REFERENCE BOOK

H.S.C. (VOCATIONAL)

RADIOLOGY TECHNICIAN

STD. XI

PAPER I-ANATOMY AND PHYSIOLOGY (S7)

(THEORY PAPER I)

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The Constitution of India

Preamble

WE, THE PEOPLE OF INDIA, having solemnly resolved to constitute India into a SOVEREIGN SOCIALIST SECULAR DEMOCRATIC REPUBLIC and to secure to all its citizens:

JUSTICE, social, economic and political;

LIBERTY of thought, expression, belief, faith and worship;

EQUALITY of status and of opportunity; and to promote among them all;

FRATERNITY assuring the dignity of the individual and the unity and integrity of the Nation;

IN OUR CONSTITUENT ASSEMBLY this twenty-sixth day of November, 1949, do HEREBY ADOPT, ENACT AND GIVE TO OURSELVES THIS CONSTITUTION.

****

NATIONAL ANTHEM

Jana-gana-mana-adhinayaka jaya he

Bharata-bhagya-vidhata

Punjaba-Sindhu-Gujarata-Maratha

Dravida-Utkala-Banga

Vindhya-Himachala-Yamuna-Ganga

Uchchala-jaladhi-taranga

Tava subha name jage, tava subha asisa mage,

Gahe tava jaya-gatha,

Jana-gana-mangala-dayaka jaya he

Bharata-bhagya-vidhata,

Jaya he, Jaya he, Jaya he,

Jaya jaya jaya jaya he.

****

PLEDGE

India is my country. All Indians are my brothers and sisters.

I love my country and I am proud of its rich and varied heritage. I shall always strive to be worthy of it.

I shall give my parents, teachers and all elders respect and treat everyone with courtesy.

To my country and my people, I pledge my devotion. In their well-being and prosperity alone lies my happiness.

PREFACE

The national policy of education (1986) envisages that the introduction of systematic, well planned and rigorously implemented programme of vocational education is crucial in the proposed educational reorganization. In accordance with the policy of Govt. of India, State govt. of Maharashtra introduces +2 Vocationlization of Education in 1988-89. During last 25 years no substantial efforts has been taken to revamp the curriculum.

Ministry of Human Resource Development, Govt. of India developed the National Skill Qualification Framework (NSQF) to introduce vocational courses according to series of levels of knowledge & skills. Qualifications are made up of vocational standards for specific areas of learning units or units of competency. Units of competency are the specification of the knowledge and skill to the standard of performance expected in the workplace. The unit of competency or National Occupation Standards comprising generic and technical competencies an employee should possess is laid down by the Sector Skill Council of the respective economic or social sector.

The challenges before us were to make smooth transition of curriculum from knowledge based to skill based and rapid technological changes in all sectors of economy. Hence, the few obsolete courses were either merge with core courses or deleted. Hence, in first phase 30 courses were converted into 20 courses. In second phase 20 more courses can be added sector wise as per National Occupational Standards.

I acknowledge the hard team work done by District Vocational Education & Training Officer, who were the coordinators for curriculum designing, theory & practical books writing, along with the vocational teachers of various vocational field & experts from the industry. Shri.S.M.Haste, Joint Director & Shri.A.G.Gavit, Dy.Director has taken the sincere efforts from Directorate to produce the best text material with limited resources & time.

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INDEX

UNIT 1- INTRODUCTION

Objectives-

At the end of this lesson you shall be able to-

- Define anatomy and physiology and pathology
- Correlate anatomy, physiology and Radiological services
- State the structure of cell and functions of cell
- Describe the specialized cells of human body
- Describe the parts of the human cell and their functions
- State the definition of tissue and its types
- State the names of various organ systems of the body
- Understand the radiological services

1.1 Definitions of Anatomy, Physiology and Pathology :

For a radiology technician the knowledge of Anatomy and Physiology is necessary to image the organs or parts of the body by various imaging techniques to offer the radiological services. These two branches are closely related because anatomy is the study of parts of the body while physiology is the study of how these parts work together.

Definitions-

- **Anatomy**-It is study of structure and structural relationships of the body and/or its parts.
- **Physiology**- It is the scientific study of functions of body parts and the body as a whole.
- **x-ray anatomy**- It is the study of organs and tissues based on their visualization by x-rays in both living and dead bodies.
- **Pathology**- The study of the essential nature of diseases and especially of the structural and functional changes produced by them or something abnormal:

a : the structural and functional deviations from the normal that constitute disease or characterize a particular disease

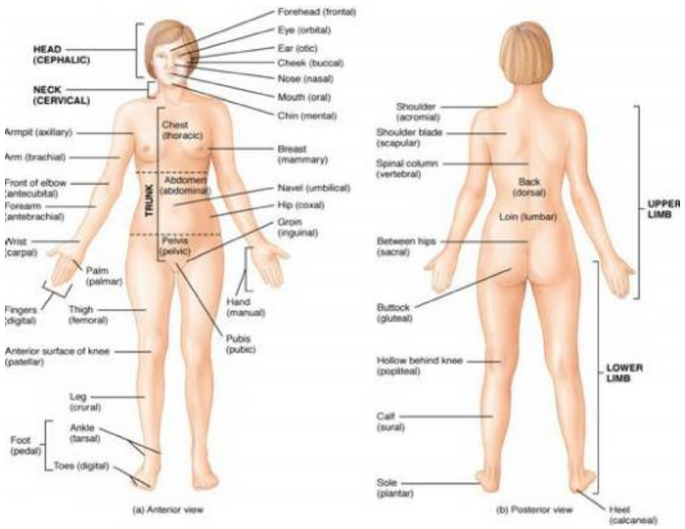
b : deviation from propriety or from an assumed normal state of something nonliving or nonmaterial

Anatomical position and directional terms :

Anatomy and physiology has its own terminology. In order to provide exquisite care and understand the inner workings of the human body, anatomical terminology is necessary. We'll begin by going over "anatomical position and directional terms".

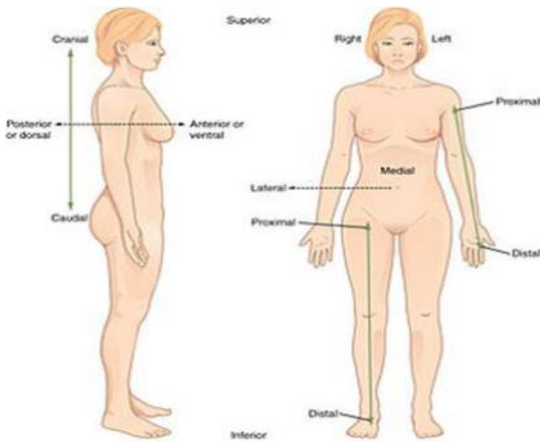
In order to describe body parts and positions correctly, the medical community has developed a set of anatomical positions and directional terms widely used in the healthcare industry. The anatomical reference point is a standard body position called the anatomical position. In the anatomical position, the body is erect, the palms of the hand face forward, the thumbs point away from the body, and the feet are slightly apart. It's important to understand the anatomical position because most directional terms are based off it.

Orientation and directional terms :



- **Superior (cranial)**– toward the head or upper part of the body; above
- **Inferior (caudal)**– away from the head or toward the lower part of the body; below
- **Ventral (anterior)**– toward or at the front of the body; in front of
- **Dorsal (posterior)**– toward or at the back of the body; behind
- **Medial**– toward or at the midline of the body
- **Lateral**– away from the midline of the body
- **Intermediate**– between a medial and lateral position
- **Proximal**– closer to the origin of the body part or point of attachment of a limb to the body trunk
- **Distal**– away from the origin of a body part or point of attachment of a limb to the body trunk
- **Superficial (external)**– toward or at the body surface
- **Deep (internal)**– Away from the body surface

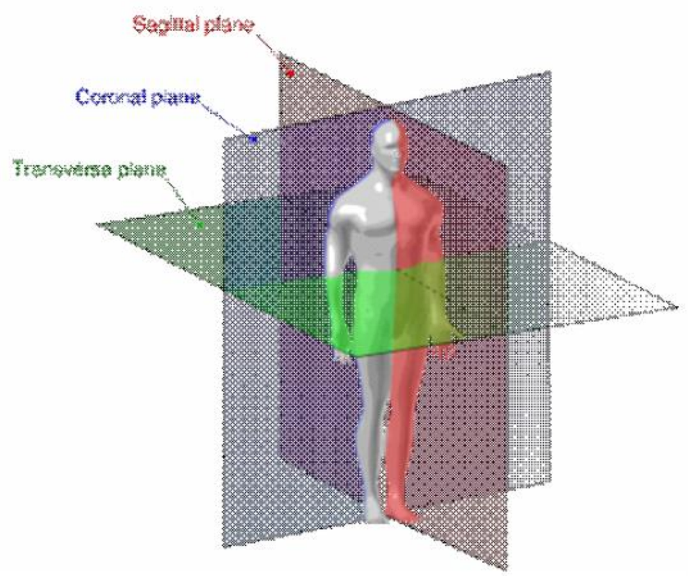
Directional terms allow us to explain where one body part is when compared to another.



Regional Terms :

The two main divisions of the body are its axial and appendicular parts. The axial part makes up the main axis of the body and includes the head, neck, and trunk. The appendicular part consists of the limbs (appendages) attached to the body's axis. View the image above for an in depth look into all the regional terms used to designate specific areas within the human body. You will have to know them!

Body planes and sections :



For anatomical purposes, the body is often sectioned into flat surfaces called planes. Those frequently used body planes are the sagittal, transverse, and frontal planes. The image above shows how the body is cut into corresponding planes.

- **Saggital plane**– is a vertical plane that divides the body into right and left parts
- **midsaggital plane**- is the saggital plane that lies directly in the midline
- **parasaggital planes**– are saggital planes offset from the midline
- **Frontal plane (coronal plane)**– also lies vertically; divides the body into posterior and anterior sections
- **Transverse plane (horizontal plane)**– runs horizontally; divides the body into inferior and superior sections

The human body includes the entire structure of a human being and comprises a head, neck, trunk (Which includes the thorax and abdomen), arms and hands, legs and feet. Every part of the body is composed of various types of cells, the fundamental unit of life.

1.2 Cell and Tissue :

What is a Cell ?

A cell is a structural as well as a functional unit of life.

Every living thing has cells: bacteria, protozoan, fungi, plants, and animals are the main group of living things. Some organisms are made up of just one cell are called unicellular. (e.g. bacteria and protozoan), but animals, including human beings, are multi-cellular. An adult human body is composed of about 100,000,000,000,000 cells! Each cell has basic requirements to sustain it, and the body's organ systems are largely built around providing the many trillions of cells with those basic needs (such as oxygen, food, and waste removal).

There are about 200 different kinds of specialized cells in the human body. When many identical cells are organized together it is called a tissue (such as muscle tissue, nervous tissue, etc). Various tissues organized together for a common purpose are called organs (e.g. the stomach is an organ, and so are the skin, the brain, and the uterus).

If a person's cells are healthy, then that person is healthy. All physiological processes, disease, growth and development can be described at the cellular level.

Specialized Cells of the Human Body:

Although there are specialized cells - both in structure and function - within the body, all cells have similarities in their structural organization and metabolic needs (such as maintaining energy levels via conversion of carbohydrate to ATP and using genes to create and maintain proteins).

Here are some of the different types of specialized cells within the human body.

- **Nerve Cells** : Also called Neurons, these cells are in the nervous system and function to process and transmit information (it is hypothesized). They are the core components of the brain, spinal cord and peripheral nerves. They use chemical synapses that can evoke electrical signals, called action potentials, to relay signals throughout the body.

- **Epithelial cells** : Functions of epithelial cells include secretion, absorption, protection, transcellular transport, sensation detection, and selective permeability. Epithelium lines both the outside (skin) and the inside cavities and lumen of bodies.

- **Exocrine cells** : These cells secrete products through ducts, such as mucus, sweat, or digestive enzymes. The products of these cells go directly to the target organ through the ducts. For example, the bile from the gall bladder is carried directly into the duodenum via the bile duct.

- **Endocrine cells** : These cells are similar to exocrine cells, but secrete their products directly into the bloodstream instead of through a duct. Endocrine cells are found throughout the body but are concentrated in hormone-secreting glands such as the pituitary. The products of the endocrine cells go throughout the body in the blood stream but act on specific organs by receptors on the cells of the target organs. For example, the hormone estrogen acts specifically on the uterus and breasts of females because there are estrogen receptors in the cells of these target organs.

- **Blood Cells** : The most common types of blood cells are:

- Red blood cells (erythrocytes)- The main function of red blood cells is to collect oxygen in the lungs and deliver it through the blood to the body tissues. Gas exchange is carried out by simple diffusion.

- Various types of white blood cells (leukocytes)- They are produced in the bone marrow and help the body to fight infectious disease and foreign objects in the immune system. White cells are found in the circulatory system, lymphatic system, spleen, and other body tissues.

- Platelets (Thrombocytes)- The main function of platelets is coagulation of blood.

Cell Size :

Cells are the smallest structural & functional living units within our body, but play a big role in making our body function properly. Many cells never have a large increase in size like eggs, after they are first formed from a parental cell. Typical stem cells reproduce, double in size, and then reproduce again. Most Cytosolic contents such as the endomembrane system and the cytoplasm easily scale to larger sizes in larger cells.

If a cell becomes too large, the normal cellular amount of DNA may not be adequate to keep the cell supplied with RNA. Large cells often replicate their chromosomes to an abnormally high amount or become multinucleated. Large cells that are primarily for nutrient storage can have a smooth surface membrane, but metabolically active large cells often have some sort of folding of the cell surface membrane in order to increase the surface area available for transport functions.

Cell Membranes :

The boundary of the cell, sometimes called the plasma membrane, separates internal metabolic events from the external environment and controls the movement of materials into and out of the cell. This membrane is very selective about what it allows to pass through; this characteristic is referred to as "selective permeability." For example, it allows oxygen and nutrients to enter the cell while keeping toxins and waste products out.

Parts of the Human Cell

The cell contains various structural components to allow it to maintain life which are known as organelles. All the organelles are suspended within a gelatinous matrix, the cytoplasm, which is contained within the cell membrane. One of the few cells in the human body that lacks almost all organelles are the red blood cells.

The main organelles are as follows-(Fig.1.1)

- cell membrane
- endoplasmic reticulum
- Golgi apparatus
- lysosomes
- mitochondria
- nucleus
- perioxisomes
- microfilaments and microtubules

Cell Membrane

The cell membrane is the outer coating of the cell and contains the cytoplasm, substances within it and the organelle. It is a double-layered membrane composed of proteins and lipids. The lipid molecules on the outer and inner part (lipid bilayer) allow it to selectively transport substances in and out of the cell.

Endoplasmic Reticulum

The **endoplasmic reticulum** (ER) is a membranous structure that contains a network of tubules and vesicles. Its structure is such that substances can move through it and be kept in isolation from the rest of the cell until the manufacturing processes conducted within are completed. There are two types of endoplasmic reticulum – rough (granular) and smooth (agranular).

- The **rough endoplasmic reticulum** (RER / granular ER) contains a combination of proteins and enzymes. These parts of the endoplasmic reticulum contain a number of ribosomes giving it a rough appearance. Its function is to synthesize new proteins.

- The **smooth endoplasmic reticulum** (SER / agranular ER) does not have any attached ribosomes. Its function is to synthesize different types of lipids (fats). The smooth ER also plays a role in carbohydrate and drug metabolism.

Golgi Apparatus

• The Golgi apparatus is a stacked collection of flat vesicles. It is closely associated with the endoplasmic reticulum in that substances produced in the ER are transported as vesicles and fuses with the Golgi apparatus. In this way, the products from the ER are stored in the Golgi apparatus and converted into different substances that are necessary for the cell's various functions.

Lysosomes

• Lysosomes are vesicles that break off from the Golgi apparatus. It varies in size and function depending on the type of cell. Lysosomes contain enzymes that help with the digestion of nutrients in the cell and break down any cellular debris or invading microorganisms like bacteria.

• A structure that is similar to a lysosome is the secretory vesicle. It contains enzymes that are not used within the cell but emptied outside of the cell, for example the secretory vesicles of the pancreatic acinar cell release digestive enzymes which help with the digestion of nutrients in the gut.

Perioxisomes

• These organelles are very similar to the lysosomes and contain enzymes that act together in the form of hydrogen peroxide to neutralize substances that may be toxic to the cell. Perioxisomes are formed directly from the endoplasmic reticulum rather than from the Golgi apparatus like lysosomes.

Mitochondria

• These are the powerhouses of the cell and break down nutrients to yield energy. Apart from producing its own energy, it also produces a high-energy compound called ATP (adenosine triphosphate) which can be used as a simple energy source elsewhere. Mitochondria are composed of two membranous layers – an outer membrane that surrounds the structure and an inner membrane that provides the physical sites of energy production. The inner membrane has many infoldings that form shelves where enzymes attach and oxidize nutrients. The mitochondria also contain DNA which allows it to replicate where and when necessary.

Nucleus

• The nucleus is the master control of the cell. It contains genes, collections of DNA, which determines every aspect of human anatomy and physiology. The DNA which is arranged into chromosomes also contains the blueprint specific for each type of cell which allows for replication of the cell. Within the nucleus is an area known as the nucleolus. It is not enclosed by a membrane but is just an accumulation of RNA and proteins within the nucleus. The nucleolus is the site where the ribosomal RNA is transcribed from DNA and assembled.

Microfilaments and Microtubules

Microfilaments and microtubules are rigid protein substances that form the internal skeleton of the cell known as the cytoskeleton. Some of these microtubules also make up the centrioles and mitotic spindles within the cell which are responsible for the division of the cytoplasm when the cell divides. The microtubules are the central component of cilia, small hair-like projections that protrude from the surface of certain cells. It is also the central component of specialized cilia like the tail of the sperm cells which beats in a manner to allow the cell to move in a fluid medium.

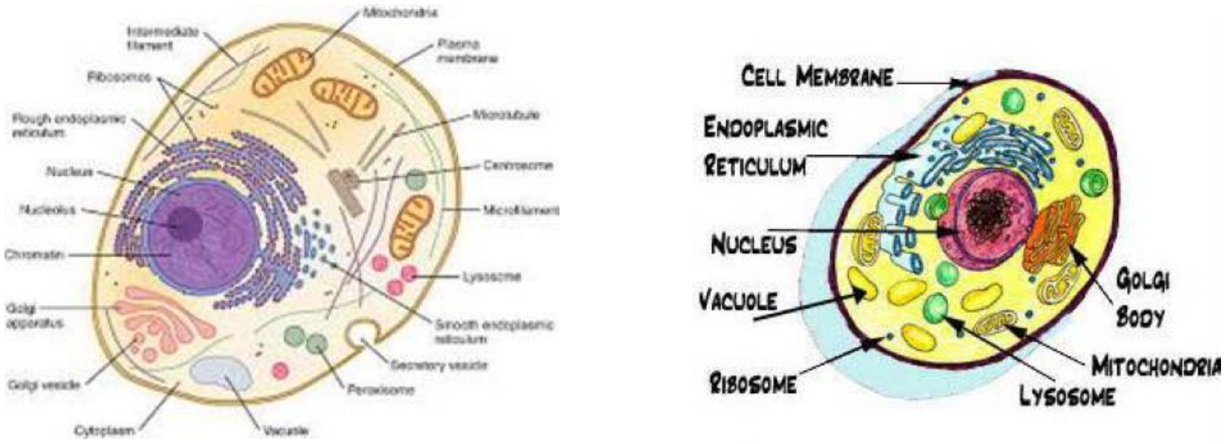


Fig1.1 Diagram of the human cell illustrating the different parts of the cell

Functions of the Human Cell :

The functions of the human cell vary based on the type of cell and its location in the human body. All the organelles work together to keep the cell alive and allow it to carry out its specific function. Sometimes these organelles are highly specialized and can vary in size, shape and number.

Its functions include intake of nutrients and other substances, processing of these compounds, production of new substances, cell replication and energy production. In specialized cells that need to be motile, like sperm cells, tail-like projections allow for cellular locomotion.

The function of each organelle has already been discussed but they shall be summarized as follows-

- The cell membrane allows substances to enter and leave the cell. While certain substance like oxygen can easily diffuse through the cell membrane, others have to actively transport through the process of endocytosis. Small particles are transported by the process of pinocytosis while larger particles are moved by the process of phagocytosis. These functions can become highly specialized to allow cells to perform specific activities, like the macrophages that phagocytose invading bacteria to neutralize it.

- Small and large substances that do not dissolve in the cytoplasm are contained within vesicles. Lysosomes attach to the vesicles and digest this material.

- The endoplasmic reticulum and Golgi apparatus synthesize different substances like protein and fats as required by the cell or designated according to its specific function. It utilizes basic nutrient molecules that are either dissolved in the cytoplasm or specific substances contained within vesicles.

- Some nutrients, specifically carbohydrates, are transported to the mitochondria where it is broken down further to yield energy. In the process, high-energy molecules known as ATP (adenosine tri-phosphate) are manufactured and provide energy for other organelles.

- The genetic material housed in the nucleus provides the blueprint necessary for the production of specific compounds by the endoplasmic reticulum and Golgi apparatus. The genes also help the cell replicate and codes for the formation of new cells.

- Secretory vesicles store some of the enzymes and other specialized substances formed by the endoplasmic reticulum and Golgi apparatus. These stored substances are released from the cell when necessary in order to complete various functions that allow the body to function as a whole.

Tissue-

Definition -Tissues are groups of similar cells that perform a common function.

Types- There are four categories of tissues in the human body: (Fig. 1.2)

i) epithelial, ii) connective, iii) muscle and iv) nervous

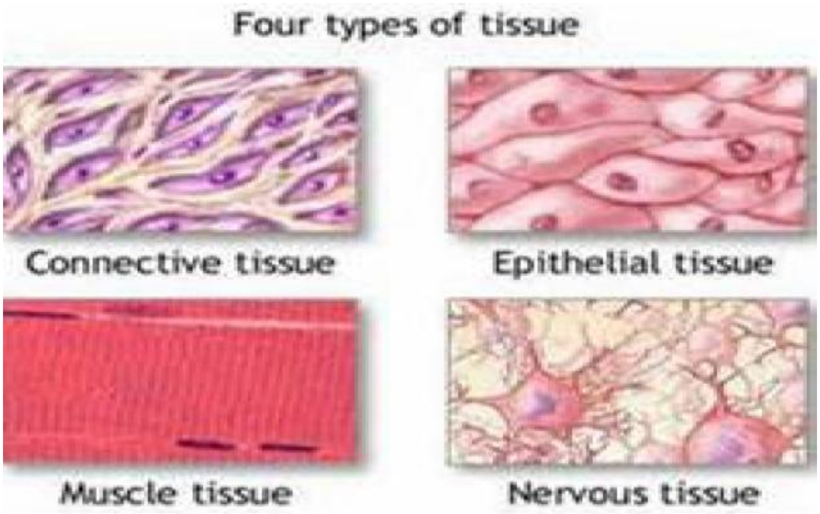


Fig. 1.2 Types of tissues

i) **Epithelial tissue**- Epithelial is made of cells arranged in a continuous sheet with one or more layers, has apical & basal surfaces. A basement membrane is the attachment between the basal surface of the cell & the underlying connective tissue.

It protects our body from moisture loss, bacteria, and internal injury.

There are two types of epithelial tissues :

(1) Covering & lining epithelia and (2) Glandular Epithelium.

• Covering and lining epithelium covers or lines almost all of your internal and external body surfaces; for example, the outermost layer of your skin and other organs, and the internal surface lining of your lymph vessels and digestive tract.

• Glandular epithelium secretes hormones or other products such as stomach acid, sweat, saliva, and milk.

The number of cell layers & the shape of the cells in the top layer can classify epithelium.

• **Simple Epithelium** - one cell layer

• **Stratified epithelium** - two or more cell layers

• **Pseudo stratified Columnar Epithelium** - When cells of an epithelial tissue are all anchored to the basement Membrane but not all cells reach the apical surface.

• **Glandular Epithelium** – (1) Endocrine: Release hormones directly into the blood stream and (2) Exocrine - Secrete into ducts.

ii) **Connective Tissue** - It generally provides structure and support to the body. There are two types of connective tissue:

• Loose connective tissue holds structures together. For example, loose connective tissue holds the outer layer of skin to the underlying muscle tissue. This tissue is also found in your fat layers, lymph nodes, and red bone marrow.

• Fibrous connective tissue also holds body parts together, but its structure is a bit more rigid than loose connective tissue. Fibrous connective tissue is found in ligaments, tendons, cartilage, and bone.

Classification of Connective Tissue :

• **Loose Connective** - fibers & many cell types in gelatinous matrix, found in skin, & surrounding blood vessels, nerves, and organs.

• **Dense Connective** - Bundles of parallel collagen fibers& fibroblasts, found in tendons& ligaments.

• **Cartilage** - Cartilage is made of collagen & elastin fibers embedded in a matrix glycoprotein & cells called chondrocytes, which was found in small spaces.

Cartilage has three subtypes :

a) **Hyaline cartilage** – Weakest, most abundant type, Found at end of long bones, & structures like the ear and nose,

b) **Elastic cartilage**- maintains shape, branching elastic fibers distinguish it from hyaline and

c) **Fibrous Cartilage** - Strongest type, has dense collagen & little matrix, found in pelvis, skull & vertebral discs.

iii) **Muscle tissue**- It differs from other tissue types in that it contracts. Muscle tissue comes in three types: cardiac, smooth, and skeletal. Those muscle tissues are made up of muscle fibers. The muscle fibers contain many myofibrils, which are the parts of the fiber that actually contract.

There are three kinds of muscle tissues: (Fig. 1.3)

i) **Skeletal Muscle** – voluntary, striated, striations perpendicular to the muscle fibers and it is mainly found attached to bones and causes movements of the body.

ii) **Cardiac Muscle** – involuntary, striated, branched and has intercalated discs and is found in the heart.

iii) **Smooth Muscle** – involuntary, non-striated, spindle shaped and is found in blood vessels & the GI tract. Smooth muscle lines the walls of blood vessels and certain organs such as the digestive and urogenital tracts.

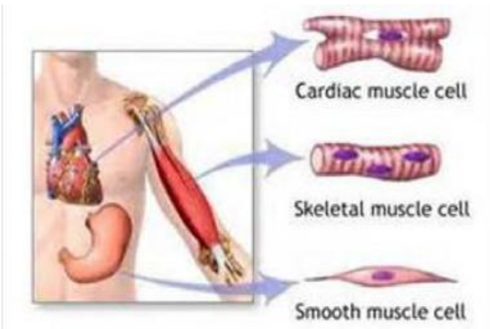


Fig. 1.3 Types of muscle tissue

iv) Nervous tissue- It forms the nervous system, which is responsible for coordinating the activities and movements of our body through its network of nerves. It consists of only two cell types in the central nervous system (CNS) & peripheral nervous system (PNS). Parts of the nervous system are the brain, spinal cord, and nerves that branch off of those two key parts.

Nervous tissue consists of two kinds of nerve cells:

i) **Neurons** - Cells that convert stimuli into electrical impulses to the brain, and ii) Neuralgia – supportive cells.

i) **Neurons**- They are the basic structural units of the nervous system. Each cell consists of the cell body, dendrites, and axon. There are 3 types of neurons:

• **Motor Neuron** – carry impulses from CNS to muscles and glands,

• **Interneuron** - interpret input from sensory neurons and end responses to motor neurons

• **Sensory Neuron** – receive information from environment and transmit to CNS.

(ii) **Neuralgia** is made up of astrocytes, oligodendrocytes, ependymal cells and microglia in the CNS, and Schwann cells and satellite cells in the PNS.They provide support functions for the neurons, such as insulation or anchoring neurons to blood vessels.

Development : All tissues of the body develop from the three primary germ cell layers that form the embryo:

• **Mesoderm –** develops into epithelial tissue, connective tissue and muscle tissue.

• **Ectoderm –** develops into nervous tissue and epithelial tissue.

• **Endoderm –** develops into epithelial tissue.

Organ Systems of the human body–

The human body is made up of multiple systems that work together to form life. Body systems are an organized group of tissue that forms a particular function. (Fig. 1.4) These functions work with other systems in the body.

Some of major organ systems and their main functions are : —

(1) The integumentary system supports and protects, regulates body temperature, makes chemicals and hormones, and acts as a sense organ.

(2) The skeletal system supports and protects, makes movement easier (with joints and muscles), stores minerals and makes blood cells in the marrow.

(3) The muscular system brings about body movement, maintains posture, and produces heat.

(4) The nervous system allows a person to communicate with the environment and integrate and controls the body.

(5) The endocrine system secretes hormones into the blood that serve to communicate with, integrate, and control mechanisms.

(6) The circulatory system transports substances through the body and establishes immunity.

(7) The lymphatic system is a subdivision of the circulatory system. It does not contain blood, but rather lymph, which is formed from the fluid surrounding body cells and diffused into lymph vessels. The major functions of the lymphatic system are the movement of fluid and its critical role in the defense mechanism of the body against disease. It also returns excess fluid back to the blood.

(8) The respiratory system exchanges oxygen from the air for the waste product carbon dioxide in the blood.

(9) The digestive system breaks down food, absorbs nutrients, and excretes solid waste.

(10) The urinary system cleans waste products from blood in the form of urine and maintains electrolyte balance, water balance, and acid-base balance.

(11) The reproductive system produces sex cells, allows transfer of sex cells and fertilization to occur, permits development and birth of offspring, nourishes offspring, and produces sex hormones.

Understanding these systems helps to know how the body functions and why the health of each of them is important for overall quality of life.

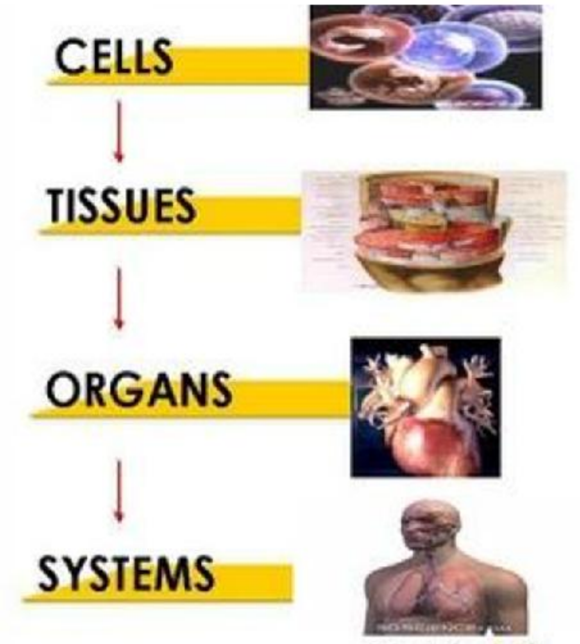


Fig. 1.4 showing how systems are formed

We will study all the systems in detail in further chapters.

1.3 Radiological Services-

- **Duties and Responsibilities of X-Ray Technician-**

The x-ray technicians are regarded as some of the most reliable and valuable professionals of the health care industry alongside paramedics and emergency medical technicians (EMTs). Accuracy and efficiency are prime qualities demanded by this profile. Besides, the applicants are expected to hold good knowledge about the medical terminologies. Medical x-ray technicians need detailed knowledge of x-ray procedures and the ability to explain the procedures to a patient. X-ray technicians are extremely important in the medical field. The education and training require for it is not that difficult.

These efficient first-responders play a critical role in diagnosing major diseases and health issues suffered by the patients. Their main job is to obtain x-ray images of the patients through the process of radiographic imaging. Along with proper diagnosis, these radiologic images are employed by the physicians to create accurate treatment plans for the patients. The processing of the x-ray images is done according to the instructions given by the physicians. Since health illnesses can occur at any given point of time, they are needed to be available for on-call and night shifts in particular.

Radiation Protection:

Medical x-ray technicians must follow regulations for protecting patients, coworkers and themselves from unnecessary exposure to radiation from the equipment and environment. Precautions to reduce the potential hazardous radiation include gloves, aprons and other shielding devices. Badges are worn to measure the radiation in a given work area, and detailed records are kept on the accumulation of radiation exposure throughout an x-ray technician's working life.

Specializations

Specialties for medical x-ray technicians include mammography, computed tomography (CT) and magnetic resonance imaging (MRI). Mammographers produce images of the breast with low-dose x-rays. CT scans and MRIs image cross sections of the body to produce a 3-dimensional image.

Besides this following are the duties of X-ray technician-

- Taking x-ray images of the patients and developing the films to reveal their skeletal or bone structures for diagnosis
- X-Ray Tech. Coordinate with various members of population and perform appropriate x-rays for same.
- Supervise efficient treatment for patients and conduct appropriate diagnosis for patients.
- Maintain and perform regular inspection on all x-ray equipments.
- Monitor equipments and ensure clean equipments to perform appropriate diagnosis.
- Manage and ensure efficient disposal of various waste material.
- Evaluate all x-ray films and coordinate with physicians on same.
- Assist patients with abnormal x-ray finding and provide results to physicians for appropriate evaluation.
- Stabilizing the patients and ensuring preparedness by educating them about the entire procedure, appropriately positioning them on the examining table, and covering them with protective clothing
- Maintain records of all X-rays and prepare reports for same.
- Prepare and update logbook and register patient number, x-ray procedure and date of procedure.
- Ensure and maintain records of x-ray films and associate cassettes.
- Schedule appointments for patients appropriate x-ray clinics.
- Manage radiographs, prepare solutions and wash all x-ray films.
- Assist patients to prepare for x-ray and operate associate machinery.
- Manage and operate x-ray machine according to patient specification.
- Evaluate angle and range of equipments and assist in appropriate results.
- Arranging timely servicing of the radiographic equipment and making minor repairs
- Interviewing the patients, determining their exact medical concerns, collecting the surveyed data, and documenting it in the system are other important duties of the technicians.
- They are also needed to position the patients correctly and ensure that there are no injuries while executing the radiologic imaging processes. For this purpose, they give prior information to the patients, comfort and prepare them for the imaging procedure.
- Sometimes, assisting the surgeons to conduct special vascular and angiography procedures
- Evaluating the dimension of the area to be radiographed

- Making copies of the x-rays and keeping a precise record of the patients who have undergone the imaging procedure
- Coordinating the work schedules and purchase of the required instruments
- Overexposure to x-rays can cause grave complications in the human body such as cancer. Though these professionals are open to severe risks like receiving harmful radiations, the protective measures observed by them keep them departed from such risks.

A rarely known fact tells that the experienced technicians are capable and skilled to identify ruptures, breakages, and other medical issues by just reviewing the images.

In many accident cases, the victims suffer injury to the body which causes fractures. The x-ray technicians take the x-rays thus reducing the work of a bone specialist.

Importance of Record Keeping of X-ray films-

X-ray files are retained for long periods to ensure the protection of individual rights, as evidence in potential claims against the Government, and for other reasons. They are often used to

- Monitor the health of Federal employees exposed to radiation or other problems related to industrial hygiene
- Diagnose the health of persons entering or separating from military service
- Treat enlisted personnel and qualified dependents
- Monitor the health of Native Americans receiving treatment at Government-administered medical clinics
- Serve as baseline data in long-term epidemiological studies
- Document the management of nuclear reactors, construction of buildings, and the analysis of equipment or products
- Provide evidence in court processing

Record managers should-

- Become familiar with the storage requirements for basic types of X-ray films
- Ensure that separate series of X-ray films are placed in storage conditions appropriate for the number of years films are to be retained
- Ensure that steps are taken to replace harmful filing enclosures or envelopes
- Ensure that conditions of storage and use protect individuals' medical privacy.

Assignments/Test

Q.1. Multiple choice questions :—

Choose the correct word and rewrite the sentences.

(1) …… is the study of structure of the human body parts.

(a) Physiology

(b) Anatomy

(c) Cytology

(d) Pathology

(2) ……… is the study of functions of the human body parts.

(a) Physiology

(b) Anatomy

(c) Cytology

(d) Pathology

(3) ……… is the study of disorders of the human body parts.

(a) Physiology

(b) Anatomy

(c) Cytology

(d) Pathology

(4) …….is the structural and functional unit of the body.

(a) organ

(b) Cell

(c) System

(d) Tissue

(5) ……… is a vertical plane that divides the body into right and left parts.

(a) Sagittal plane

(b) Transverse plane

(c) Coronal plane

(d) Oblique plane

(6) …….are the powerhouses of the cell.

(a) Ribosome

(b) Golgi bodies

(c) Mitochondria

(d) Lysosomes.

Q. 2 . Answer the following :—

(1) Define anatomy.

(2) Define physiology.

(3) Define pathology.

(4) Draw and label the diagram of cell.

(5) What are the parts of a cell?

(6) What is tissue? What are its types?

(7) What are the various anatomical planes of the body?

(8) What are the duties of radiology technician?

(9) Write about the radiological services.

(10) What is the importance of X-ray film record keeping?

(11) How will you protect yourself from radiation?

UNIT 2- MUSCULO-SKELETAL SYSTEM

Objectives : *At the end of this Unit you shall be able to—*

- *State the anatomical structure of skeletal system*
- *State the types and functions of bones and describe them*
- *State general Anatomical structure and functions of skull bones, vertebral column, bones of upper extremity and lower extremity*
- *State the functions of skull bones*
- *State the bones of pectoral girdle and pelvic girdle*
- *State the functions of the vertebral column as a whole*
- *Identify the general anatomical structure of vertebrae*
- *State the characteristics of individual vertebrae*
- *Determine the spinal deformities*
- *State the definition of joints and its types*

The skeletal system is divided into two parts-the axial skeleton and appendicular skeleton. (Fig .2.1)

- The axial skeleton includes the skull, spinal column, ribs and sternum. The appendicular skeleton includes all upper and lower extremities, the shoulder girdle and the pelvic girdle.
- Bones come in four main shapes, long, short, flat and irregular and are composed of webs of collagen fibers reinforced with calcium and phosphorous.
- The collagen provides flexibility while the minerals provide tensile strength.

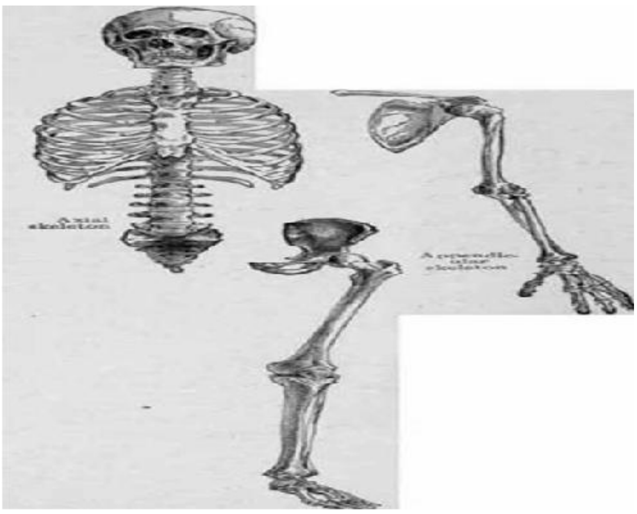


Fig.2.1 Axial and appendicular skeleton

Main functions of skeletal system(Bones)-

The skeletal system has five main functions in the body, three of which are external and visible to the naked eye, and two of which are internal.

