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# BIOLOGY - ZOOLOGY

A publication under Free Textbook Programme of Government of Tamil Nadu

Department of School Education

Untouchability is Inhuman and a Crime

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**Government of Tamil Nadu**

First Edition - 2018

Revised Edition - 2019, 2020, 2022, 2023

Reprint - 2021, 2024

(Published under New Syllabus)

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**Content Creation**

State Council of Educational Research and Training

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**Printing & Publishing**

Tamil Nadu Textbook and Educational Services Corporation

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# HOW TO USE THE BOOK ?

STROKE VOLUME IS DEPENDENT ON VENOUS RETURN

Conceptual picture with caption relating to every chapter is given in this text book.

**Chapter Outline** — Presents a complete overview of the chapter

**Learning Objectives:** — Goals to transform the classroom processes into learner centric with a list of bench marks

Amazing facts, Rhetorical questions to lead students to biological inquiry

**Note:** — Additional inputs to content is provided

**Activity** — Directions are provided to students to conduct activities in order to explore, enrich the concept.

**Infographics** — Visual representation of the lesson to enrich learning .

**CASE STUDY** — Superfluous information about a personality or day to day life experience relating to the content

To motivate the students to further explore the content digitally and take them to virtual world

**ICT** — To enhance digital Science skills among students

**Concept Map** — Conceptual diagram that depicts relationships between concepts to enable students to learn the content schematically

**Glossary** — Explanation of scientific terms

**Evaluation** — Assess students to pause, think and check their understanding

**Career corner** — List of professions particular to that chapter

**References** — List of related books for further details of the topic

**Web links** — List of digital resources



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# Career options in Zoology

| Courses | Institutions | Professions and Scope for Future Studies |
|---|---|---|
| **Medical course**<br>• MBBS – Allopathy<br>• MD • MS<br>• BUMS – Unani • BNYS _ Naturopathy<br>• BHMS – Homeopathy • BDS _ Dental<br>• BAMS – Ayurveda • BSMS _ Siddha<br> | ▸ AIIMS, New Delhi<br>▸ JIPMER<br>▸ Government & Private Medical Colleges<br>▸ AFMC, AMU | Civil surgeon / Civil assistant surgeon in central and state govt hospitals and in private sector. Specialist in various medical fields like Cardiologist, Endocrinologist, Neurologist, Orthopedician, Paediatrician, Haematologist, Pathologist and Anaesthetist.<br>• Cardiology • Pulmonology • Nephrology • Diabetology • Dermatology,<br>• Anaesthesiology • Ophthalmology • Obstetrics and Gynaecology |
| **Veterinary Course**<br>• B. V. Sc. (Bachelor of Veterinary Sciences)<br> | ▸ State Veterinary Universities & Colleges | (Veterinary Surgeon/ Veterinary Assiatant Surgeon in central and state govt hospitals and in private sector).<br>• Animal Biochemistry • Dairy Science<br>• Animal Biotechnology • Dairy Technologisty<br>• Animal Genetics and Breeding • Livestock Production Management<br>• Animal Nutrition • Animal Physiology<br>• Bio-Statisticis • Food Quality and Safety Assurance<br>• Poultry Science<br>• Veterinary Bacteriology • Indian Traditional Foods Preservation & Packaging<br>• Veterinary Immunology |
| **Agri Courses**<br>• B. Sc. (Agriculture)<br>• B. Tech (Agriculture)<br>• B. Sc. (Horticulture)<br>• B. Sc. (Forestry)<br>• B. Sc. (Sericulture)<br>• B. F. Sc. (Bachelor of Fisheries Sciences)<br> | ▸ IARI, Delhi<br>▸ Agriculture Universities & Colleges<br> | (Agriculture Officer in state and central government service and other private employment oppurtunites )<br>• Agricultural Engineer • Environmental Sciences<br>• Agronomist • Fruit Sciences and Horticultural Technology<br>• Bioinformatics<br>• Entomologist • Plant Pathology<br>• Soil science & Agro Chemistry |
| **Para Medical courses**<br>• B. Sc. (Nursing)<br>• B. Sc. (Trauma Care Management)<br>• B. Pharm, D. Pharm<br>• BPT (Bachelor of Physiotherapy)<br>• BOT (Bachelor of Occupational Therapy)<br>• B. Optom. (Bachelor of Optometry)<br> | ▸ All India Institutes of Medical Sciences (AIIMS), New Delhi, Bhopal, Bhubaneswar, Jodhpur, Patna, Raipur, Rishikesh.<br>▸ JIPMER, Puducherry<br>▸ All Government & Private Medical Colleges | • Nursing • Nuclear Medicine Technician Occupational therapist<br>• Pharmacy<br>• Anaesthesia Technician • Operation Theatre Technician<br>• Cardiac Technician • Ophthalmic Assistant<br>• Dental Mechanic • Physiotherapst<br>• Health Inspector • Radiographic Assistant<br>• Medical Imaging & Technician • Radiotherapy Technician<br>• Medical Lab Techician • Rehabilitation Technician<br>• Medical X-ray Technican • Respiratory Therapy Technician<br>• Blood Transfusion Technician |
| **General Courses**<br>• B.Sc. Zoology • B.Sc. Food Technology<br>• B.Sc. Dietician & Nutritionist • B.Sc. Dairy Technology<br>• B.Sc. Sericulture • B.Sc. Mass Communication<br>• B.Sc. Oceanography • B.Sc. Multimedia<br>• B.Sc. Forensic Sciences • B.Sc. 3D Animation | Government Arts and Science Colleges in TamilNadu | Zoo keepers, Creators, Bird watchers in Airports and Lab Technician. |
| Bachelor of Science and Education (BSc, B.Ed)<br>M.phil in Education IDGC Ph.D | Regional Institute of Education (Mysore, Ajmeer, Bhopal,Bhuvaneswar), Shillong | BT.Assistant (Science teacher for secondary level) |

Post graduation and Doctorate courses in National and State level institutes

*Civil Service Exams for all india services (IAS, IPS, IFoS) and other central services &*Other service exams conducted by TNPSC, IBPS, NDA, CDS, SSC and RRB.



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# Career options in Zoology

| | | |
|---|---|---|
| Master of science and Education (MSc, B.Ed) | Regional Institute of Education (Mysore, Ajmeer, Bhopal,Bhuvaneswar) | PG.Assistant (Zoology, teachers, professors in collegeslectures and universities higher secondary level) |
| Master of science in Zoology | Government arts and science colleges in TamilNadu - Madras University | Researchers in variegated subjects in zoology and life science, Scientist, Environmetologyist, Dietician and Nutritionist |
| Master of science in Marine Zoology | National institute of Oceanography<br>► Andhra University(Visakhapatnam)<br>► Anna University (Chennai)<br>► Dr. Babasaheb Ambedkar Marathwada University Marine Research Laboratory (Maharashtra)<br>► Bharathidasan University (Tiruchirappalli) | Career opportunities in National Marine park and Marine Engineers |
| Master of science in zoology with specialization in Medical Microbiology | ► Co-operative institute of health science (Kerala)<br>► Dolphin institute of Bio-Medical and Natural Science (Dehradun)<br>► Himalayan University (Arunachal Pradesh) | • Lab Technician<br>• Medical Imaging and technician<br>• Respiratory therapy technician<br>• Nuclear Medicine<br>• Health Inspector<br>• Blood transfusion technician |
| Master of philosophy and Ph.D in Zoology | ► State Universities | Professor, Research scholar<br>Scientist in University , Documentarist in National Geographic Channel, Animal clinics, National parks, Museum Fisheries and aquaculture Pharmaceutical companies, animal trainers. |

**Medicine Related Entrance Exams**

| Exam | Selection Process & Test Pattern | No. of Questions | Tentative Schedule |
|---|---|---|---|
| NEET<br>www.aipmt.nic.in<br>**Time:** 3 Hours<br>**Timing:** NA<br>**Mode:** Pen and Paper | Physics<br>Chemistry<br>Biology<br>**Total Questions** | 45<br>45<br>90<br>**180** | **Form out:** Last week of Jan.<br>**Last Date:** 1st week of March<br>**Test Date:** 1st week of May<br>**Negative Marking:** +4/-1<br>**Marks:** 720<br>**Forms Available:** Online |
| AIIMS<br>All India Institute of Medical Sciences<br>www.aiimsexams.org<br>**Time:** 3.5 Hours<br>**Timing :** NA<br>**Mode:** Computer based | Physics<br>Chemistry<br>Biology<br>GK<br>**Total questions** | 60<br>60<br>60<br>20<br>**200** | **Form out:** Mid Jan<br>**Last Date:** Mid Feb<br>**Test Date:** Mid May<br>**Negative Marking:** +1/- 1/3 rd<br>**Marks:** 200<br>**Forms Available:** Online |
| JIPMER<br>Jawaharlal Institute of Postgraduate Medical Education & Research<br>www.jipmer.edu.in<br>**Time:** 2.5 Hours<br>**Timing:** NA<br>**Mode:** Computer based | Physics<br>Chemistry<br>Biology<br>Logic & Quantitative Reasoning<br>English Comprehension<br>**Total Questions** | 60<br>60<br>60<br>10<br>10<br>**200** | **Form out:** Last week of March<br>**Last Date:** 1st week of May<br>**Test Date:** 1st week of June<br>**Negative Marking:** Nil<br>**Marks:** 800<br>**Forms Available:** Online |

- The Details given above are tentative and have been prepared as per trends of previous years.
- Please visit individual exam/institute website for exact details.



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# Famous National Institutes for Biologists

## AIIMS

**Undergraduate Courses (UG)**

- MBBS
- B.Sc Nursing (post Certificate)
- B.Sc. (Hons.) Nursing
- Paramedical Courses (PM)
- B.Sc. (Hons.) Opthalmic Techniques
- B.Sc. (Hons.) Medical Technology

**Postgraduate Courses (PG)**

- M.D/M.S/M.D.S
- M.Ch. (5 year course)
- M.Sc. / M. Biotechnology

## IARI

**Undergraduate Courses (UG)**

- Agricultural chemicals
- Agronomy
- Bioinformatics
- Entomology
- Horticulture
- Molecular biology and biotechnology
- Environmental sciences
- Plant pathology
- Plant genetic resources
- Nematology
- Microbiology

## JIPMER

**Undergraduate Courses (UG)**

- M B B S
- B Sc Nursing
- B Sc Allied medical Sciences
- B.Sc. Medical Laboratory Technology
- B.Sc. Cardiac Laboratory Technology
- B.Sc. Dialysis Technology
- B.Sc. Neuro Technology
- B.Sc. Nuclear Medicine Technology
- B.Sc. Operation Theatre Technology
- B.Sc. Perfusion Technology
- B.Sc. Radiotherapy Technology
- BASLP (Bachelor in Audiology & Speech Language Pathology) (Collaboration with AIISH, Mysore, RCI approved)

**Postgraduate Courses (PG)**

- General Surgery
- Obstetrics & Gynaecology
- Ophthalmology
- Orthopedic Surgery
- Oto-Rhino Laryngology (E.N.T.)

## IIT (Chennai)

- Biological Sciences - Dual Degree (BS & MS)

## NDRI

**Undergraduate Courses (UG)**

- B.Tech. (Dairy Technology)

**Postgraduate Courses (PG)**

- Dairy Microbiology
- Dairy Chemistry
- Dairy Technology
- Dairy Engineering
- Animal Biochemistry
- Animal Genetics & Breeding
- Livestock Production & Management
- Animal Nutrition
- Animal Physiology
- Dairy Economics
- Dairy Extension Education
- Animal Biotechnology
- Agronomy (Forage production)
- Animal Reproduction, Gynecology and Obstetrics
- Food Quality and Safety Assurance

## NIN ( Hyderabad)

- MSc (APPLIED NUTRITION)
- POST-GRADUATE CERTIFICATE COURSE IN NUTRITION

## SIDDHA

**PG programme in Siddha**

- Maruthuvam
- Gunapadam
- Pura Maruthuvam
- Varma Maruthuvam
- Siddhar Yoga Maruthuvam
- Kuzhandhai Maruthuvam
- Noi Nadal
- Nanju Maruthuvam

**PH.D PROGRAMME**

- Maruthuvam
- Gunapadam
- Sirappu Maruthuvam
- Kuzhandai Maruthuvam
- Noi Nadal
- Nanju Maruthuvam

## IVRI

- MVSc
- BVSc & AH
- Animal Biochemistry
- Animal Biotechnology
- Animal Genetics and Breeding
- Animal Nutrition
- Bio-Statistics
- Epidemiology
- Livestock Economics
- Livestock Production and Management
- Livestock Products Technology
- Poultry Science
- Veterinary Bacteriology
- Veterinary Extension Education
- Veterinary Gynaecology and Obstetrics
- Veterinary Immunology
- Veterinary Medicine
- Veterinary Parasitology
- Veterinary Pathology
- Veterinary Pharmacology
- Veterinary Physiology
- Veterinary Public Health
- Veterinary Surgery & Radiology
- Veterinary Virology

**National Diploma**

- National Diploma in Animal Husbandry (NDAH) Division of Animal Nutrition
- National Diploma in Animal Reproduction (NDAR) Division of Animal Reproduction
- National Diploma in Veterinary Biological Products (NDBP) Division of Biological Products
- National Diploma in Equine Husbandry, Medicine and Surgery (NDEHMS)
- National Diploma in Fodder and Feed Technology(NDFFT) Division of Animal Nutrition
- National Diploma in Meet and Meat Products Technology (NDMPT) Division of Livestock Products Technology
- National Diploma in Poultry Husbandry (NDPH) CARI
- National Diploma in Preventive Veterinary Medicines (NDPVM) Div. of B & M

**PhD**

- Animal BiochemistryB.V.Sc.& AH with Master's degree in concerned discipline.
- Animal BiotechnologyBVSc & AH with Master's degree in Biotechnology/ Animal Biotechnology/Animal Biochemistry/ Microbiology/ Immunology/ Virology
- Animal Genetics and BreedingBVSc & AH with Master's degree in concerned discipline
- Animal NutritionB.V.Sc.& AH with Master's degree in concerned discipline.
- Livestock Production and ManagementB.V.Sc.& AH with Master's degree in concerned discipline.
- Livestock Products TechnologyB.V.Sc.& AH with Master's degree in concerned discipline.
- Poultry ScienceB.V.Sc.& AH with Master's degree in concerned discipline.
- Veterinary BacteriologyBVSc & AH with Master's degree in Vet. Bacteriology/Vet. Virology/ Vet. Microbiology/ Vet. Public Health/ Avian Diseases/ Vet. Immunology/Epidemiology/ Biotechnology
- Veterinary Extension EducationBVSc & AH with Master's degree in concerned discipline/ Vet. Medicine/ Vet. Gynaecology & Obstetrics/ Vet. Surgery/ Animal Nutrition
- Veterinary Gynaecology and ObstetricsB.V.Sc. & AH with Master's degree in concerned discipline
- Veterinary ImmunologyBVSc & AH with Master's degree in Vet. Immunology or MVSc in Vet. Microbiology/Virology/ Bacteriology/ Pathology/Biotechnology/Avian Diseases/Parasitology/ Animal Biochemistry with minor in Vet. Immunology
- Veterinary MedicineB.V.Sc.& AH with Master's degree in concerned discipline



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# BIOLOGY - ZOOLOGY



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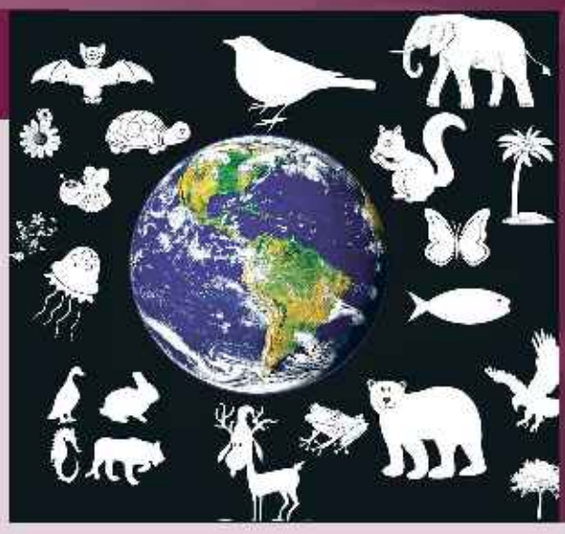
UNIT I

# Chapter 1

# The Living World

**Chapter Outline**


1.1. Diversity in the Living world
1.2. Need for Classification
1.3. Taxonomy and Systematics
1.4. Three Domains of life
1.5. Taxonomic Hierarchy
1.6. Nomenclature
1.7. Concept of Species
1.8. Tools for study of taxonomy

*"Our task must be to...*
*embrace all living creatures and*
*the whole of nature and its beauty."*
*— Albert Einstein*

## Learning Objectives:

- *Learns the importance of the living world and its diversity*
- *Understands the need for classification*
- *Creates an interest in systematics and understands the importance of taxonomy for classification of animals*
- *Knows the key rules of nomenclatures and their uses*

All living forms co-exist with each other. There are about 8.7 million Eukaryotic species of organisms have been estimated to exist on earth. A study reports that 86% of all species on the land and 91% of those in the seas are yet to be discovered, described and catalogued. Though humans are placed in the top most position on the hierarchy, they have to depend on plants and animals for food. Animals are also used as source of labour, in farming, as pets, and for other economic benefits. Understanding animals and their unique characteristics, habitats, behaviour and evolutionary relationships is very important. This chapter deals with, diversity in the living world, need for classification, types of classification, taxonomical hierarchy, nomenclature and tools for studying taxonomy.

## 1.1 Diversity in the Living World

Earth has numerous habitats with a wide range of living organisms inhabiting them. Plants and animals are present in almost all the places, from polar icecaps to volcanic hot springs, from shallow lagoons to the deepest oceans, from tropical rain forests to dry and parched deserts. There are a variety of species that have been adapted



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successfully to live in diverse ecosystems. Ecosystem is a community of biotic and a biotic factors and their interrelationships (**A.G. Tansley, 1935**). The presence of a large number of species in a particular ecosystem is called 'biological diversity' or in short **'biodiversity'.** The term biodiversity was first introduced by **Walter Rosen (1985),** and defined by E.D. Wilson.

### Characterstic features of living organisms

Living organisms show a variety of unique characters different from non-living matter. The key characters of living organisms are, cellular organization, nutrition, respiration, metabolism, growth, response to stimuli, movement, reproduction, excretion, adaptation and homeostasis. Numerous scientists and taxonomists have made tremendous contribution and documentation in the observation and study of even minute characters in living organisms. Their keen observations have led to the classification of living organisms and the study of their interrelationships.

## 1.2 Need for classification

We come across many places where things are arranged in specific categories. In super markets, the shelves can have rows and columns of groceries, cosmetics, toys, stationeries, snacks and utensils. If it is not arranged in a well organized manner, customers and sales persons will waste lot of time in finding an item. In the same way, libraries also organize the books alphabetically or genres-wise into autobiographies, novels, kids stories, science fictions, etc. Likewise it is nearly impossible to study all the living organisms. Hence it becomes necessary to device some means and methods to make this possible and this process is called **classification**. Classification is a process by which things are grouped in convenient categories, based on easily observable characters. The scientific term used for these categories is **taxa** (taxon–singular). Taxa indicates categories at different levels, for example Kingdom Animalia, includes multicellular animals such as reptiles, mammals, etc. Based on their characteristics, all living organisms can be classified into different taxa. This science of classification is called **taxonomy**. External and internal structures along with developmental processes and ecological information of organisms are essential, as they form basis of the taxonomical studies. Hence, characterisation, identification, nomenclature and classification are the scientific stages that are basic to taxonomy.

The basic need for classifications are:

- To identify and differentiate closely related species
- To know the variation among the species
- To understand the evolution of the species
- To create a phylogenetic tree among the different groups
- To conveniently study living organisms

## 1.3 Taxonomy and Systematics

Taxonomy (G. *taxis*- arrangement; *nomos*-law) is the science of arrangement of living organisms along with classification,



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description, identification, and naming of organisms which includes all flora and fauna including microorganisms of the world. The word taxonomy was coined by **Augustin Pyramus de Candole (1813).** Taxonomy is a theoretical study of classification with well defined principles, rules and procedures. **Aristotle** is called the father of taxonomy (classical) and **Carolus Linnaeus is** the father of modern taxonomy.

## Systematics (G. *System*/sequence)

The objectives of taxonomy and systematics are very similar; their goal is to classify organisms with stipulated rules. The main criteria of systematics is identifying, describing, naming, arranging, preserving and documenting the organisms. Apart from the above said features, evolutionary history of the species and the environmental adaptations and interrelationship between species are also being investigated in systematics.

Carolus Linnaeus is the father of modern taxonomy, which is the system of classifying and naming organisms. One of his contributions was the development of a hierarchical system of classification of nature. Today, this system includes eight taxa: domain, kingdom, phylum, class, order, family, genus, and species.

## History of Classification

Early classification of organisms were based on only two criteria, beneficial or harmful animals. An ancient classification system recognized 5 animal groups - domestic, wild, creeping, flying and sea animals. Initially the classification was based on organism's fundamental characteristics such as the habitat and morphology only.

**Aristotle** (384 to 322 BC), was the first to classify all animals in his **History of Animals** (*Historia Animalium* in Latin). He attempted a basic classification of all living organisms into Plants and Animals. Animals were classified based on locomotion; walking (terrestrial), flying (aerial) and swimming (aquatic). Based on the presence or absence of red blood he classified the animals into two as *Enaima* with blood and those without blood as *Anaima.*

Aristotle's classification system had limitations and many organisms were not fitting into his classification. For example, the tadpoles of frogs are born in water and have gills but when they metamorphosed into adult frogs they have lungs and can live both in water and on land. How to classify frogs and where to place them? Aristotle classified organisms based on locomotion, hence, birds, bats, and flying insects were grouped together just by observing one single characteristic feature, the flying ability. On the contrary to the above said example, the ostrich, emu and penguin are all birds but cannot fly. So Aristotle would not have classified them as birds. In spite of these limitations Aristotle's classification system was followed for more than 2000 years upto 1700.



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After Aristotle, his student **Theophrastus** (372-287 BC) continued his research on the classification of plants, and he was known as the "Father of Botany." There was a huge gap till 16th century, then the English naturalist **John Ray** (1627–1705) wrote several important works through his life. His most important contribution was the establishment of species as the ultimate unit of taxonomy. In 1682 he published the *Methodus Plantarum Nova*, which contained about **18,000** plant species, a result of a relatively narrow species concept. His complicated classification was based on many combined characters, as opposed to earlier taxonomists. John Ray also aimed at publishing a complete system of nature, which included works on mammals, reptiles, birds, fishes and insects. The Swedish biologist **Carolus Linnaeus (1707 - 1788)** father of modern taxonomy and founder of modern systematics developed a scientific system of taxonomy and binomial nomenclature, which is still (with modifications) in use.

Aristotle to Linnaeus employed easily observable single to few traits for classification of organisms. With increased knowledge of the several biological domains, many characters were considered for classifying organisms. This represented the phase of classical taxonomy which was based on overall similarities or affinities derived from morphology, anatomy and embryology of organisms. A modification of this system is the numerical taxonomy, which evolved in the 1950s. This system evaluates the resemblances and differences through statistical methods followed by computer analyses to establish the numerical degree of relationship among individuals. Later on biologists initiated studies on the evolutionary and genetic relationships among organisms, which led to the emerge of **phylogenetic classification or cladistics.** It is an evolutionary classification based on how a common ancestry was shared. Cladistic classification summarizes the genetic differences between all species in the 'phylogenetic tree'. **Ernst Haeckal** introduced the method of representing evolutionary relationships with the help of a tree diagram known as **cladogram**.

This system of classification takes into account ancestral characters (traits of basic body design which would be in the entire group) and derived characters (traits whose structure and functions differs from those of ancestral characters). One or more derived characters which appeared during evolution resulted in the formation of new subspecies. In a cladogram each evolutionary step produces a branching and all the members of the branch would possess the derived character which will not be seen in organisms below the particular branch point. Arranging organisms on the basis of their similar or derived characters which differ from the ancestral

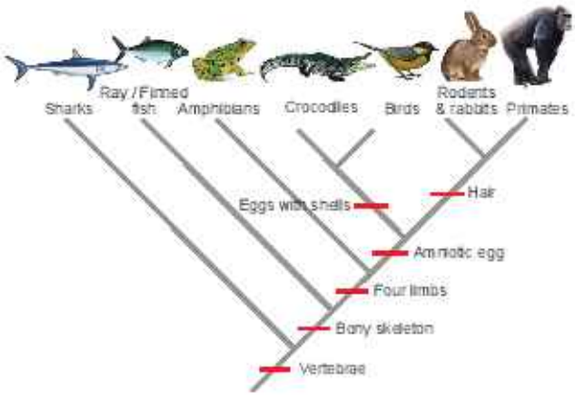


**Figure 1.1** Example of a Cladogram



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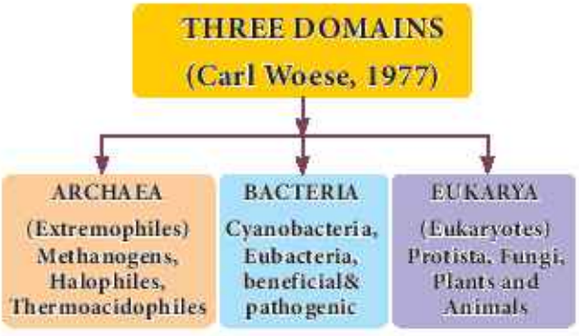
characters produced a **phylogenetic tree or cladogram** (Figure 1.1).

Depending on the system of classification, organisms were classified into two or three kingdoms. Later into four, five, six and now into seven kingdoms. **R.H.Whittaker** (1969) proposed the **Five kingdom Classification**, the Kingdoms defined by him were **Monera, Protista, Fungi, Plantae, and Animalia** based on the cell structure, mode of nutrition, mode of reproduction and phylogenetic relationships. Table 1. gives a comparative account of different characteristics of the five kingdoms.

Classification has come a long way and now takes into an account even molecular level DNA and RNA identification. The advancement in molecular techniques and biochemical assays has led to a new classification - The "**Three Domain" classification**.

## 1.4 Three Domains of life

Three domain classification was proposed by **Carl Woese** (1977) and his co-workers. They classified organisms based on the difference in 16S rRNA genes. The three domain system adds the taxon 'domain' higher than the kingdom. This system emphasizes the separation of Prokaryotes into two domains, Bacteria and Archaea, and all the eukaryotes are placed into the domain Eukarya. Archaea appears to have more in common with the Eukarya than the Bacteria. Archaea differ from bacteria in cell wall composition and differs from bacteria and eukaryotes in membrane composition and rRNA types.




### 1. Domain Archaea

This domain includes single celled organisms, the prokaryotes which have the ability to grow in extreme conditions like volcano vents, hot springs and polar ice caps, hence are also called **extremophiles.** They are capable of synthesizing their food without sunlight and oxygen by utilizing hydrogen sulphide and other chemicals from the volcanic vents. Some of the them produced methane (methanogens), few live in salty environments (Halophiles) and are thermoacidophiles which thrive in acidic environments and at high temperatures.

*Thermus aquatics* is a bacterium which can tolerate high temperatures. The first DNA polymerase enzyme was isolated from *T. aquaticus* it is used in **PCR** (Polymerase Chain Reaction) for DNA amplification.

### 2. Domain Bacteria

Bacteria are prokaryotic, their cells have no definite nucleus and DNA exists as a circular chromosomes and do not have histones associated with it. They do not possess membrane bound organelles except for ribosome (70S type). Their cell wall contains peptidoglycans. Many are decomposers, some are photo-synthesizers and few cause diseases. There are beneficial **probiotic** bacteria



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and harmful **pathogenic** bacteria which are diversely populated. Cyanobacteria are photosynthetic blue green algae which produce oxygen. These had played a key role in the changes of atmospheric oxygen levels from anaerobic to aerobic during the early geologic periods.

### 3. Domain Eukarya (Eukaryotes)

Eukaryotes are animals which have true nucleus and membrane bound organelles. DNA in the nucleus is arranged as a linear chromosome with histone proteins, ribsosomes of 80S type in the cytosol and 70S type in the chloroplast and mitochondria. Organisms in this domain are classified under kingdoms, namely, Protista, Fungi, Plantae and Animalia.

In 1987, **Cavalier-Smith** revised the six kingdom system to **Seven Kingdom system.** The concept of super kingdom was introduced and revised to seven kingdom classification. The classification is divided into two Super Kingdoms (Prokaryota and Eukaryota) and seven kingdoms, two Prokaryotic Kingdoms (Eubacteria and Archaebacteria) and five Eukaryotic Kingdoms (Protozoa, Chromista, Fungi, Plantae and Animalia). (Table 1.1).

**CURD** IS ONE OF THE BEST SOURCES OF PROBIOTICS, WHICH ARE FRIENDLY BACTERIA THAT CAN IMPROVE OUR HEALTH. E.G. *LACTOBACILLUS SP.*

**THE THREE-DOMAIN SYSTEM**

ARCHAEA | BACTERIA | EUKARYA

**The traditional Five – Kingdom system**

Monera | Protista | Fungi | Plantae | Animalia

**The Six –Kingdom system**

Bacteria | Archaea | Protista | Fungi | Plantae | Animalia

**THE SEVEN – KINGDOM SYSTEM**

EUBACTERIA | ARCHAEA BACTERIA | PROTOZOA | CHROMISTA | FUNGI | PLANTAE | ANIMALIA

**Table 1.1 Five Kingdom Classification**

| Salient features | KINDS OF KINGDOM | | | | |
|---|---|---|---|---|---|
| | Monera | Protista | Fungi | Plantae | Animalia |
| Cell type | Prokaryotic | Eukaryotic | Eukaryotic | Eukaryotic | Eukaryotic |
| Cell wall | Non-cellulose structure | Present in some | Present | Present | Absent |
| Body organisation | Cellular | Cellular | Multicelluar Tissue | Tissue Organ | Tissue Organ Organ system |
| Mode of nutrition | Autotrophic Heterotrophic | Autotrophic Heterotrophic | Heterotrophic | Autotrophic | Heterotrophic |



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## 1.5 Taxonomic hierarchy

In biological classification, the taxonomical hierarchy includes seven major categories namely kingdom, phylum, class, order, family, genus and species and other intermediate categories such as subkingdom, grade, division, subdivision, subphylum, superclass, subclass, superorder, suborder, superfamily, subfamily and subspecies.

### Species

Species is the basic unit of classification in the taxonomic hierarchial system. It is a group of animals having similar morphological features (traits) and is reproductively isolated to produce fertile offspring. There are some exceptional animals which can produce **sterile offspring** because of mating with closely related species (Figure 1.2).

**Genus:** It is a group of closely related species which have evolved from a common ancestor. In some genus there is only one species which is called as **monotypic genus** (e.g. Red panda is the only species in the genus *Ailurus* : *Ailurus fulgens*). If there are more than one species in the genus it is known as **polytypic genus,** for example 'cats' come under the Genus *Felis*, which has a number of closely related species, *Felis domestica* (domestic cat), *Felis margarita* (jungle cat), *Felis silvestris* (wild cat)

**Family:** It is a taxonomic category which includes a group of related genera with less similarity as compared to genus and species. For example, the family Felidae includes the genus *Felis* (cats) and the genus *Panthera* (lions, tigers, leopards).

**Order:** This category includes an assemblage of one or more related families which show few common features. One or more similar families are grouped together to form an order. For example, family *Canidae* and *Felidae* are placed in the order Carnivora.

**Class**: This category includes one or more related orders with some common characters. For example order Primata comprising monkeys, apes and man is placed in the Class Mammalia, along with

**Figure 1.2** Sterile offsprings

**Crosses between**

Male horse and Female Donkey results in **Hinny** (Sterile).

Male Donkey and Female Horse results in **Mule** (Sterile)

Male Lion and Female Tiger results in **Liger**

Male Tiger and Female Lion results in **Tigon**



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**Systematics of Human being**

**KINGDOM**
**Animalia** - Animals are multicellular eukaryotic organisms

**PHYLUM**
**Chordata** – Animals with a notochord or vertebral column (Back bone)

**CLASS**
**Mammalia** – Body covered with hair or fur. Mammary glands are present

**ORDER**
**Primata** – Mammals with forward looking eyes and grasping fingers

**FAMILY**
**Hominidae** – Primates with relatively flat faces and binocular vision

**GENUS**
**Homo** – Hominids with large brain and upright posture

**SPECIES**
**sapiens** – Bipedal and higher intelligence

### Recently discovered species in South India

Scientists have discovered a new and unusual species of frog in the Western Ghats in India in August 2017. The frog has shiny, purple skin, a light blue ring around its eyes, and a pointy pig-nose. It is named as Bhupathy's purple frog (*Nasikabatrachus bhupathi*) to honour Dr.Subramaniam Bhupathy, herpetologist who lost his life in the Western Ghats in 2014.

the order Carnivora which includes dogs and cats.

**Phylum:** The group of classes with similar distinctive characteristics constitute a phylum. The classes Pisces, Amphibia, Reptilia, Aves and Mammalia constitute the next higher category, phylum Chordata. These classes share some common features like presence of a notochord and a dorsal tubular nerve cord hence included in the phylum Chordata.

**Kingdom:** All living animals belonging to various phyla are included

In July, 2017, a 9 years old boy discovered a new Freshwater species of Jellyfish in the Kodaikanal lake, Tamilnadu.

A newly discovered Himalayan forest thrush bird was named after the birdman of India, Ornithologist Dr. Salim Ali. The name of the bird is "*Zoothera salimalii*". A fruit bat is also named after him "*Latidens salimalii*"



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in the Kingdom Animalia and it is the top most of the taxonomic hierarchy.

## 1.6 Nomenclature

*Giza, Inimene, Emberi, Manna,*
*Duine, Umano .....*

In all probability these words must be new to you...but they all mean "Human" in different foreign languages! There are presently more than 6000 languages in the world and an animal can be named in more than 6000 ways! Unfortunately it is impossible for anyone to have a good functioning knowledge of most languages and hence there arises a need for a universally accepted scientific naming system for all organisms. The process of assigning scientific names to animals or taxonomic group is called nomenclature. For example, worldwide, the scientific name *Homo sapiens* denotes *human*. Classification and grouping were done to facilitate a deeper understanding of the unique characteristics of each organism and its interrelationship among closely related species. It plays a vital role in the arrangement of known species based on their similarities and dissimilarities. Numerous characters such as morphology, genetic information, habitat, feeding pattern, adaptations, evolution, etc., are examined before an organism is named.

One of the primary responsibilities of systematic biology is the development of biological nomenclature and classification. Nomenclature is not an end to systematics and taxonomy but it is necessary in organizing information about biodiversity. Nomenclature, functions to provide names for all taxa at all levels in the hierarchy of life. Naming of the organisms is done based on the guidelines of the International Code of Zoological Nomenclature (ICZN). The scientific name ensures that each organism has only one name.

### Binomial nomenclature
### (L. *Bi*-two; *Nomen*-Name)

Biologists follow universally accepted principles to provide scientific names to known organisms. Each name has two components, a generic name and a specific epithet. This system of naming the organism is called **Binomial Nomenclature** which was popularised by Carolus Linnaeus and practised by biologists all over the world. Example, the National Bird (Indian Peafowl) – *Pavo cristatus,* the National Animal tiger as *Panthera* tigris, and the Tamil Nadu State bird is the common Emerald dove *Chalcophaps indica*.

Biological nomenclature derives from the binomial (orbinominal) nomenclature that was originally codified in the works of Linnaeus, *Species Plantarum* (1753) and *Systema Naturae*, 10th Edition (1758). These publications are the starting points for the modern biological nomenclature in most groups of plants and animals.

If you find an animal with four legs, with two eyes, paired ear pinna, covered with fur, possessing mammary gland , which class will you position it? How will you give a binomial name, if you are the first person to discover and report that animal.



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### Trinominal nomenclature (*Tri* – three)

This naming system was proposed by Huxley and Stricklandt, Trinomen means, three names: generic name, species name and sub-species name. When members of any species which have large variations then trinomial system is used. On the basis of dissimilarities, this species gets classified into subspecies. It is the extension of binominal nomenclature system which has an addition of subspecies. All the three names are set in italics and only the first letter of generic name is capitalized, if handwritten then it should be underlined separately E.g.*Corvus splendens splendens* (Indian house crow)

Tautonymy: The practice of naming the animals in which the generic name and species name are the same, is called Tautonymy. e.g. *Naja naja* (The Indian Cobra).

**Rules of Nomenclature**

- The scientific name should be italicized in printed form and if handwritten, it should be underlined separately.
- The generic name's (*Genus*) first alphabet should be in uppercase.
- The specific name (*species*) should be in lowercase.
- The scientific names of any two organisms are not similar.
- The name or abbreviated name of the scientist who first publishes the scientific name may be written after the species name along with the year of publication. For example Lion-*Felis leo* Linn., 1758 or *Felis leo* L., 1758.
- If the species name is framed after any person's name the name of the species shall end with i, ii or ae.

For example, a new species of a ground-dwelling lizard (Cyrtodactylus) has been discovered and named after Scientist Varad Giri, *Cyrtodactylus varadgirii*.

## 1.7 Concept of species

Species is the basic unit of classification. The term species was coined by **John Ray**, and in his book **"*Historia Generalis Plantarum*"** (3 volumes) in 1693 described species as a group of morphologically similar organisms arising from a common ancestor. Carolus Linnaeus in his book **"*Systema naturae*"** considered species as the basic unit of classification. Species can be defined as a group of organisms that have similar morphology and physiology and can interbreed to produce fertile offsprings. In 1859 Charles Darwin in his book **Origin of species** explains the evolutionary connection of species by the process of natural selection.

## 1.8 Tools for study of taxonomy

Tools and taxonomical aids may be different for the study of plants and animals. Herbarium and Botanical garden



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may be used as tools for the study of plant taxonomy. In the case of animal studies, the classical tools are Museum, Taxonomical Keys and Zoological and Marine parks.

The important components of the taxonomical tools are field visits, survey, identification, classification, preservation and documentation. Many tools are being used for taxonomical studies, amongst them some of the important tools are discussed below:

**Arignar Anna Zoological Park,** also known as the Vandalur Zoo is in the south western part of Chennai, Tamil Nadu, spreads over an area of 1500 acres, is one of the largest zoological parks in India. The zoo houses 2,553 species of both flora and fauna.

## The classical taxonomical tools

**Taxonomical Keys**: Keys are based on comparative analysis of the similarities and dissimilarities of organisms. There are separate keys for different taxonomic categories.

**Museum**: Biological museums have collection of preserved plants and animals for study and ready reference. Specimens of both extinct and living organisms can be studied.

**Zoological parks**: These are places where wild animals are kept in protected environments under human care. It enables us to study their food habits and behaviour.

**Marine parks:** Marine organisms are maintained in protected enviroments.

**Printed taxonomical tools** consist of identification cards, description, field guides and manuals.

## Molecular taxonomical tools

Technological advancement has helped to evolve molecular taxonomical tools from classical tools to molecular tools. The accuracy and authenticity is more significant in the molecular tools. The following methods are being used for taxonomical classification.

Molecular techniques and approaches such as **DNA barcoding** (short genetic marker in an organism's **DNA** to identify it as belonging to a particular species), **DNA hybridization** (measures the degree of genetic similarity between pools of DNA sequences), **DNA fingerprinting** (to identify an individual from a sample of DNA by looking at unique patterns in their DNA), Restriction Fragment Length Polymorphisms (RFLP) analysis (difference in homologous DNA sequences that can be detected by the presence of fragments of different lengths after digestion of the DNA samples), and Polymerase Chain Reaction (PCR) sequencing ( to amplify a specific gene, or portion of gene,) are used as taxonomical tools.

## Automated species identification tools

It consists of Cyber tools. For example: ALIS, DAISY, ABIS, SPIDA, Draw wing, etc.

**ALIS** → Automated Leafhopper Identification System.

**DAISY** → Digital Automated Identification System.

**ABIS** → Automatic Bee Identification System.

**SPIDA** → Species Identified Automatically (spiders, wasp and bee wing characters).

**Draw wing** → Honey bee wing identification.



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**Neo taxonomical tools** – This is based on Electron Microscopy images to study the molecular structures of cell organelles.

**Ethology of taxonomical tools** – Based on the behaviour of the organisms it can be classified. For example sound of birds, bioluminescence, etc.

**e-Taxonomic resources** – INOTAXA is an electronic resource for digital images and description about the species which was developed by Natural History Museum, London. **INOTAXA** means **In**tegrated **O**pen **TAX**onomic **A**ccess.

## Summary

Earth has numerous habitats with a wide range of living organisms inhabiting it. Living organisms show a variety of unique characters different from non-living matter. Classification is the process by which anything is grouped in a convenient category based on some easily observable characters.

Taxonomy is the science of arrangement of living organisms. R. H. Whittaker proposed the five kingdom classification. Three domain classification was proposed by Carl Woese and his co-workers.

The taxonomical hierarchy includes seven categories namely kingdom, phylum, class, order, family, genus and species. The process of assigning scientific names to animal or taxonomic group is called nomenclature. Each scientific name has two components, generic name and a specific epithet. The important component of the taxonomical tools are field visits, survey, identification, classification, preservation and documentation. Molecular taxonomical tools are more accurate, authentic and significant for taxonimical classification.

## Activity

The main objective of this activity is to check the students understanding about animals and its characteristics before learning the lesson. Observe the picture given below, identify the animals and classify them according to your own understanding; write one character about each class of animals.

Take the students to the school ground and ask them to observe and identify few invertebrates (insects, earthworm, spiders etc). Ask the students to write few characteristics of each animal which they have observed.

| Sl.No. | Name of the Animal | Known Character | Class | Habitat |
|---|---|---|---|---|
| 1 | | | | |
| 2 | | | | |
| 3 | | | | |
| 4 | | | | |



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## Evaluation

1. A living organism is differentiated from non-living structure based on
   a. Reproduction
   b. Growth
   c. Metabolism **d. All the above**
2. A group of organisms having similar traits of a rank is
   **a. Species** b. Taxon
   c. Genus d. Family
3. Every unit of classification regardless of its rank is
   **a. Taxon** b. Variety
   c. Species d. Strain
4. Which of the following is not present in same rank?
   a. Primata b. Orthoptera
   c. Diptera **d. Insecta**
5. What taxonomic aid gives comprehensive information about a taxon?
   **a. Taxonomic Key** b. Herbarium
   c. Flora d. Monograph
6. Who coined the term biodiversity?
   **a. Walter Rosen** b. AG Tansley
   c. Aristotle d. AP de Candole
7. Cladogram considers the following characters
   a. Physiological and Biochemical
   **b. Evolutionary and Phylogenetic**
   c. Taxonimic and systematic
   d. None of the above
8. Molecular taxonomic tool consists of
   **a. DNA and RNA**
   b. Mitochondria and Endocplamic reticulum
   c. Cell wall and Membrane proteins
   d. All the above
9. Differentiate between probiotics and pathogenic bacteria.
10. Why mule is sterile in nature?
11. List any five salient features of the family *Felidae*.
12. What is the role of Charles Darwin in relation to concept of species?
13. Why elephants and other wild animals are entering into human living area?
14. What is the difference between a Zoo and wild life sanctuary?
15. Can we use recent molecular tools to identify and classify organisms?
16. Explain the role of Latin and Greek names in Biology.

## ICT Corner Deep Tree

**Let's do this activity to know the position of a particular species in the Evolution path.**

**Step – 1**: Type the URL in the browser. Click 'Play Game' button then use your personal or school id to login. Otherwise use Guest Pass to enter. Then click the DEEP TREE icon that is given below The Evolution Lab to start the activity.

**Step – 2**: Input the common name of any animal in the SEARCH tab given at the bottom of the activity window, select the appropriate Zoological name from the list appeared.

**Step – 3**: The Classification and the place of the species in the animal Kingdom can be viewed by clicking the Icon placed next to the search tab.

**Step – 4**: Two different species can be compared by clicking on the RELATE button given at the bottom of the activity window. The relation between those species can be learnt by clicking the DNA icon appeared.

DEEP TREE url
http://www.pbs.org/wgbh/nova/labs/lab/evolution/



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UNIT I

# Chapter 2

# Kingdom Animalia

**Chapter Outline**


2.1 Basis of Classification

2.2 Classification of Kingdom Animalia

2.3 Non Chordates (Invertebrata)

2.4 Phylum: Chordata

March 20th is celebrated as World Sparrow day to conserve this endangered species, House sparrow (*Passer domesticus*)

## Learning Objectives:

- *Justifies the need for classification.*
- *Understands the salient features of the animal phyla.*

H6A8L

Kingdom Animalia comprises millions of animal species and studying them without a basic classification may lead to confusion. In addition to this, there are several new species of animals being constantly discovered. Classification is very essential for identification, naming and assigning a systematic position to the newly discovered species. Animal Kingdom is classified mainly based on the closely resembling characteristic features. Kingdom Animalia is characterised of eukaryotic, multicellular, heterotrophic organisms. They include about 35 phyla of which 11 are considered as major phyla. Almost 99 percent of animals are invertebrates or animals without backbone. The remaining represents vertebrates or animals with backbone. On the basis of the presence or absence of notochord (vertebral column), animals are also categorised into two major groups and they are non chordates and chordates.

## 2.1 Basis of Classification

Multicellular organisms are structurally and functionally different but yet they possess certain common fundamental features such as the arrangement of cell layers, the levels of organisation, nature of coelom, the presence or absence of segmentation, notochord and the organisation of the organ system.

### 2.1.1 Levels of Organisation

All members of Kingdom Animalia are metazoans (multicellular animals) and exhibit different patterns of cellular organisation. The cells of the metazoans are not capable of



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independent existence and exhibit division of labour. Among the metazoans, cells may be functionally isolated or similar kinds of cells may be grouped together to form tissues, organ and organ systems.

### Cellular Level of Organisation

This basic level of organisation is seen in sponges. The cells in the sponges are arranged as loose aggregates and do not form tissues, i.e. they exhibit cellular level of organisation. There is division of labour among the cells and different types of cells are functionally isolated. In sponges, the outer layer is formed of pinacocytes (plate-like cells that maintain the size and structure of the sponge) and the inner layer is formed of choanocytes. These are flagellated collar cells that create and maintain water flow through the sponge thus facilitating respiratory and digestive functions.

Animals such as sponges lack nervous tissue and muscle tissue, what does this tell you about sponges?

### Tissue Level of Organisation

In some animals, cells that perform similar functions are aggregated to form tissues. The cells of a tissue integrate in a highly coordinated fashion to perform a common function, due to the presence of nerve cells and sensory cells. This tissue level of organisation is exhibited in diploblastic animals like cnidarians. The formation of tissues is the first step towards evolution of body plan in animals (*Hydra* - Coelenterata).

### Organ Level of Organisation

Different kinds of tissues aggregate to form an organ to perform a specific function. Organ level of organisation is a further advancement over the tissue level of organisation and appears for the first time in the Phylum Platyhelminthes and seen in other higher phyla.

### Organ System Level of Organisation

The most efficient and highest level of organisation among the animals is exhibited by flatworms, nematodes, annelids, arthropods, molluscs, echinoderms and chordates. The evolution of mesoderm in these animals has led to their structural complexity. The tissues are organised to form organs and organ systems. Each system is associated with a specific function and show organ system level of organisation. Highly specialized nerve and sensory cells coordinate and integrate the functions of the organ systems, which can be very primitive and simple or complex depending on the individual animal. For example, the digestive system of Platyhelminthes has only a single opening to the exterior which serves as both mouth and anus, and hence called an **incomplete digestive system**. From Aschelminthes to Chordates, all animals have a **complete digestive system** with two openings, the mouth and the anus.

Similarly, the circulatory system is of two types, the **open type**: in which the blood remains filled in tissue spaces due to the absence of blood capillaries. (arthropods, molluscs, echinoderms and urochordates) and the **closed type:** in which the blood is circulated through blood vessels of varying diameters (arteries, veins and capillaries) as in annelids, cephalochordates and vertebrates.



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### 2.1.2 Diploblastic and Triploblastic Organisation

During embryonic development, the tissues and organs of animals originate from two or three embryonic germ layers. On the basis of the origin and development, animals are classified into two categories: Diploblastic and Triploblastic.

Animals in which the cells are arranged in two embryonic layers (Figure 2.1), the external ectoderm, and internal endoderm are called **diploblastic animals**. In these animals the ectoderm gives rise to the epidermis (the outer layer of the body wall) and endoderm gives rise to gastrodermis (tissue lining the gut cavity). An undifferentiated layer present between the ectoderm and endoderm is the mesoglea. (Corals, Jellyfish, Sea anemone)

Animals in which the developing embryo has three germinal layers are called **triploblastic** animals and consists of outer ectoderm (skin, hair, neuron, nail, teeth, etc)., inner endoderm (gut, lung, liver) and middle mesoderm (muscle, bone, heart). Most of the triploblastic animals show organ system level of organisation (Flat worms to Chordates).

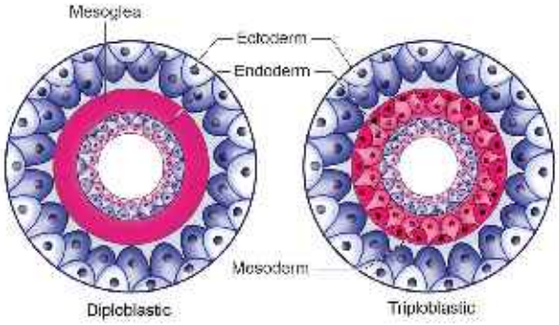


**Figure 2.1** Germinal layers

### 2.1.3 Patterns of Symmetry

Symmetry is the body arrangement in which parts that lie on opposite side of an axis are identical. An animal's body plan results from the animal's pattern of development. The simplest body plan is seen in sponges (Figure 2.2). They do not display symmetry and are **asymmetrical**. Such animals lack a definite body plan or are irregular shaped and any plane passing through the centre of the body does not divide them into two equal halves (Sponges). An asymmetrical body plan is also seen in adult gastropods (snails).

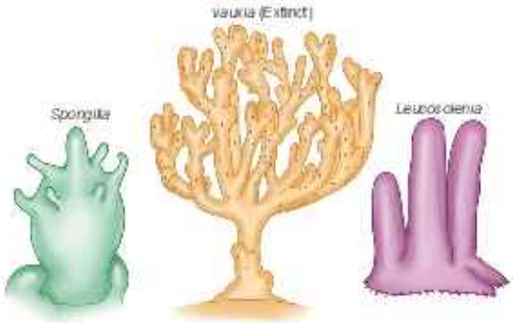


**Figure 2.2** Asymmetry in sponges

Symmetrical animals have paired body parts that are arranged on either side of a plane passing through the central axis. When any plane passing through the central axis of the body divides an organism into two identical parts, it is called **radial symmetry**. Such radially symmetrical animals have a top and bottom side but no dorsal (back) and ventral (abdomen) side, no right and left side. They have a body plan in which the body parts are organised in a circle around an axis. It is the principal symmetry in diploblastic animals. Cnidarians such as sea anemone and corals (Figure 2.3) are radially symmetrical. However, triploblastic animals like echinoderms (e.g., starfish) have five planes of symmetry and show **Pentamerous radial symmetry**.

Animals which possess two pairs of symmetrical sides are said to be



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**biradially symmetrical** (Figure 2.4). Biradial symmetry is a combination of radial and bilateral symmetry as seen in ctenophores. There are only two planes of symmetry, one through the longitudinal and sagittal axis and the other through the longitudinal and transverse axis. (e.g., Comb jellyfish – *Pleurobrachia*)

Animals which have two similar halves on either side of the central plane show **bilateral symmetry** (Figure 2.5). It is an advantageous type of symmetry in triploblastic animals, which helps in seeking food, locating mates and escaping from predators more efficiently. Animals that have dorsal and ventral sides, anterior and posterior ends, right and left sides are bilaterally symmetrical and exhibit cephalisation, in which the sensory and brain structures are concentrated at the anterior end of the animal.

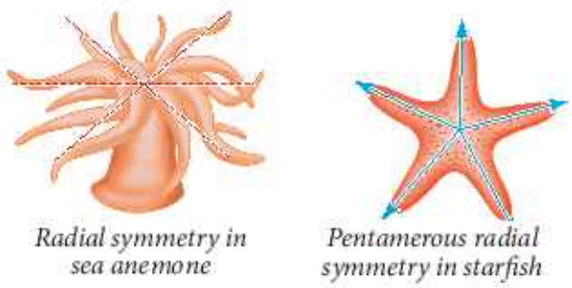


**Figure. 2.3** Radial and Pentamerous radial symmetry

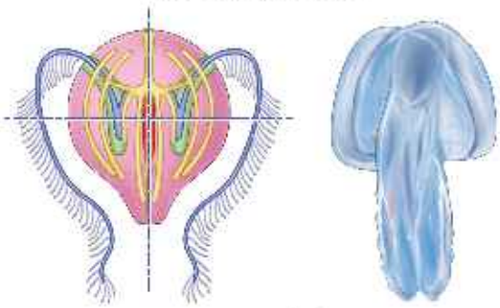

**Figure 2.4** Biradial symmetry in comb jelly

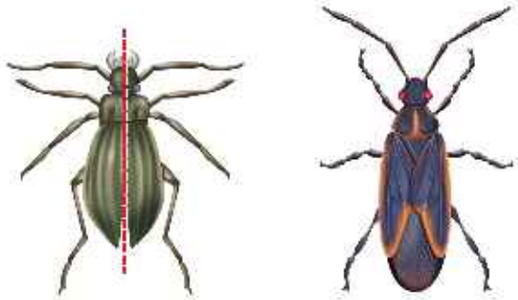

**Figure 2.5** Bilateral symmetry in Insects

## 2.1.4 Coelom

The presence of body cavity or coelom is important in classifying animals. Most animals possess a body cavity between the body wall and the alimentary canal, and is lined with mesoderm (Figure 2.6)

Animals which do not possess a body cavity are called **acoelomates**. Since there is no body cavity in these animals their body is solid without a perivisceral cavity, this restricts the free movement of internal organs. (e.g., Flatworms)

In some animals, the body cavity is not fully lined by the mesodermal epithelium, but the mesoderm is formed as scattered pouches between the ectoderm and endoderm. Such a body cavity is called a **pseudocoel** and is filled with pseudocoelomic fluid. Animals that possess a pseudocoel are called **pseudocoelomates** e.g., Round worms. The pseudocoelomic fluid in the pseudocoelom acts as a hydrostatic skeleton and allows free movement of the visceral organs and for circulation of nutrients.

**Eucoelom** or true coelom is a fluid-filled cavity that develops within the mesoderm and is lined by mesodermal epithelium called peritoneum. Such animals with a true body cavity are called coelomates or **eucoelomates**. Based on the mode of formation of coelom, the eucoelomates are classified into two types, **Schizocoelomates** – in these animals the



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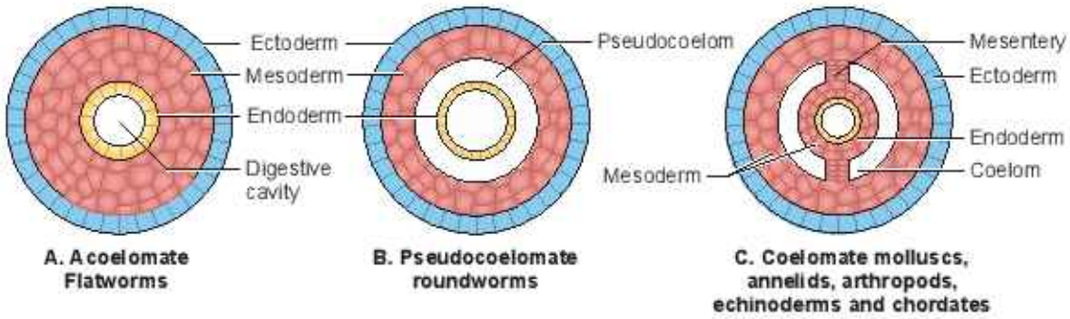


**Figure 2.6** Diagrammatic representation of coelom in animals

body cavity is formed by splitting of mesoderm. (e.g., annelids, arthropods, molluscs). In **Enterocoelomate animals** the body cavity is formed from the mesodermal pouches of archenteron. (e.g., Echinoderms, hemichordates and chordates) (Figure 2.7).

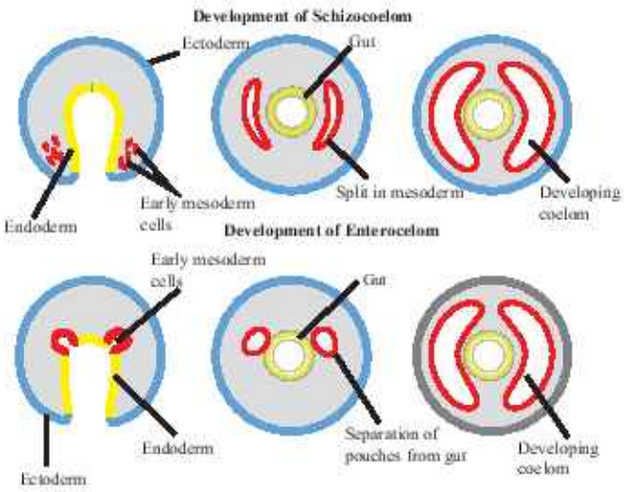


**Figure 2.7** Development of Schizocoelomata and Enterocoelomata

What is the advantage of true coelom over a pseudocoelom?

### 2.1.5 Segmentation and Notochord

In some animals, the body is externally and internally divided into a series of repeated units called segments with a serial repetition of some organs **(Metamerism)**. The simplest form of segmentation is found in Annelids in which each unit of the body is very similar to the next one. But in arthropods (cockroach), the segments may look different and has different functions.

Animals which possess notochord at any stage of their development are called chordates. Notochord is a mesodermally derived rod like structure formed on the dorsal side during embryonic development in some animals. Based on the presence or absence of notochord, animals are classified as chordates (Cephalochordates, Urochordates, Pisces to Mammalia) and nonchordates (Porifera to Hemichordata).

## 2.2 Classification of Kingdom Animalia

Animal kingdom is divided into two sub-kingdoms, the Parazoa and Eumetazoa based on their organisation.

**1. Parazoa**: These include the multicellular sponges and their cells are loosely aggregated and do not form tissues or organs.

**2. Eumetazoa**: These include multicellular animals with well defined tissues, which are organised as organs and organ systems. Eumetazoans includes two taxonomic levels called grades. They include **Radiata** and **Bilateria**.



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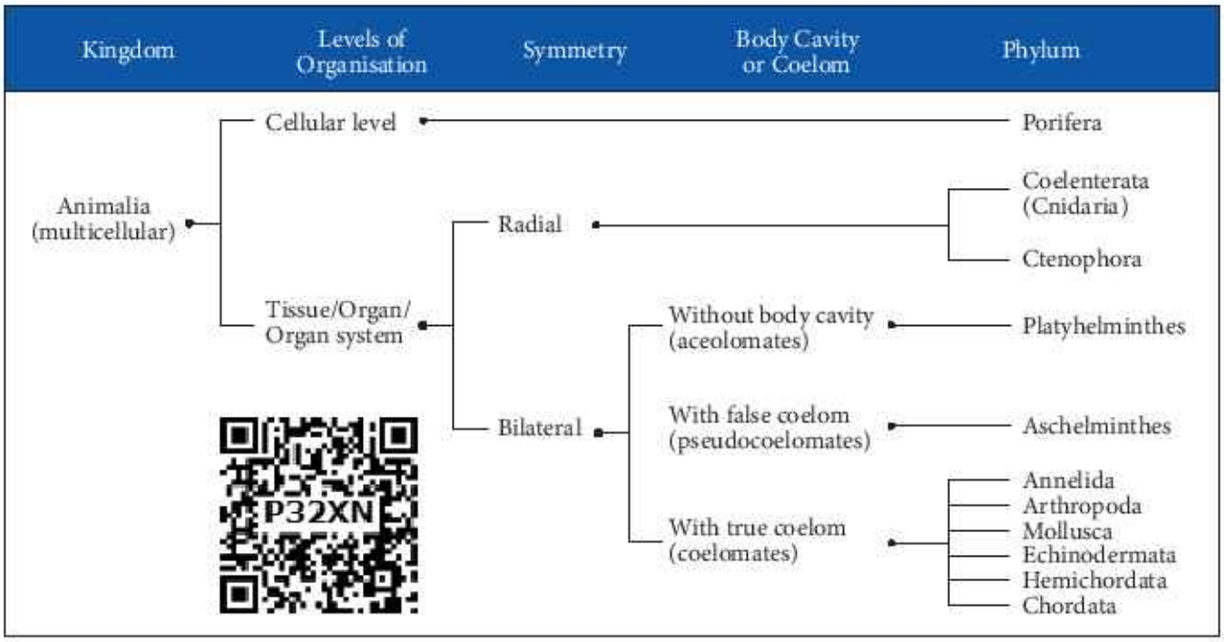


**Figure 2.8** Classification of Kingdom Animalia based on common fundamental features

### Grade 1: Radiata

Among the eumetazoa, a few animals have an organisation of two layers of cells, the outer ectoderm and inner endoderm, separated by a jelly like mesoglea. They are radially symmetrical and are diploblastic. Examples: Cnidarians (sea anemone, jelly fish) and Ctenophores (comb jellies).

### Grade 2: Bilateria

The eumetazoans other than Radiata, show organ level of organisation and are bilaterally symmetrical and triploblastic. The grade Bilateria includes two taxonomic levels called **Division.**

### Division 1: Protostomia

**(*Proto*: first; *stomium*: mouth)**

Protostomia includes the eumetazoans in which the embryonic blastopore develops into mouth. This division includes three subdivisions namely **acoelomata, pseudocoelomata and schizocoelomata.**

### Division 2: Deuterostomia

**(*deuteron*: secondary; *stomium*: mouth)**

Eumetazoans in which anus is formed from or near the blastopore and the mouth is formed away from the blastopore. It includes only one subdivision **Enterocoelomata.** They have a true coelom called enterocoel, formed from the archenteron.

## 2.3 Non Chordates (Invertebrata)

### 2.3.1 Phylum: Porifera

(L. *poros*-pore; *ferre*-to bear)

These pore bearing animals are commonly called **sponges.** They are aquatic, mostly marine, asymmetrical and a few species live in freshwaters. They are primitive, multicellular, sessile animals with cellular level of organisation in which the cells are loosely arranged. They are either radially symmetrical or asymmetrical animals.

They possess a water transport system or **canal system** where water enters through minute pores called **ostia** lining the body wall through which the water enters into a



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central cavity (**spongocoel**) and goes out through the osculum. This water transport system is helpful in food gathering, circulation, respiration and removal of waste. **Choanocytes** or collar cells are special flagellated cells lining the spongocoel and the canals. The body is supported by a skeleton made up of calcareous and siliceous **spicules** or **spongin** or both. Nutrition is holozoic and intracellular. All sponges are hermaphrodites (i.e.) the ova and sperms are produced by the same individual. They also reproduce asexually by fragmentation or **gemmule formation** and sexually by the formation of gametes. Development is indirect with different types of larval stages such as **parenchymula and amphiblastula**.

Examples: *Sycon* (Scypha), *Spongilla* (fresh water sponge), *Euspongia* (bath sponge) *Euplectella* (Venus flower basket) (Figure 2.9).

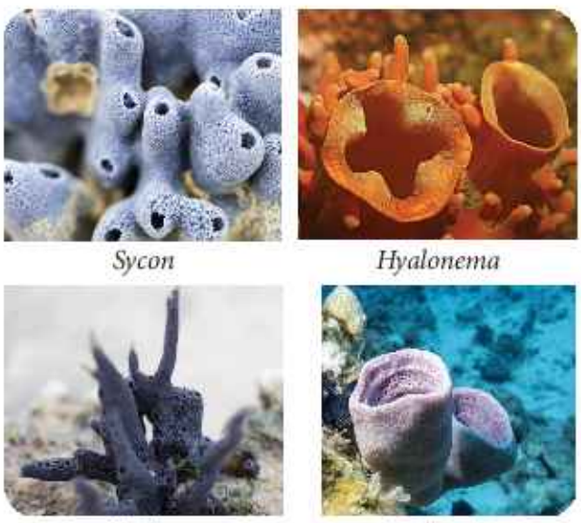


**Figure 2.9** Examples of Porifera

The underwater sea bed is the new habitat where the discovery and development of Marine Pharmaceuticals are in peak. Anticancerous, Antimalarial drugs and other bioactive molecules have been isolated and tested successfully.

### 2.3.2 Phylum: Cnidaria

(G. *knode* -needle or sting cells)

Cnidarians (were previously called Coelenterata), are aquatic, sessile or free swimming, solitary or colonial forms with radial symmetry The name Cnidaria is derived from **cnidocytes** or **cnidoblasts** with **stinging cells** or **nematocyst** on tentacles. Cnidoblasts are used for anchorage, defense, and to capture the prey. Cnidarians are the first group of animals to exhibit tissue level organisation and are diploblastic. They have a central vascular cavity or **coelenteron** (serves both digestion and circulatory function) with a single opening called mouth or hypostome, which serves the process of ingestion and egestion. Digestion is both extracellular and intracellular. The nervous system is primitive and is formed of diffused nerve net. Cnidarians like corals have a skeleton made up of calcium carbonate. Cnidarians exhibit two basic body forms, polyp and medusa. The **polyp** forms are sessile and cylindrical (e.g. *Hydra, Adamsia*), whereas the **medusa** are umbrella shaped and free swimming. Cnidarians which exist

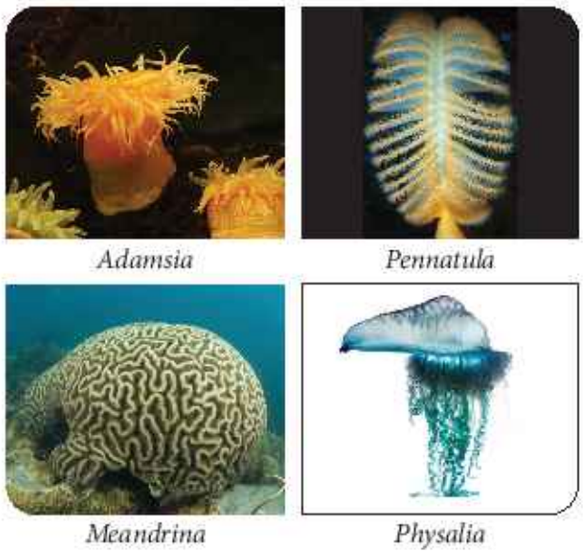


**Figure 2.10** Examples of Cnidarians



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in both forms, also exhibit alternation of generations in their life cycle (**Metagenesis**). The polyp represents the asexual generation and medusa represents the sexual generation. Polyps produce medusa asexually and medusa forms polyps sexually. Development is indirect and includes a free swimming ciliated **planula larva**.

Examples: *Physalia* (Portugese man of war), *Adamsia* (Sea anemone), Pennatula (Sea pen), *Meandrina* (Brain coral) (Figure 2.10).

Compare the advantages and disadvantages of direct and indirect development.

### 2.3.3 Phylum: Ctenophora

(G. *Ktenos* -comb; *phoros* -bearing)

Ctenophora are exclusively marine, biradially symmetrical, diploblastic animals with tissue level of organisation. Though they are diploblastic, their mesoglea is different from that of cnidaria. It contains amoebocytes and smooth muscle cells. They have eight external rows of ciliated comb plates (comb jellies) which help in locomotion, hence commonly called **comb jellies** or **sea walnuts**. **Bioluminescence** (the ability of a living organism to emit light) is well marked in ctenophores. They lack nematocysts but possess special cells called **lasso cells** or **colloblasts** which help in food capture. Digestion is both extracellular and intracellular. Sexes are not separate (monoecious). They reproduce only by sexual means. Fertilization is external and development is indirect and includes a larval stage called **cydippid larva**. e.g., *Pleurobrachia* (Figure 2.11).

Examples : *Pleurobrachia and Ctenoplana*.

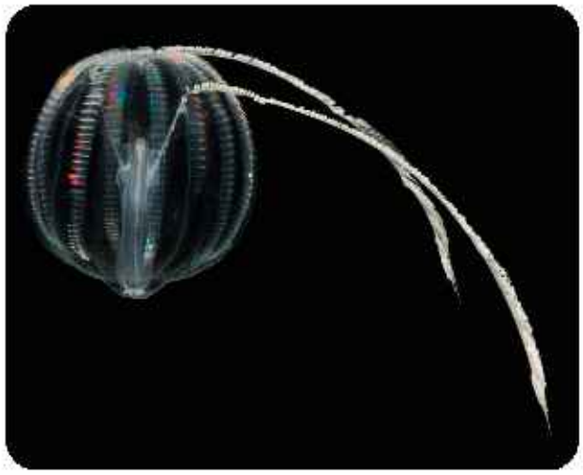

**Figure 2.11** Example of Ctenophora- *Pleurobrachia*

### 2.3.4 Phylum: Platyhelminthes (Flatworms)

(G. *Platy* -broad or flat; *helmin*-worm)

They have a dorsoventrally flattened body and hence called flatworms. These animals are bilaterally symmetrical, triploblastic, acoelomate with organ system level of organisation. They show moderate cephalization and unidirectional movement. They are, mostly endoparasites of animals including human beings. Hooks and suckers are present in the parasitic forms and serve as organs of attachment. Their body is not segmented, but some exhibit pseudosegmentation. Some of the parasitic flatworms absorb nutrients directly from the host through their body surface. However, flatworms like liver fluke have an incomplete digestive system. Specialized excretory cells called **flame cells** help in osmoregulation and excretion. Sexes are not separate (monoecious); fertilisation is internal and development is through larval stages (miracidium, sporocyst, redia, cercaria). **Polyembryony**



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*Planaria* *Liverfluke* *Tape worm*

**Figure 2.12** Examples of Platyhelminthes

is common in some flatworms (Liver flukes). Some members like *Planaria* show high regeneration capacity ( Figure 2.12).

Examples: *Taenia solium* (Tape worm), *Fasciola hepatica* (Liver fluke), *Schistosoma* (Blood fluke).

### 2.3.5 Phylum: Aschelminthes (Round Worms)

(G. *Askes* –cavity; *helminths* – worms)

Previously called Nematoda, this phylum is now named as Aschelminthes. The body of these worms is circular (round) in cross section and hence are called round worms. They are free living or parasitic on aquatic and terrestrial plants and animals. They are bilaterally symmetrical, triploblastic and pseudocoelomate animals with organ system level of organisation. The body is unsegmented and covered by a transparent, tough and protective collagenous layer called cuticle. The alimentary canal is complete with a well developed mouth, muscular pharynx and anus. Excretory system consists of renette glands. Sexes are separate; and exhibit sexual dimorphism; often females are longer than males. Fertilisation is internal; majority are oviparous (e.g. *Ascaris*) few are ovoviviparous (*Wuchereria*). Development may be direct or indirect.

Examples. *Ascaris lumbricoides* (Round worm), *Enterobius vermicularis* (Pin worm), *Wuchereria bancrofti* (Filarial worm), *Ancylostomaa deuodenale* (Hook worm) (Figure 2.13).

### 2.3.6 Phylum: Annelida (Segmented Worm)

(L. *annulus* -a ring, and G. *edios*- form)

Annelids were the first segmented animals to evolve. They are aquatic or terrestrial, free living but some are parasitic. They are triploblastic, bilaterally

*Ascaris* *Filarial worm* *Hook worm*

**Figure 2.13** Examples of Aschelminthes



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*Earthworm* *Nereis* *Leech*

**Figure 2.14** Examples of Annelida

symmetrical, schizocoelomates and exhibit organ system level of body organisation. The coelom with coelomic fluid creates a hydrostatic skeleton and aids in locomotion. Their elongated body is metamerically segmented and the body surface is divided into segment or metameres. Internally the segments are divided from one another by partitions called septa. This phenomenon is known as **metamerism**. The longitudinal and circular muscles in the body wall help in locomotion. Aquatic annelids like *Nereis* have lateral appendages called **parapodia**, which help in swimming. Chitinous setae in Earthworms and suckers in Leech help in locomotion. The circulatory system is of closed type and the respiratory pigments are **haemoglobin** and **chlorocruorin**. Nervous system consists of paired ganglion connected by the lateral nerves to the double ventral nerve cord. They reproduce sexually. Development is direct or indirect and includes a **trochophore larva**. Some are monoecious (earthworms) while some are dioecious (Neries and Leech). (Figure 2.14)

Examples: *Lampito mauritii* (earthworm), *Neries* (sand worm), *Hirudinaria* (leech).

How is cephalisation advantageous to animals in finding food?

**Filariasis** has been a major public health problem in India next only to malaria. The disease was recorded in India as early as 6th century B.C. by the famous Indian physician, Susruta in his book **Susruta Samhita.** In 7 th century A.D., **Madhavakara** described signs and symptoms of the disese in his treatise ' Madhava Nidhana' which holds good even today. In 1709, Clarke identified elephantoid legs in Cochin. The **microfilariae** in the peripheral blood was first identified by Lewis in 1872 in Calcutta (Kolkata).

### 2.3.7 Phylum: Arthropoda

(G. *arthros*- jointed; podes- feet)

This is the largest phylum of the Kingdom Animalia and includes the largest class called **insecta** (total species ranges from 2-10 million). They are bilaterally symmetrical, segmented, triploblastic and schizocoelomate animals with organ system grade of body organisation. They have jointed appendages which are used for locomotion, feeding and are sensory in function. Body is covered by chitinous exoskeleton for protection and to prevent water loss, It is shed off periodically by a process called **moulting** or **ecdysis**. The body consists of a head, thorax, and abdomen with a body



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cavity called **haemocoel**. Respiratory organs are gills, book gills, book lungs and trachea. Circulatory system is of open type. Sensory organs like antennae, eyes (compound and simple), statocysts (organs of balance/ equilibrium) are present. Excretion takes place through **malpighian tubules**, **green glands**, **coxal glands**, etc. They are mostly dioecious and oviparous; fertilization is usually internal. Development may be direct or indirect. Life history includes many larval stages followed by metamorphosis.

Examples : *Limulus* (King crab, a living fossil), *Palamnaeus* (Scorpion), *Eupagarus* (Hermit crab), *Apis* (Honey bee), *Musca* (House fly), Vectors- *Anopheles*, *Culex*, *Aedes* (mosquitoes), Economically important insects - *Apis*- (Honey bee), *Bombyx* (Silk worm), *Laccifer* (Lac insects), Gregarious pest - *Locusta* (Locust) (Figure 2.15)

Spider silk is five times stronger than steel of the same diameter. It has been suggested that a Boeing 747 could be stopped in flight by a single pencil-width strand and spider silk is almost as strong as Kevlar, the toughest man-made polymer.

### 2.3.8 Phylum: Mollusca

(L. *molluscs* –soft bodied)

This is the second largest animal phylum. Molluscs are terrestrial and aquatic (marine or fresh water) and exhibit organ system level of body organisation. They are bilaterally symmetrical (except univalves eg. apple snail) triploblastic and coelomate animals. Body is covered by a calcareous shell and is unsegmented with a distinct head, muscular foot and a visceral hump or visceral mass. A soft layer of skin forms a mantle over the visceral hump. The space between the visceral mass and **mantle** (pallium) is called the mantle cavity in which a number of feather like gills (**ctenidia**) are present, which are respiratory in function. The digestive system is complete and mouth contains a rasping organ called **radula** with transverse rows of chitinous teeth for feeding (radula is absent in bivalves). The sense organs are tentacles, eyes and **osphraidium** (to test the purity of water and present in bivalves and gastropods). Excretory organs are nephridia. Open type of circulatory system is seen except for cephalopods such as squids, cuttle fishes and octopus. Blood contains **haemocyanin**, a copper containing

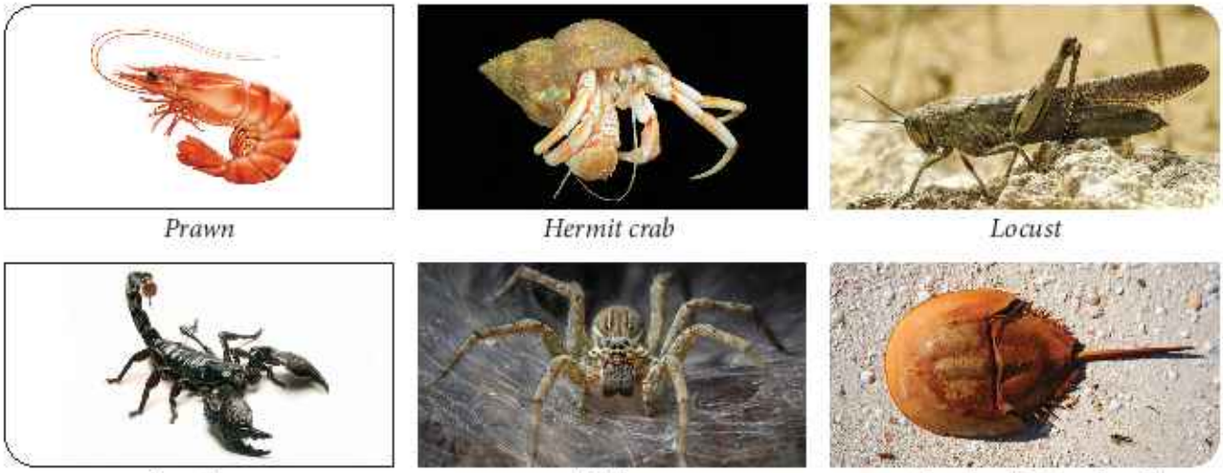


**Figure 2.15** Examples of Arthropoda



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respiratory pigment. They are dioecious and oviparous. Development is indirect with a **veliger larva** (a modified trochophore larva).

Examples: *Pila* (Apple snail), *Lamellidens* (Mussel), *Pinctada* (Pearl oyster), *Sepia* (Cuttlefish), *Loligo* (Squid), *Octopus* (Devil fish) (Figure 2.16).

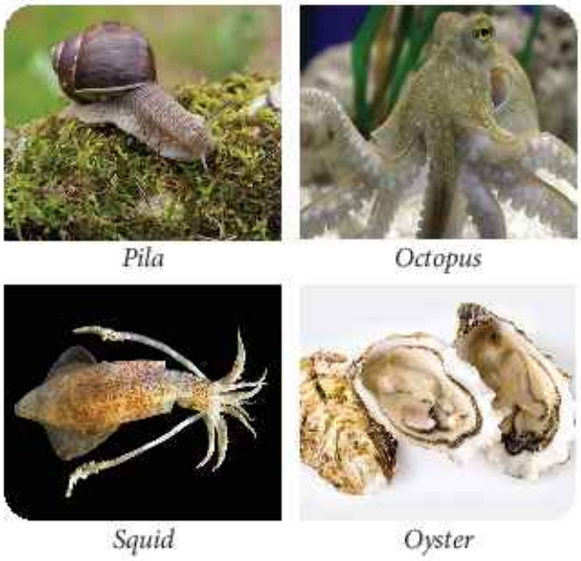


**Figure 2.16** Examples of Mollusca

**Marbled Cone Snail**
(*Conus marmoreus*)

This cone-shaped snail can deliver dangerous venom which may result in vision loss, respiratory failure, muscle paralysis and eventually death. There is no anti-venom available.

## 2.3.9 Phylum: Echinodermata

(G. *Echinos* – spiny; *dermos* –skin)

All Echinoderms are marine animals. The adults are **radially symmetrical** but the larvae are **bilaterally symmetrical**. These animals have a mesodermal endoskeleton of calcareous ossicles and hence the name Echinodermata (spiny skin). They are exclusively marine with organ system level of organisation. The most distinctive feature of echinoderms is the presence of the **water vascular system** or **ambulacral system** with **tube feet** or **podia**, which helps in locomotion, capture and transport of food and respiration. The digestive system is complete with mouth on ventral side and anus on the dorsal side. Excretory organs are absent. The nervous system and sensory organs are poorly developed. The circulatory system is open type without heart and blood vessels. Sexes are separate. Reproduction is sexual and fertilization is external. Development is indirect with free swimming bilaterally symmetrical larval forms. Some echinoderms exhibit autotomy with remarkable powers of **regeneration.** e.g. Star fish. (Figure 2.17)

Examples: *Asterias* (Starfish or Sea star), *Echinus* (Sea-urchin), *Antedon* (Sea-lily), *Cucumaria* (Sea-cucumber), *Ophiura* (Brittle star)

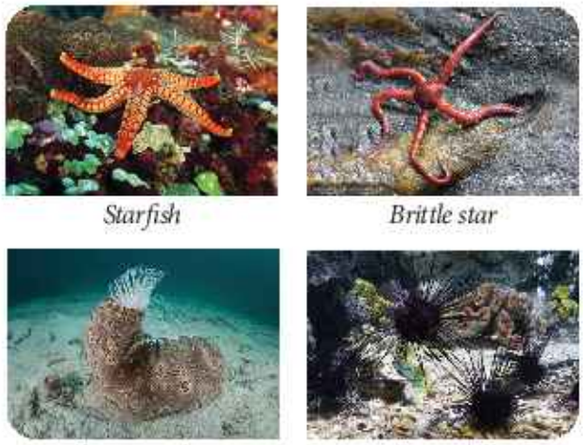


**Figure 2.17** Examples of Echinodermata



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### 2.3.10 Phylum: Hemichordata

(G.*hemi* –half; *chorda*-string)

Hemichordates were earlier treated as a subphylum of Chordata (or Prochordata). They are now regarded to be an independent phylum of invertebrates, close to Echinodermata. The animals of this group possess the characters of invertebrates as well as chordates.

This phylum consists of a small group of worm-like, soft marine animals, mostly tubiculous and commonly called the **'acorn worms'** or **'tongue worms'**. They are bilaterally symmetrical, triploblastic and coelomate animals with organ system level of organisation. Their body is cylindrical and is divided into three regions, the anterior proboscis, a short collar and a long trunk. Most hemichordates are ciliary feeders. Their circulatory system is simple and open or lacune type with a dorsal heart. Respiration is through paired gill slits opening into the pharynx. Excretion is by a single **proboscis gland** or **glomerulus** situated in the proboscis. Nervous system is primitive. Sexes are separate and exhibit sexual mode of reproduction; Fertilization is external. Development is indirect with a free swimming **tornaria larva**.

**Figure 2.18** Example of Hemichordata - Balanoglossus

Examples: *Balanoglossus*, *Saccoglossus*, *Ptychodera flava* (Indian Hemichordate found in Kurusadai islands in Tamilnadu) (Figure 2.18).

## 2.4 Phylum: Chordata

(G. *Chorda –string*)

Chordata is the largest phylum with most familiar group of animals, such as fishes, amphibians, reptiles, birds and mammals and less known forms such as **lancelets** (Amphioxus) and **tunicates** (Ascidian). All chordates possess three fundamental distinct features at some stage of their life cycle (Figure 2.19), they are:

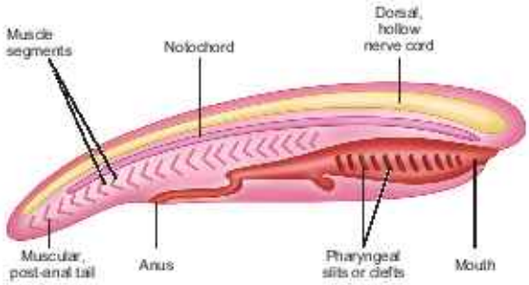


**Figure 2.19** A Typical Chordate

1. Presence of elongated rod like notochord below the nerve cord and above the alimentary canal. It serves as a primitive internal skeleton. It may persist throughout life in lancelets and lampreys. In adult vertebrates, it may be partially or completely replaced by backbone or vertebral column.
2. A dorsal hollow or tubular fluid filled nerve cord lies above the notochord and below the dorsal body wall. It serves to integrate and co-ordinate the body functions. In higher chordates, the anterior end of the nerve cord gets enlarged to form the brain and the posterior part becomes the spinal cord, protected inside the vertebral column.
3. Presence of pharyngeal gill slits or clefts in all chordates at some stage of their lifecycle. It is a series of gill slits or clefts that perforates the walls of pharynx and appears during the development of every



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**Table. 1** Comparison of chordates and non-chordates

| Chordates | Non-chordates |
|---|---|
| Notochord is present | Notochord is absent |
| Dorsal, hollow and single nerve cord | Double ventral solid nerve cord |
| Pharynx perforated by gill slits | Gill slits absent |
| Heart is ventrally placed | Heart is dorsal or laterally placed or absent |
| A post anal tail is present | A post anal tail is absent |
| Alimentary canal is placed ventral to the nerve cord | Alimentary canal is placed dorsal to the nerve cord |

chordate. In aquatic forms, pharyngeal gill slits are vascular, lamellar and form the gills for respiration. In terrestrial chordates, traces of non-functional gill clefts appear during embryonic developmental stages and disappear later. Besides the above said features, chordates are bilaterally symmetrical, triploblastic, coelomates with organ system level of organisation; they possess post anal tail, closed circulatory system with a ventral myogenic heart except in *Amphioxus*.

List the three features common to all chordates at sometime in their life.

### 2.4.1 Subphylum: Urochordata or Tunicata

(G. *Oura* – A tail; L. *Chord* – cord)

They are exclusively marine and are commonly called **sea squirts**. Mostly sessile, some pelagic or free swimming, exist as solitary and colonial forms. Body is unsegmented and covered by a test or tunic. Adult forms are sac like. Coelom is absent, but has an atrial cavity surrounding the pharynx. Notochord is present only in the tail region of the larval stage, hence named urochordata. Alimentary canal is complete and circulatory system is of open type. The heart is ventral and tubular. Respiration is through gill slits and clefts. Dorsal tubular nerve cord is present only in the larval stage and a single dorsal ganglion is present in the adults. Mostly hermaphrodites, development indirect and includes a free swimming **tadpole larva** with chordate characters. **Retrogressive metamorphosis** is seen (Figure 2.20).

Examples: *Ascidia, Salpa, Doliolum*

### 2.4.2 Subphylum: Cephalochordata

( L. *Cephalo*- 'head' ; G. *chorda* 'cord'.)

Cephalochordates are marine forms, found in shallow waters, leading a burrowing mode of life. They are small

*Ascidia*

*Salpa*

*Doliolum*

**Figure 2.20** Examples of Urochordata



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fish like coelomate forms with chordate characters such us notochord, dorsal tubular nerve cord and pharyngeal gill slits throughout their life. Closed type of circulatory system is seen without heart. Excretion is by **protonephridia**. Sexes are separate, Fertilization is external. Development is indirect and includes a free swimming larva (Figure 2.21).

Example: *Branchiostoma* (Amphioxus or lancelet)

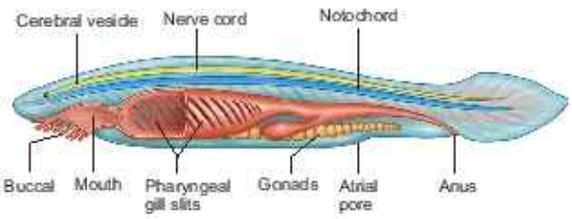


**Figure 2.21** Example of Cephalochordata - Amphioxus

### 2.4.3 Subphylum: Vertebrata

(L. *Vertebrus* –back bone )

Vertebrates are also called higher chordates and they possess notochord during embryonic stage only. The notochord is replaced by a cartilaginous or bony vertebral column in the adult. **Hence all vertebrates are chordates but all chordates are not vertebrates.** Vertebrates possess paired appendages such as fins or limbs. Skin is covered by protective skeleton comprising of scales, feathers, hairs, claws, nails, etc. Respiration is aerobic through gills, skin, buccopharyngeal cavity and lungs. Vertebrates have a ventral muscular heart with two, three or four chambers and kidneys for excretion and osmoregulation.

Subphylum Vertebrata is divided into two divisions, **Agnatha** and **Gnathostomata**. Agnatha includes jawless fish-like aquatic vertebrates without paired appendages. Notochord persists in the adult. Gnathostomata includes jawed vertebrates with paired appendages. Notochord is replaced partly or wholly by the vertebral column. Agnatha includes one important class – Cyclostomata. **Gnathostomata** includes **jawed fishes** (Pisces) and **Tetrapoda** ( amphibia, reptilia, aves and mammals). The superclass Pisces includes all fishes which are essentially aquatic forms with paired fins for swimming and gills for respiration. Pisces includes cartilaginous fishes (Chondrichthyes) and bony fishes (Osteichthyes).

### 2.4.4 Class: Cyclostomata

(G.*cyklos*–circle; *stomata* -mouth)

All members of cyclostomata are primitive, poikilothermic, jawless aquatic vertebrates and are ectoparasites on some fishes. Body is slender and eel-like bearing six to fifteen pair of gill slits for respiration. Mouth is circular without jaws and suctorial. Heart is two chambered and circulation is of closed type. No paired appendages. Cranium and vertebral column are cartilaginous. Cyclostomes are marine but migrate to fresh waters for spawning **(anadromous migration)**. After spawning within a few days they die. The larvae **(ammocoete)** after metamorphosis returns to the ocean. Examples: *Petromyzon* (Lamprey) and *Myxine* (Hag fish) (Figure 2.22).

*Lamprey* *Hag fish*

**Figure 2.22** Examples of Cyclostomata



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### 2.4.5 Class: Chondrichthyes

(*G. chondros* –cartilage; *ichthys* -fish)

They are marine fishes with cartilaginous endoskeleton. Notochord is persistent throughout life. Skin is tough covered by dermal **placoid scales** and the caudal fin is **heterocercal** (asymmetrical both externally and internally). Mouth is located ventrally and teeth are modified placoid scales which are backwardly directed. Their jaws are very powerful and are predaceous animals. Respiration by **lamelliform gills** without operculum (gill cover). Excretory organs are **mesonephric** kidneys. Two chambered heart is present. Cartilaginous fishes are **ureotelic** and store urea in their blood to maintain osmotic concentration of body fluids. They are **poikilothermic** and **viviparous**. Sexes are separate. In males pelvic fins bear claspers to aid in internal fertilisation.

Examples: *Scoliodon* (Shark), *Trygon* (Sting ray), *Pristis* (Saw fish) (Figure 2.23).

### 2.4.6 Class: Osteichthyes

(G. *osteon* –bone; *ichthys* -fish)

It includes both marine and freshwater fishes with bony endoskeleton and spindle shaped body. Skin is covered by **ganoid**, **cycloid** or **ctenoid scales**. Respiration is by four pairs of filamentous gills and is covered by an operculum on either side. Air bladder is present with or without a connection to the gut. It helps in gaseous exchange (lung fishes) and for maintaining buoyancy in most of the ray finned fishes. They have a ventrally placed two chambered heart. Excretory organs are **mesonephric kidneys** and are **ammonotelic**. Presence of well developed **lateral line sense organ**. Sexes are separate, external fertilization is seen and most forms are oviparous (Figure 2.24).

Examples: *Exocoetus* (Flying fish), *Hippocampus* (Sea horse), *Labeo* (Rohu), *Catla* (Catla), *Echeneis* (Sucker fish), *Pterophyllum* (Angel fish)

### 2.4.7 Class: Amphibia

(G. *amphi*-both; *bios* -life)

Amphibians are the first vertebrates and tetrapods to live both in aquatic as well as terrestrial habitats.They are **poikilothermic**. Their body is divisible into the head and trunk and most of them have two pairs of limbs; tail may or may not be present. Their

*Shark* *Pristis* *Sting ray*

**Figure 2.23** Examples of Chondrichthyes

*Flying fish* *Sea horse* *Angel fish* *Carp* *Sucker fish*

**Figure 2.24** Examples of Osteichthyes



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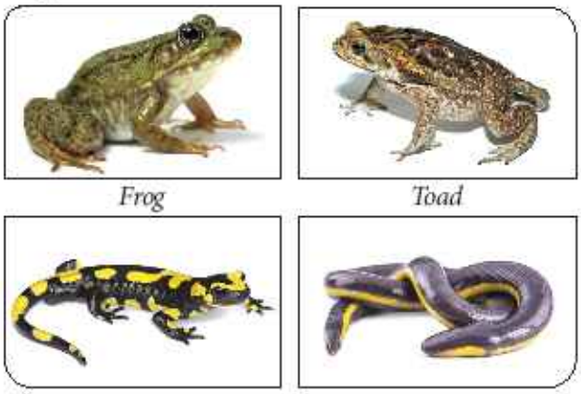
skin is smooth or rough, moist, pigmented and glandular. Eyes have eyelids and the tympanum represents the ear. Respiration is by gills, lungs and through the skin. Heart is three chambered. Kidneys are **mesonephric.** Sexes are separate and fertilization is external. They are oviparous and development is indirect. They show **hibernation** and **aestivation**.

Examples: *Bufo* (Toad), *Rana* (Frog), *Hyla* (Tree frog), *Salamandra* (Salamander), *Icthyophis* (Limbless amphibians) (Figure 2.25).



*Frog* *Toad*

*Salamander* *Icthyophis (Caecilians)*

**Figure 2.25** Examples of Amphibia

## 2.4.8 Class: Reptilia

(*L. repere* or *reptum* – to creep or crawl)

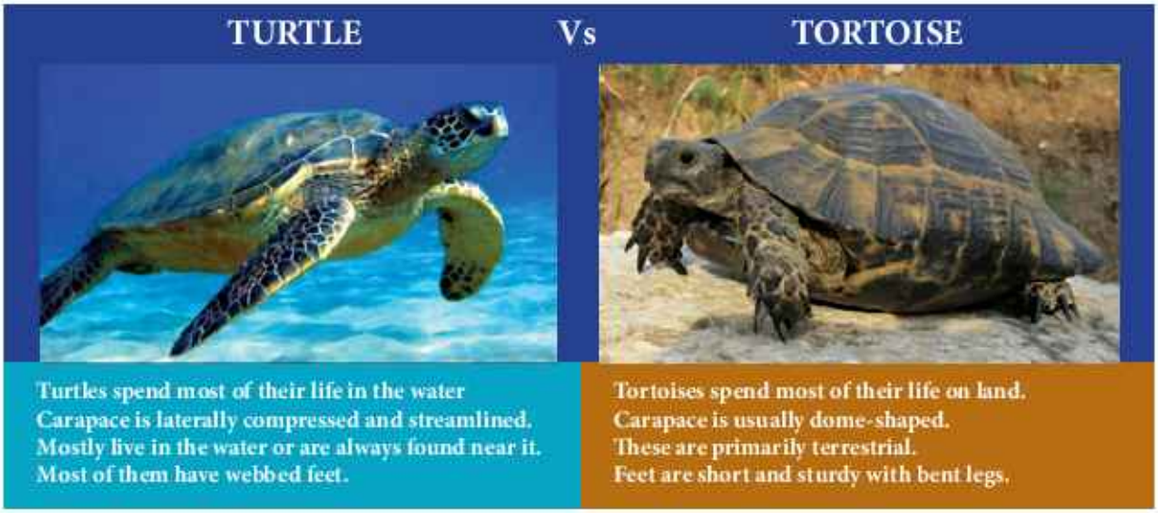
They are mostly terrestrial animals and their body is covered by dry, and cornified skin with epidermal scales or scutes. Reptiles have three chambered heart but four chambered in crocodiles. All are cold blooded amniotes (poikilotherms). Most reptiles lay **cleidoic eggs** with extraembryonic membranes like **amnion, allantois, chorion and yolk sac**. Excretion by metanephric kidneys and are uricotelic. Sexes are separate with well marked sexual dimorphism. Internal fertilization takes place and all are oviparous.

Examples : *Chelone* (Turtle), *Testudo* (tortoise), *Hemidactylus* (House lizard), *Chameleon* (Tree lizard), *Calotes* (Garden lizard), *Draco* (Flying lizard), *Crocodilus* (crocodile), Poisonous snakes - *Naja* (Cobra), *Bangarus* (Krait), *Vipera* (Viper) (Figure 2.26).

*King cobra* *Draco (Flying Lizard)*

*Crocodile* *Chameleon*

**Figure 2.26** Examples of Reptiles



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### 2.4.9 Class: Aves (L. *Avis* –bird)

Aves are commonly known as birds. The characteristic feature of Aves is the presence of feathers and the ability to fly except for flightless birds (Eg. *Ostrich, Kiwi, Penguin*). The forelimbs are modified into wings, and the hind limbs are adapted for walking, running, swimming and perching. The skin is dry and devoid of glands except the **oil gland** or **preen gland** at the base of the tail. The exoskeleton consists of epidermal feathers, scales, claws on legs and the horny covering on the beak. The endoskeleton is fully ossified (bony) and the long bones are hollow with air cavities **(pneumatic bones)**. The pectoral muscles of flight **(pectoralis major** and **pectoralis minor)** are well developed. Respiration is by compact, elastic, spongy lungs that are continuous with air sacs to supplement respiration. The heart is four chambered. Aves are **homeothermic**. Migration and parental care is well marked. Urinary bladder is absent. Sexes are separate with well marked sexual dimorphism. In males, the testes are paired but in females, only the left ovary is well developed while the right ovary is atrophied. All birds are oviparous. Eggs are **megalecithal** and **cleidoic**. Fertilization is internal.

**Hooded Pitohui**
(*Pitohui dichrous*)

The Hooded Pitohui is a songbird found in the rain forests of New Guinea, The first poisonous bird to be documented A neurotoxin called Homobatrachotoxin is found in its skin and feathers, causes numbness and tingling in those touching the bird.

Examples *Corvus* (Crow), *Columba* (Pigeon), *Psittacula* (Parrot), *Pavo* (Peacock), *Aptenodytes* (Penguin), *Neophron* (Vulture), *Chalcophaps indica* (Tamilnadu state bird, Common Emerald Dove) (Figure 2.27).

