A TEXT BOOK

PHARMACY INDIA PUBLICATION

HUMAN ANATOMY

PHYSIOLOGY & PATHOPHYSIOLOGY

BP104T

As per NEP 2020

Bachelor of Pharmacy

1st Semester

Author

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FULLY COLOURED BOOK

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PREFACE

The study of Human Anatomy, Physiology, and Pathophysiology forms the foundation of pharmaceutical education by providing students with a comprehensive understanding of the structure and function of the human body in both health and disease. A thorough knowledge of these concepts enables pharmacy students to understand the scientific basis of disease processes, drug action, therapeutic interventions, and patient care. The Human Anatomy, Physiology and Pathophysiology I (BP104T), has been carefully developed in accordance with the Pharmacy Council of India (PCI) National Education Policy (NEP) 2020 B.Pharm curriculum, ensuring complete coverage of the prescribed syllabus for first-semester pharmacy students.

The book presents the subject in a logical, student-friendly, and clinically relevant manner. It begins with the fundamental concepts of anatomy, physiology, and pathophysiology, followed by the organization of the human body from the cellular and tissue levels to various organ systems. It further explains the principles of homeostasis, cellular communication, mechanisms of cellular injury, inflammation, and adaptation before introducing the anatomy, physiology, and common pathological conditions of the integumentary, skeletal, muscular, nervous, cardiovascular, lymphatic, and special sensory systems as prescribed in the PCI syllabus.

Special emphasis has been placed on simplifying complex physiological mechanisms through clear explanations, well-labeled illustrations, flowcharts, tables, and clinical correlations. Pathophysiological concepts have been integrated with normal anatomy and physiology to help students appreciate how structural and functional alterations lead to disease. This integrated approach strengthens conceptual understanding and prepares students for advanced subjects such as pharmacology, pathology, pharmacotherapeutics, and clinical pharmacy.

Each chapter has been designed to facilitate effective learning through clearly stated learning objectives, concise explanations, key points, illustrative diagrams, summary tables, and review questions. The content encourages analytical thinking and helps students relate basic biomedical sciences to pharmaceutical practice and patient-centered healthcare.
While every effort has been made to ensure scientific accuracy, clarity, and completeness, suggestions from teachers, students, academicians, and healthcare professionals for improving future editions will always be sincerely welcomed.

It is our sincere hope that this book will serve as a reliable companion for B.Pharm students, assist teachers in delivering the curriculum effectively, and contribute to developing competent pharmacy professionals with a strong understanding of human anatomy, physiology, and the mechanisms underlying disease.

Authors

HUMAN ANATOMY PHYSIOLOGY & PATHOPHYSIOLOGY SYLLABUS

UNIT-I — HOURS: 12

Introduction to Human Body
Cellular and tissue level of organization. Definition and scope of anatomy, physiology and pathophysiology. Levels of structural organization and body systems, basic life processes, homeostasis, basic anatomical terminologies. Structure and functions of cell, transport across cell membrane, cell division, cell junctions. General principles of cell communication, forms of intracellular signalling) Contact-dependent, b) Paracrine, c) Synaptic, d) Endocrine Classification of tissues, structure, location and functions of epithelial, muscular and nervous and connective tissues.

Basic principles of cell injury and adaptation
Components and types of feedback systems, causes of cellular injury, pathogenesis (cell membrane damage, mitochondrial damage, ribosome damage and nuclear damage), morphology of cell injury – adaptive changes (atrophy, hypertrophy, hyperplasia, metaplasia, dysplasia), cell swelling, intra cellular accumulation and cell death. Definitions of commonly used relevant medical terminologies.

UNIT-II — HOURS: 12

Integumentary system and wound healing
Structure and functions of skin. Skin disorders: Psoriasis and dermatitis and pathophysiology of Leprosy. Basic principles of wound healing.

Skeletal system and joints
Divisions of skeletal system, types of bones, salient features and functions of bones of axial and appendicular skeletal system. Organization of skeletal muscle, physiology of muscle contraction, neuromuscular junction. Structural and functional classification of joints.

Diseases of bones and joints
Pathophysiology of rheumatoid arthritis, osteoporosis and gout.

UNIT-III — HOURS: 12

Body fluids, blood and lymphatic system
Body fluids, composition and functions of blood, hemopoiesis, formation of haemoglobin, mechanisms of coagulation, blood grouping, Rh factors and transfusion. Lymphatic organs and tissues, lymphatic vessels, lymph formation, circulation and functions of lymphatic system.

Basic mechanism of inflammation and repair
Introduction, classification and pathophysiology of inflammation, mediators of inflammation.

Haematological diseases
Pathophysiology of iron deficiency, megaloblastic anaemia (Vit B12 and folic acid), sickle cell anaemia, Thalassemia, hereditary acquired anaemia and haemophilia.

UNIT-IV — HOURS: 12

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.

Special senses
Structure and functions of eye, ear, nose and tongue. Pathophysiology of special sense disorders- glaucoma, cataract, myopia, otitis externa, otitis media, vertigo and anosmia

UNIT-V — HOURS: 12

Cardiovascular system
Anatomy of heart, blood circulation, blood vessels, structure and functions of artery, vein and capillaries, elements of conduction system of heart and heartbeat, its regulation by autonomic nervous system, cardiac output, cardiac cycle. Regulation of blood pressure, pulse, electrocardiogram.

Cardiovascular Diseases
Pathophysiology of hypertension, cardiac arrhythmias, congestive heart failure, ischemic heart disease (angina, myocardial infarction, atherosclerosis and coronary artery disease).

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INTRODUCTION TO HUMAN BODY

1

- Definition and scope of anatomy, physiology and pathophysiology.
- Levels of structural organization and body systems, basic life processes, homeostasis, basic anatomical terminologies.
- Structure and functions of cell, transport across cell membrane, cell division, cell junctions.
- General principles of cell communication, forms of intracellular signaling a) Contact-dependent, b) Paracrine, c) Synaptic, d) Endocrine
- Classification of tissues, structure, location and functions of epithelial, muscular and nervous and connective tissues.

1.1 INTRODUCTION

The human body is one of the most complex and highly organized structures in nature. It consists of billions of microscopic components that work together in a coordinated way to maintain life and perform all essential functions.

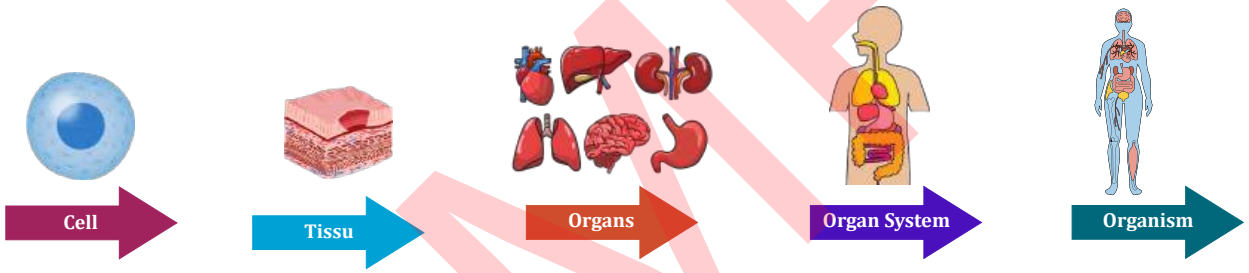


Figure 1.1: The Structural Organization of the Human Body

1. Cell

- Cells are the smallest and most basic living units of the human body, capable of carrying out life processes and reproduction.
- The human body begins as a single fertilized cell.
- All tissues and organs are formed through repeated cell division.
- Cells form the structural and functional foundation of the body.

2. Tissues

- Tissues are groups of similar cells arranged together, along with intercellular material, to perform specific functions.
- Each tissue carries out a specialized role in the body.
- Major types include muscular, nervous, epithelial, and connective tissues.
- Tissues act as an intermediate level between cells and organs.

3. Organs

- Organs are structures formed by different types of tissues working together to perform specific body functions.
- Each organ has a distinct and specialized function.
- **Example:** The stomach contains muscular, epithelial, connective, and nervous tissues.
- All tissues in an organ coordinate to ensure proper functioning.

4. Organ Systems

- Organ systems represent the highest level of organization in the human body.
- They consist of multiple organs working together.
- They perform complex and vital physiological functions.
- Different organ systems work together to keep the body healthy.
- **role:** It helps the body maintain life processes like digestion, breathing, circulation, and excretion.
- **Example:** Digestive system includes mouth, stomach, intestine, liver, pancreas.

Body tissues are classified into four categories based on their structure and function:

1. Epithelial Tissue

- This tissue covers body surfaces and lines organs, body cavities, and ducts. It also forms glands. It allows the body to interact with both internal and external environments.
- **Structure:** Comprised of closely packed cells that form continuous sheets.
- **Function:** Acts as a protective layer, covering body surfaces, lining internal organs, and cavities.
- **Types:**
  - **Squamous Epithelium:** Flat, scale-like cells (e.g., skin surface, alveoli).
  - **Cuboidal Epithelium:** Cube-shaped cells (e.g., kidney tubules).
  - **Columnar Epithelium:** Tall, column-like cells (e.g., lining of the digestive tract).
- **Special Features:** Involved in secretion, absorption, and filtration.

2. Connective Tissue

- This tissue supports and protects the body and its organs. It binds organs together, stores energy reserves, and plays a role in immunity.
- **Structure:** Consists of cells scattered within an extracellular matrix. The matrix may include fibers (collagen, elastin) and ground substance (e.g., cartilage, bone).
- **Function:** Provides support, binds other tissues together, and stores energy.
- **Types:**
  - **Loose Connective Tissue:** Fewer fibers, provides flexibility (e.g., adipose tissue).
  - **Dense Connective Tissue:** Contains more collagen fibers, providing strength (e.g., tendons, ligaments).
  - **Cartilage:** Flexible yet strong, found in joints, ears, nose.
  - **Bone:** Rigid and strong, supports the body.
  - **Blood:** Fluid tissue that transports oxygen, nutrients, and waste products.

3. Muscular Tissue

- Composed of cells specialized for contraction and force generation, muscular tissue aids movement and generates heat.
- **Structure:** Composed of elongated cells (muscle fibers) capable of contracting and generating force.
- **Function:** Facilitates movement of the body and organs.
- **Types:**
  - **Skeletal Muscle:** Voluntary control, responsible for body movements.
  - **Cardiac Muscle:** Involuntary control, found in the heart; helps in pumping blood.
  - **Smooth Muscle:** Involuntary control, found in the walls of internal organs like the stomach and intestines.

4. Nervous Tissue

- This tissue detects changes within and outside the body and responds by generating electrical signals, which control muscle contractions and glandular secretions.
- **Structure:** Consists of neurons (nerve cells) and glial cells (support cells).
- **Function:** Transmits electrical impulses, facilitates communication between different body parts.
- **Types:**
  - **Neurons:** Cells that transmit electrical signals.
  - **Glial Cells:** Support neurons, provide nourishment, and maintain homeostasis in the nervous system.

1.3 DEFINATION AND SCOPE OF ANATOMY, PHYSIOLOGY AND PATHOPHYSIOLOGY

1.3.1 Anatomy

The word anatomy is derived from the Greek words ana (meaning 'up') and tome (meaning 'to cut'). Traditionally, anatomy was defined as the science of cutting up, or dissection, of the body to study its structure.

Anatomy is the branch of science that deals with the study of the structure of the human body and its parts.

The branch of biological science that deals with the study of the structure and organization of living organisms and their component parts, including their form, position, size, and relationships to one another.

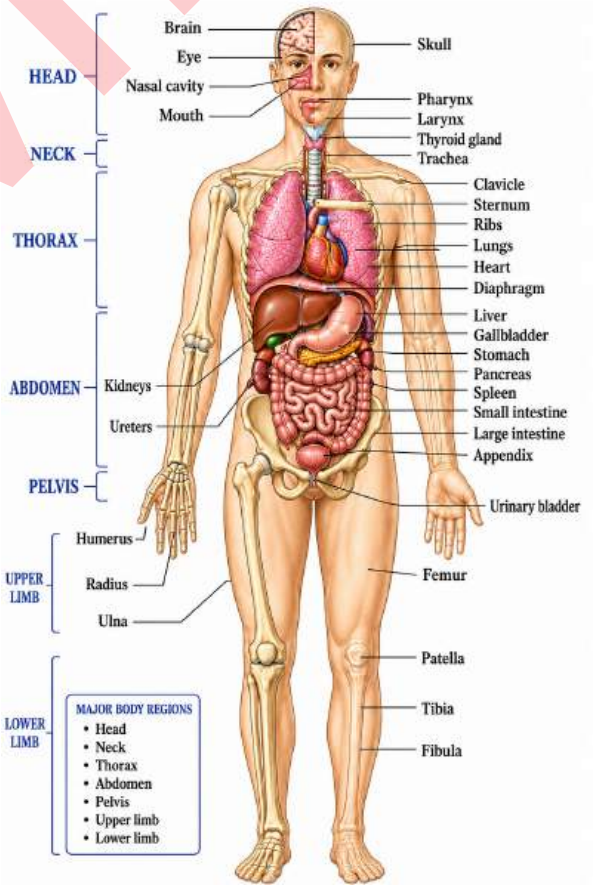


Figure 1.5: A Diagrammatic Representation of a Anatomy of Human Body

Table No. 1.15: Factors Affecting Health and Homeostasis

S. No.	Factors	Description
1.	**Environment and Behavior**	The surrounding environment and personal habits greatly affect health.
2.	**Genetic Makeup**	Inherited characteristics influence body structure, function, and disease tendency.
3.	**Air, Food, and Thoughts**	The quality of air we breathe, the food we eat, and mental stress or thoughts can affect body functions.

A healthy lifestyle supports the body's homeostatic mechanisms, while unhealthy habits may disturb them. Therefore, the way a person lives can either help or interfere with the body's ability to maintain internal balance and recover from daily stress.

1.6.6 Disorder and Disease

A disorder is any abnormality in the structure or function of the body. A disease is a specific illness that is identified by a particular group of signs and symptoms. Diseases change the normal structure and function of the body in characteristic ways.

Table No. 1.16: Classification of Diseases

Type of Disease	Description	Example
Local disease	Affects one part or a limited region of the body	Sinus infection
Systemic disease	Affects the whole body or several parts of the body	Influenza

Symptoms and Signs

A person suffering from a disease may show symptoms and signs. A symptom is a subjective change in body function that is felt by the patient but cannot be directly observed by others. Examples of symptoms include Headache, Nausea, Anxiety.

1.7 BASIC ANATOMICAL TERMINOLOGY

Basic anatomical terminology forms the foundation for the study of human anatomy. It provides a standard language used to describe the position, direction, regions, and movements of the human body.

These terms help students and healthcare professionals to understand and explain the exact location of body parts and organs clearly. By using anatomical terminology, confusion is avoided and body structures can be described in a systematic and accurate manner.

1.7.1 Anatomical Position

Anatomical position is the standard body position used in anatomy to describe the location, direction, and relationship of body parts.

In this position, the body stands upright, the face and eyes look forward, the arms are placed at the sides, the palms face forward, and the feet are flat and directed forward.

All anatomical terms for body direction, position, and movement are explained with reference to this position. Anatomical names are also used for body regions, such as the cephalic region, which means the head.

