sex corticoids.

Disorders : The failure of testosterone secretion results in **Eunuchoidism**. In this disease, secondary sexual organs such as prostate, seminal vesicles and penis remain infantile and small in size and fail to function. External sexual characters like beard, moustaches and low-pitch male voice fail to develop. Spermatozoa fail to be produced. Administration of testosterone to the patient stimulates growth and development of secondary sex organs and characters.

Castration is the surgical removal of gonads (testes)

Ovary

Female Sex Hormones : Ovaries secrete steroid hormones which regulate the female reproductive organs. They are called female sex hormones: on basis of chemical structure and functions; they are of two types, viz. **Estrogens** and **Progesterone**.

The ovary contains numerous sac-like cellular aggregates called ovarian follicles, each with a maturing ovum at its centre. Cells of a maturing ovarian follicle (**Graafian Follicle)** secrete estrogen. **Estradiol** is the principal estrogen. Maturation of the Graafian follicle and secretion of estrogen from it are stimulated by the follicle-stimulating hormone (FSH) of anterior pituitary. The luteinizing hormone (LH) of anterior pituitary brings about the rupture of Graafian follicle to release the ovum (ovulation), changes the ruptured follicle into a yellow structure called **Corpus Luteum** and stimulates the latter to secrete progesterone. In turn, high blood levels of estrogen and progesterone may cause feedback inhibition of the secretions of gonadotropins from pituitary.

At puberty, estrogen stimulates the growth, maturation and functions of female secondary sex organs such as the uterus, Fallopian tubes and the duct system of mammary glands. Estrogens also develop and maintain external female sexual characters such as the high-pitch female voice and the female pattern of body hair distribution. Alternating actions of estrogens and progesterone cause some growth and functional changes in the female sex organs to be repeated cyclically in the nonpregnant female. The ovary secretes large amounts of progesterone during pregnancy; progesterone causes most of the pregnancy related changes such as uterine growth, attachment of the embryo to the uterine wall, formation of placenta holding the foetus on the uterine wall, and growth of secretory alveoli in mammary glands.

Placental Hormones

The human placenta secretes in the mother's blood several hormones such as estrogens, progesterone and **Human Chorionic Gonadotropin (hCG).** Placental estrogens and progesterone participate in producing pregnancy changes in the female reproductive system. hCG maintains the corpus luteum in the mother's ovary and stimulates it to secrete progesterone for a longer than usual time. hCG is a glycoprotein.

Hormones Regulating Reproduction

Endocrine Gland	Hormones	Principal Action
Ovarian follicle	Estrogen	Stimulates development and maintenance of female sexual characteristics like high pitched, female voice and female pattern of body hair distribution at puberty; together with gonadotropic hormones of the anterior pituitary gland, they also regulate the menstrual cycle.
Corpus luteum	Progesterone and Estrogen	Stimulate uterine lining for embryo implantation to maintain pregnancy, foetal development prepare the mammary glands for lactation and regulate oogenesis, progesterone inhibits ovulation.
	Relaxin	Relaxes pubic symphysis and helps dilate uterine cervix near the end of pregnancy.
	Inhibin	Inhibition of FSH and LH production.
Testes	Testosterone	**Stimulates the descent of testes** into the scrotum and male pattern of development (before birth); stimulates development and maintenance of male sexual characteristics and expression of secondary sexual characteristics such as beard, moustache and low-pitched voice starting at puberty; stimulation of spermatogenesis; growth spurt.
	Inhibin	Inhibition of LH and FSH production.
Placenta	Human Chorionic Gonadotropin (hCG)	Stimulates progesterone release from the corpus luteum and maintains it.
	Human placental lactogen (HPL)	Stimulates mammary growth and decreases glucose utilization by mother's body.

Hormones of Heart, Kidney and Gastrointestinal Tract

The atrial wall of our heart secretes a very important peptide hormone called atrial natriuretic factor (ANF), which decreases blood pressure. When blood pressure is increased, ANF is secreted which causes dilation of the blood vessels. This reduces the blood pressure.

The juxtaglomerular cells of kidney produce a peptide hormone called erythropoietin which stimulates erythropoiesis (formation of RBC).

Endocrine cells present in different parts of the gastro-intestinal tract secrete four major peptide hormones, namely gastrin, secretin, cholecystokinin (CCK) and gastric inhibitory peptide (GIP). Gastrin acts on the gastric glands and stimulates the secretion of hydrochloric acid and pepsinogen. Secretin acts on the exocrine pancreas and stimulates secretion of water and bicarbonate ions. CCK acts on both pancreas and gall bladder and stimulates the secretion of pancreatic enzymes and bile juice, respectively. GIP inhibits gastric secretion and motility. Several other non-endocrine tissues secrete hormones called growth factors. These factors are essential for the normal growth of tissues and their repairing/regeneration.

Mechanism of Hormone Action

Hormones produce their effects on target tissues by binding to specific proteins called **hormone receptors** located in or on the target tissues only. Hormone receptors present on the cell membrane of the target cells are called membrane-bound receptors and the receptors present inside the target cell are called intracellular receptors, mostly nuclear receptors (present in the nucleus). Binding of a hormone to its receptor leads to the formation of a **hormone-receptor complex**. Each receptor is specific to one hormone only and hence receptors are specific. Hormone-Receptor complex formation leads to certain biochemical changes in the target tissue. Target tissue metabolism and hence physiological functions are regulated by hormones. On the basis of their chemical nature, hormones can be divided into groups :

(i) Peptide, polypeptide, protein hormones (*e.g.*, insulin, glucagon, pituitary hormones, hypothalamic hormones etc.)

(ii) Steroids (*e.g.*, cortisol, testosterone, estradiol and progesterone)

