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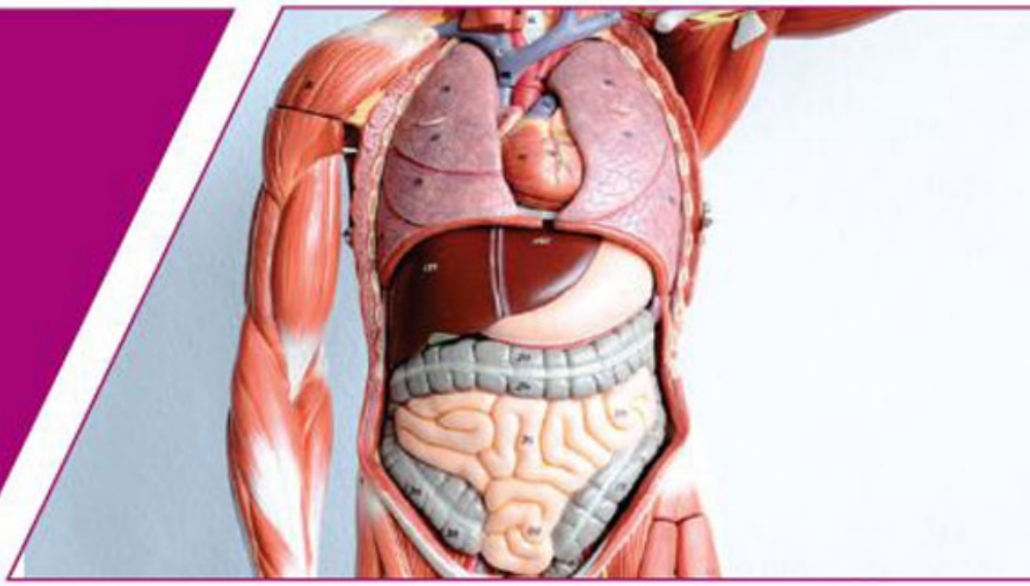
FIRST YEAR B. PHARM | SEMESTER-I

HUMAN ANATOMY AND PHYSIOLOGY-I

Dr. S. B. BHISE

Dr. A. V. YADAV



NIRALI PRAKASHAN
ADVANCEMENT OF KNOWLEDGE

A Text Book Of

HUMAN ANATOMY AND PHYSIOLOGY - I

As Per PCI Regulations

FIRST YEAR B. PHARM.

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Preface

Pharmacy Council of India, New Delhi, the apex regulatory body controlling Pharmacy Profession in the country has come out with the regulations viz. Bachelor of Pharmacy (B. Pharm) course regulations 2014 for B. Pharm degree program based on CBSC pattern. Human Anatomy and Physiology - I has been included in the course of study for Semester I. This course has been designed to provide basic knowledge required to understand the various disciplines of Pharmacy.

Especially the understanding and knowledge of Pharmacology makes the Pharmacist a vital member of the health care team. The knowledge of Anatomy and Physiology is the pre-requisite for initiating the study of Pharmacology. Keeping this requirement in mind; an attempt has been made here to provide the students with the necessary information on Human Anatomy and Physiology.

Being a basic subject of Medical Sciences large number of books are available on this subject that give minute details in voluminous form. We felt it necessary to scan the voluminous information and gather the relevant information that may cater to the needs of students of first year Bachelor of Pharmacy.

Though in general, this book may prove useful to the students of Pharmacy, Nursing and other Paramedical Sciences; in particular it complies with the requirements of First Year B. Pharm. students. We shall highly appreciate constructive suggestions including criticism from the readers.

We sincerely thank Shri. V. S. Sandansive, AM, CTC, Kalayoga Arts, Asoda Jalgaon for drawing figures in this book and for preparing the cover design of this book. Our sincere thanks to Shri. D. K. Furia, Publisher, Prof. S. B. Gokhale and the staff members of Nirali Prakashan for timely publishing the book.

August 2017

Dr. S. B. Bhise
Dr. A. V. Yadav

Syllabus

Unit I **10 Hours**

1. Introduction to Human Body

Definition and scope of anatomy and physiology, levels of structural organization and body systems, basic life processes, homeostasis, basic anatomical terminology.

2. Cellular Level of Organization

Structure and functions of cell, transport across cell membrane, cell division, cell junctions. General principles of cell communication, intracellular signaling pathway activation by extracellular signal molecule, Forms of intracellular signaling:

(a) Contact-dependent

(b) Paracrine

(c) Synaptic

(d) Endocrine

3. Tissue Level of Organization

Classification of tissues, structure, location and functions of epithelial, muscular and nervous and connective tissues.

Unit II **10 Hours**

4. Integumentary System

Structure and functions of skin.

5. Skeletal System

Divisions of skeletal system, types of bone, salient features and functions of bones of axial and appendicular skeletal system

Organization of skeletal muscle, physiology of muscle contraction, neuromuscular junction.

Joints

Structural and functional classification, types of joints movements and its articulation

Unit III **10 Hours**

6. Body Fluids and Blood

Body fluids, composition and functions of blood, hemopoeisis, formation of hemoglobin, anemia, mechanisms of coagulation, blood grouping, Rh factors, transfusion, its significance and disorders of blood, Reticulo endothelial system.

7. Lymphatic System

Lymphatic organs and tissues, lymphatic vessels, lymph circulation and functions of lymphatic system

Unit IV **08 Hours**

8. Peripheral Nervous System

Classification of peripheral nervous system: Structure and functions of sympathetic and parasympathetic nervous system.

Origin and functions of spinal and cranial nerves.

9. Special Senses

Structure and functions of eye, ear, nose and tongue and their disorders.

Unit V **07 Hours**

10. Cardiovascular System

Heart anatomy of heart, blood circulation, blood vessels structure and functions of artery, vein and capillaries, elements of conduction system of heat and heart beat, its regulation by autonomic nervous system, cardiac output, cardiac cycle. Regulation of blood pressure, pulse, electrocardiogram and disorders of heart.

***

CONTENT

UNIT III

UNIT IV

UNIT V

***

UNIT I

Chapter ... 1

INTRODUCTION TO HUMAN BODY

♦ **LEARNING OBJECTIVES** ♦

- *To understand simple concepts of complex multicellular organisation of human body.*
- *To study and appreciate the relationship between human Anatomy, Physiology and Pharmacology.*
- *To understand the co-ordinated functioning at the biochemical, cellular and tissue level of organisation.*
- *To study the basic life processes and their maintenance.*
- *To acquire the fundamental knowledge of human body required further for understanding pharmaceutical principles.*

1.1 DEFINITION AND SCOPE OF ANATOMY AND PHYSIOLOGY

The human being is a very complex multicellular organism. The study of human body is divided under two major headings, i.e. Anatomy and Physiology.

(1) Anatomy: It is the study of structure of the body as a whole, as also the study of its individual parts and their relations to one another.

(2) Physiology: It is concerned with the way in which various organs function and how they are integrated to produce a co-ordinated action of the whole body.

A cell is the smallest functional unit of an organism. Groups of cells having the same physical characteristics and performing similar specialized function, are described as tissues. Various types of tissues join to form an organ, and a system consists of a number of such organs and tissues. Although each system carries out one or more of the vital functions of the body, none of the systems can exist in isolation because of specialization of cells.

Different body organs have different structures. The variation in structures is due to the variations in the functions they perform. For example, the bony skeleton provides support to various organs; therefore, bones are rigid in structure. The heart has to pump blood through the blood vessels; hence walls of the heart are highly muscular. In the alveoli of lungs,

transfer of gases across the wall is continuous; therefore the alveolar membrane is very thin. The small intestine is responsible mainly for digestion and absorption of food; hence it contains many secretions and villi which assist in effective absorption.

1.2 LEVEL OF STRUCTURAL ORGANISATION AND BODY SYSTEM

Before discussing these specialities in structures, various systems are briefly described below:

The human body consists of the following systems:

(1) Skeletal system: It consists of the bony framework. It acts as the supporting structure and offers protection to the internal organs.

(2) Muscular system: The muscles and tendons are attached to the bones. They help to give the body its shape and power to move at will.

(3) Nervous system: It serves to control and to co-ordinate the functions of various parts of the body. It also makes an individual keenly aware of the environments in which (s)he lives.

(4) Circulatory system: It distributes the essential supply of oxygen and nutrient materials to all the parts of the body and removes the waste products, from the body.

(5) Respiratory system: It supplies the body with oxygen from the atmosphere and it disposes of carbon dioxide and water vapours from the body. It comprises of lungs and bronchi.

(6) Digestive system: It is concerned with the intake of food, its digestion and absorption. It comprises of the digestive tract from the mouth to the anus.

(7) Excretory system: It removes waste products from the body. It comprises organs like kidneys, large intestine, skin, and lungs.

(8) Endocrine system: It produces certain chemical substances through endocrine glands, which are termed as hormones. The hormones regulate the body processes.

(9) Reproductive system: It is a system of organs concerned with reproduction, especially sexual reproduction.

All these systems work as an integrated whole producing the co-ordinated efforts necessary for the maintenance of health and well-being.

The human body is built round the bony framework or skeleton which consists of the following parts:

(a) The head and neck
(b) The trunk divided into thorax, abdomen, and pelvis;
(c) The limbs, both upper and lower.

For the simplicity of description, the body is divided into four cavities, i.e.

(1) Cranial (2) Thoracic
(3) Abdominal and (4) Pelvic.

The *cranial cavity* encloses the brain. Its boundaries are formed by the bones of the skull. *The thoracic cavity* contains lungs, heart, trachea; bronchi, oesophagus, aorta; superior and inferior vena cava. The boundaries of thoracic cavity are formed by ribs, sternum and supporting muscles. *The abdominal cavity* is home to stomach, small intestine, most of the

large intestine, liver; gall bladder, pancreas, spleen; kidneys, upper part of the uterus and suprarenal glands. *The abdominal cavity* is lined by a dome-shaped muscle called diaphragm on the superior side and lumbar vertebrae and muscles on the posterior side. On the inferior side, it is continuous with the *pelvic cavity*. The pelvic cavity contains lower part of the large intestine, few loops of small intestine, urinary bladder, and lower part of the ureter: urethra and reproductive organs. The pelvic cavity is lined by pelvis, sacrum and coccyx and muscles of the pelvic floor.

Following are some of the terms used for the anatomical description of the various parts of the skeletal system.

- **Anatomical position:** This is the upright position of the human body with the head facing forward, the arms at the sides with palms of the hands facing forward and the feet together.
- **Median plane:** When the body in the anatomical position is divided longitudinally in two equal parts, it is divided in the median plane. Any structure towards the midline is termed 'medial' and the structure away from the midline is called as 'lateral'.
- **Proximal and distal:** These terms are used for describing bones of the limbs. The proximal end is nearest to the point of attachment of the limb and the distal end is the farthest.
- **Anterior or ventral:** It indicates that the part being described is nearer to the front of the body.
- **Posterior or dorsal:** It indicates that the part being described is nearer to the back of the body.
- **Superior:** It indicates a structure near the head.
- **Inferior:** It indicates a structure away from the head.
- **Border:** It is a ridge of bone which separates two surfaces.
- **Spine, spinous process or crest:** It comprises series of vertebrae extending from skull to the small of the back.
- **Tubercle:** These are small, rough bony projections for attachment of muscles or ligaments.
- **Fosse:** It is a depression or a hollow.
- **Foramen:** It is a hole in a structure.
- **Sinus:** It is a cavity within a bone.
- **Meatus:** It is a tube-shaped cavity within a bone.
- **Articulation:** It is a joint between two or more bones.
- **Suture:** It is an immovable joint between two or more bones.
- **Articulating surface:** It is that part of a bone which enters into the formation of a joint.
- **Facet:** It is a small, flat, articulating surface.
- **Condoyle:** It is a smooth rounded projection of a bone which takes part in a joint.
- **Septum:** It is a partition separating two cavities.
- **Fissure or Cleft:** It indicates a narrow slit.

1.3 THE CELL AND CELLULAR LEVEL OF ORGANISATION

The cell is a basic and the smallest functional, living unit of the body tissue. The cells are grouped together to form the tissues. Cytology is the branch of science which is concerned with the study of the cell. In an unicellular organism, a single cell performs all the functions while in multicellular organisms cells get specialized to form different tissues; each tissue performs a specific function.

Plasma or Cell Membrane

The membrane which separates the internal components of a cell from extracellular material is known as plasma membrane or cell membrane. The plasma membrane regulates passage of the substances in and out of the cell. The plasma membrane consists of equal proportion of proteins and lipids. Lipids are made up of 75 per cent of phospholipids. Lipids normally consist of phosphorus and small amount of cholesterol and glycolipids. The phospholipids are arranged in parallel layers forming a phospholipid bilayer which forms the basic framework of the plasma membrane. Phospholipids are amphipathic in nature.

Such types of amphipathic molecules have a dual nature i.e. they contain both polar and non-polar regions. The head of the polar part contains phosphate which is hydrophilic. The non-polar part is the tail which contains two fatty acids which are hydrophobic in nature. (Hydrophilic means water-loving; and hydrophobic means water-hating).

Glycolipids

These are also amphipathic in nature, and comprise 05 per cent of membrane lipids. They are present only in the layer that faces the extracellular fluid. Glycolipids contribute to the regulation of cellular growth and development.

Cholesterol

About 20 per cent of the membrane lipids are cholesterol molecules, which are found in animal cells. Cholesterol strengthens the membrane of an animal cell but decreases its flexibility.

Membrane Proteins

They are of two types: integral and peripheral. The integral proteins are glycoproteins which extend across the phospholipids bilayer between the fatty acids tails. Normally, sugar portion of glycoproteins faces the extracellular fluid. The peripheral proteins are loosely attached to the inner and outer surfaces of membrane. Some integral proteins have a pore through which certain substances can pass in or out of the cell while some act as a carrier to move a substance from one side of the membrane to other side. Integral proteins work as receptors which attach specific molecules such as nutrients, hormones, neurotransmitter and these are essential for cellular functions. The molecule which is attached to the receptor is known as **ligand**.

Physiological Properties of Membrane

The membrane serves as a cellular communication. It interacts with other body cells, foreign body cells and Ligands. It encloses the cellular contents and keeps it away from extracellular fluid. The plasma membrane maintains an electrical and chemical gradient known as 'electrochemical gradient' between the inside and outside of the cell. The plasma membrane controls entry and exit of materials. It allows passage for certain substances and restricts the passage for others; such a property of the membrane is known as selective permeability. The selective permeability depends on several factors such as lipid solubility, size, charge and presence of channels and transporters.

Transport of Material Across the Membrane

There are two main transport processes: the passive process wherein the metabolic energy is not used and an active process, in which the cell uses some of its own energy by splitting ATP to move the substance across the membrane even against concentration gradient. Passive process includes simple diffusion, osmosis, bulk flow and facilitated diffusion. In these, the transport of molecules depends on the pressure or concentration differences. The gradient of power/concentration works as the source of energy.

Simple Diffusion

Molecules and ions move under kinetic energy (energy of motion) and collide with one another. The random mixing of ions and molecules in the solution due to their kinetic energy is known as simple diffusion. In simple diffusion, high concentration of molecules or ions is present in one area and low concentration of molecules or ions is present in an other area. This difference in concentration between the two areas forms concentration gradient. When two such areas are connected, then substances will move from higher concentration to lower concentration till the concentration on both sides becomes equal.

Osmosis

In a living system, water diffuses through the permeable membrane. Water moves under osmosis across a cell membrane from the area of higher water concentration to an area of lower water concentration. For movement of water between various body compartments, osmotic pressure is important, which is creating a force for movement of water. In an isotonic solution, the cells such as RBC, maintain their shape. The concentration of water and solute in the fluid outside RBC must be same as the concentration of fluid inside the cell.

Bulk Flow

The large number of molecules, ions or particles which are dissolved in a fluid medium or air, moving in one direction, is known as bulk flow. Such type of movement occurs from higher pressure to lower pressure. Examples of bulk flow in the body are flow of blood within the vessels and movement of air into and out of lungs.

Facilitated Diffusion

In this, the substances move under the concentration gradient from an area of higher concentration to a area of lower concentration with the help of specific integral proteins in the membrane which work as carriers for each type of substances, such as ions, urea, glucose, fructose, galactose, vitamins. These substances are also lipid soluble and can diffuse through phospholipids bilayer and cross plasma membrane by facilitated diffusion.

Active Transport

Some substances which enter or leave the body cells do not move passively across the cell membrane because they are also supposed to move against the concentration gradient. These substances move across membrane by active processes. For active transport ATP is required, and particular integral membrane proteins act as ATP driven pumps to push certain ions and smaller molecules across cell membrane. In vesicular transport, there is formation of vesicles. These vesicles either detach from plasma membrane during material transport into cell or merge with the plasma membrane to release material from the cell. Particles such as bacteria, RBC and large molecules such as polysaccharides, and proteins, may enter or leave the cell by vesicular transport. There are several types of vesicular transport methods. These are phagocytosis, pinocytosis, receptor-mediated endocytosis and exocytosis.

- **Phagocytosis:** It is the process by which a phagocyte engulfs a solid particle to form an interval compartment known as phagosome. It is involved in acquisition of nutrients for some cells. In immune system, it removes pathogens and cell debris.

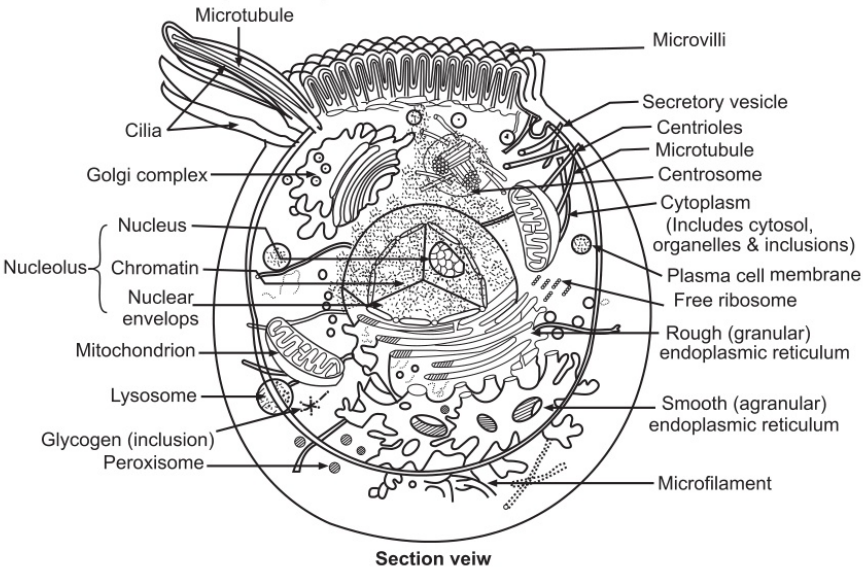
- **Pinocytosis:** It is the process of absorbing fluid together with its contents in the cell. The cell does it by forming narrow channels through its membrane. These channels surround the liquid and its contents and then pinch off into vesicles, hence the liquid is successfully absorbed into the cell.
- **Receptor Mediated Endocytosis (RME):** It is the process by which a cell absorbs nutrients via. selective receptors on the cell membrane by engulfing them. The molecules of receptor are specialised proteins.
- **Exocytosis:** It is a form of active transport in which a cell transports molecules out of it by expelling them in an energy - using process. In this process, membrane bound secretory vesicles are carried to the cell membrane and their contents are emptied into extracellular environment.

1.4 ORGANELLES

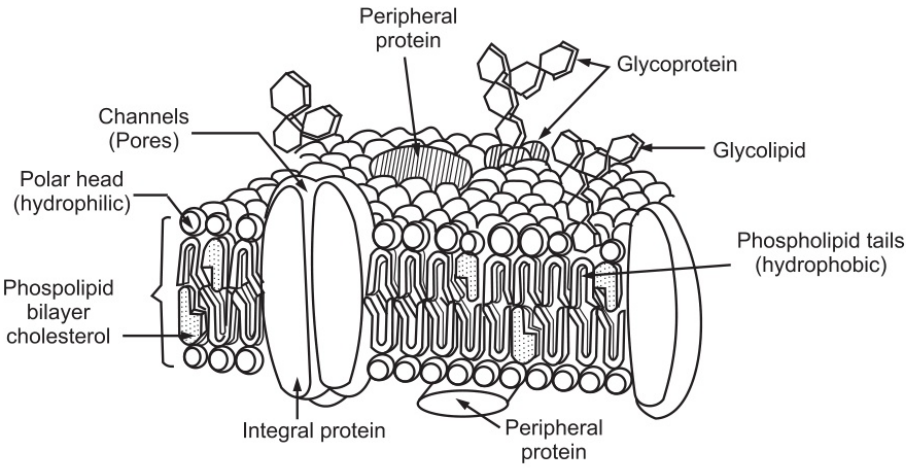
Inside the cell, there are specialized structures which have a specific role in growth, maintenance, repair and control. These specialized structures provide compartments inside the cells and are called Organelles.

Nucleus

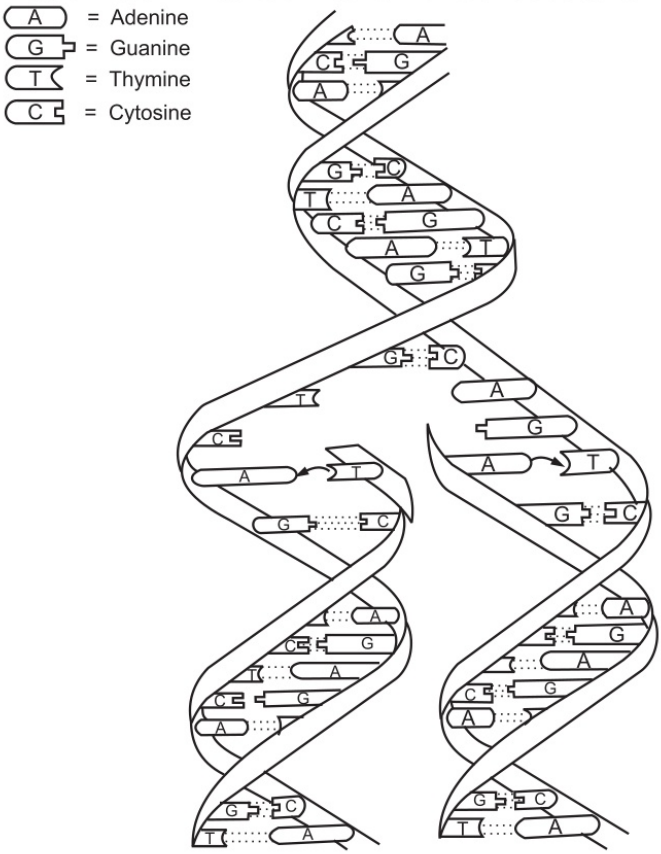
It is the largest structure in the cell, and is usually spherical or oval in shape. Nucleus contains hereditary units called genes. These genes control the cellular activities and the structure. Genes are arranged in a single unit along structures known as chromosomes. Human body contains 46 chromosome in 23 pairs. Nucleus has a double membrane known as nuclear envelope which separates the nucleus from the cytoplasm. Envelope also consists of a phospholipids bilayer which has nuclear pores. It allows ions and water soluble molecules to pass between nucleus and cytoplasm. Inside the nucleus, there are spherical bodies called nucleoli, which are the sites for ribosome biogenesis. The chromosomes are clusters of DNA molecules. DNA molecule is a sequence of nucleotides and each nucleotide has three components, a sugar molecule, phosphate group and nitrogen containing base. Also there are four bases in DNA: adenine (A), thiamine (T), guanine (G) and cytosine (C). Ribosomes are essential for protein synthesis.



(a) Generalized Animal Cell-based on Electron Microscope



(b) CYTOSOL - Details of Plasma Membrane Structure



(c) Structure of Nucleic Acid

Fig. 1.1

Ribosome

Ribosomes are fine granules which contain ribosomal RNA, synthesized by DNA in the nucleolus. They synthesize proteins from amino acids. When these ribosomes are present in free units or in small clusters in the cytoplasm, the ribosomes make proteins for use within the cell. Ribosomes are also present on the outer surface of rough endoplasmic reticulum.

Endoplasmic reticulum

Some of the inward projections penetrate into the centre of the cell in the form of channels which widen out into vesicles. This complex within the cell is called endoplasmic reticulum. At many places, the endoplasmic reticulum carries granules called ribosomes which synthesize proteins. The endoplasmic reticulum without ribosomes helps in the synthesis of lipid substance.

Golgi apparatus

Golgi apparatus is present near the nucleus. The Golgi apparatus stores secretory substances and prepare the substances for final secretion. It consists of flattened sacs called cisterns, which are situated upon each other like a pile of plates. Small Golgi vesicles are associated with cisterns. Golgi complex has a number of functions, such as sorting, packaging and delivery of proteins and lipids to the plasma membrane and formation of Lysosomes and secretory vesicles.

Lysosomes

Lysosomes are another intracellular structures surrounded by a lipoprotein unit membrane. They are filled with large number of small granules which are aggregates of digestive enzymes. These enzymes digest proteins, nucleic acids, mucopolysaccharides and glycogen. Normally, the membrane surrounding Lysosomes prevents the enclosed digestive enzymes from coming in contact with other substances in the cell. Lysosomal enzymes work best in an acidic pH. Interior of the Lysosomes has a pH of 05. Lysosomal enzymes digest bacteria and other substances which enter the cell in phagocytic vesicles and pinocytic vesicles.

Peroxisome

Peroxisomes have a similar structure to Lysosomes, but they are smaller and contain one or two enzymes which use oxygen to oxidize various organic substances and to form hydrogen peroxide. The enzyme known as catalase uses H_2O_2, formed by other enzyme to oxidize various substances, such as phenol, formic acid, formaldehyde and alcohol. These substances are toxic in nature.

Mitochondria

Mitochondria are small intracellular organelles which are surrounded by double unit of membrane. Enfolding of the inner unit membrane form shelves on which oxidative enzymes of cell are absorbed. When nutrients and oxygen come in contact with these enzymes they combine to form carbon dioxide and water and the liberated energy is utilized to synthesize adenosine triphosphate (ATP). ATP then diffuses throughout the cell and releases its stored energy for performing the cellular functions. The mitochondria contain a special type of deoxyribonucleic acid and are probably self-replicative. Their main function is to act as store house of energy.

Microtubules

Many cells contain fine tubular structures called microtubules which are arranged in bundles. These are stiff structures that break if bent too severely. The primary function of microtubules is to provide rigid physical structures for certain parts of cells like cilia. They are also used for movement of cytoplasm. The cytoplasm of each cell contains two centrioles, which are small cylindrical structures and play an important role in cell division.

Flagella and Cilia

The cells have some projections on their body that help the cell in locomotion or for moving substances along the external surface of the cell. These are known as flagella or cilia. In flagella, the projections are few and very long as compared to size of the cell, e.g. sperm cell. In cilia projections are numerous and short, having hairs. Such types of cells are present in the respiratory tract.

The centrosomes are present near the nucleus where it forms a dense area of cytoplasmic material with radiating microtubules.

Reproduction in Cells

There are various well-defined stages in the process of reproduction. They reproduce by mitosis. They are as follows:

1. **Prophase**

This is the first stage of mitosis. During prophase the centrosomes divide into two parts which migrate to either pole of the cell. They form spindles in between them. Each chromosome then divides into two and the pair is held together by centromere. This is the first stage of mitosis called prophase. During early prophase, the chromatin fibres condense and shorten into chromosomes. Condensation may prevent entangling of the long DNA strands as they move during mitosis or meiosis. DNA replication occurs during interphase.

2. **Metaphase**

It is a second stage of mitosis. During metaphase the nuclear membrane disappears and chromosomes arrange themselves at the centre of the cell and are attached to the spindles between the centrosomes. This midpoint region is known as the Metaphase plate or equatorial plane region.

3. **Anaphase**

It is a third state of mitosis. It is characterized by splitting and separation of centromere and movement of the two sister chromatids of each pair towards opposite poles of the cell. After separation, sister chromatids are known as daughter chromosomes. These chromosomes move due to shortening of kinetochore microtubules. Elongation of also non-kinetochore microtubules occurs, this type of process helps in increasing the distance between the two separated chromosomes.

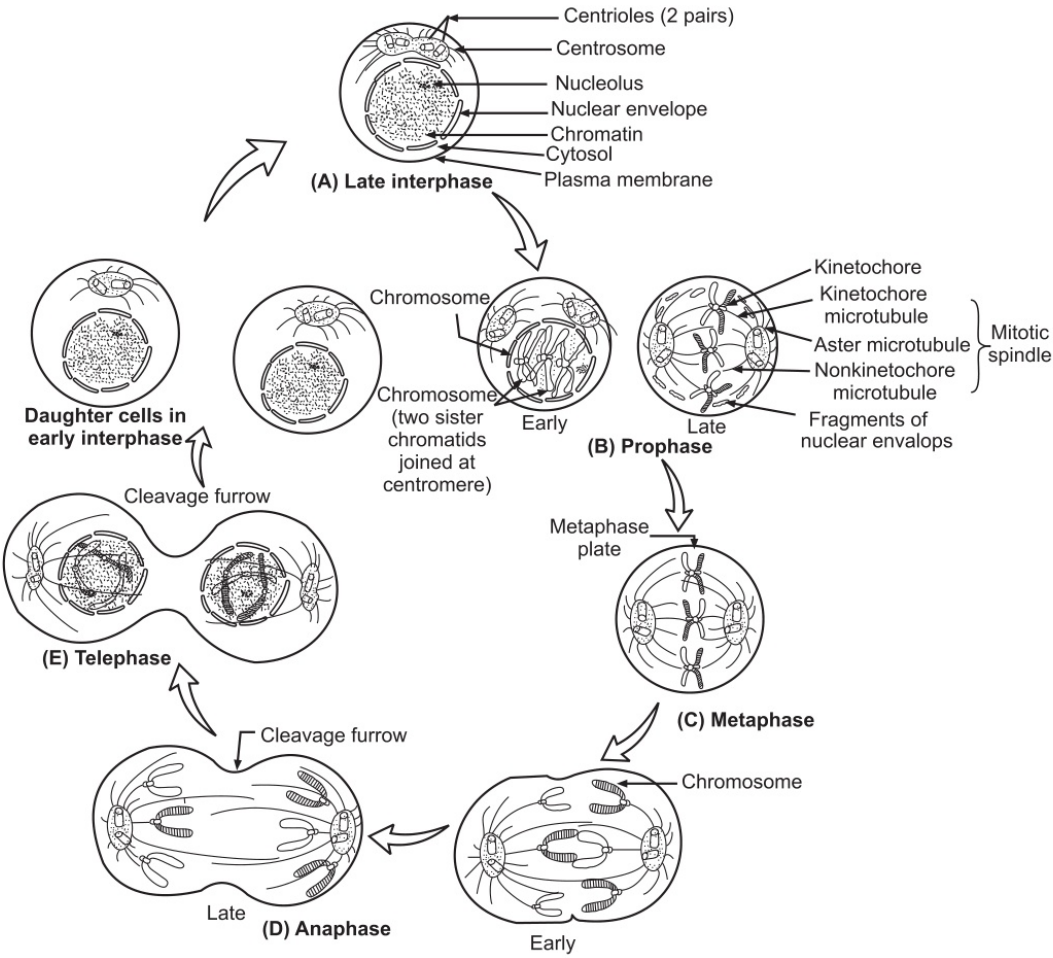


Fig. 1.2: Mitosis

4. Telophase

It is the final state of mitosis. This state starts as the movement of chromosomes stop. In this state, the nuclear membrane reappears, the spindles disappear and the constriction develops round the middle of the cell body. This finally leads to two daughter cells.

1.5 HOMEOSTASIS

Homeostasis is the property of a system within the body of a living organism in which a variable, such as concentration of a substance in solution, is actively regulated to remain very nearly constant. The word originates from two words: homeo and stasis. In Greek language, homoios means similar and stasis means standing still. Thus, the word indicates "staying the same". In human body, there are internal and external variables operating at various points of

time. Inspite of such variables, the body maintains a fairly constant environment due to mechanisms of homeostasis.

The concept of homeostasis was first described by a French physiologist Claude Bernard in 1865 and the word homeostasis was coined by American physiologist Walter Canon in 1926. Canon postulated that homeostasis was a process of synchronized adjustments in the internal environment resulting in the maintainence of specific physiological variables within defined parameters; and that these parameters included blood pressure, temperature, pH and others; all with clearly defined normal ranges. Canon further postulated that threats to homeostasis might originate from the external environment like extremes of temperature or internal environment like infection. The threats can be physical, psychological or even emotional. Canon's work outlined that the maintainence of the internal physical and psychological balance, homeostasis, demands an internal network of communication, with sensors capable of identifying deviations from the acceptable ranges and effectors to return these deviations back within acceptable limits. He identified negative feed back systems and emphasized that the response to variables within the body would be same.

The metabolic process of all living organisms can only take place in very specific physical and chemical environments. The best known homeostasis in human body is related to maintaining temperature, pH, osmolarity and concentrations of sodium, potassium, calcium, glucose, carbon dioxide and oxygen. Take the case of body temperature. Core body temperature is regulated by a homeostat, with sensors in hypothalamus of brain. The set point of the regulator is regularly reset. Body temperature in humans follows a circadian rhythm, with lowest temperatures occuring at night, and the highest in the afternoons. The temperature is 36.4°C from 2 a.m. to 6 a.m. and 37.5°C from 10 a.m. to 6 p.m. The regulator's set point is readjusted in adult women at the beginning of luteal phase of the menstrual cycle. The set point is again reset during infections to produce a fever.

Homeostasis does not govern every activity in the body. Take the case of blood pressure in mammals. It is homeostatically controlled, and measured by stretch receptors in the walls of aortic arch and carotid sinuses. The sensors send messages via sensory nerves to the medulla oblongata of the brain indicating variation in blood pressure. Subsequently, the medulla oblongata sends messages through motor or efferent nerves to a variety of effector organs. One of the effector organs is the heart. Stimulation of heart rate leads to tachycardia while lowering of heart rate is called as bradycardia. Tachycardia or bradycardia may be set in when the blood pressure deviates below or above set points of 80-120 mm of mercury. Thus, the heart rate for which there is no sensor in the body, is not homeostatically controlled; however it is one of the effector responses to errors in arterial blood pressure. Another example is of rate of sweating. We sweat more in summer to maintain body temperature. Unlike this, we do not sweat in winter. We wear warm clothing to maintain body temperature.

Apart from the entities which are homeostatically controlled in the internal environment of the body, there are some variables which are neither homeostatically controlled nor

involved in the operation of homeostasis. The blood urea concentration is an example. There are no sensors for urea. The blood urea is generated in liver during metabolism of amino acids of proteins. It is excreted by kidneys without active resorption or excretion by renal tubules. A high protein diet produces a high blood urea concentration. A poor protein diet with low blood plasma urea concentration leads to no secretion of urea in urine.

1.5.1 Homeostatic Mechanisms

There are two kinds of feed backs in a chain like event in human body. The mechanisms are called as negative feed back and positive feed back respectively. Take a case of chain reaction in which A is converted to B; B is converted to C; C to D and D to E. Quite often every change is controlled by activity of an enzyme. The rate of every enzymatic reaction can vary. The slowest reaction is termed as rate limiting step. If any of the intermediate from A to E is over produced, then higher concentration of the intermediate slows down the reaction leading to its generation. This is termed as negative feed back. Thus, negative feed back limits higher production of an intermediate through a self controlling mechanism. Alternatively, if production of an intermediate is reduced below certain limits then related enzymes may be activated to restore level of the intermediate. This is called as positive feed back mechanism.

Control of arterial pressure involves pressure monitoring system, volume monitoring system, hormonal mechanisms, reflex regulation, autonomic control etc. Bradycardia due to higher blood pressure is an example of negative feed back mechanism. In a cascade of reactions in coagulation, activation of one clotting factor leading to activation of other factors promoting coagulation to limit blood loss is an example of positive feed back mechanism.

Operation of the feed back mechanisms involves three components:

- The sensor
- The control center
- The effector

The sensor contains receptors which monitor change of the variable and provide sensory signal to the controlling center as soon as the change is detected. The carotid sinus and the aortic arch contain baro receptors in their valve to detect changes in blood pressure. They send signals to controlling center located in medullary oblongata.

The control centers are usually located in CNS. Centers for blood pressure regulation are located in medulla oblongata and hypothalamus.

Effector is the target organ which carries out the demand of the control center to achieve an effective response. Blood vessels and heart are the effector organs related to blood pressure. Through bradycardia or tachycardia at heart and through vasodilation or vasoconstriction, they help in maintaining blood pressure.

Following control systems are important for regulation of human body:

- Core body temperature
- Blood glucose
- Plasma ionised calcium
- Blood partial pressure of oxygen and carbon dioxide
- Blood oxygen content
- Arterial blood pressure
- Extra cellular sodium concentration
- Extra cellular potassium concentration
- Volume of body water
- Extra cellular fluid pH

As an illustration homeostasis of one parameter i.e. volume of body water is discussed below.

1.5.2 Homeostasis of Volume of Body Water

The volume of water in the body is measured by stretch receptors in the atria of heart. They are also indirectly sensed by measurement of the osmolality of plasma by the hypothalamus. Measurement of the plasma osmolality gives an indication of the water content of the body. It relies on the fact that water losses from the body through sweat, gut fluids in the form of fecal water and through vomitting/diarrhoea and the exhaled air, are all hypotonic. It means that fluids like saliva, tears are less salty than plasma. Tears have almost the same salt content as that of extra cellular fluids while saliva is hypotonic with respect to plasma. Thus, taste of saliva is not salty while tears are decidedly salty. Nearly all normal and abnormal losses of body water make extra cellular fluids hyper-osmolar. Conversely, excessive water intake dilutes the extra cellular fluids making it hypo-osmolar. Only after loss of water through urine body can become isotonic. Hence excessive water intake leads to frequent urination.

When the hypothalamus detects a hyper-osmolar extra cellular environment, it causes secretion of the hormone called antidiuretic hormone (ADH). For ADH, kidney is the effector organ. The effect of ADH on kidney tubules leads to reabsorption of water from distal convoluted tubules and collecting ducts, thus preventing further water loss. Simultaneously, hypothalamus stimulates thirst center in the brain to stimulate urge of drinking water. The caessation of urine flow prevents the hypovolemia and hypertonicity from getting worse. Thus, drinking of water corrects the defect.

Hypo-osmolarity leads to very low plasma ADH levels. This results in inhibition of water reabsorption from kidney tubules, causing high volumes of very dilute urine to be excreted, thus getting rid of excess water in the body.

It is to be noted that urinary water loss, when the body water homeostat is intact, is a compensatory water loss, correcting excess of water in the body. Alternatively thirst reflex is an important second effector mechanism of the body water homeostat, correcting any water deficit in the body.