- The external functions are: structure, movement and protection.
    - (i) **Structure-** Like the steel framework of a building, bones provide rigidity, which gives the body shape and supports the weight of the muscles and organs.

(ii) **Movement-** The skeletal system provides the levers and anchors for the muscles to pull against. All skeletal muscles have an origin and insertion point.

(iii) **Protection-** Bones protect the vital organs like brain, heart, lungs and kidneys.

The internal functions are: blood cell production and storage.

- **Blood cell formation-** Red and white blood cells are made in the red marrow of bones. At birth, and in early childhood, all bone marrow is red. As the person ages, about half of the body's marrow turns to yellow marrow – which is composed of fat cells.

- **Storage-** Bones are the depot of Calcium and phosphorous. The body uses calcium and phosphorous for bodily processes like muscle contraction. Some of those minerals are found in our diet, but they are also taken from bone. When the body needs calcium, if there isn't a ready supply in the blood, the endocrine system releases hormones that initiate the process of taking calcium from bone and releasing it into the bloodstream. When there is a surplus of blood calcium, it's put back into the bones.

Skeletal system-(Fig.2.2)

- A typical adult human skeleton consists of 206 bones, not counting many small and often variable sesamoid bones and ossicles.

- Individuals may have more or fewer bones than this owing to anatomical variations. The most common variations include additional (i.e. supernumerary) cervical ribs or lumbar vertebrae.

- Sesamoid bone counts also may vary among individuals. The figure of 206 bones is commonly repeated, but must be noted to have some peculiarities in its method of counting.

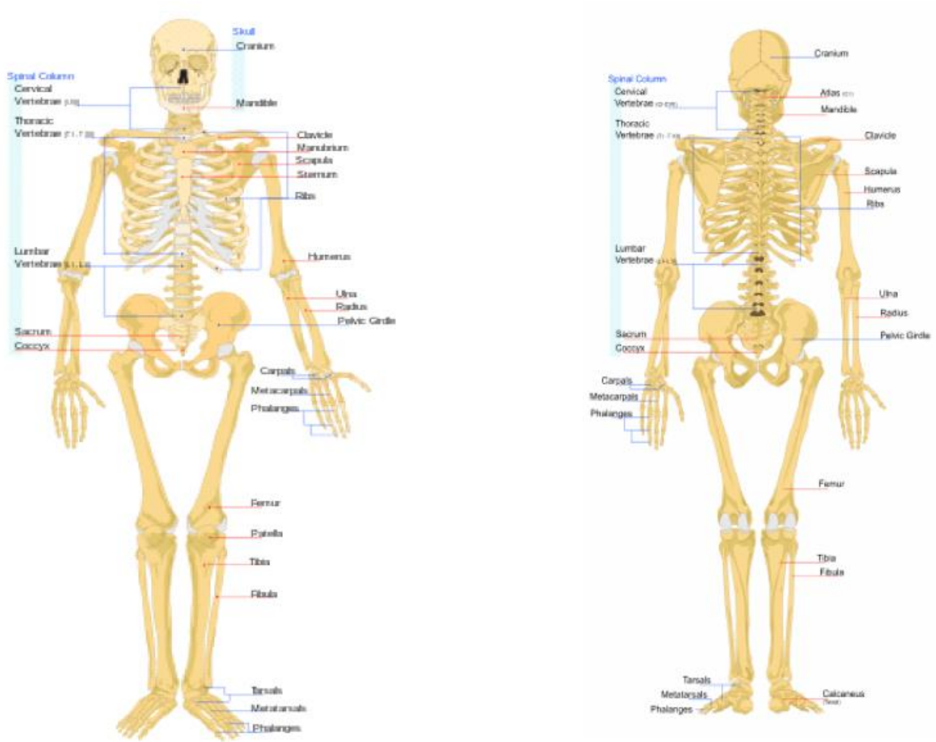


Fig .2.2 skeletal system-A) Anterior view B) posterior view

Bones in Human Body-

Human Body (206)			
Axial Skeleton (80)		Appendicular Skeleton (126)	
Skull (28)	**Torso (52)**	**Upper Extremity (32 x 2= 65)**	**Lower Extremity (31 x 2 = 62)**
Paired Bones (11 x 2 = 22) 1. Nasal 2. Lacrimal 3. Inferior Nasal Concha 4. Maxiallary 5. Zygomatic 6. Temporal 7. Palatine 8. Parietal 9. Malleus 10. Incus 11. Stapes 1. Frontal 2. Ethmoid 3. Vomer 4. Sphenoid 5. Mandible 6. Occipital	Paired Bones (12 x 2 = 24) 1. Rib 1 2. Rib 2 3. Rib 3 4. Rib 4 5. Rib 5 6. Rib 6 7. Rib 7 8. Rib 8 (False) 9. Rib 9 (False) 10. Rib 10 (False) 11. Rib 11 (Floating) 12. Rib 12 (Floating) 1. Hyoid 2. Sternum 3. Cervical Vertebra 1 (atlas) 4. C2 (axis) 5. C3 6. C4 7. C5 8. C6 9. C7 10. Thoracic Vertebrae 1 11. T2 12. T3 13. T4 14. T5 15. T6 16. T7 17. T8 18. T9 19. T10 20. T11 21. T12 22. Lumbar Vertebrae 1 23. L2 24. L3 25. L4 26. L5 27. Sacrum 28. Coccyx	1. Scapula 2. Clavicle 3. Humerus 4. Radius 5. Ulna 6. Scaphoid 7. Lunate 8. Triquetrum 9. Pisiform 10. Hamate 11. Capitate 12. Trapezoid 13. Trapezium 14. Metacarpal 1 15. Proximal Phalynx 1 16. Distal Phalynx 1 17. Metacarpal 2 18. Proximal Phalanges 2 19. Middle Phalanges 2 20. Distal Phalanges 2 21. Metacarpal 3 22. Proximal Phalange 3 23. Middle Phalange 3 24. Distal Phalanges 3 25. Metacarpal 4 26. Proximal Phalanges 4 27. Middle Phalanges 4 28. Distal Phalanges 4 29. Metacarpal 5 30. Proximal Phalanges 5 31. Middle Phalanges 5 32. Distal Phalanges 5	1. Hip (Ilium, Ischium, Pubis) 2. Femur 3. Patella 4. Tibia 5. Fibula 6. Talus 7. Calcaneum 8. Navicular 9. Medial Cuneiform 10. Middle Cuneiform 11. Lateral Cuneiform 12. Cuboid 13. Metacarpal 1 14. Proximal Phalynx 1 15. Distal Phalynx 1 16. Metacarpal 2 17. Proximal Phalange 2 18. Middle Phalange 2 19. Distal Phalange 2 20. Metacarpal 3 21. Proximal Phalange 3 22. Middle Phalange 3 23. Distal Phalange 3 24. Metacarpal 4 25. Proximal Phalanges 4 26. Middle Phalanges 4 27. Distal Phalanges 4 28. Metacarpal 5 29. Proximal Phalanges 5 30. Middle Phalanges 5 31. Distal Phalanges 5

Types of Bones in Human Body-

There are following types of bones in the human body :—

(1) Long bones

(2) Short bones

(3) Flat bones

(4) Irregular bones

(5) Sesamoid bones

(6) Pneumatic bones

(7) Short long bones (Miniature in size)

1. Long Bones - Long bones are some of the longest bones in the body, such as the Femur (Fig.2.3), Humerus and Tibia but are also some of the smallest including the Metacarpals, Metatarsals and Phalanges. The classification of a long bone includes having a body which is longer than it is wide, with growth plates (epiphysis) at either end, having a hard outer surface of compact bone and a spongy inner known an cancellous bone containing bone marrow. Both ends of the bone are covered in hyaline cartilage to help protect the bone and aid shock absorption.

Fig. 2.3. Femur-long bone

2. Short Bones - Short bones are defined as being approximately as wide as they are long and have a primary function of providing support and stability with little movement. Examples of short bones are the Carpals (Fig.2.4) and Tarsals - the wrist and foot bones. They consist of only a thin layer of compact, hard bone with cancellous bone on the inside along with relatively large amounts of bone marrow.

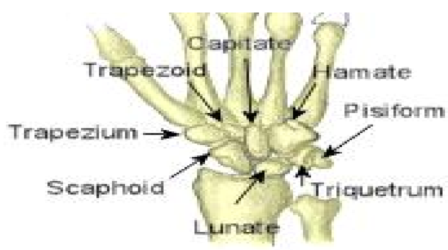


Fig. 2.4 carpals- short bones

3. Flat Bones - Flat bones are as they sound, strong, flat plates of bone with the main function of providing protection to the vital organs and being a base for muscular attachment. The classic example of a flat bone is the Scapula (shoulder blade) (Fig. 2.5). The Sternum (breast bone), Cranium (skull), os coxae (hip bone) Pelvis and Ribs are also classified as flat bones. Anterior and posterior surfaces are formed of compact bone to provide strength for protection with the centre consisting of cancellous (spongy) bone and varying amounts of bone marrow. In adults, the highest number of red blood cells is formed in flat bones.

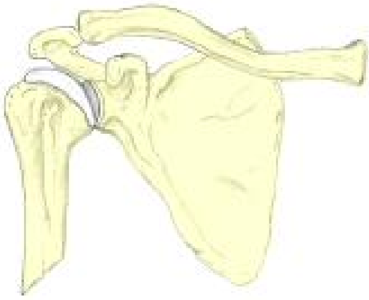


Fig. 2.5 The scapula - a flat bone

4. Irregular Bones - These are bones in the body which do not fall into any other category, due to their non-uniform shape. Good examples of these are the Vertebrae (Fig.2.6), Sacrum and Mandible (lower jaw). They primarily consist of cancellous bone, with a thin outer layer of compact bone.

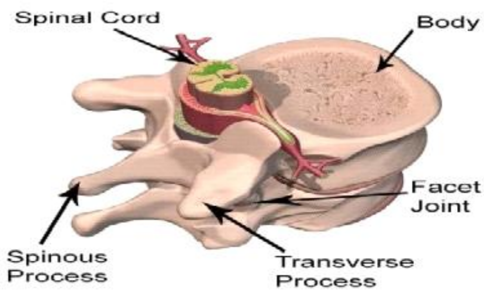


Fig.2.6 Vertebrae - irregular bones

5. Sesamoid Bones -Sesamoid bones are usually short or irregular bones, imbedded in a tendon. The most obvious example of this is the Patella (knee cap) which sits within the Patella (Fig.2.7) or Quadriceps tendon. Other sesamoid bones are the Pisiform (smallest of the Carpals) and the two small bones at the base of the 1st Metatarsal. Sesamoid bones are usually present in a tendon where it passes over a joint which serves to protect the tendon.

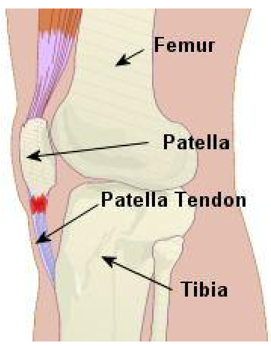


Fig. 2.7 The patella - a sesamoid bone

6. Pneumatic bones - The bones are flat or irregular and possessing hollow spaces within their body which contains air. E.g. Ethmoid, maxilla, mastoid and body of sphenoid

7. Short long bones (Miniature in size) - The length of the bones exceeds the other measurements. The shape of the bones is the same as compare to long bones but is miniature in size, e.g. metacarpals, metatarsals and phalanges.

2.1 Skull -

Bones of the Skull

Skull : Cranium and Facial Bones :

The skull consists of 8 cranial bones and 14 facial bones. The bones are listed in Table , but note that only six types of cranial bones and eight types of facial bones are listed because some of the bones (as indicated in the table) exist as pairs. (Fig. 2.8)

The cranial bones - are 8 in no.

- The occipital bone-1
- The parietal bone-2
- The frontal bone-1
- The temporal bone-2
- The sphenoid bone-1
- The ethmoid bone-1

The facial bones - are 14 in no.

- The nasal bones-2
- The maxillae (upper jaw)-2
- The lacrimal bone-2
- The zygomatic bone-2
- The palatine bone-2
- The inferior nasal concha-2
- The vomer-1
- The mandible (lower jaw)-1

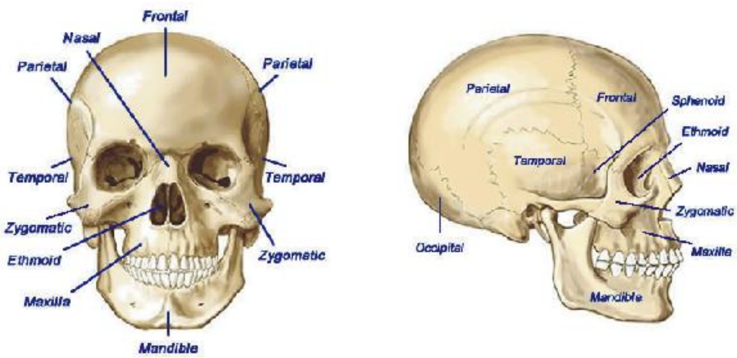


Fig. 2.8 Skull bones

Functions of skull bones -

- The bones of the skull provide protection for the brain and the organs of vision, taste, hearing, equilibrium, and smell.
- The bones also provide attachment for muscles that move the head and control facial expressions and chewing.

Figure 2.11 and Fig.2.12 illustrate specific characteristics of these bones.

General features of the skull are as follows :—

- Sutures are immovable interlocking joints that join skull bones together.
- Fontanels are spaces between cranial bones that are filled with fibrous membranes. The spaces provide pliability for the skull when it passes through the birth canal and for brain growth during infancy. Bone growth eventually fills the spaces by age two.
- Sutural (Wormian) bones are very small bones that develop within sutures. Their number and location vary.
- The cranial vault denotes the top, sides, front, and back of the cranium. The cranial floor (base) denotes the bottom of the cranium.
- Cranial fossae are three depressions in the floor of the cranium. These fossae, called the anterior, middle, and posterior cranial fossae, provide spaces that accommodate the shape of the brain.
- The nasal cavity is formed by cartilage and several bones. Air entering the cavity is warmed and cleansed by mucus lining the cavity.
- Sinuses (paranasal sinuses) are mucus-lined cavities inside cranial and facial bones that surround the nasal cavity. The cavities secrete mucus that drains into the nasal cavity. The cavities also act as resonance chambers that enhance vocal (and singing) quality.

Sutures of the skull – (Fig.2. 9)

- The bones of the skull are united together by immovable joints called sutures, with the exception of one of the bones of the face, the mandible or lower jaw, which articulates with the temporal at the temporo mandibular joint.
- The principal sutures are :—

(i) The coronal suture between the frontal bone and two parietal bones.

(ii) The sagittal suture between the two parietal bones, running from before backwards long the top of the skull.

(iii) The lambdoid suture between the occipital bone and the two parietal bones.

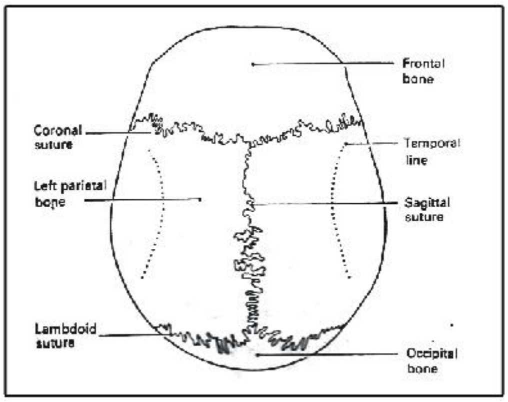


Fig.2.9 Sutures of the skull

The Fontanellae –

The bones of the skull of an infant at birth are not completely ossified. The spaces between the bones are filled in by membrane, and at the angles of the bones these membranes are called fontanellae. The largest of these is situated at the junction of the frontal and the two parietal bones, where the coronal sagittal sutures meet. This is called the anterior fontanelle. It is diamond shaped, measures about 4 cm (1 1/2inches) from back to front, and forms and spot on the head of an infant through which the brain can be felt pulsating. This fontanelle normally closes at the age of eighteen months.

The posterior fontanelle lies at the junction of the two parietal and the occipital bones. It closes soon after birth.

The paranasal sinuses- are air-filled spaces located within the bones of the skull and face.

- They are centered on the nasal cavity and have various functions, including lightening the weight of the head, humidifying and heating inhaled air, increasing the resonance of speech, and serving as a crumple zone to protect vital structures in the event of facial trauma. Four sets of paired sinuses exist: maxillary, frontal, sphenoid, and ethmoid (see the Fig.2.10 below).

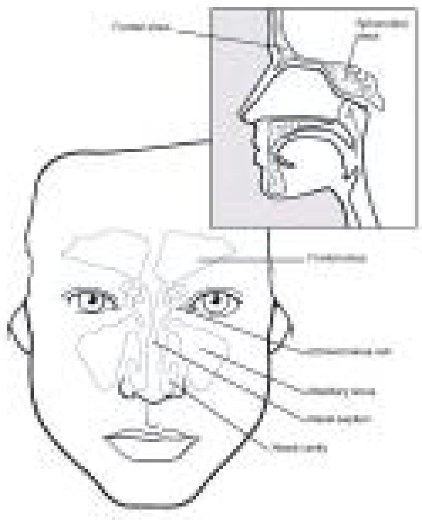


Fig.2.10 Sinuses, anterior and sectioned views

Maxillary sinus-

- The maxillary sinus is the largest paranasal sinus and lies inferior to the eyes in the maxillary bone. It is the first sinus to develop and is filled with fluid at birth. It grows according to a biphasic pattern, in which the first phase occurs during years 0-3 and the second during years 6-12. The earliest phase of pneumatization is directed horizontally and posteriorly, whereas the later phase proceeds inferiorly toward the maxillary teeth.
- This development places the floor of the sinus well below the floor of the nasal cavity. The shape of the sinus is a pyramid, with the base along the nasal wall and the apex pointing laterally toward the zygoma. The natural ostium of the maxillary sinus is located in the superior portion of the medial wall.

- The anterior maxillary sinus wall houses the infra-orbital nerve, which runs through the infra-orbital canal along the roof of the sinus and sends branches to the soft tissues of the cheek. The thinnest portion of the anterior wall is above the canine tooth, called the canine fossa, which is an ideal entry site for addressing various disease processes of the maxillary sinus.
- The roof of the maxillary sinus is the floor of the orbit. Behind the postero-medial wall of the maxillary sinus lies the pterygo-palatine fossa, a small inverted space that houses several important neurovascular structures and communicates with several skull base foramina. The infra-temporal fossa lies behind the posterolateral wall of the maxillary sinus.
- The maxillary sinus is supplied by branches of the internal maxillary artery, which include the infra-orbital, alveolar, greater palatine, and spheno-palatine arteries. It is innervated by branches of the second division of the trigeminal nerve, the infraorbital nerve, and the greater palatine nerves.

Frontal sinus-

- The frontal sinus is housed in the frontal bone superior to the eyes in the forehead. It is formed by the upward movement of anterior ethmoid cells after the age of 2. Growth of this sinus increases at the age of 6 and continues until the late teenage years. The frontal sinuses are funnel-shaped structures with their ostia located in the most dependent portion of the cavities. The posterior wall of the frontal sinus, which separates the sinus from the anterior cranial fossa, is much thinner than its anterior wall.
- The frontal sinus is supplied by the supra-orbital and supra trochlear arteries of the ophthalmic artery. It is innervated by the supra orbital and supra trochlear nerves of the first division of the trigeminal nerve.

Sphenoid sinus-

- The sphenoid sinus originates in the sphenoid bone at the center of the head. It arises from the nasal embryonic lining. The sinus reaches its full size by the late teenage years. The sphenoid sinus is variably pneumatized and may extend as far as the foramen magnum in some patients.
- The thickness of the walls of the sphenoid sinus is variable, with the antero-superior wall and the roof of the sphenoid sinus (the planum sphenoidale) being the thinnest bones. The sphenoid sinus ostium is located on the anterosuperior surface of the sphenoid face, usually medial to the superior turbinate.
- The sphenoid sinus is supplied by the spheno-palatine artery, except for the planum sphenoidale, which is supplied by the posterior ethmoidal artery. Innervation of the sphenoid sinus comes from branches of the first and second divisions of the trigeminal nerve.

Ethmoid sinus-

- The ethmoid sinuses arise in the ethmoid bone, forming several distinct air cells between the eyes. They are a collection of fluid-filled cells at birth that grow and pneumatize until the age of 12. The ethmoid cells are shaped like pyramids and are divided by thin septa. They are bordered by the middle turbinate medially and the medial orbital wall laterally. The ethmoid labyrinth may extend above the orbit, lateral and superior to the sphenoid, above the frontal sinus, and into the roof of the maxillary sinus.

- The ethmoid sinuses are supplied by the anterior and posterior ethmoidal arteries from the ophthalmic artery (internal carotid system), as well as by the sphenopalatine artery from the terminal branches of the internal maxillary artery (external carotid system).

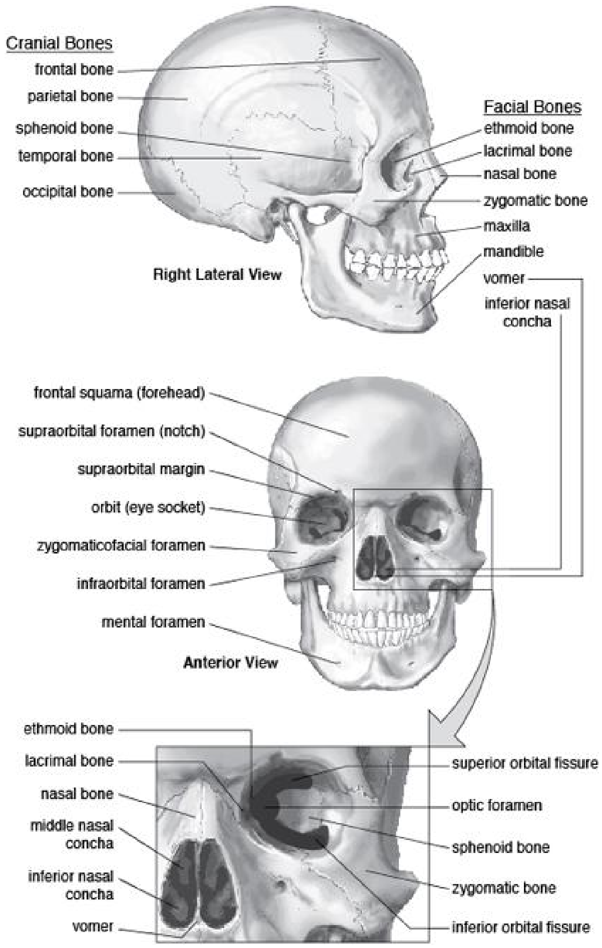


Figure. 2. 11. The right lateral view and anterior view of the skull bones

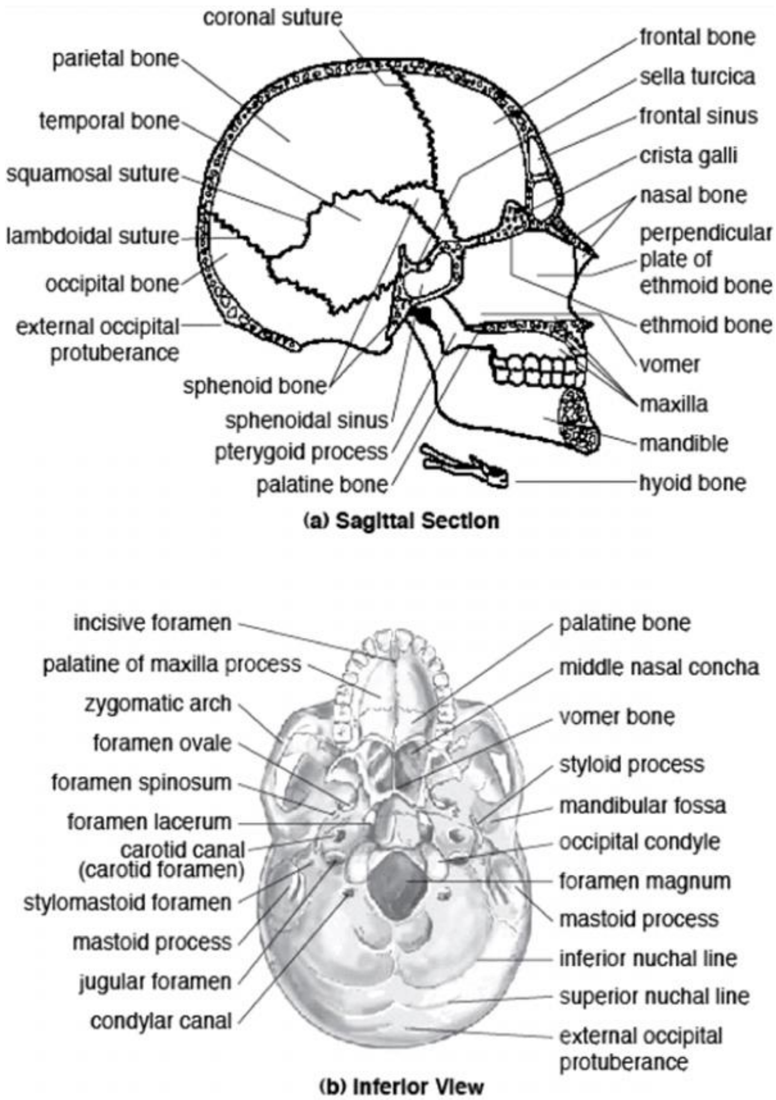


Figure 2.12 The sagittal section and inferior view of the skull bones

2.2 The Vertebral Column:

The vertebral column (also known as the backbone or the spine), is a column of approximately 33 small bones, called vertebrae. (Fig.2.13) The column runs from the cranium to the apex of the coccyx, on the posterior aspect of the body. It contains and protects the spinal cord.

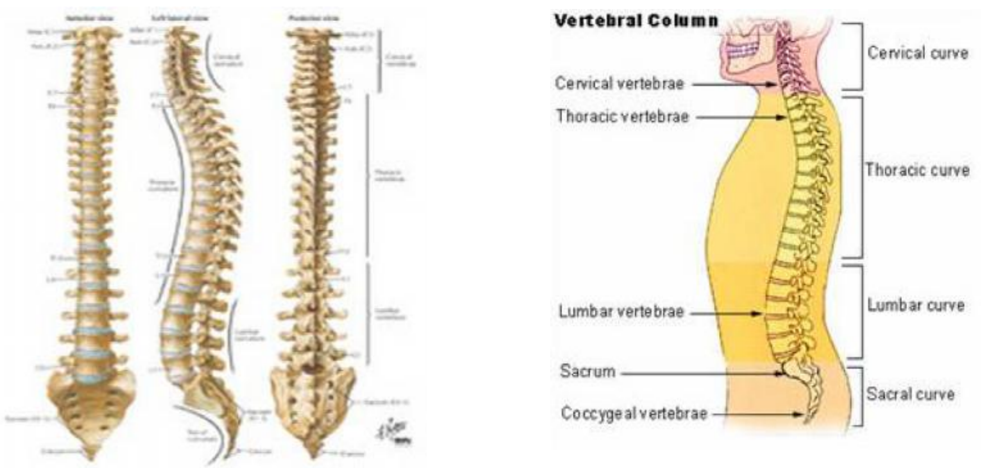


Fig . 2.13 – The vertebral column viewed from the side.
The five different regions are shown and labeled.

Vertebral curves or curvatures: (Fig. 2.14)

A] In sagittal plane- Antero-posterior curvatures in the vertebral column are of two types – primary and secondary.

Primary curves are present at the time of birth and are mainly due to the shape of vertebral bodies. These are concave forwards. Thoracic curve and sacral curve are the primary curves.

Secondary curves are formed due to the posture and appear after birth and are mainly due to the shape of inter vertebral discs. The secondary curves are convex forwards. Cervical curve and lumbar curves are the secondary curves. Cervical curve appear during 4-9 months after birth, when infant start supporting his head. The lumbar curve appears during 12- 18 months, when the child assumes upright posture.

B] In coronal plane- The side to side or lateral curvature is a slight curve in the thoracic region which is convex towards the right side possibly due to the greater use of the right upper limb and the pressure of the aorta. Due to the curves vertebral column is elastic. The numbers of curves give it a higher resistance to weight.

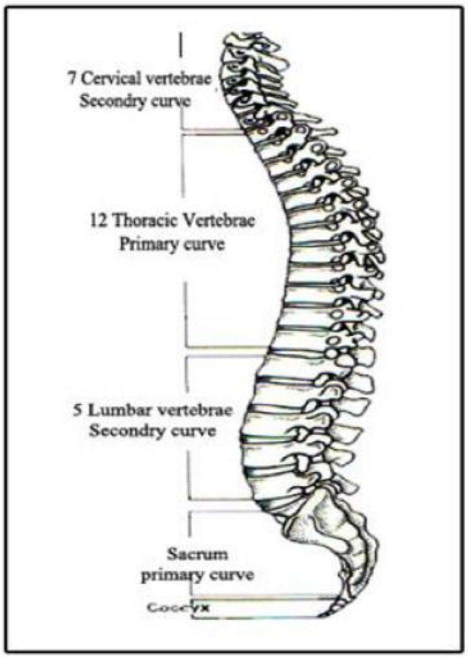


Fig.2.14 Lateral view of spine showing Vertebral curves

Movements of spine-

1. Flexion is bending forwards.
2. Extension is bending backwards.
3. Lateral flexion is bending side to side.
4. Rotation is twisting the trunk.
5. Circumduction is combination of movements.

Functions of the Vertebral Column-

The most important functions of the vertebral column are as follows:

- **Protection**: it encloses the spinal cord, shielding it from damage
- **Support**: it carries the weight of the body above the pelvis (below the pelvis, the lower limbs take over)
- **Axis**: the vertebral column forms the central axis of the body.
- **Movement**: it has roles in both posture and movement

The vertebral column can be separated into five different regions. Each region is characterised by a different vertebral structure. Before looking, at individual structures, we first need to look at the general blueprint of a vertebrae.

The General Structure of Vertebra-Although the vertebrae do have significant differences in size and shape between groups, they have the same basic structure. Each vertebra consists of a vertebral body, situated anteriorly, and a posterior vertebral arch.(Fig.2.15)

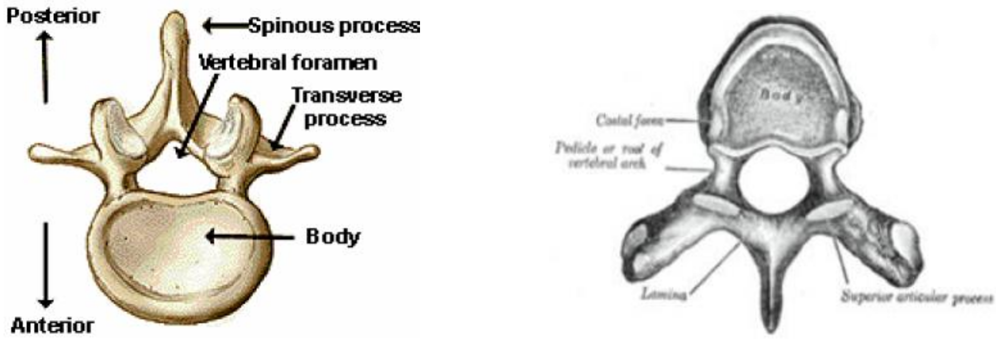


Fig. 2.15 Typical vertebra

Vertebral Body-This is the anterior part of the vertebrae. It it the weight baring component, and its size increases as the vertebral column descends (having to bare increasing amounts of weight each time). The superior and inferior aspects of the vertebral body are lined with hyaline cartilage. Due to their dense bony structure, a radiograph of the vertebral column can be used clinically to diagnose osteoporosis.

Vertebral arch (or neural arch) is the posterior part of a vertebra. It consists of:

- a pair of pedicles
- a pair of laminae, and
- 7 processes:
- 2 superior articular processes
- 2 inferior articular processes
- 2 transverse processes
- 1 spinous process
- Adjacent vertebral bodies are separated by a fibrocartilginous intervertebral disk.(Fig. 2.16)

Features of intervertebral disk-

- The intervertebral disk is a fibrocartilage cylinder that lies between the vertebrae, joining them together.
- They act to permit the flexibility of the spine, and as a shock absorber. In the lumbar and thoracic regions, they are wedge shaped, supporting the curvature of the spine.
- There are two regions in the vertebral disk; the nucleus pulposus and annulus fibrosus. The annulus fibrosis is tough and collagenous, surrounding the nucleus pulposus. The nucleus pulposus is jelly like, and is located posteriorly.

Clinical Relevance: Herniated Intervertebral Disks (P.I.D.)

• In a herniation of the intervertebral disk, the nucelus pulposus ruptures, breaking through the outer layer. This occurs in a posterior and lateral direction, putting pressure on the spinal cord, resulting in a variety of neurological and muscular symptoms.

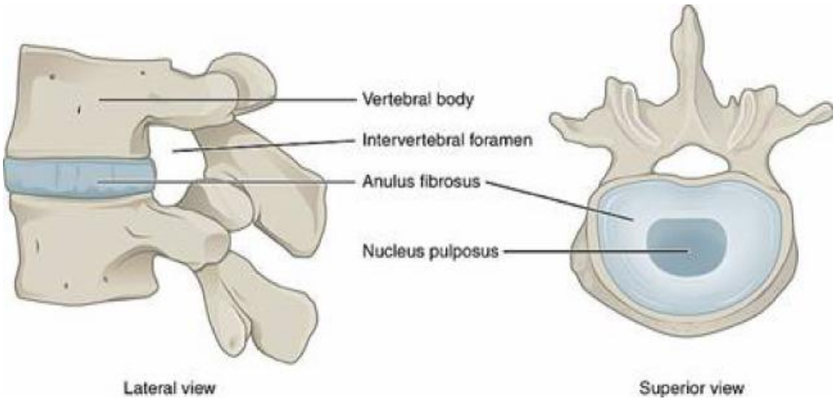


Fig 2.16 – Diagram of a typical intervertebral disk.

Vertebral Arch- The vertebral arch refers to the lateral and posterior parts of the vertebrae.With the vertebral body, the vertebral arch forms an enclosed hole, called a vertebral foramen. The foramina of the all vertebrae line up to form the vertebral canal, which encloses the spinal cord.The vertebral arches have a number of bony prominences, acting as attachment sites for muscles and ligaments:

• **Pedicles**: There are two of these, one left and one right. They point posteriorly, meeting the flatter laminae.

• **Lamina**: The bone between the transverse and spinal processes

• **Transverse processes**: These extend laterally and posteriorly away from the pedicles. In the thoracic vertebrae, the transverse processes articulate with the ribs

• **Articular processes**: At the junction of the lamina and the pedicles, superior and inferior processes arise. These articulate with the articular processes of the vertebrae above and below.

• **Spinous processes**: Posterior and inferior projection of bone, a site of attachment for muscles and ligaments

Characteristics of Individual Vertebrae-

• Cervical Vertebrae-

There are seven cervical vertebrae in the human body. They have three main distinguishing features:(Fig.2.17)

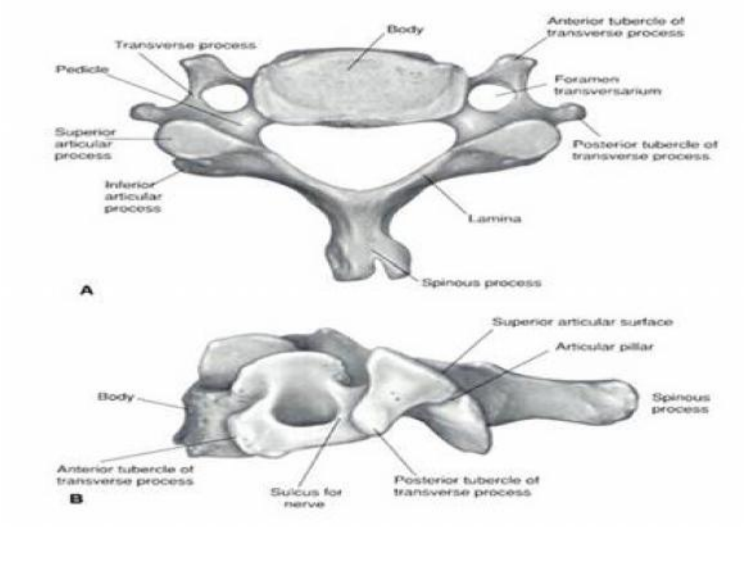


Fig 2.17– Distinguishing features of a cervical vertebrae. (Note the triangular shape of the vertebral foramen.)

- The spinous process bifurcates into two, known as a bifid spinous process.
- There is also a foramen (known as foramen transversarium) in the each transverse process. The the vertebral arteries pass through the holes in each vertebrae as they ascend to supply the brain.
- The vertebral foramen in triangular in shape
- There are some cervical vertebrae that are unique within themselves. C1 and C2 (called the atlas and axis respectively), are specialized to allow for the movement of the head. (Fig. 2.18)

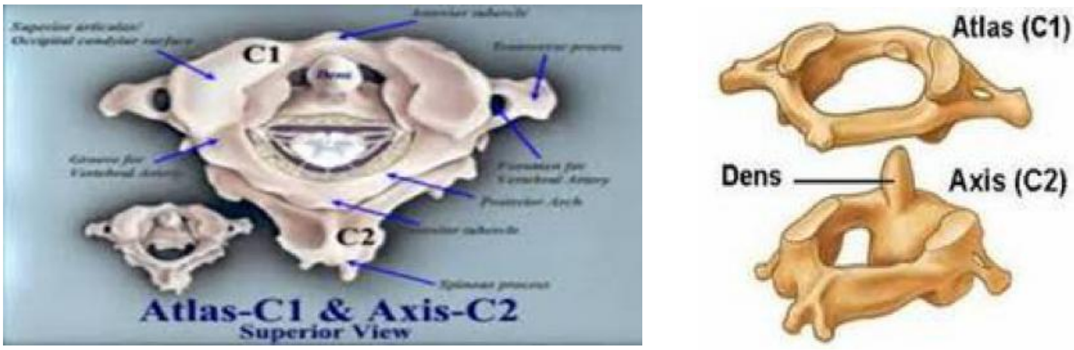


Fig.2.18- Atlas and Axis

- The C7 vertebra has a much longer spinous process, which does not bifurcate.