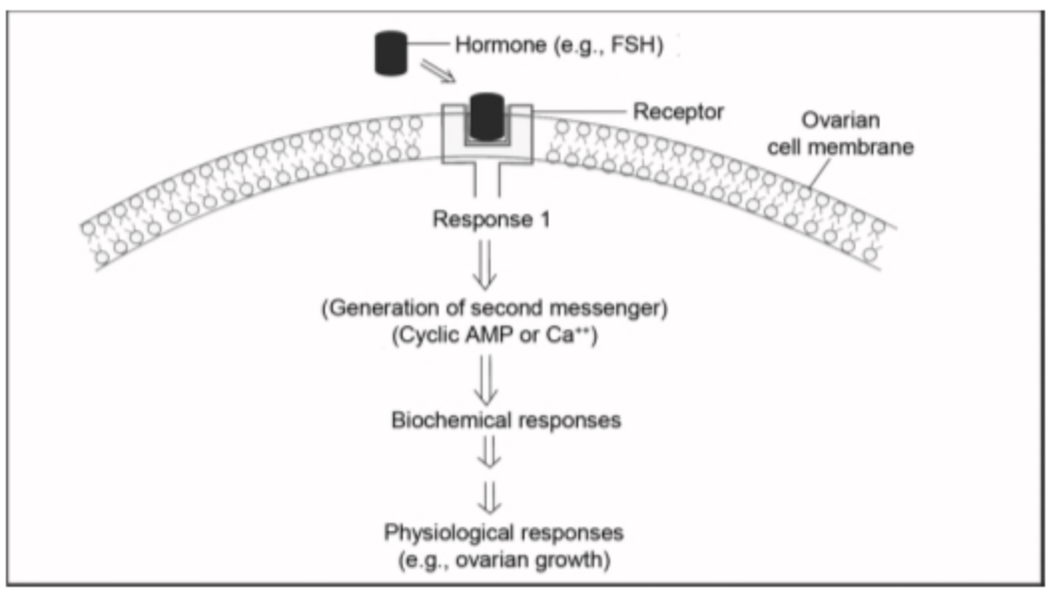
(iii) Iodothyronines (thyroid hormones)

(iv) Amino-acid derivatives (*e.g.*, epinephrine).

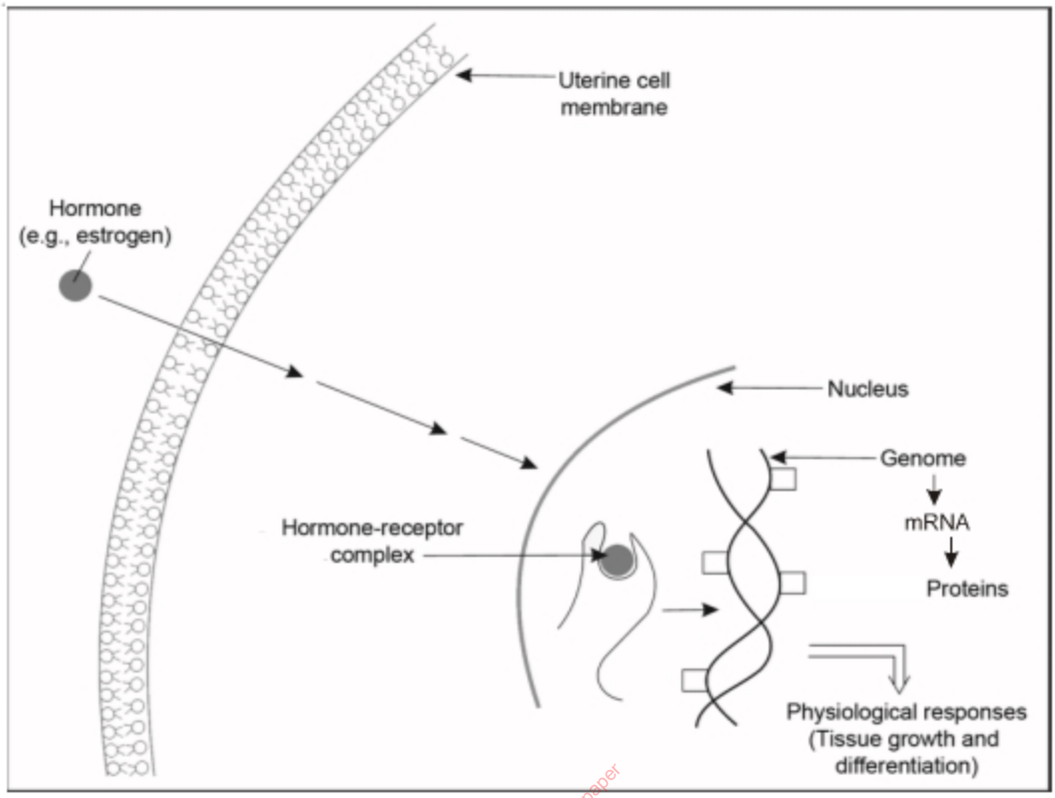
Hormones which interact with membrane-bound receptors normally do not enter the target cell, but generate second messengers (*e.g.*, cyclic AMP, IP_3, Ca^{++} etc) which in turn regulate cellular metabolism. Hormones which interact with intracellular receptors (*e.g.*, steroid hormones, iodothyronines, etc.) mostly regulate gene expression or chromosome function by the interaction of hormone-receptor complex with the genome. Cumulative biochemical actions result in physiological and developmental effects.

Antagonistic Effect : Many cells express more than one secondary messenger. In heart cells, *e.g.*, **c-AMP** serves as a secondary messenger, speeding up muscle cell contraction in response to **adrenaline**, while cyclic guanosine monophosphate **(c-GMP)** serves as another secondary messenger, slowing muscle contraction in response to **acetylcholine**. It is in this way that the sympathetic and parasympathetic nervous systems achieve antagonistic effects on heartbeat rate. Another example of antagonistic effect is actions of insulin which lowers blood sugar level and glucagon which raises it.

Synergistic Effect : Another type of hormonal interaction is known as synergistic effect. Here, two or more hormones complement each other's actions and both are needed for full expression of hormonal effects. *e.g.*, the production rate, secretion and ejection of milk by mammary gland requires the synergistic effect of estrogens, progesterone, prolactin and oxytocin.



(a)



(b)

Fig. : Diagrammatic representation of the mechanism of hormone action
(a) Protein hormone (b) Steroid hormone