Stretching of the right atrium of the heart is a sign of excessive blood volume. It causes stretch receptors to secrete a hormone called as atrial natriuretic peptide (ANP) into blood. It causes kidneys to get rid of sodium along with water loss into urine. The net result is reducing volume of circulating blood.

Thus, hypervolemia / hypovolemia is corrected by hormones like ADH / ANP. Water intake through thirst center or urination by kidney leads to homeostasis of volume of body water.

1.5.3 Homeostatic Breakdown

Many diseases are the result of failure of one or more homeostat(s) in the body. The body water homeostat can be disrupted by inability to secrete ADH in response to even the normal body water losses via the exhaled air, the feces and sweating. On not receiving ADH signal, the kidneys produce huge unchanging volumes of very dilute urine, causing dehydration and even death.

Another example is of type I diabetes mellitus. In this case, blood glucose homeostat ceases to function due to destruction of beta cells of pancreas. This means that the glucose sensor is absent and the effector pathway of insulin level in blood remains unchanged. The blood glucose concentration rises to very high levels, while the body's proteins are degraded in to amino acids and are used for generating energy via gluconeogenesis. If untreated, the condition can be fatal.

EXERCISE

1. Draw a well labeled diagram of cell and its organelles.
2. Explain in detail transport across cell membrane. Give functions of mitochondria and golgi body.
3. Discuss in detail different forms of intracellular signaling.
4. Explain the process of cell division.
5. Define homeostasis and discuss in brief the homeostatic mechanisms.

***

Chapter ... 2

TISSUE LEVEL OF ORGANISATION

♦ LEARNING OBJECTIVES ♦

- *To understand the structural features of tissues, their types and their organisations to form organs of the body.*
- *To study and appreciate the relationship between structural features and the functions that tissues perform.*
- *To learn the characteristic features of tissues and thus be able to understand their functions.*
- *To study the specialized activities of organs and systems of the body and their relationship with the tissue level organisation.*

2.1 INTRODUCTION

Though cell is considered as the structural and functional unit of the body, it cannot function in isolation. The cells group and work together. A group of cells similar in structure (due to their common embryonic origin) and function is known as tissue. The science that deals with the microscopic structure of the tissues is known as Histology.

According to the structural and functional characteristics; the body tissues are classified into four fundamental types.

1. Epithelial 2. Connective 3. Muscle 4. Nervous

In a tissue, the cells remain in place due to their attachment with other cells, basement membrane and binding connective tissue. Different tissues organise to form organs and organs organise to form systems of the body. Every cell in the body is bathed in a fluid called extracellular fluid (ECF). This provides a medium for transporting the substances and carrying out chemical reactions. Thus, there are microscopic spaces between the cells in a tissue, where this extracellular fluid (also called as interstitial fluid) is present.

2.2 EPITHELIAL TISSUE

Origin

The embryonic tissues from which all tissues and organs of the body develop are known as the germ layers, i.e. ectoderm, mesoderm and endoderm. The epithelial tissue develops from all three types of germ layers.

Characteristics

Most important feature of epithelial tissue is that the cells are closely packed together with very little intercellular substance. The epithelial cells are arranged in continuous sheets

in either single or multiple layers. The cells are attached to a basement membrane, which is composed of mucopolysaccharides, proteins and collagen fibrils. The basement membrane is attached to connective tissue. The cells are held together by means of cell junctions on the lateral surface; close to the outer surface of cells. The epithelial tissue is vascular and the cells are dependent on underlying connective tissue for their nourishment.

Certain epithelial cells are specialized for the reception of sensory stimuli, e.g. taste buds of tongue, olfactory area of nose, the rod and cone cells of retina. Such specialized epithelium is referred to as the neuroepithelium.

As epithelial tissue lines and covers the organs, it is subjected to frequent wear and tear; hence it has high capacity of renewal.

Location

Epithelial tissue covers the body surface, lines the body cavities, forms the inner coat of blood vessel and lymphatic system and composes of both the endocrine and exocrine glands.

Functions

Corresponding to variety of locations the tissue has diverse functions. Thus, as a skin layer it protects the body; as lining of body cavities it functions as absorptive, excretory and secretory surface. In specialized activities epithelium contributes in sensory reception and formation of reproductive cells.

Types of Epithelial Tissue

Depending on the number of cell layers and their attachment to basement membrane, epithelium is classified into three main classes as follows:

1. **Simple epithelium:** It is formed by a single layer of cells and all are in contact with the basement membrane.
2. **Stratified epithelium:** It is formed by two or more layers of cells with only one layer in contact with the basement membrane.
3. **Pseudostratified epithelium:** The tissue appears to be formed by several layers but is actually formed by a single layer with all cells touching the basement membrane.

Depending on the shape of cells simple epithelium is further classified into squamous epithelium (cells are flat in shape), Cuboidal epithelium (cells are cuboidal in shape) and columnar epithelium (cells are tubular in shape). Similarly, on the basis of shape of apical layer of cells, stratified epithelium is further classified into stratified squamous epithelium, stratified cuboidal epithelium, stratified columnar epithelium and transitional epithelium. Pseudostratified epithelium is in fact a columnar epithelium.

2.3 SIMPLE EPITHELIUM

(a) Simple Squamous Epithelium

Formed by a single layer of flat cells, it appears as a thin sheet. In general, it appears in organs where filtration and diffusion occurs, e.g. lining of blood vessels, lining of alveoli and the glomerular capsule of nephron.

(b) Simple Cuboidal Epithelium

Cuboidal epithelial cells are in a single layer of cube like cells with a large spherical central nucleus. Simple cuboidal epithelia are found on the surface of ovaries, lining of

Nephron, the walls of renal tubules; the parts of the eye and the thyroid. On these surfaces the cells perform secretion and absorption.

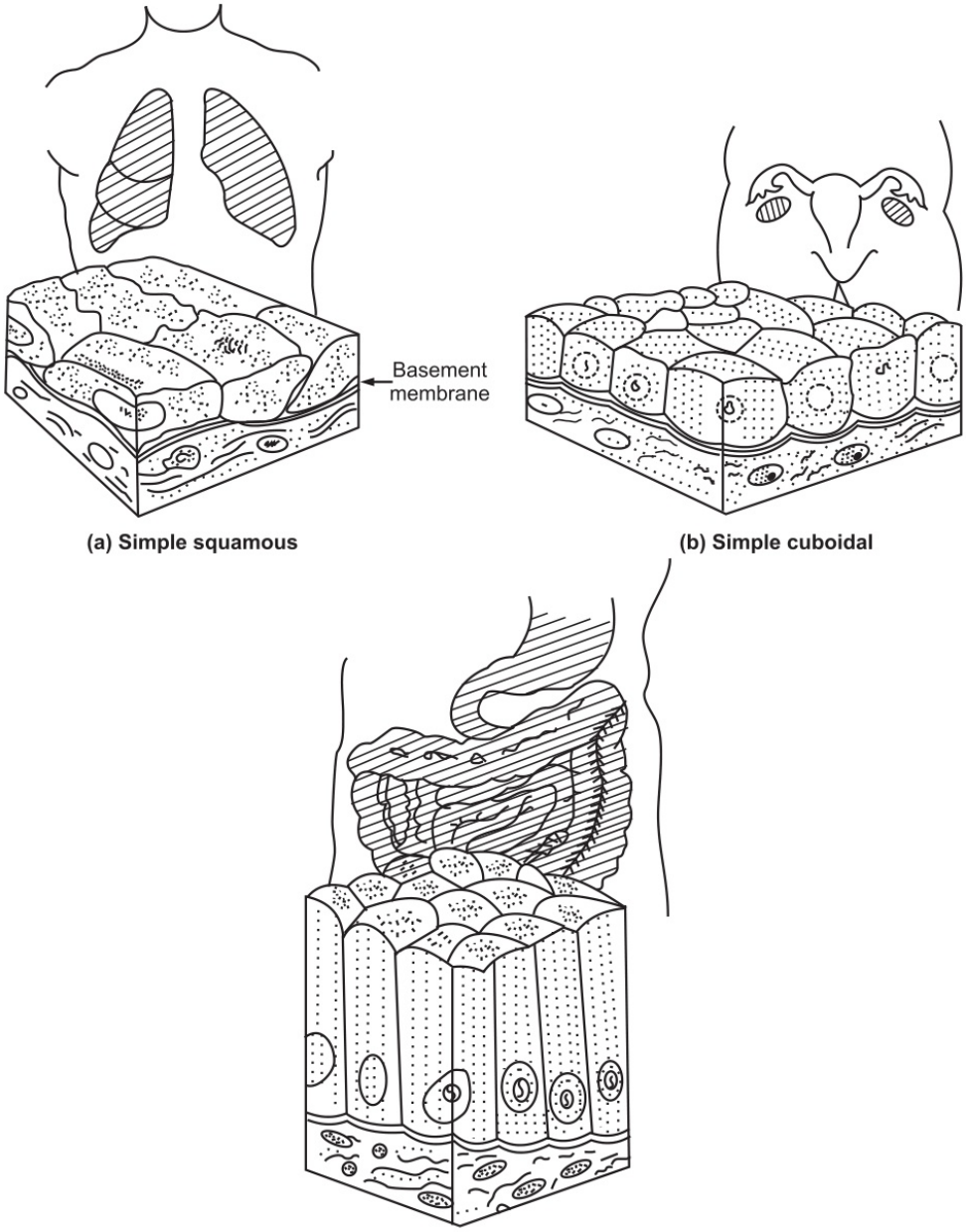


Fig. 2.1: Simple Epithelium

(c) Simple columnar epithelium

This is formed by a single layer of rectangular cells; it lines the gastrointestinal tract and at this location their apical surfaces possess microvilli. It also lines the ducts of many glands. Its function is secretion and absorption.

When the apical surface of simple columnar epithelium shows presence of hair like processes called cilia, it is termed as simple ciliated columnar epithelium. It lines the upper respiratory tract, uterine tubes, uterus and central canal of spinal cord. The movement of cilia pushes fluid or particles along the tube.

2.4 STRATIFIED EPITHELIUM

(a) Stratified squamous epithelium: Several layers of cells are placed on basement membrane with varying shapes. The cells near the basement membrane are cuboidal in shape and as they move upwards they become columnar in shape and finally apical cells are flat in shape. As an outer layer of skin, where the flat cells show presence of Keratin, it is known as keratinized stratified squamous epithelium. The non-keratinised stratified epithelium lines the mouth cavity, oesophagus, and vagina. Its function is protection.

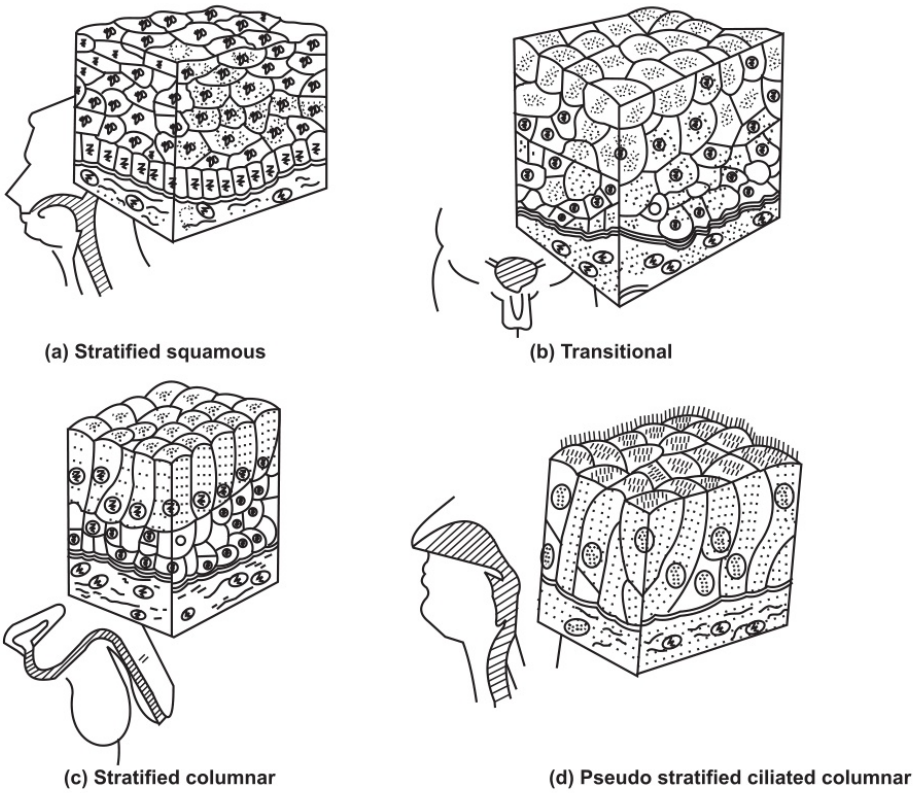


Fig. 2.2: Stratified Epithelium

(b) Stratified cuboidal epithelium: Usually two but sometimes more layers of cube shaped cells are found in ducts of sweat glands and male and female urethra these are mainly protective in function.

(c) Stratified columnar epithelium: Several layers of cells, those near the basement membrane are small and rounded while apical (surface layer) cells are columnar in shape. It is found in pharynx, anus and the male urethra. It plays the role of protection and secretion.

(d) Transitional epithelium: It lines all hollow organs that can change in size due to contraction and distention. Depending on the functional state of organ; the appearance of the tissue changes; hence named as transitional. It lines the urinary bladder, ureter and upper part of urethra. When the bladder is empty (contracted) the surface cells are round and large while in distended bladder, the surface cells are flat in shape. When the bladder distends the cells flatten and slide over each other thus allowing the bladder to expand with minimal tissue resistance.

(e) Pseudostratified columnar epithelium: It is much common than truly stratified columnar epithelium. All the cells contact the basement membrane but some of them are shorter than others and therefore do not reach the free surface. It is found in large ducts of glands and in regions of the male urethra. The free surface of this tissue often shows cilia and is known as Pseudostratified ciliated columnar epithelium and along with goblet cells it lines most of the respiratory tract including trachea. Secretion and movement of the mucous by ciliary action are the functions of this tissue.

Classification of Epithelium Tissue according to Location or Function

The same epithelial tissue which we have already classified on the basis of shape and number of layers of cells may be conveniently classified on the basis of its location and function as follows:

(a) Mucous Membranes

The lining of hollow tracts that open to the exterior of the body such as digestive, respiratory, urinary and reproductive tracts are formed mostly by stratified, squamous or simple columnar epithelium and are known as mucous membranes. The most common secretion of secretory cells is mucuos, a sticky fluid that keeps the tract moist. The mucous membrane of the digestive tract is absorptive too.

(b) Serous Membranes

The serous membranes form both the parietal and visceral portions of the pleura, the pericardium and the peritoneum. The serous membrane consists of a thin layer of loose connective tissue covered by a surface layer of simple squamous epithelium called mesothelium. The cells of mesothelium secrete 'serous fluid' a clear watery fluid that keeps the membrane moist.

(c) Endothelium

The lining of heart blood vessels and lymphatic, made up of simple squamous epithelium is known as endothelium. As it is very thin, the diffusion occurs readily through it. The wall of blood capillaries is made up of the endothelium; hence the substances easily diffuse in and out through it.

(d) Glandular Epithelium

The glands both endocrine and exocrine of the body are made up of epithelial tissue. They produce secretions such as mucous, enzymes, hormones, milk, and sweat etc. The mucous secreting goblet cells found in the epithelium lining respiratory and digestive tract are examples of single cells functioning as glands. However, most of the glands are multicellular.

The multicellular glands can be classified on the basis of their structure or the manner in which they produce their secretions. Structurally, the ducts of the glands may be unbranched or branched. Glands with unbranched ducts are called the simple glands. The glands with branched ducts are the compound glands. Compound glands are further classified based on the structure of their secreting portion, into tubular, alveolar, and tubuloalveolar as shown in the Fig. 2.3.

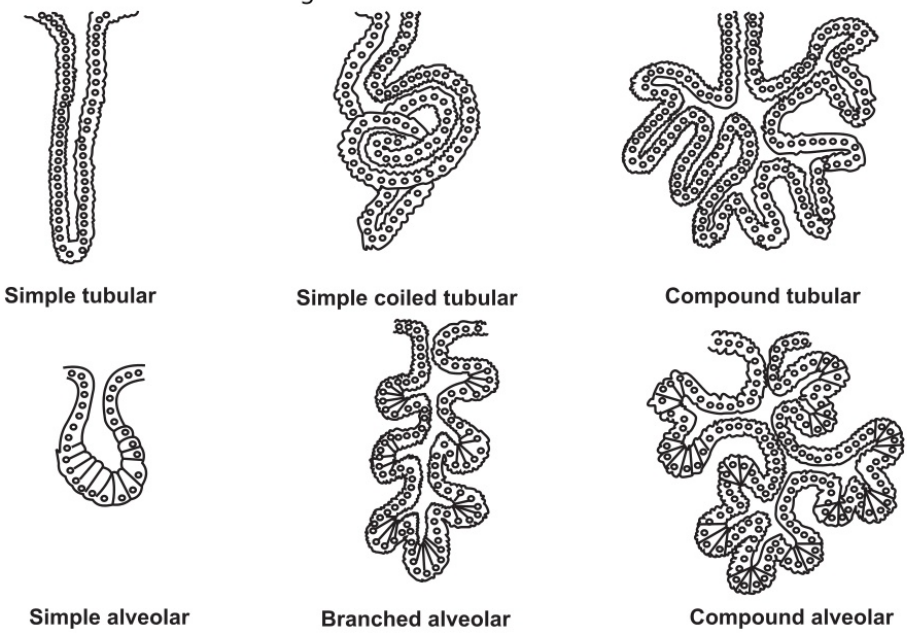


Fig. 2.3: Compound Glands

On the basis of their manner of secretion, the glands are classified as exocrine glands, holocrine glands and apocrine glands.

(a) Exocrine glands: The secretions do not accumulate in gland cells. They secrete intermittently. The cells remain intact, e.g. salivary glands, pancreas, and sweat glands.

(b) Holocrine glands: The secretion accumulates within the cells. The secretion is released on disintegration of cell, e.g. sebaceous glands.

(c) Apocrine glands: The secretion accumulates towards the free surface of cells. The portion of the cell containing secretion is pinched off to release the secretion, e.g. mammary glands.

2.5 CONNECTIVE TISSUE

Origin

The connective tissue develops from mesoderm.

Characteristics

The most important feature of connective tissue is that the cells are widely separated from each other by an intercellular substance. The intercellular substance is known as matrix; and consists of ground substance and fibres. The matrix is secreted by the immature cells of connective tissue such as fibroblast, osteoblast and chondroblasts. Once the matrix is formed the immature cells differentiate and become mature cells. The mature cells are named by the suffix-cyte, e.g. Osteocytes, chondrocytes etc.

Connective tissue cells: Several types of cells are associated with connective tissues; but the most common are the fibroblasts and macrophages. Other cells found in various types of connective tissues are the plasma cells, mast cells, fat cells and leucocytes.

Fibroblasts: These are immature, large, spindle shaped cells with branching processes. They secrete ground substance and fibres that are characteristic of connective tissues.

Macrophages: These are irregular shaped cells derived from monocytes. They have strong phagocytic capacity and by this action they provide the body with a defense mechanism. Some of them can move by amoeboid movement and migrate to infected tissue, while others remain fixed in certain organs of the body.

Plasma cells: They are developed from *B. lymphocytes*. These are small, round or irregular shaped cells. They produce antibodies and thus, provide the body with its defense mechanism.

Mast cells: Small rounded cells that synthesize and store histamine in granular form. As a tissue response to injury, the histamine is released and it causes vasodilation. Mast cells also contain heparin that acts as an anticoagulant.

Fat cells (Adipose cells): These are found either singly or in groups and are specialized to store fat, the reserve food of the body.

Leucocytes: The white blood cells, lymphocytes, neutrophils, monocytes and eosinophil from the blood and lymph migrate to loose connective tissue depending on the physiological condition of the body. Fig. 2.4 shows diagrammatic representation of connective tissue with various cells and fibres.

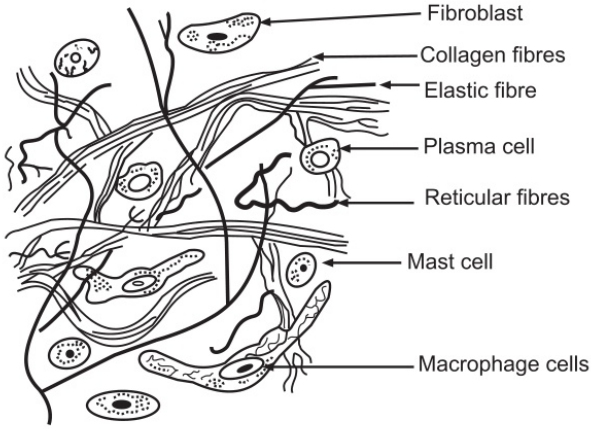


Fig. 2.4: Diagrammatic Representation of Loose (Areola) Connective Tissue

Connective tissue matrix: The intercellular material (matrix) is formed of ground substances and fibres. The ground substance is produced by the cells of connective tissue. It varies in consistency from fluid to semisolid gas. A variety of large molecules are found in ground substance, e.g. Hyaluronic acid, dermatan sulfate, chondroitin sulphate etc. The adhesion proteins present in ground substance help in fixing the cells in position. The ground substance supports and binds cells and provides a medium through which exchange of substances occur between cells and blood.

The Fibres: The fibres found in varying amounts within ground substance are also produced by tissue cells (Fibroblasts). There are three types of fibres, i.e. collagenous fibres, elastic fibres and reticular fibres. The fibres provide strength and support to the tissue.

Collagenous fibres: Chemically, these are composed of a protein collagen. Each fibre is composed of bundles of smaller fibrils. These are very tough and inelastic. The closely packed fibres appear white in colour; hence sometimes referred to as white fibres. They are found abundantly in bone, cartilage and tendons.

Elastic fibres: These are long thread-like branching fibres, having slight yellow colour. They are composed of a protein elastin. They are highly elastic and provide elasticity to the organ. They are found in skin, blood vessels and lungs.

Reticular fibres: These are short, thin and branch freely to form a network called reticulum. They are composed of collagen and glycoprotein. They provide support and form internal framework of glands to which epithelial cells are attached. They are inelastic.

Other characteristics of connective tissue are that the tissue is innervated and highly vascular (exception - cartilage). The nature of matrix is varied: as in blood it is fluid (not secreted by blood cells) and in bones it is hard.

Functions of connective tissue: As body organs are formed by different tissues bound together by connective tissue; it is most widely distributed in the body as connecting tissue. In addition, it supports and strengthens other tissues in the body. It has an important role in protection, transport and repair activities of the body. Adipose tissue acts as stores of reserve food of the body.

Classification of Connective Tissue

Depending on nature of matrix, ground substance, the fibres and proportion of fibres and types of cells composing the tissue, it may be classified into the following classes.

I.	**Loose connective tissue:**	1. Areolar connective tissue
		2. Adipose tissue
		3. Reticular connective tissue
II.	**Dense connective tissue:**	1. Dense regular connective tissue
		2. Dense irregular connective tissue
		3. Elastic connective tissue.
III.	**Cartilage:**	1. Hyaline cartilage
		2. Elastic cartilage
		3. Fibro cartilage

IV. Bone tissue

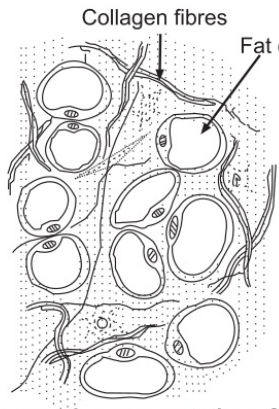
V. Blood (vascular tissue)

I. Loose Connective Tissue:

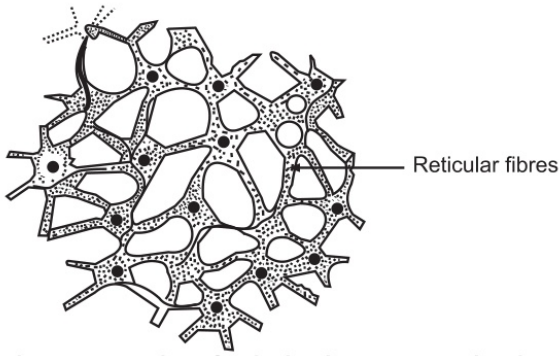
It consists of loose network of fibres. It has semi-fluid ground substance embedded in which are many collagenous fibres and few elastic and reticular fibres. Cells are found widely separated from each other in this tissue.

(a) Areolar tissue: Loose network of fibres, leaves many spaces between them; hence known as Areola (Areola means space) connective tissue. It is one of the most widely distributed connective tissues in the body. All kinds of connective tissue cells are found in this tissue. The ground substance being semi-fluid in nature, forms the internal environment of the body as it carries nutrients to and waste products away from, the cells. It is found in almost every part of the body, connecting and supporting other tissues; e.g. under the skin, between muscles, supporting blood vessels and nerves, in alimentary canal and in glands supporting secretory cells.

(a) Loose (areolar)



(b) Diagrammatic representation of adipose tissue



(c) Diagrammatic representation of reticular tissue as seen in a lymph node

Fig. 2.5: Loose Connective Tissue

(b) Adipose tissue: It consists of collection of fat cells (adipocytes) which stores triglycerides (neutral fat). Each cell contains a large droplet of fat, which pushes the cytoplasm and nucleus to the periphery of the cell. It is found in supporting organs such as kidneys, eyes, between bundles of muscle fibres, and in Areolar tissue under the skin. It serves the following three special functions.

1. It forms a food reserve from which the body can draw food when needed,
2. Fat being poor conductor of heat, helps to retain body heat and
3. It supports and protects the delicate organs.

(c) Reticular connective tissue: The matrix of this tissue shows predominantly the reticular fibres arranged in small bundles. Within this network of bundles are found the cells of the tissue. It forms the stroma of liver, spleen and lymph nodes.

II. Dense Connective Tissue

In this tissue, the fibres are closely interwoven, leaving little space between them. The other characteristics are similar to that of loose connective tissue. It is stronger than the loose connective tissue.

(a) Dense regular connective tissue: The fibres in the matrix are predominantly collagenous, in closely packed parallel bundles. Sometimes referred to as the white fibrous tissue, which is tough and forms the tendons of muscles and ligaments of joints.

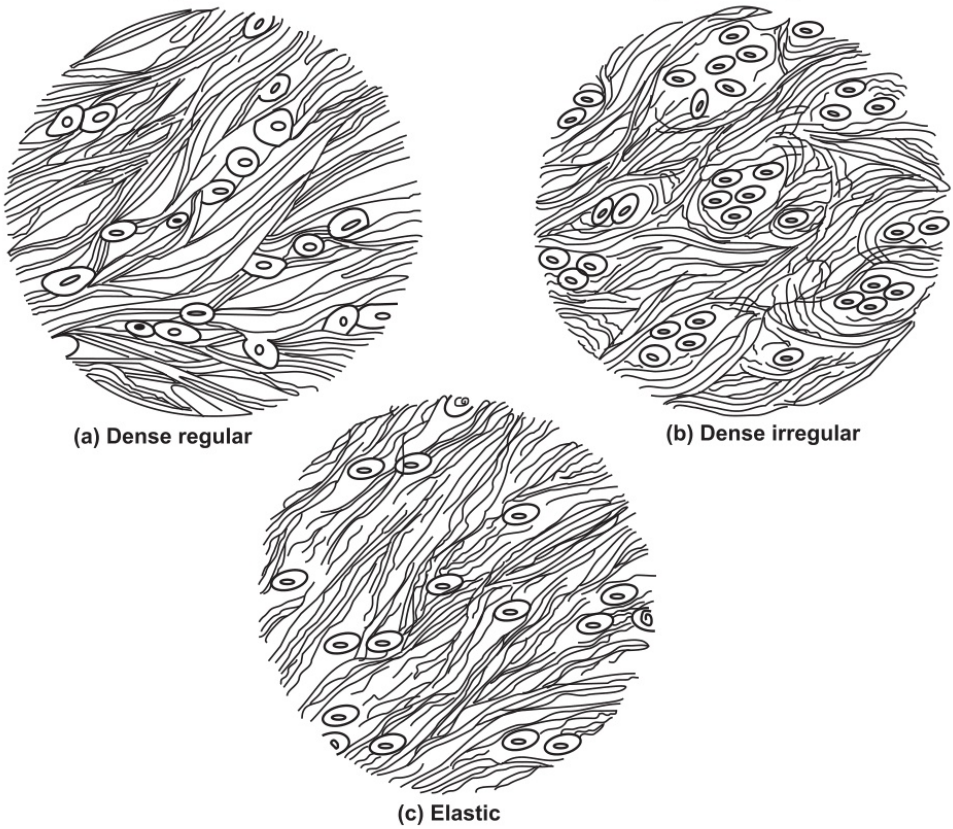


Fig. 2.6: Dense Connective Tissue

(b) Dense irregular connective tissue: It is essentially a dense areola tissue that contains all the same elements as loose connective tissue but has fewer cells and comparatively more collagenous fibres. The fibres are closely packed forming a compact tissue making it stronger. It is found in the dermis layer of skin.

(c) Elastic connective tissue: In contrast to dense regular connective tissue (white fibrous connective tissue) this tissue contains more elastic fibres than collagenous fibres. Although it is tough it allows some stretching. It is found in walls of the arteries, the trachea and vocal cords.

III. Cartilages

It is a specialized type of fibrous connective tissue. It contains numerous collagenous fibres embedded within a firm matrix of chondrin (Protein carbohydrate complex). The fibres

and matrix of cartilage are produced by the cells called chondroblasts. On forming enough matrix and fibres the chondroblasts mature and form chondrocytes. The chondrin matrix is non-vascular. The blood supply to cartilage is provided by blood vessels present in fibrous connective tissue membrane that covers the cartilage. The cartilage is both tough and flexible. There are three types of cartilages: Hyaline, elastic and fibro cartilage.

(a) Hyaline cartilage: It appears as a smooth bluish white tissue. The chondrocytes appear in groups of two or more called lacunae. The matrix is solid and smooth. It is found:

(a) On the surface of the cells of the parts of bones which form joints.

(b) As costal cartilages that attach ribs to the sternum and

(c) Forming part of the larynx, trachea and bronchi.

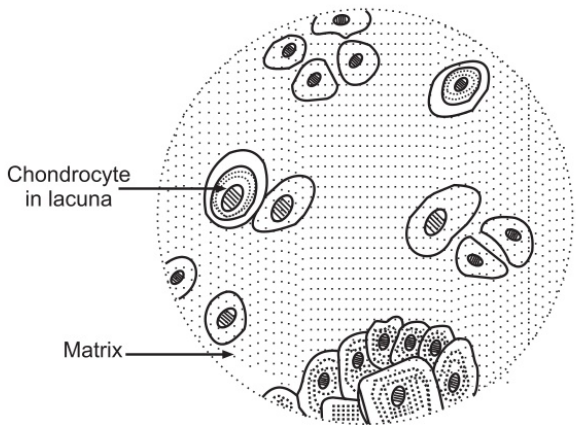


Fig. 2.7: (a) Diagrammatic Representation of Hyaline Cartilage

(b) Elastic cartilage: It consists of yellow elastic fibres running through solid matrix. It is firm but elastic and helps to maintain the shape of certain organs. It is found in epiglottis, external ear and eustachian tubes.

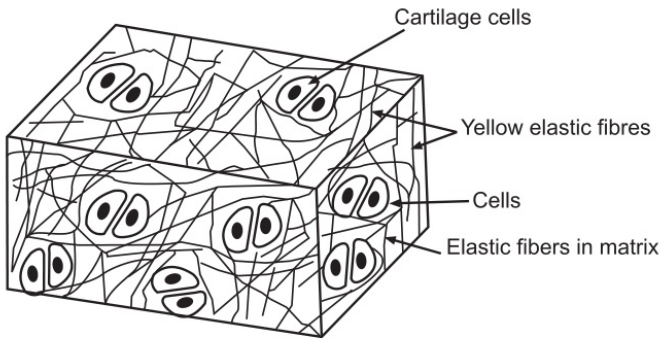


Fig. 2.7: (b) Yellow Elastic Fibro Cartilage

(c) Fibro cartilage: It consists of dense masses of white fibres in a solid matrix with the chondrocytes widely dispersed. It is tough and slightly flexible tissue. It is found :

(i) As intervertebral discs between bodies of vertebrae.

(ii) Between articulating surfaces of bones of knee joint and

(iii) Surrounding the rim of the bony sockets of hip and shoulder joints.

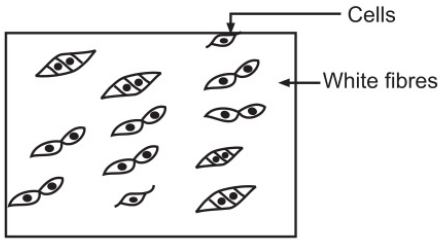


Fig. 2.7: (c) White Fibro Cartilage

IV. Bone Tissue

It is one of the hardest connective tissues of the body. It consists of specialized type of fibrous material which in fact is a fibrous tissue hardened by deposits of mineral salts chiefly calcium phosphate derived from plasma. The fibrous material gives it toughness while the mineral matter gives it rigidity. In addition to bone tissue other components of bone that are also connective tissue include the periostenum (covering around bone), red and yellow bone marrow and the endostenum (lining of a space in bone that stores yellow marrow). This tissue forms the skeletal system of the body. There are two types of bone tissues: compact bone tissue and cancellous bone tissue.

(a) Compact bone: It consists of a large number of units called Haversian systems which have well-defined characteristics.

(i) A central haversian canal runs longitudinally and contains blood, lymph capillaries and nerves.

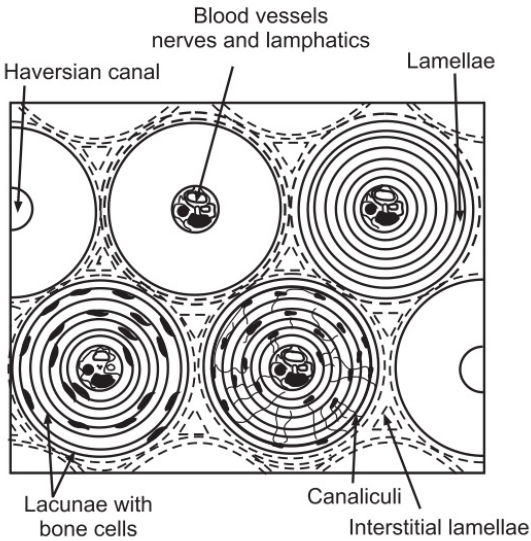
(ii) The canals are surrounded by concentric plates of bones known as lamellae.

(iii) Between the lamella there are spaces called lacunae containing lymph and bone cells called osteocytes.

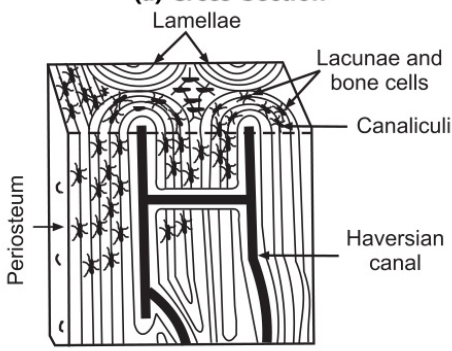
(iv) The haversian canals and the lacunae are linked with fine channels called canaliculi. Lymph carrying nourishment flows through the canaliculi.

(v) In the spaces between the haversian systems there are interstitial lamellae.

(b) Cancellous bone: It looks like a sponge. The haversian canals are much larger and there are fewer lamellae as compared to compact bone. Red bone marrow is always present with cancellous tissue.



(a) Cross-Section



(b) Longitudinal-Section

Fig. 2.8: The Bone

V. Blood (vascular tissue)

Blood is a specialized type of connective tissue, with a fluid matrix called blood plasma. Variety of cells and cell fragments are suspended in blood plasma. Detailed account of blood is given in the Chapter No. 5 of this book.

2.6 MUSCLE TISSUE

The cells of muscle tissue are elongated and often taper at their ends; hence these cells are called muscle fibres. The fibres are typically designed and constructed to produce a force of contraction. Thus, the tissue is contractile and able to produce movements.

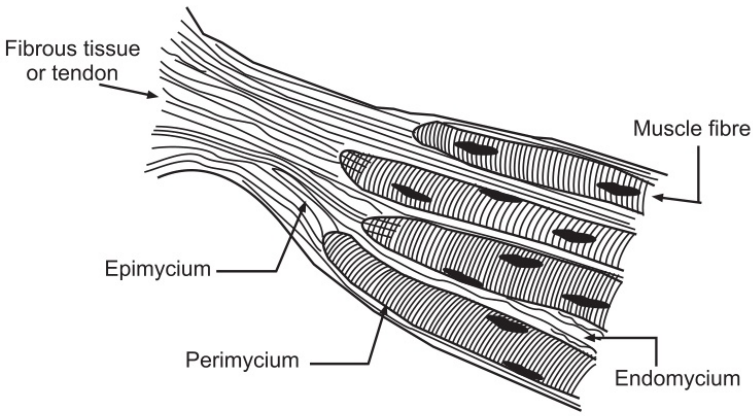
On the basis of structural and functional characteristics, the muscles are classified into three types:

1. Striated or voluntary muscle;
2. Smooth or involuntary muscle; and
3. Cardiac muscle.

(a) Striated Muscle

It is described as skeletal, striated, striped or voluntary muscle. It works under the control of the will. It is found in skeletal muscle. The cells of voluntary muscle, about 10-40 millimeters in length are roughly cylindrical in shape. Sarcolemma is the fine sheath surrounding each muscle fibre and several nuclei are situated under it. The muscle fibres lie parallel to one another and show transverse dark and light bands.

(a) A Striated Muscle Fibre



(b) A Bundle of striated Muscle fibres and their connective tissue

Fig. 2.9: A Striated Muscle

The muscles consist of a large number of muscle fibres. Each fibre is enclosed in and attached to fibrous tissue called endomycium. Small bundles of fibres are enclosed in perimycium and the whole muscle in epimycium. The fibrous tissue extends beyond the muscle fibres to become the tendon which attaches the muscle to bone or skin.

(b) Smooth Muscle

It is described as involuntary, plain or visceral muscle. It is not under the control of our will. It is made up of spindle shaped cells, with only one central nucleus. There are no distinct sarcolemma but a very fine membrane surrounds each fibre. The bundles of cells form a sheet. During contraction and relaxation the cells glide over one another. It is found in the walls of the blood vessel, lymph vessels, alimentary canal, respiratory tract, the urinary bladder and uterus.