*Common Emerald Dove (Tamil Nadu State Bird)*

*Vulture*

*Humming Bird*

*Penguin*

**Figure 2.27** Examples of Aves

### 2.4.10 Class: Mammalia
(L. *Mamma* – Breast)

They are found in a variety of habitats. Their body is covered by hair, a unique feature of mammals. Some of them are adapted to fly or live in water. Presence of **mammary glands** is the most unique feature of mammals. They have two pairs of limbs adapted for walking, running, climbing, burrowing, swimming and flying. Their skin is glandular in nature, consisting of sweat glands, scent glands and sebaceous glands. Exoskeleton includes horny epidermal horns, spines, scales, claws, nails, hooves and bony dermal plates. Teeth are **thecodont**, **heterodont** and **diphyodont**. External ears or pinnae are present. The heart is four chambered and possess a left systematic arch. Mature RBCs are circular, biconcave and non nucleated. Mammals have a large brain when compared to other animals They show greatest intelligence among all animals. Their kidneys are **metanephric** and are **ureotelic**. All are homeothermic, sexes are separate and fertilization is internal.



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Examples Oviparous- *Ornithorhynchus* (Platypus), Viviparous- *Macropus* (Kangaroo), *Pteropus* (Flying fox), *Macaca* (Monkey), *Canis* (Dog), *Felis* (Cat), *Elephas* (Elephant), *Equus* (Horse), *Delphinus* (Common dolphin) *Balaenoptera* (Blue whale), *Panthera tigris* (Tiger), *Panther leo* (Lion), *Homo sapiens* (Human) *Bos* (Cattle) (Figure 2.28).

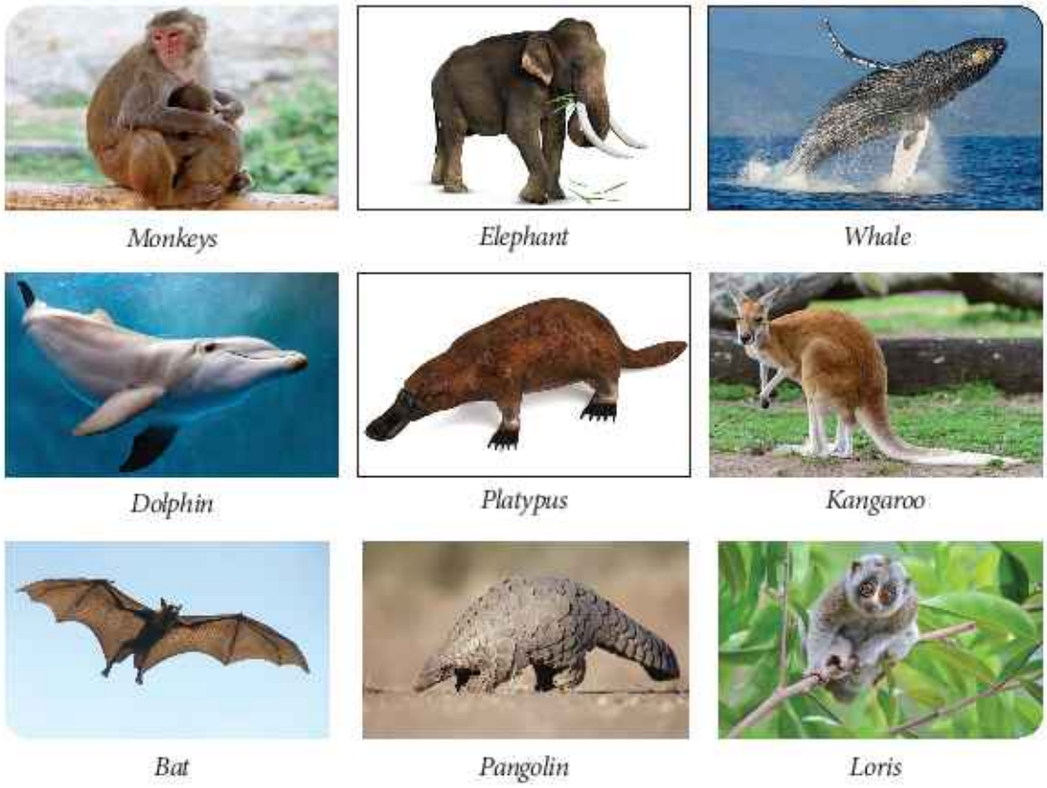


**Figure 2.28** Examples of Mammals

## Summary

Kingdom Animalia comprises of a broad range of animal species, from tiny parasitic nematodes to the largest mammal the blue whale. The basic fundamental features such as levels of organisation, diploblastic and triploblastic organisation, patterns of symmetry, coelom, segmentation and notochord have enabled us to broadly classify the animal kingdom. Besides the fundamental features, there are many other distinctive characters which are specific for each phyla or class.

Animals are broadly classified into invertebrates and chordates. The animals which lack vertebral column are called invertebrates. The chordates are characterized by the presence of notochord, solid ventral nerve cord and gill slits. Kingdom Animalia are classified into eleven animal phyla as Porifera, Cnidaria, Ctenophora, Platyhelminthes, Aschelminthes, Annelida, Arthropoda, Mollusca, Echinodermata, Hemichordata and Chordata. Chordata is the largest phylum with three sup phyla Urochordata, Cephalochordata and Vertebrata. Subphylum Vertebrata includes two divisions, Agnatha and Gnathostomata. Agnatha comprises of the class Cyclostomata. Gnathostomata includes jawed fishes (Pisces) and Tetrapoda which includes the classes amphibia, reptilia, aves and mammals.



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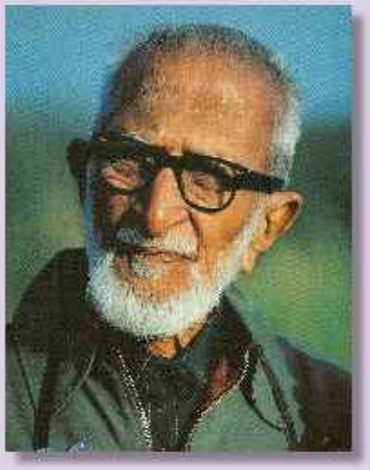
## CASE STUDY



Sálim Moizuddin Abdul Ali is the leading pioneer of Indian Ornithology and generally referred as **"Bird Man of India"**. He was born on 12 November 1896 in Bombay and he was the most respected and influential naturalist of 20th century in India, He passed away on 20 June 1987. Young Salim got interested in birds when he was at the age of ten. Later he has conducted many systematic bird surveys across India and the neighboring countries. He authored many bird books and popularized ornithology in India. 'Book of Indian birds' and the 'Hand book of Birds of India and Pakistan' are the most important books he has written. His autobiography **'Fall of a sparrow'** narrates the beginning and experience of his life with birds. Government of India honoured him with the award of Padma Bhusahan in 1958 and Padma Vibhushan 1976. He was nominated to Rajyasabha in 1985. Salim Ali through his books motivated thousands of people to the field of ornithology and natural history. Most of the environmentalists in India trace back their initial motivation to bird watching and Salim Ali's books.

In 1990, Government of India started a national research institution in his honour called Sálim Ali Centre for Ornithology and Natural History (SACON) in Coimbatore, Tamil Nadu. SACON is a Centre of excellence in research supported by the Ministry of Environment, Forest and Climate Change, Government of India. All the researches and activities of SACON is devoted to the cause of conservation of India's Biodiversity with focus on birds. The main campus of SACON is situated in the sylvan surrounding of Anaikatty, 24 kilometers northwest of Coimbatore city, within the Nilgiri Biosphere Reserve. SACON's mission is to help conserve India's biodiversity and its sustainable use through research, education and people's participation with birds at the centre stage. SACON conducts research in Ornithology covering all aspects of biodiversity and natural history. More than 50 research scholars have completed PhD in Ornithology and Natural history from SACON in its 25 years of existence. SACON is known for its many research papers published in national and international journals. Nature Education programme of SACON is very popular in the region which is inculcating love for birds and nature to thousands of people especially to school children every year. Children's Ecology Congress of SACON and Salim Ali Trophy Nature Competitions are flagship events. Salim Ali Naturalist Forum of SACON is the people's bird watching movement in Coimbatore facilitated by SACON.



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## Activity

**Objectives:**

Some Groups of organisms with their distinguishing characteristics are given. Construct a cladogram, interpret and analyze the cladogram in terms of how it shows common ancestry and degrees of evolutionary relationship.

**Procedure:**

Step 1. Refer your text book and identify the characteristics of the given animals. In the data table provided, place an "x" in the box if the animal has the characteristic.

Step 2: Below the Data Table on the Worksheet, make a Venn diagram, placing animals in groups to illustrate those characteristics which different animals have in common.

Step 3: Using the Venn diagram draw a cladogram to illustrate the ancestry of these animals. The diagram should reflect the shared characteristics as time proceeds.

Step 4: Draw the Venn diagram to reflect the shared characteristics of the given animal and draw a cladogram.

| Sets | Traits | Kangaroo | Lamprey | Monkey | Frog | Human | Tortoise | Fish |
|---|---|---|---|---|---|---|---|---|
| Set#1 | Dorsal Nerve cord, Notochord | | | | | | | |
| Set#2 | Paired Appendages Vertebral column | | | | | | | |
| Set#3 | Paired legs | | | | | | | |
| Set#4 | Amnion (Amniotic sac) | | | | | | | |
| Set#5 | Mammary gland | | | | | | | |
| Set#6 | Placenta | | | | | | | |
| Set#7 | Canine teeth | | | | | | | |
| | Total 'X' s | | | | | | | |

## Evaluation

M4UL2

1. The symmetry exhibited in cnidarians is
   **a. Radial**
   b. Bilateral
   c. Pentamerous radial
   d. Asymmetrical
2. Sea anemone belongs to phylum
   a. Protozoa b. Porifera
   **c. Coelenterata** d. Echinodermata
3. The excretory cells that are found in platyhelminthes are
   a. Protonephridia **b. Flame cells**
   c. Solenocytes d. All of these
4. In which of the following organisms, self fertilization is seen.
   a. Fish b. Round worm
   c. Earthworm **d. Liver fluke**
5. Nephridia of Earthworms are performing the same functions as
   a. Gills of prawn
   **b. Flame cells of Planaria**
   c. Trachea of insects
   d. Nematoblasts of Hydra



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6. Which of the following animals has a true coelom ?
   a. *Ascaris* **b. *Pheretima***
   c. *Sycon* d. *Taenia solium*
7. Metameric segmentation is the main feature of
   **a. Annelida** b. Echinodermata
   c. Arthropoda d. Coelenterata
8. In *Pheretima* locomotion occurs with the help of
   a. circular muscles
   b. longitudinal muscles and setae
   **c. circular, longitudinal muscles and setae**
   d. parapodia
9. Which of the following have the highest number of species in nature?
   **a. Insects** b. Birds
   c. Angiosperms d. Fungi
10. Which of the following is a crustacean?
   **a. Prawn** b. Snail
   c. Sea anemone d. Hydra
11. The respiratory pigment in cockroach is
   a. Haemoglobin b. Haemocyanin
   c. Haemoerythrin **d. None of the above**
12. Exoskeleton of which phylum consists of chitinous cuticle?
   a. Annelida b. Porifera
   **c. Arthropoda** d. Echinodermata
13. Lateral line sense organs occur in
   a. Salamander b. Frog
   c. Water snake **d. Fish**
14. The limbless amphibian is
   **a. Icthyophis** b. Hyla
   c. Rana d. Salamander
15. Four chambered heart is present in
   a. Lizard b. Snake
   c. Scorpion **d. Crocodile**
16. Which of the following is not correctly paired?
   a. Humans – Ureotelic
   b. Birds – Uricotelic
   c. Lizards – Uricotelic
   **d. Whale – Ammonotelic**
17. Which of the following is an egg laying mammal?
   a. *Delphinus* b. *Macropus*
   **c. *Ornithorhynchus*** d. *Equus*
18. Pneumatic bones are seen in
   a. Mammalia **b. Aves**
   c. Reptilia d. Sponges
19. Match the following columns and select the correct option.

| Column – I | Column – II |
|---|---|
| (p) Pila | (i) Devil fish |
| (q) Dentalium | (ii) Chiton |
| (r) Chaetopleura | (iii) Apple snail |
| (s) Octopus | (iv) Tusk shell |

   a. p – (ii), q – (i), r – (iii), s – (iv)
   **b. p – (iii), q – (iv), r – (ii), s – (i)**
   c. p – (ii), q – (iv), r – (i), s – (iii)
   d. p – (i), q – (ii), r – (iii), s – (iv)
20. In which of the following phyla, the adult shows radial symmetry but the larva shows bilateral symmetry?
   a. Mollusca **b. Echinodermata**
   c. Arthropoda d. Annelida
21. Which of the following is correctly matched?
   **a. Physalia – Portugese man of war**
   b. Pennatula – Sea fan
   c. Adamsia – Sea pen
   d. Gorgonia – Sea anemone
22. Why are spongin and spicules important to a sponge?
23. What are the four characteristics common to most animals?
24. List the features that all vertebrates show at some point in their development.
25. Compare closed and opened circulatory system.



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26. Compare Schizocoelom with enterocoelom.
27. Identify the structure that the archenteron becomes in a developing animal.
28. Observe the animal below and answer the following questions.

   a. Identify the animal.
   b. What type of symmetry does this animal exhibit?
   c. Is this animal Cephalized?
   d. How many germ layers does this animal have?
   e. How many openings does this animal's digestive system have?
   f. Does this animal have neurons?
29. Choose the term that does not belong in the following group and explain why it does not belong?

    Notochord, cephalisation, dorsal nerve cord and radial symmetry.
30. Why flatworms are called acoelomates?
31. What are flame cells?
32. Concept Mapping - Use the following terms to create a concept map that shows the major characteristic features of the phylum nematoda:

    Round worms, pseudocoelomates, digestive tract, cuticle, parasite, sexual dimorphism
33. In which phyla is the larva trochopore found?
34. Which of the chordate characteristics do tunicates retain as adults?
35. List the characteristic features that distinguish cartilaginous fishes with living jawless fishes.
36. List three features that characterise bony fishes.
37. List the functions of air bladder in fishes.
38. Write the characteristics that contributes to the success of reptiles on land.
39. List the unique features of bird's endoskeleton.
40. Could the number of eggs or young ones produced by an oviparous and viviparous female be equal? Why?

## ICT Corner Cladogram

**Let's do this activity to know about Cladogram.**

**Step – 1** Type the URL given below in the browser. Press 'Play Game' button then use your personal or school id to login. Otherwise use Guest Pass to enter and start the activity.

**Step – 2** Initially you will be provided with two species and their characteristics. You should drag them into the small box provided and match them.

**Step – 3** Use the mouse to drag and place the characteristics on the tree.

**Step – 4** If you correctly match the tree, the game will proceed to the next level. If you fail to match them start from the beginning and play the game again until you learn the characteristics.

Evolution Lab's URL:

**http://www.pbs.org/wgbh/nova/labs/lab/evolution/**

MENQ9

* Pictures are indicative only



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UNIT II **Chapter 3**

# Tissue Level of Organisation

**Chapter Outline**


3.1 Animal Tissues
3.2 Epithelial Tissue
3.3 Connective Tissue
3.4 Muscle Tissue
3.5 Neural Tissue

A reflective layer of tissue called tapetum lucidum, enhances night time vision in most of the animals like cat.

## Learning Objectives:

- *Recognises the types of tissues based on their characteristic features*
- *Understands the description, location, functions and modification of tissues.*
- *Understands the significance of muscles, connective and neural tissues.*

VG16M

In multicellular organisms, cells do not operate independently, instead, they form tight cell communities that live and work together. Individual body cells are specialized, with each type performing specific functions that helps to maintain homeostasis and benefits the body as a whole. Cell specialization is obvious. How the muscle cell looks and acts differs greatly from skin cells. Cell specialization allows the body to function in co-ordinated ways. Groups of cells that are similar in structure and perform common or related functions are called '**tissues**'.

Tissues are organized in specific proportions and patterns to form **organs** like lungs, heart, stomach, kidneys, ovaries, testes etc; hence the tissues are called the '**living fabrics**'. If two or more organs perform common physical and chemical functions they are called '**organ systems**', Eg: digestive system, respiratory system, circulatory system, excretory system, etc. Most organs contain different types of tissues and their arrangement determines the organs structure and functions. The study of tissues is called **histology** complements the study of gross anatomy. Together they provide the structural basis for understanding organ physiology.

## 3.1 Animal Tissues

Animal tissues are classified according to the size, shape and function of the cells. There are four primary (basic) tissue types that interweave to form the 'fabric' of the body. They are, the epithelial tissue (covering), the connective tissue (support), the muscle tissue (movement) and the nervous tissue (control) (Figure 3.1).



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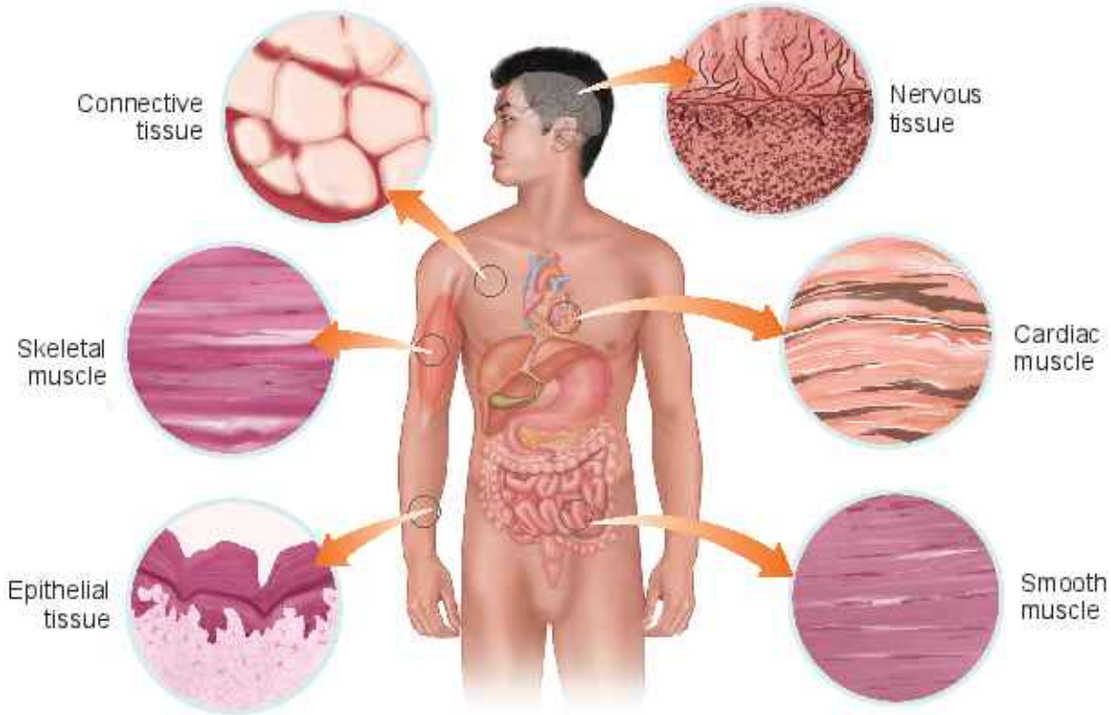


**Figure 3.1** Types of Tissues in Human

## 3.2 Epithelial Tissue

Epithelial tissue is a sheet of cells that covers the body surface or lines the body cavity. It occurs in the body as a **covering, as a lining epithelium and as glandular, epithelium**. The functions of epithelium includes **protection, absorption, filtration, excretion, secretion** and **sensory reception.**

Based on the structural modification of the cells, the epithelial tissues are classified into simple epithelium and compound epithelium or stratified epithelium.

**Simple epithelium** is composed of a single layer of cells. They are found in the organs of absorption, secretion and filtration. Simple epithelial tissue is further classified

**Classification of Animal Tissues**

- **Epithelial Tissue**
  - **Simple Tissue**
    1. Squamous
    2. Cuboidal
    3. Columnar
    4. Ciliated
    5. Pseudostratified
  - **Compound Tissue**
    - **Stratified**
      - **Squamous**
        1. Keratinized
        2. Non-Keratinized
      - **Cuboidal**
      - **Columnar**
    - **Transitional**
- **Connective Tissue**
- **Muscular Tissue**
- **Neural Tissue**



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into squamous epithelium, cuboidal epithelium, columnar epithelium, ciliated epithelium and pseudostratified epithelium (Figure 3.2). The **squamous epithelium** is made of a single thin layer of flattened cells with irregular boundaries. They are found in the kidney glomeruli, air sacs of lungs, lining of heart, blood vessels and lymphatic vessels and are involved in functions like forming a diffusion boundary and filtration in sites where protection is not important. The **cuboidal epithelium** is made of a single layer of cube like cells. This tissue is commonly found in the kidney tubules, ducts and secretory portions of small glands and surface of the ovary. Its main functions are secretion and absorption. The **columnar epithelium** is composed of single layer of tall cells with round to oval nuclei at the base. It lines the digestive tract from the stomach to the rectum. The two modifications of this lining are the presence of **microvilli** on the apical surface of the absorptive cells and **Goblet cell** which secretes the protective lubricating mucus. The functions of this epithelium include absorption, secretion of mucus, enzymes and other substances. If the columnar cells bear cilia on their free surfaces they are called **ciliated epithelium**. This **ciliated type** propels mucus by ciliary actions and it lines the small bronchioles, fallopian tubes and uterus. **Nonciliated type** lines most of the digestive tract, gall bladder and secretory ducts of glands.

**Pseudo-stratified epithelial** cells are columnar, but unequal in size. Although the epithelium is single layered yet it appears to be multi-layered because the nuclei lie at different levels in different cells. Hence, it is also called pseudostratified epithelium and

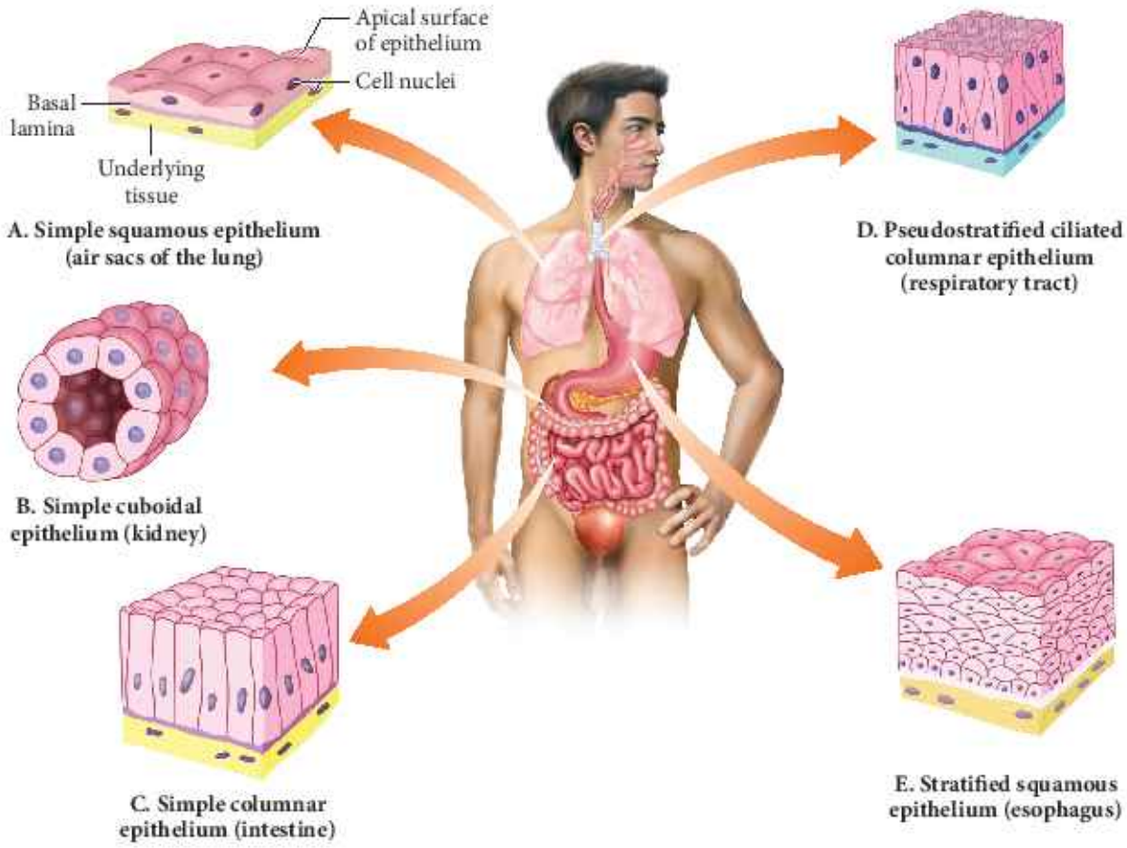


**Figure 3.2** Types of Epithelial tissues



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its functions are protection, secretion and absorption. Ciliated forms line the trachea and the upper respiratory tract. The non ciliated forms, line the epididymis, large ducts of a glands and tracts of male urethra

**Important epithelial tissue disorders:**
Eczema, Psoriasis, Epithelial carcinoma and severe asthma

### Glandular Epithelium

Some of the cuboidal or columnar cells get specialized for secretion and are called **glandular epithelium** (Figure 3.3). They are mainly of two types: unicellular, consisting of isolated glandular cells (goblet cells of the **alimentary canal**), and multicellular, consisting of cluster of cells (**salivary gland**). On the basis of the mode of pouring of their secretions, glands are divided into two categories namely exocrine and endocrine glands. **Exocrine glands** secrete mucus, saliva, earwax, oil, milk, digestive enzymes and other cell products. These products are released through ducts or tubes. In contrast endocrine glands do not have ducts. Their secretions called hormones are secreted directly into the fluid bathing the gland. The exocrine glands are classified as unicellular and multicelluar glands. The multicelluar glands are further classified based on the structure as **simple** and **compound glands,** based on their secretory units as **tubular, alveolar (Acinus)** and **tubulo alveolar**. Based on the mode of secretion exocrine glands are classified as **merocrine, holocrine** and **apocrine**.

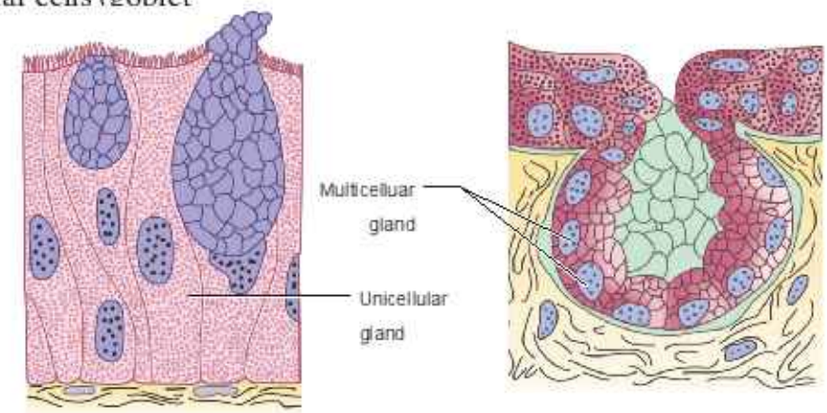


**Figure 3.3** Glandular Epithelium:

**Glandular Epithelium**

- **Endocrine glands**
- **Exocrine glands**
  - **Unicellular**
  - **Multicellular**
    - **Based on structure**
      1. Simple glands
      2. Compound glands
    - **Based on their secretory units**
      1. Tubular
      2. Alveolar(Acinus)
      3. Tubulo alveolar
    - **Based on their mode of secretion**
      1. Merocrine
      2. Holocrine
      3. Apocrine



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**Compound epithelium** is made of more than one layer (multi-layered) of cells and thus has a limited role in secretion and absorption(Figure 3.4). The compound epithelia may be stratified and transitional. Their main function is to provide protection against chemical and mechanical stresses. They cover the dry surface of the skin, the moist surface of buccal cavity, pharynx, inner lining of ducts of salivary glands and of pancreatic ducts. There are four types of compound epithelium namely, stratified squamous epithelium, cuboidal epithelium, columnar epithelium and transitional epithelium. **Stratified squamous epithelium** is of two types called **keratinized type** which forms the dry epidermis of the skin and the **non keratinized type** forms the moist lining of the oesophagus, mouth, conjunctiva of the eyes and vagina. **Stratified cuboidal epithelium** mostly found in the ducts of sweat glands and mammary glands. **Stratified columnar epithelium** has limited distribution in the body, found around the lumen of the pharynx, male urethra and lining of some glandular ducts. **Transitional Epithelium** is found lining the ureters, urinary bladder and part of the urethra. This epithelium allows stretching and is protective in function.

All cells of the epithelium are held together with little intercellular material. In most of the animal tissues, specialized 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.

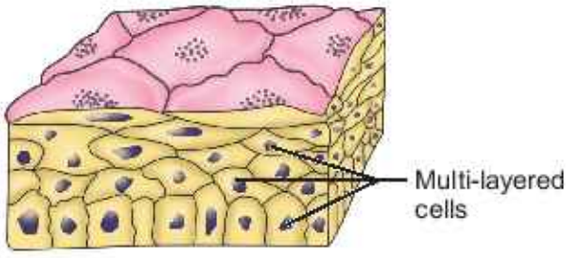


**Figure 3.4** Compound Epithelium

Stratified epithelia are "built" for protection or to resist abrasion. What are the simple epithelia better at?

## 3.3 Connective Tissue

Connective tissue develops from the **mesoderm** and is widely distributed in the body. There are three main classes namely Loose connective tissue, Dense connective tissue and Specialized connective tissue. Major functions of connective tissues are **binding, support, protection, insulation** and **transportation**

WQJ8S

**Connective Tissues**

| Loose Connective Tissues | Dense Connective Tissues | Specialised Connective Tissues |
|---|---|---|
| 1. Areolar Tissue | 1. Dense Regular | 1. Cartilage |
| 2. Adipose Tissue | 2. Dense Irregular | 2. Bone |
| 3. Reticular Tissue | 3. Elastic | 3. Blood |

1. What type of connective tissue is damaged when one get cut on his index finger accidently?
2. The stored lipids are in the form of adipose tissue. Are they coloured? why?



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## Components of Connective Tissue

All connective tissues consist of three main components namely fibres, ground substance and cells. The **'Fibres'** of connective tissue provide support. Three types of fibres are found in the connective tissue matrix. They are **collagen**, **elastic** and **reticular** fibres. Connective tissues are of three types namely, **Loose connective tissues** (Areolar, Adipose and Reticular) and **Dense connective tissues** (dense regular, dense irregular and elastic) and **Specialized connective tissues** (cartilage, bone and blood).

## Loose Connective Tissues

In this tissue the cells and fibres are loosely arranged in a semi fluid ground substances. For example the **Areolar connective tissue** beneath the skin acts as a support framework for epithelium and acts as a reservoir of water and salts for the surrounding body tissues, hence aptly called ***tissue fluid.*** It contains fibroblasts, macrophages, and mast cells (Figure 3.5).

**Adipose Tissue** is similar to areolar tissue in structure and function and located beneath the skin. Adipocytes commonly called **adipose** or **fat cells** predominate and account for 90% of this tissue mass. The cells of this tissue store fats and the excess nutrients which are not utilised immediately are converted to fats and are stored in tissues. Adipose tissue is richly vascularised indicating its high metabolic activity. While fasting, these cells maintain life by producing and supplying energy as fuel. Adipose tissues are also found in subcutaneous tissue, surrounding the kidneys, eyeball, heart, etc. Adipose tissue is called '**white fat**' or **white adipose tissue.** The adipose tissue which contains abundant mitochondria is called '**Brown fat**' or **Brown adipose tissue.** White fat stores nutrients whereas brown fat is used to heat the blood stream to warm the body. Brown fat produces heat by **non-shivering thermogenesis** in neonates.

**Reticular Connective Tissue** resembles areolar connective tissue, but, the matrix is filled with fibroblasts called reticular cells. It forms an internal framework (**stroma**) that supports the blood cells (largely lymphocytes) in the lymph nodes, spleen and bone marrow.

## Dense Connective Tissues (Connective Tissue Proper)

Fibres and fibroblasts are compactly packed in the dense connective tissues. Orientation of fibres show a regular or

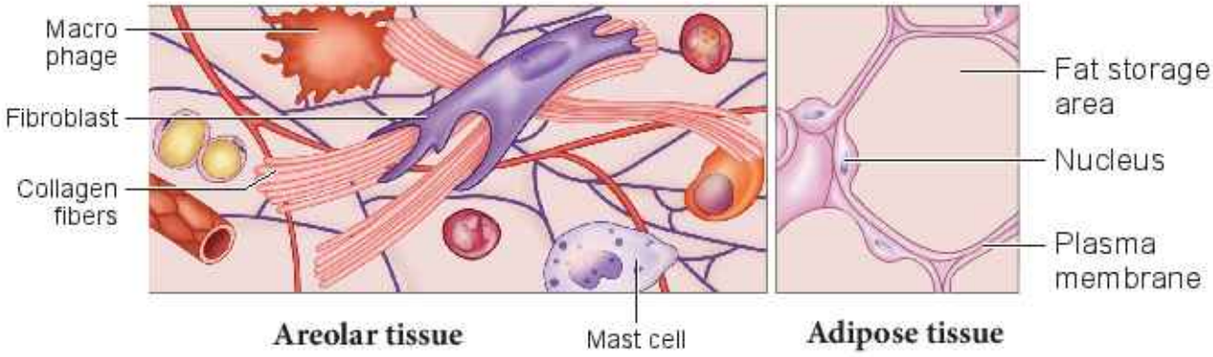


**Figure 3.5** Loose connective tissues



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irregular pattern and is called dense regular and dense irregular tissues. **Dense regular connective tissues** primarily contain collagen fibres in rows between many parallel bundles of tissues and a few elastic fibres. The major cell type is **fibroblast.** It attaches muscles and bones and withstands great tensile stress when pulling force is applied in one direction. This connective tissue is present in **tendons,** that attach skeletal muscles to bones and ligaments attach one bone to another. **Dense irregular connective tissues** have bundles of thick collagen fibres and fibroblasts which are arranged irregularly. The major cell type is the **fibroblast**. It is able to withstand tension exerted in many directions and provides structural strength. Some elastic fibres are also present. It is found in the skin as the leathery dermis and forms fibrous capsules of organs such as kidneys, bones, cartilages, muscles, nerves and joints.

**Elastic Connective Tissue** contains high proportion of elastic fibres. It allows recoil of tissues following stretching. It maintains the pulsatile flow of blood through the arteries and the passive recoil of lungs following inspiration. It is found in the walls of large arteries; ligaments associated with **vertebral column** and within the walls of the **bronchial tubes.**

**Specialised Connective Tissues** are classified as cartilage, bones and blood. The intercellular material of **cartilage** is solid and pliable and resists compression. Cells of this tissue (chondrocytes) are enclosed in small cavities within the matrix secreted by them (Figure 3.6). Most of the cartilages in vertebrate embryos are replaced by bones in adults. Cartilage is present in the tip of nose, outer ear joints, ear pinna, between adjacent bones of the vertebral column, limbs and hands in adults.

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

**Blood** is the fluid connective tissue containing plasma, red blood cells (RBC), white blood cells (WBC) and platelets. It functions as the transport medium for the cardiovascular system, carrying nutrients, wastes, respiratory gases throughout the body. You will learn more about blood in Chapter 7.

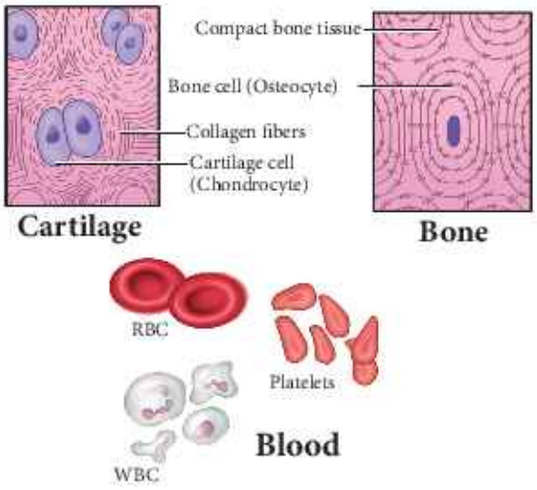


**Figure 3.6** Specialized Connective Tissues

You are looking at a slide of a tissue through the compound microscope and you see striped branching cells that connect with one another. What type of muscle are you viewing?



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**Important connective tissue disorders: (Heritable types)**

1. **Ehler's -Danlos syndrome –** Defect in the synthesis of collagen in the joints, heart valves, organ walls and arterial walls.
2. **Stickler syndrome –** Affects collagen and results in facial abnormalities.
3. **Rhabdomyosarcoma** – Life threatening soft tissue tumour of head, neck and urinogenital tract.

**Autoimmune connective tissue disorders**

1. **Rheumatoid arthritis:** The immune cells attack and inflame the membranes around the joints. It can also affect heart, lungs and eyes.
2. **Sjogren's syndrome:** Progressive inability to secrete saliva and tears.

## 3.4 Muscle Tissue

Each muscle is made of many long, cylindrical fibres arranged in parallel arrays. These fibres are composed of numerous fine fibrils, called **myofibrils**. Muscle fibres contract (shorten) in response to stimulation, then relax (lengthen) and return to their uncontracted state in a coordinated fashion. In general muscles play an active role in all the movements of the body.

Muscles are of three types, skeletal, smooth and cardiac. **Skeletal Muscle tissue** is closely attached to skeletal bones. In a typical muscle such as the biceps, the striated (striped) skeletal muscle fibres are bundled together in a parallel fashion. A sheath of tough connective tissue encloses several bundles of muscle fibres (You will learn more about this in Chapter 9).

The **smooth muscle** fibres taper at both ends (fusiform) and do not show striations (Figure 3.7). Cell junctions hold them together and they are bundled together in a connective tissue sheath. The walls of internal organs such as the blood vessels, stomach and intestine contain this type of muscle tissue. Smooth muscles are 'involuntary' as their functions cannot be directly controlled. Unlike the smooth muscles, skeletal muscles can be controlled by merely thinking.

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

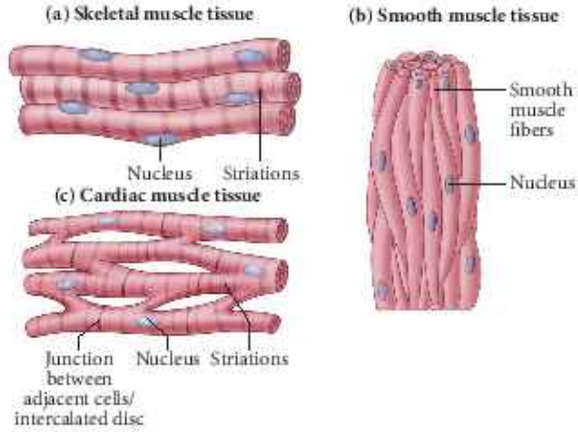


**Figure 3.7** Muscle Tissues

**Palmaris Muscle:**

This long narrow muscle runs from the elbow to the wrist and is important for hanging and climbing in primates, is missing in 11% of humans today.

## 3.5 Neural Tissue

Nervous tissue exerts the greatest control over the body's responsiveness to changing conditions. Neurons, the



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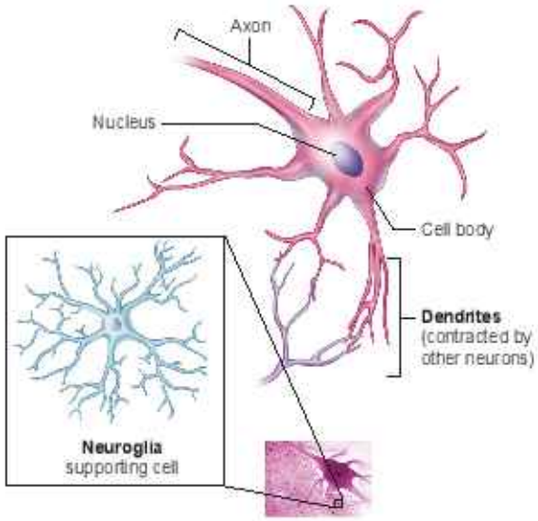


**Figure 3.8** Nervous Tissues with Neuroglia

unit of neural system are excitable cells (Figure 3.8). The neuroglial cells which constitute the rest of the neural system protect and support the neurons. **Neuroglia** makes up more than one-half of the volume of neural tissue in our body.

When a neuron is suitably stimulated, an electrical disturbance is generated which swiftly travels along its plasma membrane. Arrival of the disturbance at the neuron's endings, or output zone, triggers events that may cause stimulation or inhibition of adjacent neurons and other cells (You will study in detail in Chapter 10)

**Diseases of Nervous System:**

1. **Parkinson's disease:** A degenerative disorder of the nervous system that affects movement, often including tremors.
2. **Alzheimer's Disease:** It is a chronic neurodegenerative disease which includes the symptoms of difficulty in remembering recent events, problems with language, disorientation and mood swings.

**Biopsy** is an examination of tissue or liquid removed from a living body to discover the presence, cause or extent of a disease.

**Autopsy** is a post-mortem (dissection of a dead body) examination to discover the cause of death or the extent of disease.

The field of **Forensic science** effectively uses the histological techniques to trace out crimes.

## Summary

The body cells combine to form four different types of tissues; epithelial, connective, muscle and nervous tissues. Though the cells of these tissues share certain features in common, by no means they are identical. They belong together because they have basic fundamental resemblances. The important concept to carry away with you is that tissues, despite their unique abilities, cooperate to keep the body safe, healthy, viable and whole.

## Activity

1.Students are asked to identify the unlabelled slides of tissues and to classify them. Similar exercise can also be accomplished by projecting unlabelled histological images on a screen. They can identify the slides of different tissues through microscope

2.The preparation of smear of stratified squamous epithelia from the inner lining of cheek allows the students to make their own slides using biological stain. They will have the experience of examining their cheek cells.



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## Evaluation

1. The main function of the cuboidal epithelium is
   a. Protection
   b. Secretion
   c. Absorption
   **d. Both (b) and (c)**
2. The ciliated epithelium lines the
   a. Skin  b. Digestive tract
   c. Gall bladder  **d. Trachea**
3. What type of fibres are found in connective tissue matrix?
   **a. Collagen**  b. Areolar
   c. Cartilage  d. Tubular
4. Prevention of substances from leaking across the tissue is provided by
   **a. Tight junction**
   b. Adhering junction
   c. Gap junction
   d. Elastic junction
5. Non-shivering thermogenesis in neonates produces heat through
   a. White fat  **b. Brown fat**
   c. Yellow fat  d. Colourless fat
6. Some epithelia are pseudostratified. What does this mean?
7. Differentiate white adipose tissue from brown adipose tissue.
8. Why blood is considered as a typical connective tissue?
9. Differentiate between elastic fibres and elastic connective tissue.
10. Name any four important functions of epithelial tissue and provide at least one example of a tissue that exemplifies each function.
11. Write the classification of connective tissue and their functions
12. What is an epithelium? Enumerate the characteristic features of different epithelia.

### ICT Corner

#### The Online Epithelium

Let's explore the anatomy and functions of **Epithelium Tissues**.

**Step – 1** Use the URL to open 'The Online Epithelium' page. Click any of the organ given in the list to view the interactive epithelial tissues present in that organ.

**Step – 2** Click the play icon to load the 3D interactive. The loaded 3DTissue can be viewed 360 degree by click and drag of the mouse.

**Step – 3** Roll the mouse over the interactive diagram and click the number on the diagram. A brief description of the parts will appear, description can be viewed by selecting the parts given at the bottom of the activity window.

**Step – 4** Additional information regarding the particular epithelial tissue can be learned from the descriptions given below the 3D interactive diagram.

The Online Epithelium'sURL:

**http://www.epithelium3d.com/index.html**

* Pictures are indicative only



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UNIT II

# Chapter 4

## Organ and Organ Systems in Animals

**Chapter Outline**


4.1 Earthworm - *Lampito mauritii*

4.2 Cockroach - *Periplaneta americana*

4.3 Frog - *Rana hexadactyla*

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

### Learning Objectives:

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

OLGAX

### Introduction

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

## 4.1 Earthworm - *Lampito mauritii*

**Classification**

| | | |
|---|---|---|
| Phylum | : | Annelida |
| Class | : | Clitellata |
| Order | : | Opisthopora |
| Genus | : | *Lampito* |
| Species | : | *mauritii* |

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



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

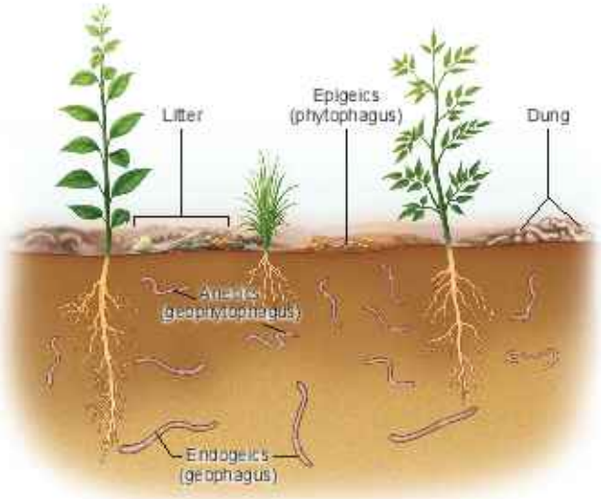


**Figure 4.1** Earthworm classification based on ecological strategies

## Morphology

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

The external apertures are the mouth, anus, dorsal pores, spermathecal openings, genital openings and nephridiopores. The dorsal pores are present from the $10^{th}$ segment onwards. The coelomic fluid communicates to the exterior through these pores and keeps the body surface moist and free from harmful microorganisms. Spermathecal openings are three pairs of small ventrolateral apertures



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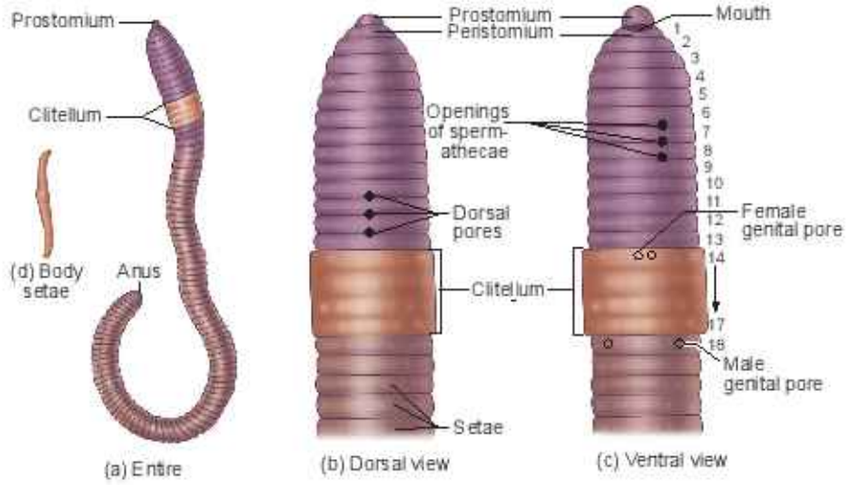


**Figure 4.2** *Lampito mauritii*

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

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

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



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## Anatomy

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

## Digestive System

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

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

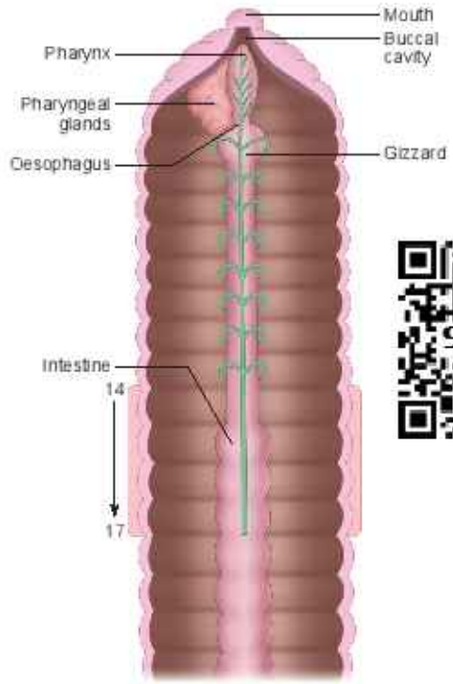


**Figure 4.3** *Lampito mauritii* – Digestive System

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

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

**Intestinal Caeca**

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



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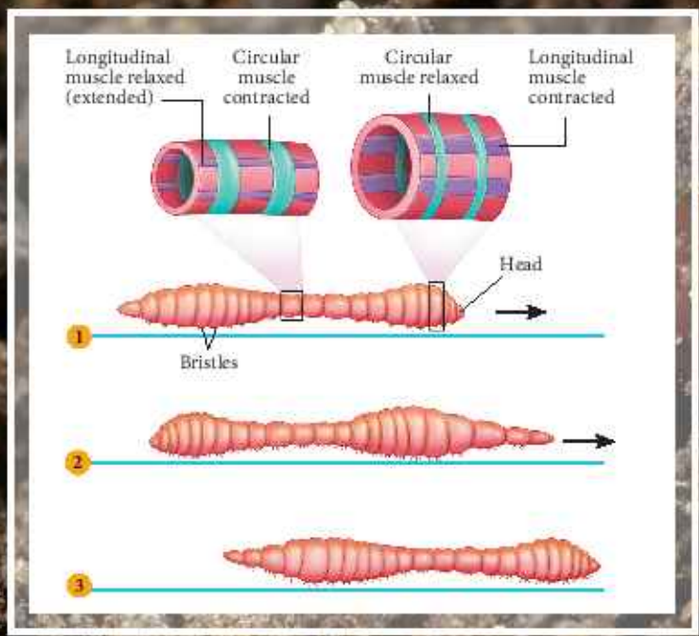
## An earthworm uses its hydrostatic skeleton to crawl




The earthworms normally crawl with the help of their body muscles, setae, and buccal chamber. The outer circular and inner longitudinal muscle layers lies below the epidermis of the body wall. The contraction of circular muscles makes the body long and narrow, while that of the longitudinal muscle makes the body short and broad. The locomotion of the earthworm is brought about by the contraction and relaxation of the muscular body wall and is aided by the turgence of the coelomic fluid hence called the Hydrostatic skeleton. The alternate waves of extensions and contractions are aided by the leverage afforded by the buccal chamber and the setae.

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

### Respiratory System

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

### Circulatory System

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



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

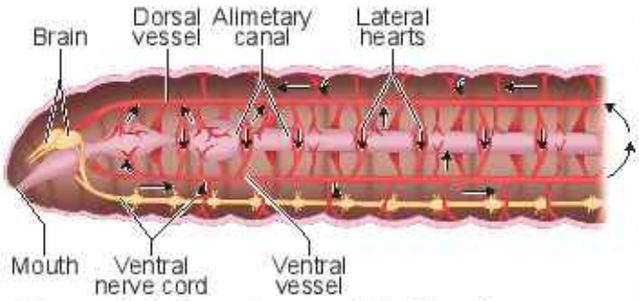


**Figure 4.4** *Lampito mauritii*: Circulatory system and Nervous System

## Nervous System

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

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

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

## Excretory System

Excretion is the process of elimination of metabolic waste products from the body. In earthworm, excretion is effected by segmentally arranged, minute coiled, paired tubules called nephridia. There are three

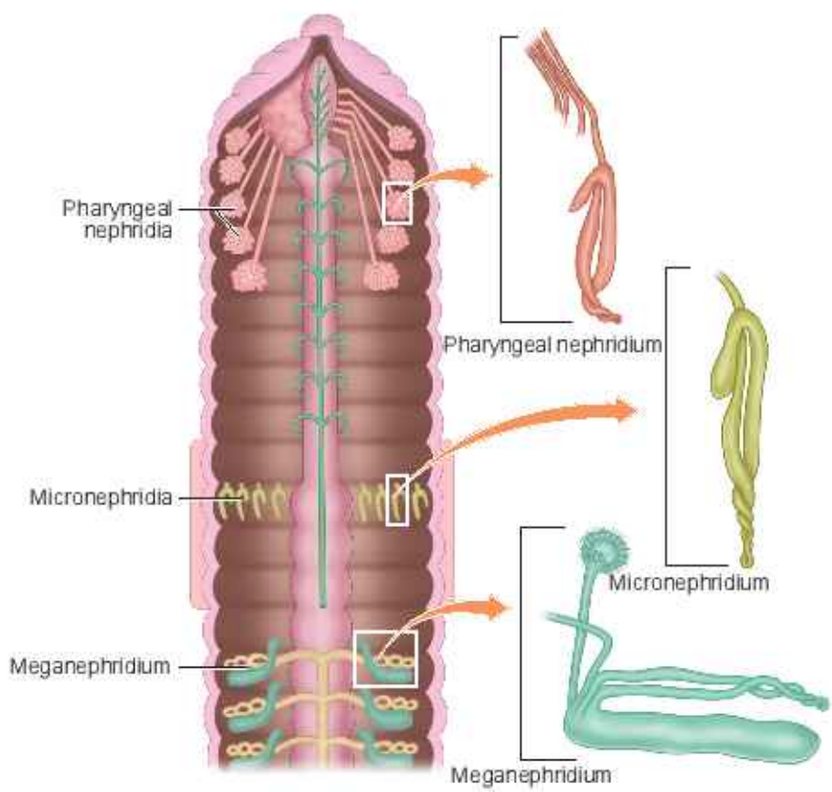


**Figure 4.5** *Lampito mauritii* – Types of Nephridia



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types of nephridia; (i) **pharyngeal** or **tufted nephridia** – present as paired tufts in the 5th - 9th segments (ii) **Micronephridia** or **Integumentary nephridia** – attached to the lining of the body wall from the14th segment to the last which open on the body surface (iii) **Meganephridia** or **septal nephridia** – present as pair on both sides of intersegmental septa of the 19th segment to the last and open into intestine (Figure 4.5). The meganephridium has an internal funnel like opening called the nephrostome, which is fully ciliated. The nephrostome is in the preceding segment and the rest of the tube is in the succeeding segment. This tube consists of three distinct divisions, the ciliated, the glandular and the muscular region. The waste material collected through the ciliated funnel is pushed into the muscular part of nephridium by the ciliated region. The glandular part extracts the waste from the blood and finally the wastes exit out through the nephridiopore.

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

## Reproductive System

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

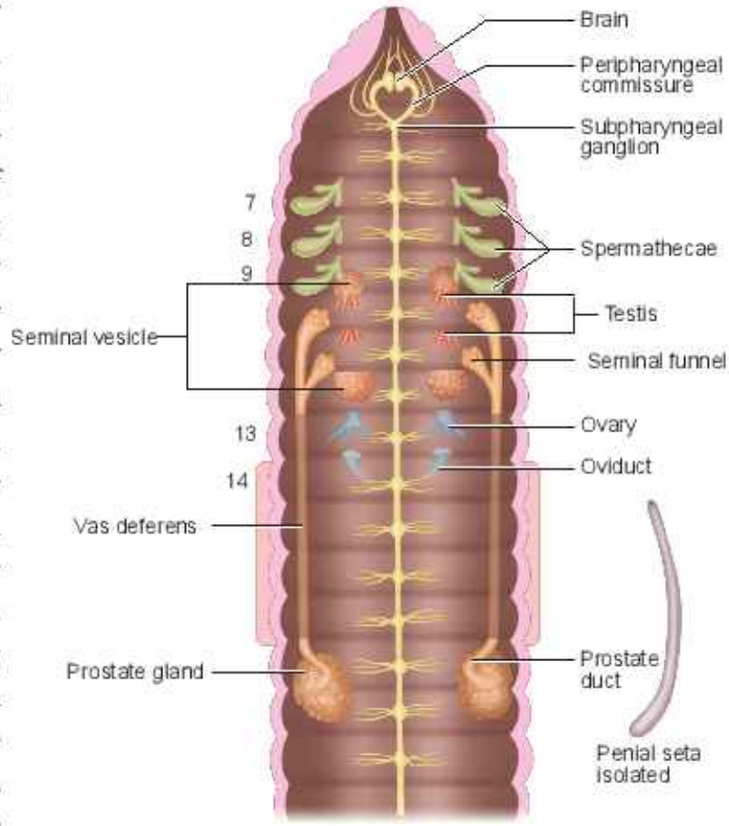


**Figure 4.6** *Lampito mauritii*: Reproductive System.

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



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

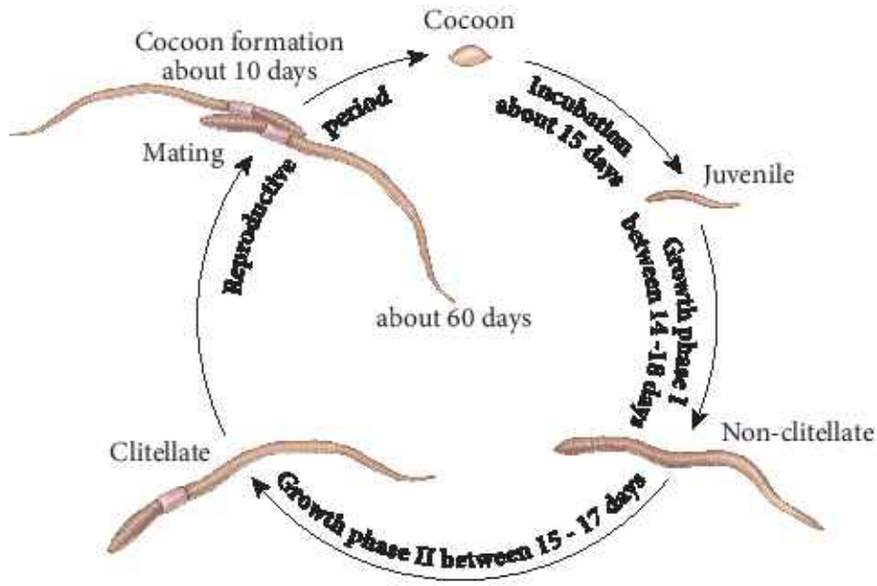


**Figure 4.7** Life cycle of *Lampito mauritii*

**Regeneration**

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

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

## Life Cycle

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



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## 4.2 Cockroach - *Periplaneta americana*

| Classification | | |
|---|---|---|
| Phylum | : | Arthropoda |
| Class | : | Insecta |
| Order | : | Blattodea |
| Genus | : | *Periplaneta* |
| Species | : | *americana* |

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

### Morphology

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

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

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

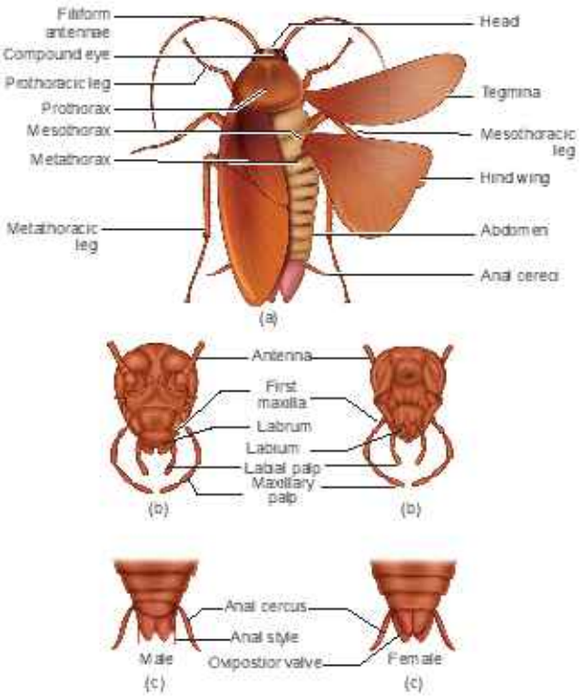


**Figure 4.8** *Periplaneta americana:*

(a) External features (b) Head dorsal and ventral view (c) Male and Female ventral view of posterior segment of abdomen



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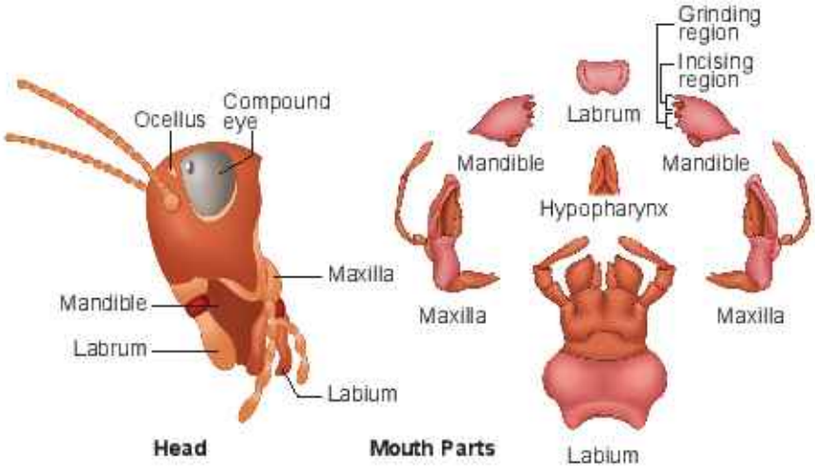


**Figure 4.9** *Periplaneta americana*

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

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

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

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



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**Table 4.2:** Differences between male and female cockroach

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

## Anatomy

### Digestive System

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

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

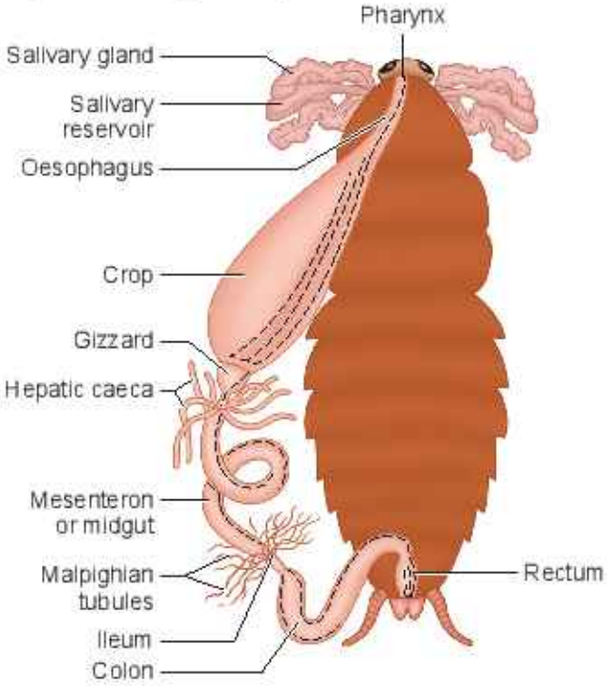


**Figure 4.10** *Periplaneta americana*: Digestive system



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## Respiratory System

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

SPIRACLES → TRACHEA → TRACHEOLES → TISSUES

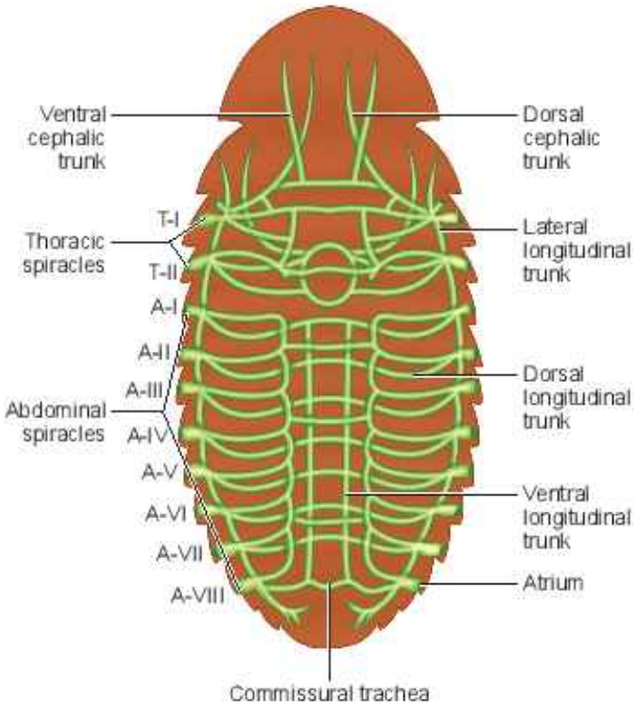


**Figure 4.11** *Periplaneta americana*: Tracheal system in dorsal view

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

## Circulatory System

*Periplaneta* has an open type of circulatory system (Figure 4.12) Blood vessels are poorly developed and opens into the haemocoel in which the blood or haemolymph flows freely. Visceral organs located in the haemocoel are bathed in blood. The haemolymph is colourless and consists of plasma and haemocytes which are 'phagocytic' in nature. Heart is an elongated tube with muscular wall lying mid dorsally beneath the thorax. The heart consists of 13 chambers with ostia on either side. The blood from the sinuses enters the heart through the **ostia** and is pumped anteriorly to sinuses again. The triangular muscles that are responsible for blood circulation in the cockroach are called **alary muscles** (12 pairs). One pair of these muscles is found in each segment on either side of the heart. In cockroach, there is an accessory **pulsatile vesicle** at the base of each antenna which also pumps blood.

**Cockroaches survive without a head**

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



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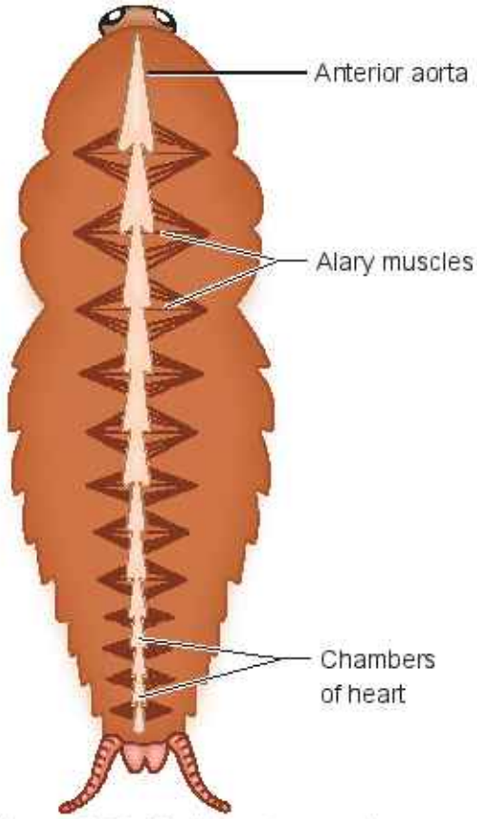


**Figure 4.12** *Periplaneta americana*: Circulatory system

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

## Nervous System

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

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

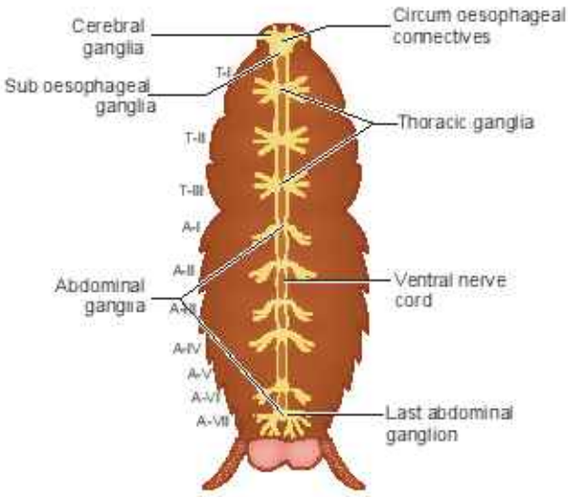


**Figure 4.13** *Periplaneta americana*: Nervous system



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

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

What is the difference between compound eyes and simple eyes?

Why is mosaic vision with less resolution seen in cockroaches?

## Excretory System

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

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

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

## Reproductive System

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



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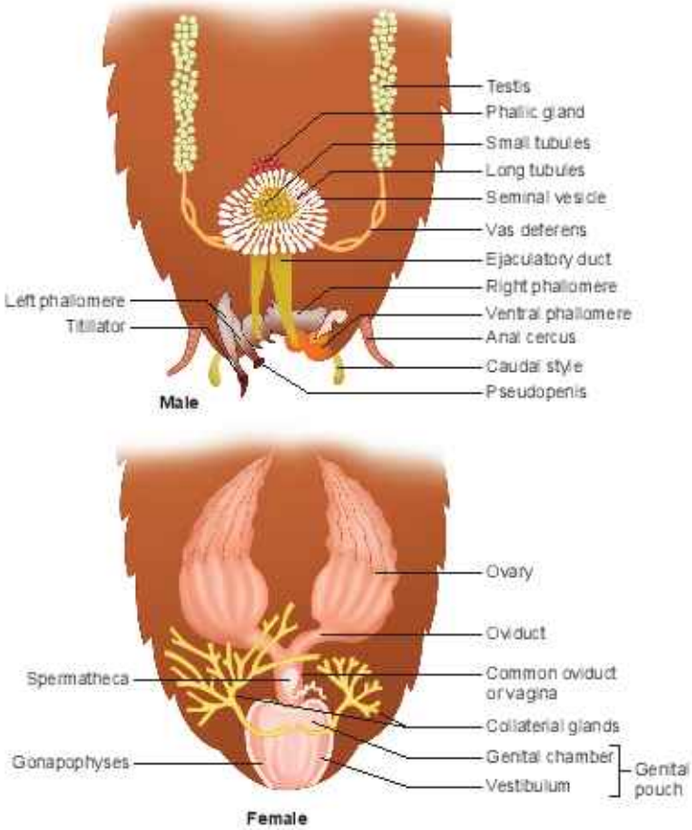


**Figure 4.14** *Periplaneta americana reproductive system*

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

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

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



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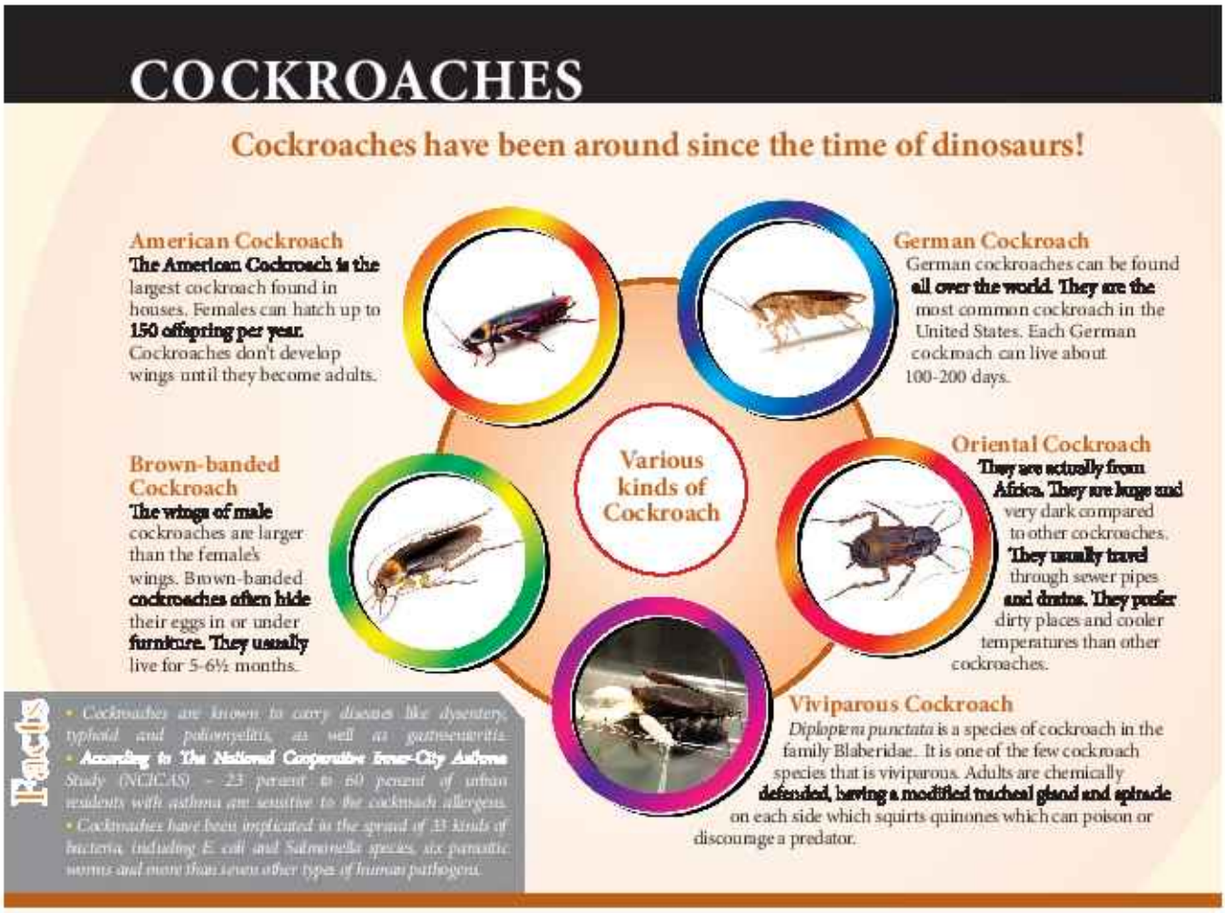

*Diploptera punctata*, a viviparous cockroach, produces a nutritionally dense crystalline "milk" to feed their live-born young. It is found in Myanmar, China, Fiji, Hawaii, and India. Scientists think Cockroach milk could be the super food of the future.

## 4.3 Frog - Rana Hexadactyla

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

### Morphology of Frog

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



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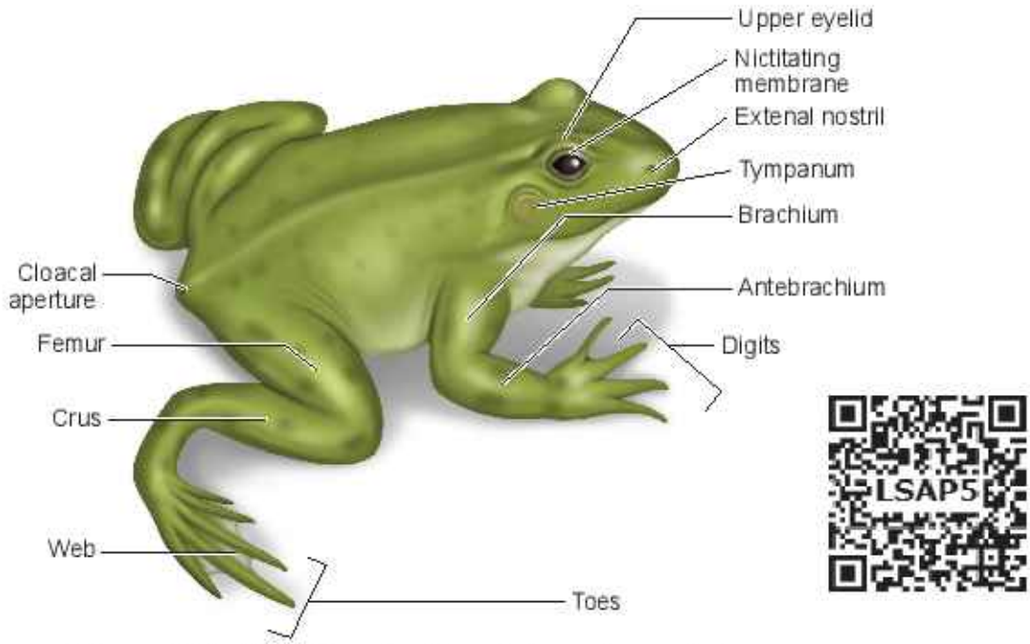


**Figure 4.15** *Rana hexadactyla* - External morphology

**Table 4.3:** Differences between a Frog and Toad

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

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

**Order - Anura (Frogs and Toads)**

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



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

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

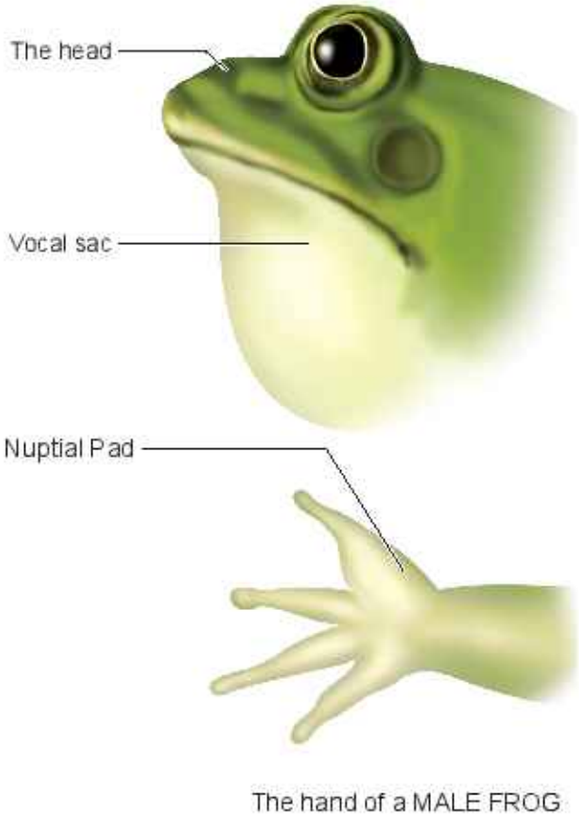


**Figure 4.16** Male *Rana hexadactyla* with vocal sacs and nuptial pad

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

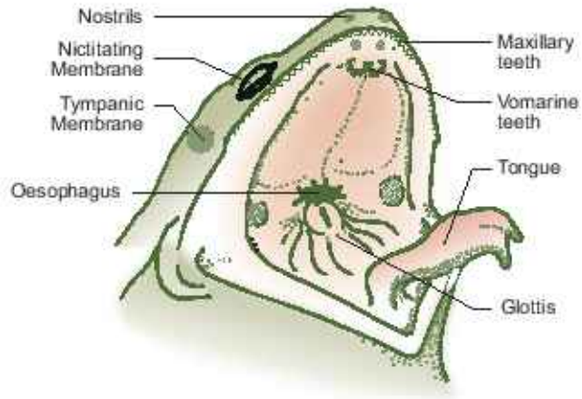


**Figure 4.17** The Buccal Cavity of *Rana hexadactyla*



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## Anatomy

### The Digestive System

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

Food is captured by the bifid tongue. Digestion of food takes place by the action of **Hydrochloric acid** and **gastric juices** secreted from the walls of the stomach. Partially digested food called chyme is passed from the stomach to the first part of the intestine, the duodenum. The duodenum receives bile from the gall bladder and pancreatic juices from the pancreas through a common bile duct. **Bile** emulsifies fat and **pancreatic juices** digest carbohydrates, proteins and lipids. Final digestion takes place in the intestine. Digested food is absorbed by the numerous finger-like folds in the inner wall of **intestine** called **villi** and **microvilli.** The undigested solid waste moves into the **rectum** and passes out through the **cloaca.**

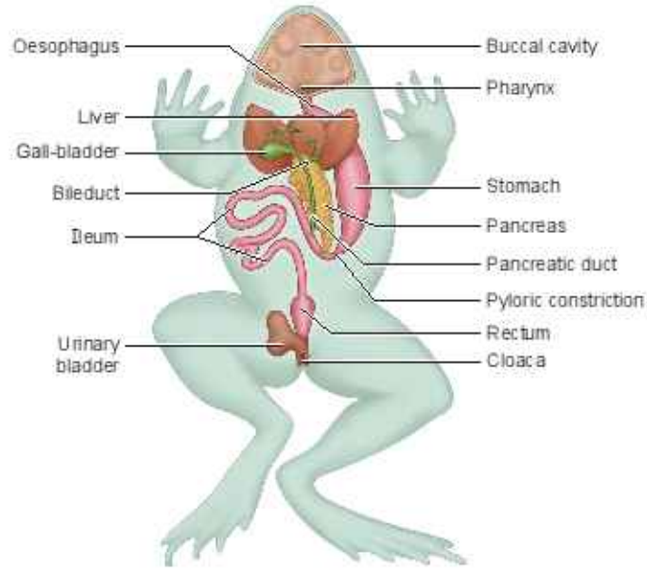


**Figure 4.18** Digestive System of *Rana hexadactyla*

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

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

## Respiratory System

Frog respires on land and in the water by two different methods. In water, **skin** acts



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as aquatic respiratory organ (**cutaneous respiration**). Dissolved oxygen in the water gets, exchanged through the skin by diffusion. On land, the buccal cavity, skin and lungs act as the respiratory organs. In **buccal respiration** on land, the mouth remains permanently closed while the nostrils remain open. The floor of the buccal cavity is alternately raised and lowered, so air is drawn into and expelled out of the buccal cavity repeatedly through the open nostrils. Respiration by lungs is called **pulmonary respiration**. The lungs are a pair of elongated, pink coloured sac-like structures present in the upper part of the trunk region (thorax). Air enters through the nostrils into the buccal cavity and then to the lungs. During **aestivation** and **hibernation** gaseous exchange takes place through skin.

## The Blood-Vascular System

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

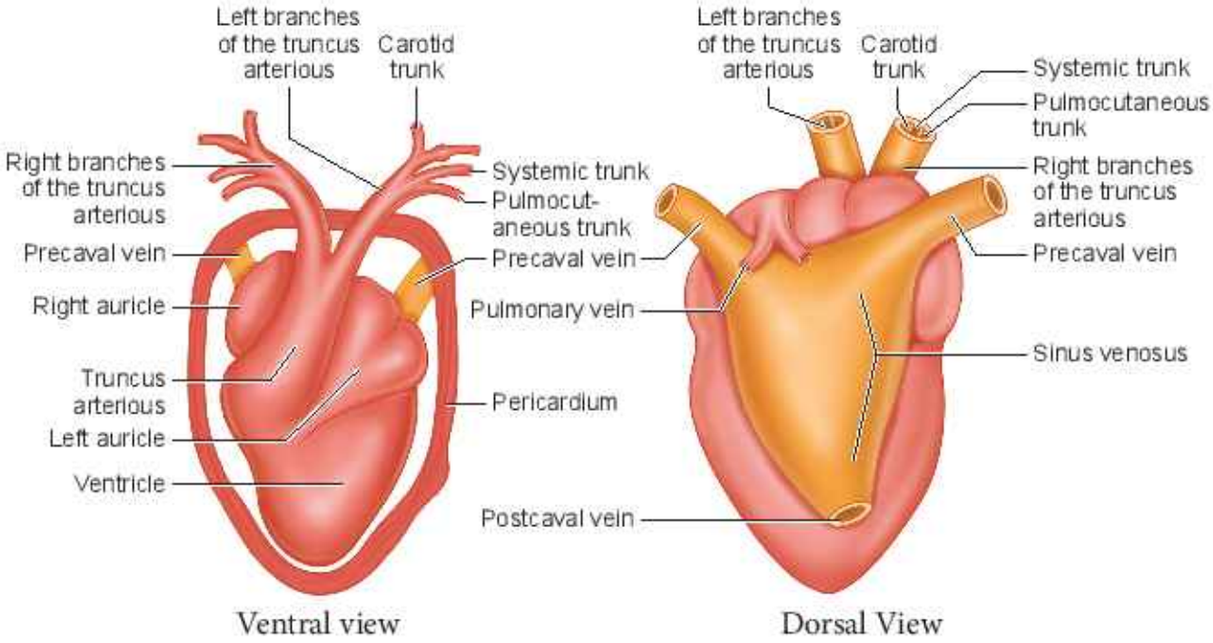


**Figure 4.19** *Rana hexadactyla* - Structure of Heart



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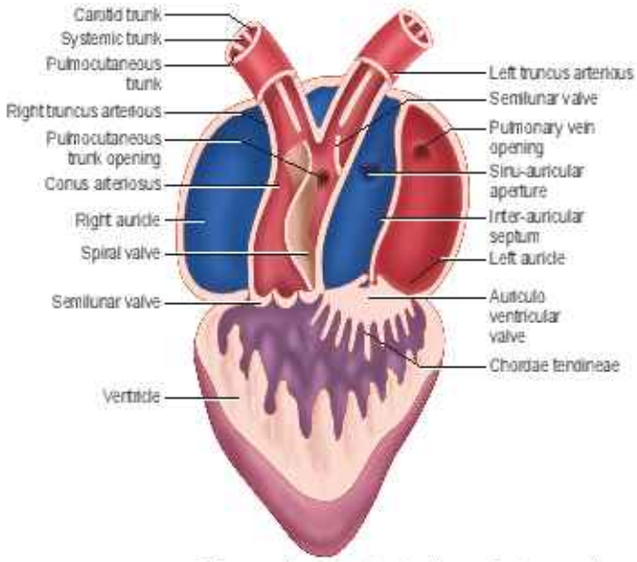


**Figure 4.20** *Rana hexadactyla - Internal Structure of Heart*

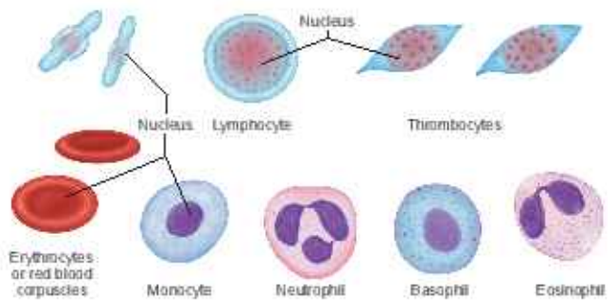


**Figure 4.21** *Rana hexadactyla* – Blood cells

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

## The Nervous System

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

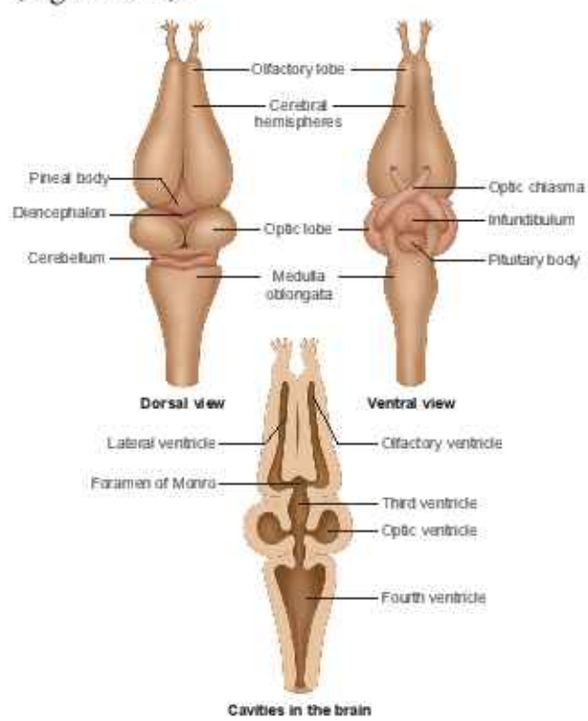


**Figure 4.22** *Rana hexadactyla* – Brain dorsal and ventral view



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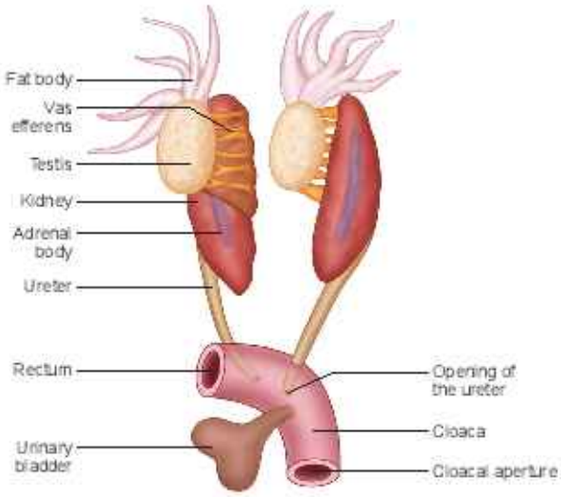


**Figure 4.23** *Rana hexadactyla* - Male Urinogenital System

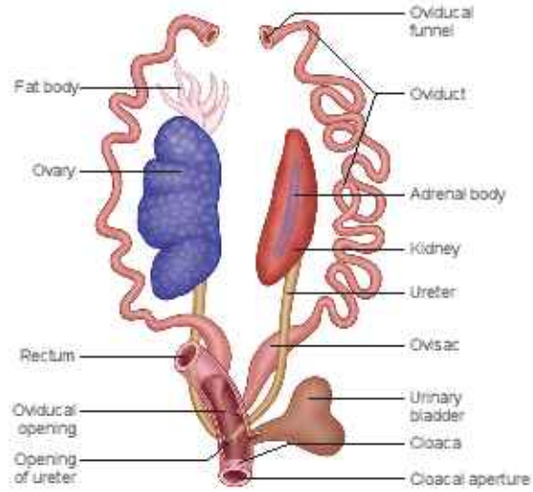


**Figure 4.24** *Rana hexadactyla* - Female Urinogenital System

## Excretory System

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

## Reproductive System

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

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

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



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## Economic Importance of Frog

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

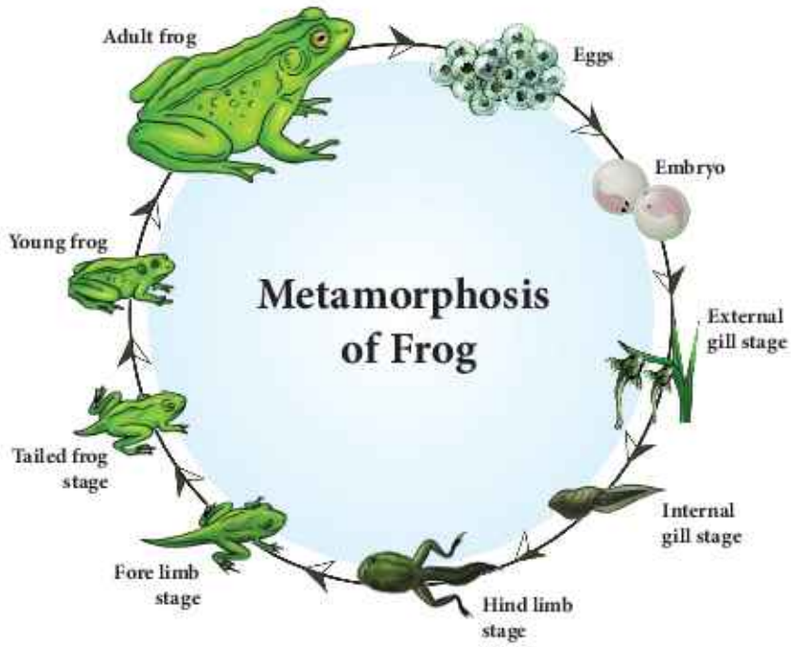


**Figure 4.25** *Rana hexadactyla* - Metamorphosis

## Summary

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

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

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



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## Evaluation

1. The clitellum is a distinct part in the body of earthworm *Lampito mauritii*, it is found in?
   a. Segments 13 - 14
   **b. Segments 14 - 17**
   c. Segments 12 - 13
   d. Segments 14 - 16

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

3. State whether the statement is true or false

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

   a. True **b. False**

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

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

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

7. How many abdominal segments are present in male and female Cockroaches?
   **a. 10, 10** b. 9, 10
   c. 8, 10 d. 9, 9

8. Which of the following have an open circulatory system?
   a. Frog b. Earthworm
   c. Pigeon **d. Cockroach**

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

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



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



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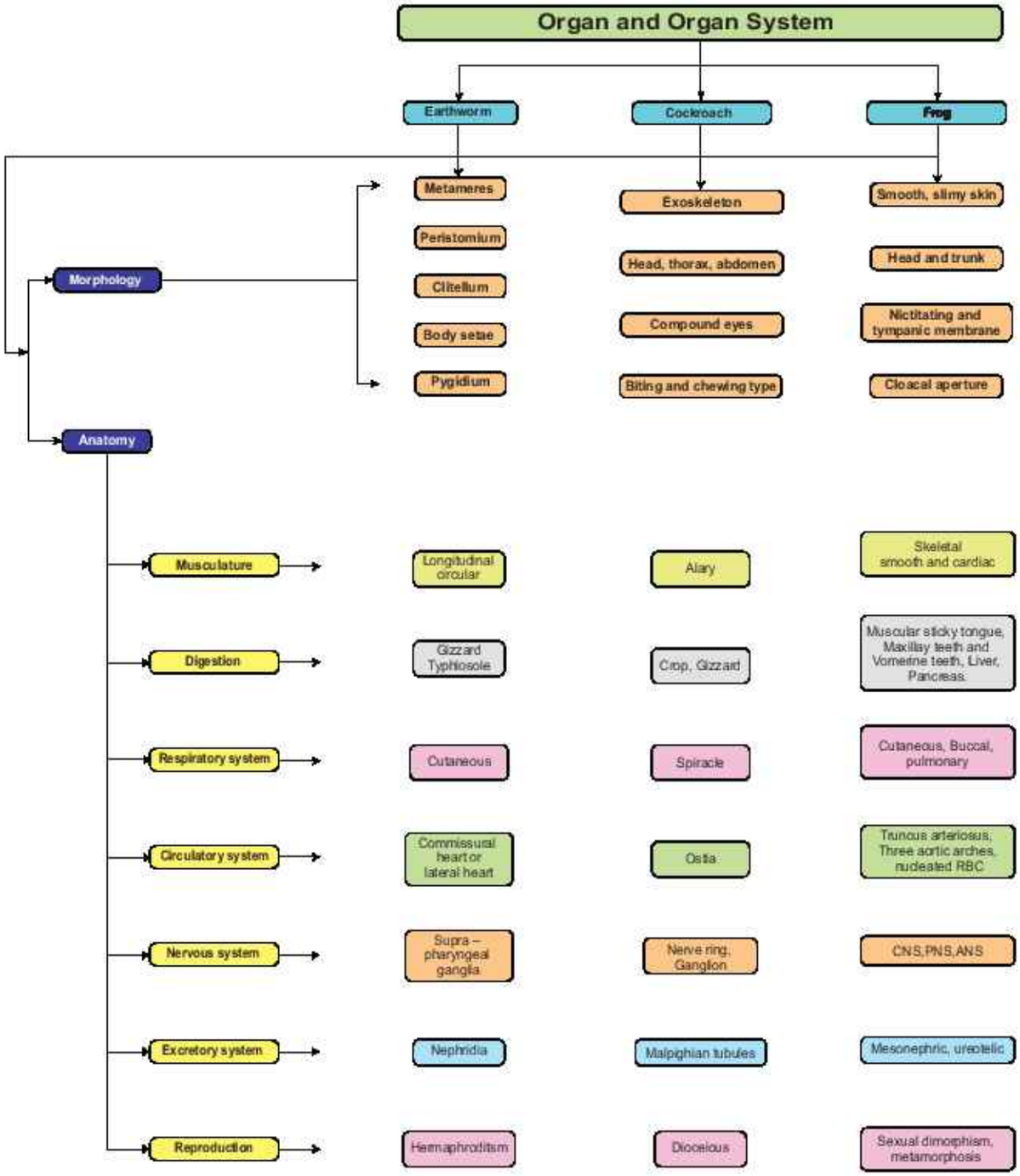
# Concept Map



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UNIT III

# Chapter 5

# Digestion and Absorption

**Chapter Outline**


5.1 Digestive system

5.2 Digestion of food and role of digestive enzymes

5.3 Absorption and assimilation of proteins, carbohydrates and fats

5.4 Egestion

5.5 Caloric value of carbohydrates, proteins and fats

5.6 Nutritional and digestive disorders

Obtaining and utilizing nutrients is a fundamental process in all living organisms.

## Learning Objectives:

095RO

- *Identifies and explains the major parts of the alimentary canal and digestive glands.*
- *Learns the process of digestion in various parts of the alimentary canal.*
- *Understands the role of enzymes in the process of digestion.*
- *Learns the symptoms of digestive disorders.*
- *Learns the role of nutrients in energy production, body building and maintenance and regulation of body activities.*
- *Creates awareness about the nutritional disorders and alimentary canal disorders.*

We all eat food. If you do not take breakfast in the morning how do you feel by noon? The food we eat provides energy and organic substances for growth and for replacement of worn and damaged tissues. It also regulates and coordinates the various activities that take place in our body. The components of our food are carbohydrates, proteins, lipids, vitamins, minerals, fibre and water. We obtain food from plant and animal sources. The food, we eat are macromolecules and cannot directly enter into our cells. These have to be broken into smaller micromolecules in absorbable forms, for which we need a digestive system. Plants however are autotrophs and synthesize their food, hence they do not require a digestive system. The primary function of the digestive system in the animals is to bring



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the nutrients, water and electrolytes from the external environment into every cell in the body through the circulatory system.

## 5.1 Digestive System

The process of digestion involves intake of the food (Ingestion), breakdown of the food into micromolecules (Digestion), absorption of these molecules into the blood stream (Absorption), the absorbed substances becoming components of cells (Assimilation) and elimination of the undigested substances (Egestion). Digestive system includes the alimentary canal and associated digestive glands.

### 5.1.1 Structure of the Alimentary Canal

The alimentary canal is a continuous, muscular digestive tract that begins with an anterior opening, the mouth and opens out posteriorly through the anus. The alimentary canal consists of mouth, buccal cavity, pharynx, oesophagus, stomach, intestine, rectum and anus (Figure. 5.1). The mouth is concerned with the reception of food and leads to the buccal cavity or oral cavity (Figure. 5.2). Mechanical digestion is initiated in the buccal cavity by chewing with the help of teeth and tongue. Chemical digestion is through salivary enzymes secreted by the salivary glands.

Each tooth is embedded in a socket in the jaw bone this type of attachment is called **thecodont**. Human beings and many mammals form two sets of teeth during their life time, a set of 20 temporary milk teeth (deciduous teeth) which gets replaced by a set of 32 permanent teeth (adult teeth). This type of dentition is called **diphyodont**. The permanent teeth are of four different types (**heterodont**), namely, Incisors (I) chisel like cutting teeth, Canines (C) dagger shaped tearing teeth, Pre molars (PM) for grinding, and Molars (M) for grinding and crushing. Arrangement of teeth in each half of the upper and lower jaw, in the order of I, C, PM and M can be represented by a dental formula, in human the dental formula is

$$\frac{2123}{2123} \times 2$$

Mineral salts like calcium and magnesium are deposited on the teeth and form a hard layer of '**tartar' or calculus** called plaque. If the plaque formed on teeth is not removed regularly, it would spread down the tooth into the narrow gap between the gums and enamel and causes inflammation called **gingivitis**, which leads to redness and bleeding of the gums and to bad smell. The hard chewing surface of the teeth is made of enamel and helps in mastication of food.

Tongue is a freely movable muscular organ attached at the posterior end by the frenulum to the floor of the buccal cavity and is free in the front. It acts as a universal tooth brush and helps in intake food, chew and mix food with saliva, to swallow food and also to speak. The upper surface of the tongue has small projections called papillae with taste buds.