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Try Yourself

SECTION - A

Objective Type Questions

1. The hormones released by neurons of hypothalamus are carried to
   (1) Anterior lobe of pituitary by portal vein
   (2) Posterior lobe of pituitary by portal vein
   (3) Intermediate lobe of pituitary by portal blood vessel
   (4) Both (1) & (2)
2. Sella turcica is a/an
   (1) Cavity of skull enclosing ear
   (2) Depression in the sphenoid bone enclosing pituitary
   (3) Endocrine gland
   (4) Fibrous capsule enclosing the testes
3. The anterior pituitary hormone that does not stimulate another endocrine gland is
   (1) Somatotropin (2) Thyrotropin
   (3) Gonadotropin (4) Adrenocorticotropin
4. Corticotrophs, principal cell types of anterior lobe of pituitary, synthesize
   (1) STH (2) FSH
   (3) ACTH and MSH (4) Prolactin
5. Which of the following statements is **correct**?
   (1) Neurons regulate endocrine activity but not vice versa
   (2) Endocrine glands regulate neural activity and nervous system regulates endocrine glands
   (3) Neither hormones control neural activity nor neurons control endocrine activity
   (4) Endocrine glands regulate neural activity but not vice versa
6. Complete failure of secretion of the anterior lobe of pituitary causes
   (1) Addison's disease (2) Acromegaly
   (3) Simmond's disease (4) Cushing's disease
7. Which of the following is called milk ejection hormone and birth hormone?
   (1) Vasopressin
   (2) Oxytocin
   (3) Somatotrophic hormone
   (4) Pancreozymin
8. Which of the following statements is **incorrect** w.r.t. melatonin hormone?
   (1) Shows diurnal variation
   (2) Antigonadial hormone
   (3) Secreted by pineal body
   (4) Synthesized from tyrosine amino acid
9. Symptoms like pot-belly, pigeon like chest and protruding tongue indicate
   (1) Myxoedema (2) Cretinism
   (3) Cushing's syndrome (4) Addison's disease
10. Exophthalmic goitre is caused due to
    (1) Hyperthyroidism (2) Hypothyroidism
    (3) Hyperparathyroidism (4) Hypoparathyroidism
11. The non-iodinised hormone secreted by parafollicular cells of thyroid is
    (1) Calcitonin (2) Oxytocin
    (3) Vasopressin (4) Gonadotropin
12. If the immune system of the body starts forming antibodies which destroy the thyroid gland, the disease is called
    (1) Addison's disease (2) Hashimoto's disease
    (3) Myxoedema (4) Cretinism
13. Which hormone has a calorigenic effect in the body?
    (1) Adrenalin (2) FSH
    (3) Growth hormone (4) Thyroxine
14. Hormone responsible for osteitis fibrosa cystica is
    (1) Thyroxine (2) Parathormone
    (3) Growth hormone (4) All of these

15. The plasma calcium level is very effectively maintained by a balance between the activities of
(1) Thyroxine and parathormone
(2) Calcitonin and Parathormone
(3) Epinephrine and nor epinephrine
(4) Progesterone and estrogen

16. A tumor of parathyroid gland causes
(1) Parathyroid tetany
(2) Grave's disease
(3) Osteitis fibrosa cystica
(4) Hypocalcemic tetany

17. Which of the following symptoms pertain to Addison's disease?
(1) Low plasma Na^+, high plasma K^+, increased urinary Na^+, low blood sugar, vomiting, nausea and diarrhoea
(2) High blood sugar, obesity, wasting of limb muscles, fall in plasma K^+, high blood Na^+, rise in blood volume and high blood pressure
(3) Stunted growth, retarded sexual development, mental backwardness
(4) Increase in heart rate, rise in blood pressure, nervousness, bulging eyes, warm skin

18. Adrenal virilism results due to
(1) Poor secretion of sex corticoids
(2) Excess secretion of sex corticoids
(3) Excess secretion of aldosterone
(4) Poor secretion of aldosterone

19. Body reactions in stress are helped by
(1) FSH
(2) LH
(3) Both (1) & (2)
(4) Adrenaline and nor-adrenaline

20. After receiving a hormonal shot, an asthma patient gets relief in exhaling the air. The hormone injected would be
(1) Oxytocin (2) Adrenaline
(3) Insulin (4) Thyroxine

21. Feeling the tremors of an earthquake, a scared resident of seventh floor of a multi-storyed building starts climbing down the stairs rapidly. Which hormone initiates this process?
(1) Gastrin (2) Thyroxine
(3) Adrenaline (4) Glucagon

22. Which hormone causes dilation of blood vessels and increases oxygen consumption and glucogenesis?
(1) ACTH (2) Insulin
(3) Adrenaline (4) Glucagon

23. Hormone secreted during allergy is
(1) Glucocorticoid
(2) Mineralocorticoid
(3) Insulin
(4) Thyroxine

24. Mammalian thymus is mainly concerned with
(1) Regulation of body temperature
(2) Regulation of body growth
(3) Immunological functions
(4) Secretion of thyrotropin

25. Glucagon stimulates
(1) Increase in breakdown of glycogen to blood glucose
(2) Formation of glucose from amino acids
(3) Rise in blood sugar level
(4) All of these

26. Failure of secretion of testosterone results in
(1) Myxoedema
(2) Eunuchoidism
(3) Cretinism
(4) Cushing's syndrome

27. Sertoli cells are regulated by the pituitary hormone known as
(1) FSH
(2) GH
(3) Prolactin
(4) LH

28. High pitched juvenile voice in males can be retained by
(1) Ovariectomy
(2) Castration
(3) Synorchidism
(4) Hysterectomy

29. Luteinising hormone (LH) in female
(1) Helps in the appearance of secondary sexual characters
(2) Stimulates ovaries to secrete estradiols
(3) Helps in release of ovum from the ovary
(4) Controls the blood pressure

30. Withdrawl of which of the following hormones is the immediate cause of menstruation?
(1) Estrogen (2) FSH
(3) LH (4) Progesterone

31. Placental hormone called chorionic gonadotropin (hCG) which stimulates secretion of progesterone by the ovaries during pregnancy is
(1) Proteinaceous in nature
(2) Steroid in nature
(3) Biogenic amine
(4) Both (1) & (3)

32. Inhibin hormone is secreted by
(1) Placenta (2) Corpus luteum
(3) Kidney (4) Both (1) & (2)

33. Which of the following acts as second messengers during hormonal action?
(1) Ca^{2+}
(2) IP_3
(3) Cyclic AMP
(4) All of these

34. Which of the following hormones can directly pass into the cell without interacting with extra - cellular receptor proteins?
(1) Catecholamines (2) Peptide hormones
(3) Adrenaline (4) Testosterone

35. Which of the following is **not** a second messenger in hormone's action?
(1) c-GMP (2) Calcium
(3) Sodium (4) c-AMP

SECTION - B

Previous Years Questions

1. Which one of the following pairs of hormones are the examples of those that can easily pass through the cell membrane of the target cell and bind to a receptor inside it (mostly in the nucleus) **[AIPMT 2012]**
(1) Somatostatin, oxytocin
(2) Cortisol, testosterone
(3) Insulin, glucagon
(4) Thyroxin, Insulin

2. The Leydig cells as found in the human body are the secretory source of **[AIPMT 2012]**
(1) Glucagon (2) Androgens
(3) Progesterone (4) Intestinal mucus

3. What is **correct** to say about the hormone action in humans? **[AIPMT 2012]**
(1) In females, FSH first binds with specific receptors on ovarian cell membrane
(2) FSH stimulates the secretion of estrogen and progesterone
(3) Glucagon is secreted by β-cells of Islets of Langerhans and stimulates glycogenolysis
(4) Secretion of thymosins is stimulated with aging