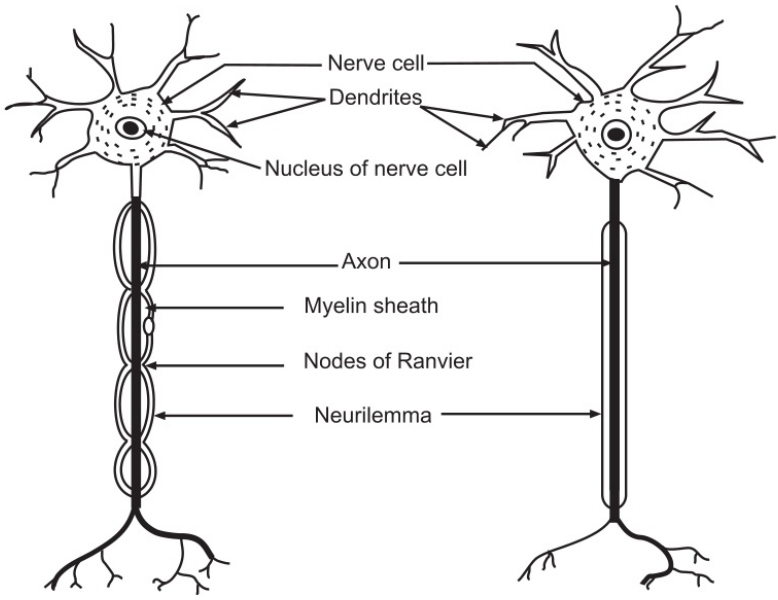
(c) Cardiac Muscle

It is found exclusively in the wall of the heart. The cardiac muscle cells show cross-stripes similar to those of voluntary muscle. Each cell has a nucleus and one or more

branches. The ends of the cells and their branches are in close contact with each other forming "intercalated discs" which look like thicker and darker lines. This arrangement gives cardiac muscle an appearance of a sheet of muscle rather than fibres. Each fibre does not need to be stimulated as the impulse spreads from cell to cell across intercalated discs.

2.7 NERVOUS TISSUE

The nervous tissue carries out the special function of carrying messages of stimuli within the body. The properties of 'irritability' and 'conductivity' are specially developed in the nervous tissue. The impulses are conducted along the special cells 'neurons' which form a unit structure of the nervous tissue. The neurons are supported by a special type of connective tissue called neuralgia. Each neuron consists of a nerve cell and its processes are called axon and dendrites.



(a) Myelinated neuron **(b) Non-Myelinated neuron**

Fig. 2.10: The Neuron

Nerve cells: The nerve cells considerably vary in size and shape. They form gray matter of the nervous system and are found at the periphery of the brain, in the centre of the spinal cord, in groups called ganglia outside the brain and the spinal cord and as single cells in walls of organs.

Axons and Dendrites: These are the processes of the nerve cells and form the white matter of the nervous system. They are found deep in the brain and at the periphery of the spinal cord and are described as nerves or nerve fibres outside the brain and the spinal cord.

The axon consists of the following parts:

(a) Axo lemma: It is the membrane of axon and contains axoplasm.

(b) Myelin: It is a sheath of fatty material which surrounds most axons and gives them white appearance. The myelin sheath is absent at intervals along the length of the axon and near its branching end. These intervals are called 'Nodes of Rangier' and they contribute to rapid transmission of nerve impulses along the myelinated fibres.

The axons of the neurons which do not possess myelin sheath together form non-myelinated fibres.

(c) Neurilemma: It is a very fine, delicate membrane surrounding the axons of all peripheral nerves. It consists of a series of 'Schwann cells' which surround the axon and the myelin sheath.

Dendrites: These are the processes on nerve cells which carry impulses towards nerve cells. These are shorter than axon and each neuron has many dendrites.

Types of Neurons

1. Sensory or Afferent neurons: These neurons transmit impulses from the periphery of the body to the spinal cord and then to the brain where they are interpreted and sensed, e.g. sense of taste, sight, touch etc.

2. Motor or Efferent neurons: These neurons convey impulses from the brain and spinal cord to other parts of the body stimulating glandular secretion or causing muscle contraction.

3. Intercalated neurons: These are found between sensory and motor neurons and form links in the pathways of nerves.

Synapse: In the transmission of a nerve impulse, whether sensory or motor, more than one neuron is always involved. The point at which the nerve impulse passes from one neuron to another is called synapse. Various chemicals known as transmitters are secreted in the synapse and are involved in the transmission of information across the synapse.

Tissue repair: The embryonic tissues are capable of dividing by mitosis enabling the tissues to grow and repair. As the body continues to develop, the ability of cells of certain tissues to divide is greatly reduced and lost. Thus, muscular and nervous tissues loose their ability to divide on their complete development. On the other hand, other tissues of the body remain mitotically active and are capable of undergoing repair.

Following tissue damage its repair begins with an inflammatory response. In tissue damage, the damage to blood vessels results into formation of a blood clot. The fibroblasts migrate into the blood clot and begin to form fibres that replace the clot and bridge the damaged surfaces of tissue. During this process, the blood vessels revascularise the area. In case of major tissue damage the active fibroblasts produce actively growing connective

tissue called granulating tissue. While fibroblasts produce fibrous tissue, the epithelial cells surrounding the damaged tissue undergo mitotic division forming new cells. The fibrous connective tissue is either resorbed as the new epithelial cells are formed, or else it remains as a permanent scar.

EXERCISE

1. Define tissue. Explain in detail four different types of epithelial tissues.
2. Differentiate between smooth and skeletal muscle. Explain physiology of smooth muscle contraction.
3. Classify connective tissues.
4. Explain features and functions of cardiac muscle and skeletal muscle.
5. Explain in details adipose tissue.
6. Define muscular tissue. Write a short note on muscular tissue.
7. Write a short note on nervous tissue.
8. Define cartilage. What are the various types of cartilages? Name the organs in the body where white fibrocartilage is found.
9. List the primary tissues of the body and their functions.
10. What are cilia? What is their function? Name the organs in the body having ciliated epithelium.

***

UNIT II

Chapter ... 3

INTEGUMENTARY SYSTEM

♦ LEARNING OBJECTIVES ♦

- *To study the system that basically covers and protects the human body.*
- *To understand the structural features of the skin which help in performing its varied functions.*
- *To appreciate the specialized activities of the skin that balances and regulates the body conditions to adjust with the external environment.*

3.1 INTRODUCTION

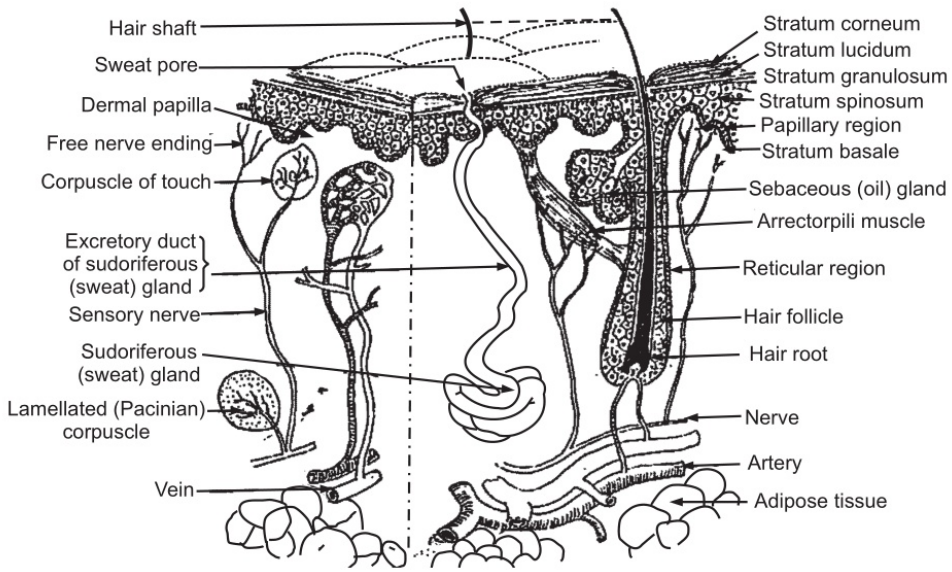


Fig. 3.1: Section of Skin

The surface area of skin in an adult is approximately about 01.5-02 m^2; however it may vary according to the individual; age and other factors. Skin has normally two layers, epidermis and dermis and below the dermis there is a fatty layer, called as subcutaneous layer. (See Fig. 3.1).

3.2 THE EPIDERMIS

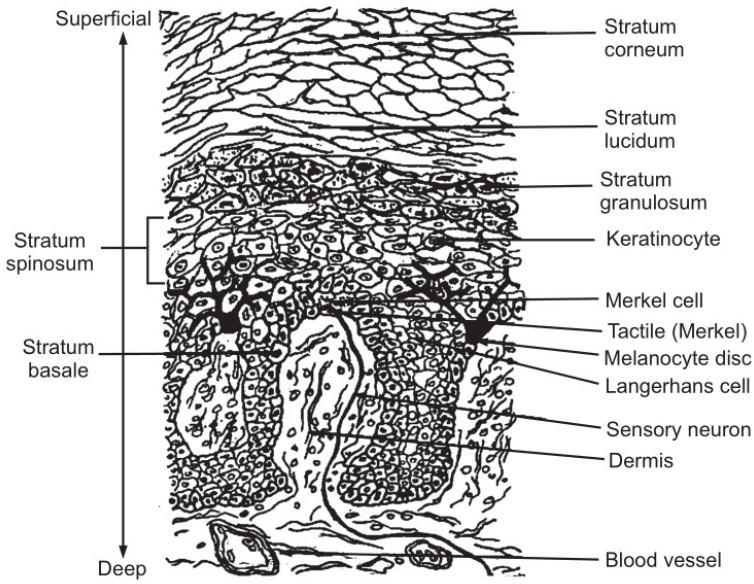


Fig. 3.2: Cell Types and Layers in the Epidermis of Skin

Epidermis is made up of stratified epithelium and thickness of the layer varies according to the site or position of the body. The soles of feet and palms of hands are little thicker than the rest of the body. Blood vessels are absent in this area and the inner part has interstitial fluid, coming from the dermis. This layer provides nutrients and oxygen. The stratum corneum is constantly replaced by deep layers, because the stratum corneum is constantly cast-off and is replaced by deeper layer, this change in replacement takes place in about approximately 40–45 days. The neat and healthy surface of skin is essential, but it depends upon several factors, such as cell division or Keratinisation or cells etc. The various structures enter through epidermis, the sweat duct, sebaceous gland secretion, and the hair etc.

The surface of epidermis looks slightly uneven, but it is due to papillae formed in uppermost part of dermis. The colour shown by the skin depends on various reasons. The lowermost part of terminative zone contains melanocyte secreting pigment melanin. The epidermis has ridges due to projection of the papillae. The ridge development varies according to individuals which may help in fingerprints. The terminative zone provides nutrition to epidermal cells. Also, the colour of the skin depends upon level of oxygen in the

haemoglobin bile pigment present in the blood and amount of melanin circulating in the blood.

The epidermis has three layers, the stratum corneum which is the uppermost layer of skin. This layer has flat cells, but no nuclei; the protoplasm present in these cells has been converted into hard substance called Keratin. Below the stratum corneum is stratum lucidum which has distinct nuclei, and protoplasm in these cells is less; and below the stratum lucidum is the stratum granulose. In this layer fine granules are present. These three layers together are known as Horney zone. Below this zone, there are two different layers of cells. The prickle cells (stratum spongium) have different shapes and size. These cells have short thorn like protoplasmic processes, which intermingle with each other. Below this layer is the basal layer of different shapes and sizes; it has nuclei and protoplasm. These two layers together are known as terminative zone.

3.3 DERMIS

It is the inner layer below the epidermis and made of elastic tissues. This layer is composed of collagen fibres forming network with elastic fibres. If the skin is overstretched, the elastic fibres may rupture; such overstretching of skin is observed in pregnancy condition. The collagen fibres bind with water but as age advances water binding ability decreases: the skin shows wrinkling. In the deepest layer there are areolar tissue and fat bodies. The structure of dermis contains various other structures, such as lymph vessels, blood vessels, sensory nerve endings; sweat glands, sweat duct, hair roots; hair follicle, hair bulb, and hair, the involuntary muscles such as erector pilorum and sebaceous glands.

The lymphatic system provides lymph vessels which form network throughout the dermis region.

Blood vessels

There is a network of blood vessels which supply blood to sweat glands, sebaceous glands, hair root, hair follicle and rest part of the dermis. The epidermis obtains nutrition and oxygen from the interstitial fluid, which has been derived from blood vessels present in the papillae region. The sensory nerve endings respond to touch, temperature, pressure and pain. The skin is the most important sensory organ; thus a person is aware of pain, temperature touch and pressure. Due to stimulation of nerve endings, the impulses are generated; these impulses are carried through the sensory nerve to the sensory area of cerebral cortex of brain. But when there is over stimulation the person senses pain.

Sweat gland

These glands are present throughout the skin and are found in maximum number in the soles of feet, palms of the hand, groins and axillae. Sweat glands are mainly made up of the epithelial cells and the glands look coiled in appearance in the dermis. Sweat duct leads away from the gland, goes through dermis, and epidermis and opens into small pore at the

surface of skin where the sweat is poured and some of the ducts also open into hair follicles. In axillae region, the sweat is decomposed by microbes, producing unpleasant odour of sweat. Sweat glands assist in regulation of body temperature. The sweat takes away the heat from the body when evaporation of sweat takes place. Sweat formation is controlled by temperature regulating centre present in hypothalamus. If there is excessive sweating, the individual may suffer from dehydration and loss of sodium chloride. It can be balanced by taking water and some salt.

Hair Follicle, Hair Bulb, Hair Root

The hair follicle is a downward growth of epidermal cells. Below the follicle, there is widened part, this part is called as hair bulb. The cells of bulb multiply and gives rise to hair, the hair coming from hair root, goes to upper side, away from the nutritional supply, so the cells die and they are non-keratinized. The hair above skin is known as shaft and remaining lower part is known as root. The colour of the hair depends on the presence of melanin.

The arrestor pilorum are involuntary muscle fibres, attached to hair follicles. Due to the contraction of arrestor pilorum, the hair gets pulled downwards, and hence the hair stands erect. These muscles are stimulated by sympathetic nerve fibres.

Sebaceous Glands

These glands are present throughout the skin, except sole of feet and palms of hands. Sebaceous glands are composed of secretory epithelial cells, secreting oily substance called sebum. The sebum is poured into the hair follicle. Sebaceous glands are maximal in the face and scalp region. Sebum keeps the hair soft and shiny in texture and appearance. It provides waterproofing to the skin and acts as fungicidal and bactericidal agent, preventing entry of micro-organism into the body. It also prevents drying of skin when individual is exposed to heat.

3.4 SKIN FUNCTIONS

It is the main protective organ of the body. Mostly deeper organs are protected. It prevents the invasion of pathogenic organisms and entrance of harmful chemicals. The skin forms a waterproof layer, so dehydration is prevented. The skin contains nerve endings, so it can feel thus preventing the body from harm by its stimulus reaction.

1. Temperature Regulation in the Body

The normal temperature of the body is about 36.5°C. In healthy person, there is slight variation in temperature say about 0.5–0.75°C. During certain changes in physiological condition, such as exercise, just before ovulation and in the evening, there is slight rise in temperature besides change in the metabolic rate; either temperature decreases or increases. During the metabolism of fats, carbohydrates or protein food, some energy is produced in the form of heat and also due to contraction of voluntary muscles, maximum heat is produced. In the liver, various chemical activities takes place and large amount of

heat is produced. Even during digestion, there is contraction of smooth muscles, which also produces the heat. Heat loss from the body occurs by various ways and maximum heat is lost through skin. Some amount is lost during excretion, such as urine excretion, faces, or even exhaled air. But the heat lost through skin can be controlled to maintain a constant body temperature. In the hypothalamus, there is heat regulating centre, which controls the temperature of the circulating blood. The medulla oblongata contains vasomotor centre that controls the diameter of blood vessels. Due to dilation of the blood vessels, there is increase in loss of heat by radiation, conduction and convection and by narrowing the blood vessel, heat loss from the body is reduced.

The skin contributes to thermoregulation, the homeostatic regulation of body temperature occurs in two ways:

(i) By liberating sweat at its surface by adjusting the flow of blood in the dermis.

(ii) In response to high environmental temperature or heat produced by exercise, sweat production increases; the evaporation of sweat from skin surface helps to lower body temperature.

In addition, blood vessels in the dermis of the skin dilate; consequently more blood flows through the dermis, which increases the amount of heat loss from the body. In response to low environmental temperature, production of sweat is decreased, which helps to conserve heat. Also, the blood vessels in the dermis of the skin constrict, which decreases blood flow through the skin and reduces heat loss from the body. If there is slight rise in temperature, sweat glands become active to secrete sweat. This sweat is carried towards surface of skin by sweat duct. Sweat is evaporated, so it helps in cooling body temperature.

2. Blood reservoir: The dermis houses an extensive network of blood vessels that carry 8-10% of the total blood flow in resting adult. For this reason, the skin acts as a blood reservoir.

3. Protection: The skin provides protection to the body in various ways.

(i) Keratin protects underlying tissues from microbes, abrasion, heat and chemicals and tightly interlocked keratinocytes resist invasion by microbes.

(ii) The oily sebum from the sebaceous glands keeps skin and hairs from drying out and contain bactericidal chemicals that kill surface bacteria.

(iii) The acidic pH of perspiration retards the growth of some microbes.

(iv) The pigment melanin helps shield against the damaging effects of UV light.

(v) The lipids released by lamellar granules retard evaporation of water from the skin surface, thus guarding against dehydration; they also retard entry of water across the skin surface during showers and swims.

4. Cutaneous sensation: Cutaneous sensations are sensations that arise in the skin, including tactile sensations-touch, pressure, vibration and tickling as well as thermal sensations such as warmth and coolness. Another cutaneous sensation, pain, usually is an indication of impeding or actual tissue damage. There are wide variety of nerve endings and receptors distributed throughout the skin, including the tactile discs of the epidermis, the corpuscles of touch in the dermis, and the hair root plexus around each hair follicle.

5. Excretion and Absorption: The skin normally has a small role in excretion, the elimination of substances from the body and absorption, the passage of materials from the external environment into body cells.

(i) Despite the almost waterproof nature of the stratum corneum, about 400 ml of water evaporates through it daily. A sedentary person loses an additional 200 ml of per day as sweat; a physically active person loses much more.

(ii) Besides removing water and heat from the body, sweat also is a vehicle for excretion of small amounts of salts, carbon dioxide, two organic molecules that result from the breakdown of protein i.e. urea and ammonia.

(iii) The absorption of water soluble substances through the skin is negligible, but certain lipid-soluble materials do penetrate the skin. These includes fat-soluble vitamins (A, D, E and K), certain drugs, and gases oxygen and carbon dioxide.

(iv) Toxic materials that can be absorbed through the skin include organic solvents such as acetone (in some nail polish removers) and carbon tetrachloride (dry cleaning fluid); salts of heavy metals such as lead, mercury and arsenic; and substances in poison ivy and poison oak.

(v) Since, topically applied steroids such as cortisone, are lipid soluble, they move easily into the papillary region of the dermis. Here, they exert their anti-inflammatory properties by inhibiting histamine production by mast cells.

6. Synthesis of Vitamin D: Synthesis of vitamin D requires activation of a precursor molecule in the skin by UV rays in sunlight. Enzymes in the liver and kidneys then modify the activated molecule, finally producing calcitrol, the most active form of vitamin D. Calcitrol is a hormone that aids in the absorption of calcium in foods from the gastrointestinal tract into the blood.

EXERCISE

1. Draw a labelled diagram of V.S. of skin.
2. Name and describe the skin glands.
3. What is sebum? What are its functions?
4. Describe the functions of skin.
5. Explain the role of skin in maintenance of body temperature.

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Chapter ... 4

SKELETAL SYSTEM

♦ LEARNING OBJECTIVES ♦

- *To study the tissue system that forms the framework of the body.*
- *To learn and appreciate the structural characteristics of bones that constitute the skeleton.*
- *To study the types of bones and their related functions.*
- *To learn the varied functions of bones and disorders in the joints.*

4.1 INTRODUCTION

Skeleton constitutes the bony framework of the body.

The skeletal system consists of about 206 bones to make a strong, movable living framework for the body. It supports and protects softer, delicate tissues and organs and they form joints for the movement of the body. The bones making up the skeleton are of various types e.g. long bones, short bones, flat bones, irregular bones etc.

The bones perform following important functions:

(1) They form the supporting framework of the body;

(2) They form boundaries for the cranial, thoracic and pelvic cavities;

(3) They give protection to delicate organs;

(4) They form joints which are essential for the movement of the body;

(5) They provide attachment for the voluntary muscles. This helps in the movements of joints;

(6) They form blood cells in the red bone marrow in cancellous bone; and

(7) They act as a store house of calcium salts.

The bones of the skeleton are divided into two groups:

(1) The Axial Skeleton: It consists of the bones which form the skull, the vertebral column and the thoracic cage.

(2) The Appendicular Skeleton: It consists of shoulder girdles, upper limbs, pelvic girdle and lower limbs.

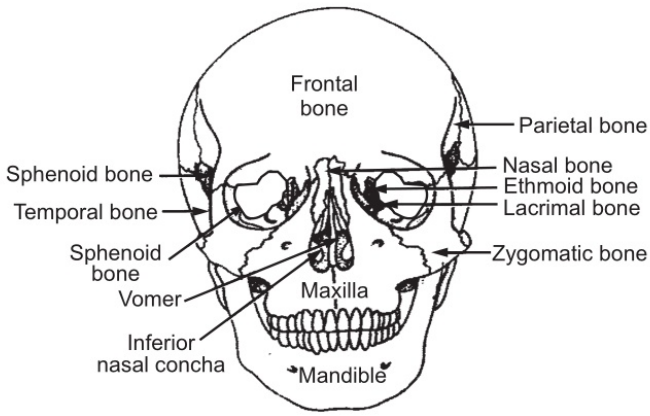
4.2 THE AXIAL SKELETON

The bones of the axial skeleton constitute the central bony core of the body.

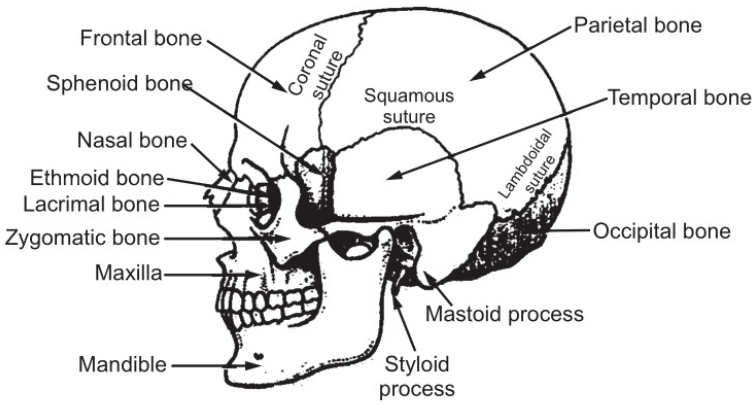
4.2.1 The Skull

It rests upon the upper end of the vertebral column and its bony structure is divided into two parts viz., cranium and face.

The Cranium: It provides bony protection to the brain. It is described in two parts: base and vault. The base is a part on which the brain rests and the surrounding part is termed as the vault. The base is divided into the anterior, middle and posterior cranial fossae. The inner surfaces of all the cranial bones are supplied with blood vessels. The bones which form the cranium [Fig. 4.1 (a) and (b)] are: one frontal bone; two parietal bones; one occipital bone; one sphenoid bone; one ethmoid bone and two temporal bones.



(a) The Bones of the Skull (Anterior View)



(b) The Bones of the Skull (Lateral View)

Fig. 4.1

1. The Frontal Bone:

The frontal bone is a large flat bone which forms the forehead and also the upper part of the orbital cavities. It develops in two parts which gradually fuse into one bone. It contains two cavities called the frontal sinuses which lie one over each orbit. They contain air which enters by a small opening leading from nasal cavities. These sinuses give lightness to the bone and resonance to the voice, acting as sounding chambers.

2. The Parietal Bones:

The parietal bones are two flat bones forming sides and roof of the skull. They articulate with each other and with frontal, occipital and temporal bones. The inner surface is concave and is grooved by the brain and blood vessels.

3. The Occipital Bone:

The occipital bone forms back of the head and part of the base of the skull. It forms immovable joints with parietal, temporal and sphenoid bones. On the outer surface, there is a roughened area called occipital protuberance. In this bone, there is a large opening known as the foramen magnum, for the passage of spinal cord.

4. The Temporal Bones:

The temporal bones lie on each side of the head (Fig. 4.2). Each temporal bone is divided into four parts. They are:

(1) The squamous part is the fan shaped portion.

(2) The mastoid process is a thickened part of bone and can be felt just behind the ear. It contains a large number of small air sinuses which communicate with middle ear. A styloid process projecting from it gives attachment to muscles.

(3) The petrous portion is thick and forms a part of the base or floor of the skull and contains the organ of hearing.

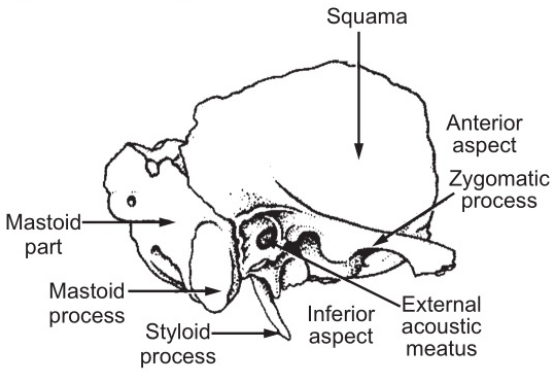


Fig. 4.2: The Temporal Bone (Lateral View)

(4) The zygomatic process is directed forward and articulates with the zygomatic bone to form zygomatic arch.

5. The Sphenoid Bone:

The sphenoid bone is an irregular bone in the shape of a bat with its wings outstretched and lies in the centre of the base of the skull (Fig. 4.3). On the superior surface of the middle of the bone, there is a depression in which the pituitary gland rests. The wings are perforated by many openings for the passage of nerves and blood vessels.

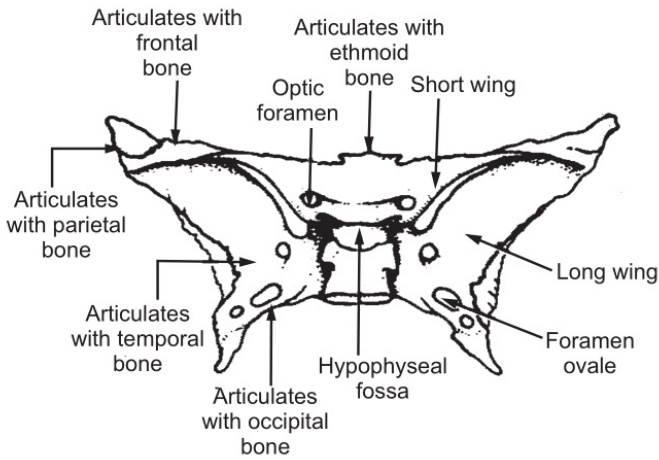


Fig. 4.3: Sphenoid Bone (from Above)

6. The Ethmoid Bone:

The ethmoid bone is a very light, fragile, irregular bone and occupies an anterior part of the base of the skull and helps to form the orbital cavity, the nasal septum and the lateral walls of the nasal cavity (Fig. 4.4).

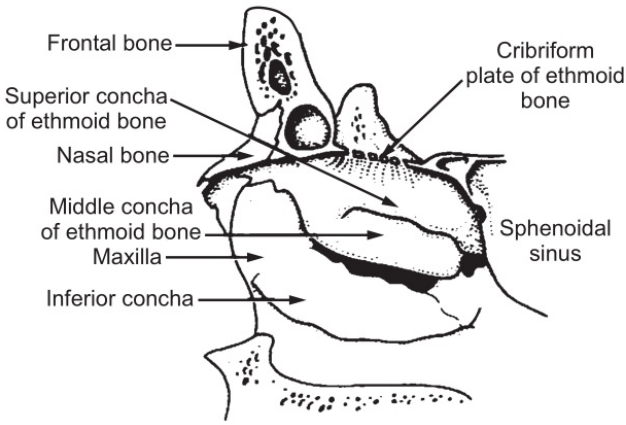


Fig. 4.4: Ethmoid Bone

It has a horizontal flattened part called cribriform plate which has many fine openings like a sieve. The openings are for the passage of the nerves of smell called the olfactory nerves. It also contains a flat vertical portion between the two nasal cavities. Two spongy portions form an outer wall of the upper part of the nasal cavity and inner wall of the orbit. On each side, the spongy portions present two projections into nasal cavities which are called turbinated processes. The spongy portions contain a number of air cavities which communicate with the nose.

The Face: There are thirteen bones which form the skeleton of face. They are two zygomatic or cheek bones; one maxilla; two nasal bones; two lacrimal bones; one vomer; two palatine bones; two inferior conchae or turbinated bones and one mandible (Fig. 4.1).

Each zygomatic bone forms the prominence of cheek and part of the floor and lateral walls of orbital cavity. It articulates with zygomatic process of the temporal bone to form a zygomatic arch.

Maxilla or upper jaw bone forms the upper jaw, the anterior part of the roof of the mouth, the lateral walls of the nasal cavities and part of the floor of orbital cavities. It presents the alveolar ridge which projects downwards and carries the upper teeth. On each side, there is a large air sinus, the maxillary sinus which is lined with ciliated mucous membranes and communicates with the nasal cavity.

The nasal bones are two small bones which form greater part of the lateral and superior surfaces of the bridge of the nose. They articulate with each other medially.

The lacrimal bones are two very small bones located in a position posterior and lateral to the nasal bones. They also form the inner wall of the orbit. They are grooved and the groove contains lacrimal sac and nasal duct. It carries tears or lacrimal fluid from eye down to the nasal cavity.

The vomer is a thin flat bone which extends upwards from middle of the hard plate to separate the two nasal cavities.

The palatine bones are two irregular bones which form the back of the hard palate and extend upto the outer wall of the nasal cavity into the floor of the orbit.

The turbinate bones are two small scroll-shaped flat bones which form a part of the lateral wall of the nasal cavity.

The mandible is the strongest bone of the face and is the only movable bone of the skull. It has two identical parts. Each part consists of (1) a curved body on the superior surface of which there is the alveolar ridge containing the lower teeth and (2) a ramus which projects upward (Fig. 4.5). At the upper end, the ramus is divided into two processes; the condyloid process which articulates with the temporal bone and the coronoid process which gives attachment to muscles and ligaments. The point where the ramus joins the body is called the angle of the jaw.

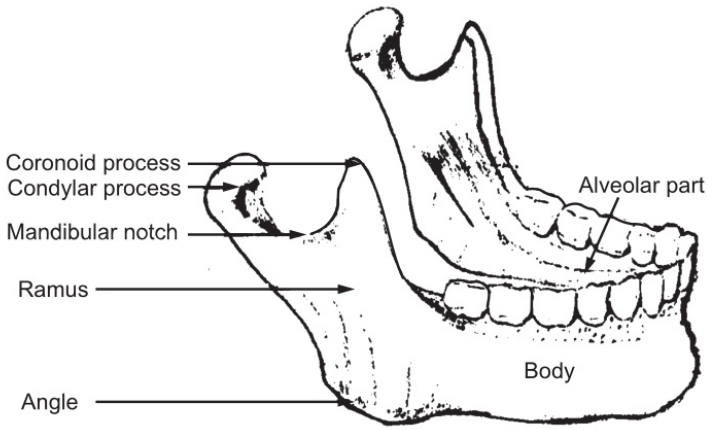


Fig. 4.5: The Mandible (Lateral View)

The hyoid is an isolated horse-shoe-shaped bone lying in the soft tissue of the neck. It lies at the base of the tongue and gives attachment to the tongue muscle. It does not articulate with any other bone of the head or trunk but is attached to the styloid process of the temporal bone by ligaments.

4.2.2 The Vertebral Column

It consists of twenty-four separate, movable, irregular bones called vertebrae which are divided into three groups viz.; cervical (seven); thoracic (twelve) and lumbar (five). (Fig. 4.6). In addition, the sacrum consisting of five fused bones and the coccyx consisting of four fused bones which also form a part of the vertebral column. When viewed from the side, the vertebral column shows four anteroposterior curves. They are: cervical curve, in the neck which is convex forwards; thoracic curve, convex backwards; lumbar curve, convex forwards and the pelvic curve convex backwards. Posteriorly convex curves, thoracic and pelvic, are called primary curves and anteriorly convex curves are called secondary curves.

Each vertebra consists of: (1) A disc-shaped body lying in the front and (2) An arc of bone pointing backwards from the body and enclosing a space between body and arch called the neural or spinal canal through which the spinal cord passes. This arch carries three rough processes for muscle attachment. One spinous process which projects backwards and two transverse processes one on either side. On the superior and inferior surfaces of the neural arch, there are two articular processes (Fig. 4.7), which carry smooth surfaces to articulate with similar processes on the vertebrae above and below. The arch carries a notch on either side on the under surface. The narrow part of the arch above the notch is known as the pedicle (Fig. 4.7). The wide part of the arch carrying the spinous process is known as the lamina, which forms the back wall of the vertebral column. The vertebrae lie body over body and arch, over arch forming a continuous column.

The bodies are joined to each other by thick pads of fibrocartilage called the intervertebral discs. The discs consists of a ring of fibrocartilage and a softer pulpy centre called the nucleus. The discs serve to allow slight movement of bone on bone and yet make very strong joints. They also absorb shock to prevent its passage to the brain.

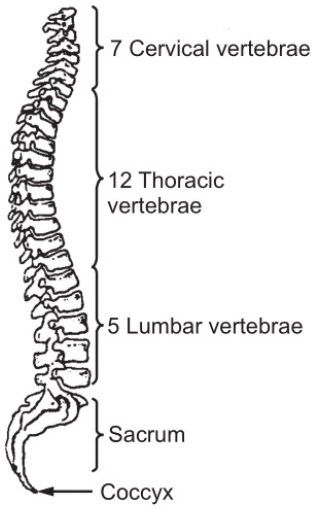


Fig. 4.6: The Vertebral Column. Lateral View

The Cervical Vertebrae: These are the smallest separate vertebrae with relatively large openings; they run down the neck forming a slightly forward curve. They have two special features: (a) Each transverse process carries an opening through which a vertebral artery passes upwards to the brain. (b) The spinous process is forked or bifid giving attachment to muscles and ligaments.

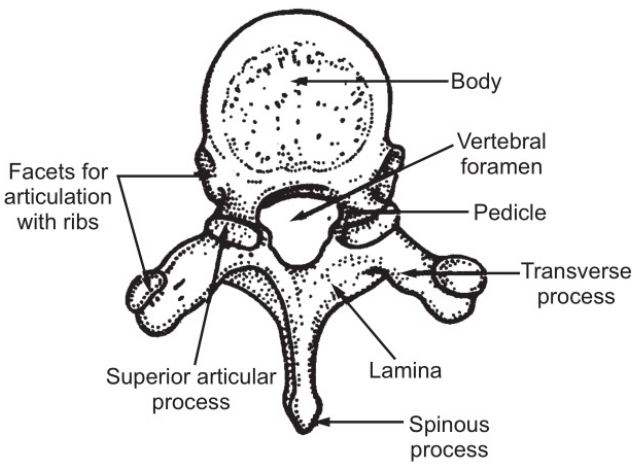


Fig. 4.7: A Typical (Lumbar) Vertebra

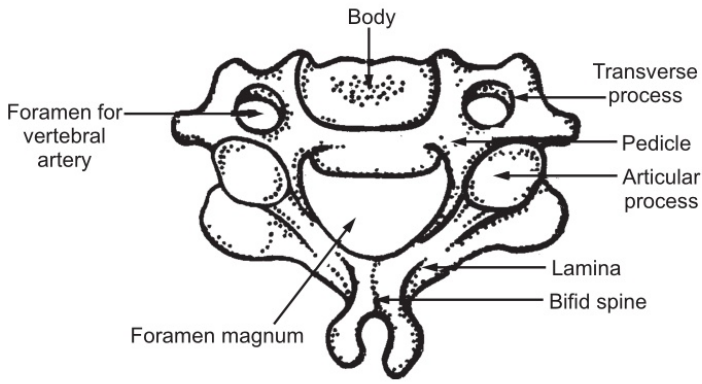


Fig. 4.8: A Cervical Vertebra

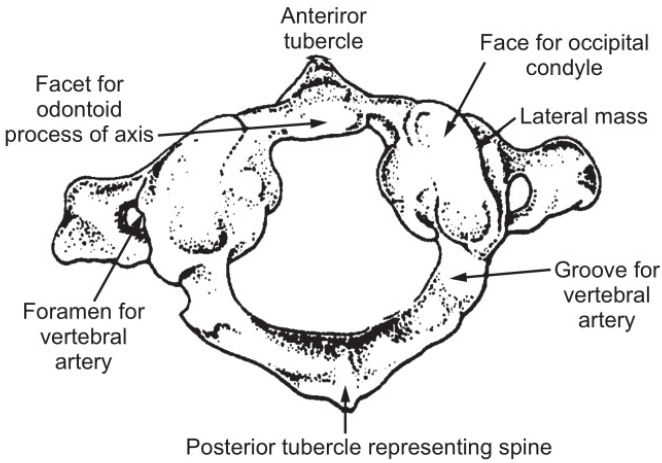


Fig. 4.9: The Atlas

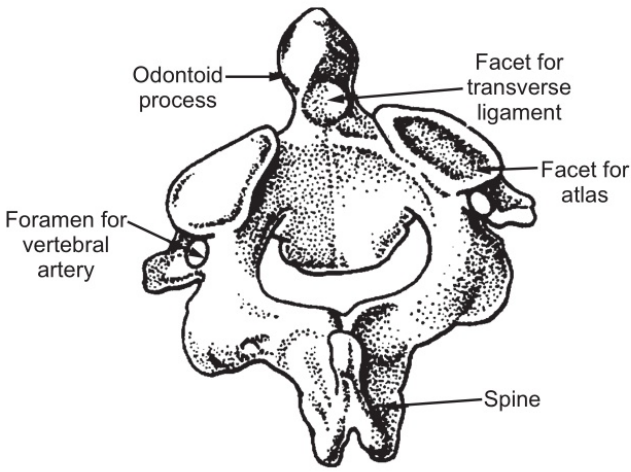


Fig. 4.10: The Axis

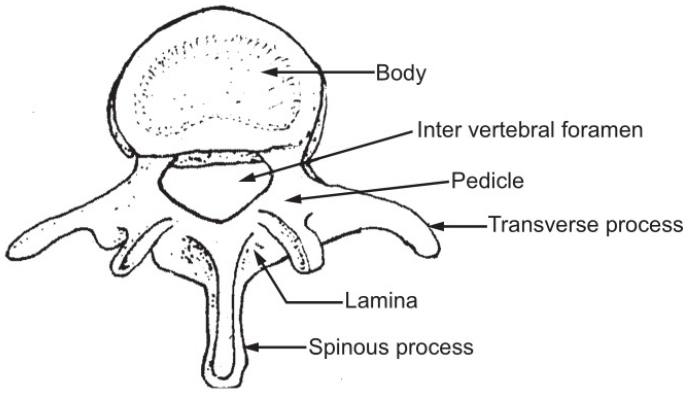


Fig. 4.11: A Thoracic Vertebra

Atlas (Fig. 4.9): It is the first cervical vertebra consisting of a ring of bone with two short transverse processes. The ring is divided into two parts.