The oral cavity leads into a short common passage for food and air called pharynx. The oesophagus and the trachea (wind pipe) open into the pharynx. Food passes into the oesophagus through a wide opening called gullet at the back of the pharynx. A cartilaginous flap called epiglottis prevents the entry of food into the glottis (opening of trachea) during



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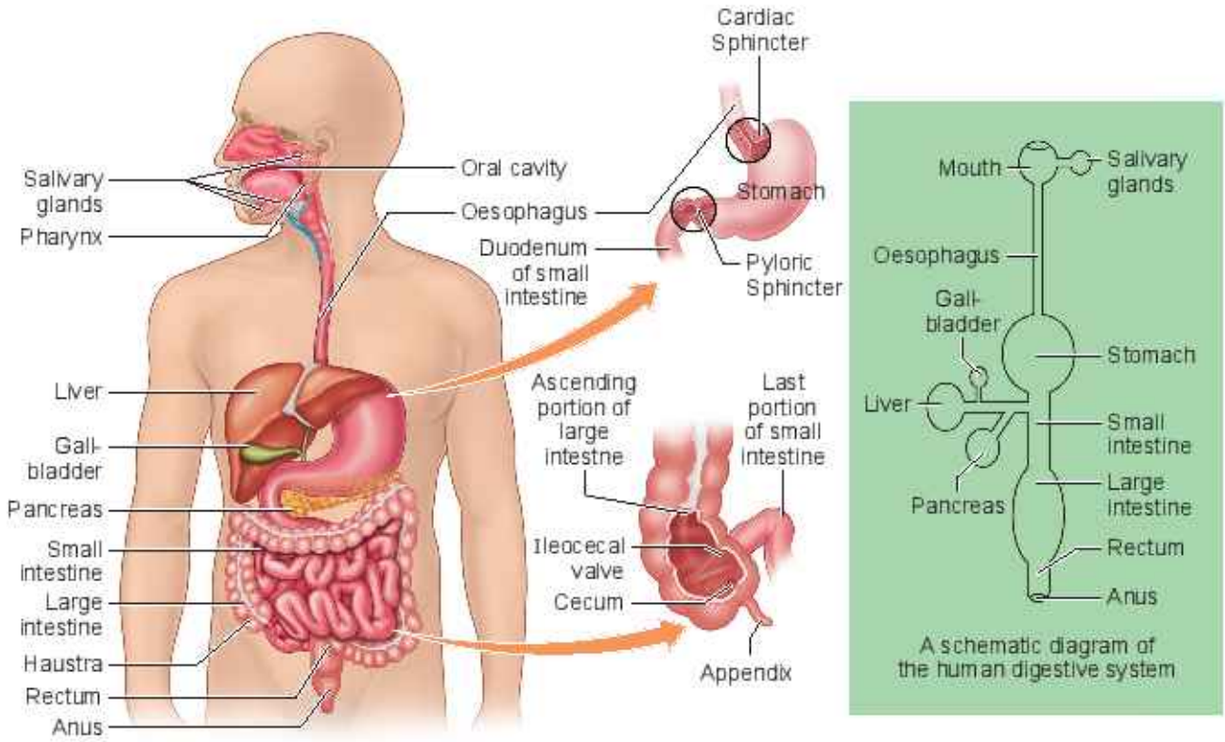


**Figure 5.1** The Human Digestive System

swallowing. Two masses of lymphoid tissue called tonsils are also located at the sides of the pharynx.

Oesophagus is a thin long muscular tube concerned with conduction of the food to a 'J' shaped stomach passing through the neck, thorax and diaphragm. A cardiac sphincter (gastro oesphageal sphincter) regulates the opening of oesophagus into the stomach (Figure. 5.1). If the cardiac sphincter does not contract properly during the churning action of the stomach the gastric juice with acid may flow back into the oesophagus and cause heart burn, resulting in **GERD** (Gastero Oesophagus Reflex Disorder).

The stomach functions as the temporary storage organ for food and is located in the upper left portion of the abdominal cavity. It consists of three parts – a cardiac portion into which the oesophagus opens a fundic portion and a pyloric portion that opens into the duodenum. The opening of the stomach into the duodenum is guarded by the pyloric sphincter. It periodically allows partially digested food to enter the duodenum and also prevents regurgitation of food. The inner wall of stomach has many folds called **gastric rugae** which unfolds to accommodate a large meal.

The small intestine assists in the final digestion and absorption of food. It is the longest part of the alimentary canal and has three regions, a 'U' shaped duodenum (25cm long), a long coiled middle portion jejunum (2.4m long) and a highly coiled ileum (3.5m long). The wall of the duodenum has **Brunner's glands** which secrete mucus and enzymes. Ileum is the longest part of the small intestine and opens into the caecum of the large intestine. The ileal mucosa has numerous vascular projections called **villi** which are



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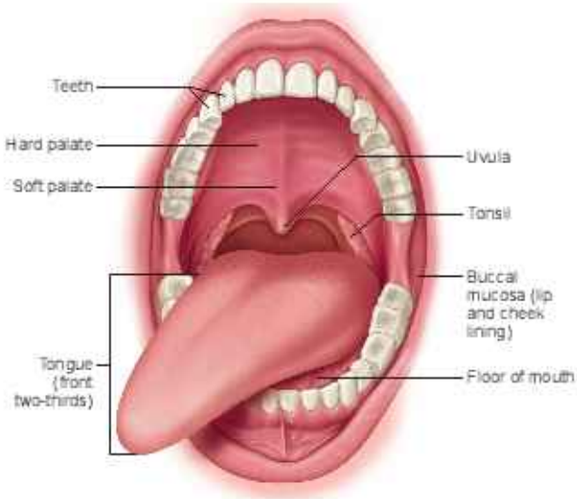


**Figure 5.2** Buccal Cavity

involved in the process of absorption and the cells lining the villi produce numerous microscopic projections called microvilli giving a brush border appearance that increase the surface area enormously. Along with villi, the ileal mucosa also contain mucus secreting goblet cells and lymphoid tissue known as **Peyer's patches** which produce lymphocytes. The wall of the small intestine bears crypts between the base of villi called **crypts of Leiberkuhn** (Figure.5.3).

The large intestine consists of caecum, colon and rectum. The caecum is a small blind pouch like structure that opens into the colon and it possesses a narrow finger like tubular projection called **vermiform appendix**. Both caecum and vermiform appendix are large in herbivorous animal and act as an important site for cellulose digestion with the help of symbiotic bacteria. The colon is divided into four regions – an ascending, a transverse, a descending part and a sigmoid colon. The colon is lined by dilations called **haustra** (singular – haustrum) (Figure.5.4). The "S" shaped sigmoid colon (pelvic colon) opens into the rectum. Rectum is concerned with temporary storage of faeces. The rectum open out through the anus. The anus is guarded by two anal sphincter muscles. The anal mucosa is folded into several vertical folds and contains arteries and veins called anal columns. Anal column may get enlarged and causes **piles** or **haemorrhoids**.

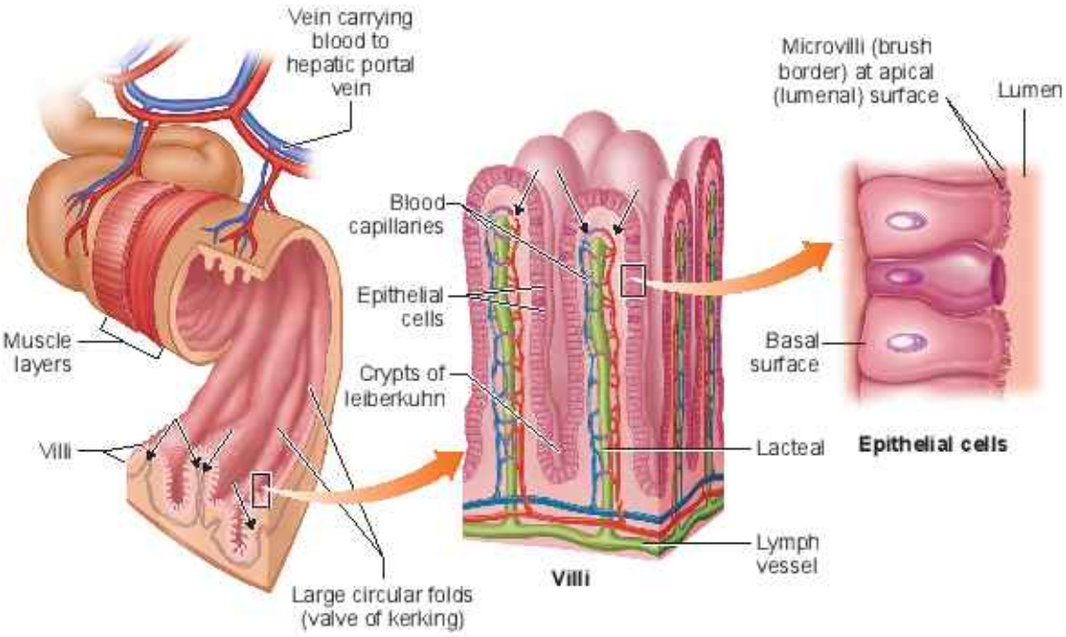


**Figure 5.3** Small Intestine with Villi



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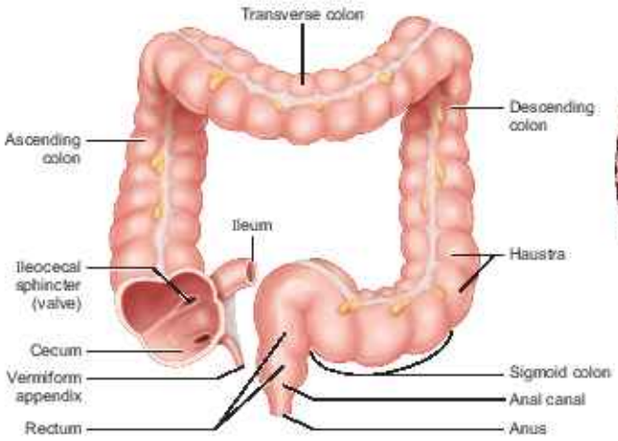


**Figure 5.4** Large intestine

## 5.1.2 Histology of the Gut

The wall of the alimentary canal from oesophagus to rectum consists of four layers (Figure 5.5) namely **serosa, muscularis, sub-mucosa and mucosa.** The serosa (visceral peritoneum) is the outermost layer and is made up of thin squamous epithelium with some connective tissues. Muscularis is made of smooth circular and longitudinal muscle fibres with a network of nerve cells and parasympathetic nerve fibres which controls peristalsis. The submucosal layer is formed of loose connective tissue containing nerves, blood, lymph vessels and the sympathetic nerve fibres that control the secretions of intestinal juice. The innermost layer lining the lumen of the alimentary canal is the mucosa which secretes mucous.

## 5.1.3 Digestive Glands

Digestive glands are exocrine glands which secrete biological catalysts called enzymes. The digestive glands associated with the alimentary canal are salivary glands, liver and pancreas. Stomach wall has gastric glands that secrete gastric juice and the intestinal mucosa secretes intestinal juice.

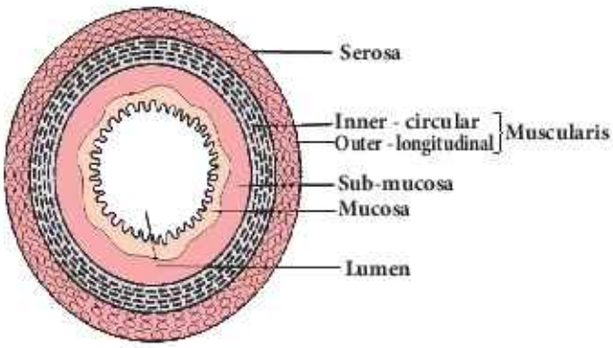


**Figure 5.5** The layers of the alimentary canal

### Salivary Glands

There are three pairs of salivary glands in the mouth. They are the largest parotids gland in the cheeks, the sub-maxillary/ sub-mandibular in the lower jaw and the sublingual beneath the tongue. These glands have ducts such as **Stenson's duct, Wharton's duct and Bartholin's duct or duct of Rivinis** respectively (Figure. 5.6). The salivary juice secreted by the salivary glands reaches the mouth through these ducts. The daily secretion of saliva from salivary glands ranges from 1000 to 1500mL.

### Gastric Glands

The wall of the stomach is lined by gastric glands. Chief cells or **peptic cells or zymogen cells** in the gastric glands secrete gastric enzymes and **Goblet cells** secrete mucus. The **Parietal or oxyntic cells** secrete HCl and an intrinsic factor responsible for the absorption of Vitamin $B_{12}$ called **Castle's intrinsic factor**.

### Liver

The liver, the largest gland in our body is situated in the upper right side of the abdominal cavity, just below the diaphragm. The liver consists of two major left and right lobes and two minor lobes. These lobes are connected with diaphragm. Each lobe has many hepatic lobules (functional unit of liver) and is covered by a thin connective



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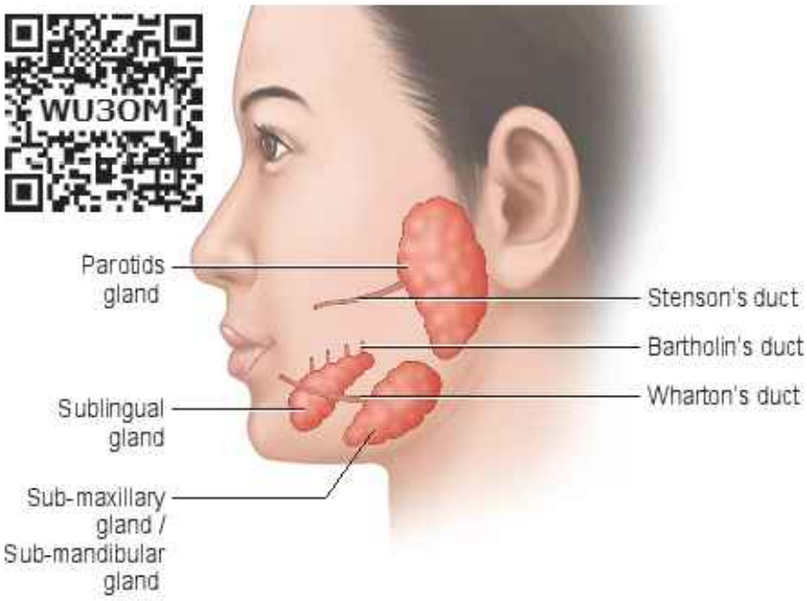


**Figure 5.6** Salivary Glands

Though the bile juice of liver has no digestive enzyme but is very essential for proper digestion of food, especially of the fats. Discuss the following?

a) What is composition of bile?

b) How it helps in digestion of fats and other nutrients of food?

c) How it helps in absorption of fats?

tissue sheath called the **Glisson's capsule**. Liver cells (hepatic cells) secrete bile which is stored and concentrated in a thin muscular sac called the gall bladder. The duct of gall bladder (cystic duct) along with the hepatic duct from the liver forms the common bile duct. The bile duct passes downwards and joins with the main pancreatic duct to form a common duct called hepato-pancreatic duct. The opening of the hepato-pancreatic duct into the duodenum is guarded by a sphincter called the **sphincter of Oddi** (Figure.5.7). Liver has high power of regeneration and liver cells are replaced by new ones every 3-4 weeks.

Apart from bile secretion, the liver also performs several functions

1. Destroys aging and defective blood cells
2. Stores glucose in the form of glycogen or disperses glucose into the blood stream with the help of pancreatic hormones
3. Stores fat soluble vitamins and iron
4. Detoxifies toxic substances.
5. Involves in the synthesis of non-essential amino acids and urea.

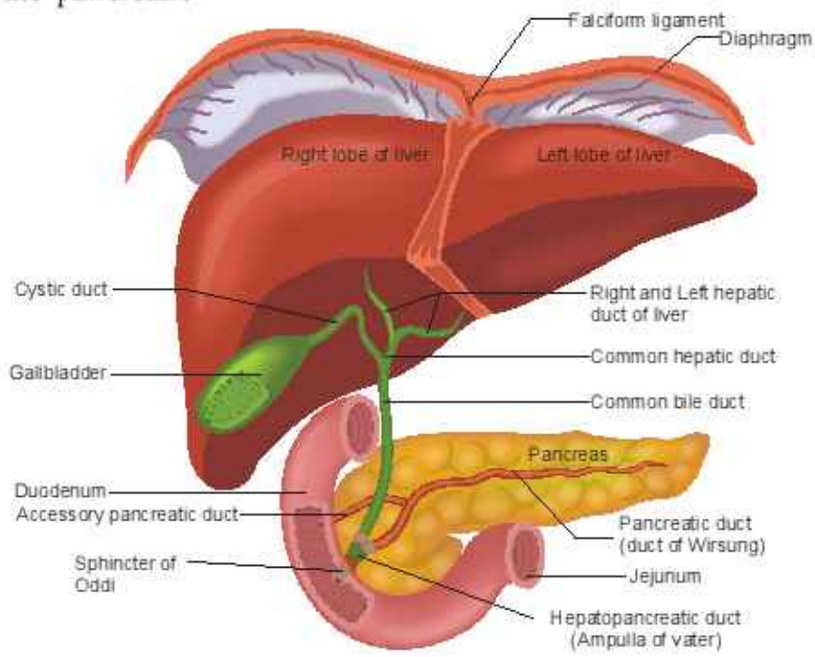


**Figure 5.7** Liver and Pancreas



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**Pancreas**

The second largest gland in the digestive system is the Pancreas, which is a yellow coloured, compound elongated organ consisting of exocrine and endocrine cells. It is situated between the limbs of the 'U' shaped duodenum. The exocrine portion secretes pancreatic juice containing enzymes such as pancreatic amylase, trypsin and pancreatic lipase and the endocrine part called Islets of Langerhans, secretes hormones such as insulin and glucagon. The pancreatic duct directly opens into the duodenum.

List the chemical preservatives, artificial enhancers found in the food items available in the market. How can you avoid such harmful substances in your food?

## 5.2 Digestion of Food and Role of Digestive Enzymes

The process of digestion converts the solid food into absorbable and assimilable forms. This is accomplished by mechanical and chemical processes.

### Digestion in the Buccal Cavity

The smell, sight and taste as well as the mechanical stimulation of food in the mouth, triggers a reflex action which results in the secretion of saliva. The mechanical digestion starts in the mouth by grinding and chewing of food. It is called mastication. The saliva contain water, electrolytes ($Na^+$, $K^+$, $Cl^-$, $HCO_3^-$), salivary amylase (ptyalin), antibacterial agent lysozyme and a lubricating agent mucus (a glycoprotein). The mucus in saliva prepares the food for swallowing by moistening, softening, lubricating and adhering the masticated food into a bolus. About 30 percent of polysaccharide, starch is hydrolyzed by the salivary amylase enzyme into disaccharides (maltose). The **bolus** is then passed into the pharynx and then into the oesophagus by swallowing or **deglutition**. The bolus further passes down through the oesophagus to the stomach by successive waves of muscular contraction called **peristalsis**. The **gastro oesphageal sphincter** controls the passage of food into the stomach.

### Digestion in the Stomach

Food remains in the stomach for 4 to 5 hours, the rhythmic peristaltic movement churns and mixes the food with gastric juice and make it into a creamy liquid called **chyme**. The gastric secretion is partly controlled by autonomic reflexes. The secretion of gastric juice begins when the food is in the mouth. The gastric juice contains HCl and proenzymes. The proenzyme pepsinogen, on exposure to HCl gets converted into the active enzyme pepsin which converts proteins into proteoses and peptones (peptides). The HCl provides an acidic medium which is optimum for pepsin, kills bacteria and other harmful organisms and avoids putrifaction. The mucus and bicarbonates present in the gastric juice play an important role in lubrication and protection of the mucosal epithelium from the eroding nature of the highly acidic HCl (Figure. 5.8). Another proteolytic enzyme found in gastric juice of infants is rennin helps in the digestion of milk protein, caseinogen to casein in the presence of calcium ions. This enzyme secretion gradually reduces with aging.



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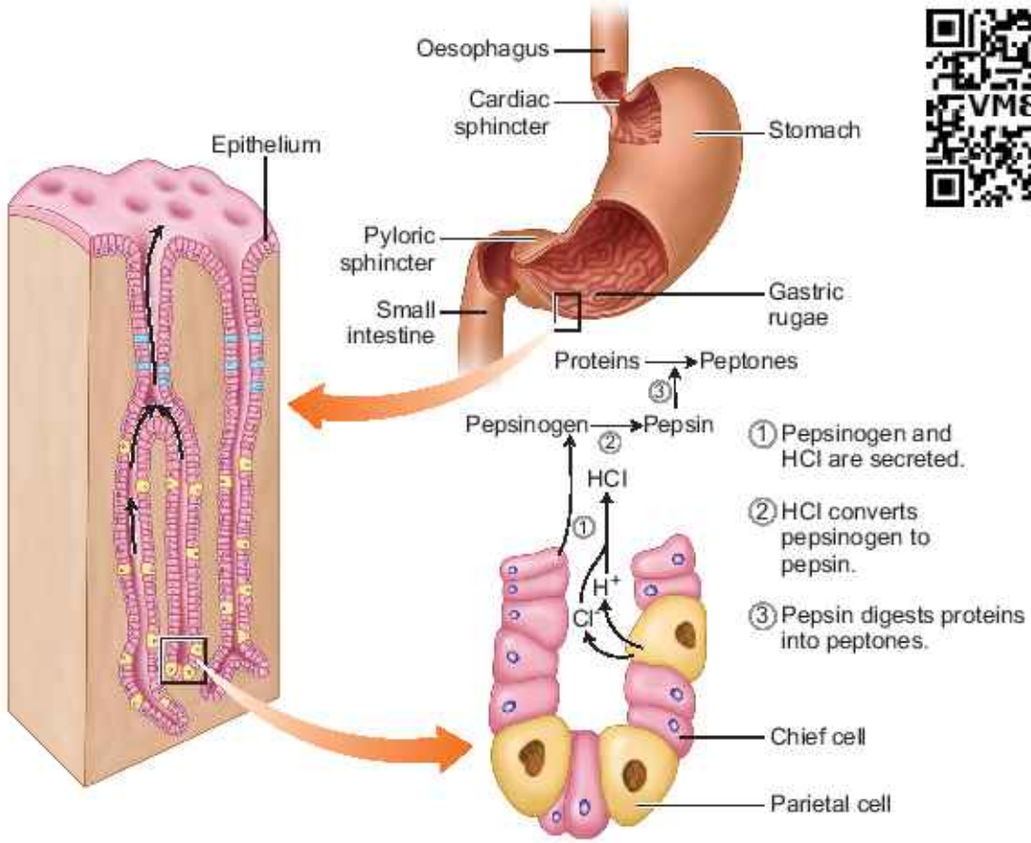


**Figure 5.8** The Stomach and Gastric Secretions

Bicarbonates in the saliva make the pH 5.4 to 7.4. If the bicarbonates level in saliva is reduced the saliva becomes acidic and the tooth enamel may get dissolved.

What would happen if HCl is not secreted in the stomach?

## Digestion in the Small Intestine

The bile, pancreatic juice and intestinal juice are the secretions released into the small intestine. Movements generated by the muscularis layer of the small intestine helps in the thorough mixing of the food with various secretions in the intestine and thereby facilitate digestion.

The bile contains bile pigments (bilirubin and biliverdin) as the break down products of hemoglobin of dead RBCs, bile salts, cholesterol and phospholipids but has no enzymes. Bile helps in emulsification of fats. Bile salts reduce the surface tension of fat droplets and break them into small globules. Bile also activates lipases to digest lipids Proteins and partially digested proteins in the chyme on reaching the intestine are acted upon by the proteolytic enzymes of pancreatic juice.The pancreatic juice contains enzymes such as trypsinogen, chymotrypsinogen, carboxypeptidases, pancreatic amylases, pancreatic lipases and nucleases. Trypsinogen is activated by an enzyme, enterokinase, secreted by the intestinal mucosa into active trypsin, which in turn activates the enzyme chymotrypsinogen in the pancreatic juice.



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Trypsin hydrolyses proteins into polypeptides and peptones, while chymotrypsin hydrolyses peptide bonds associated with specific amino acids.

The pancreatic amylase converts glycogen and starch into maltose. Lipase acts on emulsified fat (triglycerides) and hydrolyses them into free fatty acid and monoglycerides. Monoglycerides are further hydrolysed to fatty acid and glycerol. Nucleases in the pancreatic juice break the nucleic acid into nucleotides and nucleosides.

The secretions of the Brunner's gland along with the secretions of the intestinal glands constitute the intestinal juice or **succus entericus**. The enzymes in the intestinal juice such as maltase, lactase, sucrase (invertase), peptidases, lipases, nucleotidases and nucleosidases act on the breakdown products of bile and pancreatic digestion.

| | | |
|---|---|---|
| Maltose | $\xrightarrow{\text{Maltase}}$ | glucose + glucose |
| Sucrose | $\xrightarrow{\text{Sucrase}}$ | glucose + fructose |
| Lactose | $\xrightarrow{\text{Lactase}}$ | glucose + galactose |
| Dipeptides, Tripeptides | $\xrightarrow{\text{Peptidase}}$ | amino acids |
| Nucleotides | $\xrightarrow{\text{Nucleotidase}}$ | Nucleoside + Phosphoric acid |
| Nucleoside | $\xrightarrow{\text{Nucleosidase}}$ | Sugar + Nitrogen base |
| Diglycerides and monoglycerides | $\xrightarrow{\text{Lipases}}$ | Fatty acids + glycerol |

The mucus along with the bicarbonate ions from the pancreas provides an alkaline medium (pH 7.8) for the enzymatic action. As a result of digestion, all macromolecules of food are converted into their corresponding monomeric units.

Carbohydrates $\longrightarrow$ monosaccharides (glucose, fructose, galactose)

Proteins $\longrightarrow$ amino acids

Lipids $\longrightarrow$ fatty acids and glycerol

The simple substances thus formed are absorbed in the jejunum and ileum region of the small intestine. The undigested and unabsorbed substances are propelled into the large intestine. The activities of the gastro-intestinal tract are carried out by the neural and hormonal control for proper coordination of different parts. Gastric and intestinal secretions are stimulated by neural signals. Hormonal control of the secretion of digestive juices is carried out by local hormones produced by the gastric and intestinal mucosa.

## 5.3 Absorption and Assimilation of Proteins, Carbohydrates and Fats

Absorption is a process by which the end product of digestion passes through the intestinal mucosa into the blood and lymph. The villi in the lumen of ileum are the absorbing units, consisting of a lacteal duct in the middle surrounded by fine network of blood capillaries. The process of absorption involves active, passive and facilitated transport. Small amounts of glucose, amino acids and electrolytes like chloride ions are generally absorbed by simple diffusion. The passage of these substances into the blood depends upon concentration gradients. However, some of the substances like fructose are absorbed with the help of the carrier ions like $Na^+$. This mechanism is called facilitated transport.



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Nutrients like amino acids, glucose and electrolytes like $Na^+$ are absorbed into the blood against the concentration gradient by active transport. The insoluble substances like fatty acids, glycerol and fat soluble vitamins are first incorporated into small, spherical water soluble droplets called micelles and are absorbed into the intestinal mucosa where they are re-synthesized into protein coated fat globules called chylomicrons which are then transported into the lacteals within the intestinal villi and eventually empty into lymphatic duct. The lymphatic ducts ultimately release the absorbed substances into the blood stream. While the fatty acids are absorbed by the lymph duct, other materials are absorbed either actively or passively by the capillaries of the villi (Figure. 5.9). Water soluble vitamins are absorbed by simple diffusion or active transport. Transport of water depends upon the osmotic gradient.

Absorption of substances in the alimentary canal takes place in mouth, stomach, small intestine and large intestine. However maximum absorption takes place in the small intestine. Absorption of simple sugars, alcohol and medicines takes place in the stomach. Certain drugs are absorbed by blood capillaries in the lower side of the tongue and mucosa of mouth. Large intestine is also involved in absorption of more amounts of water, vitamins, some minerals and certain drugs.

Absorbed substances are transported through blood and lymph to the liver through the hepatic portal system. From the liver, nutrients are transported to all other regions of the body for utilization. All the body tissues utilize the absorbed

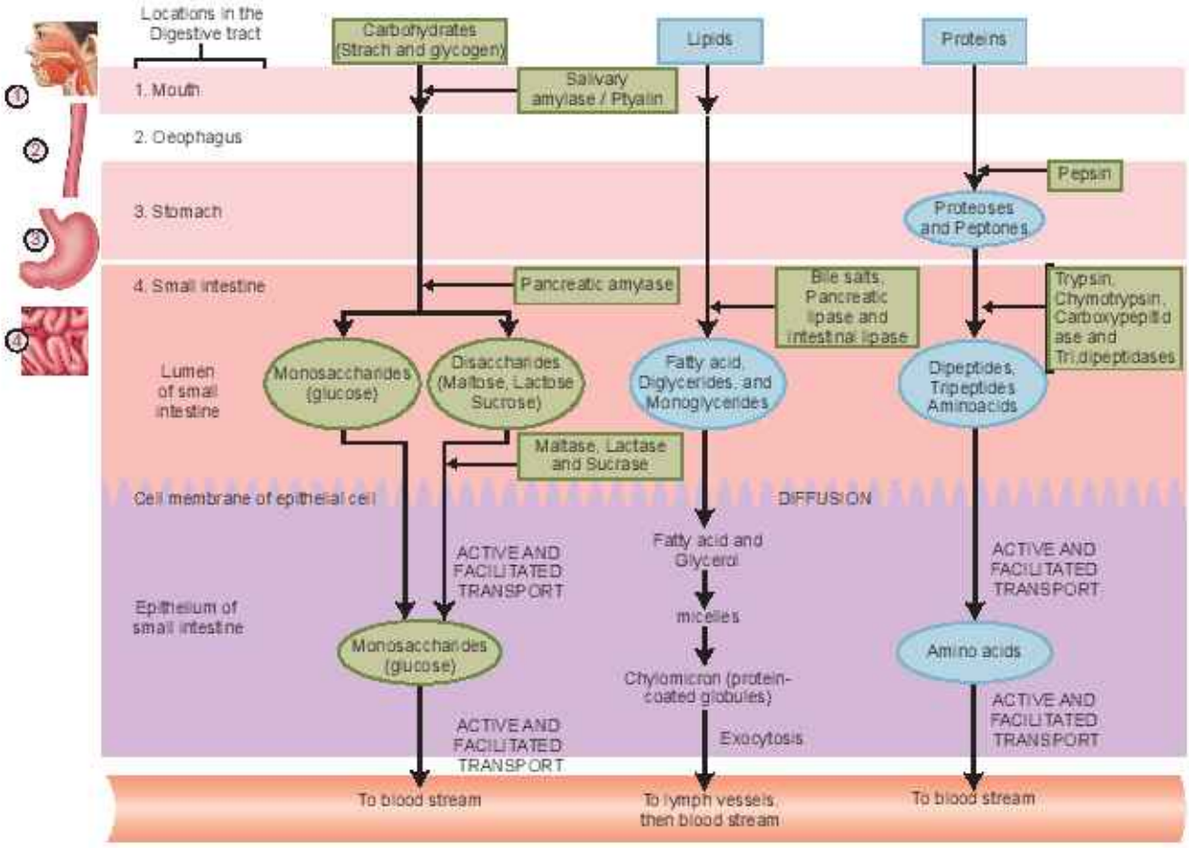


**Figure 5.9** Process of Digestion and Absorption



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substance for their activities and incorporate into their protoplasm, this process is called assimilation.

## 5.4 Egestion

The digestive waste and unabsorbed substances in the ileum enter into the large intestine and it mostly contains fibre called roughage. The roughage is utilized by symbiotic bacteria in the large intestine for the production of substances like vitamin K and other metabolites. All these substances are absorbed in the colon along with water. The waste is then solidified into faecal matter in the rectum. The faecal matter initiates a neural reflex causing an urge or desire for its removal. The egestion of faeces through the anal opening is called defaecation. It is a voluntary process and is carried out by a peristaltic movement.

## 5.5 Caloric Value of Carbohydrates, Proteins and Fats

We obtain 50% energy from carbohydrates 35% from fats and 15% from proteins. We require about 400 to 500 gm of carbohydrates, 60 to 70 gm of fats and 65 to 75 gm of proteins per day. Balanced diet of each individual will vary according to their age, gender, level of physical activity and others conditions such as pregnancy and lactation.

**Carbohydrates** are sugar and starch. These are the major source of cellular fuel which provides energy. The caloric value of carbohydrate is 4.1 Kcal per gram and its physiological fuel value is 4 Kcal per gram.

**Lipids** are fats and derivatives of fats, are also the best reserved food stored in our body which is used for production of energy. Fat has a caloric value of 9.45 Kcal and a physiological fuel value of 9 Kcal per gram.

**Proteins** are source of amino acids required for growth and repair of body cells. They are stored in the body only to a certain extent large quantities are excreted as nitrogenous waste. The caloric value and physiological fuel value of one gram of protein are 5.65 Kcal and 4 Kcal respectively. According to ICMR (Indian Council of Medical Research and WHO (World Health Organization), the daily requirement of protein for an average Indian is 1gm per 1 kg body weight.

Many research findings have proven that usage of chemical preservatives and artificial enhancers lead to highly harmful effects. It includes heart ailments, hypertension, infertility, gastrointestinal disorders, early puberty in girls, weakening of bones, damage in organs like kidney and liver, chronic obstructive pulmonary diseases, headache, allergies, asthma, skin rashes and even cancer. Remember that nothing will beat and overtake the taste and safety of homemade foods. "East or west home preparation is the best."

## 5.6. Nutritional and Digestive Disorders

Intestinal tract is more prone to bacterial, viral and parasitic worm infections. This infection may cause inflammation of the inner lining of colon called **colitis**. The most common symptoms of colitis are rectal bleeding, abdominal cramps, and diarrhoea.



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### Protein Energy Malnutrition: (PEM)

Growing children require more amount of protein for their growth and development. Protein deficient diet during early stage of children may lead to protein energy malnutrition such as **Marasmus and Kwashiorkor**. Symptoms are dry skin, pot-belly, oedema in the legs and face, stunted growth, changes in hair colour, weakness and irritability. Marasmus is an acute form of protein malnutrition. This condition is due to a diet with inadequate carbohydrate and protein. Such children are suffer from diarrhoea, body becomes lean and weak (emaciated) with reduced fat and muscle tissue with thin and folded skin.

### Indigestion

It is a digestive disorder in which the food is not properly digested leading to a feeling of fullness of stomach. It may be due to inadequate enzyme secretion, anxiety, food poisoning, over eating, and spicy food.

### Constipation

In this condition, the faeces are retained within the rectum because of irregular bowel movement due to poor intake of fibre in the diet and lack of physical activities.

### Vomiting

It is reverse peristalsis. Harmful substances and contaminated food from stomach are ejected through the mouth. This action is controlled by the vomit centre located in the medulla oblongata. A feeling of nausea precedes vomiting.

### Jaundice

It is the condition in which liver is affected and the defective liver fails to break down haemoglobin and to remove bile pigments from the blood. Deposition of these pigments changes the colour of eye and skin yellow. Sometimes, jaundice is caused due to hepatitis viral infections.

### Liver Cirrhosis

Chronic disease of liver results in degeneration and destruction of liver cells resulting in abnormal blood vessel and bile duct leading to the formation of fibrosis. It is also called deserted liver or scarred liver. It is caused due to infection, consumption of poison, malnutrition and alcoholism.

### Gall Stones

Any alteration in the composition of the bile can cause the formation of stones in the gall bladder. The stones are mostly formed of crystallized cholesterol in the bile. The gall stone causes obstruction in the cystic duct, hepatic duct and also hepato-pancreatic duct causing pain, jaundice and pancreatitis.

### Appendicitis

It is the inflammation of the vermiform appendix, leading to severe abdominal pain. The treatment involves the removal of appendix by surgery. If treatment is delayed the appendix may rupture and results in infection of the abdomen, called **peritonitis**.

IJBV6

### Hiatus Hernia (Diaphragmatic Hernia)

It is a structural abnormality in which superior part of the stomach protrudes slightly above the diaphragm. The exact cause of hiatus hernias is not known. In some people, injury or other damage may weaken muscle tissue, by applying too much pressure (repeatedly) on the muscles around the stomach while coughing, vomiting, and straining during bowel movement and lifting heavy object. Heart burn is also common in those with a hiatus hernia. In this condition, stomach



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contents travel back into the oesophagus or even into oral cavity and causes pain in the centre of the chest due to the eroding nature of acidity (Figure.5.10).

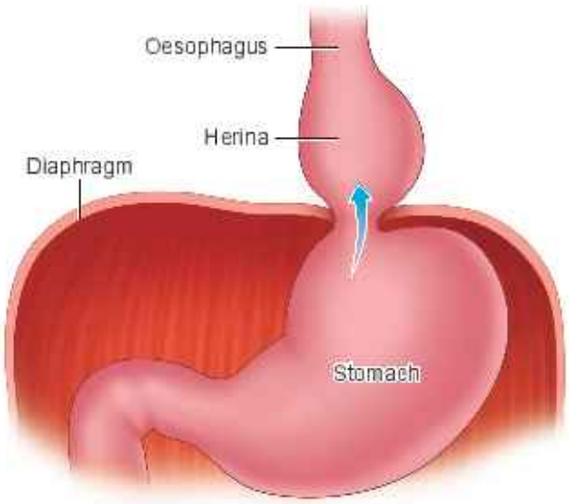


**Figure 5.10** Hiatus Hernia

## Diarrhoea

It is the most common gastrointestinal disorder worldwide. It is sometimes caused by bacteria or viral infections through food or water. When the colon is infected, the lining of the intestine is damaged by the pathogens, thereby the colon is unable to absorb fluid. The abnormal frequency of bowel movement and increased liquidity of the faecal discharge is known as diarrhoea. Unless the condition is treated, dehydration can occur. Treatment is known as **oral hydration therapy**. This involves drinking plenty of fluids – sipping small amounts of water at a time to rehydrate the body.

## Peptic Ulcer

It refers to an eroded area of the tissue lining (mucosa) in the stomach or duodenum. Duodenal ulcer occurs in people in the age group of 25 - 45 years. Gastric ulcer is more common in persons above the age of 50 years. Ulcer is mostly due to infections caused by the bacterium ***Helicobacter pylori.*** It may also be caused due to uncontrolled usage of aspirin or certain antiinflammatory drugs. Ulcer may also be caused due to smoking, alcohol, caffeine and psychological stress.

Nobel Prize for the year 2005 was awarded to Robin Warren and Barry Marshall for the discovery of *Helicobacter pylori* which causes peptic ulcer.

## Obesity

It is caused due to the storage of excess of body fat in adipose tissue. It may induce hypertension, atherosclerotic heart disease and diabetes. Obesity may be genetic or due to excess intake of food, endocrine and metabolic disorders. Degree of obesity is assessed by body mass index (**BMI**). A normal BMI range for adult is 19-25 above 25 is considered as obese. BMI is calculated as body weight in Kg, divided by the square of body height in meters. For example, a 50 Kg person with a height of 160 cms would have a BMI of 19.5.

That is BMI = $50 /(1.6)^2 = 19.5$

Food adulterants cause harmful effects in the form of headaches, palpitations, allergies, cancers and in addition reduces the quality of food. Common adulterants are addition of citric acid to lemon juice, papaya seeds to pepper, melamine to milk, vanillin for natural vanillin, red dyes to chillis, lead chromate and lead tetraoxide to turmeric powder, etc.,



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## Summary

The digestive system of human consists of the mouth (oral cavity), pharynx, esophagus, stomach, small intestine, large intestine, rectum and anus. The accessory digestive glands include the salivary glands, the liver (with gall bladder) and the pancreas. The process of digestion involves intake of the food (Ingestion), breakdown of the food into micromolecules (Digestion), absorption of these molecules into the blood stream (Absorption), the absorbed substances becoming components of cells (Assimilation) and elimination of the undigested substances (Egestion).

Food comprises of macronutrients and micronutrients. The nutrients required in larger quantities are called macronutrients, whereas those required in small quantities are called micronutrients. Essential nutrients cannot be synthesized by the body; they have to be included in the diet. Macronutrients are lipids, carbohydrates, proteins and the micronutrients are vitamins and minerals. Water plays an important role in the metabolic processes and prevents dehydration of the body.

Intestinal tract is more prone to bacterial, viral and parasitic worm infections. Such infection, called colitis, may couse inflammation of the inner lining of the colon. Growing children require more protein for their growth and development. Protein deficient diet during early stage of children may lead to protein energy malnutrition such as Marasmus and Kwashiorkor.

Alimentary canal faces a conflict between the need of nutrient absorption and to keep our intestinal tract free from pathogenic bacteria and virus. About 7 litres of digestive juice are poured into the alimentary canal and are reabsorbed each day. If this does not happen the body gets rapidly dehydrated and may lead to reduction in the blood pressure.

### Activity

**Test for Starch:** Add a few drops of iodine to the given warm food sample. If any starch is present in the given food sample it will change the colour of the iodine from brown to blue-black.

**Test for protein:** Mix the given food sample with 3mL of water in a test tube. Shake the mixture, and then add a few drops of Biuret solution. If protein is present, the colour of the solution will change to purple.

**Test for glucose:** Mix the given food sample with 3mL of water in a test tubes. Shake the mixture, and then add a few drops of Benedict's solution. Keep the test tube in a water bath and heat carefully. If glucose is present, the colour of the solution will change from blue to green to brick red depending upon the amount of glucose.



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## The human digestive system is pretty amazing.

Turning the food we eat into fuel the body uses for energy and to help us grow. However sometimes even small changes in our everyday routine can get in the way of healthy digestion.

**Do you know?** Digestive system associated disorders are gastritis, bloating, diarrhoea, constipation, heartburn and acid reflux, jaundice, gall stones obesity, etc...

Digestion begins as soon as food enters into the mouth.

### 1 Mouth:

Three pairs of salivary glands secrets saliva.
Enzymes in the saliva mix with food particles and start breaking them down while chewing.

### 2 Oesophagus:

The oesophagus is a tube connecting the mouth to the stomach. After swallow, the food travels down through the esophagus to the stomach.

**Do you know?** The oesophagus takes your chewed food and squeezes it downward using muscle contractions called peristalsis.

### 3 Cardiac sphincter:

The Cardiac sphincter is where the oesophagus meets the stomach. This group of muscles acts like a gate to prevent stomach acid from going back up (refluxing) into the oesophagus.

### 4 Stomach:

Gastric juice contain HCl and gastric enzymes.

Hydrochloric acid (HCl) helps to digest proteins and other foods by pepsin enzymes while minimizing harmful bacteria.

### 5 Liver:

The liver secrete bile. Bile helps the small intestine by breaking downs fats and making them easier to absorb.

### 6

Gall bladder stores bile secretion.

**Do you know?** The liver is also an important detoxification organ. It helps to filter and elimate harmful toxins from our body.

### 7 Pancreas

The pancreas is connected to the duodenum where three important digestive enzmyes are made:

| Protease | Lipase | Amylase |
|---|---|---|
| Helps digest protein | Helps digest fats | Helps digest carbohydrates |

**Fun fact:**
There are two kinds of fibre, and both support a healthy colon.

| Soluble fibre | Insolube fibre |
|---|---|
| soaks up toxins and waste in the digestive system | ("roughage") moves bulk through the intestine to help with regular bowel movements. |

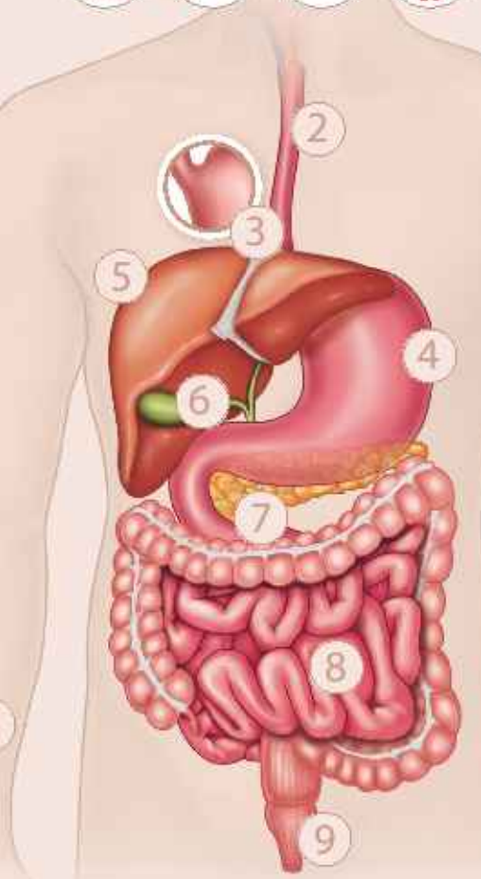
### 8 Small intestine:

Most of the nutrients form food are digested and absorbed in the small intestine.

**Do you know?**
Small intestine is lined with mucosa, a layer of tissue that helps to absorb nutrients, produce digestive enzymes, and make mucus to protect the delicate intestinal wall.

### 9 Large intestine (Colon):

Most of the bacteria living in the digestive tract can be found in the large intestine. This is where the digestive process comes to an end.




There are more then **100 trillion** bacterial cells in your body.

The digestive tract is home to a natural balance of good, bad, and neutral bacteria.

**Do you know?**
Good bacteria, also called probiotics, support overall digestive and immune health.

**Do you know?** Up to 70% of our natural immune system support is in the digestive tract.

Here are 5 simple things you can do every day to maintain a healthy, balanced gut:

- Eat a healthy diet
- Drink plenty of water
- Stay phyically active
- Manage stress
- Take a daily probiotic supplement



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## Evaluation

1. Choose the incorrect sentence from the following:
   a. Bile juice emulsifies the fat.
   b. Chyme is a digestive acidic food in stomach.
   c. Pancreatic juice converts lipid into fatty acid and glycerol.
   **d. Enterokinase stimulates the secretion of pancreatic juice.**
2. What is chyme….?
   a. The process of conversion of fat into small droplets.
   b. The process of conversion of micelles substances of glycerol into fatty droplet.
   **c. The process of preparation of incompletely digested acidic food through gastric juice.**
   d. The process of preparation of completely digested liquid food in midgut.
3. Which of the following hormones stimulate the production of pancreatic juice and bicarbonate?
   a. Angiotensin and epinephrine
   b. Gastrin and insulin
   **c. Cholecystokinin and secretin**
   d. Insulin and glucagon
4. The sphincter of Oddi guards
   **a. Hepatopancreatic duct**
   b. Common bile duct
   c. Pancreatic duct
   d. Cystic duct
5. In small intestine, active absorption occurs in case of
   a. Glucose  b. Amino acids
   **c. Na+**  d. All the above
6. Which one is incorrectly matched?
   a. Pepsin – stomach
   **b. Renin – liver**
   c. Trypsin – intestine
   d. Ptyalin – mouth
7. Absorption of glycerol, fatty acids and monoglycerides takes place by
   **a. Lymph vessels within villi**
   b. Walls of stomach
   c. Colon
   d. Capillaries within villi
8. First step in digestion of fat is
   **a. Emulsification**
   b. Enzyme action
   c. Absorption by lacteals
   d. Storage in adipose tissue
9. Enterokinase takes part in the conversion of
   a. Pepsinogen into pepsin
   **b. Trypsinogen into trypsin**
   c. Protein into polypetide
   d. Caseinogen into casein
10. Which of the following combinations are not matched?

| Column I | Column II |
|---|---|
| **a. Bilirubin and biliverdin** | **(i) Intestinal juice** |
| b. Hydrolysis of starch | (ii) Amylases |
| c. Digestion of fat | (iii) Lipases |
| d. Salivary gland | (iv) Parotid |

11. Match column I with column II and choose the correct option

| Column – I | Column – II |
|---|---|
| (P) Small intestine | (i) Largest factory |
| (Q) Pancreas | (ii) Absorption of Water |
| (R) Liver | (iii) Carrying electrolytic solution |
| (S) Colon | (iv) Digestion and absorption |



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**a. ( P-iv ) ( Q -iii ) ( R- i ) ( S – ii )**

b. ( P-iii ) ( Q -ii ) ( R- i ) ( S – iv )

c. ( P-iv ) ( Q -iii ) ( R- ii ) ( S – i)

d. ( P-ii ) ( Q -iv ) ( R- iii ) ( S – i )

12. Match column I with column II and choose the correct option

| Column – I | Column – II |
|---|---|
| (P) Small intestine | (i) 23 cm |
| (Q) Large intestine | (ii) 4 meter |
| (R) Oesophagus | (iii) 12.5 cm |
| (S) Pharynx | (iv) 1.5 meter |

a. ( P-iv ) ( Q -ii ) ( R- i ) ( S – iii )

**b. ( P-ii ) ( Q -iv ) ( R- i ) ( S – iii )**

c. ( P-i ) ( Q -iii ) ( R- ii ) ( S – iv )

d. ( P-iii ) ( Q -i ) ( R- ii ) ( S – iv )

13. Match column I with column II and choose the correct option

| Column – I | Column – II |
|---|---|
| (P) Lipase | (i) Starch |
| (Q) Pepsin | (ii) Cassein |
| (R) Renin | (iii) Protein |
| (S) Ptyalin | (iv) Lipid |

a. ( P-iv ) ( Q -ii ) ( R- i ) ( S – iii )

b. ( P-iii ) ( Q -iv ) ( R- ii ) ( S – i )

**c. ( P-iv ) ( Q -iii ) ( R- ii ) ( S – i )**

d. ( P-iii ) ( Q -ii ) ( R- iv ) ( S – i )

14. Which of the following is not the function of liver?

**a. Production of insulin**

b. Detoxification

c. Storage of glycogen

d. Production of bile

15. **Assertion (A):** Large intestine also shows the presence of villi like small intestine.

**Reason (B):** Absorption of water takes place in large intestine.

a. Both A and B are true and B is the correct explanation of A

b. Both A and B are true but B is not the correct explanation of A

c. A is true but B is false

**d. A is false but B is true**

16. Which of the following is not true regarding intestinal villi?

a. They possess microvilli.

b. They increase the surface area.

c. They are supplied with capillaries and the lacteal vessels.

**d. They only participate in digestion of fats.**

17. Why are villi present in the intestine and not in the stomach?

18. Bile juice contains no digestive enzymes, yet it is important for digestion. Why?

19. List the chemical changes that starch molecule undergoes from the time it reaches the small intestine.

20. How do proteins differ from fats in their energy value and their role in the body?

21. Digestive secretions are secreted only when needed. Discuss.



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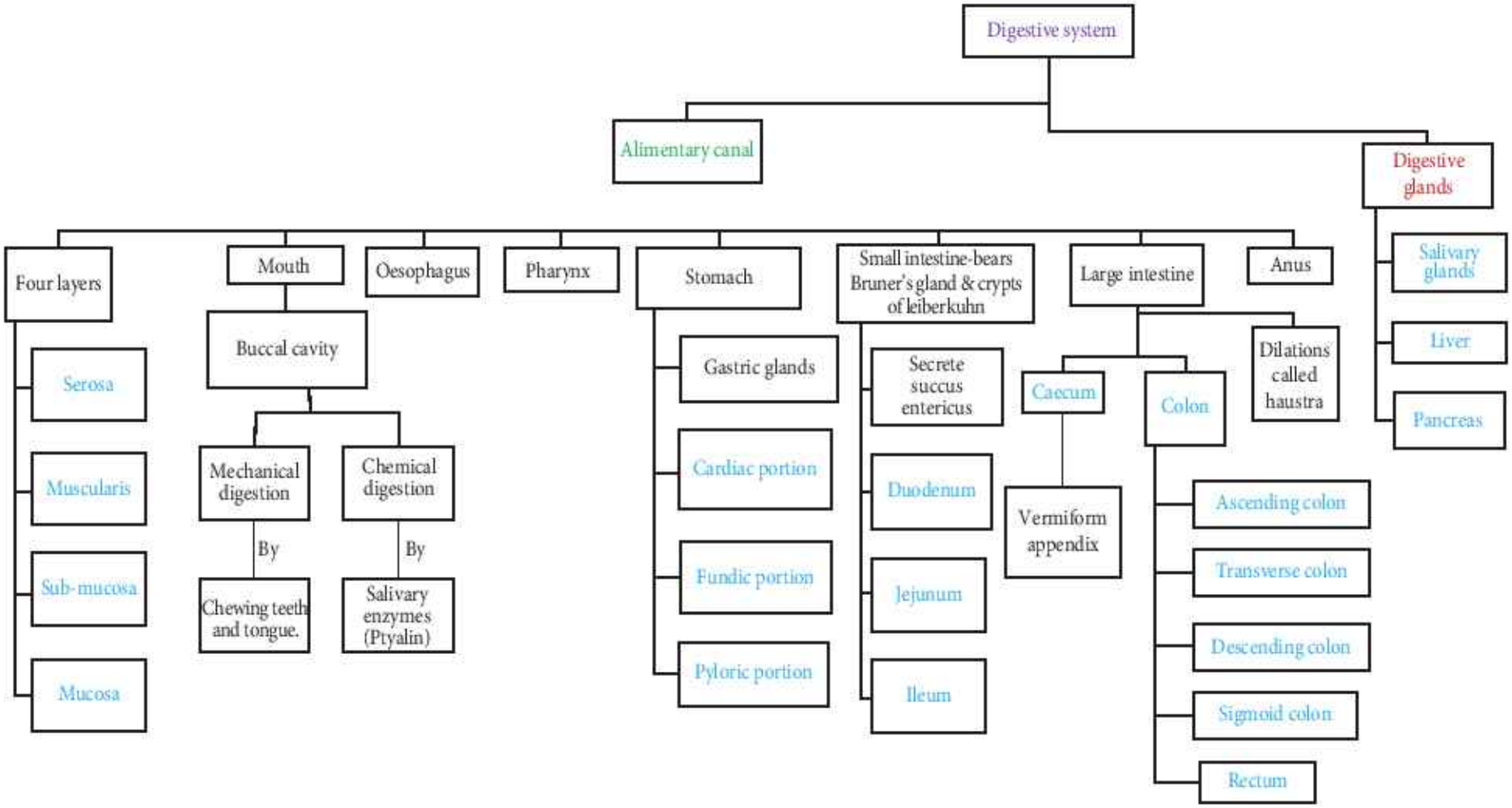
## Concept Map



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## ICT Corner

### Let's Digest

Let's explore the activity to know process of **digestion**.

**Step – 1**

Use the URL to open the 'Interactive Digestive System' page. Click the 'View Digestive System'.

**Step – 2**

Roll the mouse over the interactive diagram and place the cursor on any of the parts to learn about the parts.

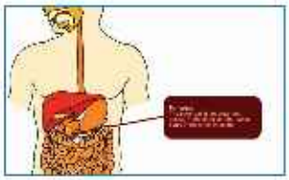
**Step – 3**

Click the 'Explore the digestive system' to observe the process of digestion right from the mouth to the anus.

**Step – 4**

During the exploration, questions will be asked and only correct answers will lead you to proceed. Answer all the questions and finish the process of digestion.

Step 1



Step 2

Step 3

Step 4

Explore your digestive system'sURL:

http://www.open.edu/openlearn/nature-environment/natural-history/explore-your-digestive-system

BUVE5

* Pictures are indicative only



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UNIT III

# Chapter 6

# Respiration

## Chapter Outline


6.1 Respiratory function

6.2 Respiratory organs in various organisms

6.3 Mechanism of breathing

6.4 Exchange of gases

6.5 Transport of gases

6.6 Regulation of respiration

6.7 Problems in oxygen transport

6.8 Disorders of the respiratory system

6.9 Effects of smoking

Exercise increases the rate and depth of breathing and supplies extra oxygen to the muscles and removes more $CO_2$ from the tissues.

## Learning Objectives:

- *Learns to describe the gross structure of the human gaseous exchange system*
- *Observes and draws the tissues and organs associated with the respiratory system*
- *Understands the process of gaseous exchange and transport of respiratory gases*
- *Knows the problems associated with oxygen transport*
- *Gains knowledge on the ill-effects of smoking.*

We inhale and exhale air. Why is breathing so important for life? What happens when we breathe? Why energy is required for the body to perform various life processes? Where does the energy come from? We eat food for energy. Though the above raised questions look disconnected, we should know that the process of breathing is connected to the process of release of energy from food. Oxygen is utilized by the organisms to breakdown the biomolecules like glucose and to derive energy. During this breakdown carbondioxide, which is a harmful gas is also released. It is very obvious that oxygen has to be provided to cells continuously and the $CO_2$ to be released immediately by the cells. So the need of a respiratory system is essential for life.



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We have discussed in the previous chapter how food provides energy for growth and repair of tissues. As mentioned earlier along with food, oxygen is necessary for breakdown of glucose to energy. In this chapter we shall discuss the respiratory organs of human, the mechanism of breathing, exchange and transport of gases and a few respiratory disorders.

The term respiration refers to the exchange of oxygen and carbondioxide between environment and cells of our body where organic nutrients are broken down enzymatically to release energy.

## 6.1 Respiratory Functions

The five primary functions of the respiratory system are –

i. To exchange $O_2$ and $CO_2$ between the atmosphere and the blood.
ii. To maintain homeostatic regulation of body pH.
iii. To protect us from inhaled pathogens and pollutants.
iv. To maintain the vocal cords for normal communication (vocalization).
v. To remove the heat produced during cellular respiration.

## 6.2 Respiratory Organs in various Organisms

Different animals have different organs for exchange of gases, depending upon their habitats and levels of organization. The amount of dissolved oxygen is very low in water compared to the amount of oxygen in the air. So the rate of breathing in aquatic organisms is much faster than land animals.

In animals like sponges, coelenterates and flatworms exchange of gases takes place through the body surface by simple diffusion. Earthworms use their moist skin, whereas insects have tracheal tubes. Gills are used as respiratory organs in most of the aquatic Arthropods and Molluscs. Among vertebrates, fishes use gills whereas amphibians, reptiles, birds and mammals have well vascularised lungs. Frogs spend most of their time in water and also use their moist skin for respiration along with lungs and bucco pharynx

### 6.2.1 Human Respiratory System

The respiratory system includes external nostrils, nasal cavity, pharynx, larynx, trachea, bronchi and bronchioles and lungs which contain **alveoli** (Figure 6.1). The parts starting from the external nostrils up to the terminal bronchioles constitute the conducting zone, whereas the alveoli and the ducts are called the respiratory zone. The parts of the conducting zone, humidifies and warms the incoming air.

In human beings, air enters the upper respiratory tract through the external nostrils. The air passing through the nostrils is filtered by fine hairs and mucus lining the passage. The external nostrils lead to the nasal chamber which opens into the nasopharynx which opens through the glottis of the larynx region into the trachea. The ciliated epithelial cells lining the trachea, bronchi and bronchioles secrete mucus. **Mucus membrane** lining the airway contains **goblet cells** which secrete mucus, a slimy material rich in glycoprotein. Microorganisms and dust particles attach in the mucus films and are carried upwards to pass down the



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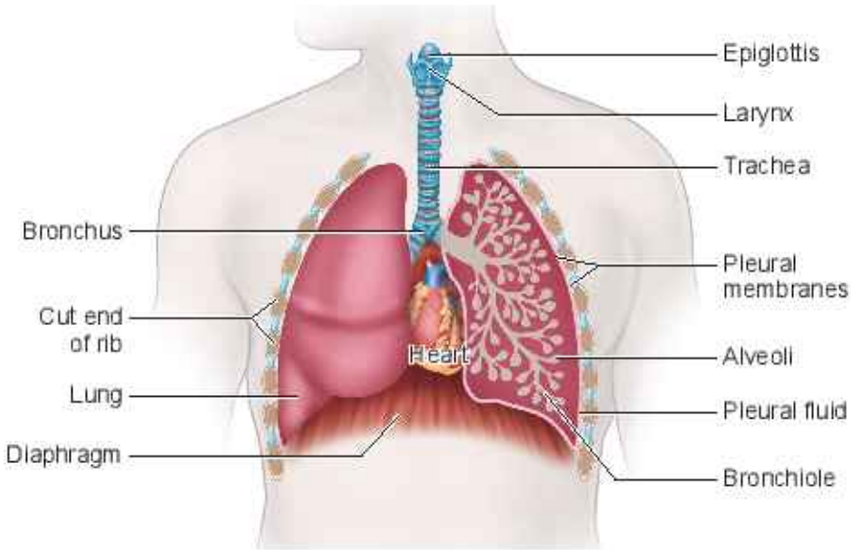


**Figure 6.1** The Human Respiratory System

gullet during normal swallowing. During swallowing a thin elastic flap called epiglottis prevents the food from entering into the larynx and avoids choking of food.

The trachea is semiflexible tube supported by multiple cartilaginous rings which extends up to the midthoracic cavity and at the level of the 5$^{th}$ thoracic vertebra where it divides into right and left primary bronchi, one bronchus to each lung. Within the lungs the bronchi divides repeatedly into secondary and tertiary bronchi and further divides into terminal bronchioles and respiratory bronchioles.

Bronchi have 'C' shaped curved cartilage plates to ensure that the air passage does not collapse or burst as the air pressure changes during breathing. The bronchioles are without cartilaginous rings and have rigidity that prevent them from collapsing but are surrounded by smooth muscle which contracts or relaxes to adjust the diameter of these airways.

The fine respiratory bronchioles terminate into highly vascularised thin walled pouch like air sacs called alveoli meant for gaseous exchange (Figure 6.2, 6.3). The diffusion membrane of alveolus is made up of three layers – the thin squamous epithelial cells of the alveoli, the endothelium of the alveolar capillaries and the basement substance found in between them. The thin squamous epithelial cells of the **alveoli** are composed of Type I and Type II cells. Type I cells are very thin so that gases can diffuse rapidly through them. Type II cells are thicker, synthesize and secrete a substance called **Surfactant**.

The lungs are light spongy tissues enclosed in the thoracic cavity surrounded by an airtight space. The thoracic cavity is bound dorsally by the vertebral column and ventrally by the sternum, laterally by the ribs and on the lower side by the dome shaped diaphragm.

The lungs are covered by double walled pleural membrane containing a several layers of elastic connective tissues and capillaries, which encloses the pleural fluid. Pleural fluid reduces friction when the lungs expand and contract.

**Characteristic Features of Respiratory Surface:**

- surface area must be very large and richly supplied with blood vessels
- should be extremely thin and kept moist
- should be in direct contact with the environment
- should be permeable to respiratory gases



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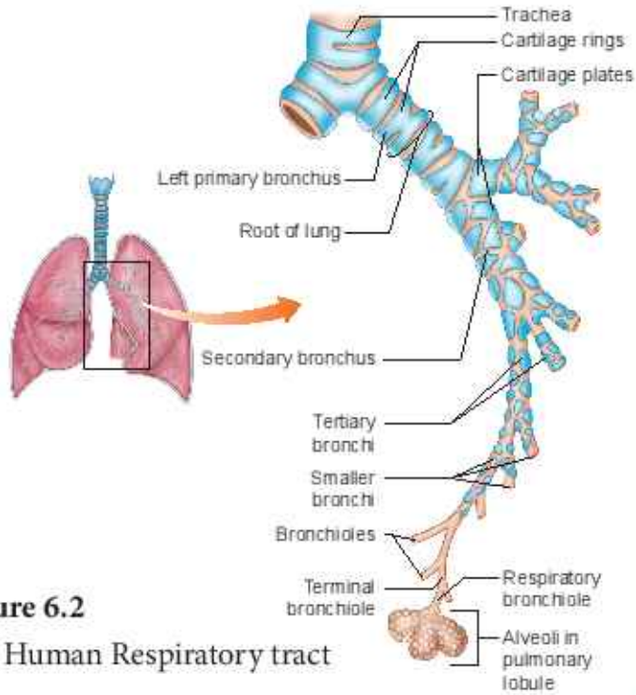


**Figure 6.2**
The Human Respiratory tract

**SURFACTANTS** are the thin non-cellular films made of protein and phospholipids covering the alveolar membrane. The surfactant lowers the surface tension in the alveoli and prevents the lungs from collapsing. It also prevents pulmonary oedema. Premature Babies have low levels of surfactant in the alveoli may develop the new born respiratory distress syndrome (NRDS) because the synthesis of surfactants begins only after the 25th week of gestation.

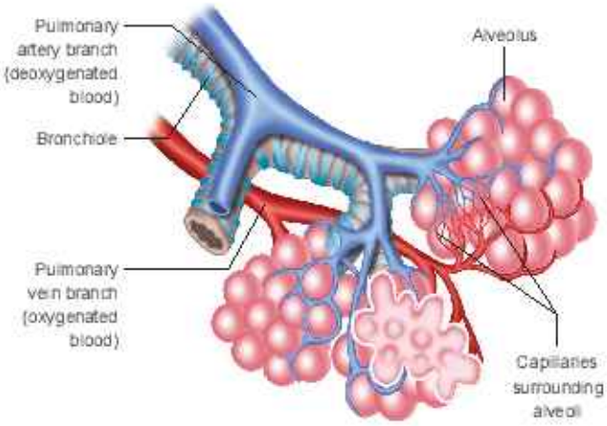


**Figure 6.3** Structure of Alveoli

The steps involved in respiration are

i. The exchange of air between the atmosphere and the lungs.

ii. The exchange of $O_2$ and $CO_2$ between the lungs and the blood.

iii. Transport of $O_2$ and $CO_2$ by the blood.

iv. Exchange of gases between the blood and the cells.

v. Uptake of $O_2$ by the cells for various activities and the release of $CO_2$.

## 6.3 Mechanism of Breathing

The movement of air between the atmosphere and the lungs is known as ventilation or breathing. Inspiration and expiration are the two phases of breathing. Inspiration is the movement of atmospheric air into the lungs and expiration is the movement of alveolar air that diffuse out of the lungs. (Figure 6.4)

Lungs do not contain muscle fibres but expands and contracts by the movement of the ribs and diaphragm. The diaphragm is a sheet of tissue which separates the thorax from the abdomen. In a relaxed state, the diaphragm is domed shaped. Ribs are moved by the intercostal muscles. External and internal intercostal muscles found between the ribs and the diaphragm helps in creating pressure gradients. Inspiration occurs if the pressure inside the lungs (intrapulmonary pressure) is less than the atmospheric pressure likewise expiration takes place when the pressure within the lungs is higher than the atmospheric pressure.



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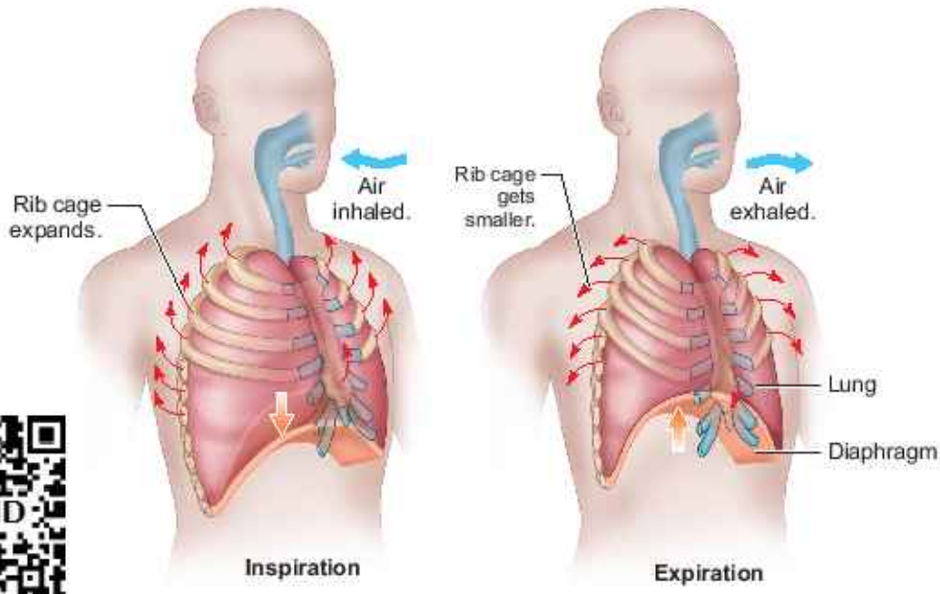


**Figure 6.4** Mechanism of Breathing

**Events in Inspiration and Expiration**

| Inspiration | Expiration |
|---|---|
| Respiratory centre initiates the stimuli during inspiration. ↓ The diaphragm and external intercostal muscles contract. ↓ The thoracic volume increases as the chest wall expands. ↓ The intra pulmonary pressure is reduced. ↓ The alveolar pressure decreases than the atmospheric pressure ↓ Air is taken inside due to expansion of alveoli. ↓ Air flows into the alveoli until the alveolar pressure equalizes the atmospheric pressure and the alveoli get inflated. | Respiratory centre terminates the stimuli during expiration. ↓ The diaphragm relax but internal intercostal muscles contract. ↓ The thoracic volume decreases as the chest wall contracts. ↓ The intra pulmonary pressure is increased. ↓ The alveolar pressure increases than the atmospheric pressure. ↓ Air is sent out due to the contraction of alveoli. ↓ Air flows out of the alveoli until the alveolar pressure equalizes the atmospheric pressure and the alveoli get deflated. |



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Inspiraton is initiated by the contraction of the diaphragm muscles and external intercostal muscles, which pulls the ribs and sternum upwards and outwards and increases the volume of the thoracic chamber in the dorso–ventral axis, forcing the lungs to expand the pulmonary volume. The increase in pulmonary volume and decrease in the intrapulmonary pressure forces the fresh air from outside to enter the air passages into the lungs to equalize the pressure. This process is called **inspiration.**

Relaxation of the diaphragm allows the diaphragm and sternum to return to its dome shape and the internal intercostal muscles contract, pulling the ribs downward reducing the thoracic volume and pulmonary volume. This results in an increase in the intrapulmonary pressure slightly above the atmospheric pressure causing the expulsion of air from the lungs. This process is called **expiration.**

On an average, a healthy human breathes 12–16 times/minute. An instrument called **Spirometer** is used to measure the volume of air involved in breathing movements for clinical assessment of a person's pulmonary function.

You are at high level in a mountain above the sea level. Suddenly you get palpitation and nausea. What condition are you suffering from? What are the other symptoms for this disease and how can it be reduced?

### 6.3.1 Respiratory Volumes and Capacities

The volume of air present in various phases of respiration is denoted as

**Respiratory Volumes:** (Figure 6.5)

- **Tidal Volume (TV)** Tidal volume is the amount of air inspired or expired with each normal breath. It is approximately 500 mL., i.e. a normal human adult can inspire or expire approximately 6000 to 8000mL of air per minute. During vigorous exercise, the tidal volume is about 4–10 times higher.
- **Inspiratory Reserve volume (IRV)** Additional volume of air a person can inspire by forceful inspiration is called Inspiratory Reserve Volume. The normal value is 2500–3000 mL.
- **Expiratory Reserve volume (ERV)** Additional volume of air a person can forcefully exhale by forceful expiration is called Expiratory Reserve Volume. The normal value is 1000–1100 mL.
- **Residual Volume (RV)** The volume of air remaining in the lungs after a forceful expiration. It is approximately 1100–1200 mL.

**Respiratory Capacities:**

- **Vital capacity (VC)** the maximum volume of air that can be moved out during a single breath following a maximal inspiration. A person first inspires maximally then expires maximally. VC = ERV+TV+IRV
- **Inspiratory capacity (IC)** The total volume of air a person can inhale after normal expiration. It includes tidal volume and inspiratory reserve volume. IC = TV+IRV
- **Expiratory capacity (EC)** The total volume of air a person can exhale after normal inspiration. It includes



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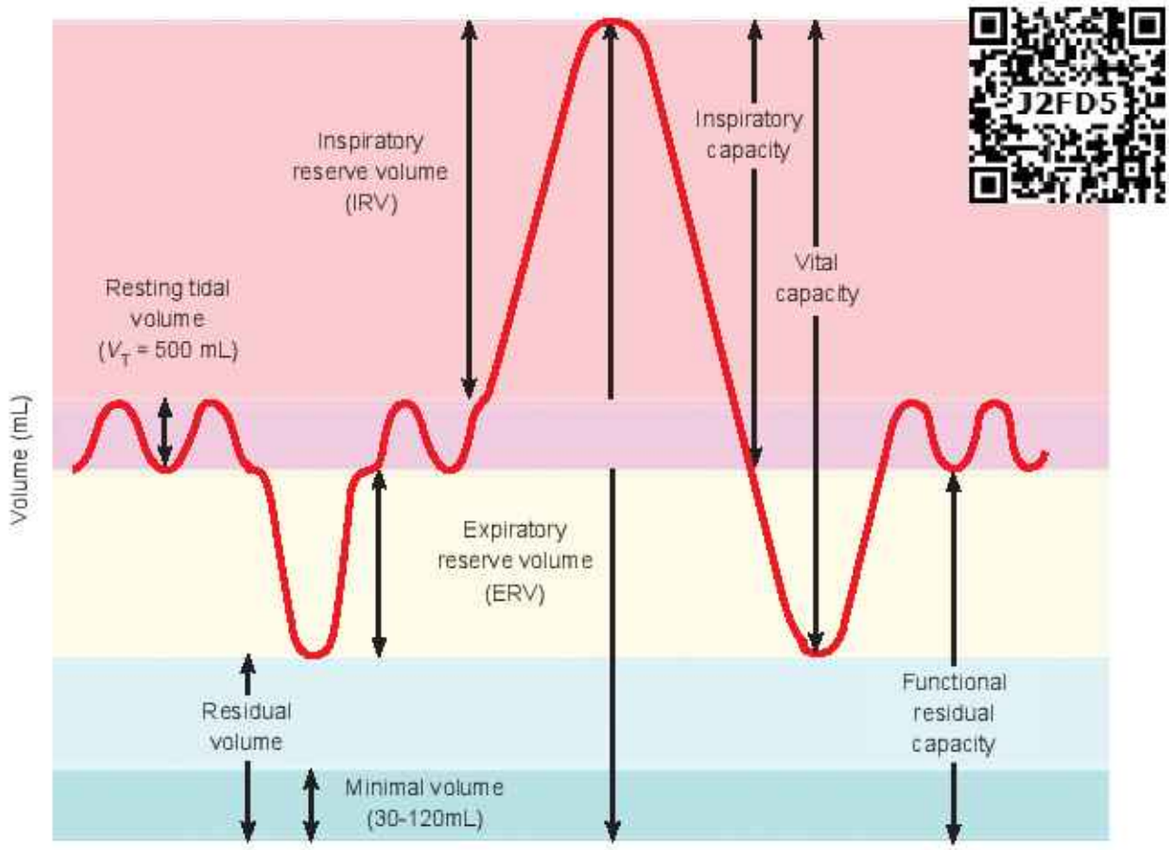


**Figure 6.5** Lung Volumes and Capacity

tidal volume and expiratory reserve volume. EC=TV+ERV

- **Total Lung Capacity (TLC)** The total volume of air which the lungs can accommodate after forced inspiration is called Total Lung Capacity. This includes the vital capacity and the residual volume. It is approximately 6000mL. TLC=VC+RV
- **Minute Respiratory Volume** The amount of air that moves into the respiratory passage per minute is called minute respiratory volume.

  Normal TV = 500mL; Normal respiratory rate = 12 times/minute

  Therefore, minute respiratory volume = 6 Litres/minute (for a normal healthy man).

***Why do some people snore?*** – Breathing with a hoarse sound during sleep is caused by the vibration of the soft palate. Snoring is caused by a partially closed upper air way (nose and throat) which becomes too narrow for enough air to travel through the lungs. This makes the surrounding tissues to vibrate and produces the snoring sound.

Healthy lungs contain large amounts of elastic connective tissue around the alveoli, containing elastin, which makes the lung tissue elastic. People with emphysema and bronchitis have difficulty in exhaling because the enzyme elastase destroys the elastin around the alveoli and reduces the elasticity of the lungs.



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### Dead Space

Some of the inspired air never reaches the gas exchange areas but fills the respiratory passages where exchange of gases does not occur. This air space is called dead space.

Dead space is not involved in gaseous exchange. It amounts to approximately 150mL.

## 6.4 Exchange of Gases

The primary site for the exchange of gases is the alveoli. The uptake of $O_2$ and the release of $CO_2$ occur between the blood and tissues by simple diffusion driven by partial pressure gradient of $O_2$ and $CO_2$. Partial pressure is the pressure contributed by an individual gas in a mixture of gases. It is represented as $pO_2$ for oxygen and $pCO_2$ for carbon–dioxide. Due to pressure gradients, $O_2$ from the alveoli enters into the blood and reaches the tissues. $CO_2$ enters into the blood from the tissues and reaches alveoli for elimination. As the solubility of $CO_2$ is 20–25 times higher than that of $O_2$, the partial pressure of $CO_2$ is much higher than that of $O_2$ (Table 6.1 and Figure 6.6).

### Respiratory Pigments

#### Haemoglobin

Haemoglobin belongs to the class of conjugated protein. The iron containing pigment portion haem constitutes only 4% and the rest colourless protein globin belongs to histone class. Haemoglobin has a molecular weight of 68,000 daltons and contains four atoms of iron, each of which can combine with a molecule of oxygen.

#### Methaemoglobin

If the iron component of the haem is in the ferric state, than the normal ferrous state, it is called methaemoglobin. Methaemoglobin does not bind with $O_2$. Normally RBC contains less than 1% methaemoglobin.

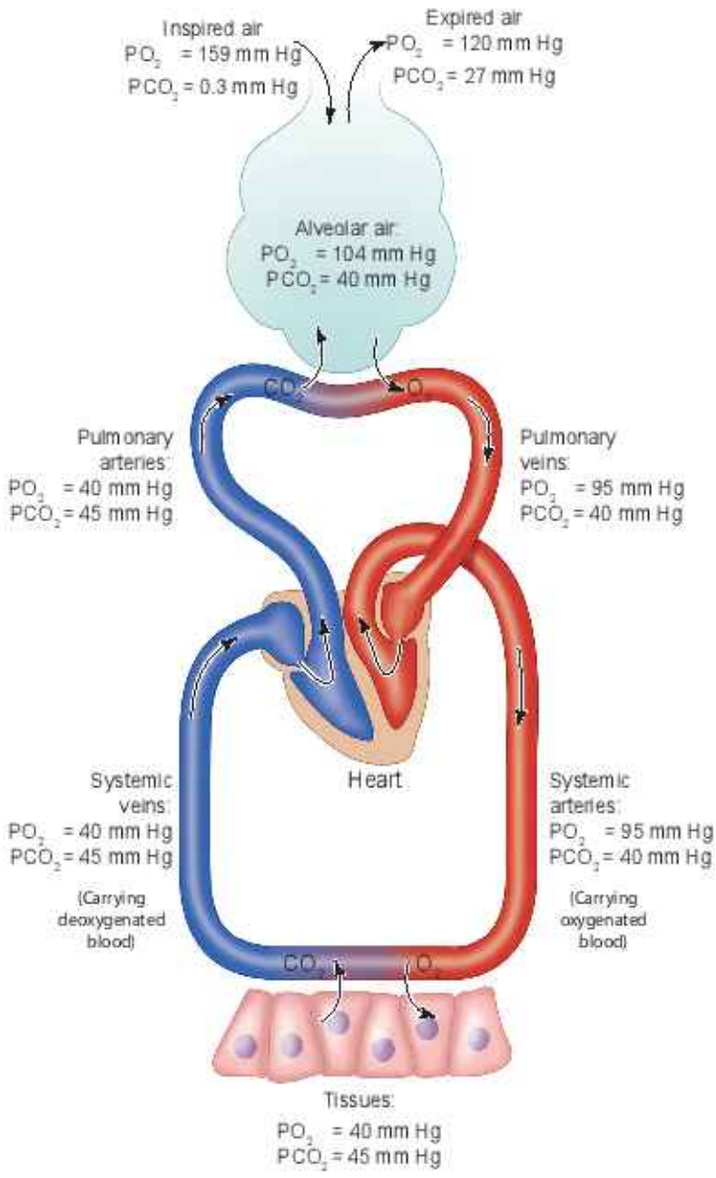


**Figure 6.6** Exchange of Gases at the Alveolus and the Tissue with blood and transport of Oxygen and Carbondioxide



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| Respiratory gases | Partial pressure mm Hg | | | | |
|---|---|---|---|---|---|
| | Atmospheric air | Alveoli | Deoxygenated Blood | Oxygenated blood | Tissues |
| $O_2$ | 159 | 104 | 40 | 95 | 40 |
| $CO_2$ | 0.3 | 40 | 45 | 40 | 45 |

**Table 6.1** Partial pressure of Oxygen and Carbon dioxide (in mmHg) in comparison to those gases in the atmosphere

## 6.5 Transport of Gases

### 6.5.1 Transport of Oxygen

Molecular oxygen is carried in blood in two ways bound to haemoglobin within the red blood cells and dissolved in plasma. Oxygen is poorly soluble in water, so only 3% of the oxygen is transported in the dissolved form. 97% of oxygen binds with haemoglobin in a reversible manner to form oxyhaemoglobin ($HbO_2$). The rate at which haemoglobin binds with $O_2$ is regulated by the partial pressure of $O_2$. Each haemoglobin carries maximum of four molecules of oxygen. In the alveoli high $pO_2$, low $pCO_2$, low temperature and less $H^+$ concentration, favours the formation of oxyhaemoglobin, whereas in the tissues low pO2, high $pCO_2$, high $H^+$ and high temperature favours the dissociation of oxygen from oxyhaemoglobin.

Breathing through nose is healthier than through mouth– Why?

A **sigmoid curve** (S–shaped) is obtained when percentage saturation of haemoglobin with oxygen is plotted against $pO_2$. This curve is called **oxygenhaemoglobin dissociation curve** (Figure 6.7). This S–shaped curve has a steep slope for $pO_2$ values between 10 and 50 mmHg and then flattens between 70 and 100 mm Hg.

Under normal physiological conditions, every 100mL of oxygenated blood can deliver about 5mL of $O_2$ to the tissues.

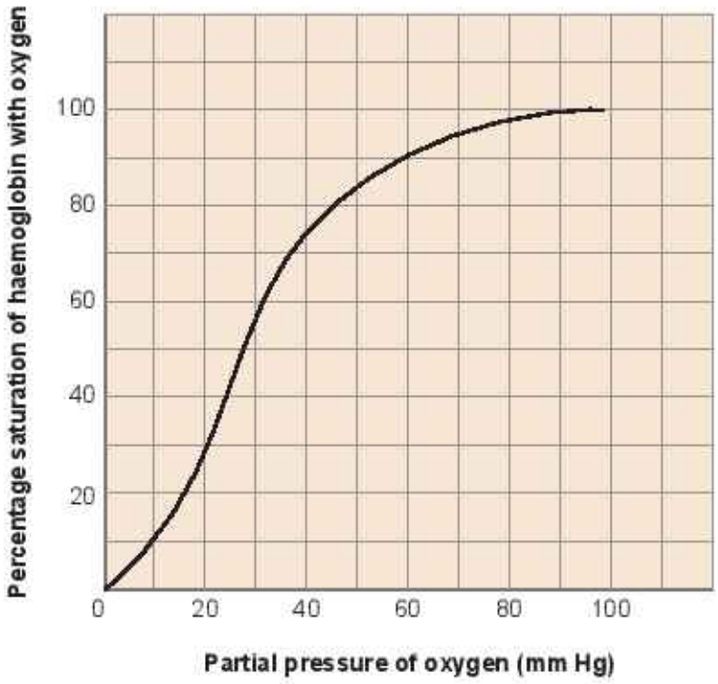


**Figure 6.7** Oxygen dissociation curve

### 6.5.2 Transport of Carbon–dioxide

Blood transports $CO_2$ from the tissue cells to the lungs in three ways



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i. **Dissolved in plasma** About 7 – 10% of $CO_2$ is transported in a dissolved form in the plasma.

ii. **Bound to haemoglobin** About 20 – 25% of dissolved $CO_2$ is bound and carried in the RBCs as carbaminohaemoglobin (Hb $CO_2$)

$$CO_2 + Hb \rightleftharpoons Hb\,CO_2$$

iii. **As bicarbonate ions in plasma** about 70% of $CO_2$ is transported as bicarbonate ions

This is influenced by $pCO_2$ and the degree of haemoglobin oxygenation. RBCs contain a high concentration of the enzyme, carbonic anhydrase, whereas small amounts of carbonic anhydrase is present in the plasma.

At the tissues the $pCO_2$ is high due to catabolism and diffuses into the blood to form $HCO_3^-$ and $H^+$ ions. When $CO_2$ diffuses into the RBCs, it combines with water forming carbonic acid ($H_2CO_3$) catalyzed by carbonic anhydrase. Carbonic acid is unstable and dissociates into hydrogen and bicarbonate ions.

Carbonic anhydrase facilitates the reaction in both directions.

$$CO_2 + H_2O \underset{}{\overset{\text{carbonic anhydrase}}{\rightleftharpoons}} H_2CO_3$$

$$H_2CO_3 \underset{}{\overset{\text{carbonic anhydrase}}{\rightleftharpoons}} HCO_3^- + H^+$$

The $HCO_3^-$ moves quickly from the RBCs into the plasma, where it is carried to the lungs. At the alveolar site where $pCO_2$ is low, the reaction is reversed leading to the formation of $CO_2$ and water. Thus $CO_2$ trapped as $HCO_3^-$ at the tissue level is transported to the alveoli and released out as $CO_2$. Every 100mL of deoxygenated blood delivers 4mL of $CO_2$ to the alveoli for elimination.

## 6.6 Regulation of Respiration

A specialised respiratory centre present in the medulla oblongata of the hind brain called **respiratory rhythm centre** is responsible for this regulation. **Pneumotaxic centre** present in pons varoli region of the brain moderates the function of the respiratory rhythm centre to ensure normal breathing. The chemosensitive area found close to the rhythm centre is highly sensitive to $CO_2$ and $H^+$. And $H^+$ are eliminated out by respiratory process. Receptors associated with the aortic arch and carotid artery send necessary signals to the rhythm centre for remedial action. The role of $O_2$ is insignificant in the regulation of respiratory rhythm.

**Particulate matter PM** 2.5 in the air is increasing day by day which causes respiratory illness. Central Pollution Control Board (CPCB) reports that the quality of air is not good due to soot and smoke. So some cities in India are using CNG (Compressed Natural Gas) as fuel.

## 6.7 Problems in Oxygen Transport

When a person travels quickly from sea level to elevations above 8000ft, where the atmospheric pressure and partial pressure of oxygen are lowered, the individual responds with symptoms of **acute mountain sickness** (AMS)– headache, shortness of breath, nausea and dizziness due to poor binding of $O_2$ with haemoglobin. When the person moves on a long–term basis to mountains from sea level, the body begins to make respiratory



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and haematopoietic adjustments. To overcome this situation kidneys accelerate production of the hormone erythropoietin, which stimulates the bone marrow to produce more RBCs.

When a person descends deep into the sea, the pressure in the surrounding water increases which causes the lungs to decrease in volume. This decrease in volume increases the partial pressure of the gases within the lungs. This effect can be beneficial, because it tends to drive additional oxygen into the circulation, but this benefit also has a risk, the increased pressure can also drive nitrogen gas into the circulation. This increase in blood nitrogen content can lead to a condition called **nitrogen narcosis.** When the diver ascends to the surface too quickly a condition called **'bends' or decompression sickness** occurs and nitrogen comes out of solution while still in the blood forming bubbles. Small bubbles in the blood are not harmful, but large bubbles can lodge in small capillaries, blocking blood flow or can press on nerve endings. Decompression sickness is associated with pain in joints and muscles and neurological problems including stroke. The risk of nitrogen narcosis and bends is common in **scuba divers**.

**Allergy** is caused by allergens. When we enter a polluted area, immediately we start sneezing and coughing. The allergens in that place affect our respiratory tracts and the responses to the allergens start within minutes. Allergens provoke an inflammatory response. A common manifestation of allergy is Asthma.

During carbon–dioxide poisoning, the demand for oxygen increases. As the $O_2$ level in the blood decreases it leads to suffocation and the skin turns bluish black.

## 6.8 Disorders of the Respiratory System

Respiratory system is highly affected by environmental, occupational, personal and social factors. These factors may be responsible for a number of respiratory disorders. Some of the disorders are discussed here.

### Asthma

It is characterized by narrowing and inflammation of bronchi and bronchioles and difficulty in breathing. Common allergens for asthma are dust, drugs, pollen grains, certain food items like fish, prawn and certain fruits etc.

### Emphysema

Emphysema is chronic breathlessness caused by gradual breakdown of the thin walls of the alveoli decreasing the total surface area of a gaseous exchange. i.e., widening of the alveoli is called emphysema. The major cause for this disease is cigarette smoking, which reduces the respiratory surface of the alveolar walls.

### Bronchitis

The bronchi when it gets inflated due to pollution smoke and cigarette smoking, causes bronchitis. The symptoms are cough, shortness of breath and sputum in the lungs.

### Pneumonia

Inflammation of the lungs due to infection caused by bacteria or virus is called pneumonia. The common symptoms are sputum production, nasal congestion, shortness of breath, sore throat etc.



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### Tuberculosis

Tuberculosis is caused by *Mycobacterium tuberculae*. This infection mainly occurs in the lungs and bones. Collection of fluid between the lungs and the chest wall is the main complication of this disease.

### Occupational Respiratory Disorders

The disorders due to one's occupation of working in industries like grinding or stone breaking, construction sites, cotton industries, etc. Dust produced affects the respiratory tracts.

Long exposure can give rise to inflammation leading to fibrosis. **Silicosis** and **asbestosis** are occupational respiratory diseases resulting from inhalation of particle of silica from sand grinding and asbestos into the respiratory tract. Workers, working in such industries must wear protective masks.

## 6.9 Effects of Smoking

Today due to curiosity, excitement or adventure youngsters start to smoke and later get addicted to smoking. Research says about 80% of the lung cancer is due to cigarette smoking.

Smoking is inhaling the smoke from burning tobacco. There are thousands of known chemicals which includes nicotine, tar, carbon monoxide, ammonia, sulphur–dioxide and even small quantities of arsenic. Carbon monoxide and nicotine damage the cardiovascular system and tar damages the gaseous exchange system. Nicotine is the chemical that causes addiction and is a stimulant which makes the heart beat faster and the narrowing of blood vessels results in raised blood pressure and coronary heart diseases. Presence of carbon monoxide reduces oxygen supply. Lung cancer, cancer of the mouth and larynx is more common in smokers than non–smokers. Smoking also causes cancer of the stomach, pancreas and bladder and lowers sperm count in men.

Smoking can cause lung diseases by damaging the airways and alveoli and results in emphysema and chronic bronchitis. These two diseases along with asthma are often referred as **Chronic Obstructive Pulmonary Disease** (COPD). When a person smokes, nearly 85% of the smoke released is inhaled by the smoker himself and others in the vicinity, called **passive smokers**, are also affected. Guidance or counselling should be done in such users to withdraw this habit.

## Summary

The process of intake of oxygen rich air and giving out of air rich in carbon dioxide is generally called respiration. Pollutants and microorganisms are filtered from the inspired air by the hair and mucus present in the nostrils. The two main steps in the mechanism of respiration are inspiration and expiration which takes place due to pressure gradient in the atmosphere and lungs.

$O_2$ is transported in blood in dissolved form and is also bound to haemoglobin. One molecule of haemoglobin can bind four molecules of $O_2$. The Sigmoid shape of the $O_2$ haemoglobin dissociative curve shows increased affinity for each $O_2$ molecule.

$CO_2$ is transported in blood in dissolved form as carbamino haemoglobin and as $H_2CO_3$. It is produced in RBCs from $CO_2$ and water catalysed by carbonic anhydrase. Breathing is controlled by medullary respiratory centre.



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Respiratory volumes and capacities indicate the amount of air inspired and expired during normal respiration. Our respiratory system can be affected by pollutants, pathogens and other chemical substances found in air. Lung cancer and emphysema cannot be cured and these diseases are common among cigarette smokers.

People at higher level than the sea level are prompted to altitude sickness as the barometric pressure is low in those regions. Surfactant, emphysema, Asthma and Dead space have been discussed. During vigorous exercise the rate of respiration increases.

## Evaluation

1. Breathing is controlled by
   a. cerebrum
   **b. medulla oblongata**
   c. cerebellum
   d. pons
2. Intercostal muscles are found between the
   a. vertebral column b. sternum
   **c. ribs** d. glottis
3. The respiratory structures of insects are
   **a. tracheal tubes** b. gills
   c. green glands d. lungs
4. Asthma is caused due to
   **a. inflammation of bronchus and bronchioles.**
   b. inflammation of bronchione
   c. damage of diaphragm.
   d. infection of lungs
5. The Oxygen Dissociation Curve is
   **a. sigmoid**
   b. straight line
   c. curved
   d. rectangular hyperbola
6. The Tidal Volume of a normal person is
   a. 800 mL b. 1200 mL
   **c. 500 mL** d. 1100 – 1200 mL
7. During inspiration, the diaphragm
   a. expands.
   b. unchanged
   c. relaxes to become domed–shaped.
   **d. contracts and flattens**
8. $CO_2$ is transported through blood to lungs as
   a. carbonic acid
   b. oxyhaemoglobin
   **c. carbamino haemoglobin**
   d. carboxy haemoglobin
9. When 1500 mL air is in the lungs, it is called
   **a. vital capacity**
   b. tidal volume
   c. residual volume
   d. inspiratory reserve volume
10. Vital capacity is
    a. TV + IRV b. TV + ERV
    c. RV + ERV **d. TV + IRV + ERV**
11. After a long deep breath, we do not respire for some seconds due to
    a. more $CO_2$ in the blood
    **b. more $O_2$ in the blood**
    c. less $CO_2$ in the blood
    d. less $O_2$ in the blood
12. Which of the following substances in tobacco smoke damage the gas exchange system?
    a. carbon monoxide and carcinogens
    b. carbon monoxide and nicotine
    **c. carcinogens and tar**
    d. nicotine and tar
13. Column I represents diseases and column II represents their symptoms. Choose the correctly paired option



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| Column I | Column II |
|---|---|
| (P) Asthma | (i) Recurring of bronchitis |
| (Q) Emphysema | (ii) Accumulation of W.B.C in alveolus |
| (R) Pneumonia | (iii) Allergy |

**a. P = iii, Q = ii, R = i**
b. P = iii, Q = i, R = ii
c. P = ii, Q = iii, R = i
d. P = ii, Q = i, R = iii

14. Which of the following best describes the process of gas exchange in the lungs?
    a. Air moves in and out of the alveoli during breathing.
    b. Carbon dioxide diffuses from deoxygenated blood in capillaries into the alveolar air.
    **c. Oxygen and carbon dioxide diffuse down their concentration gradients between blood and alveolar air.**
    d. Oxygen diffuses from alveolar air into deoxygenated blood.

15. Make the correct pairs.

| Columan–I | Column–II |
|---|---|
| (P) IC | i. maximum volume of air breathed in after forced inspiration. |
| (Q) EC | ii. Volume of air present after expiration in lungs. |
| (R) VC | iii. Volume of air inhaled after expiration. |
| (S) FRC | iv. Volume of air present after inspiration in lungs. |

(a) P – i , Q – ii , R – iii , S – iv
(b) P – ii , Q – iii , R – iv , S – i
(c) P – ii , Q – iii , R – i , S – iv
(d) P – iii , Q – iv , R – i , S – ii

16. Make the correct pairs.

| Column–I | Column–II |
|---|---|
| (P) Tidal volume | i. 1000 to 1100 ml |
| (Q) Residual volume | ii. 500 ml |
| (R) Expiratory reserve volume | iii. 2500 to 3000 ml |
| (S) Inspiratory reserve volume | iv. 1100 to 1200 ml |

**(a) P – ii , Q – iv , R – i , S – iii**
(b) P – iii , Q – ii , R – iv , S – i
(c) P – ii , Q – iv , R – iii , S – i
(d) P – iii , Q – iv , R – i , S – ii

17. Name the respiratory organs of flatworm, earthworm, fish, prawn, cockroach and cat.
18. Name the enzyme that catalyses the bicarbonate formation in RBCs.
19. Air moving from the nose to the trachea passes through a number of structures. List in order of the structures.
20. Which structure seals the larynx when we swallow?
21. Resistance in the airways is typically low. Why? Give two reasons.
22. How the body makes long–term adjustments when living in high altitude.
23. Why is pneumonia considered a dangerous disease?
24. Diffusion of gases occurs in the alveolar region only and not in any other part of the respiratory system. Discuss.
25. Sketch a flow chart to show the path way of air flow during respiration.
26. Explain the conditions which creates problems in oxygen transport.