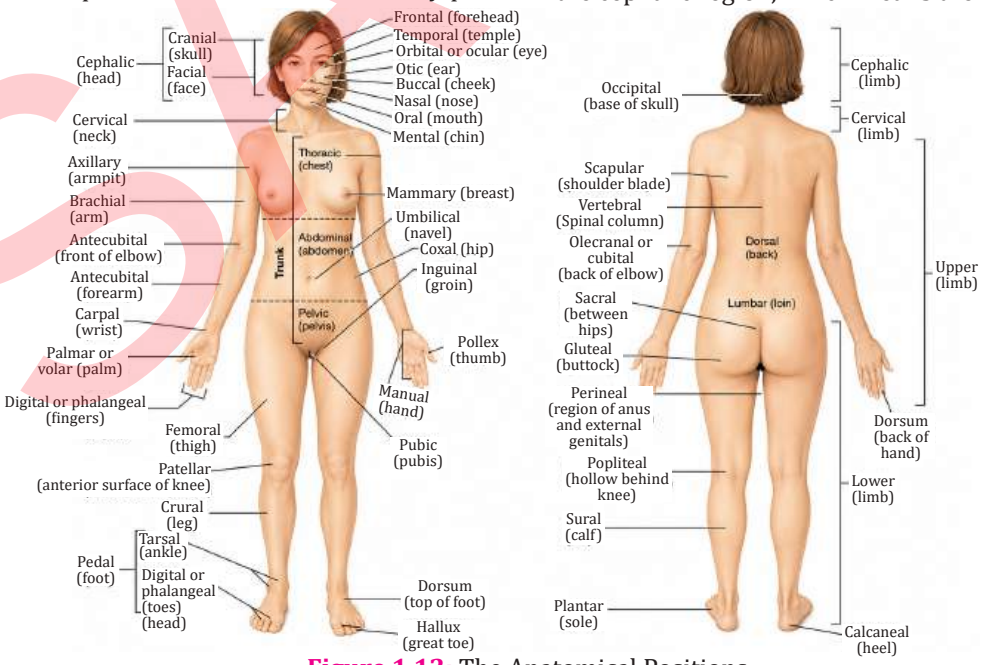


Figure 1.12: The Anatomical Positions

membrane, such as sodium ions, potassium ions, chloride ions, and calcium ions. These substances move with the help of specific membrane proteins.

C. Osmosis

Osmosis is a special type of passive transport in which water molecules move across a semipermeable membrane. Water moves from a region of low solute concentration to a region of high solute concentration.

In osmosis, only water molecules move across the membrane. The direction of water movement depends on the concentration of solutes on both sides of the membrane.

Water always moves toward the side where the solute concentration is higher.

Example: Water moves into and out of cells depending on the concentration of the surrounding solution.

Table No. 1.22: Types of Solutions Based on Osmosis

Solution	Definition	Effect on Cell
Hypotonic Solution	Outside solution has lower solute concentration than inside the cell	Cell swells
Hypertonic Solution	Outside solution has higher solute concentration than inside the cell	Cell shrinks
Isotonic Solution	Solute concentration is equal inside and outside the cell	No net change

2. Active Transport

Active transport is the movement of substances across the cell membrane with the use of energy or ATP. In active transport, substances move from a region of lower concentration to a region of higher concentration. This movement occurs against the concentration gradient. Active transport is defined as the movement of molecules or ions across the cell membrane from lower concentration to higher concentration with the help of energy in the form of ATP.

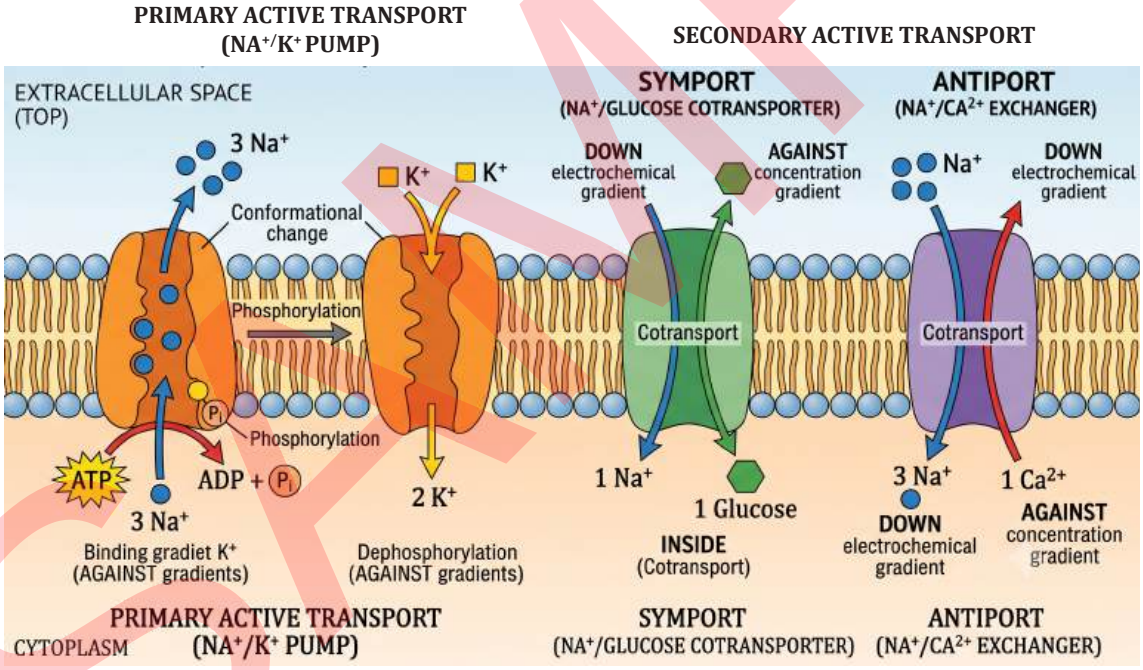


Figure 1.23: Active Transport

Characteristics of Active Transport

1. It requires ATP.
2. Substances move against the concentration gradient.
3. Movement occurs from lower concentration to higher concentration.
4. It requires carrier proteins or pumps.
5. It is important for maintaining ionic balance.
6. It helps in nerve impulse transmission and muscle contraction.

Types of Active Transport

Active transport is mainly of two types i.e., primary active transport and secondary active transport.

A. Primary Active Transport

Primary active transport uses ATP directly to move substances across the cell membrane.

Primary active transport is the movement of substances across the membrane by direct use of ATP.

Example: The most important example of primary active transport is the sodium-potassium pump. The sodium-potassium pump is present in the plasma membrane of cells. It helps maintain the concentration of sodium and potassium ions inside and outside the cell. For each ATP

Cells may communicate over a very short distance, with nearby cells, across synapses, or with distant cells through the bloodstream. On the basis of the distance travelled by the signal and the method of communication, cell signaling is mainly classified into the following types:

1. Contact-dependent signaling
2. Paracrine signaling
3. Synaptic signaling
4. Endocrine signaling

1. Contact-Dependent Signaling

Contact-dependent signaling is a type of cell signaling in which the signaling cell and target cell must be in direct physical contact. In this process, the signalingmolecule remains attached to the surface of the signaling cell and binds to a specific receptor on the target cell. This interaction produces a specific cellular response.

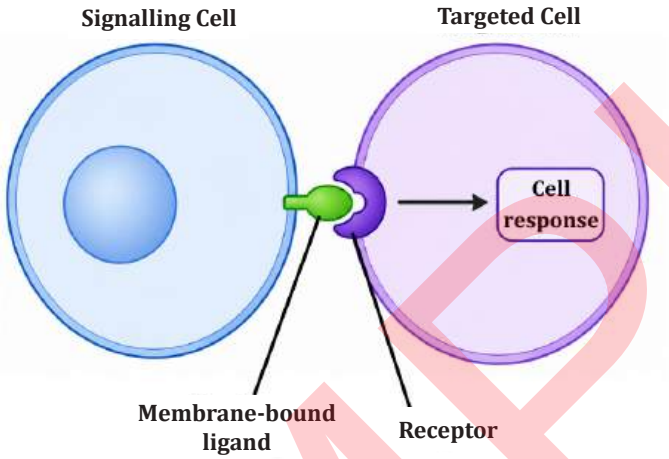


Figure 1.33: Contact-dependent signaling

Function of Contact-Dependent Signaling

- It requires direct contact between two cells.
- The signaling molecule remains attached to the cell membrane of the signaling cell.
- The target cell must have a specific receptor.
- It is important in cell recognition and immune responses.
- It allows very specific communication between neighboring cells.

Example

A common example of contact-dependent signaling is cell-to-cell recognition in the immune response. Immune cells identify other cells by recognizing specific molecules present on their surface.

2. Paracrine Signaling

Paracrine signaling is a type of cell signaling in which the signaling molecule acts on nearby target cells. In this process, the signaling cell releases chemical substances into the surrounding tissue fluid. These substances diffuse locally and bind to receptors on nearby cells. The signal does not travel through blood and does not affect distant organs.

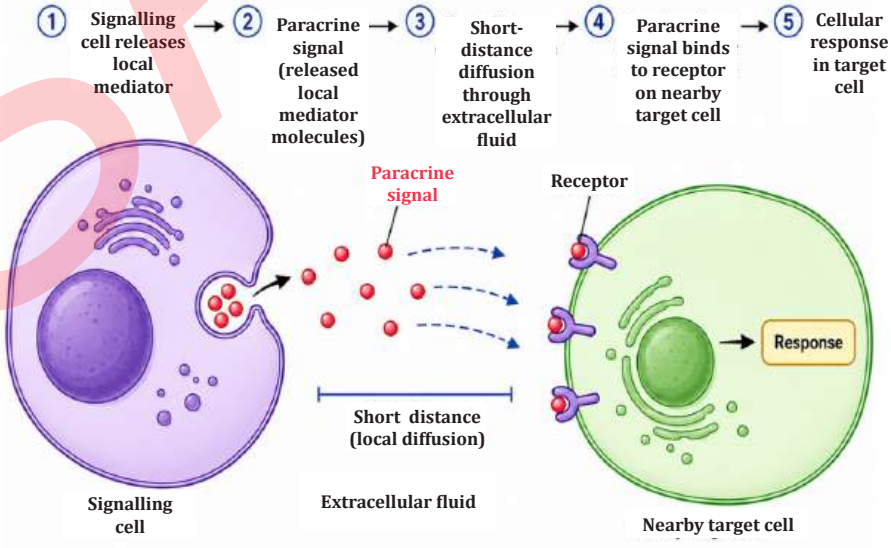


Figure 1.34: Paracrine signaling

9. Classify and describe the different types of cell junctions. Also explain the general principles and major forms of cell communication.
10. Classify human tissues. Describe the structure, location and functions of epithelial, connective, muscular and nervous tissues with suitable examples.

MULTIPLE-CHOICE QUESTIONS

1. Which cell organelle is primarily responsible for ATP production?
(a) Lysosome (b) Mitochondrion
(c) Golgi apparatus (d) Ribosome

2. In the standard anatomical position, the palms are directed:
(a) Backward (b) Downward
(c) Forward (d) Inward

3. Which component of a homeostatic control system detects a change in the internal environment?
(a) Effector (b) Control centre
(c) Receptor (d) Set point

4. In which type of signalling does the chemical mes senger travel through the bloodstream to distant target cells?
(a) Contact-dependent signalling
(b) Paracrine signa lling
(c) Synaptic signalling
(d) Endocrine signalling

5. Which tissue is characterized by cells scattered with in an abundant extracellular matrix?
(a) Epithelial tissue (b) Connective tissue
(c) Muscular tissue (d) Nervous tissue

6. The highest level of structural organization in the human body is the:
(a) Cellular level (b) Tissue level
(c) Organ-system level (d) Organismal level

7. Which transport process requires energy and moves substances against their concentration gradient?
(a) Osmosis (b) Facilitated diffusion
(c) Active transport (d) Simple diffusion

8. The study of abnormal functional changes produced by disease is called:
(a) Anatomy (b) Histology
(c) Physiology (d) Pathophysiology

9. During which stage of mitosis do sister chromatids separate and move towards opposite poles?
(a) Prophase (b) Metaphase
(c) Anaphase (d) Telophase

10. Most absorption of digested nutrients occurs in the:
(a) Stomach (b) Small intestine
(c) Large intestine (d) Oesophagus

11. Which cell junction forms a seal between adjacent epithelial cells and prevents leakage?
(a) Gap junction (b) Desmosome
(c) Tight junction (d) Hemidesmosome

12. The scientific study of the structure of the human body is called:
(a) Physiology (b) Anatomy
(c) Pathology (d) Cytology

13. A group of organs working together to perform a common function forms a/an:
(a) Tissue (b) Cell
(c) Organ system (d) Organism only

14. Which organelle modifies, sorts and packages proteins for secretion?
(a) Golgi apparatus (b) Nucleus
(c) Mitochondrion (d) Peroxisome

15. Blood glucose homeostasis is mainly regulated by:
(a) Thyroxine and calcitonin
(b) Insulin and glucagon
(c) Adrenaline and melatonin
(d) Oestrogen and progesterone

16. The movement of water across a selectively permeable membrane is known as:
(a) Filtration (b) Active transport
(c) Osmosis (d) Exocytosis

17. Meiosis normally produces:
(a) Two identical diploid cells
(b) Four genetically different haploid cells
(c) Four identical diploid cells
(d) Two genetically different haploid cells

18. Which type of muscle tissue is voluntary and attached mainly to bones?
(a) Smooth muscle (b) Cardiac muscle
(c) Skeletal muscle (d) Visceral muscle

19. The energy released during cellular respiration is mainly stored in the form of:
(a) DNA (b) ATP
(c) Glycogen only (d) RNA

20. The anatomical term "superior" means:

BASIC PRINCIPLES OF CELL INJURY AND ADAPTATION

2

- Components and types of feedback systems
- Cell injury
- Reversible and irreversible cell injury
- Causes of cell injury
- Cell membrane damage, mitochondrial damage, ribosome damage and nuclear damage
- Morphology of cell injury
- Adaptive changes (atrophy, hypertrophy, hyperplasia, metaplasia, dysplasia)
- Cell swelling
- Intra cellular accumulation and cell death.
- Definitions of commonly used relevant medical terminologies

2.1 HOMEOSTASIS

Homeostasis is the process by which the body maintains the composition of its internal environment within a narrow and stable range. Although the word homeostasis literally means "unchanging," it actually refers to a dynamic condition in which constant adjustments take place to keep the internal environment balanced.

Homeostasis is maintained by control systems that detect changes in the body and respond appropriately. A control system has three main components: a detector, a control centre, and an effector.

2.1.1 Feedback System

A feedback system (or feedback loop) is a series of events in which the body monitors, evaluates, changes, and reassesses a body condition. This system involves tracking variables like body temperature or blood pressure, which are called controlled conditions.

2.1.2 Components of Feedback System

A feedback system includes three basic components i.e., receptor, control center and an effector.

a. **Receptor:** A body structure that monitors changes in a controlled condition. Sends information to the control center via the afferent pathway (information flows toward the control center).
   Example: Nerve endings in the skin detect temperature changes.

b. **Control Center:** Sets the narrow range (set point) in which the controlled condition should be maintained. Evaluates the information it receives from receptors and generates output commands when needed. Output typically occurs as nerve impulses or hormones via the efferent pathway (information flows away from the control center).

c. **Effector**: A structure that receives output from the control center and produces a response to change the controlled condition. Nearly every organ or tissue can act as an effector.
   Example: When body temperature drops, the brain sends nerve impulses to skeletal muscles (effectors) to generate heat by shivering, raising body temperature.

2.1.3 Types of Feedback System

1. **Negative Feedback:** Negates or reverses the change in the controlled condition.
2. **Positive Feedback:** Enhances or amplifies the change in the controlled condition.

Negative Feedback System

Negative feedback is the most common and important mechanism of homeostasis. In this mechanism, any change in the internal environment of the body is detected, and a corrective response is produced to oppose that change. As a result, the altered condition is brought back towards the normal range. In simple words, negative feedback works against the original change and helps the body maintain a stable internal environment.

Example: Regulation of Body Temperature

When the heart beats faster or harder, BP increases. If an internal or external stimulus causes BP to rise beyond normal levels, a sequence of events occurs. Baroreceptors, which are pressure-sensitive nerve cells located in the walls of certain blood vessels, detect the increased pressure. These receptors send nerve impulses to the brain (control center), which interprets the impulses and responds by sending nerve signals to the heart and blood vessels (effectors).

As a response, the heart rate slows down and the blood vessels widen, which helps lower blood pressure. These changes bring blood pressure back to its normal level and maintain homeostasis. This process is called a negative feedback system because it reverses or reduces the original stimulus, that is, increased blood pressure, and restores the body to its normal controlled state.