(i) The anterior part is occupied by the odontoid process of the axis which is held in position by a transverse ligament.

(ii) The posterior part is the vertebral foramen and is occupied by the spinal cord. On its superior surface, it has two facets which form joints with the condyles of the occipital bone. The nodding movements of the head takes place at these joints.

Axis: It is the second cervical vertebra. The body is small and has an upward projecting tooth-like 'odontoid process' or the 'dens'. This process articulates with the atlas (Fig. 4.10).

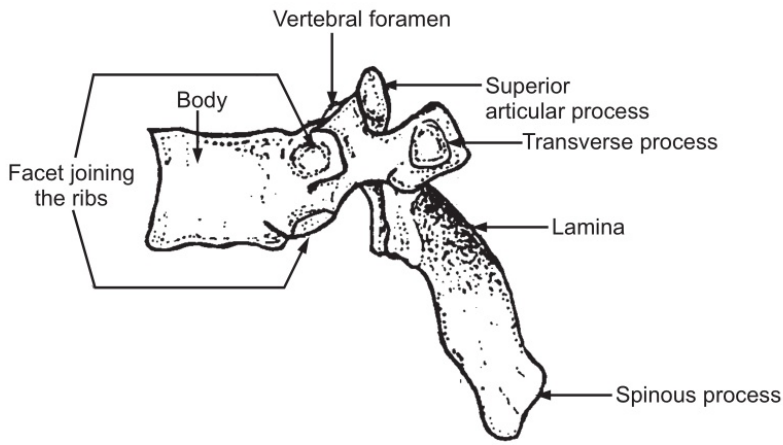


Fig. 4.12: Thoracic Vertebra (Viewed from the Side)

Other cervical vertebrae are typical. The seventh cervical vertebra does not have a forked spinous process; its process projects considerably and is, therefore, an important anatomical land-mark.

The Thoracic Vertebrae: They have two special features (Figs. 4.11 and 4.12):

(a) The spinous processes are long and point downwards, so that they partly overlap each other.

(b) Since, the vertebrae articulate with the ribs, they have six facets, out of which four articulate with the ribs.

The heads of the ribs lie between the vertebrae, and articulate with one facet on the vertebra above and the other below this vertebra being numbered according to the rib which lies above it.

The Lumbar Vertebrae: The bodies of these vertebrae are largest and the vertebral foramina are smallest. The spinous processes are short, flat-sided and project straight back (Fig. 4.7) giving attachment to the powerful muscles supporting the back.

The Sacral Vertebrae: These are fused together to form one bone known as sacrum (Fig. 4.13). This runs down the back of the pelvis forming a backward curve and the upper projecting curve forming the promontory of the sacrum. The upper part of the base of the bone articulates with the fifth lumbar vertebra. On each side, it articulates with the ilium to form sacroiliac joint and at its inferior tip, it articulates with the coccyx. On each side of the vertebral foramina, there is a series of foramina, one below the other for the passage of the nerves.

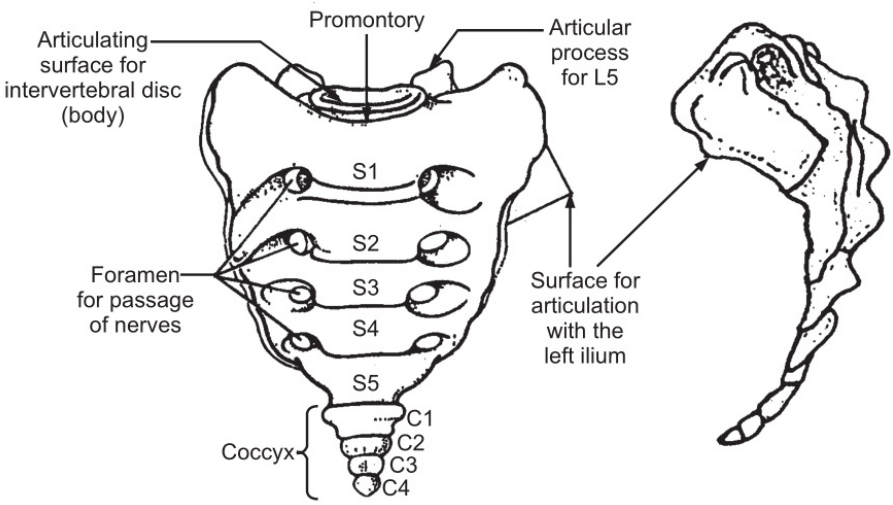


Fig. 4.13: The Sacrum and Coccyx

The Coccygeal Vertebrae: Coccyx consists of four terminal vertebrae fused together to form a small triangular bone, the broad base of which articulates with the tip of the sacrum.

The movements of individual bones of the vertebral column are very limited. The movements of the column as a whole which include bending forward, backward, sidewise or turning around are quite extensive. There are more movements in the cervical and lumber regions than elsewhere.

Functions of the Vertebral Column:

(1) It provides a strong bony protection for the delicate spinal cord lying within it. Spinal nerves, blood vessels and lymph vessels pass through intervertebral foramina.

(2) It supports the skull which is protected from shock by the presence of the intervertebral discs.

(3) It forms the axis of the trunk and gives attachment to the ribs, the shoulder girdle and the upper limbs, the pelvic girdle and the lower limbs.

4.2.3 The Thoracic Cage

The bones of the thoracic cage (Fig. 4.14) are as follows: 1 sternum; 12 pairs of ribs and 12 thoracic vertebrae.

The Sternum [Fig. 4.15 (a)]: It is a flat bone in the middle of the chest. It is shaped like a dragger and is described in three parts.

1. The manubrium is the uppermost part and presents two articular facets on its lateral borders for articulation with the clavicles.
2. The body or middle portion is called gladiolus. It presents facets on the lateral borders for the attachment of the ribs.
3. The Xiphoid process is the tip of the bone which gives attachment to the diaphragm and muscles of the anterior abdominal wall. The process is also called Xiphisternum. The ribs join the sternum by strips of cartilage.

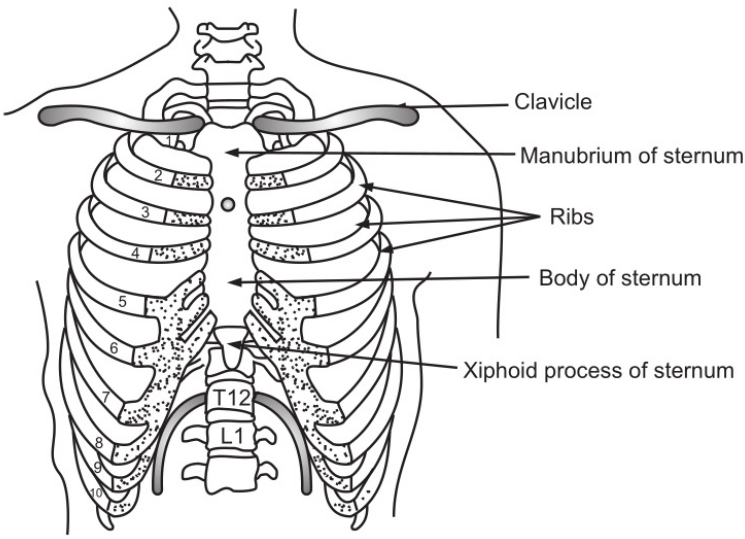
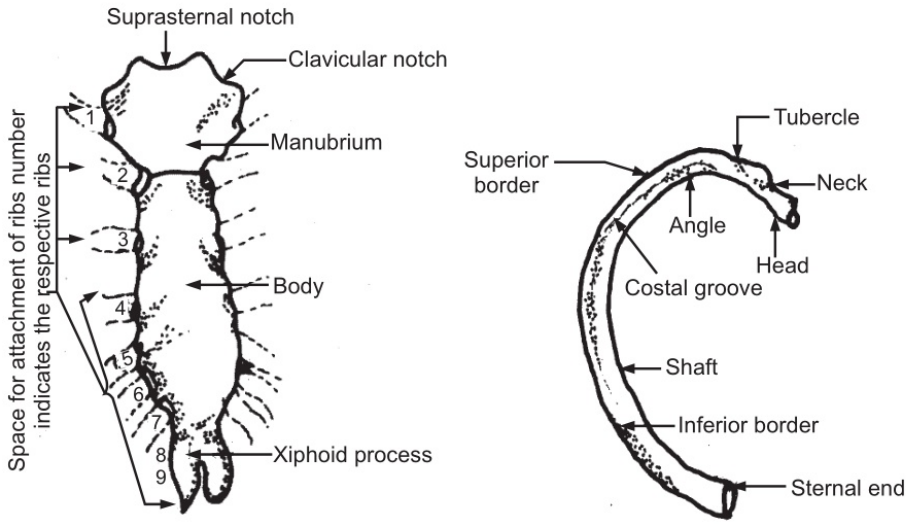


Fig. 4.14: The Thoracic Cage

The Ribs: There are twelve pairs of ribs which form bony lateral walls of the thoracic cage. The first seven are described as true ribs; the eighth, ninth and tenth are called false ribs and the last two are called floating ribs. All the pairs articulate posteriorly with thoracic vertebrae. Anteriorly, the first seven ribs are directly attached to the sternum; the latter three are only indirectly attached to the sternum and the last two pairs have no anterior attachment.

Each rib is a flat curved bone having a head, neck, tubercle, angle, sternal end, anterior and posterior surface and a superior and inferior border. Fig. 4.15 (b). The head articulates



(a) The Sternum **(b) A typical rib**

Fig. 4.15

posteriorly with bodies of two adjacent vertebrae. The neck is a constricted portion next to head and between the head and the tubercle. The tubercle articulates with the transverse process of thoracic vertebra. The angle is the point at which the bone bends. The sternal end is attached to the sternum by a costal cartilage. The superior border is rounded and smooth while the inferior border exhibits a marked groove occupied by blood vessels and nerves. The first rib does not move during respiration.

Spaces between the ribs are occupied by intercostal muscles. During respiration, when these muscles contract, the ribs and sternum are lifted upwards and downwards increasing the capacity of thoracic cavity. The ribs increase in size from above to downwards so that the thoracic cavity is roughly cone-shaped. The thoracic vertebrae are described earlier.

4.3 THE APPENDICULAR SKELETON

It consists of shoulder girdles with upper limbs and pelvic girdle with lower limbs. Each shoulder girdle consists of one clavicle and one scapula. On each side of the shoulder girdle following bones are attached: one humerus, one radius, one ulna, eight carpal bones; five metacarpal bones and fourteen phalanges.

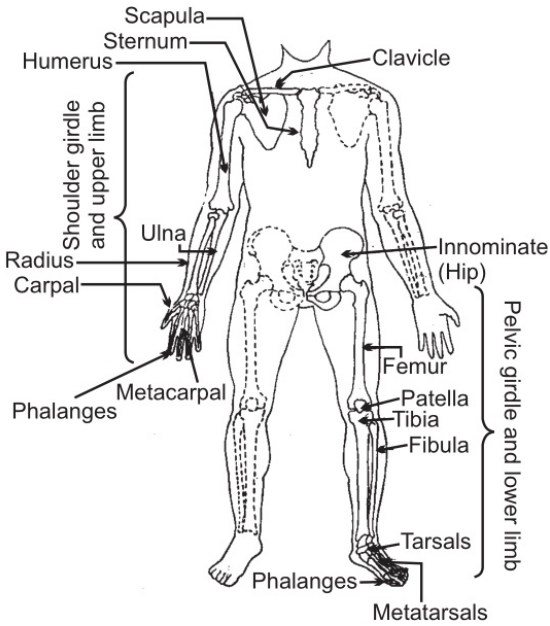


Fig. 4.16: The Bones of the Appendicular Skeleton

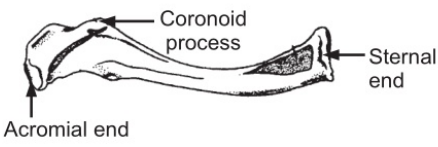


Fig. 4.17: The Clavicle

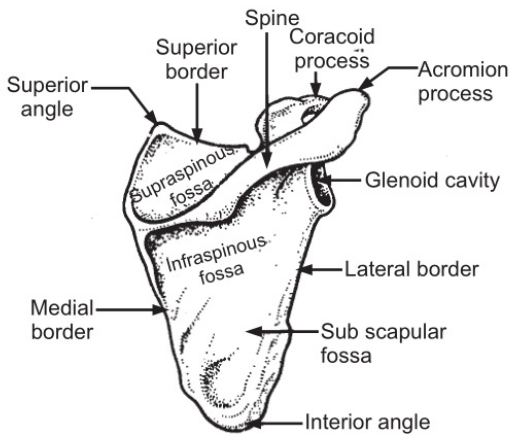


Fig. 4.18: The Scapula (Posterior View)

The clavicle is a long bone which is roughly S-shaped (Fig. 4.17). On one end it articulates with the manubrium of the sternum and on the other end it forms joint with 'acromion process' of scapula. This clavicle is the only bony link between the upper extremity and the axial skeleton. It lies close under the skin and is easily felt. It keeps the scapula in position.

Scapula or shoulder blade is a flat triangular bone lying on the posterior chest wall, superficial to the ribs (Fig. 4.18). It is held in place by muscles which attach it to the ribs and the vertebral column. It has three borders called medial, superior and lateral and three angles named as superior, inferior and lateral. Superior and medial borders meet at superior angle and lateral and medial borders meet at inferior angle. The point at which superior, and lateral borders meet at lateral angles represents a shallow articular surface called glenoid cavity which together with the head of the humerus forms the shoulder joint. It has two processes, one of them is coracoid process which projects forward from the superior border of the bone. The posterior surface of the scapula is divided by a spine.

The spinous process projects beyond the lateral angle as the acromion process and overhangs the shoulder joint. Both these processes give attachment to muscles and keeps the head of humerus in place preventing upward dislocation.

Humerus: It is a long bone and is the largest in the upper limb (Fig. 4.19). It consists of a proximal end or head, neck, shaft and distal end. The head is smooth and rounded and fits into glenoid cavity of the scapula forming the shoulder joint. The neck is a slightly constricted part next to the head. Between the neck and the shaft there are two tubercles called greater and lesser tubercles. These are divided by a deep groove which is occupied by one of the tendons of the biceps muscle. At the proximal end the shaft is cylindrical in shape but is flattened at its anterior and posterior surfaces towards the distal end. The distal end of the bone presents two articular surfaces, the capitulum and the trochlea (Fig. 4.19).

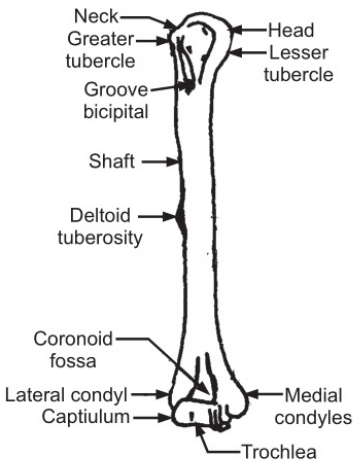


Fig. 4.19: The Humerus

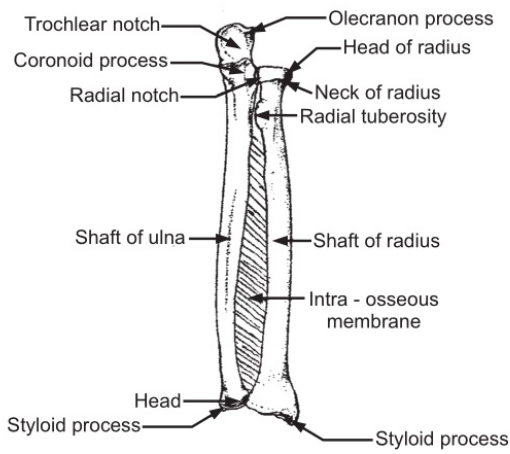


Fig. 4.20: The Radius and Ulna

Immediately above the articular surface, the anterior side of the bone contains coronoid fossa and the posterior surface contains olecranon fossa (Fig. 4.19). The lower end of the bone also contains two condyles for articulation with the radius and ulna respectively. Above the condyles on either side are median and lateral epicondyles (Fig. 4.19).

Ulna and radius are the two bones of the forearm. There is an interosseous membrane between the bones.

Ulna: This is a long bone consisting of proximal end, shaft and distal end or head (Fig. 4.20). It is located on the inner side of the forearm and is slightly bigger than radius. The proximal end contains a semilunar notch called trochlear notch (Fig. 4.20), which articulates with the trochlea of the humerus. At its proximal end, there is the olecranon process which forms the point of an elbow and fits into the olecranon fossa of the humerus when the arm is straight. At its distal end of the trochlear notch lies the coronoid process which fits into the coronoid fossa of the humerus when the arm is bent. A smaller joint cavity, the radial notch, faces outwards and forms a pivot joint with the head of the radius which rotates against it. This joint produces turning movements of a hand.

Shaft of the bone is triangular in shape and carries a sharp ridge for its attachment to the sheet of fibrous tissue. The lower extremity is much smaller and is joined to a wrist joint by a pad of white fibrous tissue. It also carries a styloid process from the posterior end which gives attachment to ligaments.

Radius: It is a long bone and is the outer bone of a forearm. It consists of head, neck, tuberosity, shaft and distal extremity (Fig. 4.20). The head is disc-shaped and flat on the top and articulates with the capitulum of the humerus.

The circumference of head articulates with the radial notch of ulna. At the upper end of the shaft, there is a radial tuberosity which gives attachment to muscles. The shaft carries a sharp ridge facing ulna. The distal end of the bone is expanded. It articulates with the carpal bones to form a wrist joint and with the ulna to form a radiolunar joint (Fig. 4.20). It also carries a styloid process which is felt at the base of the thumb. It gives attachment to ligaments and muscles.

The **carpal bones** are eight in number and are arranged in two rows each consisting of four bonds (Fig. 4.21). The bones are as follows:

Proximal row: Scaphoid, lunate, triquetrum, pisiform.

Distal row: Trapezium, trapezoid, capitate, hamate.

The upper row forms the wrist joint, articulating with the radius, and the lower row articulates with the metacarpus. These bones are closely fitted together and held in position by ligaments which allow certain amount of movements between them.

The metacarpal bones or the bones of hand are five in number and form a structure of palm of a hand. Their upper extremities articulate with carpus and the lower extremities with phalanges.

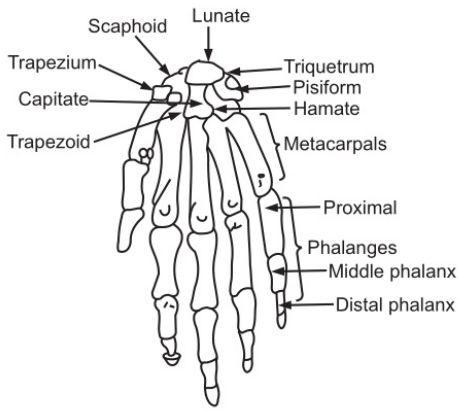


Fig. 4.21: The Carpal Bones

Phalanges or bones of the fingers are fourteen in number and are so arranged that there are three in each finger and two in the thumb. The upper end of these bones is the largest and articulates with the corresponding metacarpal bone at one end and with the middle phalanges at the other end. The lower phalanges are the smallest and form tips of fingers.

The Pelvic Girdle and Lower Limb: Bones of pelvic girdle are two innominate bones and one sacrum. The bones of the lower extremity are as follows:

One femur; one tibia; one fibula; one patella; seven tarsal bones; five metatarsal bones and fourteen phalanges.

Innominate Bone:

Each of the innominate or the hip bones consists of three bones: ilium, ischium and pubis, fused together to form one large irregular bone (Fig. 4.22). On its outer surface, it has a deep depression called acetabulum with which the head of femur forms the hip joint. Ilium is the upper flattened part of the bone and contains the iliac crest (Fig. 4.22). Pubis is an anterior part of the bone and articulates with the pubis of the other hip bone at a cartilagenous joint called symphysis pubis. It also contains a large opening called obturator foramen (Fig. 4.22). Ischium is an inferior and posterior part of the bone which contains ischial tuberosity. The external surfaces of the innominate bones are markedly ridged for the attachment of muscles.

Pelvis (Fig. 4.23) is formed by innominate bones which articulate anteriorly with symphysis pubis and posteriorly with sacrum. The two pubic bones join one another in the middle line. It is divided into greater or false pelvis above and lesser or true pelvis below. The ridge of the bone (Fig. 4.23) called the brim of the pelvis is a separating line for these two parts.

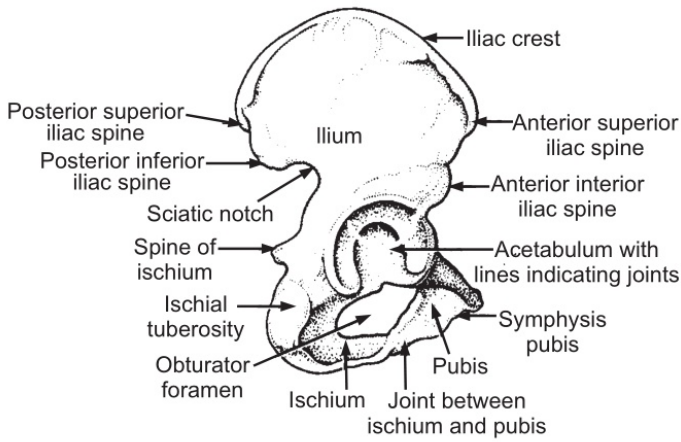


Fig. 4.22: The Innominate Bone

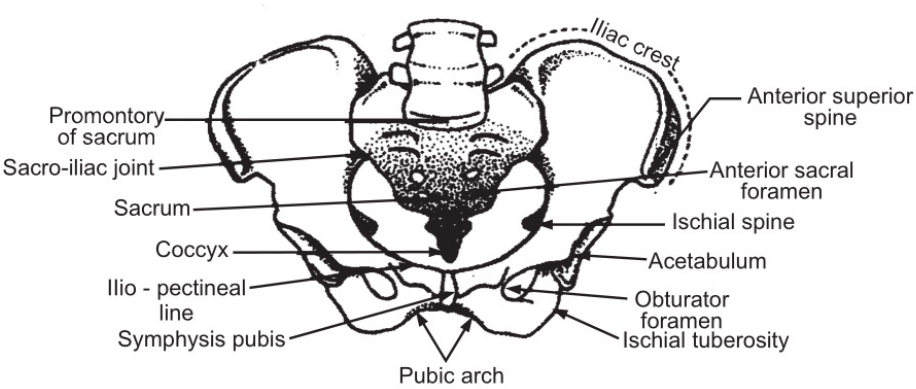


Fig. 4.23: The Pelvis

There are distinct differences between pelvis of male and female. They are as follows:

	Female	Male
Bones	Lighter and smaller	Heavier and longer
Cavity	Shallow and round	Deep and funnel-shaped
Sacrum	More concave anteriorly, making the true pelvis broader	Less concave, making the true pelvis narrower at the outlet.
Pubic-arch	The angle made at the symphysis pubis is wider. The bones are movable for convenience in delivery	The angle of the pubic arch is narrower. The bones are immovable.

Femur:

Femur or a thigh bone is the longest and strongest of all the bones of the body (Fig. 4.24). Proximal extremity consists of head, neck and greater and lesser trochanters. The head is almost spherical and fits into acetabulum of the hip bone. Two trochanters and intertrochanteric line (Fig. 4.24) give attachment to muscles which move hip joint.

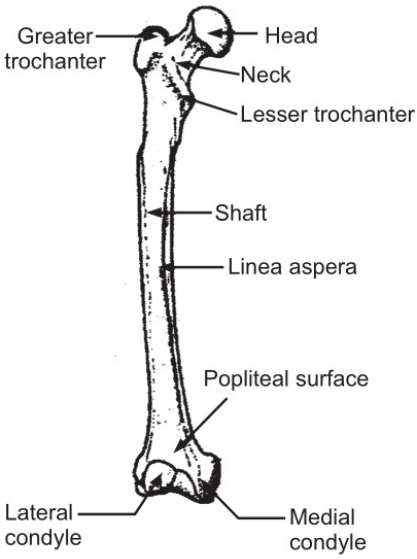


Fig. 4.24: The Femur

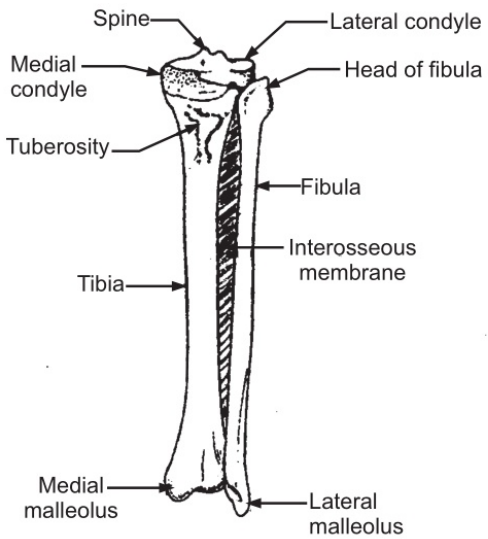


Fig. 4.25: The Tibia and Fibula

The shaft of the bone is slightly convex anteriorly and is broader towards its distal end. Posterior surface forms a flat triangular area called popliteal surface. Distal extremity presents two condyles which take part in the formation of a knee joint. Between the condyles, there is a depression called intercondylar fossa.

Tibia:

Tibia (Fig. 4.25) is a long bone running on the inner side of a leg. Its upper extremity is broad and thick and has two shallow condyles which receive the condyles of the femur, forming a knee joint. Between these condyles is the intercondylar eminence. On the front side, there is a tuberosity of tibia which gives attachment to muscles. The lateral condyle has a facet which articulates with the head of the fibula. The shaft of the bone is roughly triangular and the surfaces are called medial, lateral and posterior surfaces.

The crest of tibia is a ridge which can be felt very close to the surface on arterior aspect of leg. Distal extremity of tibia forms an ankle joint with talus. Tibia carries a process which projects downwards forming the prominence on the inner side of the ankle joint called the medial malleolus.

Fibula:

Fibula is a long slender bone which is lateral to tibia (Fig. 4.25). The head articulates with the lateral condyle of tibia and the lower extremity articulates with its lower extremity and projects further to form lateral malleolus, and takes part in the formation of the ankle joint. The shaft of the bone is ridged for the attachment of muscles.

Patella:

Patella or knee cap is a sesamoid (developed in a muscle tendon) bone associated with knee joint. It is roughly triangular and lies with the apex pointing downwards. Its anterior surface is in the patellar tendon and the posterior surface articulates with patellar surface of the femur in the knee joint.

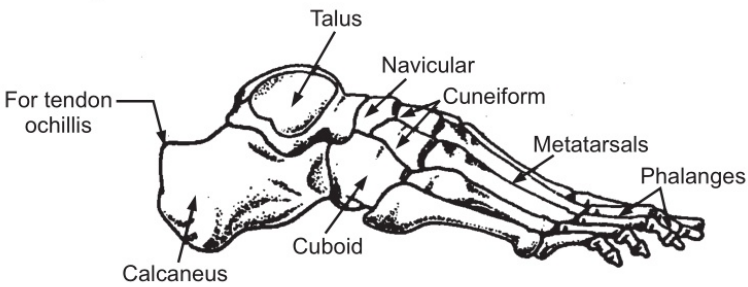


Fig. 4.26: The Tarsal Bones

Tarsals:

Tarsal or ankle bones (Fig. 4.26) are seven in number and form the posterior part of the foot. The bones are one talus; one calcaneous; one navicular; three cuneiform and one cuboid.

Talus articulates with tibia and fibula at the ankle joint. Calcaneous or heel bone is roughened for the attachment of muscles. Navicular is situated on the medial side of the foot distal to talus (Fig. 4.26). The medial, intermediate and lateral cuneiform and cuboid form a row of bones (Fig. 4.26) which articulate with the other three tarsal bones proximally and with the five metatarsal bones distally. The metatarsal bones are five in number. Their proximal ends articulate with the tarsal bones and the distal ends with phalanges. There are fourteen phalanges in each foot, two in the great toe and three each in other toes.

The arrangement of bones of a foot is such that it is not a rigid structure. The bones have a bridge-like arrangement and are supported by muscles and ligaments so that four arches such as medial longitudinal, lateral longitudinal and two transverse arches are formed.

4.4 THE JOINTS

A joint is the site at which any two or more bones come together. The joints are classified as fibrous, cartilagenous and synovial. In fibrous or fixed joint, there is no movement between the bones concerned. There is a fibrous tissue between their ends e.g., the joints between the bones of the skull and the joints between the teeth and the maxilla and mandible. In cartilagenous joints, there is a pad of white fibrocartilage between the ends of the bones. Movement is possible because of the compression of the pad of cartilage, e.g. symphysis pubis and joints between the bodies of the vertebrae.

Synovial joints are characterized by the presence of synovial membrane. A considerable amount of movement is possible. Limitations on movement is mainly due to the shape of the bony surface which forms the joint. They are subdivided according to the movements possible.

(1) Ball and Socket Joint: A hemispherical head fits into a cup-shaped socket e.g., shoulder and hip.

(2) Hinge Joints: These joints allow movement in one direction only, e.g. elbow, knee and ankle.

(3) Double Hinge Joints (Condyloid): These allow movement like a hinge in two directions, e.g. the wrist joints and the joints between metacarpus or metatarsus and the phalanges.

(4) Gliding joints: The bones glide on one another, e.g. between various carpal and tarsal bones.

(5) Pivot joints: One bone turns on another e.g., the radius on the ulna at the elbow and the atlas on the axis.

Some of the joints are capable of the following types of movements:

(1) Flexion or bending, usually forward but occasionally backward.

(2) Extension means strengthening or bending backward.

(3) Abduction is the movement away from midline of the body.

(4) Adduction is the movement towards midline of the body.

(5) Rotation is the movement round the long axis of a bone.

(6) Pronation means turning the palm of the hand down.

(7) Supination means turning the palm of the hand up.

(8) Circumduction is the combination of flexion, extension, abduction, and adduction. It involves movements of the limbs through a circle.

(9) Inversion is the turning the sole of the foot inwards.

(10) Exversion is turning the sole of the foot outward.

Different types of joints help to make different kinds of movements. The ball-and-socket joints are freely movable allowing flexion and extension, abduction, adduction, circumduction and external and internal rotation. The hinge joints allow flexion and extension only. Double hinge joints allow flexion, extension, adduction, abduction and circumduction. In the gliding joints, there is only a slight movement increasing the range of movement in all directions. The pivot joints permit rotation around the point where they are pivoted.

The joints are movable, but the movements are carried out by the various muscles. The muscles also run from bone to bone and help to hold the bones in position and give support to the joint capsule, as long as the normal tone is sustained.

Disorders of joints: Any or all of the structures of joints may be damaged by disease.

Inflammation of the joints is called arthritis. Arthritis is of two types; acute and chronic.

(a) Acute Arthritis: In Rheumatic arthritis, there is an acute synovitis with the excess of turbid fluid in the joint. Extreme tenderness is the characteristics of a swollen and acutely inflammed joint. In the case of traumatic synovitis, the inflammation is confined to the synovial membrane without any destruction of tissue.

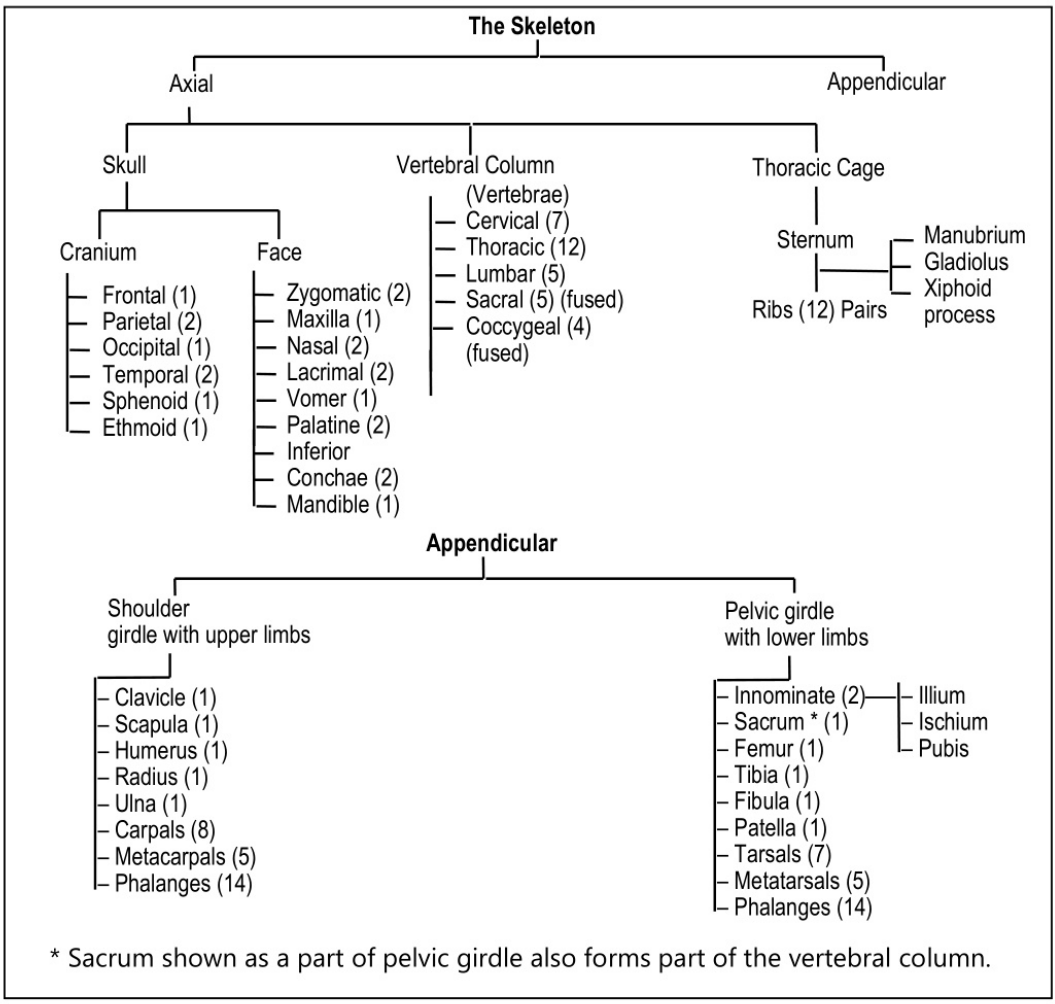
(b) Chronic Arthritis: There are various types of chronic arthritis. Tuberculous arthritis is a disease very common in children. When it occurs in an adult, it is more likely to be primary in the synovial membrane. The synovial fluid is usually scanty but highly fibrous so that it contains flakes of fibrin which may develop into foreign bodies. Rheumatoid arthritis is a common, tragic and crippling disease particularly affecting small joints of hands and feet; the larger joints may affect later. It causes pains and swelling of the joints together with increasing stiffness and disability. In the later stages, the joints become distorted and deformed. During this condition, the patient may suffer from mild fever, anemia, sweating etc. Osteoarthritis involves degeneration of articular cartilage and bone. This is a disease which normally occurs in the old age. Large joints are commonly affected, very often only one joint, i.e. particularly the hip joint. Gout is yet another disease involving joints. The disease involves over-production of uric acid which is deposited in the joint and the

surrounding soft tissues. The deposits occur in the synovial membrane and capsule. Kidneys may also suffer from the deposits.

The intervertebral disc also can be a site of disorder. The disc may be protruded or herniated into the vertebral canal and press the spinal cord or stretch the nerves. The disorder causes low back pain and sciatica or pain passing down the back of the leg along the course of the sciatica nerve.

A few other dysfunctions related to the joint may occur. If the bone from a joint is displaced, the condition is called dislocation. Individuals especially women past middle age, are frequently depleted of calcium. Bones of such individuals lack in calcium and therefore become relatively more fragile. This condition is called osteoporosis.

SUMMARY



* Sacrum shown as a part of pelvic girdle also forms part of the vertebral column.

EXERCISE

1. Name the bones in the appendicular skeleton. Describe a shoulder joint.
2. Differentiate between male and female pelvic girdle.
3. Name the bones of axial skeleton.
4. Define skeleton, bone and articulation (Joint). Classify the bones with suitable examples.
5. Classify the joints with examples of each class.
6. Name the primary and secondary curves of vertebral column. Describe each.
7. What are the functions of bones ?
8. Explain the features and functions of vertebral column.
9. What is dislocation ?
10. What is osteoporosis and rheumatic disorder ?
11. Describe the structure and functions of typical synovial joint.
12. Discuss characteristics and different types of synovial joint.

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UNIT III

Chapter ... 5

BODY FLUIDS AND BLOOD

♦ LEARNING OBJECTIVES ♦

- *To appreciate and learn the role of a fluid tissue that acts as a communication link between different systems of the body.*
- *To study the genesis, composition and functions of blood, a major transport system in the body.*
- *To understand the specialized functions especially the transport of gases by the blood.*
- *To understand the importance of blood grouping, blood clotting and the significance of blood disorders.*

5.1 INTRODUCTION

Blood is described as a connective tissue. It carries:

- Oxygen from the lungs to the tissues and carbon dioxide from the tissues to lungs for elimination.
- Nutrients from the alimentary tract to the tissues and waste materials from the tissues to the kidney for excretion.
- Hormones secreted by endocrine glands to their target organs.
- Heat produced in active tissues to other less active tissues.
- Protective substances, e.g. antibodies to the sites of infection.
- Clotting factors which help in preventing loss of blood.

Blood constitutes about 8 per cent of the body weight. For a 70 kg man, the volume of blood is expected to be 5.6 lit. Blood in the vessels is always in motion. The flow is such that the cells have a fairly constant environment.

5.2 COMPOSITION OF BLOOD

It is composed of a yellowish fluid, plasma, in which different types of cells are suspended. Plasma constitutes about 55 per cent and cells constitute about 45 per cent of the blood volume.

Plasma

It consists of about 90-92 per cent water in which the following substances are dissolved:

- **Plasma proteins:** Albumin, globulin, fibrinogen, clotting factors.
- **Inorganic salts:** Sodium chloride, sodium bicarbonate, potassium, magnesium, phosphorus, iron, calcium, iodine, and cobalt.
- **Nutrients obtained from digested food:** Monosaccharides from carbohydrates, amino acids from proteins, fatty acids and glycerol from fats and vitamins from food.
- **Organic waste materials:** Urea, uric acid, creatinine.
- **Hormones**
- **Enzymes**
- **Antibodies**
- **Gases:** Oxygen, carbon dioxide, nitrogen.

Plasma Proteins

Plasma proteins remain in the blood vessels. A small amount of them may enter the tissues through the capillary wall.