Thoracic Vertebrae

- The thoracic vertebrae increase in size from T1 through T12 and represent the 12 thoracic vertebrae. The thoracic vertebrae are situated between the cervical (neck) vertebrae and the lumbar vertebrae.
- These thoracic vertebrae provide attachment for the ribs and make up part of the back of the thorax or chest, producing the bony thorax.
- Each thoracic vertebrae has two 'demi facets' on each side of its vertebral body. These articulate with the head of its respective rib, and the rib inferior to it. (.(Fig.2.19)
- On the transverse processes of the thoracic vertebrae there is a costal facet for articulation with its respective rib.
- The spinous processes are slanted inferiorly and anteriorly. This offers increased protection to the spinal cord, preventing an object like a knife entering the spinal canal through the intervetebral discs.
- In contrast to the cervical vertebrae, the vertebral foramen is circular.

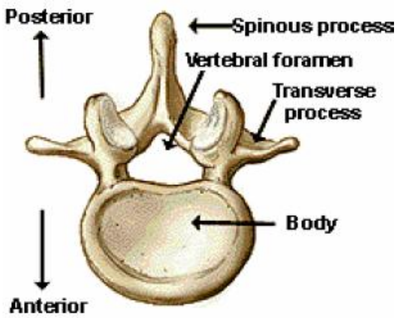


Fig 2.19–Anterior, posterior view of a thoracic vertebra

Lumbar Vertebrae

- These are the largest of the vertebrae, of which there are five.
- They act to support the weight of the upper body, and have various specialisations to enable them do this.
- Lumbar vertebrae have very large vertebral bodies, which are kidney shaped. (Fig.2.20)
- They lack the characteristic features of other vertebrae, with no foramen transversarium, costal facets, or bifid spinous processes.
- However, like the cervical vertebrae, they have a triangular shaped vertebral foramen.

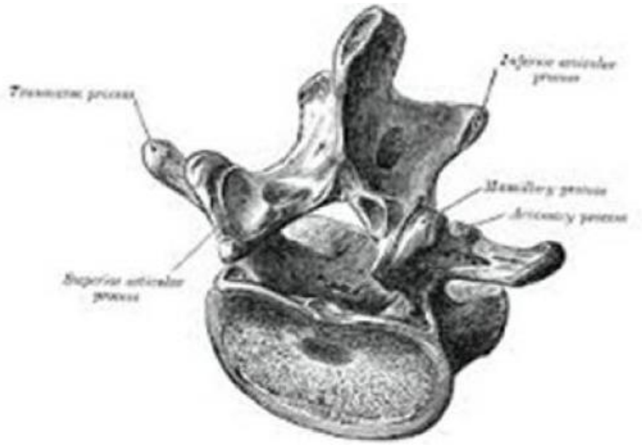


Fig.2.20- Features of lumbar vertebra

Sacrum and Coccyx

The sacrum is a collection of five fused vertebrae. It is described as a upside down triangle, with the apex pointing inferiorly. On the lateral walls of the sacrum are facets, for articulation with the pelvis at the sacro-iliac joints. The coccyx is a small bone, which articulates with the apex of the sacrum. It is recognized by its lack of vertebral arches. (Fig 2.21) Due to the lack of vertebral arches, there is no vertebral canal, and so the coccyx does not transmit the spinal cord.

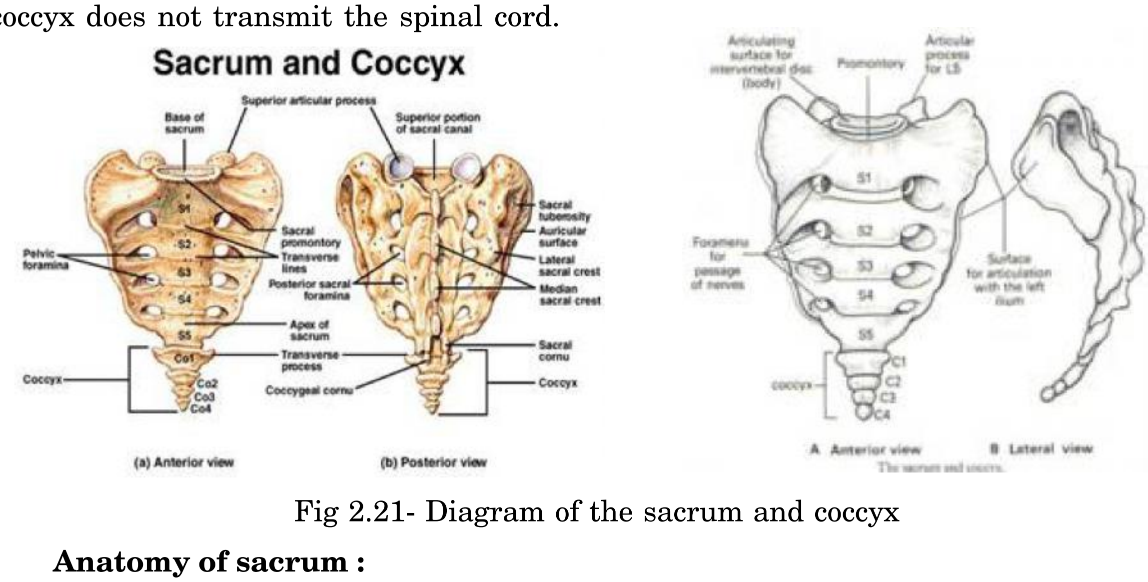


Fig 2.21- Diagram of the sacrum and coccyx

Anatomy of sacrum :

It is a large flattened, triangular bone formed by the fusion of 5 sacral vertebrae. It forms the posterior part of the bony pelvis, articulating on either side with hip bone at the sacro-iliac joint. The upper part of sacrum is massive because it supports the body weight and transmits it to hip bones. The lower part tapers rapidly. It is a triangular bone having a base or superior surface, an apex or lower end and four surfaces- pelvic, dorsal and a pair of lateral. Pelvic surface is smooth and concave, the dorsal surface is irregular and convex, lateral surfaces are irregular and partly articular. Sacrum is divided by two rows of foramina into a median portion traversed by sacral canal and a pair of lateral masses formed by the fusion of the transverse processes posteriorly and the costal process anteriorly.

Anatomy of coccyx :

Coccyx is a small triangular bone formed by fusion of four rudimentary coccygeal vertebrae which progressively diminish in size from above downwards. Occasionally the number of vertebrae is 5 and rarely 3. The bone is directed downwards and forwards, making a continuous

Joints of the Vertebral Column-For every vertebra, there are five articulations. The vertebral bodies indirectly articulate with each other, and the articular processes also form joints. (Fig. 2.22) The vertebral body joints are cartilaginous joints, designed for weight bearing. The articular surfaces are covered by hyaline cartilage, and are connected by a fibro cartilage intervertebral disk. There are two ligaments that strengthen these joints; the anterior and posterior longitudinal ligaments. The anterior longitudinal ligament is thick and prevents hyperextension of the vertebral column. The posterior longitudinal ligament is weaker and prevents hyperflexion.

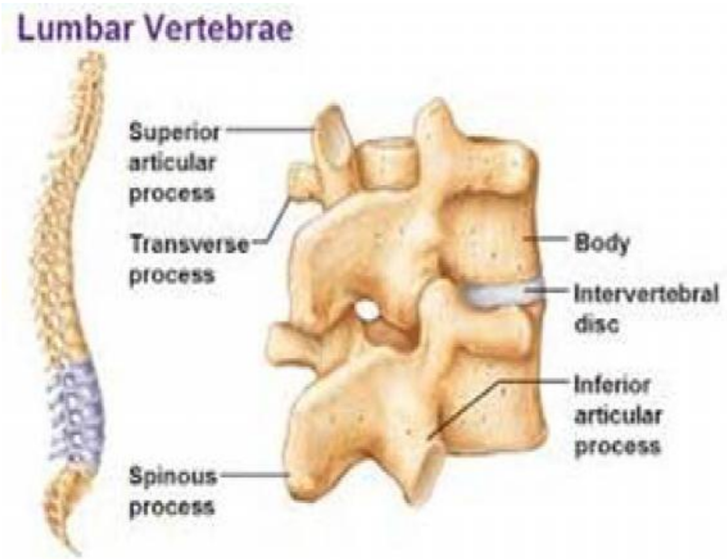


Fig.2.22 - Joints of vertebrae

The joints between the articular facets are called facet joints. These allow for some gliding motions between the vertebrae. They are strengthened by various ligaments:

- **Ligamentum Flava** : extends from lamina to lamina
- **Infraspinous and Supraspinous** : joins the spinous processes together
- **Intertransverse ligaments** : extends between transverse ligaments

Spinal Deformities

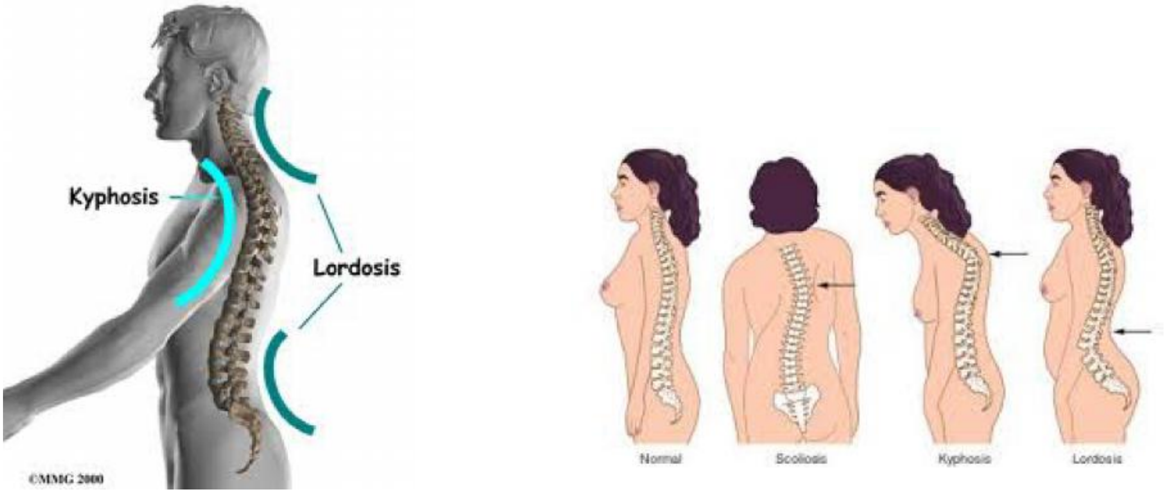
There are several clinical syndromes resulting from an abnormal curvature of the spine:(Fig.2.23)

Kyphosis : Excessive thoracic curvature, causing a hunchback deformity.

Lordosis : Excessive lumbar curvature, causing a swayback deformity.

Scoliosis : A lateral curvature of the spine, usually of unknown cause.

Cervical Spondylosis : A decrease in the size of the intervertebral foramina, usually due to degeneration of the joints of the spine. The smaller size of the intervertebral foramina puts pressure on the exiting nerves, causing pain.



Fig– 2.23 Deformities of the Spine- a) Scoliosis b) Kyphosis c) Lordosis

2.3 **Pectoral Girdle-**

BONES OF PECTORAL GIRDLE

1. SCAPULA

The scapula is a flat triangular bone, located on the posterolateral thoracic wall. They are two in no. in the human body.

Features-

The scapula has three angles: (Fig.2.24)

- the inferior,
- the lateral
- the superior

Between them are the three borders:

- the medial – which runs parallel to the vertebral column
- the lateral – which is directed laterally and down
- the superior border – which has a suprascapular notch for passage of nerves and blood vessels.

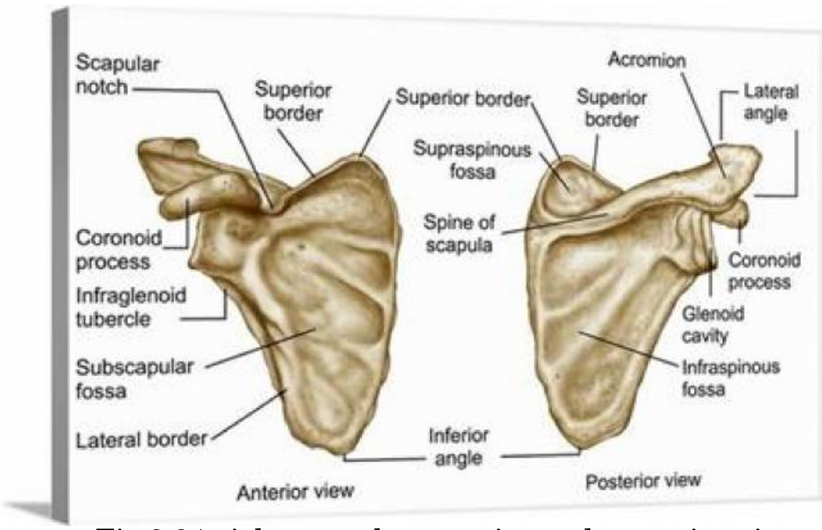


Fig.2.24 right scapula- anterior and posterior view

Other Landmarks-

• The costal surface of the scapula faces the ribs in the front and has a shallow subscapular fossa.

• The dorsal surface of the scapula is convex and has a crest extending backwards called the spine of scapula. Above this crest there is a depression called the supraspinous fossa and the below it is the infraspinous fossa. These fossae are filled by homonymous muscles.

• The lateral end of the scapular spine forms a broad flattened process called the acromion.

• On the top of the acromion there is an articular facet which forms a joint with the clavicle. The broad lateral angle of the scapula forms an articular fossa (glenoid cavity) which articulates with the head of the humerus. Above and below the articular fossa there are, respectively: the supraglenoid and infraglenoid tubercles. These tubercles are sites of attachment of muscles of the arm. A curved coracoid process extends to the front from the upper border of the scapula.

2. CLAVICLE

The clavicle is a long curved bone situated between the acromion and the clavicular notch of sternum. (Fig.2.25)They are two in no. in the human body.

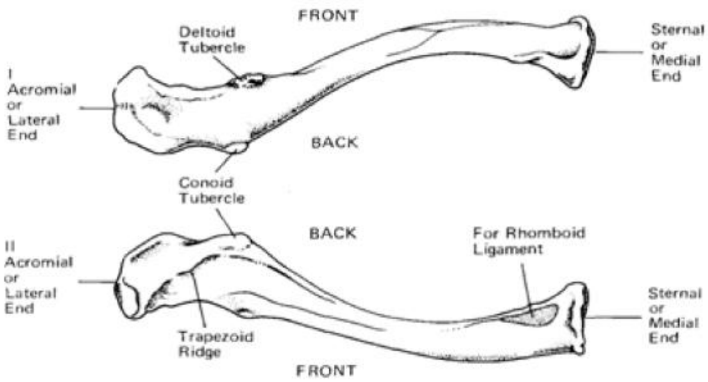


Fig.2.25 Left clavicle- superior and inferior view

Features-

The clavicle has a body and two ends: acromial and sternal.

On its inferior surface, closer to the acromial end, there are two tuberosities: the conoid tubercle and trapezoid line. These are attachment site of ligaments.

2.4 BONES OF UPPER EXTREMITY

1. ARM (HUMERUS)- The “Arm” bone is called the Humerus, the largest, longest bone of the upper limb. (Fig.2.26)They are two in no. in human body. Humerus is a long tubular bone with two ends (epiphyses) and a body (its diaphysis).

Landmarks-

• The superior epiphysis is thickened forming the head of the humerus.

• Near the spherical head are the greater and lesser tubercles which serve for attachment of muscles. The greater tubercle is situated laterally to the lesser tubercle. Down from the greater tubercle extends a crest of the greater tubercle.

• Between the two tubercles there is an intertubercular sulcus. In this groove lies the tendon of the long head of biceps.

• The thinnest place between the head and the body of the humerus is the surgical neck. It is the most frequent site of fractures of the upper end of the humerus. The body of the humerus is cylindrical in its upper half and trihedral in its lower half. Almost halfway down the lateral side of the bone there is the deltoid tuberosity. This is an attachment site for the deltoid muscle.

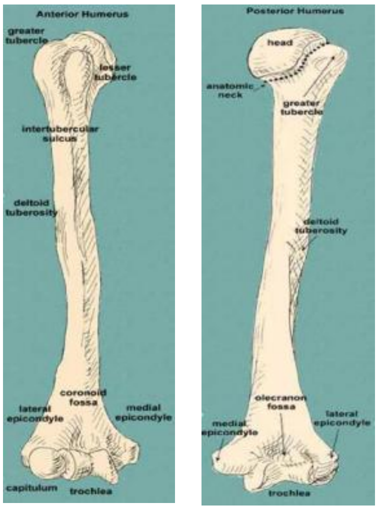


Fig.2.26 Right Humerus- anterior and posterior view

• On the posterior surface is a radial groove spiraling downwards medial to lateral.

• The large distal end forms the condyle of the humerus.

• The medial part of the condyle—called the trochlea—articulates with the ulnar.

• The lateral part, the capitulum, articulates with the radius.

• On the anterior surface of the humerus, above the trochlea, is the coronoid fossa, and to its lateral one is the radial fossa.

• On the posterior surface above the trochlea is the olecranon fossa.

• On the lateral and medial surfaces, above the condyle, are two protuberances called the lateral and medial epicondyles.

• On the posterior surface of the medial epicondyle is the groove for ulnar nerve.

• The epicondyles continue into the medial and lateral supracondylar crests.

2. FOREARM

The “Forearm” has two parallel long bones, called the Radius and the Ulna.(Fig2.27)

• Ulna, situated medially and the radius, situated laterally.

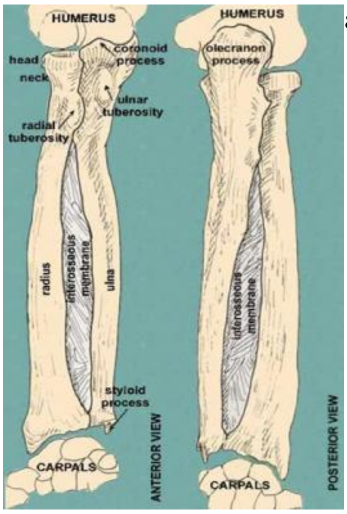
• Between their diaphyses is the interosseus space of the forearm.

• Each bone has three borders including the interosseus border which is turned towards the neighbouring bone.

Radius-

• Proximally the head of the radius articulates with the condyle capitulum of the humerus.

• The head has a flat depression which is the articular facet. Beneath it is a cylindrical neck of the radius. On the front medial surface of the bone above the neck is the radial tuberosity. This is the site of attachment of biceps brachii tendon. On the medial side of the distal end of the radius is the ulnar notch. On the lateral side is the styloid process. On the inferior side of the distal end is the carpal articular surface. It articulates with the carpal bones.



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Ulna

• The larger proximal end of the ulnar has a trochlear notch, which articulates with the trochlea of the humerus.

• This notch ends with two processes: one is the larger posterior ulnar process (olecranon) and the other is the coronoid process. The latter is shorter than the olecranon and has a radial facet for articulation with the head of the radius.

• There is a radial tuberosity above the coronoid process, which serves for attachment for muscles.

• The distal part of the ulna ends with its head, which continue medially into styloid process.

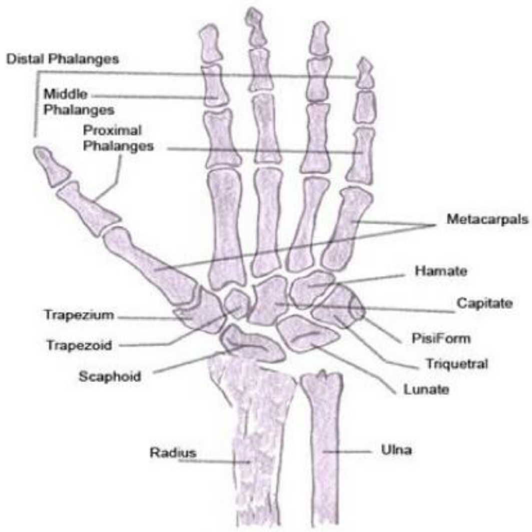
• The head has a circular articular circumference for articulating with the radius.

3. HAND– This is the distal portion of upper limb. It consists three sets of bones which are 27 in number. (Fig.2.28)

1) 8 "wrist" bones or Carpals

2) 5 "hand" bones or Metacarpals

3) 14 "finger" bones or Phalanges



HAND ANATOMY

Carpals-

• Scaphoid/Navicular, Lunate, Triquetral and Pisiform- These bones articulate with the radius and ulna

• Trapezium, Trapezoid, Capitate and Hamate- These bones articulate with the Metacarpals

and form the palm of hand.

Metacarpals are numbered 1-5

Each metacarpal has a:

- Base= proximal end, articulates with carpals
- Shaft= middle portion
- Head= distal end, form your knuckles

Phalanges form fingers.

• Each finger, except for the thumb, has three phalanges– Proximal, middle, and distal

• Each one is numbered from 1-5

1= thumb,

2=index finger,

3=middle finger,

4=ring finger,

5=little finger

2.5 **Bones of the Lower Extremity**

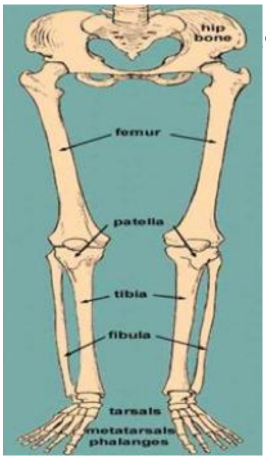
The lower limb is sub-divided by hip joint, knee joint and ankle joint into following regions-

- Pelvic girdle (pelvis)
- Thigh
- Leg
- Foot

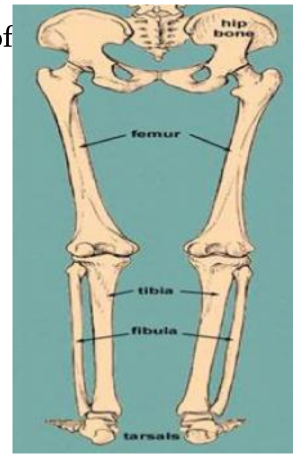
There are 32 bones in each lower limb as follows-(Fig.2.29)

- hip bone (1)
- femur (1)
- patella (1)
- tibia (1)
- fibula (1)
- tarsals (8)
- metatarsals (5)
- proximal phalanges (5)
- intermediate phalanges (5)
- distal phalanges (4)
- The bones of the leg and foot form part of the appendicular skeleton that supports

the many muscles of the lower limbs. These muscles work together to produce movements such as standing, walking, running, and jumping. At the same time, the bones and joints of the leg and foot must be strong enough to support the body's weight while remaining flexible enough for movement and balance.



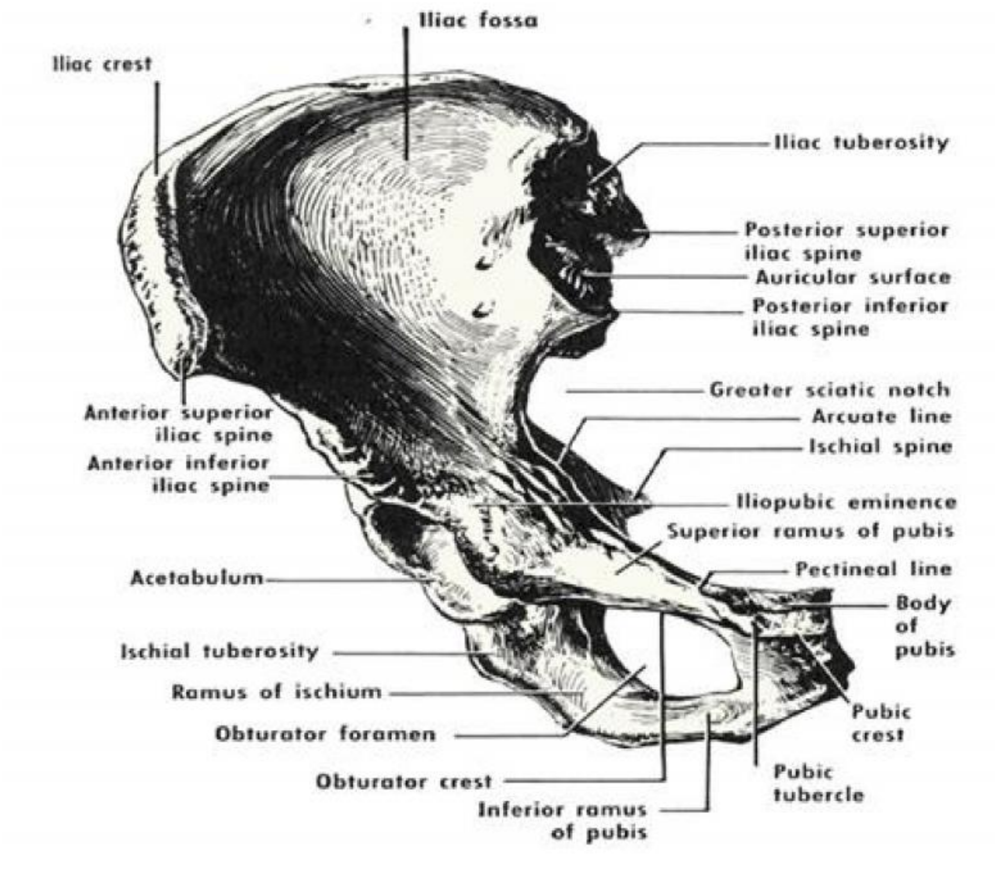
9 Bones of

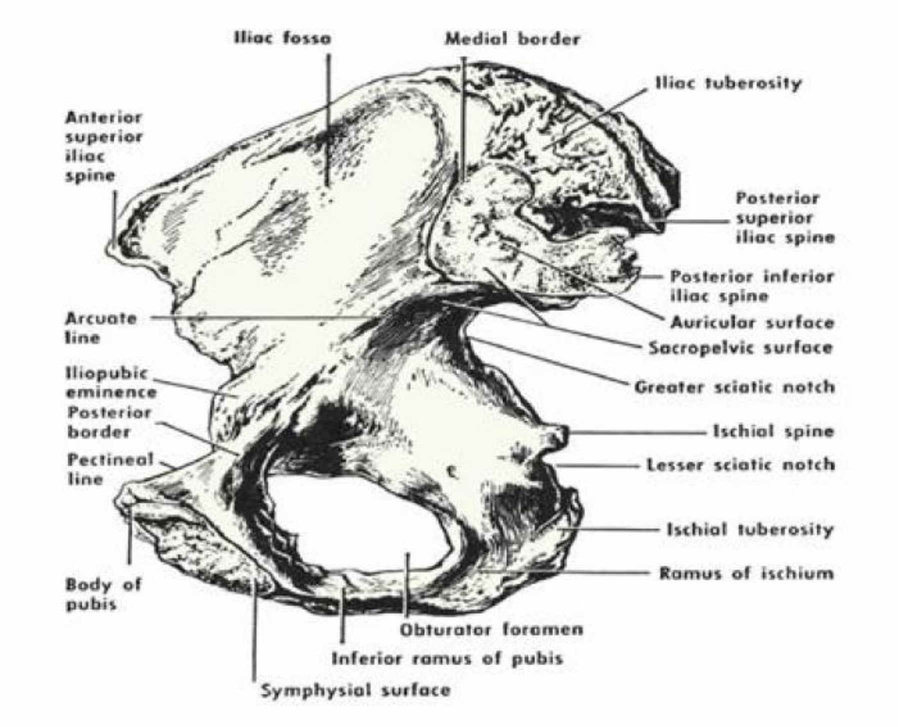


Hip bone

It is also called as innominate bone.(Fig. 2.30) Each hip bone (os coxae) has an:

- Ilium: The large upper portion, often called "hip bone".
- Ishium: The posterior/inferior bone, often called "seat bone".
- Pubis: The anterior/inferior bone, which connects in front at the pubic symphysis.
- Acetabulum: point of fusion of all three, also called "hip socket".





Landmarks for the Ilium-

- Iliac crest: the thick, upper margin
- Iliac fossa: anterior smooth surface
- Anterior superior/ Anterior inferior Iliac spine: sites for muscle attachments
- Posterior superior/ Posterior inferior Iliac spine: sites for muscle attachments
- Greater sciatic notch
- Auricular surface

Landmarks for the Ishium :

- Ishial tuberosity: site for attachment of hamstring muscles
- Ishial spine: site for ligament attachment, measurement site for pelvic opening.
- Obturator foramen: the only "hole" or opening for nerves/blood vessels.
- Ishial ramus: point of connection with inferior ramus of pubis.

Landmarks for the Pubis :

- Superior/inferior ramus
- Pubic crest and tubercle: site of attachment for abdominal muscles
- Pubic symphysis: articulation point that connects the two pubic bones together
- Pubic arch: helps to determine male vs. female pelvis

Bone of thigh-Femur

• Single bone of the thigh; is the largest, longest, and strongest bone in the body.(Fig.2.31)

• The femur cannot be palpated (felt) because it is covered by large muscles.

• The head of the femur articulates with the acetabulum of the os coxae, and has a small, pit shaped depression called the fovea capitis, which is where the ligamentum teres helps to secure the head into the acetabulum.

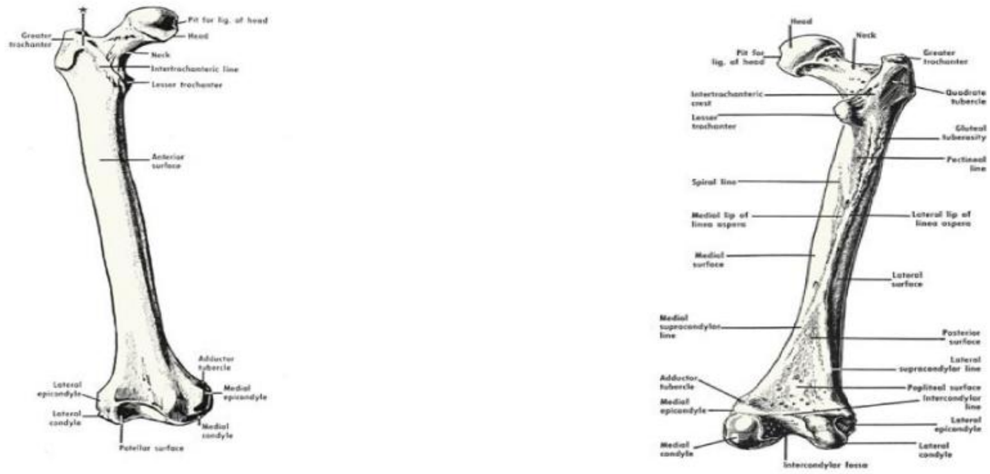


Fig.2.31 Right Femur- anterior, posterior view

Landmarks of the femur :

• Head; fovea capitis

• Neck: often a site for fracture

• Greater and lesser trochanter: attachment site for muscles

• Intertrochanteric line and crest: line is anterior, crest is posterior

• Linea aspera: "rough line" on the posterior aspect of shaft

• Medial and lateral condyle: articulation with the tibia

• Medial and lateral epicondyle: only part of the femur that can be felt at the knee

• Intercondylar fossa or notch: cruciate ligaments attach here.

• Patellar surface: the smooth surface above the condyles on the anterior side that articulates with the patella

• Popliteal surface: surface above the condyles on the posterior side of patella

Patella- It is the largest sesamoid bone in the body (Fig.2.32). It is also known as knee cap.

• The patella is a triangular shaped sesamoid bone encased in the patellar tendon.

• The patellar tendon attaches the quadriceps femoris muscle to the tibia.

• It has two surfaces; the rounded, convex anterior surface, and the smooth, articular posterior surface.

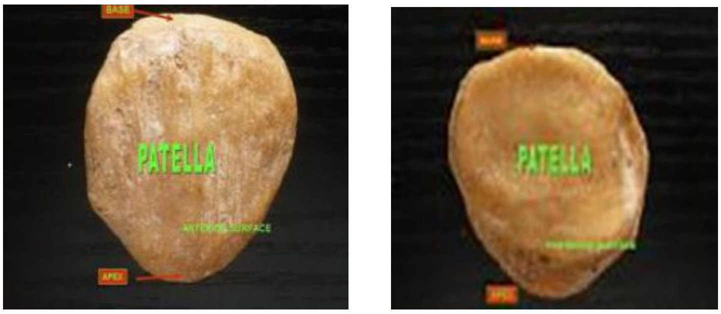


Fig.2.32 Patella- anterior and posterior surface

Bones of leg- (Fig.2.33)

1) **Tibia**- It is the medial bone of leg. The tibia bears most of the body's weight. The tibia forms the flexible ankle joint with the tarsal bones of the foot.

2) **Fibula**- It is the lateral bone of leg. The fibula supports the muscles of balance in the lower leg and ankle.

Tibia

• The bone on the medial side of the lower leg. It is the weight-bearing bone of the lower leg. ("Tough Tibia") (Fig.2.33)

Landmarks of proximal tibia (upper portion)-

• Medial and lateral condyle- Articulates with the medial and lateral condyle of the femur.

• Intercondylar eminence- The ridge of bone that projects upwards between the condyles. It is the attachment site for the cruciate ligaments, medial meniscus, and lateral meniscus.

• Fibular facet- Just below the lateral condyle where the head of the fibula articulates with Tibia.

Other Landmarks:

• Tibial tuberosity: roughened protuberance on the anterior surface just below the condyles. Is the attachment site of the patellar ligament.

• Anterior crest: On the anterior surface of the body. Can palpate the entire length, also called 'shin'.

• Medial malleolus: Large bony prominence on the medial side of ankle

• Fibular notch: Distal end of tibia, where it articulates with the distal end of the fibula.

Fibula

• The slender bone on the lateral side of the lower leg. 'Fine Fibula'. (Fig.2.33)

Landmarks :

• Head: The enlarged proximal end, articulating with the fibular facet of the tibia

• Shaft or body: Long slender portion

• Lateral malleolus: Large prominence on the lateral, distal end. Articulates with the lateral surface of the talus.

• Malleolar fossa: Small fossa on the distal end opposite lateral malleolus

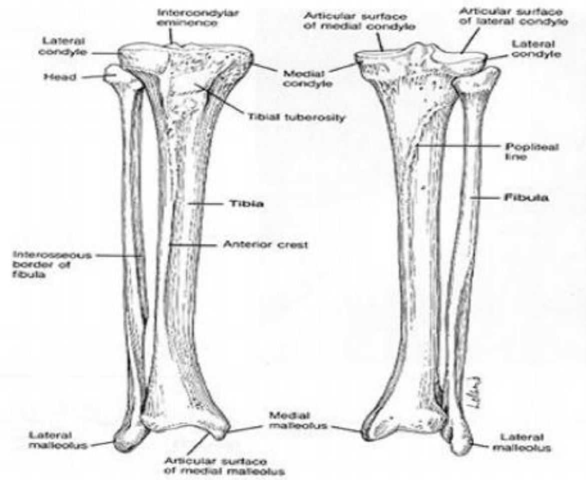


Fig.2.33 The bones of leg- Tibia and fibula

Bones of the Foot-

The human foot and ankle is a strong and complex mechanical structure containing exactly 26 bones, 33 joints (20 of which are actively articulated). (Fig.2.34)

The foot can be subdivided into the hind foot, the mid foot, and the forefoot:

The hind foot is composed of the talus (or ankle bone) and the calcaneus (or heel bone). The two long bones of the lower leg, the tibia and fibula, are connected to the top of the talus to form the ankle. Connected to the talus at the subtalar joint, the calcaneus, the largest bone of the foot, is cushioned inferiorly by a layer of fat.

The five irregular bones of the mid-foot, the cuboid, navicular, and three cuneiform bones, form the arches of the foot which serves as a shock absorber. The midfoot is connected to the hind- and fore-foot by muscles and the plantar fascia.

The forefoot is composed of five toes and the corresponding five proximal long bones forming the metatarsus. Similar to the fingers of the hand, the bones of the toes are called phalanges and the big toe has two phalanges while the other four toes have three phalanges. The joints between the phalanges are called interphalangeal and those between the metatarsus and phalanges are called metatarsophalangeal joints.

Both the mid-foot and forefoot constitute the dorsum (the area facing upwards while standing) and the planum (the area facing downwards while standing).

The instep is the arched part of the top of the foot between the toes and the ankle.

In short there are three sets of bones in the foot. These are –

1) Bones of the ankle are TARSALS- They are 7 in no. and named as-Talus, calcaneum, cuboid, lateral cuneiform, intermediate cuneiform, medial cuneiform and Navicular (boat shaped)

2) Bone of the "ball" of foot are called METATARSALS- In between the tarsals and toes (phalanges)

3) Bones of toes are called PHALANGES (plural). A singular bone is called a phalanx

Body weight is distributed among the seven tarsals, which can shift slightly to provide minute adjustments to the position of the ankle and foot. The calcaneum, or heel bone, is the largest tarsal bone and rests on the ground when the body is standing.

The tarsal bones and the five long metatarsal bones together form the arches of the foot. Body weight supported by the foot is spread across the arches from the tarsal and metatarsal bones, which make contact with the ground while standing. Like the tarsal bones, the position of the metatarsals can be adjusted to change the shape of the foot and affect balance and posture of the body.

Extending from the distal end of the metatarsals are the tiny phalanges of the toes. The phalanges connect to several muscles in the leg via long tendons. The phalanges can flex or extend to change the shape of the foot for balance, and provide added leverage to the foot during walking.