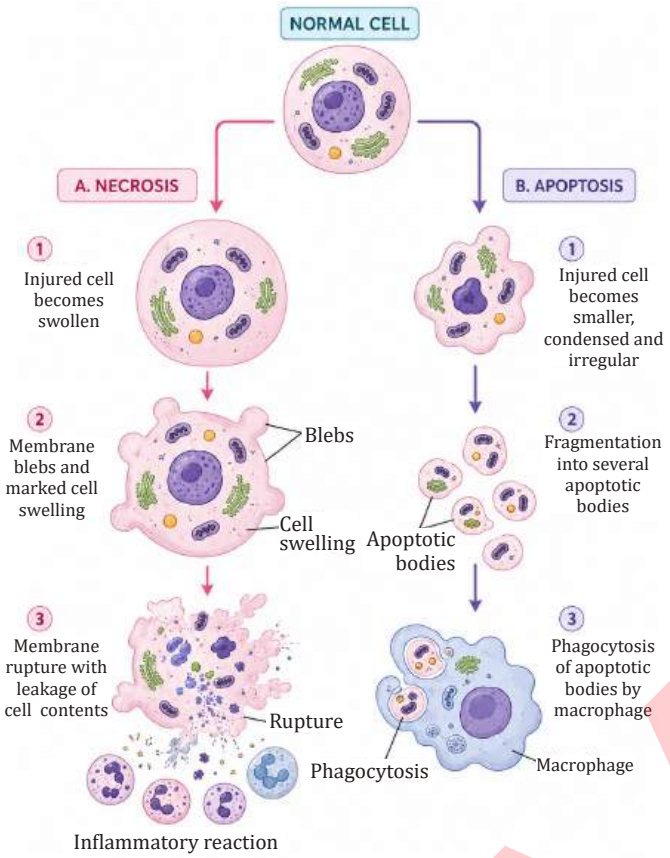


Figure 2.16: Necrosis and Apoptosis.

Various harmful agents can cause necrosis, including hypoxia, chemicals, physical injury, microbial infections, and immune-mediated damage. In all types of necrosis, two important changes indicate irreversible cell injury.

The first change is digestion of the cell by lytic enzymes. Morphologically, this appears as a homogeneous and deeply eosinophilic cytoplasm. In some cases, cytoplasmic vacuolation or dystrophic calcification may also be seen.

The second change is denaturation of proteins. This mainly produces characteristic nuclear changes in necrotic cells. These include pyknosis, in which nuclear chromatin becomes condensed; karyolysis, in which the nucleus dissolves; and karyorrhexis, in which the nucleus breaks into small granular fragments.

Types of Necrosis

On the basis of morphological appearance, necrosis is mainly classified into five types: coagulative necrosis, liquefactive or colliquative necrosis, caseous necrosis, fat necrosis, and fibrinoid necrosis.

3. Apoptosis

Apoptosis is a controlled and internally programmed form of cell death. It is also known as programmed cell

Table 2.3 Types of Necrosis

Type of Necrosis	Main Cause	Common Sites / Conditions	Morphological Appearance	Common Examples
Coagulative Necrosis	Sudden interruption of blood supply (ischaemia); less commonly bacterial toxins or chemicals	Solid organs such as heart, kidney, spleen	Tissue architecture is preserved for some time; cells lose nuclei; cytoplasm becomes intensely eosinophilic	Renal infarction, myocardial infarction
Liquefactive / Colliquative Necrosis	Ischaemic injury, bacterial infection, fungal infection	Brain, abscesses	Dead tissue is digested by hydrolytic enzymes, causing softening and liquefaction	Brain infarction, abscess
Caseous Necrosis	Usually due to tuberculosis	Centre of tuberculous lesions	Cheese-like appearance; amorphous, granular, eosinophilic debris; loss of normal tissue architecture	Tuberculous granuloma
Fat Necrosis	Enzymatic digestion of fat or trauma	Pancreas, peritoneal fat, breast	Necrosis of adipose tissue; fat is broken down by lipases	Acute pancreatitis, traumatic fat necrosis of breast
Fibrinoid Necrosis	Immunologic injury, immune complex deposition, vascular damage	Walls of blood vessels	Deposition of fibrin-like material with staining properties similar to fibrin	Immune complex vasculitis, autoimmune disease, Arthus reaction, hypertension-related arteriolar damage, peptic ulcer

also called oil glands, are simple branched acinar glands. They are usually connected to hair follicles, and their secreting part lies in the dermis. In some areas such as the lips, glans penis, labia minora, and eyelids, they open directly onto the skin surface. These glands are absent in the palms and soles. Sebaceous glands secrete an oily substance called sebum, which contains triglycerides, cholesterol, proteins, and inorganic salts. Sebum keeps hair soft, prevents dryness, reduces water loss from the skin, keeps the skin soft and flexible, and inhibits the growth of some bacteria.

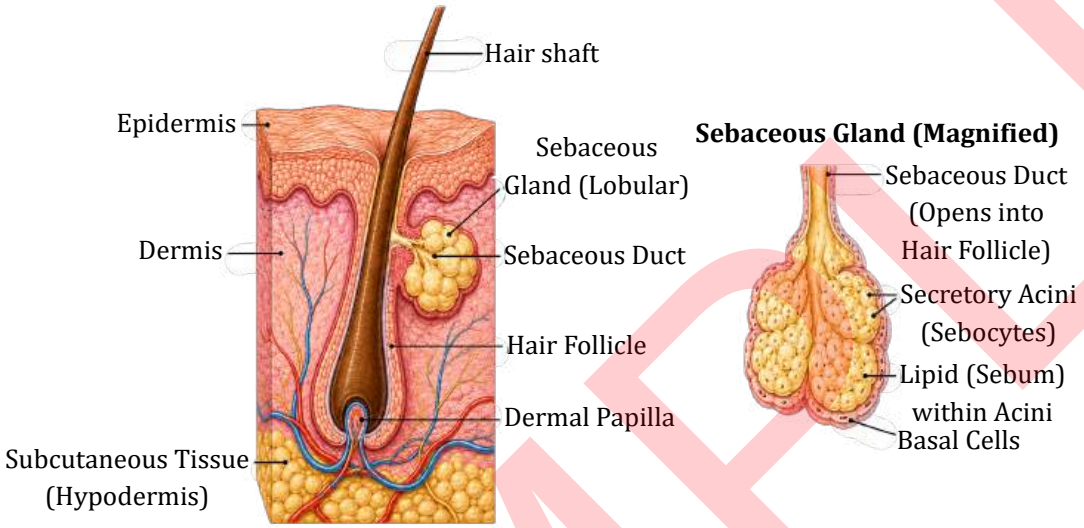


Figure 3.4: Structure of Sebaceous Gland

- **Sudoriferous Glands:** Sudoriferous glands, also called sweat glands, are present in large numbers in the body. They release sweat or perspiration either into hair follicles or directly onto the skin surface through pores. Sweat glands are mainly of two types: eccrine sweat glands and apocrine sweat glands.

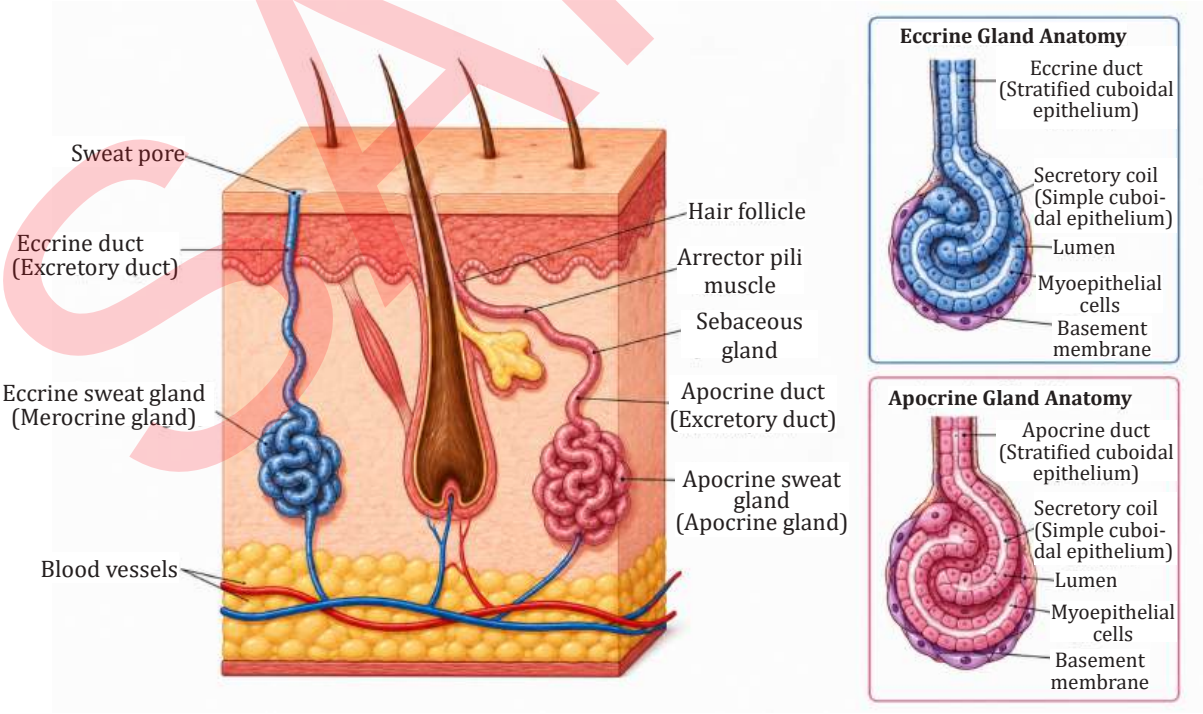


Figure 3.5: Structure of Sudoriferous Glands

SKELETAL SYSTEM AND JOINTS

4

- Skeletal system and joints
  Divisions of skeletal system, types of bones, salient features and functions of bones of axial and appendicular skeletal system.
- Organization of skeletal muscle, physiology of muscle contraction, neuromuscular junction.
  Structural and functional classification of joints.
- Diseases of bones and joints
  Pathophysiology of rheumatoid arthritis, osteoporosis and gout

4.1 SKELETAL SYSTEM

The skeletal system is one of the major organ systems of the human body that forms the supporting framework of the body. It is composed of bones, cartilage, joints, and associated connective tissues. In an adult human, the skeleton consists of 206 bones arranged in a highly organized manner.

The skeletal system provides shape, support, and stability to the body and enables movement by serving as attachment sites for muscles. It also protects vital organs such as the brain, spinal cord, heart, and lungs from injury.

Apart from support and protection, the skeletal system performs several important physiological functions. Bones act as reservoirs for minerals, especially calcium and phosphorus, which are essential for various body functions. The bone marrow present within certain bones is responsible for the production of blood cells, a process known as haematopoiesis.

4.1.1 Divisions Of Skeletal System

The skeletal system is divided into two main parts:

1. Axial Skeleton

The axial skeleton forms the central axis of the body. It includes the skull, vertebral column, ribs, and sternum. Its main function is to provide support to the body and protect important vital organs such as the brain, spinal cord, heart, and lungs.

2. Appendicular Skeleton

The appendicular skeleton consists of the bones of the limbs and girdles. It includes the bones of the upper limbs, bones of the lower limbs, pectoral or shoulder girdle, and pelvic girdle. Its main function is to help in movement and locomotion of the body.

4.1.2 Axial Skeleton

Table 4.1 Axial Skeletal System

Main Division	Bones / Parts	Number
Skull Skeleton	Cranial Bones	8
	Facial Bones	14
	Hyoid Bone	1
	Ear Ossicles - Malleus, Incus, Stapes	2 × 3 = 6
Ribs	True Ribs	14
	False Ribs	10
Sternum	Sternum	1
Vertebral Column	Cervical	7
	Thoracic	12
	Lumbar	5
	Sacrum	1
	Coccyx	1
Grand Total		80

	Radius	2
	Carpals	16
	Metacarpals	10
	Phalanges	28
Pelvic / Hip Girdle	Hip / Pelvic / Coxal Bone	2
Lower Limbs	Femur	2
	Patella	2
	Fibula	2
	Tibia	2
	Tarsals	14
	Metatarsals	10
	Phalanges	28
Total		126

4.1.3.1 Upper Limbs

1. **Humerus:** The humerus is the long bone of the upper arm. Its rounded head fits into the glenoid cavity of the scapula to form the shoulder joint. Near the head are two projections called the greater and lesser tubercles, separated by the bicipital groove. The lower end of the humerus joins with the radius and ulna to form the elbow joint.
2. **Ulna and Radius:** The ulna and radius are the two bones of the forearm. The ulna is longer and lies on the little finger side, while the radius lies on the thumb side. In anatomical position, both bones remain parallel. They articulate with the humerus at the elbow joint and with the carpal bones at the wrist joint. The two bones are connected by an interosseous membrane, which helps maintain stability and proper positioning.
3. **Carpal Bones (Wrist Bones):** The wrist contains eight carpal bones arranged in two rows of four bones each.
   - **Proximal Row:** Scaphoid, Lunate, Triquetrum, Pisiform
   - **Distal Row:** Trapezium, Trapezoid, Capitate, Hamate

   These bones are connected by ligaments, allowing limited movement and flexibility of the wrist. The proximal row articulates with the forearm bones, while the distal row joins with the metacarpals. Strong fibrous bands called retinacula hold the tendons close to the wrist bones.
4. **Metacarpal Bones:** The metacarpals are five bones that form the palm of the hand. They are numbered from the thumb side inward. Their proximal ends articulate with the carpal bones, and their distal ends articulate with the phalanges.
5. **Phalanges (Finger Bones):** Phalanges are the bones of the fingers and thumb. Each finger has three phalanges, while the thumb has two. These bones articulate with the metacarpals and with each other through hinge joints, allowing finger movements.

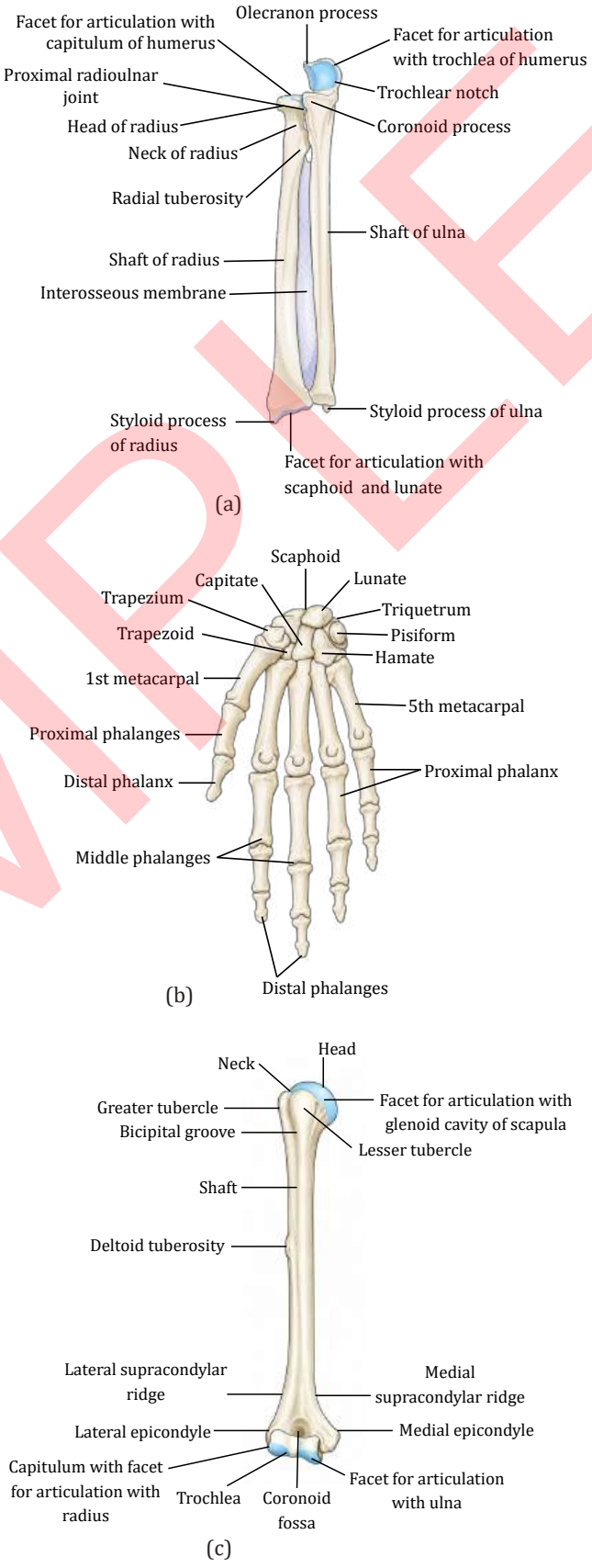


Figure 4.9: Upper Limb (a) Ulna and Radius (b) Carpal, Metacarpal Bones and Phalanges (c) Humerus

Angular Movements

In angular movements, the angle between two articulating bones either increases or decreases. The main angular movements include flexion, extension, lateral flexion, hyperextension, abduction, adduction, and circumduction.