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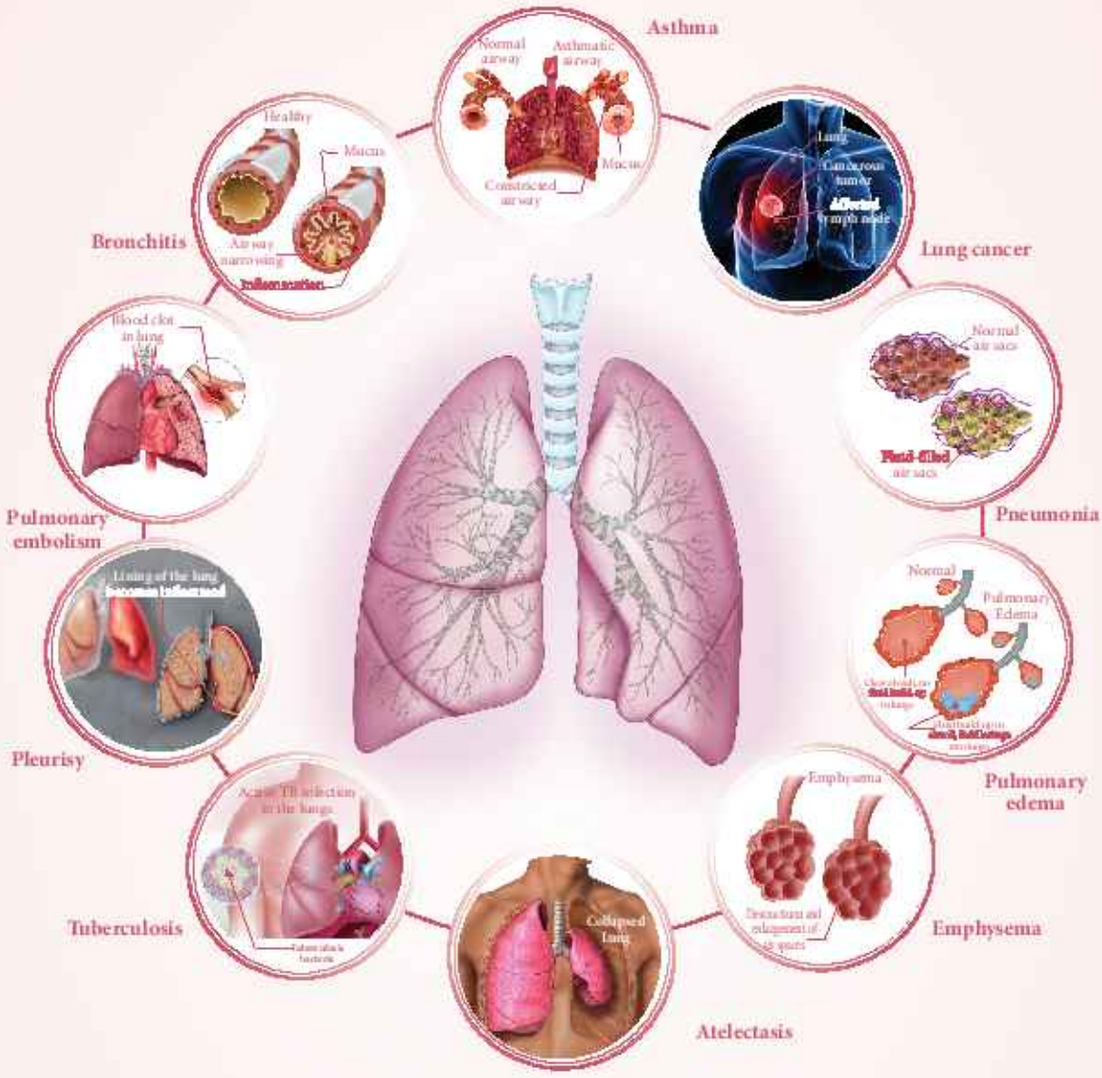
# Disorders of Respiratory System

**Respiratory system is highly affected by environmental, occupational, personal and social factors. These factors may be responsible for a number of respiratory disorders.**




- **Pulmonary embolism** is a blood clot that occurs in the lungs.
- **Bronchitis** **is an inflammation of the lining of your** bronchial tubes.
- **Asthma** is a condition in which airways narrow and swell and produce extra mucus.
- **Lung cancer** **-The number one cause of cancer** deaths. Smoking is the risk factor for lung cancer.
- **Pneumonia** **is an inflammatory condition of the lung affecting primarily the small air sacs known as** alveoli.
- **Pulmonary edema** **is a fluid accumulation in the** tissue and air spaces of the lungs.
- **Emphysema** A lung condition that causes shortness of breath due to widening of alveoli.
- **Atelectasis** is a collapse of a lung or lobe of a lung develops when alveoli within the lung become **deflated.**
- **Tuberculosis** is an infectious disease caused due to *Mycobacterium tuberculae* .
- **Pleurisy** is a condition in which the pleura becomes **inflamed.**



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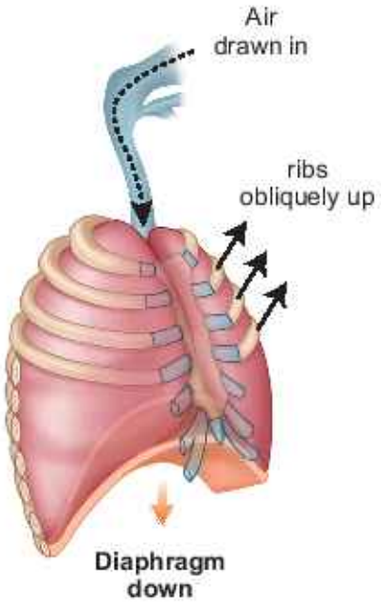
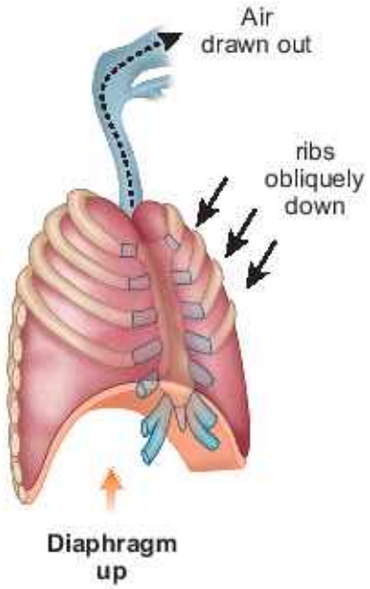
# Concept map

**Mechanism of Respiration**

- Inspiration and Expiration happens due to pressure changes in the thoracic cavity.
- By the contraction and expansion of diaphragm, external intercostal muscles and internal intercostal muscles the volume of the thoracic cavity is reduced or increased.
- The act of breathing is performed by expansion and contraction of the thoracic cavity.
- **INSPIRATION**
  - An active process by which fresh air is drawn into the lungs.
  - The contraction of external intercostal muscle causes the ribs to move anteriorly and outwardly.
  - The contraction of the diaphragm leads to flattening of inelastic, dome shaped central part of the diaphragm.
- **EXPIRATION**
  - A passive process by which air is exhaled from the lungs.
  - The diaphragm relaxes and rises to resume its original dome shape.
  - The ribs take their original position as a result of contraction of the internal intercostal muscles.



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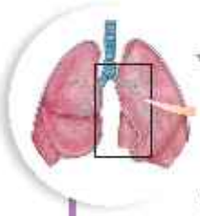
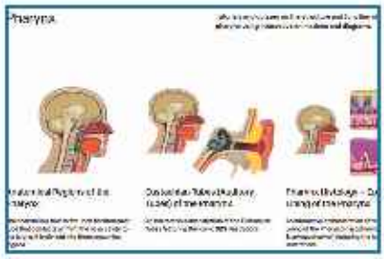
## ICT Corner

# Respire



Let's explore the anatomy and function of the **Respiratory system.**



**Step – 1**

Use the URL to reach the 'Respiratory System' page. In the grid select 'Nasal cavity' and explore its structure and the functions.

**Step – 2**

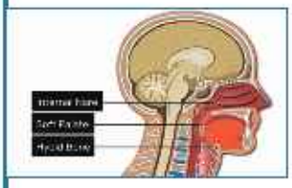
Now click back button on the top of the window or use the 'Backspace' key. Select 'Pharynx' from the grid and explore its anatomical regions.

**Step – 3**

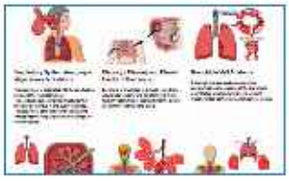
Follow the above steps to explore each part and its functions.

**Step – 4**

Use the reference given below the page to acquire additional details.



Step 1



Step 2

Step 3

Step 4

Respiratory System's URL:

https://www.getbodysmart.com/respiratory-system

Schematics of Gas exchange:

https://www.wisc-online.com/learn/general-education/anatomy-and-physiology2/ap2404/respiratory-system-gas-exchange

* Pictures are indicative only



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UNIT III **Chapter 7**

# Body Fluids and Circulation

**Chapter Outline**


7.1 Body fluids

7.2 Blood vessels – Arteries, Veins and capillaries

7.3 Circulatory path ways

7.4 Human circulatory system

7.5 Double circulation

7.6 Regulation of cardiac activity

7.7 Disorders of the circulatory system

7.8 Cardio pulmonary resuscitation (CPR)

Stroke volume is dependent on venous return

## Learning Objectives:

- *Understands the importance of body fluids.*
- *Identifies and describes the blood cells, different types of blood groups and blood coagulating factors.*
- *Differentiate the blood vessels and its properties*
- *Understands the human circulatory system.*
- *Understands the cardiac cycle and relate with the peaks of ECG.*
- *Identifies the disorders of circulatory system.*

Animals particularly larger animals like mammals, are more active. They depend on locomotion to find food which is an energy consuming process. Nervous system is required to coordinate activities by sending nerve impulses that involves energy. All living cells have to be supplied with nutrients, oxygen and other substances and have to remove $CO_2$ and waste products from them. It is therefore essential to have efficient mechanisms for transport of these substances to and from the cells. Different groups of animals have evolved different methods of transport. Very small organisms like the sponges and coelenterates lack a circulatory system. Water from their surroundings enters their body cavity to facilitate the cells to exchange substances by **diffusion**. More complex organisms use special fluids and well organized transport systems within their body to transport such materials by **bulk flow** or connective transport with pumps. The phenomenon of bulk flow is fundamental to many physiological processes like respiration, digestion and excretion. The bulk flow of fluids can transport substances to long distances faster than by diffusion. The



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human circulatory system can circulate a millilitre of blood from the heart to feet and back again within 60 sec, rather than 60 years which may be needed if it were by diffusion.

Within our body, the oxygen and carbon dioxide are exchanged in the lungs and tissues whereas nutrients from the digestive system are carried to the liver and the wastes from the tissues are carried by the blood and finally removed by the kidneys. The hormones are transported to their target organs. Circulatory system helps to maintain the homeostasis of the body fluids and body temperature (heat exchange).

The homeostatic regulation of the cardio-vascular system maintains blood flow, or perfusion, to the heart and brain. In vasovagal syncope (fainting), signals from the nervous system cause a sudden decrease in blood pressure, and the individual faints from lack of oxygen to the brain.

In this chapter you will learn how the heart and blood vessels work together most of the time to prevent such problems.

## 7.1 Body Fluids

The body fluid consists of water and substances dissolved in them. There are two types of body fluids, the intracellular fluid present inside the cells and the extracellular fluid present outside the cells. The three types of extracellular fluids are the **interstitial fluid** or tissue fluid (surrounding the cell), the **plasma** (fluid component of the blood) and **lymph**. The blood flowing into the capillary from an arteriole has a high hydrostatic pressure. This pressure is brought about by the pumping action of the blood and it tends to force water and small molecules out through the permeable walls of the capillary into the tissue fluid.

The volume of fluid which leaves the capillary to form tissue fluid is the result of two pressures (hydrostatic pressure and Colloidal Osmotic pressure). At the anterior end of the capillary bed, the water potential is lesser than hydrostatic pressure inside the capillary bed which is enough to push fluid into the tissues. The tissue fluid has low concentration of protein than that of plasma. At the venous end of the capillary bed, the water potential is greater than the hydrostatic pressure and the fluid from the tissues flows into the capillary and water is drawn back into the blood, taking with it waste products produced by the cells.

### Composition of Blood

Blood is the most common body fluid that transports substances from one part of the body to the other. Blood is a connective tissue consisting of plasma (fluid matrix) and formed elements. The plasma constitutes 55% of the total blood volume. The remaining 45% is the formed elements that consist of blood cells. The average blood volume is about 5000ml (5L) in an adult weighing 70 Kg.

### 7.1.1 Plasma

Plasma mainly consists of water (80-92%) in which the plasma proteins, inorganic constituents (0.9%), organic constituents (0.1%) and respiratory gases are dissolved. The four main types of plasma proteins synthesized in the liver are albumin, globulin, prothrombin and fibrinogen. **Albumin** maintains the osmotic pressure of the blood. **Globulin** facilitates the transport of ions, hormones, lipids and assists in



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immune function. Both **Prothrombin** and **Fibrinogen are** involved in blood clotting. **Organic constituents** include urea, amino acids, glucose, fats and vitamins and the **inorganic constituents** include chlorides, carbonates and phosphates of potassium, sodium, calcium and magnesium.

The composition of plasma is not always constant. Immediately after a meal, the blood in the hepatic portal vein has a very high concentration of glucose as it is transporting glucose from the intestine to the liver where it is stored. The concentration of the glucose in the blood gradually falls after sometime as most of the glucose is absorbed. If too much of protein is consumed, the body cannot store the excess amino acids formed from the digestion of proteins. The liver breaks down the excess amino acids and produces urea. Blood in the hepatic vein has a high concentration of urea than the blood in other vessels namely, hepatic portal vein and hepatic artery.

**Liver receives its blood supply from two sources:** the hepatic artery brings oxygenated blood from the heart, while the hepatic portal vein brings blood from the intestine and other abdominal organs. The blood is returned from the liver to the heart by the hepatic veins.

### 7.1.2 Formed Elements

Red blood cells/corpuscles (Erythrocytes), white blood cells/corpuscles (Leucocytes) and platelets are collectively called formed elements (Thrombocytes).

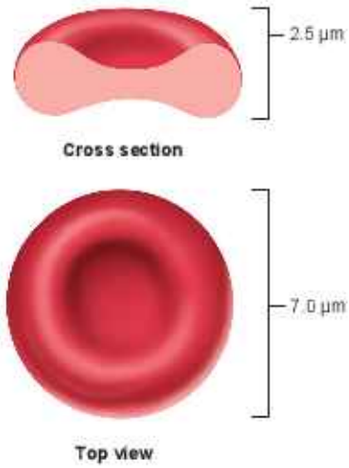


**Figure 7.1** Structure of RBC

### Red Blood Cells

Red blood cells are abundant than the other blood cells. There are about 5 million to 5.5 millions of RBC $mm^{-3}$ of blood in a healthy man and 4.5-5.0 millions of RBC $mm^{-3}$ in healthy women. The RBCs are very small with the diameter of about 7µm (micrometer). The structure of RBC is shown in Figure 7.1. The red colour of the RBC is due to the presence of a respiratory pigment, haemoglobin dissolved in the cytoplasm. Haemoglobin plays an important role in the transport of respiratory gases and facilitates the exchange of gases with the fluid outside the cell (tissue fluid).

The biconcave shaped RBCs increases the surface area to volume ratio, hence oxygen diffuses quickly in and out of the cell. The RBCs are devoid of nucleus, mitochondria, ribosomes and endoplasmic reticulum. The absence of these organelles accommodates more haemoglobin thereby maximising the oxygen carrying capacity of the cell.

The average life span of RBCs in a healthy individual is about 120 days after which they are destroyed in the spleen (graveyard / cemetery of RBCs) and the iron component returns to the bone marrow



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for reuse. **Erythropoietin** is a hormone secreted by the kidneys in response to low oxygen and helps in differentiation of stem cells of the bone marrow to erythrocytes (erythropoiesis) in adults. The ratio of red blood cells to blood plasma is expressed as **Haematocrit** (packed cell volume).

## White Blood Cells

White blood cells (leucocytes) are colourless, amoeboid, nucleated cells devoid of haemoglobin and other pigments. Approximately 6000 to 8000 per cubic mm of WBCs are seen in the blood of an average healthy individual. The different types of WBCs are shown in Figure 7.2. Depending on the presence or absence of granules, WBCs are divided into two types, **granulocytes** and **agranulocytes**.

## Granulocytes

Granulocytes are characterised by the presence of granules in the cytoplasm and are differentiated in the bone marrow. The granulocytes include **neutrophils, eosinophils and basophils**.

**Neutrophils** are also called heterophils or polymorphonuclear (cells with 3-4 lobes of nucleus connected with delicate threads) cells which constitute about 60%- 65% of the total WBCs. They are phagocytic in nature and appear in large numbers in and around the infected tissues.

**Eosinophils** have distinctly bilobed nucleus and the lobes are joined by thin strands. They are non-phagocytic and constitute about 2-3% of the total WBCs. Eosinophils increase during certain types of parasitic infections and allergic reactions.

**Basophils** are less numerous than any other type of WBCs constituting 0.5%-1.0% of the total number of leucocytes. The cytoplasmic granules are large sized, but fewer than eosinophils. Nucleus is large sized and constricted into several lobes but not joined by delicate threads. Basophils secrete substances such as heparin, serotonin and histamines. They are also involved in inflammatory reactions.

## Agranulocytes

Agranulocytes are characterised by the absence of granules in the cytoplasm and are differentiated in the lymph glands and spleen. These are of two types, **lymphocytes** and **monocytes**.

**Lymphocytes** constitute 30% of WBCs. These have large round nucleus and small amount of cytoplasm. The two types of lymphocytes are B and T cells. Both B and T cells are responsible for the immune responses of the body. B cells produce antibodies to neutralize the harmful effects of foreign substances and T cells are involved in cell mediated immunity.

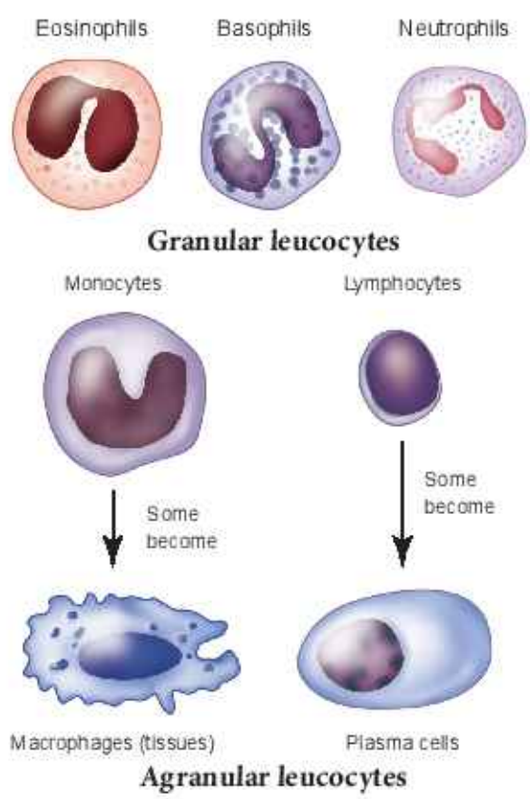


**Figure 7.2** Different Types of WBC



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**Monocytes** (Macrophages) are phagocytic cells that are similar to mast cells and have kidney shaped nucleus. They constitute 1-3% of the total WBCs. The macrophages of the central nervous system are the '**microglia**', in the sinusoids of the liver they are called **'Kupffer cells'** and in the pulmonary region they are the **'alveolar macrophages'**.

### Platelets

Platelets are also called **thrombocytes** that are produced from **megakaryocytes** (special cells in bone marrow) and lack nuclei. Blood normally contains 1,50,000 - 3,50,000 platelets $mm^{-3}$ of blood. They secrete substances involved in coagulation or clotting of blood. The reduction in platelet number can lead to clotting disorders that result in excessive loss of blood from the body.

## 7.1.3 Blood Groups

Commonly two types of blood groupings are done. They are ABO and Rh which are widely used all over the world.

### ABO Blood Grouping

Depending on the presence or absence of surface antigens on the RBCs, blood group in individual belongs to four different types namely, A, B, AB and O. The plasma of A, B and O individuals have natural antibodies (agglutinins) in them. Surface antigens are called **agglutinogens**. The antibodies **(agglutinin)** acting on agglutinogen A is called anti A and the agglutinin acting on agglutinogen B is called anti B. Agglutinogens are absent in O blood group. Agglutinogens A and B are present in AB blood group and do not contain anti A and anti B in them. Distribution of antigens and antibodies in blood groups are shown in Table 7.1. A, B and O are major allelic genes in ABO systems. All agglutinogens contain sucrose, D-galactose, N-acetyl glucosamine and 11 terminal amino acids. The attachments of the terminal amino acids are dependent on the gene products of A and B. The reaction is catalysed by glycosyl transferase.

**Table 7.1** Distribution of antigens and antibodies in different blood groups

| Blood group | Agglutinogens (antigens) on the RBC | Agglutinin (antibodies) in the plasma |
|---|---|---|
| A | A | Anti B |
| B | B | Anti A |
| AB | A and B | No antibodies |
| O | No antigens | Anti A and Anti B |

**Rh factor** is a protein **(D antigen)** present on the surface of the red blood cells in majority (80%) of humans. This protein is similar to the protein present in Rhesus monkey, hence the term Rh. Individuals who carry the antigen D on the surface of the red blood cells are $Rh^+$ (Rh positive) and the individuals who do not carry antigen D, are $Rh^-$ (Rh negative). Rh factor compatibility is also checked before blood transfusion. When a pregnant women is $Rh^-$ and the foetus is $Rh^+$ incompatibility (mismatch) is observed. During the first pregnancy, the $Rh^+$ antigens of the foetus does not get exposed to the mother's blood as both their blood are separated by placenta. However, small amount of the foetal antigen becomes exposed to the mother's blood during the birth of the first child. The mother's blood starts to synthesize D antibodies. But during subsequent pregnancies the Rh antibodies from the mother ($Rh^-$) enters the foetal circulation and destroys the foetal RBCs. This



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becomes fatal to the foetus because the child suffers from anaemia and jaundice. This condition is called **erythroblastosis foetalis**. This condition can be avoided by administration of anti D antibodies (**Rhocum**) to the $Rh^-$ mother immediately after the first child birth.

### 7.1.4 Coagulation of Blood

If you cut your finger or when you get yourself hurt, your wound bleeds for some time after which it stops to bleed. This is because the blood clots or coagulates in response to trauma. The mechanism by which excessive blood loss is prevented by the formation of clot is called **blood coagulation** or **clotting of blood**. Schematic representation of blood coagulation is shown Figure 7.3. The clotting process begins when the endothelium of the blood vessel is damaged and the connective tissue in its wall is exposed to the blood. Platelets adhere to collagen fibres in the connective tissue and release substances that form the platelet plug which provides emergency protection against blood loss. Clotting factors released from the clumped platelets or damaged cells mix with clotting factors in the plasma. The protein called **prothrombin** (Inactive form) is converted to its active form called **thrombin** in the presence of calcium and vitamin K. Thrombin helps in the conversion of soluble fibrinogen to insoluble fibrin threads. The threads of fibrins become interlinked into a patch that traps blood cell and seals the injured vessel until the wound is healed. After sometime fibrin fibrils contract, squeezing out a straw-coloured fluid through a meshwork called **serum** (Plasma without fibrinogen is called serum). **Heparin** is an **anticoagulant** produced in small quantities by mast cells of connective tissue which prevents coagulation in small blood vessels.

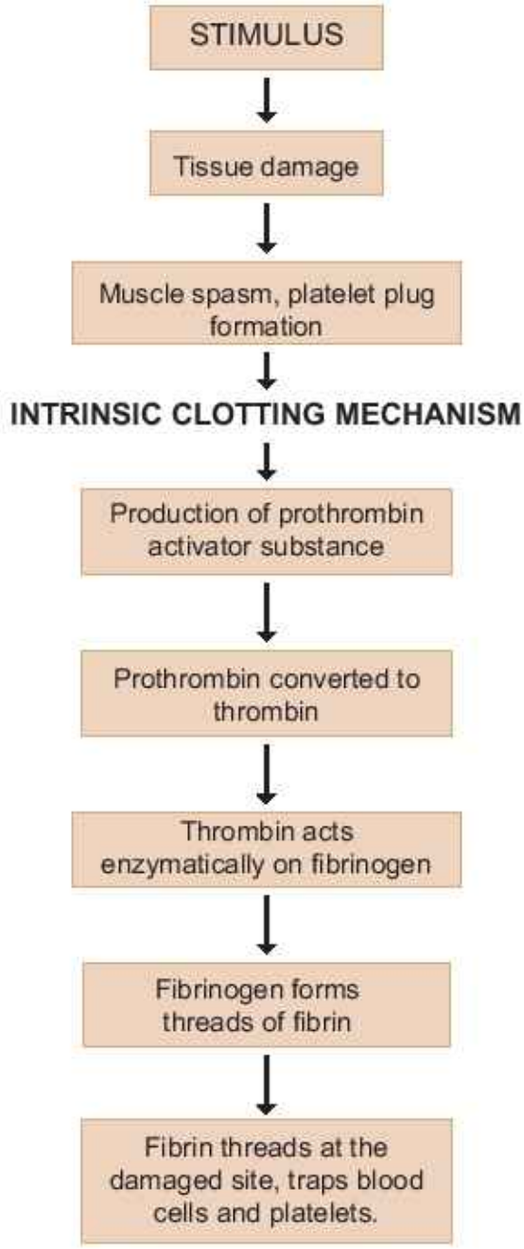


**Figure 7. 3** Schematic Representation of Blood Coagulation in an injured Blood Vessel

### 7.1.5 Composition of Lymph and its Functions

About 90% of fluid that leaks from capillaries eventually seeps back into the capillaries and the remaining 10% is collected and returned to blood system



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by means of a series of tubules known as **lymph vessels** or **lymphatics.** The fluid inside the lymphatics is called **lymph**. The lymphatic system consists of a complex network of thin walled ducts (lymphatic vessels), filtering bodies (lymph nodes) and a large number of lymphocytic cell concentrations in various lymphoid organs. The lymphatic vessels have smooth walls that run parallel to the blood vessels, in the skin, along the respiratory and digestive tracts. These vessels serve as return ducts for the fluids that are continually diffusing out of the blood capillaries into the body tissues. The end of a vessel is shown in Figure 7.4.

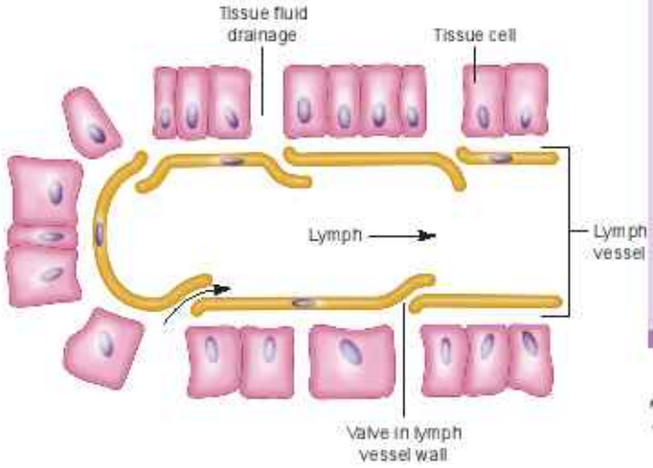


**Figure 7.4** Drainage of Tissue fluid into a Lymph Vessel

Lymph fluid must pass through the lymph nodes before it is returned to the blood. The lymph nodes that filter the fluid from the lymphatic vessels of the skin are highly concentrated in the neck, inguinal, axillaries, respiratory and digestive tracts. The lymph fluid flowing out of the lymph nodes flow into large collecting duct which finally drains into larger veins that runs beneath the collar bone, the subclavian vein and is emptied into the blood stream. The narrow passages in the lymph nodes are the sinusoids that are lined with macrophages. The lymph nodes successfully prevent the invading microorganisms from reaching the blood stream. Cells found in the lymphatics are the **lymphocytes**. Lymphocytes collected in the lymphatic fluid are carried via the arterial blood and are recycled back to the lymph. Fats are absorbed through lymph in the lacteals present in the villi of the intestinal wall.

1. Why protein molecules of larger size can pass through the lymph vessel?
2. We have seen that capillary walls are not permeable to plasma proteins. Suggest where the protein comes from.
3. The disease kwashiorkor is caused by a diet which is very low in protein. The concentration of proteins in blood becomes much lower than usual. One of the symptoms of kwashiorkor is edema. Give reasons.

## 7.2 Blood vessels – Arteries, Veins and Capillaries

The vessels carrying the blood are of three types; they are the arteries, veins and capillaries. These vessels are hollow structures and have complex walls surrounding the lumen. The blood vessels in humans are composed of three layers, **tunica intima, tunica media** and **tunica externa**. The inner layer, tunica intima or tunica interna supports the vascular endothelium, the middle layer, tunica media is composed of smooth muscles and an extra cellular matrix which contains a protein, elastin. The contraction and relaxation of the smooth muscles results



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in vasoconstriction and vasodilation. The outer layer, tunica externa or tunica adventitia is composed of collagen fibres. The structure of blood vessels is illustrated in Figure 7.5.

## Arteries

The blood vessels that carry blood away from the heart are called **arteries**. The arteries usually lie deep inside the body. The walls of the arteries are thick and non-collapsible to withstand high pressure. Valves are absent and have a narrow lumen. All arteries carry oxygenated blood, except the pulmonary artery. The largest artery, the **aorta** (2.5 cm in diameter and 2 mm thick) branch into smaller arteries and culminates into the tissues as feed arteries. In the tissues the arteries branches into arterioles.

As blood enters an arteriole it may have a pressure of 85 mm Hg (11.3 KPa) but as it leaves and flows into the capillary, the pressure drops to 35 mm Hg (4.7 KPa). (Note 1 mm Hg =0.13 KPa. SI unit of mm Hg is KiloPascal (KPa)). Arterioles are small, narrow, and thin walled which are connected to the capillaries. A small sphincter lies at the junction between the arterioles and capillaries to regulate the blood supply. Arteries do not always branch into arterioles, they can also form anastomoses.

What are anastomoses? These are connections of one blood vessel (arteries) with another blood vessel. They provide alternate route of blood flow if the original blood vessel is blocked. For e.g., Arteries in the joints contain numerous anastomoses. This allows blood to flow freely even if one of the arteries closes during bending of the joints.

## Capillaries

Capillary beds are made up of fine networks of capillaries. The capillaries are thin walled and consist of single layer of squamous epithelium. Tunica media and elastin fibres are absent. The capillary beds are the site for exchange of materials between blood and tissues. The blood volume in the capillaries is high but the flow of blood is slow. Mixed blood (oxygenated and deoxygenated) is present in the capillaries. The capillary bed may be flooded with blood or may be completely

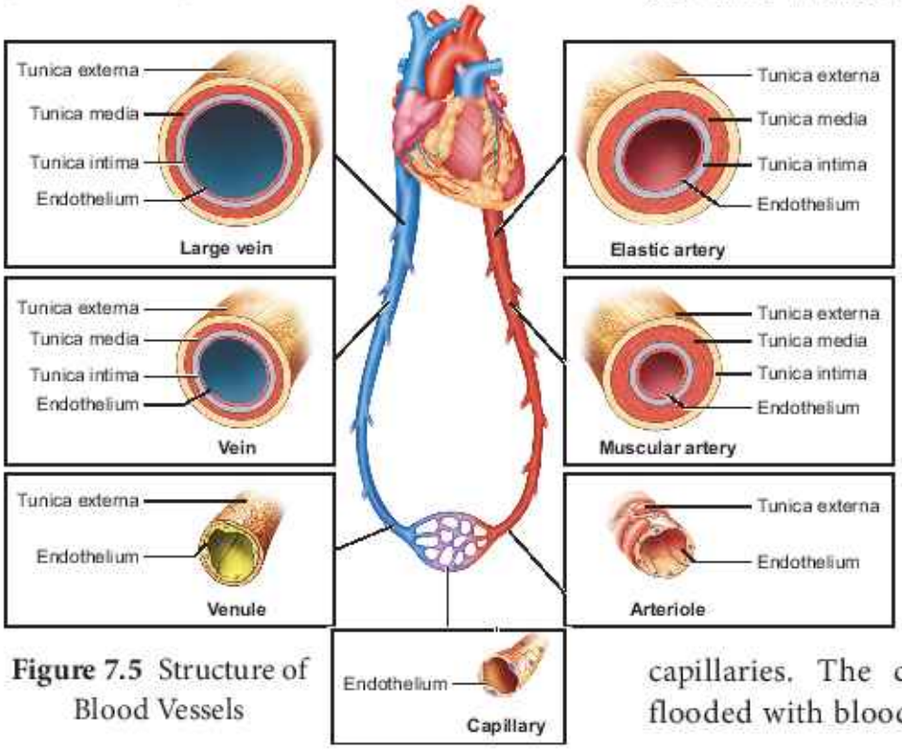


**Figure 7.5** Structure of Blood Vessels



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bypassed depending on the body conditions in a particular organ.

Why there are no blood capillaries in the cornea of the eye and cartilage? How are these regions supplied with the required nutrients?

Suggest why arteries close to the heart have more elastic fibers in their walls than arteries further away from the heart?

### Veins

Veins have thinner walls and a larger lumen and hence can be easily stretched. They carry deoxygenated blood except, the pulmonary vein. The blood pressure is low and the lumen has a wide wall which is collapsible. Tunica media is thinner in veins than in arteries. Unidirectional flow of blood in veins is due to the presence of semilunar valves that prevents backflow of blood. Blood samples are usually taken from the veins rather than artery because of low pressure in the veins.

### 7.2.1 Coronary Blood Vessels

Blood vessels that supply blood to the cardiac muscles with all nutrients and removes wastes are the coronary arteries and veins. Heart muscle is supplied by two arteries namely right and left coronary arteries. These arteries are the first branch of the aorta. Arteries usually surround the heart in the manner of a crown, hence called coronary artery (L. *Corona* - crown).

Right ventricle and posterior portion of left ventricle are supplied by the right coronary artery. Anterior and lateral part of the left ventricle is supplied by the left coronary arteries.

**The Law of Laplace is used to understand the structure and function of blood vessels and the heart.** Laplace law states that the tension in the walls of the blood vessel is proportional to the blood pressure and vessel radius. Blood vessels such as aorta that is subjected to high pressures have thicker walls than the arterioles that are subjected to low pressures.

## 7.3 Circulatory Pathways

There are two types of circulatory systems, open and closed circulatory systems. **Open circulatory system** has haemolymph as the circulating fluid and is pumped by the heart, which flows through blood vessels into the sinuses. Sinuses are referred as **haemocoel**. Open circulatory system is seen in Arthropods and most Molluscs. In **closed circulatory system** blood is pumped by the heart and flows through blood vessels. Closed circulating system is seen in Annelids, Cephalopods and Vertebrates.

All vertebrates have muscular chambered heart. Fishes have two chambered heart. The heart in fishes consists of sinus venosus, an **atrium**, one **ventricle** and **bulbus arteriosus** or **conus arteriosus**. Single circulation is seen in fishes. Amphibians have two auricles and one ventricle and no inter ventricular septum whereas reptiles except crocodiles have two auricles and one ventricle and an incomplete inter ventricular septum. Thus mixing of oxygenated and deoxygenated



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blood takes place in the ventricles. This type of circulation is called **incomplete double circulation**. The left atrium receives oxygenated blood and the right atrium receives deoxygenated blood. Pulmonary and systemic circuits are seen in Amphibians and Reptiles. The Crocodiles, Birds and Mammals have two auricles or atrial chambers and two ventricles, the auricles and ventricles are separated by inter auricular septum and inter ventricular septum. Hence there is complete separation of oxygenated blood from the deoxygenated blood. Pulmonary and systemic circuits are evident. This type of circulation is called **complete double circulation**.

## 7.4 Human Circulatory System

The structure of the heart was described by **Raymond de viessens**, in 1706. Human heart is made of special type of muscle called the **cardiac muscle**. It is situated in the thoracic cavity and its apex portion is slightly tilted towards left. It weighs about 300g in an adult. The size of our heart is roughly equal to a closed fist. Heart is divided into four chambers, upper two small auricles or atrium and lower two large ventricles. The walls of the ventricles are thicker than the auricles due to the presence of papillary muscles. The heart wall is made up of three layers, the outer **epicardium**, middle **myocardium** and inner **endocardium**. The space present between the membranes is called pericardial space and is filled with pericardial fluid.

The two auricles are separated by **inter auricular septum** and the two ventricles are separated by **inter ventricular septum** The separation of chambers avoids mixing of oxygenated and deoxygenated blood. The auricle communicates with the ventricle through an opening called **auriculo ventricular aperture** which is guarded by the **auriculo ventricular valves**. The opening between the right atrium and the right ventricle is guarded by the **tricuspid valve** (three flaps or cusps), whereas a **bicuspid** (two flaps or cusps) or **mitral valve** guards the opening between the left atrium and left ventricle (Figure 7.6). The valves of the heart allows the blood to flow only in one direction, i.e., from the atria to the ventricles and from the ventricles to the pulmonary artery or the aorta. These valves prevent backward flow of blood.

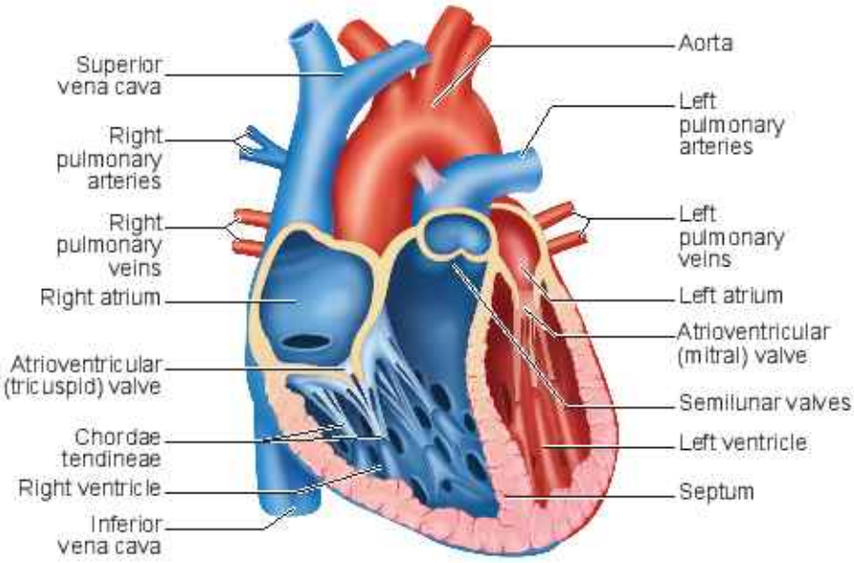


**Figure 7.6** L.S of Heart

The opening of right and left ventricles into the pulmonary artery and aorta are guarded by aortic and pulmonary valves and are called **semilunar valves**.



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Each semilunar valve is made of three half-moon shaped cusps. The myocardium of the ventricle is thrown into irregular muscular ridges called **trabeculae corneae**. The trabeculae corneae are modified into **chordae tendinae**. The opening and closing of the auriculo ventricular valves are achieved by the chordae tendinae. The chordae tendinae are attached to the lower end of the heart by papillary muscles. Heart receives deoxygenated blood from various parts of the body through the inferior venacava and superior venacava which open into the right auricle. Oxygenated blood from lungs is drained into the left auricle through four pulmonary veins.

### 7.4.1 Origin and Conduction of Heart Beat

The heart in human is myogenic (cardiomyocytes can produce spontaneous rhythmic depolarisation that initiates contractions). The sequence of electrical conduction of heart is shown in Figure 7.7. The cardiac cells with fastest rhythm are called the **Pacemaker cells**, since they determine the contraction rate of the entire heart. These cells are located in the right **sinuatrial (SA) node/ Pacemaker**. On the left side of the right atrium is a node called **auriculo ventricular node** (AV node). Two special cardiac muscle fibres originate from the auriculo ventricular node and are called the **bundle of His** which runs down into the interventricular septum and the fibres spread into the ventricles. These fibres are called the **Purkinje fibres**.

Pacemaker cells produce excitation through depolarisation of their cell membrane. Early depolarisation is slow and takes place by sodium influx and reduction in potassium efflux. Minimum potential is required to activate voltage gated calcium (Ca+) channels that causes rapid depolarisation which results in action potential. The pace maker cells repolarise slowly via $K^+$ efflux.

**HEART BEAT** - Rhythmic contraction and expansion of heart is called **heart beat**. The contraction of the heart is called **systole** and the relaxation of the heart is called **diastole**. The heart normally beats 70-72 times per min in a human adult. During each cardiac cycle two sounds are produced that can be heard through a **stethoscope**. The first heart sound lub is associated with the closure

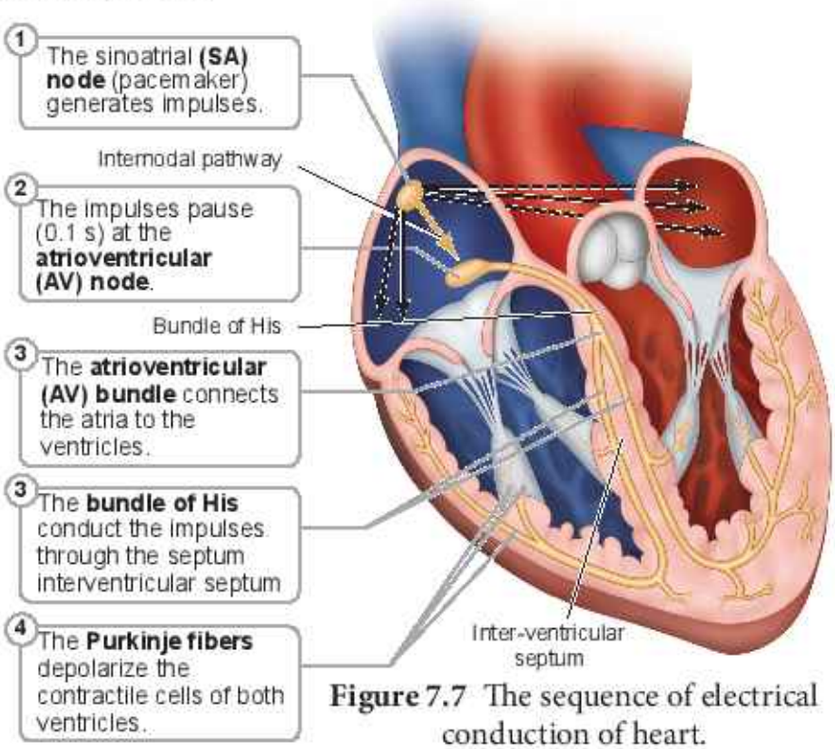


**Figure 7.7** The sequence of electrical conduction of heart.



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of the tricuspid and bicuspid valves at the beginning of ventricular systole whereas second heart sound dub is associated with the closure of the semilunar valves at the end of ventricular systole. These sounds are of clinical diagnostic significance. An increased heart rate is called **tachycardia** and decreased heart rate is called **bradycardia**.

### 7.4.2 Cardiac Cycle

The events that occur at the beginning of heart beat and lasts until the beginning of next beat is called cardiac cycle. It lasts for 0.8 seconds. The series of events that takes place in a **cardiac cycle** are as follows;

PHASE 1**: Ventricular Diastole**- The pressure in the auricles increases than that of the ventricular pressure. AV valves are open while the semi lunar valves are closed. Blood flows from the auricles into the ventricles passively.

PHASE 2: **Atrial Systole** - The atria contracts while the ventricles are still relaxed. The contraction of the auricles pushes maximum volume of blood to the ventricles until they reach the end diastolic volume (EDV). EDV is related to the length of the cardiac muscle fibre. More the muscle is stretched, greater the EDV and the stroke volume.

PHASE 3: V**entricular Systole** (isovolumetric contraction) - The ventricular contraction forces the AV valves to close and increases the pressure inside the ventricles. There is no change in the size of the muscle fibre length and ventricular chamber volume (isovolumetric contraction).

PHASE 4: **Ventricular Systole** (ventricular ejection) - Increased ventricular pressure forces the semilunar valves to open and blood is ejected out of the ventricles through the aorta and pulmonary artery without backflow of blood. This point is the end of systolic volume (ESV).

PHASE 5: **(Ventricular Diastole)** -The ventricles begins to relax, pressure in the arteries exceeds ventricular pressure, resulting in the closure of the semilunar valves. The heart returns to phase 1 of the cardiac cycle.

### 7.4.3 Cardiac Output

The amount of blood pumped out by each ventricle per minute is called **cardiac output(CO)**. It is a product of **heart rate** (HR) and **stroke volume** (SV). Heart rate or pulse is the number of beats per minute. Pulse pressure = systolic pressure – diastolic pressure. Stroke volume (SV) is the volume of blood pumped out by one ventricle with each beat. SV depends on ventricular contraction.

$$CO = HR \times SV$$

SV represents the difference between EDV (amount of blood that collects in a ventricle during diastole) and ESV (volume of blood remaining in the ventricle after contraction). SV = EDV - ESV.

According to Frank – Starling law of the heart, the critical factor controlling SV is the degree to which the cardiac muscle cells are stretched just before they contract. The most important factor in stretching cardiac muscle is the amount of blood returning to the heart and distending its ventricles, venous return. During vigorous exercise, SV may double as a result of venous return. Heart's pumping action normally maintains a balance between cardiac output and venous return. Because the heart is a double pump, each side can fail



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independently of the other. If the left side of the heart fails, it results in **pulmonary congestion** and if the right side fails, it results in peripheral congestion. Frank – Starling effect protects the heart from abnormal increase in blood volume.

When blood volume drops down abruptly, what happens to the stroke volume? State whether it increases or decreases?

## Blood Pressure

Blood pressure is the pressure exerted on the surface of blood vessels by the blood. This pressure circulates the blood through arteries, veins and capillaries. There are two types of pressure, the systolic pressure and the diastolic pressure. Systolic pressure is the pressure in the arteries as the chambers of the heart contracts. Diastolic pressure is the pressure in the arteries when the heart chambers relax. Blood pressure is measured using a **sphygmomanometer** (BP apparatus). It is expressed as systolic pressure / diastolic pressure. Normal blood pressure in man is about **120/80mm Hg**.

Mean arterial pressure is a function of cardiac output and resistance in the arterioles. The primary reflex pathway for homeostatic control of mean arterial pressure is the **baroreceptor reflex**. The baroreceptor reflex functions every morning when you get out of bed. When you are lying flat the gravitational force is evenly distributed. When you stand up, gravity causes blood to pool in the lower extremities. The decrease in blood pressure upon standing is known as **orthostatic hypotension**. Orthostatic reflex normally triggers baroreceptor reflex. This results in increased cardiac output and increased peripheral resistance which together increase the mean arterial pressure.

### 7. 4. 4 Electrocardiogram (ECG)

An electrocardiogram (ECG) is a simple test that records the electrical activity of the heart over a period of time using electrodes placed on the skin, arms, legs and chest. It records the changes in electrical potential across the heart during one cardiac cycle. The special flap of muscle which initiates the heart beat is called as **sinu-auricular node** or **SA node** in the right atrium. It spreads as a wave of contraction in the heart. The waves of the ECG are due to depolarization and not due to contraction of the heart. This wave of depolarisation occurs before the beginning of contraction of the cardiac muscle. A normal ECG shows 3 waves designated as P wave, QRS complex and T wave as shown in Figure 7.8 and the stages of the ECG graph are shown in Figure 7.9.

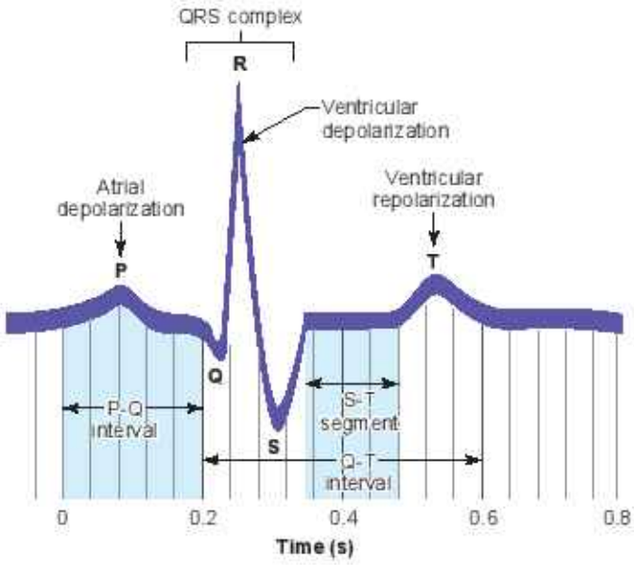


**Figure 7.8** Graph of a normal ECG

### P Wave (Atrial Depolarisation)

It is a small upward wave and indicates the depolarisation of the atria. This is the time taken for the excitation to spread through



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atria from SA node. Contraction of both atria lasts for around 0.08 - 0.1 sec.

### PQ Interval (AV Node Delay)

It is the onset of P wave to the onset of QRS complex. This is from the start of depolarisation of the atria to the beginning of ventricular depolarisation. It is the time taken for the impulse to travel from the atria to the ventricles (0.12-0.21sec). It is the measure of AV conduction time.

### QRS Complex (Ventricular Depolarisation)

No separate wave for atrial repolarisation in the ECG is visible. Atrial depolarisation occurs simultaneously with the ventricular depolarisation. The normal QRS complex lasts for 0.06-0.09 sec. QRS complex is shorter than the P wave, because depolarisation spreads through the Purkinjie fibres. Prolonged QRS wave indicates delayed conduction through the ventricle, often caused due to ventricular hypertrophy or due to a block in the branches of the bundle of His.

### ST Segment

It lies between the QRS complex and T wave. It is the time during which all regions of the ventricles are completely depolarised and reflects the long plateau phase before repolarisation. In the heart muscle, the prolonged depolarisation is due to retardation of K+ efflux and is responsible for the plateau. The ST segment lasts for 0.09 sec.

### T wave (Ventricular Repolarisation)

It represents ventricular repolarisation. The duration of the T wave is longer than QRS complex because repolarisation takes place simultaneously throughout the ventricular depolarisation. The duration of T wave is 0.2 - 0.4 sec.

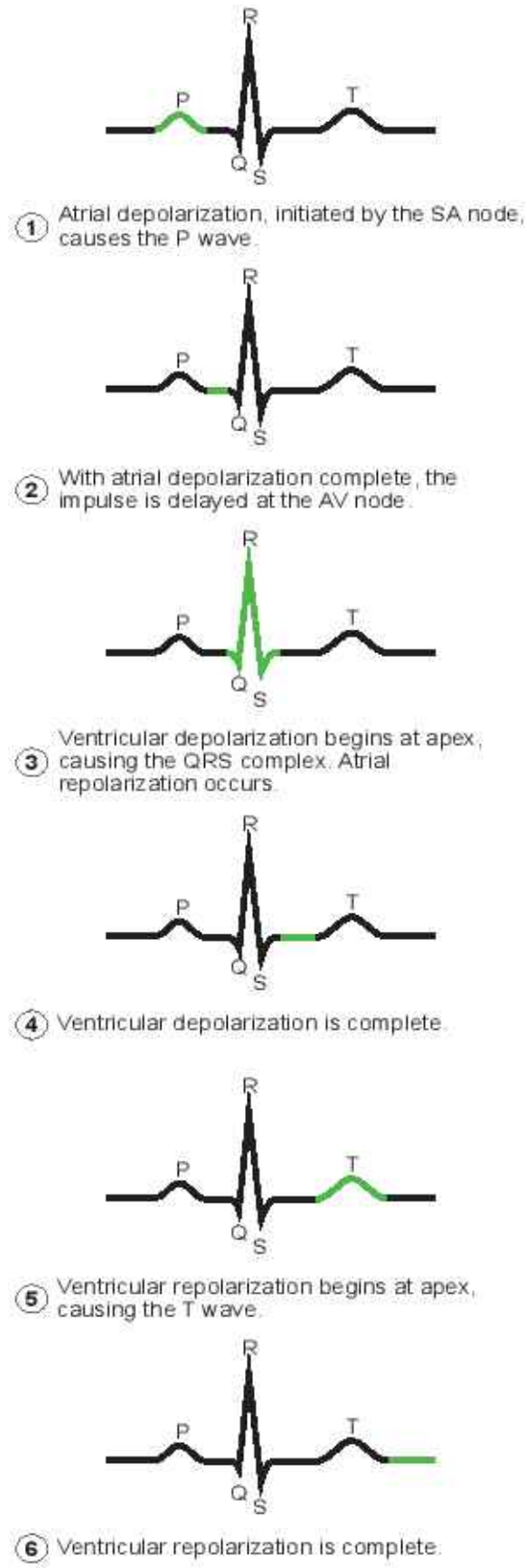


**Figure 7.9** Stages of ECG graph



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## 7.5. Double Circulation

Circulation of the blood was first described by **William Harvey** (1628). There are two types of blood circulation in vertebrates, **single circulation** and **double circulation** which is shown in Figure 7.10 (a and b) and 7.11.

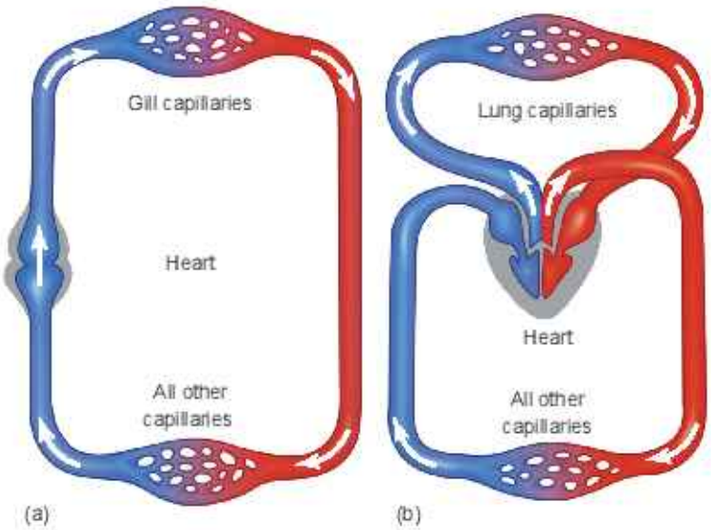


**Figure 7.10** Diagrammatic representation of (a) single circulation (b) double circulation

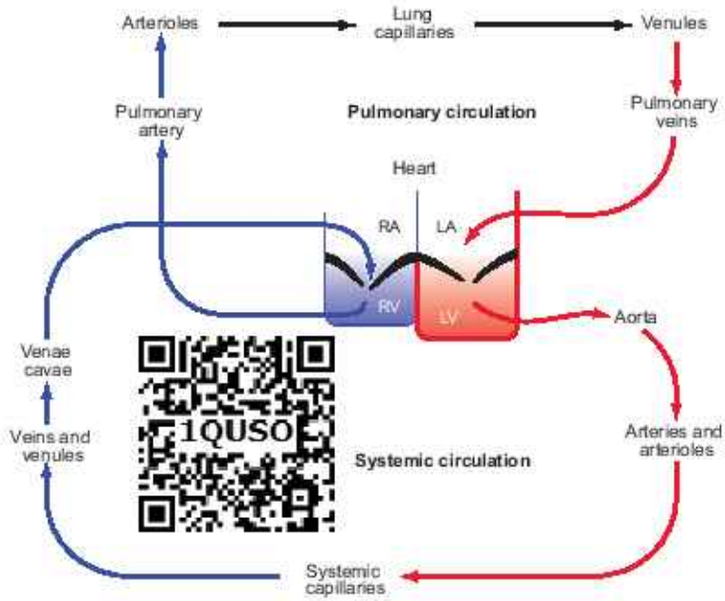


**Figure 7.11** Diagrammatic representation of the Double circulation

The blood circulates twice through the heart first on the right side then on the left side to complete one cardiac cycle. The complete double blood circulation is more prominent in mammals because of the complete partition of all the chambers (Auricles and ventricles) in the heart.

In **systemic circulation**, the oxygenated blood entering the aorta from the left ventricle is carried by a network of arteries, arterioles and capillaries to the tissues. The deoxygenated blood from the tissue is collected by venules, veins and vena cava and emptied into the right atrium. In **pulmonary** circulation, the blood from heart (right ventricle) is taken to the lungs by pulmonary artery and the oxygenated blood from the lungs is emptied into the left auricle by the pulmonary vein.

Completely separated circuits have an important advantage. Different pressures are maintained in the pulmonary and systemic circulation. Why is this advantageous? In the lungs the capillaries must be very thin to allow gas exchange, but if the blood flows through these thin capillaries under high pressure the fluid can leak through or ruptures the capillary walls and can accumulate in the tissues. This increases the diffusion distance and reduces the efficiency of the gas exchange. In contrast high pressure is required to force blood through the long systemic circuits. Hence the arteries close to the heart have increased pressure than the arteries away from the heart. Completely separated circuits (pulmonary and systemic) allow these two different demands to be met with.



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## 7. 6 Regulation of Cardiac Activity

The type of heart in human is myogenic because the heart beat originates from the muscles of the heart. The nervous and endocrine systems work together with paracrine signals (metabolic activity) to influence the diameter of the arterioles and alter the blood flow. The neuronal control is achieved through autonomic nervous system (sympathetic and parasympathetic). Sympathetic neurons release **nor-epinephrine** and adrenal medulla releases **epinephrine**. The two hormones bind to β – adrenergic receptors and increase the heart rate. The parasympathetic neurons secrete acetylcholine that binds to **muscarinic receptors** and decreases the heart beat. **Vasopressin** and **angiotensin II**, involved in the regulation of the kidneys, results in vasoconstriction while **natriuretic peptide** promotes vasodilation. Vagus nerve is a parasympathetic nerve that supplies the atrium especially the SA and the AV nodes.

## 7.7 Disorders of the Circulatory System

### Hypertension

**Hypertension** is the most common circulatory disease. The normal blood pressure in man is 120/80 mm Hg. In cases when the systolic pressure exceeds 150 mm Hg and the diastolic pressure exceeds 90 mm Hg persistently, the condition is called hypertension. Uncontrolled hypertension may damage the heart, brain and kidneys.

### Coronary Heart Disease

**Coronary heart disease** occurs when the arteries are lined by **atheroma**. The build-up of atheroma contains cholesterol, fibres, dead muscle and platelets and is termed **Atherosclerosis**. The cholesterol rich atheroma forms plaques in the inner lining of the arteries making them less elastic and reduces the blood flow. Plaque grows within the artery and tends to form blood clots, forming coronary **thrombus**. Thrombus in a coronary artery results in **heart attack**.

### Stroke

Stroke is a condition when the blood vessels in the brain bursts, **(Brain haemorrhage)** or when there is a block in the artery that supplies the brain, (atherosclerosis) or thrombus. The part of the brain tissue that is supplied by this damaged artery dies due to lack of oxygen **(cerebral infarction)**.

### Angina Pectoris

**Angina pectoris** (ischemic pain in the heart muscles) is experienced during early stages of coronary heart disease. Atheroma may partially block the coronary artery and reduce the blood supply to the heart. As a result, there is tightness or choking with difficulty in breathing. This leads to **angina** or chest pain. Usually it lasts for a short duration of time.

### Myocardial Infarction (Heart Failure)

The prime defect in heart failure is a decrease in cardiac muscle contractility. The Frank- Starling curve shifts downwards and towards the right such that for a given EDV, a failing heart pumps out a smaller stroke volume than a normal healthy heart.

When the blood supply to the heart muscle or myocardium is remarkably reduced it leads to death of the muscle fibres. This condition is called **heart attack** or **myocardial infarction**. The blood clot



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or **thrombosis** blocks the blood supply to the heart and weakens the muscle fibres. It is also called **Ischemic** heart disease due to lack of oxygen supply to the heart muscles. If this persists it leads to **chest pain** or **angina**. Prolonged angina leads to death of the heart muscle resulting in heart failure.

### Rheumatoid Heart Disease

Rheumatic fever is an autoimmune disease which occurs 2-4 weeks after throat infection usually a streptococcal infection. The antibodies developed to combat the infection cause damage to the heart. Effects include fibrous nodules on the mitral valve, fibrosis of the connective tissue and accumulation of fluid in the pericardial cavity.

## 7.8 Cardio Pulmonary Resuscitation (CPR)

In 1956, **James Elam** and **Peter Safar** were the first to use **mouth to mouth resuscitation**. CPR is a life saving procedure that is done at the time of emergency conditions when a person's breath or heart beat has stopped abruptly in case of drowning, electric shock or heart attack. CPR includes rescue of breath, which is achieved by mouth to mouth breathing, to deliver oxygen to the victim's lungs by external chest compressions which helps to circulate blood to the vital organs. CPR must be performed within 4 to 6 minutes after cessation of breath to prevent brain damage or death. Along with CPR, defibrillation is also done. Defibrillation means a brief electric shock is given to the heart to recover the function of the heart.

YWHGF

**Varicose veins** The veins are so dilated that the valves prevent back flow of blood. The veins lose their elasticity and become congested. Common sites are legs, rectal-anal regions (haemorrhoids), the oesophagus and the spermatic cord.

**Embolism** is the obstruction of the blood vessel by abnormal mass of materials such as fragment of the blood clot, bone fragment or an air bubble. Embolus may lodge in the lungs, coronary artery or liver and leads to death.

**Aneurysm** The weakened regions of the wall of the artery or veins bulges to form a balloon like sac. Unruptured aneurysm may exert pressure on the adjacent tissues or may burst causing massive haemorrhage.

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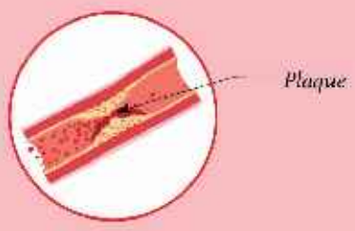
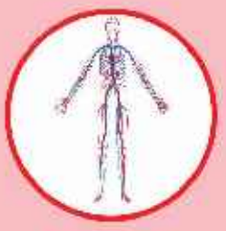
# Heart Diseases

**Heart disease includes any disorder of the heart, 50% of all heart attacks in Indians occur under 50 years of age and 25% of all heart attacks in Indians occur under 40 years of age.**



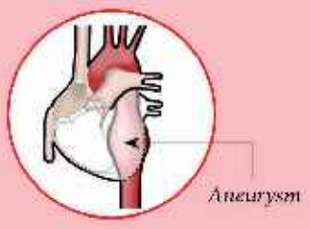

### Coronary heart disease

Blocked or clogged arteries limit blood flow to the heart and starving it of oxygen and nutrients.



### Vascular disease

Heart disease is often related to diseases of the circulatory system, including arteries, veins and lymph vessels, or blood disorders.

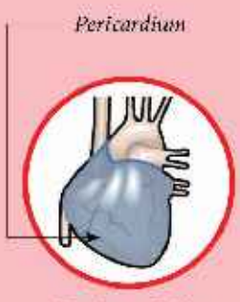



### Aorta disease

A portion of the aortic wall weakens and balloons out, forming an aneurysm.

### Arrhythmia

The heart beats irregularly.




### Pericarditis

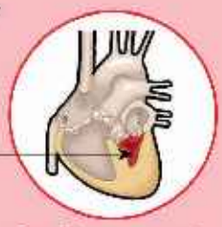
An inflammation of one or more layers of the pericardium, a thin membrane that lines the heart.

### Heart failure

The heart cannot pump as powerfuly as it needs to, in order to supply the body with oxygen and nutrients, causing the heart muscles to overwork and weaken.

### Heart valve disease

One of more of the hearts' valves - which control blood flow into and out of the heart - does not work.




### Cardiomyopathy

An enlarged or abnormally stiff or thick heart, causing the heart to pump weaker than normal and sometimes leading to heart failure or arrhythmia.

## Summary

Vertebrates circulate blood in their body, to transport essential substances to the cells and to carry waste substances from them. Blood is carried away from the heart, passes through tissues in capillaries and is returned to the heart in veins. Blood pressure drops gradually as it passes along this system. Arteries have thick, elastic walls which allow them to withstand high blood pressure. Arterioles are small arteries that help to reduce blood pressure and control the amount of blood flow to different tissues. Capillaries are only just wide enough to allow the passage of red blood cells, and have very thin wall to allow efficient and rapid transfer of materials between blood and cells. Veins have thinner walls than arteries and possess valves that allow blood to flow back to the heart even at low pressure.

Blood consist of plasma and formed elements. Blood plasma leaks from capillaries to form tissue fluid. This is collected into lymphatics as lymph, and returned to the blood in the subclavian veins. Tissue fluid and lymph are almost identical in composition. They contain fewer plasma protein molecules than blood plasma as these proteins are too large to pass through the pores in the capillary walls. The formed elements of blood constitute RBC, WBC and Platelets.

The mammalian heart has four chambers, right and left artia and right and left ventricles. The separation of chambers in the heart results in complete double circulation. The cardiac cycle is a continuous process but can be considered in five stages. Beating of the heart is initiated by the sinoatrial node (SAN) or pacemaker which has its own myogenic rhythm. Blood pressure is the force exerted by blood on the walls of blood vessels, and it is responsible for moving blood through the vessels.

Cardiovascular disease accounts for more deaths each year in the India. Cardiovascular conditions include systemic hypertension, atherosclerosis, coronary artery disease, angina pectoris, myocardial infarction and stroke. Cardiovascular diagnostic techniques and treatments include cardiac angiography, balloon angioplasty, and coronary artery bypass. The circulatory system contributes to homeostasis by transporting $O_2$, $CO_2$, wastes, electrolytes, and hormones from one part of the body to another.

## Evaluation

DH7EK

1. What is the function of lymph?
   a. Transport of $O_2$ into brain
   b. Transport of $CO_2$ into lungs
   **c. Bring interstitial fluid in blood**
   d. Bring RBC and WBC in lymph node

2. Which one of the following plasma proteins is involved in the coagulation of blood?
   a. Globulin **b. Fibrinogen**
   c. Albumin d. Serum amylase

3. Which of the following is not involved in blood clotting?
   a. Fibrin b. Calcium
   c. Platelets **d. Bilirubin**

4. Lymph is colourless because
   a. WBC are absent
   b. WBC are present
   **c. Haemoglobin is absent**
   d. RBC are absent



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5. Blood group is due to the presence or absence of surface
   a. Antigens on the surface of WBC
   b. Antibodies on the surface of RBC
   **c. Antigens on the surface of RBC**
   d. Antibodies on the surface of WBC
6. A person having both antigen A and antigen B on the surface of RBCs belongs to blood group
   a. A b. B **c. AB** d. O
7. Erythroblastosis foetalis is due to the destruction of
   **a. Foetal RBCs**
   b. Foetus suffers from atherosclerosis
   c. Foetal WBCs
   d. Foetus suffers from mianmata
8. Dub sound of heart is caused by
   a. Closure of atrio-ventricular valves
   b. Opening of semi-lunar valves
   **c. Closure of semi-lunar values**
   d. Opening of atrio-ventricular valves.
9. Why is the velocity of blood flow the lowest in the capillaries?
   a. The systemic capillaries are supplied by the left ventricle, which has a lower cardiac output than the right ventricle.
   b. Capillaries are far from the heart, and blood flow slows as distance from the heart increases.
   **c. The total surface area of the capillaries is larger than the total surface area of the arterioles.**
   d. The capillary walls are not thin enough to allow oxygen to exchange with the cells.
10. An unconscious patient is rushed into the emergency room and needs a fast blood transfusion. Because there is no time to check her medical history or determine her blood type, which type of blood should you as her doctor, give her?
    a. $A^-$ b. AB **c. $O^+$** d. $O^-$
11. Which of these functions can be carried out by a matured red blood cell?
    a. Protein synthesis
    b. Cell division
    c. Lipid synthesis
    **d. Active transport**
12. At the venous end of the capillary bed, the osmotic pressure is
    **a. Greater than the hydrostatic pressure**
    b. Result in net outflow of fluids
    c. Results in net absorption of fluids
    d. No change occurs
13. A patient's chart reveals that he has a cardiac output of 7500mL per minute and a stroke volume of 50 mL. What is his pulse rate (in beats / min)
    a. 50 b. 100 **c. 150** d. 400
14. At any given time there is more blood in the venous system than that of the arterial system. Which of the following features of the veins allows this?
    a. relative lack of smooth muscles
    **b. presence of valves**
    c. proximity of the veins to lymphatic's
    d. thin endothelial lining
15. Distinguish between arteries and veins.
16. Distinguish between open and closed circulation.



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17. Distinguish between mitral valve and semi lunar valve.

18. Right ventricular wall is thinner than the left ventricular wall. Why?

19. What might be the effect on a person whose diet has less iron content?

20. Describe the mechanism by which the human heart beat is initiated and controlled.

21. What is lymph? Write its function.

22. What are the heart sounds? When and how are these sounds produced?

23. Select the correct biological term.

    Lymphocytes, red cells, leucocytes, plasma, erythrocytes, white cells, haemoglobin, phagocyte, platelets, blood clot.

    a. Disc shaped cells which are concave on both sides.

    b. Most of these have a large, bilobed nucleus.

    c. Enable red cells to transport blood.

    d. The liquid part of the blood.

    e. Most of them move and change shape like an amoeba.

    f. Consists of water and important dissolved substances.

    g. Destroyed in the liver and spleen after circulating in the blood for four months.

    h. The substances which gives red cells their colour.

    i. Another name for red blood cells.

    j. Blood that has been changed to a jelly.

    k. A word that means cell eater.

    l. Cells without nucleus.

    m. White cells made in the lymphatic tissue.

    n. Blocks wound and prevent excessive bleeding.

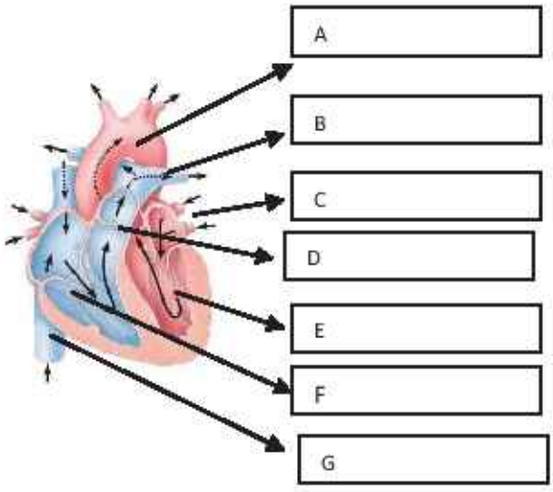
    o. Fragment of cells which are made in the bone marrow.

    p. Another name for white blood cells.

    q. Slowly releases oxygen to blood cells.

    r. Their function is to help blood clot in wounds.

24. Name and Label the given diagrams to show A, B, C, D, E, F, and G



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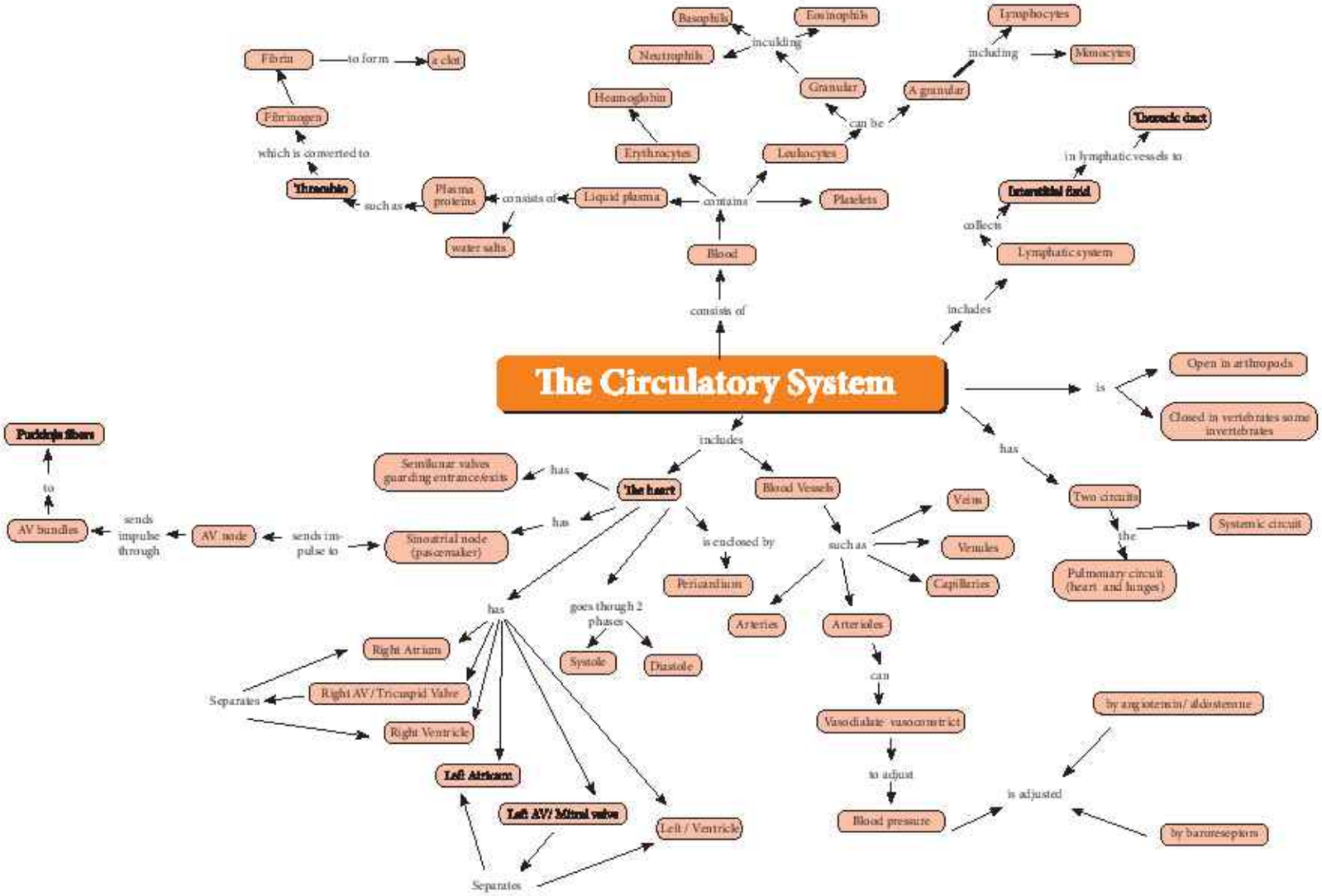
# Concept Map



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## ICT Corner

### The vital flow

Let's explore the **circulatory system** and learn the the 'Phases of Cardiac Cycle'.

**Step – 1**

Type the following URL in the browser. 'Circulatory System page will open. Select 'Phases of Cardiac Cycle' from the grid.

**Step – 2**

From the given Phases of Cardiac Cycle, Play one after another using 'Play' button and observe the valve movements and blood circulation in the heart.

**Step – 3**

The last animation shows the entire functions and flows of the Cardiac cycle. Use Play, Forward and Backward buttons and observe the nuances of Heart function.

**Step – 4**

Use the links below the Phases to get more details about the locations, size, chambers and pericardium structures.

Step 1

Step 2

Step 3

Step 4

Phases of the Cardiac Cycle's URL:

**https://www.getbodysmart.com/circulatory-system**

Y5O6W

* Pictures are indicative only



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UNIT III

# Chapter 8

# Excretion

**Chapter Outline**


8.1 Modes of Excretion

8.2 Human excretory system

8.3 Mechanism of urine formation in human

8.4 Regulation of kidney function

8.5 Micturition

8.6 Role of other organs in excretion

8.7 Disorders related to the excretory system

8.8 Haemodialysis

*Seabirds have no problem in drinking sea water*

## Learning Objectives:

- *Understands different modes of excretion in animals.*
- *Learns the structure of the human excretory system.*
- *Understands the structure of a nephron, mechanism of urine formation - glomerular filtration reabsorption and secretion from the renal tubules.*
- *Visualizes the blood supply to the kidney including the nephrons*
- *Learns about the possible kidney related diseases.*

Earliest animal life forms arose around 700 million years ago. They were marine organisms like the modern sponges. Each cell of a modern sponge is surrounded by sea water, but it maintains an intracellular ionic composition different from that of the sea water. Evolution led to changes in the organisation of the tissue layers followed by formation of specialized external tissue layers. This provided a barrier between the external environment and internal fluid resulting in the formation of extracellular fluid. Major changes in osmoregulation and ionic regulation occurred during the evolution of chordates. The ability to control extracellular fluid composition was essential for the diversification of animals to inhabit brackish water, fresh water and land. Animals that invaded land had the risk of desiccation and were unable to excrete metabolic waste directly into the water; hence there was a need for an alternate pathway to dispose the nitrogenous wastes.

Most animals rely on kidneys to control ionic and water balance. Some



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animals depend on external tissues such as the gills, skin and digestive mucosa to collectively regulate three homeostatic processes namely, osmotic regulation, ionic regulation and nitrogen excretion. Osmotic regulation is the control of tissue osmotic pressure which acts as a driving force for movement of water across biological membranes. Ionic regulation is the control of the ionic composition of body fluids. The process by which the body gets rid of the nitrogenous waste products of protein metabolism is called excretion. Nitrogen excretion is the pathway by which animals excrete ammonia, the toxic nitrogenous end product of protein catabolism. The removal of ammonia or other metabolic alternatives such as urea and uric acid is linked to ionic and osmotic homeostasis.

Fresh water vertebrates maintain higher salt concentrations in their body fluids; marine vertebrates maintain lower salt concentrations in their body fluids and terrestrial animals have more water in their body than the surrounding hence tend to lose water by evaporation. Osmoconformers are able to change their internal osmotic concentration with change in external environment as in marine molluscs and sharks. Osmoregulators maintain their internal osmotic concentration irrespective of their external osmotic environment (example: Otters). Depending on the ability to tolerate changes in the external environment, animals are classified as stenohaline and euryhaline. The stenohaline animals can tolerate only narrow fluctuations in the salt concentration (example: Gold fish), whereas the euryhaline animals are able to tolerate wide fluctuations in the salt concentrations eg., *Artemia, Tilapia* and Salmons.

The major nitrogenous waste products are ammonia, urea and uric acid. Other waste products of protein metabolism are trimethyl amine oxide (TMO) in marine teleosts, guanine in spiders, hippuric acid, allantonin, allantoic acid, ornithuric acid, creatinine, creatine, purines, pyramidines and pterines.

## 8.1 Modes of Excretion

Excretory system helps in collecting nitrogenous waste and expelling it into the external environment. Animals have evolved different strategies to get rid of these nitrogenous wastes. Ammonia produced during amino acid breakdown is toxic hence must be excreted either as ammonia, urea or uric acid. The type of nitrogenous end product an animal excretes depends upon the habitat of the animal. Ammonia requires large amount of water for its elimination, whereas uric acid, being the least toxic can be removed with the minimum loss of water, and urea can be stored in the body for considerable periods of time, as it is less toxic and less soluble in water than ammonia.

Animals that excrete most of its nitrogen in the form of ammonia are called **ammonoteles.** Many fishes, aquatic amphibians and aquatic insects are ammonotelic. In bony fishes, ammonia diffuses out across the body surface or through gill surface as ammonium ions. Reptiles, birds, land snails and insects excrete uric acid crystals, with



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| | | | |
|---|---|---|---|
| Animals | Most aquatic animals | Birds and most reptiles, insects and land snails | Mammals, most amphibians, sharks, reptiles and terrestrial invertebrates |
| Nitrogenous wastes | Ammonia | Uric acid | Urea |

**Figure 8.1** Excretory products in different groups of animals.

a minimum loss of water and are called **uricoteles**. In terrestrial animals, less toxic urea and uric acid are produced to conserve water. Mammals and terrestrial amphibians mainly excrete urea and are called **ureoteles**. Earthworms while in soil are ureoteles and when in water are ammonoteles. Figure 8.1 shows the excretory products in different groups of animals.

The animal kingdom presents a wide variety of excretory structures. Most invertebrates have a simple tubular structure in the form of primitive kidneys called **protonephridia** and **metanephridia.** Vertebrates have complex tubular organs called kidneys. Protonephridia are excretory structures with specialized cells in the form of **flame cells** (cilia) in Platyhelminthes (example tapeworm) and **Solenocytes** (flagella) in *Amphioxus*. Nematodes have **rennette cells, Metanephridia** are the tubular excretory structures in annelids and molluscs. **Malpighian tubules** are the excretory structures in most insects. **Antennal glands** or **green glands** perform excretory function in crustaceans like prawns. Vertebrate kidney differs among taxa in relation to the environmental conditions. Nephron is the structural and functional unit of kidneys. Reptiles have reduced glomerulus or lack glomerulus and Henle's loop and hence produce very little hypotonic urine, whereas mammalian kidneys produce concentrated (hyperosmotic) urine due to the presence of long Henle's loop. The Loop of Henle of the nephron has evolved to form hypertonic urine. Aglomerular kidneys of marine fishes produce little urine that is isoosmotic to the body fluid. Amphibians and fresh water fish lack Henle's loop hence produce dilute urine (hypoosmotic).

## 8.2 Human excretory system

### 8.2.1 Structure of kidney

Excretory system in human consists of a pair of kidneys, a pair of ureters, urinary bladder and urethra (Figure. 8.2). Kidneys are reddish brown, bean shaped structures that lie in the superior lumbar region between the levels of the last thoracic and third lumber vertebra close to the dorsal inner wall of the abdominal cavity. The right kidney is placed slightly lower than the left kidney. Each kidney weighs an average of 120-170 grams. The outer



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layer of the kidney is covered by three layers of supportive tissues namely, renal fascia, perirenal fat capsule and fibrous capsule.

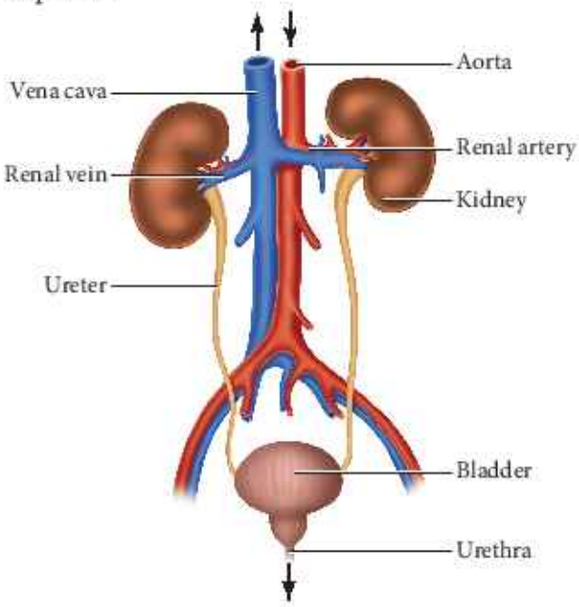


**Figure 8.2** Human Excretory System

The longitudinal section of kidney (Figure. 8.3) shows, an outer cortex, inner medulla and pelvis. The medulla is divided into a few conical tissue masses called medullary pyramids or renal pyramids. The part of cortex that extends in between the medullary pyramids is the renal columns of **Bertini.** The centre of the inner concave surface of the kidney has a notch called the renal **hilum,** through which ureter, blood vessels and nerves innervate. Inner to the hilum is a broad funnel shaped space called the renal pelvis with projection called calyces. The renal pelvis is continuous with the ureter once it leaves the hilum. The walls of the calyces, pelvis and ureter have smooth muscles which contracts rhythmically. The calyces collect the urine and empties into the ureter, which is stored in the urinary bladder temporarily. The urinary bladder opens into the urethra through which urine is expelled out.

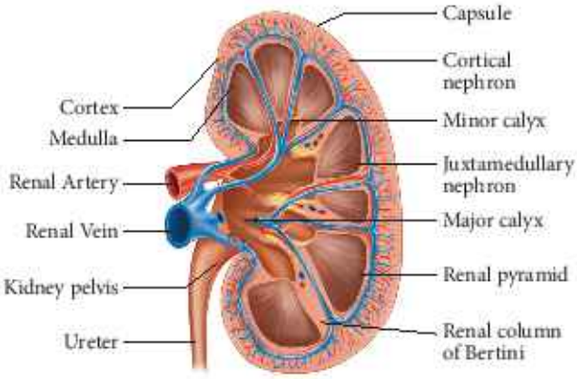


**Figure 8.3** L S of kidney

### 8.2.2 Structure of a nephron

Each kidney has nearly one million complex tubular structures called nephron (Figure 8.4). Each nephron consists of a filtering corpuscle called renal corpuscle (malpighian body) and a renal tubule. The renal tubule opens into a longer tubule called the collecting duct. The renal tubule begins with a double walled cup shaped structure called the Bowman's capsule, which encloses a ball of capillaries that delivers fluid to the tubules, called the glomerulus. The Bowman's capsule and the glomerulus together constitute the **renal corpuscle.** The endothelium of glomerulus has many pores (fenestrae). The external parietal layer of the Bowman's capsule is made up of simple squamous epithelium and the visceral layer is made of epithelial cells called podocytes. The podocytes end in foot processes which cling to the basement membrane of the glomerulus. The openings between the foot processes are called filtration slits.



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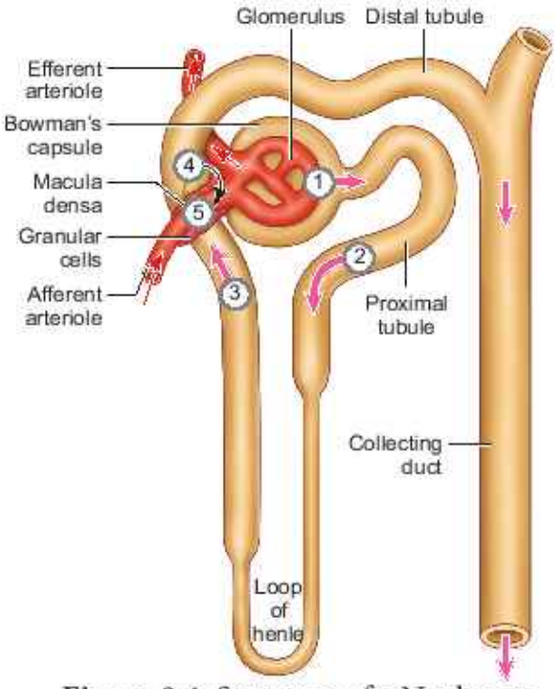


**Figure 8.4** Structure of a Nephrons

The renal tubule continues further to form the proximal convoluted tubule [PCT] followed by a U-shaped loop of Henle (Henle's loop) that has a thin descending and a thick ascending limb. The ascending limb continues as a highly coiled tubular region called the distal convoluted tubule [DCT]. The DCT of many nephrons open into a straight tube called collecting duct. The collecting duct runs through the medullary pyramids in the region of the pelvis. Several collecting ducts fuse to form papillary duct that delivers urine into the calyces, which opens into the renal pelvis.

In the renal tubules, PCT and DCT of the nephron are situated in the cortical region of the kidney whereas the loop of Henle is in the medullary region. In majority of nephrons, the loop of Henle is too short and extends only very little into the medulla and are called **cortical nephrons.** Some nephrons have very long loop of Henle that run deep into the medulla and are called **juxta medullary nephrons (JMN)** (Figure 8.5 a and b)

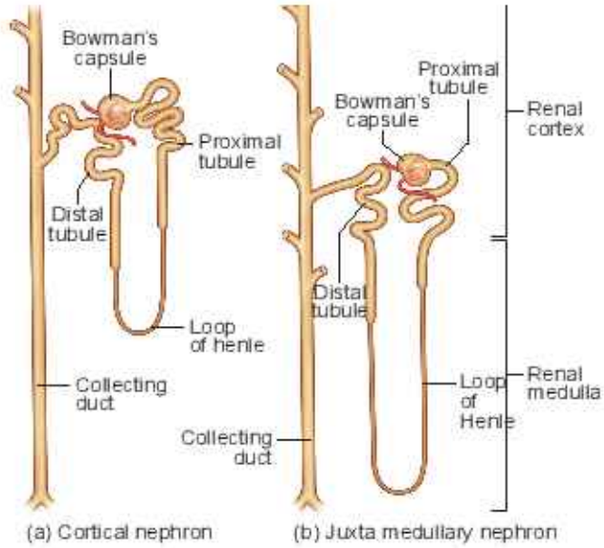


**Figure 8.5** (a) Cortical nephrons are located predominantly in the outer cortex. (b) Juxtamedullary nephrons are mainly located in the inner medulla.

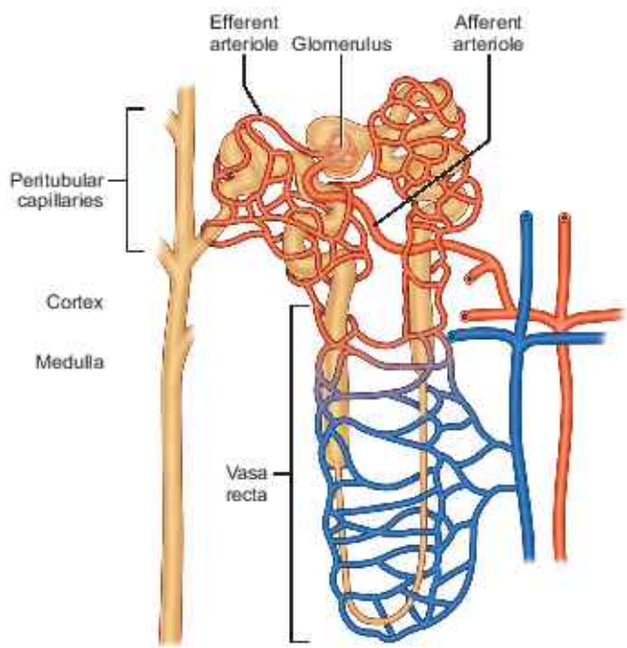


**Figure 8.6** Blood Vessels of the Nephron

**The capillary bed of the nephrons-** First capillary bed of the nephron is the glomerulus and the other is the peritubular capillaries. The glomerular capillary bed is different from other capillary beds in that it is supplied by the afferent and drained by the efferent arteriole. The efferent



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arteriole that comes out of the glomerulus forms a fine capillary network around the renal tubule called the peritubular capillaries. The efferent arteriole serving the juxta medullary nephron forms bundles of long straight vessel called vasa recta and runs parallel to the loop of Henle. Vasa recta is absent or reduced in cortical nephrons (Figure 8.6).

What is the importance of having a long loop of Henle and short loop of Henle in a nephron?

## 8.3 Mechanism of Urine Formation in Human

The nitrogenous waste formed as a result of breakdown of amino acids is converted to urea in the liver by the Ornithine cycle or urea cycle (Figure 8.7).

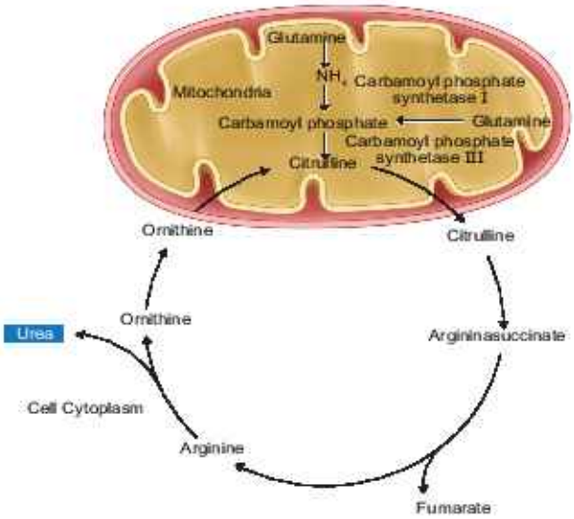


**Figure 8.7** Ornithine cycle

Urine formation involves three main processes namely, glomerular filtration, tubular reabsorption and tubular secretion.

i) **Glomerular Filtration**: Blood enters the kidney from the renal artery, into the glomerulus. Blood is composed of large quantities of water, colloidal proteins, sugars, salts and nitrogenous end product. The first step in urine formation is the filtration of blood that takes place in the glomerulus. This is called glomerular filtration which is a passive process. The fluid that leaves the glomerular capillaries and enters the Bowman's capsule is called the glomerular filtrate. The glomerular membrane has a large surface area and is more permeable to water and small molecules present in the blood plasma. Blood enters the glomerulus faster with greater force through the afferent arteriole and leaves the glomerulus through the efferent arterioles, much slower. This force is because of the difference in sizes between the afferent and efferent arteriole (afferent arteriole is wider than efferent arteriole) and glomerular hydrostatic pressure which is around 55mm Hg.

Kidneys produce about 180L of glomerular filtrate in 24 hours. The molecules such as water, glucose, amino acids and nitrogenous substances pass freely from the blood into the glomerulus. Molecules larger than 5nm are barred from entering the tubule. Glomerular pressure is the chief force that pushes water and solutes out of the blood and across the filtration membrane. The glomerular blood pressure (approximately 55 mmHg) is much higher than in other capillary beds. The two opposing forces are contributed by the plasma proteins in the capillaries. These includes, colloidal osmotic pressure (30 mmHg) and the capsular hydrostatic pressure (15 mmHg) due to the fluids in the glomerular capsule. The net filtration pressure of 10 mmHg is responsible for the renal filtration.



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Net filtration Pressure = Glomerular hydrostatic pressure − (Colloidal osmotic pressure + Capsular hydrostatic pressure).

Net filtration pressure = 55 mmHg − (30 mmHg + 15 mmHg)= 10mmHg

The effective glomerular pressure of 10 mmHg results in **ultrafiltration.** Glomerular filtration rate (GFR) is the volume of filtrate formed $min^{-1}$ in all nephrons (glomerulus) of both the kidneys. In adults the GFR is approximately 120-125mL/min. Blood from the glomerulus is passed out through the efferent arteriole. The smooth muscle of the efferent arteriole contract resulting in vasoconstriction. Table 8.1 shows the relative concentrations of substances in the blood plasma and the glomerular filtrate. The glomerular filtrate is similar to blood plasma except that there are no plasma proteins. In cortical nephrons, blood from efferent arteriole flows into peritubular capillary beds and enters the venous system carrying with it recovered solutes and water from the interstitial fluid that surrounds the tubule.

**Table 8.1** Concentration of substances in the blood plasma and in the glomerular filtrate

| Substance | Concentration in blood Plasma/g $dm^{-3}$ | Concentration in glomerular filtrate/g $dm^{-3}$ |
|---|---|---|
| Water | 900 | 900 |
| Proteins | 80.0 | 0.05 |
| Aminoacids | 0.5 | 0.5 |
| Glucose | 1.0 | 1.0 |
| Urea | 0.3 | 0.3 |
| Uric acid | 0.04 | 0.04 |
| Creatinine | 0.01 | 0.01 |
| Inorganic ions (mainly $Na^+$, $K^+$ and $Cl^-$) | 7.2 | 7.2 |

A person with cirrhosis of the liver has lower than normal levels of plasma proteins and higher than normal GFR. Explain why a decrease in plasma protein would increase GFR.

**ii) Tubular Reabsorption**

This involves movement of the filtrate back into the circulation. The volume of filtrate formed per day is around 170-180 L and the urine released is around 1.5 L per day, i.e., nearly 99% of the glomerular filtrate that has to be reabsorbed by the renal tubules as it contains certain substances needed by the body. This process is called selective reabsorption. Reabsorption takes place by the tubular epithelial cells in different segments of the nephron either by active transport or passive transport, diffusion and osmosis.

**Proximal Convoluted Tubule (PCT)**- Glucose, lactate, amino acids, $Na^+$ and water in the filtrate is reabsorbed in the PCT. Sodium is reabsorbed by active transport through sodium- potassium ($Na^+$ $K^+$) pump in the PCT. Small amounts of urea and uric acid are also reabsorbed.

**Descending limb** of Henle's loop is permeable to water due the presence of aquaporins, but not permeable to salts. Water is lost in the descending limb, hence $Na^+$ and $Cl^-$ gets concentrated in the filtrate.

**Ascending limb of Henle's loop** is impermeable to water but permeable to solutes such as $Na^+$, $Cl^-$ and $K^+$.

The **distal convoluted tubule** recovers water and secretes potassium into the tubule. $Na^+$, $Cl^-$ and water remains in the filtrate of the DCT. Most of the



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reabsorption from this point is dependent on the body's need and is regulated by hormones. Reabsorption of bicarbonate ($HCO_3^-$) takes place to regulate the blood pH. Homeostasis of $K^+$ and $Na^+$ in the blood is also regulated in this region.

Aquaporins are water–permeable channels (membrane transport proteins) that allow water to move across the epithelial cells in relation to the osmotic difference from the lumen to the interstitial fluid.

**Collecting duct** is permeable to water, secretes $K^+$ (potassium ions are actively transported into the tubule) and reabsorbs $Na^+$ to produce concentrated urine. The change in permeability to water is due to the presence of number of water-permeable channels called **aquaporins**.

**Tubular secretion**- Substances such as $H^+$, $K^+$, $NH_4^+$, creatinine and organic acids move into the filtrate from the peritubular capillaries into the tubular fluid. Most of the water is absorbed in the proximal convoluted tubule and $Na^+$ is exchanged for water in the loop of Henle. Hypotonic fluid enters the distal convoluted tubule and substances such as urea and salts pass from peritubular blood into the cells of DCT. The urine excreted contains both filtered and secreted substances. Once it enters the collecting duct, water is absorbed and concentrated hypertonic urine is formed. For every $H^+$ secreted into the tubular filtrate, a $Na^+$ is absorbed by the tubular cell. The $H^+$ secreted combines with $HCO_3^-$, $HPO_3^-$ and $NH_3^-$ and gets fixed as $H_2CO_4^+$, $H_2PO_4^+$ and $NH_4^+$ respectively. Since $H^+$ gets fixed in the fluid, reabsorption of $H^+$ is prevented.

Osmolarity - The solute concentration of a solution of water is known as the solutions osmolarity, expressed as milliosmoles /liter (mOsm/L)

**Formation of concentrated urine**
Formation of concentrated urine is accomplished by kidneys using counter current mechanisms. The major function of Henle's loop is to concentrate $Na^+$ and $Cl^-$. There is low osmolarity near the cortex and high osmolarity towards the medulla. This osmolarity in the medulla is due to the presence of the solute transporters and is maintained by the arrangement of the loop of Henle, collecting duct and vasa recta. This arrangement allows movement of solutes from the filtrate to the interstitial fluid. At the transition between the proximal convoluted tubule and the descending loop of Henle the osmolarity of the interstitial fluid is similar to that of the blood – about 300mOsm.

**Ascending and descending limbs of Henle, create a counter current multiplier** (interaction between flow of filtrate through the limbs of Henle's and JMN) by active transport. Figure 8.8 (a) shows the counter current multiplier created by the long loops of **Henle of the JM nephrons which creates medullary osmotic gradient.**

As the fluid enters the descending limb, water moves from the lumen into the interstitial fluid and the osmolarity of interstitial fluid decreases. To counteract this dilution the region of the ascending limb actively pumps solutes from the lumen into the interstitial fluid and the osmolarity increases to about 1200mOsm in medulla. This mismatch between water



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and salts creates osmotic gradient in the medulla. The osmotic gradient is also due to the permeability of the collecting duct to urea.