4. A person entering an empty room suddenly finds a snake right in front on opening the door. Which one of the following is likely to happen in his neuro-hormonal control system? **[AIPMT 2012]**
(1) Hypothalamus activates the parasympathetic division of brain
(2) Sympathetic nervous system is activated releasing epinephrine and norepinephrine from adrenal cortex
(3) Sympathetic nervous system is activated releasing epinephrin and norepinephrin from adrenal medulla
(4) Neurotransmitters diffuse rapidly across the cleft and transmit a nerve impulse

5. Which one of the following pairs of chemical substances, is **correctly** categorised? **[AIPMT 2012]**
(1) Calcitonin and thymosin – Thyroid hormones
(2) Pepsin and prolactin – Two digestive enzymes secreted in stomach
(3) Troponin and myosin – Complex proteins in striated muscles
(4) Secretin and rhodopsin – polypeptide hormones

6. Which of the following statement is **correct** in relation to the endocrine system? **[NEET 2013]**
(1) Organs in the body like gastrointestinal tract, heart, kidney and liver do not produce any hormones.
(2) Non-nutrient chemicals produced by the body in trace amount that act as intercellular messenger are known as hormones.
(3) Releasing and inhibitory hormones are produced by the pituitary gland.
(4) Adenohypophysis is under direct neural regulation of the hypothalamus.

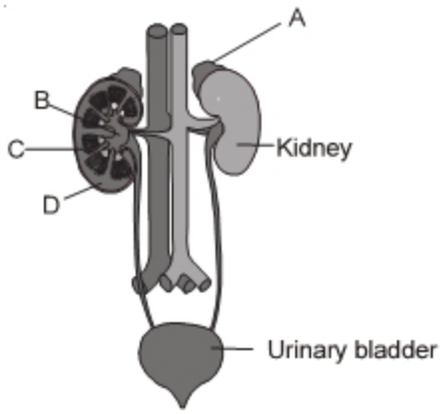
7. A pregnant female delivers a baby who suffers from stunted growth, mental retardation low intelligence quotient and abnormal skin. This is the result of **[NEET 2013]**

(1) Low secretion of growth hormone
(2) Cancer of the thyroid gland
(3) Over secretion of pars distalis
(4) Deficiency of iodine in diet

8. Select the answer which correctly matches the endocrine gland with the hormone it secretes and its function/ deficiency symptom **[NEET 2013]**

	Endocrine gland	Hormone	Function/ deficiency symptoms
(1)	Posterior pituitary	Growth Hormone (GH)	Oversecretion stimulates abnormal growth
(2)	Thyroid gland	Thyroxine	Lack of iodine in diet results in goitre
(3)	Corpus luteum	Testosterone	Stimulates spermatogenesis
(4)	Anterior pituitary	Oxytocin	Stimulates uterus contraction during child birth

9. Figure shows human urinary system with structures labelled A to D. Select option which correctly identifies them and gives their characteristics and/ or functions **[NEET 2013]**



(1) B-Pelvis-broad funnel shaped space inner to hilum, directly connected to loops of Henle
(2) C-Medulla - inner zone of kidney and contains complete nephrons
(3) D-Cortex - outer part of kidney and do not contain any part of nephrons
(4) A-Adrenal gland-located at the anterior part of kidney. Secrete Catecholamines which stimulate glycogen breakdown

10. Identify the hormone with its correct matching of source and function **[AIPMT 2014]**

(1) Oxytocin - posterior pituitary, growth and maintenance of mammary glands
(2) Melatonin - pineal gland, regulates the normal rhythm of sleepwake cycle
(3) Progesterone - corpus-luteum, stimulation of growth and activities of female secondary sex organs
(4) Atrial natriuretic factor - ventricular wall increases the blood pressure

11. Fight-or-flight reactions cause activation of **[AIPMT 2014]**

(1) The parathyroid glands, leading to increased metabolic rate
(2) The kidney, leading to suppression of reninangiotensin-aldosterone pathway
(3) The adrenal medulla, leading to increased secretion of epinephrine and norepinephrine
(4) The pancreas leading to a reduction in the blood sugar levels

12. Which one of the following hormones is not involved in sugar metabolism? **[Re-AIPMT-2015]**

(1) Glucagon (2) Cortisone
(3) Aldosterone (4) Insulin

13. Which one of the following hormones though synthesised elsewhere, is stored and released by the master gland? **[Re-AIPMT-2015]**

(1) Melanocyte stimulating hormone
(2) Antidiuretic hormone
(3) Luteinizing hormone
(4) Prolactin

14. A chemical signal that has both endocrine and neural roles is **[AIPMT-2015]**

(1) Cortisol (2) Melatonin
(3) Calcitonin (4) Epinephrine

15. Which of the following pairs of hormones are **not** antagonistic (having opposite effects) to each other? **[NEET-2016]**

(1) Relaxin - Inhibin
(2) Parathormone - Calcitonin
(3) Insulin - Glucagon
(4) Aldosterone - Atrial Natriuretic Factor

16. The amino acid Tryptophan is the precursor for the synthesis of **[NEET-2016]**
(1) Cortisol and Cortisone
(2) Melatonin and Serotonin
(3) Thyroxine and Triiodothyronine
(4) Estrogen and Progesterone

17. Graves' disease is caused due to **[NEET (Phase-2) 2016]**
(1) Hyposecretion of thyroid gland
(2) Hypersecretion of thyroid gland
(3) Hyposecretion of adrenal gland
(4) Hypersecretion of adrenal gland

18. Name a peptide hormone which acts mainly on hepatocytes, adipocytes and enhances cellular glucose uptake and utilization. **[NEET (Phase-2) 2016]**
(1) Insulin (2) Glucagon
(3) Secretin (4) Gastrin

19. The posterior pituitary gland is **not** a 'true' endocrine gland because **[NEET (Phase-2) 2016]**
(1) It is provided with a duct
(2) It only stores and releases hormones
(3) It is under the regulation of hypothalamus
(4) It secretes enzymes

20. Hypersecretion of Growth Hormone in adults does not cause further increase in height, because **[NEET-2017]**
(1) Growth Hormone becomes inactive in adults
(2) Epiphyseal plates close after adolescence
(3) Bones loose their sensitivity to Growth Hormone in adults
(4) Muscle fibres do not grow in size after birth

21. Which of the following is an amino acid derived hormone? **[NEET 2018]**
(1) Estradiol (2) Ecdysone
(3) Epinephrine (4) Estriol

22. Which of the following hormones can play a significant role in osteoporosis? **[NEET 2018]**
(1) Estrogen and Parathyroid hormone
(2) Progesterone and Aldosterone
(3) Aldosterone and Prolactin
(4) Parathyroid hormone and Prolactin