Flexion, Extension, Lateral Flexion, and Hyperextension

Flexion and extension are opposite movements. In flexion, the angle between bones decreases, while in extension, the angle increases. Extension often brings a body part back to its anatomical position after flexion. These movements usually occur in the sagittal plane.

Examples of flexion include bending the head forward toward the chest, bending the trunk forward, moving the arm forward at the shoulder joint, bending the elbow, moving the palm toward the forearm at the wrist, making a fist by bending the fingers, moving the thigh forward at the hip joint, and bending the knee by moving the heel toward the buttock.

Although flexion and extension commonly occur in the sagittal plane, there are some exceptions. For example, flexion of the thumb occurs when the thumb moves across the palm. Sideways bending of the trunk to the right or left is called lateral flexion, and it occurs in the frontal plane.

Hyperextension means extension beyond the normal anatomical position. Examples include bending the head backward, bending the trunk backward, moving the arm backward at the shoulder, moving the palm backward at the wrist, and moving the thigh backward at the hip. In hinge joints such as the elbow, knee, and interphalangeal joints, hyperextension is usually limited by ligaments and bone arrangement.

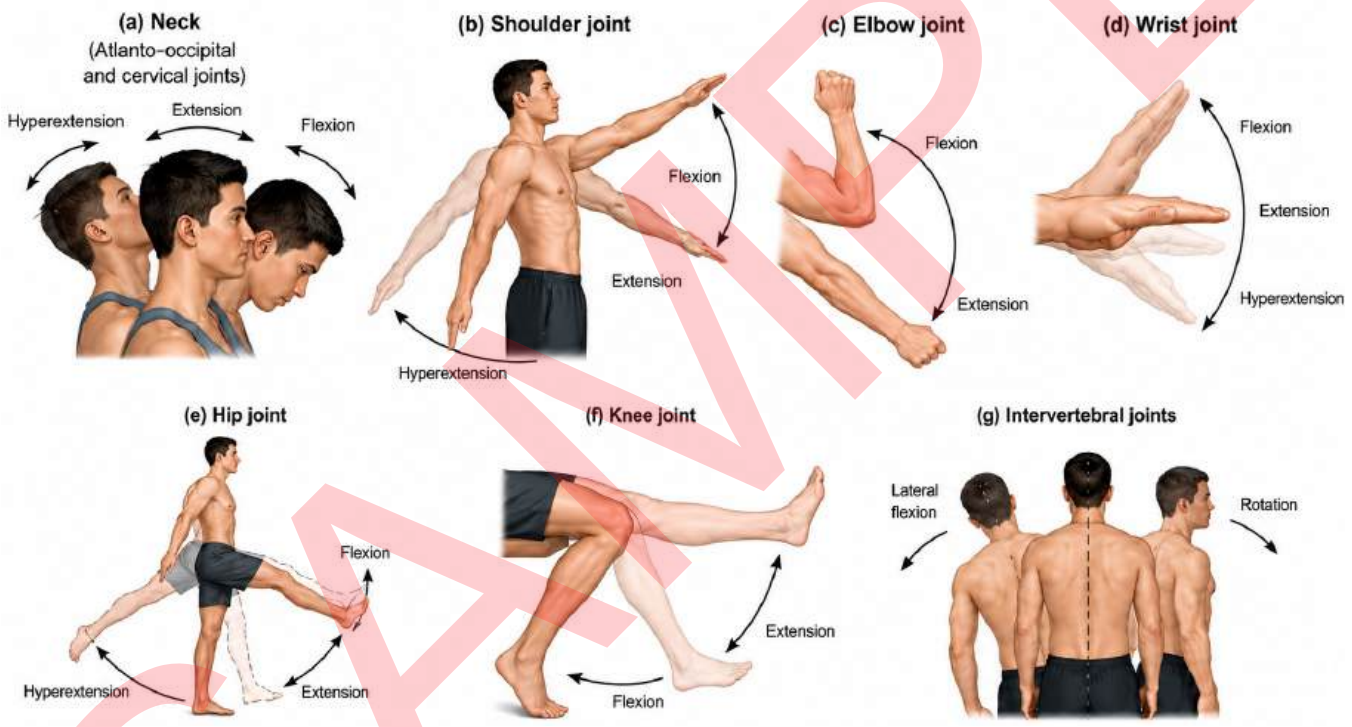


Figure 4.28: Angular movements at synovial joints— Flexion, Extension, Lateral Flexion, and Hyperextension

Abduction, Adduction, and Circumduction

Abduction is the movement of a bone away from the midline of the body, while adduction is the movement of a bone toward the midline. These movements generally occur in the frontal plane.

Examples of abduction include moving the arm sideways away from the body at the shoulder, moving the palm laterally at the wrist, and moving the thigh laterally at the hip. Returning these parts back to the anatomical position is called adduction.

For fingers and toes, the midline of the body is not used as the reference point. In the fingers, abduction means spreading the fingers away from the middle finger. In the toes, abduction occurs away from the second toe. Adduction brings the fingers or toes back together. In the thumb, abduction moves the thumb away from the palm, while adduction brings it back toward the palm.

Circumduction is a circular movement of the distal end of a body part. It is not a separate movement by itself, but a combination of flexion, abduction, extension, adduction, and sometimes rotation. Examples include moving the arm in a circle at the shoulder joint, moving the hand in a circle at the wrist joint, moving the thumb in a circle, moving the fingers in a circular manner, and moving the thigh in a circle at the hip joint. Circumduction occurs more freely at the shoulder joint than at the hip joint because the hip joint has stronger ligaments, deeper socket support, and more muscle tension.

SHORT QUESTIONS

1. Define and classify the skeletal system. Write its major functions and divisions.
2. Describe the main components of the axial and appendicular skeleton.
3. Describe the structure and important functions of the vertebral column.
4. Classify bones according to their shape with suitable examples.
5. Describe the microscopic organization of skeletal muscle and its connective tissue coverings.
6. Explain the sliding filament mechanism of skeletal muscle contraction.
7. Describe the structure and working of the neuromuscular junction.
8. Explain the structural and functional classification of joints with examples.
9. Explain the pathophysiology of rheumatoid arthritis.
10. Write short notes on the pathophysiology of osteoporosis and gout.

LONG QUESTIONS

1. Describe the divisions, components and major functions of the human skeletal system.
2. Describe the bones of the axial skeleton, including the skull, vertebral column and thoracic cage.
3. Describe the appendicular skeleton, including the pectoral girdle, upper limb, pelvic girdle and lower limb.
4. Explain the structure of a typical long bone and classify bones according to their shapes with examples.
5. Describe the gross and microscopic organization of skeletal muscle with a well-labelled diagram of a sarcomere.
6. Explain the physiology of skeletal muscle contraction according to the sliding filament theory.
7. Describe the structure and transmission of impulses across the neuromuscular junction.
8. Classify joints structurally and functionally. Describe the structure and movements of a synovial joint.
9. Define rheumatoid arthritis. Discuss its causes, pathophysiology and important clinical features.
10. Discuss the pathophysiology of osteoporosis and gout, including their important causes and clinical manifestations.

MULTIPLE-CHOICE QUESTIONS

1. The total number of bones in an adult human skeleton is:
(a) 126 (b) 206 (c) 208 (d) 212

2. Which of the following is an important function of red bone marrow?
(a) Fat storage (b) Blood cell formation
(c) Joint lubrication (d) Muscle contraction

3. The axial skeleton consists of:
(a) 60 bones (b) 80 bones
(c) 126 bones (d) 206 bones

4. The foramen magnum is present in the:
(a) Frontal bone (b) Temporal bone
(c) Occipital bone (d) Sphenoid bone

5. The appendicular skeleton consists of:
(a) 80 bones (b) 106 bones
(c) 126 bones (d) 206 bones

6. The longest and strongest bone of the human body is the:
(a) Tibia (b) Humerus
(c) Femur (d) Fibula

7. The connective tissue surrounding an individual muscle fibre is called:
(a) Epimysium (b) Perimysium
(c) Endomysium (d) Sarcolemma

8. The functional unit of skeletal muscle contraction is the:
(a) Fascicle (b) Sarcomere
(c) Sarcolemma (d) Tendon

9. Calcium ions initiate muscle contraction by binding to:
(a) Actin (b) Myosin
(c) Troponin (d) Titin

BODY FLUIDS, BLOOD & LYMPHATIC SYSTEM

5

- Body fluids, composition and functions of blood, hemopoiesis, formation of haemoglobin, mechanisms of coagulation, blood grouping, Rh factors and transfusion.
- Lymphatic organs and tissues, lymphatic vessels, lymph formation, circulation and functions of lymphatic system.

5.1 BODY FLUIDS

Body fluids are the liquid substances present in the human body that are essential for maintaining normal physiological functions. They help in transporting nutrients, oxygen, hormones, and waste products, while also regulating body temperature and maintaining internal balance.

Total Body Water

Total body water in an adult of average build is about 60% of body weight. This proportion is higher in young individuals and in adults with lower body weight, while it is reduced in elderly individuals and in those with obesity. Of the total body water, approximately 22% of body weight is extracellular fluid (ECF) and about 38% is intracellular fluid (ICF).

Table 5.1 Average Water Content in Various Tissues of the Body

Constituents	Weight in kg	% of body weight	% of H_2O content	H_2O content in litres
Body	75	—	57.68	43.26
Skeleton	11	16	22	2.5
Muscles	30	42	76	23
Fatty tissues	13	18	30	4

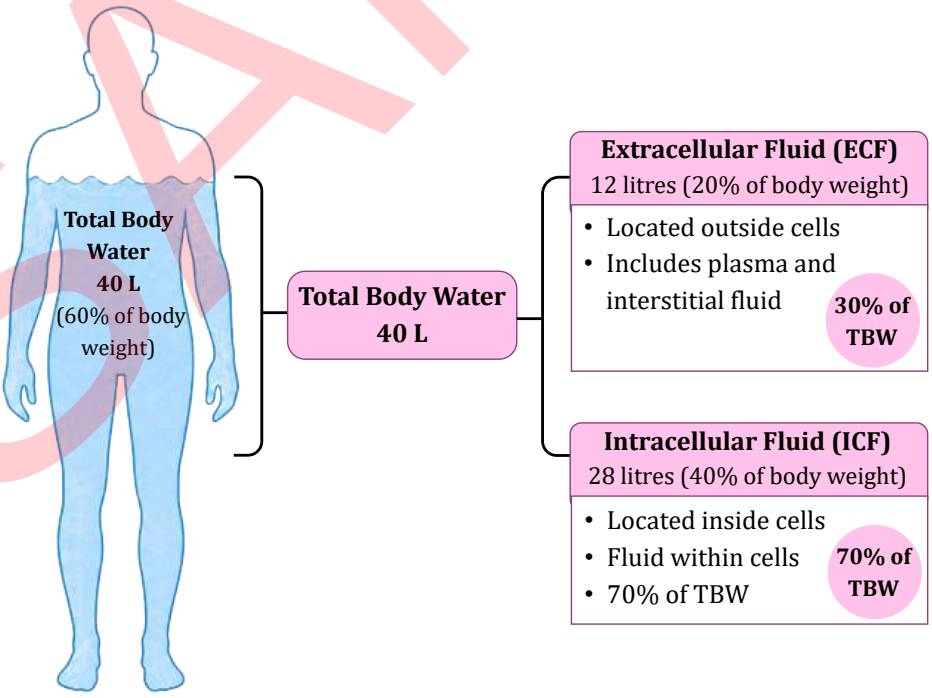


Figure 5.1: Distribution of body water in a 70 kg person

As age increases, the rate of blood cell formation decreases. In long bones, red bone marrow present in the medullary cavity becomes inactive and is gradually replaced by yellow bone marrow. Yellow bone marrow mainly contains fat cells.

Conversion of Yellow Marrow into Red Marrow

Under special conditions, such as severe blood loss, yellow bone marrow can become active again and change back into red bone marrow.

This occurs when blood-forming stem cells from red bone marrow move into yellow bone marrow and repopulate it with pluripotent stem cells.

Functions of Stem Cells in Red Bone Marrow

Stem cells in red bone marrow can reproduce themselves, increase in number, and differentiate into different cell types.

They give rise to blood cells, macrophages, reticular cells, mast cells, and adipocytes.

Some stem cells may also form osteoblasts, chondroblasts, and muscle cells. Because of this ability, they may be useful in tissue repair and replacement of bone, cartilage, and muscle tissue.

Role of Reticular Cells

Reticular cells present in red bone marrow produce reticular fibers. These fibers form the supporting framework, called the stroma, which supports developing blood cells in red bone marrow.

Blood Supply of Red Bone Marrow

Blood reaches the bone through nutrient and metaphyseal arteries. It then enters enlarged, leaky capillaries called sinuses. These sinuses surround the red bone marrow cells and fibers. After new blood cells are formed, they enter these sinuses and then pass into blood vessels. Finally, they leave the bone through nutrient and periosteal veins.

Division After Leaving Bone Marrow

Most formed elements of blood do not divide after they leave the red bone marrow. The main exception is lymphocytes, which can divide later during immune responses.

Myeloid and Lymphoid Stem Cells

To produce blood cells, pluripotent stem cells form two main types of stem cells i.e., Myeloid stem cells and Lymphoid stem cells. Both types can develop into several specific blood cell types.

Myeloid stem cells begin their development in red bone marrow. They give rise to red blood cells, platelets, monocytes, neutrophils, eosinophils, basophils, and mast cells.

Lymphoid stem cells also begin their development in red bone marrow, but they complete their development in lymphatic tissues. They produce lymphocytes and natural killer cells. Although different stem cells have unique cell identity markers on their plasma membranes, they cannot be easily distinguished under a microscope because they resemble lymphocytes.

Progenitor Cells

During hemopoiesis, some myeloid stem cells develop into progenitor cells. Progenitor cells cannot reproduce themselves like stem cells. They are already committed to producing specific types of blood cells (Figure 5.4).

Cytokines are small glycoproteins produced by cells such as red bone marrow cells, leukocytes, macrophages, fibroblasts, and endothelial cells. They usually act as local hormones and regulate nearby cells. Cytokines stimulate the proliferation of progenitor cells in red bone marrow. They also control the activity of cells involved in nonspecific defense and immune responses.