**The vasa recta, maintains the medullary osmotic gradient via counter current exchanger** (the flow of blood through the ascending and descending vasa recta blood vessels) by passive transport. Figure 8.8 (b) shows counter current exchanger where the vasa recta preserves the medullary gradient while removing reabsorbed water and solutes. **This system does not produce an osmotic gradient, but protects the medulla** by removal of excess salts from the interstitial fluid and removing reabsorbed water. The vasa recta leave the kidney at the junction between the cortex and medulla. The interstitial fluid at this point is iso-osmotic to the blood.

When the blood leaves the efferent arteriole and enters vasa recta the osmolarity in the medulla increases (1200mOsm) and results in passive uptake of solutes and loss of water in descending vasa recta. As the blood enters the cortex, the osmolarity in the blood decreases (300mOsm) and the blood loses solutes and gains water.

At the final stage in collecting duct to form concentrated urine (hypertonic). Human kidneys can produce urine nearly four times concentrated than the initial filtrate formed.

List the pathways involved in the homeostatic compensation in case of severe dehydration.

## 8.4 Regulation of Kidney Function

### ADH and Diabetes Insipidus

The functioning of kidneys is efficiently monitored and regulated by hormonal feedback control mechanism involving the hypothalamus, juxta glomerular

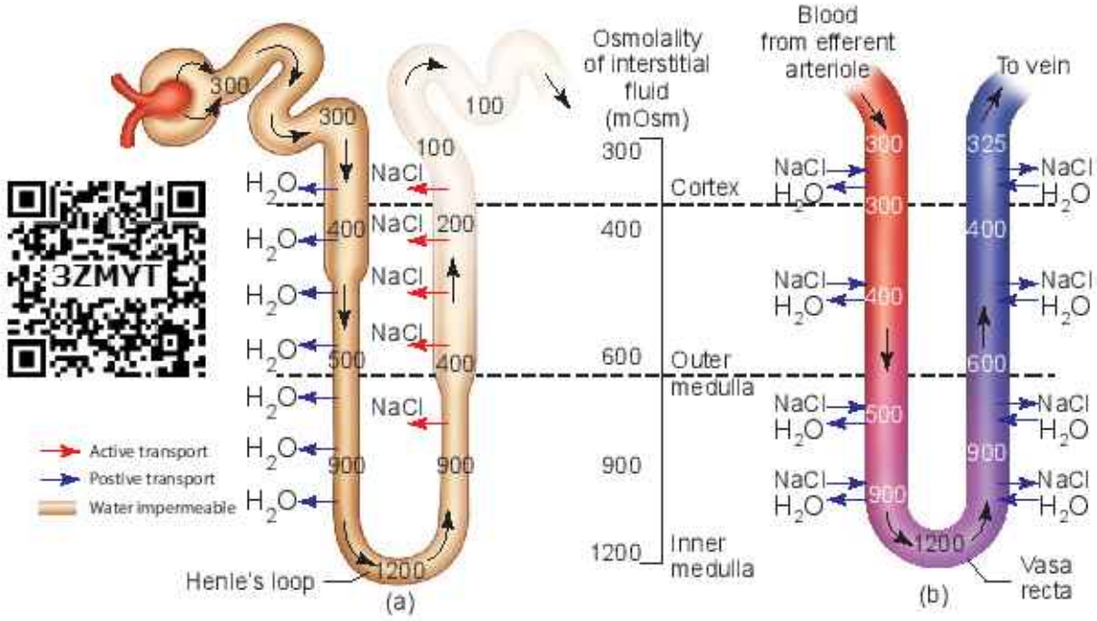


**Figure 8.8** (a) Counter current multiplier – the long loops of Henle of the juxtamedullary nephrons create the medullary osmotic gradient (b) Counter current exchanger – Vasa recta preserves the medullary gradient while removing reabsorbed water and solutes.



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apparatus and to a certain extent the heart. Osmoreceptors in the hypothalamus are activated by changes in the blood volume, body fluid volume and ionic concentration. When there is excessive loss of fluid from the body or when there is an increase in the blood pressure, the osmoreceptors of the hypothalamus respond by stimulating the neurohypophysis to secrete the antidiuretic hormone (ADH) or vasopressin (a positive feedback). ADH facilitates reabsorption of water by increasing the number of aquaporins on the cell surface membrane of the distal convoluted tubule and collecting duct. This increase in aquaporins causes the movement of water from the lumen into the interstitial cells, thereby preventing excess loss of water by diuresis. When you drink excess amounts of your favourite juice, osmoreceptors of the hypothalamus is no longer stimulated and the release of ADH is suppressed from the neurohypophysis (negative feedback) and the aquaporins of the collecting ducts move into the cytoplasm. This makes the collecting ducts impermeable to water and the excess fluid flows down the collecting duct without any water loss. Hence dilute urine is produced to maintain the blood volume. Vasopressin secretion is controlled by positive and negative feedback mechanism. Defects in ADH receptors or inability to secrete ADH leads to a condition called diabetes insipidus, characterized by excessive thirst and excretion of large quantities of dilute urine resulting in dehydration and fall in blood pressure.

## Renin Angiotensin

Juxta glomerular apparatus (JGA) is a specialized tissue in the afferent arteriole of the nephron that consists of macula densa and granular cells. The macula densa cells sense distal tubular flow and affect afferent arteriole diameter, whereas the granular cells secrete an enzyme called renin. A fall in glomerular blood flow, glomerular blood pressure and glomerular filtration rate, can activate JG cells to release renin which converts a plasma protein, angiotensinogen

Angiotensin Converting Enzyme inhibitors (ACE inhibitors) are used to treat high blood pressure. Using a flow chart, explain why these drugs are helpful in treating hypertension.

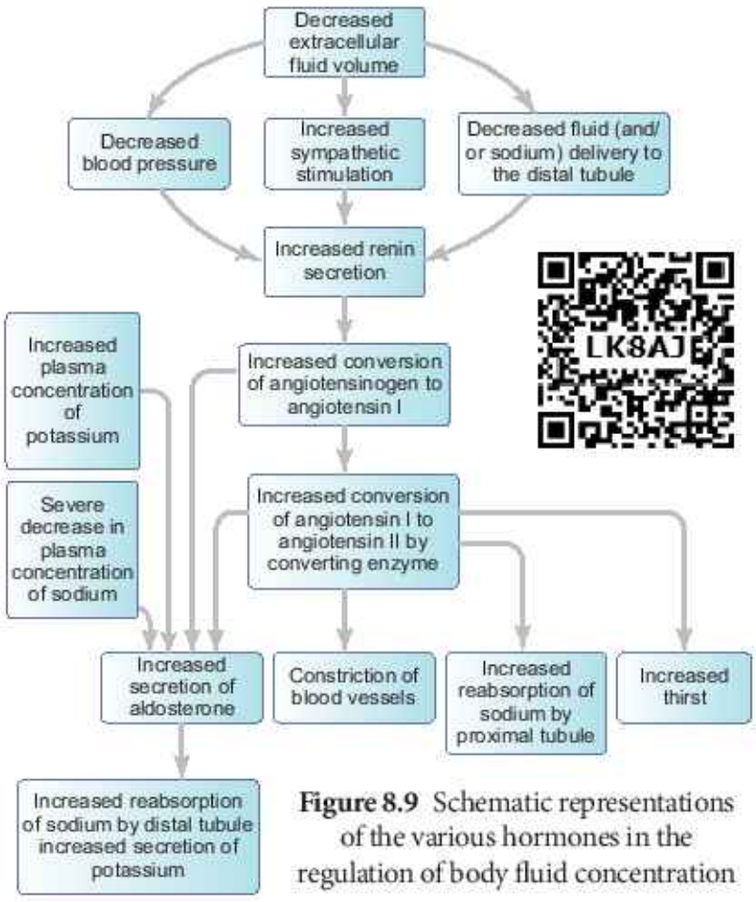


**Figure 8.9** Schematic representations of the various hormones in the regulation of body fluid concentration



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(synthesized in the liver) to angiotensin I. Angiotensin converting enzyme (ACE) converts angiotensin I to angiotensin II. Angiotensin II stimulates $Na^+$ reabsorption in the distal convoluted tubule by vasoconstriction of the blood vessels and increases the glomerular blood pressure. Angiotensin II acts at different sites such as heart, kidney, brain, adrenal cortex and blood vessels. It stimulates adrenal cortex to secrete aldosterone that causes reabsorption of $Na^+$, $K^+$ excretion and absorption of water from the distal convoluted tubule and collecting duct. This increases the glomerular blood pressure and glomerular filtration rate. This complex mechanism is generally known as **Renin- Angiotensin-Aldosterone System** (RAAS). Figure 8.9 shows the schematic representation of the various hormones in the regulation of body fluid concentration.

### Atrial Natriuretic Factor

Excessive stretch of cardiac atrial cells cause an increase in blood flow to the atria of the heart and release Atrial Natriuretic Peptide or factor (ANF) travels to the kidney where it increases $Na^+$ excretion and increases the blood flow to the glomerulus, acting on the afferent glomerular arterioles as a vasodilator or on efferent arterioles as a vasoconstrictor. It decreases aldosterone release from the adrenal cortex and also decreases release of renin, thereby decreasing angiotensin II. ANF acts antagonistically to the renin- angiotensin system, aldosterone and vasopressin.

## 8.5 Micturition

The process of release of urine from the bladder is called micturition or urination. Urine formed by the nephrons is ultimately carried to the urinary bladder where it is stored till it receives a voluntary signal from the central nervous system. The stretch receptors present in the urinary bladder are stimulated when it gets filled with urine. Stretching of the urinary bladder stimulates the CNS via the sensory neurons of the parasympathetic nervous system and brings about contraction of the bladder. Simultaneously, somatic motor neurons induce the sphincters to close. Smooth muscles contracts resulting in the opening of the internal sphincters passively and relaxing the external sphincter. When the stimulatory and inhibitory controls exceed the threshold, the sphincter opens and the urine is expelled out.

An adult human on an average excretes 1 to 1.5 L of urine per day. The urine formed is a yellow coloured watery fluid which is slightly acidic in nature (pH 6.0), Changes in diet may cause pH to vary between 4.5 to 8.0 and has a characteristic odour. The yellow colour of the urine is due to the presence of a pigment, urochrome. On an average, 25-30 gms of

Hypotonic urine is formed when osmotic pressure of the body fluid is decreased due to water retention or solute loss when ADH secretion is lowered. If you drink large volume of water without eating anything salty, the total body fluid volume increases quickly and the osmolarity decreases. The kidneys increases the volume of urine excreted. The reverse happens when you eat salty food without drinking water.



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urea is excreted per day. Various metabolic disorders can affect the composition of urine. Analysis of urine helps in clinical diagnosis of various metabolic disorders and the malfunctioning of the kidneys. For example the presence of glucose (glucosuria) and ketone bodies (ketonuria) in the urine are indications of diabetes mellitus.

## 8.6 Role of other Organs in Excretion

Apart from kidneys, organs such as lungs, liver and skin help to remove wastes. Our lungs remove large quantities of carbon dioxide (18 L/day) and significant quantities of water every day. Liver secretes bile containing substances like, bilirubin and biliverdin, cholesterol, steroid hormones, vitamins and drugs which are excreted out along with the digestive wastes.

Sweat and sebaceous glands in the skin eliminate certain wastes through their secretions. Sweat produced by the sweat glands primarily helps to cool the body and secondarily excretes $Na^+$ and $Cl^-$, small quantities of urea and lactate. Sebaceous glands eliminate certain substances like sterols, hydrocarbons and waxes through sebum that provides a protective oily covering for the skin. Small quantities of nitrogenous wastes are also excreted through saliva.

## 8.7 Disorders related to the Excretory System

### Urinary Tract Infection

Female's urethra is very short and its external opening is close to the anal opening, hence improper toilet habits can easily carry faecal bacteria into the urethra. The urethral mucosa is continuous with the urinary tract and the inflammation of the urethra (urethritis) can ascend the tract to cause bladder inflammation (cystitis) or even renal inflammation (pyelitis or pyelonephritis). Symptoms include dysuria (painful urination), urinary urgency, fever and sometimes cloudy or blood tinged urine. When the kidneys are inflammed, back pain and severe headache often occur. Most urinary tract infections can be treated by antibiotics.

### Renal Failure (Kidney Failure)

Failure of the kidneys to excrete wastes may lead to accumulation of urea with marked reduction in the urine output. Renal failure are of two types, Acute and chronic renal failure. In acute renal failure the kidney stops its function abruptly, but there are chances for recovery of kidney functions. In chronic renal failure there is a progressive loss of function of the nephrons which gradually decreases the function of kidneys.

### Uremia

Uremia is characterized by increase in urea and other non-protein nitrogenous substances like uric acid and creatinine in blood. Normal urea level in human blood is about 17-30mg/100mL of blood. The urea concentration rises as 10 times of normal levels during chronic renal failure.

### Renal Calculi

Kidney stone or calculi, also called renal stone or nephrolithiasis, is the formation of hard stone like masses in the renal tubules of renal pelvis. It is mainly due to the accumulation of soluble crystals of salts of sodium oxalates and certain phosphates.



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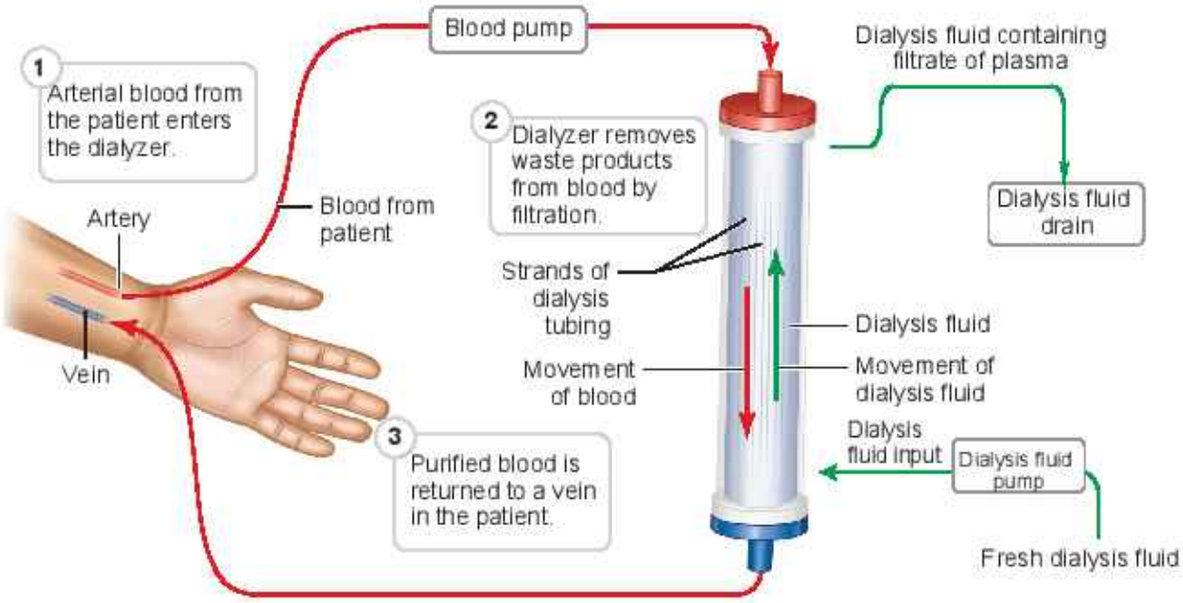


**Figure 8.10** Simplified diagram of Hemodialysis

This result in severe pain called "renal colic pain" and can cause scars in the kidneys. Renal stones can be removed by techniques like pyleothotomy or lithotripsy.

### Glomerulonephritis

It is also called Bright's disease and is characterized by inflammation of the glomeruli of both kidneys and is usually due to post-streptococcal infection that occurs in children. Symptoms are haematuria, proteinuria, salt and water retention, oligouria, hypertension and pulmonary oedema.

## 8.8 Haemodialysis

Malfunctiong of the kidneys can lead to accumalation of urea and other toxic substances, leading to kidney failure. In such patients toxic urea can be removed from the blood by a process called haemodialysis. A dialyzing machine or an artificial kidney is connected to the patient's body. A dialyzing machine consists of a long cellulose tube surrounded by the dialysing fluid in a water bath. The patient's blood is drawn from a conveinent artery and pumped into the dialysing unit after adding an anticoagulant like heparin. The tiny pores in the dialysis tube allows small molecules such as glucose, salts and urea to enter into the water bath, whereas blood cells and protein molecules do not enter these pores. This stage is similar to the filtration process in the glomerulus. The dialysing liquid in the water bath consists of solution of salt and sugar in correct proportion in order to prevent loss of glucose and essential salts from the blood. The cleared blood is then pumped back to the body through a vein Figure 8.10.

**Kidney Transplantation**

It is the ultimate method for correction of acute renal failures. This involves transfer of healthy kidney from one person (donor) to another person with kidney failure. The donated kidney may be taken from a healthy person who is declared brain dead or from sibling or close relatives to minimise the chances of rejection by the immune system of the host. Immunosuppressive drugs are usually administered to the patient to avoid tissue rejection.



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The world's first successful human kidney transplantation was performed from one twins to antoher by Joseph E. Murray and his colleagues at Peter Bent Brigham Hospital, Boston in 1954. The first ever human kidney transplant performed in India was done at the King Edward Memorial Hospital at Mumbai in May 1965, using a cadaver donor in a non-renal failure patient who had had hypernephroma. The first successful live donor kidney transplant in India was done at Christian Medical College Hospital, Vellore in January 1971 by Dr. Johnny and Dr. Mohan Rao.

## Summary

Epithelial tissues are the interface between internal fluids and the external environment, creating osmotic barriers in lower organisms. Other specialized epithelial tissues that mediate osmotic and ionic regulation are gills, digestive tract and specialized excretory tissues in different animal groups. Animals remove toxic ammonia to less toxic forms by excretion. Three main strategies of nitrogen excretion are ammonoteles (ammonium), Uricoteles (uric acid) and Ureotelism (Urea). Most aquatic animals are ammonotelic, whereas terrestrial animals are uricotelic (reptiles and birds) or ureoteles (mammals). Urea is produced by the Ornithine cycle/Urea cycle in the liver.

Invertebrates have primitive kidneys such as protonephridia and metanephridia. Water balance in insects is regulated by Malphigian tubules. Ion and water regulation in vertebrates are carried out by the kidneys. The functional units of kidney is the nephron. Urine is formed by 3 processes, Glomerular filtration, tubular reabsorption and tubular secretion. Filtration occurs at the glomerulus, a ball of capillaries surrounded by the Bowman's capsule. From the Bowman's capsule the primary urine enters the proximal tubule, and proceeds to the loop of Henle, with its ascending and descending limbs. The hypertonic fluid then flows to the distal tubule and through the collecting duct into the ureters, the urinary bladder, after a short storage it is sent out of the urethra. Central to the nephron is the counter current system set up between the loop of Henle and the collecting duct along with the capillaries that serve the nephron.

Kidney function is regulated at different levels. GFR is affected by colloidal osmotic pressure and capsular hydrostatic pressure between the glomerulus and Bowman's capsule, surface area available for filtration are the factors that affect filtration pressure. The kidneys act only on the plasma, yet the extra cellular fluid consists of both plasma and interstitial fluid. The interstitial fluid is the true internal fluid environment of the body. Interstitial fluid is the only component that comes in direct contact with the cells. Thus by performing regulatory and excretory roles on the plasma, the kidneys maintains the proper interstitial fluid environment for optimum cell functioning.

Various hormones control diuresis. Vasopressin alters the permeability of the collecting duct, the renin- angiotensin system, sympathetic system and aldosterone act together to regulate $Na^{+}$·$K^{+}$, water and pressure balance.



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## Activity

Visit a nearby health center to observe the analysis of urine. Dip strips can be used to test urine for a range of different factors such as pH, glucose, ketones and proteins. Dip sticks used for detecting glucose contain two enzymes namely, glucose oxidase and peroxidase. These two enzymes are immobilized on a small pad at one end of the stick. The pad is immersed in urine. If the urine contains glucose, a brown coloured compound is produced. The resulting colour pad is matched against a colour chart. The colour does not indicate the current blood glucose concentrations.

Both the kidneys of Ravi (28 years) were not functioning and he was undergoing dialysis. He was admitted to a hospital with renal failure. His mother Suganthi (47 years) was willing to donate one of her kidneys to her son after she was given counseling. Their blood groups were matching and later approval was obtained from transplant committee and technical committee. Operation was performed for 5 hrs. He was administered with immunosuppressive drugs and anti inflammatory drugs. He recovered from the operation and returned home.

1. Name the disease Ravi was suffering from.
2. What relation is the donor of the kidney
3. Name the type of matching done to perform the transplant.
4. Why approval has to be got from transplant committee and technical committee?
5. What do you think about Suganthi donating her kidney?

## Evaluation

1. Concentration of urine depends upon which part of the nephron
   a. Bowman's capsule
   **b. Length of Henle's loop**
   c. P.C.T.
   d. Network of capillaries arising from glomerulus
2. If Henle's loop were absent from mammalian nephron, which one of the following is to be expected?
   a. There will be no urine formation
   b. There will be hardly any change in the quality and quantity of urine formed
   c. The urine will be more concentrated
   **d. The urine will be more dilute**
3. What will happen if the stretch receptors of the urinary bladder wall are totally removed?
   **a. Micturition will continue**
   b. Urine will be continue to collect normally in the bladder
   c. There will be micturition
   d. Urine will not collection the bladder
4. The end product of Ornithine cycle is
   a. carbon dioxide  b. uric acid
   **c. urea**  d. ammonia



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5. Identify the wrong match

| | |
|---|---|
| a. Bowman's capsule | - Glomerular filteration |
| b. DCT | - Absorption of glucose |
| c. Henle's loop | - Concentration of urine |
| **d. PCT** | **- Absorption of $Na^+$ and $K^+$ ions** |

6. Podocytes are the cells present on the
   a. Outer wall of Bowman's capsule
   **b. Inner wall of Bowman's capsule**
   c. Neck of nephron
   d. Wall glomerular capillaries
7. Glomerular filtrate contains
   a. Blood without blood cells and proteins
   b. Plasma without sugar
   **c. Blood with proteins but without cells**
   d. Blood without urea
8. Kidney stones are produced due to deposition of uric acid and
   a. silicates
   b. minerals
   c. calcium carbonate
   **d. calcium oxalate**
9. Animal requiring minimum amount of water to produce urine are
   a. ureotelic b. ammonotelic
   **b. uricotelic** d. chemotelic
10. Aldosterone acts at the distal convoluted tubule and collecting duct resulting in the absorption of water through
    **a. Aquaphorins** b. spectrins
    c. GLUT d. Chloride channels
11. The hormone which helps in the reabsorption of water in kidney tubules is
    a. cholecystokinin
    b. angiotensin II
    **c. antidiuretic hormone**
    d. pancreozymin
12. Malpighian tubules remove excretory products from
    a. mouth b. oesophagus
    **c. haemolymph** d. alimentary canal.
13. Arrange the following structures in the order that a drop of water entering the nephron would encounter them.
    e. Afferent arteriole
    f. Bowman's capsule
    g. Collecting duct
    h. Distal tubule
    i. Glomerulus
    j. Loop of Henle
    k. Proximal tubule
    l. Renal pelvis
14. Name the three filtration barriers that solutes must come across as they move from plasma to the lumen of Bowman's capsule. What components of the blood are usually excluded by these layers?
15. What forces promote glomerular filtration? What forces opposes them? What is meant by net filtration pressure?
16. Identify the following structures and explain their significance in renal physiology?
    a. Juxtaglomerular apparatus
    b. Podocytes
    c. Sphincters in the bladder
17. In which segment of the nephron most of the re-absorption of substances takes place?



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18. When a molecule or ion is reabsorbed from the lumen of the nephron, where does it go? If a solute is filtered and not reabsorbed from the tubule, where does it go?

19. Which segment is the site of secretion and regulated reabsorption of ions and pH homeostasis?

20. What solute is normally present in the body to estimate GFR in humans?

21. Which part of the autonomic nervous system is involved in micturition process?

22. If the afferent arteriole of the nephron constricts, what happens to the GFR in that nephron? If the efferent arteriole constricts what happens to the GFR in that nephron? Assume that no auto regulation takes place.

23. Identfiy the biological term

Excretion, glomerulus, urinary bladder, glomerular filtrate, ureters, urine, Bowman's capsule, urinary system, reabsorption, micturition, osmosis, proteins.

a. A liquid which gathers in the bladder.

b. Produced when blood is filtered in a Bowman's capsule.

c. Temporary storage of urine.

d. A ball of inter twined capillaries.

e. Removal of unwanted substances from the body.

f. Each contains a glomerulus.

g. Carry urine from the kidneys to the bladder.

h. Scientific term for urination.

i. Regulation of water and dissolved substances in blood and tissue fluid.

j. Consists of the kidneys, ureters and bladder.

k. Removal of useful substances from glomerular filtrate.

l. What solute the blood contains that are not present in the glomerular filtrate?

24. With regards to toxicity and the need for dilution in water, how different are ureotelic and uricotelic excretions? Give examples of animals that use these types of excretion?

25. Differentiate protonephridia from metanephridia.

26. What is the nitrogenous waste produced by amphibian larvae and by the adult animal?

27. How is urea formed in the human body?

28. Differentiate cortical from medullary nephrons.

29. What vessels carry blood to the kidneys? Is this blood arterial or venous?

30. Which vessels drain filtered blood from the kidneys?

31. What is tubular secretion? Name the substances secreted through the renal tubules.

32. How are the kidneys involved in controlling blood volume? How is the volume of blood in the body related to arterial pressure?

33. Name the three main hormones involved in the regulation of the renal function?

34. What is the function of antidiuretic hormone? Where is it produced and what stimuli increases or decreases its secretion?

35. What is the effect of aldosterone on kidneys and where is it produced?

36. Explain the heart's role in secreting a hormone that regulates renal function? What hormone is this?



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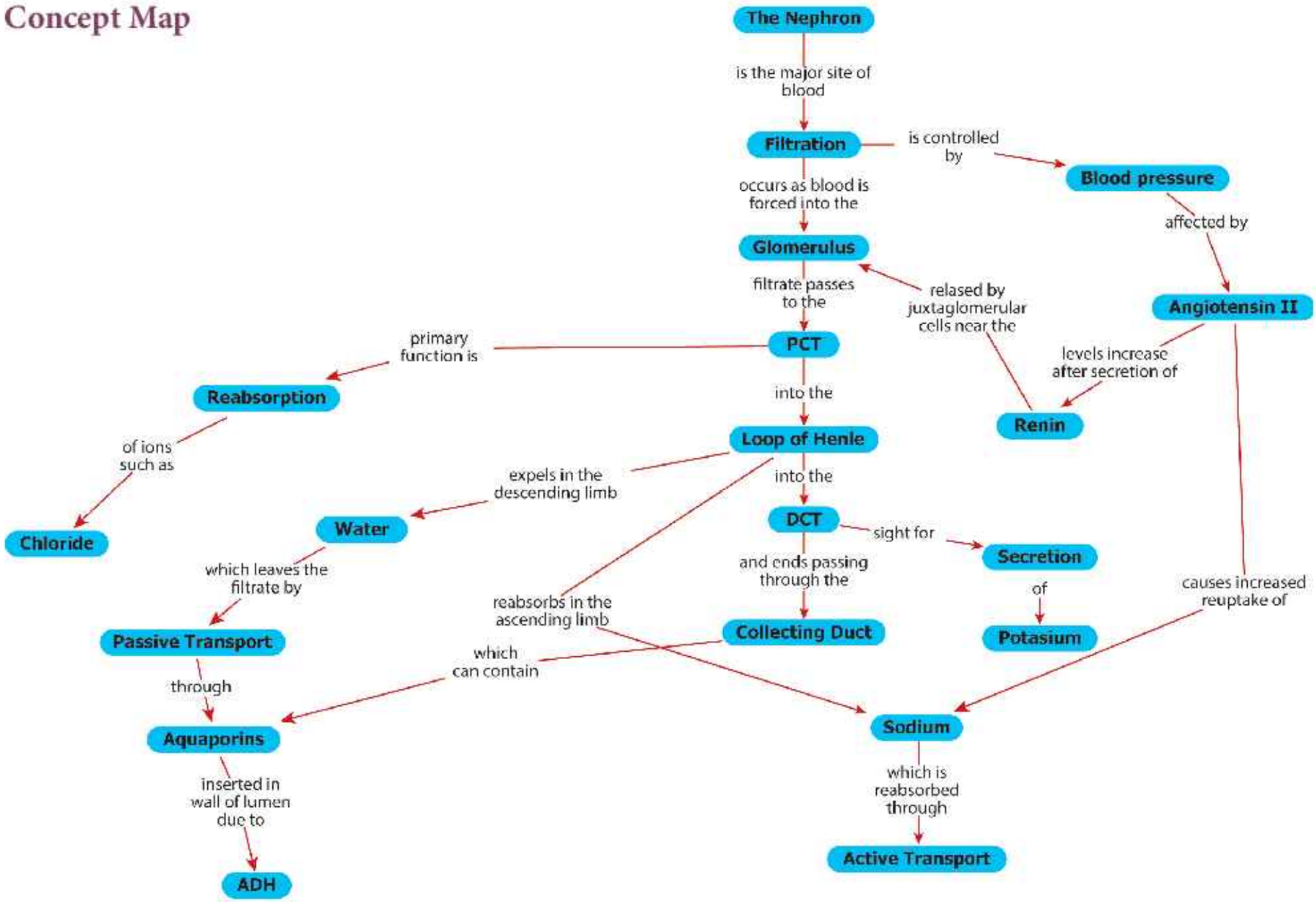
# Concept Map



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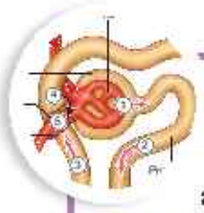
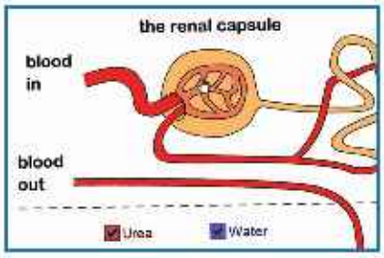
## ICT Corner

### Let go away



Let's explore the Biomed Heads-Kidney and understand the **functions of the nephron**.




**Step – 1**

Use the URL to land in 'Biomed heads-Kidney' page. Click 'Continue' button near the kidney diagram to download an interactive flash file.

**Step – 2**

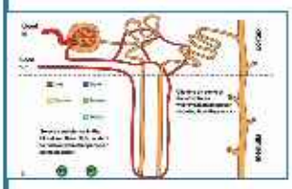
Open the flash file and then click 'Continue' button to start the interactive activity.

**Step – 3**

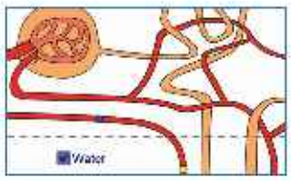
By selecting the molecules given in the list, you can understand how the nephrons process these molecules in accordance to their properties.

**Step – 4**

Use the drop-down menu on the top right corner of the window to understand the parts of the nephron and their functions.



Step 1

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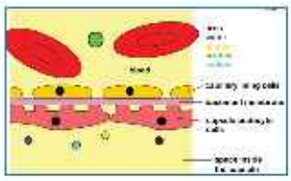

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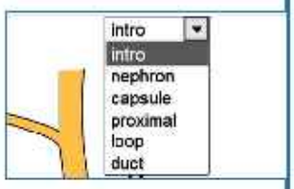


Step 4

Biomed heads-Kidney function's URL:

http://www.biomedheads.com/kidney--nephrons.html

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* Pictures are indicative only



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UNIT IV | Chapter 9

# Locomotion and Movement

**Chapter Outline**


9.1 Types of movement
9.2 Types of muscles
9.3 Skeletal muscle
9.4 Structure of contractile proteins
9.5 Mechanism of muscle contraction
9.6 Types of skeletal muscle contraction
9.7 Skeletal system and its functions
9.8 The Axial skeleton
9.9 The Appendicular skeleton
9.10 Types of joints
9.11 Disorders of muscular and skeletal system
9.12 Benefits of regular Exercise

Leaping movement is effected by the coordination of skeletal and neuromuscular systems.

## Learning Objectives:

- *Relates the structure of skeletal muscle with its function.*
- *Learns to identify bones of the skeletal system.*
- *Gains knowledge about the disorders related to muscular and skeletal systems.*
- *Understands the benefits of regular exercise.*

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Have you ever wondered how a dancer performs intricate dance steps or how a swimmer skillfully does a butterfly stroke? The muscles of our body work simultaneously with one another and with the skeletal system to perform the various movements. Our muscles have two functions: to generate motion and force. All these activities are controlled and coordinated by the skeletal, muscular and nervous system. The human body is capable of a wide range of movements from the gentle blinking of eye to running a 20 km marathon. Movement of organism from one place to another in search of food, shelter, mate and to escape from predators is called locomotion. Locomotion has evolutionary significance.

## 9.1 Types of Movement

The different types of movements that occur in the cells of our body are amoeboid, ciliary, flagellar and muscular movement.

**Amoeboid Movement** - Cells such as macrophages exhibit amoeboid movement



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for engulfing pathogens by pseudopodia formed by the streaming movement of the cytoplasm.

**Ciliary Movement** - This type of movement occurs in the respiratory passages and genital tracts which are lined by ciliated epithelial cells.

**Flagellar Movement** - This type of movement occurs in the cells which are having flagella or whip-like motile organelle. The sperm cells show flagellar movement.

**Muscular Movement** -The movement of hands, legs, jaws, tongue are caused by the contraction and relaxation of the muscle which is termed as the muscular movement.

## 9.2. Types of Muscles

Muscles are specialized tissues which are derived from the embryonic **mesoderm**. They are made of cells called **myocytes** and constitute 40 – 50 percent of body weight in an adult. These cells are bound together by a connective tissue to form a muscular tissue. The muscles are classified into three types, namely **skeletal, visceral** and **cardiac muscles.**

## 9.3 Skeletal Muscle (Voluntary Muscle)

Skeletal muscle is attached to the bone by a bundle of collagen fibres known as **tendon**. Each muscle is made up of bundles of **muscle fibres** called **fascicle**. Each muscle fibre contains hundreds to thousands of rod-like structures called **myofibrils** that run parallel to its length. The connective tissue covering the whole muscle is the **epimysium**, the covering around each fascicle is the **perimysium** and the muscle fibre is surrounded by the **endomysium**. They control the voluntary actions such as walking, running, swimming, writing hence termed as voluntary muscles.

### 9.3.1. Structure of a Skeletal Muscle Fibre

Each muscle fibre is thin and elongated. Most of them taper at one or both ends. Muscle fibre has multiple oval nuclei just beneath its **plasma membrane** or **sarcolemma**. The cytoplasm of the muscle fibre is called the **sarcoplasm**. It contains glycosomes, myoglobin and sarcoplasmic reticulum. **Myoglobin** is a red- coloured respiratory pigment of the muscle fibre. It is similar to haemoglobin and contains iron group that has affinity towards oxygen and serves as the reservoir of oxygen. **Glycosomes** are the granules of stored glycogen that provide glucose during the period of muscle fibre activity. Actin and myosin are muscle proteins present in the muscle fibre.

Along the length of each myofibril there are a repeated series of dark and light bands (Figure 9.1). The dark **A-bands** (Anisotropic bands) and the light **I-bands** (Isotropic bands) are perfectly aligned with one another. This type of arrangement gives the cell a striated appearance. Each dark band has a lighter region in its middle called the **H-Zone** (H-Helles: means clear). Each H-zone is bisected vertically by a dark line called the M-line (M-for middle). The light I-bands also have a darker mid line area called the **Z–disc** (from the German



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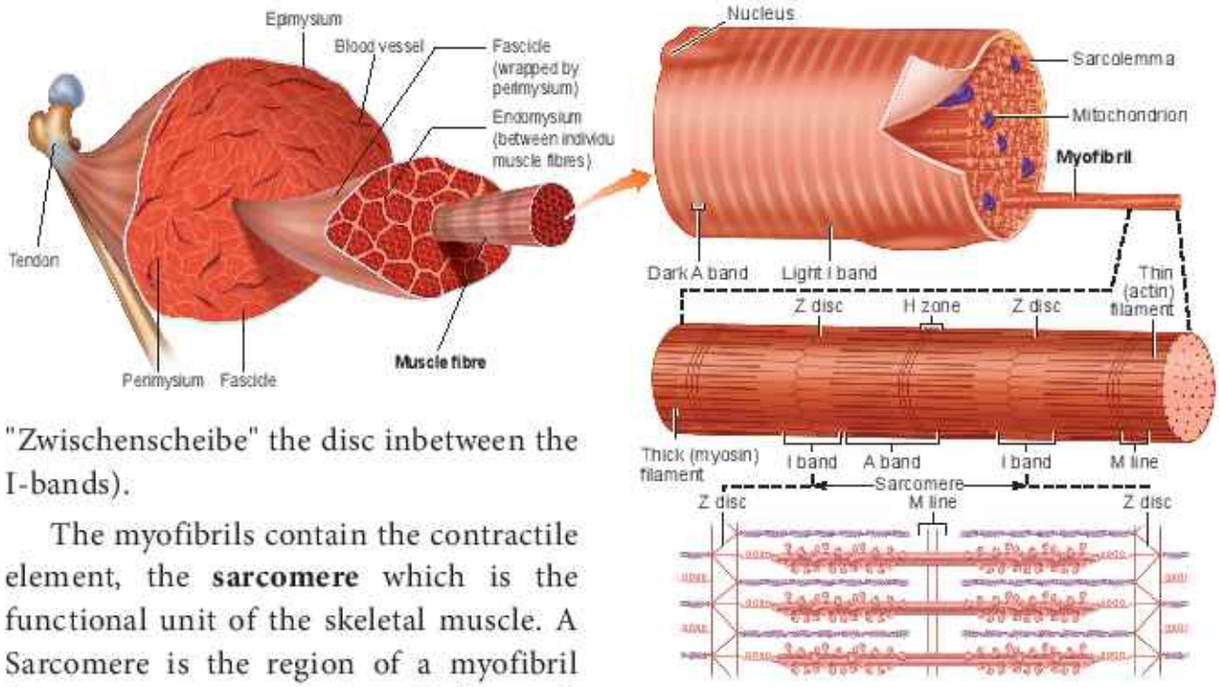


**Figure 9.1** Organizational Level of a Skeletal Muscle

"Zwischenscheibe" the disc inbetween the I-bands).

The myofibrils contain the contractile element, the **sarcomere** which is the functional unit of the skeletal muscle. A Sarcomere is the region of a myofibril between two successive Z-discs. It contains an A-band with a half I-band at each end. Inside the sarcomere two types of filaments are present namely the **thick** and **thin filaments**.

The thick filaments extend the entire length of the A-band, the thin filaments extend across the I-band and partly into the A-band. The invagination of the sarcolemma forms transverse tubules **(T–tubules)** and they penetrate into the junction between the A and I-bands.

**Muscle Terminology**

| General Term | Muscle Equivalent |
|---|---|
| Cell | Muscle fibre/ Myofibril |
| Plasma membrane | Sarcolemma |
| Cytoplasm | Sarcoplasm |
| Endoplasmic reticulum | Sarcoplasmic reticulum |

## 9.4 Structure of Contractile Proteins

Contraction of the muscle depends on the presence of contractile proteins (Figure 9.2) such as **actin** and **myosin** in the myofilaments. The thick filaments are composed of the protein myosin which are bundled together whose heads produce at opposite ends of the filament. Each myosin molecule is made up of a monomer called meromyosin. The meromyosin has two regions, a globular head with a short arm and a tail. The short arm constitutes the heavy meromyosin (HMM). The tail portion forms the light meromyosin (LMM). The head bears an actin-binding site and an ATP- binding site. It also contains ATPase enzyme that split ATP to generate energy for the contraction of muscle. The thin filaments are composed of two interwined actin molecules. Actin has polypeptide subunits called globular actin or G–actin and filamentous form or F-actin. Each thin filament is made of two F-actins helically wound to each other. Each F-actin is a polymer of monomeric G-actins. It also contains a binding site for myosin. The thin filaments also



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contain several regulatory proteins like **tropomyosin** and **troponin** which help in regulating the contraction of muscles along with **actin** and **myosin**.

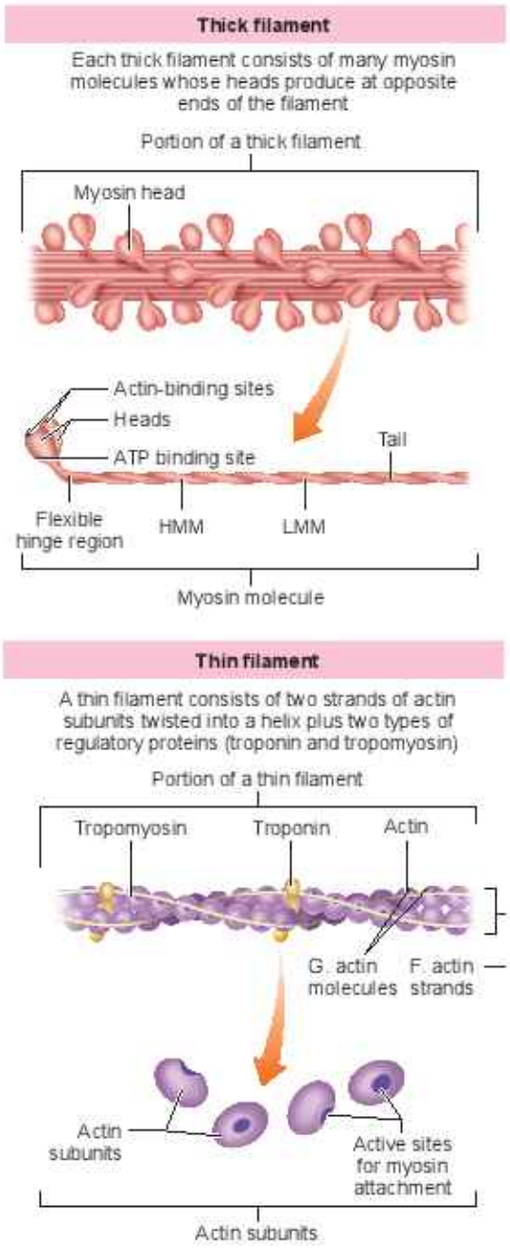


**Figure 9. 2** Composition of thick and thin filaments

## 9.5 Mechanism of Muscle Contraction

**Sliding filament theory:** In 1954, Andrew F. Huxley and Rolf Niedergerke proposed the sliding-filament theory to explain muscle contraction. According to this theory, overlapping actin and myosin filaments of fixed length slide past one another in an energy requiring process, resulting in muscle contraction. The contraction of muscle fibre is a remarkable process that helps in creating a force to move or to resist a load. The force which is created by the contracting muscle is called muscle tension. The load is a weight or force that opposes contraction of a muscle. Contraction is the creation of tension in the muscle which is an active process and relaxation is the release of tension created by contraction. Muscle contraction is initiated by a nerve impulse sent by the central nervous system (CNS) through a motor neuron. The junction between the motor neuron and the sarcolemma of the muscle fibre is called the neuromuscular junction or motor end plate. When nerve impulse reaches a neuromuscular junction, acetylcholine is released. It initiates the opening of multiple gated channels in sarcolemma. The action potential travels along the T-tubules and triggers the release of calcium ions from the sarcoplasmic reticulum. The released calcium ions bind to troponin on thin filaments. The tropomyosin uncovers the myosin-binding sites on thin filaments. Now the active sites are exposed to the heads of myosin to form a cross-bridge (Figure 9.3). During cross-bridge formation actin and myosin form a protein complex called actomyosin. Utilizing the energy released from hydrolysis of ATP, the myosin head rotates until it forms a 90° angle with the long axis of the filament. In this position myosin binds to an actin and activates a contraction – relaxation cycle which is followed by a power stroke.



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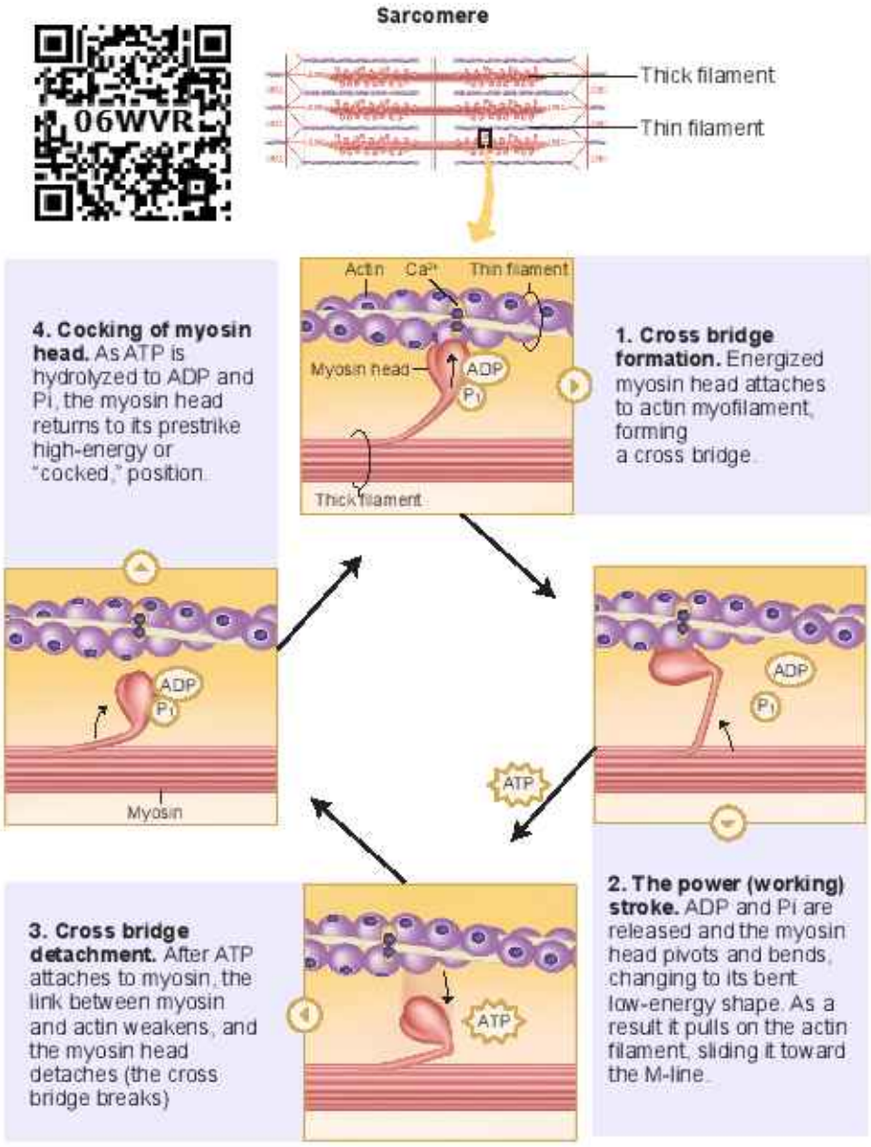


**Figure 9.3** Cross-bridge cycle of muscle contraction

The power stroke (cross-bridge tilting) begins after the myosin head and hinge region tilt from a 90° angle to a 45° angle. The cross-bridge transforms into strong, high-force bond which allows the myosin head to swivel. When the myosin head swivels it pulls the attached actin filament towards the centre of the A-band. The myosin returns back to its relaxed state and releases ADP and phosphate ion. A new ATP molecule then binds to the head of the myosin and the cross-bridge is broken. At the end of each power stroke, each myosin head detaches from actin, then swivels back and binds to a new actin molecule to start another contraction cycle. This movement is similar to the motion of an oar on a boat. At the end of each power stroke, each myosin head detaches from actin, then swivels back and binds to a new actin molecule to start another contraction cycle. The power stroke repeats many times until a muscle fibre contracts. The myosin heads bind, push and release actin molecules over and over as the thin filaments move toward the centre of the sarcomere. The repeated formation of cross-bridge cycles cause the sliding of the filaments only but there is no change in the lengths of either the thick or thin filaments. The Z- discs attached to the actin filaments are also pulled inwards from both the sides, causing the shortening of the sarcomere (i.e. contraction). This process continues as long as the muscle receives the stimuli and with a steady flow of calcium ions. When motor impulse stops, the calcium ions are pumped back into the sarcoplasmic reticulum which result in the masking of the active sites of the actin filaments.The myosin head fails to bind with the active sites of actin and these changes cause the return of Z- discs back to their original position, i.e. relaxation. (Figure 9.3)



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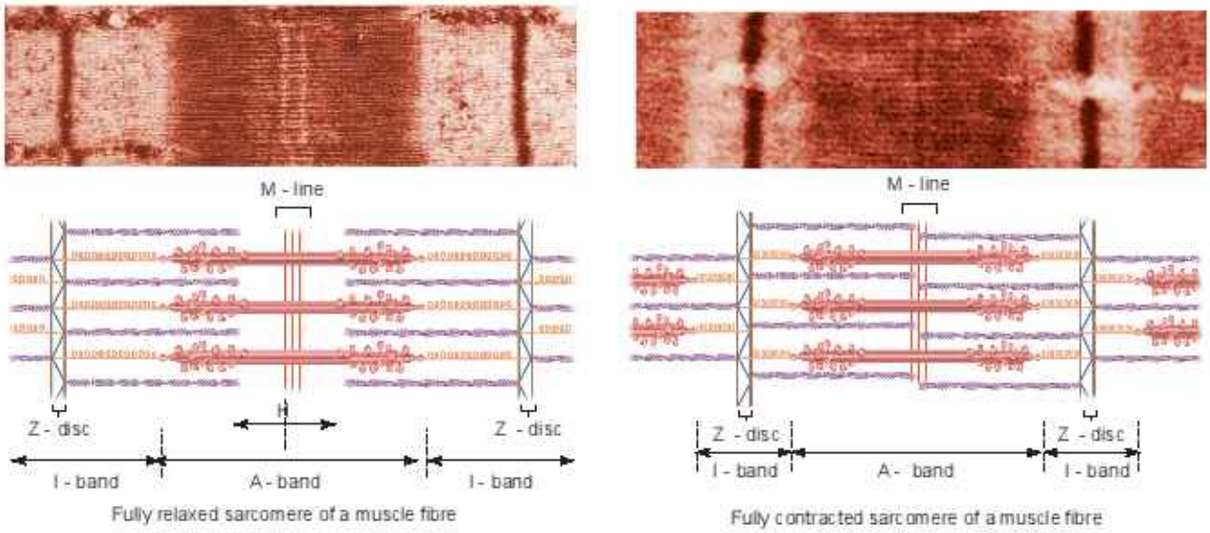


**Figure 9.4** Sliding filament model of muscle contraction

**Schematic Presentation of Muscle Contraction**

Muscle contraction is initiated by the signal from CNS
↓
Release of acetylcholine at the neuromuscular junction
↓
Causes action potential in muscle fibre
↓
Triggers the release of calcium ions from sarcoplasmic reticulum
↓
Calcium ions combine with troponin and tropomyosin uncovers the binding sites on actin and initiates contraction
↓
Myosin binding sites on actin exposed. Myosin head binds to actin
↓
Myosin head executes power stroke
↓
Actin filament slides towards the centre of sarcomere (contraction)
↓
Signal from CNS stops; calcium ions are pumped back into the sarcoplasmic reticulum
↓
Tropomyosin masks the binding sites. Filaments pulled back to the original position (relaxation)

## 9.6. Types of Skeletal Muscle Contraction

There are two primary types of muscle contractions. They are **isotonic contraction** and **isometric contraction**. The types of contractions depend on the changes in the length and tension of the muscle fibres at the time of its contraction.

**Isotonic Contraction (iso- same, ton- weight/resistance)**

In isotonic contraction the length of the muscle changes but the tension remains constant. Here, the force produced is unchanged. Example: lifting dumb bells and weightlifting.

**Isometric Contraction ( iso- same, metric-distance)**

In isometric contraction the length of the muscle does not change but the tension of the muscle changes. Here, the force produced is changed. Example: pushing against a wall, holding a heavy bag.

**Types of Skeletal Muscle Fibres**

The muscle fibres can be classified on the basis of their rate of shortening, either fast



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or slow and the way in which they produce the ATP needed for contraction, either oxidative or glycolytic. Fibres containing myosin with high ATPase activity are classified as fast fibres and with lower ATPase activity are classified as slow fibres. Fibres that contain numerous mitochondria and have a high capacity for oxidative phosphorylation are classified as **oxidative fibres**. Such fibres depend on blood flow to deliver oxygen and nutrients to the muscles. The oxidative fibres are termed as **red muscle fibres**. Fibres that contain few mitochondria but possess a high concentration of glycolytic enzymes and large stores of glycogen are called **glycolytic fibres**. The lack of myoglobin gives pale colour to the fibres, so they are termed as **white muscle fibres**.

Skeletal muscle fibres are further classified into three types based on the above classification. They are slow – oxidative fibres, fast – oxidative fibres and fast – glycolytic fibres.

1. **Slow – oxidative fibres** have low rates of myosin ATP hydrolysis but have the ability to make large amounts of ATP. These fibres are used for prolonged, regular activity such as long distance swimming. Long – distance runners have a high proportion of these fibres in their leg muscles.
2. **Fast – oxidative fibres** have high myosin ATPase activity and can make large amounts of ATP. They are particularly suited for rapid actions.
3. **Fast – glycolytic fibres** have myosin ATPase activity but cannot make as much ATP as oxidative fibres, because their source of ATP is glycolysis. These fibres are best suited for rapid, intense actions, such as short sprint at maximum speed.

Which myofilament has the binding sites for calcium? Name the specific molecule that binds with calcium.

**Skeletal Muscle Glycogen Analysis (SMGA)** –Used to measure an Athlete's sporting performance by taking muscle biopsies. It is a standard method to measure muscle glycogen. Muscle glycogen provides the main source of energy during anaerobic exercise. Furthermore, total glycogen stores within the body also contribute significantly to energy metabolism in endurance-type events lasting longer in duration. A single glycogen molecule may contain 5000 glucose units compared to that of 5000 individual glucose molecules.

## 9.7 Skeletal System and its Function

The skeletal system is constituted by a framework of bones and cartilages. It is derived from the embryonic **mesoderm**. Muscles are attached to the bones by means of tendons and provide the necessary force required for the bones of the skeleton to operate as levers. There are three types of skeletal systems. They are,

**Hydrostatic skeleton,** which is found in soft-bodied invertebrates. It is a fluid filled-cavity encircled by muscles (e.g. Earth worm).



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**Exoskeleton,** which is found in invertebrates. It is a rigid hard case present outside the body of animals (e.g. Cockroach).

**Endoskeleton,** which is found inside the body of vertebrates. It is composed of bones and cartilages, surrounded by muscles. (eg. Human being).

In human beings, the skeletal system is made up of 206 bones and cartilages. It is grouped into two principal divisions – the **axial skeleton** and the **appendicular skeleton**. The axial skeleton consists of 80 bones and the appendicular skeleton consists of 126 bones (Figure 9.6 and Table.1).

**Functions of skeletal system**

- **Support** –It forms a rigid framework and supports the weight of the body against gravity.
- **Shape** - It provides and maintains the shape of the body.
- **Protection** – It protects the delicate internal organs of the body.
- **Acts as reservoir** – It stores minerals such as calcium and phosphate. Fat (Triglyceride) is stored in yellow bone marrow and represents a source of stored energy for the body.
- **Locomotion** – It acts as lever along with the muscles attached to it.
- **Strength** – It can withstand heavy weight and absorbs mechanical shock.
- **As a haemopoietic tissue** – Red and White blood cells are produced in the bone marrow of the ribs, spongy bones of vertebrae and extremities of long bones.

All muscles produce movement, but only skeletal muscle is responsible for locomotion. What is meant by this statement?

## 9.8 The Axial Skeleton

Axial skeleton forms the main axis of the body. It consists of the skull, hyoid bone, vertebral column and thoracic cage.

### a) The Skull

The skull is composed of two sets of bones – cranial and facial bones. It consists of 22 bones of which 8 are cranial bones and 14 are facial bones (Figure 9.5). The cranial bones form the hard protective outer covering of the brain and called the brain box. The capacity of the cranium is 1500 $cm^3$. These bones are joined by sutures which are immovable. They are a **paired parietal, paired temporal** and **individual bones** such as the **frontal, sphenoid, occipital and ethmoid**.

The large hole in the temporal bone is the **external auditory meatus**. In the facial bones **maxilla, zygomatic, palatine, lacrimal, nasal, inferior nasal concha** are paired bones whereas **mandible** or **lower jaw** and **vomer** are **unpaired bones**. They form the front part of the skull. A single U-shaped **hyoid bone** is present at the base of the buccal cavity. It is the only one bone without any joint. Each middle ear contains three tiny bones- **malleus**, **incus** and **stapes** collectively are called **ear ossicles**. The upper jaw is formed of the **maxilla** and the lower jaw is formed of the **mandible**. The upper jaw is fused with the cranium and is immovable. The lower jaw is connected to the cranium by muscles and is movable. The most prominent openings in the skull are **the orbits** and **the nasal cavity**. **Foramen magnum** is a large opening found at the posterior base of the skull. Through this opening the medulla oblongata of the brain descends down as the spinal cord.



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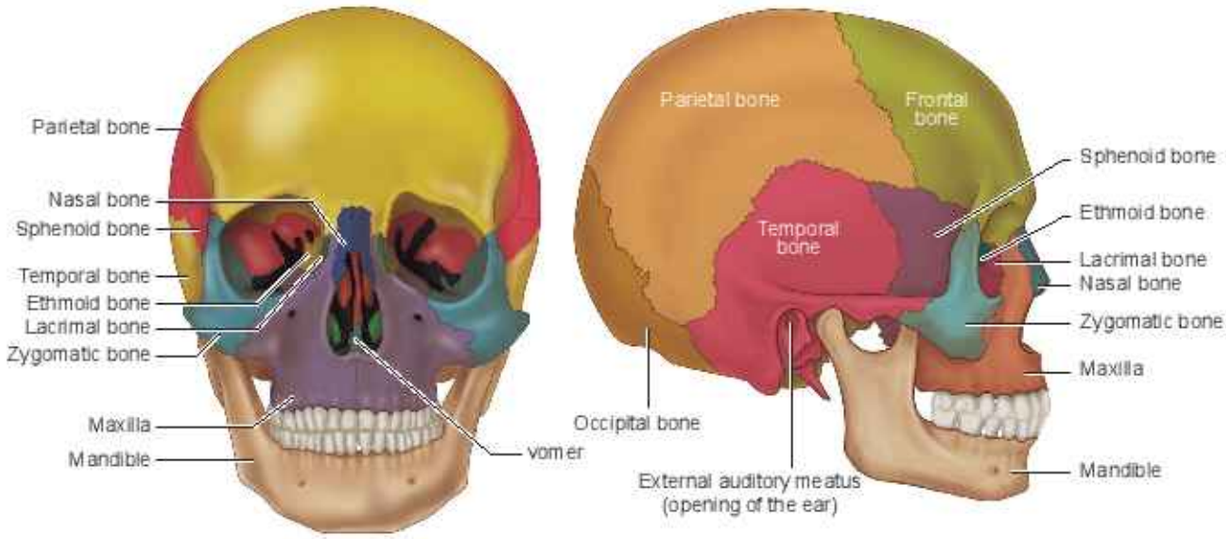


Anterior view Lateral view

**Figure 9. 5** Structure of the skull

**b) The Vertebral Column**

Vertebral column is also called the back bone. It consists of 33 serially arranged vertebrae which are interconnected by cartilage known as intervertebral disc (Figure 9.6). The vertebral column extends from the base of the skull to the pelvis and forms the main frame work of the trunk. The vertebral column has five major regions. They are, **the Cervical**, **Thoracic**, **Lumbar**, **Sacrum** (5 sacral vertebrae found in the infant which are fused to form one bone in the adult) and **Coccyx** (4 coccygeal vertebrae found in the infant which are fused to form one bone in the adult).

Each vertebra has a central hollow portion, the neural canal, through which the spinal cord passes. The first vertebra is called as the **atlas** and the second vertebra is called as the **axis**. Atlas is articulated with the occipital condyles.

The vertebral column protects the spinal cord, supports the head and serves as the point of attachment for the ribs and musculature of the back.

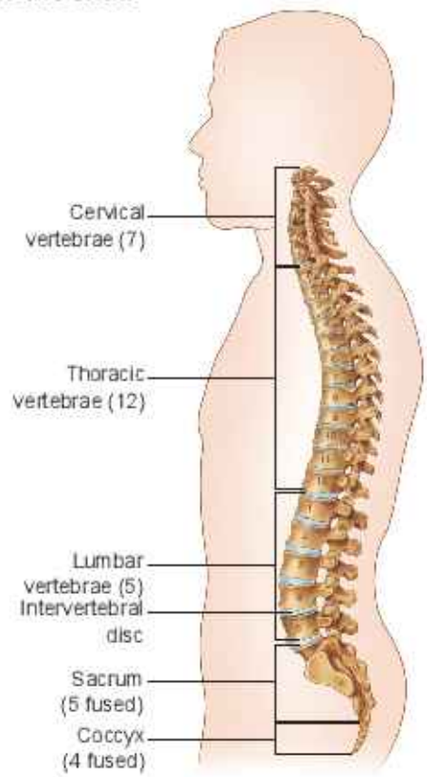


**Figure 9. 6** Vertebral Column

**(c) The Sternum (Chest bone)**

Sternum is a flat bone on the mid ventral line of the thorax. It provides space for the attachment of the thoracic ribs and abdominal muscles.

**(d) The Rib Cage**

There are 12 pairs of ribs (Figure 9.7). Each rib is a thin flat bone connected dorsally to



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the vertebral column and ventrally to the sternum. It has two articulation surfaces on its dorsal end, hence called bicephalic. The first seven pairs of ribs are called **'true ribs'** or **vertebro–sternal ribs**. Dorsally they are attached to the thoracic vertebrae and ventrally connected to the sternum with the help of hyaline cartilages. The 8th, 9th and 10th pairs of ribs do not articulate directly with the sternum but joined with the cartilaginous (hyaline cartilage) part of the seventh rib. These are called **'false ribs'** or **vertebro-chondral ribs**. The last 11th and 12th pairs of ribs are not connected ventrally. Therefore, they are called as **'floating ribs'** or **vertebral ribs**. Thoracic vertebrae, ribs and sternum together form the ribcage.

Rib cage protects the lungs, heart, liver and also plays a role in breathing.

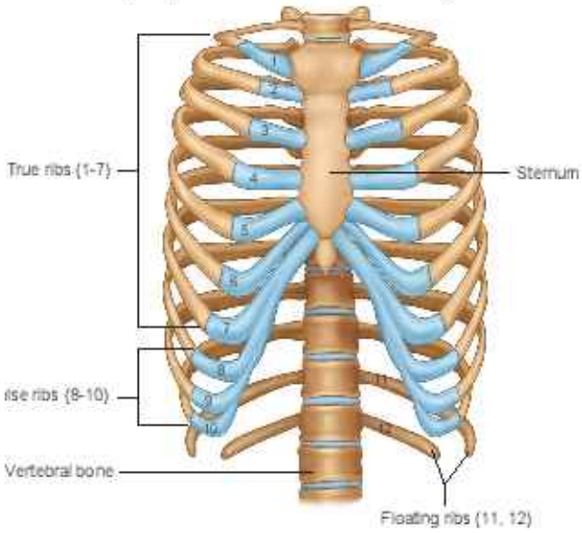


**Figure 9.7** Rib cage

## 9.9 The Appendicular Skeleton

The bones of the upper and lower limbs along with their girdles constitute the appendicular skeleton. The appendicular skeleton is composed of 126 bones.

### (a) The Pectoral girdle

The upper limbs are attached to the pectoral girdles. These are very light and allow the upper limbs a degree of mobility not seen anywhere else in the body. The girdle is formed of two halves. Each half of the pectoral girdle (Figure 9.8) consists of **a clavicle** or **collar bone** and a **scapula**. The scapula is a large, thin, triangular bone situated in the dorsal surface of the ribcage between the second and seventh ribs. It has a slightly elevated ridge called the spine which projects as a flat, expanded process called the **acromion**. The clavicle articulates with this process. Below the acromion is a depression called the **glenoid cavity** which articulates with the head of the humerus to form the shoulder joint. Each clavicle is a long slender bone with two curvatures which lies horizontally and connects axial skeleton with appendicular skeleton.

### The Upper Limb

The upper limb consists of 30 separate bones and is specialized for mobility. The skeleton of the arm, the region between the shoulder and elbow is the **humerus**. The head of humerus articulates with the **glenoid cavity** of the scapula and forms the shoulder joint. The distal end of humerus articulates with the two forearm bones the **radius** and **ulna**. The forearm is the region between the elbow and the wrist. **Olecranon process** is situated at the upper end of the ulna which forms the pointed portion of the elbow.The hand consists of **carpals, metacarpals** and **phalanges.**

**Carpals,**the wrist bones, 8 in number are arranged in two rows of four each. The anterior surface of the wrist has tunnel-like appearance, due to the arrangement of carpals with the ligaments. This tunnel is termed as **carpal tunnel**.



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**CTS-(Carpal Tunnel Syndrome)** – The narrow passage (tunnel) bounded by bones and ligaments in the wrist gets narrowed and pinches the median nerve. This syndrome is mostly seen among the clerks, software professionals and pregnant women and people who constantly play or text in mobile phones.

**Metacarpals,**the palm bones are 5 in number and **phalanges** the digits bones are 14 in number.

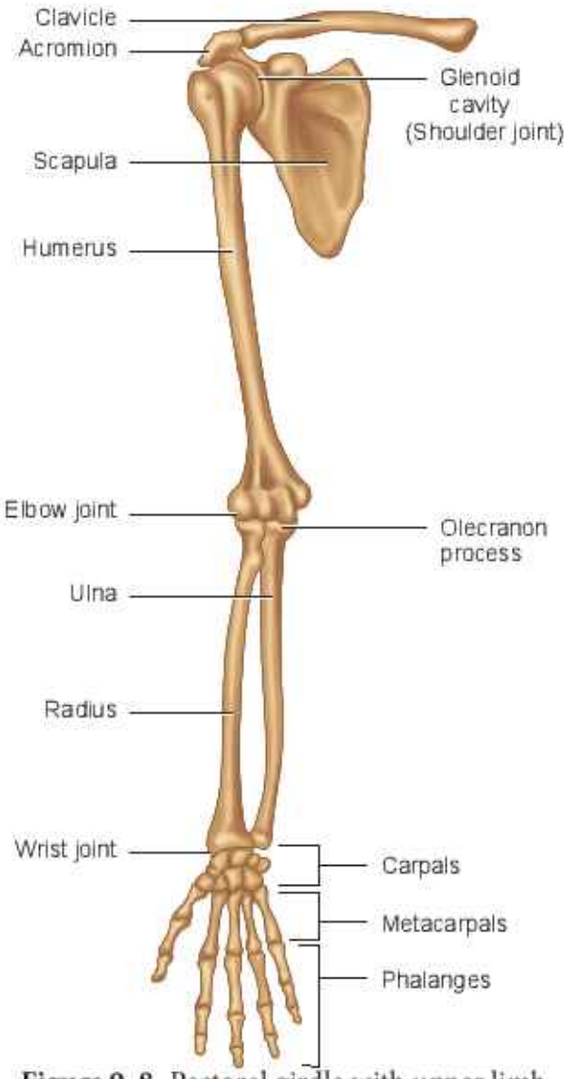


**Figure 9. 8** Pectoral girdle with upper limb

### (b) Pelvic Girdle

The pelvic girdle is a heavy structure specialized for weight bearing. It is composed of two hip bones called coxal bones that secure the lower limbs to the axial skeleton (Figure 9.9). Together, with the sacrum and coccyx, the hip bones form the basin-like bony pelvis.

Each coxal bone consists of three fused bones, **ilium, ischium** and **pubis**. At the point of fusion of ilium, ischium, and pubis a deep hemispherical socket called the acetabulum is present on the lateral surface of the pelvis. It receives the head of the femur or thigh bone at the hip joint and helps in the articulation of the femur. Ventrally the two halves of the pelvic girdle meet and form the **pubic symphysis** containing fibrous cartilage.

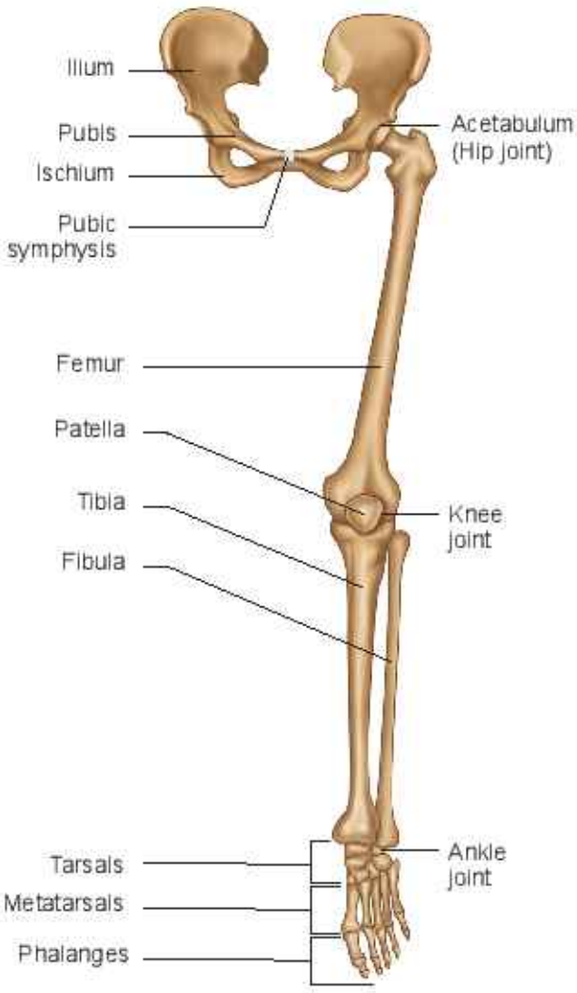


**Figure 9.9** Pelvic girdle with lower limb



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The **ilium** is the superior flaring portion of the hip bone. Each ilium forms a secure joint with the sacrum posteriorly. The **ischium** is a curved bar of bone. The V-shaped **pubic bones** articulate anteriorly at the **pubic symphysis**. The pelvis of male is deep and narrow with larger heavier bones and the female is shallow, wide and flexible in nature, and this helps during pregnancy which is influenced by female hormones.

The pelvic girdle is a heavy, strong girdle. How does its structure reflect its function?

## The Lower Limb

The lower limb consists of 30 bones which carries the entire weight of the erect body and is subjected to exceptional forces when we jump or run. The bones of the lower limbs are thicker and stronger than the upper limbs. The three segments of each lower limb are **the thigh**, **the leg** or **the shank** and **the foot**. **The femur** is the single bone of the thigh. It is the largest, longest and strongest bone in the body. The head of femur articulates with **the acetabulum** of the pelvis to form the hip joint. Two parallel bones, **the tibia** and **fibula**, form the skeleton of the shank. A thick, triangular **patella** forms the knee cap, which protects the knee joint anteriorly and improves the leverage of thigh muscles acting across the knee. The foot includes the bones of ankle, **the tarsus**, **the metatarsus** and **the phalanges or toe bones**. The foot supports our body weight and acts as a lever to propel the body forward, while walking and running. **The tarsus** is made up of seven bones called tarsals. **The metatarsus** consists of five bones called metatarsals. The arrangement of the metatarsals is parallel to each other. There are 14 **phalanges** in the toes which are smaller than those of the fingers.

## Structure of a Typical Long Bone

A typical long bone has a **diaphysis**, **epiphyses** (singular-epiphysis) and **membranes** (Figure 9.10). A tubular diaphysis or shaft, forms the long axis of the bone. It is constructed of a thick collar of compact bone that surrounds a central **medullary cavity** or **marrow cavity**. The epiphyses are the bone ends. Compact bone forms the exterior of epiphyses and their interior contains spongy bone with red marrow. The region where the diaphysis and epiphyses meet is called the **metaphysis**. The external surface of the entire bone except the joint surface is covered by a double-layered membrane called the **periosteum**. The outer fibrous layer is dense irregular connective tissue. The inner osteogenic layer consists of **osteoblasts** (bone- forming cells) which secrete bone matrix elements and **osteoclasts** (bone-destroying cells). In addition, there are primitive stem cells, osteogenic cells, that give rise to the osteoblasts. The periosteum is richly supplied with nerve fibres, lymphatic vessels and blood vessels. Internal bone surfaces are covered with a delicate connective tissue membrane called the **endosteum**. The endosteum covers the trabeculae of spongy bone and lines the canals that pass through the compact bone. It also contains both osteoblasts and osteoclasts. Between the epiphysis and diaphysis **epiphyseal plate** or **growth plate** is present.



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**Table: 9.1** Bones of the Skeletal System

| Skeleton | Name of Bone | | Number of Bones | Total Number of Bones |
|---|---|---|---|---|
| **Axial skeleton (80 bones)** | Skull | Cranium<br>Facial bone<br>Bones of middle ear<br>Hyoid bone | 8<br>14<br>6<br>(2 × 3)<br>1 | 29 |
| | Vertebral column | Cervical<br>Thoracic<br>Lumbar<br>Sacral<br>Coccyx | 7<br>12<br>5<br>5 bones fused to 1 bone<br>4 bones fused to 1 bone | 26 (in adults) |
| | Sternum | | 1 | 1 |
| | Ribs | | 12 × 2 = 24 | 24 |
| **Appendicular skeleton (126bones)** | Fore limb | Humerus<br>Radius<br>Ulna<br>Carpals<br>Metacarpals<br>Phalanges | 1<br>1<br>1<br>8<br>5<br>14 | (2 × 30)<br>60 |
| | Hind limb | Femur<br>Tibia<br>Fibula<br>Tarsal<br>Metatarsals<br>Phalanges<br>Patella (Knee bone) | 1<br>1<br>1<br>7<br>5<br>14<br>1 | (2 × 30)<br>60 |
| | Pectoral girdle | Scapula<br>Clavicle | 1<br>1 | (2 × 2)<br>4 |
| | Pelvic girdle | Innominate (Ilium, ischium and pubis fused into one bone) | 1 | (1 × 2)<br>2 |
| | | | Total number of bones in adults | 206 |



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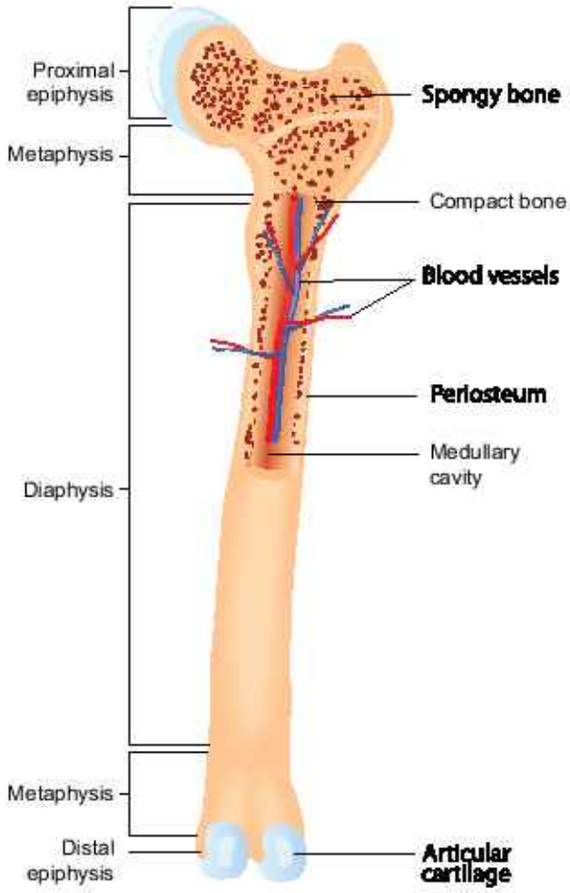


**Figure 9.10** Structure of a long bone

## 9.10 Types of joints

Joints are essential for all types of movements performed by the bony parts of the body. The joints are points of contact (Figure 9.11) between bones.

Sometimes they are playing a protective role in the process. Force generated by the muscles are used to carry out the movement through joints which helps human functional activity of daily living and ambulation. The joint acts as a fulcrum of a lever.

(i) **Fibrous joints or Synarthroses:** They are immovable fixed joints in which no movement between the bones is possible. Sutures of the flat skull bones are fibrous joints.

(ii) **Cartilaginous joints or Amphiarthroses:** They are slightly movable joints in which the joint surfaces are separated by a cartilage and slight movement is only possible. E.g., Joints of adjacent vertebrae of the vertebral column.

(iii) **Synovial joints or Diarthroses joints:** They are freely movable joints, the articulating bones are seperated by a cavity which is filled with synovial fluid.

**Figure 9. 11** Types of joints

| | |
|---|---|
| Pivot joint | between atlas and axis |
| Plane/gliding joint | between the carpals |
| Saddle joint | between the first carpal and metacarpal |
| Ball and socket joint | between humerus and pectoral girdle |
| Hinge joint | knee joint |
| Condyloid or Angular or Ellipsoid | between radius and carpal |



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An exhausted student was attending a lecture. After 30 minutes or so, he lost interest and he let go with a tremendous yawn. To his great distress he couldn't close his mouth –his lower jaw was locked open. What do you think would have caused it?

## 9.11 Disorders of muscular and skeletal system

### (a) Disorders of muscular system

#### Myasthenia Gravis

An autoimmune disorder affecting the action of acetylcholine at neuro-muscular junction leading to fatigue, weakening and paralysis of skeletal muscles. Acetylcholine receptors on the sarcolemma are blocked by antibodies leading to weakness of muscles. When the disease progresses, it can make chewing, swallowing, talking and even breathing difficult.

#### Tetany

Rapid muscle spasms occur in the muscles due to deficiency of parathyroid hormone resulting in reduced calcium levels in the body.

#### Muscle Fatigue

Muscle fatigue is the inability of a muscle to contract after repeated muscle contractions. This is due to lack of ATP and accumulation of lactic acid by anaerobic breakdown of glucose

#### Atrophy

A decline or cessation of muscular activity results in the condition called atrophy which results in the reduction in the size of the muscle and makes the muscle to become weak, which occurs with lack of usage as in chronic bedridden patients.

#### Muscle Pull

Muscle pull is actually a muscle tear. A traumatic pulling of the fibres produces a tear known as sprain. This can occur due to sudden stretching of muscle beyond the point of elasticity. Back pain is a common problem caused by muscle pull due to improper posture with static sitting for long hours.

#### Muscular Dystrophy

The group of diseases collectively called the muscular dystrophy are associated with the progressive degeneration and weakening of skeletal muscle fibres, leading to death from lung or heart failure. The most common form of muscular dystrophy is called **Duchene Muscular Dystrophy (DMD)**.

### b) Disorders of Skeletal System

Arthritis and osteoporosis are the major disorders of skeletal system.

#### 1. Arthritis

Arthritis is an inflammatory (or) degenerative disease that damages the joints. There are several types of arthritis.

(i) **Osteoarthritis:** The bone ends of the knees and other freely movable joints wear away as a person ages. The joints of knees, hip, fingers and vertebral column are affected.

(ii) **Rheumatoid Arthritis:** The synovial membranes become inflamed and there is an accumulation of fluid in the joints. The joints swell and become extremely painful. It can begin at any age but symptoms usually emerge before the age of fifty.

(iii) **Gouty Arthritis or Gout:** Inflammation of joints due to accumulation of uric acid crystals or inability to excrete it. It gets deposited in synovial joints.



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### 2. Osteoporosis

It occurs due to deficiency of vitamin D and hormonal imbalance. The bone becomes soft and fragile. It causes rickets in children and osteomalacia in adult females. It can be minimized with adequate calcium intake, vitamin D intake and regular physical activities.

## 9.12 Benefits of Regular Exercise

Exercise and physical activity fall into four basic categories. Endurance, Strength, Balance and Flexibility.

**Endurance** or aerobic activities increase the breathing and heart rate. They keep the circulatory system healthy and improve overall fitness.

**Strength exercises** make the muscles stronger. They help to stay independent and carry out everyday activities such as climbing stairs and carrying bags.

**Balance exercises** help to prevent falls which is a common problem in older adults. Many strengthening exercises also improves balance.

**Flexibility exercises** help to stretch body muscles for more freedom of joint movements. Regular exercises can produce the following beneficial physiological changes:

- The muscles used in exercise grow larger and stronger.
- The resting heart rate goes down.
- More enzymes are synthesized in the muscle fibre.
- Ligaments and tendons become stronger.
- Joints become more flexible.
- Protection from heart attack.
- Influences hormonal activity.
- Improves cognitive functions.
- Prevents Obesity.
- Promotes confidence, esteem.
- Aesthetically better with good physique.
- Over all well-being with good quality of life.
- Prevents depression, stress and anxiety.

During muscular exercise, there is an increase in metabolism. The $O_2$ need of the muscles is increased. This requirement is met with more oxygen rich RBCs available to the active sites. There is an increase in heart rate and cardiac output. Along with balanced diet, physical activity plays a significant role in strengthening the muscles and bones.

## Summary

Movement is one of the significant features of living organisms. The different types of movements are amoeboid movement, ciliary movement, flagellar movement and muscular movement. Three types of muscles are present in human beings. They are the skeletal muscle, visceral muscle and cardiac muscle. The skeletal muscles are attached to the bones by tendons.

The most striking microscopic feature of skeletal muscle is a series of light and dark bands. The muscles exhibit the properties such as excitability, contractibility, conductibility and elasticity. There are two types of muscle contraction. They are isotonic and isometric contractions.

The skeletal system consists of a frame work of bones and cartilages. The skeletal system is grouped into two principal divisions: the axial skeleton and the appendicular skeleton. There are three types of joints present in the body: fibrous, cartilaginous and synovial joints.



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The disorders related to muscular system are myasthenia gravis, muscular dystrophy, tetany, muscle fatigue, muscle pull, atrophy and rigor mortis. The disorders of the skeletal system are arthritis and osteoporosis. Regular body exercise keeps the body fit and healthy.

## Evaluation

1. Muscles are derived from
   a. ectoderm
   **b. mesoderm**
   c. endoderm d. neuro ectoderm
2. Muscles are formed by
   **a. myocytes** b. leucocytes
   c. osteocytes d. lymphocytes
3. The muscles attached to the bones are called
   **a. skeletal muscle**
   b. cardiac muscle
   c. involuntary muscle
   d. smooth muscles
4. Skeletal muscles are attached to the bones by
   **a. tendon** b. ligament
   c. pectin d. fibrin
5. The bundle of muscle fibres is called
   a. Myofibrils **b. fascicle**
   c. sarcomere d. sarcoplasm
6. The pigment present in the muscle fibre to store oxygen is
   **a. myoglobin** b. troponin
   c. myosin d. actin
7. The functional unit of a muscle fibre is
   **a. sarcomere** b. sarcoplasm
   c. myosin d. actin
8. The protein present in the thick filament is
   **a. myosin** b. actin
   c. pectin d. leucin
9. The protein present in the thin filament is
   a. myosin **b. actin**
   c. pectin d. leucin
10. The region between two successive Z-discs is called a
    **a. sarcomere** b. microtubule
    c. myoglobin d. actin
11. Each skeletal muscle is covered by
    **a. epimysium** b. perimysium
    c. endomysium d. hypomysium
12. Knee joint is an example of
    a. saddle joint **b. hinge joint**
    c. pivot joint d. gliding joint
13. Name of the joint present between the atlas and axis is
    a. synovial joint **b. pivot joint**
    c. saddle joint d. hinge joint
14. ATPase enzyme needed for muscle contraction is located in
    a. actinin b. troponin
    **c. myosin** d. actin
15. Synovial fluid is found in
    a. Ventricles of the brain
    b. Spinal cord
    c. immovable joint
    **d. freely movable joints.**
16. Inflammation of joints due to accumulation of uric acid crystals is called as
    **a. Gout** b. myasthenia gravis
    c. osteoporosis d. osteomalacia
17. Acetabulum is located in
    a. collar bone **b. hip bone**
    c. shoulder bone d. thigh bone
18. Appendicular skeleton is
    **a. girdles and their limbs**
    b. vertebrae
    c. skull and vertebral column
    d. ribs and sternum



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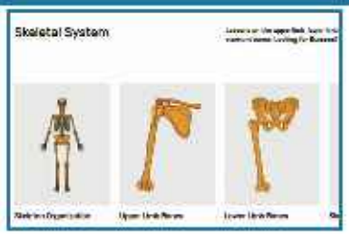
19. The type of movement exhibits by the macrophages are
    a. flagellar  b. ciliary
    c. muscular  **d. amoeboid**
20. The pointed portion of the elbow is
    a. acromion process
    b. glenoid cavity
    **c. olecranon process**
    d. symphysis
21. Name the different types of movement.
22. Name the filaments present in the sarcomere.
23. Name the contractile proteins present in the skeletal muscle.
24. When describing a skeletal muscle, what does "striated" mean?
25. How does an isotonic contraction take place?
26. How does an isometric contraction take place?
27. Name the bones of the skull.
28. Which is the only jointless bone in human body?
29. List the three main parts of the axial skeleton
30. How is tetany caused?
31. What are the functions of the skeletal system?
32. What are the different types of rib bones that form the rib cage?
33. What are the bones that make the pelvic girdle?
34. List the disorders of the muscular system.
35. Explain the sliding- filament theory of muscle contraction.
36. What are the benefits of regular exercise?

## ICT Corner  We like to move

**Let's explore the skeletal system page to understand the skeletal organization.**

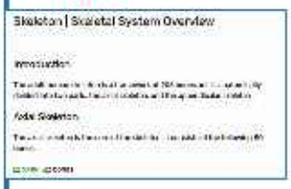



**Step – 1** Use the URL to reach the 'Skeletal System' page. From grid select 'Skeleton Organization' and explore the skeleton's general anatomical arrangement and functions.

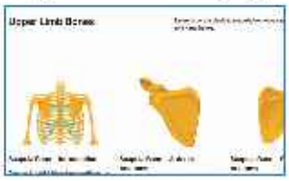
**Step – 2** Then reach the 'Skeleton Organization page by clicking back button on the top of the window or use the 'Backspace' key. Select 'Upper Limb Bones' from the grid and explore the anatomy and functions of the clavicle, scapula, humerus, radius, ulna, carpal, and hand bones.

**Step – 3** Follow the above steps and explore the interactives of each part and its functions.

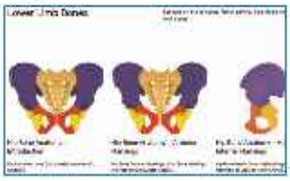
**Step – 4** Use the reference given below the page to acquire additional details about 'Skeletal System'.




Step 1




Step 2




Step 3

Step 4

Skeletal System's URL:

https://www.getbodysmart.com/skeletal-system

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* Pictures are indicative only



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UNIT IV

Chapter 10

# Neural Control And Coordination

**Chapter Outline**


10.1 Neural system

10.2 Human Neural System

10.3 Neuron as a structural and functional unit of neural system

10.4 Central neural system

10.5 Reflex action and reflex arc

10.6 Sensory reception and processing

Gamma-aminobutyric acid, or GABA, is the brain's major inhibitory neurotransmitter that reduces neuronal excitability.

## Learning Objectives:

- *Understands the structure of neuron and neural system of human beings*
- *Learns to differentiate the functions of sensory and motor neuron*
- *Understands the conduction of nerve impulses and learns the importance of myelin sheath-saltatory conduction.*
- *Outlines the role of synapse and neuromuscular junction.*
- *Learns the structure and functions of central neural system*
- *Understands the structure, sensory reception and processing in Photo, Phono, Olfactory, Gustatory and Skin Receptors*

Did you ever wonder how our body functions? The body maintains a stable condition even when the outside environment changes; Our eyes help to see things around us; Ears help us to hear various sounds; Heart beats continuously and rhythmically; Air goes in and out of lungs; Eyes shed tears when our limbs get hurt. Each cell of the body works in a coordinated manner. Do you know how it is coordinated and controlled?

The neural system of our body coordinates all the other systems to work together effectively and smoothly. Every second, diverse functions in our body are performed by the neural system. Day and night, millions of messages pass as stimuli through the cells of the neural system to stimulate the heart to beat; kidney to excrete waste; and mouth to relish the delicious food. An even more remarkable



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feature of the neural system is its ability to respond simultaneously to several stimuli, for instance, we can play piano and sing; listen to music and do household chores. In all such coordinated movements, whether skilled performances or routine tasks like cycling or driving, the integrating power of the neural system is involved. In this chapter, you will understand how neural system is organized; how it integrates all organs and what kind of cellular events underlie its functioning.

## 10.1 Neural System

The neural system comprises of highly specialized cells called **neurons**, which can detect, receive, process and transmit different kinds of stimuli. Simple form of neural system as nerve net is seen in lower invertebrates. The neural system of higher animals are well developed and performs the following basic functions:

- **Sensory functions**- It receives sensory input from internal and external environment.
- **Motor functions**- It transmits motor commands from the brain to the skeletal and muscular system.
- **Autonomic functions**- Reflex actions.

## 10.2 Human Neural System

The human neural system is divided into two, **the central neural system (CNS)** and **the peripheral neural system (PNS)**. The structural and functional units of the neural system are neurons that transmit nerve impulses. The non-nervous special cells called **neuroglia** form the supporting cells of the nervous tissue.

There are three functional classes of neurons. They are the **afferent neurons** that take sensory impulses to the Central Neural system (CNS) from the sensory organs; the **efferent neurons** that carry motor impulses from the CNS to the effector organs; and **interneurons** that lie entirely within the CNS between the afferent and efferent neurons.

The central neural system lacks connective tissue, so the interneuron space is filled by neuroglia. They perform several functions such as providing nourishment to the surrounding neurons; involving the memory process; repairing the injured tissues due to their dividing and regenerating capacity; and acting as phagocyte cells to engulf the foreign particles at the time of any injury to the brain.

Glial cells do not lose the ability to undergo cell division; so most brain tumours of neural origin consists of glial cells. Neurons themselves do not form tumours because they are unable to divide and multiply.

## 10.3 Neuron as a Structural and Functional Unit of Neural System

A neuron is a microscopic structure composed of three major parts namely **cell body** (soma), **dendrites** and **axon.** The cell body is the spherical part of the neuron that contains all the cellular organelles as a typical cell (except centriole). The plasma membrane covering the neuron is called **neurilemma** and the axon is **axolemma.** The repeatedly branched



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short fibres coming out of the cell body are called **dendrites,** which transmit impulses towards the cell body. The cell body and the dendrites contain cytoplasm and granulated endoplasmic reticulum called **Nissl's granules.**

An axon is a long fibre that arises from a cone shaped area of the cell body called the **Axon hillock** and ends at the branched distal end. Axon hillock is the place where the nerve impulse is generated in the motor neurons. The axon of one-neuron branches and forms connections with many other neurons. An axon contains the same organelles found in the dendrites and cell body but lacks Nissl's granules and Golgi apparatus.

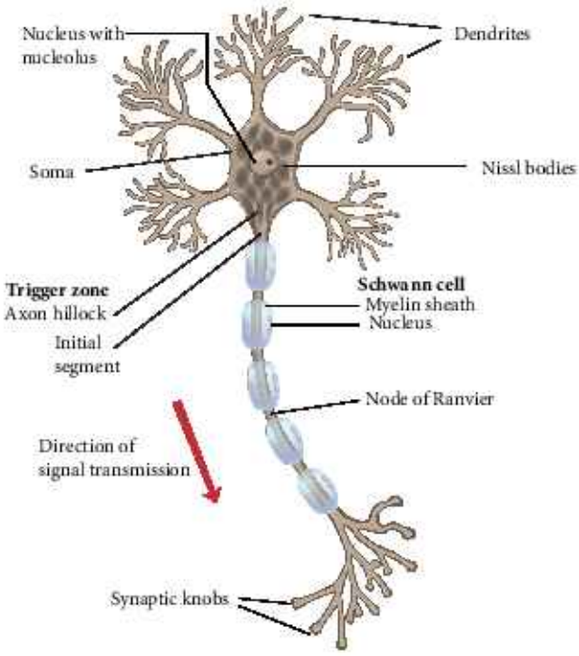


**Figure 10.1** Neuron

The axon, particularly of peripheral nerves is surrounded by **Schwann cells** (a type of glial cell) to form myelin sheath, which act as an insulator. **Myelin sheath** is associated only with the axon; dendrites are always non-myelinated. Schwann cells are not continuous along the axon; so there are gaps in the myelin sheath between adjacent Schwann cells. These gaps are called **Nodes of Ranvier**. Large myelinated nerve fibres conduct impulses rapidly, whereas non-myelinated fibres conduct impulses quite slowly (Figure 10.1).

The longest cells in the human body are the **neurons**. The **longest** axons in the **human body**, for example, are those of the sciatic nerve, which run from the base of the spine to the big toe of each foot. These single-cell fibers may extend a meter or even longer. The axons of the inter neurons in the CNS are the shortest.

Each branch at the distal end of the axon terminates into a bulb like structure called **synaptic knob** which possesses **synaptic vesicles** filled with **neurotransmitters**. The axon transmits nerve impulses away from the cell body to an **inter neural space** or to a **neuro-muscular junction.**

The neurons are divided into three types based on number of axon and dendrites they possess (Figure.10.2).

**1. Multipolar neurons** have many processes with one axon and two or more dendrites. They are mostly interneurons.

**2. Bipolar neurons** have two processes with one axon and one dendrite. These are found in the retina of the eye, inner ear and the olfactory area of the brain.

**3. Unipolar neurons** have a single short process and one axon. Unipolar neurons are located in the ganglia of cranial and spinal nerves.



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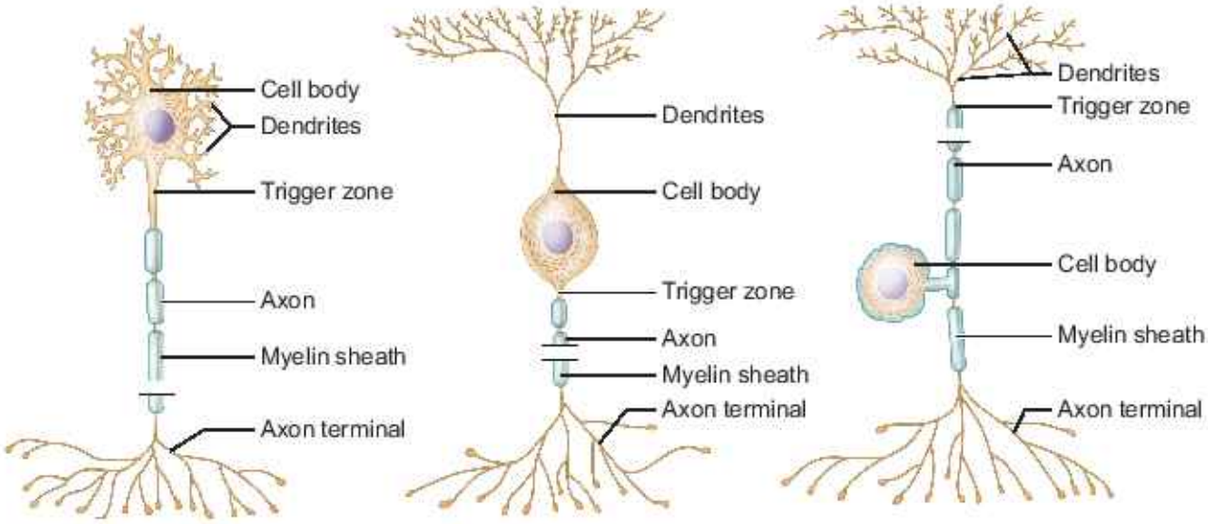


**Figure 10.2.** Types of Neurons

### 10.3.1 Generation and Conduction of Nerve Impulses

This section deals with how the nerve impulses are produced and conducted in our body. Sensation felt in the sensory organs are carried by the nerve fibres in the form of electrical impulses. A nerve impulse is a series of electrical impulses, which travel along the nerve fibre. Inner to the axolemma, the cytoplasm contains the **intracellular fluid** (ICF) with large amounts of potassium and magnesium phosphate along with negatively charged proteins and other organic molecules. The **extra cellular fluid** (ECF) found outside the axolemma contains large amounts of sodium chloride, bicarbonates, nutrients and oxygen for the cell; and carbon dioxide and metabolic wastes released by the neuronal cells. The ECF and ICF (cytosol) contains negatively charged particles (anions) and positively charged particles (cations). These charged particles are involved in the conduction of impulses.

The neurons maintain an uneven distribution of various inorganic ions across their axolemma for transmission of impulses. This unequal distribution of ions establishes the membrane potential across the axolemma. The axolemma contains a variety of membrane proteins that act as ionic channels and regulates the movement of ions across the axolemma. (Shown in Table 10.1).

### 10.3.2 Transmission of Impulses

The transmission of impulse involves two main phases; **Resting membrane potential** and **Action membrane potential.**

**Resting membrane Potential:** The electrical potential difference across the plasma membrane of a resting neuron is called the **resting potential** during which the interior of the cell is negative due to greater efflux of $K^+$ outside the cell than

**Note:** The charged particles have potential energy. The potential difference is the measure of potential energy between two points which is measured in volts or millivolts.



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**Table: 10.1** Ionic Channels in the Axolemma

| | |
|---|---|
| **Leakage Channels** are ionic channels that remain open all the time | $K^+$ leakage channels are more in number than the $Na^+$ leakage channels. Sarcolemma has greater permeability to $K^+$ ions than $Na^+$ ions. These ions keep moving continuosly maintain the potential difference across the axolemma. |
| **Ligand-gated Channels** are chemically gated channels which open or close in response to a chemical stimuli. | They are located between the presynaptic membrane of the first axon and post synaptic membrane of the cell body of second neuron [i.e. dendrites and cell bodies]. The neurotransmitter acetylcholine opens ligand channels that allow $Na^+$ and $Ca^{++}$ ions diffuse inward and $K^+$ ions diffuse outward. |
| **Voltage-gated Channels** are mechanically gated channels which open in response to a physical stimulus in the form of vibration such as touch and pressure. | These channels open in response to a change in membrane potential.<br>There are two types of voltage-gated channels.<br>**i. Sodium voltage-gated channel**<br>**ii. Potassium voltage-gated channel** |

$Na^+$ influx into the cell. When the axon is not conducting any impulses i.e. in resting condition, the axon membrane is more permeable to $K^+$ and less permeable to $Na^+$ ions, whereas it remains impermeable to negatively charged protein ions.