23. How does steroid hormone influence the cellular activities? **[NEET-2019]**
(1) Changing the permeability of the cell membrane
(2) Binding to DNA and forming a gene-hormone complex
(3) Activating cyclic AMP located on the cell membrane
(4) Using aquaporin channels as second messenger

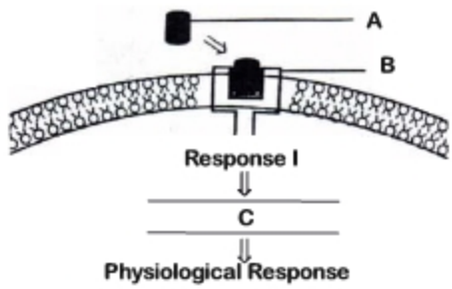
24. Match the following hormones with the respective disease

(a) Insulin	(i) Addison's disease
(b) Thyroxin	(ii) Diabetes insipidus
(c) Corticoids	(iii) Acromegaly
(d) Growth Hormone	(iv) Goitre
	(v) Diabetes mellitus

Select the **correct** option. **[NEET-2019]**

	(a)	(b)	(c)	(d)
(1)	(v)	(i)	(ii)	(iii)
(2)	(ii)	(iv)	(iii)	(i)
(3)	(v)	(iv)	(i)	(iii)
(4)	(ii)	(iv)	(i)	(iii)

25. Identify A, B and C in the diagrammatic representation of the mechanism of hormone action.



Select the correct option from the following : **[NEET-2019 (Odisha)]**
(1) A = Protein Hormone; B = Cyclic AMP; C = Hormone-receptor Complex
(2) A = Steroid Hormone; B = Hormone-receptor Complex; C = Protein
(3) A = Protein Hormone; B = Receptor C = Cyclic AMP
(4) A = Steroid Hormone; B = Receptor; C = Second Messenger

26. Artificial light, extended work-time and reduced sleep-time disrupt the activity of

[NEET-2019 (Odisha)]

(1) Posterior pituitary gland

(2) Thymus gland

(3) Pineal gland

(4) Adrenal gland

27. Which of the following conditions will stimulate parathyroid gland to release parathyroid hormone?

[NEET-2019 (Odisha)]

(1) Rise in blood Ca^{+2} levels

(2) Fall in active Vitamin D levels

(3) Fall in blood Ca^{+2} levels

(4) Fall in bone Ca^{+2} levels

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Sample Question Paper

Choose the correct answer :

1. Find the **wrongly** matched pair w.r.t. the structure and its function in earthworm.
   (1) Chromophil cells – Secretion of saliva which contains mucus and proteolytic enzyme
   (2) Chloragogen cells – Analogous to vertebrate liver as it synthesizes urea
   (3) Typhlosole – Enlarged dorsal villi that increases surface area for absorption
   (4) Lateral heart – Present in 10^{th} and 11^{th} segment

2. Choose the **mismatch.**

	Structure		Function
(1)	Flame cells	–	Excretion and osmoregulation
(2)	Archaeocyte cells	–	Totipotent cells
(3)	Paragastric cavity	–	Digestion
(4)	Collar cells	–	Movement of water

3. Which of the following statements is **true**?
   (1) Sea anemone is represented by polyp
   (2) Nematodes are acoelomate
   (3) *Taenia* shows cross fertilization between different mature proglottids when present singly in intestine of human
   (4) *Schistosoma* is bisexual

4. Characteristic that distinguishes arthropods from annelids and molluscs are
   a. Tracheal system for respiration
   b. Chitinous exoskeleton
   c. Schizocoelom
   d. Jointed legs
   (1) a & b (2) a & c
   (3) a, b & d (4) a, b, c & d

5. Match the following and choose the **correct** option

	Column I		Column II
a.	*Babesia*	(i)	*Rhizopoda*
b.	*Paramecium*	(ii)	Flagellata
c.	*Leishmania*	(iii)	Sporozoan
d.	*Amoeba*	(iv)	Ciliata

   (1) a(ii), b(iv), c(iii), d(i) (2) a(iii), b(i), c(iv), d(ii)
   (3) a(iv), b(ii), c(iii), d(i) (4) a(iii), b(iv), c(ii), d(i)

6. Which of the following characters is **not correct** w.r.t. ctenophora?
   a. Shows bioluminescence
   b. Absence of cnidoblast
   c. Eight rows of comb plates
   d. Fresh water habitat
   (1) a & c (2) a & b
   (3) Only a (4) Only d

7. Choose the **mismatch.**

	Feature		Example
(1)	Bilateral symmetry	–	Fish
(2)	First triploblastic	–	Flatworm
(3)	Free living flatworm	–	*Planaria*
(4)	Radial symmetry	–	*Herdmania*

8. Which statement is **correct** w.r.t. reptilia, aves and mammalia?
   (1) They are amniotes
   (2) Mesonephric kidney
   (3) Respires through gills
   (4) External fertilisation

9. Embryo of *Taenia* present in ripe proglottid is
   (1) Bladder worm (2) Hexacanth
   (3) Miracidium (4) Cysticercus

10. Dicondylic skull with 12 pairs of cranial nerve is found in
    (1) Fishes (2) Amphibians
    (3) Birds (4) Mammals

11. Which of the following conditions will facilitate the dissociation of oxygen?
    (1) Increase in temperature
    (2) Increase in pCO_2
    (3) Increase in DPG
    (4) All of these

12. Main fat digesting enzyme is
    (1) Amylopsin (2) Rennin
    (3) Erepsin (4) Steapsin

13. Protein coated water soluble fat droplets called chylomicrons are formed
    (1) Inside the lumen of intestine
    (2) Inside intestinal cells
    (3) Within lacteals
    (4) Within blood capillaries

14. Mark the **incorrect** statement.
    (1) Steroid and thyroid hormones are lipid soluble
    (2) Lipid soluble hormones bind to intracellular receptors
    (3) The action of lipid soluble hormones are faster and for shorter duration
    (4) cAMP is considered as secondary messenger

15. Mark the **incorrect** match
    (1) Cretinism – Hypothyroidism
    (2) Addison's disease – Tuberculosis in adrenal cortex
    (3) Conn's disease – Hypotension
    (4) Osteitis fibrosa cystica – Hyperparathyroidism

16. Type of linkage present in chitin is
    (1) α 1 $\rightarrow$ 4 (2) β 1 $\rightarrow$ 4
    (3) β 2 $\rightarrow$ 1 (4) α 1 $\rightarrow$ 6