Albumin

It is formed in the liver. It is the most abundant plasma protein and its main function is to maintain the osmotic pressure of about 25 mm Hg.

Globulins

Some of them are formed in the liver and some in lymphoid tissues. They are associated with the following functions:

- The immune response to the presence of antigens.
- Transportation of some hormones and mineral salts, e.g. thyroid hormone, iodine, iron, and copper.
- Inhibition of some proteolytic enzymes, e.g. trypsin, chymotrypsin.

Clotting Factors

These are essential for the coagulation of blood.

Fibrinogen

It is synthesized in the liver and is essential for blood coagulation.

Serum is plasma wherefrom clotting factors have been removed. Viscosity of plasma is due to presence of plasma proteins, mainly albumin and fibrinogen. In certain diseases viscosity of the blood may be altered.

Inorganic Salts

These are involved in activities like cell formation, contraction of muscles, transmission of nerve impulses, formation of secretions, and maintenance of the balance between acids and alkalis in health. The blood is slightly alkaline. The pH of blood is maintained between 7.35 and 7.45 by an ongoing series of chemical activities, involving buffering systems.

Nutrients

Post-digestion food is converted into monosaccharides, amino acids, fatty acids and glycerol. Vitamins along with minerals are required by all body cells to provide energy, heat, materials for repair and replacement and for the synthesis of other blood components and body secretions.

Organic Waste Products

Urea, creatinine and uric acid are the waste products of protein metabolism. They are formed in the liver and transported to the kidneys via. blood for excretion. Carbon dioxide, excreted by all cells, is sent to the lungs for excretion.

Hormones

These are chemical secretions originating from endocrine glands; poured directly into the blood stream to be carried to the target tissues and organs.

Antibodies (Immunoglobulin)

These are protective substances consisting of proteins, produced by lymphoid cells to produce protective antibodies.

Gases

Oxygen, carbon dioxide and nitrogen are transported in the body through plasma. Oxygen and carbon dioxide are transported in combination with haemoglobin in red blood cells. Atmospheric nitrogen enters the body and is present in plasma; however it has no physiological function.

Cellular Contents of the Blood

There are three types of blood cells.

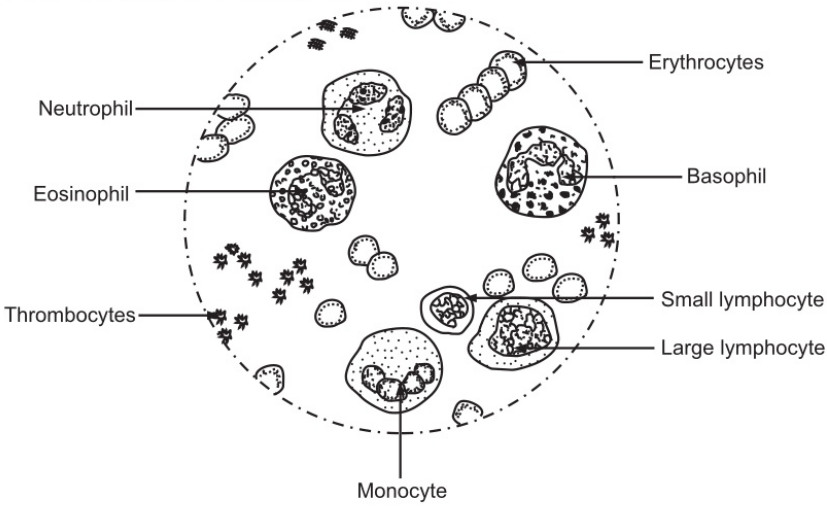

Fig. 5.1: Blood Cells, after Staining in the Laboratory, Viewed through a Microscope

- Erythrocytes or red blood cells (RBC).
- Leucocytes or white blood cells (WBC).
- Thrombocytes or platelets.

All blood cells originate from stem cells called haemocytoblasts and undergo several stages of development before entering the blood. Different types of blood cells follow separate lines of development. The process of blood cell formation is called *haemopoiesis.* (See figure 5.2) and takes place within the red bone marrow. For initial few years, red marrow occupies the entire bone capacity and then over next twenty years, it is gradually replaced by fatty yellow marrow that has no erythropoietic function. In adults, erythropoiesis is limited to flat bones, irregular bones and ends of long bones.

Erythrocytes (RBCs)

These are circular biconcave, non-nucleated discs with a diameter of about seven microns. Following are important features associated with RBCs.

- **Erythrocyte count:** It is the number of erythrocytes per litre or per cubic mm of blood. The normal value is $04.5–06.5 \times 10^{12}$ / L or $04.5–06.5 \times 10^{6}$ / mm^3.
- **Haematocrit (Packed cell volume):** It is the volume of red cells in one litre or 1000 ml of whole blood. The normal value is 0.4-0.5 1/1 or 40-50 / mm^3.
- **Mean corpuscular volume (MCV):** It is the average volume of cells, measured in femtolitres. The normal value is 80-96 fl (1fl = 10^{-15} litres).
- **Haemoglobin:** It is the weight of haemoglobin in whole blood, measured in grams/decilitre. The normal value is 13-18 g/dl (in males) and 11.5-16.5 g/dl (in females) 1dl = 10^{-1} litre).
- **Mean corpuscular haemoglobin (MCH):** It is the average amount of haemoglobin in each cell, measured in picograms (pg). The normal value is 27-32 pg/cell (1 pg = 10^{-12} gram).
- **Mean corpuscular haemoglobin concentration (MCHC):** It is the amount of the haemoglobin in 01 dl or 100 ml of red cells. The normal value is 30-35 g/dl of cells.

Development and Life Span of RBCs

Erythrocytes are formed in red bone marrow, present in the ends of long bones and in flat and irregular bones. Their life span is about 120 days and they pass through various stages of development during this period. The process of development of RBCs from haemocytoblasts takes about 07 days, and is called as erythropoiesis. See Fig. 5.3.

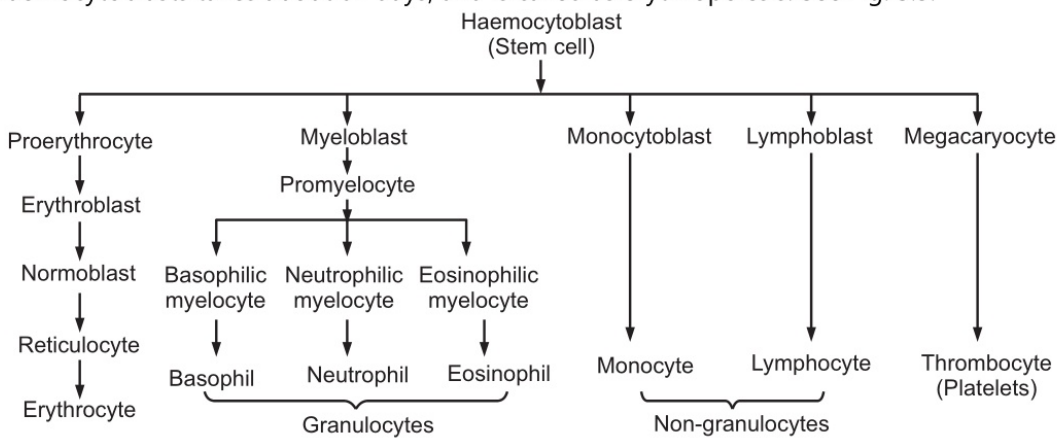

Fig. 5.2: Haemopoiesis: Stages in the Development of Blood Cells

Erytropoiesis is characterized by two main features.

- Maturation of the cell.
- Formation of haemoglobin inside the cell.

Maturation of the Cell

During the maturation process the cell decreases in size and loses its nucleus. The changes depend on presence of vitamin B_{12} and folic acid. These factors are present in milk products, meat, and green vegetables. Absorption of vitamin B_{12} depends on presence of a glycoprotein called *intrinsic factor* secreted by *parietal cells* present in gastric glands. The normal daily requirement of vitamin B_{12} is 01-02 µg. Since, the vitamin is stored in the liver, effects of deficiency in intake may not be sensed immediately. Folic acid is absorbed by cells in the walls of the duodenum and jejunum where it undergoes change before entering the blood. The normal daily requirement of folic acid is 100-200 µg. Deficiency in intake is sensed within a few months.

Formation of Haemoglobin inside the Cell:

Haemoglobin is a complex protein, consisting of globin and iron containing component called heme. It is synthesized inside developing erythrocytes in red bone marrow. A normal diet containing meat, eggs, whole meal bread and green vegetables contains enough iron. Haemoglobin combines with oxygen to form oxyhaemoglobin, giving characteristic red colour to the blood. It is also involved in transport of CO_2 from the body cells to the lungs for excretion.

Control of Erythropoiesis

The number of RBCs is fairly constant. It indicates that the rate of production of RBCs in the bone marrow is matched by the rate of its destruction. This is due to a negative feedback mechanism controlling the process of erythropoiesis. The stimulus for erythropoiesis is hypoxia, i.e. deficient oxygen supply to body cells. Hypoxia occurs in the following conditions.

- The oxygen carrying capacity of blood is reduced either by haemorrhage, i.e. loss of blood or haemolysis, i.e. excessive erythrocyte breakdown.
- Reduction in the oxygen tension at high altitudes.

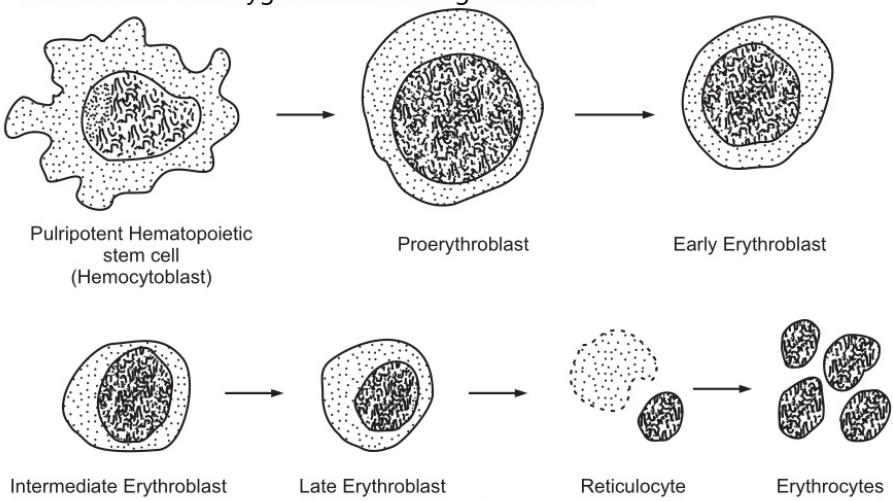

Fig. 5.3: The Erythropoiesis

Hypoxia stimulates the production of a hormone called erythropoietin, primarily by the kidneys. The hormone stimulates an increase in the production of pro-erythroblasts and release of increased number of reticulocytes in the blood. The production of erythropoietin declines when the stimulus of hypoxia is corrected.

Destruction of Erythrocytes

The breakdown of erythrocytes, or haemolysis, is carried out by phagocyte reticuloendothelial cells. The main sites of haemolysis are the spleen, bone marrow and liver. Iron is released by haemolysis and is retained in the body for future use. Biliverdin is formed from the protein part of erythrocytes. It is further reduced to a yellow pigment called bilirubin, before it is bound to plasma globulin and transported to the liver. In the liver, it is changed from a fat-soluble to a water soluble form and is excreted as a constituent of bile.

5.3 BLOOD GROUPS

Different blood groups are associated with genetically determined differences in antigens on the surface of membrane of RBCs and antibodies in blood serum. There are two main systems used to classify blood donated for administration by transfusion. If the donor's blood does not match with that of the recipient, the incompatibility results in agglutination and lysis of donated red cells after transfusion. The agglutinated cells block capillaries and the products of lysis, when in excessive amounts, damage the kidney tubules. The resultant condition is serious and can cause death.

ABO System

In some people there are genetically determined antigens on the surface of membrane of RBCs and natural antibodies in serum. The antibodies are inherited and are not associated with acquired immunity. Summary of ABO system is presented as follows.

Summary of the ABO system

Blood group	Red cells antigens	Antibodies in Serum	Can donate to groups	Can receive from groups
AB	A and B	none	AB	All groups
A	A	anti-B	A & AB	A & O
B	B	anti-A	B & AB	B & O
O	none	anti-A & anti-B	All groups	O

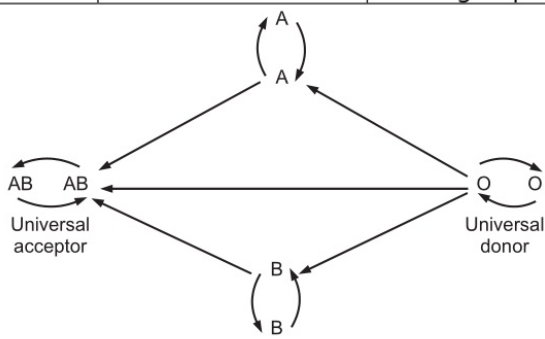

Fig. 5.4: Blood groups showing their compatibility

Rhesus System

In over 80 per cent of people the Rhesus factor is present on the membrane of red cells i.e. they are rhesus positive (Rh+ve). The Rhesus factor consists of a number of antigens of which D is the most common. Individuals with D antigen are classified as Rh+ve. Administration of Rh+ve blood to Rh-ve recipients stimulates an immune response with the production of antibodies that cause haemolysis of the transfused red cells. Second and subsequent encounters with Rh+ve red cells lead to a sharp increase in antibody production.

Erythroblastosis Foetalis

The most common problem with Rh incompatibility may arise during pregnancy. Normally, there is no direct contact between maternal and foetal blood when a woman is pregnant. However, if a small amount of Rh+ve blood leaks from the foetus through the placenta into the bloodstream of Rh-ve mother, the mother will start to make anti-Rh antibodies. Since, the greatest possibility of foetal blood transfer occurs at delivery, the newborn baby will be affected. If the mother becomes pregnant again, her anti–Rh antibodies can cross the placenta and enter the bloodstream of the foetus. If the foetus is Rh–ve, there is no problem, because Rh-ve blood does not have Rh antigen. If the foetus is Rh+ve, haemolysis may occur in foetal blood. The haemolysis brought about on by foetal – maternal incompatibility is called as Erythroblastosis foetalis. This condition is prevented by giving all Rh-ve mothers an injection of anti-Rh antibodies called anti-Rh γ globulin (Rheogram) soon after every delivery, miscarriage, or abortion.

Leucocytes or White Blood Cells (WBCs)

These cells have an important function in defending the body against microbes and other foreign materials. They are the largest blood cells and account for about 01 per cent of the blood volume. They contain nuclei and some of them have granules in their cytoplasm. They are of two main types:

- Granulocytes (Polymorphonuclear leucocytes): Neutrophils, Eosinophils and Basophils.
- Agranulocytes: Monocytes and Lymphocytes.

Number and types of leucocytes

Type of cell	Number $\times 10^3$/1	Per cent of total
Granulocytes		
Neutrophils	02.5 –07.5	40–75
Eosinophils	0.04–0.44	01–06
Basophils	0.015–0.1	< 01
Agranulocytes		
Monocytes	0.2–0.8	02–10
Lymphocytes	01.5–03.5	20–50
Total	05–09	100

Granulocytes

Their formation is termed as granulopoiesis. During development, they follow a common line of development through myeloblast to myelocyte before differentiating into three types.

Fig. 5.5: The Granulocytes

All granulocytes have multilobed nuclei. Their names represent the dyes which they take up when stained in the laboratory. Eosinophils take up the red acid dye, eosin; basophils take up alkaline methylene blue; and neutrophils are purple because they take up both dyes.

Neutrophils

Their main function is to protect the body against any foreign material which gains entry into it, mainly microbes and to remove waste materials, e.g. cell debris. They are attracted in large numbers to any area of infection by chemical substances, released by damaged cells, called chemotoxins. Neutrophils pass through the capillary walls in the affected area by amoeboid movement. (Fig. 5.6). Subsequently they ingest and kill the microbes by phagocytosis. (Fig. 5.7).

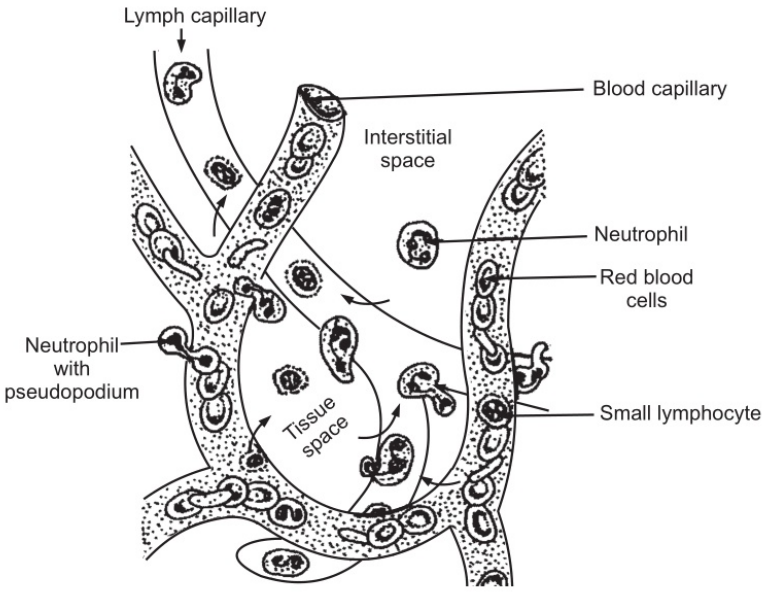

Fig. 5.6: Amoeboid Movement of Leucocytes

Their granules are lysosomes and contain enzymes which degrade the ingested material. The pus that may form in the affected area consists of dead tissue cells, dead and live microbes, and phagocytes killed by microbes. There is a physiological increase in circulating neutrophils following strenuous exercise and in the later stages of normal pregnancy. Numbers are also increased in the following conditions.

- Microbial infection.
- Tissue damage, e.g. myocardial infarction, burns, crushes injuries.
- Metabolic disorders, e.g. diabetic ketoacidosis, acute gout.
- Leukemia.
- Heavy smoking.
- Use of oral contraceptives.

Neutrophils stimulate the production of interferon, which are released by virus-infected tissue cells and lymphocytes. Interferons then diffuse in tissue fluid and protect adjacent cells from invasion by viruses.

Eosinophils

Many of the eosinophils migrate out of the blood to the areas of the body exposed to the external atmosphere, i.e. connective tissue just under the skin, in the mucous membrane of the respiratory and digestive system and in the lining of vagina and uterus. Their cytoplasmic granules are lysosomes. They are believed to protect the body against foreign materials, especially invasion by parasites. They neutralize histamine and transport plasminogen which is the precursor of plasmin. Plasmin is involved in fibrinolysis and the later stage of wound healing. The number of eosinophils is increased in allergic conditions like asthma, hay fever, food and drug sensitivities and skin conditions.

Basophils

Two major substances, i.e. histamine and heparin are present in the cytoplasmic granules of basophils. Histamine causes vasodilatation and increases the permeability of small blood vessel wall; it also assesses in the movement of phagocytes and protective substances like antibodies, into the tissue spaces. Heparin prevents coagulation of blood. Together with mast cells basophils accumulate in the tissues in areas of local inflammation at the healing stage. Mast cells are found in the tissues, closely associated with small blood vessels and they are involved in allergic reaction.

Agranulocytes

These are leucocytes with a large nucleus and no granules in their cytoplasm. Together they make up 25–50 per cent of all leucocytes. These are of two types:

1. Monocytes
2. Lymphocytes

Monocytes

These are large mononuclear cells originating in the red bone marrow. Some of them circulate in the blood and are actively motile and phagocytic while others migrate into the tissues where they develop into macrophages.

Both types of cell produce *interleukin I* which has the following functions:

- It acts on the hypothalamus, causing rise in body temperature associated with microbial infections.
- It stimulates the production of some globulins by the liver.
- It enhances the production of activated T-lymphocytes.

Macrophages have important functions in inflammation and immunity. Macrophages function in close association with monocytes in the blood and lymphocytes which influence their activity. They are actively phagocytes, and if they encounter large amount of foreign or waste material, they tend to multiply at the site and 'cordon off ' the area, isolating the material, e.g. in the lungs when foreign material has been inhaled. Their numbers are increased in microbial infections, collagen diseases and some non-infective bowel conditions.

Lymphocytes

They have large nuclei and there are two distinct subtypes of lymphocytes: T-lymphocytes and B-lymphocytes. They circulate in the blood and are present in great numbers in the lymphatic tissue such as lymph nodes and the spleen. They develop from haemocytoblasts (stem cells) in red bone marrow, then spread into the blood to lymphoid tissue elsewhere in the body where they are activated i.e. they become immunocompetent which means that they are able to respond to antigens. Following are some of the types of antigens:

- Cells regarded by lymphocytes as abnormal, e.g. cells invaded by viruses, cancer cells, tissue transplant cells.
- Pollen from flowers and plants
- Fungi
- Bacteria
- Few large molecule drugs

The two types of lymphocytes sometimes function independently but usually in collaboration. T-lymphocytes are activated by thymosin in the thymus gland and B-lymphocytes are activated in red bone marrow and in lymphoid tissue elsewhere in the body, possibly the walls of intestine. Thereafter some cells of both types circulate in the blood; some settle in lymphoid tissue, mainly in lymph nodes, the spleen and the aggregated glands in the wall of the upper respiratory tract and the intestine. When activated lymphocytes encounter antigens they develop specific protective capabilities. Each type divides into two groups: effector cells that promote destruction of their specific antigen; and memory cells that remain in lymphoid tissue and multiply, passing on their specific protective abilities to subsequent generation of cells. The memory cells confer immunity, and subsequent encounters with the same antigen lead to proliferation of more sensitized lymphocytes. Activated lymphocytes can respond to specific antigens by producing:

- Cell-mediated, immunity-mediated by T-lymphocytes and specialized T-cells that combat cells containing antigens.
- Humoral immunity mediated by B-lymphocytes which involves the production of antibodies that neutralize antigens directly.

Thrombocytes or Platelets

These are very small non-nucleated disc-type cells, 02–04 µm in diameter. They are derived from the cytoplasm of megakaryocytes in red bone marrow. They contain a variety of substances which help in clotting of blood. The normal blood platelet count is between 200–350 $\times$ 10^9 / 1 (200,000–350,000 / mm^3). The stimulus to formation of platelets is believed to be a substance called thrombopoietin. The life span of platelets is 08–11 days, and those not used in the process of homeostasis are destroyed by macrophages, mainly in the spleen.

Homeostasis

When a blood vessel is damaged the subsequent loss of blood is stopped and healing occurs in a series of overlapping processes in which platelets plays an important role.

1. **Vasoconstriction:** When platelets come in contact with a damaged blood vessel, their surface becomes sticky and they adhere to the damaged wall. Then they release serotonin which is also called as 5-hydroxytryptamine. It causes vasoconstriction, i.e. narrowing of blood vessels, reducing blood flow through the vessels. Other chemicals causing vasoconstriction are also released by the damaged vessel.

2. **Platelet plug formation:** The adherent platelets clump to each other and release adenosine diphosphate (ADP) that attract more platelets to the site. Passing platelets stick to those already at the damaged vessel and they too release ADP. This is a positive feedback system whereby many platelets rapidly arrive at the site of vascular damage and quickly form a temporary seal of the platelet plug.

3. **Coagulation (Blood clotting):** This is a complex process which also involves positive feedback system. Various factors are involved in the process of coagulation as follows:

Blood clotting factors

No.	Name
I.	Fibrinogen
II.	Prothrombin
III.	Tissue factor
IV.	Calcium
V.	Labile factor, proaccelerin, Ac-globulin
VII.	Stable factor, proconvertin
VIII.	Antihaemophlic globulin (AHG), antihaemophilic factor A
IX.	Christmas factor, plasma thromboplastin component (PTC) antihaemophilic factor B
X.	Stuart – Power factor
XI.	Plasma thromboplastin antecedent (PTA) antihaemophilic factor C
XII.	Hageman factor
XIII.	Fibrin stabilizing factor

There is no factor VI. Vitamin K is essential for synthesis of factors II, VII, IX, X.

Number of the factors represents the order in which they were discovered. Blood clotting is a complex process whereby blood forms clots. Herein a damaged blood vessel is covered by a platelet and fibrin containing clot to stop bleeding and commence repair of the blood vessel. Thrombin then acts on another protein called fibrinogen and converts it to prothrombin.

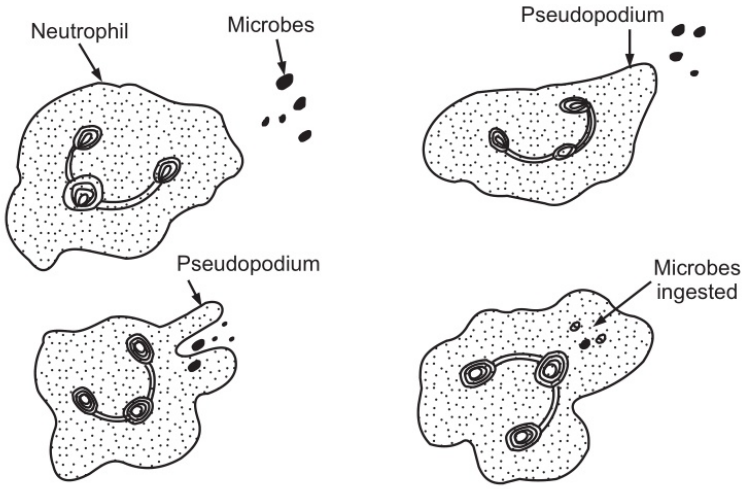

Fig. 5.7: Phagocytic Action of Neutrophils

Prothrombin activator can be formed by two pathways: extrinsic and intrinsic pathways. Extrinsic pathway occurs very rapidly, i.e. in seconds, when there is tissue damaged outside the circulation, and it is initiated when chemicals secreted by damaged tissue enter the circulation. Relatively, the intrinsic pathway is slower and takes about 03–06 minutes. It is confined to the circulation. It is triggered by damage to a blood vessel lining, i.e. endothelium and the effects of platelets adhering to it. After sometime, the clot shrinks, squeezing out serum.

4. Fibrinolysis

After the formation of clot the process of removing it and healing the damaged blood vessel begins. The breakdown of the clot or fibrinolysis is the first stage. An inactive substance called plasminogen is present in the clot and is converted to the enzyme plasmin by activators released from the damaged endothelial cells. Plasmin initiates the breakdown of fibrin to soluble products and these are treated as waste material and removed by phagocytosis. As the clot is removed, the healing process restores the integrity of the blood vessel wall.

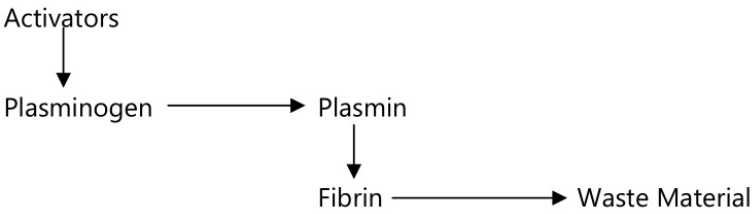

Fig. 5.8: Fibrinoloysis

Factors hastening coagulation of blood:

(i) Temperature slightly excess than body temperature.

(ii) Contact of blood with rough surface and injury to the blood platelets.

(iii) Excessive slowness of blood flow.

(iv) Snake bite.

Factors retarding coagulation of blood:

(i) Low temperature;

(ii) Contact of blood with smooth surface;

(iii) Presence of sodium or potassium citrate.

Normally, a blood clot is formed on the surface where the injury has occured. When such a clot is formed within the circulation, it is called thrombus. Whenever a portion of a clot gets detached and enters the circulating blood, it is called embolus.

5.4 DISORDERS OF BLOOD

Major disorders of blood are:

(i) Anemias, (ii) Polycythemia,

(iii) Bleeding disease, (iv) Leukemias

(v) Agranulocytosis, (vi) Thalassemia.

(i) Anemia signifies reduction in the amount of oxygen - carrying haemoglobin in a given volume of blood. There are several types of anemia. In pernicious anemia, the intrinsic factor responsible for the absorption of vitamin B_{12} from gastric mucosa is absent. As a result, the number of erythrocytes goes down and their average size is increased. Hence, it is a type of macrocytic anemia. In contrast to this, in the case of microcytic anemia, the average diameter of the red cells is smaller. The cause is mainly deficiency of iron; however, the clinical symptoms are similar to those of pernicious anemia. Haemolytic anemias are characterized by a shortened life span of red cells with resulting haemolysis. It may be either hereditary or because of circulating antibodies which become adherent to red cells. The hereditary defect may involve abnormal red cells or abnormal haemoglobin. In sickle cell anemia, the defect is in the haemoglobin molecule; the shape of a large number of the red cells is crescentic or sickle and their life span is, considerably shortened.

(ii) In Thalassemia, the haemoglobin defect results in a decreased life span of the circulating red cells. The shape of red cells is altered, but a large number of nucleated cells are also observed. Many haemolytic anemias are caused by certain drugs, bacterial toxins, malarial parasite etc. Rh incompatibility can cause haemolytic disease of the newborn. Aplasia or atrophy of the bone marrow can cause aplastic anemia which results in the reduction in the number of red cells, leukocytes and blood platelets.

(iii) Polycythemia refers to increase in the number of blood cells, especially red blood cells. In primary polycythemia, along with increased number of red cells, the bone marrow is also markedly hyperplastic; skin and mucous membrane of mouth are red and conjuctiva is red. In secondary polycythemia, there is a compensating increase in red cells in the conditions of sufficient oxygenation.

(iv) Bleeding diseases are those in which the normal mechanism for the control of haemorrhage is deficient or deranged. The bleeding time and coagulation time are the tests used to confirm this disease. Haemophilia is characterized by prolonged bleeding following a cut. It is hereditary in nature.

(v) The important feature of leukemia is proliferation of leukoblastic tissues resulting in a great increase in the white blood cells. It is essentially a cancer of bone marrow.

(vi) Agranulocytosis is a remarkable disappearance of granulocytic leukocytes from blood. It may be associated with lesions of the mouth involving gums, tonsils and even the bones of a jaw.

EXERCISE

1. Classify W.B.C. and explain their functions.
2. Discuss the process of coagulation and mention the factors preventing the coagulation.
3. Write composition and functions of blood.
4. Discuss ABO system and Rh factor of blood group.
5. Define the following terms:

   Polycythemia, Thalassemia, Leukemias.
6. Write a note on haemopoiesis and add a note on hemolystic disease of newborn (HDN).
7. Explain any three types of anaemia. What is the role of haemoglobin in respiration?
8. Outline the life cycle of red cell.
9. What is haemoglobin? What is its function? Mention its normal count.

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Chapter ... 6

THE LYMPHATIC SYSTEM

♦ **LEARNING OBJECTIVES** ♦

- *To understand the need and importance of different body fluids including lymph.*
- *To appreciate the relationship between blood circulatory system and the lymphatic system.*
- *To learn the functions of lymph and lymphatic system.*
- *To study the structure and functions of lymph nodes and spleen.*

6.1 INTRODUCTION

The good health and survival of an individual depends upon the prevention of attacks by disease producing micro-organisms, known as pathogens. It is also essential to neutralize the toxic products produced by pathogens or to guard the body from other harmful things such as ultraviolet rays or to cure the body from wounds, cuts, burns etc.

The lymphatic system is responsible for certain defence mechanisms. To protect the body, body resistance is essential. Lack of resistance is called susceptibility. Immunity takes part in the activation of specific lymphocytes which destroy the foreign particles or pathogens.

Lymphatic system contains the fluid known as lymph, which flows through several organs and lymphatic vessels. The lymph is the diffusible part of the blood and waste products from the cells. The composition of plasma and lymph is nearly same but some additional components are also present in the lymph.

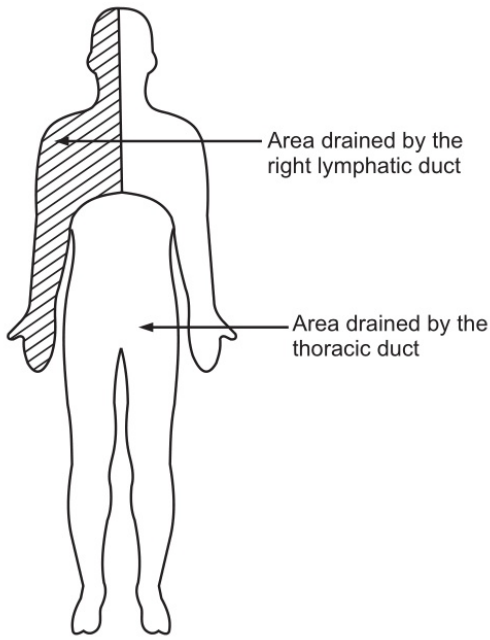

Fig. 6.1: Diagram of Lymph Drainage

The lymph capillaries start from blind end tubes in the interstitial spaces. The walls of the lymphatic capillaries are made up of a single layer of endothelial cells which is similar to the structure of blood capillaries. The lymphatic capillary walls are more permeable to all types of components. These capillaries join to form large lymphatic vessels. The large lymphatic vessels and small veins are similar in nature as regards their structure. The valves present in the lymph vessels, help to push the lymph in one direction, towards the thorax. This occurs due to the contraction of vessels. The lymph vessels join to form thoracic duct and right lymphatic duct. This duct is about 40–42 cm in length. It starts in front of the body's first and second lumbar vertebrae where dilation of the lymph vessels occurs. The thoracic duct opens into the left subclavian vein which is present at the root of the neck. The thoracic duct carries lymph from the legs, the pelvic and the abdominal cavities, the left half of the thorax, head, neck and left arm. Due to dilation of the lymph vessel, the right lymphatic duct is formed which is about 01 cm long. It is present at the root of the neck. This duct opens into the right subclavian vein and carries lymph from the right half of the thorax, head, neck and right arm.

The lymph vessels perform some important functions, such as returning excess tissue fluid and plasma proteins to the blood. Breakdown of some materials occurs in the lymph node and this material is carried by the lymph vessels. After the digestion of fat, the fatty acids are absorbed in the villi of the small intestine. They enter into lacteals which contain the milky fluid called chyle and are carried towards thoracic duct.

6.2 LYMPH NODES

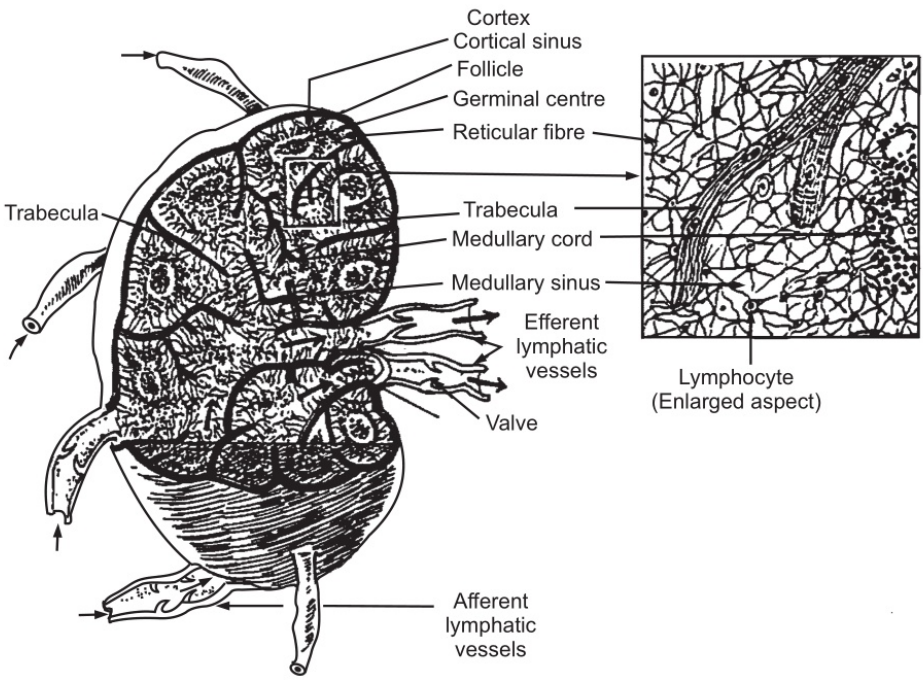

Fig. 6.2: Section of Lymph Node

These nodes are present at strategic positions throughout the body. The small lymph vessels carry lymph towards these nodes. From here, the lymph passes in to the blood.

Structure of Lymph Nodes:

These are oval or bean shaped organs present along the length of the lymphatic vessels. The size of lymphatic gland is variable and ranges from 01–25 mm in length. These glands are found in maximum numbers in the axillae, groins and mammary glands.

The node has a coating of dense connective tissue and these tissues extend into the node. These extensions are known as trabeculae. The trabeculae help to divide the nodes into different compartments, provide a passage way to blood vessels and give support. The capsule, trabeculae, reticular fibres, and fibroblasts, form the framework of the lymph node. The lymph node has two parts: the outer part is the cortex and the inner is the medulla. The cortex consists of many follicles that serve as a site for densely packed lymphocytes. The outer rim of each follicle contains T-cells i.e. T-lymphocytes and macrophages. The central area of the follicles is lighter where B-lymphocytes proliferate into antibody secreting plasma cells. In the medullar region, the lymphocytes are tightly packed in strands known as medullary cords. These cords also consist of plasma cells and macrophages. The afferent lymph vessels enter the lymph node and efferent vessels carry lymph from the node. Being a bean shaped organ, it has a concave surface, called hilum through which the arteries pass and veins and efferent lymph vessels leave.

Functions

During the passage of the lymph through the lymph node, the lymph is filtered. Some of the particulate matter containing microbes, dead and live phagocytes containing ingested micro-organisms, broken or damaged tissues, inhaled particles, etc. are filtered. Those particles which are not filtered enter the blood. Incomplete phagocytosis of microbes causes inflammation and enlargement of the lymph nodes. The multiplication of T and B lymphocytes occurs in the lymph node.

The Spleen

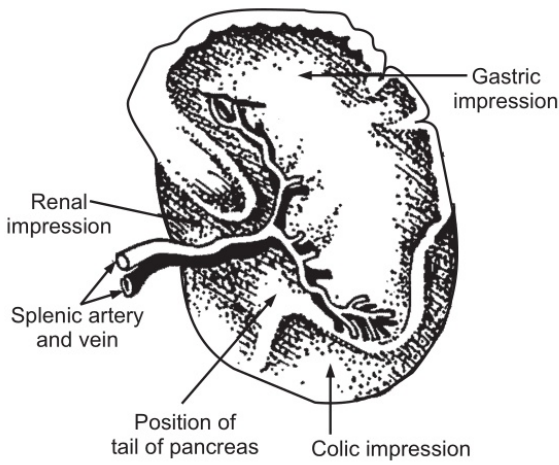

Fig. 6.3: Spleen

The spleen is the largest lymph organ and it is formed by lymphatic and reticular tissues. The spleen is located in the left hypochondriac region of the abdominal cavity. It lies between the diaphragm and fundus of the stomach. The average weight of the spleen is 200 gm. It is 12 cm long, 07 cm in width and 02.5 cm thick.