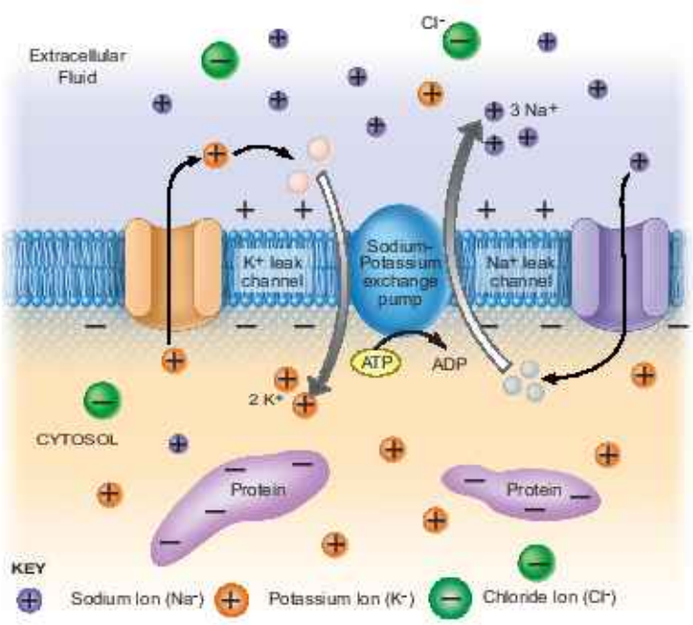


**Figure 10.3** Ionic channels

The axoplasm contains high concentration of $K^+$ and negatively charged proteins and low concentration of $Na^+$ ions. In contrast, fluid outside the axon (ECF) contains low concentration of $K^+$ and high concentration of $Na^+$, and this forms a concentration gradient. This ionic gradient across the resting membrane is maintained by ATP driven **Sodium-Potassium** pump, which exchanges $3Na^+$ outwards for $2K^+$ into the cells. In this state, the cell membrane is said to be **polarized**. In neuron, the **resting membrane potential** ranges from **-40mV** to **-90mV**, and its normal value is **-70mV**. The minus sign indicates that the inside of the cell is negative with respect to the outside (Figure 10.4).



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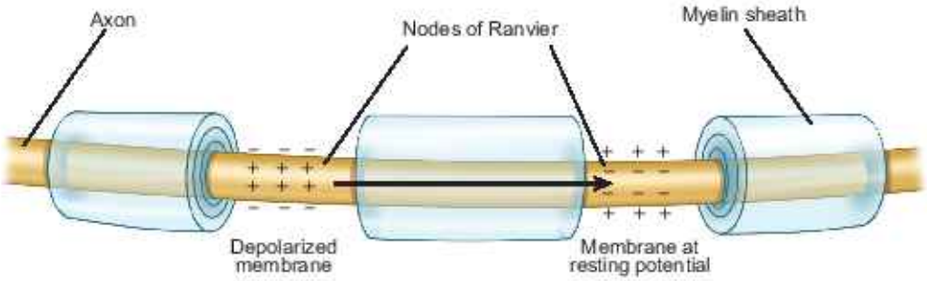


**Figure 10.4** Conduction of nerve impulse

**Action membrane potential**

An action potential occurs when a neuron sends information down an axon, away from the cell body. It includes following phases, depolarization, repolarisation and hypo polarization.

**Depolarization – Reversal of Polarity**

When a nerve fibre is stimulated, **sodium voltage-gate opens** and makes the **axolemma** permeable to $Na^+$ ions; meanwhile **the potassium voltage gate** closes. As a result, the rate of flow of $Na^+$ ions into the **axoplasm** exceeds the rate of flow of $K^+$ ions to the outside fluid [ECF]. Therefore, the axolemma becomes positively charged inside and negatively charged outside. This reversal of electrical charge is called **Depolarization**.

During depolarization, when enough $Na^+$ ions enter the cell, the action potential reaches a certain level, called **threshold potential** [-55mV]. The particular stimulus which is able to bring the membrane potential to threshold is called **threshold stimulus**.

The action potential occurs in response to a **threshold stimulus** but does not occur at **subthreshold stimuli**. This is called **all or none principle.** Due to the rapid influx of $Na^+$ ions, the membrane potential shoots rapidly up to +45mV which is called the **Spike potential**.

**Repolarisation [Falling Phase]**

When the membrane reaches the spike potential, **the sodium voltage-gate closes** and **potassium voltage-gate opens**. It checks influx of $Na^+$ions and initiates the efflux of $K^+$ions which lowers the number of positive ions within the cell. Thus, the potential falls back towards the resting potential. The reversal of membrane potential inside the axolemma to negative occurs due to the efflux of $K^+$ ions. This is called **Repolarisation**.

**Hyperpolarization**

If repolarization becomes more negative than the resting potential -70 mV to about -90 mV, it is called **Hyperpolarization**.

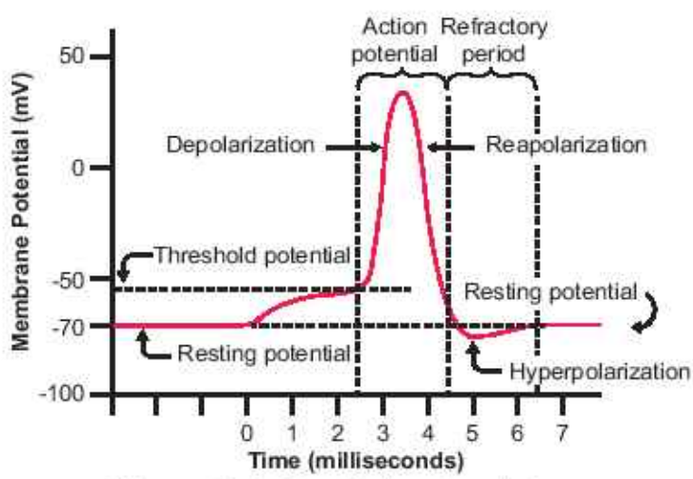


**Figure 10.5** Graph showing Action potential in Neuron



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During this, $K^+$ ion gates are more permeable to $K^+$ even after reaching the threshold level as it closes slowly; hence called **Lazy gates**. The membrane potential returns to its original **resting state** when $K^+$ ion channels close completely. During hyperpolarization the $Na^+$ voltage gate remains closed (Figure 10.5).

**Conduction Speed of a nerve impulse**

The conduction speed of a nerve impulse depends on the diameter of axon. The greater the axon's diameter, the faster is the conduction. The **myelinated axon** conducts the impulse faster than the **non-myelinated axon**. The voltage-gated $Na^+$ and $K^+$ channels are concentrated at the **nodes of Ranvier**. As a result, the impulse jumps node to node, rather than travelling the entire length of the nerve fibre. This mechanism of conduction is called **Saltatory Conduction**. Nerve impulses travel at the speed of 1-300 m/s.

### 10.3.3 Synaptic Transmission

The junction between two neurons is called a **Synapse** through which a nerve impulse is transmitted. The first neuron involved in the synapse forms the **pre-synaptic neuron** and the second neuron is **the post-synaptic neuron**. A small gap between the pre and postsynaptic membranes is called **Synaptic Cleft** that forms a structural gap and a functional bridge between neurons. The axon terminals contain synaptic vesicles filled with **neurotransmitters**. When an impulse [action potential] arrives at the axon terminals, it depolarizes the pre-synaptic membrane, opening the voltage gated calcium channels. Influx of calcium ions stimulates the synaptic vesicles towards the pre-synaptic membrane and fuses with it. In the neurilemma, the vesicles release their neurotransmitters into the synaptic cleft by **exocytosis.** The released neurotransmitters bind to their specific receptors on the post-synaptic membrane, responding to chemical signals. The entry of the ions can generate a new potential in the post-synaptic neuron, which may be either **excitatory** or **inhibitory**. Excitatory post-synaptic potential causes depolarization whereas inhibitory post-synaptic potential causes **hyperpolarization** of post-synaptic membrane (Figure 10.6).

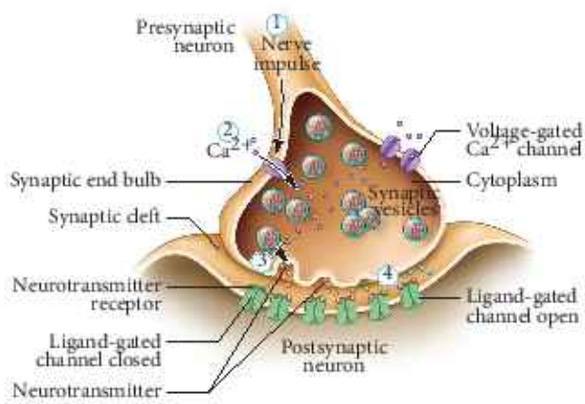


**Figure 10.6** Synaptic Transmission

## 10.4 Central Neural System (CNS)

The CNS includes the brain and the spinal cord, which are protected by the bones of the skull and vertebral column. During its embryonic development, CNS develops from the ectoderm.

Can you state why some areas of the brain and spinal cord are grey and some are white?

### 10.4.1 Brain

The brain acts as the command and control system. It is the site of information



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processing. It is located in the cranial cavity and is covered by three cranial meninges. The outer thick layer is **Duramater** which lines the inner surface of the cranial cavity; the median thin layer is **Arachnoid mater** which is separated from the duramater by a narrow **subdural space.** The innermost layer is **Piamater** which is closely adhered to the brain but separated from the arachnoid mater by the **subarachnoid space**. The brain is divided into three major regions: Forebrain, Midbrain and Hindbrain.

**Fore Brain**

It comprises the following regions: **Cerebrum** and **Diencephalon**. Cerebrum is the 'seat of intelligence' and forms the major part of the brain. The cerebrum consists of an outer cortex, inner medulla and **basal nuclei.** The superficial region of the cerebrum is called **cerebral cortex**, which looks grey due to the presence of unmyelinated nerve cells. Cerebral cortex consists of neuronal cell body, dendrites, associated glial and blood vessels. The surface of the cerebrum shows many convolutions (folds) and grooves. The folds are called **gyri** (singular gyrus); the shallow grooves between the gyri are called **sulci** (singular sulcus) and deep grooves are called fissures. These sulci and gyri increase the surface area of the cerebral cortex. Several sulci divide the cerebrum into eight lobes: a pair of **frontals, parietals, temporals and occipital lobes** (Figure10.7 & Table 10.2).

A median longitudinal fissure divides the cerebrum longitudinally into two cerebral hemispheres (Figure 10.7). A transverse fissure separates the cerebral hemispheres from the cerebellum. The hemispheres are connected by a tract of nerve fibres called **corpus callosum**. Cerebral cortex has three functional areas namely **sensory areas** occur in the parietal, temporal and occipital lobes of the cortex. They receive and interpret the sensory impulses. **Motor area** of the cortex which controls voluntary muscular movements lies in the posterior part of the frontal lobes. The areas other than sensory and motor areas are called **Association areas** that deal with integrative functions such as memory, communications, learning and reasoning. Inner to the cortex is **medulla** which is white in colour and acts as a nerve tract between the cortex and the diencephalon.

**Table 10.2** Functions of brain lobes

| Structure | Functions |
|---|---|
| Frontal | Behaviour, Intelligence, Memory, Movement |
| Parietal | Language, Reading, Sensation |
| Temporal | Speech, Hearing, Memory |
| Occipital | Visual processing |

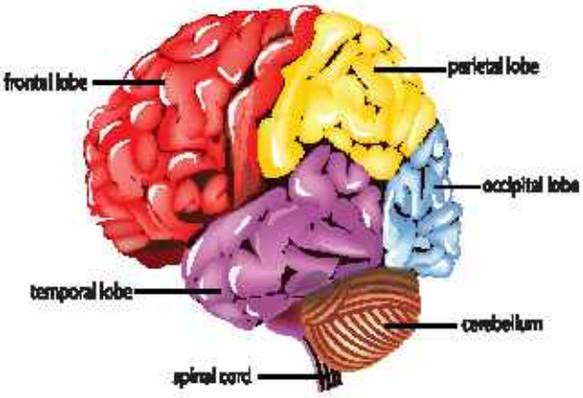


**Figure 10.7** Lobes of Cerebral hemisphere

**Diencephalon** consists largely of following three paired structures.

**Epithalamus** forms the roof of the diencephalon and it is a non-nervous tissue. The anterior part of epithalamus is vascular and folded to form the anterior **choroid**



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**plexus.** Just behind the choroid plexus, the epithalamus forms a short stalk which ends in a rounded body called **pineal body** which secretes the hormone, **melatonin** which regulates sleep and wake cycle.

**Thalamus** is composed of grey mater which serves as a relay centre for impulses between the spinal cord, brain stem and cerebrum. Within the thalamus, information is sorted and edited and plays a key role inlearning and memory. It is a major coordinating centre for sensory and motor signalling.

Human brain is formed of a large number of parts like cerebrum, thalamus, hypothalamus, pons, cerebellum and medulla oblongata. Each part performs some specialized function and all the parts are essential for the survival of a person. Discuss the following statements :

a) Thalami are called relay centres of the brain.

b) Damage to medulla may cause the death of organism.

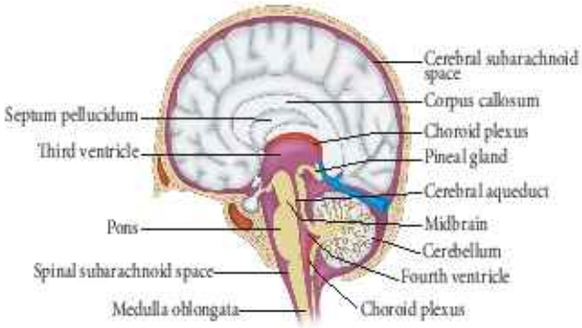


**Figure 10.8** Mid sagittal section of brain

**Hypothalamus** forms the floor of the diencephalon. The downward extension of the hypothalamus, the **infundibulum** connects the hypothalamus with the pituitary gland. The hypothalamus contains a pair of small rounded body called **mammillary bodies** that are involved in olfactory reflexes and emotional responses to odour. Hypothalamus maintains homeostasis and has many centres which control the body temperature, urge for eating and drinking. It also contains a group of neurosecretory cells which secrete the hypothalamic hormones. Hypothalamus also acts as the **satiety centre.**

**Depression** is a functional deficiency of **seratonin** or **norepinephrine** or both. This disorder is characterized by a pervasive negative mood, loss of interest, an inability to experience pleasure and suicidal tendencies. Antidepressant drugs increase the available concentration of these neurotransmitters in the CNS. Hence depression is treatable.

**Limbic System**

The inner part of the cerebral hemisphere constitutes the limbic system. The main components of limbic system are **olfactory bulbs, cingulate gyrus, mammillary body, amygdala, hippocampus and hypothalamus.** The limbic system is called 'emotional brain' because it plays a primary role in the regulation of pleasure, pain, anger, fear, sexual feeling and affection. The hippocampus and amygdala also play a role in memory (Figure 10.9).

**Brain stem** is the part of the brain between the spinal cord and the diencephalon. It consists of mid brain, pons varolii and medulla oblongata (Figure 10.10).



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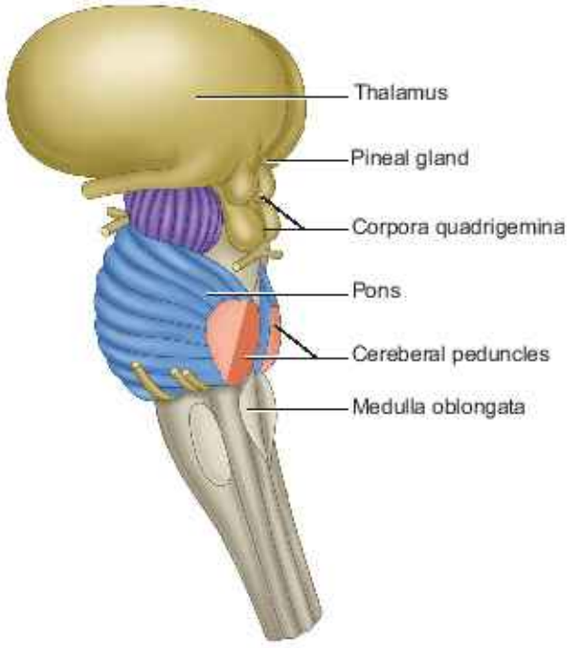


**Figure 10.10** Brain stem

### Mid brain

The mid brain is located between the diencephalon and the pons. The lower portion of the midbrain consists of a pair of longitudinal bands of nervous tissue called **cerebral peduncles** which relay impulses back and forth between cerebrum, cerebellum, pons and medulla. The dorsal portion of the midbrain consists of four rounded bodies called **corpora quadrigemina** which acts as a reflex centre for vision and hearing.

### Hind brain

Rhombencephalon forms the hind brain. It comprises of cerebellum, pons varolii and medulla oblongata. **Cerebellum** is the second largest part of the brain. It consists of two **cerebellar hemispheres** and central worm shaped part, **the vermis.** The cerebellum controls and coordinates muscular movements and body equilibrium. Any damage to cerebellum often results in uncoordinated voluntary muscle movements.

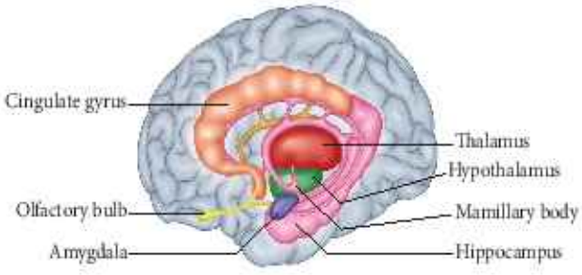


**Figure 10.9** Limbic system

**Pons varoli** lies infront of the cerebellum between the midbrain and the medulla oblongata. The nerve fibres in the pons varolii form a bridge between the two cerebellar hemispheres and connect the medulla oblongata with the other region of the brain. The respiratory nuclei found in the pons cooperate with the medulla to control respiration.

**Medulla oblongata** forms the posterior most part of the brain. It connects the spinal cord with various parts of the brain. It receives and integrates signals from spinal cord and sends it to the cerebellum and thalamus. Medulla contains vital centres that control cardio vascular reflexes, respiration and gastric secretions.

### Ventricles of the brain

The brain has four hollow, fluid filled spaces. The C- shaped space found inside each cerebral hemisphere forms the lateral **ventricles I and II** which are separated from each other by a thin membrane called the **septum pellucidum.** Each lateral ventricle communicates with the narrow III ventricle in the diencephalon through an opening called **interventricular foramen (foramen of Monro).** The ventricle III is continuous with the ventricle IV in the hind brain through a canal called **aqueduct of Sylvius (cerebral aqueduct).** Choroid plexus is a network of blood capillaries found in the roof of



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the ventricles and forms **cerebro spinal fluid (CSF)** from the blood. CSF provides buoyancy to the CNS structures; CSF acts as a shock absorber for the brain and spinal cord; it nourishes the brain cells by transporting constant supply of food and oxygen; it carries harmful metabolic wastes from the brain to the blood; and maintains a constant pressure inside the cranial vessels.

### 10.4.2 Spinal Cord

The spinal cord is a long, slender, cylindrical nervous tissue. It is protected by the vertebral column and surrounded by the three membranes as in the brain. The spinal cord that extends from the brain stem into the vertebral canal of the vertebral column up to the level of 1st or 2nd lumbar vertebra. All the cervical (8) and thoracic (12) nerves and first lumbar spinal nerve pairs emerge out directly from the intervertebral foramen. Since the spinal cord ends in L1 or L2 region, the remaining nerves are greatly elongated to exit the vertebral column at their appropriate space. This thick bundle of elongated nerve roots within the lower vertebral canal is called the **cauda equina** (horse's tail) because of its appearance.

In the cross section of spinal cord (Figure 10.11), there are two indentations: the posterior median sulcus and the anterior median fissure. Although there might be slight variations, the cross section of spinal cord is generally the same throughout its length. In contrast to the brain, the grey matter in the spinal cord forms an inner butterfly shaped region surrounded by the outer white matter. The grey matter consists of neuronal cell bodies and their dendrites, interneurons and glial cells. White matter consists of bundles of nerve fibres. In the center of the grey matter there is a central canal which is filled with CSF. Each half of the grey matter is divided into **a dorsal horn, a ventral horn** and **a lateral horn.**

The dorsal horn contains cell bodies of interneurons on which afferent neurons terminate. The ventral horn contains cell bodies of the efferent motor neurons supplying the skeletal muscle. Autonomic nerve fibres, supplying cardiac and smooth muscles and exocrine glands, originate from the cell bodies found in the lateral horn. In the white matter, the bundles of nerve fibres form two types of

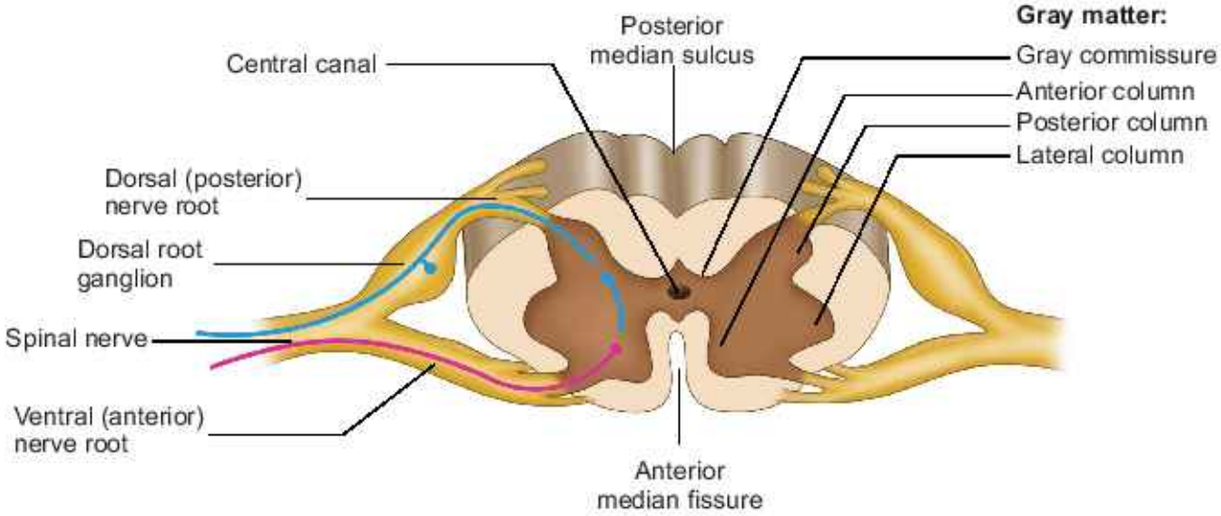


**Figure 10.11** C.S. of Spinal cord



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tracts namely **ascending tracts** which carry sensory impulses to the brain and descending **tracts** which carry motor impulses from the brain to the spinal nerves at various levels of the spinal cord. The spinal cord shows two enlargements, one in the cervical region and another one in the lumbosacral region. The **cervical enlargement** serves the upper limb and **lumbar enlargement** serves the lower limbs.

## 10.5 Reflex Action and Reflex Arc

On touching a hot pan, the hand is withdrawn rapidly. Do you know how this happens?

The spinal cord remains as a connecting functional nervous structure in between the brain and effector organs. But sometimes when a very quick response is needed, the spinal cord can effect motor initiation as the brain and brings about an effect. This rapid action by spinal cord is called reflex action. It is a fast, involuntary, unplanned sequence of actions that occurs in response to a particular stimulus. The nervous elements involved in carrying out the reflex action constitute a reflex arc or in other words the pathway followed by a nerve impulse to produce a reflex action is called a reflex arc (Figure 10.12).

### Functional Components of a Reflex Arc

**Sensory Receptor** - It is a sensory structure that responds to a specific stimulus.

**Sensory Neuron** - This neuron takes the sensory impulse to the grey (afferent) matter of the spinal cord through the dorsal root of the spinal cord.

**Interneurons** - One or two interneurons may serve to transmit the impulses from the sensory neuron to the motor neuron.

**Motor Neuron** - it transmits impulse from CNS to the effector organ.

**Effector Organs** -It may be a muscle or gland which responds to the impulse received.

There are two types of reflexes. They are

1) **Unconditional reflex** is an inborn reflex for an unconditioned stimulus. It does not need any past experience, knowledge or training to occur; Ex: blinking of an eye when a dust particle about to fall into it, sneezing and coughing due to foreign particle entering the nose or larynx.
2) **Conditioned reflex** is a respone to a stimulus that has been acquired by learning. This does not naturally exists in animals. Only an experience makes it a part of the behaviour. Example: Saliva formation in the dog immediately after hearing the bell in Pavlov's experiment. The conditioned reflex was first demonstrated by the Russian physiologist **Pavlov** in his classical conditioning experiment in a dog. The cerebral cortex controls the conditioned reflex.

### Peripheral Neural System (PNS)

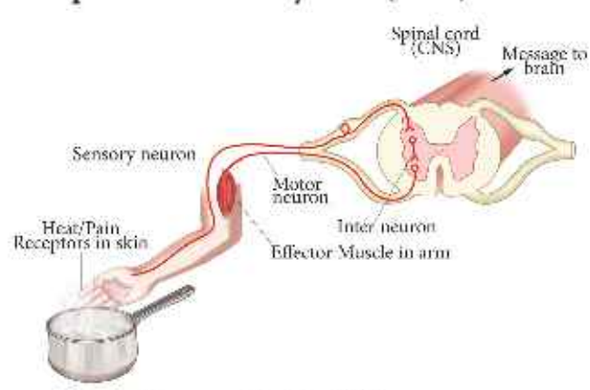


**Figure 10.12** Reflex arc



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PNS consists of all nervous tissue outside the CNS. Components of PNS include nerves, ganglia, enteric plexuses and sensory receptors. A nerve is a chord like structure that encloses several neurons inside. Ganglia (singular-ganglion) are small masses of nervous tissue, consisting primarily of neuron cell bodies and are located outside the brain and spinal cord. Enteric plexuses are extensive networks of neurons located in the walls of organs of the gastrointestinal tract. The neurons of these plexuses help in regulating the digestive system. The specialized structure that helps to respond to changes in the environment i.e. stimuli are called **sensory receptor** which triggers nerve impulses along the afferent fibres to CNS. PNS comprises of cranial nerves arising from the brain and spinal nerves arising from the spinal cord.

**(A) Cranial nerves:** There are 12 pairs of cranial nerves, of which the first two pairs arise from the fore brain and the remaining 10 pairs from the mid brain. Other than the Vagus nerve, which extends into the abdomen, all cranial nerves serve the head and face.

**(B) Spinal nerves:** 31 pairs of spinal nerves emerge out from the spinal cord through spaces called the **intervertebral foramina** found between the adjacent vertebrae. The spinal nerves are named according to the region of vertebral column from which they originate

i. Cervical nerves (8 pairs)
ii. Thoracic nerves (12 pairs)
iii. Lumbar nerves (5 pairs)
iv. Sacral nerves (5 pairs)
v. Coccygeal nerves (1 pair)

Each spinal nerve is a mixed nerve containing both afferent (sensory) and efferent (motor) fibres. It originates as two roots:1) a posterior dorsal root with a ganglion outside the spinal cord and 2) an anterior ventral root with no external ganglion.

**Somatic Neural System** (SNS)

The **somatic neural system** (SNS or voluntary neural system) is the part of the peripheral neural system associated with the voluntary control of body movements via skeletal muscles. The somatic neural system comprises of the sensory and motor nerves. Major functions of the somatic neural system include voluntary movement of the muscles and organs, and reflex movements.

In adult, the total CSF volume is about 150 ml and is replaced every 8 hours. About 500 ml of CSF is formed daily. The choroid plexus helps cleanse the CSF by removing waste products.

**Autonomic Neural System**

The autonomic neural system is auto functioning and self governed. It is a part of peripheral neural system that innervates smooth muscles, glands and cardiac muscle. This system controls and coordinates the involuntary activities of various organs. ANS controlling centre is in the hypothalamus.

Autonomic neural system comprises the following components:

**Preganglionic neuron** whose cell body is in the brain or spinal cord; its myelinated axon exits the CNS as part of cranial or spinal nerve and ends in an autonomic ganglion.

**Autonomic ganglion** consists of axon of preganglionic neuron and cell bodies of postganglionic neuron.



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**Postganglionic neuron** conveys nerve impulses from autonomic ganglia to visceral effector organs.

The autonomic neural system consists of **Sympathetic neural system** and **Parasympathetic neural system.**

Your friend is returning home after his visit to USA. All at home are waiting for his arrival. How would you feel? State the division of ANS that predominates and mention few changes that take place in your body.

## 10. 6 Sensory Reception and Processing

Our senses make us aware of changes that occur in our surroundings and also within our body. **Sensation** [awareness of the stimulus] and **perception** [interpretation of the meaning of the stimulus] occur in the brain.

Receptors are classified based on their location: **1. Exteroceptors** are located at or near the surface of the body. These are sensitive to external stimuli and receive sensory inputs for hearing, vision, touch, taste and smell. **2. Interoceptors** are located in the visceral organs and blood vessels. They are sensitive to internal stimuli. **Proprioceptors** are also a kind of interoceptors. They provide information about position and movements of the body. These are located in the skeletal muscles, tendons, joints, ligaments and in connective tissue coverings of bones and muscles. Receptors based on the type of stimulus are shown in Table 10.3.

### 10.6.1 Photoreceptor - Eye

Eye is the organ of vision; located in the orbit of the skull and held in its position with the help of six extrinsic muscles. They are **superior, inferior, lateral, median rectus muscles, superior oblique and inferior oblique** muscles. These muscles aid in the movement of the eyes and they receive their nerve innervation from III, IV and VI cranial nerves. Eyelids, eye lashes and eye brows are the accessory structures useful in protecting the eyes. The eye lids protect the eyes from excessive light and foreign objects and spread lubricating secretions over the eyeballs.

Eyelashes and the eyebrows help to protect the eyeballs from foreign objects, perspiration and also from the direct rays of sunlight. **Sebaceous glands** at the base of the eyelashes are called **ciliary glands** which secrete a lubricating fluid into the hair follicles. **Lacrymal glands,** located in the upper lateral region of each orbit, secrete tears. Tears are secreted at the rate of 1mL/day and it contains salts, mucus and **lysozyme** enzyme to destroy bacteria.

**Table: 10.3** Types of receptors

| Receptors | Stimulus | Effector organs |
|---|---|---|
| Mechano receptors | Pressure and vibration | Mechano receptors are present in the cochlea of the inner ear and the semi circular canal and utriculus |
| Chemoreceptors | Chemicals | Taste buds in the tongue and nasal epithelium |
| Thermoreceptors | Temperature | Skin |
| Photoreceptors | Light | Rod and cone cells of the retina in the eye |



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The conjunctiva is a thin, protective mucous membrane found lining the outer surface of the eyeball (Figure 10.13).

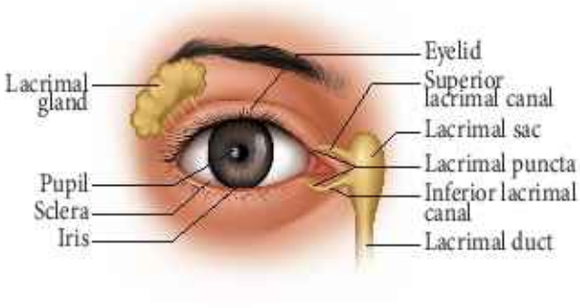


**Figure.10.13** The human eye

The eye has two compartments, the **anterior** and **posterior compartments**. The anterior compartment has two chambers, first one lies between the cornea and iris and the second one lies between the iris and lens. These two chambers are filled with watery fluid called **aqueous humor**. The posterior compartment lies between the lens and retina and it is filled with a jelly like fluid called **vitreous humor** that helps to retain the spherical nature of the eye. **Eye lens** is transparent and biconvex, made up of long columnar epithelial cells called **lens fibres**. These cells are accumulated with the proteins called **crystalline**.

### The Eye Ball

The eye ball is spherical in nature. The anterior one- sixth of the eyeball is exposed; the remaining region is fitted well into the orbit. The wall of the eye ball consists of three layers: fibrous **Sclera**, vascular **Choroid** and sensory **Retina** (Figure 10.14).

The outer coat is composed of dense non-vascular connective tissue. It has two regions: the anterior **cornea** and the posterior **sclera**. Cornea is a non-vascular transparent coat formed of stratified squamous epithelium which helps the cornea to renew continuously as it is very vulnerable to damage from dust. Sclera forms the white of the eye and protects the eyeball. Posteriorly the sclera is innervated by the optic nerve. At the junction of the sclera and the cornea, is a channel called **'canal of schlemm'** which continuously drains out the excess of aqueous humor.

Dilation and congestion of the blood vessels of the conjunctiva due to local irritation or infection are the cause of bloodshot eye (conjunctivitis - commonly called Madras eye). Infection of ciliary glands by bacteria causes a painful, pus filled swelling called a Sty.

The cornea is the only tissue in the body that can be transplanted from one person to another with little or no possibility of rejection. This is because cornea does not have blood vessels.

**Choroid** is highly vascularized pigmented layer that nourishes all the eye layers and its pigments absorb light to prevent internal reflection.

Anteriorly the choroid thickens to form the ciliary body and iris. Iris is the coloured portion of the eye lying between the cornea and lens. The aperture at the centre of the iris is the **pupil** through which the light enters the inner chamber. Iris is made of two types of muscles the **dilator papillae** (the radial muscle) and the **sphincter papillae** (the circular muscle).In the bright light, the circular muscle in the iris contract; so that the size of pupil decreases and less light enters the eye. In dim light, the radial muscle



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in the iris contract; so that the pupil size increases and more light enters the eye. Smooth muscle present in the ciliary body is called the **ciliary muscle** which alters the convexity of the lens for near and far vision. The ability of the eyes to focus objects at varying distances is called **accommodation** which is achieved by **suspensory ligament, ciliary muscle** and **ciliary body**. The suspensory ligament extends from the ciliary body and helps to hold the lens in its upright position. The ciliary body is provided with blood capillaries that secrete a watery fluid called **aqueous humor** that fills the anterior chamber.

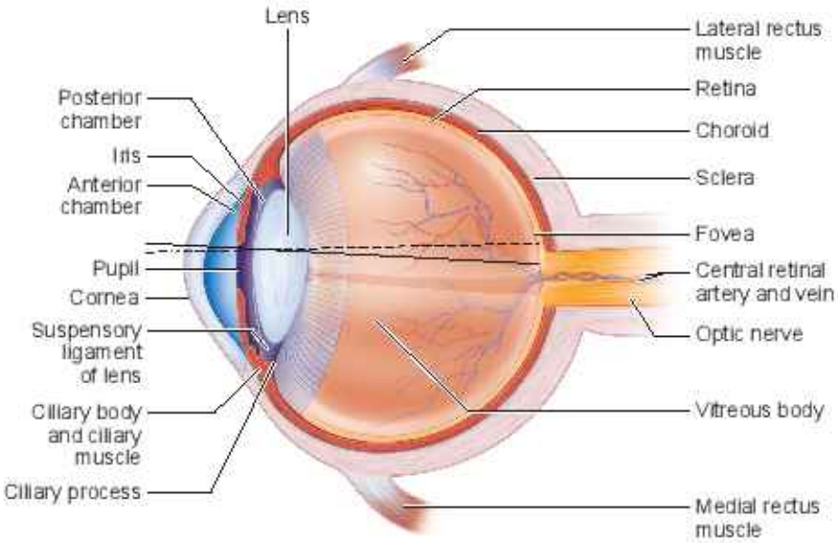


**Figure 10.14** L.S. of the eye

**Figure 10.15** Rod and Cone cells

**Retina** forms the inner most layer of the eye and it contains two regions: A sheet of **pigmented epithelium** (non visual part) and **neural visual regions.** The neural retina layer contains three types of cells: photoreceptor cells – **cones and rods** (Figure 10.15 and Table 10.4), **bipolar cells and ganglion cells.** The yellow flat spot at the centre of the posterior region of the retina is called **macula lutea** which is responsible for sharp detailed vision. A small depression present in the centre of the yellow spot is called **fovea centralis** which contains only cones. The optic nerves and the retinal blood vessels enter the eye slightly

**Table: 10.4** Differences between rod and cone cells

| Rod cells | Cone cells |
|---|---|
| Rods are responsible for vision in dim light | The cones are responsible for colour vision and works best in the bright light. |
| The pigment present in the rods is rhodopsin, formed of a protein scotopsin and retinal (an aldehyde of vitamin A ) | The pigment present in the cones is photopsin, formed of opsin protein and retinal. |
| There are about 120 millions rod cells | There may be 6-7 millions cone cells |
| Rods are predominant in the extra fovea region | Cones are concentrated in the fovea region |



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below the posterior pole, which is devoid of photo receptors; hence this region is called **blind spot.**

**Mechanism of Vision**

When light enters the eyes, it gets refracted by the **cornea, aqueous humor and lens and it is focused** on the retina and excites the rod and cone cells. The photo pigment consists of **Opsin**, the protein part and **Retinal**, a derivative of vitamin A. Light induces dissociation of retinal from opsin and causes the structural changes in opsin. This generates an action potential in the photoreceptor cells and is transmitted by the optic nerves to the visual cortex of the brain, via bipolar cells, ganglia and optic nerves, for the perception of vision.

**Refractive Errors of Eye**

**Myopia** (near sightedness): The affected person can see the nearby objects but not the distant objects. This condition may result due to an elongated eyeball or thickened lens; so that the image of distant object is formed in front of the yellow spot. This error can be corrected using concave lens that diverge the entering light rays and focuses it on the retina.

**Hypermetropia** (long sightedness): the affected person can see only the distant objects clearly but not the objects nearby. This condition results due to a shortened eyeball and thin lens; so the image of closest object is converged behind the retina. This defect can be overcome by using convex lens that converge the entering light rays on the retina.

**Presbyopia:** Due to aging, the lens loses elasticity and the power of accommodation. Convex lenses are used to correct this defect.

**Astigmatism** is due to the rough (irregular) curvature of cornea or lens. Cylindrical glasses are used to correct this error (Figure 10.16).

**Cataract:** Due to the changes in nature of protein, the lens becomes opaque. It can be corrected by surgical procedures.

Visual pigments for colour vision are i) the red cones having the visual pigment, Erythropsin is sensitive to long wavelength close to 560 nm. ii) The green cones having the pigment, chloropsin is sensitive to medium wavelength of 530 nm iii) the blue cones having the pigment, cyanopsin is sensitive to short wavelength of 420 nm.

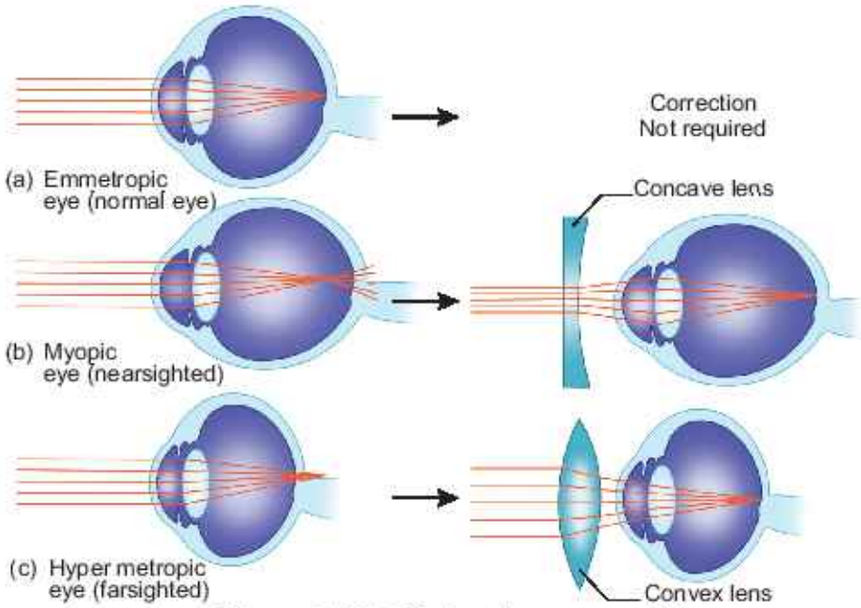


**Figure 10.16** Refractive errors of the eye



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Aqueous humour supplies nutrients and oxygen to the lens, cornea and some retinal cells. The aqueous humor is produced and drained at the same rate, maintaining a constant intra ocular pressure of about 16 mmHg. Any block in the canal of schlemm increases the intra-ocular pressure of aqueous humor and leads to 'Glaucoma' where the optic nerve and the retina are compressed due to pressure.

### 10.6.2 Phonoreceptor

The ear is the site of reception of two senses namely hearing and equilibrium. Anatomically, the ear is divided into three regions: the external ear, the middle ear and internal ear.

The external ear consists of **pinna, external auditory meatus** and **ear drum**. The pinna is flap of elastic cartilage covered by skin. It collects the sound waves. The external auditory meatus is a curved tube that extends up to the tympanic membrane [the ear drum]. The tympanic membrane is composed of connective tissues covered with skin outside and with mucus membrane inside.

There are very fine hairs and wax producing sebaceous glands called **ceruminous glands** in the external auditory meatus. The combination of hair and the **ear wax** [cerumen] helps in preventing dust and foreign particles from entering the ear.

**The middle ear** is a small air-filled cavity in the temporal bone. It is separated from the external ear by the eardrum and from the internal ear by a thin bony partition; the bony partition contains two small membrane covered openings called the oval window and the round window.

The middle ear contains three ossicles: **malleus** [hammer bone], **incus** [anvil bone] and **stapes** [stirrup bone] which are attached to one another. The malleus is attached to the tympanic membrane and its head articulates with the incus which is the intermediate bone lying between the malleus and stapes. The stapes is attached to the oval window in the inner ear. The ear ossicles transmit sound waves to the inner ear. A tube called Eustachian tube connects the middle ear cavity with the pharynx. This tube helps in equalizing the pressure of air on either sides of the ear drum.

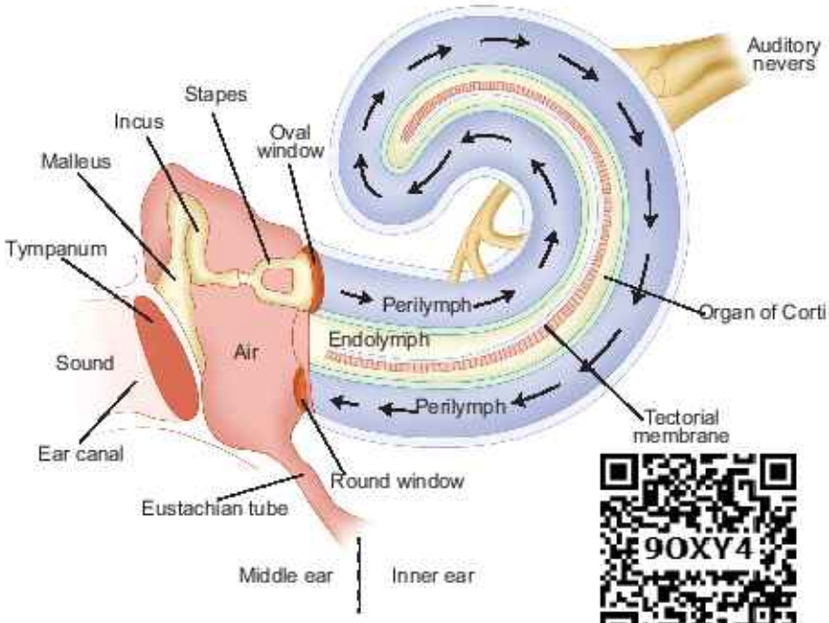


**Figure 10.17** Path of Sound wave

**Inner ear** is the fluid filled cavity consisting of two parts, the bony labyrinth and the membranous labyrinths. The bony labyrinth consists of three areas: **cochlea, ve**stibule and semicircular canals. The cochlea is a coiled portion consisting of 3 chambers namely: scala vestibuli and scala tympani- these two are filled with perilymph; and the scala media is filled



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with endolymph. At the base of the cochlea, the scala vestibule ends at the 'oval window' whereas the scala tympani ends at the 'round window' of the middle ear. The chambers scala vestibuli and scala media are separated by a membrane called Reisner's membrane whereas the scala media and scala tympani are separated by a membrane called Basilar membrane (Figure 10.17)

### Organ of Corti

The **organ of Corti** (Figure.10.18) is a sensory ridge located on the top of **the Basilar membrane** and it contains numerous hair cells that are arranged in four rows along the length of the basilar membrane. Protruding from the apical part of each hair cell is hair like structures known as **stereocilia.** During the conduction of sound wave, stereocilia makes a contact with the stiff gel membrane called **tectorial membrane,** a roof like structure overhanging the organ of corti throughout its length.

### Mechanism of Hearing

Sound waves entering the external auditory meatus fall on the tympanic membrane. This causes the ear drum to vibrate, and these vibrations are transmitted to the oval window through the three auditory ossicles. Since the tympanic membrane is 17-20 times larger than the oval window, the pressure exerted on the oval window is about 20 times more than that on the tympanic membrane. This increased pressure generates pressure waves in the fluid of perilymph. This pressure causes the round window to alternately bulge outward and inward meanwhile the basilar membrane along with the organ of Corti move up and down. These movements of the hair alternately open and close the mechanically gated ion channels in the base of hair cells and the action potential is propagated to the brain as sound sensation through cochlear nerve.

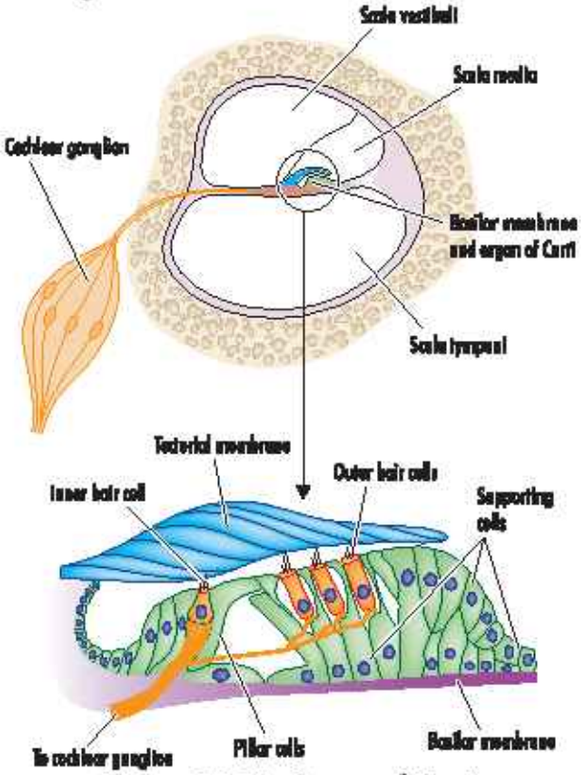


**Figure 10.18** Organ of Corti

### Defects of Ear

Deafness may be temporary or permanent. It can be further classified into **conductive deafness** and **sensory-neural deafness**. Possible causes for conductive deafness may be due to

i. the blockage of ear canal with earwax,
ii. Rupture of eardrum
iii. Middle ear infection with fluid accumulation
iv. Restriction of ossicular movement.In **sensory-neural deafness**, the defect may be in the organ of Corti or the auditory nerve or in the ascending auditory pathways or auditory cortex.

### Organ of Equilibrium

Balance is part of a sense called proprioception, which is the ability to sense



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the position, orientation and movement of the body. The organ of balance is known as the **vestibular system** which is located in the inner ear next to the cochlea. The vestibular system is composed of a series of fluid filled sacs and tubules.These sacs and tubules contain endolymph and are kept in the surrounding perilymph (Figure 10.19). These two fluids, perilymph and endolymph, respond to the mechanical forces, during changes occurring in body position and acceleration.

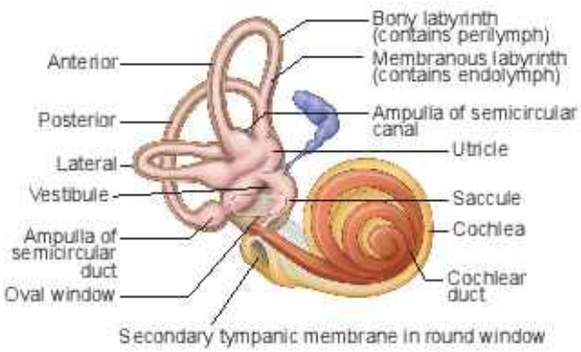


**Figure 10.19** Organ of Equilibrium

Name the parts of the organ of equilibrium involved in the following functions.

a) Linear movement of the body

b) Changes in the body position

c) Rotational movement of the head.

The utricle and saccule are two membranous sacs, found nearest the cochlea and contain equilibrium receptor regions called **maculae** that are involved in detecting the linear movement of the head. The maculae contain the hair cells that act as mechanorecptors. These hair cells are embeded in a gelatinous otolithic membrane that contains small calcareous particles called **otoliths**. This membrane adds weight to the top of the hair cells and increase the inertia.

The canals that lie posterior and lateral to the vestibule are semicircular canals; they are **anterior, posterior and lateral canals** oriented at right angles to each other. At one end of each semicircular canal, at its lower end has a swollen area called **ampulla**. Each ampulla has a sensory area known as **crista ampullaris** which is formed of sensory hair cells and supporting cells. The function of these canals is to detect rotational movement of the head.

The intensity of sound is measured in decibels (dB). 0 dB is the threshold of hearing for normal ear. Severe hearing loss occurs with frequent or prolonged exposure to sound with intensities greater than 90dB. For meaningful conversations the intensity should be in the 50 dB range.

### 10.6.3 Olfactory Receptors

The receptors for taste and smell are the chemoreceptors. The smell receptors are excited by air borne chemicals that dissolve in fluids. The yellow coloured patches of olfactory epithelium form the olfactory organs that are located on the roof of the nasal cavity. The olfactory epithelium is covered by a thin coat of mucus layer below and olfactory glands bounded connective tissues, above. It contains three types of cells: **supporting cells, Basal cells** and millions of pin shaped **olfactory receptor cells** (which are unusual bipolar cells). The olfactory glands and the supporting cells secrete the mucus. The unmyelinated axons of the olfactory receptor cells are gathered to form the filaments of olfactory nerve [cranial nerve I] which synapse with cells of olfactory bulb. The impulse, through the olfactory nerves, is transmitted to the frontal



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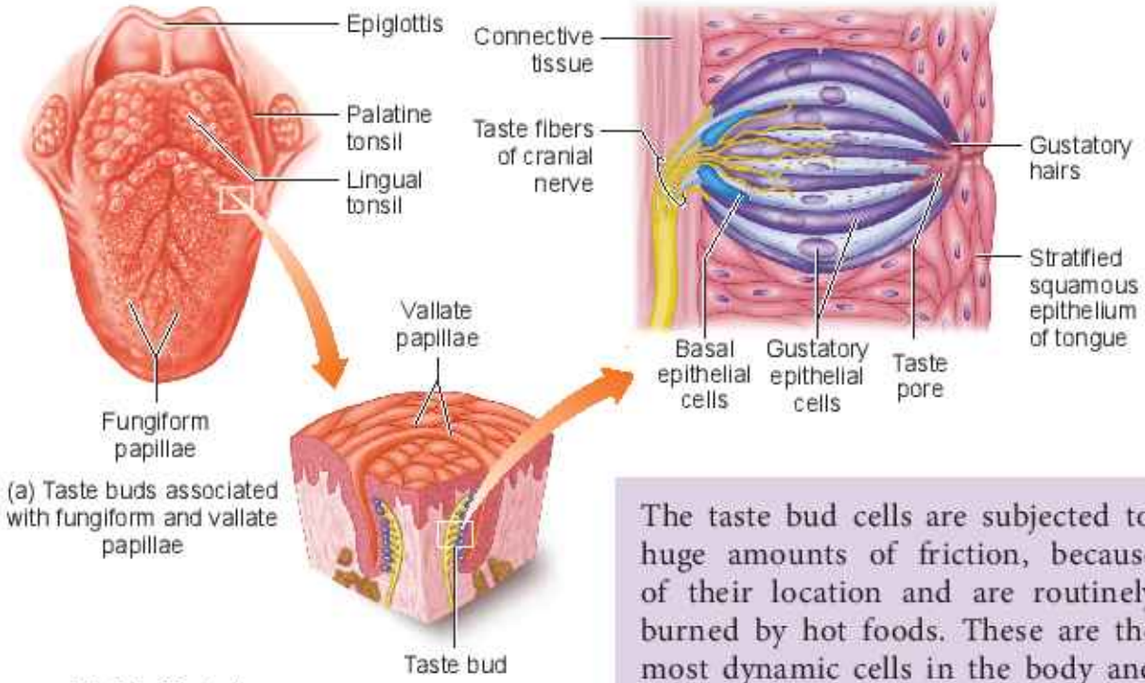


**Figure 10.20** Gustatory receptor

The taste bud cells are subjected to huge amounts of friction, because of their location and are routinely burned by hot foods. These are the most dynamic cells in the body and are replaced every seven to ten days.

lobe of the brain for identification of smell and the limbic system for the emotional responses to odour.

**Gustatory receptor:** The sense of taste is considered to be the most pleasurable of all senses. The tongue is provided with many small projections called **papillae** which give the tongue an abrasive feel. Taste buds are located mainly on the papillae which are scattered over the entire tongue surface. Most taste buds are seen on the tongue (Figure 10.20) few are scattered on the soft palate, inner surface of the cheeks, pharynx and epiglottis of the larynx. Taste buds are flask-shaped and consist of 50 – 100 epithelial cells of two major types.

**Gustatory epithelial cells** (taste cells) and **Basal epithelial cells** (Repairing cells) Long microvilli called **gustatory hairs** project from the tip of the gustatory cells and extends through a taste pore to the surface of the epithelium where they are bathed by saliva. Gustatory hairs are the sensitive portion of the gustatory cells and they have sensory dendrites which send the signal to the brain. The basal cells that act as stem cells, divide and differentiate into new gustatory cells (Figure 10.20).

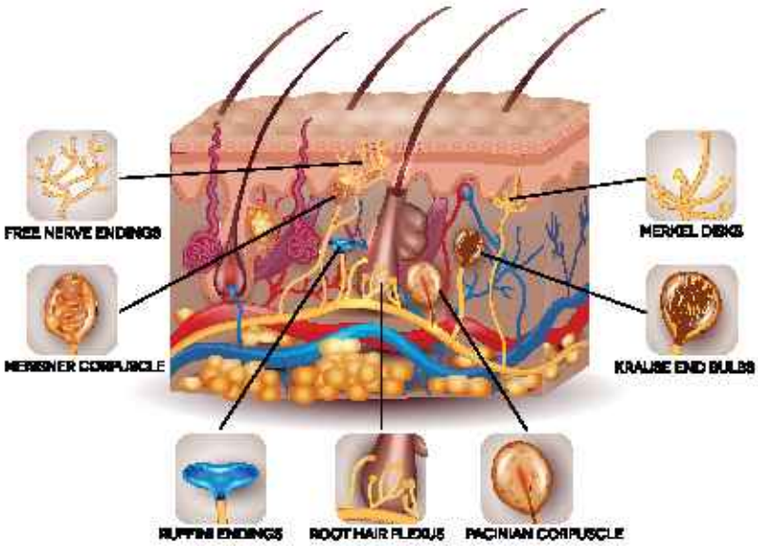


**Figure 10.21** Skin receptors

### Skin-Sense of Touch

Skin is the sensory organ of touch and is also the largest sense organ. This



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sensation comes from millions of microscopic sensory receptors located all over the skin and associated with the general sensations of contact, pressure, heat, cold and pain. Some parts of the body, such as the finger tips have a large number of these receptors, making them more sensitive. Some of the sensory receptors present in the skin (Figure 10.21) are:

- **Tactile merkel disc** is light touch receptor lying in the deeper layer of epidermis.
- **Hair follicle receptors** are light touch receptors lying around the hair follicles.
- **Meissner's corpuscles** are small light pressure receptors found just beneath the epidermis in the dermal papillae. They are numerous in hairless skin areas such as finger tips and soles of the feet.
- **Pacinian corpuscles** are the large egg shaped receptors found scattered deep in the dermis and monitoring vibration due to pressure. It allows to detect different textures, temperature, hardness and pain
- **Ruffini endings** which lie in the dermis responds to continuous pressure.
- **Krause end bulbs** are thermoreceptors that sense temperature.

Melanocytes are the cells responsible for producing the skin pigment, melanin, which gives skin its colour and protects it from the sun's UV rays. Vitiligo (Leucoderma) is a condition in which the melanin pigment is lost from areas of the skin, causing white patches, often with no clear cause. Vitiligo is not contagious. It can affect people of any age, gender, or ethnic group. The patches appear when melanocytes fails to synthesis melanin pigment.

## Summary

Neural system coordinates and integrates the functions of all organs and responds to changes in the internal and external environments.

Neural system includes two types of cells neurons and neuroglia. Neuron forms the structural and functional unit of the neural system.

CNS includes brain and spinal cord. The major parts of the brain are the cerebrum, diencephalon, cerebellum and the brain stem. The brain is protected by the cranium and meninges. CSF provides mechanical protection and nutrients to the CNS.

The spinal cord is the continuation of the medulla oblongata and ends at the second lumbar vertebra as conus medullaris. The components involved in reflex action are called reflex arc.

There are 12 pairs of cranial nerves which arise from the brain and 31 pairs of spinal nerves from the spinal cord make the PNS. The PNS is further divided into Somatic Neural system and Autonomic Neural system. The SNS operates under conscious control. The ANS usually operates unconsciously.

The motor portion of ANS has two major divisions: sympathetic and parasympathetic.

Sensation is the conscious or subconscious awareness of changes in the external or internal environment. Four events namely stimulation, transduction, generation of impulses and integration occurs typically for a sensation to take place.

Simple receptors are associated with the general senses such as somatic senses (skin); complex receptors are associated with the special senses such as smell, taste, vision, hearing and equilibrium.



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# Nervous System

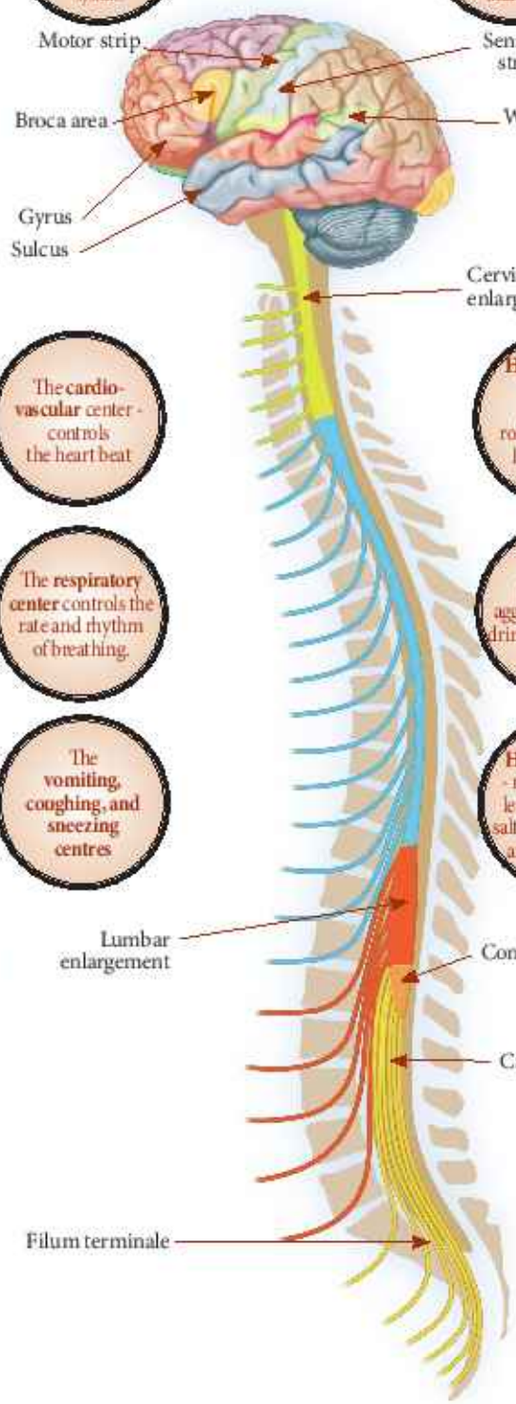
The Nervous system is a complex collection of specialized nerve cells known as neurons that transmit signals between different parts of the body.

The precentral gyrus is called as **Motor Strip** that controls the **voluntary movements** of the skeletal system.

The postcentral gyrus is called as Sensory Strip that controls the **five senses — sight, smell, taste, touch and hearing.**

Broca area, region of the brain that contains neurons involved in **speech function.**

Wernicke area, region of the brain that contains motor neurons involved in the **comprehension of speech.**




**The Medulla Oblongata**

**The Vital functional centres of medulla are:**

- The **cardio-vascular** center - controls the heart beat
- The **respiratory center** controls the rate and rhythm of breathing.
- The **vomiting, coughing, and sneezing centres**

**Limbic Systems**

- **Hippocampus** plays an important role in emotion, learning and memory.
- **Amygdala** plays role in aggression, eating, drinking and sexual behaviors.
- **Hypothalamus** - monitors blood levels of glucose, salt, blood pressure and hormones.

A **blood brain barrier** protects the brain by preventing many foregin substances in our vascular system from reaching the brain.

Although sensations and feelings are processed in our brain, the **brain itself cannot feel pain,** as it lacks pain receptors.

The barriers does not work for some substances like **Nicotine** which rushes into the brain in mere 7 seconds and **Alcohol** on the other hand takes 6 minutes.

75% of the total brain mass is water. It is the **fattest organ** in the body, contains **100 billion nerve cells.**



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## Evaluation

1 Which structure in the ear converts pressure waves to action potentials?

a. Tympanic membrane

b. Organ of Corti

**c. Oval window**

d. Semicircular canal

2. Which of the following pairings is correct?

**a. Sensory nerve – afferent**

b. Motor nerve - afferent

c. Sensory nerve – ventral

d. Motor nerve – dorsal

3. During synaptic transmission of nerve impulse, neurotransmitter (P) is released from synaptic vesicles by the action of ions (Q). Choose the correct P and Q.

**a. P = Acetylcholine, Q = Ca++**

b. P = Acetylcholine, Q = Na+

c. P = GABA, Q=Na+

d. P = Cholinesterase, Q = Ca++

4. Examine the diagram of the two cell types A and B given below and select the correct option.

a. Cell-A is the rod cell found evenly all over retina

b. Cell-A is the cone cell more concentrated in the fovea centralis

**c. Cell-B is concerned with colour vision in bright light**

d. Cell-A is sensitive to bright light intensities

5. **Assertion:** The imbalance in concentration of $Na^+$, $K^+$ and proteins generates action potential.

**Reason:** To maintain the unequal distribution of $Na^+$ and $K^+$, the neurons use electrical energy.

**a. Both Assertion and Reason are true and Reason is the correct explanation of the Assertion.**

b. Both Assertion and Reason are true but the Reason is not the correct explanations of Assertion.

c. Assertion is true, but Reason is false.

d. Both Assertion and Reason are false.

6. Which part of the human brain is concerned with the regulation of body temperature?

a. Cerebellum

b. Cerebrum

c. Medulla oblongata

**d. Hypothalamus**

7. The respiratory centre is present in the

**a. Medulla oblongata**

b. Hypothalamus

c. Cerebellum

d. Thalamus

8. Match the following human spinal nerves in column I with their respective number in column II and choose the correct option

| column I | column II |
|---|---|
| P. Cervical nerves | i. 5 pairs |
| Q. Thoracic nerve | ii. 1 pair |
| R. Lumbar nerve | iii. 12 pair |
| S. Coccygeal nerve | iv. 8 pair |

**a. ( P-iv ),( Q-iii ),( R-i ),( S-ii )**

b. ( P-iii ), ( Q-i ), ( R-ii ), ( S-iv )

c. ( P-iv ),( Q-i ),( R-ii ),( S-iii )

d. ( P-ii ), ( Q-iv ), ( R-i ), ( S-iii )

9. The abundant intracellular cation is

a. $H^+$ **b. $K^+$** c. $Na^+$ d. $Ca^{++}$



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10. Which of the following statements is wrong regarding conduction of nerve impulse?

**a. In a resting neuron, the axonal membrane is more permeable to $K^+$ ions and nearly impermeable to $Na^+$ ions.**

b. Fluid outside the axon has a high concentration of $Na^+$ ions and low concentration of $K^+$, in a resting neuron.

c. Ionic gradient s are maintained by $Na^+$ $K^+$ pumps across the resting membrane, which transport 3Na ions outwards for $2K^+$ into the cell.

d. A neuron is polarized only when the outer surface of the axonal membrane possess a negative a charge and its inner surface is positively charged.

11. All of the following are associated with the myeline sheath except

a. Faster conduction of nerve impulses

b. Nodes of Ranvier forming gaps along the axon

**c. Increased energy output for nerve impulse conduction**

d. Saltatory conduction of action potential

12. Several statements are given here in reference to cone cells which of the following option indicates all correct statements for cone cells ?

Statements

(i) Cone cells are less sensitive in bright light than Rod cells

(ii) They are responsible for colour vision

(iii) Erythropsin is a photo pigment which is sensitive to red colour light

(iv) They are present in fovea of retina

a. (iii), (ii) and (i)

**b. (ii) , (iii) and (iv)**

c. (i), (iii) and (iv)

d. (i), (ii) and (iv)

13. Which of the following statement concerning the somatic division of the peripheral neural system is incorrect?

a. Its pathways innervate skeletal muscles

b. Its pathways are usually voluntary

c. Some of its pathways are referred to as reflex arcs

**d. Its pathways always involve four neurons**

14. When the potential across the axon membrane is more negative than the normal resting potential, the neuron is said to be in a state of

a. Depolarization

b. Hyperpolarization

**c. Repolarization**

d. Hypopolarization

15. Why is the blind spot called so?

16. Sam's optometrist tells him that his intraocular pressure is high. What is this condition called and which fluid does it involve?

17. The action potential occurs in response to a threshold stimulus; but not at sub threshold stimuli. What is the name of the principle involved?

18. Pleasant smell of food urged Ravi to rush into the kitchen. Name the parts of the brain involved in the identification of food and emotional responses to odour.

19. Cornea transplant in humans is almost never rejected. State the reason.



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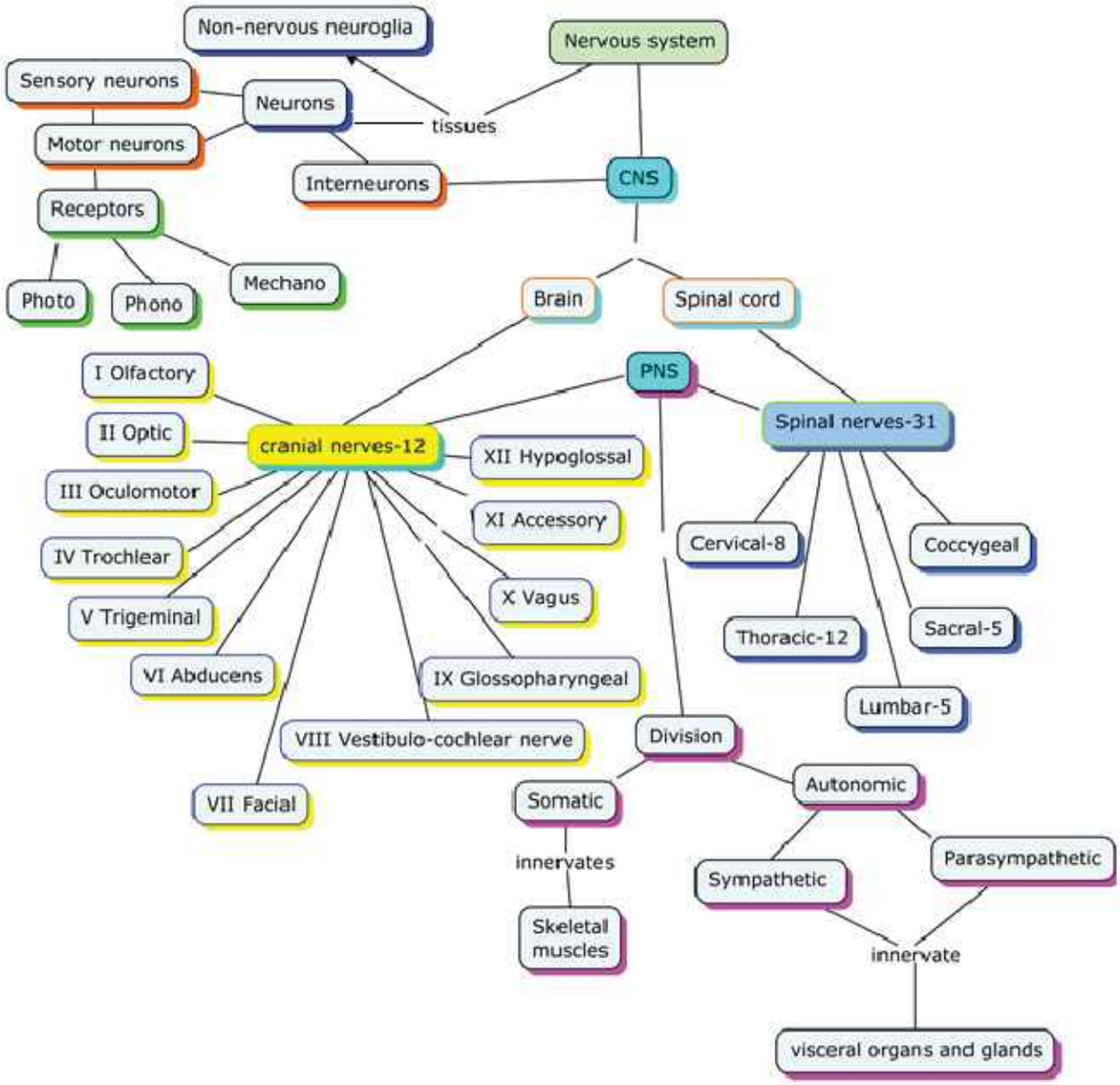
20. At the end of repolarization, the nerve membrane gets hyperpolarized. Why?
21. The choroid plexus secretes cerebrospinal fluid. List the function of it.
22. What is ANS? Explain the components of ANS.
23. Why the limbic system is called the emotional brain? Name the parts of it.
24. Classify receptors based on type of stimuli.
25. Differentiate between rod and cone cells.
26. The sense of taste is considered to be the most pleasurable of all senses.

    Describe the structure of the receptor involved with a diagram.
27. Describe the sensory receptors present in the skin.

## Concept Map



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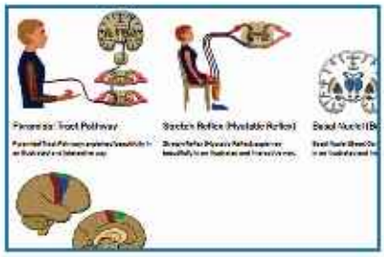
## ICT Corner

### The Transmitters

Let's explore the structure and various functions of the **Nervous System.**



**Step – 1**

Use the URL to reach the 'Nervous system' page. Select 'Nervous System organization' from grid and explore the autonomic and somatic organizations of nervous system.

**Step – 2**

Then reach the 'Nervous system' page by clicking back button on the top of the window or use the 'Backspace' key. Select 'Nerve cells' from the grid and explore.

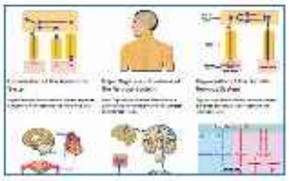
**Step – 3**

Follow the above steps and explore each and every parts and their functions of nervous system.

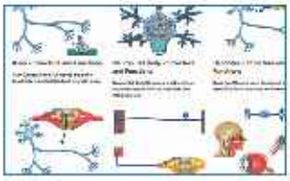
**Step – 4**

Use the reference given below to acquire additional details about nervous system.

Step 1



Step 2



Step 3

Step 4

Nervous System's URL:

https://www.getbodysmart.com/nervous-system

3D-Brain:
http://www.brainfacts.org/3d-brain#intro=false&focus=Brain&zoom=false

3D-Ear:
https://www.amplifon.com/web/uk/interactive-ear/index.html

* Pictures are indicative only



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UNIT IV

# Chapter 11

# Chemical Coordination and Integration

**Chapter Outline**


11.1 Endocrine glands and hormones
11.2 Human endocrine system
11.3 Hypo and hyper activity of endocrine glands and related disorders
11.4 Mechanism of hormone action.

**Klotho** an anti-aging hormone makes people smart, enhances cognitive abilities and longevity.

## Learning Objectives:

- *Understands the positions of the various endocrine glands and their secretions.*
- *Learns the mechanism of hormone action.*
- *Understands the disorders related to hypo and hyper activity of the endocrine glands.*
- *Learns the role of gastro intestinal hormones.*

MIQ95

While hearing your test marks, some may have anxiety and some may hesitate to hear and some may be worried. Do you know the reasons for such immediate changes? While seeing any unexpected happenings, we get goose bumps. Do you know the reason, why?

These are all due to the biochemical changes happening in our body, Which are created by the endocrine system. The above mentioned biochemical changes are due to the hormone adrenalin (Epinephrine or flight, fright and fight hormone).

## 11.1 Endocrine Glands and Hormones

Physiological functions of our human body is regulated and coordinated by both neural and endocrine systems. The endocrine system influences the metabolic activities by means of **hormones** (hormone means *to excite*) which are chemical messengers released into the blood and circulated as chemical signals and acts specifically on certain organs or tissues called target organs or target tissues. Hormones may speed up or slow down or alter the activity of the target organs. The hormones secreted do not remain permanently in the blood but are converted by the liver into inactive compounds and excreted by the kidneys.

Hormones are chemical messengers because they act as organic catalysts and coenzymes to perform specific functions in the target organs. The target organs contain receptor molecules either on the surface or within the cell. Although different hormones come in contact with cells, only



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the cells that contain receptor molecules specific for the hormone are physiologically activated. A single hormone may have multiple effects on a single target tissue or on different target tissues.

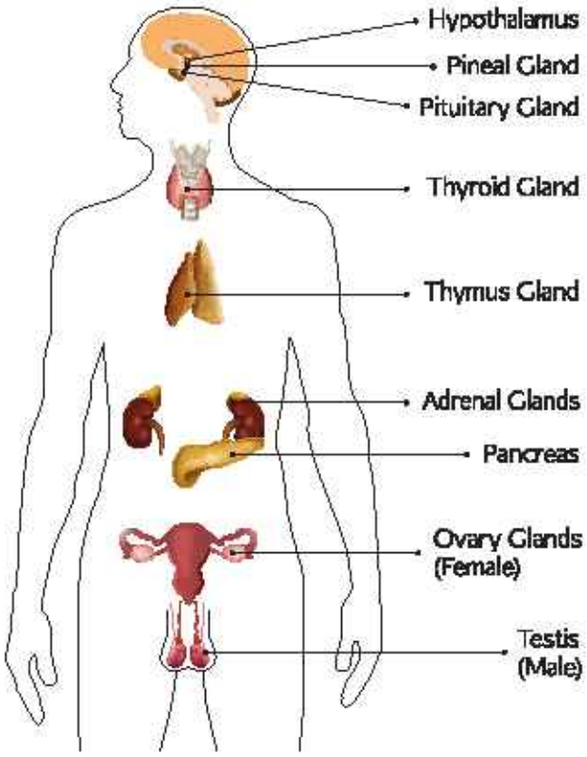


**Figure :11. 1** Location of various endocrine glands

Many hormones exhibit long term changes like growth, puberty and pregnancy. Hormones often influence many organs and organ systems at the same time. Serious deficiency or excess secretion of hormones leads to disorders. Hormones coordinate different physical, physiological, mental activities and maintain **homeostasis.** Hormones are composed of water soluble proteins or peptides or amines or fat soluble steroids.

**Homeostasis:** Maintenance of constant internal environment of the body by the different coordinating system.

## 11.2 Human Endocrine System

There are two glandular systems such as the exocrine glands and the endocrine glands. The exocrine glands secrete enzymes, saliva and sweat and have ducts that carry their substances to the membrane surfaces. Example: salivary gland and gastric gland. The endocrine glands, called ductless glands produce hormones and lack ducts; they release their hormone to the surrounding tissue fluid. The hormones circulate around the body and eventually reach the target organs. Endocrine glands (Figure: 11. 1) include the pituitary, thyroid, parathyroid, pineal, adrenal, thymus and are also known as **exclusive endocrine glands**. The hypothalamus along with its neural function also produces hormones and is considered as a **neuro endocrine gland.** In addition several organs such as pancreas, gastro intestinal tract epithelium, kidney, heart, gonads and placenta are also have endocrine tissues and are known as **partial endocrine glands.**

**Table. 11.1.** Chemical nature of hormones

| Class | Chemical properties | Example |
|---|---|---|
| Amines | Small, water soluble derived from tyrosine or tryptophan | Adrenalin, nor adrenalin, melatonin and thyroid hormone |
| Protein/Peptides | Water soluble | Insulin, glucagon and pituitary hormones |
| Steroids | Derived from cholesterol mostly lipid soluble | Cortisol, aldosterone, testosterone, oestrogen, progesterone. |



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### 11.2.1 Hypothalamus

Hypothalamus is a small cone shaped structure that projects downward from the brain ending into the pituitary stalk. It interlinks both the nervous system and endocrine system. Though pituitary gland is known as master endocrine glands that controls the other endocrine glands, but it is, in turn controlled by the hypothalamus. Hypothalamus contains groups of neurosecretory cells. It produces neurotransmitters which regulate the secretions of the pituitary (Figure11. 2). The hormones produced by the hypothalamus act either as a releasing hormone or as an inhibitory hormone.

In the basal region of the brain, the **hypothalamic hypophyseal portal blood vessel** connects hypothalamus and anterior pituitary. It allows hypothalamic hormones to control anterior pituitary secretion. The posterior pituitary is connected with hypothalamus by a nerve bundle called **hypothalamic hypophyseal axis**. It produces nerve signal that control the posterior pituitary secretion. Hypothalamus maintains homeostasis, blood pressure, body temperature, cardio and fluid electrolyte balance of the body. As the part of limbic system it influences various emotional responses.

In mammals, the role of pars intermedia is insignificant, but in other vertebrates it secretes **melanocyte stimulating hormone** (MSH). MSH induces pigmentation in skin.

### 11.2.2 Pituitary Gland or Hypophysis

The pituitary gland (means to grow under) is ovoid in shape and is located in the **sella turcica**, a bony cavity of the sphenoid bone at the base of brain and connected to the hypothalamic region of the brain by a stalk called **infundibulum**. It is about one centimetre in diameter and 0.5 gm in weight. The pituitary consists of two lobes, anterior glandular adenohypophysis and posterior neural neurohypophysis. The anterior lobe originates from the embryonic invagination of pharyngeal epithelium called **Rathke's pouch** and the posterior lobe is originates from the base of the brain as an outgrowth of hypothalamus. Anatomically the adenohypophysis has three lobes or zones namely pars intermedia, pars distalis and pars tuberalis. The neurohypophysis is otherwise known as pars nervosa.

**Table11.2 The major hypothalamic hormones and their functions**

| S.No. | Hormones | Functions |
|---|---|---|
| 1. | Thyrotropin releasing hormone (TRH) | Stimulates the secretion of TSH |
| 2. | Gonadotropin releasing hormone(GnRH) | Stimulates the secretion of FSH |
| 3. | Corticotropin releasing hormone (CRH) | Stimulates the secretion of ACTH |
| 4. | Growth hormone releasing hormone(GHRH) | Stimulates the secretion of GH |
| 5. | Prolactin releasing hormone (PRH) | Stimulates the secretion of Prolactin |
| 6. | Luteinizing hormone releasing hormone (LHRH) | Stimulates the secretion of LH |
| 7. | MSH releasing hormone | Stimulates the secretion of MSH |
| 8. | Growth hormone-inhibiting hormone (GHIH) | Inhibits the secretion of GH |
| 9. | Prolactin inhibiting hormone (PIH) | Inhibits the secretion of Prolactin |
| 10. | MSH inhibiting hormone | Inhibits the secretion of MSH |



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The anterior lobe of pituitary secretes six tropic hormones such as growth hormone (GH), thyroid stimulating hormone (TSH), adreno corticotropic hormone (ACTH), follicle stimulating hormone (FSH), luteinizing hormone (LH), luteotropic hormone (LTH) and melanocyte stimulating hormone (MSH) (in lower animals only). The posterior lobe of pituitary stores and releases the hormones namely vasopressin and oxytocin.

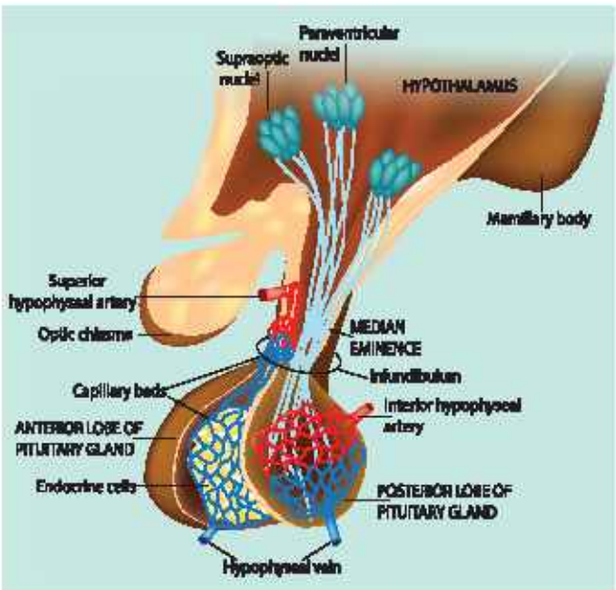


**Figure.11. 2** Hypothalamus and pituitary gland

## Hormones of Adenohypophysis

**i) Growth hormone (GH):** It is also known as somatotropic hormone (STH) or Somatotropin. It is a peptide hormone. Growth hormone promotes growth of all the tissues and metabolic process of the body. It influences the metabolism of carbohydrates, proteins and lipids and increases the rate of protein biosynthesis in the cells. It stimulates chondrogenesis (cartilage formation), osteogenesis (bone formation) and helps in the retention of minerals like nitrogen, potassium, phosphorus, sodium etc., in the body. GH increases the release of fatty acid from adipose tissue and decreases the rate of glucose utilization for energy by the cells. Thus it conserves glucose for glucose dependent tissues, such as the brain.

**ii) Thyroid stimulating hormone (TSH) or thyrotropin:** TSH is a glycoprotein hormone, which stimulates the thyroid gland to secrete Tri-iodothyronine ($T_3$) and thyroxine ($T_4$). TSH secretion is regulated by negative feedback mechanism. It's release from the anterior pituitary is induced by the thyrotropin releasing hormone (TRH). When thyroxine level in the blood increases, TRH acts on both the pituitary and hypothalamus to inhibit TSH secretion.

**iii) Adreno cortico tropic hormone (ACTH):** ACTH is a peptide hormone that stimulates the adrenal cortex to secrete glucocorticoids and mineralocorticoids. It stimulates melanin synthesis in melanocytes, induces the release of fatty acids from adipose tissues and stimulates insulin secretion. ACTH secretion is regulated by **negative feedback mechanism.**

**iv) Follicle stimulating hormone (FSH):** FSH is a glycoprotein hormone which regulates the functions of the gonads (ovary and testis). In males, FSH along with androgens acts on the germinal epithelium of seminiferous tubules and stimulates the production and release of sperms (spermatogenesis). In females, FSH acts on the ovaries and brings about the development and maturation of graffian follicles.

**v) Luteinizing hormone (LH):** LH is a glycoprotein hormone which is also known as interstitial cell stimulating



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hormone (ICSH). In males, ICSH acts on the interstitial cells of testis to produce the male sex hormone, testosterone. In females, LH along with FSH matures the ovarian follicles. LH independently induces ovulation, maintains the corpus luteum and promotes synthesis and release of ovarian hormones. FSH and LH are collectively referred as gonadotropins. FSH and LH are not produced during childhood. The secretion of FSH and LH starts only during pre pubertal period.

**vi) Luteotropic hormone (LTH):** LTH is also called luteotropin or lactogenic hormone or prolactin or mammotropin. It is a protein hormone which stimulates milk secretion after the child birth in females. High prolactin secretion during lactation suppresses LH secretion and ovulation since it induces the corpus luteum hence named as luteo tropic hormone.

### Hormones of Neurohypophysis

**i) Vasopressin or antidiuretic hormone (ADH) :** ADH is a peptide hormone which promotes reabsorption of water and electrolytes by distal tubules of nephron and thereby reduces loss of water through urine. Hence it is called as anti diuretic hormone. It also causes constriction of blood vessels when released in large amount and increases blood pressure. ADH deficiency causes ***Diabetes insipidus*** which induces the production of large amount of urine.

**ii) Oxytocin** (means quick birth): It is a peptide hormone which stimulates vigorous contraction of the smooth muscles of uterus during child birth and ejection of milk from the mammary glands.

Vasopressin and oxytocin are composed of nine amino acids and are almost identical and they differ in only **two amino acids** and yet they have dramatically different physiological effects.

Amino acid sequence of **vasopressin**: cysteine-tyrosine-**phenyl alanine**-glutamine-aspargine-cysteine-proline-**arginine**-glycine

Amino acid sequence of **oxytocin**:cysteine-tyrosine-**isoleu sine**-glutamine-aspargine-cysteine-proline-**leucine**-glycine.

Pituitary gland is located in a depression in the sphenoid bone of skull below the brain, so is also called hypothalamus cerebri. Discuss the following :

a. Pituitary gland is commonly called "master gland" of the body.

b. Discuss the role of hypothalamus and pituitary as a coordinated unit in maintaining physiological processes.

c. How does the posterior lobe of pituitary help in osmoregulation?

## 11.2.3 Pineal Gland

In human, the pineal gland or epiphysis cerebri or conarium is located behind the third ventricle of brain and is formed of parenchymal cells and interstitial cells. It secretes the hormone, **melatonin** and its precursor serotonin. Melatonin induces sleep and serotonin induces waking up thus playing a central role in the regulation of circadian rhythm of our body.

It maintains the normal sleep wake cycle. It also regulates the timing of sexual maturation of gonads. In addition melatonin also influences metabolism, pigmentation, menstrual cycle and defence mechanism of our body.



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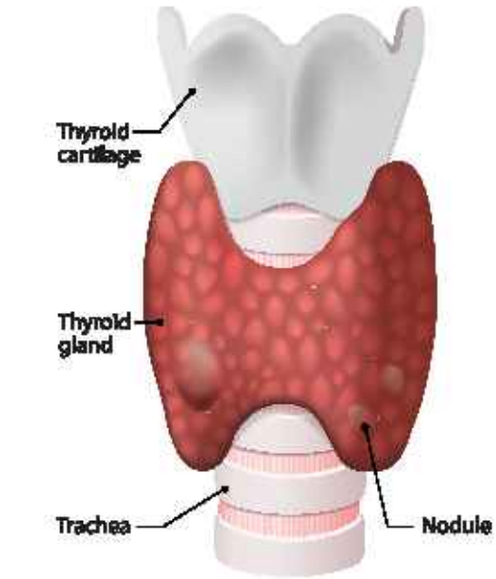
Melatonin is secreted at night, Light falling on the retina of eye decreases melatonin production. Serotonin is secreted during day time.

**Circadian rhythm** is the 24 hour cycle of biological activities associated with natural periods of light and darkness. Example sleep wake cycle, body temperature, appetite etc.

## 11.2.4. Thyroid Gland

The butterfly shaped thyroid gland is a bilobed gland located below the larynx on each side of upper trachea. It is the largest endocrine gland in the body. Its two lateral lobes are connected by a median tissue mass called **isthmus**. Each lobe is made up of many lobules .The lobules consist of follicles called **acini (acinus in singular)**. Each acinus is lined with glandular, cuboidal or squamous epithelial cells. The lumen of acinus is filled with colloid, a thick glycoprotein mixture consisting of thyroglobulin molecules.

Hormones of the thyroid gland are often called the major metabolic hormones. The follicular cells of thyroid gland secrete two hormones namely tri-iodothyronine ($T_3$) and thyroxine or tetra- iodothyronine ($T_4$). The parafollicular cells or 'C' cells of thyroid gland secrete a hormone called thyrocalcitonin. Iodine is essential for the normal synthesis of thyroid hormones. Thyroid releasing hormone from the hypothalamus stimulates the adenohypophysis to secrete TSH, which inturn stimulates the thyroid gland to secrete the thyroid hormones. Thyroid hormones show a negative feedback effect on the hypothalamus and pituitary (Figure11. 4).



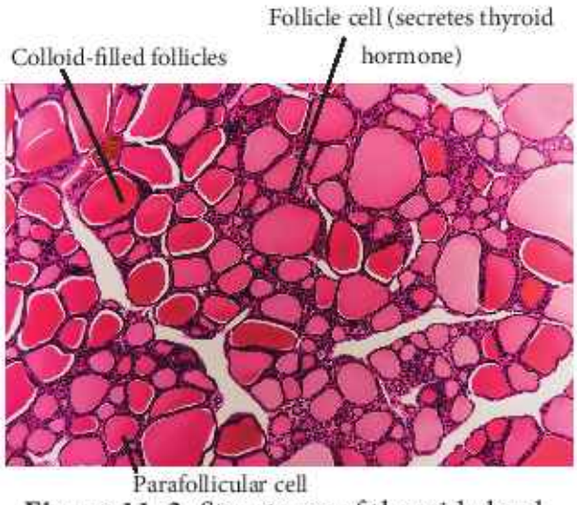




**Figure.11. 3** Structures of thyroid gland

**Functions of thyroxine or tetra-iodothyronine (T4):** Thyroxine regulates the basal metabolic rate (BMR) and body heat production. It stimulates protein synthesis and promotes growth. It is essential for the development of skeletal and nervous system. Thyroxine plays an important role in maintaining blood pressure. It reduces serum cholesterol levels, Optimum levels of thyroxine in blood is necessary for gonadial functions.

**Sporodic goitre** is a genetic disease and is not caused by iodine or thyroxine deficiency.



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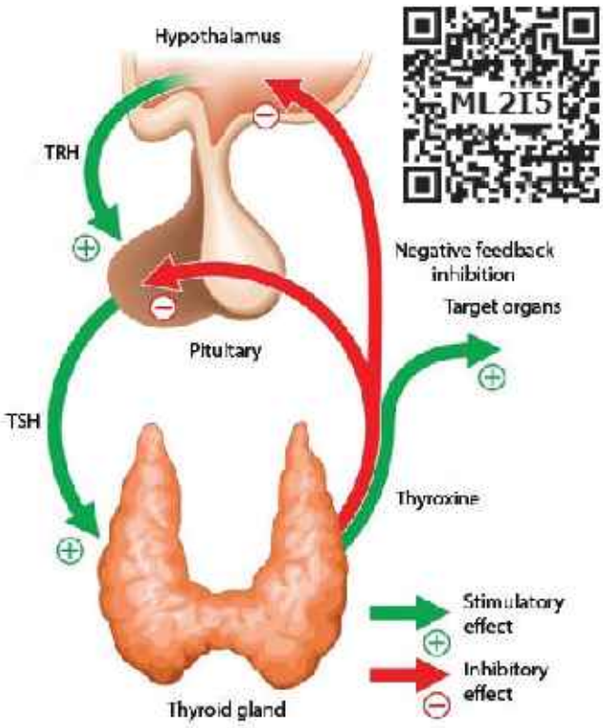


**Figure: 11.4.** Negative feedback mechanism

**Functions of thyrocalcitonin (TCT):** TCT is a polypeptide hormone, which regulates the blood calcium and phosphate levels. It reduces the blood calcium level and opposes the effects of parathyroid hormone.

**Iodine is required for formation of thyroxine:** To produce normal quantities of thyroxine, about 1mg/week of iodine is required. To prevent iodine deficiency common table salt is iodised with 1 part sodium iodide to every 1,00,000 parts of sodium chloride

## 11.2.5 Parathyroid Gland

In human, four tiny parathyroid glands are found in the posterior wall of the thyroid glands. This gland is composed of two types of cells, the chief cells and oxyphil cells. The chief cells secrete parathyroid hormone (PTH) and the functions of oxyphil cells are not known.

### Parathyroid Hormone or Parathormone (PTH)

PTH is a **hypercalcemic hormone**. It is a peptide hormone involved in controlling the calcium and phosphate homeostasis. The secretion of PTH is controlled by calcium level in the blood. It increases the blood calcium level by stimulating osteoclasts to dissolve the bone matrix. As a result calcium and phosphate are released into the blood. PTH enhances the reabsorption of calcium and excretion of phosphates by the renal tubules and promotes activation of vitamin D to increase calcium absorption by intestinal mucosal cells.

## 11.2.6 Thymus Gland

Thymus gland is partially an endocrine and partially a lymphoid organ. It is a bilobed structure located just above the heart and aorta, behind the sternum. It is covered by fibrous capsule and anatomically it is divisible into an outer cortex and an inner medulla. It secretes four hormones such **as thymulin, thymosin, thymopoietin and thymic humoral factor (THF).** The primary function of thymus is the production of immuno competent 'T' lymphocytes which provides cell mediated immunity.

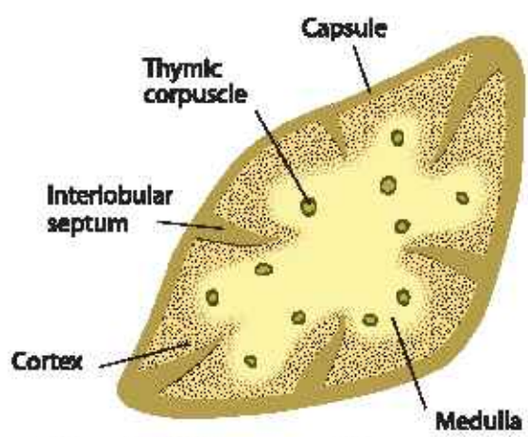


**Figure 11. 5** Structure of thymus gland



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**Old age people are sick often, why?**
Due to degeneration of thymus gland, thymosine level decreases, as a result the immunity of old age people becomes weak and causes sickness.

### 11.2.7 Adrenal Gland

A pair of adrenal glands are located at the anterior end of the kidneys, hence also called suprarenal glands. Anatomically the outer region is the cortex and the inner region is the medulla. Histologically the adrenal cortex has three distinct zones, zona glomerulosa, zona fasciculata and zona reticularis. **Zona glomerulosa** an outer thin layer constitutes about 15% of adrenal cortex, and secretes mineralocorticoids. **Zona fasciculata**, the middle widest layer constitutes about 75% of adrenal cortex and secretes glucocorticoids such as cortisol, corticosterone and trace amounts of adrenal androgen and oestrogen. **Zona reticularis**, an inner zone of adrenal cortex constitute about 10% of adrenal cortex and secretes the adrenal androgen, trace amount of oestrogen and glucocorticoids.

Laughing is good for health, because it reduces the stress hormone (adrenalin) secretion and makes us to relax.

**Adrenal medulla:** It is the central part of adrenal gland and is composed of ovoid and columnar cells, which are found around the network of blood capillaries. Adrenalin (epinephrine) and nor adrenalin (nor epinephrine) are the two hormones secreted by the adrenal medulla. Both adrenalin and nor adrenalin are **catecholamines.**

**Function of adrenal hormones**: **Glucocorticoids** stimulate gluconeogensis, lipolysis and proteolysis (the life saving activity). **Cortisol** is a glucocorticoid involved in maintaining cardio vascular and kidney functions. It produces anti-inflammatory reactions and suppresses the immune response. It stimulates the RBC production. It is also known as stress combat hormone. **Mineralocorticoid**s regulates water and electrolyte balance of our body. **Aldosterone** stimulates the reabsorption of sodium and water and eliminates potassium and phosphate ions through excretion, thus it helps in maintaining electrolytes, osmotic pressure and blood pressure. Adrenal androgen plays a role in hair growth in the axial region, pubis and face during puberty.

The **adrenal medulla** secretes the hormones adrenalin (epinephrine) and noradrenalin (norepinephrine) and are referred as "3F hormone" (fight, flight and fright hormone). Adrenalin increases liver glycogen breakdown into glucose and increases the release of fatty acids from fat cells. During emergency it increases heart beat rate and blood pressure. It stimulates the smooth muscles of cutaneous and visceral arteries to decrease blood flow. It increases blood flow to the skeletal muscles thereby increases the metabolic rate of skeletal muscles, cardiac muscles and nervous tissue.

The general function of noradrenalin is to mobilize the brain and body for action. It's secretion is less during sleep, more during wakefulness and reaches much higher levels during stress situations. This response is known as **'fight or flight'** response.