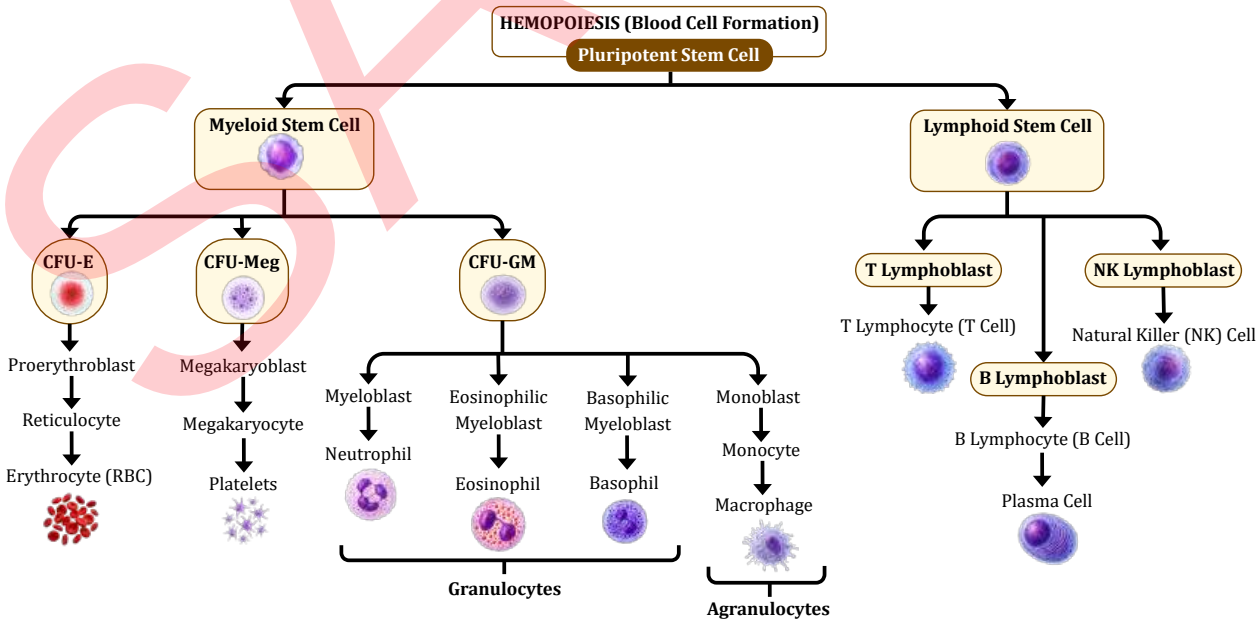


Figure 5.6: Process of Hemopoiesis

- **Cortex:** The outer cortex contains lymphatic follicles rich in B lymphocytes. Secondary follicles contain germinal centres where activated B cells multiply and develop into antibody-producing plasma cells and memory B cells. The inner cortex mainly contains T lymphocytes and dendritic cells.
- **Medulla:** Contains B lymphocytes, plasma cells, macrophages, medullary cords, and lymph-filled sinuses.

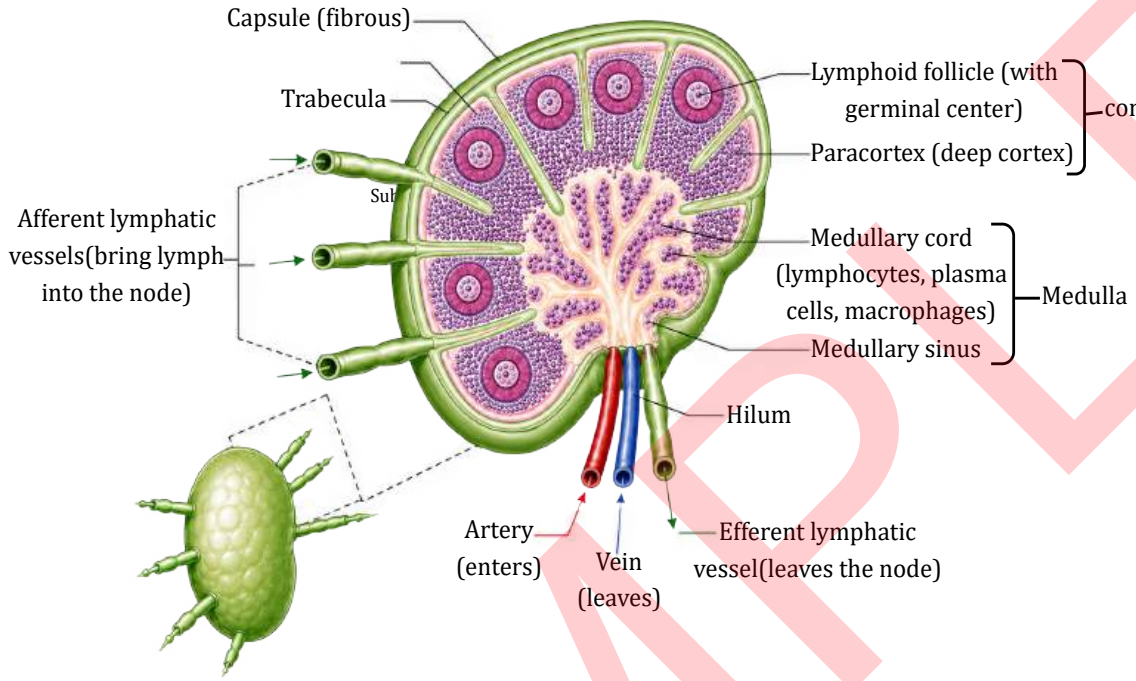


Figure 5.16: Structure of Lymph Node

Functions

1. Lymph nodes filter lymph before it returns to the bloodstream.
2. Reticular fibres trap bacteria, foreign particles, damaged cells, and cellular debris.
3. Macrophages remove these materials by phagocytosis, while B and T lymphocytes initiate specific immune responses.
4. The presence of several afferent vessels and fewer efferent vessels slows the flow of lymph, providing sufficient time for filtration and immune-cell activity.

D. Spleen

The spleen is a soft, oval-shaped, and encapsulated organ. It forms the largest single collection of lymphatic tissue in the human body. Its size may vary, but it is generally about 12 cm long and is approximately equal to the size of an open hand.

The spleen is located in the left hypochondriac region of the abdominal cavity. It lies between the stomach and the diaphragm

Structure

The upper surface of the spleen is smooth and convex and fits against the curved lower surface of the diaphragm. Its visceral surface shows several depressions formed by neighboring organs. These impressions include:

- **Gastric impression:** Formed by the stomach
- **Renal impression:** Formed by the left kidney
- **Colic impression:** Formed by the left colic flexure of the large intestine

1. Hilum of the Spleen

A depression known as the hilum is present on the visceral surface of the spleen. The splenic artery enters the organ through the hilum, whereas the splenic vein and efferent lymphatic vessels leave through it.

2. Coverings and Supporting Framework

The spleen is surrounded by a capsule of dense connective tissue. This capsule is externally covered by the visceral peritoneum. Extensions of the capsule pass inward and form trabeculae.

The capsule, trabeculae, reticular fibres, and fibroblasts together form the supporting framework, or stroma, of the spleen.

3. Parenchyma of the Spleen

The functional tissue, or parenchyma, of the spleen is divided into two main parts:

- White pulp
- Red pulp

White Pulp

The white pulp consists mainly of lymphatic tissue. It contains lymphocytes and macrophages arranged around branches of the splenic artery called central arteries.

B lymphocytes and T lymphocytes present in this region participate in immune responses. Macrophages remove microorganisms and other harmful substances circulating in the blood by phagocytosis.

BASIC MECHANISM OF INFLAMMATION & REPAIR

6

- Introduction, classification and pathophysiology of inflammation,mediators of inflammation.

6.1 INTRODUCTION

Inflammation is a local protective response of living vascularised tissues to injury caused by physical, chemical, infectious, immunological, or other harmful agents. Its main purpose is to eliminate or restrict the damaging agent, remove necrotic cells and tissues, and initiate the process of healing.

Although inflammation usually protects the body, an excessive or prolonged response may cause tissue injury. Harmful effects of inflammation may be observed in conditions such as anaphylaxis, rheumatoid arthritis, atherosclerosis, tissue fibrosis, and intestinal adhesions.

6.1.1 Causes of Inflammation

Inflammation may be produced by the following agents:

1. **Infectious agents:** Bacteria, viruses, fungi, parasites, and microbial toxins.
2. **Immunological agents:** Antigen–antibody reactions and cell-mediated immune responses.
3. **Physical agents:** Heat, cold, radiation, mechanical injury, and trauma.
4. **Chemical agents:** Organic and inorganic chemicals, poisons, acids, and irritants.
5. **Foreign materials:** Splinters, sutures, dust particles, and other inert substances.

6.1.2 Inflammation and Infection

Inflammation and infection are not identical. Infection refers to the entry, multiplication, and harmful effects of microorganisms within the body. Inflammation is the protective tissue response produced against infectious as well as non-infectious causes.

Therefore, infection may cause inflammation, but inflammation can also occur without infection.

6.1.3 Cardinal Signs of Inflammation

The four classical signs of inflammation described by Celsus are:

- **Rubor:** Redness
- **Tumor:** Swelling
- **Calor:** Heat
- **Dolor:** Pain
- **Functio laesa:** Loss or impairment of function

Redness and heat are mainly caused by increased blood flow. Swelling results from the accumulation of inflammatory fluid, while pain is produced by chemical mediators and pressure on sensory nerve endings.

6.2 CLASSIFICATION OF INFLAMMATION

Inflammation is mainly classified according to its duration and the nature of the tissue response.

A. Acute Inflammation

Acute inflammation is a rapid and short-lasting response, generally continuing for less than two weeks. It represents the immediate reaction of the body to tissue injury and is usually followed by resolution or healing.

Main Features

- Accumulation of fluid and plasma proteins at the injured site
- Vasodilatation and increased vascular permeability
- Activation of platelets
- Predominance of neutrophils
- Rapid onset and comparatively short duration

A very rapid and severe form of acute inflammation is called fulminant acute inflammation.

B. Chronic Inflammation

Chronic inflammation is a prolonged inflammatory response. It may develop when the cause of acute inflammation persists or when the harmful stimulus produces chronic inflammation from the beginning.

Main Features

- Presence of macrophages, lymphocytes, and plasma cells
- Continuous tissue destruction
- Formation of granulation tissue
- Fibroblast proliferation and fibrosis
- New blood vessel formation
- Granuloma formation in certain conditions

Chronic Active Inflammation

Chronic active inflammation is a form of chronic inflammation in which episodes of acute inflammatory activity occur during the course of a long-standing disease.

HAEMATOLOGICAL DISEASES

7

- Pathophysiology of iron deficiency, megaloblastic anaemia (Vit B12 and folic acid), sickle cell anaemia, Thalassemia, hereditary acquired anaemia and haemophilia

7.1 INTRODUCTION

Hematological diseases are disorders affecting blood, blood -forming organs (bone marrow), and blood components like red blood cells (RBCs), white blood cells (WBCs), platelets, and plasma proteins (including clotting factors).

Table 7.1: Classification of Hematological Disorders

Category	Affects	Example diseases
Anaemias	Red blood cells	Iron deficiency anaemia, thalassaemia, sickle cell anaemia, pernicious anaemia, aplastic anaemia
Leukaemias	White blood cells (marrow)	Acute lymphoblastic leukaemia, acute myeloid leukaemia, chronic lymphocytic leukaemia, chronic myeloid leukaemia
Lymphomas	Lymphocytes (lymph nodes)	Hodgkin lymphoma, non-Hodgkin lymphoma, Burkitt lymphoma
Myeloproliferative disorders	Overproduction in marrow	Polycythaemia vera, essential thrombocythaemia, myelofibrosis
Plasma cell disorders	Plasma cells (antibody-producing)	Multiple myeloma, monoclonal gammopathy of undetermined significance (MGUS)
Bleeding disorders	Clotting factors, platelets	Haemophilia A and B, von Willebrand disease, vitamin K deficiency
Clotting/thrombotic disorders	Excess clot formation	Deep vein thrombosis, pulmonary embolism, antiphospholipid syndrome, Factor V Leiden
Platelet disorders	Platelet number or function	Immune thrombocytopenic purpura (ITP), thrombotic thrombocytopenic purpura (TTP)
Bone marrow failure syndromes	Marrow's ability to produce cells	Aplastic anaemia, myelodysplastic syndromes, Fanconi anaemia

7.2 IRON DEFICIENCY ANAEMIA

Iron deficiency anaemia (IDA) is the most common form of anaemia worldwide, occurring when the body lacks sufficient iron to produce adequate haemoglobin—the protein in red blood cells responsible for carrying oxygen to tissues throughout the body. As iron stores become depleted, the body's ability to manufacture healthy, oxygen-carrying red blood cells declines, leading to the characteristic features of anaemia: fatigue, pallor, weakness, and reduced exercise tolerance.

Iron plays a central role in human physiology beyond haemoglobin synthesis, contributing to enzymatic reactions, immune function, and cellular energy metabolism. The body obtains iron primarily through dietary intake, absorbed mainly in the duodenum and upper jejunum, and maintains a delicate balance between absorption, utilisation, storage, and loss. When this balance is disrupted—whether through inadequate intake, impaired absorption, increased physiological demand, or chronic blood loss—iron deficiency develops, progressing through stages from depleted iron stores to overt anaemia if left unaddressed.

7.2.1 Ateiology

Iron-deficiency anaemia develops when the body's available iron is insufficient for normal haemoglobin production.

examples include:

- Methotrexate
- Trimethoprim
- Pyrimethamine

Methotrexate is a strong inhibitor of this enzyme, whereas trimethoprim and pyrimethamine have comparatively weaker effects. Co-trimoxazole may worsen the severity of existing megaloblastic anaemia by interfering with folate metabolism.

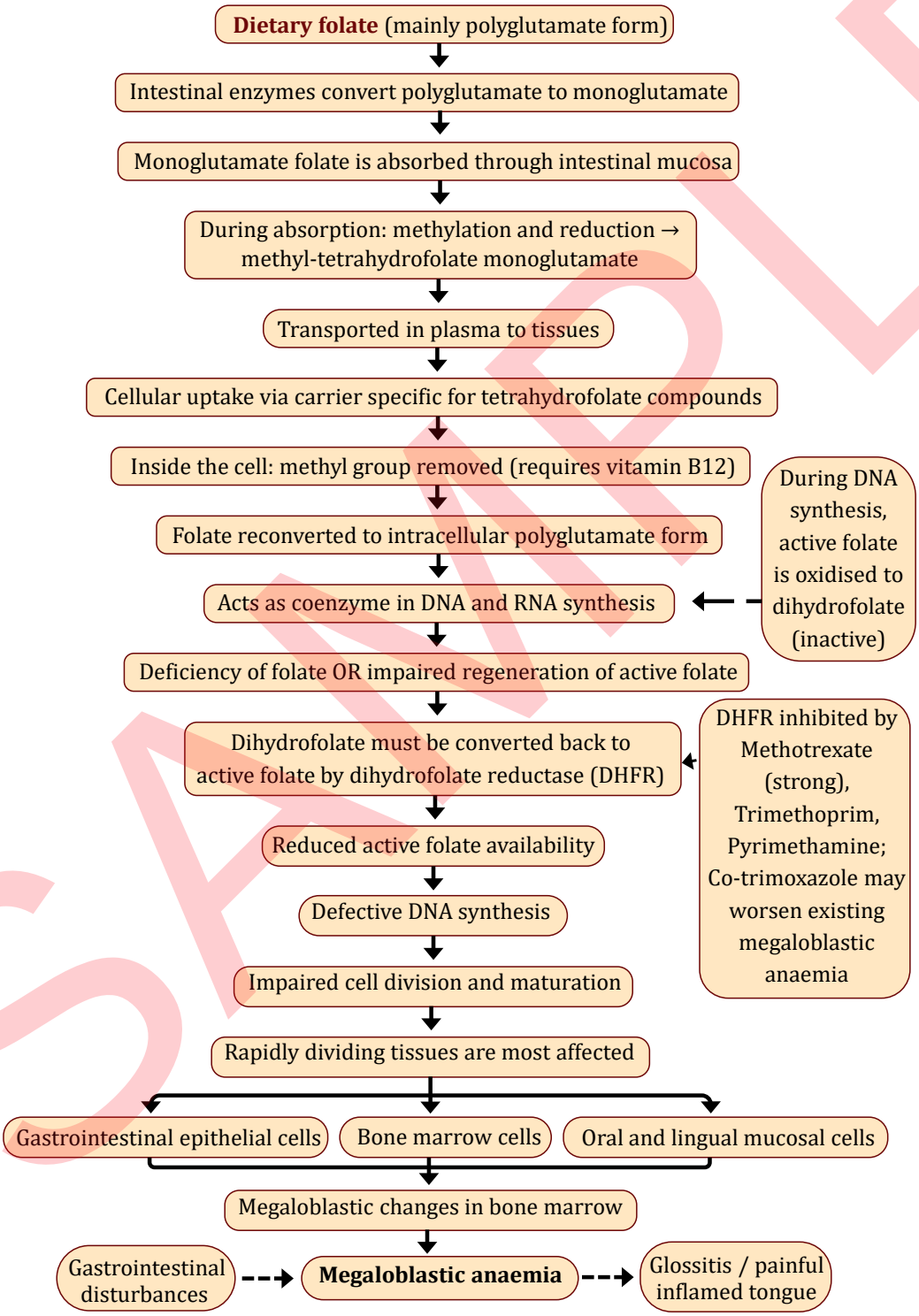


Figure 7.2: Pathophysiology of Folate Deficiency Megaloblastic Anaemia

PERIPHERAL NERVOUS SYSTEM

8

- Classification of peripheral nervous system: structure and functions of sympathetic and parasympathetic nervous system.
- Origin and functions of spinal and cranial nerves.