Structure

It is oval in shape. The hilum lies on the lower medial broader. The spleen is covered with fibroelastic tissue called as capsule. The fibroelastic tissue extends inwards to form trabeculae. The splenic pulp is composed of lymphocytes and macrophages. This lies between the trabeculae. The pulp has a red portion (red pulp) and a white portion (white pulp) which consists of lymphatic tissues. Lymphocytes and macrophages are seen in this part. The splenic artery and nerves enter the spleen while the splenic vein and lymph vessels (efferent vessel) leave the spleen. The splenic pulp is supplied by blood through the sinuses which have pores in endothelial cells.

Functions of Spleen

The old erythrocytes or abnormal red blood cells are destroyed by the spleen. Haemoglobin from the destroyed erythrocytes gets separated into various constituents such as bilirubin, biliverdin and iron. These components are carried towards the liver via the portal veins. Other components such as micro-organisms platelets, leucocytes are destroyed or phagocytosed by the spleen. In the foetal stage, spleen produces erythrocytes.

EXERCISE

1. Explain anatomy and physiology of spleen. Give functions of spleen.
2. Discuss structure and function of lymph nodes.
3. How formation and flow of lymph occurs?
4. Write a note on lymphomas.
5. Write a note on splenomegaly.
6. Give composition of lymph. Name two main lymphatic ducts. Where do they communicate with the blood circulatory system?

***

UNIT IV

Chapter ... 7

PERIPHERAL NERVOUS SYSTEM

♦ **LEARNING OBJECTIVES** ♦

- *To learn the mechanism of how different activities of the body are regulated.*
- *To appreciate the complex nature and maintenance of delicate balance between different activities of the body.*
- *To know how the body activities are adjusted with external stimuli and internal environment.*
- *To study the sensory and motor functions of nervous system.*

7.1 INTRODUCTION

The peripheral nervous system consists of the following components:

- 31 pairs of spinal nerves
- 12 pairs of cranial nerves
- The autonomic part of the nervous system

Most of the nerves of the peripheral nervous system are composed of sensory nerve fibres conveying impulses from sensory organs to the brain. Motor nerve fibres convey impulses from the brain through the spinal cord to the effector organs like skeletal muscles, smooth muscles and glands. Each nerve consists of numerous nerve fibres formed into bundles. Each bundle has several covering of protective connective tissue.

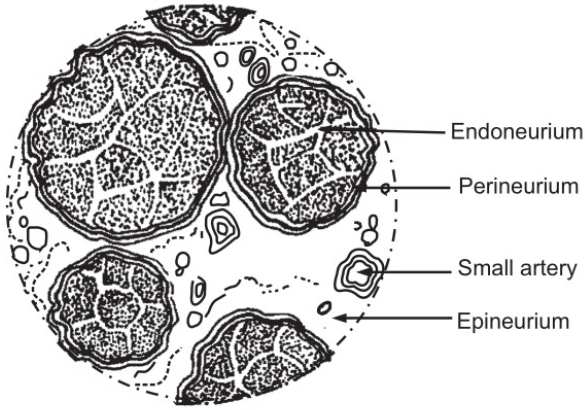

Fig. 7.1: Transverse Section of a Peripheral Nerve

- Endoneurium is a delicate tissue surrounding each individual fibre, and passes inwards from the perineurium.
- Perineurium is a smooth tissue, surrounding each bundle of fibres.
- Epineurium is the tissue which surrounds and encloses a number of bundles of nerve fibres. Most large nerves are covered by epineuria.

7.2 SPINAL NERVES

There are 31 pairs of spinal nerves, that leave from the vertebral coloumn. The nerves pass through the intervertebral foramina formed by adjacent vertebrae. They are named and grouped as follows:

- 8 Cervical • 12 Thoracic • 5 Lumbar • 5 Sacral • 1 Coccygeal.

Although there are only 07 cervical vertebrae, there are 08 cervical nerves; because the first pair leaves the vertebral canal between the occipital bone and the atlas and the eighth pair leaves below the last cervical vertebra. The lumbar, sacral and coccygeal nerves leave the spinal cords near its termination at the level of the first lumbar vertebra, and extend downwards inside the vertebral canal in the subarachnoid space, forming a sheath of nerves that resembles a horse's tail, the *caudal equina*. These nerves leave the vertebral canal at the appropriate lumbar, sacral or coccygeal level, depending on their destination.

Each spinal nerve is formed by the union of a motor and a sensory nerve root and is, therefore, termed as mixed nerve. Each spinal nerve is associated with sympathetic part of the autonomic nervous system in the form of a preganglionic fibre.

7.3 PLEXUSES

Immediately after emerging from the intervertebral foramina each spinal nerve divides into a ramus communicant, a posterior ramus and an anterior ramus. The *rami communicants* are part of preganglionic sympathetic neurons of the autonomic nervous systems. The posterior rami pass backwards and divide into medial and lateral branches to supply skin and muscles of small areas of posterior part of head, neck and trunk. The anterior rami supply the anterior and lateral parts of the neck, trunk and the upper and lower limbs.

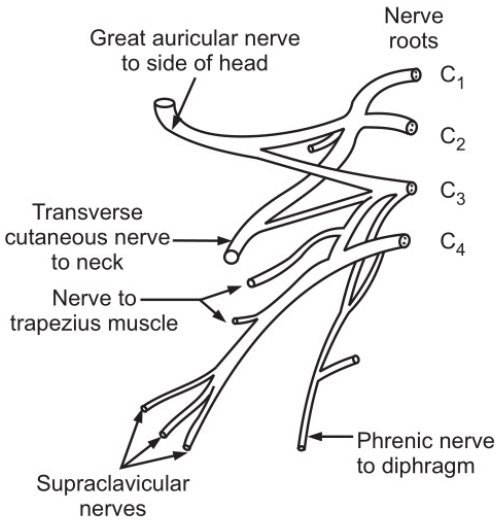

Fig. 7.2: The Cervical Plexus

In the cervical, lumbar and sacral regions, the anterior rami unite near their origins to form large masses of nerves or *plexuses*, where nerve fibres are regrouped and rearranged before proceeding to supply skin, bones, muscles and joints of a particular area.

In the thoracic region the anterior rami do not form plexuses.

There are 05 large plexuses of mixed nerves formed on each side of the vertebral column. They are as follows:

- Cervical plexuses
- Brachial plexuses
- Lumbar plexuses
- Sacral plexuses
- Coccygeal plexuses.

1. Cervical Plexus:

It is formed by the anterior rami of the first four cervical nerves. The superficial branches supply the structures at the back and side of the head and the skin of the front of the neck to the level of the sternum. The deep branches supply muscles of the neck. The phrenic nerve originates from cervical roots 03, 04 and 05 and passes downwards through the thoracic cavity in front of the root of the lung to supply the muscles of the diaphragm.

2. Brachial Plexus:

It is formed by the anterior rami of the lower four cervical nerves and a large part of the first thoracic nerve. It is situated above and behind the subclavian vessels and in the axillae. The branches of the brachial plexus supply the skin and muscles of the upper limbs and some of the chest muscles. Five large nerves and a number of smaller ones emerge from this plexus. Each nerve has a contribution from more than one nerve root, containing sensory, motor and an autonomic fibre.

Following are the names of these nerves:

- Axillary nerve
- Radial nerve
- Musculocutaneous nerve
- Median nerve
- Ulnar nerve
- Medial cutaneous nerve

The axillary nerve supplies to the deltoid muscle, shoulder joint and overlying skin. The radial nerve supplies the triceps muscle behind the humerus, crosses in front of the elbow joint and further extends to the wrist and finger joints. It continues into the back of the hand to supply the skin of the thumb, the first two fingers and the lateral half of the third finger. The musculocutaneous nerve supplies muscles of the upper arm and the skin of the forearm. The median nerve supplies the muscles of the front of the forearm. It continues into the hand where it supplies small muscles and the skin of the front of the thumb, the first two fingers and the lateral half of the third finger. The ulnar nerve supplies the muscles on the ulnar aspect of the forearm. It continues to supply the muscles in the palm of the hand and the skin of the whole of the little finger and the medial half of the third finger.

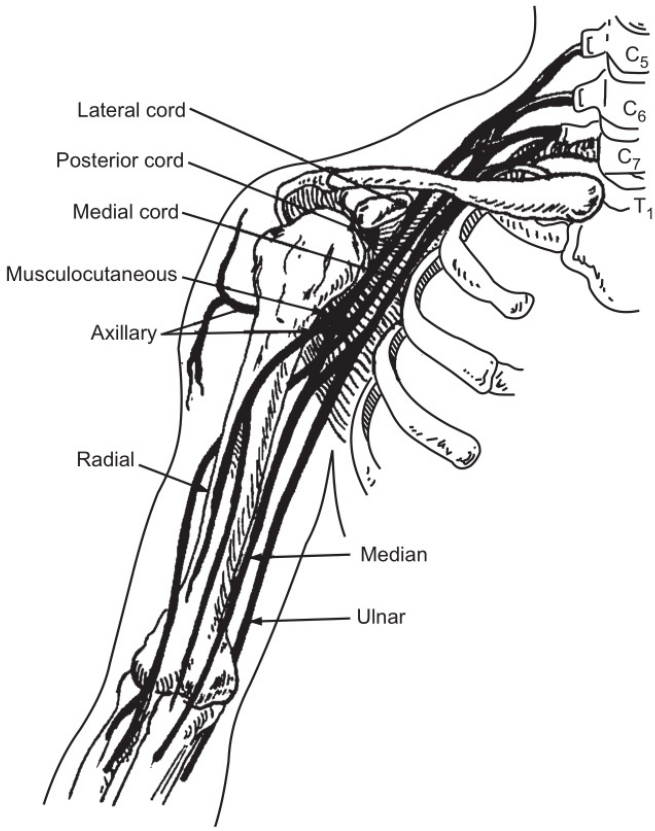

Fig. 7.3: The Brachial Plexus and the Nerves of the Upper Limb

3. Lumbar Plexus

It is formed by the anterior rami of the first three and a part of the fourth lumbar nerves. The main branches and their nerve roots are:

- Iliohypogastric nerve
- Ilioinguinal nerve
- Genitofemoral nerve
- Lateral cutaneous nerve of thigh
- Femoral nerve
- Obturator nerve
- Lumbosacral trunk

The Iliohypogastric, Ilioinguinal and Genitofemoral nerves supply impulses to the muscles and the skin in the area of the lower abdomen, upper and medial aspects of the thigh and the inguinal region. The lateral cutaneous nerve of the thigh supplies impulses to the skin of the lateral aspect of the thigh including part of the anterior and posterior surfaces. The femoral nerve divides into cutaneous and muscular branches to supply the skin and muscles of the front of the thigh. One of the branches termed as *saphenous* nerve supplies the medial aspect of the leg, ankle and foot. The Obturator nerve supplies impulses to the adductor muscles of the thigh and skin of the medial aspect of the thigh. It aims above the level of the knee joints. The Lumbosacral trunk descends into the pelvis and supplies impulses to the sacral plexus.

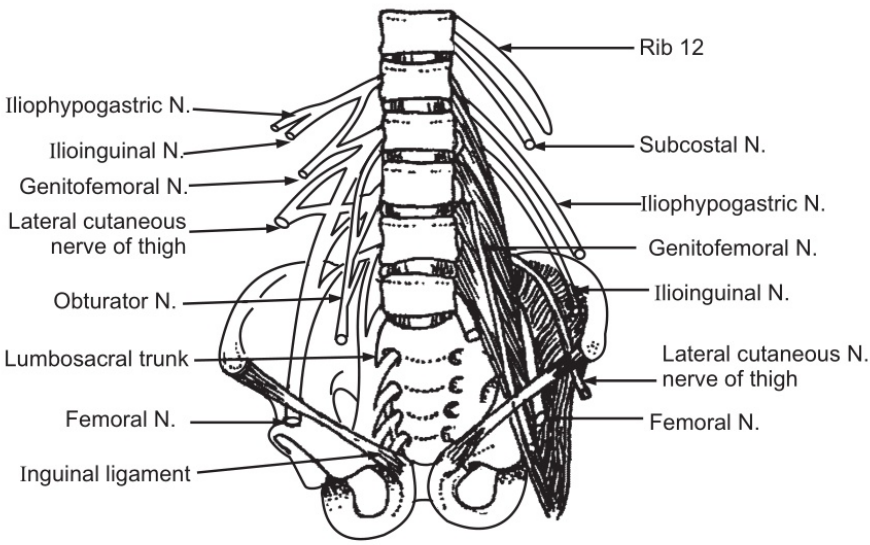

Fig. 7.4: The Lumbar Plexus

4. Sacral Plexus:

It is formed by the anterior rami of the lumbosacral trunk and the first, second and third sacral nerves. The sacral plexus divides into number of branches supplying impulses to the muscles and the skin of the pelvic floor, muscles around the hip joint and the pelvic organs. It also provides the *sciatic nerve*.

The sciatic nerve supplies impulses to the hamstring muscles. At the level of the middle of the femur, it divides to form the tibial and the common peroneal nerves: The tibial nerve supplies impulses to the muscles and skin of the sole of the foot and toes. One of the main branches is the *sural nerve* which supplies the tissues in the area of the heel, the lateral aspect of the ankle and a part of the foot. The common peroneal nerve after division into *deep peroneal and superficial peroneal* nerves, supply impulses to the skin and muscles of the anterior aspect of the leg, the foot and toes. The *pudendal nerve* supplies impulses to the external anal sphincter, the external urethral sphincter and adjacent skin.

5. Coccygeal Plexus:

It is formed by a part of the 4th and 5th sacral and coccygeal nerves. It supplies impulses to the skin in the area of the coccyx and coccygeus muscles of the pelvic floor and the external anal sphincter.

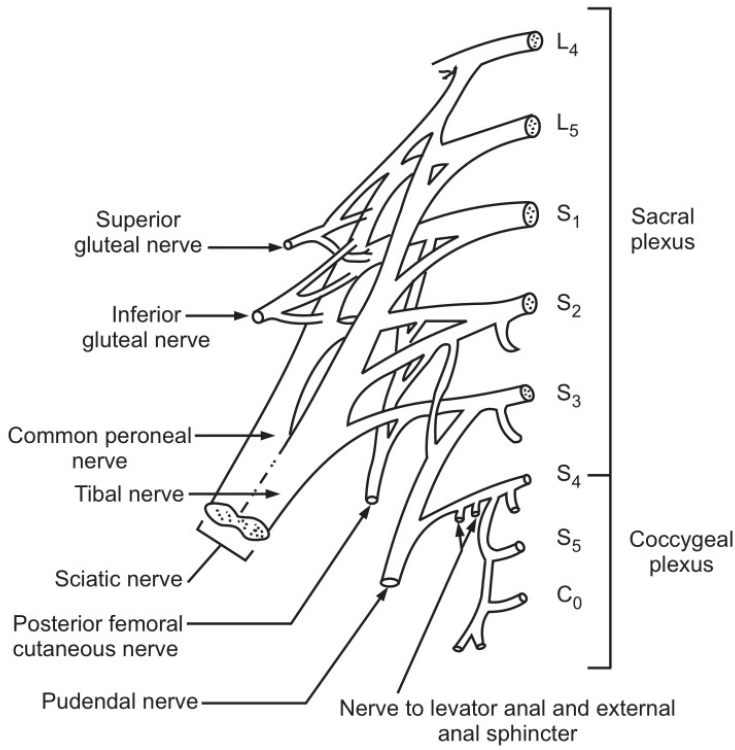

Fig. 7.5: The Sacral and Coccygeal Plexuses

Thoracic Nerves

These nerves do not mix to form plexuses. There are 12 pairs and the first 11 are the intercostal nerves, the 12th pair is a subcostal nerve.

Cranial Nerves

There are 12 pairs of cranial nerves originating from nuclei in the inferior surface of the brain. Some of them are sensory while others are motor in nature.

Their names, connections and functions are listed below:

Summary of the Cranial Nerves

Name and No.	Central connection	Peripheral connection	Function
I. Olfactory (Sensory)	Smell area in temporal lobe of cerebrum through olfactory bulb	Mucous membrane in roof of nose	Sense of smell
II. Optic (Sensory)	Sight area in occipital lobe of cerebrum	Retina of the eye	Sense of sight Balance
III. Oculomotor (motor)	Nerve cells near floor of aqueduct of midbrain	Superior, inferior and medial rectus muscles of the eye Ciliary muscles of the eye Circular muscle fibres of the iris	Moving the eyeball Focussing Regulating the size of the pupils
IV. Trochlear (motor)	Nerve cells near floor of aqueduct of midbrain	Superior oblique muscles of the eye	Movement of the eyeball
V. Trigeminal (mixed)	Motor fibres from the Pons varolli	Muscles of mastication Sensory to gums, cheek, lower jaw, iris, cornea	Chewing, Sensing from the face
VI. Abducent (motor)	Floor of fourth ventricle	Lateral rectus muscle of the eye	Movement of the eye
VII. Facial (mixed)	Pons varolli	Lateral rectus muscles of eye	Sense of taste
VIII. Vestibulocochlear (Sensory) (a) Vestibular (b) Cochlear	Cerebellum	Sensory fibres to the tongue Motor fibres to the muscles of the face	Movement of facial expression
IX. Glossopharyngeal (mixed)	Hearing area of cerebrum	Semicircular canals in the inner ear Organ of corgi in cochlea	Maintenance of balance Sense of hearing
X. Vagus (mixed)	Medulla Oblongata		Maintenance of balance sense of hearing
XI. Accessory (motor)	Medulla oblongata	Pharynx, larynx; organs, glands, ducts, blood vessels in the thorax and abdomen	
XII. Hypoglossal (motor)	Medulla oblongata	Sternocleidomastoid, trapeziums, laryngeal and pharyngeal muscles Tongue	Movement of the head, shoulders, pharynx and larynx Movement of tongue

7.4 AUTONOMIC NERVOUS SYSTEM

The autonomic nervous system primarily controls involuntary functions of the body which are carried out almost automatically. The stimulus for activities of the autonomic nervous system initiate in the brain below the level of the cerebrum. Although the actions are not voluntary in nature, the individual is aware of the actions exerted by the autonomic nervous system, e.g. variation in heart rate. The effects of autonomic nervous system are essential for homeostasis and include stimulation or depression of glandular secretions and contraction of cardiac and smooth muscle tissues.

The efferent or motor nerves of the autonomic nervous system originate from nerve cell in the brain and emerge at various levels between the midbrain and the sacral region of the spinal cord. Many of them travel along the same nerve sheath, as that of the peripheral nerves of the central nervous system.

The autonomic nervous system is divided into the following two parts:

- Sympathetic nervous system (Thoracolumbar outflow)
- Parasympathetic nervous system (craniofacial outflow)

The two sub-parts have structural and functional differences. By and large, physiologically, they are opposite in functions; as a result their working helps in maintaining homeostasis and restoring balance of the body. The sympathetic nervous system is said to be the part controlling 'fight, flight and fright'; while the parasympathetic nervous system controls activities related to maintenance and development during rest.

Sympathetic Nervous System

Three neurons are involved and convey impulses from their origin in the hypothalamus, reticular formation and medulla oblongata to different effector organs and tissues. Neurone 01 has its cell body in the brain and its fibre extends into the spinal cords. Neurone 02 has its cell body in the lateral column of grey matter in the spinal cord, between the levels of the first thoracic and second or third lumbar vertebrae. Neurone 03 has its cell body in a ganglion and terminates in the organ or tissue.

Sympathetic Ganglia

Various sympathetic ganglia originate on either sides of the spinal cord. These are chains of ganglia extending from the upper cervical level to the sacrum. The ganglia are attached to each other by nerve fibres. The fibre from the spinal cord up to ganglia is termed as *preganglionic fibre,* while the fibre from the ganglia to the effector organ is called as *postganglionic fibre*.

Most of the organs are supplied with both sympathetic and parasympathetic fibres; however there are few exceptions. Sweat glands, the skin and blood vessels of skeletal muscles are not supplied with parasympathetic nervous system. The effects of stimulation of various structures by the sympathetic nervous system and their consequent function are mentioned in the Fig. 7.6.

There are three prevertebral ganglia situated in the abdominal cavity close to the arteries. Their names are as follows:

- Celiac ganglion
- Superior mesenteric ganglion
- Inferior mesenteric ganglion

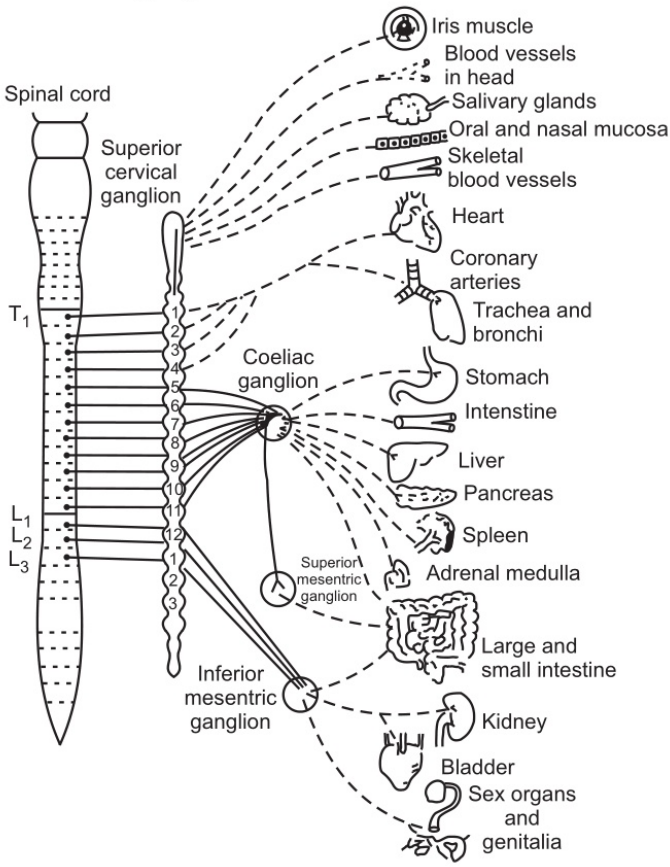

Fig. 7.6: The Sympathetic Outflow, the Main Structures supplied and the Effects of Stimulation. Solid lines preganglionic fibres, broken lines-postganglionic fibres there is a right and left lateral chain of ganglia

The ganglia consist of nerve cells diffusely distributed among a network of nerve fibres which form plexuses.

Parasympathetic Nervous System

Two neurons are involved in the transmission of impulses from their source to the effector organ. Neuron 01 has its cell body either in the brain or in the spinal cord. Those originating in the brain are the cranial nerves III, VII, IX, XI arising from nuclei in the midbrain and brainstem, and their nerve fibres terminate outside the brain. The cell body of the sacral outflow is in the lateral columns of grey matter at the distal end of this spinal cord. Neuron 02 has its cell body either in a ganglion or in the wall of the organ supplied.

Neurotransmitters

Noradrenaline is the chemical secreted at the postganglionic nerve endings of sympathetic nervous system; the only exception to this is neuron 02 of the sympathetic nervous system. Acetylcholine is the chemical secreted at the postganglionic nerve endings of the parasympathetic nervous system. Both the chemical messengers of the autonomic nervous system are termed as neurotransmitters. All ganglion transmissions, of the parasympathetic and sympathetic nervous system, are mediated by acetylcholine.

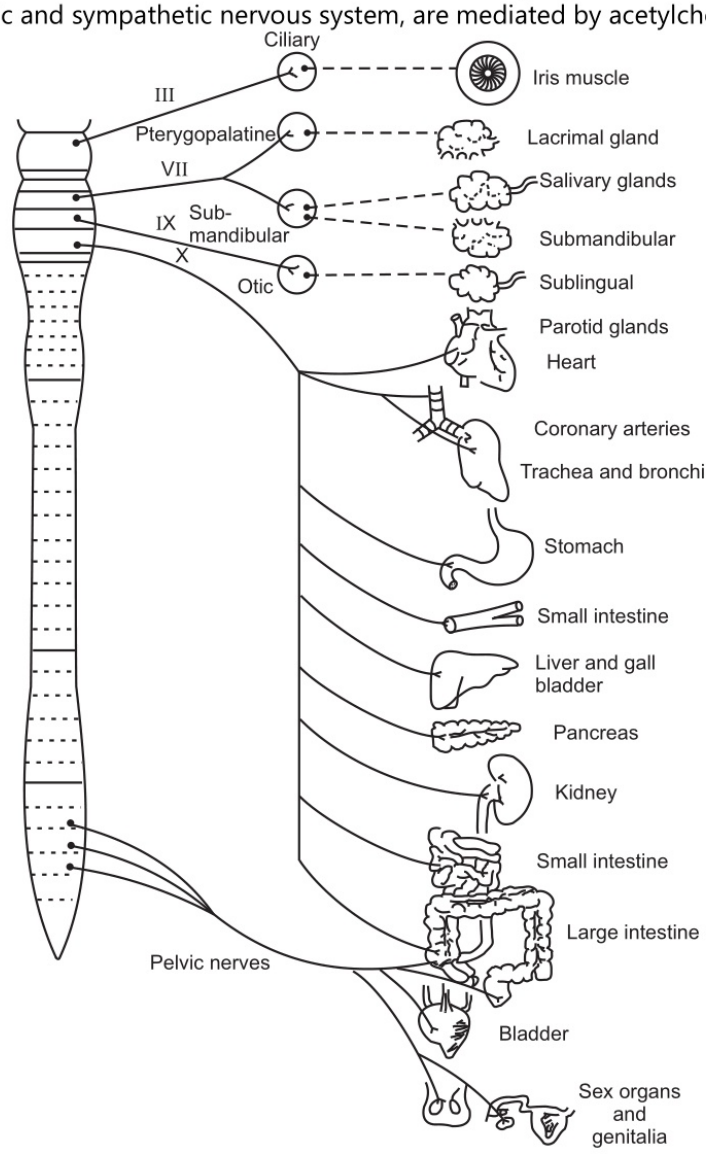

Fig. 7.7: The Parasympathetic Outflow.
The Main Structures Supplied and the Effects of Stimulation

Physiology of ANS:

Sympathetic Stimulation (adrenergic effect)	Organ	Parasympathetic Stimulation (Chollnergic Effect)
Dilates the pupil causing mydriasis	Eye (Iris)	Constrict the pupil causing miosis
No effect	Cilliary muscles	Constrict the muscles and causes accommodation of lens for near vision.
No effect	Lacrimal glands	Stimulates secretion
Dilates the bronchial tubes (bronchodilation)	Bronchi	Constrict the bronchial tubes (Bronchospasm)
Increases heart rate. Increases the force of contraction.	Heart	Slow the heart rate. Decreases the force of contraction
	Blood Vessels	
Vasodilation	(i) Coronary artery	Vasconstriction
Vasodilation	(ii) Skeletal blood vessels	Vasoconstriction
Vasoconstriction	(iii) All other blood vessels	Vasodilation
Relaxation of muscles, reduces motility, sphincters constricted	Smooth muscles of gastrointestial tract	Increase the movement and the sphincters relax
	Glands	
Increase the sweating	(i) Sweat glands	No innervation
Decrease the salivation	(ii) Salivary glands	Increase the salivation
Secretion inhibits	(iii) Gastric and intestinal glands	Secretion increases
Inhibits bile flow	(iv) Bile	Stimulates bile flow
Increase secretion	(v) Adrenal glands	No innervation
	Kidney	
Vasoconstriction, which leads to decrease in urine flow	(i) Blood flow	No effect
Muscle wall relaxed, internal sphincter constricted	(ii) Urinary bladder	Muscle wall contracted, internal sphincter relaxed
Metabolism markedly increased, liver releases glycogen	Metabolic effect	No effect
Contraction of uterine muscles, ductus, deferens, seminal vesicle, vasoconstriction	Sex organs	Vasodilation and erection

Note: Increased sweating and increased secretion of adrenal glands is cholinergic and not adrenergic though it is sympathetic stimulation.

EXERCISE

1. What are cranial nerves? Prepare a list.
2. Name the biggest cranial nerve. What are its functions?
3. Describe the characteristics of ANS.
4. What are the branches of ANS? Explain their relationship with each other.
5. Compare the anatomy of SNS with that of PSNS.
6. Compare the functions of SNS with that of PSNS.

***

Chapter ... 8

SENSE ORGANS

♦ LEARNING OBJECTIVES ♦

- *To appreciate the manner in which we respond to surrounding; through special senses.*
- *To understand the mechanisms by which we perceive the stimuli and respond to it through special senses.*
- *To study the structural features and their related functions of sense organs viz. eye, nose, tongue and ear.*
- *To learn the importance of activities of sense organs in day-to-day life activities.*

8.1 THE EYE

Eye is a special sense organ of sight present in the orbital cavity. It is spherical in shape and about 2.5 cm in diameter. The orbit of eye is formed by different bones which protect the eye-ball.

Anatomically, the wall of the eye ball is divided into three layers.

(a) Outermost layer is the fibrous coat, consisting of sclera and cornea.

(b) The middle layer is a vascular coat, consisting of choroid, ciliary body, and iris.

(c) The innermost layer is made up of nervous tissue, consisting of the retina.

There are six muscles, called as external muscles. These muscles connect the eyeball to the orbital cavity. These six muscles are four rectus muscles, i.e. superior, inferior, lateral and medial and two oblique muscles, superior and inferior.

Anterior to the eyeball are eyelids, which protect eyeball from dust and intense light. At the margin of eyelid, eyelashes are present which further protect the eyeball. The mucous membrane which lies in the inner surface of each eyelid is known as conjunctiva. This conjunctiva covers the exposed area of eyeball.

8.1.1 Eye Structure

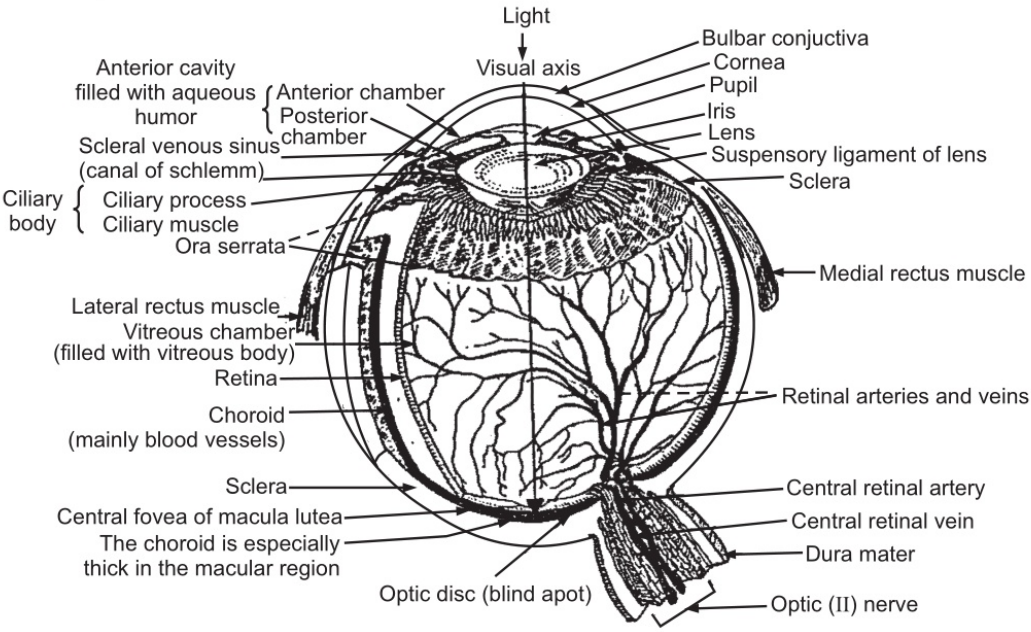

Fig. 8.1: Superior View of Transverse Section of the left Eyeball

The Lachrymal Apparatus

It is composed of lachrymal gland, where tears are produced. The lacrimal canaliculi, lachrymal sac and nasal lachrymal ducts, all assist in carrying tears to nasal cavity. The lachrymal glands are present in the depression of the frontal bone. Each gland is provided by about twelve ducts. These ducts open at the surface of conjunctiva at the upper-eyelid where fluid is pored. This fluid has a anti-bacterial action which protects the eye from foreign materials.

The Sclera and Cornea

The sclera is the outermost coat of the eye consisting of fibrous tissue. This layer is tough and maintains the shape of eye. It also gives attachment to extrinsic muscle of the eye. But anteriorly, the sclera becomes transparent membrane called as cornea, made of epithelial tissue. This part of cornea is used for passing light rays to reach at the retina. The cornea is convex anteriorly, used for bending the light rays to focus them on the retina.

The Choroid

Choroid is the middle coat which lines the sclera inside the posterior for about five-sixths part. It is very highly vascularized part, deep chocolate brown in colour. The light rays pass into the eye through the pupil and the nerve endings in the retina are stimulated by light rays. Choroid provides the nutrients to posterior part of retina. The chocolate brown colour of choroid is mainly due to pigment, melanin which is produced by melanocytes.

The anterior part of choroid contains ciliary body which consists of non-striated muscle fibres, i.e. ciliary muscles and also contains epithelial cells. The ciliary body contains ciliary processes, which is an extension of internal surface of ciliary body, containing blood vessels. The epithelial cells secrete a watery fluid known as aqueous humor. The circular band of smooth muscle is called ciliary muscle which helps in altering the shape of lens for far or near vision. The aqueous humor is present in front of lens. Nerve supply to ciliary body is from parasympathetic nerve, the branches of Oculomotor nerve.

The iris commence anteriorly from ciliary body which covers anterior one-sixth of the eye. Iris is present between cornea and lens and is attached to the outer margin of ciliary processes. Iris consists of circular and radial smooth muscles. The aperture in the centre of iris is called as pupil.

Main function of iris is to control the light rays entering in the eye. When there is bright light, the parasympathetic neuron stimulates the circular muscle of iris to contract which helps to decrease the size of the pupil whereas in dim light, sympathetic neuron stimulates the radial muscles of the iris to contract causing dilating the pupil. The dilation and constriction of pupil are autonomic reflexes. The lens is circular - biconvex transparent body. The suspensory ligaments from the ciliary body holds the lens and is enclosed within the capsule. Lens is elastic in nature and lies behind the pupil. The thickness of lens is controlled by ciliary muscle through the suspensory ligament.

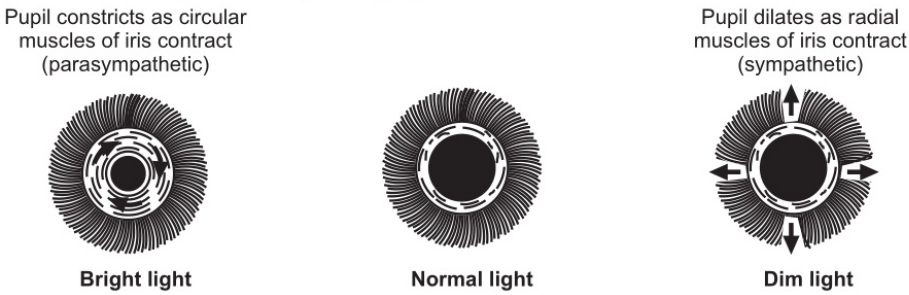

Fig. 8.2: Anterior View of Responses of the Pupil to varying Brightness of Light

The Retina

The retina lines the inner surface of choroid and is very delicate and easily stimulated by light rays. Retina is composed of nerve cells and nerve fibres and these nerve cells and nerve fibres are mounted on pigmented layers of epithelial cells and are attached to choroid. Nerve cells and nerve fibres are called rods and cones that are highly sensitive to light rays. Magnified image of retina can be seen through pupil by ophthalmoscope. During hypertension and diabetes, some pathological changes in blood can be observed. At the posterior end inside of eyeball, the retina occupies three quarters space. A very thick layer is present at the back and it thins out anteriorly up to ciliary body. At the centre of retina, there is a small depression containing yellow coloured cells known as macula lutea. Fovea centralis is present at the centre, having small depression which contains only cone shaped cells. This portion is a very sensitive part of retina. As the retina advances to anterior side,

there are more rod shaped cells and very few cone-shaped cells. Retina has slight purple colour due to presence of visual purple in the rods. Near the macula lutea, the fibres of the retina come together to form the optic nerve which passes out backside to eye-ball through the sphenoid bone to reach occipital lobe of the cerebrum. Here at the optical nerve where it leaves the eye, light sensitive cells are absent, this area is called as optic disc or blind spot.

The ciliary arteries and central arteries supply the oxygenated blood to the eye and they come from the ophthalmic artery which is also a branch of internal carotid artery. The central retinal vein drains venous blood from retina through the optic disc. Retina has pigment epithelium and neural part. Melanin is present in the choroid and pigment epithelium in the retina; absorbs light rays, and helps to prevent scattering of light within the eyeball. This ensures that the image produced on the retina by the cornea and lens remains sharp and clear. The neural part of the retina is the multilayered outgrowth of the brain. Retina consists of about 06 million cones and 120 million rods. Rods help in observing shades of gray in dim light and also help to see shape and movement. Cones help in colour vision in bright light. Colours cannot be seen in moonlight as only rods are functioning because the light is too less to stimulate the cone.

At the anterior side of the eye, there is a space between cornea and lens. This part is completely divided into anterior and posterior chambers by the iris. Both these chambers are filled up with watery fluid called aqueous humor. At the back of lens, the eyeball cavity is filled with vitreous humor which is soft, colourless, and transparent and a jelly like substance; contains 99 per cent water, some salts and protein. Vitreous humor helps in maintaining intraocular pressure to support retina against the choroid.