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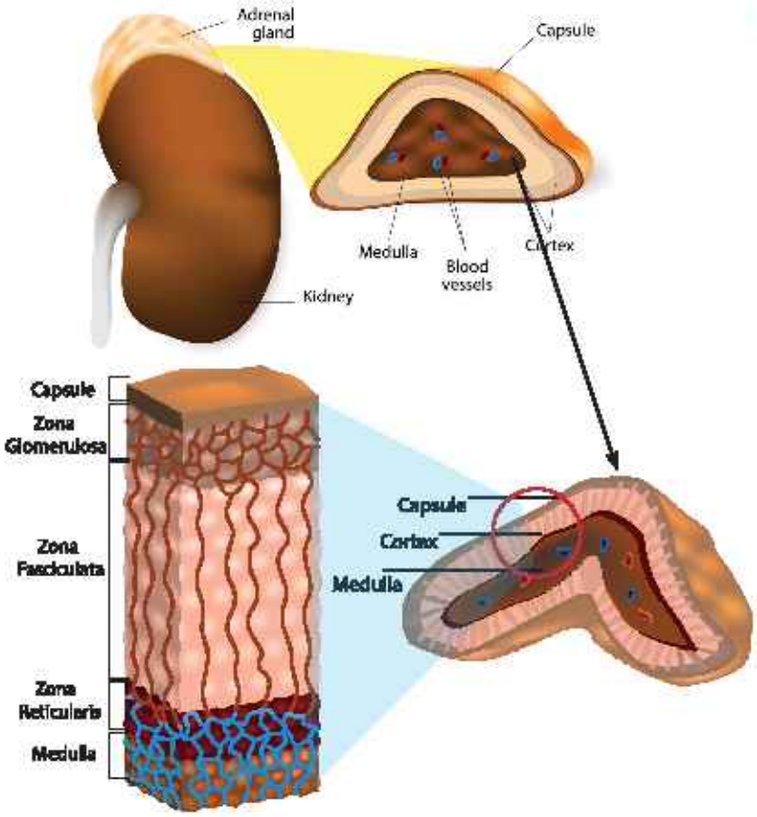


Figure 11.6 Structure of adrenal gland

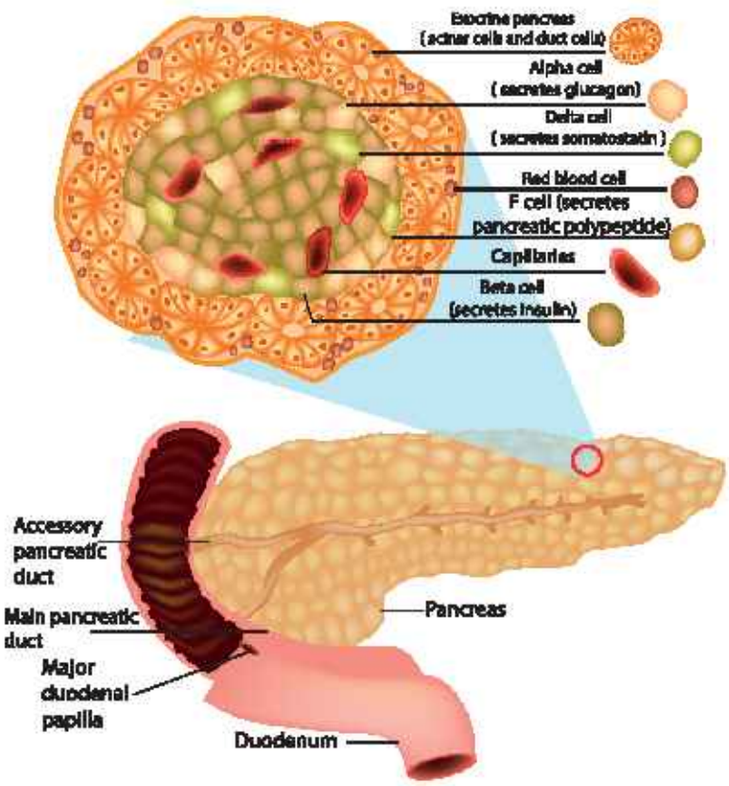


Figure 11.7 Structure of Islets of langerhans (pancreas)

## 11.2.8 Pancreas

Pancreas is a composite gland which performs both exocrine and endocrine functions. It is located just below the stomach as a leaf like structure. The pancreas is composed of two major tissues such the acini and islets of langerhans. Acini secretes digestive enzymes and the islets of langerhans secretes hormones like insulin and glucagon. Human pancreas has one to two million islets of langerhans. In each islet about 60% cells are beta cells, 30% cells are alpha cells and 10% cells are delta cells. The alpha cells secrete glucagon, the beta cells secrete insulin and delta cells secrete somatostatin.

**Insulin:** Insulin is a peptide hormone and plays an important role in glucose homeostasis. It's main effect is to lower blood glucose levels by increasing the uptake of glucose into the body cells, especially muscle and fat cells. Insulin also inhibits the breakdown of glycogen to glucose, the conversion of amino acids or fats to glucose, so insulin is rightly called a hypoglycemic hormone.

**Glucagon:** Glucagon is a polypeptide hormone. It is a potent hyperglycemic hormone that acts on the liver and promotes the breakdown of glycogen to glucose (Glygogenolysis), synthesis of glucose from lactic acid and from non-carbohydrate molecules (Gluconeogenesis). Glucagon releases glucose from the liver cells, increasing the



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blood glucose levels. Since glucagon reduces the cellular uptake and utilisation of glucose it is called a hyperglycemic hormone. Prolonged hyperglycemia leads to the disorder called diabetes mellitus.

**Humulin N: Human insulin is produced by recombinant DNA technology (genetic engineering) and administered to diabetic patients as injection and not by oral consumption. Reason: Digestive enzymes digest it.**

**Insulin:** The half life period of insulin (in plasma) is 6 minutes

It is cleared from the circulation within 10-15 minutes

Endocrine glands control and coordinate the body functions through secreting certain chemical messengers called hormones. Due to certain physiological reasons, the blood glucose level of an otherwise normal person.

a. Give the possible cause for the increases in blood glucose level.

b. What is the chemical nature of this hormone? Discuss its role in the body.

c. How can this condition be reversed?

### 11.2.9 Gonads

**Testis:** A pair of testis is present in the scrotal sac of males. The testis functions as a sex organ and also as an endocrine gland. The testis is composed of seminiferous tubules and interstitial cells or Leydig cells. The Leydig cells secrete several male sex hormones, collectively called androgens, mainly testosterone.

**Functions of testosterone:** Under the influence of FSH and LH, testosterone initiates maturation of male reproductive organs, and the appearance of secondary sexual characters, muscular growth, growth of facial and axillary hair, masculine voice and male sexual behaviour. It enhances the total bone matrix and plays a stimulating role in the process of spermatogenesis.

**Ovary:** Females have a pair of ovaries located in the pelvic region of the abdomen. The ovary is composed of ovarian follicles and stromal tissues. It produces the eggs or ova. The ovaries secrete the steroid hormones oestrogen and progesterone. **Oestrogen** is responsible for the maturation of reproductive organs and the development of secondary sexual characters at puberty. Along with progesterone, oestrogens promotes breast development and initiate the cyclic changes during menstrual cycle. **Progesterone** prepares the uterus for implantation of the fertilized ovum. It decreases the uterine contraction during pregnancy and stimulates the development of mammary glands and milk secretion. It is responsible for premenstrual changes in the uterus and is essential for the formation of placenta.

Identify the peaks of FSH, LH, Oestrogen and Progesterone hormones through out the menstrual cycle.

Urine pregnancy test is done to test the presence of Human Chorionic Gonadotrophin (HCG) in the urine. HCG can be detected in the urine one or two weeks after conception.



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### 11.2.10 Hormones of heart, kidney and gastro intestinal tract

Some tissues of the heart, kidney and gastro intestinal tract acts as partial endocrine glands. In the heart, cardiocytes on the atrial wall's secretes an important peptide hormone called atrial natriuretic factor (ANF). When blood pressure is increased, ANF is secreted and causes dilation of the blood vessels to reduce the blood pressure.

In kidneys, hormones such as renin, erythropoietin and calcitriol are secreted. **Renin** is secreted by juxta glomerular cells (JGA), which increases blood pressure when angiotensin is formed in blood. **Erythropoietin** is also secreted by the JGA cells of the kidney and stimulates erythropoiesis (formation of RBC) in bone marrow. **Calcitriol** is sercreted by proximal tubules of nephron. It is an active form of vitamin $D_3$ which promotes calcium and phosphorus absorption from intestine and accelerates bone formation.

#### Gastro intestinal tract hormones

Group of specialized endocrine cells present in gastro-intestinal tract secretes hormones such as gastrin, cholecystokinin (CCK), secretin and gastric inhibitory peptides (GIP). **Gastrin** acts on the gastric glands and stimulates the secretion of HCl and pepsinogen. **Cholecystokinin (CCK)** is secreted by duodenum in response to the presence of fat and acid in the diet. It acts on the gall bladder to release bile into duodenum and stimulates the secretion of pancreatic enzymes and its discharge. **Secretin** acts on acini cells of pancreas to secrete bicarbonate ions and water to neutralize the acidity. **Gastric inhibitory peptide (GIP)** inhibits gastric secretion and motility.

## 11.3 Hypo and Hyper activity of Endocrine Glands and related disorders

The hyper secretion and hypo secretion of hormones leads to several disorders

**Dwarfism** is due to hyposecretion of growth hormone (GH) in children, skeletal growth and sexual maturity is arrested. They attain a maximum height of 4 feet only (Figure 11.8).

**Figure. 11.8 Dwarfism**

**Gigantism** is due to hypersecretion of growth hormone (GH) in children. Overgrowth of skeletal structure occurs (up to 8 feet) and the visceral growth is not appropriate with that of limbs. Figure 11.9.

**Acromegaly** is due to excessive secretion of growth hormone in adults. Over growth of hand bones, feet bones, jaw bones, malfunctioning of gonads, enlargement of viscera, tongue, lungs, heart, liver, spleen and endocrine gland like thyroid, adrenal etc., are the symptoms of acromegaly. (Figure 11.10)



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**Figure. 11.9 Gigantism**

**Figure. 11.10 Acromegaly**

In infants, hypothyroidism causes **cretinism.** A cretin shows retarded skeletal growth, absence of sexual maturity, retarded mental ability, thick wrinkled skin, protruded enlarged tongue, bloated face, thick and short limbs occurs. The other symptoms are low BMR, slow pulse rate, subnormal body temperature and elevated blood cholesterol levels. (Figure 11.11)

**Figure. 11.11 Cretinism**

Hyposecretion of thyroid in adults causes **myxodema**. It is otherwise called **Gull's disease**. This disease is characterised by decreased mental activity, memory loss, slowness of movement, speech, and general weakness of body, dry coarse skin, scarce hair, puffy appearance, disturbed sexual function, low BMR, poor appetite, and subnormal body temperature. (Figure 11.12)

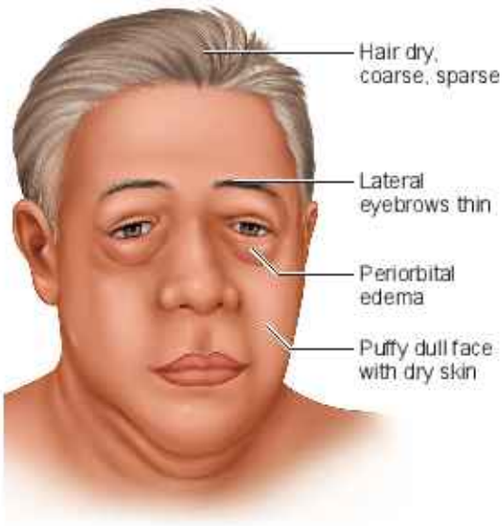


**Figure. 11.12 myxodema**

**Grave's disease** also called as **thyrotoxicosis** or **exophthalmic goitre**. This disease is caused due to hyper



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secretion of thyroid. It is characterised by enlargement of thyroid gland, increased BMR (50% - 100%), elevated respiratory and excretory rates, increased heart beat, high BP, increased body temperature, protrusion of eyeball and weakness of eye muscles and weight loss. (Figure 11.13)

**Figure. 11.13 Grave's disease**

**Simple goitre** is also known as **Endemic goitre**. It is caused due to hyposecretion of thyroxine. The symptoms includes enlargement of thyroid gland, fall in serum thyroxine level, increased TSH secretion. (Figure 11.14)

**Figure. 11.14 Simple goitre**

**Tetany** is caused due to the hyposecretion of parathyroid hormone (PTH). Due to hyposecretion of PTH serum calcium level decreases (Hypocalcemia), as a result serum phosphate level increases. Calcium and phosphate excretion level decreases. Generalized convulsion, locking of jaws increased heart beat rate, increased body temperature, muscular spasm are the major symptoms of tetany.

**Hyperparathyroidism** is caused due to excess PTH in blood. Demineralisation of bone, cyst formation, softening of bone, loss of muscle tone, general weakness, renal disorders are the symptoms of hyperparathyroidism.

**Addison's disease** is caused due to hyposecretion of glucocorticoids and mineralocorticoids from the adrenal cortex. Muscular weakness, low BP., loss of appetite, vomiting, hyper pigmentation of skin, low metabolic rate, subnormal temperature, reduced blood volume, weight loss are the symptoms that occur in Addison's disease (Figure 11.15). Reduced aldosterone secretion increases urinary excretion of Na Cl. and water and decreases potassium excretion leading to dehydration.

**Figure. 11.15 Addison's disease**



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**Cushing's syndrome** is caused due to excess secretion of cortisol. Obesity of the face and trunk, redness of face, hand, feet, thin skin, excessive hair growth, loss of minerals from bone (osteoporosis) systolic hypertension are features of Cushing's syndrome. Suppression of sexual function like atrophy of gonads are the other symptoms of Cushing's syndrome. (Figure 11.16)

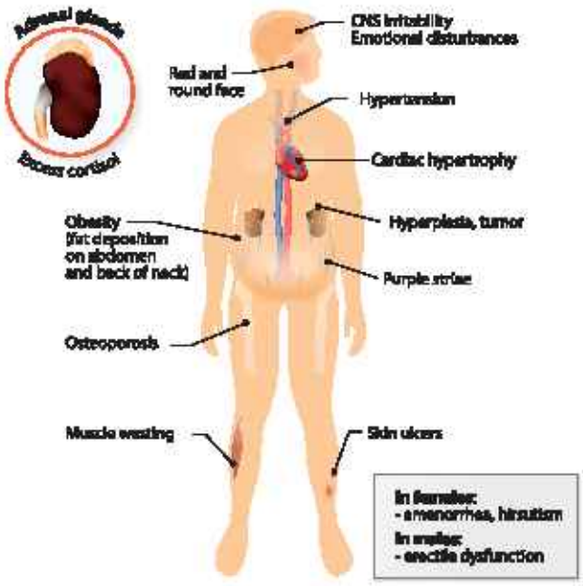


**Figure. 11.16 Cushing's syndrome**

**Hypoglycaemia is** due to increased secretion of insulin thereby blood glucose level decreases. In this disorder blood glucose level lowers than normal fasting index. Increased heartbeat, weakness, nervousness, headache, confusion, lack of co-ordination, slurred speech, serious brain defects like epilepsy and coma occurs.

**Normal blood glucose level:**

Preprandial : 70 – 110 mg/dl (Before food) – (Fasting)

Postprandial : 110 – 140 mg/dl (About two hours after food)

**Hyperglycaemia** is otherwise known as **Diabetes mellitus**. It is caused due to reduced secretion of insulin. As the result, blood glucose level is elevated. Diabetes mellitus is of two types, **Type I Diabetes** and **Type II Diabetes**. Type I diabetes is also known Insulin dependent diabetes, caused by the lack of insulin secretion due to illness or viral infections. Type II diabetes is also known as Non- Insulin dependent diabetes, caused due to reduced sensitivity to insulin, often called as insulin resistance. Symptoms of diabetes includes, polyurea (excessive urination), polyphagia (excessive intake of food), polydipsia (excessive consumption liquids due to thirst), ketosis (breakdown of fat into glucose results in accumulation of ketone bodies) in blood. Gluconeogenesis (Conversion of non- carbohydrate form like amino acids and fat into glucose) also occur in diabetes.

**Avoid use of synthetic soft drinks**

The branded soft drinks damage our endocrine system. While consuming soft drinks, the sugar level increases in blood which leads to elevated insulin secretion to reduce the blood glucose level. The elevated insulin level diminishes immunity and cause obesity, cardio-vascular disorders etc.

**Diabates insipidus** is caused due to hyposecretion of vasopressin (ADH) from neurohypophysis. The symptom includes frequent urination (polyurea) and excessive consumption of liquids due to thirst (polydipsia).



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## 11.4 Mechanism of Hormone Action

Hormones circulate in the blood but their concentration can increase or decrease based on the requirement of the body. This is controlled by feedback mechanisms.

These mechanisms control the secretion of endocrine glands by stimulating the hypothalamus, pituitary or both, which inturn governs the secretion of a particular hormone. In positive feedback, the secretion of the hormone increases where as in negative feedback further secretion of hormone slows down. Feedback mechanisms are the key factors for maintaining homeostasis in our body.

Hormones are classified into three major groups as peptide hormones, steroid hormones and amino acid derived hormones based on their chemical structure.

Peptide hormones cannot cross the phospolipid cell membrane and bind to the receptors on the exterior cell surface. They are are transported to the golgi, which is the site of modification. It acts as a **first messenger** in the cell. Hormones on binding to their receptors do not enter the target cell but generate the production of **second messengers** such as cyclic AMP (c AMP), which in turn regulates cellular metabolism. This is catalyzed by the enzyme **adenylate cyclase**. The interaction between the hormone at the surface and the effect brought out by cAMP within the cell is known as signaling cascade. At each step there is a possibility of amplification. (Figure 11.17)

1. One hormone molecule may bind to multiple receptor molecules before it is degraded.
2. Each receptor may activate several adenylate cyclases each of which make much c AMP.
3. Thus there is more signal after each step.

The actions of cAMP are terminated by phosphodiesterases. The effect of peptide hormones like insulin, glucagon, somatotropin are usually short lived because they work through second messenger system.

Steroid hormones can easily cross the cell membrane, and bind to their receptors, which are intracellular or intranuclear. Upon binding to the receptors, they pair up with another receptor – hormone complex (dimerize).This dimer can then bind to DNA and alter its transcription. (Figure 11.18)

The effect of steroid hormones such as aldosterone, oestrogen are long lived, as they alter the amount of mRNA and protein in a cell.

Amino acid derived hormones are derived from one or two aminoacid with a few additional modifications. Thyroid hormone is synthesised from tyrosine and includes the addition of several iodine atoms.

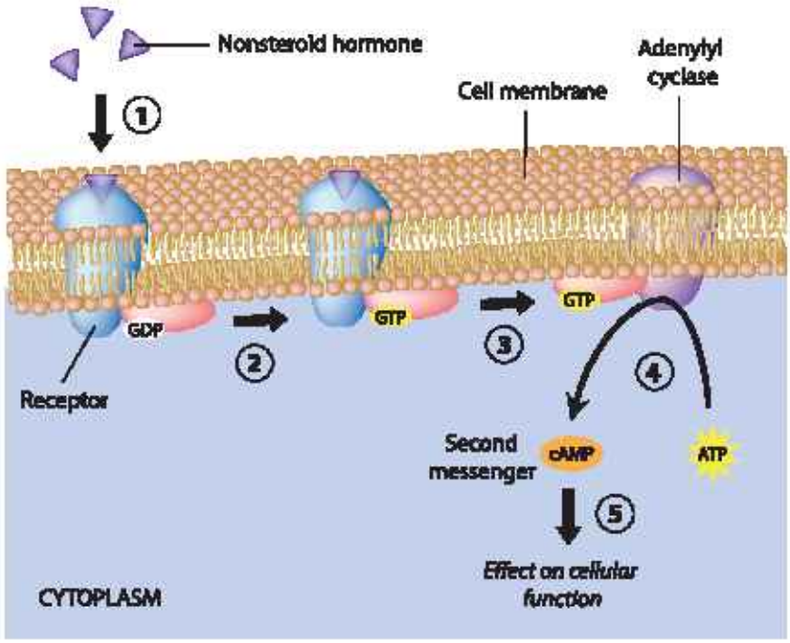


**Figure 11.17: Mechanism of peptide hormone action**



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Epinephrine an amino acid derivative may function through second messenger system like peptide hormones or they may actually enter the cell and function like steroid hormones.

**Avoid use of steroid components**

The abuse of anabolic steroids can cause serious health problems like high BP, heart diseases, liver damage, cancer, stroke and blood clots. Other side effects of steroid use includes nausea, vomiting, ligament and tendon injuries, head ache, joint pain, muscle cramps, diarrhoea, sleep problem etc.

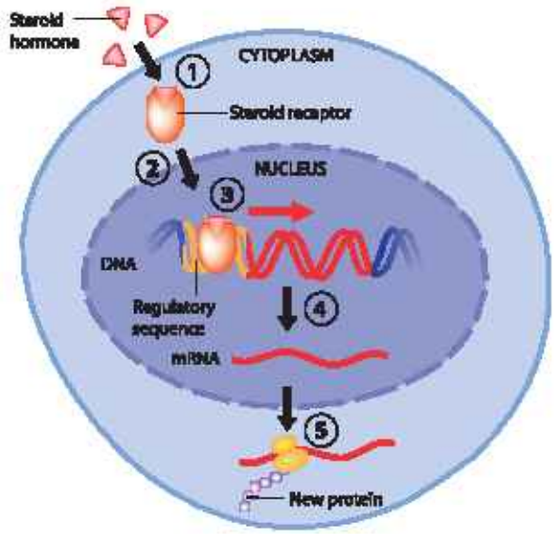


**Figure 11.18 Mechanism of steroid hormone action**

## Summary

Endocrine glands: secrete hormones which diffuse into blood and induce the target organs. They are chemical messengers or organic catalysts which interact with receptor in the target organs.

Hormones speed up or slow down or alter the activities of target organs. The hypo or hyper secretion of hormones leads to serious effects on human beings. Hormones coordinate different physical and mental activities to maintain homeostasis.

Hypothalamus interlinks nervous system and endocrine system. It is located in the diencephalon of cerebrum and controls the pituitary secretion. Pituitary gland secretes six tropic hormones which regulates various physiological functions of our body. Posterior pituitary gland secretes vasopressin that regulates water and electrolyte balance. Oxytocin helps during child birth. Melatonin secreted by pineal gland regulates circadian rhythm of our body. The thyroid gland secretes thyroxine which stimulates the nervous system, skeletal growth, and regulates basal metabolic rate.

Parathyroid gland regulates calcium level in our body. Thymus gland plays a vital role in cell mediated immunity by promoting T lymphocytes maturation. Pancreas regulates blood glucose homeostasis through its secretion of insulin and glucagon.

Adrenal cortex secretes mineralocorticoids which regulates mineral metabolism, glucocorticoids regulates carbohydrate metabolism. Adrenal medulla secretes the hormones adrenalin and noradrenalin. In male, reproductive functions are controlled by testosterone secreted by the testis. In female, ovary secretes three hormones oestrogen, progesterone and relaxin that regulates reproductive functions.

Hormonal deficiency causes serious harmful effects in human. It alters physiological and biochemical functions of the body. This leads into various disorders like acromegaly, dwarfism, tetany, diabetes etc.



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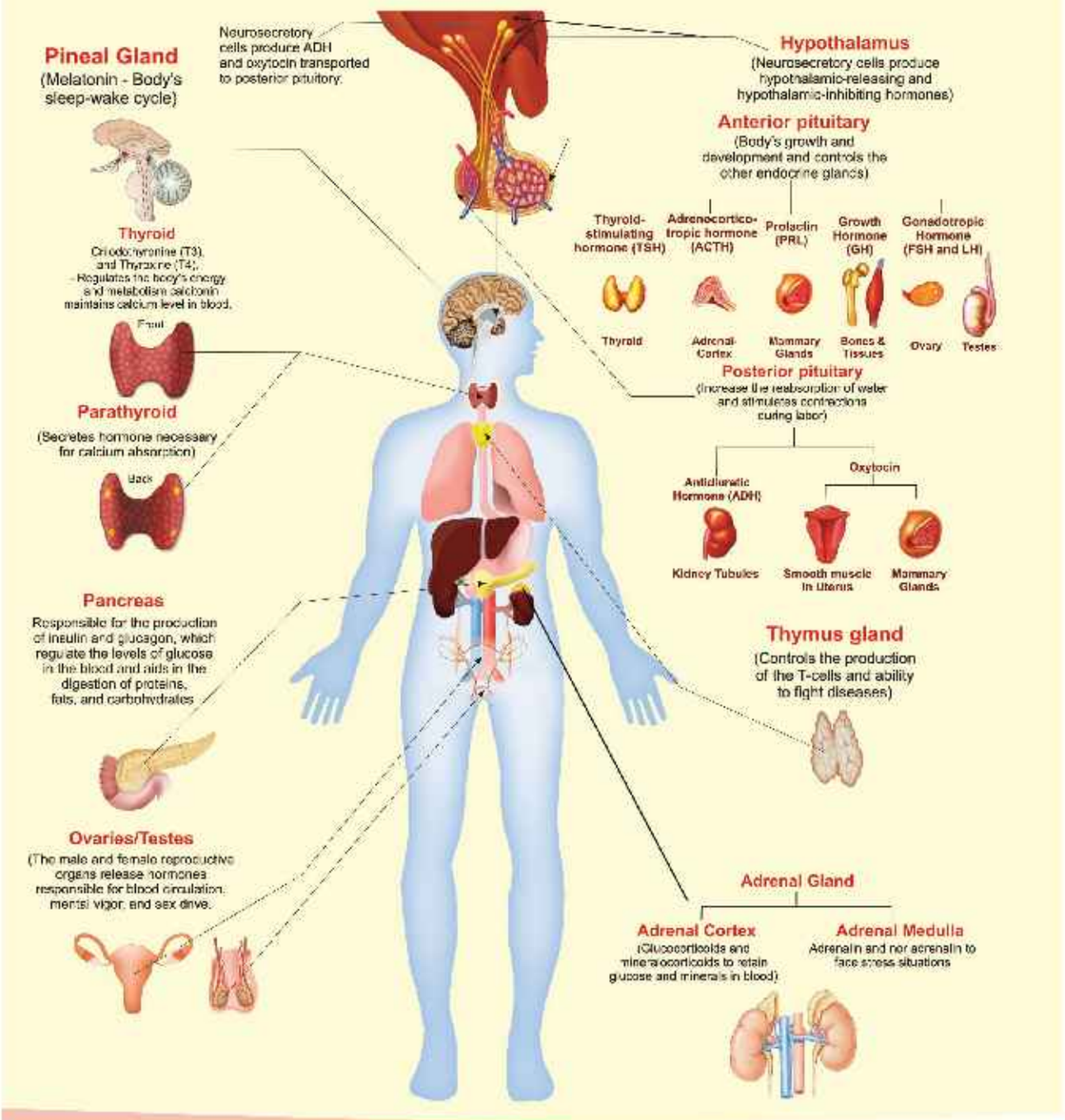
# Location of major endocrine glands - their secretions and storage,




**Hypothalamus found deep inside the brain, its products are releasing and inhibiting hormones and controls the pituitary. Together, the hypothalamus and pituitary control the other endocrine glands in our body to make the hormones that control and co-ordinates various physical and physiological activities.**



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## Evaluation

1. The maintenance of constant internal environment is referred as
   a. Regulation
   **b. homeostasis**
   c. co-ordination
   d. hormonal control
2. Which of the following are exclusive endocrine glands?
   a. Thymus and testis
   b. adrenal and ovary
   **c. parathyroid and adrenal**
   d. pancreas and parathyroid
3. Which of the following hormone is not secreted under the influence of pituitary gland?
   a. thyroxine **b. insulin**
   c. oestrogen d. glucocorticoids
4. Spermatogenesis in mammalian testes is controlled by
   **a. Luteinising hormone**
   b. Follicle stimulating hormone
   c. FSH and prolactin
   d. GH and prolactin
5. Serum calcium level is regulated by
   a. Thyroxine b. FSH
   c. Pancreas **d. Thyroid and parathyroid**
6. Iodised salt is essential to prevent
   a. rickets b. scurvy
   **c. goitre** d. acromegaly
7. Which of the following gland is related with immunity?
   a. Pineal gland b. adrenal gland
   **c. thymus** d. parathyroid gland
8. Which of the following statement about sex hormones is correct?
   **a. Testosterone is produced by Leydig cells under the influence of luteinizing hormone**
   b. Progesterone is secreted by corpus luteum and softens pelvic ligaments during child birth
   c. Oestrogen is secreted by both sertoli cells and corpus luteum
   d. Progesterone produced by corpus luteum is biologically different from the one produced by placenta.
9. Hypersecretion of GH in children leads to
   a. Cretinism **b. Gigantism**
   c. Graves disease d. Tetany
10. A pregnant female delivers a baby who suffers from stunted growth, mental retardation, low intelligence quotient and abnormal skin. This is the result of
    **a. Low secretion of growth hormone**
    b. Cancer of the thyroid gland
    c. Over secretion of pars distalis
    d. Deficiency of iodine in diet.
11. The structure which connects the hypothalamus with anterior lobe of pituitary gland is the
    a. Dendrites of neuro hypophysis
    b. Axons of neurohypophysis
    c. Bands of white fibers from cerebellar region
    **d. Hypophyseal portal system**
12. Which one of the following statement is correct
    a. Calcitonin and thymosin are thyroid hormones
    b. Pepsin and prolactin are secreted in stomach
    c. Secretin and rhodopsin are polypeptide hormones
    **d. Cortisol and aldosterone are steroid hormones**
13. which of the given option shows all wrong statements for thyroid gland

    **Statements**

    (i) It inhibits process of RBC formation



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(ii) It helps in maintenance of water and electrolytes

(iii) Its more secretion can reduce blood pressure

(iv) It Stimulates osteoblast

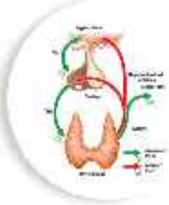
(a) (i) and (ii) (b) (iii) and (iv)

(c) (i) and (iv) **(d) (i) and (iii)**

14. Comment on homeostasis.
15. Hormones are known as chemical messenger. Justify.
16. Write the role of oestrogen in ovulation.
17. Comment on Acini of thyroid gland.
18. Write the causes for diabetes mellitus and diabetes insipidus.
19. Specify the symptoms of acromegaly.
20. Write the symptoms of cretinism.
21. Briefly explain the structure of thyroid gland.
22. Name the layers of adrenal cortex and mention their secretions.
23. Differentiate hyperglycemia from hypoglycemia.
24. Write the functions of (CCK) Cholecystokinin.
25. Growth hormone is important for normal growth. Justify the statement.
26. Pineal gland is an endocrine gland, write its role.
27. Comment on the functions of adrenalin.
28. Predict the effects of removal of pancreas from the human body.
29. Enumerate the role of kidney as an endocrine gland.
30. Write a detailed account of gastro intestinal tract hormones.

## ICT Corner

### Endocrine system



**Let's explore the position and functions of Endocrine system.**

**Step – 1** Use the URL to land in the Endocrine system page.

**Step – 2** Click on the gland to find out the position and functions of the gland.

**Step – 3** Click on the Hormone name to get additional details about it.

**Step – 4** Click the main menu on the top right corner to search back and go through the next gland.

Step 1

Step 2

Step 3

Step 4

Endocrine system's URL:

**http://www.e-learningforkids.org/health/lesson/endocrine-system/**

* Pictures are indicative only



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UNIT V

# Chapter 12

# Trends in Economic Zoology

**Chapter Outline**


12.1 Scope of Zoology
12.2 Vermiculture
12.3 Sericulture
12.4 Apiculture
12.5 Lac culture
12.6 Aquaponics
12.7 Aquaculture
12.8 Animal Husbandry and management


97YAH

Give a man a fish and you feed him for a day; teach a man to fish and you feed him for a lifetime.

## Learning Objectives:

- *Creating awareness on self employment opportunities in various fields*
- *Understands the economic importance of earthworm, honeybee, lac insect, silk worm, fish, cattle and birds*
- *Knows the techniques and tools required for various culture methods*
- *Learns to manage the culture practices*

Zoology is a branch of science which deals with the study of animals. For someone who is interested in pursuing a career in Zoology, there are several specializations that the students can venture into. There are physiologists, who study the metabolic processes of animals; there are taxonomists who deal with the naming and the classification of animal species; embryologist whose job is to study and focus on the early developmental stages of animal life. **Zoology as a career** has a number of specializations and students are presented with a plethora of career options once they chose to be associated with this field. This field is concerned with the preservation and management of animal kingdom and a career in it would mean that you are a part of that responsibility. A zoologist might even get to travel because the nature of his/her job. Channels like National Geographic, Animal Planet, and Discovery Channel are in constant need of Zoologists for research and documentaries. Zoologists are also hired for zoos, wildlife services, botanical gardens, conservation organizations, national parks, nature reserves, universities, laboratories, aquariums, animal clinics, fisheries and aquaculture, museums, research, pharmaceutical companies, veterinary hospitals, etc.

If you want to be an entrepreneur you have to learn the methods of culturing farm animals and their importance, since



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farm animals possess great economic value. Since prehistoric time human beings taken maximum advantage from animals by keeping them under their control through domestication. The economic success of the industries, based on animals and their products, depends on the proper production, management and development of the next generation of farm animals.

## 12.1 Scope of Zoology

Studying Zoology can provide self employment opportunities and you can become an entrepreneur. Economic Zoology is a branch of science that deals with economically useful animals. It involves the study of application of animals for human welfare. The need of Zoology is not just to improve our economic condition but also to provide food security and provide employment opportunities. Based on the economic importance, animals can be categorized as:

1. Animals for food and food products
2. Economically beneficial animals
3. Animals of aesthetic importance
4. Animals for scientific research

## 12.2 Vermiculture

**Vermiculture** is the process of using earthworms to decompose organic food waste, into a nutrient-rich material capable of supplying necessary nutrients which helps to sustain plant growth. The aim is to continually increase the number of worms to have a sustainable harvest. The excess worms can either be used to expand a vermicomposting operation or sold to customers. Vermicompost is the primary goal of vermiculture. Technically, the worm castings are pure worm waste and are fine and nutrient rich organic soil amendment. Vermicompost on the other hand, is comprised of the castings, bits of bedding and other organic matter. Essentially, though the terms are used interchangeably, they are both worm manure and are valuable for improving soil health. Applications of earthworm in technology of composting and bioremediation of soils and other activities is called Vermitech (Sultan Ismail, 1992).

The disposal of solid wastes (bio-degradable and non- biodegradable) remains a serious challenge in most of the countries. Earthworms play a vital role in maintaining soil fertility; hence these worms are called as **"farmer's friends"**. These are also called as **"biological indicators of soil fertility"**. The reason is that they support bacteria, fungi, protozoans and a host of other organisms which are essential for sustaining a healthy soil. The breakdown of organic matter by the activity of the earthworms and its elimination from its body is called vermicast. It is a finely divided granular material and is noted for its porosity, aeration, drainage and moisture holding capacity and serves as rich organic manure.

Earthworms are divided into two major groups. The first group, the **humus formers**, dwell on the surface and feed on organic matter. They are generally darker in colour. These worms are used for vermicomposting. The second group, the **humus feeders**, are burrowing worms that are useful in making the soil porous, and mixing and distributing humus through out the soil. There are different **endemic** (native) species of earthworms cultured



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in India for vermicomposting such as *Periyonyx excavatus, Lampito mauritii, Octochaetona serrata.* Some earthworm species have been introduced from other countries and called as **exotic species** Eg. *Eisenia fetida, Eudrilus eugeniae.*

## Vermicomposting

**Vermicompost** is the compost produced by the action of earthworms in association with all other organisms in the compost unit. Vermicompost bed may be selected on upland or an elevated level as it prevents the stagnation of water. You may construct a cement pit of 3×2×1m size (L×W×D) over ground surface using bricks. The size of pit may vary as per availability of raw materials. Cement pot or well rings are practically good. Provision should be made for excess water to drain. The vermibed should not be exposed to direct sunlight and hence shade may be provided (Figure. 12.1). The first layer of vermibed contains gravel at about 5 cm in height, followed by coarse sand to a thickness of 3.5 cm, which will facilitate the drainage of excess water.

Earthworms collected from native soil prefer a layer of local soil in their compost beds. If local soil earthworms are used, add a layer of native loamy soil for about 15 cm on top of the gravel sand layer and introduce earthworms into it. For exotic species such as *Eisenia fetida* and *Eudrilus eugeniae,* the layer of soil is not needed. The unit can now be loaded with digested biomass or animal dung such as cow dung that has lost its heat. The number of earthworms to be introduced in an unit depends on the size of the vermibed prepared. Earthworms such as *Periyonyx excavatus, Eisenia fetida* or *Eudrilus eugeniae* are introduced on the top. Jute bags or cardboards or broad leaves are used to cover the unit. As worms require moisture, water management is most important for the survival of the earthworms. Too little or too much of water is not good for the worms.

Earthworms release their castings on the surface. One can start harvesting this from the surface on noticing the castings on the surface. It may take several days for the entire biomass to be composted depending on the amount of biomass. When all the compost is harvested, earthworms can be handpicked by creating small conical heaps of harvested compost and leaving in sunlight for a few hours. The earthworms then move down and settle at the bottom of the heap as a cluster. Earthworms from the lower layers of the compost can be recovered and the worms can be transferred to new composting units.

**Vermiwash** is a liquid collected after the passage of water through a column

**Figure 12.1** Vermiculture unit and Earthworms



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of vermibed. It is useful as a foliar spray to enhance plant growth and yield. It is obtained from the burrows or **drilospheres** formed by earthworms. Nutrients, plant growth promoter substances and some useful microorganisms are present in vermiwash.

Earthworms can be used for recycling of waste food, leaf, litter and biomass to prepare a good fertilizer in container known as **wormery** or **wormbin**.

### Earthworm Pests and Diseases

Earthworms are subjected to attack by a variety of pests. Most outbreaks are the result of poor bed management. Earthworm enemies include ants, springtails, centipedes, slugs, mites, certain beetle larvae, birds, rats, snakes, mice, toads, and other insects or animals which feed on worms. The earthworm has a number of internal parasites including numerous protozoa, some nematodes, and the larvae of certain flies. Larger predators can be excluded from worm beds by proper construction of the bins, and by use of screens or gratings at the bottom and top of the beds.

My vermicompost manufacturing unit is plagued by a number of red ants. Are there any bio-friendly measures to tackle the menace as I do not want to use any chemicals?

### Advantages of Using Vermicompost

People are aware about benefits of organic inputs in farming. Vermicompost is excellent organic manure for sustainable agro-practices. So, marketing vermicompost is now a potential and flourishing industry. Retail marketing of vermicompost in urban areas is most promising. Vermicompost is neatly packed in designed and printed packets for sale. People of different age groups are involved in the production and selling of vermicompost. Marketing of vermicompost can provide a supplementary income.

i. Vermicompost is rich in essential plant nutrients.
ii. It improves soil structure texture, aeration, and water holding capacity and prevents soil erosion
iii. Vermicompost is a rich in nutrients and an eco-friendly amendment to soil for farming and terrace gardening.
iv. It enhances seed germination and ensures good plant growth

## 12.3 Sericulture

Silk is Nature's gift to mankind and a commercial fiber of animal origin other than wool. Being eco-friendly, biodegradable and self-sustaining material; silk has assumed special relevance in present age. Sericulture is an agro –based industry, the term which denotes commercial production of silk through silkworm rearing. Historical evidence reveals that sericulture was practiced in China long back and they preserved the secret for more than 3000 years and maintained monopoly in silk trade with the rest of the world. According to Western historians, mulberry cultivation spread to India about 140BC from China through Tibet. The fabulous silk from China and India were carried to European countries. The 7000 mile lengthy road, historically called the "**Silk road**" passing through Baghdad, Tashkent, Damascus and Istanbul was used for silk transport. Today more than 29 countries in the world are practicing sericulture and producing different kinds of silk. India stands second in silk production next to China.

Production of silk from the silk worm, by rearing practices on a commercial



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**Table 12.1** Different types of Silkworm

| Species of silkmoth | Silk Producing States | Preferred Food (Leaves) | Type Of Silk |
|---|---|---|---|
| *Bombyx mori* | Karnataka, Andhra Pradesh and Tamil Nadu | Mulberry | Mulberry Silk |
| *Antheraea assamensis* | Assam, Meghalaya. Nagaland, Arunachala Pradesh and Manipur | Champa | Muga Silk |
| *Antheraea mylitta* | West Bengal, Bihar and Jharkand | Arjun | Tassar Silk |
| *Attacus ricini* | Assam, Meghalaya. Nagaland, Arunachala Pradesh and Manipur | Castor | Eri Silk |

scale is called sericulture. It is an agro-based industry comprising three main components: **i) cultivation of food plants for the silkworms, ii) rearing of silkworms, and iii) reeling and spinning of silk**. The first two are agricultural and the last one is an industrial component. Only few species of silkworms are used in the sericulture industry (Table 12. 1 and Figure 12. 2).

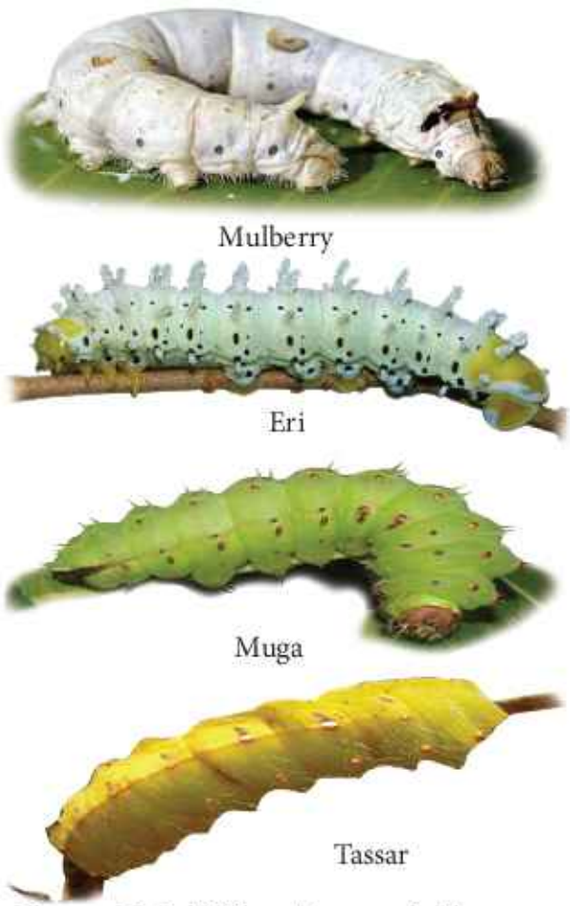


**Figure 12.2** Different types of silkworms

### Life cycle of *Bombyx mori*

The adult of *Bombyx mori* is about 2.5 cm in length and pale creamy white in colour. Due to heavy body and feeble wings, flight is not possible by the female moth. This moth is unisexual in nature and does not feed during its very short life period of 2-3 days. Just after emergence, male moth copulates with female for about 2-3 hours and if not separated, they may die after few hours of copulating with female. Just after copulation, female starts egg laying which is completed in1-24 hours. A single female moth lays 400 to 500 eggs depending upon the climatic conditions. Two types of eggs are generally found namely diapause type and non-diapause type. The diapause type is laid by silkworms inhabiting the temperate regions, whereas silkworms belonging to subtropical regions like India lay non-diapause type of eggs. The eggs after ten days of incubation hatch into larva called as caterpillar. The newly hatched caterpillar is



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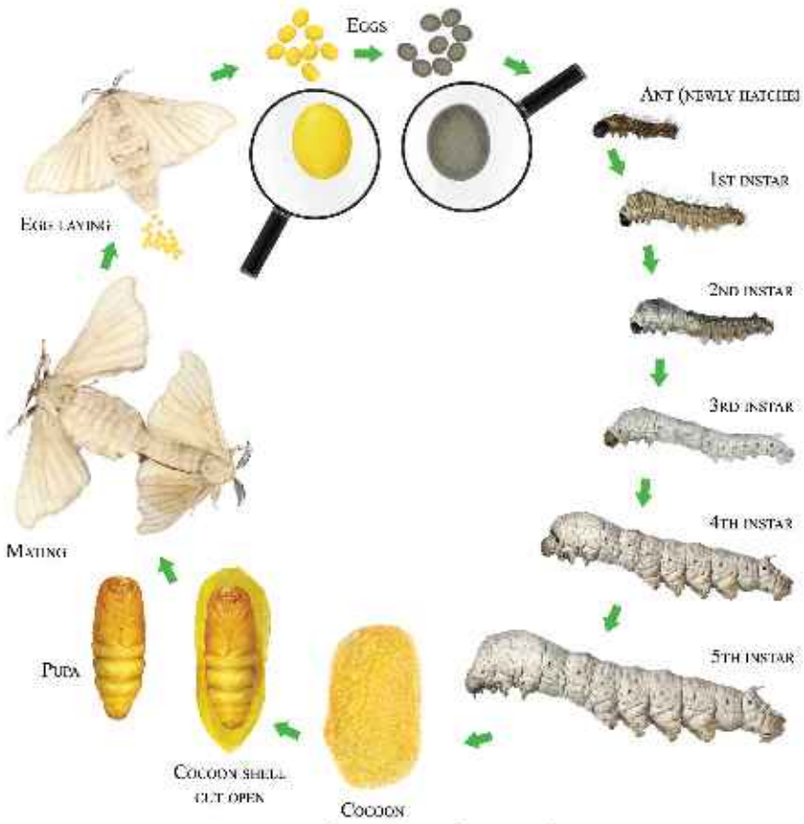


**Figure 12.3** Life cycle of *Bombyx mori*

about 3 mm in length and is pale, yellowish-white in colour. The caterpillars are provided with well developed mandibulate type of mouth-parts adapted to feed easily on the mulberry leaves.

After 1st, 2nd, 3rd and 4th moultings caterpillars get transformed into 2nd, 3rd, 4th and 5th instars respectively (Figure12.3). It takes about 21 to 25 days after hatching. The fully grown caterpillar is 7.5 cm in length. It develops salivary glands, stops feeding and undergoes pupation. The caterpillars stop feeding and move towards the corner among the leaves and secretes a sticky fluid through their silk gland. The secreted fluid comes out through spinneret (a narrow pore situated on the hypopharynx) and takes the form of long fine thread of silk which hardens on exposure to air and is wrapped around the body of caterpillar in the form of a covering called as cocoon. It is the white coloured bed of the pupa whose outer threads are irregular while the inner threads are regular. The length of continuous thread secreted by a caterpillar for the formation of cocoon is about 1000-1200 metres which requires 3 days to complete. The pupal period lasts for 10 to 12 days and the pupae cut through the cocoon and emerge into adult moth.

On the basis of the moults which they undergo during their larval life, *B. mori* is divided into three races – tri-moulters, tetra-moulters and penta-moulters. Based on voltinism (the number of broods raised per year), three kinds of races are recognized in mulberry silkworm – univoltines (one brood only), bivoltines (two broods only) and multivoltines (more than two broods).

India has the distinction of producing all the four types of silk i.e. (a) Mulberry silk (91.7%); (b) Tasar silk (1.4%); (c) Eri silk (6.4%); and (d) Muga silk (0.5%) which are produced by different species of silkworms. Name the species that produces large amount and least amount of silk in India.

**Cultivation of food plants for the silkworms**

The first component, is to grow the food plants for the silkworms. Mulberry leaves



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are widely used as food for silkworm *Bombyx mori* and the cultivation of mulberry is called as **Moriculture**. Presently improved mulberry varieties like Victory1, S36, G2 and G4 which can withstand various agro - climatic and soil conditions are used for planting. The favourable season for cultivating of the mulberry plants is June, July, November and December. The mulberry crop production technology includes land preparation, preparation of cutting, planting techniques, maintenance of mulberry nursery, disease and pest management and uprooting for raising new mulberry gardens. Mulberry is also being grown as tree plant at an height of 123-152 cm with 20 × 20 cm or 25 × 25 cm spacing to harvest better silkworm cocoon crops.

**Rearing of silkworms**

The second component is the rearing of silkworm. A typical rearing house (6m x 4m x 3.5m) is constructed on an elevated place under shade to accommodate 100 dfls (disease free layings). Space of 1m should be provided surrounding the rearing house. Sufficient windows and ventilators should be provided for free circulation of air inside the rearing house. The windows and ventilators should be covered with nylon net to restrict the entry of uzi flies and other insects. Apart from the specified area of the rearing house; the following appliances such as hygrometer, power sprayers, rearing stands, foam pads, wax coated paraffin papers, nylon nets, baskets for keeping leaves, gunny bags, rotary or bamboo mountages and drier are needed for effective rearing of silkworms. The steps involved in rearing process of silkworm are disinfection of rearing house, incubation of eggs, brushing, young larval rearing and late age larval rearing.

The selected healthy silk moths are allowed to mate for 4 hours. Female moth is then kept in a dark plastic bed, it lays about 400 eggs in 24 hours; the female is taken out, crushed and examined for any disease, only certified disease-free eggs are reared for industrial purpose. The eggs are incubated in an incubator. The small larvae (caterpillars) hatch between 7-10 days. These larvae are kept in trays inside a rearing house at a temperature of about 20°C - 25°C. These are first fed on chopped mulberry leaves. After 4-5 days fresh leaves are provided. As the larvae grow, they are transferred to fresh leaves on clean trays, when fully grown they spin cocoons. Their maturity is achieved in about 45 days. At this stage the salivary glands (silk glands) starts secreting silk to spin cocoons.

**Post cocoon processing**

The method of obtaining silk thread from the cocoon is known as post cocoon processing. This includes **stifling** and **reeling.**

The process of killing the cocoons is called stifling. The process of removing the threads from the killed cocoon is called reeling. For reeling silk the cocoons are gathered about 8 -10 days after spinning had begun. The cocoons are first treated by steam or dry heat to kill the insect inside. This is necessary to prevent the destruction of the continuous fibre by the emergence of the moth. The cocoons are then soaked in hot water (95° -97°C) for 10-15 minutes to soften the gum that binds the silk threads together. This process is called cooking. The "cooked" cocoons



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are kept in hot water and the loose ends of the thread are caught by hand. Threads from several cocoons are wound together on spinning wheels (Charakhas) to form the reels of raw silk. Only about one-half of the silk of each cocoon is reelable, the remainder is used as a silk waste and formed into spun silk. Raw silk thus obtained is processed through several treatments to bring about the luster on the thread.

New silkworm diet produces coloured silk. The Institute of Materials Research and Engineering (IMRE) in Singapore has developed a way to replace the traditional dying process necessary to make coloured silk. A simple dietary change (feeding a diet of mulberries treated with fluorescent dye) for the silkworm larva and they are able to produce silk in a variety of colors. The colour directly integrated into the fibers.

**Uses of Silk**

1. Silk fibers are utilized in preparing silk clothes. Silk fibers are now combined with other natural or synthetic fibers to manufacture clothes like **Teri-Silk, Cot-Silk** etc. Silk is dyed and printed to prepare ornamented fabrics. They are generally made from Eri-silk or spun silk.
2. Silk is used in industries and for military purposes.
3. It is used in the manufacture of fishing fibers, parachutes, cartridge bags, insulation coils for telephone, wireless receivers, tyres of racing cars, filter fibres, in medical dressings and as suture materials.

## Diseases and Pests of Silkworm:

The profitable silk industry is threatened by various diseases caused by the virus, fungal, bacterial and protozoan infections but also by insect predators, birds and other higher animals. Ants, crows, kites, rats, feed upon silk worms thereby causing a great loss to silk industry. Pebrine, is a dangerous disease to in silkworms and the causative organism is *Nosema bombycis* , a protozoan. This silkworm disease is transmitted through the egg of the mother silkworm and also through ingestion of contaminated food. Flacherie generally occurs in the mature larvae and is caused mainly by bacteria like *Streptococcus* and *Staphylococcus*. Grasserie is a most dominant and serious viral disease. It is caused by *Bombyx mori* nuclear polyhedrosis virus (BmNPV) a *Baculovirus*, which belongs to sub group 'A' of the Baculoviridae. Among the fungal diseases, white muscardine is common. This disease is caused by fungus *Beauveria bassiana*.



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## 12.4 Apiculture

Ever since the beginning of civilization, man has been trying to make use of organisms around him for various purposes and to rear them for increasing their number. One of the finest discoveries is our knowledge regarding the procurement of honey collected by honey bees. Care and management of honey bees on a commercial scale for the production of honey is called **Apiculture** or **Bee Keeping**. The word 'apiculture' comes from the Latin word '*apis*' meaning bee. Bees are reared in apiaries that are areas where a lot of bee hives can be placed. There are five well recognized types of bees in the world. They are *Apis dorsata* (Rock bee), *Apis florea* (Little bee), *Apis indica* (Indian bee), *Apis mellifera* (European bee) and *Apis adamsoni* (African bee).

### Social organization of honey bees

In honey bees, a highly organized division of labour is found. A well developed honey bee colony consists of the Queen, Drones and Workers (Figure 12.4). All the three types depend on each other for their existence. There is normally one queen, 10,000 to 30,000 workers and few hundred drones (male bees) in a colony.

**Queen bee** is a functional female bee present in each hive and feeds on Royal Jelly. Its sole function is to lay eggs throughout its life span. The virgin queen bee mates only once in her life. During the breeding season in winter, a unique flight takes place by the queen bee followed by several drones. This flight is called ***"nuptial flight"***. The queen bee produces a hormonal chemical substance called pheromone. The drones in the area are attracted to the pheromone and mating takes place. During mating, the drone releases large number of sperms for sufficient fertilization. In a life span of two to four years, a queen bee lays about 15 lakh eggs. When the queen bee loses its capacity to lay eggs, another worker bee starts feeding on the Royal Jelly and develops into a new queen.

Among the honey bees, **workers** are sterile females and smallest but yet function as the main spring of the complicated machinery in the colony. Worker bee lives in a chamber called 'Worker Cell' and it takes about 21 days to develop from the egg to adult and its lifespan is about six weeks. Each worker has to perform different types of work in her life time. During the first half of her life, she becomes a nurse bee attending to indoor duties such as secretion of royal jelly, prepares bee-bread to feed the larvae, feeds the queen, takes care of the queen and drones, secretes bees wax, builds combs, cleans and fans the bee hive.

Honey bee uses its long-tube like tongue to extract sugary liquid called nectar from the flowers. The nectar is stored in the stomach and the enzyme *invertase* transforms it into honey. This increases the storage life of honey and also contributes to its medicinal value.



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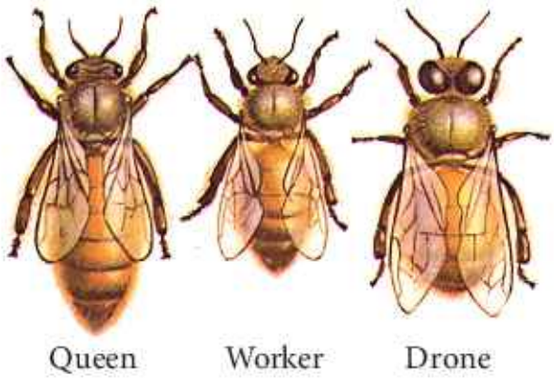


**Figure 12.4** Social organization of honey bees

Then she becomes a soldier and guards the bee hive. In the second halfher life lasting for three weeks, she searches and gathers the pollen, nectar, propolis and water.

The **drone** is the functional male member of the colony which develops from an unfertilized egg. It lives in a chamber called drone cell. Drones totally depend on workers for honey. The sole duty of the drone is to fertilize the virgin queen hence called "King of the colony". During swarming (the process of leaving the colony by the queen with a large group of worker bees to form a new colony) the drones follows the queen, copulates and dies after copulation.

### Structure of a Bee Hive

The house of honey bee is termed as bee hive or comb. The hive consists of hexagonal cells made up of wax secreted by the abdomen of worker bees arranged in opposite rows on a common base. These hives are found hanging vertically from the rocks, building or branches of trees. The young stages of honey bees accommodate the lower and central cells of the hive called the **brood cells**. In *Apis dorsata*, the brood cells are of similar in size and shape but in other species, brood cells are of three types *viz*., queen cell for queens, worker cell for workers and drone cells for drones (Figure.12.5). The cells are intended for storage of honey and pollen in the upper portion of the comb whereas the lower portions are for brood rearing.

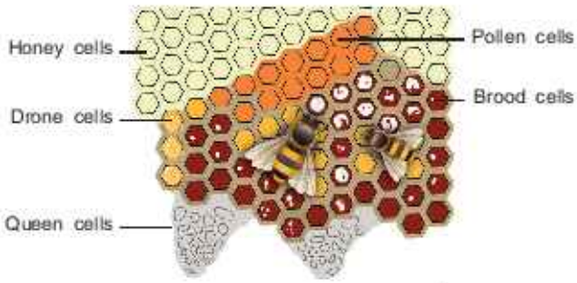


**Figure 12.5** Structure of a hive showing various cells

### Methods of Bee keeping

The main objective is to get more and more quality honey. There are two methods used by apiculturists. They are indigenous method and the modern method. In indigenous method, the honey extracted from the comb contains wax. To overcome the drawbacks of the indigenous method, the modern method has been developed to improve the texture of hives. In India, there are two types of beehives in practice namely, **Langstroth** and **Newton.**

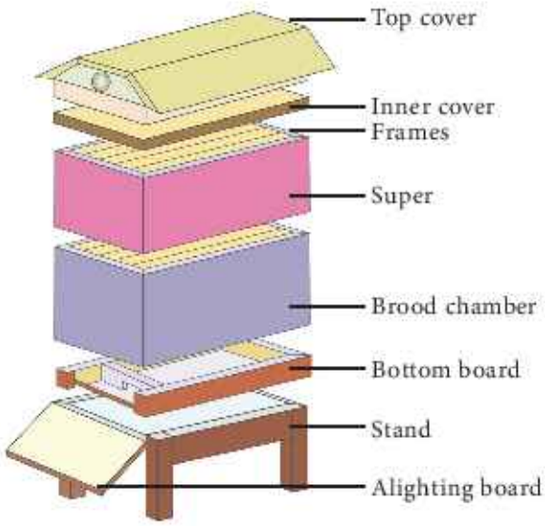


**Figure 12.6** - Langstroth bee hive



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The Langstroth bee hive is made up of wood and consists of six parts (Figure 12.6) namely **Stand, Bottom board, Brood chamber, Super, Inner cover** and **Top cover.** Besides the above primary equipments, other accessory equipments are used in beekeeping. They are **Queen Excluder, Comb foundation, Bee gloves, Bee veil**, **Smoker, Hive Tool, Uncapping knife, Bee brush, Queen introducing cage, Feeder, Honey Extractor** and **Hive Entrance Guard .**

**Products of bee keeping and their economic importance**

The chief products of bee keeping industry are honey and bee wax.

**Honey** is the healthier substitute for sugar. The major constituents of honey are: levulose, dextrose, maltose, other sugars, enzymes, pigments, ash and water. It is an aromatic sweet material derived from nectar of plants. It is a natural food, the smell and taste depends upon the pollen taken by the honey bee. It is used as an antiseptic, laxative and as a sedative. It is generally used in Ayurvedic and Unani systems of medicine. It is also used in the preparation of cakes, breads and biscuits

**Bee wax** is secreted by the abdomen of the worker bees at the age of two weeks. The wax is masticated and mixed with the secretions of the cephalic glands to convert it into a plastic resinous substance. The resinous chemical substance present in the wax is called **propolis** which is derived from pollen grains. The pure wax is white in colour and the yellow colour is due to the presence of carotenoid pigments. It is used for making candles, water proofing materials, polishes for floors, furniture, appliances, leather and taps. It is also used for the production of comb foundation sheets in bee keeping and used in pharmaceutical industries.

Bees teach us a lesson to work with cooperation. Imagine the hardwork of the bees! A single honey bee travels about double the distance of the circumference of the earth's globe for preparing 453.5ml of honey.

## 12.5 Lac Culture

The culture of lac insect using techniques for the procurement of lac on large scale is known as Lac culture. Lac is produced by the lac insect *Tachardia lacca* previously known as *Laccifer lacca*. It is a minute, resinous crawling scale insect which inserts its probosics into the plant tissues and sucks juice, grows and secretes lac from the hind end of the body as a protective covering for its body. Moreover the insect is a parasite on host plants i.e., Karanagalli (*Acacia catechu*), Karuvelai (*Acacia nilotica*) and Kumbadiri (*Schleichera oleosa*). The quality of lac depends upon the quality of the host plant. The female lac insect is responsible for large scale production of lac, which is larger than the male lac insect.

**Economic importance of Lac**

a. Lac is largely used as a sealing wax and adhesive for optical instruments. It is used in electric industry, as it is a good insulator.
b. It is used in preparations of shoe and leather polishes and as a protective coating of wood.



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c. It is used in laminating paper board, photographs, engraved materials and plastic moulded articles.

d. Used as a filling material for gold ornaments

Hyper-parasitism - A condition in which a secondary parasite develops within a previously existing parasite or a hyperparasite is the parasite whose host is also a parasite.

## 12.6 Aquaponics

Aquaponics is a technique which is a combination of aquaculture (growing fish) and hydroponics (growing plants in non-soil media and nutrient-laden water). Aquaponics may also prevent toxic water runoff. It also maintains ecosystem balance by recycling the waste and excretory products produced by the fish. In India, aquaponics was started in 2013. Some primary methods of aquaponic gardening that are in use nowadays are as follows: **(i) Deep water culture** is otherwise known as raft based method. In this method a raft floats in water. Plants are kept in the holes of raft and the roots float in water. This method is applicable for larger commercial scale system. By this method fast growing plants are cultivated. **(ii) Media based method** involves growing plants in inert planting media like clay pellets or shales. This method is applicable for home and hobby scale system. Larger number of fruiting plants, leafy green plants, herbs and other varieties of plants can be cultivated (Figure 12. 7) **(iii) Nutrient Film technique** involves the passage of nutrient rich water through a narrow trough or PVC pipe. Plants are kept in the holes of the pipe to allow the roots to be in free contact with in the water stream. (iv) **Aqua vertica** is otherwise known as vertical aquaponics. Plants are stacked on the top of each other in tower systems. Water flows in through the top of the tower. This method is suitable for growing leafy greens, strawberries and other crops that do not need supporting solid substratum to grow.

**Advantages of Aquaponic gardening**

**Water conservation**: No need of water discharge and recharge as the water is maintained by recycling process.

**Soil**: Bottom soil may be loaded with freshwater. Microbes in water can convert the waste materials into usable forms like ammonia into nitrates which are used by the plants. Thus the soil fertility is maintained

**Pesticides**: In this system use of pesticides is avoided and hence it is eco-friendly.

**Weeds**: Since the plants are cultured in confined conditions, growth of weeds is completely absent. The utilization of nutrient by plants is high in this method

**Artificial food for fishes**: In this system plant waste and decays are utilized by fishes as food. So, the need for the use of supplementary feed can be minimized.

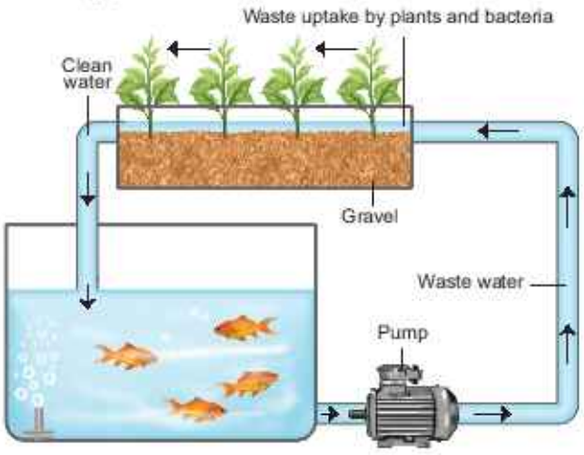


**Figure12.7** Aquaponics – Media based method



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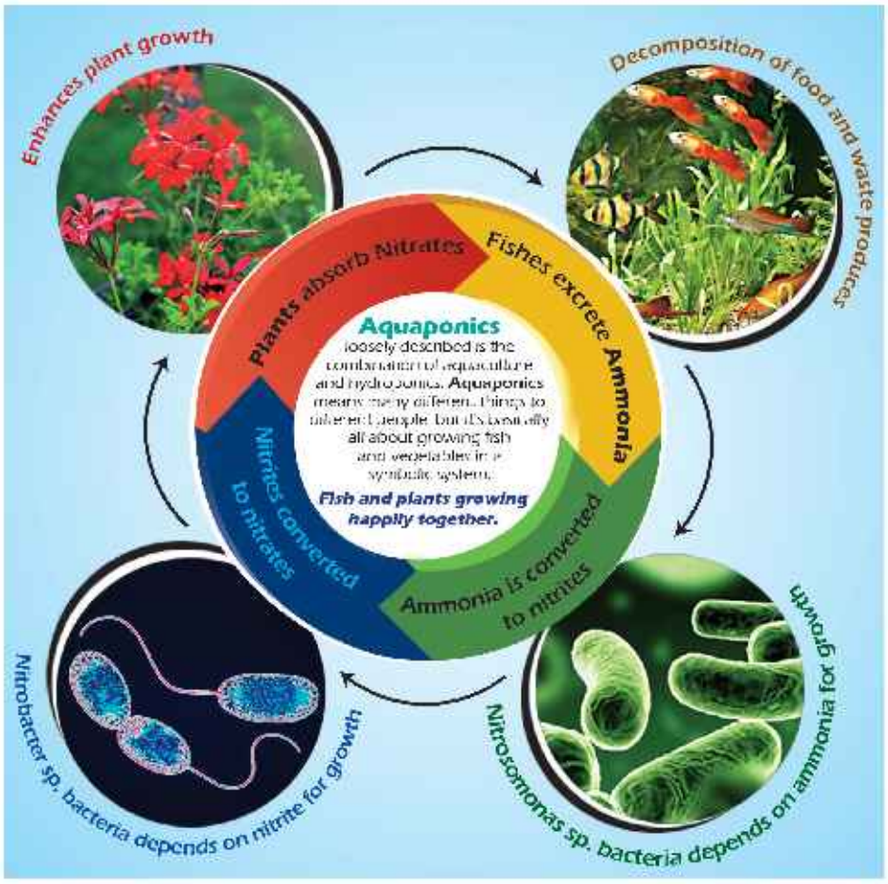


a. Growing fish or other aquatic animals and plants together in an integrated system. The fish wastes provides nutrients for the plants and the plants filter the water. Additionally bacteria break down by-products such as ammonia.

b. Growing plants in a nutrient solution instead of soil. Fish kept in the water provide the required nutrients.

Write the appropriate scientific terms for above (a) and (b) and differentiate between them..

**Fertilizer usage**: Artificial or chemical fertilizers is not required for this system since the plants in the aquaponics utilize the nutrients from the fish wastes dissolved in water

Cultivable fishes like tilapia, trout, koi, gold fish, bass etc., are cultured in aquaponics. Common cultivable plants like tomato, pepper, lettuce, cucumber, and rose are co-cultivated in this method.

## 12.7 Aquaculture

Aquaculture has been practiced in varying forms for centuries dating to the time of the Phoenicians. India offers a huge potential for aquaculture development. Fish culture received notable attention in Tamil Nadu in 1911. Aquaculture is a branch of science that deals with the farming of aquatic organisms such as fish, molluscs, crustaceans and aquatic plants.

On the basis of source, aquaculture can be classified into three categories. They are (a) **Freshwater aquaculture** (b) **Brackish water aquaculture** (c) **Marine water aquaculture**. Culturing of fishes is called fish culture or pisciculture. Inland water bodies include freshwater bodies like rivers, canals, streams, lakes, flood plain wetlands, reservoirs, ponds, tanks and other derelict water bodies and ponds constructed for fresh water aquaculture. The pH of the freshwater should be around neutral and salinity below 0.5 ppt (parts per thousand).

Brackish water fishes spend most of its life in river mouths (estuaries) back



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waters, mangrove swamps and coastal lagoons. Estuarine fish are more common in Bengal and Kerala. Culturing of animals in the water having salinity range 0.5 – 30 ppt are called as brackish water culture. Fishes cultured in brackish water are Milk fish (*Chanos Chanos)*, Sea bass ('Koduva'), Grey mullet ('Madavai'), *Pearl spots ('Kari'meen)* etc.,

Marine Fisheries deal with fishing operations along seacoasts. The Indian subcontinent approximately has a 5600 kms long coastline. About 80% of India's marine fish are supplied by the west coast and the remaining 20% by the east coast. The premier varieties are mackerels, sardines, sharks, and catfish. Marine edible fishes of Tamilnadu coast include both cartilaginous and bony fishes. Culturing of animals in the water salinity ranges from 30 - 35 ppt is called Mariculture. Some fishes like *Chanos* sp, *Mugil cephalus* are cultured here. Culturing of animals in the salinity ranges from 36 - 40 ppt is called Metahaline culture. Eg, Brine shrimp (*Artemia salina)*. Artemia is commonly known as the brine shrimp. It is a crustacean and lives in high saline waters because of its high osmoregulatory capacity.

### 12.7.1 Fish Culture

**Characteristics of cultivable fishes**

The special characteristic features of cultivable fishes are:

i. Fishes should have high growth rate in short period for culture.
ii. They should accept supplementary diet.
iii. They should be hardy enough to resist some common diseases and infection of parasites.
iv. Fishes proposed for polyculture should be able to live together without interfering or attacking other fishes.
v. They should have high conversion efficiency so that they can effectively utilize the food.

**Types of cultivable fish**

Cultivable fish are of 3 types(Figure 12. 8).

a. Indigenous or native fresh water fishes (Major carps, *Catla*, *Labeo*, *Clarias*)
b. Salt water fishes acclimatized for fresh water (*Chanos*, Mullet).
c. Exotic fishes or imported from other counties (Common carps)

Among these, major carps have proved to be best suited for culture in India, because the carps

1. Feed on zooplanktons and phytoplanktons, decaying weeds, debris and other aquatic plants.
2. They can survive in turbid water with slightly higher temperature
3. Can tolerate $O_2$ variations in water.
4. Can be transported from one place to other easily.
5. They are highly nutritive and palatable.

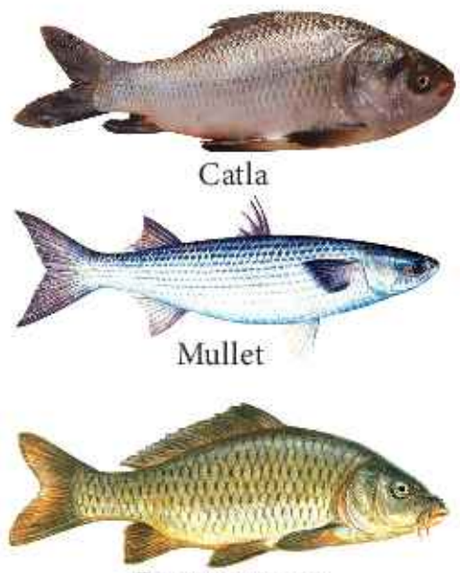


**Figure 12.8** Different types of freshwater cultivable fishes



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**External factors affecting fish culture**

The factors that affect fish culture are temperature, light, rain, water, flood, water current, turbidity of water, pH hardness, salinity and dissolved $O_2$. Light and temperature also play an important role in fish breeding.

**Management of fish farm**

To culture fish, one should have an idea about different stages of fish culture such as topographic situation, quality, source, physical, chemical and biological factors of water. Breeding, hatching, nursing, rearing and stocking fishes in ponds has to be managed properly. Keeping in view the various stages of fishes, the following different types of ponds have been recommended to manage them.

**Breeding pond**

The first step in fish culture is the breeding of fishes, therefore, for proper breeding special types of ponds are prepared called breeding ponds. These ponds are prepared near the rivers or other natural water resources.

**Types of breeding**

Depending on the mode of breeding, they are divided into

1. **Natural breeding** (Bundh breeding)

These are special types of ponds where natural riverine conditions or any natural water resources are managed for breeding of culturable fishes. There bundhs are constructed in large low-lying areas that can accommodate large quantity of rain water. The shallow area of such bundhs is used as spawning ground.

2. **Induced breeding**

The fish seed is commonly collected from breeding grounds but does not guarantee that all fish seeds belong to the same species. Hence advanced techniques have been developed to improve the quality of fish seed by artificial method of fertilization and induced breeding. Artificial fertilization involves removal of ova and sperm from female and male by artificial mechanical process and the eggs are fertilized. For artificial fertilization the belly of mature female fish is held upward. Stripping is done with the thumb of the right hand from the anterior to posterior direction for the ejection of eggs due to force. In this way eggs are collected separately. Further, the male fish is caught with its belly downwards. The milt of fish is striped and collected separately, and then the eggs are fertilized.

Induced breeding is also done by hypophysation (removal of pituitary gland). The gonadotropin hormone (FSH and LH) secreted by the pituitary gland influences the maturation of gonads and spawning in fishes. Pituitary gland is removed from a healthy mature fish. Pituitary extract is prepared by homogenising in 0.3% saline or glycerine and centrifuged for 15 minutes at 8000rpm. The supernatant is injected intramuscularly at the base of the caudal fin or intra-peritonealy at the base of pectoral fin. Male and female fishes start to spawn (release of gametes) and eggs are fertilized. The fertilized eggs are removed from the spawning place and kept into hatching **hapas**.

**Fish seed**

Fish seed is collected from breeding ponds. The spawn collecting net is commonly called Benchijal (Shooting net) and transferred to the hatching pits.



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### Hatching pit

The fertilized eggs are kept in hatching pits. The hatching pits should be nearer to the breeding grounds, should be smaller in size with good quality water. There are two types of hatching pits, hatcheries are small sized pond in which unfertilized eggs are transferred and hatching happens. Hatching hapas are rectangular trough shaped tanks made up of mosquito net cloth supported by bamboo poles and fixed in the river (Figure 12.9).

**Figure 12.9** A fish pond-showing fish breeding hapas

### Nursery pond

The newly hatched fries are transported from the hatching happa to nursery ponds where they grow into fingerlings.

### Rearing pond

Fingerlings are transferred to rearing ponds that is long and narrow and allows long distance swimming. The rearing pond should be free from toxicants and predators. Antibiotics are used for washing the fingerlings and then transferred to the stocking ponds.

### Stocking ponds

Stocking ponds should be devoid of weeds and predatory fishes. Proper organic manuring should be done to increase the production with cow dung and chemical fertilizing should also be done.

### Harvesting

Harvesting is done to capture the fishes from the water. Well grown fishes are taken out for marketing. Small sized fishes are again released into the stocking ponds for further growth. Different methods of fishing are carried out to harvest fishes. These include Stranding, Angling, Traps, Dipnets, Cast nets, Gill nets, Drag nets and purse nets. The harvested fishes are preserved by refrigeration, Deep freezing, freeze drying, sun drying, salting, smoking and canning.

### Composite fish farming

Few selected fishes belonging to different species are stocked together in proper proportion in a pond. This mixed farming is termed composite fish farming or polyculture. The advantages include,

1. All available niches are fully utilized.
2. Compatible species do not harm each other.
3. No competition among different species is found.
4. *Catla catla, Labeo rohita* and *Cirrhinus mrigala* are the commonly used fish species for composite fish farming.

### Exotic fishes

The fishes imported into a country for fish culture are called exotic fishes and such fish culture is known as exotic fish culture. Examples of such exotic fishes introduced in India are *Cyprinus carpio* and *Oreochromis mossambicus*.

### Disease Management

Diseases can be of viral or bacterial origin. Regular monitoring of parameters



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like water quality, aeration, regular feeding, observation for mortality should be checked. Parasitic infestations and microbial infections should be observed periodically.

**Economic importance of fish**

Fishes from a rich source of protein food and provide a good staple food to tide over the nutritional needs of man. Fish species such as sardines, mackerel, tuna, herrings have high amino acids concentrations particularly histidine which is responsible for the meaty flavor of the flesh. It is rich in fat such as omega 3 fatty acids. Minerals such as calcium, magnesium, phosphorus, potassium, iron, manganese, iodine and copper. Some of the fish by - products are:

**Fish oil** is the most important fish by product. It is derived from fish liver and from the fish body. Fish liver oil is derived from the liver which is rich in vitamin A and D, whereas fish body oil has high content of iodine, not suitable for human consumption, but is used in the manufacture of laundry soaps, paints and cosmetics.

**Fish meal** is prepared from fish waste after extracting oil from the fish. The dried wastes are used to prepare food for pig, poultry and cattle. The wastes obtained during the preparation of fish meal are widely used as manure.

**Isinglass** is a high-grade collagen produced from dried air bladder or swim bladder of certain fishes viz. catfish and carps. The processed bladder which is dissolved in hot water forms a gelatin having adhesive property. It is primarily used for clarification of wine, beer and vinegar.

Why are fish so efficient at converting feed to flesh?

### 12.7.2 Prawn Culture

Most important aquatic crustacean is prawn, which is widely cultured prawn flesh is palatable and rich in glycogen, protein with low fat content.

Types of prawn fishery

1. **Shallow water prawn fishery** – located on the west coast restricted to shallow waters.
2. **Estuaries and back waters or saline lake prawn fishery** - The area of production of prawns are the back waters seen along the Western coast, Ennur, Pulicat, Chilka lake and Estuaries of Ganga and Brahmaputra rivers.
3. **Freshwater prawn fishery** - Prawns are caught from the rivers and lakes throughout India.
4. **Marine prawn fishery** – Most of the marine prawns are caught along the Indian coast belonging to the family Penaeidae.

**Species of prawn**

A number of species of prawn are distributed in water resources such as *Penaeus indicus, Penaeus monodon, Metapenaeus dobsoni and Macrobrachium rosenbergii.*

**Culture of freshwater prawn**

*Macrobrachium rosenbergii* (Figure 12.10) is commonly seen in rivers, fields and low-saline estuaries. The prawn collected from ponds, river, and paddy fields are transferred to the tanks which are aerated. For fertilization, one pair of prawn are kept



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in a separate tank. After mating, the eggs are laid. Spawning tanks of different sizes should be prepared with proper aeration. Temperature ($24^0$ C – $30^0$ C) and pH (7-8) should be maintained in the hatching tank. The eggs hatch into first and second stage larva. Artificial feed is supplied. Young ones of 5cm length (60 days old) can be reared in fresh or slightly brackish water ponds and paddy fields. Harvesting of prawns can be done twice in a year.

**Figure 12.10** *Macrobrachium rosenbergii*

**Culture of marine prawn**

Several factors that determine the success of marine prawn culture includes selection of site, water quality, soil quality and availability of seed.

**Preparation of farm**

For the preparation of ponds for algal growth and for the subsequent stocking of prawns it is essential to drain off the water and sundry the bottom followed by light tilling. Agricultural lime should be applied to absorb excess $CO_2$ and to supply calcium which is required for moulting. Fertilizers like rice, bran, poultry, and cattle dung are used to increase the fertility of the soil. Prawns are commonly caught in crafts and gears using different types of nets such as cast nets, bag nets, drag nets, trawl nets and barrier nets. Preservation of prawns is done by peeling and deveining or by cooking and peeling.

### 12.7.3 Pearl Culture

Pearl is a white, highly shining globular concretion found within the shell of an Oyster. Pearl oysters are sedentary animals. In India it was cultured for the first time in 1973 at Thoothukudi. Pearl oysters are found along the coast of Kanyakumari and in the Gulf of Kutch. High quality pearls are obtained from pearl oysters of Genus *Pinctada* that can be cultured in the salinity range of 30 ppt in racks, raft and long line methods. Freshwater bivalve *Lamellidens* is also used in artificial pearl culture. Mostly the pearl oysters inhabit the ridges of rocks or dead corals, forming extensive pearl banks. These pearl beds produce best quality of pearls called as "Lingha Pearl".

**Pearl Formation**

When a foreign particle accidently enters into the space between mantle and shell of the oyster, it adheres to the mantle. The mantle epithelium encloses it like a sac and starts to secrete concentric layers of nacre around it as a defensive mechanism. Nacre is secreted continuously by the epithelial layer of the mantle and is deposited around the foreign particle and over a period time the formation of repeated layers of calcium carbonate makes the hard and glossy pearl. When the pearl enlarges the oyster dies. The shell is then carefully opened and the pearls are manually separated and graded (Figure 12. 11).

**Composition of pearl**

Pearl comprises of water, organic matter, calcium carbonate and the residue.

| | | |
|---|---|---|
| (1) Water | : | 2-4% |
| (2) Organic matter | : | 3.5-5.9% |
| (3) Calcium carbonate | : | 90% |
| (4) Residue | : | 0.1-0.8% |



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### Quality of pearl

The pearls obtained are of variable shapes and sizes. They may be white, or cream red or pink red in colour. The spherical pearls of rainbow colour are rarely found. The best quality of pearl is obtained from marine oysters. Pearl obtained from freshwater bivalves are not as valuable as those obtained from the marine oysters (Mishra, 1961).

## 12.8 Animal Husbandry and Management

Animal husbandry is the practice of breeding and raising livestock cattles like cows, buffaloes, and goats and birds etc. that are useful to human beings. Parameters such as adequate ventilation, temperature, sufficient light, water and proper housing accommodation should be taken into account to maintain dairy and poultry farms. Animals should be cared and protected from diseases. Records should be maintained after the regular visits by Veterinarian. More over the selection of good breeds with high yielding potential combined and resistance to diseases is very important.

### Animal Breeding

Human beings have been depending on animals and animal products for food from very early times. Generally high yielding animals produced by hybridization are reared in poultry and dairy farms. In earlier days, animals were produced and selected based on specific characters. With the gain in knowledge on the principles of heredity and genetics, human beings have been successful in rearing animals with the superior qualities through hybridization

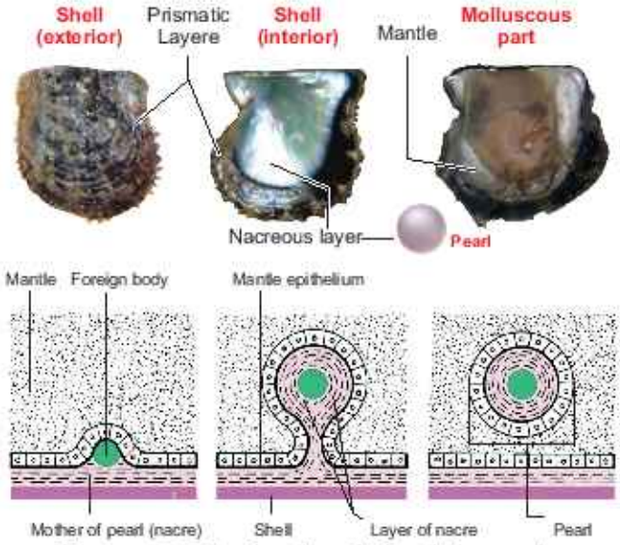


**Figure 12.11** Pearl and Pearl Formation

experiments. Complex issues are faced by the animal breeder during hybridization experiments. Hence animals with maximum desirable characters should be selected.

A group of animals related by descent and with similar characters like general appearance, features, size etc., are said to belong to a breed. Why should we breed animals? Through animal breeding, improved breeds of animals can be produced by improving their genotype through selective breeding.

### Objectives of Animal breeding:

a. To improve growth rate
b. Enhancing the production of milk, meat. Egg etc.,
c. Increasing the quality of the animal products
d. Improved resistance to diseases
e. Increased reproductive rate

### Methods of Animal breeding:

There are two methods of animal breeding, namely inbreeding and outbreeding

**1. Inbreeding:** Breeding between animals of the same breed for 4-6 generations is



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called inbreeding. Inbreeding increases homozygosity and exposes the harmful recessive genes. Continuous inbreeding reduces fertility and even productivity, resulting in "inbreeding depression". This can be avoided by breeding selected animals of the breeding population and they should be mated with superior animals of the same breed but unrelated to the breeding population. It helps to restore fertility and yield.

**2. Outbreeding:** The breeding between unrelated animals is called outbreeding. Individuals produced do not have common ancestors for 4-6 generations. Outbreeding helps to produce new and favourable traits, to produce hybrids with superior qualities and helps to create new breeds. New and favourable genes can be introduced into a population through outbreeding.

**i. Out crossing**: It is the breeding between unrelated animals of the same breed but having no common ancestry. The offspring of such a cross is called outcross. This method is suitable for breeding animals below average in productivity.

**ii. Cross breeding:** Breeding between a superior male of one breed with a superior female of another breed. The cross bred progeny has superior traits ( hybrid vigour or heterosis).

**iii. Interspecific hybridization:**

In this method of breeding mating is between male and female of two different species. The progeny obtained from such crosses are different from their parents, and may possess the desirable traits of the parents. Have you heard about Mule? It was produced by the process of interspecific hybridization between a male donkey and a female horse.

**Controlled breeding experiments**

**Artificial insemination:**

Artificial insemination is a technique in which the semen collected from the male is injected to the reproductive tract of the selected female. Artificial insemination is economical measure where fewer bulls are required and maximum use can be made of the best sire.

Thawing means to melt or become liquid. When the semen collected for artificial insemination is taken to far off places/stored for a long time in frozen condition it should be brought to room temperature slowly before use. This process is called thawing.

**Advantages of artificial insemination**

i. It increases the rate of conception

ii. It avoids genital diseases

iii. Semen can be collected from injured bulls which have desirable traits.

iv. Superior animals located apart can be bred successfully.

**Multiple ovulation embryo transfer technology (MOET)**

It is another method of propagation of animals with desirable traits. This method is applied when the success rate of crossing is low even after artificial insemination. In this method Follicle stimulating hormone (FSH) is administered to cows for inducing follicular maturation and super ovulation. Instead of one egg per cycle, 6-8 eggs can be produced by this technology. The eggs are carefully recovered non-surgically from the genetic mother and fertilized artificially.



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The embryos at 8-32 celled stages are recovered and transferred to a surrogate mother. For another round of ovulation, the same genetic mother is utilized. This technology can be applied to cattle, sheep and buffaloes. Advantage of this technology is to produce high milk yielding females and high-quality meat yielding bulls in a short time.

**Breeds of Dairy animals**

Dairying is the production and marketing of milk and its products. Dairy operation consists of proper maintenance of cattle, the collection and processing the milk and its by products. There are 26 well defined breeds of cattle and 6 breeds of buffaloes in India. Cattles are classified under three groups based on the purpose they serve to man (Figure 12. 12). They are

i. **Dairy breeds or Milch breeds**: They are high milk yielders with extended lactation. Eg., Sindhi, Gir, Sahiwal, Jersy, Brown Swiss, Holstein cattle.

ii. **Draught purpose breeds**: Bullocks are good for draught purpose. Eg. Kangayam, Malvi.

iii. **Dual Purpose breeds**: Cows are meant for yielding more milk and bullocks are used for better drought purpose. Eg. Ongole, Hariana.

Vechur breed is the smallest breed of Cow as per World Guinness Records.

Average length: 124cms

Average height: 87 cms

Origin: Vechur village, Kottayam District of Kerala

It produces large amount of milk in relation to the food consumption

India is the largest producer of Milk, globally.

India has many popular breeds of cows and buffaloes.

**Prominent indigenous cow breeds in India** - Gir, Red sindhi, Sahiwal, Hallikar, Amritmahal, Khillari, Kangayam, Bargur, Umblachery, Pulikulam, Alambadi, Tharparkar, Haryana, Kankrej, Ongole, Krishna valley and Deoni.

To meet the milk demand of the growing population, milk breeds are preferred by farmers in small scale farms. Goats are also used all over India for supplementing deficiencies in milk production. Some of the breeds of cattle that are good milkers are Jamunapari in Ganga-Jamuna riverine tracts, Beetal in Punjab, Bar–bari in Uttarpradesh.

**Figure 12.12** Different breeds of cattle



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**Common diseases of cattle:** A healthy animal eat, drinks and sleeps well regularly. Healthy cattle appear bright, alert and active in their movement with a shiny coat. Cattle are affected by a large number of diseases. Cattle in ill health appear dull, restless and change posture frequently with drop in milk yield. The main diseases of dairy cattle are rinderpest, foot and mouth disease, cow pox, hemorrhagic fever, anthrax.

**Uses of dairy products:**

**Milk products:** Milk is produced by dairy animals which is an emulsion of fat and lactose. Milk also contains enzymes which are destroyed during pasteurization. Milk is a rich source of vitamin A, $B_1$, $B_2$, and deficient in Vitamin C. Due to its high nutrition value, it serves as a complete food for infants. Dairy products such as yoghurt, cheese, butter, ice cream, condensed milk, curd, and milk powder processed from milk make dairy, a highly farming attraction.

**Meat:** Meat is rich in protein and also contains many minerals like iron, zinc, vitamins and selenium. It also contains vitamins needed for human diet.

**Land management:** Grazing of livestock is sometimes used as a way to control weeds and undergrowth.

**Manure:** Manure can be spread on agriculture fields to increase crop yields.

## Poultry Farming

The word poultry refers to the rearing and propagation of avian species such as chicken, ducks, turkeys, geese, quail and guinea fowls. The most common and commercially farmed birds are chicken and ducks. Poultry farming is essential for the purpose of meat, eggs and feather production. Commercial poultry farming is also profitable. In this part we are discussing about an overview of the chicken and duck breeds, farming practices and its advantages.

**Types of Chicken breeds:** There are more than 100 breeds. The commonly farmed chicken breeds are categorized into five based on the purpose for which it is farmed. They are egg layers, broiler type, dual type, games and ornamental types (Figure 12.13).

1. **Egg layers:** These are farmed mainly for the production of egg.

**Leghorn:** This is the most popular commercial breed in India and originated from Italy. They are small, compact with a single comb and wattles with white, brown or black colour. They mature early and begin to lay eggs at the age of 5 or 6 months. Hence these are preferred in commercial farms. They can also thrive well in dry areas.

**Chittagong:** It is the breed chiefly found in West Bengal. They are golden or light yellow coloured. The beak is long and yellow in colour. Ear lobes and wattles are small and red in colour. They are good egg layers and are delicious.

2. **Broiler type:** These are well known for fast growth and soft quality meat.

**White Plymouth rock:** They have white plumage throughout the body. It is commonly used in broiler production. This is an American breed. It is a fast growing breed and well suitable for growing intensively in confined farms.

3. **Dual purpose breeds:** These are for both meat and egg production purpose.

**Brahma:** It is a breed popularly known for its massive body having heavy bones, well feathered and proportionate body. Pea comb is one of the important breed characters. It has two common varieties namely, Light Brahma and Dark Brahma.



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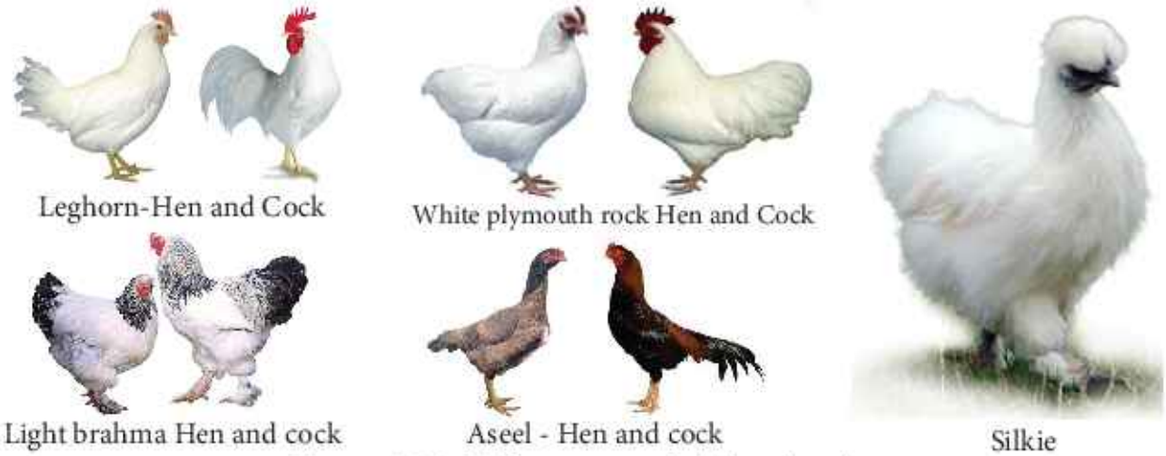


**Figure 12.13** Different types of chicken breeds

4. **Game breeds:** Since ancient times, special breed of roosters have been used for the sport of cockfighting.

**Aseel:** This breed is white or black in colour. The hens are not good egg layers but are good in incubation of eggs. It is found in all states of India. Aseel is noted for its pugnacity, high stamina, and majestic gait and dogged fighting qualities. Although poor in productivity, this breed is well-known for their meat qualities.

5. **Ornamental breeds:** Ornamental chicken are reared as pets in addition to their use for egg production and meat.

**Silkie**: It is a breed of chicken has a typical fluffy plumage, which is said to feel like silk and satin. The breed has numerous additional special characters, such as black skin and bones, blue earlobes, and five toes on each foot, while the majority chickens only have four. They are exhibited in poultry shows, and come out in various colours. Silkies are well recognized for their calm, friendly temperament. Silkie chicken is especially simple to maintain as pets.

**Types of Poultry farming:** There are different methods used to rear both broiler and layer chicken. The types of poultry farming are Free range farming, Organic method, Yarding method, Battery cage method and Furnished cage method.

Among these, Battery cage method is widely used in large scale poultry farms. The Free range, Organic and Yarding methods are eco-friendly and the eggs produced by such farming practices are preferred in the market.

**Stages involved in rearing:**

There are some steps involved in rearing of chicken.

1. **Selection of the best layer:** An active intelligent looking bird, with a bright comb, not obese should be selected.
2. **Selection of eggs for hatching:** Eggs should be selected very carefully. Eggs should be fertile, medium sized, dark brown shelled and freshly laid eggs are preferred for rearing. Eggs should be washed, cleaned and dried.
3. **Incubation and hatching:** The maintenance of newly laid eggs in optimum condition till hatching is called incubation. The fully developed chick emerges out of egg after an incubation period of 21 – 22 days. There are two types of incubation namely natural incubation and artificial incubation.In the natural incubation method, only a limited number of eggs can be incubated by a mother hen. In artificial incubation, more number of eggs can be incubated in a chamber (**Incubator**).



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4. **Brooding:** Caring and management of young chicks for 4 – 6 weeks immediately after hatching is called brooding. It can also be categorized into two types namely natural and artificial brooding.
5. **Housing of Poultry:** To protect the poultry from sun, rain and predators it is necessary to provide housing to poultry. Poultry house should be moisture- proof, rat proof and it should be easily cleanable and durable.
6. **Poultry feeding:** The diet of chicks should contain adequate amount of water, carbohydrates, proteins, fats, vitamins and minerals.

**Poultry products:**
The main products of poultry farming are eggs and meat. In India, the primary aim of poultry farming is to obtain eggs. The eggs and poultry meat are the richest sources of proteins and vitamins.

**Poultry byproducts:**
The feathers of poultry birds are used for making pillows and quilts. Droppings of poultry can be used as manure in fields. The droppings are rich in nitrogen, potash and phosphates.

A number of poultry byproducts like blood-meal, feather meal, poultry by-product meal and hatchery by-product meal are used as good sources of nutrients for meat producing animals and poultry. These byproducts supply proteins, fats, vitamins and good amount of minerals.

**Poultry diseases:** Ranikhet, Coccidiosis, and Fowl pox are some common poultry diseases.

**Benefits of Poultry farming:**
The advantages of poultry farming are

- It does not require high capital for construction and maintenance of the poultry farming.
- It does not require a big space.
- It ensures high return of investment within a very short period of time.
- It provides fresh and nutritious food and has a huge global demand.
- It provides employment opportunities for the people.

Chickens communicate with more than 24 vocalizations, each with a distinct meaning, including warning their friends about different types of predators or letting their mothers know whether they're comfortable

## Duck Farming

Duck is an aquatic bird and forms only 6% of our country's poultry population. There are about 20 breeds of ducks. The native one includes Indian Runner and Syhlet meta. The exotic breeds include Muscori, Pekin, Aylesbury and Campbell. Domesticated ducks have been derived from the wild duck named Mallard (*Anas boscas*). Farming ducks is profitable as it can be combined with aquafarming practices.

**Peculiarity of ducks:**
The body is fully covered with oily feathers. They have a layer of fat under their skin which prevents it from getting wet. They lay eggs at night or in the morning. The ducks feed on rice bran, kitchen wastes, waste fish and snails.

**Types of breeds:** There are three types of ducks depending on the purpose for which it is formed. They are meat productive duck breeds, egg productive duck breeds, and breeds for both meat and egg production.

**Advantages of duck farming:**
They can be reared in small backyards where water is available and needs less care and management as they are very hardy. They can adapt themselves to all types of environmental conditions and are breed for feed efficiency, growth rate and resistance to diseases.



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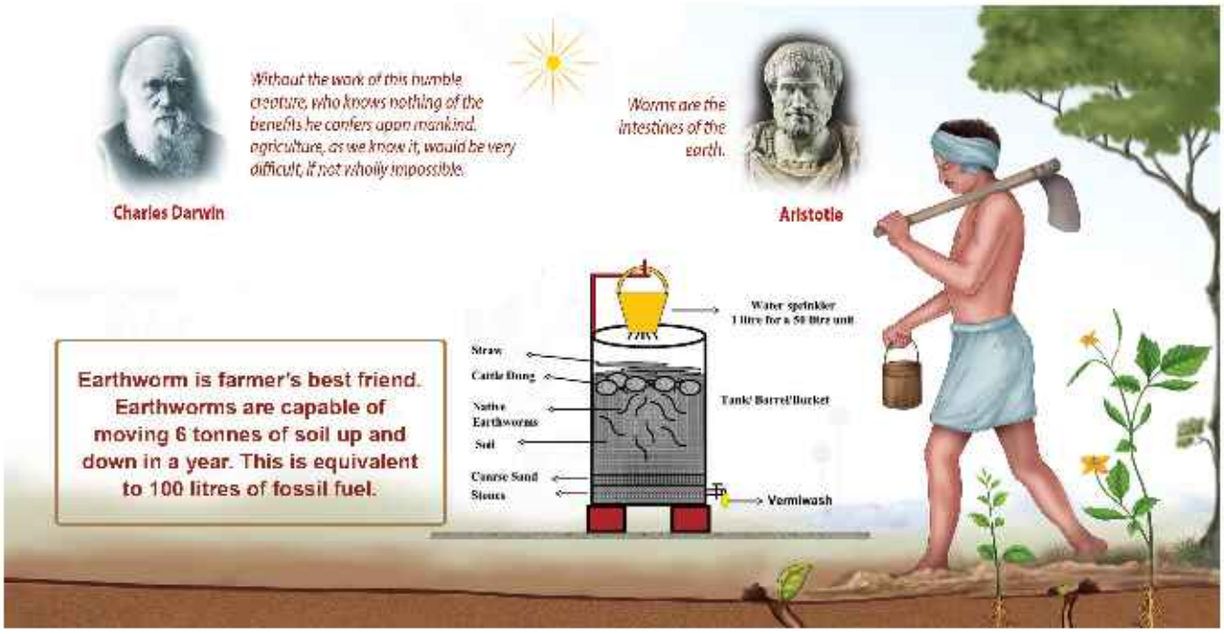
## Summary

Economic Zoology involves the study of application of animals for human welfare. The need of Zoology is to improve our economic condition, to provide food security and employment opportunities. Based on the economic importance, animals can be categorized as Animals for food and food products, economically beneficial animals, Animals of aesthetic importance and Animals for scientific research. Vermiculture is the process of using earthworms to decompose organic food waste, into a nutrient-rich material capable of supplying necessary nutrients to sustain plant growth. Sericulture is the production of silk from the silk worm. It is an agro-based industry comprising three main components. They are cultivation of food plants for the silkworms, rearing of silkworms and reeling and spinning of silk. Care and management of honey bees for the production of honey is called Apiculture. Lac is produced by the lac insect.