17. Bee wax is combination of
    (1) Phellonic acid and glycerol
    (2) Palmitic acid and mericyl alcohol
    (3) Fatty acids, phosphoric acid and choline
    (4) Stearic acid and cholesterol

18. Plasma proteins are involved in following functions
    a. Maintains blood pH
    b. Acts as antibodies
    c. Transport of thyroxine and Fe^{+++}
    d. Coagulation blood
    (1) a & b (2) a, b & d
    (3) a, b, c & d (4) a, c & d

19. Mark the **incorrect** match
    (1) Nucleus pulposus – Remnant of notochord
    (2) Clavicle – Investing bone
    (3) Apocrine gland – Mammary gland
    (4) Brown fat – Present in adult human

20. Mark the **incorrect** one w.r.t. birds.
    (1) Furcula formed by fusion of two clavicles and one interclavicle
    (2) Synsacrum is formed by fusion of posterior thoracic, lumbar, sarcal and anterior caudal vertebrae
    (3) Copulatory organ is absent in most of the birds
    (4) External fertilization, oviparous and direct development

21. Open type blood circulation is found in
    (1) Insects
    (2) Non cephalopod molluscs
    (3) Tunicates
    (4) All of these

22. Retrogressive metamorphosis is exhibited by
    (1) Ammocoete larva
    (2) Ascidian tadpole larva
    (3) Tornaria larva
    (4) Trochophore larva

23. Identify the snake with following characters
    a. Cylindrical tail
    b. Ventral scales are broad, fully cover belly
    c. 4th infralabial scales largest
    d. Vertebrals scales are hexagonal
    (1) Cobra (2) Krait
    (3) Viper (4) Sea snake

24. Male frog can be distinguished from the female by the
    (1) Presence of amplexusary pads
    (2) Presence of vocal sacs, act like resonators
    (3) Presence of articular pads
    (4) Both (1) & (2)

25. High level of which component in blood may help to reduce our risk of coronary heart diseases?
(1) HDL (2) LDL
(3) Oils (4) Cholesterol

26. Which of the following is **not** found in female cockroach?
(1) Anal styles (2) Anal cerci
(3) Hepatic caeca (4) Spiracles

27. In earthworm coelomic fluid which keeps the skin moist therefore helping in cutaneous respiration oozes out through
(1) Dorsal pores (2) Nephridio pores
(3) Genital pores (4) Spermathecal pores

28. Match the column I with column II

Column I	Column II
a. Hyaline cartilage	(i) Supra scapula in frog
b. Calcified cartilage	(ii) Pinna of ear
c. Elastic cartilage	(iii) Articular cartilage
d. White fibrous cartilage	(iv) Pubis symphysis

(1) a(i), b(iii), c(ii), d(iv) (2) a(iv), b(i), c(ii), d(iii)
(3) a(iii), b(i), c(ii), d(iv) (4) a(i), b(iv), c(ii), d(iii)

29. Which of the following is known as milk let down /ejection hormone?
(1) Prolactin (2) Mammotropin
(3) Estrogen (4) Oxytocin

30. Aqueous humour of eye is secreted from
(1) Iris (2) Ciliary body
(3) Lacrimal gland (4) Meibomian gland

31. One of the examples of the action of the autonomous nervous system is
(1) Swallowing of food
(2) Pupillary reflex
(3) Peristalsis of the intestine
(4) Knee jerk response

32. At resting stage nerve cell has
(1) Low K^+ outside and high Na^+ inside
(2) High K^+ inside and high Na^+ outside
(3) High K^+ inside and low Na^+ outside
(4) High K^+ outside and low Na^+ inside

33. Sympathetic nerves in mammals arise from
(1) Sacral region of spinal cord
(2) Cervical region of spinal cord
(3) Thoraco-lumbar region of spinal cord
(4) Cranial nerves and sacral region of spinal cord

34. The black pigment in the eye, which reduces the internal reflection, is located in
(1) Sclera (2) Sclerotic
(3) Choroid (4) Cornea

35. A person passes excessive urine and drinks much water but his glucose level is normal. It is due to
(1) Increased secretion of glucagon
(2) Fall in glucose released in urine
(3) Reduction in insulin secretion
(4) Reduction in vasopressin secretion

36. The "Lubb" sound of the heart is due to
(1) Closing of the AV valve
(2) Closing of the semilunar valve
(3) Filling of ventricles
(4) Blood rushing out of the ventricles

37. In Ca^{++} homeostasis, the hormone counter acting calcitonin action is
(1) Glucagon (2) Thyroxine
(3) Insulin (4) Parathormone

38. Which of the following is **not** transported through hypothalmo-hypophyseal portal vein?
(1) Somatostatin
(2) Thyrotrophin releasing hormone
(3) Prolactin releasing hormone
(4) Somatotrophin

39. Mark the **correct** statement
(1) Nearly 99% of the filtrate has to be reabsorbed by renal tubule
(2) Tubular secretion helps in maintenance of ionic and acid base balance by body fluids
(3) A fall in GFR can activate the JG cells to release renin
(4) All of these

40. In response to decrease in blood volume and blood pressure, which of the following will not occur?
(1) Increase in the level of ADH
(2) Increase in the level of aldosterone
(3) Increase in the level of renin
(4) Increase in the level of ANF

41. Which of the following is **not** concerned with parasympathetic nervous system?
    (1) Constriction pupil
    (2) Narrowing of air passage
    (3) Dilation of arteries, lowers the blood pressure
    (4) Contraction of internal sphincter of urinary bladder

42. Cerebral aqueduct connect
    (1) Paracoel and diocoel
    (2) Diocoel and metacoel
    (3) Metacoel and subarachnoid space
    (4) Two lateral ventricles

43. If the pituitary gland of human is surgically removed, which of the gland will be least affected?
    a. Adrenal cortex b. Gonad
    c. Adrenal medulla d. Thyroid
    e. Islets of langerhans
    (1) b, c & e
    (2) c & e
    (3) c, d & e
    (4) a, c & e

44. Mark the hormone secreted by gastro intestinal tract which inhibits gastric secretion / motility
    (1) Gastric inhibitory peptide
    (2) Secretin
    (3) Gastrin
    (4) Both (1) & (2)

45. Mucus and bicarbonate present in gastric juice play an important role in
    (1) Lubrication
    (2) Protection of mucosal epithelium from HCl
    (3) Churning movement
    (4) Both (1) & (2)