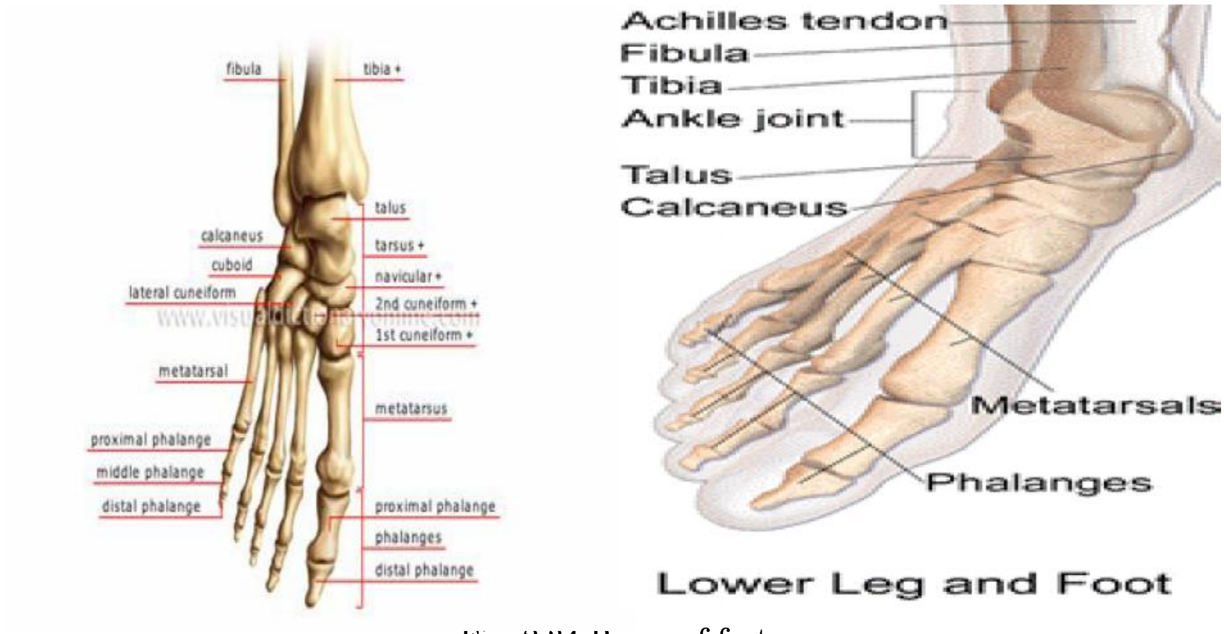


Fig. 2.34 Bones of foot

2.6 Thoracic Cage

It consists of- (Fig.2.35)

- Ribs
- Thoracic vertebrae
- Sternum

Functions of the thoracic cage- The ribs serve several important purposes.

- They protect the heart and lungs from injuries and shocks that might damage them.
- Ribs also protect parts of the stomach, spleen, and kidneys.
- Provide the space for intercostals muscles
- Helps in breathing; As you inhale, the muscles in between the ribs lift the rib cage up, allowing the lungs to expand. When you exhale, the rib cage moves down again, squeezing the air out of your lungs.

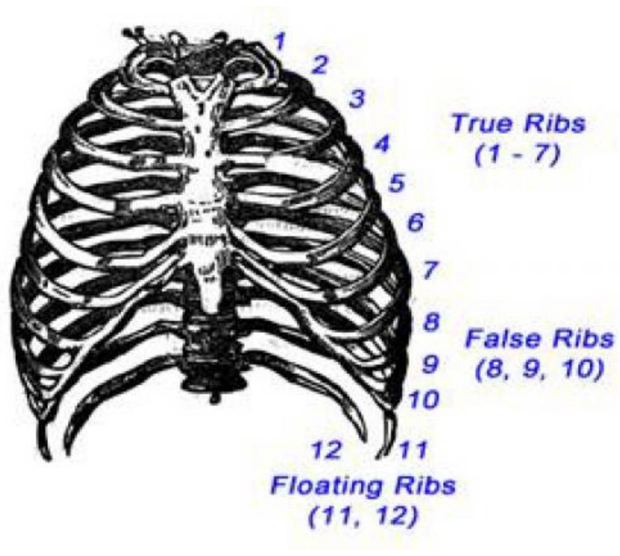


Fig.2.35 Thoracic cage

Ribs-

- The ribs are elastic arches of bone, which form a large part of the thoracic skeleton.
- They are twelve in number on either side; but this number may be increased by the development of a cervical or lumbar rib, or may be diminished to eleven.
- The first seven are connected behind with the vertebral column, and in front, through the intervention of the costal cartilages, with the sternum; they are called true or vertebro-sternal ribs. R1-R7 pairs. (Fig.2.36)
- The remaining five are false ribs; of these, the first three have their cartilages attached to the cartilage of the rib above (vertebro-chondral) 8-10 (Fig.2.36)
- The last two are free at their anterior extremities and are termed floating or vertebral ribs. (Fig.2.37)
- The ribs vary in their direction, the upper ones being less oblique than the lower; the obliquity reaches its maximum at the ninth rib, and gradually decreases from that rib to the twelfth.
- The ribs are situated one below the other in such a manner that spaces called intercostal spaces are left between them. The length of each space corresponds to that of the adjacent ribs and their cartilages; the breadth is greater in front than behind, and between the upper than the lower ribs.
- The ribs increase in length from the first to the seventh, below which they diminish to the twelfth. In breadth they decrease from above downward; in the upper ten the greatest breadth is at the sternal extremity.
- Vertebrosternal = "True ribs" -ribs 1 to 7 attach directly to the sternum through their costal cartilage.
- Vertebrochondral = "False ribs" =ribs 8-10 costal cartilage articulate indirectly with the sternum by joining the costal cartilages of ribs above.
- Vertebral Ribs = "Floating ribs" ribs 11 and 12 no anterior attachment. They are free and palpable.

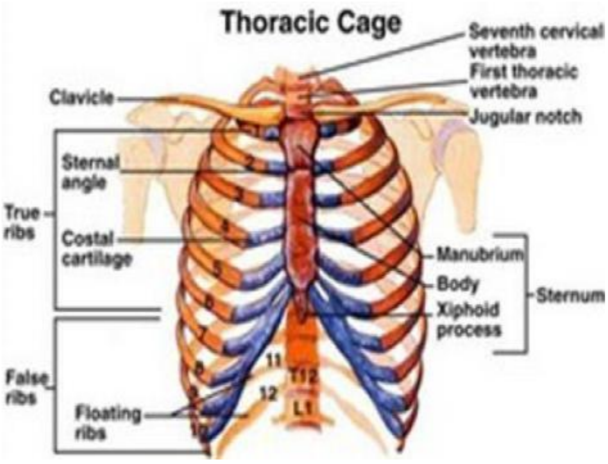


Fig.2.36 True ribs, false ribs and floating ribs

Fig.2.37 Floating Ribs

Characteristics of a typical rib-

- Each rib has two extremities- posterior or vertebral and an anterior or sternal and an intervening portion- the body or shaft. (Fig.2.38)

Posterior Extremity.—The posterior or vertebral extremity presents for examination a head, neck, and tubercle.

• The head is marked by a kidney-shaped articular surface, divided by a horizontal crest into two facets for articulation with the depression formed on the bodies of two adjacent thoracic vertebræ; the upper facet is the smaller; to the crest is attached the interarticular ligament.

• The neck is the flattened portion which extends laterally from the head; it is about 2.5 cm. long, and is placed in front of the transverse process of the lower of the two vertebræ with which the head articulates. Its anterior surface is flat and smooth, its posterior rough for the attachment of the ligament of the neck, and perforated by numerous foramina. Of its two borders the superior presents a rough crest for the attachment of the anterior costotransverse ligament; itsinferior border is rounded.

• On the posterior surface at the junction of the neck and body, and nearer the lower than the upper border, is an eminence—the tubercle; it consists of an articular and a non-articular portion. The articular portion, the lower and more medial of the two, presents a small, oval surface for articulation with the end of the transverse process of the lower of the two vertebræ to which the head is connected. The non-articular portion is a rough elevation, and affords attachment to the ligament of the tubercle. The tubercle is much more prominent in the upper than in the lower ribs.

Body—The body or shaft is thin and flat, with two surfaces, an external and an internal; and two borders, a superior and an inferior.

• The external surface is convex, smooth, and marked, a little in front of the tubercle, by a prominent line, directed downward and laterally; and is called the angle. At this point the rib is bent in two directions, and at the same time twisted on its long axis. The distance between the angle and the tubercle is progressively greater from the second to the tenth ribs. The portion between the angle and the tubercle is rounded, rough, and irregular, and serves for the attachment of the Longissimus dorsi.

• The internal surface is concave, smooth, directed a little upward behind the angle, a little downward in front of it, and is marked by a ridge which commences at the lower extremity of the head; this ridge is strongly marked as far as the angle, and gradually becomes lost at the junction of the anterior and middle thirds of the bone.

• Between it and the inferior border is a groove, the costal groove, for the intercostal vessels and nerve. At the back part of the bone, this groove belongs to the inferior border, but just in front of the angle, where it is deepest and broadest, it is on the internal surface. The superior edge of the groove is rounded and serves for the attachment of an Intercostalis internus; the inferior edge corresponds to the lower margin of the rib, and gives attachment to an Intercostalis externus. Within the groove are seen the orifices of numerous small foramina for nutrient vessels which traverse the shaft obliquely from before backward.

• The superior border, thick and rounded, is marked by an external and an internal lip, more distinct behind than in front, which serve for the attachment of Intercostalis externus and internus.

• The inferior border is thin, and has attached to it an Intercostalis externus.

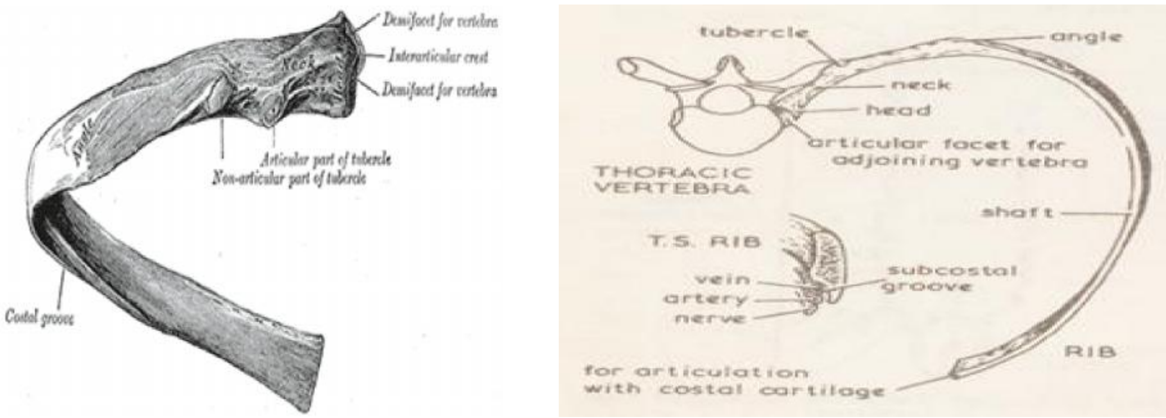


Fig.2.38 Typical rib

Atypical ribs – Features are not similar, they are having special features- 1St, 2nd, 10th 11th and 12th pairs

Anterior Extremity- The anterior or sternal extremity is flattened, and presents a porous, oval, concave depression, into which the costal cartilage is received.

Sternum

It is the antero-medial bone of chest. It consists of manubrium, a body (gladiolus) and a xiphoid process (most inferior portion of the sternum).It is also known as the breastbone. (Fig.2.39)

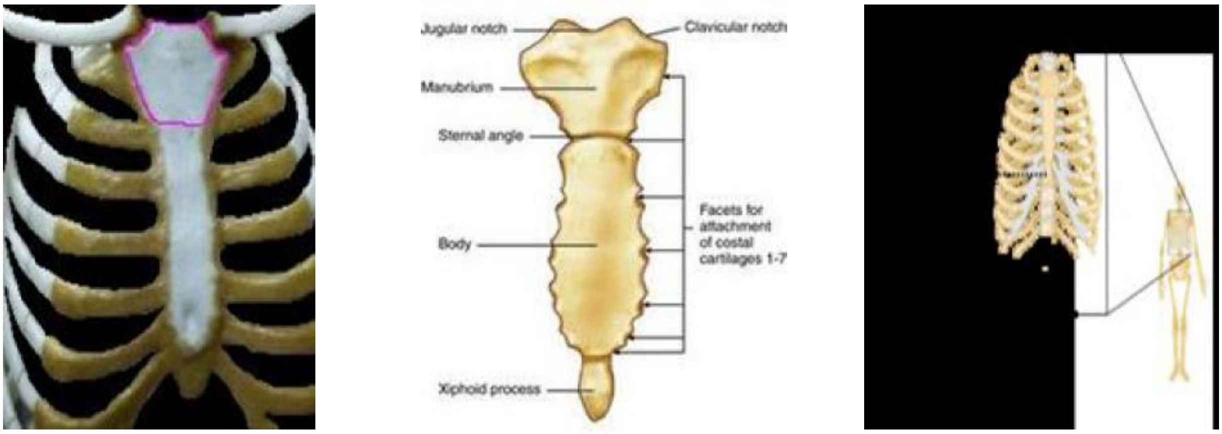


Fig.2.39 Sternum and its parts

• Body-It is long ,narrow and thin nearly rectangular lies opposite to 5th to 9th thoracic vertebra. It possesses two surfaces, two ends, two lateral borders.

• Manubrium-It is a triangular shaped region on which articulates with the clavicles of the appendicular skeleton and with the cartilages of the first two pairs of ribs. It forms Sterno clavicular joints (S.C.J.)

• Xiphoid Process-This structure is the most inferior of the sternebrae. In a young person it is hyaline cartilage, but is bone by the time one is 40 years old. It is sometimes broken when a person receives CPR. It is part of the origin for the diaphragm and insertion for the rectus abdominis muscle. It also has a demifacet on each side that articulates with the inferior portion of the costal cartilage of 7th rib.

2.7 The pelvic (or hip) girdle (Pelvis) : (Fig.2.40)

• Attaches the lower limbs to the axial skeleton

• Transmits the weight of the upper body to the lower limbs

• Supports the visceral organs of the pelvis

• Some of the strongest ligaments of the body support the pelvic girdle

• Formed by a pair of "hip" bones called coxal bones, and the sacrum

Anatomy of pelvis-

• Pelvis is a ring of bones which is placed between the lower portion of the trunk and lower limbs. It is formed posteriorly by the sacrum and anteriorly by two hip bones. It supports the pelvic organs and rests on the bones of the lower limbs. It transfers the weight of the trunk and upper limbs from the vertebral column to the lower limbs. The pelvis is divided by the plane of pelvic inlet into two parts- a) the upper part is known as the greater pelvis(false pelvis) b) the lower part is known as the lesser pelvis (true pelvis)

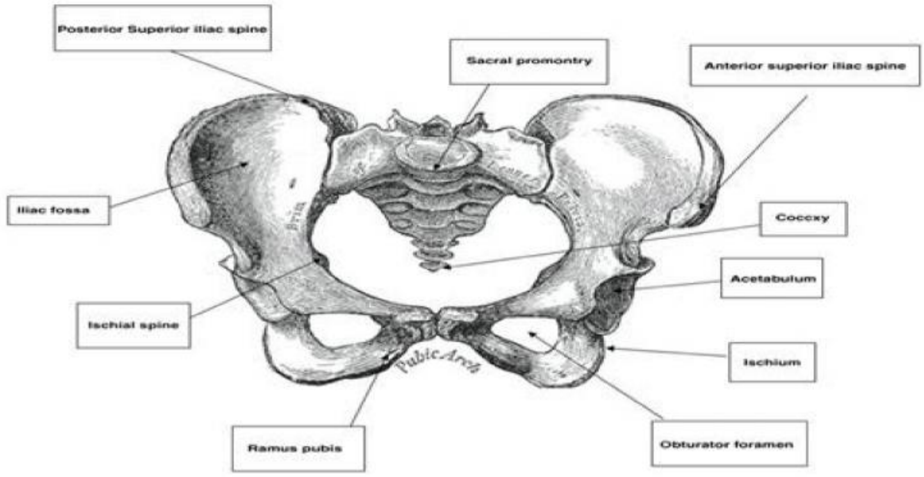


Fig.2.40 Pelvic girdle (Pelvis)

• The greater pelvis includes two iliac fossae and forms a part of posterior abdominal wall. The lesser pelvis is the actual pelvis which contains the pelvic viscera, to which the term pelvis is frequently applied, it is of importance to obstetrician. Pelvic inlet is slightly heart shaped in male but is more circular or transversely oval in female. It is bounded by the sacral promontory posteriorly, by the upper margin of pubic symphysis anteriorly and by the linea terminalis on each side. The pelvic outlet is the lower margin and is formed anteriorly by the lower border of pubic symphysis, laterally by the ischial tuberosities and posteriorly by the tip of the coccyx. The pubic arch is formed by the ischio-pubic rami of the two sides and the lower margin of pubic symphysis which is rounded off by the accurate ligament.

• Pelvic walls of the lesser pelvis are formed anteriorly by pubic symphysis and bodies of pubic bones, posteriorly by the sacrum and coccyx and on each side by the two rami of pubis.

Difference in male and female pelvis- (Fig. 2.41)

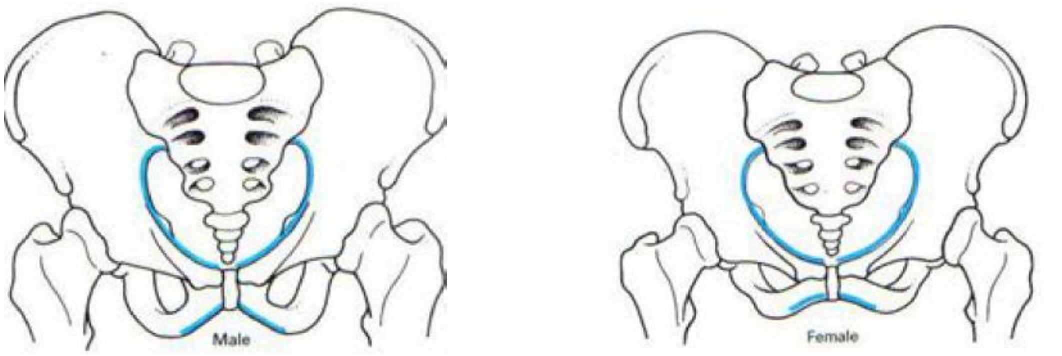


Fig. 2.41 Male and female pelvis

Male pelvis

1. It is heavier and stronger.
2. Pelvic inlet is smaller and heart shaped.
3. Pelvic outlet is smaller and sub pubic angle is narrower.
4. Greater sciatic notch is narrower.
5. Lesser sciatic notch is narrower.
6. Pelvic cavity is longer and more conical.

Female pelvis

1. It is lighter and thinner.
2. Pelvic inlet more circular or transversely oval.
3. Pelvic outlet is larger and sub pubic angle is wider.
4. Greater sciatic notch is wider.
5. Lesser sciatic notch is wider.
6. Pelvic cavity is shorter and more cylindrical.

2.8-Joints and Its Types

Objectives-

At the end of this topic you shall be able to-

- Define joint and to identify joints
- State types and movements of joints
- State the joints of upper limb and lower limb

Definition : A joint or articulation (or articulate surface) is the location at which bones connect. (Fig.2.42) They are constructed to allow movements (except for skull bones- Joints in the skull bones are immovable except Tempero-mandibular joint and are known as sutures.) and provide mechanical support, and are classified structurally and functionally.

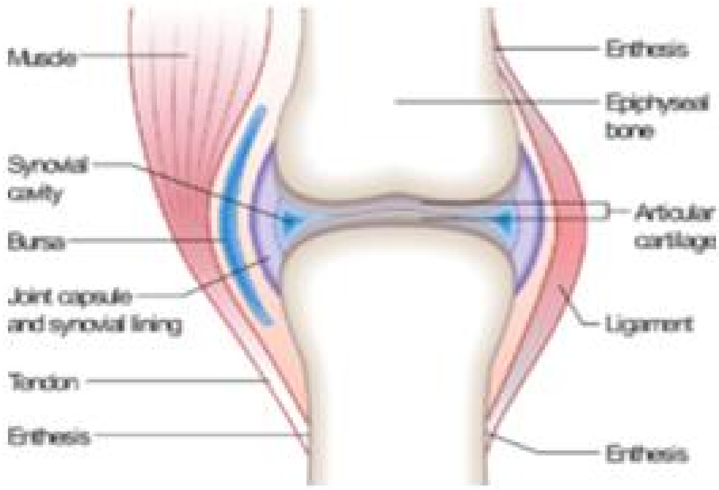


Fig 2.42 structure of joint

Types of joints-

Joints are mainly classified stucturally and functionally

- Structural classification is determined by how the bones connect to each other,
- While functional classification is determined by the degree of movement between the articulating bones.
- An articulate facet is generally seen as a small joint, especially used when speaking of the joints of the ribs.

Structural classification (binding tissue)

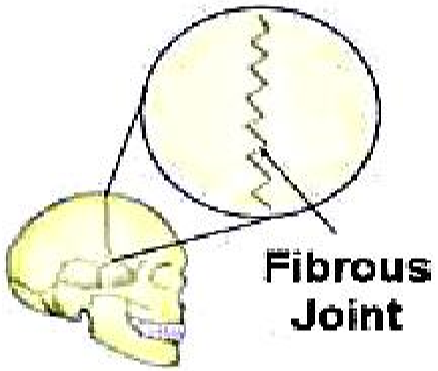
Structural classification names and divides joints according to the type of binding tissue that connects the bones to each other.

There are three structural classifications of joints :

1) Fibrous joint – joined by dense regular connective tissue that is rich in collagen fibers.

(Fig.2.43)

Fig.2.43 Fibrous joint



2) Cartilaginous joint – joined by cartilage e.g. costo-chondral joint

3) Synovial joint – not directly joined – the bones have a synovial cavity and are united by the dense irregular connective tissue that forms the articular capsule that is normally associated with accessory ligaments.

Synovial joints are subdivided as follows-

i) Hinge joint : (Fig.2.44) Movements- Flexion/Extension, e.g. hip joint, knee joint(Fig.2.45)

Fig.2.45 knee joint

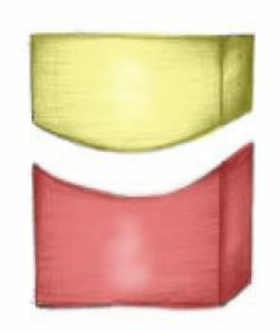


Fig.2.44 Hinge joint- structure

ii) Pivot joint : Movements- rotation of one around another (Fig2.47), e.g. Atlanto-axial joint (fig.2.46)

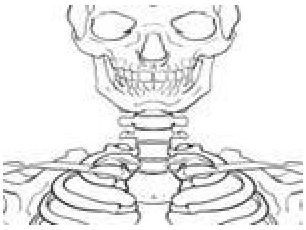


Fig.2.46 Atlanto-axial joint

Fig.2.47 Pivot joint - structure

iii) Ball and socket joint : (Fig.2.49) movements- Flexion/Extension/Adduction/ Abduction/Internal & External Rotation, e.g. Hip joint (Fig.2.48), shoulder joint

Fig.2.48 Hip joint

Fig.2.49 Ball and socket joint - structure

iv) **Saddle joint** : (Fig.2.51) movements- Flexion/Extension/Adduction/ Abduction/Circumduction, e.g. Carpo-metacarpal joint of thumb (Fig.2.50)

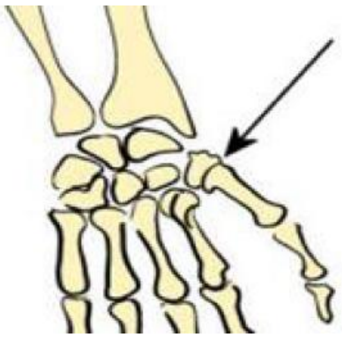


Fig.2.50 Carpo-metacarpal joint of thumb

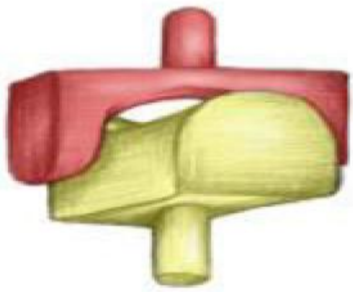


Fig.2.51 saddle joint

v) Condyloid joint : (Fig2.53) Movements- Flexion/Extension/Adduction/Abduction/ Circumduction, e.g. Wrist joint (Fig.2.52), metacarpo-phalyngeal joint, metatarso-phalyngeal joint

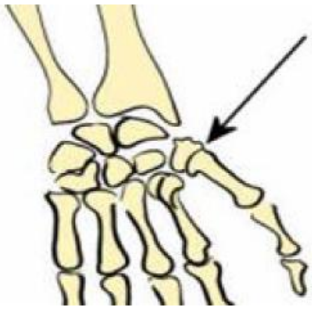


Fig.2.52 Wrist joint

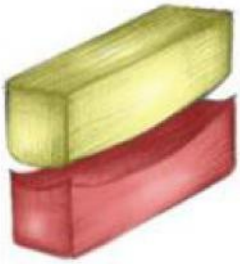


Fig.2.53 Condyloid joint - structure

vi) **Gliding joint** : Movements- gliding movements(Fig.2.55), e.g. intercarpal joints (Fig.2.54)

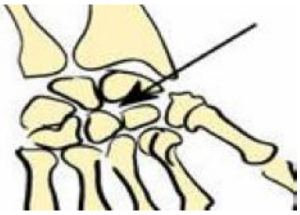


Fig.2.54 intercarpal joints

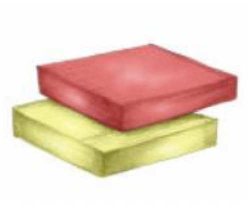


Fig.2.55 Gliding joint - structure

Functional classification (movement)

Joints can also be classified functionally according to the type and degree of movement they allow.

1) synarthrosis – permits little or no mobility. Most synarthrosis joints are fibrous joints (e.g., skull sutures).

2) amphiarthrosis – permits slight mobility. Most amphiarthrosis joints are cartilaginous joints (e.g., intervertebral discs).

3) diarthrosis – freely movable. All diarthrosis joints are synovial joints (e.g., shoulder, hip, elbow, knee, etc.), and the terms "diarthrosis" and "synovial joint" are considered equivalent.

Biomechanical classification

Joints can also be classified based on their anatomy or on their biomechanical properties. According to the anatomic classification, joints are subdivided into simple and compound, depending on the number of bones involved, and into complex and combination joints:

1. Simple joint: two articulation surfaces (e.g. shoulder joint, hip joint)
2. Compound joint: three or more articulation surfaces (e.g. radiocarpal joint)
3. Complex joint: two or more articulation surfaces and an articular disc or meniscus (e.g. knee joint)

The **movements** possible with synovial joints are:

- abduction: movement away from the mid-line of the body
- adduction: movement toward the mid-line of the body
- extension: straightening limbs at a joint
- flexion: bending the limbs at a joint
- rotation: a circular movement around a fixed point

JOINTS OF UPPER LIMB

1. STERNOCLAVICULAR JOINT (S.C.J.)-

The sterno-clavicular joint is a gliding joint of synovial variety. The joint is formed by the large sternal end of clavicle which articulates with the clavicular notch present on manubrium of sternum. Slight movements are possible by this joint.

2. ACROMIOCLAVICULAR JOINT (A.C.J.)-

The acromioclavicular joint is a gliding joint of synovial variety. The joint is formed by flattened lateral or acromial end of clavicle which articulates with acromion process of scapula. Through this joint a slight gliding movement is possible between clavicle and scapula to enhance free movement of humerus.

3. SHOULDER JOINT-

The shoulder joint is synovial joint of ball and socket variety .(Fig.2.56)

Formation of shoulder joint- The head of humerus forming one third of a sphere articulates within the glenoid cavity of scapula with presence of synovial sheath membrane and synovial fluid.

Movement – (i) Flexion, (ii) Extension, (iii) Adduction, (iv) Abduction and Rotation (v) Circumduction –is the movement performed only by shoulder joint.

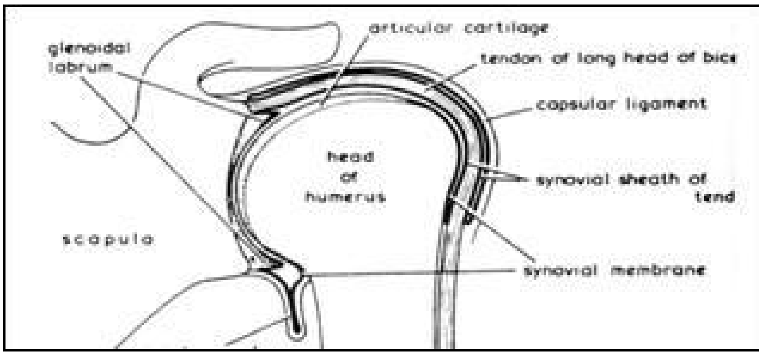


Fig.2.56 Structure of shoulder joint

4. ELBOW JOINT- (Fig. 2.57)

The elbow joint is hinge joint between trochlear surface of lower extremity of humerus and trochlear notch of the ulna and the head of radius articulates with capitulum of humerus forming the humeroradial joint.

Movements – 1) Flexion 2) Extension

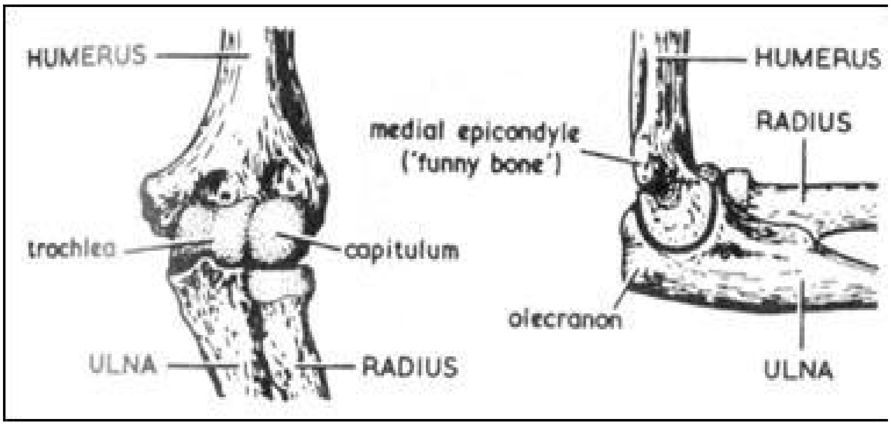


Fig. 2.57 Elbow joint anterior and lateral aspect

5. **WRIST JOINT**-(Fig. 2.58)

Wrist joint is radio carpal joint of condyloid type between the lower end of radius and the articular disc below the head of the ulna which together form a concave surface from the reception of upper aspect of scaphoid, lunate and triquetral bones

Movements –(i) Fle ion (iv) Radial deviation.

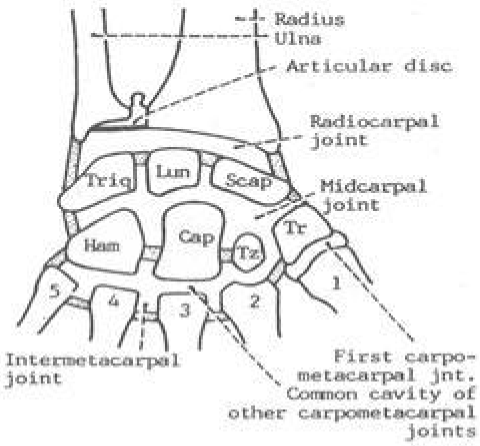


Fig. 2.58 Wrist joint

6. **JOINTS IN HAND**- (i) Intercarpal joints (ii) Carpo-metacarpal joints (iii) Metacarpo-phalyngeal joints(iv) Interphalyngeal joints

JOINTS OF LOWER LIMB

1. **HIP JOINT**- It is ball and socket type of joint of synovial variety. It is formed by the articulation of head of the femur and acetabulum. (Fig.2.59) Anteriorly it is closely related to the femoral artery. The capsule of the hip joint is very strong. Anteriorly it covers the neck of the femur and extends to the intertrochanteric line but posteriorly it does not cover the whole of the neck of femur. So the fractures of the neck of the femur and greater trochanter are very common in old age.

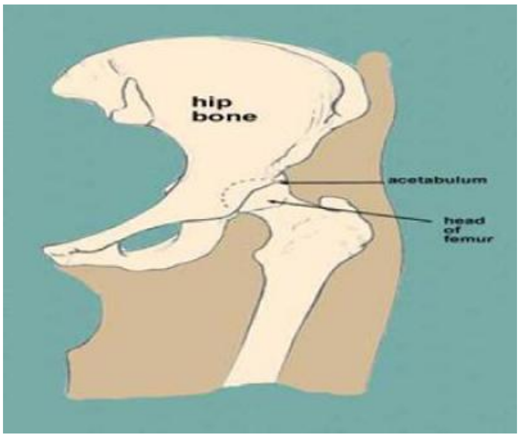


Fig.2.59 Structure of hip joint

Movements of the hip joint are- i) flexion, ii) extension, iii) adduction, iv) abduction and v) rotation.

2. **KNEE JOINT**- It is a modified hinge joint of synovial variety. It is formed by two condyles of the femur articulating with the superior surfaces of the condyles of the tibia. (Fig.2.60) The patella lies over the smooth patellar surface of the femur over which it glides during the movements of knee.

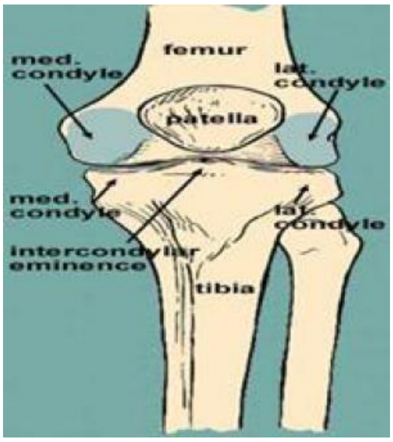


Fig.2.60 Structure of knee joint

Movements – i) Flexion, ii) extension, iii) slight medial rotation.

3. **ANKLE JOINT**- It is a condyloid joint of synovial variety formed between the lower extremity of the tibia and it`s medial malleolus and the lateral malleolus of the fibula which together from a socket to receive the body of the talus. (Fig.2.61) The deltoid ligament passes from the medial malleolus to the adjoining tarsal bones and is often badly torn in severe sprains of the ankle.

Movements - Flexion, extension, inversion, eversion

Fig.2.61 Ankle joint

4. **JOINTS IN HAND**- (i) Intertarsal joints (ii) Tarso-metatarsal joints (iii) Metatarso-phalyngeal joints (iv)Interphalyngeal joints

Joint disorders- A joint disorders are termed as Arthropathies and when there is inflammation of one or more joints the disorder is called an arthritis, most joint disorders involve arthritis, but joint damage by external physical trauma are not termed as arthritis.

Arthropathies are called polyarticular (multiarticular) when involving many joints and monoarticular when involving only a single joint.

Glossary

- **Condyle-** a rounded process that articulates with another bone

e.g. occipital condyle

- **crest-** a narrow, ridge-like projection; eg. iliac crest
- **Epicondyle-** a projection situated above a condyle

e.g. medial epicondyle of humerus

- **Facet-** a small smooth surface

e.g. rib facet of a thoracic vertebra

- **Foramen-** an opening for the passage of b.v. &/or nerves

e.g. foramen magnum

- **Fossa-** a relatively deep pit or depression; e.g. olecranon fossa
- fovea- a tiny pit or depression; e.g. fovea capitis
- **Head-** an enlargement at the end of a bone; e.g. femoral head
- **Linea-** a narrow line-like ridge; e.g. linea aspera of femur
- **Meatus-** a tube-like passageway within a bone

e.g. external auditory meatus

- **Process-** a prominent projection of a bone

e.g. mastoid process of temporal bone

- **Ramus-** a branch-like process; e.g. ramus of mandible
- **Sinus-** a cavity within a bone; e.g. frontal sinus
- **Spine-** a sharp projection; e.g. spine of scapula
- **Styloid-** a pen-like projection; e.g. styloid process of ulna
- **Suture-** interlocking junction between cranial bones; e.g. coronal suture
- **Trochanter-** a relatively large process; e.g. greater trochanter of femur
- **Tubercle-** a small knob-like process; e.g. tubercle of rib
- **Tuberosity-** a knob-like process larger than a tubercle; e.g. tibial tuberosity

Assignments/Tests

Q. Choose the correct word and rewrite the sentence.

1. Total no. of bones in human body is---------

a) 239

b) 215

c) 206

d) 208

2. Skull, spinal column, ribs and sternum are the parts of---------

a) Axial skeleton

b) Appendicular skeleton

c) Upper limb

d) Pectoral girdle

3. -------------is the largest sesamoid bone in the body.

a) patella

b) thumb

c) scaphoid

d) lunate

4. First seven ribs are called as -----------

a) False ribs

b) True ribs

c) Floating ribs

d) Flat ribs

5. 8th to 10th ribs are called as----------

a) False ribs

b) True ribs

c) Floating ribs

d) Flat ribs

6. 11th and 12th ribs are called as-----------

a) False ribs

b) True ribs

c) Floating ribs

d) Flat ribs

7. Hip bone is also called as------.

a) Pelvic bone

b) Flat bone

c) Innominate bone

d) spinal bone

8. ------------is the antero-medial bone of chest.

a) Sternum

b) Rib

c) Thoracic vertebra

d) Hyoid bone

9. ---------vertebra has greater spinous process.

a) 4th cervical

b) 1st cervical

c) 2nd cervical

d) 7th cervical

10. Atlas is -------------vertebra.

a) 4th cervical

b) 1st cervical

c) 2nd cervical

d) 7th cervical

11. Axis is-----------vertebra.

a) 4th cervical

b) 1st cervical

c) 2nd cervical

d) 7th cervical

12. Excessive thoracic curvature is called as-------------

a) Scoliosis

b) Kyphosis

c) Lordosis

d) Hypnosis

13. Lumbar curvature is called as---------------

a) Scoliosis

b) Kyphosis

c) Lordosis

d) Hypnosis

14. Lateral curvature is called as-------------

a) Scoliosis

b) Kyphosis

c) Lordosis

d) Hypnosis

15. Hip bone contains a hollow cavity on its lateral surface which is named as -------.

a) Glenoid cavity

b) Acetabulum

c) Obturator foramen

d) Fovea

16. The--------- is the largest part of hip bone.

a) Ilium

b) Ischium

c) Pubis

d) Acetabulum

Q. Match the correct pairs.

Group 'A'	Group 'B'
1. Hip bone	a) flat bone
2. Radius	b) sesamoid bone
3. Mastoid	c) irregular bone
4. Metatarsal	d) Pneumatic bone
5. Patella	e) short bone
6. Scapula	f) long bone

Q. Answer the following.

1. Draw and label the humerus bone.
2. Draw and label the hip bone.
3. Draw and label the rib bone.
4. Draw and label the femur bone.
5. Draw and label the mandible bone.
6. Draw and label the tibia bone.
7. How pelvic girdle is formed?
8. Differentiate male and female pelvis.
9. Describe the following in short –
   (i) Radius (ii) Clavicle (iii) Scapula (iv) Ulna (v) Elbow joint (vi) Shoulder Joint (vii) Wrist joint (viii) Tarsal (ix) Metatarsal (x) Femur (xi) Patella (xii) Fibula (xiii) Ankle joint (xiv) Knee joint (xv) Contents of the thoracic cage (xvi) Functions of thoracic cage
10. Write long forms of- (i) A.C.J. (ii) SCJ (iii) P.N.S.
11. What are the characteristics of cervical vertebrae?
12. What are the characteristics of thoracic vertebrae?
13. What are the characteristics of lumbar vertebrae?
14. Write about the spinal deformities.
15. Write an anatomy of sacrum.
16. Draw and label the typical vertebra.
18. What are the functions of vertebral column?
19. Describe in detail the thoracic cavity.
20. Draw and label Sternum.
21. Enlist the bones of the skull.
22. Enlist the facial bones.
23. Write about the sutures of the skull.
24. What are the functions of skull bones?
25. What are the general features of skull bones?