8.1 INTRODUCTION

The peripheral nervous system (PNS) is the part of the nervous system that lies outside the brain and spinal cord. The brain and spinal cord form the central nervous system (CNS), whereas the nerves, ganglia and sensory receptors present outside the CNS form the peripheral nervous system.

The peripheral nervous system serves as a link between the central nervous system and the rest of the body. It carries sensory information from different body parts to the CNS and transmits motor commands from the CNS to muscles and glands. In this way, the PNS helps the body to receive information, interpret changes and produce suitable responses. The main components of the PNS are:

- Nerves
- Sensory receptors

Nerves

A nerve is a cord-like structure composed of hundreds or thousands of nerve fibres, known as axons. These axons are supported and protected by connective tissue and supplied by blood vessels.

Nerves carry electrical impulses between the central nervous system and different regions of the body. Each nerve follows a specific pathway and generally supplies a particular organ, muscle or body region.

Table 8.1: The Nerves of the Peripheral Nervous System

Type of Nerve	Description
Cranial nerves	12 pairs of cranial nerves, which arise mainly from the brain and brainstem
Spinal nerves	31 pairs of spinal nerves, which emerge from the spinal cord

Sensory Receptors

Sensory receptors are specialised structures that detect changes occurring within or outside the body. They convert these changes into nerve impulses that can be transmitted to the central nervous system. Examples include:

- Touch receptors in the skin
- Temperature and pain receptors
- Photoreceptors in the eyes
- Olfactory receptors in the nose
- Taste receptors on the tongue
- Receptors concerned with hearing and equilibrium

8.2 CLASSIFICATION OF PNS

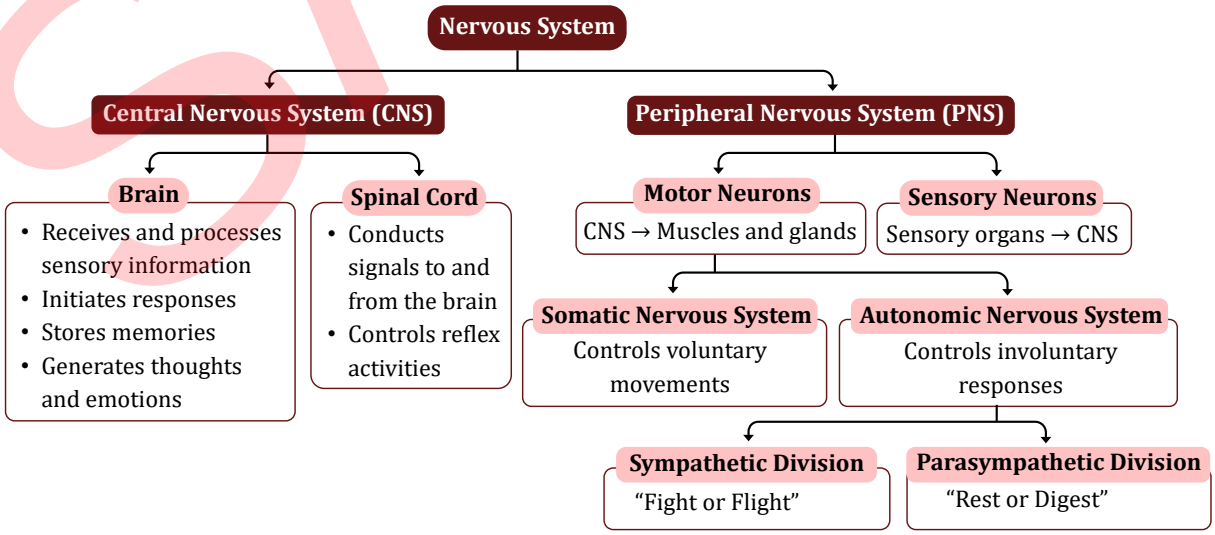


Figure 8.1: Classification of Peripheral Nervous System

pathetic and parasympathetic divisions. This arrangement is called dual innervation. The two divisions commonly have opposing effects on the same organ. For example:

- Sympathetic stimulation increases heart rate.
- Parasympathetic stimulation decreases heart rate.

These opposing actions help maintain internal stability and allow rapid adjustment to changing physiological conditions.

Enteric Nervous System

The enteric nervous system (ENS) is an extensive network of neurons located within the walls of the gastrointestinal tract. It contains:

- Sensory neurons
- Interneurons
- Motor neurons

Enteric Sensory Neurons

Enteric sensory neurons detect:

- Chemical changes within the gastrointestinal tract
- Composition of intestinal contents
- Stretching of the gastrointestinal walls

Enteric Interneurons

Interneurons receive and integrate sensory information. They then transmit appropriate signals to enteric motor neurons.

Enteric Motor Neurons

Enteric motor neurons regulate:

- Contraction of gastrointestinal smooth muscle
- Movement of food through the digestive tract
- Secretion from gastrointestinal glands
- Local blood flow within the digestive system

The ENS can operate independently to a considerable extent, but its activity is also modified by the sympathetic and parasympathetic divisions.

8.2.2.3 Autonomic Motor Pathway

Most autonomic motor pathways consist of two neurons connected in sequence:

1. Preganglionic neuron
2. Postganglionic neuron

This arrangement differs from the somatic motor pathway, in which a single motor neuron extends from the central nervous system directly to skeletal muscle.

Preganglionic Neuron

The cell body of a preganglionic neuron lies within the brain or spinal cord. Its axon:

- Leaves the central nervous system through a cranial or spinal nerve
- Is usually a small, myelinated type B fibre
- Extends to an autonomic ganglion
- Forms a synapse with a postganglionic neuron

Preganglionic neurons carry impulses from the central nervous system to autonomic ganglia.

Postganglionic Neuron

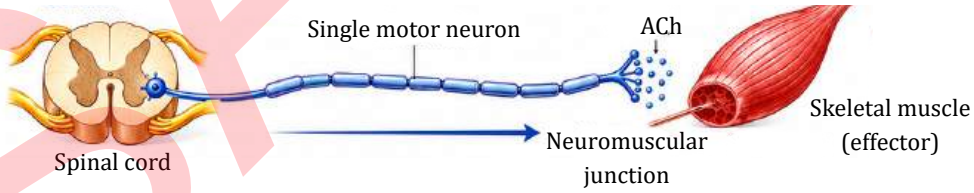
The cell body of a postganglionic neuron lies within an autonomic ganglion in the peripheral nervous system. Its axon:

- Is generally a small, unmyelinated type C fibre
- Extends from the autonomic ganglion to a visceral effector
- Supplies cardiac muscle, smooth muscle or glands

Postganglionic neurons transmit impulses from autonomic ganglia to the target organs.

Autonomic Ganglia

An autonomic ganglion is a collection of neuronal cell bodies located outside the central nervous system. It acts as a relay station between preganglionic and postganglionic neurons.



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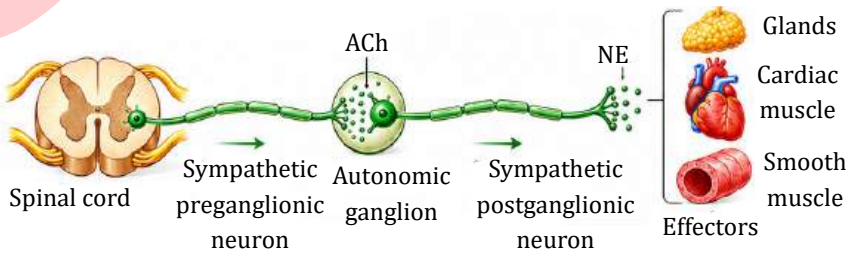

(b)

SPECIAL SENSES 9

- Structure and functions of eye, ear, nose and tongue.
- Pathophysiology of special sense disorders- glaucoma, cataract, myopia, otitis externa, otitis media, vertigo and anosmia.

9.1 EYE

The eye is the specialized sensory organ responsible for vision. It is located within the orbital cavity and transmits visual information to the brain through the optic nerve, which is the second cranial nerve.

Each eyeball is nearly spherical and measures approximately 2.5 cm in diameter. The space between the eyeball and the walls of the orbit is filled with adipose tissue. This fatty tissue cushions the eye, while the surrounding bones of the orbit provide additional protection against injury.

Although the two eyes are anatomically separate, their movements and visual activities are closely coordinated, allowing them to function together as a single visual system. Vision is still possible with only one functioning eye; however, binocular or three-dimensional vision becomes reduced. As a result, the ability to estimate depth and judge the distance of objects is less accurate.

9.1.1 Structure

The wall of the eyeball is formed by three concentric tissue layers, also called tunics (Figure 9.1:):

1. Outer fibrous layer
- Sclera
- Cornea

2. Middle vascular layer or uveal tract
- Choroid
- Ciliary body
- Iris

3. Inner nervous layer
- Retina

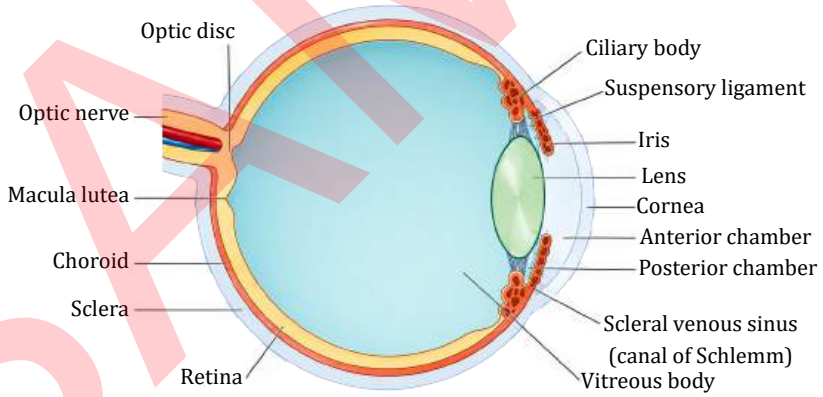

Figure 9.1: Structure of the Eye.

The principal structures present inside the eyeball include:
- Lens
- Aqueous humour
- Vitreous humour

9.1.1.1 Outer Fibrous Layer

The outer fibrous layer provides protection, maintains the shape of the eyeball and offers attachment to the muscles responsible for eye movement. It consists of the sclera posteriorly and the cornea anteriorly.

Sclera

The sclera is the firm, opaque, white portion of the outer layer of the eye. It covers most of the posterior and lateral surfaces of the eyeball and is commonly referred to as the white of the eye. It is composed mainly of dense fibrous connective tissue.

Functions of the Sclera

The sclera:
- Protects the delicate internal structures of the eye
- Maintains the shape of the eyeball

nearby objects to be seen clearly (Figure 9.5, 9.6). Objects within approximately 6 metres require three major responses:

1. Constriction of the pupils
2. Convergence of the eyeballs
3. Increased curvature of the lens

These coordinated changes are often called the near response.

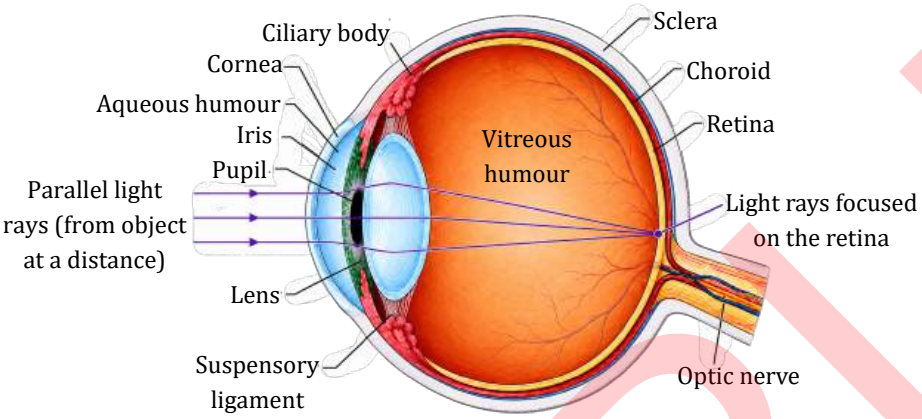

Figure 9.6: Cross-Section of the Eye Showing Light Rays Focused on the Retina

Constriction of the Pupils

Pupil constriction narrows the beam of incoming light. This allows light to pass mainly through the central portion of the lens, where refraction is more accurate, and helps improve image sharpness.

Convergence of the Eyes

Light from a nearby object enters each eye at a slightly different angle. To focus the image on corresponding areas of both retinae, the extraocular muscles rotate both eyes inward towards the object.

The closer the object is to the face, the greater the degree of convergence required. For example, looking at the tip of the nose produces marked inward rotation of the eyes.

Failure of proper convergence causes the two eyes to focus on different points. As a result, the brain receives two separate images, producing double vision or diplopia. If this continues for a prolonged period, the brain may begin to suppress the image received from the misaligned eye.

Increased Refractive Power of the Lens

During near vision, the ciliary muscles remain contracted and the lens becomes more convex. The amount of lens adjustment depends on how close the object is.

Continuous focusing on nearby objects may cause eye fatigue because the ciliary muscles must remain active.

Distant Vision

Objects located more than approximately 6 metres away are generally focused on the retina without significant accommodation or convergence.

During distant vision:

- The ciliary muscles are relaxed.
- The suspensory ligaments are tense.
- The lens is relatively thin and flat.
- The eyes remain nearly parallel.
- Pupil constriction associated with the near response is not required.

Functions of the Retina

The retina is the light-sensitive layer of the eye. It contains two main types of photoreceptor cells:

- Rods
- Cones

When light reaches these cells, it produces chemical changes in their visual pigments. These changes generate electrical impulses that pass through retinal neurons into the optic nerves. The impulses are then transmitted to the visual cortex in the occipital lobes, where they are interpreted as sight.

Rods

Rods are highly sensitive photoreceptors that function mainly in dim light.

Their important characteristics include:

- They are more sensitive to light than cones.
- They are responsible for night and low-light vision.
- They do not provide colour vision.
- They produce less detailed images.
- They are more numerous in the peripheral retina.
- They contain the visual pigment rhodopsin, also called visual purple.

Rods are especially useful for detecting movement and objects located towards the edges of the visual field.

Cones

Cones function most effectively in bright light and are responsible for colour vision and detailed visual perception.

Their main characteristics include:

- They require greater light intensity for stimulation.
- They allow colours to be distinguished.
- They provide sharp and detailed vision.
- They are concentrated mainly in the macula lutea.
- Their highest concentration is present in the fovea centralis.

9.3 NOSE

9.3.1 Structure

The nasal cavity forms the beginning of the respiratory tract. It is a large, irregularly shaped space situated within the facial part of the skull.