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ANSWERS

Chapter 1 : Animal Kingdom

Section - A : Objective Type Questions

1.	(4)	2.	(3)	3.	(3)	4.	(3)	5.	(3)	6.	(4)	7.	(3)
8.	(4)	9.	(2)	10.	(3)	11.	(4)	12.	(4)	13.	(3)	14.	(3)
15.	(3)	16.	(1)	17.	(4)	18.	(2)	19.	(1)	20.	(1)	21.	(2)
22.	(1)	23.	(4)	24.	(1)	25.	(1)	26.	(3)	27.	(4)	28.	(2)
29.	(1)	30.	(1)	31.	(1)	32.	(3)	33.	(2)	34.	(3)	35.	(4)
36.	(3)	37.	(2)	38.	(4)	39.	(4)	40.	(1)	41.	(2)	42.	(3)
43.	(4)	44.	(2)	45.	(1)	46.	(2)	47.	(2)	48.	(4)	49.	(2)
50.	(4)	51.	(3)	52.	(3)	53.	(2)	54.	(3)	55.	(2)	56.	(1)
57.	(3)	58.	(2)	59.	(1)	60.	(3)	61.	(3)	62.	(1)	63.	(3)
64.	(1)	65.	(3)	66.	(4)	67.	(4)	68.	(4)	69.	(4)	70.	(4)
71.	(4)	72.	(4)	73.	(4)	74.	(1)	75.	(4)	76.	(3)	77.	(1)
78.	(1)	79.	(4)	80.	(2)	81.	(1)	82.	(4)	83.	(3)	84.	(3)
85.	(4)	86.	(2)	87.	(1)	88.	(4)	89.	(3)	90.	(2)	91.	(2)
92.	(3)	93.	(3)	94.	(4)	95.	(4)	96.	(4)	97.	(1)	98.	(2)
99.	(2)	100.	(2)	101.	(1)	102.	(3)	103.	(2)	104.	(1)	105.	(3)
106.	(4)	107.	(4)	108.	(1)	109.	(1)	110.	(3)	111.	(2)	112.	(3)
113.	(4)	114.	(3)	115.	(1)	116.	(3)	117.	(1)	118.	(3)	119.	(2)
120.	(1)	121.	(2)	122.	(2)	123.	(2)	124.	(2)	125.	(3)	126.	(4)
127.	(4)	128.	(4)	129.	(2)	130.	(3)	131.	(2)	132.	(4)	133.	(3)
134.	(1)	135.	(2)	136.	(1)	137.	(2)	138.	(1)	139.	(4)	140.	(1)
141.	(3)	142.	(1)	143.	(1)	144.	(1)	145.	(4)	146.	(1)	147.	(2)

Section - B : Previous Years Questions

1.	(3)	2.	(4)	3.	(2)	4.	(4)	5.	(4)	6.	(4)	7.	(2)
8.	(4)	9.	(2)	10.	(1)	11.	(4)	12.	(2)	13.	(2)	14.	(2)
15.	(4)	16.	(4)	17.	(3)	18.	(4)	19.	(3)	20.	(3)	21.	(1)
22.	(4)	23.	(2)	24.	(4)	25.	(1)	26.	(2)	27.	(3)	28.	(3)
29.	(3)	30.	(2)	31.	(2)	32.	(1)	33.	(3)	34.	(1)	35.	(2)
36.	(3)	37.	(1)										

Chapter 2 : Structural Organization in Animals

Section - A : Objective Type Questions

1.	(3)	2.	(4)	3.	(2)	4.	(2)	5.	(3)	6.	(2)	7.	(2)
8.	(1)	9.	(1)	10.	(2)	11.	(4)	12.	(1)	13.	(3)	14.	(2)
15.	(3)	16.	(4)	17.	(3)	18.	(3)	19.	(3)	20.	(2)	21.	(4)
22.	(3)	23.	(2)	24.	(1)	25.	(3)	26.	(2)	27.	(1)	28.	(3)

29. (3) 30. (4) 31. (1) 32. (3) 33. (4) 34. (4) 35. (3)
36. (1) 37. (2) 38. (3) 39. (1) 40. (2) 41. (4) 42. (4)
43. (3) 44. (3) 45. (3)

Section - B : Previous Years Questions

1. (1) 2. (4) 3. (1) 4. (4) 5. (2) 6. (4) 7. (3)
8. (2) 9. (3) 10. (1) 11. (1) 12. (4) 13. (4) 14. (2)
15. (4) 16. (1) 17. (4) 18. (4) 19. (2)

Chapter 3 : Biomolecules

Section - A : Objective Type Questions

1. (3) 2. (2) 3. (2) 4. (1) 5. (2) 6. (2) 7. (2)
8. (2) 9. (4) 10. (2) 11. (4) 12. (3) 13. (4) 14. (2)
15. (2) 16. (2) 17. (1) 18. (3) 19. (2) 20. (1) 21. (2)
22. (2) 23. (4) 24. (4) 25. (3) 26. (2) 27. (1) 28. (4)
29. (3) 30. (1) 31. (4) 32. (3) 33. (3) 34. (1) 35. (3)
36. (2) 37. (3) 38. (1) 39. (2) 40. (4)

Section - B : Previous Years Questions

1. (4) 2. (2) 3. (1) 4. (1) 5. (1) 6. (2) 7. (3)
8. (2) 9. (3) 10. (4) 11. (2) 12. (2) 13. (4) 14. (1)
15. (1) 16. (4) 17. (3) 18. (1) 19. (2) 20. (4) 21. (2)
22. (4) 23. (2) 24. (4) 25. (3) 26. (2) 27. (2) 28. (3)
29. (3) 30. (3)

Chapter 4 : Digestion and Absorption

Section - A : Objective Type Questions

1. (4) 2. (3) 3. (4) 4. (2) 5. (2) 6. (2) 7. (2)
8. (1) 9. (3) 10. (4) 11. (2) 12. (1) 13. (3) 14. (2)
15. (4) 16. (3) 17. (1) 18. (2) 19. (2) 20. (2) 21. (3)
22. (3) 23. (2) 24. (2) 25. (1) 26. (2) 27. (2) 28. (1)
29. (1) 30. (3)

Section - B : Previous Years Questions

1. (3) 2. (1) 3. (4) 4. (3) 5. (2) 6. (2) 7. (4)
8. (3) 9. (3) 10. (1) 11. (3) 12. (3) 13. (2) 14. (1)
15. (3) 16. (4) 17. (4) 18. (2) 19. (3) 20. (2) 21. (4)
22. (1) 23. (1)

Chapter 5 : Breathing and Respiration

Section - A : Objective Type Questions

1. (4) 2. (3) 3. (2) 4. (1) 5. (1) 6. (1) 7. (4)
8. (2) 9. (3) 10. (3) 11. (1) 12. (4) 13. (2) 14. (4)
15. (2) 16. (4) 17. (1) 18. (4) 19. (2) 20. (2) 21. (1)