26. Write the structure of joint.

27. Define joint. What are its types? Give examples of each.

28. What are the functions of bones?

29. What are the types of bones? Give examples of each.

30. Write short notes on the following-

    i) Fontanelle

    ii) Paranasal sinuses (P.N.S.)

    iii)Vertebral curves

    iv) Hip joint

    v) Sacro-iliac joint

    vi) Acetabulum

UNIT 3 - CARDIO-VASCULAR SYSTEM

Objectives—

At the end of this Unit you shall be able to—

- Describe the various parts of cardio-vascular system
- State the importance of cardiovascular system in the body
- Define cardiac output
- State the structure of heart and blood vessels
- Differentiate arteries and veins
- Names of the vessels supplying heart muscles and arising from heart
- State the cardiac cycle
- State the structure of electrical conduction system of heart
- State the electro chemical mechanism of heart

Introduction-

The heart is the life-giving, ever-beating muscle in the chest. From inside the womb until death, the thump goes on. The heart for the average human shall contract about 3 billion times; never resting, never stopping to take a break except for a fraction of a second between beats. The primary function of the heart is to pump blood through the arteries, capillaries, and veins. There are an estimated 60,000 miles of vessels throughout an adult body. Blood transports oxygen, nutrients, disease causing viruses, bacteria, hormones and has other important functions as well. The heart is the pump that keeps blood circulating properly

Parts of Cardio-vascular system

The cardiovascular system consists of the heart, blood vessels, and the approximately 5 liters of blood that the blood vessels transport. Responsible for transporting oxygen, nutrients, hormones, and cellular waste products throughout the body, the cardiovascular system is powered by the body's hardest-working organ — the heart, which is only about the size of a closed fist. Even at rest, the average heart easily pumps over 5 liters of blood throughout the body every minute.(Fig.3.1)

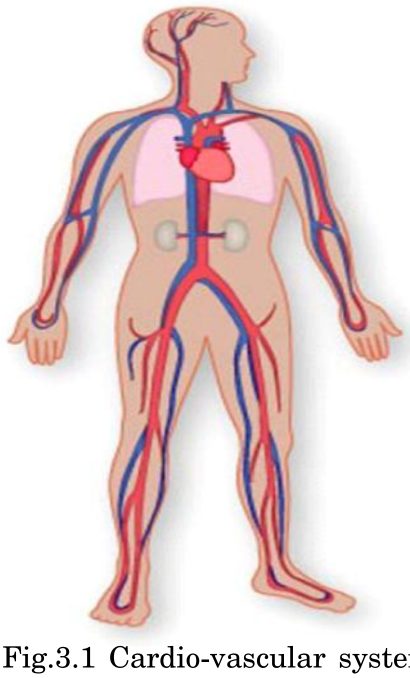


Fig.3.1 Cardio-vascular system

3.1-Heart

- The heart is a muscular pumping organ located medial to the lungs along the body's midline in the thoracic region about the size of a fist.
- The bottom tip of the heart, known as its apex, is turned to the left, so that about 2/3 of the heart is located on the body's left side with the other 1/3 on right.
- The top of the heart, known as the heart's base, connects to the great blood vessels of the body: the aorta, vena cava, pulmonary trunk, and pulmonary veins.
- It is responsible for pumping blood through the blood vessels by repeated, rhythmic contractions.
- The heart is composed of cardiac muscle, an involuntary muscle tissue that is found only within this organ.
- The term "cardiac" (as in cardiology) means "related to the heart" and comes from the Greek word kardia, for "heart."
- It has a four-chambered, double pump and is located in the thoracic cavity between the lungs.
- The cardiac muscle is self-exciting, meaning it has its own conduction system. This is in contrast with skeletal muscle, which requires either conscious or reflex nervous stimuli.
- The heart's rhythmic contractions occur spontaneously, although the frequency or heart rate can be changed by nervous or hormonal influence such as exercise or the perception of danger.

Endocardium

The endocardium is the innermost lining of the heart which consists of the endothelial cells forming a smooth membrane in places,

Myocardium

The myocardium is the muscular tissue of the heart. The myocardium is composed of specialized cardiac muscle cells with an ability not possessed by muscle tissue elsewhere in the body. Cardiac muscle, like other muscles, can contract, but it can also conduct electricity, like nerves. The blood to the myocardium is supplied by the coronary arteries. If these arteries are occluded by atherosclerosis and/or thrombosis, this can lead to angina pectoris or myocardial infarction due to ischemia (lack of oxygen). Failure of the heart to contract properly (for various reasons) is termed heart failure, generally leading to fluid retention, edema, pulmonary edema, renal insufficiency, hepatomegaly, a shortened life expectancy and decreased quality of life.

Epicardium

The outer most layer next to the myocardium is known as the Epicardium. This is the outer layer after endocardium and myocardium that consists of a thin layer of connective tissue and fat.

Pericardium

The pericardium is the thick, membranous sac that surrounds the heart. It protects and lubricates the heart. There are two layers to the pericardium: the fibrous pericardium and the serous pericardium. The serous pericardium is divided into two layers; in between these two layers there is a space called the pericardial cavity.

Heart Chambers

The heart has four chambers, two atria and two ventricles. (Fig. 3.2) The atria are smaller with thin walls, while the ventricles are larger and much stronger.

Atrium

There are two atria on either side of the heart. On the right side is the atrium that contains blood which is poor in oxygen. The left atrium contains blood which has been oxygenated and is ready to be sent to the body. The right atrium receives de-oxygenated blood from the superior vena cava and inferior vena cava. The left atrium receives oxygenated blood from the left and right pulmonary veins. Atria facilitate circulation primarily by allowing uninterrupted venous flow to the heart, preventing the inertia of interrupted venous flow that would otherwise occur at each ventricular systole.

Ventricles

The ventricle is a heart chamber which collects blood from an atrium and pumps it out of the heart. There are two ventricles: the right ventricle pumps blood into the pulmonary circulation for the lungs, and the left ventricle pumps blood into the aorta for systemic circulation to the rest of the body. Ventricles have thicker walls than the atria, and thus can create the higher blood pressure. Comparing the left and right ventricle, the left ventricle has thicker walls because it needs to pump blood to the whole body. This leads to the common misconception that the heart lies on the left side of the body.

Septum

The inter ventricular septum (ventricular septum, or during development septum inferius) is the thick wall separating the lower chambers (the ventricles) of the heart from one another. The ventricular septum is directed backward and to the right, and is curved toward the right ventricle. The greater portion of it is thick and muscular and constitutes the muscular ventricular septum. Its upper and posterior part, which separates the aortic vestibule from the lower part of the right atrium and upper part of the right ventricle, is thin and fibrous, and is termed the membranous ventricular septum.

Valves

The two atrioventricular (AV) valves are one-way valves that ensure that blood flows from the atria to the ventricles, and not the other way. The two semilunar (SL) valves are present in the arteries leaving the heart; they prevent blood from flowing back into the ventricles. The sound heard in a heartbeat is the heart valves shutting. The right AV valve is also called the tricuspid valve because it has three flaps. It is located between the right atrium and the right ventricle. The tricuspid valve allows blood to flow from the right atrium into the right ventricle when the heart is relaxed during diastole. When the heart begins to contract, the heart enters a phase called systole, and the atrium pushes blood into the ventricle. Then, the ventricle begins to contract and blood pressure inside the heart rises. When the ventricular pressure exceeds the pressure in the atrium, the tricuspid valve snaps shut. The left AV valve is also called the bicuspid valve because it has two flaps. It is also known as the mitral valve due to the resemblance to a bishop's mitre (liturgical headdress). This valve prevents blood in the left ventricle from flowing into the left atrium. As it is on the left side of the heart, it must withstand a great deal of strain and pressure; this is why it is made of only two cusps, as a simpler mechanism entails a reduced risk of malfunction. There are two remaining valves called the Semilunar Valves. They have flaps that resemble half moons. The pulmonary semilunar valve lies between the right ventricle and the pulmonary trunk. The aortic semilunar valve is located between the ventricle and the aorta.

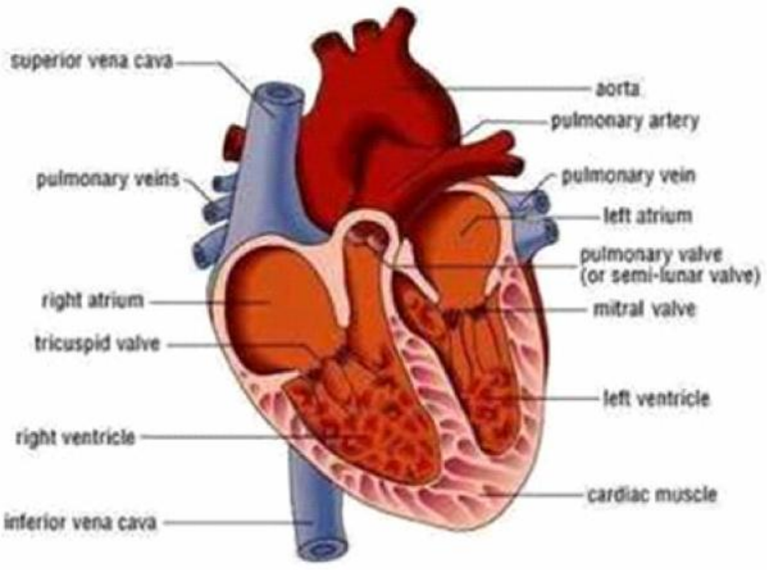


Fig3.2 Internal Structure of heart

Circulatory Loops-

There are 2 primary circulatory loops in the human body: the pulmonary circulation loop and the systemic circulation loop.

1. Pulmonary circulation transports deoxygenated blood from the right side of the heart to the lungs, where the blood picks up oxygen and returns to the left side of the heart. The pumping chambers of the heart that support the pulmonary circulation loop are the right atrium and right ventricle.

2. Systemic circulation carries highly oxygenated blood from the left side of the heart to all of the tissues of the body (with the exception of the heart and lungs). Systemic circulation removes wastes from body tissues and returns deoxygenated blood to the right side of the heart. The left atrium and left ventricle of the heart are the pumping chambers for the systemic circulation loop.

3.2 Arterial System and Venous system

Blood Vessels-

Blood vessels are the body's highways that allow blood to flow quickly and efficiently from the heart to every region of the body and back again. The size of blood vessels corresponds with the amount of blood that passes through the vessel. All blood vessels contain a hollow area called the lumen through which blood is able to flow. Around the lumen is the wall of the vessel, which may be thin in the case of capillaries or very thick in the case of arteries.

- All blood vessels are lined with a thin layer of simple squamous epithelium known as the endothelium that keeps blood cells inside of the blood vessels and prevents clots from forming. The endothelium lines the entire circulatory system, all the way to the interior of the heart, where it is called the endocardium.

- There are three major types of blood vessels: arteries, capillaries and veins. (Fig.3.3) Blood vessels are often named after either the region of the body through which they carry blood or for nearby structures. For example, the brachiocephalic artery carries blood into the brachial (arm) and cephalic (head) regions. One of its branches, the subclavian artery, runs under the clavicle; hence the name subclavian. The subclavian artery runs into the axillary region where it becomes known as the axillary artery.

1. **Arteries and Arterioles :** Arteries are blood vessels that carry blood away from the heart. Blood carried by arteries is usually highly oxygenated, having just left the lungs on its way to the body's tissues. The pulmonary trunk and arteries of the pulmonary circulation loop provide an exception to this rule – these arteries carry deoxygenated blood from the heart to the lungs to be oxygenated.

Arteries face high levels of blood pressure as they carry blood being pushed from the heart under great force. To withstand this pressure, the walls of the arteries are thicker, more elastic, and more muscular than those of other vessels. The largest arteries of the body contain a high percentage of elastic tissue that allows them to stretch and accommodate the pressure of the heart.

Smaller arteries are more muscular in the structure of their walls. The smooth muscles of the arterial walls of these smaller arteries contract or expand to regulate the flow of blood through their lumen. In this way, the body controls how much blood flows to different parts of the body under varying circumstances. The regulation of blood flow also affects blood pressure, as smaller arteries give blood less area to flow through and therefore increases the pressure of the blood on arterial walls.

Arterioles are narrower arteries that branch off from the ends of arteries and carry blood to capillaries. They face much lower blood pressures than arteries due to their greater number, decreased blood volume, and distance from the direct pressure of the heart. Thus arteriole walls are much thinner than those of arteries. Arterioles, like arteries, are able to use smooth muscle to control their aperture and regulate blood flow and blood pressure.

2. **Capillaries :** Capillaries are the smallest and thinnest of the blood vessels in the body and also the most common. They can be found running throughout almost every tissue of the body and border the edges of the body's avascular tissues. Capillaries connect to arterioles on one end and venules on the other.

Capillaries carry blood very close to the cells of the tissues of the body in order to exchange gases, nutrients, and waste products. The walls of capillaries consist of only a thin layer of endothelium so that there is the minimum amount of structure possible between the blood and the tissues. The endothelium acts as a filter to keep blood cells inside of the vessels while allowing liquids, dissolved gases, and other chemicals to diffuse along their concentration gradients into or out of tissues.

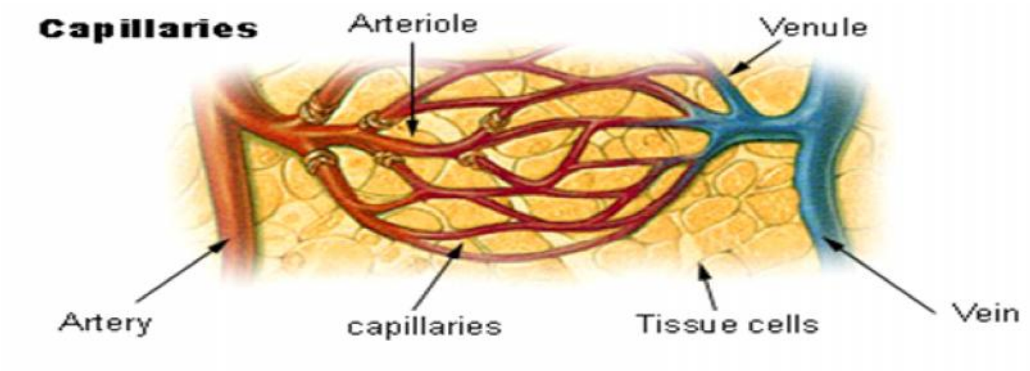


Fig 3.3 Blood vessels

3. Veins and Venules: Veins are the large return vessels of the body and act as the blood return counterparts of arteries. Because the arteries, arterioles, and capillaries absorb most of the force of the heart's contractions, veins and venules are subjected to very low blood pressures. This lack of pressure allows the walls of veins to be much thinner, less elastic, and less muscular than the walls of arteries.

Veins rely on gravity, inertia, and the force of skeletal muscle contractions to help push blood back to the heart. To facilitate the movement of blood, some veins contain many one-way valves that prevent blood from flowing away from the heart. As skeletal muscles in the body contract, they squeeze nearby veins and push blood through valves closer to the heart.

When the muscle relaxes, the valve traps the blood until another contraction pushes the blood closer to the heart. Venules are similar to arterioles as they are small vessels that connect capillaries, but unlike arterioles, venules connect to veins instead of arteries. Venules pick up blood from many capillaries and deposit it into larger veins for transport back to the heart.

3.3 Cardiac Cycle-

- The cardiac cycle is the sequence of events that occurs in one complete beat of the heart.
- The pumping phase of the cycle, also known as systole, occurs when heart muscle contracts.
- The filling phase, which is known as diastole, occurs when heart muscle relaxes. At the beginning of the cardiac cycle, both atria and ventricles are in diastole.
- During this time, all the chambers of the heart are relaxed and receive blood. The atrioventricular valves are open. Atrial systole follows this phase.
- During atrial systole, the left and right atria contract at the same time and push blood into the left and right ventricles, respectively. The next phase is ventricular systole.
- During ventricular systole, the left and right ventricles contract at the same time and pump blood into the aorta and pulmonary trunk, respectively. In ventricular systole, the atria are relaxed and receive blood.
- The atrioventricular valves close immediately after ventricular systole begins to stop blood going back into the atria.
- However, the semilunar valves are open during this phase to allow the blood to flow into the aorta and pulmonary trunk.
- Following this phase, the ventricles relax that is ventricular diastole occurs. The semilunar valves close to stop the blood from flowing back into the ventricles from the aorta and pulmonary trunk.
- The atria and ventricles once again are in diastole together and the cycle begins again.

Components of the Heartbeat

- The adult heart beats around 70 to 80 times a minute at rest.
- When you listen to your heart with a stethoscope you can hear your heart beat. The sound is usually described as “lubb-dupp”.
- The “lubb” also known as the first heart sound, is caused by the closure of the atrioventricular valves.
- The “dupp” sound is due to the closure of the semilunar valves when the ventricles relax (at the beginning of ventricular diastole).
- Abnormal heart sounds are known as murmurs. Murmurs may indicate a problem with the heart valves, but many types of murmur are no cause for concern.

Electrocardiogram

The heart has an inbuilt rhythm of contraction and relaxation. A small group of heart muscle cells called the pacemaker help achieve this. The pacemaker generates an electrical impulse which spreads over the atria, making them contract. This impulse then spreads to the ventricles, causing them to contract. The electrical changes that spread through the heart can be detected at the surface of the body by an instrument called the electrocardiograph. Electrodes are placed in a number of positions over the chest and the electrical changes are recorded on moving graph paper as an electrocardiogram (ECG).

E.C.G stands for Electrocardiogram and represents the electrophysiology of the heart. Cardiac electrophysiology is the science of the mechanisms, functions, and performance of the electrical activities of specific regions of the heart. The ECG is the recording of the heart's electrical activity as a graph. The graph can show the heart's rate and rhythm, it can detect enlargement of the heart, decreased blood flow, or the presence of current or past heart attacks. ECG's are inexpensive, Non-invasive, quick, and painless. Depending on the results, the patient's medical history, and a physical exam; further tests or a combination of medications and lifestyle changes may be ordered.

Electrical Conduction System of the Heart

Structure-

Signals arising in the SA node stimulate the atria to contract and travel to the AV node. After a delay, the stimulus is conducted through the bundle of His to the Purkinje fibers and the endocardium at the apex of the heart, then finally to the ventricular epicardium. (Fig. 3.4)

Electrical impulses propagate freely between cells in every direction, so that the myocardium functions as a single contractile unit. This property allows rapid, synchronous depolarization of the myocardium. While advantageous under normal circumstances, this property can be detrimental, as it has potential to allow the propagation of incorrect electrical signals. These gap junctions can close to isolate damaged or dying tissue, as in a myocardial infarction.

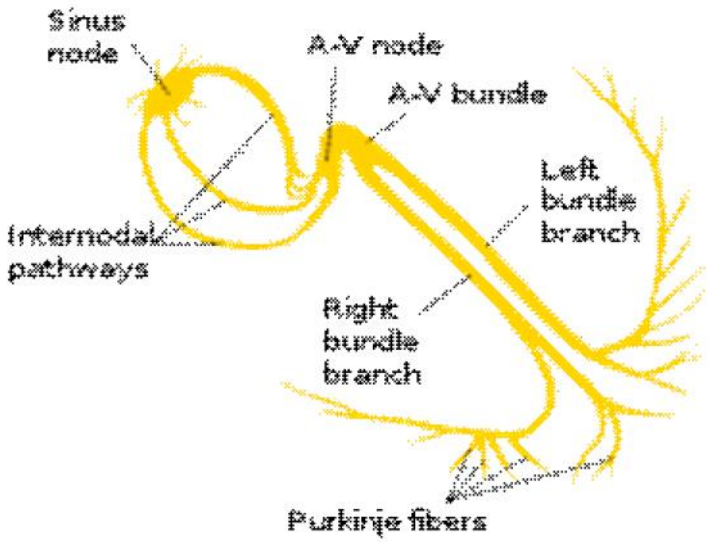


Fig.3. 4 Electrical conduction system of heart

Electrochemical mechanism-

Cardiac muscle has some similarities to neurons and skeletal muscle, as well as important unique properties. Like a neuron, a given myocardial cell has a negative membrane potential when at rest. Stimulation above a threshold value induces the opening of voltage-gated ion channels and a flood of cations into the cell. The positively charged ions entering the cell cause the depolarization characteristic of an action potential. Like skeletal muscle, depolarization causes the opening of voltage-gated calcium channels and release of Ca2+from the t-tubules. This influx of calcium causes calcium-induced calcium release from the sarcoplasmic reticulum, and free Ca2+ causes muscle contraction. After a delay, Potassium channels reopen and the resulting flow of K+ out of the cell causes repolarization to the resting state.

Note that there are important physiological differences between nodal cells and ventricular cells; the specific differences in ion channels and mechanisms of polarization give rise to unique properties of SA node cells, most important, the spontaneous depolarizations necessary for the SA node's pacemaker activity.

Impulses Generated by Heart—

Each impulse generated by the S.A. node and passing through the conducting system of the heart causes a series of electrical changes in the heart muscles which preceed the associated mechanical events.

The ECG complex. P=P wave, PR=PR interval, QRS=QRS complex, QT=QT interval, ST=ST segment, T=T wave (Fig3.5)

- SA node: P wave

Under normal conditions, electrical activity is spontaneously generated by the SA node, the physiological pacemaker. This electrical impulse is propagated throughout the right atrium, and through Bachmann's bundle to the left atrium, stimulating the myocardium of the atria to contract. The conduction of the electrical impulse throughout the atria is seen on the ECG as the P wave.

As the electrical activity is spreading throughout the atria, it travels via specialized pathways, known as internodal tracts, from the SA node to the AV node.

- AV node/Bundles: PR interval

The AV node functions as a critical delay in the conduction system. Without this delay, the atria and ventricles would contract at the same time, and blood wouldn't flow effectively from the atria to the ventricles. The delay in the AV node forms much of the PR segment on theECG. And part of atrial repolarization can be represented by PR segment.

The distal portion of the AV node is known as the Bundle of His. The Bundle of His splits into two branches in the interventricular septum, the left bundle branch and the right bundle branch. The left bundle branch activates the left ventricle, while the right bundle branch activates the right ventricle. The left bundle branch is short, splitting into the left anterior fascicle and the left posterior fascicle. The left posterior fascicle is relatively short and broad, with dual blood supply, making it particularly resistant to ischemic damage. The left posterior fascicle transmits impulses to the papillary muscles, leading to mitral valve closure. As the left posterior fascicle is shorter and broader than the right, impulses reach the papillary muscles just prior to depolarization, and therefore contraction, of the left ventricle myocardium. This allows pre-tensioning of the chordae tendinae, increasing the resistance to flow through the mitral valve during left ventricular contraction. This mechanism works in the same manner as pre-tensioning of car seatbelts.

- Purkinje fibers/ventricular myocardium: QRS complex

The two bundle branches taper out to produce numerous Purkinje fibers, which stimulate individual groups of myocardial cells to contract.

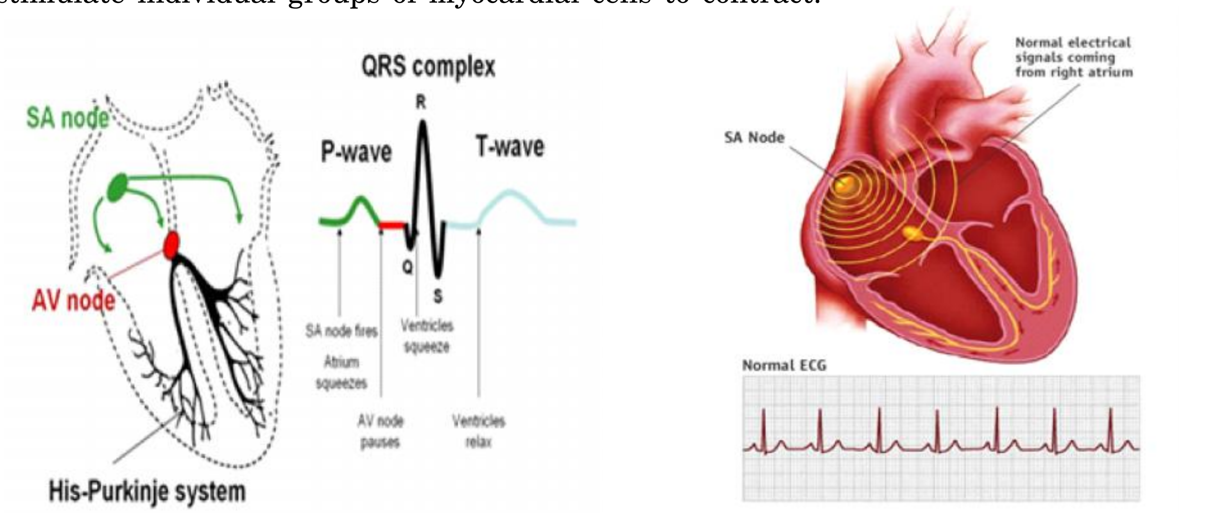


Fig3.5 Electrical signals of the heart and waves produced on ECG

The spread of electrical activity through the ventricular myocardium produces the QRS complex on the ECG.

- Ventricular repolarization

The last event of the cycle is the repolarization of the ventricles. It is the restoring of the resting state.

In the ECG, repolarization includes the J wave, ST-segment, and T- and U-waves.

ECG Waveform (Fig.3. 6)

- P wave- indicates that the atria are electrically stimulated (depolarized) to pump blood into the ventricles.
- QRS complex- indicates that the ventricles are electrically stimulated (depolarized) to pump blood out.
- ST segment- indicates the amount of time from the end of the contraction of the ventricles to the beginning of the T wave.
- T wave- indicates the recovery period (repolarization) of the ventricles.
- U wave- rarely seen, and thought to possibly be the repolarization of the papillary muscles

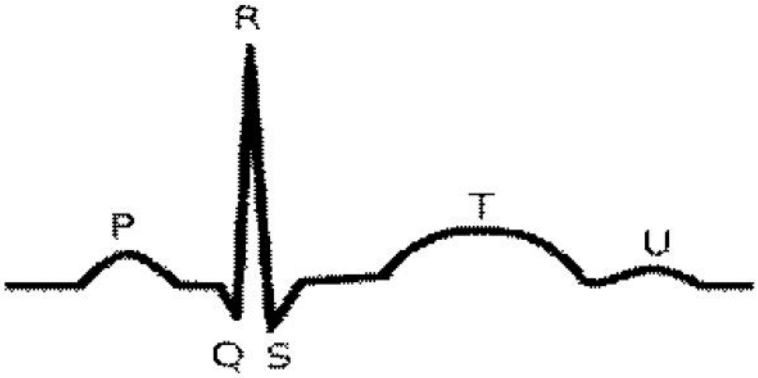


Fig-3.6 ECG waveforms

Clinical significance-

ECG -The electrocardiogram (ECG or EKG) is often used to examine the electrical conduction system of the heart.

Arrhythmia- An 'arrhythmia' refers to an abnormal rhythm or speed of rhythm of the heartbeat. An abnormal rhythm or speed is defined as one which is not physiological.

Speed- A resting heart that beats slower than 60 beats per minute or faster than 100 beats per minute; is regarded as having an arrhythmia. A heartbeat slower than 60 beats per minute is known as bradycardia and a heartbeat faster than 100 is known as a tachycardia.

Physiological- Some individuals, for example trained athletes, may have heart beats slower than 60 beats per minute when not exercising. If the SA node fails to initialize, the AV junction can take over as the main pacemaker of the heart. The AV junction "surrounds" the AV node (the AV node is not able to initialize its own impulses) and has a regular rate of 40 to 60 beats/ minute. These "junctional" rhythms are characterized by a missing or inverted P-Wave. If both the SA node and the AV junction fail to initialize the electrical impulse, the ventricles can fire the electrical impulses themselves at a rate of 20 to 40 beats/ minute and shall have a QRS complex of greater than 120 ms.

Pacemakers- In the event of arrhythmia, a pacemaker may be surgically inserted into the conduction system.

3.4-Blood-Contents and Functions

It is a liquid connective tissue. It is slightly alkaline in nature. The PH of blood is 7.4.

The average human body contains about 4 to 5 liters of blood or 1/8th of the total body weight.

Functions of blood-

i) It transports many substances through the body and helps to maintain homeostasis of nutrients, wastes, and gases.

ii) It helps in defense mechanism.

iii) It controls the body temperature.

iv) It acts as a vehicle for hormones.

v) It acts as a buffering agent.

vi) Clotting of blood prevents haemorrhage

Contents of blood- Blood is made up of red blood cells, white blood cells, platelets, and liquid plasma.

• **Red Blood Cells :** Red blood cells, also known as erythrocytes, are by far the most common type of blood cell and make up about 45% of blood volume. Erythrocytes are produced inside **of red bone marrow**. The shape of erythrocytes is biconcave—disks with a concave curve on both sides of the disk so that the center of an erythrocyte is its thinnest part. The unique shape of erythrocytes gives these cells a high surface area to volume ratio and allows them to fold to fit into thin capillaries. Immature erythrocytes have a nucleus that is ejected from the cell when it reaches maturity to provide it with its unique shape and flexibility. The lack of a nucleus means that red blood cells contain no DNA and are not able to repair themselves once damaged.

Erythrocytes transport oxygen in the blood through the red pigment hemoglobin. Hemoglobin contains iron and proteins joined to greatly increase the oxygen carrying capacity of erythrocytes. The high surface area to volume ratio of erythrocytes allows oxygen to be easily transferred into the cell in the lungs and out of the cell in the capillaries of the systemic tissues.

• **White Blood Cells :** White blood cells, also known as leukocytes, make up a very small percentage of the total number of cells in the bloodstream, but have important functions in the body's **immune system**. There are two major classes of white blood cells: granular leukocytes and agranular leukocytes.

1. **Granular Leukocytes :** The three types of granular leukocytes are neutrophils, eosinophils, and basophils. Each type of granular leukocyte is classified by the presence of chemical-filled vesicles in their cytoplasm that give them their function. Neutrophils contain digestive enzymes that neutralize bacteria that invade the body. Eosinophils contain digestive enzymes specialized for digesting viruses that have been bound to by antibodies in the blood. Basophils release histamine to intensify allergic reactions and help protect the body from parasites.

2. **Agranular Leukocytes :** The two major classes of agranular leukocytes are lymphocytes and monocytes. Lymphocytes include T cells and natural killer cells that fight off viral infections and B cells that produce antibodies against infections by pathogens. Monocytes develop into cells called macrophages that engulf and ingest pathogens and the dead cells from wounds or infections.

• **Platelets :** Also known as thrombocytes, platelets are small cell fragments responsible for the clotting of blood and the formation of scabs. Platelets form in the red bone marrow from large megakaryocyte cells that periodically rupture and release thousands of pieces of membrane that become the platelets. Platelets do not contain a nucleus and only survive in the body for up to a week before macrophages capture and digest them.

• Plasma: Plasma is the non-cellular or liquid portion of the blood that makes up about 55% of the blood's volume. Plasma is a mixture of water, proteins, and dissolved substances. Around 90% of plasma is made of **water**, although the exact percentage varies depending upon the hydration levels of the individual. The **proteins** within plasma include antibodies and albumins. Antibodies are part of the immune system and bind to antigens on the surface of pathogens that infect the body. Albumins help maintain the body's osmotic balance by providing an isotonic solution for the cells of the body. Many different substances can be found dissolved in the plasma, including glucose, oxygen, carbon dioxide, electrolytes, nutrients, and cellular waste products. The plasma functions as a transportation medium for these substances as they move throughout the body.

3.5- Circulation of Blood

The general circulation of the body is known as systemic circulation and the circulation of lungs is called as pulmonary circulation.

The Pulmonary Circulation

In the pulmonary circuit, blood is pumped to the lungs from the right ventricle of the heart. It is carried to the lungs via pulmonary arteries. At lungs, oxygen in the alveolae diffuses to the capillaries surrounding the alveolae and carbon dioxide inside the blood diffuses to the alveolae. As a result, blood is oxygenated which is then carried to the heart's left half -to the left atrium via pulmonary veins. Oxygen rich blood is prepared for the whole organs and tissues of the body. This is important because mitochondria inside the cells should use oxygen to produce energy from the organic compounds.

The Systemic Circulation

The systemic circuit supplies oxygenated blood to the organ system. Oxygenated blood from the lungs is returned to the left atrium, then the ventricle contracts and pumps blood into the aorta. Systemic arteries split from the aorta and direct blood into the capillaries. Cells consume the oxygen and nutrients and add carbon dioxide, wastes, enzymes and hormones. The veins drain the deoxygenated blood from the capillaries and return the blood to the right atrium.

Aorta

The aorta is the largest of the arteries in the systemic circuit. The blood is pumped from the left ventricle into the aorta and from there it branches to all parts of the body. The aorta is an elastic artery, and as such is able to distend. When the left ventricle contracts to force blood into the aorta, the aorta expands. This stretching gives the potential energy that shall help maintain blood pressure during diastole, as during this time the aorta contracts passively.

Superior Vena Cava

The superior vena cava (SVC) is a large but short vein that carries de-oxygenated blood from the upper half of the body to the heart's right atrium. It is formed by the left and right brachiocephalic veins (also referred to as the innominate veins) which receive blood from the upper limbs and the head and neck. The azygous vein (which receives blood from the ribcage) joins it just before it enters the right atrium.

Inferior Vena Cava

The inferior vena cava (or IVC) is a large vein that carries de-oxygenated blood from the lower half of the body into the heart. It is formed by the left and right common iliac veins and transports blood to the right atrium of the heart. It is posterior to the abdominal cavity, and runs along side of the vertebral column on its right side.

Coronary Circulation

The coronary circulation consists of the blood vessels that supply blood to, and remove blood from, the heart muscle itself. The heart has its own set of blood vessels that provide the myocardium with the oxygen and nutrients necessary to pump blood throughout the body. The vessels that supply blood high in oxygen to the myocardium are known as coronary arteries.(Fig.3.5.1) The vessels that remove the deoxygenated blood from the heart muscle are known as cardiac veins. The left and right coronary arteries branch off from the aorta and provide blood to the left and right sides of the heart. The coronary sinus is a vein on the posterior side of the heart that returns deoxygenated blood from the myocardium to the vena cava.

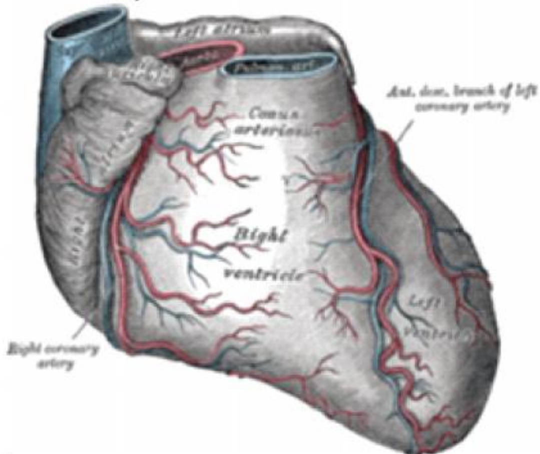


Fig.3.5.1 Heart showing the Coronary Arteries

Coronary Arteries

The coronary arteries are classified as "end circulation", since they represent the only source of blood supply to the myocardium: there is very little redundant blood supply, which is why blockage of these vessels can be so critical. In general there are two main coronary arteries, the left and right. • Right coronary artery • Left coronary artery both of these arteries originate from the beginning (root) of the aorta, immediately above the aortic valve. As discussed below, the left coronary artery originates from the left aortic sinus, while the right coronary artery originates from the right aortic sinus. Four percent of people have a third, the posterior coronary artery. In rare cases, a patient shall have one coronary artery that runs around the root of the aorta.

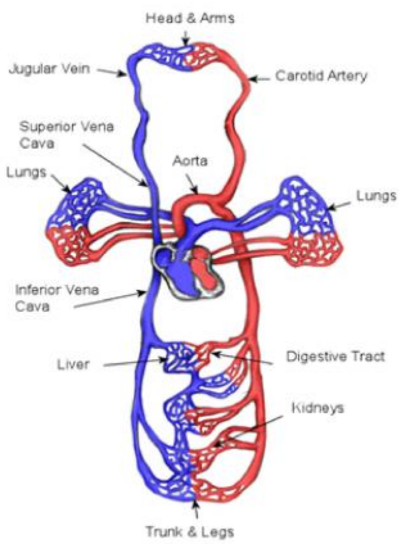


Fig.3.7 Blood circulation

Hepatic Portal Circulation-

The veins of the stomach and intestines perform a unique function: instead of carrying blood directly back to the heart, they carry blood to the liver through the hepatic portal vein. Blood leaving the digestive organs is rich in nutrients and other chemicals absorbed from food. The liver removes toxins, stores sugars, and processes the products of digestion before they reach the other body tissues. Blood from the liver then returns to the heart through the inferior vena cava.(Fig.3.7)

3.6-Blood Groups-

There are many clinical conditions when patient shall require blood transfusion. In addition Rh incompatibility in pregnancy is recognized hazard in pregnancy. When blood from one person is transfused to another person, it must be ensured that Donor's blood matches perfectly with the blood of recipient, otherwise there shall be mismatching between these two blood which may cause even death. This phenomenon gave the origin to blood group. The blood groups were discovered by Dr. Karl Landsteiner of Germany.

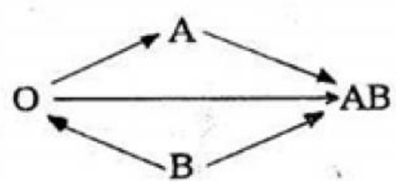
There are various blood grouping systems as follows-

vii) ABO
viii) Rh
ix) M and N
x) Kell
xi) Luther and Duffy

(i) ABO system- This was discovered in 1900. On the RBC membrane several classes of antigens A and B (Agglutinogens) are present and in the plasma antibodies Anti-A and Anti-B (Agglutinins) are present. According to this in ABO system there are A, B, AB and O blood groups. These blood groups are also called as classical blood groups. The process of agglutination is caused by a substance, called an agglutinogen, which is present on the red cells, of one group react with a substance called an agglutinin which is present in the plasma of another group. The distribution of agglutinogens and agglutinins in people with different ABO blood group is shown in following table.