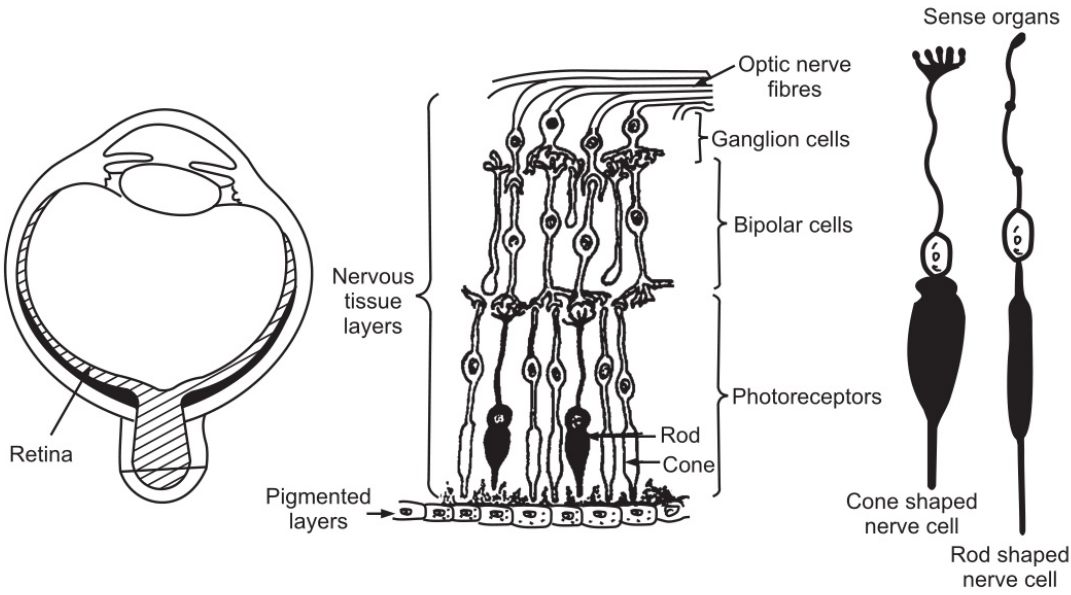

Fig. 8.3: The Retina

Rods

Rods are very sensitive to dim light and its function is in night vision. Rod consists of a photosensitive chemical known as rhodopsin. Rhodopsin is a combination of vitamin 'A' (retinol) and a protein called pepsin. But when the retina is exposed to bright light rhodopsin vanishes. Regeneration of rhodopsin occurs under reduced illumination which helps in adjustment of the eyes to dim light, known as dark adaptation. During this process, the iris increases the diameter of the pupil. Vitamin A deficiency shows the shortage of rhodopsin which causes night blindness, i.e. inability to see objects in night (dim light).

Cones

Cones are essential for day light vision and colour vision. There are three types of cones, having different pigments, mostly sensitive to red, blue or green light. When there is stimulation in correct proportion in the three types of cones, sensation is white. When one type of cone is stimulated, there is sensation of the light, corresponding to the type of the cone stimulated. When two types of cones are stimulated, the sensation is of a colour. Normal colour vision mainly depends upon the combination of these three primary colours in the sensory cortex. In colour blindness, the individual cannot differentiate between red and green because there is deficiency of red-sensitive or green sensitive pigment.

Physiology of Vision

When an image of the object is focused on the retina, it stimulates the photoreceptors which transfer the light stimulus on to the bipolar cells. The bipolar cells communicate with ganglion cells which extend their axons to the lateral geniculation body of the thalamus. Fibres carrying visual nerve impulse from the thalamus goes to the primary visual cortex in the occipital lobe.

Outer part of segments of cones is cone-shaped whereas those of rods are rod-shaped. The conversion of light into an electrical signal occurs in the outer part of segment. Nucleus is present in the inner part of segment. Golgi complex and mitochondria are also present. The photoreceptor is expanded into a bulk-like synaptic terminal at the proximal end and the light is absorbed by the photopigment. These are coloured proteins and are present in the outer segment membranes. These proteins, due to absorption of light, undergo structural changes and the changes help for production of receptor potential. There is photopigment present in the rods is known as rhodopsin. The photo proteins are present in plasma membrane. Some of the photo proteins form discs from plasma membrane. Normally, 1000 discs are present in the outer segments of each rod. Photoreceptor at the outer segments is renewed at an astonishingly rapid pace. Every hour about one to three discs are added at the base of the outer segments and old discs are cast out at the tip and phagocytosed by pigment epithelial cells. The photo protein contains glycoprotein called opsin and a derivative of vitamin A known as retinal. The individual can see better by taking adequate diet such as carrots, spinach or meats etc. which contain vitamin A. Deficiency of vitamin–A can cause night blindness. The visual photopigment is responsible for absorbing the light.

Optic nerve track

The optic nerve fibres originate from the retina of the eye and converge at a point approximately 0.5 cm to the nasal side of the macula lutea to become optic nerve. Optic nerve passes through the choroid and sclera and goes backwards and medially through the orbital cavity, and then it goes backwards through the optic foramen of the sphenoid bone and centrally to meet the nerve from the other eye at the optic chiasm. Optic chiasm is present in front and above the pituitary gland. The optic nerve fibres in the optic chiasma come from nasal side of each retina, cross over to the opposite side. Those fibres coming from temporal side of the retina do not cross but continue backwards on the same side.

Optic tract

It is the pathway at the backside of optic chiasma. The tract consists of nasal fibres from the retina of one eye and temporal fibres of the retina of other eye. Tracts go backwards to meet a group of nerve cells called lateral geniculation bodies in the cerebrum. Lateral geniculation bodies lie behind and below the thalamus which works as relay station for the optic nerve. The nerve fibres work as optic radiations and go backwards and divide in the visual area of cerebral cortex in the occipital lobes of the cerebrum.

Accommodation

When the surfaces of lens are curved outward (convex) then the lens refract incoming rays towards each other so that they can intersect. But when the surface of lens is curved inward, then the rays bend away from each other. This position of lens is concave. The focusing power depends upon increase or decrease in curvature of lens. When a person wants to focus on near objects, the lens curvature increases to bend the rays towards the fovea centralis. This increase in the curvature of the lens, to see near objects clearly is known as accommodation. When the eyes have to focus on distant objects, the ciliary muscle relaxes and the lens becomes more flat because it is stretched in all direction by suspensory ligaments. To focus on near objects, the ciliary muscles contracts and pulls the ciliary processes and choroid forward towards the lens. This releases the tension in lens and suspensory ligaments. All these changes can occur due to elastic nature of lens.

When the light rays from an object enters the eyes, they go in at different angle. But it is important that the light rays should stimulate two retinae. If this does not occur, then a person complains about double vision. When a person sees near object, both the eyeballs move inwards, so that their visual axes converge on the object. So nearer the object, greater is the convergence. But when a person sees distant object, less convergence is necessary. All these movements of eyeball occur due to extrinsic muscle of the eyes.

8.1.2 Eye Abnormalities

Myopia or Near sightedness

When there is a long distance between the cornea and lens or lens and retina or sometimes there is too powerful lens, the person suffers from myopia. In this particular situation, the image of a distant object falls in front of the retina. That is, when the object distance is 20 feet, light rays go into the eye almost parallel. In such type of condition, individual has to wear concave lens to adjust the light rays coming from distant object, so that image can fall on retina.

Hyperopia or Farsightedness

When there is short distance between cornea and lens or lens and retina or there is a weak lens, the person suffers from Hyperopia. The image of distant object falls behind the retina. In such situations, by using proper convex lens the image of object can fall on retina.

Presbyopia

The old persons suffer from such a condition. In this, the lens slowly looses its elasticity and interferes with correct accommodation. By using the convex lens, accommodation can be corrected.

Cataract

As a person's age advances, this condition interferes with vision. There is lens opacity and loss of transparency due to scattering of light in this region. It may be due to certain disease condition or drug or exposure to X-ray.

Glaucoma

When there is excessive accumulation of aqueous humor, the intraocular tension increases; this can lead to severe eye disease, the retina may get damaged and person suffers from blindness.

Conjunctivitis

Conjunctivitis may occur due to bacteria or dust, this may lead to inflammation and increase in tear flow.

Colour blindness

This is the sex-linked inherited disease. About 0.4 per cent of female population and about 08 per cent of the male population suffer from this abnormality. Some of the people are totally colourblind and every object is seen in terms of black and white and some are partially colourblind and can sense only some colours.

Night Blindness

It is caused due to deficiency of vitamin A. Such a person cannot see in dim light.

8.2 SENSE OF SMELL

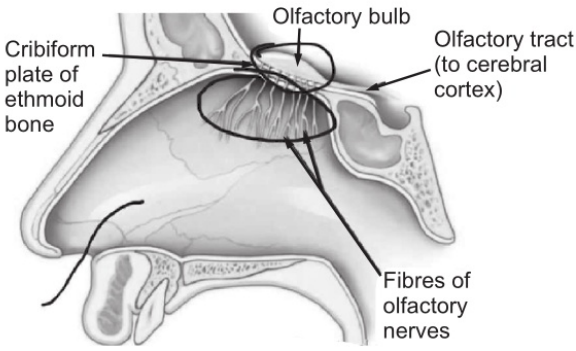

Fig. 8.4

The superior nasal conches consist of chemoreceptor nerve cells which are situated in mucous membrane of roof of the nose. Both sides of nasal septum, the nerve fibres from the cell septum, and the nerve fibres from the cell bodies enter through the cribriform plate of

the ethmoidal bone to meet olfactory bulb. Number of nerve fibres which form the olfactory tract, from where it goes backwards to the olfactory area in the temporal lobe of the cerebral cortex in each hemisphere. Here impulses are interpreted and odour is sensed.

Smell Physiology

The odorous material spreads chemical particles, and the particles during inhalation are carried towards nose. Particles stimulate nerve cells of the olfactory region when they dissolve in the mucous. When the air enters the nose, it is heated and the particles go to the roof of nose and olfactory receptor cells get stimulated, perception of smell occurs. The sense of smell may affect the appetite, either it may increase or decrease, depending upon the smell.

But when a person is more than familiar with a particular odour, the perception of odour quickly decreases. When there is irritation to nasal mucosa, it prevents odorous substances from reaching olfactory area of nose and may cause loss of sense of smell.

8.3 TASTE SENSATION

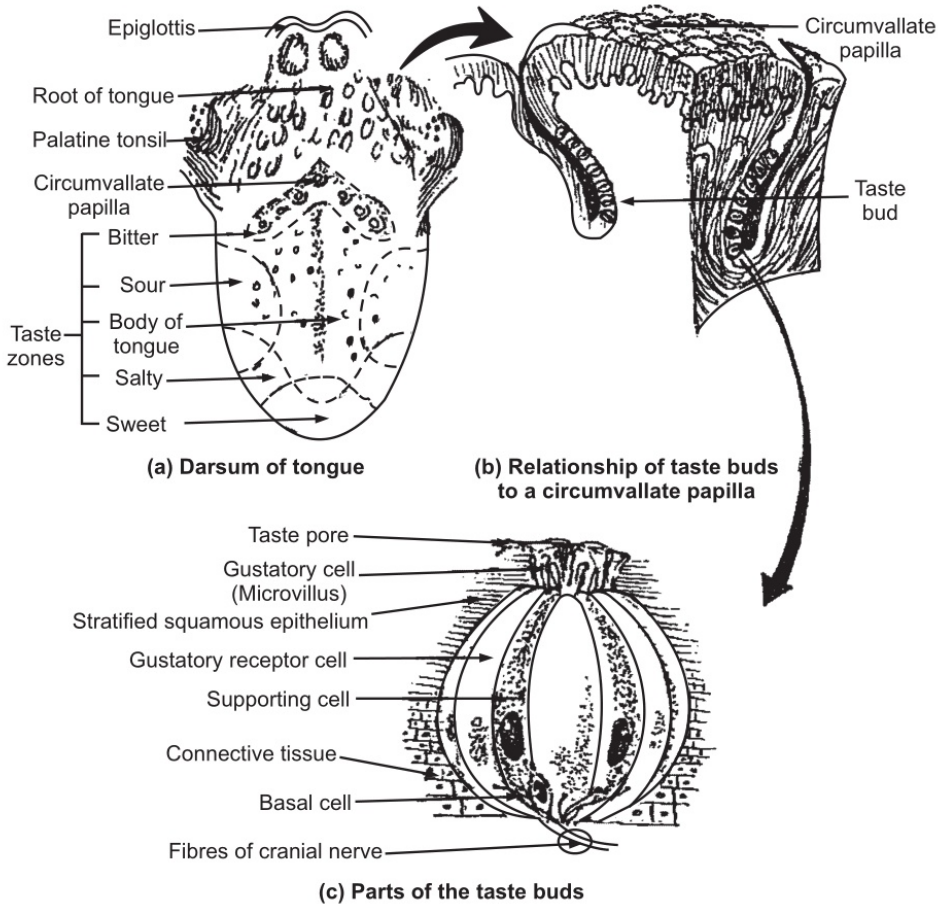

Fig. 8.5: Taste Buds

The taste sensation is associated with the tongue. The taste buds assist in ingesting food, i.e. which food is to be eaten or which food is to be discarded is decided upon by the taste buds. Approximately, 9000 taste buds are present on the tongue. The person tastes normally four tastes, i.e. bitter, sweet, sour and salty. The taste buds consist of small bundles of cell bodies and glossopharyngeal nerve endings, also facial and vagus nerves. Each taste bud is 50-70 micrometers in diameter, also contains supporting cells and 05-18 hair cells or gustatory receptors. The hair is projected into taste pore. The taste buds are round on the papillae on the tongue. The valrate papillae form a V-line on the posterior part of the tongue and the fungi form papillae are present on the tip and sides of the tongue.

Taste Physiology

When the substance goes in solution form, the gustatory receptors get stimulated which produce change in electrical potentials. The receptor potentials of taste cells generate impulses in sensory neuron endings which innervates the taste cells.

The facial nerve works for anterior two third of tongue and glossopharyngeal nerve works for posterior two-third of tongue. Axons of these nerves go to taste nuclei in medulla, then to thalamus and from here to taste area of cerebral cortex of brain.

8.4 EAR

Ear is the origin of hearing. The VIII cranial nerve carries sensation of hearing towards cerebral cortex of brain in the hearing area where interpretation occurs.

Most part of ear is situated in the petrous part of the temporal bone except the pinna lying outside.

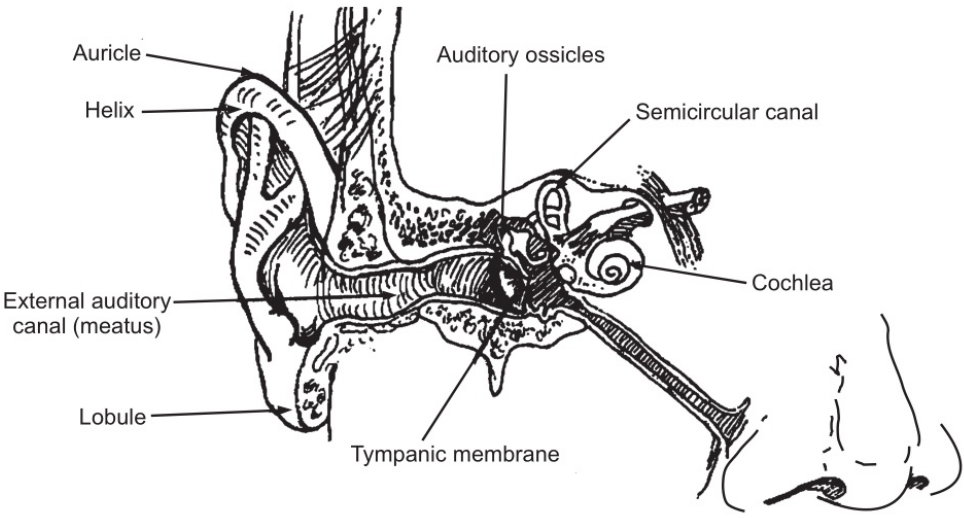

Fig. 8.6: Structure of the Ear (Right Ear)

Structure

The ear has three parts: external ear, middle ear and internal ear.

External Ear

External ear consists of pinna and external auditory meatus.

Pinna or auricle is the outer part of ear which is a expanded part, projecting from the side of head. This part is made of fibroelastic cartilage which is covered with the skin. The size of the pinna is variable in different animals. The expanded outer edge is known as helix and the lower most part is known as lobule. It is composed of fibrous and adipose tissue, supplied with blood capillaries.

External Auditory Meatus

It is the irregular shaped long tube about 02.5 cm in length; it starts from the pinna to reach tympanic membrane or eardrum. It is divided into two parts: Cartilaginous part which is about one third of the canal and osseous part, lying medially two third of canal. The ceremonious glands lie in cartilaginous portion. The ceremonious glands are modified sweat gland which secrete wax called ceriman. The ceriman helps to trap the unwanted particles entering in the ear, such as dust or insects.

Tympanic membrane or eardrum separates the external ear from the middle ear. Eardrum is round and oval in shape and composed of three layers of tissues. Outer layer is made up of stratified epithelium; middle layer is made up of fibrous tissue, and inner layer contains cuboidal epithelium.

The Middle Ear

It is also known as tympanic cavity. It is the irregular shaped cavity lying in the temporal bone. It is filled up with air by auditory tube which comes from the pharynx. Auditory tube is about 04 cm long. Air reaches the cavity through Eustacian tube which extends from nasopharynx. The pressure on the eardrum is maintained by air coming from atmosphere through the external auditory meatus and air coming through auditory tube. So the eardrum remains in a stretched condition which helps for vibration due to sound waves. The lateral side of middle ear is made up of the tympanic membrane, roof and floor is formed by temporal bone. The posterior wall is also made up of temporal bone. It has a small opening which extends to mastoid atrium. It is used for passing air to reach mastoid cells.

In the medial wall, there are two openings, oval window or fenestrate vestibule where a small bone called stapes fits and the round window or fenestrate cochleae which are closed by thin sheet of fibrous tissue.

The middle ear contains chain of small three bones called auditory ossicles. One end of auditory ossicle is attached to eardrum and other to fenestrate vestibule. Auditory ossicle contains small bones called, the malleus, the incus and the stapes. The malleus is hammer shaped which contain head, neck and handle. The handle of the malleus is attached to eardrum and head shows movable joint with incus. The incus is anvil shaped, present in the middle part of chain. It contains head, neck, two limbs and a base. The body is attached to malleus and process with the stapes. The stapes is stirrup shaped; contain head, neck, two

limbs and a base. The head of stapes is fixed with incus and base is fixed in fenestrate vestibule. With the help of ligaments, these three bones maintain their position.

The Internal Ear

It contains bony portion, called bony labyrinth and membranous portion, called the membranous labyrinth. The cavity of bony labyrinth is larger than the membranous labyrinth. The membranous labyrinth fits into bony labyrinth. There is a space between two labyrinths which contains a fluid called per lymph whereas membranous labyrinth also contains fluid called endolymph. The bony labyrinth contains three parts: the vestibule, the cochlea, and three semicircular canals. The expanded part near the middle ear is known as vestibule, containing vestibule and fenestra cochlea. The cochlea looks like snail's shape which has a broad base and the apex. The semi-circular canals are continuous with the vestibule. The shape of membranous labyrinth is similar. This part is smaller than bony labyrinth. The vestibule contains utricle and saccade. The membranous cochlea has the duct of the cochlea. Inside part is known as basilar membrane. On the basilar membrane lies the nerve cells and nerve fibres. The cells are long and narrow and situated side by side and hair are present on the cells. All nerve cells and nerve fibres form a true organ of hearing called organ of corgi. The nerve fibre combines with each other to form the auditory nerve-VIII cranial nerve. Auditory nerve goes backwards through temporal bone to reach hearing area of cerebral cortex of brain.

Physiology of Hearing

Any sound in the atmosphere produces the sound waves or vibrations and the sound waves travel at a certain speed, say about 1089 feet/per meter/second. Because of the shape of the auricle, it captures any sound wave, and relays it through the auditory canal, so that eardrum can vibrate. Due to the vibration of eardrum, the auditory ossicle moves to and fro and it sets the per lymph in motion and end lymph present inside the membranous labyrinth gets stimulated, and thus kept in motion.

The nerve cells present on basilar membrane get stimulated; and consequently the nerve fibres carry impulse through auditory nerve to hearing area of the cerebral cortex, where the interpretation of the waves take place.

Disorder of Ear

Deafness: There are many reasons for deafness, it may due to improper sound transmission in the external ear or damage to the neural pathways. The nerve deafness may be caused by acoustic nerve degeneration or tumors in the acoustic meatus. Whereas conducting deafness may be caused by wax deposition in the external auditory meatus or damage to auditory ossicles or thickening of eardrum etc.

EXERCISE

1. Describe the structure of the outer, middle and inner parts of the ear.
2. Write a note on physiology of hearing.
3. Draw a neat labelled diagram of section eye and explain structure of eye.
4. Discuss physiology of sight.
5. Explain the physiology of smell.
6. Write a note on otitis media.
7. Write a note on glaucoma and cataract.
8. Write a note on retinopathy.

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UNIT V

Chapter ... 9

CARDIOVASCULAR SYSTEM

♦ LEARNING OBJECTIVES ♦

- *To learn and appreciate, how different systems of body communicate and co-ordinate with each other through circulation of blood.*
- *To study the structural characteristics and related functions of organs constituting blood circulatory system.*
- *To understand the mechanisms involved in the pumping action of heart.*
- *To learn the fundamental concepts of blood pressure, blood volume, blood circulation and their importance in synchronised functioning of body.*
- *To study the disorders of cardiovascular system and their pathological implications.*

9.1 THE HEART

The heart is a roughly cone-shaped hollow muscular organ. It is about 10 cm long and is of the size of a person's fist. It weighs about 300 grams in an adult.

It is located in the thoracic cavity in the mediastinum between the lungs. It lies obliquely, a little more to the left than the right, and presents a base above, and an apex below. It is about 12 cm long, 09 cm wide at its broadest point, and 06 cm thick.

The apex is about 09 cm to the left of the midline at the level of the fifth intercostal space; the base extends to the level of second rib.

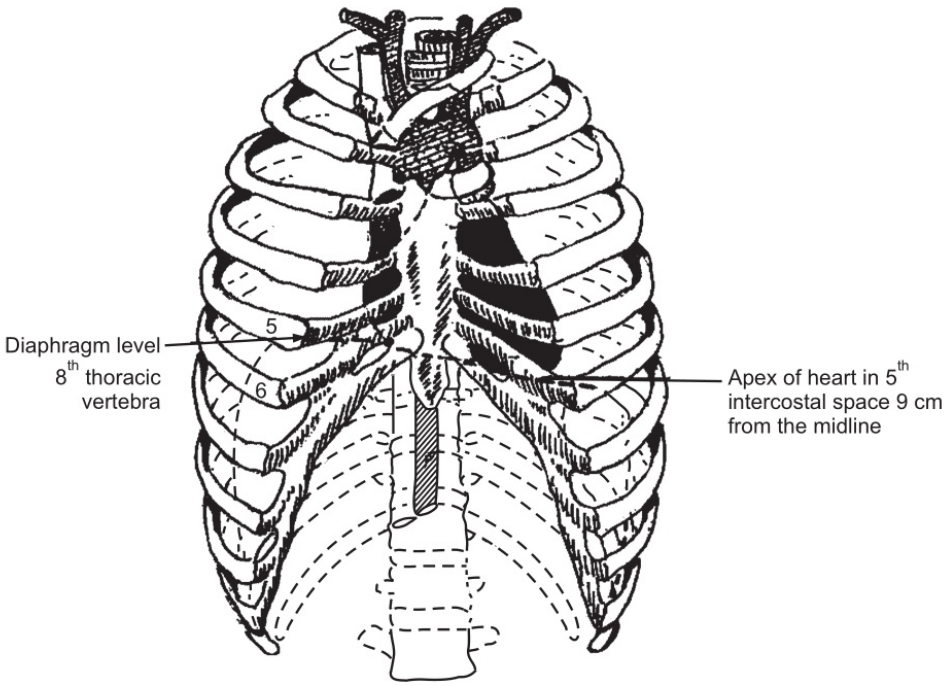


Fig. 9.1: Position of the Heart in the Thorax

Following organs are associated with the heart:

- **Inferiorly:** The apex rests on the central tendon of the diaphragm.
- **Superiorly:** The great blood vessels, i.e. the aorta, superior vena cava, pulmonary artery and pulmonary veins.
- **Posteriorly:** The oesophagus, trachea, left and right bronchus, descending aorta, inferior vena cava and thoracic vertebrae.
- **Laterally:** The lungs; the left lung overlaps the left side of the heart.
- **Anteriorly:** The sternum, ribs and intercostal muscles.

9.2 STRUCTURE

The heart is composed of three layers of tissue: pericardium, myocardium and endocardium.

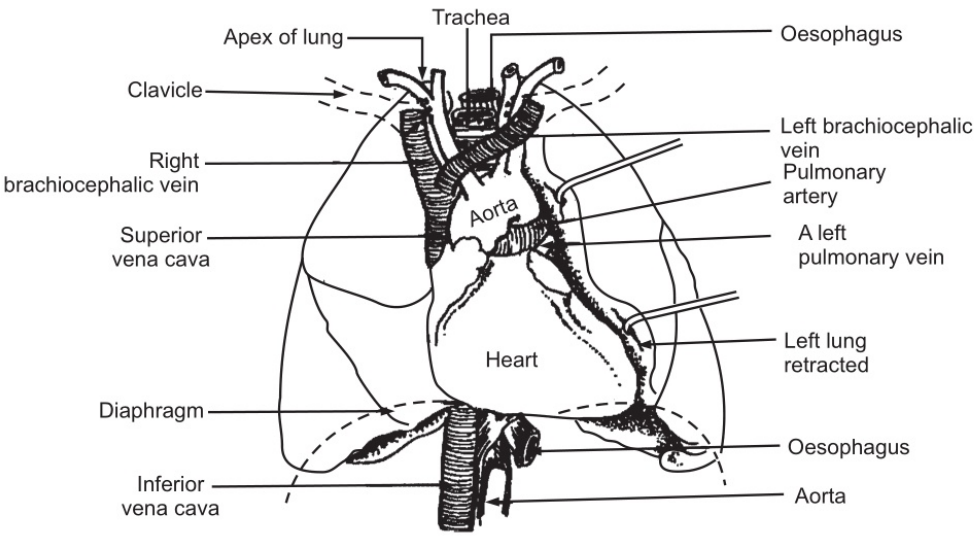


Fig. 9.2: Organs associated with the Heart

(a) Pericardium

It is made up of two sacs. The outer sac consists of fibrous tissue and the inner of a double layer of serous membrane. The outer fibrous sac is continuous with the tunica adventitia of the great blood vessels above and is adherent to the diaphragm below. Its fibrous nature prevents over distension of the heart. The serous membrane consists of flattened epithelial cells. It secretes serous fluid into the space between the visceral and parietal layers which allows smooth movement between them when the heart beats. The space between the parietal and visceral pericardium is only a potential space.

(b) Myocardium

It is composed of specialized cardiac muscle tissue found only in the heart. It is formed with the help of cardiac fibres. Each fibre has a nucleus and one or more branches. The ends of the cells and their branches are in close contact with the ends and branches of adjacent cells. Microscopically these joints or *intercalated discs* are observed as thicker, darker lines.

Fig. 9.3: Cardiac Muscle with Fibres separated

This arrangement gives cardiac muscle appearance of being a sheet of muscle rather than a large number of individual cells. When an impulse is initiated it spreads from cell to cell via the branches and intercalated discs over the whole sheet of muscle, causing contraction. For this reason, heart is termed as a 'functional syncytial'. The myocardium is thickest at the apex and thins out towards the base. It is thickest in the left ventricle. The atria and ventricles are separated by a ring of fibrous tissue. When a wave of electrical activity passes over the atrial muscle, it can only spread to the ventricles through the conductive system which extends across the fibrous ring from atria to ventricles.

(c) Endocardium

It forms the lining of the myocardium and the heart valves. It is thin, smooth, glistening membrane which permits smooth flow of blood inside the heart. It consists of epithelial cells, continuous with the endothelium that lines the blood vessels.

9.3 INTERIOR OF THE HEART

The heart is divided into a right and left side by a partition consisting of myocardium covered by endocardium. Each side is divided by an atrioventricular valve into an upper chamber, the *atrium*, and a lower chamber, the *ventricle*. The atrioventricular valves are formed by double folds of endocardium strengthened by a little fibrous tissue. The right atrioventricular valve (tricuspid valve) has three flaps or *cusps* and *the left atrioventricular valve* (mitral valve) has two cusps. The valves, between the atria and ventricles, open and close passively according to changes in pressure in the chambers. They open when the pressure in the atria is greater than that in the ventricles. During ventricular systole (contraction) the pressure in the ventricles rises above that in the atria and the valves shut for a short while preventing back flow of blood. The valves are prevented from opening upwards into the atria by tendinous cords, *chordae tendineae*, which extend from the inferior surface of the cusps to little projections of myocardium covered with endothelium, called *papillary muscles*.

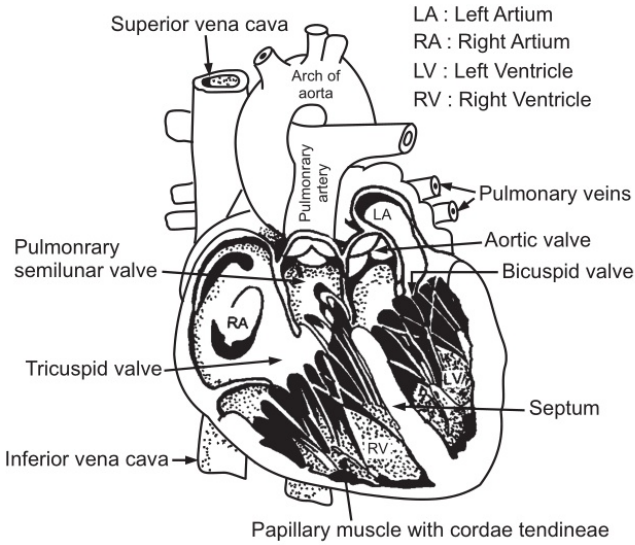


Fig. 9.4: Interior of the Heart

9.4 FLOW OF THE BLOOD THROUGH THE HEART

The superior and inferior venae cavae are the two largest veins in the body. They empty their contents into the right atrium. This blood passes through the right atrioventricular valve into the right ventricle, and from there it is pumped into the pulmonary artery, which carries deoxygenated blood to the lungs. The opening of pulmonary artery is controlled by the pulmonary valve, formed by three semi lunar cusps. This valve prevents the back flow of blood into the right ventricle when the ventricle muscle relaxes. The pulmonary artery then divides into left and right pulmonary arteries which carry the venous blood to the lungs where it gets purified.

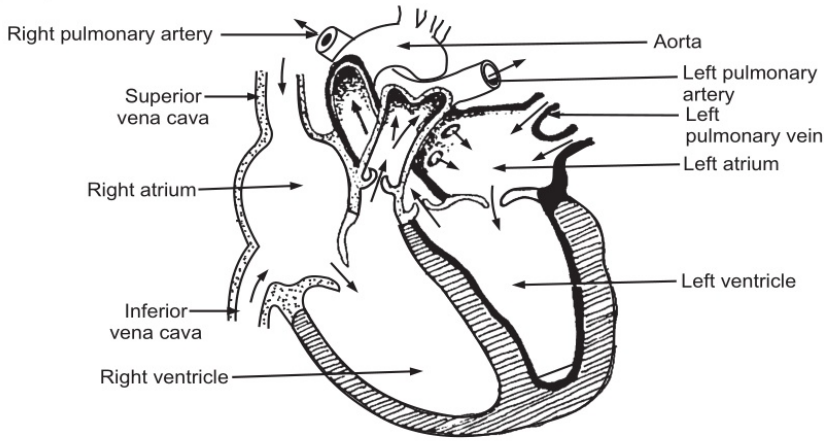
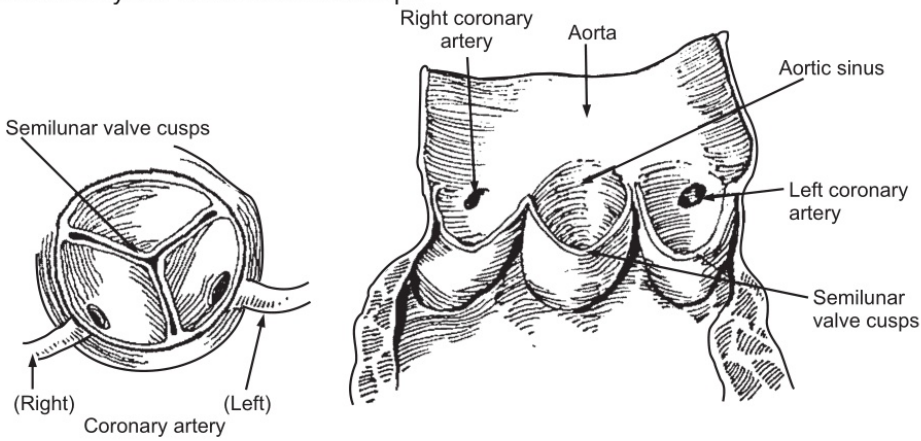


Fig. 9.5: Diagram showing Blood flow through Heart

Two pulmonary veins from each lung carry oxygenated blood to the left atrium. Then it passes through the left atrioventricular valve into the left ventricle, from where it is pumped into the aorta for general circulation. The opening of the aorta is controlled by the aortic valve, formed by the three semilunar cusps.



(a) A Closed Aortic Valve

(b) An Aortic Orifice cut and opened to show the Semilunar Valve

Fig. 9.6: Aortic Valve

It is to be noted that both atria contract at the same time and this is followed by the simultaneous contraction of both ventricles. The muscle layer of the walls of the atria is very thin in comparison with that of the ventricles. The muscle layer is thickest in the wall of the left ventricle. The pulmonary trunk leaves the heart from the upper part of the right ventricle, and the aorta leaves from the upper part of the left ventricle.

9.5 BLOOD SUPPLIED TO THE HEART

Arterial circulation

The heart is supplied with the right and left coronary arteries which branch from the aorta next to the aortic valve. The coronary arteries receive about 05 per cent of the blood from the heart. The coronary arteries traverse the heart, eventually by forming a large network of capillaries.

Venous circulation

Most of the venous blood is collected into several small veins that join to form coronary sinus which opens into the right atrium. The remainder passes directly into the heart chambers through little venous channels.

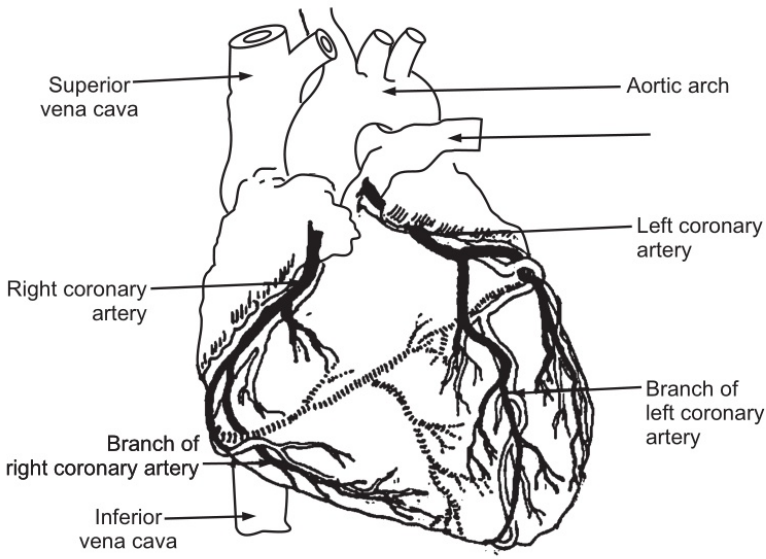


Fig. 9.7: Coronary Arteries

9.6 CONDUCTING SYSTEM OF THE HEART

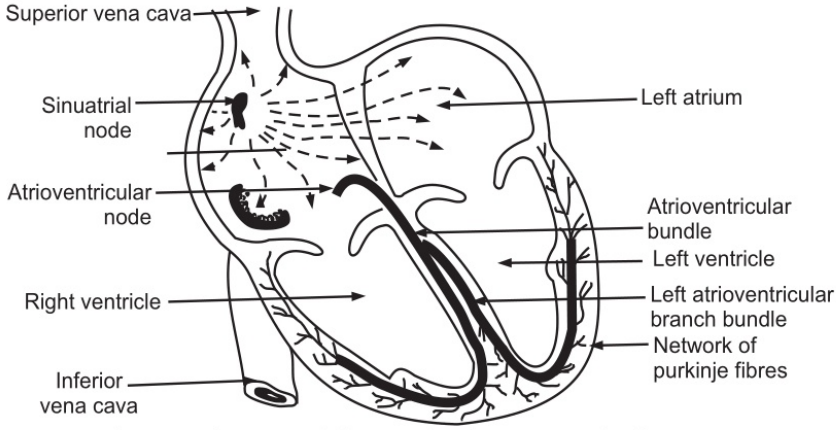


Fig. 9.8: Diagram of the Conducting System in the Heart

The heart has an intrinsic system whereby the cardiac muscle is automatically stimulated to contract; however it can be stimulated or depressed by the nerve impulses initiated in the brain and by the circulating neurotransmitters or hormones. There are small groups of specialized neuromuscular cells in the myocardium which initiate and conduct impulses causing coordinated and synchronized contraction of the heart muscle.

Sinoatrial Node (SA node)

It is a small mass of specialized cells in the wall of the right atrium near the opening of the superior vena cava. The SA node is termed as '*pace-maker*' of the heart. Normally, it initiates impulses more rapidly than other groups of the neuromuscular cells.

Atrioventricular Node (AV node)

It is a small mass of neuromuscular tissue, situated in the wall of the atrial septum near the atrioventricular valves. Normally, AV node is stimulated by impulses initiated in the atrial myocardial; however it is also capable of initiating impulses which can cause contractions at a rate slower than that of SA node.

Atrioventricular bundle: (AV bundle or bundle of HIS)

It consists of a mass of specialized fibres originating from the AV node. The AV bundle crosses the fibrous range that separates atria and ventricles. At the upper end of the ventricular septum, it divides into right and left bundle branches. Within the ventricular myocardium the branches break into fine fibres, called the *Purkinje fibres*. The AV bundle, bundle branches and *Purkinje fibres* convey impulses of contraction from the AV node to the apex of the myocardium where the wave of ventricular contraction begins, then sweeps upwards and outwards, pumping blood into the pulmonary artery and the aorta.

Nerve supply to the heart

In addition to the intrinsic impulses generated within the heart, it is also influenced by autonomic nerves originating in the cardiac center in the medulla oblongata which reach through the autonomic nervous system. It is controlled by both parasympathetic and sympathetic nerves. The vagus nerves (parasympathetic) supply mainly the SA, AV node and

atrial muscle. Stimulation of vagus reduces the heart rate and the force of contraction. The sympathetic nerves supply the SA and AV node and the myocardium of atria and ventricles. Sympathetic stimulation increases the rate and force of contraction.

Factors affecting Heart Rate

Following are the factors influencing the heart rate:

- Autonomic nervous system.
- Circulating neurohormones.
- Exercise.
- Emotional states.
- Gender.
- Age.
- Temperature.
- Baroreceptor reflex.

The Cardiac Cycle

The heart acts as a pump and its action consists of a series of events known as cardiac cycle. During each cardiac cycle, the heart contracts and then relaxes. The period of contraction is called systole and that of relaxation, diastole.

Normally, there are 60–80 cardiac cycles per minute. Taking 74 as average number of cardiac cycles per minute, every cycle lasts for about 0.8 seconds. Each cycle consists of the following events:

- Atrial systole-contraction of the atria.
- Ventricular systole-contraction of the ventricles.
- Complete cardiac diastole-relaxation of the atria and ventricles.

The sequence of events of a cardiac cycle is related to flow of blood from the beginning of one heartbeat to the beginning of next beat.