22. (4) 23. (2) 24. (4) 25. (4) 26. (3) 27. (2) 28. (1)
29. (2) 30. (4)

Section - B : Previous Years Questions

1. (1) 2. (2) 3. (2) 4. (1) 5. (3) 6. (3) 7. (2)
8. (4) 9. (3) 10. (3) 11. (2) 12. (2) 13. (3) 14. (2)
15. (2) 16. (1) 17. (3) 18. (3)

Chapter 6 : Body Fluids and Circulation

Section - A : Objective Type Questions

1. (1) 2. (4) 3. (2) 4. (2) 5. (3) 6. (1) 7. (3)
8. (4) 9. (2) 10. (2) 11. (1) 12. (3) 13. (3) 14. (2)
15. (4) 16. (3) 17. (2) 18. (1) 19. (3) 20. (3) 21. (2)
22. (2) 23. (3) 24. (1) 25. (2) 26. (3) 27. (2) 28. (2)
29. (3) 30. (2) 31. (4) 32. (4) 33. (3) 34. (3) 35. (2)

Section - B : Previous Years Questions

1. (4) 2. (3) 3. (4) 4. (1) 5. (1) 6. (1) 7. (4)
8. (3) 9. (4) 10. (4) 11. (4) 12. (3) 13. (4) 14. (1)
15. (3) 16. (4) 17. (1) 18. (3) 19. (1) 20. (1)

Chapter 7 : Excretory Products and their Elimination

Section - A : Objective Type Questions

1. (3) 2. (2) 3. (3) 4. (2) 5. (1) 6. (2) 7. (2)
8. (1) 9. (4) 10. (1) 11. (3) 12. (4) 13. (4) 14. (2)
15. (3) 16. (1) 17. (4) 18. (2) 19. (3) 20. (1) 21. (1)
22. (2) 23. (4) 24. (4) 25. (2) 26. (3) 27. (3) 28. (4)
29. (2) 30. (4)

Section - B : Previous Years Questions

1. (1) 2. (1) 3. (3) 4. (1) 5. (1) 6. (2) 7. (4)
8. (4) 9. (2) 10. (2) 11. (1) 12. (4) 13. (2) 14. (2)
15. (3) 16. (3) 17. (4)

Chapter 8 : Locomotion and Movement

Section - A : Objective Type Questions

1. (2) 2. (3) 3. (2) 4. (1) 5. (4) 6. (2) 7. (4)
8. (3) 9. (2) 10. (4) 11. (2) 12. (3) 13. (2) 14. (4)
15. (4) 16. (1) 17. (1) 18. (1) 19. (4) 20. (4) 21. (3)
22. (3) 23. (2) 24. (2) 25. (4) 26. (1) 27. (1) 28. (3)
29. (4) 30. (1) 31. (2) 32. (2) 33. (2) 34. (2) 35. (3)

Section - B : Previous Years Questions

1. (4) 2. (2) 3. (1) 4. (2) 5. (4) 6. (1) 7. (4)
8. (2) 9. (4) 10. (1) 11. (4) 12. (1) 13. (3) 14. (3)
15. (1) 16. (3) 17. (2) 18. (4) 19. (2) 20. (2)

Chapter 9 : Neural Control and Coordination

Section - A : Objective Type Questions

1.	(2)	2.	(2)	3.	(2)	4.	(1)	5.	(2)	6.	(4)	7.	(2)
8.	(3)	9.	(3)	10.	(2)	11.	(2)	12.	(1)	13.	(2)	14.	(3)
15.	(3)	16.	(2)	17.	(4)	18.	(1)	19.	(2)	20.	(2)	21.	(3)
22.	(2)	23.	(2)	24.	(2)	25.	(2)	26.	(1)	27.	(4)	28.	(4)
29.	(3)	30.	(4)	31.	(3)	32.	(4)	33.	(2)	34.	(3)	35.	(3)
36.	(2)	37.	(3)	38.	(1)	39.	(1)	40.	(3)	41.	(1)	42.	(3)
43.	(4)	44.	(1)	45.	(2)	46.	(1)	47.	(3)	48.	(2)	49.	(2)
50.	(1)												

Section - B : Previous Years Questions

1.	(1)	2.	(1)	3.	(4)	4.	(4)	5.	(4)	6.	(3)	7.	(2)
8.	(3)	9.	(3)	10.	(3)	11.	(3)	12.	(3)	13.	(1)	14.	(4)
15.	(2)	16.	(3)	17.	(2)	18.	(2)	19.	(4)	20.	(4)	21.	(1)

Chapter 10 : Chemical Coordination and Regulation

Section - A : Objective Type Questions

1.	(1)	2.	(2)	3.	(1)	4.	(3)	5.	(2)	6.	(3)	7.	(2)
8.	(4)	9.	(2)	10.	(1)	11.	(1)	12.	(2)	13.	(4)	14.	(2)
15.	(2)	16.	(3)	17.	(1)	18.	(2)	19.	(4)	20.	(2)	21.	(3)
22.	(3)	23.	(1)	24.	(3)	25.	(4)	26.	(2)	27.	(1)	28.	(2)
29.	(3)	30.	(4)	31.	(1)	32.	(4)	33.	(4)	34.	(4)	35.	(3)

Section - B : Previous Years Questions

1.	(2)	2.	(2)	3.	(1)	4.	(3)	5.	(3)	6.	(2)	7.	(4)
8.	(2)	9.	(4)	10.	(2)	11.	(3)	12.	(3)	13.	(2)	14.	(4)
15.	(1)	16.	(2)	17.	(2)	18.	(1)	19.	(2)	20.	(2)	21.	(3)
22.	(1)	23.	(2)	24.	(3)	25.	(3)	26.	(3)	27.	(3)		

Sample Question Paper

1.	(4)	2.	(3)	3.	(1)	4.	(3)	5.	(4)	6.	(4)	7.	(4)
8.	(1)	9.	(2)	10.	(4)	11.	(4)	12.	(4)	13.	(2)	14.	(3)
15.	(3)	16.	(2)	17.	(2)	18.	(3)	19.	(4)	20.	(4)	21.	(4)
22.	(2)	23.	(2)	24.	(4)	25.	(1)	26.	(1)	27.	(1)	28.	(3)
29.	(4)	30.	(2)	31.	(3)	32.	(2)	33.	(3)	34.	(3)	35.	(4)
36.	(1)	37.	(4)	38.	(4)	39.	(4)	40.	(4)	41.	(4)	42.	(2)
43.	(2)	44.	(4)	45.	(4)								

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