Name of blood group	Agglutinogen present on RBC membrane	Agglutinin present in plasma
A	A	Anti-B
B	B	Anti-A
AB	Both are present	Both are absent
O	Both are absent	Both are present

Since blood group AB has no agglutinins in the plasma, persons of this blood group can often be transfused with blood of the other groups (universal receipient) whereas blood group O has no agglutinogen (universal donor) can donate blood to others without much complications. Thus blood transfusion may be given along with the lines indicated by the arrows.



ii) Rh system- In 1940 another important blood group was discovered and has been named Rhesus factor or Rh system. Rh owes its name to Rhesus monkey. Unlike ABO system, no preformed Rhesus agglutinin (Anti D) is found. However, a Rhesus negative (Rh-ve) person, can make Anti-D following sensitization with Rhesus positive blood.

The ABO and rhesus blood group systems are the main groups but there are others such as the M,N, Kell, Luther and Duffy which may be occasional causes of blood transfusion reactions.

Glossary

- Aortic arch: The second section of the aorta; it branches into the brachiocephalic trunk, left common carotid artery, and left subclavian artery.
- Aortic valve: Located at the base of the aorta, the aortic valve has three cusps and opens to allow blood to leave the left ventricle during contraction.
- Arteries: Elastic vessels able to carry blood away from the heart under high pressure.
- Arterioles: Subdivisions of arteries; they are thinner and have muscles that are innervated by the sympathetic nervous system.
- Atria: The upper chambers of the heart; they receive blood returning to the heart.
- Atrioventricular node (AV node):A mass of specialized tissue located in the inferior interatrial septum beneath the endocardium; it provides the only normal conduction pathway between the atrial and ventricular syncytia.
- AV bundle: The bundle of His; a large structure that receives the cardiac impulse from the distal AV node. It enters the upper part of the interventricular septum.
- Blood volume: The sum of formed elements and plasma volumes in the vascular system; most adults have about 5 L of blood.
- Capillaries: The smallest-diameter blood vessels, which connect the smallest arterioles to the smallest venules.
- Cardiac conduction system:The initiation and distribution of impulses through the myocardium that coordinates the cardiac cycle.
- Cardiac cycle: A heartbeat; it consists of a complete series of systolic and diastolic events.
- Cardiac output: The volume discharged from the ventricle per minute, calculated by multiplying stroke volume by heart rate, in beats per minute.
- Cardiac veins: Those veins that branch out and drain blood from the myocardial capillaries to join the coronary sinus.
- Carotid sinuses: Enlargements near the base of the carotid arteries that contain baroreceptors and help to control blood pressure.
- Chordae tendineae: Strong fibers originating from the papillary muscles that attach to the cusps of the tricuspid valve.
- Coronary arteries: The first two aortic branches, which supply blood to the heart tissues.
- Coronary sinus: An enlarged vein joining the cardiac veins; it empties into the right atrium.
- Diastole: The relaxation of a heart structure.

- Diastolic pressure: The lowest pressure that remains in the arteries before the next ventricular contraction.
- Electrocardiogram (EKG):The recording of electrical changes in the myocardium during the cardiac cycle. The EKG machine works by placing nodes on the skin that connect via wires and respond to weak electrical changes of the heart. The abbreviation EKG is more commonly used than ECG.
- Endocardium: The inner layer of the heart wall.
- Epicardium: The outer layer of the heart wall.
- Hepatic portal system: The veins that drain the abdominal viscera, originating in the stomach, intestines, pancreas, and spleen, to carry blood through a hepatic portal vein to the liver.
- Inferior vena cava: Along with the superior vena cava, one of the two largest veins in the body; it is formed by the joining of the common iliac veins.
- Mitral valve: The bicuspid valve; it lies between the left atrium and left ventricle, preventing blood from flowing back into the left atrium from the ventricle.
- Myocardium: The thick middle layer of the heart wall that is mostly made of cardiac tissue.
- Pacemaker: The term used to refer to the sinoatrial node (SA node).
- Papillary muscles: Those muscles that contract as the heart's ventricles contract, pulling on the chordae tendineae to prevent the cusps from swinging back into the atrium.
- Pericardium: A membranous structure that encloses the heart and proximal ends of the large blood vessels and that consists of double layers.
- Peripheral resistance: A force produced by friction between blood and blood vessel walls.
- Pulmonary circuit: The venules and veins, which send deoxygenated blood to the lungs to receive oxygen and unload carbon dioxide
- Pulmonary valve: Lying at the base of the pulmonary trunk, this valve has three cusps and allows blood to leave the right ventricle while preventing backflow into the ventricular chamber.
- Purkinje fibers: Consisting of branches of the AV bundle that spread and enlarge, these fibers are located near the papillary muscles; they continue to the heart's apex and cause the ventricular walls to contract in a twisting motion.
- Septum: A solid, wall-like structure that separates the left atria and ventricle from the right atria and ventricle.
- Sinoatrial node (SA node):A small mass of specialized tissue just beneath the epicardium in the right atrium that initiates impulses through the myocardium to stimulate contraction of cardiac muscle fibers.
- Stroke volume:The volume of blood discharged from the ventricle with each contraction; it is usually about 70 mL.
- Superior vena cava: Along with the inferior vena cava, one of the two largest veins in the body; the superior vena cava is formed by the joining of the brachiocephalic veins.

- Systemic circuit: The arteries and arterioles, which send oxygenated blood and nutrients to the body cells while removing wastes.
- Systole: The contraction of a heart structure.
- Systolic pressure: The maximum pressuring during ventricular contraction.
- Thyrocervical arteries: Those that branch off to the thyroid and parathyroid glands, larynx, trachea, esophagus, pharynx, and muscles of the neck, shoulder, and back.
- Tricuspid valve: Lying between the right atrium and ventricle, this valve allows blood to move from the right atrium into the right ventricle while preventing backflow.
- Vasoconstriction: The contraction of blood vessels, which reduces their diameter.
- Vasodilation: The relaxation of blood vessels, which increases their diameter.
- Veins: Blood vessels that carry blood back to the atria; they are less elastic than arteries.
- Ventricles: The lower chambers of the heart; they receive blood from the atria, which they pump out into the arteries.
- Venules: Microscopic vessels that link capillaries to veins.
- Vertebral arteries: One of the main divisions of the subclavian and common carotid arteries; the vertebral arteries run upward through the cervical vertebrae into the skull and supply blood to the vertebrae, their ligaments, and their muscles.
- Viscosity: Thickness or stickiness; the resistance of fluid to flow. In a biologic fluid, viscosity is caused by the attraction of cells to one another.

Assignments/Tests

Q. Multiple choice questions

1……….. conducts electricity like nerves

A) Epicardium

B) Pericardium

C) Myocardium

D) Subvalaular Apparatus

E) None of these, only nerves conduct electricity

2. ……… carries the most blood at any given time in the body

A) Veins

B) Capillary Beds

C) Veins

D) Aorta

E) Vena Cava

3. The following contract together to pump blood

A) Right atrium with the right ventricle and left atrium with the left ventricle

B) Right atrium with left atrium and right ventricles with left ventricle

C) Tricuspid valve and mitral valve

D) Aorta and pulmonary artery

E) Aorta, pulmonary artery and pulmonary vein

4. ....is the pacemaker of the heart

A) AV node

B) Purkinje fibers

C) AV Bundle

D) SA node

E) None of these, a pacemaker is surgically inserted

5. When reading an ECG, this letter shows the depolarization from the AV node down to the AV bundle

A) S

B) P

C) U

D) T

E) Q

6. The T wave in an ECG shows

A) Resting potential

B) Atrial depolarization

C) SA node excitation

D) Ventricle repolarization

E) Purkinje Excitation

7. Blood pressure is the measure of........

A) Pressure exerted by the blood on the walls of the blood vessels

B) Pressure exerted by the blood on the arteries

C) Pressure exerted by the blood on the veins

D) Pressure exerted by the blood on the aorta

E) Pressure exerted by the blood on the capillaries

8. Systolic Pressure is............

A) An average of 120 mm Hg

B) Lowers steadily during ventricle systole

C) The highest when blood is being pumped out of the left ventricle into the aorta

D) An average of 80 mm Hg

E) Both A and C

F) Both B and D

9. The artery which supplies the blood to heart muscles is-------

a) Renal artery

b) Coronary artery

c) Thoracic artery

d) Brachial artery

10. Heart has----------chambers.
   a) 2
   b) 3
   c) 4
   d) 5

11. ----------is the largest artery in the body.
   a) Superior vena cava
   b) Aorta
   c) Inferior vena cava
   d) Thoracic duct

Q. Answer the following.

1. Define- i) Cardiac output ii) Blood pressure
2. What are the parts of cardio-vascular system?
3. Write an anatomy of heart.
4. Draw and label the internal structure of heart.
5. Differentiate arteries and veins.
6. Write about the blood vessels.
7. Write short notes on the following-
   i) Pulmonary circulation
   ii) Systemic circulation
   iii) Coronary circulation
   iv) Coagulation
   v) Cardiac cycle
   vi) Blood groups
8. What are the contents of blood?
9. What are the functions of blood?
10. What are the types of WBCs?
11. What are the functions of cardio-vascular system?
12. What are the types of blood pressure?
13. What are the components of heart beats?
14. Write in detail about ECG.
15. Write about the electrical conduction system of heart.
16. Write the clinical significance of ECG.
17. Write about the waveforms on ECG tracings.

Q. Match the correct pairs.

Group 'A'	Group 'B'
i) Red blood cells	a) Thrombocytes
ii) White blood cells	b) Erythrocytes
iii) Platelets	c) Leukocyte

UNIT 4 - LYMPHATIC SYSTEM

Objectives-

At the end of this Unit you shall be able to-

- State the organs of lymphatic system
- State the relation between the immune and lymphatic system
- State the structure of the organs of lymphatic system
- State the nature of lymph and its contents
- Describe the structure of lymphatic nodules
- State the process of lymphatic circulation
- State the functions of lymphatic system
- State the clinical significance of lymphatic system

The blood leaves the heart by arteries, and is returned to it by veins. Some of the fluid which leaves the circulation is returned to it by the lymphatics, which permeate the tissue spaces.

Composition of lymph- Lymph is similar to plasma but contains less protein. The lymph glands add lymphocytes to the lymph so that there are numbers of them in the large lymphatic vessels. There are no other cells. The lymph in the vessels is moved onwards by the contraction of the muscles surrounding them aided by the presence of valves in some of the larger lymphatic channels.

Organs of lymphatic system-

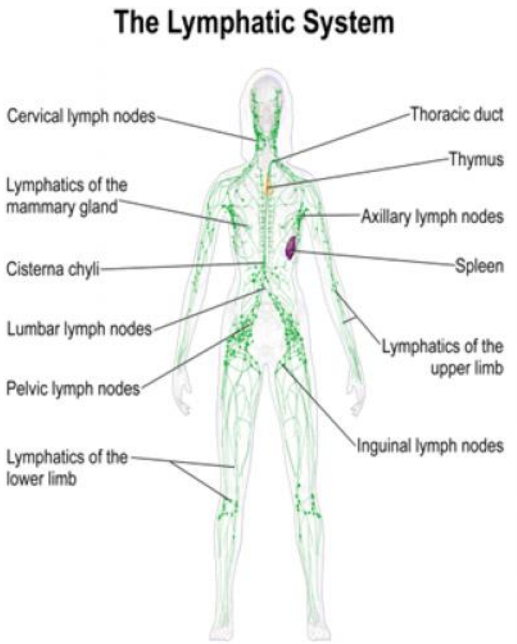
1) The lymphatic system is a system of capillaries, vessels, nodes and other organs that transport a fluid called lymph from the tissues as it returns to the blood stream (Fig.4.1). The lymphatic tissue of these organs filters and cleans the lymph of any debris, abnormal cells, or pathogens.

2) The lymphatic system also transports fatty acids from the **intestines** to the circulatory system. The lymphatic system is a vascular network of tubules and ducts that collect, filter, and return lymph to blood circulation.

3) Lymph is a clear fluid that comes from blood plasma, which exits blood vessels at capillary beds. This fluid becomes the interstitial fluid that surrounds cells. Lymph contains water, proteins, salts, lipids, white blood cells, and other substances that must be returned to the blood.

4) The primary functions of the lymphatic system are to drain and return interstitial fluid to the blood, to absorb and return lipids from the digestive system to the blood, and to filter fluid of pathogens, damaged cells, cellular debris, and cancerous cells.

5) The immune and lymphatic systems are two closely related organ systems that share several organs and physiological functions (Fig.4.2). The immune system is our body's defense system against infectious pathogenic viruses, bacteria, and fungi as well as parasitic animals.



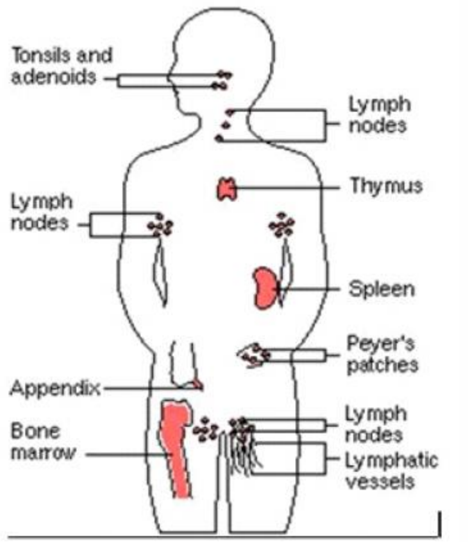


Fig.4.1 Lymphatic System Fig.4.2 Lymphatic and Immune system

4.1 Lymphatic Glands and Vessels

The major components of the lymphatic system include lymph, lymphatic vessels, and lymphatic organs that contain lymphoid tissues.

Lymph Capillaries-

As blood passes through the tissues of the body, it enters thin-walled capillaries to facilitate diffusion of nutrients, gases, and wastes. Blood plasma also diffuses through the thin capillary walls and penetrates into the spaces between the cells of the tissues. Some of this plasma diffuses back into the blood of the capillaries, but a considerable portion becomes embedded in the tissues as interstitial fluid. To prevent the accumulation of excess fluids, small dead-end vessels called lymphatic capillaries extend into the tissues to absorb fluids and return them to circulation.

Lymph-

- The interstitial fluid picked up by lymphatic capillaries is known as lymph.
- Lymph very closely resembles the plasma found in the veins: it is a mixture of about 90% water and 10% solutes such as proteins, cellular waste products, dissolved gases, and hormones.
- Lymph may also contain bacterial cells that are picked up from diseased tissues and the white blood cells that fight these pathogens.
- In late-stage cancer patients, lymph often contains cancerous cells that have metastasized from tumors and may form new tumors within the lymphatic system.
- A special type of lymph, known as chyle, is produced in the digestive system as lymph absorbs triglycerides from the intestinal villi. Due to the presence of triglycerides, chyle has a milky white coloration to it.

Lymphatic Vessels-

- Lymphatic capillaries merge together into larger lymphatic vessels to carry lymph through the body. The structure of lymphatic vessels closely resembles that of veins: they both have thin walls and many check valves due to their shared function of carrying fluids under low pressure.

- Lymph is transported through lymphatic vessels by the skeletal muscle pump—contractions of skeletal muscles constrict the vessels to push the fluid forward.
- Check valves prevent the fluid from flowing back toward the lymphatic capillaries.

Lymph Nodes-(Fig.4.3)

- Lymph nodes are small, kidney-shaped organs of the lymphatic system. There are several hundred lymph nodes found mostly throughout the thorax and abdomen of the body with the highest concentrations in the axillary (armpit) and inguinal (groin) regions.
- The outside of each lymph node is made of a dense fibrous connective tissue capsule. Inside the capsule, the lymph node is filled with reticular tissue containing many lymphocytes and macrophages.

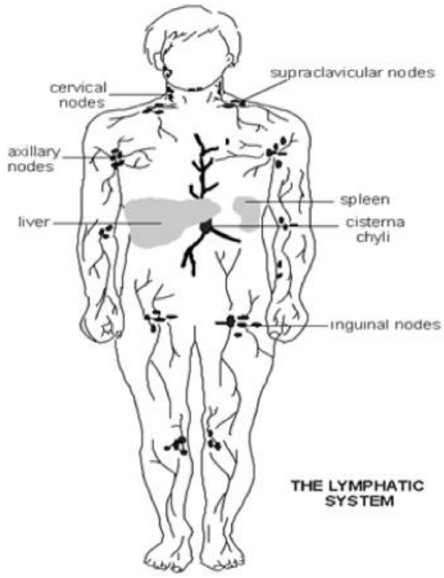


Fig.4. 3 Lymph nodes

- The lymph nodes function as filters of lymph that enters from several afferent lymph vessels. The reticular fibers of the lymph node act as a net to catch any debris or cells that are present in the lymph. Macrophages and lymphocytes attack and kill any microbes caught in the reticular fibers. Efferent lymph vessels then carry the filtered lymph out of the lymph node and towards the lymphatic ducts.

Lymphatic Ducts-(Fig.4.4)

All of the lymphatic vessels of the body carries lymph toward the 2 lymphatic ducts: the thoracic duct and the right lymphatic ducts. These ducts serve to return lymph back to the venous blood supply so that it can be circulated as plasma.

- **Thoracic duct-** The **thoracic duct** connects the **lymphatic vessels** of the legs, abdomen, left arm, and the left side of the head, neck, and thorax to the **left brachiocephalic vein**. It is the largest lymphatic duct. The lymphatics from the right side of the head and chest and the right arm are seen draining into the junction of the right internal jugular and the right subclavian veins. The thoracic duct terminates by emptying its contents into the same position on the left. The right upper limb and the right side of the chest, and empties it into the veins at the right side of the root of the neck.

Right lymphatic duct- The **right lymphatic duct** connects the **lymphatic vessels of the right arm** and the right side of the head, neck, and thorax to the **right brachiocephalic vein.**

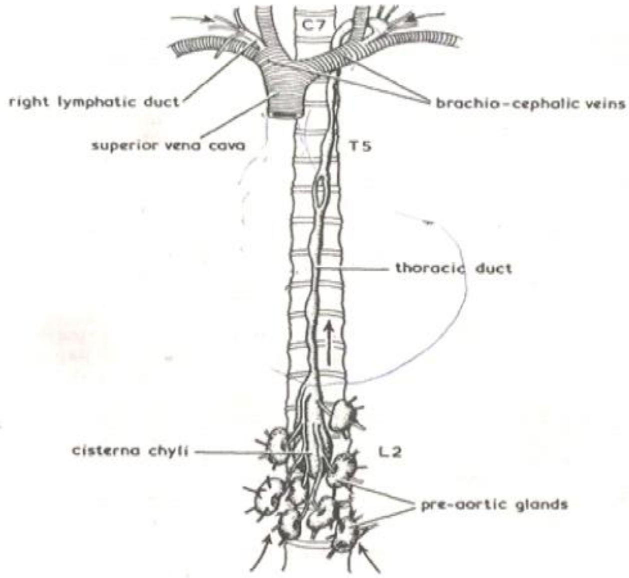


Fig. 4.4 Lymphatic duct

During an infection the lymphatic vessels and glands may become inflamed, as shall be seen in the swollen painful glands in the axilla or groin in the case of a septic finger or toe.

Lymphatic Nodules-

Outside of the system of lymphatic vessels and lymph nodes, there are masses of non-encapsulated lymphatic tissue known as lymphatic nodules. The lymphatic nodules are associated with the mucous membranes of the body, where they work to protect the body from pathogens entering the body through open body cavities.(Fig.4.5)

- **Tonsils-** There are 5 tonsils in the body—2 lingual, 2 palatine, and 1 pharyngeal. The lingual tonsils are located at the posterior root of the tongue near the pharynx. The **palatine tonsils** are in the posterior region of the mouth near the pharynx. The pharyngeal pharynx, also known as the **adenoid**, is found in the **nasopharynx** at the posterior end of the nasal cavity. The tonsils contain many T and B cells to protect the body from inhaled or ingested substances. The tonsils often become inflamed in response to an infection.
- **Peyer's patches- Peyer's patches** are small masses of lymphatic tissue found in the ileum of the **small intestine.**
- **Spleen-** The **spleen** is a flattened, oval-shaped organ located in the upper left quadrant of the abdomen lateral to the stomach. The spleen is made up of a dense fibrous connective tissue capsule filled with regions known as red and white pulp. Red pulp, which makes up most of the spleen's mass, is so named because it contains many sinuses that filter the blood. Red pulp contains reticular tissues whose fibers filter worn out or damaged red blood cells from the blood. Macrophages in the red pulp digest and recycle the hemoglobin of the captured red blood cells. The red pulp also stores many platelets to be released in response to blood loss. White pulp is found within the red pulp surrounding the arterioles of the spleen. It is made of lymphatic tissue and contains many T cells, B cells, and macrophages to fight off infections.
- **Thymus-** The **thymus** is a small, triangular organ found just posterior to the sternum and anterior to the heart. The thymus is mostly made of glandular epithelium and hematopoietic connective tissues. The thymus produces and trains T cells during fetal development and childhood. T cells formed in the thymus and

red bone marrow mature, develop, and reproduce in the thymus throughout childhood. By the time a person reaches puberty, the immune system is mature and the role of the thymus is diminished. After puberty, the inactive thymus is slowly replaced by adipose tissue.

4.2 Circulation of Lymphatic –

The Lymphatic System parallels the Circulatory System, but runs purely on water and muscle movement to propel it along its way. The Lymphatic System picks up waste from body cells.

The lymphatic system is a complex system of fluid drainage and transport, and immune response and disease resistance. Fluid that is forced out of the bloodstream during normal circulation is filtered through lymph nodes to remove bacteria, abnormal cells and other matter. This fluid is then transported back into the bloodstream via the lymph vessels.(Fig4.5) Lymph only moves in one direction, toward the heart. (Fig. 4.6 and Fig.4.7)

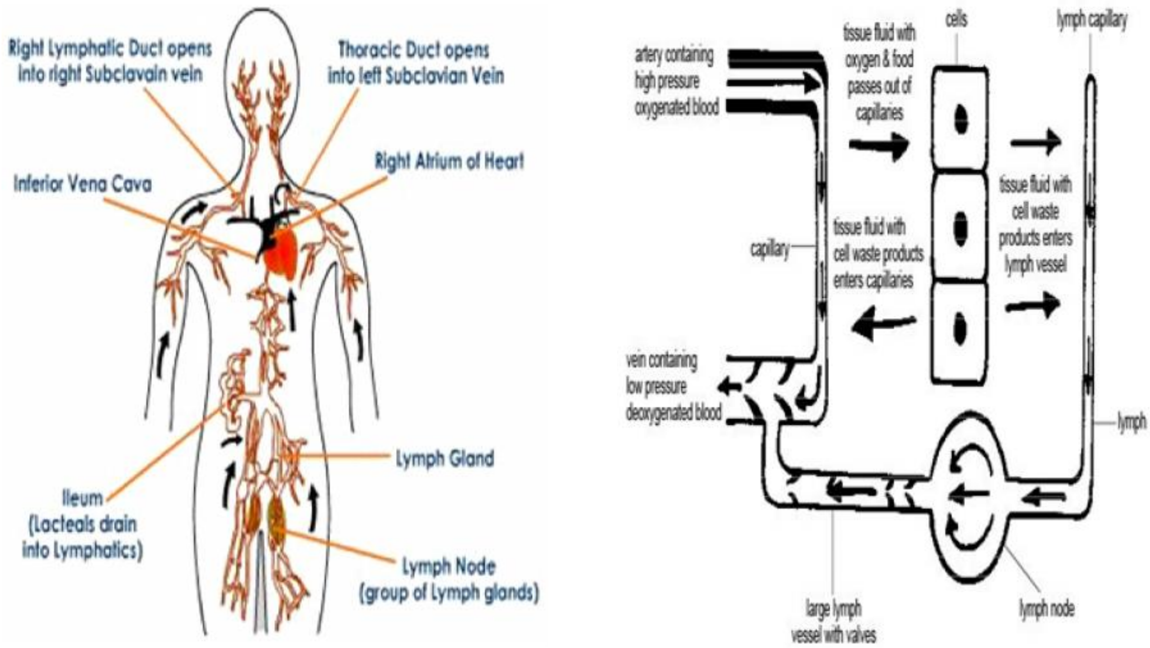


Fig.4.5 Lymph Circulation

Functions of Lymphatic System-

The lymphatic system has multiple interrelated functions:

- The lymphatic system plays a vital role in the proper functioning of the body.
- One of the major roles of this organ system is to drain excess fluid surrounding tissues and organs and return it to the blood.
- Returning lymph to the blood helps to maintain normal blood volume and pressure.
- It also prevents edema, the excess accumulation of fluid around tissues.
- The lymphatic system is also a component of the immune system.
- As such, one of its essential functions involves the development and circulation of immune cells, specifically lymphocytes. These cells destroy pathogens and protect the body from disease.
- In addition, the lymphatic system works in conjunction with the cardiovascular system to filter blood of pathogens, via the spleen, before returning it to circulation.

- The lymphatic system works closely with the digestive system as well to absorb and return lipid nutrients to the blood.
- It is responsible for the removal of interstitial fluid from tissues
- It absorbs and transports fatty acids and fats as chyle from the digestive system
- It transports white blood cells to and from the lymph nodes into the bones.
- The lymph transports antigen-presenting cells (APCs), such as dendritic cells, to the lymph nodes where an immune response is stimulated.

Clinical Significance-

- The study of lymphatic drainage of various organs is important in diagnosis, prognosis, and treatment of cancer.
- The lymphatic system, because of its physical proximity to many tissues of the body, is responsible for carrying cancerous cells between the various parts of the body in a process called metastasis.
- The intervening lymph nodes can trap the cancer cells. If they are not successful in destroying the cancer cells the nodes may become sites of secondary tumors.

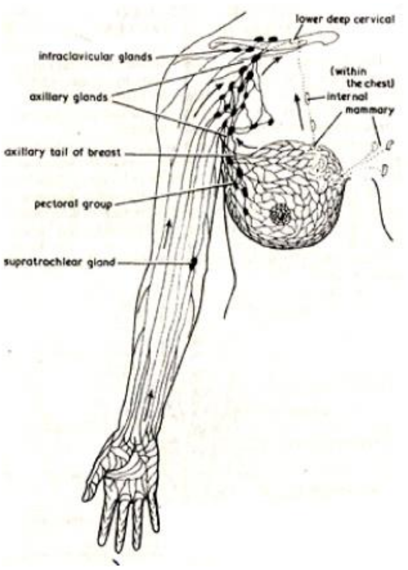


Fig. 4.6 Lymphatic drainage of right arm

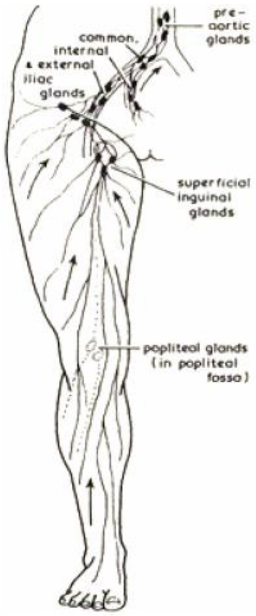


Fig.4.7 Lymphatic drainage of right leg

Glossary

- **Lymph** -This is the name for fluid once it has entered the lymphatics.
- **Lymphatics** -This is the system of drainage vessels that collect interstitial fluid and returns it to the bloodstream. (AKA- Lymphatic Vessels)
- **Lymphatic Capillaries** -These are the vessels where lymph first enters the lymphatics. These are made up of loose endothelial cells that form flaplike minivalves held outward by collagen filaments which give them extreme permeability.
- **Lacteals** -These are highly specialized lymphatic capillaries found in the villi in the intestinal mucosa. Named for its white appearance.
- **Chyle** -This is the milky white lymph drained from intestine through lacteals.
- **Lymphatic Trunks** -These are formed by the largest lymphatic collecting vessels.

- **Lymphatic Collecting Vessels** -These receive lymph from lymphatic capillaries, contain more valves than veins, superficial and deep, pass through lymph nodes where it is monitored and cleared of pathogens and cancer cells
- **Right Lymphatic Duct** -receives lymph from the right upper part of the body
- **Thoracic Duct** -the major duct of the lymphatic system
- **Cisterna Chyli** -an enlarged pouch on the thoracic duct that serves as a storage area for lymph moving toward its point of entry into the venous system
- **Lymphangitis** -inflammation of a lymph vessel
- **Lymphedema** -swelling (usually in the legs) caused by lymph accumulating in the tissues
- **Lymphocytes** -The two types of white blood cells that are part of the body's immune system
- **T Lymphocytes**- Lymphocytes that develop in the thymus and are responsible for cell-mediated immunity. Their cell-surface antigen receptor is called the T-cell receptor.
- **B Lymphocytes** -form in the bone marrow and release antibodies that fight bacterial infections.
- **Plasma Cells**- cells that develop from B cells and produce antibodies.
- **Macrophages** -Found within the lymph nodes, they are phagocytes that destroy bacteria, cancer cells, and other foreign matter in the lymphatic stream.
- **Dendritic Cells** -specialized white blood cells that patrol the body searching for antigens that produce infections
- **Reticular Cells** -produce reticular fiber stroma (network for other cells)
- **Stroma** -the supporting tissue of an organ (as opposed to parenchyma)
- **Lymphoid Tissue** -An important component of the immune system, mainly because 1) houses and provides a proliferation site for lymphocytes and 2) furnishes an ideal surveillance vantage point for lymphocytes and macrophages.
- **Reticular Connective Tissue** -Composed of reticular fibers within a gel-like ground substance. Cellular components are fibroblasts, lymphocytes, and other blood cells. Located in lymph nodes, spleen, bone marrow.
- **Diffuse Lymphatic Tissue** -scattered reticular tissue elements and associated lymphocytes; found in about every organ but especially in mucous membrane lining the respiratory and digestive tracts
- **Lymphoid Follicles** -solid, spherical bodies consisting of tightly packed reticular elements and cells- often form parts of larger lymphoid organs (found isolated in distal small intestine and appendix)
- **Capsule** -a sticky, gelatinous substance around the cell wall; allows cells to stick together or to the host cell
- **Trabeculae** -connective tissue strands that extend in to divide the node into compartments
- **Cortex** -the tissue forming the outer layer of an organ or structure in plant or animal
- **Medulla** -the inner part of an organ or structure in plant or animal

- **Medullary Cords** -extend from the cortex and contain B cells, T cells, and plasma cells
- **Lymph Sinuses** - Spaces between these groups of lymphatic tissues. These spaces contain a network of fibers and the macrophage cells.
- **Afferent Lymphatic Vessels** -Vessels that bring lymph draining from connective tissue into a lymph node en route to the blood.
- **Subcapsular Sinus** -region within lymph node immediately deep to capsule, contains relatively sparse lymphocytes, allows lymph to flow freely through it
- **Hilum** -(anatomy) a depression or fissure where vessels or nerves or ducts enter a bodily organ
- **Efferent Lymphatic Vessels** -Vessels leaving the lymph node
- **Spleen** -a large dark-red oval organ on the left side of the body between the stomach and the diaphragm
- **White Pulp** -That region of the spleen within PALS; predominant immune cell is the T cell and where primary T cell responses can occur.
- **Red Pulp** -consists of reticular cells and fibers(cords of Billroth), surrounds the splenic sinuses
- **Thymus** -a ductless glandular organ at the base of the neck that produces lymphocytes and aids in producing immunity
- **Lymphoid Organs** -Lymph nodes, spleen, and thymus gland are examples of what?
- **Palatine Tonsils** - located on the left and right sides of the throat in the area that is visible through the mouth
- **Lingual Tonsils** - Collection of lymphoid follicles on the base, posterior, or pharyngeal portion of the dorsum of the tongue.
- **Pharyngeal Tonsils** -a collection of lymphatic tissue in the throat behind the uvula (on the posterior wall and roof of the nasopharynx)
- **Tubal Tonsils** -These are a pair of lymphoid organs which lie just behind the openings of the pharyngo-tympanic tubes into the pharynx;
- **Tonsillar Crypts** -portion of tonsils that trap and destroy bacteria and particulate matter.
- **Appendix** -a vestigial process that extends from the lower end of the caecum and that resembles a small pouch
- **Hodgkin's Disease** -painless progressive enlargement of lymph nodes, spleen, and lymphoid tissue; symptoms include anorexia, lassitude, weight loss, fever, itching, night sweats, and anemia
- **Lymphadenopathy** -chronic abnormal enlargement of the lymph nodes (usually associated with disease)
- **Lymphangiography** -radiographic examination of lymph nodes and lymph vessels after injection of a radio-opaque contrast medium
- **Lymphoma** -a neoplasm (tumor) of lymph tissue that is usually malignant
- **Peyer's Patches** -Lymphoid follicles situated along the wall of the small intestine that trap antigens from the gastrointestinal tract and provide sites where B and T cells can interact with antigen

Assignments/Tests

Q. Choose the correct word and rewrite the sentence.

1. After puberty, the inactive --------is slowly replaced by adipose tissue.
   a) Thymus
   b) Ovary
   c) Brain
   d) Liver
2. The lymphatic system is intimately connected with the ----------
   a) Circu¬latory system
   b) Digestive system
   c) Respiratory system
   d) Reproductive system
3. The lymphatic system is also a component of the -----------
   a) Immune system
   b) Respiratory system
   c) Endocrinal system
   d) Nervous system
4. Lymph is a clear fluid which comes from-----------
   a) Blood plasma
   b) Urine
   c) Sweat
   d) Digestive juice
5. Chyle is produced in --------
   a) Digestive system
   b) Circulatory system
   c) Sweat
   d) Bones
6. Chyle has milky white colour due to---------
   a) Nitrates
   b) Salts
   c) Triglycerides
   d) Sugar
7. ----------- is our body's defense system against infectious pathogens.
   a) The immune system
   b) Nervous system
   c) Muscular system
   d) Excretory system

Q. Answer the following.

1. Write the composition of lymph.
2. What are the functions of lymphatic system.
3. Write an anatomy of lymphatic vessels.
4. What are the organs of lymphatic system?
5. Write the structure of lymphatic ducts.
6. Write the clinical significance of the study of lymphatic system.
7. Write about the lymphatic circulation.
8. Write an anatomy of lymphatic nodes.
9. Explain how lymphatic system is related to immune system.
10. What are the lymph nodules?

UNIT 5 - DIGESTIVE SYSTEM

Objective : At the end of the Unit you shall be able to-

- Study the human digestive system
- Demonstrate the parts of the digestive system
- State the functions of the digestive system.
- State the structure of biliary tract
- State the functions of hepatobiliary system
- State the pathway of transportation of bile
- Familiarize the clinical significance of Biliary tract
- State the dental formula and structure of tooth

Introduction:

The digestive system is a group of organs working together to convert food into energy and basic nutrients to feed the entire body. Food passes through a long tube inside the body known as the alimentary canal or the gastrointestinal tract (GI tract). The alimentary canal is made up of the oral cavity, pharynx, esophagus, stomach, small intestines, and large intestines. In addition to the alimentary canal, there are several important accessory organs that help your body to digest food. (Fig.5.1)

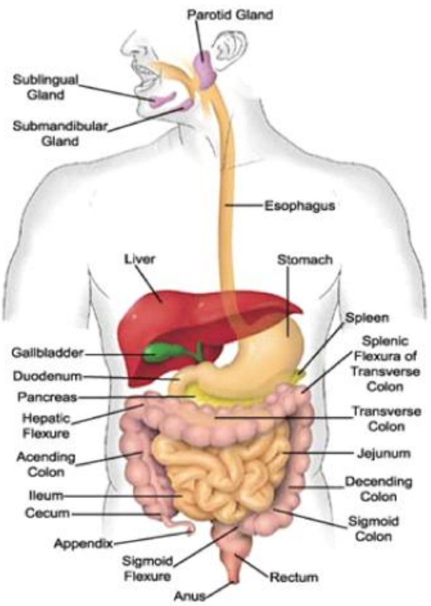


Fig. 5.1 Gastrointestinal tract (digestive system)

The human gastrointestinal tract (GI tract) is an organ system responsible for consuming and digesting foodstuffs, absorbing nutrients, and expelling waste. The tract is commonly defined as the stomach and intestine ,and is divided into the upper and lower gastrointestinal tracts .The GI tract includes all structures between mouth and the anus .On the other hand the digestive system is a broader term that includes other structures including the digestive organs and their accessories .The tract may also be divided into foregut ,and hind gut, reflecting the embryological origin of each segment .

The GI tract releases hormones to help regulate the digestive process. These hormones including gastrin, secretin, cholecystokinin, and ghrelinnn are medicated through either intracrine or autocrine mechanisms indicating that the cells releasing these hormones are conserved structures throughout evolution.

5.1 Anatomy and Physiology of Digestive System

Anatomy of Digestive System

- **Mouth**-Food begins its journey through the digestive system in the mouth, also known as the oral cavity. (Fig.5.2) Inside the mouth are many accessory organs that aid in the digestion of food—the tongue, teeth, and salivary glands. Teeth chop food into small pieces, which are moistened by saliva before the tongue and other muscles push the food into the pharynx.