A central partition called the nasal septum divides the cavity into right and left passages of approximately equal size.

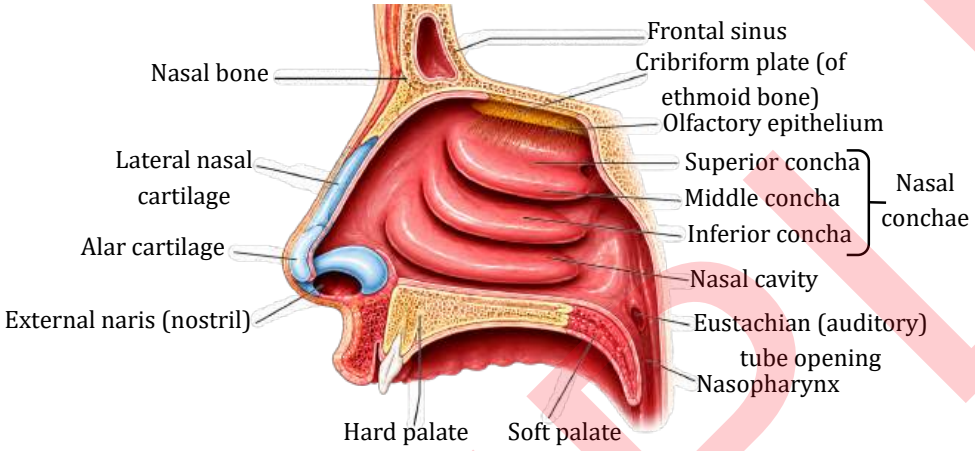

Figure 9.17: Lateral wall of right Nasal Cavity

1. Nasal Septum

The nasal septum is formed by both bone and cartilage.
Its posterior bony portion consists mainly of:

- Perpendicular plate of the ethmoid bone
- Vomer

Its anterior portion is formed by flexible hyaline cartilage.
The septum separates the two nasal passages and supports the external shape of the nose.

Boundaries of the Nasal Cavity

Roof

The roof of the nasal cavity is formed by parts of several bones, including:

- Cribriform plate of the ethmoid bone
- Sphenoid bone
- Frontal bone
- Nasal bones

The cribriform plate contains numerous small openings through which olfactory nerve fibres pass from the nasal cavity to the olfactory bulb.

Floor

The floor of the nasal cavity is formed by the roof of the mouth.
It consists of:

- Hard palate anteriorly
- Soft palate posteriorly

The hard palate is formed mainly by the maxillae and palatine bones. It separates the nasal cavity from the oral cavity. The soft palate is composed mainly of muscle and connective tissue. It moves during swallowing and helps prevent food from entering the nasal part of the pharynx.

Medial Wall

The medial wall of each nasal passage is formed by the nasal septum.

Lateral Walls

The lateral walls are formed mainly by:

- Maxilla
- Ethmoid bone
- Inferior nasal conchae

Curved bony projections called the nasal conchae extend from the lateral walls. They increase the surface area of the nasal lining and create turbulence in the inspired air.

Posterior Boundary

Posteriorly, the nasal cavity communicates with the nasal part of the pharynx through the posterior nasal openings.

2. Lining of the Nasal Cavity

Most of the nasal cavity is lined by a highly vascular ciliated mucous membrane. This lining consists mainly of ciliated columnar epithelial cells and mucus-producing goblet cells. The rich blood supply helps warm incoming air, while mucus and cilia help trap and remove foreign particles. At the anterior nostrils, the mucous membrane becomes continuous with the skin. Posteriorly, it continues into the mucous membrane lining the nasopharynx.

Openings of the Nasal Cavity

a. Anterior Nares

The anterior nares, commonly called the nostrils, are the external openings through which air enters the nasal cavity.

Coarse hairs are present near these openings. They

CARDIOVASCULAR SYSTEM

10

- Anatomy of heart, blood circulation, blood vessels, structure and functions of artery, vein and capillaries, elements of conduction system of heart and heartbeat, its regulation by autonomic nervous system, cardiac output, cardiac cycle. Regulation of blood pressure, pulse, electrocardiogram.

10.1 INTRODUCTION

The cardiovascular system is described under two closely connected divisions: the circulatory system and the lymphatic system. These systems communicate with each other and work together to maintain the transport of substances throughout the body.

1. Circulatory System

The circulatory system consists of the heart and blood vessels. The heart functions as a muscular pump, while the blood vessels provide pathways through which blood circulates to different parts of the body.

2. Lymphatic System

The lymphatic system consists mainly of lymph vessels and lymph nodes. A clear, colourless fluid called lymph flows through the lymphatic vessels. This system is closely associated with the circulatory system and helps maintain fluid balance and support immune defence.

Circulations of Blood

The heart pumps blood through two anatomically distinct circulatory pathways (Figure 10.1):

a. Pulmonary circulation
b. Systemic circulation

a. Pulmonary Circulation

The right side of the heart pumps deoxygenated blood to the lungs through the pulmonary circulation. In the lungs, gaseous exchange takes place. Carbon dioxide moves from the blood into the lungs for removal, while oxygen passes from the lungs into the blood.

The oxygenated blood then returns to the left side of the heart.

b. Systemic Circulation

The left side of the heart pumps oxygenated blood into the systemic circulation, which supplies all parts of the body except the lungs.

At the tissue level, body cells receive oxygen and nutrients from the blood. At the same time, metabolic waste products produced by the cells enter the blood and are transported to the appropriate organs for excretion.

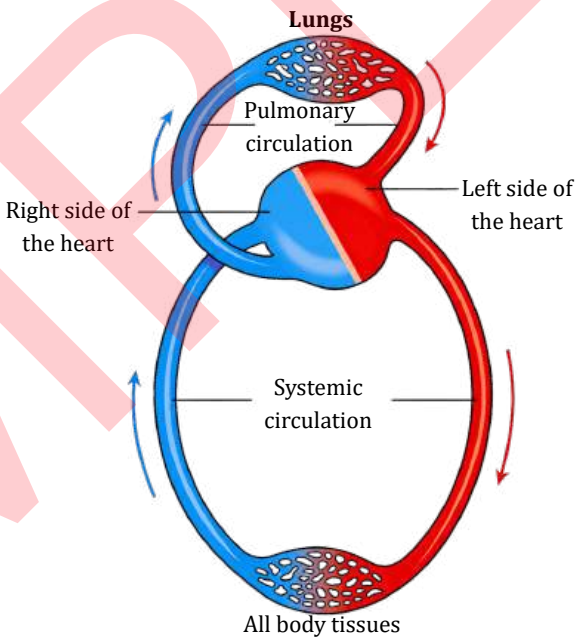

Figure 10.1: Interrelationship of Pulmonary and Systemic Circulations

Importance of Continuous Blood Circulation

The circulatory system maintains a continuous supply of blood to all body tissues. Blood flow is constantly adjusted according to the physiological requirements of different organs and tissues.

These adjustments ensure that body cells receive adequate amounts of oxygen and nutrients for normal growth, metabolism, and function.

10.2 ANATOMY OF HEART

The heart is a hollow, muscular organ with a roughly cone-shaped appearance. It measures approximately 10 cm in length and is about the size of the individual's closed fist. Its average weight is nearly 225 g in women and approximately 310 g in men.

Position of the Heart

The heart is located in the thoracic cavity within the me-

Circle of Willis

The circle of Willis is an arterial arrangement located at the base of the brain. It connects the internal carotid and vertebrobasilar circulations, helping maintain cerebral blood flow when blood flow through one contributing artery is reduced (Figure 10.11).

Formation of the Circle of Willis

The circle is formed mainly by:

- Two anterior cerebral arteries
- One anterior communicating artery
- Terminal portions of two internal carotid arteries
- Two posterior communicating arteries
- Two posterior cerebral arteries

The basilar artery contributes to the posterior cerebral circulation but is not itself usually considered part of the arterial ring.

Anterior Part

The anterior cerebral arteries arise from the internal carotid arteries and are connected by the anterior communicating artery.

Posterior Part

The two vertebral arteries unite to form the basilar artery. The basilar artery travels along the brainstem and divides into the right and left posterior cerebral arteries. Each posterior cerebral artery communicates with the corresponding internal carotid artery through a posterior communicating artery.

Table 10.5: Distribution of Cerebral Arteries

Branches	Area Supplied
Anterior Cerebral Arteries	Anterior and medial regions of the cerebral hemispheres
Middle Cerebral Arteries	Much of the lateral surface of the brain
Posterior Cerebral Arteries	Posterior and inferior regions of the brain
Branches of Basilar and Vertebral Arteries	Brainstem, cerebellum and related structures

Venous Return from the Head and Neck

Venous blood from the head and neck returns through superficial and deep veins (Figure 10.12).

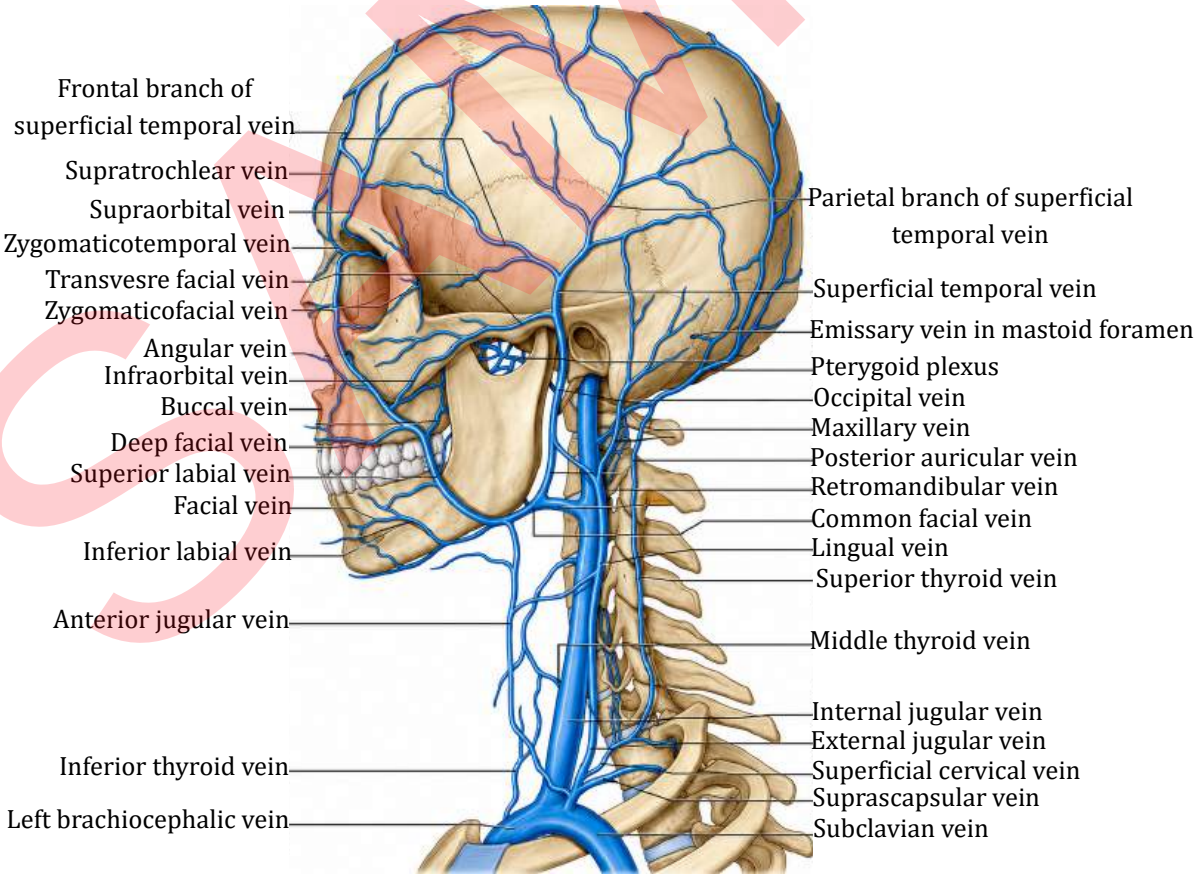

Figure 10.12: Venous Return from the Head and Neck

beats per minute, although it may vary between individuals and at different times in the same person.

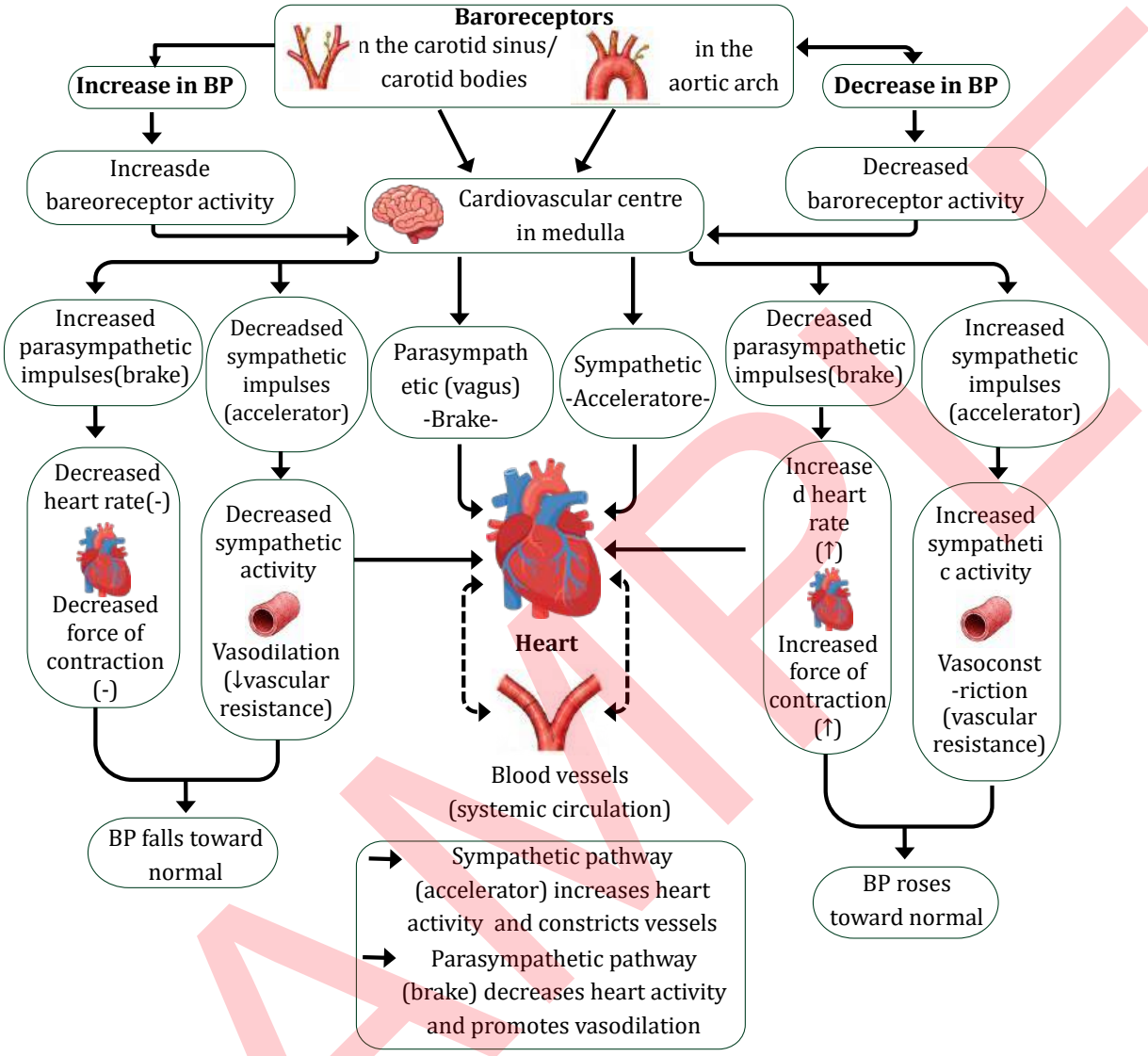

Figure 10.26: Baroreceptor Reflex

10.9.2.1 Characteristics of the Pulse

Examination of the pulse provides important information about the functioning of the heart and circulatory system. The main characteristics assessed are pulse rate, rhythm, volume, tension and the condition of the arterial wall.