Aquaponics is a combined technique of aquaculture and hydroponics. It prevents toxic water runoff and also maintains ecosystem balance by recycling the waste and excretory products produced by the fish. Aquaculture deals with the farming of aquatic organisms such as fish, molluscs, crustaceans and aquatic plants. On the basis of water resources, aquaculture can be classified into Freshwater aquaculture, brackish water aquaculture and Marine water aquaculture. It includes culture of fishes, prawn, crab and oyster.

Animal husbandry is the practice of breeding and raising livestock cattles like cows, buffaloes, and goats and birds etc. that are useful to human beings. Dairying is the production and marketing of milk and its products. Dairy operation consists of proper maintenance of cattle, collection and processing the milk and its byproducts. Poultry refers to the rearing and propagation of avian species such as chicken, ducks, turkeys, geese, quail and guinea fowls. The commonly farmed chicken breeds are categorized into five based on the purpose for which it is farmed. They are egg layers, broiler type, dual type, games and ornamental types.



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## Evaluation

1. Which one of the following is not related to vermiculture?
   i. Maintains soil fertility
   ii. Breakdown of inorganic matter
   iii. Gives porosity, aeration and moisture holding capacity
   iv. Degradation of non biodegradable solid waste

   a. i and ii is correct
   b. iii and iv is correct
   **c. ii and iv is not correct**
   d. i and iii is not correct

2. Which one of the following is not an endemic species of earthworm?
   *a. Perionyx* *a. Lampito*
   ***b. Eudrillus*** *c. Octochaetona*

3. Match the following and select the correct option

| | | |
|---|---|---|
| 1. *Bombyx mori* | - i. Champa | - I. Muga |
| 2. *Antheraea assamensis* | - ii. Mulberry | - II. Eri |
| 3. *Antheraea mylitta* | - iii. Arjun | - III. Tassar |
| 4. *Attacus ricini* | - iv. Castor | - IV. Mulberry |

   **a) 1 – ii – IV** b) 2 – iii – II
   c) 3 - i - I d) 4 - iv - III

4. Silk is obtained from ….
   a. *Laccifer lacca*
   b. *Nosema bombycis*
   **c. *Attacus ricini***
   d. *Attacus mylitta*

5. **Assertion:** Nuptial flight is a unique flight taken the queen bee followed by several drones.

   **Reason:** The queen bee produces a chemical substance called pheromone. The drones in that area are attracted to the pheromone and then mating takes place.

   a. Assertion and reason is correct but not related
   b. Assertion and reason is incorrect but related
   **c. Assertion and reason is correct but related**
   d. Assertion and reason is incorrect but not related

6. Rearing of honey bee is called
   a. Sericulture
   b. Lac culture
   c. Vermiculture
   **d. Apiculture**

7. Which of the statement regarding Lac insect is TRUE?
   a. A microscopic, resinous crawling scale insect
   b. Inserts its proboscis into plant tissue suck juices and grows
   c. Secretes lac from the hind end of body.
   **d. The male lac insect is responsible for large scale production of lac.**

8. Prawn belongs to the class
   **a. crustacea**
   b. Annelida
   c. Coelenterata
   d. Echinodermata

9. Aquaponics is a technique which is
   a. A combination of aquaculture and fish culture
   **b. A combination of aquaculture and hydroponics**



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c. A combination of vermiculture and hydroponics

d. A combination of aquaculture and prawn culture.

10. Inland fisheries are

a. deep sea fishing

b. capturing fishes from sea coast

**c. Raising and capturing fishes in fresh water**

d. oil extraction from fish

11. Induced breeding technique is used in

a. Marine fishery

b. Capture fishery

c. Culture fishery

**d. Inland fishery**

12. Isinglass is used in

a. Preparation

**b. Clearing of wines**

c. Distillation of wines

d. Preservation of wines

13. Choose the correctly matched pair

a. Egg layers – Brahma

b. Broiler types - Leghorn

c. Dual purpose – White Plymouth rock

**d. Ornamental breeds – Silkie**

14. Polyculture of fishes is highly advantageous. Discuss.

15. Write the advantages of vermicomposting.

16. Name the three castes in a honey bee colony.

17. Name the following:

i. The largest bee in the colony.

ii. The kind of flight which the new virgin queen takes along with the drones out of the hive.

18. What are the main duties of a worker bee?

19. What happens to the drones after mating flight?

20. Give the economic importance of Silkworm.

21. What are the Nutritive values of fishes?

22. Give the economic importance of prawn fishery.

23. Give the economic importance of lac insect.

24. Name any two trees on which lac insect grows.

25. Define cross breeding.

26. What are the advantages of artificial insemination?

27. Discuss the various techniques adopted in cattle breeding?

28. Mention the advantages of MOET.

29. Write the peculiar characters of duck.

30. Explain the life cycle of *bombyx mori*.



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## GLOSSARY

**Acetylecholine** – A neurotransmitter found throughout the nervous system.

**Acidosis** – condition characterised by lower blood pH, due to the increase of keto acids (ketosis).

**Acinus** – Cells arranged into a circular secretory unit.

**Adenosine triphosphate (ATP)** – A nucleotide molecule consisting of adenine, ribose and three phosphate molecules. It plays a central role in energy exchange in biological systems.

**Adipocyte** – Large cell (up to 200 microns) with only a thin film of cytoplasm due to the presence of a large fat droplet.

**Adipose tissue** – A group of adipocytes.

**Alternation of generation** – Alternation of haploid sexual and diploid asexual generation in the life cycle of an animal.

**Ampulla of Vater** – Common duct called hepato-pancreatic duct.

**Ampulla** – The widened opening for each of the semicircular canals, containing sensory innervations.

**Apnoea** – Temporary stopping of respiration.

**Berger's waves** – are neural oscillations in the frequency range of 7.5–12.5 Hz arising from synchronous and coherent (in phase or constructive) electrical activity of thalamic pacemaker cells in humans.

**Bicuspid valve** – also called mitral valve. Left Auricular ventricular valve with two flaps that is present between the left auricle and left ventricle.

**Biological indicator** – refers to organisms, species or community whose characteristics show the presence of specific environmental conditions.

**Bipedal** – Walk or stand on two feet.

**Blood pressure** – (BP) is the pressure exerted by the circulating blood against the walls of blood vessels.

**Book gills** – Respiratory organs in aquatic Limulus.

**Book lungs** – Respiratory organs of Scorpions and most spiders.

**Brood** – a family of birds produced at one hatching or birth.

**Catecholamines** – Naturally occurring amines that function as neurotransmitters. They are characterised by catechol group in which an amine group is attached. Ex: Epinephrine.

**Cocoon** – It is a bag like structure secreted by the clitellum. Eggs and sperms are deposited into it. Fertilization and development occurs within the cocoon.

**Collagen** – A triple helix protein which allows for great tensile strength.

**Dioecious** – Animals in which male and female reproductive organs occur in separate individuals.

**Drilosphere** – is the part of the soil influenced by earthworm secretions, burrowing and castings.

**Dyspnoea** – painful respiration.

**Electromagnetic (EM) radiation** – Electromagnetic radiation is a form of energy that is all around us and takes many forms, such as radio waves, microwaves, X-rays and gamma rays.

**Evisceration (Autotomy)** - Ejection of viscera as a defensive action by an animal.

**Falciform ligament** – Sickle shaped thin fibrous structure that connects the liver with diaphragm.

**Functional Respiratory Capacity (FRC)** - Volume of air present after expiration in lungs.

**Goblet cell** – special mucus secreting columnar epithelial cell located in the respiratory tract and intestine.

**Hypopharynx** – The hypopharynx is a somewhat globular structure, located medially to the mandibles and the maxillae. In many species it is membranous and associated with salivary glands. It assists in swallowing the food.

**Hypoxia** – the failure of tissues for any reason to receive an adequate supply of oxygen.

**Incubator** – is a device used to grow and maintain microbiological cultures or cell cultures. and maintains optimal temperature, humidity and other conditions such as the carbon dioxide ($CO_2$) and oxygen content of the atmosphere inside.



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**Isovolumetric ventricular contraction** – Isovolumetric means constant volume and length. During ventricular contraction, when all valves are closed, no blood can enter or leave the ventricle during this time. Because no blood leaves or enters the ventricles the ventricular chamber has a constant volume and the muscle fibres stay at a constant length.

**Juxtaglomerular apparatus** – The ascending limb of Henle returns to the glomerular region of its own nephron, where it passes through the fork formed by the afferent and efferent arterioles. Both the tubular and vascular cells at this point are specialized to form juxtaglomerular apparatus that lie next to the glomerulus. (Juxta means "next to").

**Juxtamedullary nephrons** – the glomeruli of the juxtaglomerular nephrons lie in the inner layer of cortex next to the medulla and the loops of Henle plunges through the entire depth of the medulla Concentrated urine is formed in these nephrons.

**Lacunae** – A cavity or depression especially in the bone.

**Macrophages** – Immune cells derived from monocytes; engaged in phagocytosis of microbes and debris.

**Mast cells** – Cells filled with basophilic granules found in numbers in connective tissue and releases histamine and other substances during inflammatory and allergic reactions.

**Mesentery** – A thin double walled epithelial membrane that support alimentary canal and other organs in the abdominal cavity.

**Phylogeny** – Relationships among various biological species based upon similarities and differences in their physical or genetic characteristics.

**Piezoelectric Effect** – It is the ability of certain materials to generate an electric charge in response to applied mechanical stress.

**Pneumothorax** – presence of air in the pleural cavity which causes collapsing of lungs.

**Poikilotherms** – Cold blooded organisms/ Body temperature fluctuates according to environmental temperature.

**Properioception** – The ability to sense stimuli arising within the body regarding position, motion and equilibrium.

**Sclerites** – Sclerite is hard armor like structure for arthopods (even cockroaches) soft body. Sclerites are really deposition of Calcium or cross linking of protein to make the exoskeleton stronger.

**Septum pellucidum** – Located in the midline of the brain, between the two cerebral hemispheres. It separates the lateral ventricles I and II.

**Setae** – They are small, S- Shaped chitinous structures present in the pits of the body wall of earthworms. They aid in locomotion. Some setae are modified into Penial setae in the male genital opening and these help in copulation.

**Shared character** – A shared character is one that have two lineages in common.

**Spawning** - Process of shedding of mass eggs or sperms in water.

**Sphincter of Boydon** – Sphincter which guard opening of the bile duct before it joins with the pancreatic duct.

**Sphincter of Oddi** – Sphincter which guard the opening of the ampulla of vater into the duodenum.

**Taeniae coli** – Longitudinal muscular chords in the colon.

**Typhlosole** – A median dorsal internal fold in the intestine of several types of animals, including the earthworm.

**Valves of kerkring or plicae circulares** – Circular folds in the lumen of ileum.

**Vasa recta** – (straight vessels) The peritubular capillaries of the juxtaglomerular nephrons forms vascular loops which run in close association with the loops of Henle.

**Vectors** –A vector is an organism that does not cause disease itself but which spreads infection by conveying pathogens from one host to another.

**Villus** – A minute finger-like process from intestinal lining of vertebrates.

**Yawning** – prolonged inspiration due to increase in $CO_2$ concentration.



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# Glossary

| | |
|---|---|
| பாடம் 1 : **The Living world-உயிருலகம்** | |
| Diversity | பல்லுயிரியல்பு / பல்லுயிர்த்தன்மை |
| Systematics | இனத்தொடர்பு தொகுப்பமைவு |
| Hierarchy | படிநிலை |
| Nomenclature | பெயரிடும் முறைகள் |
| Biodiversity | பல்லுயிர் தன்மை |
| Autotrophic | தன்னூட்டம் ஊட்டமுறை |
| Phylogenentic tree | பரிணாம மரம் |
| Heterotrophic | சார்ந்துண்ணிகள், பிறஊட்ட உயிரிகள் |
| Thermoacidophiles | வெப்பம் மற்றும் அமிலத்தன்மையை தாங்கி வாழும் தன்மை |
| Tautonymy | பெரினப்பெயரும்/ சிற்றினப் பெயரும் / ஒரே மாதிரியாக இருத்தல் |
| Bioluminescence | உயிர் ஒளிர்தல் |
| | |
| பாடம் 2 : **Kingdom Animalia – விலங்குகள்** | |
| Pinacocytes | கடற்பஞ்சுகளின் தட்டையான புறப்படை செல்கள் |
| Diploblastic animals | ஈரடுக்கு விலங்குகள் |
| Asymmetrycal | சமச்சீரற்ற தன்மை |
| Radial symmetry | ஆரசமச்சீர் அமைப்பு |
| Biradial symmetrical | இரு ஆரசமச்சீர் |
| Parazoa | தனிச்சியான பலசெல் |
| Eumetazoa | பல செல் உயிரிகள் |
| Mesoglea | மீசோகிளியா |
| Deutrostomia | முளைக்குழியிலிருந்து வாய் தோன்றுதல் |
| Cnidocytes(or) cnidoblasts | கொட்டும் செல்கள் |
| Polyembryony | பல கருநிலை |
| Haemocoel | இரத்தம் உடற்குழி |
| Water vascular system | நீர் குருதியோட்ட மண்டலம் |
| பாடம் 3 : **Tissue Level of Organisation – விலங்குத் திசுக்கள்** | |
| Epithelial tissues | எபிதீலிய திசுக்கள் |
| Connective tissues | இணைப்புத்திசுக்கள் |
| Muscular tissues | தசைத்திசுக்கள் |
| Neural tissues | நாம்புத்திசு |
| Squamous epithelium | தட்டை வடிவ எபிதீலியம் |
| Cuboidal epithelium | கனசதுர வடிவ எபிதீலியம் |
| Columnar epithelium | தூண் வடிவ எபிதீலியம் |
| Ciliated epithelium | குறுஇழை கொண்ட எபிதீலியம் |
| Compound epithelium | கூட்டு எபிதீலியம் |
| Simple epithelium | எளிய எபிதீலியம் |
| Pseudostratified epithelium | பொய் அடுக்கினால் ஆன எபிதீலியம் |
| Stratified epithelium | அடுக்கு எபிதீலியம் |
| Histology | திசுவியல் |
| Basic/Primary tissue | அடிப்படை திசு |
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| பாடம் 4 : **Organ and organ system in Animals – விலங்குகளின் உறுப்பு மற்றும் உறுப்பு மண்டலங்கள்** | |
| Worm castings | நாங்கூழ் கட்டிகள் |
| Epigeics | மேல்மட்ட புழுக்கள் |
| Anecics | நடு மட்ட புழுக்கள் |
| Endogeics | அடிமட்ட புழுக்கள் |
| Peristomium | பெரிஸ்டோமியம் |
| Prostomium | புரோஸ்டோமியம் |
| Pygidium | பைஜிடியம் |
| Clitellum | கிளைடெல்லம் |
| Seta | சீட்டா |

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| Coelomic fluid | உடற்குழி திரவம் |
| Sperma theca | விந்து கொள்பை |
| Nephridia | நெஃப்ரிடியா |
| Genital opening | இனப்பெருக்கத் துளை |
| Gizzard | அரைவைப்பை |
| Intestinal caeca | குடல் பிதுக்கங்கள் |
| Hydrostatic skeleton | நீர்ம சட்டகம் |
| Regeneration | இழப்பு மீட்டல் |
| Commissural vessels | இணைப்பு நாளங்கள் |
| Ganglion | நாம்பு செல்திரள் |
| Photoreceptor | ஒளி உணர்வி |
| Gustatory receptor | சுவை உணர்வி |
| Olfactory receptor | நுகர் உணர்வி |
| Tactile receptor | தொடு உணர்வி |
| Chemoreceptor | வேதிஉணர்வி |
| Thermo receptor | வெப்ப உணர்வி |
| Cocoon | புழுக்கூடு |
| பாடம் 5 : **Digestion and Absorption - செரித்தல் மற்றும் உட்கிரகித்தல்** | |
| Digestive system | செரிமான மண்டலம் |
| Digestive glands | செரிமான சுரப்பிகள் |
| Salivary glands | உமிழ்நீர் சுரப்பிகள் |
| Liver | கல்லீரல் |
| Pancreas | கணையம் |
| Gastro intestinal hormones | இரைப்பை-குடல் ஹார்மோன்கள் |
| Digestive enzymes | செரிமான நொதிகள் |
| Absorption | உட்கிரகித்தல் |
| Assimilation | தன்மயமாதல் |
| Protein | புரதங்கள் |
| Carbohydrates | கார்போஹைட்ரேட்டுகள் |
| Fats | கொழுப்புப் பொருட்கள் |
| Egestion | கழிவு வெளியேற்றம் |
| Nutrients | உணவூட்டப்பொருட்கள் |
| Minerals | கனிமங்கள்/ தாது உப்புகள் |
| Caloric value | கலோரி மதிப்பு |
| Malnutrition | ஊட்ட குறைவு |
| Indigestion | செரிமானம் |
| Constipation | மலச்சிக்கல் |
| Jaundice | கல்லீரல் அழற்சி, மஞ்சள் காமாலை |
| Peptic ulcer | இரைப்பை புண் |
| Appendicitis | குடல்வால் அழற்சி |
| Hiatus hernia | குடல் இறக்கம் |
| Autotrophs | தன்னூட்ட உயிரிகள் |
| Electrolytes | மின்பகுபொருட்கள் |
| Digestive juice | செரிமான திரவம் |
| Heterotroph | சார்ந்துண்ணிகள் |
| Foregut | முன்உணவுப்பாதை |
| Midgut | நடு உணவுப்பாதை |
| Hindgut | பின் உணவுப்பாதை |
| Buccal cavity/oral cavity | வாய்க்குழி |
| Terminal sulcus | முனைப்பள்ளம் |
| Cardial portion | இரைப்பை மேல்பகுதி |
| Fundic portion | இரைப்பை நடுப்பகுதி |
| Pyloric portion | இரைப்பை பின்பகுதி |



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| Duodenum | முன்சிறுகுடல் |
| Cardiac sphincter | கார்டியாக் சுருக்குத்தசை |
| Pyloric sphincter | பைலோரிக் சுருக்குத்தசை |
| Regurgitation | மீளத்திரும்புதல் |
| Gastric rugae | இரைப்பை உட்புற மடிப்புகள் |
| Jejunum | நடுச்சிறுகுடல் |
| Ileum | பின்சிறுகுடல் |
| Chyme | இரைப்பை பாகு |
| Microvilli | குடல் உறிஞ்சிகள், நுண்குடலுறிஞ்சிகள் |
| Goblet cells | கோப்பை வடிவச்செல்கள் |
| Lymphoid tissue | நிணநீர்த்திசு |
| Peyer's patches | பேயர் திசுத்தொகுப்பு |
| Lymphocytes | லிம்போசைட்டுகள் |
| Crypts | கிரிப்ட்ஸ்/ மடிப்புகள் |
| Succus entericus | சிறுகுடல் சாறு |
| Ceacum | பிதுக்கம் |
| Colon | பெருங்குடல் |
| Rectum | மலக்குடல் |
| Vermiform appendix | குடல்வால் |
| Herbivorous animal | தாவர உண்ணிகள் |
| Symbiotic bacteria | இணைவாழ் பாக்டீரியாக்கள் |
| Anal mucosa | மலவாய் கோழைப்படலம் |
| Anal column cells | மலவாய் தூண்செல்கள் |
| Piles/haemorrhoids | மூலம் |
| Serosa | சொரஸ் உறை |
| Muscularis | தசை உறை |
| Sub mucosa | கோழைகீழ் படலம் |
| Mucosa | கோழைப்படலம் |
| Visceral peritonium | வயிற்றுறை பெரிடோனியம் |
| Submucosa plexus | கோழை கீழ் வலைப்பின்னல் |
| Biological catalysts | உயிர் வினையூக்கி |
| Parotid | மேலண்ணச் சுரப்பி |
| Submaxillary gland | கீழ்த்தாடைச் சுரப்பி |
| Sub lingual gland | நாவடிச் சுரப்பி |
| Peptic cells | இரைப்பை செல்கள் |
| Parietal cells | இரைப்பை சுவர் செல்கள் |
| Falciform ligament | அரிவாள் வடிவம் |
| Hepatic lobules | கல்லீரல் நுண் கதுப்புகள் |
| Ampulla of vater | கல்லீரல் கணையப் பொது நாளம் |
| Mastication | மெல்லுதல் |
| Bolus | உணவுக் கவளம் |
| Peristalsis | அலையியக்கம் |
| lubrication | உயவூட்டுதல் |
| Churn | கடைதல் |
| Proenzyme | முன்நொதிகள் |
| Putrifaction | அழுகுதல் |
| Emulsification | பாய்மமாதல் |
| Absorption | உட்கிரகித்தல் |
| Intestinal mucosa | குடல் கோழைப்படலம் |
| Lumen | வெற்றிடப் பகுதி |
| Facilitated transpot | பொருட்கள் வழி கடத்தல் |
| Concentration gradient | அடர்த்தி வேறுபாடு |
| Active transport | செயல்மிகு கடத்தல் |

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| Passive transport | இயல்பு கடத்தல் |
| Bartholins duct (or) Duct of Rivinis | நாவடிச் சுரப்பி நாளம் |
| Cementum | பற்கள் ஈறுடன் இணைக்கும் கடினமானப் பொருள் |
| **பாடம் 6 : Respiration - சுவாசம்** | |
| Respiratory volume | நுரையீரல் கொள்ளளவு |
| Respirometer | சுவாச அளவி |
| Spirometer | ஸ்பைரோமீட்டர் |
| Surfactants | மேல்பரப்பிகள் |
| Bio-molecules | உயிர் மூலக்கூறுகள் |
| Respiratory disorder | சுவாசக்கோளாறுகள் |
| Pollutants | மாசுபடுத்திகள் |
| Nasopharynx | நாசிப்பகுதித் தொண்டை |
| Glottis | குரல்வளைத் துளை |
| Epiglottis | குரல்வளை மூடி |
| Cartilaginous rings | குருத்தெலும்பு வளையங்கள் |
| Alveolus | காற்று நுண்ணறை |
| Chocking | சுவாச அடைப்பு |
| Trachea | மூச்சுக்குழல் |
| Bronchus | மூச்சுக்கிளைக்குழல் |
| Bronchioles | மூச்சுக்கிளை நுண் குழல்கள் |
| Basement substance | ஆதாரப் பொருட்கள்/ அடிப்படைப் பொருட்கள் |
| Conducting zone | கடத்தும் பகுதி |
| Respiratory zone | சுவாசப்பகுதி |
| Pressure gradients | அழுத்த சரிவுவாட்டம் |
| Intercostal muscles | விலா எலும்பிடைத்தசைகள் |
| Thoracic chamber | மார்பறை |
| Inspiration | உட்சுவாசம் |
| Expiration | வெளிச்சுவாசம் |
| Snoring | குறட்டை |
| Residual volume | எஞ்சிய கொள்ளளவு |
| Total lung capacity | மொத்த நுரையீரல் கொள்ளளவு |
| Inspiratrory capacity | உட்சுவாசக் கொள்ளளவு |
| Expiratory capacity | வெளிச்சுவாசக் கொள்ளளவு |
| Vital capacity | உயிர்ப்புத்திறன் |
| Inspiratory reserve volume | உட்சுவாச சேமிப்புக் கொள்ளளவு |
| Expiratory reserve volume | வெளிச்சுவாச சேமிப்புக் கொள்ளளவு |
| Partial pressure | பகுதி அழுத்தம் |
| Partial pressure gradient | பகுதி அழுத்தம் சரிவுவாட்டம் |
| Dead space | பயனற்ற இடம் |
| Bronchitis | மார்புச்சளி நோய் |
| Emphysema | நுரையீரல் அடைப்பு |
| Reversible manner | மீள்வினைத் தன்மை |
| Chemosensitive area | வேதிஉணர்பகுதி |
| Sputum | சளி |
| Nasal congestion | மூக்கடைப்பு |
| Sore throat | தொண்டை வலி |
| Fibrosis | நார்த்தசை நோய் |
| Carcinogens | புற்றுநோய்க் காரணிகள் |
| Hypoxia | ஆக்சிஜன் பற்றாக்குறை |
| Heart palpitation | இதயப் படபடப்பு |
| Nausea | வாந்தியுணர்வு |
| Anaemia | இரத்தசோகை |

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| Congenital heart disease | பிறவிக்குறை இதய நோய் |
| Hyperbarisim | மிகைஅழுத்தத் தன்மை |
| Suffocation | மூச்சுத்திணறல் |
| Conjugated protein | இணைவுப்புரதம் |
| Haem moieties | ஹீம் பகுதியின் ஒரு பாதி |
| Respiratory quotient | சுவாசக்கெழு எண் |
| $Ca^{++}$ ions | நேர்மின்அயனிகள் |
| Electrostatic attraction | மின்னிலைக் கவர்ச்சி |
| Irritants | எரிச்சலூட்டும் பொருட்கள் |
| Hiccups | விக்கல் |
| Aerobic respiration | காற்றுடைச் சுவாசம் |
| Anaerobic respiration | காற்றற்ற சுவாசம் |

**பாடம் 7 : Body fluids and circulation - உடல் திரவங்கள் மற்றும் சுற்றோட்டம்**

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| Cardiac activity | இதயச்செயல்பாடுகள் |
| Cardiac cycle | இதய சுழற்சி |
| Blood coagulating factors | இரத்த உறைதல் காரணிகள் |
| Vasovagal syncope | வேகஸ் நரம்பின் அதிகரித்த செயலால் ஏற்படும் மயக்கம் |
| Perfusion | மேற்பாவல் |
| Capillary | தந்துகி |
| Arteriole | நுண் தமனி |
| Hydrostatic pressure | இரத்த திரவ அழுத்தம் |
| Osmosis | உடுகவப்பு |
| Arterial end | தமனி முடிவுப் பகுதி |
| Venous end | சிரை முடிவுப்பகுதி |
| Formed elements | இரத்தச் செல்கள் |
| Hepatic portal vein | கல்லீரல் போர்ட்டல் சிரை |
| Hepatic vein | கல்லீரல் சிரை |
| Hepatic artery | கல்லீரல் தமனி |
| Erythropoiesis | சிவப்பணு உருவாக்கம் |
| Granulocytes | துகளுடைய வெள்ளையணுக்கள் |
| Agranulocytes | துகளற்ற வெள்ளையணுக்கள் |
| Phagocytic nature | விழுங்கும் தன்மையுடைய |
| Pus | சீழ் |
| Inflammatory reaction | வீக்கம் ஏற்படுதல் |
| Cell mediated immunity | செல்வழி நோய்த்தடைகாப்பு |
| Macrophages | மாக்ரோபேஜ்கள் |
| Sinusoids | குழியிடை அடைப்பு |
| Antigen | எதிர்ப் பொருள் |
| Antibody | எதிர்வினைப்பொருள் |
| Blood transfusion | இரத்தம் செலுத்துதல் |
| Trauma | விபத்து |
| Meshwork | வலைப்பின்னல் |
| Lymph nodes | நிணநீர் முடிச்சுகள் |
| Inguinal | தொடைப்பகுதி |
| Axillaries | அக்குள் பகுதிகள் |
| Sub clavian vein | சப்கிளேவியன் சிரை |
| Lacteals | லாக்டியல் நாளங்கள் |
| Vasoconstriction | இரத்தக்குழல் சுருக்கம் |
| Vasodilation | இரத்தக் குழல் விரிவடைதல் |
| Anastomoses | இருவேறு தமனிகள் இணைப்பிடங்கள் |
| Abdominal cramps | வயிற்றுப்புறப் பிடிப்புகள் |
| Venules | நுண் சிரைகள் |

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|---|---|
| Unidirectional flow | ஒருதிசை ஓட்டம் |
| Ventricular septum | வென்ட்ரிகுலார் இடைத்தடுப்பு |
| Auricular septum | ஆரிகுலார் இடைத்தடுப்பு |
| Double circulation | இரட்டைச் சுற்று ஓட்டம் |
| Pulmonary circuit | நுரையீரல் இரத்த ஓட்டம் (சுற்றோட்டம்) |
| Systemic circuit | சிஸ்டமிக்(அ) உடல் இரத்த ஓட்டம் (சுற்றோட்டம்) |
| Papillary muscles | பாப்பில்லரித் தசைகள் |
| Pericardial space | பெரிக்கார்டியல் குழி |
| Pericardial fluid | பெரிக்கார்டிய திரவம் |
| Auriculo ventricular valves | ஆரிக்குலோ வென்ட்ரிகுலார் வால்வுகள் |
| Inferior vena cava | கீழ்ப்பெருஞ்சிரை |
| Superior vena cava | மேற்பெருஞ்சிரை |
| Pulmonary veins | நுரையீரல் சிரைகள் |
| Myogenic heart | மயோஜெனிக் வகை இதயம் |
| Depolariation | மின்கார்த முனைப்பியக்கம் அகன்ற நிலை |
| Tachycardia | டாச்கி கார்டியா |
| Brady cardia | பிராடிகார்டியா |
| Stroke volume(SV) | விக்கக் கொள்ளவு |
| Semilunar valves | அரைச்சந்திர வால்வுகள் |
| Heart rate(HR) | இதயத்துடிப்பு வீதம் |
| Cardiac output (CO) | இதயத்திலிருந்து வெளிப்படும் இரத்த அளவு |
| Sphygmomanometer | இரத்தஅழுத்தமாணி |
| Pulse rate | நாடித்துடிப்பு |
| Atheroma | தமனிச்சுவரில் கொழுப்புப்படிவு |
| Hypertension | மிகையழுத்தம் |
| Atherosclerosis | இதய இரத்தக்குழல் அடைப்பு |
| Brain haemorrhage | மூளையில் இரத்தக் கசிவு |
| Cerebral infarction | பெருமூளைத் திசுச் சிதைவு |
| Myocardial infarction | இதயத்தசை நசிவுறல் நோய் |
| Angina pectoris | தீவிர மார்பு வலி |
| Rheumatoid heart disease | ருமாட்டிக் இதய நோய் |
| Rheumatic fever | ருமாட்டிக் காய்ச்சல் |
| Varicose veins | இரத்தநாளங்கள் சுருளுதல் |
| Embolism | தமனியில் இரத்தக் கட்டி அடைப்பு |
| Aneurysm | தமனி விரிசல், குருதிநாள நெளிவு |
| Catheter | உட்செலுத்திக் குழாய் |
| Scaffolding | சாரக்கட்டு, தூக்கிக் கட்டுதல் |
| Pump oxygenator | பம்ப்ஆக்சிஜனேட்டர் (ஆக்சிஜன்செலுத்தி) |
| Resuscitation | செயல் தூண்டல் |
| Cessation of breath | மூச்சு நிறுத்துதல் |

**பாடம் 8 : Excretion - கழிவுநீக்கம்**

| | |
|---|---|
| Nephron | நெஃப்ரான் |
| Nephron tubules | நெஃப்ரான் நுண்குழல்கள் |
| Osmoregulation | உடுகவப்பு ஒழுங்குபாடு |
| Ionic regulation | அயனி ஒழுங்குபாடு |
| Ammonotelic | அம்மோனோடெலிக் – அம்மோனியா நீக்கிகள் |
| Uriotelic | யூரியோடெலிக் – யூரியா நீக்கிகள் |
| Uricotelic | யூரிக்கோடெலிக்-யூரிக்அமில நீக்கிகள் |
| Flame cells | சுடர்ச்செல்கள் |
| Green glands | பச்சை சுரப்பிகள் |
| Malpighian tubules | மால்பிகியன் நுண்குழல்கள் |

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|---|---|
| Renal tubule | சிறுநீரக நுண்குழல் |
| Proximal Convoluted Tubule | அண்மை சுருள் நுண்குழல் |
| Distal Convoluted Tubule | சேய்மை சுருள் நுண்குழல் |
| Bowman's capsule | பௌமனின் கிண்ணம் |
| Hydrostatic pressure | நீர்ம அழுத்தம் |
| Filtrate | வடி திரவம் |
| Collecting duct | சேகரிப்பு நாளம் |
| Micturition | சிறுநீர் வெளியேற்றம் |
| Renal failure | சிறுநீரக செயலிழப்பு |
| Renal calculi | சிறுநீரகக் கற்கள் |
| Ultra filtration | நுண்வடிகட்டுதல் |
| Interstial fluid | இடையிட்டு திரவம் |
| Body fluid | உடல் திரவம் |
| Hypotonic | தாழ் உப்படர்வு |
| Hypertonic | உயர் உப்படர்வு |

| பாடம் 9 : Locomotion and movement - இடப்பெயர்ச்சி மற்றும் இயக்கம் | |
|---|---|
| Amoeboid movement | அமீபா போன்ற இயக்கம் |
| Ciliary movement | குறு இழை இயக்கம் |
| Flagellar movement | நீள்இழை இயக்கம் |
| Muscular movement | தசை இயக்கம் |
| Myocytes | தசை செல்கள் |
| Skeletal muscles | எலும்புத் தசை |
| Visceral muscles | உள்ளுறுப்புத் தசைகள் |
| Cardiac muscles | இதயத் தசைகள் |
| Tendon | தசை நாண் |
| Fascicle | ஃபாசிகிள் |
| Epimysium | எபிமைசியம் |
| perimsium | பெரிமைசியம் |
| Endomysium | எண்டோமைசியம் |
| Sarcolemma | சார்கோலெம்மா |
| Anisotropic bands (A bands) | மாறுபட்ட தன்மையுடைய பட்டைகள் |
| Isotropic bands (I bands) | ஒத்த தன்மையுடைய பட்டைகள் |
| Muscle fibre | தசைஇழை |
| Myofibril | தசை நுண்ணிழை |
| Myo filaments | தசை நாண் |
| Meromyosin | மீரோமையோசின் |
| Troponin | ட்ரோபோனின் |
| Tropomyosin | ட்ரோபோமையோசின் |
| Sliding – filament hypothesis | சறுக்கும் இழை கோட்பாடு |
| Neuro muscular junction | நரம்பு தசை சந்திப்பு |
| Motor end plate | இயக்க முடிவுத் தட்டு |
| Dark band | அடர்த்தி மிகு பட்டை |
| Light band | அடர்த்தி குறை பட்டை |
| Active sites | செயற்படு பகுதி/செயல் மிகு பகுதி |
| Cross bridge | குறுக்குப்பாலம் |
| Power stroke | விசைத்தாக்கம் |
| Motor unit | இயக்க அலகு |
| Isotonic contraction | சமநிலைச் சுருக்கம் |
| Isometric contraction | சம இழுப்புச் சுருக்கம் |
| Oxidative contraction | ஆக்ஸிஜனேற்ற தசைச் சுருக்கம் |
| Glycolytic contraction | கிளைக்கோஜன் சிதைவு தசைச் சுருக்கம் |
| fast fibres | துரித இழைகள் |
| Slow fibres | மெதுவான இழைகள் |
| Skeletal system | எலும்பு மண்டலம் |
| Hydrostatic skeleton | நீர்ம நிலைச் சட்டகம் |

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|---|---|
| Exoskeleton | புறச் சட்டகம் |
| Endoskeleton | அகச்சட்டகம் |
| Axial skeleton | அச்சுக் சட்டகம் |
| Appendicular skeleton | இணையுறுப்புச் சட்டகம் |
| External auditory meatus | வெளிச் செவித்துளை |
| Ear ossicles | செவிச்சிற்றெலும்புகள் |
| Foramen magnum | மண்டையோட்டுப் பெருந்துளை |
| Neural canal | நாடிக் கால்வாய் |
| True ribs | உண்மை விலா எலும்புகள் |
| False ribs | போலி விலா எலும்புகள் |
| Floating ribs | மிதக்கும் விலா எலும்புகள் |
| Girdle | வளையம் |
| Collar bone | காலர் எலும்பு |
| Acromion | ஏகுரோமியன் |
| Olecranon process | ஓலிக்ரானன் நீட்சி |
| accetalrlum | எலும்புக்குழி |
| Pubic symphysis | பூப்பெலும்பு இணைவு |
| Miscle fatigue | தசைச் சோர்வு |
| Muscle pull | தசைப் பிடிப்பு |
| Muscular dystrophy | தசைச் சிதைவு நோய் |
| Rigor mortis | மரண விறைப்பு |
| Arthritis | மூட்டு வலி |
| Osteoarthritis | ஆஸ்டியோ மூட்டு வலி |
| Rheumatiod arthritis | ருமாடிக் மூட்டுவலி |
| Gout | கௌட் |
| Osteoporosis | எலும்புப்புரை |
| Parietal bone | கவரெலும்பு |
| Temporal bone | பொட்டெலும்பு |
| Frontal bone | நெற்றி எலும்பு |
| Sphenoid | ஆப்பு வடிவ எலும்பு/ஸ்பினாய்டு |
| Occipital | பிடரிஎலும்பு |
| Ethmoid | எத்மாய்டு |
| Maxilla | மேல்தாடை எலும்பு |
| Zygomatic | கன்னத்தின் வளையெலும்பு |
| Palatine | அண்ணவெலும்பு |
| Lacrymal | கண்ணீர்ச் சுரப்பியின்மை எலும்பு |
| Nasal | மூக்கினிடைத்தட்டெலும்பு |
| Inferior nasal koncha | மூக்கினிடைக்கீழ் காஞ்சா |
| Mandible | கீழ்த்தாடை எலும்பு |
| Vomer | இடைராசி எலும்பு |
| Malleus | சுத்தி எலும்பு |
| Incus | பட்டடை எலும்பு |
| Stapes | அங்கவடி எலும்பு |

| பாடம் – 10 : Neural control and Co- ordination - நரம்பு கட்டுப்பாடு மற்றும் ஒருங்கிணைப்பு | |
|---|---|
| Neuron | நியூரான் (நரம்பு செல்) |
| Sensory neuron | உணர்வு நியூரான் |
| Motor neuron | இயக்கு நியூரான் |
| Automatic functions | தானியங்கு வேலைகள் |
| Afferent neurons | உட்செல் நியூரான்கள் |
| Efferent neurons | வெளிச் செல் நியூரான்கள் |
| Inter neurons | இடை நியூரான்கள் |
| Nissles granules | நிஸ்சல் துகள்கள் |
| Node of Ranvier | ரான்வியர் முடிச்சு / கணு |
| Myelin sheath | மயலின் உறை |
| Nerve impulse | நரம்புத் தூண்டல் |
| Axon hillock | ஆக்ஸான் மேடு |
| Synapsis | நரம்பு செல் சந்திப்பு |



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|---|---|
| Synaptic knob | நரம்பு செல் சந்திப்பு முடிச்சு |
| Synaptic vesicles | நரம்பு செல் சந்திப்பு பகுதி நுண்பைகள் |
| Neurotransmitters | நரம்புகடத்வு கடத்திகள் |
| Extra cellular fluid | செல்வெளித் திரவம் |
| Intra cellular fluid | செல்உள் திரவம் |
| Resting membrane potential | ஓய்வுநிலை சவ்வின் மின் அழுத்த அளவு |
| Action potential | செயல்நிலை மின் அழுத்தம் |
| Polarization | முனைப்பியக்கம் |
| Sodium-potassium pump | சோடியம்-பொட்டாசியம் உந்திக் கடத்தல் |
| Depolarization | முனைப்பியக்க நீக்கம் |
| Threshold stimulus | அவசியமான குறைந்தபட்ச தூண்டல் |
| Repolarization | முனைப்பியக்க மீட்சி |
| Spike potential | கூர்முனை மின் அழுத்த அளவு |
| Hyper polarization | மிகை முனைப்பியக்கம் |
| Synaptic cleft | நரம்பு செல் சந்திப்பு இடைவெளி |
| Exocytosis | செல்வெடித்தல் |
| All or none principle | உண்டு – இல்லை கோட்பாடு |
| Cranial nerves | மூளை நரம்புகள் |
| Olfactory nerve | நுகர்ச்சி நரம்பு |
| Optic nerve | பார்வை நரம்பு |
| Trigeminal nerve | முக்கிளை நரம்பு |
| Facial nerve | முக நரம்பு |
| Hypoglossal nerve | நாவடி நரம்பு |
| Sympathetic nervous system | பரிவு நரம்பு மண்டலம் |
| Para sympathetic nervous system | இணைப் பரிவு நரம்பு மண்டலம் |
| Mechanoreceptors | தொடு உணர்விகள் |
| Myopia | கிட்டப் பார்வை |
| Hyper metropia | தூரப் பார்வை |
| Cataract | கண்புரை |
| Proprioception | அசைவுகளை உணரும் உணர்வு |
| **பாடம் 11: Chemical co- ordination and integration** - வேதிய ஒருங்கிணைப்பு | |
| Goose bumps | ரோமங்கள்சிலிர்த்த நிலை |
| Hormones | ஹார்மோன்கள் |
| Homeostasis | உடல்சமநிலையை பேணுதல் |
| Exchaive endocrine glands | முழுமையான நாளமில்லாச் சுரப்பிகள் |
| Neuroendocrine glands | நரம்புசார் நாளமில்லாச் சுரப்பிகள் |
| Partial endocrine glands | பகுதி நாளமில்லாச் சுரப்பிகள் |
| Neuro secretory cells | நரம்பு சுரப்பு செல்கள் |
| Releasing hormone | விடுவிக்கும்ஹார்மோன் |
| Inhibitory homone | மட்டுப்படுத்தும் ஹார்மோன் |
| Hypothalamic hypophyseal portal blood vessel | ஹைபோதலாமிக் ஹைபோஃபைசியல் போர்ட்டல் இரத்தக் குழல் |
| Hypothalamic hypophyseal axis | ஹைபோதலாமிக் ஹைபோஃபைசியல்அச்சு |
| Limbic system | உணர்வுச் செயலித் தொகுப்பு |
| Sella turcica | செல்ல டர்சிகா |
| Infundibulam | இன்ஃபன்டிபுலம் |
| Anterior lobe | முன் கதுப்பு |
| Tropic hormone | தூண்டும் ஹார்மோன் |
| Feed back | பின்னூட்டம் |
| **பாடம் 12: Basic medical instrument and techniques** - அடிப்படை மருத்துவக் கருவிகள் மற்றும் தொழில் நுட்பங்கள் | |
| Diagnostic and monitoring Instruments | பரிசோதனை மற்றும் கண்காணிப்புக் கருவிகள் |
| Imaging Instruments | நிழலுரு கருவிகள் |
| Therapeutic Instruments | சிகிச்சை கருவிகள் |
| Biomedical Techniques | உயிரி – மருத்துவ தொழில் நுட்பம் |
| Stethoscope | ஸ்டெத்தஸ்கோப் |
| Sphygmomanometer | ஸ்பிக்மோமானோமீட்டர் (இரத்த அழுத்தமானி) |

| | |
|---|---|
| Autoanalyser | ஆட்டோ அனலைசர் (தானியங்கி பகுப்பாய்வி) |
| ECG | எலக்ட்ரோகார்டியோகிராம் (இதய துடிப்பு மின் வரைவி) |
| EEG | எலக்ட்ரோ என்செஃபாலோகிராம் |
| Ultra sound scanner | அல்ட்ராசவுண்ட் ஸ்கேனர் |
| CT Scanner | கம்ப்யூட்டட் டோமோகிராபி ஸ்கேனர் |
| Prognosis | முன் கணிப்பு |
| **பாடம் 13: Trends in Economic Zoology** - வணிக விலங்கியலின் போக்குகள் | |
| Apiculture | தேனீவளர்ப்பு |
| Drone | ஆண் தேனீ |
| Nuptial flight | புணரும் பறத்தல் |
| Pheromone | ஃபிரோமோன் |
| Fertilization | கருவுறுதல் |
| Sterile | மலட்டுத்தன்மை |
| Hive | தேன்கூடு/தேனடை |
| Necter | பூந்தேன் |
| Propolis | புரோபோலிஸ்/ தேன் பிசின் |
| Swarming | கூட்டமாக செல்லுதல் / கூட்டமாக பறத்தல் |
| Inoculation | நோய்தடுப்பு ஊசிமருந்து |
| Predators | கொன்றுண்ணிகள் |
| Queen Excluder | இராணித்தேனீ தடுப்பான் |
| Comb foundation | தேன்கூட்டு அடித்தளம் |
| Bee glove | தேனீக்கையுறை |
| Bee veil | முகத்திரை/ தேன் எடுக்க உதவும் முகத்திரை |
| Hive Tool | தேன்கூட்டு சாதனம் |
| Honey extractor | தேன்பிழி சாதனம் |
| Hive entrance guard | தேன் கூடு முகப்பு தடுப்பு |
| Antiseptic | நச்சுத்தடை |
| Laxative | மலமிளக்கி |
| Sedative | மயக்கமூட்டி |
| Masticated | மெல்லுதல் |
| Hyper parasitism | ஒட்டுண்ணி மேல் ஒட்டுண்ணி வாழ்க்கை |
| Aquaponics | நீர் உயிரி பயிர் வளர்ப்பு |
| Deep water culture | ஆழ் நீர் வளர்ப்பு |
| Media based culture | ஊடக அடிப்படை வளர்ப்பு |
| Nutrient film technique | ஊட்டப் பொருள் படலம் (தொழில் நுட்ப முறை) வளர்ப்பு முறை |
| Aqua vertica | செங்குத்து முறை |
| Polyculture | கலப்பின மீன் வளர்ப்பு |
| Zooplankton | விலங்கு மிதவை உயிரிகள் |
| Phytoplankton | தாவர மிதவை உயிரிகள் |
| Isinglass | இஸ்எங்கிளாஸ் |
| Milch breed | கறவை இனம் |
| Drought breed | இழுவை இனம் |
| Duel purpose breed | இரு உபயோக இனம் |
| Incubator | அடைகாப்பு சாதனம் |
| Brooding | பேணிக்காத்தல் |
| Drilospheres | மண்புழு ஏற்படுத்திய குழி |
| Reeling | பின்னுதல் |
| Spinning | நூற்றல் |
| Moriculture | மல்பெரி தாவர வளர்ப்பு |
| Moulting | தோலுரித்தல் |
| Diapause type of egg | விரைவில் பொரிக்கும் முட்டைகள் |
| Non – diapause type of egg | மெதுவாகப் பொரிக்கும் முட்டைகள் |
| Stifling | புழுக்கூட்டை கொன்று பதப்படுத்துதல் |
| Brood cells | இளம்தேனீ வளர் அறை |
| Smoker | புகையூட்டி |
| Hive tool | தேன்கூட்டுக்கருவி |
| Vermiwash | மண்புழு செறிவூட்டப்பட்ட நீர் |

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## MCQs for Higher Studies

1. Taxonomically a species is .....(PMT-94)
   a. A group of evolutionary related population
   **b. A fundamental unit in the phylogeny of organisms**
   c. Classical evolutionary taxonomy
   d. A community taken into considerationa. an evolutionary base

2. A community includes ..... (CET-98)
   a. a group of same genera
   b. a group of same population
   c. a group of individuals from same species
   **d. different populations interacting with each other**

3. Carl Linnaeus is famous for .... (GGSPU-2002)
   a. coining the term 'systematics'
   **b. introducing binomial nomenclature**
   c. giving all natural system of classification
   d. all of these

4. Which form of reproduction is correctly matched? (AIIMS 2007)
   a. Euglena - transvers binary fission
   b. Paramecium - longitudinal binary fission
   **c. Amoeba - multiple fission**
   d. Plasmodium - binary fission

5. The primitive prokaryotes responsible for the production of biogas from the ruminant animals (2016)
   a. Thermoacidophiles
   **b. methanogens**
   c. Eubacteria
   d. Halophiles

6. Salient features of Arthropoda is (RPMT-2003)
   a. Aquatic and free living
   **b. Chitinous exoskeleton and jointed appendages**
   c. Radulla
   d. None of those

7. Mollusca is (JCECE-2006)
   a. Triploblastic, acoelomate
   **b. Triploblastic, coelomate**
   c. Diploblastic, acoelomate
   d. Diploblastic, coelomate

8. Osphradium of Pila globosa is (BHU 1994, 2000, 2007)
   a. Thermoreceptor
   b. Pheretima
   **c. Chemoreceptor**
   d. Tangoreceptor

9. The endocrine gland of insects, wich secretes they juvenile hormone, is (UP-CPMT 1995)
   **a. corpora allata**
   b. corpora albicans
   c. corpora myecaena
   d. all of these

10. Wuchereria is found in (UP-CPMT 2007)
    **a. lymph nodes** b. lungs
    c. eye d. gonds

    **"Turbellarians" are free living (UP-CPMT 2008)**
    **a. flatworms** b. trematodes
    c. nematodes d. cesrtodes

11. Mouth parts of housefly are
    a. Piercing and sucking type
    b. Biting and sucking type
    **c. Sponging and sucking type**
    d. biting and chewing type

12. Fasciola hepatica is (AFMC 2007)
    a. hermaphrodite. Self fertilizing
    b. hermaphrodite, cross fertilizing
    c. unisexual
    **d. both (a) and (b)**

13. Match the excretory organs listed under column I with the animals given under column II. Choose the answer which gives the correct combination of alphabets of the column.

| Column I | Column II |
|---|---|
| A Nephridia | p *Hydra* |
| B Malpighian tubules | q Leech |
| C protonephridia | r Shark |
| D kidneys | s Round worms |
| | t Cockroack |

    **a. A = q; B = t; C= s; D = r**
    b. A =s ; B= q; C= p; D= t
    c. A = t; B = q; C = s; D = r
    d. A = q; B = s ; C =t ; D= p

14. Which of the following cell type is capable of giving rise to other cell types in sponges?
    a. Pinacocytes



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**b. Archaeocytes**
c. Thesocytes
d. Collenocytes

**15.** Sea cucumbers belong to class
a. Echinoidea
**b. Holothuroidea**
c. Ophiuroidea
d. Asteroidea

**16.** Camouflage of chameleon is associated with (AIIMS1995)
a. Chromoplast
b. Chromosome
**c. Chromatophore**
d. Chromomere

**17.** Which of the following are uricotelic animals? (AIIMS2002)
a. rohu and frog
b. camela and frog
**c. lizard and crow**
d. earthworm and eagle

**18.** Which of the following does not come under the class mammals?(AIIMS2007)
a. flying fox
b. hedgehog
c. manatee
**d. lamprey**

**19.** Excretory organ in Balanoglossus are (DPMT 1991,2008)
a. nephridia
b. antennary gland
c. collar cord
**d. proboscis gland**

**20.** Reptiles share which of the following character with birds and mammals?(DPMT 1994)
**a. Amnion**
b. Homeothermy
c. Diaphragm
d. nipple

**21.** Match the names of branches of science listed under column- I with the field study given under column-II choose the choice which gives the correct combination of the alphabets. (AMU2000)

| Colum – I (Branch of Science) | | Colum –II (Field of study) | |
|---|---|---|---|
| A | Mycology | p | Study of birds |
| B | Ornithology | q | Study of worms |
| C | Herpetology | R | Study of fishes |
| D | lethylogy | S | Study of fungi |
| | | t | Study of reptiles |

**a. A=s, B=p, C=t, D=r**
b. A=q, B=s C=r, D=t
c. A=s, B=t, C=p, D=r
d. A=p, B=s, C=r, D=t

**22.** Which of the following statements is true?(AMU 2003)
a. All chordates are vertebrates
**b. All vertebrates are chordates**
c. Invertebrates possess a tubular nerve cord
d. Nonchordates a have a vertebral column

**23.** An important characteristic that Hemichordates share with chordates is (NEET 2017)
**a. Ventral tubular nerve cord**
b. Pharynx with gill slits
c. Pharynx without gill slits
d. Absence of notochord

**24.** Match the animals listed in column-I to blood listed in column-II. (KCET 2010)

| **Column-I** | **Column-II** |
|---|---|
| (P) Man | (i) Plasma and cells are colourless |
| (Q) Earth worm | (ii) Plasma colourless and nucleated RBC |
| (R) Cockroach | (iii) Plasma colourless and enucleated RBC |
| (S) Frog | (iv) Plasma red and nucleated colourless RBC |
| | (v) Plasma and RBS have haemoglobin |

**a. (P-iii), (Q-iv), (R-i), (S-ii)**
b. (P-iv), (Q-v), (R-iii), (S-ii)
c. (P-i), (Q-iv), (R-ii), (S-iii)
d. (P-v), (Q-iii), (R-i), (S-iv)

**25.** The body cells in cockroach discharge their nitrogenous waste in the haemolymph mainly in the form of (NEET 2015)
a. Calcium carbonate
b. Ammonia
**c. Potassium urate**
d. Urea



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**26.** Frog's heart when taken out of the body continues to beat for sometime. Select the best option from the following statements. (NEET 2017)
(i) Frog is a poikilotherm.
(ii) Frog does not have any coronary circulation.
(iii) Heart is "myogenic" in nature.
(iv) Heart is autoexcitable Options:
(a) Only(iv) (b) (i) and (ii)
**(c) (iii)and(iv)** (d) Only(iii)

**27.** How pepsin is differing from trypsin? (DPMT – 1993)
**a. It digests protein in acidic medium**
b. It digests protein in alkaline medium
c. It digests carbohydrate in acidic medium
d. It digests carbohydrate in alkaline medium

**28.** In human being cellulose is digested by
a. Enzyme
**b. Symbiotic bacteria**
c. Symbiotic protozoans
d. None of the above

**29.** Dental formula shows (M.P.P.M.T. -2000)
a. Structure of teeth
b. Monophyodont or diphyodont condition
**c. Number and type of teeth in both jaws**
d. Number and type of teeth in one half of both jaws

**30.** Which of the following statement is not correct ?( NEET 2015)
**a. Bruner's glands are present in the submucosa of stomach and secrete pepsinogen**
b. Goblet cells are present in the mucosa of intestine and secrete mucus.
c. Oxyntic cells are present in the mucosa of stomach and secrete Hcl.
d. Acini are present in the pancreas and secrete carboxypeptidse

**31.** Which hormones stimulate the production of pancreatic juice and bicarbonates ? (NEET 2016)
**a. Cholycystokinin and secretin**
b. Insulin and glucogon
c. Angiotensin and epinephrine
d. Gastrin and Insuline

**32.** A baby 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)
a. Canines
b. Pre- Molars
**c. Molars**
d. Incisors

**33.** Which cells of Crypts of Lieberkuhn' secrete antibacterial lysozyme ? (NEET 2017)
**a. paneth cells**
b. Zymase cells
c. Kupffer cells.
d. Argentaffin cells

**34.** Volume of air remaining in lungs after maximum respiratory effort is (J.K.C.M.E.E.1992,Har.PMT.2003)
a. Vital capacity
**b. Residual volume**
c. Total lung capacity
d. Tidal volume

**35.** Presence of large number of alveoli around alveolar ducts opening into bronchioles in mammalian lungs is
a. Inefficient system of ventilation with little of residual air
b. Inefficient system of ventilation with high percentage of residual air
c. An efficient system of ventilation with no residual air
**d. An efficient system of ventilation with little residual air**

**36.** $CO_2$ is transported
a. dissolved in blood plasma
b. As carbonic acid
c. In carbaminohaemoglobin
**d. As carbaminolaemoglobin and carbonic acid**

**37.** Bicarbonate formed inside erythrocytes moves out to plasma while chloride of plasma pass into erythrocytes. The phenomenon is called
a. Bicarbonate shift
b. Carbonation
**c. Hamburger phenomenon**
d. None of the above

**38.** Vital capacity of lung is equal to
**a. IRV+ERV+TV**



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b. IRV+ERV+TV-RV
c.IRV+ERV+TV+RV
d.IRV+ERV

**39.** Asthma may be attributed to (AIPMT/ NEET 2016)
a. bacterial infection of the lungs
**b. allergic reaction of the mast cells in the lungs**
c. inflammation of the trachea
d. accumulation of fluid in the lungs

**40.** Name the chronic respiratory disorder caused mainly by cigarette smoking: (RE-NEET 2016)
a. Emphysema
b. Asthma
c. Respiratory acidosis
d. Respiratory alkalosis

**41.** Lungs are made up of air-filled sacs, the alveoli. They do not collapse even after forceful expiration. (NEET 2017)
a. Inspiratory Reserve Volume
b. Tidal Volume
c. Expriatory Reserve Volume
**d. Residual Volume**

**42.** Regulation and initiation of heartbeat is indicated by (CBSE - 95)
a. AV Node – bundle of His muscule – SA node – purkinje fiber
b. SA Node – purkinje fiber – AV Node – Bundle of His muscle
c. Purkinje fiber – AV Node – SA node – Bundle of His muscle
**d. SA Node – AV Node – Bundle of His muscle – Purkinje fiber**

**43.** Which is the correct statement for blood ? (APMEE – 96)
a. WBC is more than RBC
**b. RBC is more than WBC**
c. RBC is less than platelets
d. Platelets is less than RBC

**44. There is no DNA in**
**a. Mature RBCs**
b. Mature spermatozoa
c. Hair root
d. Ovum

**45. What P indicates in ECG ?**
a. End of atrium systole
**b. Starting of atrium systole**
c. End of ventricle systole
d. Starting of ventricle systole

**46.** The mechanism of urine formation in nephrone involves (CPMT 1992)
a. Utrafiltration b. Secretion
c. Reabsorption
d. All of the a**bove**

**47.** Part not belonging to uriniferous tubule is
a. Glomerules
b. Henle's loop
c. Distal convoluted tubule
d. Connecting tubule

48. Angiotensinogen is a protein produced and secreted by. (AIPMT 2006)
a. Juxtaglomerular (JG) cells
b. Macula densa cells
c. Endothelial cells of blood vessels
**d. Liver cells**

**49.** Grafted kidney may be rejected in a patient due to (RE-AIPMT 2015)
a. Innate immune response
b. Humoral immune response
**c. Cell-mediated immune response**
d. Passive immune response

**50.** Which of the following statement is correct? (NEET 2017)
a. The descending limb of loop of Henle is impermeable to water.
b. The ascending limb of loop of Henle is permeable to water
c. The descending limb of loop of Henle is permeable to electrolytes.
**d. The ascending limb of loop of Henle is impermeable to water**

**51.** Ratio of which is more in red muscle? (JIPMER -2002)
**a. Myoglobin** b. Actin
c. Myosin d. Albumin

**52.** Given below is a table comparing the effects of sympathetic and parasympathetic nervous system for four features (1-4) which one feature is correctly described? (A.I.I.M.S.2006)



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| | sympathetic | parasympathetic |
|---|---|---|
| a. Salivary gland | inhibit secretion | stimulate secretion |
| **b. pupil of the eye** | **dilate** | **constricts eye** |
| c. heart | rate decreases | increases |
| d. intestinal | stimulates | inhibits peristalsis |

**53.** Which option is correct for the few statements are given for the function of cerebrum, which of few following option is shows all correct statements.

(i) to control the sensitivity, movement, memory, vocabulary etc. through the

(ii) to control the vision and adaptation through the occipital and frontal lobes

(iii) to control the contraction of voluntary muscles through the frontal lobe

(iv) to control the temperature, taste, touch, pain etc, through the parietal lobe

**a. (i),(ii),(iii)** b. (iii),(iv),(i)

c. (i),(iii),(iv) d. (i),(ii)

**54.** Match item in column-I with those given in column-II

| column-I | column-II |
|---|---|
| p. ADH | a. Pituitary |
| q. ACTH | b. mineralocorticoid |
| r. aldosterone | c. diabetes mellitus |
| s. insulin | d. diabetes inspidus |
| t. adrenaline | e. vasodilator |

a. (p – d) (q – a) (r – c) (s – b) (t – e)

b. (p – a) (q – d) (r – b) (s – c) (t – e)

**c. (p – d) (q – a) (r – b) (s – c) (t – e)**

d. (p – d) (q – b) (r – a) (s – c) (t – e)

**55.** Match the endocrine gland, given under column-I with their respective position in the body given under column-II choose the answer which gives the correct combination of alphabets of two columns: (K.C.E.T.1998)

| column-I (Endocrine glands) | column-II (Position in body) |
|---|---|
| a. pituitary gland | p. Above kidney |
| b. Thyroid gland pancreas | q. Inside |
| c. Adrenal gland | r. On larynx |
| d. Islets of langerhans | t. At the base of brain |

**a. (a – t) (b – r) (c – p) (d – q)**

b. (a – s) (b – t) (c – p) (d – q)

c. (a – p) (b – q) (c – r) (d – t)

d. (a – q) (b – s) (c – t) (d – p)

**56.** What is the function of enterogastrone?

a. It stimulates the secretion of digestive juices in the stomach

b. It stimulates the flow of pancreatic juice

c. It regulates the flow of bile

**d. It inhibits the secretion of gastric juice**

**57.** Doctors use stethoscope to hear the sound; produced during each cardiac cycle. The second sound is heard when: (RE-AIPMT-2015)

a. AV node receives signal from SA node b. AV valves

c. Ventricular wall vibrate due to gushing of blood from atria

d. **Semilunar valves close down after the blood flows into vessels from Ventricles.**

**58.** Sliding filament theory can be best explained as (NEET 2015)

a. when myofilaments slide pass each other actin filaments shorten while myosin filaments do not shorten

b.actin and myosin filaments shorten and slide pass each other

**c.actin and myosin filaments do not shorten but rather slide pass each other**

d. when myofilaments slide pass each other myosin filaments shorten while actin filaments do not shorten

**59.** A cranial nerve with maximum branches in the body is (M.P.P.M.T.1997,A.P.M.E.E 1999)

a. Auditory **b. Trigeminal**

c. Vagus d. Facial

**60.** A person undergoing prolonged fasting his urine will be found to contain abnormal quantities of (MP PMT 2005)

a. Fats b. Amino acid

c. Glucose **d. Ketones**



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# HIGHER SECONDARY FIRST YEAR BIOLOGY-ZOOLOGY PRACTICALS

## General Instruction

In order to get maximum benefit and good training it is necessary for the students to follow the following instructions.

1. The students must attend all practical classes. Each experiment in practicals has got important relevance to theory subjects.
2. Bring this practical manual to your practicals class.
3. Bring the following objects to the practicals class – Pencils (HB), Pen, Eraser, a scale and a small hand towel.
4. Record the title, date and findings of the experiment in the observation note book.
5. Carefully listen to the instructions given by your Teacher.
6. While observation slides or models draw the structure of the specimen as you see it neatly in your observation note book. Use pencil for drawing.
7. While doing experiments neither consult your neighbours nor look into their readings or observations.
8. If the object under the microscope remains without proper focusing immediately bring it to the notice of the Teacher.
9. Do not touch or lift the models or equipments kept for your identification.
10. **No need to draw diagrams from part III to VII in the record note. Relevant photograph can be collected, pasted and notes to be written.**



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## MODEL QUESTION

**TIME: 75 Minutes**

**Marks: 7½**

| | | |
|---|---|---|
| I. | Identify the given animal 'A' (picture/specimen) draw and write any 2 diagnostic features. | (1) |
| II. | Identify the given animal tissue 'B' (slide/photograph /picture) and write any 2 comments with diagram | (1) |
| III. | Identify and comment on the given bone/joint 'C'. | (1) |
| IV. | Identify the deficiency disease / disorder in the given picture/photograph "D". Write any three symptoms. | (1) |
| V. | 1. Identify the given sample solution 'E' for the presence/activity of Ammonia/Urea/Salivary amylase (Any one). | (1½) |
| | 2. Observe and write about the given experiment 'F' - Determine Your Blind Spot / Identify the sex of cockroach (Any one) | (1) |
| VI. | Identify the photograph / picture and write its economic importance 'G' | (1) |
| | **Total** | **(7½)** |

## MARKS ALLOTMENT

**TIME: 75 Minutes**

**Marks: 7½**

| | | |
|---|---|---|
| I. | Identification and Diagram - ½ ; Diagnostic features (any 2 points) -½ | (1) |
| II. | Identification and Diagram - ½; Comments (any 2 points) – ½ | (1) |
| III. | Identification – ½; Comments – ½ (any two points) | (1) |
| IV. | Identification – ½; Symptoms – ½ (any three points) | (1) |
| V. | 1. Procedure – ½; Experiment- ½ ; Result - ½ | (1½) |
| | 2. Procedure - ½; Result - ½ / Identification - ½; Reason - ½ | (1) |
| VI. | Identification – ½; Economic importance – ½ (any two points) | (1) |
| | **Total** | **(7½)** |

**NOTE: Any relevant points, diagnostic features and comments apart from those provided in the practical manual must also be considered for evaluation.**



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# CONTENT

| QUESTION NO-I (A) | |
|---|---|
| **S.No.** | **Preserved Specimens/Photographs** |
| 1. | Spongilla |
| 2. | Sea Anemone |
| 3. | Pleurobrachia |
| 4. | Tapeworm |
| 5. | Ascaris |
| 6. | Earthworm |
| 7. | Cockroach |
| 8. | Pila (Apple Snail) |
| 9. | Starfish |
| 10. | Balanoglossus |
| 11. | Rat |

| QUESTION NO-II (B) | |
|---|---|
| **S.No.** | **Prepared Slides/Pictures/Photographs** |
| 12. | Squamous Epithelium |
| 13. | Columnar Epithelium |
| 14. | RBC |
| 15. | WBC |

| QUESTION NO-III (C) | |
|---|---|
| **S.No.** | **Models/Pictures/Photographs (Human)** |
| 16. | Humerus |
| 17. | Pelvic girdle |
| 18. | Rib cage (True ribs, Pseudo ribs, Floating ribs) |
| 19. | Ball and Socket joint |



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| QUESTION NO-IV (D) | |
|---|---|
| **S.No.** | **Pictures/Photographs** |
| 20. | Addison's disease |
| 21. | Marasmus |
| 22. | Exopthalmic Goitre |

| QUESTION NO-V (E and F) | |
|---|---|
| **S.No.** | **Experiments** |
| 23. | Test for Ammonia |
| 24. | Test for Urea |
| 25. | Test for Salivary Amylase |
| 26. | Determine Your Blind Spot |
| 27. | Identify the sex of cockroach (using hand lens) |

| QUESTION NO-VI (G) | |
|---|---|
| **S.No.** | **Photographs/pictures** |
| 28. | Kangayam bull |
| 29. | Aquaponics |
| 30. | Honey bee |
| 31. | Bombyx mori |



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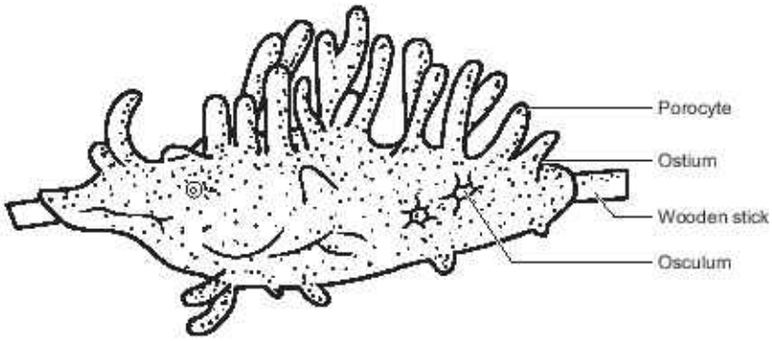
**I. Identify the given animal 'A' (picture/specimen) and write any 2 diagnostic features with diagram.**

## 1. SPONGILLA

**Identification:**

The given specimen is identified as ***Spongilla.*** It belongs to the Phylum **Porifera.**



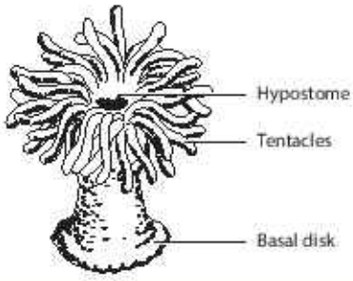

**Reasons for identification:**

- It is a pore bearing animal.
- It is an aquatic multicellular animals with cellular level of organization.
- It possess a canal system where the water enters into the central cavity, spongocoel through minute pores called ostia.
- The spongocoel is lined with special flagellated cells called choanocytes.

## 2. SEA ANEMONE

**Identification:**

The given specimen is identified as **Sea anemone.** It belongs to the Phylum **Cnidaria.**




**Reasons for identification:**

- Sea anemone is diploblastic and the first group of animals to exhibit tissue level of organization.
- It has stinging cells called nematocysts on their tentacles.
- The central vascular cavity is called coelenteron which opens out through the hypostome.
- The nervous system is formed of a diffused nerve net.
- Cnidarians exhibit 2 basic body forms, polyp and medusa.
- The polyp represents the asexual generation and the medusa represents the sexual generation (Alternation of generation).
- Development includes a ciliated Planula larva.



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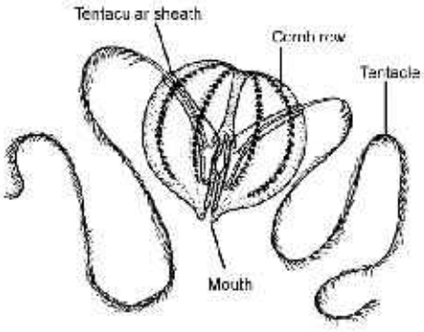
## 3. PLEUROBRACHIA

**Identification:**

The given specimen is identified as **Pleurobrachia.** It belongs to the Phylum **Ctenophora.**



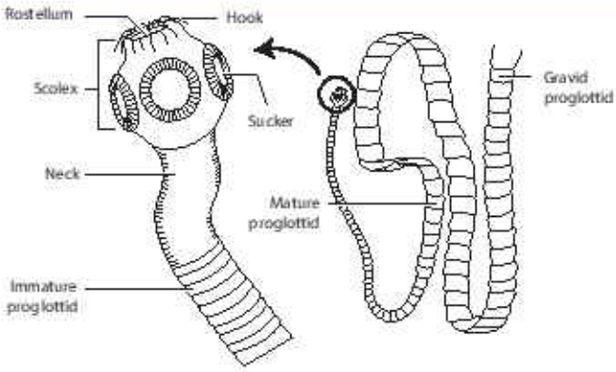

**Reasons for identification:**

- Pleurobrachia are exclusively marine, biradially symmetrical, diploblastic animals with tissue level of organisation.
- They have eight external rows of ciliated comb plates (comb jellies) which help in locomotion.
- Bioluminescence is well marked in ctenophores.
- They lack nematocysts but possess special cells called colloblasts which help in food capture.
- They reproduce only by sexual means. Fertilization is external and development is indirect and includes a larval stage called cydippid larva.

## 4. TAPEWORM

**Identification:**

The given specimen is identified as **Tapeworm.** It belongs to the Phylum **Platyhelminthes.**




**Reasons for identification:**

- It is a dorsoventrally flattened, triploblastic, acoelomate animal with organ level of organization.
- It is an endoparasite.
- Hooks and Suckers act as organs of attachment.
- Excretion is carried out by specialized cells called flame cells.



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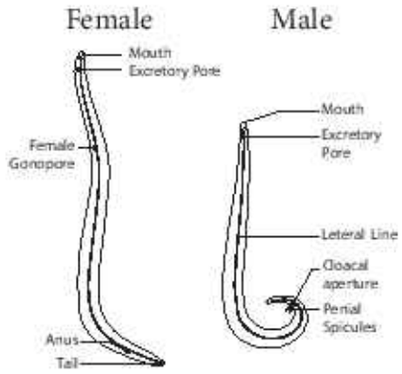
## 5. ASCARIS



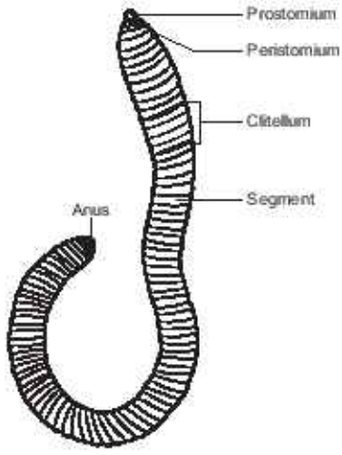

**Identification:**

The given specimen is identified as ***Ascaris.*** It belongs to the Phylum **Aschelminthes.**

**Reasons for identification:**

- Ascaris is a roundworm because it is circular in cross section.
- It is a triploblastic, pseudocoelomate animal.
- The unsegmented body is covered by a protective layer called cuticle.
- Alimentary canal is complete with a well developed mouth, pharynx and anus / cloaca.
- Sexes are separate and exhibit sexual dimorphism.
- Excretion is carried out through Rennet glands.
- It is an endoparasite.

## 6. EARTHWORM




**Identification:**

The given specimen is identified as **Earthworm.** It belongs to the Phylum **Annelida.**

**Reasons for identification:**

- Earthworm is a triploblastic, schizocoelomate animal.
- Its elongated body is segmented.
- The longitudinal and circular muscles in the body wall help in locomotion.
- The circulatory system is of closed type and the respiratory pigment haemoglobin is present in the plasma.
- It is a hermaphrodite animal.



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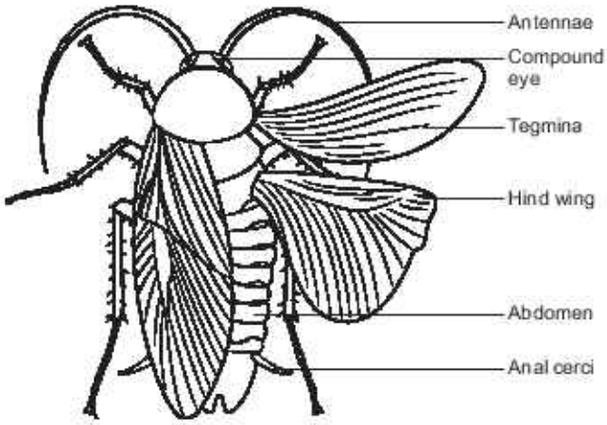
## 7. COCKROACH

**Identification:**

The given specimen is identified as **Cockroach.** It belongs to the Phylum **Arthropoda.**



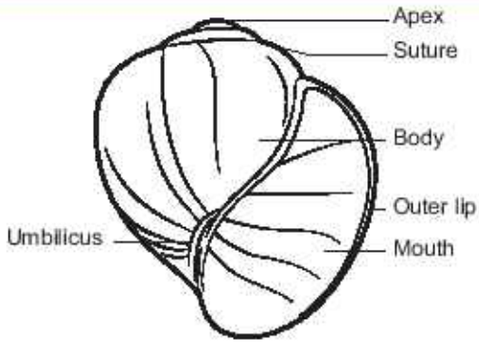

**Reasons for identification:**

- It is a triploblastic, schizocoelomate animal.
- It has jointed appendages which are used for locomotion.
- Body is covered by a chitinous exoskeleton which is shed off periodically by a process called moulting/ecdysis.
- Respiration is through trachea.
- Excretion is by malpighian tubules.

## 8. PILA

**Identification:**

The given specimen is identified as ***Pila.*** It belongs to the Phylum **Mollusca.**




**Reasons for identification:**

- It is a triploblastic, coelomate animal.
- Body is covered by a calcareous shell.
- Internal organs are covered by a soft layer of skin called mantle.
- Respiration is carried out through a number of feather like gills called ctenidia.
- The mouth contains a rasping organ called radula.
- Excretory organs are the nephridia.
- Blood contains a copper containing respiratory pigment, haemocyanin.
- Their development includes a Veliger larva.



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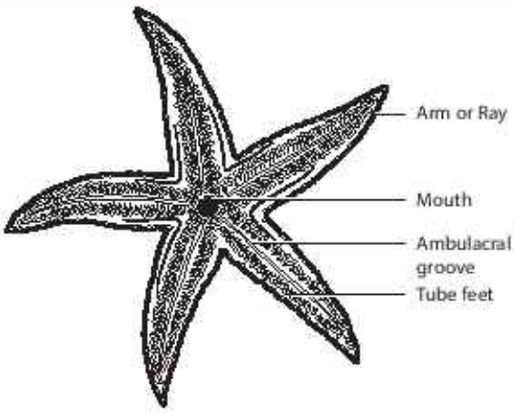
## 9. STARFISH

**Identification:**

The given specimen is identified as **Starfish**. It belongs to the Phylum **Echinodermata.**



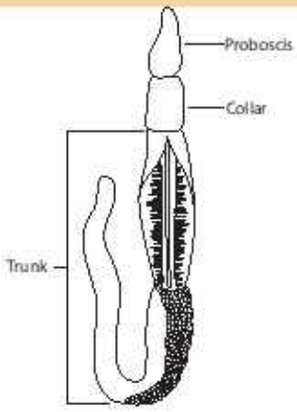

**Reasons for identification:**

- It has spiny skin.
- It has Water vascular system.
- Tube feet help in locomotion.
- The adults are radially symmetrical.
- Larvae are bilaterally symmetrical
- Circulatory system is open type without heart and blood vessels.
- It exhibits autotomy with remarkable power of regeneration.
- Bipinnaria is the first larva in its development.

## 10. BALANOGLOSSUS

**Identification:**

The given specimen is identified as ***Balanoglossus.*** It belongs to the Phylum **Hemichordata.**




**Reasons for identification:**

- It is a connecting link between invertebrates and chordates.
- The body is divided into anterior proboscis, a short collar and a long trunk.
- It is a marine and bilaterally symmetrical animal.
- Excretion is by a single proboscis gland.
- Development is indirect with a free swimming Tornaria larva.
- Presence of buccal diverticulum is the significant character of this animal.



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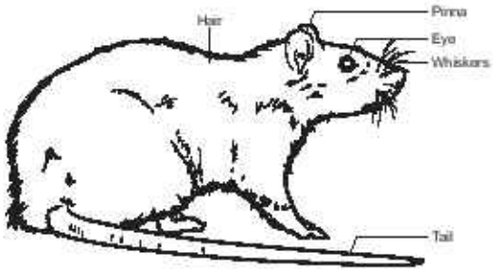
## 11. RAT

**Identification:**

The specimen kept for identification is the **Rat**. It belongs to the Phylum Chordata, Subphylum Vertebrata and Class **Mammalia**.




**Reasons for identification:**

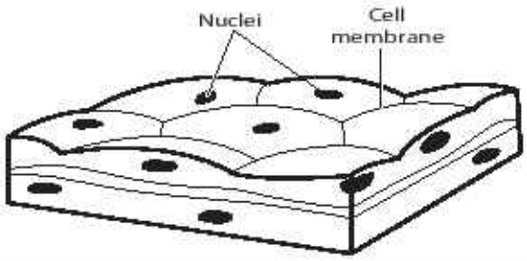
- Presence of mammary gland is the unique feature of mammals.
- Pair of pinnae or external ears are present.
- Heart is 4 chambered.
- Kidneys are metanephric and are ureotelic animal
- Rats are homeothermic and viviparous.

**II. Identify the given animal tissue 'B' (slide/photograph/picture) and give any 2 comments with diagram.**

## 12. SQUAMOUS EPITHELIUM

**Identification**

The given slide/picture is identified as **squamous epithelium.**



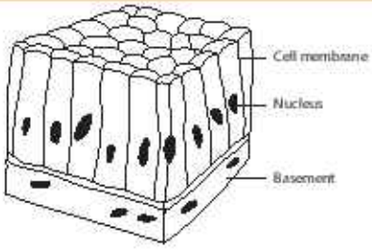

**Comments:**

- Squamous epithelium is a type of simple epithelium
- It is made of a single thin layer of flattened cells with irregular boundaries.
- Found in cheek, kidney glomeruli, air sacs of lungs, lining of heart and blood vessels.
- It is involved in diffusion and filtration.

## 13. COLUMNAR EPITHELIUM

**Identification:**

The given slide/ picture is identified as **columnar epithelium**.



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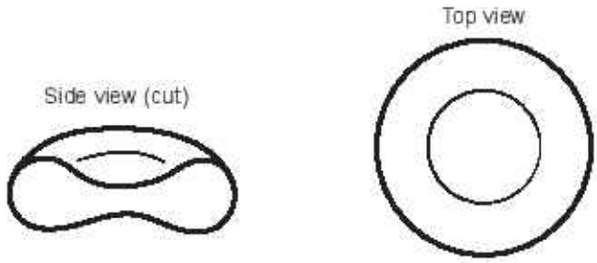
**Comments:**

- Columnar epithelium is a type of simple epithelium.
- It is composed of a single layer of tall cells with round oval nuclei at the base.
- It lines the digestive tract from the stomach to rectum.
- It is involved in absorption, secretion of mucus, enzymes and other substances.

## 14. RBC

**Identification:**

The given slide is identified as
**Red blood corpuscles (Erythrocytes).**



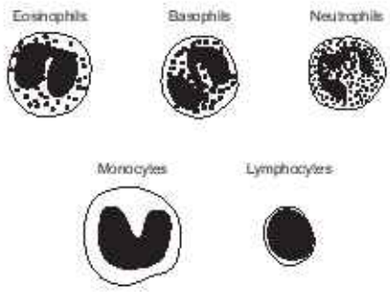

**Comments:**

- The red colour of the RBC is due to the presence of a respiratory pigment, haemoglobin.
- Haemoglobin plays an important role in the transport of respiratory gases.
- RBC's are produced in the red bone marrow of large bones and are destroyed in the spleen and liver.
- The average life span of an RBC in a healthy individual is about 120 days.

## 15. WBC

**Identification:**

The given slide is identified as
**white blood corpuscles (leucocytes).**




**Comments:**

- Leucocytes are colourless, amoeboid, nucleated cells devoid of haemoglobin and other pigments.
- Based on the presence (or) absence of granules, WBC's are divided into two types, granulocytes (Neutrophil, Basophil and Eosinophil) and agranulocytes (Lymphocyte and Monocyte).
- WBCs are involved in protecting the body against pathogens.
- The life span of a white blood cell ranges from 13 to 20 days. These are destroyed in the lymphatic system.



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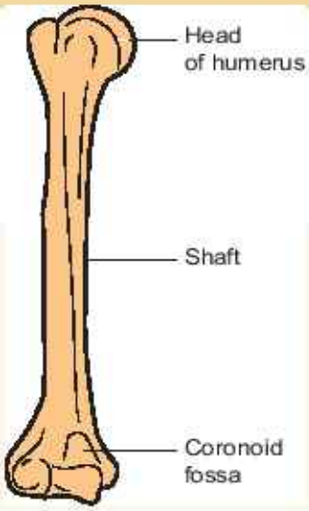
## III. Identify and comment on the given bone/joint 'C'.

### 16. HUMERUS BONE



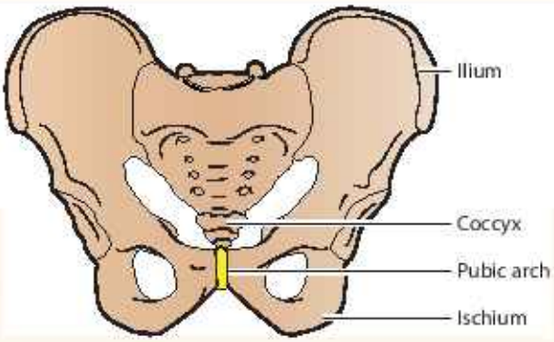

**Identification:**

The given specimen/picture kept for identification is the **human humerus bone.**

**Comments:**

- It is found between the shoulder and elbow.
- The head of humerus articulates with the glenoid cavity of the pectoral girdle.
- The other end of the humerus articulates with the two forearm bones namely the radius and ulna.

### 17. PELVIC GIRDLE



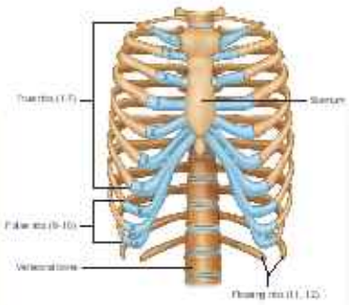

**Identification:**

The given specimen kept for identification is the **human pelvic girdle**.

**Comments:**

- It is composed of 2 hip bones called coxal bones together with the sacrum and coccyx.
- It is a heavy structure specialized for weight bearing.
- Each coxal bone consists of 3 fused bones namely the ilium, ischium and pubis.
- At the point of fusion of the 3 bones, a socket called acetabulum is present.
- The acetabulum helps in the articulation of the femer.

### 18. RIB CAGE



**Identification:**

The given specimen kept for identification is the **human ribcage**.

**Comments:**

- There are 12 pairs of ribs.
- Each rib is connected dorsally to the vertebral column and ventrally to the sternum.



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- The first 7 pairs of ribs are called true ribs.
- The 8th, 9th and 10th pairs of ribs do not articulate with the sternum but is joined with the 7th rib. They are called as false ribs.
- The last 11th and 12th pairs of ribs are not connected with sternum. They are called as floating ribs.

## 19. BALL AND SOCKET JOINT

**Identification:**

The specimen/model/picture kept for identification is the **Ball and Socket joint.**

**Comments:**

- It is a type of synovial joint.
- In this type, the ball shaped rounded bone fits into the cup like depression of another bone.
- It allows multi directional movements and rotation.
- This type of joints are found between the upper arm and shoulder and between the upper leg and hip.

## IV. Identify the deficiency disease/disorder 'D' in the given picture/photograph and write any 3 symptoms.

## 20. ADDISON'S DISEASE

**Identification:**

The picture kept for identification depicts **Addison's disease.**

**Comments:**

- It is a disorder in which the adrenal glands do not produce enough hormones.
- It is caused due to hyposecretion of glucocorticoids and mineralocorticoids from the adrenal cortex.
- Muscular weakness, low BP, loss of appetite, vomiting, hyper pigmentation of the skin are the symptoms of Addison's disease.



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## 21. MARASMUS

**Identification:**

The picture kept for identification depicts **Marasmus.**

**Comments:**

- It is a disorder due to protein deficiency in children.
- It is an acute form of protein malnutrition.
- This is due to a diet with inadequate carbohydrate and protein.
- Diarrhoea and emaciation are the symptoms of this disease.

## 22. EXOPTHALMIC GOITRE

**Identification:**

The picture kept for identification depicts **Exopthalmic goitre**.

**Comments:**

- The hyper function of thyroid gland results in exopthalmic goitre.
- It is also called as thyrotoxicosis or Grave's diseases.
- It is characterized by increased BMR (50% - 100%) with increased pulmonary ventilation and protrusion of eye balls, elevated respiratory and excretory rate with increased body temperature.

**V. 1. Identify the given sample solution 'E' f or the presence/activity of salivary amylase/ ammonia/urea.**

**2. Observe and write about the given 'F' experiment / specimen / picture. Determine Your Blind Spot / Identify the sex of cockroach**

## 23. TEST FOR AMMONIA

**Aim :** To test the presence of Ammonia in the given sample solution.

**Materials Required:** Test tube, Test tube holder and Stand.

**Solution Required:** Sample solution and Nessler's Reagent.

**Procedure:**

1) Take 2ml of the given sample solution in a clean test tube.
2) Add few drops of Nessler's reagent in the test tube containing sample solution.
3) Appearance of dark yellow/brown colour confirms the presence of Ammonia in the given sample.

**Inference:** It is inferred that ammonia is present in the given solution.



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## 24. TEST FOR UREA

**Aim:** To test the presence of urea in the given sample solution.

**Material Required:** Test tube, test tube holder and pipette / dropper.

**Required Reagents:** Phenol red and Horse gram powder (which contains the enzyme urease), sample solution.

**Procedure:**

1. Take 2 ml of sample solution in a clean test tube.
2. Add few drops of phenol red in the test tube containing sample solution.
3. Add a pinch of horse gram powder in the test tube and mix well.
4. Appearance of dark pinkish colour indicates the presence of urea in the given sample.

**Inference:** It is confirmed that the given sample solution contains urea.

## 25. TEST FOR SALIVARY AMYLASE

**Aim:** To test the presence of Amylase enzyme in the human saliva.

**Materials Required:** Test tubes, Potato, Mortar and Pestle.

**Solutions Required:** Iodine solution, Human Saliva.

**Procedure:**

1) Take mashed potato extract in a test tube and add a few drops of iodine. Note the appearance of bluish black (dark blue) colour.
2) Collect a few drops of saliva in a clean test tube and transfer the saliva into the test tube containing the sample solution and shake well.
3) Leave the sample undisturbed for 5 minutes. The solution gradually becomes colourless.
4) This confirms the presence of amylase in the human saliva.

**Inference:** It is inferred that human saliva contains the enzyme amylase that digests the starch.

## 26. DETERMINE YOUR BLIND SPOT

**Procedure:**

1. Cover your left eye.
2. Hold the figure shown about 50 to 60 cm away from your face and directly in front of your right eye.
3. Stare at the cross in the shown figure. You can also see the circle.
4. Continue to stare and slowly bring the figure nearer to your eye.



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5. Note the point at which the circle will seem to disappear. This is your blind spot.
6. Record the distance.
7. Test your other eye in a similar manner, but focus on the circle and watch for the cross to disappear.

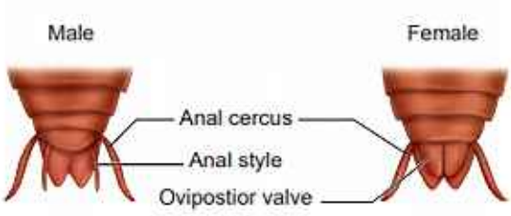
**Result:**

1) Blind spot of my right eye is _____cm
2) Blind spot of my left eye is_____cm

**27. Identify the sex of the cockroach by observing the given specimen/picture /model and write two reasons.**

**Identification :**

**Reasons:**




## VI. Identify the photograph / picture 'G' and write its economic importance

**28. KANGAYAM BULL**

**Identification:**

The photograph kept for identification is **Kangayam bull**.

**Economic importance:**

1. It originated from the place called Kangayam in Tamilnadu.
2. This breed is meant for pulling carts, ploughing fields etc.
3. This breed is exclusively used in the traditional game called Jallikattu (manju virattu) in Tamilnadu.
4. It is a best example for a draught breed.

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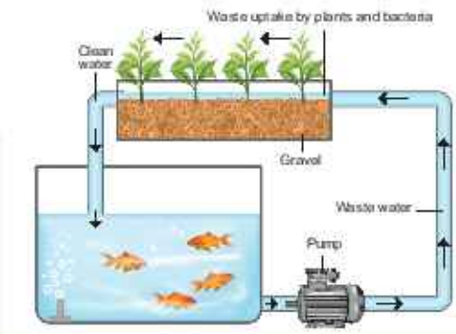
## 29. AQUAPONICS

**Identification:**

The photograph kept for identification is **Aquaponics**.




**Economic importance:**

1. Aquaponics is a technique which is a combination of Aquaculture and Hydroponics.
2. It maintains balanced ecosystem by recycling the waste and excretory products produced by the fish.
3. Cultivable fishes like Tilapia, Gold fish, Koduva etc. are cultured in aquaponics.
4. Plants like tomato, pepper and cucumber can be cultivated in this method.

## 30. HONEY BEE

**Identification:** The photograph kept for identification is **Honey bee**.

**Economic importance:**

1. The chief products of bee keeping industry are honey and bee wax.
2. Honey is the healthier substitute for sugar.
3. It is used as an antiseptic, laxative and as a sedative.
4. Bee wax secreted by the abdomen of the worker bee is used for making candles, polishes for floors and furniture etc.

## 31. Bombyx mori

**Identification:**

The photograph kept for identification is silkworm **Bombyx mori**

**Economic importance:**

1. Silk fibre produced by this silkworm is called mulberry silk.
2. It mainly feeds on mulberry leaves
3. It is used in manufacturing silk cloths, fishing fibres, tyres of racing cars, in medical dressings, parachutes etc.



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# Biology - Zoology – Class XI

## List of Authors and Reviewers

### Advisory Committee Members

**Dr. Sultan Ahmed Ismail**
Scientist
Eco-science Research Foundation, Chennai.

**Dr. P.K. Kaleena**
Associate Professor
Department of Zoology, Presidency College, Chennai.

### Authors

**Ms. P. Maheswari**
Lecturer in Zoology
DIET, Uthamapalayam, Theni District.

**Dr. S. Ganesapandian**
Biology PGT
GHSS Sathankulam, Ramanathapuram Dist.

**Dr. J. Savarimuthu Michael**
PG Assistant in Zoology
Carmel Higher Secondary School, Nagercoil, Kanyakumari Dist.

**Mr. M. Sivaguru**
Biology PGT
Sri Ramakrishna Vidyasala HSS, Chidambaram, Cuddalore Dist.

**Mrs. M. Anusua Catherina Chelliah**
Biology PGT
Presidency GHSS
Egmore, Chennai Dist.

**Mr. Alen Godfrey R. Jose**
Biology PGT
MCC Mat. HSS, Chetpet, Chennai.

**Mr. S. Maheswaran**
Biology PGT
GHSS, Johilpatti, Virudhunagar Dist.

**Mr. L. Sivan Pillai**
Biology PGT
Bharath Senior Secondary School, Adyar, Chennai.

**Mrs. T. Devikala**
Biology PGT
DAV Girls Senior Secondary School, Gopalapuram, Chennai.

### Domain Experts

**Dr. P. Sarala**
Associate Professor, Department of Zoology, Quaid-e- Millath College for Women, Chennai.

**Dr. B. Meena**
Associate Professor, Department of Zoology, Presidency College, Chennai.

**Dr. E. Malathi**
Associate Professor, Queen Mary's College, Chennai.

**Dr. (Sr.) R. Regina Mary**
Assistant Professor
Dept. of Zoology, Auxilium College, Katpadi, Vellore.

**Dr. S. Winkins Santosh**
Asst. Professor
PG and Research Dept. of Advanced Zoology and Biotechnology, Govt. Arts College, Nandanam, Chennai.

## Art and Design Team

### Illustrator

Manohar, Gopu Rasuvel, Prabha Madhavarajan, Divya, Santhanam
Art Teachers,
Government of Tamil Nadu.
Students, Government College of Fine Arts, Chennai & Kumbakonam.

### Layout

Yesurathinam
Ashok Kumar
Jerald wilson
Pakkirisamy Annadurai

### In-House QC

Kamatchi Balan Arumugam
Rajesh Thangappan

### Co-ordination

Ramesh Munisamy

### Subject Coordinator

**Dr. S. Shameem**
Deputy Director
State Council of Educational Research and Training, Chennai

### Coordinators

**Dr. V.T. Shanthi**
Senior Lecturer, DIET, Tirur.

**Mrs. B. Selvi**
Lecturer,
SCERT, Chennai

### Reviewers

**Dr. Dinesh Kumar**
Reader
NCERT, New Delhi

**Dr. Vareishang Tangu**
Assistant Professor in Zoology RIE, (NCERT) Mysore, Karnataka

**Dr. Chitralekha Ramachandran**
Professor (Rtd)
Stella Maris College, Chennai.

**Dr. S. Sambasivam**
Professor (Rtd),
Presidency College, Chennai.

**Dr. Sivashankar**
Professor
Royapettah Govt hospital,
Royapettah, Chennai - 14.

**Dr. S.S. Subramanian**
Principal & H.O.D (Physiotherapy)
Sree Balaji College of Physiotherapy & Rehabilitation Centre, Chennai.

**Dr. S. Dinakaran**
Associate Professor & Head
Dept. of Zoology, The Madhura College, Madurai.

### Career Guidance

**Dr. T. Sankara Saravanan**
Deputy Director
Tamil Nadu Textbook and Educational services Corporation

### QR Code Management Team

**R. JAGANATHAN , SGT,**
PUMS - Ganesapuram,
Polur , Thiruvannamalai.

**J.F. Paul Edwin Roy, B.T. Asst,**
PUMS -Rakkipatty, Salem.

### Translators

**Dr. S. Muthazhagu**
Associate Professor (Rtd)
A.A Govt Arts college, Cheyyar.

**Dr. N. Kumanan**
Biology PGT
ADW, GHSS. Mullangurichi, Pudukkottai Dist.

**Mrs. R. Amali**
Biology PGT
GHSS, Panruti, Cuddalore.

**Mr. R. Nagendaran**
Biology PGT
GHSS, Nathamedu, Dharmapuri Dist.

### Content Readers

**Dr. J. Ebanasar**
Associate Professor & Head
Dept. of zoology and wildlife Biology, Govt. Arts College, Ooty, The Nilgiris Dist.

**Dr. R. Raja Jeya Sekar**
Asst Professor
PG and Research Department of Zoology, South Travancore, Hindu College, Nagercoil, Kanyakumari Dist.

**Dr. Mazher Sulthana**
Associate Professor in Zoology (Rtd)
Presidency College, Chennai

**Dr. Usha**
Associate Professor in Zoology (Rtd)
Presidency College, Chennai

**Dr. R. Saravanan**
Assistant Professor in Zoology
Dr. Ambedkar Govt. Arts College, Vyasarpadi, Chennai

**Dr. N. Sarojini**
Assistant Professor in Zoology
Bharathi Women's College, Chennai

**Mr. S. Thiyagarajan**
Biology PGT
G.H.S.S. Gomangalampudhur, Pollachi.

**Mrs. A. Sudha**
Biology PGT
Municipal GHSS, Pollachi, Coimbatore Dist.

**Mrs. G. Gomathi**
Biology PGT
Govt GHSS, Tharamangalam, Salem Dist.

**Mr. L. Murugaiyan**
Biology PGT
St. Joseph HSS, Vichoor, Pudukottai Dist.

**Mr. G. Venkateswaran**
Biology PGT
GHSS, Alivalam, Thiruvarur Dist.

**Mrs. Puah G. Prime Rose**
Biology PGT
GHSS, Thittuvizhai, Kanyakumari Dist.

**Mrs. A. Packialakshmi**
Biology PGT
GHSS, Thangachimadam, Ramanathapuram Dist.

### ICT Coordinator

**Mr. A. Ajay**
SGT, PUMS, Nanthimangalam, Kumaratchi Block, Cuddalore Dist.

**This book has been printed on 80 G.S.M. Elegant Maplitho paper.**
**Printed by offset at:**



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