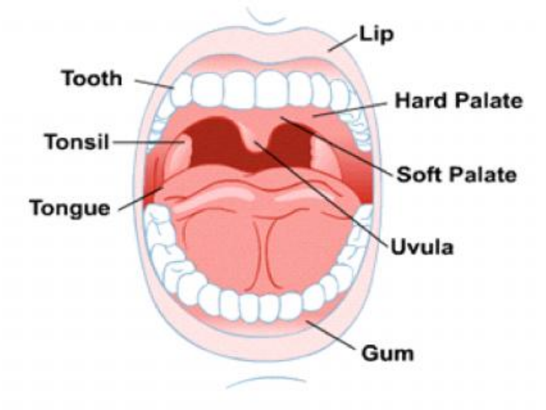


Fig. 5.2 Oral cavity

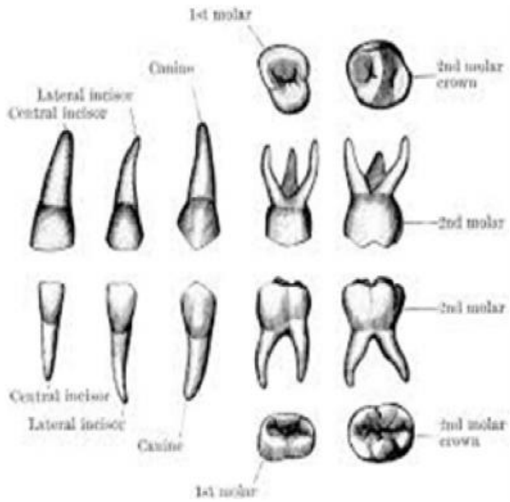


Fig.5.3teeth

- **Teeth**- The teeth are 32 small, hard organs found along the anterior and lateral edges of the mouth. (Fig.5.2 and fig.5.3) Each tooth is made of a bone-like substance called dentin and covered in a layer of enamel—the hardest substance in the body. Teeth are living organs and contain blood vessels and nerves under the dentin in a soft region known as the pulp. The teeth are designed for cutting and grinding food into smaller pieces.
- **Tongue**- The tongue is located on the inferior portion of the mouth just posterior and medial to the teeth. (Fig.5.2) It is a small organ made up of several pairs of muscles covered in a thin, bumpy, skin-like layer. The outside of the tongue contains many rough papillae for gripping food as it is moved by the tongue's muscles. The taste buds on the surface of the tongue detect taste molecules in food and connect to nerves in the tongue to send taste information to the brain. The tongue also helps to push food toward the posterior part of the mouth for swallowing.
- **Salivary Glands**- Surrounding the mouth are 3 sets of salivary glands. (Fig.5.4)

1) Parotid gland

- Largest salivary gland (15-30g), 6 x 3 cm

- Has broad superficial lobe and smaller deeper lobe, with facial nerve usually between both lobes

- Difficult to surgically remove all parotid tissue

- Stensen's duct (main duct) empties into oral cavity opposite crown of second maxillary molar

- 20% have accessory parotid gland and duct, usually overlying the masseter

- Parotid gland has own fascia (capsule), which is continuous with superficial layer of deep cervical fascia

- Contains 3-24 lymph nodes (not all with complete structural organization), usually lateral to facial nerve in superficial lobe

2) Submandibular gland

- Called submaxillary gland because British anatomists refer to mandible as "submaxilla"

- In submandibular triangle formed by anterior and posterior bellies of digastric muscle and inferior margin of mandible

- Weighs 50% of parotid gland (7-15g)

- Has own capsule, which is continuous with superficial layer of deep cervical fascia

- Wharton's duct (submandibular duct) empties into floor of mouth on both sides of tongue frenulum at sublingual caruncula

- Lingual nerve wraps around Wharton's duct, CN XII runs inferior and parallel to Wharton's duct

- No lymph nodes within capsule, but 3-6 adjacent lymph nodes in submandibular triangle

3) Sublingual gland

- Smallest of major salivary glands (2-4g)

- Lies deep to floor of oral mucosa between mandible and genioglossus muscle

- Has no true fascial capsule

- Has no single dominant duct, but is drained by 10 small ducts (ducts of Rivinus)

- Occasionally, several of more anterior ducts may join to form a common duct (Bartholin's duct), which typically empties into Wharton's duct

- Bartholin's duct unites with the submandibular duct just prior to its opening into the oral cavity at the sublingual caruncula on both sides of tongue frenulum

Minor salivary glands

- Except for the gingival and anterior hard palate, minor salivary glands (500-1000, 1-5 mm each) are located throughout the submucosa of the oral cavity

- More numerous in posterior hard palate

- Each salivary unit has its own simple duct

- Most of these minor salivary glands are mucinous with the main exception of Ebner's glands which are serous glands located in the circumvallate papillae of the tongue

The salivary glands are accessory organs that produce a watery secretion known as saliva. Saliva helps to moisten food and begins the digestion of carbohydrates. The body also uses saliva to lubricate food as it passes through the mouth, pharynx, and esophagus.

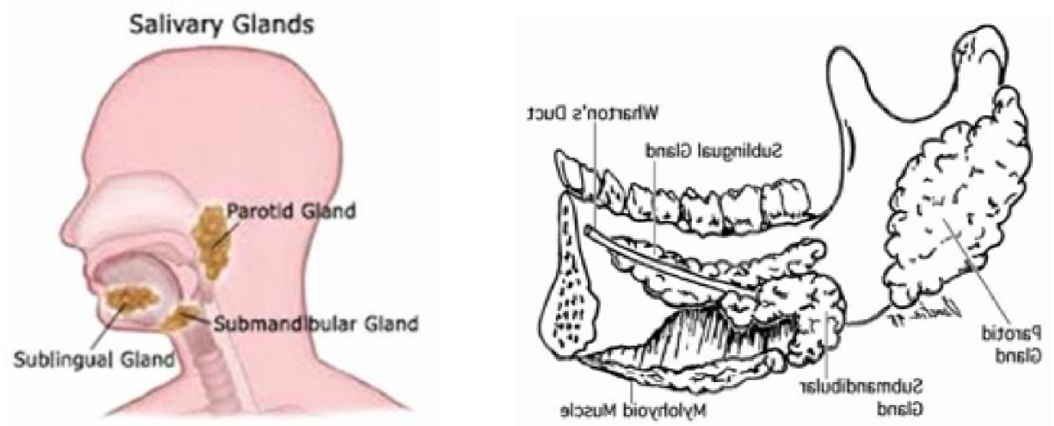


Fig.5.4 Salivary glands

- **Pharynx** - The pharynx, or throat, is a funnel-shaped tube connected to the posterior end of the mouth. (Fig.5.5) The pharynx is responsible for the passing of masses of chewed food from the mouth to the esophagus. The pharynx also plays an important role in the respiratory system, as air from the nasal cavity passes through the pharynx on its way to the larynx and eventually the **lungs**. Because the pharynx serves two different functions, it contains a flap of tissue known as the **epiglottis** that acts as a switch to route food to the esophagus and air to the **larynx**.

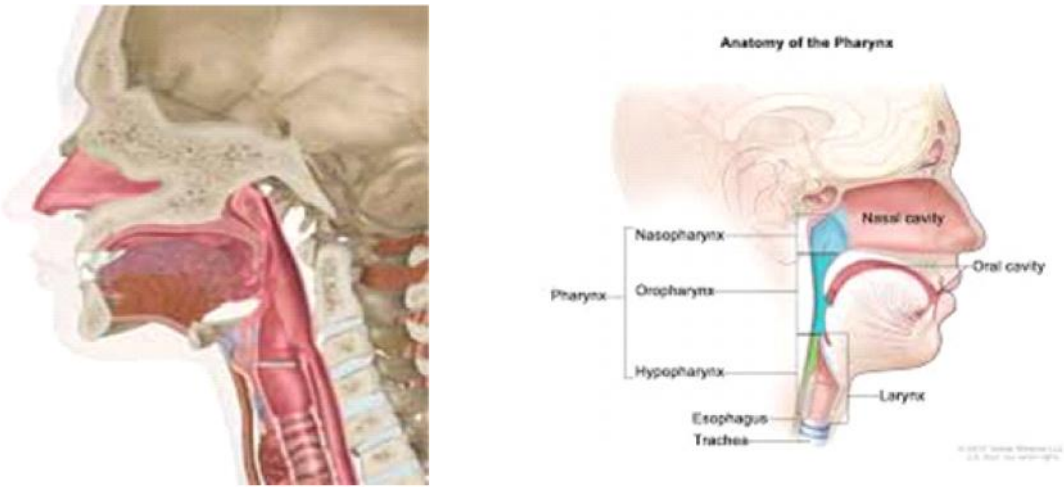


Fig.5.5 Pharynx

- **Esophagus-**The **esophagus** is a muscular tube connecting the pharynx to the stomach that is part of the **upper gastrointestinal tract**.(Fig.5.1.1) It carries swallowed masses of chewed food along its length. The length of esophagus is about 10 inches. At the inferior end of the esophagus is a muscular ring called the lower esophageal sphincter or cardiac sphinctor. The function of this sphincter is to close of the end of the esophagus and trap food in the stomach.

- **Stomach-** The **stomach** is a muscular sac that is located on the left side of the abdominal cavity, just inferior to the **diaphragm**. (Fig.5.6) In an average person, the stomach is about the size of their two fists placed next to each other. This major organ acts as a storage tank for food so that the body has time to digest large meals properly. The stomach also contains hydrochloric acid and digestive enzymes that continue the digestion of food that began in the mouth.

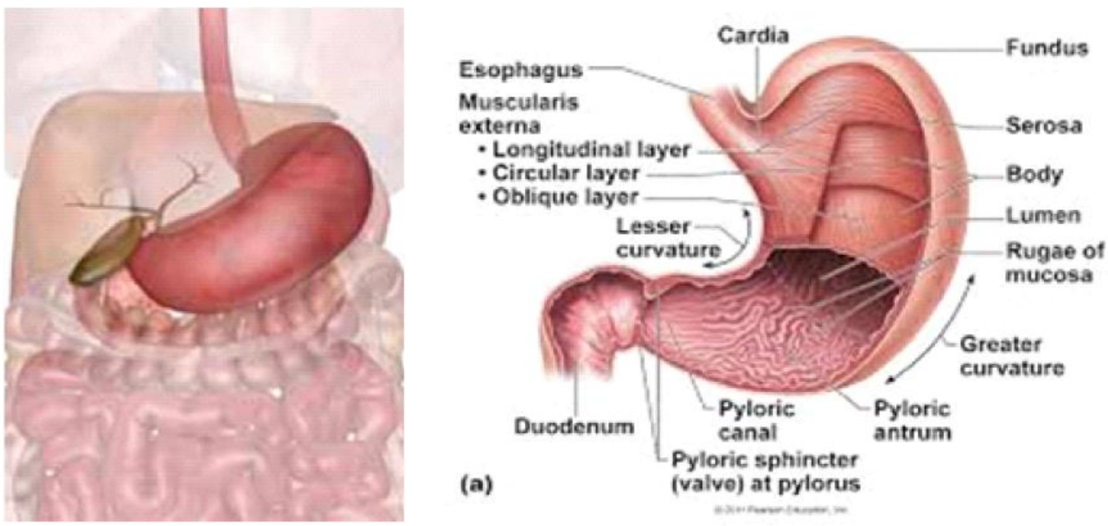


Fig.5.6 Stomach

- **Small Intestine-**The **small intestine** is a long, thin tube about 1 inch in diameter and about 6.2 meter long that is part of the lower gastrointestinal tract. (Fig.5.7) It is located just inferior to the stomach and takes up most of the space in the abdominal cavity. The entire small intestine is coiled like a hose and the inside surface is full of many ridges and folds. These folds are used to maximize the digestion of food and absorption of nutrients. By the time food leaves the small intestine, around 90% of all nutrients have been extracted from the food that entered it.

The small intestine (small bowel) lies between the stomach and the large intestine (large bowel) and includes the **duodenum, jejunum,** and **ileum**. The small intestine is so called because its lumen diameter is smaller than that of the large intestine, although it is longer in length than the large intestine.

Duodenum-The duodenum continues into the jejunum at the duodenojejunal junction or flexure, which lies to the left of L2 vertebra and is fixed to the retroperitoneum by a suspensory ligament of Treitz. The inferior mesenteric vein (IMV) lies to its left. There are several peritoneal fossae around the flexure, which may be the sites of an internal herniation of the small bowel. The rest of the small intestine is a 4-6-m long convoluted tube occupying the center of the abdomen and the pelvis, surrounded on 2 sides and above by the colon (a part of the large intestine). The ileum continues into the large intestine at the ileocecal junction.

The small intestine is differentiated from the large intestine by the presence of a mesentery (exceptions being no mesentery in the duodenum, and mesentery in the transverse and sigmoid colons) and the absence of tenia coli and appendices epiploicae. The demarcation between the jejunum (proximal) and the ileum (distal) is not very clear.

Jejunum-The jejunum constitutes about two fifths of the small intestine and the ileum about three-fifths. The jejunum has a thicker wall and a wider lumen than the ileum and mainly occupies the left upper and central abdomen.

Ileum- The ileum has a thinner wall and a smaller lumen than the jejunum and mainly occupies the central and right lower abdomen and pelvis. Mesenteric fat is abundant in the mesentery of the ileum, and vessels in the mesentery are, therefore, not well seen. (In cystic fibrosis, the jejunum is where the mesentery vessels are well seen because much less mesenteric fat is present in the jejunum than in the ileum.)

Mesentery-The mesentery is a double fold of peritoneum attached to the posterior abdominal wall. It is fan-shaped with a root of about 15 cm extending obliquely from the left L2 transverse process level to the right sacroiliac joint and crossing a third part of the duodenum, aorta and inferior vena cava (IVC) right ureter, and a 4- to 6-m periphery, which covers the entire length of the jejunum and ileum. Between the 2 leaves of the mesentery are the mesenteric vessels and lymph nodes.

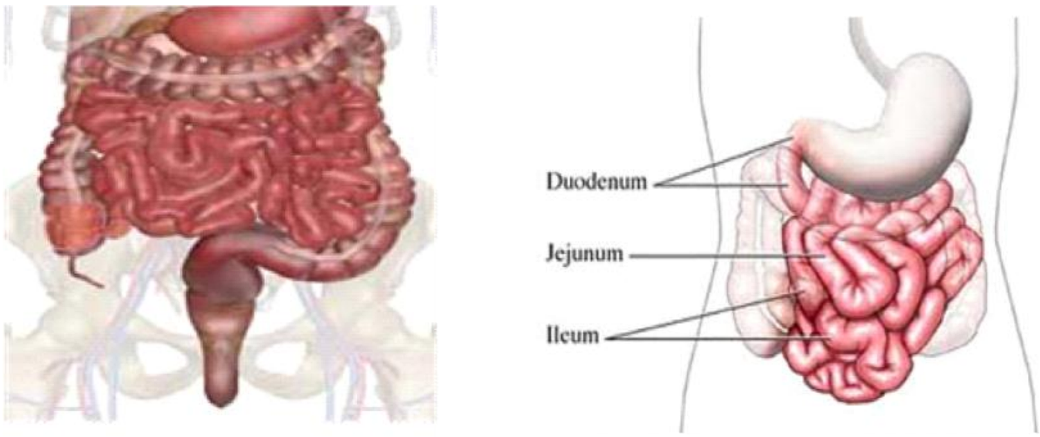


Fig.5.7 Small intestine and large intestine

- **Large Intestine**-The **large intestine** is a long, thick tube about 2 ½ inches in diameter and about 5 feet long. (Fig.5.8) It is located just inferior to the stomach and wraps around the superior and lateral border of the small intestine. The large intestine absorbs water and contains many symbiotic bacteria that aid in the breaking down of wastes to extract some small amounts of nutrients. Feces in the large intestine exit the body through the anal canal.

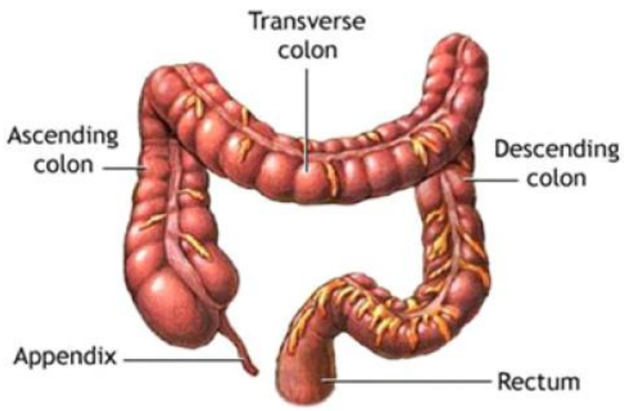


Fig.5.8 Large intestine

Physiology of Digestive System:

Introduction : The digestive system is responsible for taking whole foods and turning them into energy and nutrients to allow the body to function, grow, and repair itself.

The six primary **functions** of the digestive system include:

1. Ingestion of food
2. Secretion of fluids and digestive enzymes
3. Mixing and movement of food and wastes through the body
4. Digestion of food into smaller pieces
5. Absorption of nutrients
6. Excretion of wastes

1. Ingestion-The first function of the digestive system is ingestion, or the intake of food. The mouth is responsible for this function, as it is the orifice through which all food enters the body. The mouth and stomach are also responsible for the storage of food as it is waiting to be digested. This storage capacity allows the body to eat only a few times each day and to ingest more food than it can process at one time.

2. Secretion- In the course of a day, the digestive system secretes around 7 liters of fluids. These fluids include saliva, mucus, hydrochloric acid, enzymes, and bile. Saliva moistens dry food and contains salivary amylase, a digestive enzyme that begins the digestion of carbohydrates. Mucus serves as a protective barrier and lubricant inside of the GI tract. Hydrochloric acid helps to digest food chemically and protects the body by killing bacteria present in our food. Enzymes are like tiny biochemical machines that disassemble large macromolecules like **proteins, carbohydrates, and lipids** into their smaller components. Finally, bile is used to emulsify large masses of lipids into tiny globules for easy digestion.

3. Mixing and Movement- The digestive system uses 3 main processes to move and mix food:

- **Swallowing.** Swallowing is the process of using smooth and skeletal muscles in the mouth, tongue, and pharynx to push food out of the mouth, through the pharynx, and into the esophagus.

- **Peristalsis.** Peristalsis is a muscular wave that travels the length of the GI tract, moving partially digested food a short distance down the tract. It takes many waves of peristalsis for food to travel from the esophagus, through the stomach and intestines, and reach the end of the GI tract.
- **Segmentation.** Segmentation occurs only in the small intestine as short segments of intestine contract like hands squeezing a toothpaste tube. Segmentation helps to increase the absorption of nutrients by mixing food and increasing its contact with the walls of the intestine.

4. **Digestion-**Digestion is the process of turning large pieces of food into its component chemicals. Mechanical digestion is the physical breakdown of large pieces of food into smaller pieces. This mode of digestion begins with the chewing of food by the teeth and is continued through the muscular mixing of food by the stomach and intestines. Bile produced by the liver is also used to mechanically break fats into smaller globules. While food is being mechanically digested it is also being chemically digested as larger and more complex molecules are being broken down into smaller molecules that are easier to absorb. Chemical digestion begins in the mouth with salivary amylase in saliva splitting complex carbohydrates into simple carbohydrates. The enzymes and acid in the stomach continue chemical digestion, but the bulk of chemical digestion takes place in the small intestine thanks to the action of the pancreas. The pancreas secretes an incredibly strong digestive cocktail known as pancreatic juice, which is capable of digesting lipids, carbohydrates, proteins and nucleic acids. By the time food has left the **duodenum**, it has been reduced to its chemical building blocks—fatty acids, amino acids, monosaccharides, and nucleotides

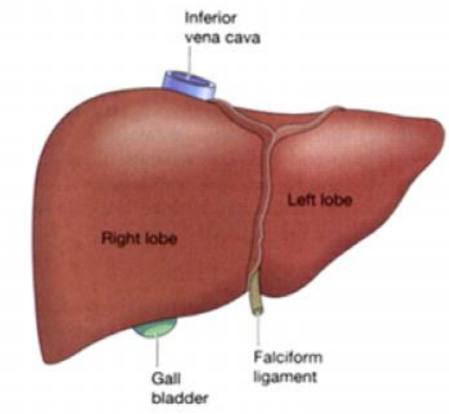
FOODSTUFF	ENZYME CLASS	END PRODUCTS
Carbohydrates	Amylases	Simple Sugars
Lipids	Lipases	Fatty Acids and Glycerol
Proteins	Proteases	Amino Acids

5. **Absorption-**Once food has been reduced to its building blocks, it is ready for the body to absorb. Absorption begins in the stomach with simple molecules like water and alcohol being absorbed directly into the bloodstream. Most absorption takes place in the walls of the small intestine, which are densely folded to maximize the surface area in contact with digested food. Small blood and lymphatic vessels in the intestinal wall pick up the molecules and carry them to the rest of the body. The large intestine is also involved in the absorption of water and vitamins B and K before feces leave the body.

6. **Excretion-**The final function of the digestive system is the excretion of waste in a process known as defecation. Defecation removes indigestible substances from the body so that they do not accumulate inside the gut. The timing of defecation is controlled voluntarily by the conscious part of the brain, but must be accomplished on a regular basis to prevent a backup of indigestible materials.

5.2 Neccessory Organs:

- Liver and Gallbladder-The liver is a roughly triangular accessory organ of the digestive system located to the right of the stomach, just inferior to the diaphragm and superior to the small intestine. (Fig.5.9)The liver weighs about 3 pounds and is the second largest organ in the body. The liver has many different functions in the body, but the main function of the liver in digestion is the production of bile and its secretion into the small intestine. The gallbladder is a small, pear-shaped organ located just posterior to the liver. (Fig.5.10) The gallbladder is used to store and recycle excess bile from the small intestine so that it can be reused for the digestion of subsequent meals.



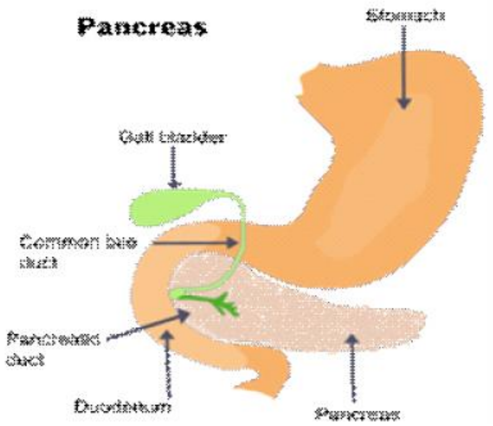


Fig.5.9 Liver

Fig.5.10 Gall bladder, pancreas, stomach

- **Pancreas-**The **pancreas** is a large gland located just inferior and posterior to the stomach. (Fig.5.1.10) It is about 6 inches long and shaped like short, lumpy snake with its "head" connected to the duodenum and its "tail" pointing to the left wall of the abdominal cavity. The pancreas secretes digestive enzymes into the small intestine to complete the chemical digestion of foods. Insulin is secreted by pancreas which regulates the blood sugar level.

Blood supply –

- **For foregut-**stomach, duodenum up to ampulla of vater) – superior mesenteric artery, coelic artery and coelic vein and superior mesenteric vein .
- **For midgut** (ampulla of vater to ilio-caecal junction ¬¬¬¬¬¬¬¬¬¬¬¬–superior mesenteric artery and vein)
- **For hindgut** (From iliocaecal junction to anal opening)-Inferior mesenteric artery and inferior vein.
- **Nerve supply** –10th cranial nerve–vagus (mixed nerve) secretomotor functions

5.3 Dental Formula and Structure of Tooth :

- **Teeth-** The teeth are 32 small, hard organs found along the anterior and lateral edges of the mouth. (Fig.5.2 and fig.5.13) Each tooth is made of a bone-like substance called dentin and covered in a layer of enamel—the hardest substance in the body. Teeth are living organs and contain blood vessels and nerves under the dentin in a soft region known as the pulp. The teeth are designed for cutting and grinding food into smaller pieces.

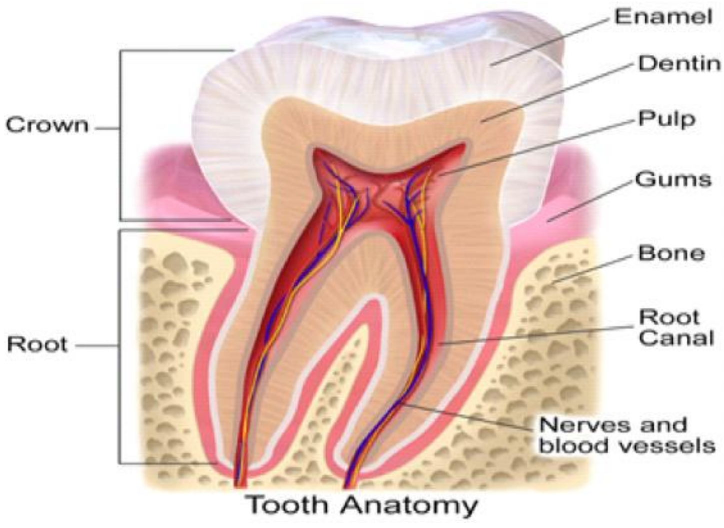


Fig.5.12 L.S. of tooth

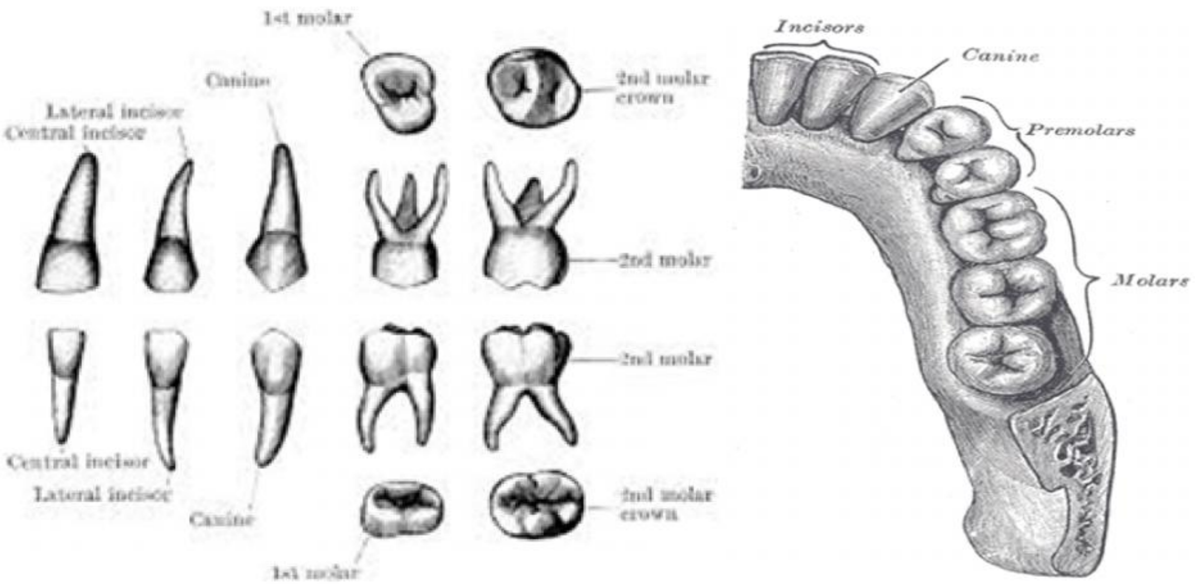


Fig.5.13 Arrangement of teeth

- **Dental Formula-**

A **dental formula** is a summary of teeth.

There are four kinds of teeth:

1. incisors
2. canines
3. premolars
4. molars

The number of teeth of each type is written as a dental formula for one side of the mouth, or quadrant, with the upper and lower teeth shown on separate rows. The number of teeth in a mouth is twice that listed as there are two sides.

In each set, incisors (I) are indicated first, canines (C) second, premolars (P) third, and finally molars (M), giving I:C:P:M. So for example, the formula 2.1.2.3 for upper teeth indicates 2 incisors, 1 canine, 2 premolars, and 3 molars on one side of the upper mouth.

The deciduous dental formula is notated in lowercase lettering preceded by the letter d: e.g. di:dc:dm. Dentition for either deciduous or permanent teeth can thus be expressed as a dental formula, written in the form of a fraction: I.C.P.M / I.C.P.M.

Since the teeth are always listed in the same order, the letters can be dropped, thus:

Deciduous teeth: 212/212; adult = 2123/2123. Both childhood molars are replaced by adult premolars. Adult total is double the formula = 32.

5.4 Hepatobiliary system (Biliary Tract):

Introduction-The hepatobiliary system refers to the liver, gall bladder and bile ducts, and how they work together to make bile. Bile consists of water, electrolytes, bile acids, cholesterol, phospholipids and conjugated bilirubin. Some components are synthesized by liver cells, the rest are extracted from the blood by the liver.

Bile is then secreted by the liver into small ducts that join to form the common hepatic duct. (Fig.5.11) Between meals, secreted bile is stored in the gall bladder, where 80%-90% of the water and electrolytes can be absorbed, leaving the bile acids and cholesterol. During a meal, the smooth muscles in the gallbladder wall contract, leading to the bile being secreted into the duodenum.

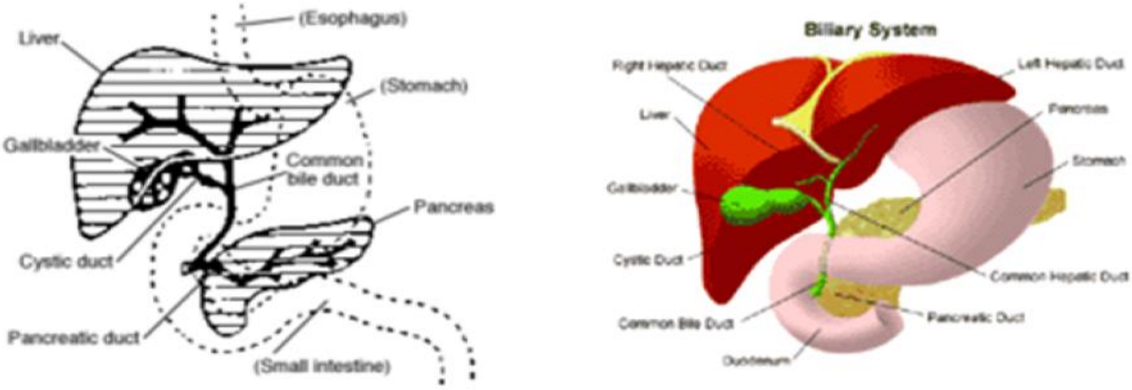


Fig.5.11 Biliary tract

The **biliary tract** (or **biliary tree, biliary system**) is the common anatomical term for the path by which bile is secreted by the liver then transported to the first part of the small intestine, also known as the duodenum. A structure common to most members of the mammal family, it is referred to as a tree because it begins with many small branches which end in the common bile duct, sometimes referred to as the trunk of the biliary tree. The duct, the branches of the hepatic artery, and the portal vein form the central axis of the portal triad. Bile flows in the direction opposite to that of the blood present in the other two channels.

The name usually excludes the liver, but sometimes does include it.

The path is as follows :—

The biliary system consists of the organs and ducts (bile ducts, gallbladder, and associated structures) that are involved in the production and transportation of bile. The transportation of bile follows this sequence:

1. When the liver cells secrete bile, it is collected by a system of ducts that flow from the liver through the right and left hepatic ducts.
2. These ducts ultimately drain into the common hepatic duct.
3. The common hepatic duct then joins with the cystic duct from the gallbladder to form the common bile duct, which runs from the liver to the duodenum (the first section of the small intestine).
4. However, not all bile runs directly into the duodenum. About 50 percent of the bile produced by the liver is first stored in the gallbladder, a pear-shaped organ located directly below the liver.
5. Then, when food is eaten, the gallbladder contracts and releases stored bile into the duodenum to help break down the fats.

- Bile canaliculi >> Canals of Hering >> intrahepatic bile ductule (in portal tracts / triads) >> interlobular bile ducts >> left and right hepatic ducts >>
- merge to form >> common hepatic duct >>
- exits liver and joins >> cystic duct (from gall bladder) >>
- forming >> common bile duct >> joins with >> pancreatic duct >>
- forming >> ampulla of Vater >> enters duodenum

Functions of the biliary system:

The biliary system's main function includes the following:

- to drain waste products from the liver into the duodenum
- to help in digestion with the controlled release of bile

Bile is the greenish-yellow fluid (consisting of waste products, cholesterol, and bile salts) that is secreted by the liver cells to perform two primary functions, including the following:

- to carry away waste
- to break down fats during digestion

Bile salt is the actual component which helps break down and absorb fats. Bile, which is excreted from the body in the form of feces, is what gives feces its dark brown color.

Clinical significance

- Pressure inside in the biliary tree can give rise to gallstones and lead to cirrhosis of the liver.
- Blockage can cause jaundice.
- The biliary tract can also serve as a reservoir for intestinal tract infections. Since the biliary tract is an internal organ, it has no somatic nerve supply, and biliary colic due to infection and inflammation of the biliary tract is not a somatic pain. Rather, pain may be caused by luminal distension, which causes stretching of the wall. This is the same mechanism that causes pain in bowel obstructions.
- An obstruction of the biliary tract can result in jaundice, a yellowing of the skin and of the eyes.

Glossary:

- **Abdomen –**The part of the body that contains the digestive organs .In human beings this is between the diaphragm and the pelvis.
- **Alimentary canal –**The passage through which the food passes, including the mouth, esophagus ,stomach ,intestines and anus .
- **Anus –**The opening at the end of the digestive system from which feces (wastes) exits the body.
- **Appendix –**A small sac located in the cecum.
- **Ascending colon –** The part of the large intestine that runs upwards, it is located after the cecum.
- **Bile –** A digestive chemical that is produced in the liver, stpred in the gall bladder and secreted into the small intestine.
- **Caecum-** The first part of the large intestine, the appendix is connected to the cecum.
- **Chyme–**Food in the stomach that is partly digested and mixedwith stomach acids. Chyme goes on to the small intestine for further digestion.
- **Descending colon –**The part of the large intestine that runs downwards after the transverse colon and before the sigmoid colon.
- **Digestive system-**The system of the body that processes the food and gets rid of waste.
- **Duodenum** The first part of the small intestine, it is C-shaped and runs from the stomach to the jejunum.
- **Epiglottis –** The flap at the back of the tongue that keeps chewed food from going down the windpipe to the lungs .When you swallow the epiglottis automatically closes .When you breath .The epiglottis opens so that the air can go in and out the wind pipe.

- **Esophagus –** A long tube between the mouth and the stomach .It uses rhythmic muscle movements (peristalsis) to force food from the throat into the stomach.
- **Gall bladder –**A small sac like organ located by the duodenum .It stores and releases bile into the small intestine.
- **Gastrointestinal tract –**Also called the G.I. tract or digestive system .It includes structures between mouth and anus.

Assignments/Tests

Q. Multiple choice questions

1) What is the digestive system?

a) The body's breathing system

b) The body's system of nerves

c) The body's food-processing system

d) The body's blood-transporting system

2) Digestion begins in the mouth. Which of the following statement is INCORRECT?

a) The tongue aids in the digestion of the food

b) The saliva changes some of the starches in the food to sugar.

c) The tongue keeps the food in place in the mouth

while the food is being chewed.

d) The digestive juices can react more easily with the food when chewed.

3) Where does food pass through between the mouth and the stomach?

a) The gullet

b) The rectum

c) The small intestine

d) The large intestine

4) Our throat divides into two separate tubes: the windpipe and the gullet. What prevents food from entering the windpipe?

a) The uvula

b) The tongue

c) The trachea

d) The epiglottis

5) What happens when food reaches the stomach?

a) Nothing. No digestion occurs in the stomach.

b) The food moves quickly into the small intestine.

c) Juices mix with the food and stomach muscles squeeze it.

d) The food is completely digested and is absorbed by tiny blood vessels in the walls of the stomach

6) Where does the partly-digested food (in liquid form) go after it leaves the stomach?

a) Gullet

b) Appendix

c) Small intestine

d) Large intestine

7) How does digested food finally reach the bloodstream?

a) It passes through the gullet into the blood.

b) It is absorbed into the blood through blood vessels.

c) It is absorbed into the blood through the walls of the lungs.

d) It passes from the small intestine into the large intestine, then into the blood.

8) The digestive system processes food into usable and unusable materials. The usable materials are sent to the body's cells as food. What happens to unusable materials?

a) It goes into the pancreas to await disposal.

b) It goes to the right ventricle to await disposal.

c) It goes into the large intestine to await disposal.

d) It goes into the small intestine to await disposal.

9) Solid waste leaves the body through the rectum then the anus. Liquid waste leaves the body after passing through the-

a) kidneys and bladder

b) blood vessels and lungs

c) large intestine and bowel

d) small intestine and large intestine

10) Digestion takes place in a long tube-like canal called the alimentary canal, or the digestive tract. Food travels through these organs in the following order:

a) Mouth, gullet, stomach, small intestine, large intestine and rectum

b) Mouth, esophagus, stomach, large intestine, small intestine and rectum

c) Mouth, stomach, esophagus, small intestine, large intestine and rectum

d) Mouth, stomach, gullet, small intestine, large intestine and rectum

11) Which of the following does NOT manufacture digestive juices?

a) Liver

b) Kidneys

c) Stomach

d) Pancreas

12) The liver is located in the abdomen and performs many functions. Which of the following is NOT a function of the liver?

a) Storing food

b) Manufacturing insulin

c) Producing digestive juices

d) Healing itself when it is damaged

Q. Answer the following.

1) Enlist the parts of digestive system.

2) What are the functions of digestive system?

3) Draw and label the stomach.

4) Draw and label the large intestine.

5) Write the path of biliary tract.

6) What are the contents of oral cavity?

7) Write short notes on the following-

i) Mouth

ii) Pharynx

iii) Salivary glands

iv) Digestion

v) Absorption of nutrients

vi) Teeth

8) Write an anatomy of biliary tract.

9) What are the functions of biliary tract?

10) Write the clinical significance of biliary tract.

UNIT 6- RESPIRATORY SYSTEM

Objectives: At the end of this Unit you shall be able to-

- State the pathway of air into the body
- Describe the organs of upper and lower respiratory system
- Describe the functions of respiratory system
- State the mechanism of breathing
- Describe the processes of respiration
- Describe the lung mechanism
- State the additional functions of respiratory system

Introduction:

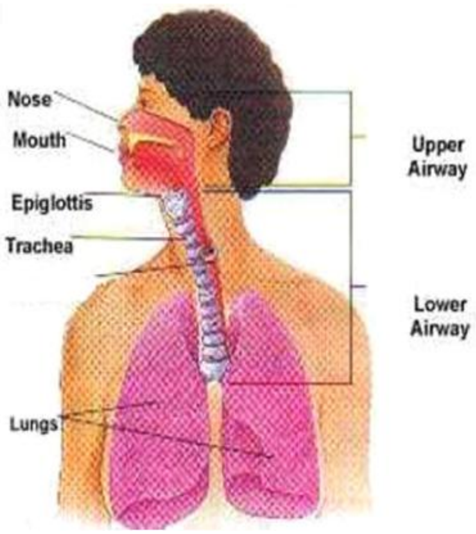
Human respiratory system is the system in humans that takes up oxygen and expels carbon dioxide which is also known as human ventilator system.

Every cell in the body requires oxygen to function. The respiratory system, which includes (Fig.6.1) air passages, pulmonary vessels, the lungs, and breathing muscles, provides oxygenated blood to the body tissues and removes waste gases.

6.1 Anatomy Upper respiratory tract

Composed of the nose, the pharynx, and the larynx, the organs of the upper respiratory tract are located outside the chest cavity.

- Nasal cavity: Inside the nose, the sticky mucous membrane lining the nasal cavity traps dust particles, and tiny hairs called cilia help move them to the nose to be sneezed or blown out.
- Sinuses: These air-filled spaces alongside the nose help make the skull lighter.
- Pharynx: Both food and air pass through the pharynx before reaching their appropriate destinations. The pharynx also plays a role in speech.
- Larynx: The larynx is essential to human speech.



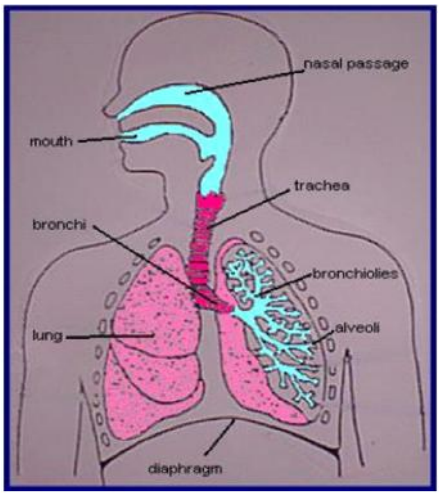


Fig. 6.1 Structure of respiratory tract

The upper respiratory tract consists of the nose and the pharynx. Its primary function is to receive the air from the external environment and filter, warm, and humidify it before it reaches the delicate lungs where gas exchange shall occur.