1. Pulse Rate

Pulse rate indicates the number of times the heart beats in one minute. An unusually rapid pulse is known as tachycardia, whereas an abnormally slow pulse is called bradycardia.

2. Pulse Rhythm

Pulse rhythm refers to the regularity of successive pulse beats. In a normal pulse, the interval between each beat is nearly equal. Unequal or irregular intervals may indicate an abnormality in the rhythm of the heart.

3. Pulse Volume

Pulse volume refers to the strength or amplitude of each pulsation. It depends mainly on the amount of blood ejected by the left ventricle and the condition of the arterial system. A strong pulse may be felt when stroke volume is increased, whereas a weak pulse may occur when cardiac output is reduced.

4. Pulse Tension and Compressibility

Pulse tension refers to the degree of pressure required to compress the artery and stop the pulse. Normally, the artery can be compressed using moderate finger pressure. A pulse that is difficult to compress may be associated with increased arterial pressure, whereas an easily compressible pulse may indicate reduced blood pressure.

10.9.2.2 Regulation of Pulse

Intrinsic or Myogenic Regulation

The sinoatrial (SA) node is the natural pacemaker of the

CARDIOVASCULAR DISEASES

11

- Pathophysiology of hypertension, cardiac arrhythmias, congestive heart failure, ischemic heart disease (angina, myocardial infarction, atherosclerosis and coronary artery disease).

11.1 HYPERTENSION

Hypertension refers to blood pressure that remains persistently above the generally accepted normal maximum level for a particular age group. Traditionally, values such as 140/90 mmHg at 20 years, 160/95 mmHg at 50 years, and 170/105 mmHg at 75 years were considered upper limits. Arteriosclerosis contributes to the gradual rise in blood pressure with increasing age, although several other factors may also be involved. Hypertension is broadly classified into essential or primary hypertension and secondary hypertension. Regardless of its cause, prolonged hypertension commonly affects the kidneys and other vital organs.

A. Essential Hypertension

Essential hypertension, also known as primary or idiopathic hypertension, is high blood pressure for which no definite underlying cause can be identified. It accounts for approximately 85–90% of all cases. Depending on the rate at which the condition progresses, essential hypertension may be described as benign or malignant.

i. Benign Hypertension

Benign hypertension, also called chronic hypertension, usually involves a mild to moderate increase in blood pressure that progresses slowly over many years. The condition may remain undetected for a long period, and complications may sometimes be the first indication of the disease. These complications may include heart failure, cerebrovascular accident, and myocardial infarction. In some cases, the condition may suddenly progress more rapidly and develop into malignant hypertension. Common predisposing factors include hereditary tendency, obesity, excessive alcohol consumption, cigarette smoking, and lack of physical exercise.

ii. Malignant Hypertension

Malignant hypertension, also known as accelerated hypertension, is a severe form of hypertension in which already elevated blood pressure rises rapidly over a period of a few months. Diastolic blood pressure commonly exceeds 120 mmHg. The effects are serious and become apparent quickly. These may include retinal haemorrhages, papilloedema or swelling around the optic disc, hypertensive encephalopathy caused by cerebral oedema, progressive renal disease, and cardiac failure.

B. Secondary Hypertension

Secondary hypertension develops as a result of another identifiable disease, disorder, or external factor. It accounts for approximately 10–15% of all cases. Common causes include kidney diseases, endocrine disorders, narrowing of the aorta, and the use of certain medicines.

Kidney Diseases

Raised blood pressure is a common complication of many kidney diseases. Damaged kidneys may release excessive amounts of renin, which causes vasoconstriction and contributes to an increase in blood pressure. Other mechanisms may also be involved in the development of renal hypertension.

Endocrine Disorders

Endocrine disorders involving the adrenal glands may cause secondary hypertension. Excessive secretion of aldosterone and cortisol from the adrenal cortex increases the retention of sodium and water by the kidneys. This increases blood volume and consequently raises blood pressure. Excess aldosterone secretion, known as Conn's syndrome, may result from a hormone-secreting tumour. Excess cortisol secretion may be caused by overstimulation of the adrenal cortex by adrenocorticotrophic hormone from the pituitary gland or by a cortisol-secreting tumour.

Excessive secretion of adrenaline and noradrenaline from the adrenal medulla also raises blood pressure by increasing cardiac activity and causing vasoconstriction. This may occur in conditions such as phaeochromocytoma.

Stricture of the Aorta

Narrowing or stricture of the aorta causes hypertension in the arteries located proximal to the site of narrowing. In congenital coarctation of the aorta, the narrowing usually occurs between the ductus arteriosus and the left subclavian artery. This produces increased blood pressure in the head, neck, and right arm. Compression of the aorta by a nearby tumour may similarly cause hypertension in the arteries situated before the narrowed area.

Drug-Induced Hypertension

Hypertension may also occur as an adverse effect of certain medicines. Drugs commonly associated with increased blood pressure include corticosteroids, non-steroidal anti-inflammatory drugs, and oral contraceptives.

11.1.1 Etiology

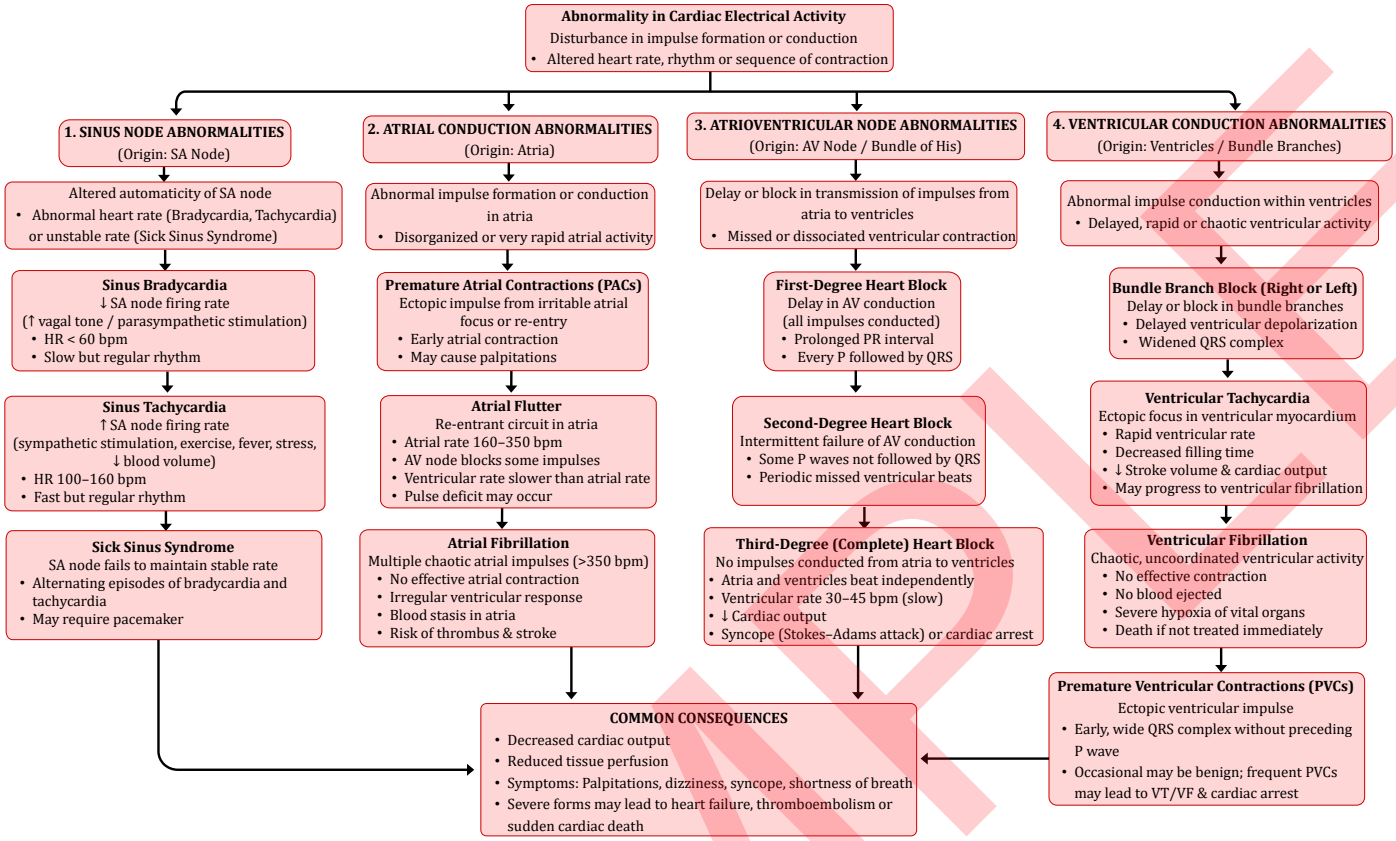

Figure 11.6: Pathophysiology of Cardiac Arrhythmia

11.2.3 Clinical Features

Palpitations

The most common symptom of a cardiac arrhythmia is palpitation, which is the awareness of an abnormal, rapid, forceful, or irregular heartbeat. However, some patients with a clearly documented arrhythmia may not experience palpitations. Arrhythmias frequently begin suddenly, and a patient may describe the onset as being "like flicking a switch." This abrupt onset supports the possibility of an arrhythmia rather than an increased awareness of sinus tachycardia, which usually develops more gradually.

Reduced Cardiac Output

The heart functions most efficiently when it is in normal sinus rhythm. Any disturbance in cardiac rhythm may interfere with the normal filling and emptying of the heart chambers, reducing the efficiency of cardiac contraction. Symptoms resulting from reduced cardiac output commonly include decreased exercise tolerance, breathlessness, weakness, and fatigue.

Angina Associated with Tachycardia

Tachycardia may cause angina even in patients who do not have coronary artery disease. A rapid heart rate increases the metabolic activity of the myocardium and consequently raises its demand for oxygen and blood flow. At the same time, myocardial perfusion occurs mainly during diastole, which becomes shorter during tachycardia. As a result, the oxygen demand of the myocardium may exceed the available supply, producing chest pain or angina.

Dizziness, Syncope and Cardiac Arrest

Both excessively slow and excessively rapid heart rhythms can cause a sudden reduction in cardiac output. Reduced blood flow to the brain may produce dizziness or presyncope, which is the sensation that fainting is about to occur. A more severe decrease in cerebral blood flow may result in temporary loss of consciousness, known as syncope. In extreme cases, a severe arrhythmia may lead to cardiac arrest and sudden death.

Thromboembolism and Stroke

Atrial tachyarrhythmias, particularly atrial flutter and atrial fibrillation, may cause ineffective atrial contraction and stagnation of blood within the atria. This may lead to the formation of an intracardiac thrombus, most commonly in the left atrial appendage.

A fragment of the thrombus may detach and travel through the systemic circulation as an embolus. Although embolisation may affect any part of the body, the most common clinical consequences are a transient ischaemic attack or an ischaemic stroke.

Effect on Heart Failure

Cardiac arrhythmias may precipitate or worsen heart failure

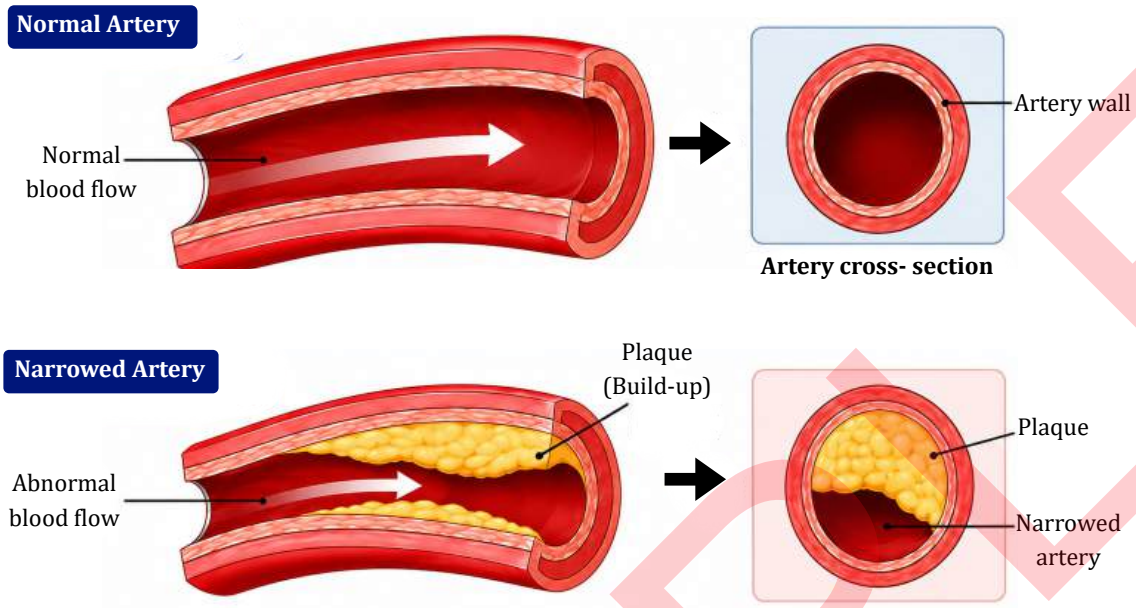

Figure 11.11: Atherosclerosis develops when fatty and calcified deposits accumulate within an artery and form plaques.

Sex

Men are more likely to develop atherosclerosis at a younger age than premenopausal women. Before menopause, oestrogen contributes to a more favourable lipid profile and may help maintain higher levels of high-density lipoprotein. After menopause, declining oestrogen levels reduce this protection, and the cardiovascular risk in women gradually increases.

Genetic and Familial Factors

Genetic factors strongly influence serum lipid concentrations, lipid metabolism, and the number and function of cellular lipoprotein receptors. Inherited disorders such as familial hypercholesterolaemia cause markedly elevated LDL cholesterol levels and may lead to premature atherosclerosis. Shared dietary habits, physical activity patterns, and other lifestyle factors within families may also contribute to the risk.

Modifiable Risk Factors

Obesity and Unhealthy Diet

Obesity and diets rich in cholesterol, saturated fats, and animal fats increase serum lipid levels, particularly LDL cholesterol. Obesity is also closely associated with metabolic syndrome, insulin resistance, hypertension, and type 2 diabetes mellitus, all of which increase the likelihood of coronary artery disease. The rising prevalence of obesity among children and adolescents is a major concern because it may lead to cardiovascular disease at an earlier age.

Cigarette Smoking

Cigarette smoking is an important preventable risk factor, and the risk generally increases with the amount and duration of tobacco exposure. Smoking damages the vascular endothelium, decreases HDL cholesterol, increases LDL cholesterol, promotes platelet adhesion, and raises fibrinogen levels. It also encourages vasoconstriction and thrombus formation, thereby accelerating the development and complications of atherosclerosis.

Sedentary Lifestyle

Physical inactivity contributes to obesity, poor circulation, hypertension, and an unfavourable lipid profile. Regular physical activity helps lower blood pressure, reduce stress, increase HDL cholesterol, and decrease LDL cholesterol and total cholesterol. A sedentary lifestyle therefore significantly increases cardiovascular risk.

Diabetes Mellitus

Diabetes mellitus, particularly when poorly controlled, promotes endothelial dysfunction and increases serum lipid levels. Persistent hyperglycaemia damages blood vessels and accelerates lipid deposition within the arterial wall. The increasing occurrence of type 2 diabetes at younger ages has also contributed to the growing burden of cardiovascular disease.

Hypertension

Poorly controlled hypertension produces continuous mechanical stress on the arterial wall, resulting in endothelial injury. The damaged endothelium becomes more permeable to lipids and more favourable for inflammation, platelet adhesion, and plaque formation. Hypertension may therefore initiate and accelerate the atherosclerotic process.

Oral Contraceptives and Smoking

The combined use of certain oral contraceptives and ciga-

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