The superior vena cava and the inferior vena cava transport deoxygenated blood into the right atrium; simultaneously four pulmonary veins convey oxygenated blood into the left atrium. The atrioventricular valves are open and blood flows through to the ventricles. The SA node emits an impulse which stimulates a wave of contraction that spreads over the myocardium of both atria, emptying the atria and completing ventricular filling. This entire event lasts for 0.1 second and is termed as atrial systole.

When the wave of contraction reaches the AV node, it is stimulated to emit an impulse which quickly spreads to the ventricular muscle via the AV bundle, the bundle branches and Purkinje fibres. This results in a wave of contraction which sweeps upwards from the apex of the heart and across the walls of both ventricles pumping the blood into the pulmonary artery and the aorta. This event, lasting for 0.3 seconds is termed as ventricular systole. The high pressure generated during ventricular contraction is greater than that in the aorta and forces atrioventricular valves to close.

After contraction of the ventricles there is complete cardiac diastole, lasting for about 0.4 seconds, during which both atria and ventricles relax. During this time the myocardium recovers until it is able to contract again.

Electrical Changes in the Heart

Since the body fluids and tissues are good conductors of electricity, the electrical activity within the heart can be detected by attaching electrodes to the surface of the body. The pattern of electrical activity can be displayed on an oscilloscope screen or traced on paper. The instrument, on which it is recorded, is termed as electrocardiograph; and the tracing is termed as electrocardiogram (ECG). The normal ECG tracing shows five waves which have been named P, Q, R, S, and T.

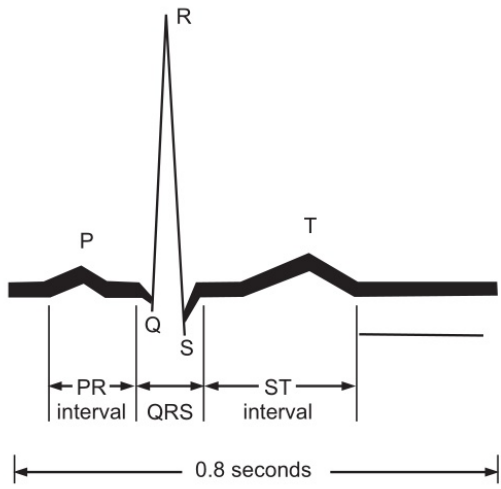


Fig. 9.9: A Normal Electrocardiogram (ECG)

The P wave arises when the impulse from the SA node sweeps over the atria. The QRS complex represents the very rapid spread of the impulse from the AV node through the AV bundle and the Purkinje fibres and the electrical activity of the ventricular muscle. The T wave represents relaxation of the ventricular muscle. The ECG originates from the SA node and is known as sinus rhythm. The rate of sinus rhythm is 60–100 beats per minute. A faster heart rate is called tachycardia and slower heart rate is termed as bradycardia. By examining the pattern of ECG waves and the time interval between cycles, pathological changes within the myocardium and conducting system of the heart can be diagnosed.

Cardiac output

The cardiac output is the amount of blood ejected from the heart. The amount expelled by each contraction of the ventricles is called as stroke volume. Cardiac output is expressed in liters per minute (*l*/min) and is calculated by multiplying the stroke volume by the heart rate (beats /min).

Cardiac output (*l*/min) = Stroke volume (ml) × Heart rate (beats/ min).

In a healthy adult at rest, the stroke volume is approximately 70 ml considering heart rate to be 72 beats/min; the cardiac output is 05 *l*/min. This can be greatly increased during exercise to around 25 *l*/min. or 35 *l*/min in case of athletes. This increase during exercise is called cardiac reserve. When increased blood supply is needed for higher requirements of tissues for oxygen and nutrients, heart rate and /or stroke volume can be increased. Following factors influence heart rate.

- Autonomic nervous system.
- Gender.
- Age.
- Body temperature.

Stroke Volume

The stroke volume is determined by the volume of blood in the ventricles immediately before they contract, i.e. the Ventricular End-Diastolic Volume (VEDV), also termed as *preload*. It depends on the amount of blood returning to the heart through the superior and inferior venae cavae; termed as venous return. Increased VEDV leads to stronger myocardial contraction, and more blood is expelled. In turn the stroke volume and cardiac output are increased. The capacity to increase the stroke volume with increasing VEDV is finite. Above this limit the heart starts failing. Other factors which increase myocardial contraction are:

- Increased stimulation of the sympathetic nerves supplying the heart.
- Hormones, e.g. adrenaline, nor-adrenaline, thyroxin.

Arterial blood pressure affects the stroke volume because it creates resistance to the flow of blood. This resistance is termed as after-load. It is determined by elasticity of the large arteries and the peripheral resistance of arterioles. Blood volume is normally kept constant by the kidneys. If stroke volume is deficient, it will reduce the blood flow. It will decrease the cardiac output and venous return. Venous return is the major determinant of cardiac output and, the heart pumps out all the blood returned to it. The force of contraction of the left ventricle ejecting blood into the aorta is not sufficient to return the blood through the veins and back to the heart. Following are additional factors influencing the venous return:

- Position of the body.
- Muscular contraction.
- Respiratory pump.

9.7 CIRCULATION OF BLOOD

Liver, kidneys and brain are the organs which get constant blood supply.

There are three types of blood circulations in the human body, viz.,

(i) Greater circulation or systemic circulation;

(ii) Pulmonary circulation or lesser circulation; and

(iii) Portal circulation.

(i) Greater Circulation: The oxygenated blood from the left ventricle is forced into aorta. The aorta divides and redivides to form arteries, arterioles and finally the blood capillaries. The walls of blood capillaries are very thin (made up of single layer of flat epithelium). Hence, oxygen and food material from the blood in the capillaries is passed to the tissue fluid. It is then supplied to the body cells. The same set of blood capillaries collect the waste material from the body cells. They unite to form venules. Different venules unite to form veins. The veins pour their blood content either into superior venacava or inferior venacava. These venacavae bring the deoxygenated blood to the right atrium of heart. This course of blood from left ventricle to the right atrium is called greater circulation.

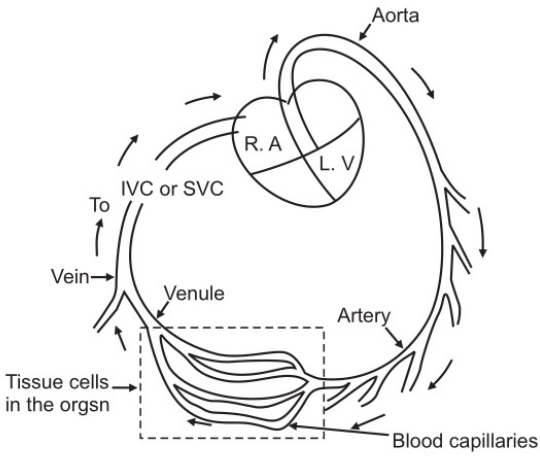


Fig. 9.10: Systemic (Greater) circulation

(i) Pulmonary Circulation: The deoxygenated blood from the right ventricle is forced into the pulmonary artery. The pulmonary artery divides into two branches each carrying blood to right and left lungs. In the lung tissue, the artery divides and redivides to form a net of blood capillaries surrounding the alveoli. Thus, the blood in blood capillaries and oxygen in the alveoli are separated by a double layer of flat epithelium (one layer is due to wall of blood capillary and another due to wall of alveoli). This membrane is called alveolar capillary membrane. The oxygen from alveoli diffuses through this membrane and passes to the blood in the capillaries. The carbon dioxide from blood capillaries diffuses into alveoli. Thus, the exchange of gases occurs in the lungs causing oxygenation of blood. The oxygenated blood from right and left lung is collected by four pulmonary veins and poured into the left atrium. This course of blood from right ventricle to the left atrium is called pulmonary circulation. As it is related only with oxygenation of blood occurring in the lungs, it is called lesser circulation.

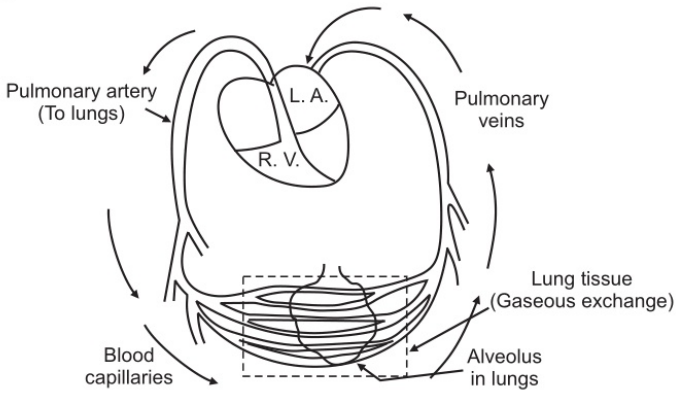


Fig. 9.11: Pulmonary Circulation (Lesser Circulation)

(iii) Portal Circulation: The venous blood from the digestive organs such as small intestine, stomach and pancreas is collected by the portal vein. It, instead of pouring its

content into inferior venacava, pours it into the liver. The portal vein is formed by joining together the veins such as splenic vein from spleen, inferior mesenteric from rectum and colon, superior mesenteric vein from small intestine, gastric vein from stomach and cystic vein from gall bladder. In this way, blood with a high concentration of nutrient materials goes to the liver first. The liver is supplied with oxygenated blood by hepatic artery. Thus, the oxygenated and deoxygenated blood carried into the liver is mixed and further collected by hepatic veins which pour it into inferior venacava. This course of blood through the liver is called portal circulation.

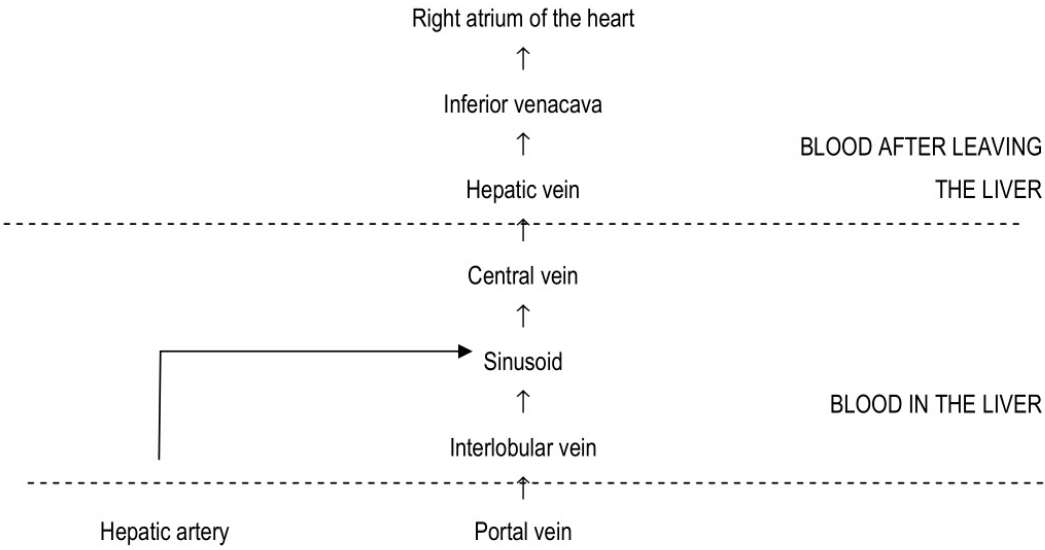


Fig. 9.12: Portal Circulation

In general, venous blood passes from the tissues to the heart by the most direct route. The only exception is the blood passing from abdominal part of the digestive system and spleen, in which case, it initially passes via liver and then to the heart via inferior venacava. Because of this 'portal circulation', nutrients present in the blood from digestive organs are modified in the liver. This helps in the regulation of these materials to other parts of the body.

9.8 THE BLOOD VESSELS

Arteries are the blood vessels which transport blood away from the heart. They consist of three layers of tissue (Fig. 9.13). Outer layer consists of fibrous tissue called tunica adventitia. The middle layer consists of smooth muscle and elastic tissue called tunica media. The inner lining consists of squamous epithelium called endothelium. In the larger arteries, the tunica media consists of more elastic tissue and less muscle. In the smaller arteries, the tunica media consists almost entirely of smooth muscle.

Veins are the blood vessels which transport blood to the heart. They also contain three layers similar to these of arteries. In the case of veins, the walls are much thinner because

there is less muscle and elastic tissue in the tunica media. Some veins possess valves, which prevent the back flow of blood. The valves are formed by a fold of tunica intima strengthened by connective tissues.

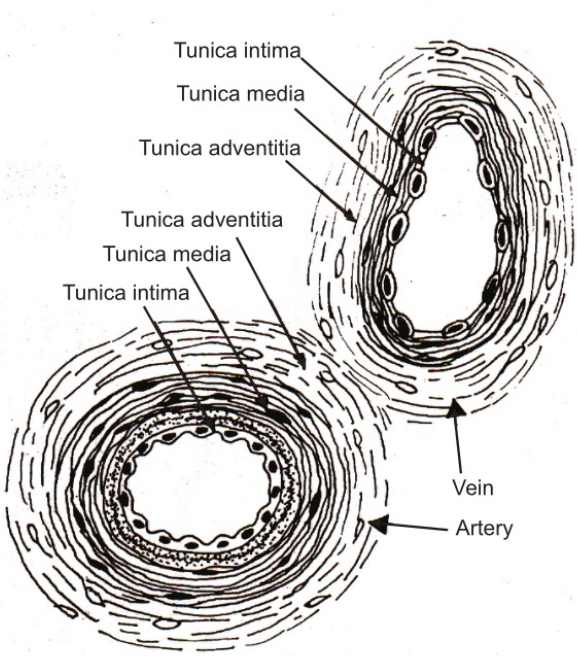


Fig. 9.13: Structure of an Artery and a Vein

The small arteries break up into minute vessels called capillaries. The wall of the capillary is composed of a single layer of endothelial cells which is very thin and permits the passage of water and other small molecules. Blood cells and large molecular weight substances do not normally pass through capillary walls. Capillaries form a vast network and link arterioles to venules.

9.9 ARTERIAL AND VENOUS SYSTEMS

9.9.1 Arterial System

The aorta after passing upwards for a short distance arches backwards and to the left. Two common carotid arteries, viz., left and right arise from the aorta. The left common carotid artery arise directly from the arch of aorta and the right one arises as a branch of brachiocephalic artery. There are two subclavian arteries out of which the right subclavian artery arises from the brachiocephalic artery and directly from the arch of the aorta. The axillary artery is a continuation of the subclavian artery and lies in the axilla. The first part is deep and then it runs superficially to become the brachial artery. It runs down the medial aspect of the upper arm and extends below the elbow joint where it divides into a radial and an ulnar artery. Together, the radial and ulnar arteries form palmar arches in the hand. Branches from the auxiliary, brachial, radial and ulnar arteries supply to all the structures in the upper limb.

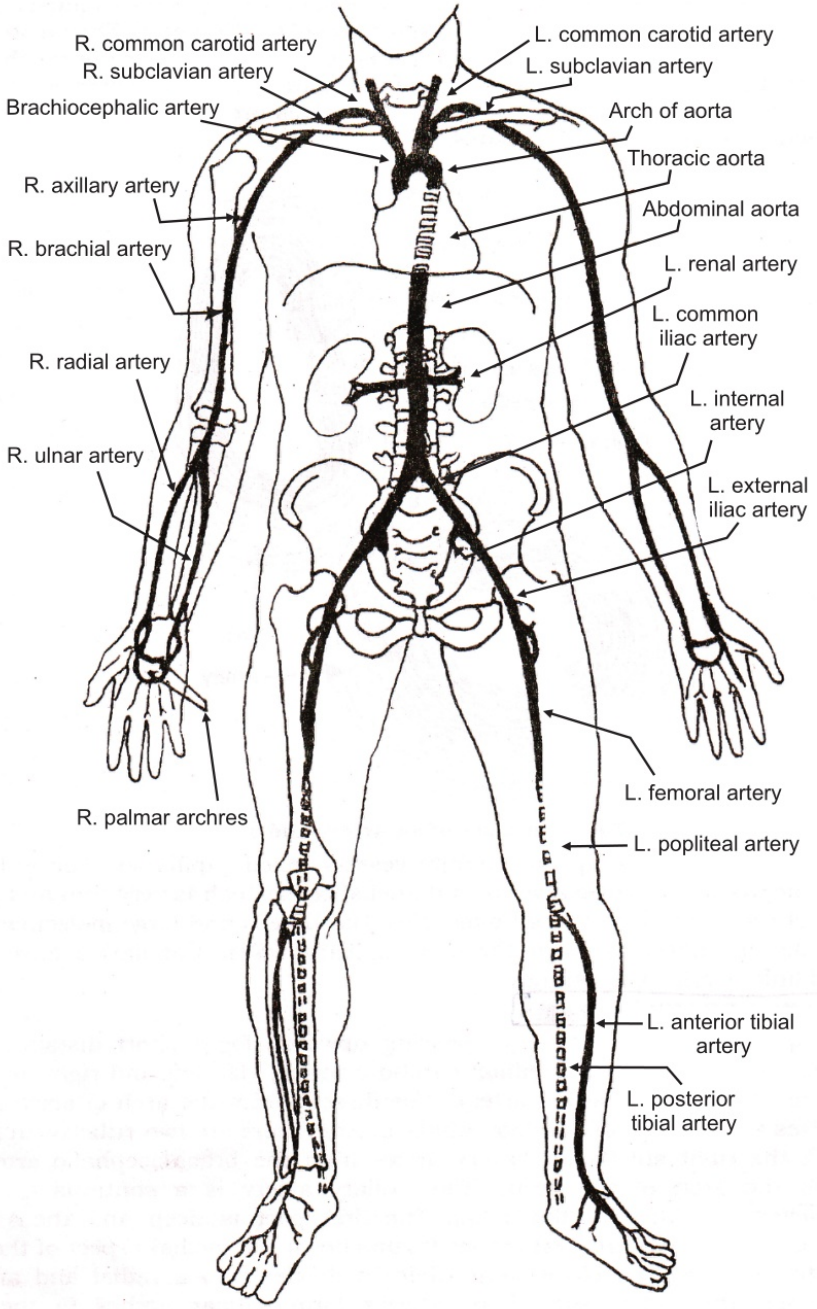


Fig. 9.14: Arterial System : Deep Arteries Shaded, Superficial Arteries Unshaded

The descending aorta is continuous with the arch of the aorta. It extends downwards to the level of the 12th thoracic vertebra where it passes behind the diaphragm to become the abdominal aorta. The thoracic aorta gives off many paired branches which supply to walls of the thoracic cavity and the organs within it.

The abdominal aorta extends from the 12th thoracic to the 4th lumbar vertebra. One of the important paired branches of the abdominal aorta is that of renal arteries which supply blood to the kidneys and give off branches to adrenal glands.

At the level of the 4th lumbar vertebra, the abdominal aorta divides into the right and left common iliac arteries. Each common iliac artery further divides into an external iliac and internal iliac artery. The external iliac artery further becomes the femoral artery which extends along the thigh and eventually passes round the medial aspect of the femur to enter the popliteal space where it becomes the popliteal artery. The popliteal artery divides into anterior and posterior tibial arteries.

9.9.2 Venous System

The external jugular vein begins in the neck and finally passes into the subclavian vein. The internal jugular vein collects blood from various regions of the brain and unites with the subclavian veins to form the brachiocephalic veins. Two brachiocephalic veins join together to form superior venacava. The superior venacava drains all the venous blood from the head, neck and upper limbs and empties its content into the right atrium.

The cephalic vein begins at the back of the hand. The median vein begins at the palmar surface of the hand and ascends on the front of the forearm. The basilic vein begins at the back of the hand on the ulnar aspect. The median veins ends with the basilic vein. In front of the elbow, the cephalic vein gives off a large branch, the median cubital vein, which slants upwards to join the basilic vein. The ulnar and the radial veins are deeply located and join together to form the brachial vein. The brachial vein further continues as the axillary vein in which the cephalic vein empties its contents. The axillary vein further continues as the subclavian vein which ultimately forms brachiocephalic vein.

Most of the venous blood from the organs in the thoracic cavity is drained into the azygos and the hemiazygos veins which empty into the superior venacava and the left brachiocephalic vein respectively.

In the abdominal region, the inferior venacava is formed when right and left common iliac veins join at the level of the 5th lumbar vertebra. Paired veins from the testes, ovaries, kidneys and adrenal glands join the inferior venacava. Blood from the remaining organs in the abdominal cavity enters portal circulation.

In the lower limbs there are two main superficial veins called short saphenous vein and long saphenous vein. The posterior and the anterior tibial veins are the deep veins which join to form the popliteal vein. The short saphenous vein ascends superficially to join the deep popliteal vein, which ultimately becomes the femoral vein and ascends in the thigh. The external iliac vein is the continuation of the femoral vein and also receives the long saphenous vein in its path. The internal iliac vein receives tributaries from several veins which drain the organs of the pelvic cavity. The external and the internal iliac veins join to form common iliac vein. Two common iliac veins from either side of the body ascend and unite to form the inferior venacava.

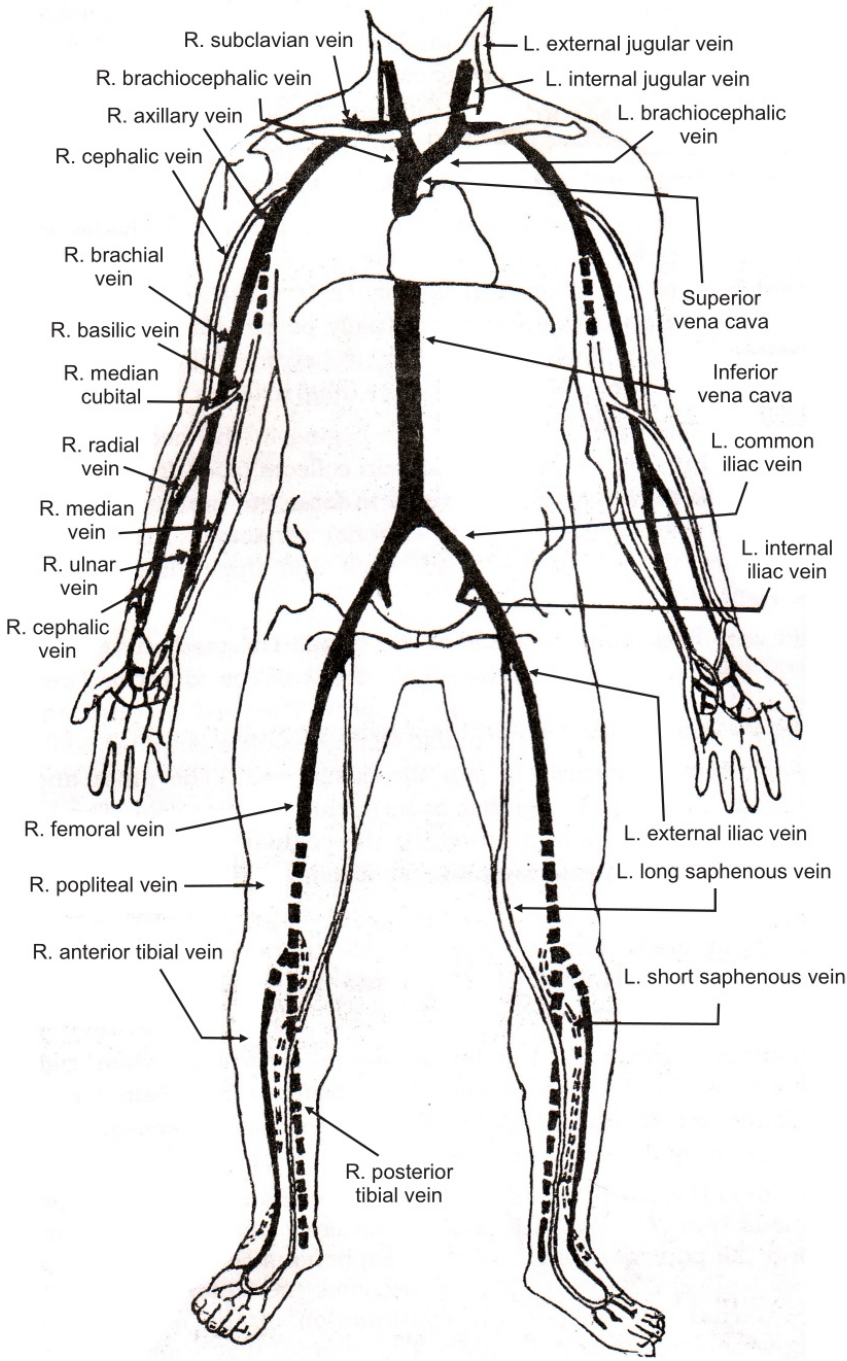


Fig. 9.15: The Venous System : Deep Veins Shaded, Superficial Veins Unshaded

9.10 BLOOD PRESSURE

It is defined as the force or pressure which the blood exerts on the walls of the blood vessels. When the left ventricle contracts and pushes blood into the aorta, the pressure produced is called the systolic pressure. In adults it is about 120 mm Hg (millimeters of mercury). When complete cardiac diastole occurs and the heart is resting, following the ejection of the blood, the pressure within the arteries is called diastolic blood pressure. In an adult it is about 80 mm Hg. These figures vary according to the time of day, the posture, gender, and age of the individual. Arterial blood pressure is measured by use of a sphygmomanometer.

Systemic arterial blood pressure maintains the essential flow of substances into and out of the organs of the body. Control of blood pressure is essential to maintain homeostasis. This is of special importance in case of vital organs like brain, heart and kidney. The blood pressure is maintained within normal limits by fine adjustments. Blood pressure is the result of two parameters, i.e. cardiac output and peripheral resistance: Blood pressure = Cardiac output × Peripheral resistance

Cardiac Output

The cardiac output is determined by the stroke volume and heart rate. Factors that affect the heart rate and stroke volume may increase or decrease cardiac output and in turn blood pressure. An increase in cardiac output raises both the systolic and diastolic pressure. An increase in the stroke volume increases the systolic pressure more than it does the diastolic pressure.

Peripheral or Arteriolar Resistance

Arterioles are the smallest arteries having tunica media composed almost entirely of smooth muscle, which responds to nerve and chemical stimulation. Constriction and dilatation of the arterioles are the important factors contributing to peripheral resistance. Vasoconstriction causes blood pressure to rise and vasodilatation causes it to fall. Dilatation and constriction of arterioles occurs selectively around the body, resulting changes in the blood flow through organs according to their needs. The highest priority is accorded to organs like brain and heart. In emergency blood to other organs may be reduced in favour of brain and heart. Normally, blood supply to an organ depends on its activity. A very active organ needs more oxygen and nutritional components than a resting organ and produces more waste material.

9.11 CONTROL OF BLOOD PRESSURE

Following mechanisms are involved in the maintenance of blood pressure. The cardiovascular centre is located in the brain and is situated in the medulla and pons. The centre receives, integrates and co-ordinates inputs from baroreceptors, chemoreceptors and

higher centres of the brain. The outputs of the centre are through autonomic nervous system to the heart and blood vessels, enabling rapid response to changes in blood pressure.

Baroreceptors

These are nerve endings sensitive to stretch, situated in the arch of the aorta and in the carotid sinuses.

There is always some degree of stretch in the Baroreceptors which can be altered by changes in blood pressure. A rise in blood pressure stretches the Baroreceptors, increasing their input to the cardiovascular centre. The centre responds by adjusting its output to the heart and blood vessels. As a result, the stroke volume of the heart decreases and the blood vessels become more dilated. The overall effect is compensatory fall in blood pressure.

Chemoreceptors

These are nerve endings situated in the carotid and aortic bodies. They are primarily involved in the control of respiration. They are sensitive to changes in the levels of carbon dioxide, oxygen and pH of the blood. Their input to the cardiovascular centre influences its output only when severe disruption of respiratory function occurs.

Higher Centres in the Brain

Input to the cardiovascular centre from the higher centres is influenced by emotional states such as fear, anxiety, pain and anger that may stimulate changes in blood pressure. The hypothalamus in the brain controls body temperature and influences the cardiovascular centre which responds by adjusting the diameter of blood vessels in the skin. This is also an important mechanism in determining heat loss and retention.

9.12 PULSE

It is described as a wave of distension and elongation felt in an artery wall due to the contraction of the left ventricle forcing about 60-80 ml. of blood into the already full aorta. When the aorta is distended, a wave passes along the walls of the arteries and can be felt at any point where an artery can be pressed gently against a bone. An average of 60–80 beats / min is common at rest. Information that can be obtained from the pulse includes:

- The rate at which the heart is beating.
- The regularity with which the heartbeats occur.
- The volume or strength of the beat.
- The tension: the artery wall should feel soft under the fingers.

Following are the factors affecting the pulse rate:

- Position.
- Age.
- Gender.
- Exercise.
- Emotion.

9.13 HYPERTENSION

Hypertension describes blood pressure which is sustained at a level higher than the generally accepted normal maximum level for a particular age group.

- At 20 years-140/90 mm Hg.
- At 50 years-160/95 mm Hg.
- At 75 years-170/105 mm Hg.

It is classified into the following subtypes:

- Essential, primary or idiopathic;
- Secondary to other diseases;

Essential Hypertension

This means hypertension of unknown cause. It accounts for 85–90 per cent of all cases and is subdivided according to the rate at which the disease progresses.

1. **Benign (chronic) hypertension:** The rise in blood pressure is usually slight to moderate and continues to rise slowly over many years. Sometimes complications are the first indication of hypertension, e.g. heart failure, cerebrovascular accident, myocardial infarction. Occasionally, the rate of progress increases and the hypertension becomes malignant. Following are the predisposing factors:
    - Inherited tendency
    - Obesity
    - Excessive alcohol intake
    - Cigarette smoking
    - Lack of exercise
2. **Malignant (accelerated) hypertension:** The blood pressure is already elevated and continues to rise rapidly over a few months. Diastolic pressure in excess of 120 mm Hg is common. The effects are serious: hemorrhages into the retina, encephalopathy (cerebral edema) and progressive renal disease leading to cardiac failure.

Secondary hypertension: Hypertension results from other diseases accounts for 10-15 per cent of all cases. It is related to following factors.

- Kidney disease
- Endocrine disorders
- Structure of the aorta

(a) Kidney disease: Raised blood pressure is a complication of many kidney diseases. The vasoconstrictor effect of excess renin released by damaged kidneys is one of the causative factors.

(b) Endocrine disorders: Secretion of excess aldosterone and cortisol stimulates the retention of excess sodium and water by the kidneys leading to increased blood volume and pressure. Over secretion of aldosterone is due to a hormone secreting tumour. Over secretion of cortisol may be due to excess stimulation of the gland by ACTH, secreted by the pituitary gland or to a hormone secreting tumour.

Secretion of excess adrenaline or noradrenaline leads to increase in blood pressure. This may be due to tumour of adrenal medulla, which is termed as pheochromocytoma.

(c) Structure of the aorta: Hypertension develops in branching arteries proximal to the site of a structure. In compression of the aorta by an adjacent tumour may cause hypertension proximal to the structure.

Hypertension may be a complication of treatment of certain drugs, e.g. corticosteroids, non-steroidal anti-inflammatory drugs, and oral contraceptives.

Pulmonary hypertension

Raised blood pressure in the pulmonary circulation is secondary to:

- Changes in blood vessels.
- Chronic disease of the respiratory system.
- Disease of the heart.
- Diseases of other organs that cause increased BP in the left side of the heart, e.g. cirrhosis of the liver, thrombosis of the portal vein.

Effects and Complications of Hypertension

The effects of long-standing and progressively rising blood pressure are serious. Hypertension predisposes to atherosclerosis, and affects the following specific organs, in particular.

- Heart
- Brain
- Kidneys

Heart: The rate and force of cardiac contraction are increased to maintain the cardiac output against a sustained rise in arterial pressure. The left ventricle increases in size and begins to fail when it reaches the upper limit of its function. This is followed by back pressure and accumulation of blood in the lungs, increase in the size of right ventricle causing the right ventricular failure. Hypertension also predisposes to other heart diseases.

Brain: Stroke, caused by cerebral hemorrhage is common, the effects depending on the position and size of the ruptured vessel. When a series of small blood vessels are ruptured at different times there is progressive disability. Rupture of a large vessel causes extensive loss of function or even death.

Kidneys: Essential hypertension causes kidney damage. If sustained for only short time, recovery may be complete. Otherwise, the kidney damage causes further hypertension, progressive loss of kidney function and kidney failure.

9.14 HEART DISEASES

Following heart diseases are indicated below:

(i) Cardiac failure

(ii) Disorders of heart valves

(iii) Ischemic heart disease

(iv) Rheumatic Heart Disease

(v) Infective endocarditic

(vi) Cardiac Arrhythmias

(vii) Congenital abnormalities.

(i) Cardiac failure:

It is further subdivided into:

- Acute cardiac failure
- Chronic cardiac failure
- Right sided or congestive cardiac failure
- Left sided or left ventricular failure

(a) Acute cardiac failure: A sudden reduction in output of blood from both ventricles causes acute reduction in the oxygen supply to all the tissues. Recovery from acute phase may be followed by chronic failure, or death may be caused due to anoxia of important centers in the brain.

(b) Chronic cardiac failure: This develops gradually and in the initial stages there may be no symptoms because of the compensation by increasing the rate and force of

contraction and the ventricles diatate. During the development of chronic renal failure, hypoxia and venous congestion cause changes in other systems, making still more demands on the heart, e.g. renal, endocrine, respiratory.

(c) Right sided or congestive cardiac failure: The right ventricle fails when pressure developed within it by the contracting myocardium is less than the force needed to push blood through the lungs. When compensation has reached its upper limit, and the ventricle is not emptying completely, the right atrium and vena cava become congested with blood; this is followed by congestion throughout the venous system. The organs affected first are liver, spleen and kidneys. Edema of the limbs and asicites i.e. excess fluid in the peritoneal cavity follows the congestion.

(d) Left sided or left ventricular failure: It occurs when the pressure develops in the left ventricle by contracting myocardium, is less than the pressure in the aorta and the ventricle can not pump out all the blood it receives. Failure of the left ventricle leads to dilatation of the atrium and an increase in pulmonary blood pressure. This is followed by a rise in the blood pressure in the right side of the heart and eventually systemic venous congestion. The congestion in the lungs leads to pulmonary edema and difficulty in breathing, often most severe at night.

(ii) Disorders of Heart Valves

The heart valves prevent backflow of blood in the heart during cardiac cycle. Damaged valves generate abnormal heart sounds. A severe valve disorder results in heart failure. Narrowing of a valve opening restricting blood flow through it is called stenosis. It occurs when inflammation of the valves roughens the edges of the cusps leading to narrowing of the valve. One more valvular defect is 'incompetence' or 'regurgitation. This is a functional defect and leads to failure of the valve to close completely, leading to back flow of blood in ventricles when they relax.

(iii) Ischemic Heart Disease

It is due to the effects of atheroma, i.e. deposition of fatty substances in the valves of arteries. It leads to narrowing or occlusion of one or more branches of the coronary arteries. This leads to either *Angina pectoris* or *Myocardial infarction.*

(a) Angina pectoris: This is a condition where there is intense chest pain because of reduced blood supply to the heart. The pain may radiate to the arms, neck and jaw. Factors like cold weather, exercise after heavy meal, strong emotions may precipitate angina. In the early stages of development of the diseases, the pain stops when the cardiac output returns to the resting level.

(b) Myocardial infarction: An *infarct* is an area of tissue that has died because of lack of oxygenated blood. The myocardium is affected when a branch of a coronary artery is occluded. The effects of complications are the maximum when the left

ventricle is involved. Myocardial infarction is usually accompanied by a very severe crushing chest pain behind the sternum, which continues even after rest. It may lead to fatal complications, e.g. severe arrhythmias, cardiac failure, rupture of ventricle wall, pulmonary or cerebral embolism.

(iv) The Rheumatic Heart Disease

Rheumatic fever is one of the autoimmune diseases occurring 02–04 weeks after a throat infection, caused by *Streptococcus pyrogens*. The antibodies developed to combat the infection damage the heart. Death rarely occurs in the acute phase but after recovery there may be permanent damage to the heart valves, leading to disability and possibly cardiac failure.

(v) Infective Endocarditic

Heart valves and margins of congenital heart defects are the most common places for infection in the heart. Infections may be caused by a wide variety of microbes, including some of the low pathogenic organisms, e.g.

- Non-hemolytic streptococci, e.g. following tooth extraction.
- *E. coli* and other normal GIT inhabitants.
- *S. aureus*.
- Microbes from infections of ciliary, urinary, respiratory tracts.
- Microbes accidentally introduced into the body.

Depressed immune response enables low-virulence bacteria, viruses, yeasts and fungi to become established and cause infections. This may be caused by use of cytotoxic drugs, corticosteroids ionizing radiation or malignant diseases like leukemia.

Infective endocarditic may be manifested as an acute or subacute condition.

(vi) Cardiac Arrhythmias

It is a disorder of heart rate or rhythm and is the result of abnormal generation or conduction of impulses. When the resting heart rate is less than 60 /min, it is termed as bradycardia; the rate above 100 /min is termed as tachycardia. When there is no electrical activity in the ventricles, it leads to systole; it may subsequently lead to cardiac arrest and death. Fibrillation is a disorderly behaviour of cardiac muscles. It may be atrial fibrillation or ventricular fibrillation. Ventricular fibrillation is more dangerous and if not treated immediately, it can lead to death due to cerebral anoxia. Heart block occurs when impulse formation is impaired or conduction is prevented, and the delay between atrial and ventricular contraction is increased. When heart block develops gradually, there is some degree of adjustment in the body to reduce cardiac output but, if progressive, it eventually leads to death from cardiac failure and cerebral anoxia.

(vii) Congenital Abnormalities

Abnormalities in the heart and great vessels at birth may be due to intrauterine developmental errors or to the failure of the heart and blood vessels to extra-uterine life. In many cases there are no symptoms in early life and the abnormality is recognized only when complications occur. The abnormalities may be related to arteries or valves.

EXERCISE

1. Discuss anatomy of heart and conduction system of heart. Explain in brief interpretation of ECG and etiology, pathophysiology of Arteriosclerosis.
2. Explain the terms: Angina pectoris, Arterioslerosis, Myocardial function.
3. Explain the term hypertension. Discuss various events in the cardiac cycle.
4. What is blood pressure? Give normal value of systolic and diastolic blood pressure and explain regulation of blood pressure. Add a note on heart sounds.
5. Explain the different disorders of cardiovascular system. Write a short note on different types of blood vessels.
6. Draw a neat labelled diagram and discuss the structure of heart. Explain the different types of causes and pathophysiology of hypertension.
7. Enlist and discuss various types of blood circulation in human body. Explain in brief ECG with its significance.
8. Describe in short the cardiac cycle.
9. Explain the flow of blood through the heart.
10. Describe the importance of portal circulation.
11. Describe the structural differences between arteries, capillaries and veins.

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