Air enters through the nostrils of the nose and is partially filtered by the nose hairs, then flows into the nasal cavity.

The nasal cavity is lined with epithelial tissue, containing blood vessels, which help warm the air; and secrete mucous, which further filters the air. The endothelial lining of the nasal cavity also contains tiny hair like projections, called cilia. The cilia serve to transport dust and other foreign particles, trapped in mucous, to the back of the nasal cavity and to the pharynx. There the mucus is either coughed out, or swallowed and digested by powerful stomach acids. After passing through the nasal cavity, the air flows down the pharynx to the larynx.

6.2 Lower Respiratory Tract:

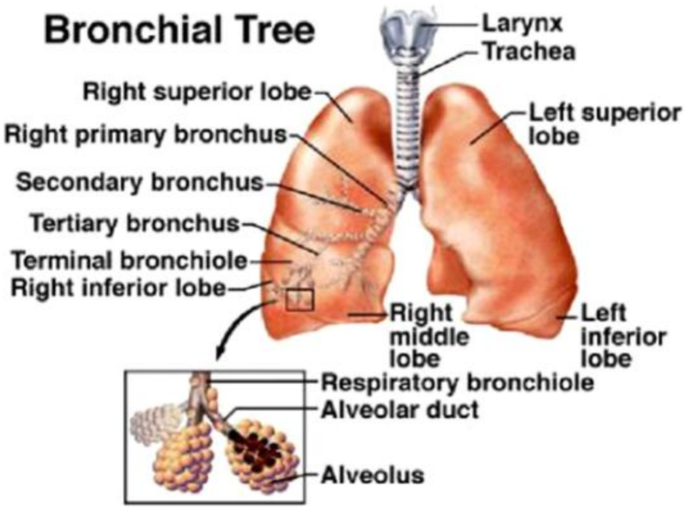


Fig-6.2-Lower Respiratory Tract

The lower respiratory tract starts with the larynx, and includes the trachea, the two bronchi that branch from the trachea, and the lungs themselves. This is where gas exchange actually takes place. (Fig-6.2)

1. Larynx- The larynx (plural larynges), colloquially known as the voice box, is an organ in our neck involved in protection of the trachea and sound production. The larynx houses the vocal cords, and is situated just below where the tract of the pharynx splits into the trachea and the esophagus. The larynx contains two important structures: the epiglottis and the vocal cords.

The epiglottis is a flap of cartilage located at the opening to the larynx. During swallowing, the larynx (at the epiglottis and at the glottis) closes to prevent swallowed material from entering the lungs; the larynx is also pulled upwards to assist this process. Stimulation of the larynx by ingested matter produces a strong cough reflex to protect the lungs.

(Note: choking occurs when the epiglottis fails to cover the trachea, and food becomes lodged in our windpipe.)

The vocal cords consist of two folds of connective tissue that stretch and vibrate when air passes through them, causing vocalization. The length the vocal cords are stretched determines what pitch the sound shall have. The strength of expiration from the lungs also contributes to the loudness of the sound. Our ability to have some voluntary control over the respiratory system enables us to sing and to speak. In order for the larynx to function and produce sound, we need air. That is why we can't talk when we're swallowing.

1. Trachea
2. Bronchi
3. Lungs

Lower respiratory tract is composed of the trachea, the lungs, and all segments of the bronchial tree (including the alveoli), the organs of the lower respiratory tract are located inside the chest cavity.

- **Trachea :** (Fig. 6.2) Located just below the larynx, the trachea is the main airway to the lungs. It is made up of C-shaped cartilaginous rings which are 15- 17 in no.The trachea is the continuation of the larynx and commences in the neck below the cricoid cartilage at the level of C6 vertebra, 5 cm above the jugular notch. Entering the thoracic inlet in the mid-line, it passes downwards and backwards behind the manubrium to bifurcate into the two principal or main bronchi on a level just below the lower border of the manubrium. The cricoid cartilage and sternal angle provide easy surface markings for the upper and lower ends of the trachea.

The thoracic part runs through the superior mediastinum in front of the esophagus to the upper part of the posterior mediastinum. In front of this part are the manubrium with sternohyoid and sternothyroid attached on each side, the inferior thyroid and left brachiocephalic veins and the remains of the thymus. The brachiocephalic and left common carotid arteries diverge on either side. The right side of the trachea is separated from the lung by the pleura which plasters the vagus nerve against the side of the tracheal wall, and the arch of the azygous vein hooks forwards over the right bronchus. The right brachiocephalic vein and superior vena cava are anterolateral to the trachea. On the left the left common carotid and subclavian arteries prevent the pleura from coming into contact with the trachea as it does on the right, and the arch of the aorta hooks backwards over the left bronchus, with the left recurrent laryngeal nerve passing upwards in the groove between trachea and esophagus.

The pulmonary trunk branches into the right and left pulmonary arteries rather to the left of the tracheal bifurcation, in front of the left bronchus. Here lies the deep part of the cardiac plexus. The right pulmonary artery crosses just below the tracheal bifurcation, and between the two is part of the tracheobronchial group of lymph nodes.

Blood supply of trachea:

Branches from the inferior thyroid and bronchial arteries form anastomotic networks in the tracheal wall. Veins drain to the inferior thyroid plexus.

Lymph drainage of trachea:

Lymphatic channels pass to the posteroinferior group of deep cervical nodes and to paratracheal nodes.

Nerve supply:

The mucous membrane is supplied by afferent (including pain) fibres from the vagi and recurrent laryngeal nerves, which also provide parasympathetic fibres of uncertain function. Sympathetic fibers from upper ganglia of the sympathetic trunks supply the smooth muscle and blood vessels.

Functions:

The structure of the trachea conforms to functional needs.

- The wall of the trachea is elastic because it must stretch. The trachea is stretched into elongation during swallowing. Elevation of the larynx elevates the upper end; the bifurcation does not move. Elastic recoil of the trachea restores its original length, pulling the larynx down to its rest position. Normally there is no call on sternothyroid to depress the larynx, and swallowing is unimpaired by loss of this muscle. Per contra, pulling down on the bifurcation by sudden descent of the diaphragm, pericardium and aortic arch produces the clinical sign of 'tracheal tug'.

- Prevention of collapse during inspiration.
- The curved bars ('rings') of hyaline cartilage are incomplete so that the diameter may be controlled by the trachealis muscle. This increases the explosive force of the blast of compressed air.
- The soiled mucus is beaten upwards to the larynx by the cilia of the surface epithelium. From the larynx it is expelled by coughing (clearing the throat). Serous glands in the mucous membrane humidify the air.

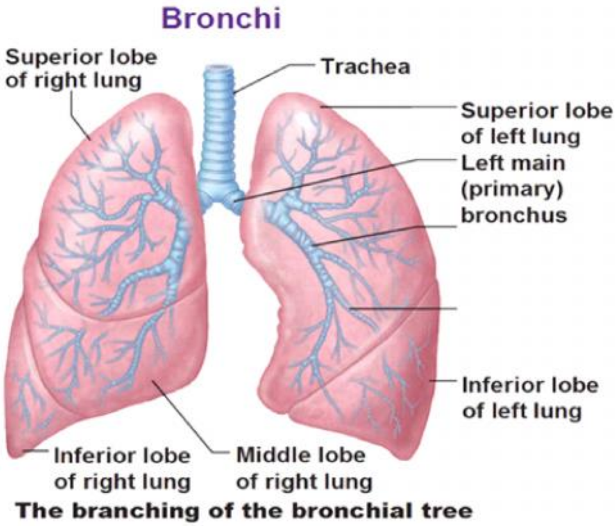


Fig-6.3Lungs-Lobes with internal structure

- **Lungs :** (Fig. 6.3) Together the lungs form one of the body's largest organs. They're responsible for providing oxygen to capillaries and exhaling carbon dioxide. Lungs are the organs of human body where gaseous exchange takes place. Human beings have two lungs known as the right and left lungs. Lungs are soft, spongy and very elastic.

If the thoracic cavity were opened, the lungs would shrink to 1/3 of their original size because of their elastic nature and atmospheric forces. Lungs are pink in color in children but in adults they become mottled and dark because of inhalation of dust particles that become trapped in the phagocytes of the lungs. This effect is especially well seen in coal miners and city dwellers. Lungs are placed in the thoracic cavity in such a way so that one lies on each side of the mediastinum and thus the two lungs are separated by heard and large blood vessels besides the other structures in mediastinum.

Shape of lungs:

Each lung is conical in outline and is covered with visceral pleura. It suspends freely in its own pleural cavity and is attached to the mediastinum only through its root (the place where blood vessels and bronchi attach to the lung at hilum).

- **Apex :** Each lung has a blunt apex projecting upward into the neck for about 1 inch above the clavicle. Base: The base of both lungs is concave, which sits on the diaphragm.
- **Costal surface:** The costal surface is convex, which corresponds to the concave chest wall.
- **Mediastinal surface :** The mediastinal surface is concave and is molded to the pericardium and other structures of the mediastinum

- **Hilum :** At about the middle of the mediastinal surface, there is a depression where the bronchi, blood vessels and nerves, which form the root, enter of leave the lung.
- **Anterior border :** The anterior border of the lungs is thin and overlaps the heart. It is here on the left lung that the cardiac notch is found.
- **Posterior border :** The posterior border is thick and lies beside the vertebral column.

Lobes and fissures of lungs :

Right lung :

Right lung is slightly larger than the left one and is divided into three lobes, the upper, middle and lower lobes, by oblique and horizontal fissures. The oblique fissure runs from the inferior border upward and backward and cross the mediastinal and costal surface until it cuts the posterior border about 2.5 inches from the apex. The horizontal fissure runs horizontally across the costal surface at the level of fourth costal cartilage and meets the oblique fissure in the mid-axillary line. The lobe of the lung above the horizontal fissure is called the upper lobe. One below the oblique fissure is called the lower lobe. The middle lobe is a small triangular lobe bounded by oblique and horizontal fissures.

Left lung :

Left lung contains only one fissure which divides into two lobes: upper and lower. The fissure, which is called the oblique fissure, is similar to the oblique fissure of the right lung. There is not horizontal fissure in the left lungs. The lobe that lies above the oblique fissure is called the upper lobe and one below it is called lower lobe.

6.3 Physiology of Respiration

Introduction : The organs of the respiratory system make sure that oxygen enters our bodies and carbon dioxide leaves our bodies.The respiratory tract is the path of air from the nose to the lungs. It is divided into two sections: Upper Respiratory Tract and the Lower Respiratory Tract. Included in the upper respiratory tract are the Nostrils, Nasal Cavities, Pharynx, Epiglottis, and the Larynx. The lower respiratory tract consists of the Trachea, Bronchi, Bronchioles, and the Lungs.

As air moves along the respiratory tract it is warmed, moistened and filtered. The lungs flank the heart and great vessels in the chest cavity.

In this chapter we shall discuss the four processes of respiration. They are-

1. BREATHING or ventilation

2. EXTERNAL RESPIRATION, which is the exchange of gases (oxygen and carbon dioxide) between inhaled air and the blood.

3. INTERNAL RESPIRATION, which is the exchange of gases between the blood and tissue fluids.

4. CELLULAR RESPIRATION In addition to these main processes, the respiratory system serves for:

- REGULATION OF BLOOD pH, which occurs in coordination with the kidneys, and as a DEFENSE AGAINST MICROBES
- Control of body temperature due to loss of evaporate during expiration

Breathing and Lung Mechanics:

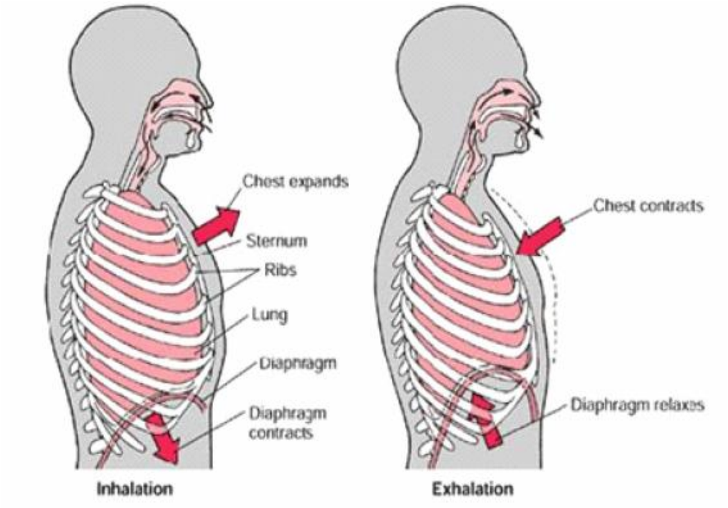


Fig-6.4 - Mechanism of Breathing

- Ventilation is the exchange of air between the external environment and the alveoli.
- Air moves by bulk flow from an area of high pressure to low pressure. All pressures in the respiratory system are relative to atmospheric pressure (760mmHg at sea level). Air shall move in or out of the lungs depending on the pressure in the alveoli.
- The body changes the pressure in the alveoli by changing the volume of the lungs. As volume increases pressure decreases and as volume decreases pressure increases.
- There are two phases of ventilation; inspiration and expiration. During each phase the body changes the lung dimensions to produce a flow of air either in or out of the lungs. The body is able to change the dimensions of the lungs because of the relationship of the lungs to the thoracic wall.

Breathing:

The diaphragm divides the body cavity into the-

- **Abdominal cavity,** which contains the viscera (e.g., stomach and intestines) and the
- **Thoracic cavity,** which contains the heart and lungs.

The inner surface of the thoracic cavity and the outer surface of the lungs are lined with pleural membranes which adhere to each other. If air is introduced between them, the adhesion is broken and the natural elasticity of the lung causes it to collapse. This can occur from trauma. And it is sometimes induced deliberately to allow the lung to rest. In either case, reinflation occurs as the air is gradually absorbed by the tissues. Because of this adhesion, any action that increases the volume of the thoracic cavity causes the lungs to expand, drawing air into them.

- **During inspiration (inhaling),**
  - o The external intercostals muscles contract, lifting the ribs up and out.
  - o The diaphragm contracts, drawing it down.

- **During expiration (exhaling),** these processes are reversed and the natural elasticity of the lungs returns them to their normal volume. At rest, we breath 15–18 times a minute exchanging about 500 ml of air.
- **In more vigorous expiration,**
  - o The internal intercostals muscles draw the ribs down and inward
  - o The wall of the abdomen contracts pushing the stomach and liver upward.

Under these conditions, an average adult male can flush his lungs with about 4 liters of air at each breath. This is called the **vital capacity**. Even with maximum expiration, about 1200 ml of **residual air** remain.

Some of the oxygen dissolves in the film of moisture covering the epithelium of the alveoli. From here it diffuses into the blood in a nearby capillary. It enters a red blood cell and combines with the hemoglobin therein. At the same time, some of the carbon dioxide in the blood diffuses into the alveoli from which it can be exhaled.

Inspiration-Inspiration is initiated by contraction of the diaphragm and in some cases the intercostals muscles when they receive nervous impulses. During normal quiet breathing, the phrenic nerves stimulate the diaphragm to contract and move downward into the abdomen. This downward movement of the diaphragm enlarges the thorax. When necessary, the intercostal muscles also increase the thorax by contacting and drawing the ribs upward and outward. As the diaphragm contracts inferiorly and thoracic muscles pull the chest wall outwardly, the volume of the thoracic cavity increases. The lungs are held to the thoracic wall by negative pressure in the pleural cavity, a very thin space filled with a few milliliters of lubricating pleural fluid. The negative pressure in the pleural cavity is enough to hold the lungs open in spite of the inherent elasticity of the tissue. Hence, as the thoracic cavity increases in volume the lungs are pulled from all sides to expand, causing a drop in the pressure (a partial vacuum) within the lung itself (but note that this negative pressure is still not as great as the negative pressure within the pleural cavity--otherwise the lungs would pull away from the chest wall). Assuming the airway is open, air from the external environment then follows its pressure gradient down and expands the alveoli of the lungs, where gas exchange with the blood takes place. As long as pressure within the alveoli is lower than atmospheric pressure air shall continue to move inwardly, but as soon as the pressure is stabilized air movement stops.

Expiration

During quiet breathing, expiration is normally a passive process and does not require muscles to work (rather it is the result of the muscles relaxing). When the lungs are stretched and expanded, stretch receptors within the alveoli send inhibitory nerve impulses to the medulla oblongata, causing it to stop sending signals to the rib cage and diaphragm to contract. The muscles of respiration and the lungs themselves are elastic, so when the diaphragm and intercostals muscles relax there is an elastic recoil, which creates a positive pressure (pressure in the lungs becomes greater than atmospheric pressure), and air moves out of the lungs by flowing down its pressure gradient.

Although the respiratory system is primarily under involuntary control, and regulated by the medulla oblongata, we have some voluntary control over it also. This is due to the higher brain function of the cerebral cortex.

When under physical or emotional stress, more frequent and deep breathing is needed, and both inspiration and expiration shall work as active processes. Additional muscles in the rib cage forcefully contract and push air quickly out of the lungs. In addition to deeper breathing, when coughing or sneezing we exhale forcibly. Our abdominal muscles shall contract suddenly (when there is an urge to cough or sneeze), raising the abdominal pressure. The rapid increase in pressure pushes the relaxed diaphragm up against the pleural cavity. This causes air to be forced out of the lungs.

Another function of the respiratory system is to sing and to speak. By exerting conscious control over our breathing and regulating flow of air across the vocal cords we are able to create and modify sounds

External Respiration

- External respiration is the exchange of gas between the air in the alveoli and the blood within the pulmonary capillaries. A normal rate of respiration is 12-25 breaths per minute.
- In external respiration, gases diffuse in either direction across the walls of the alveoli. Oxygen diffuses from the air into the blood and carbon dioxide diffuses out of the blood into the air.
- When blood enters the pulmonary capillaries, the bicarbonate ions and hydrogen ions are converted to carbonic acid (H2CO3) and then back into carbon dioxide (CO2) and water. This chemical reaction also uses up hydrogen ions. The removal of these ions gives the blood a more neutral pH, allowing hemoglobin to bind up more oxygen.
- De-oxygenated blood "blue blood" coming from the pulmonary arteries, generaly has an oxygen partial pressure (pp) of 40 mmHg and CO pp of 45 mmHg.
- Oxygenated blood leaving the lungs via the pulmonary veins has a O2 pp of 100 mmHg and CO pp of 40 mmHg. It should be noted that alveolar O2 pp is 105 mmHg, and not 100 mmHg. The reason why pulmonary venous return blood has a lower than expected O2 pp can be explained by "Ventilation Perfusion Mismatch".

Internal Respiration

Internal respiration is the exchanging of gases at the cellular level.

- The Passage Way from the Trachea to the Bronchioles- There is a point at the inferior portion of the trachea where it branches into two directions that form the right and left primary bronchus. This point is called the Carina which is the keel-like cartilage plate at the division point.
- Now at the Bronchial Tree- it is named so because it has a series of respiratory tubes that branch off into smaller and smaller tubes as they run throughout the lungs.

  Cellular Respiration:

  - First the oxygen must diffuse from the alveolus into the capillaries. It is able to do this because the capillaries are permeable to oxygen. After it is in the capillary, about 5% shall be dissolved in the blood plasma.
  - The other oxygen shall bind to red blood cells. The red blood cells contain hemoglobin that carries oxygen. Blood with hemoglobin is able to transport 26 times more oxygen than plasma without hemoglobin. Our bodies would have to work much harder pumping more blood to supply our cells with oxygen without the help of hemoglobin.
  - Once it diffuses by osmosis it combines with the hemoglobin to form oxyhemoglobin.
  - Now the blood carrying oxygen is pumped through the heart to the rest of the body. Oxygen shall travel in the blood into arteries, arterioles, and eventually capillaries where it shall be very close to body cells.

- Now with different conditions in temperature and pH (warmer and more acidic than in the lungs), and with pressure being exerted on the cells, the hemoglobin shall give up the oxygen where it shall diffuse to the cells to be used for cellular respiration, also called aerobic respiration. Cellular respiration is the process of moving energy from one chemical form (glucose) into another (ATP), since all cells use ATP for all metabolic reactions.
- It is in the mitochondria of the cells where oxygen is actually consumed and carbon dioxide produced. Oxygen is produced as it combines with hydrogen ions to form water at the end of the electron transport chain
- As cells take apart the carbon molecules from glucose, these get released as carbon dioxide. Each body cell releases carbon dioxide into nearby capillaries by diffusion, because the level of carbon dioxide is higher in the body cells than in the blood. In the capillaries, some of the carbon dioxide is dissolved in plasma and some is taken by the hemoglobin, but most enters the red blood cells where it binds with water to form carbonic acid. It travels to the capillaries surrounding the lung where a water molecule leaves, causing it to turn back into carbon dioxide. It then enters the lungs where it is exhaled into the atmosphere.

Glossary:

The Respiratory System moves air in and out of the body -- using oxygen and eliminating carbon dioxide, a gas produced when cells use oxygen. The respiratory system includes the nose, mouth, trachea, bronchi, diaphragm and lungs.

Mouth : Air enters the body through either the open mouth or the nose. It travels down the trachea to the lungs, where the oxygen in it passes into the bloodstream.

Nasal passage : Air enters the body through either the open mouth or the nose. Tiny hairs in the nose trap unwanted particles while a sticky liquid called mucus catches many of the germs before they all can go too far into the respiratory system. The mucus also warms and moistens the air.

Trachea (Windpipe) : About half of its 13 cm length is inside the chest and the other half is in the neck. The lower end of the trachea divides into two bronchi (tubes) that carry air into the lungs.

Bronchi : The lower end of the trachea divides into two bronchi (tubes) that carry air into the lungs. One bronchus goes to the left lung, the other to the right lung.

Bronchioles : Each bronchus divides into smaller and smaller tubes called bronchioles.

Alveoli : Bronchioles eventually lead to tiny, stretchy sacs called alveoli. These sacs blow up like tiny balloons when you breathe in. Oxygen from the air passes through the walls of the alveoli into capillaries while carbon dioxide is passed out.

Lung : Balloon-like structures in the chest that bring oxygen into the body and expel carbon dioxide from the body.

Diaphragm : The diaphragm is a strong muscle just below the lungs. When you breathe in and out, the diaphragm moves downwards and upwards against the lungs.

Epiglottis : A flap in the throat that blocks the windpipe when food or liquid is being swallowed.

Assignments/Test

Multiple choice questions

1. What is respiratory system?

   The body's breathing system

   The body's system of nerves

   The body's food-processing system

   The body's blood-transporting system

2. Air can enter the body and travel to the lungs...

   through the mouth and the nose

   through the oesophagus and gullet

   through the windpipe and the pores

   through the nose and the nervous system

3. What is the purpose of the little hairs inside the nose?

   To fight disease

   They serve no purpose.

   To keep dust out of the lungs

   To tickle the nose and cause sneezes

4. What is another name for the windpipe?

   Lungs

   Larynx

   Trachea

   Oesophagus

5. What happens to the windpipe, or trachea, before it reaches the lungs?

   It branches in two directions.

   It branches in three directions.

   It vibrates and creates sounds.

   It closes up so that no oxygen can escape.

6. What important activity takes place in the lungs?

   Food is digested.

   Liquid waste is filtered from the blood.

   Oxygen is exchanged for carbon dioxide.

   The trachea is exchanged for the larynx.

7. Oxygen moves from the lungs into the bloodstream through ...

   nerve fibres

   a large artery in the heart

   small blood vessels in the lungs

   a tube in the lungs called the jugular vein

8. When we breathe in, we inhale many gases, including oxygen. What happens to the gases that the body can't use?

They are exhaled.

They are changed into oxygen by the lungs.

They circulate through the body and are disposed of later.

They are absorbed into the digestive system and used to create energy.

9. Which organ is made up of air-carrying tubes and tiny sacs?

The brain

The lungs

The stomach

The diaphragm

10. What body structure protects the lungs from outside harm?

Cartilage

Tiny sacs

The rib cage

The diaphragm

11. To go on living, the body's cells need food, water, chemicals, and ...

helium

oxygen

vegetables

carbon dioxide

12. The nasal chamber does what to incoming air?

A. Absorbs it

B. Speeds it up

C. Warms it

D. Stops it

13. Which is not correct about what lungs excrete?

A. Water

B. Carbon Dioxide

C. Heat

D. Energy

14. Which is a factor that does NOT affect haemoglobin's affinity for oxygen?

A. pH of blood

B. Partial pressure of the oxygen

C. Amount of oxygen available

D. Temperature

E. Repiratory rate

15. Which of the following is not part of the upper respiratry system?

A. Nose

B. Oral cavity

C. Pharynx

D. Trachea

E. Nasal meatuses

Q. Answer the following.

1. What are the organs of respiratory system?
2. What are the functions of respiratory system?
3. What are the four processes of respiration?
4. Describe the physiology of breahing.
5. Write short notes on –

   i) Inspiration

   ii) Expiration

   iii) Gas exchange

   iv) Homeostasis

6. Write an anatomy of lung.
7. Write an anatomy of pleura.
8. Write an anatomy of trachea.
9. Write an anatomy of larynx.
10. Write an anatomy of bronchial tree.

UNIT 7-NERVOUS SYSTEM

Objectives - At the end of this Unit you shall be able to-

- State the main components of nervous system
- State the divisions of nervous system
- State the various parts of central nervous system
- State the various parts of peripheral nervous system
- Describe the distinct regions of brain
- State the names of cranial nerves
- Describe the structure of spinal cord, spinal nerves
- State the functions of nervous system
- Describe the reflexes of the body
- State the functions of cranial nerves
- Describe the sensory physiology

7.1- Anatomy of Brain, Ventricles and Spinal Cord:

Introduction : The human nervous system is made up of two main components: (Fig.7.1)

(i) Central nervous system (CNS) ii) Peripheral nervous system (PNS).

- The CNS is composed of the brain, the cranial nerves, and the spinal cord.
- The PNS is made up of the nerves that exit from the spinal cord at various levels of the spinal column as well as their tributaries.
- The autonomic nervous system (divided into the sympathetic and parasympathetic nervous system) is also considered to be a part of the PNS and it controls the body's many vegetative (non-voluntary) functions.

Divisions of the Nervous System-

1. Central Nervous System

The brain and spinal cord together form the central nervous system, or CNS. The CNS acts as the control center of the body by providing its processing, memory, and regulation systems. The CNS takes in all of the conscious and subconscious sensory information from the body's sensory receptors to stay aware of the body's internal and external conditions. Using this sensory information, it makes decisions about both conscious and subconscious actions to take to maintain the body's homeostasis and ensure its survival. The CNS is also responsible for the higher functions of the nervous system such as language, creativity, expression, emotions, and personality. The brain is the seat of consciousness and determines who we are as individuals.

2. Peripheral Nervous System-

The peripheral nervous system (PNS) includes all of the parts of the nervous system outside of the brain and spinal cord. These parts include all of the cranial and spinal nerves, ganglia, and sensory receptors.

Somatic Nervous System-

The somatic nervous system (SNS) is a division of the PNS that includes all of the voluntary efferent neurons. The SNS is the only consciously controlled part of the PNS and is responsible for stimulating skeletal muscles in the body.

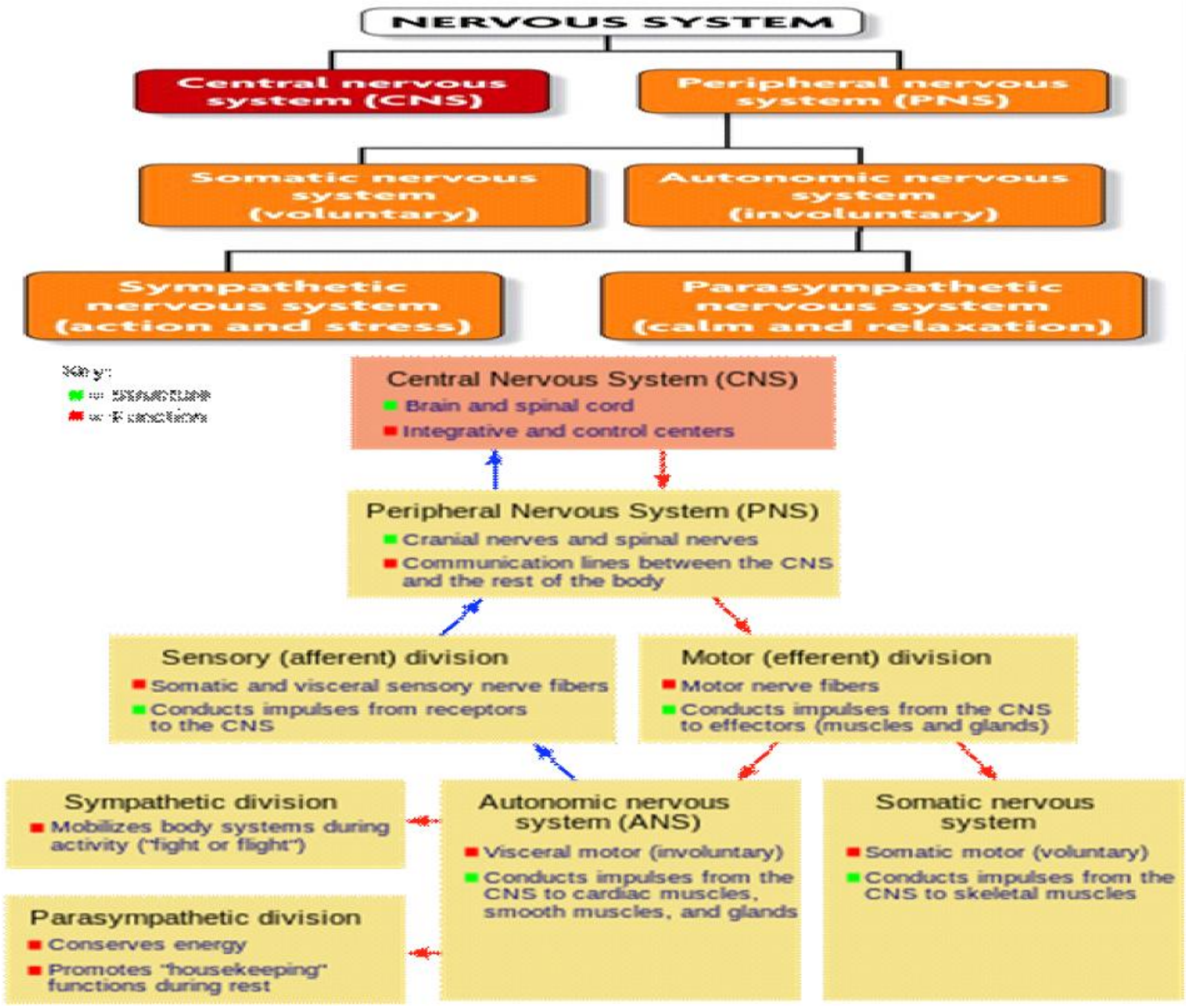


Fig.7.1 Main components of nervous system

Autonomic Nervous System-

The autonomic nervous system (ANS) is a division of the PNS that includes all of the involuntary efferent neurons. The ANS controls subconscious effectors such as visceral muscle tissue, cardiac muscle tissue, and glandular tissue.

There are 2 divisions of the autonomic nervous system in the body: the sympathetic and parasympathetic divisions. (Fig.7.2)

- Sympathetic- The sympathetic division forms the body's "fight or flight" response to stress, danger, excitement, exercise, emotions, and embarrassment. The sympathetic division increases respiration and heart rate, releases adrenaline and other stress hormones, and decreases digestion to cope with these situations.
- Parasympathetic- The parasympathetic division forms the body's "rest and digest" response when the body is relaxed, resting, or feeding. The parasympathetic works to undo the work of the sympathetic division after a stressful situation. Among other functions, the parasympathetic division works to decrease respiration and heart rate, increase digestion, and permit the elimination of wastes.

Anatomy of Brain-

The **brain**, a soft, wrinkled organ that weighs about 3 pounds, is located inside the cranial cavity, where the **bones of the skull** surround and protect it. The approximately 100 billion neurons of the brain form the main control center of the body. The brain and spinal cord together form the central nervous system (CNS), where information is processed and responses originate. The brain, the seat of higher mental functions such

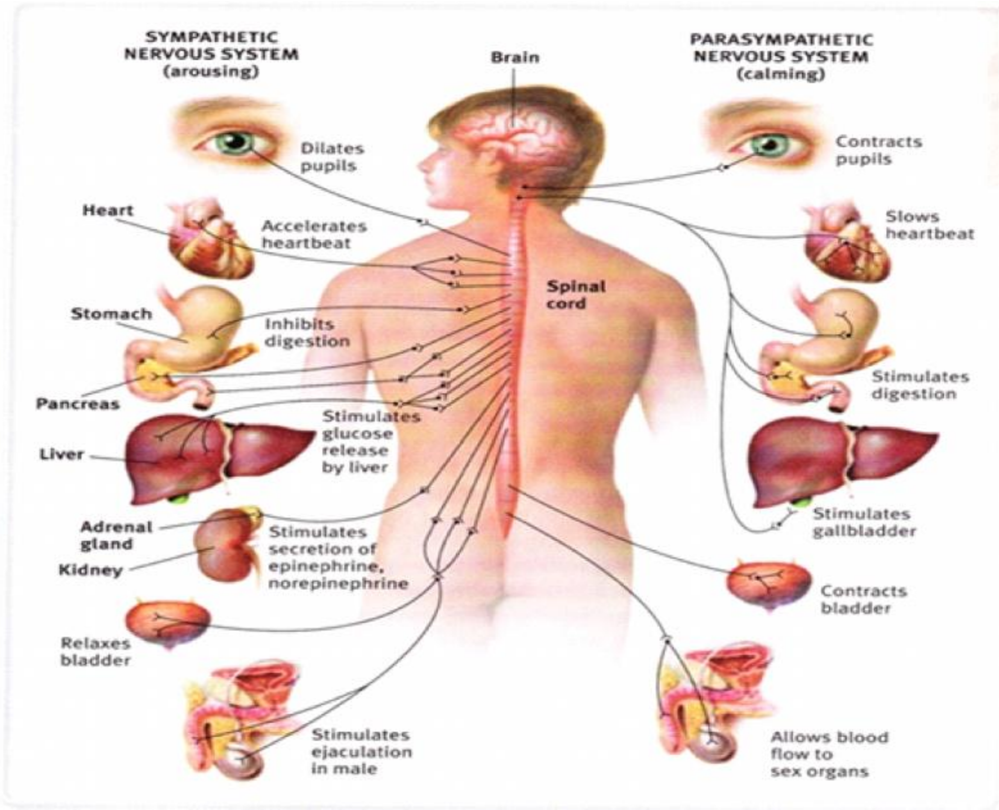


Fig.7.2 sympathetic and parasympathetic nervous system

as consciousness, memory, planning, and voluntary actions, also controls lower body functions such as the maintenance of respiration, heart rate, blood pressure, and digestion, imagination, speech, and limb movements to secretion hormones and control of various organs within the body. These functions are controlled by many distinct parts that serve specific and important tasks.

The brain can be subdivided into several distinct regions: (Fig. 7.3)

- **The cerebral hemispheres** form the largest part of the brain, occupying the anterior and middle cranial fossae in the skull and extending backwards over the tentorium cerebelli. They are made up of the cerebral cortex, the basal ganglia, tracts of synaptic connections, and the ventricles containing CSF.
- **The Diencephalon** (not shown above) includes the thalamus, hyopthalamus, epithalamus and subthalamus, and forms the central core of the brain. It is surrounded by the cerebral hemispheres.
- **The Midbrain** (not shown) is located at the junction of the middle and posterior cranial fossae.
- **The Pons** sits in the anterior part of the posterior cranial fossa- the fibres within the structure connect one cerebral hemisphere with its opposite cerebellar hemisphere.
- **The Medulla Oblongata** is continuous with the spinal cord, and is responsible for automatic control of the respiratory and cardiovascular systems.
- **The Cerebellum** overlies the pons and medulla, extending beneath the tentorium cerebelli and occupying most of the posterior cranial fossa. It is mainly concerned with motor functions that regulate muscle tone, coordination, and posture.

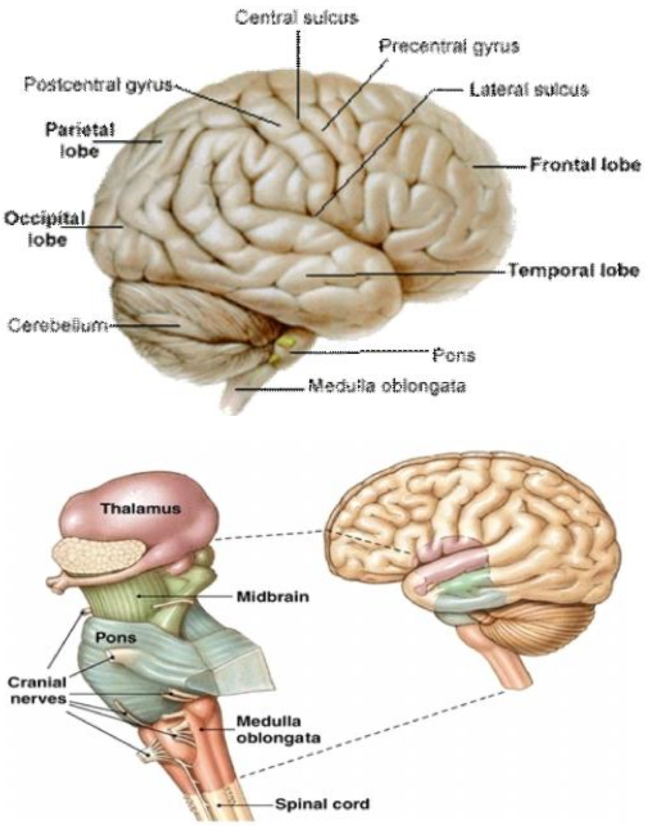


Fig. 7.3 Parts of the brain

Brain Cells : The brain is made up of two types of cells: neurons (yellow cells in the image below) and glial cells (pink and purple cells in the image below). (Fig. 7.4) Neurons are responsible for all of the functions that are attributed to the brain while the glial cells are non-neuronal cells that provide support for neurons. In an adult brain, the predominant cell type is glial cells, which outnumber neurons by about 50 to 1. Neurons communicate with one another through connections called synapses.

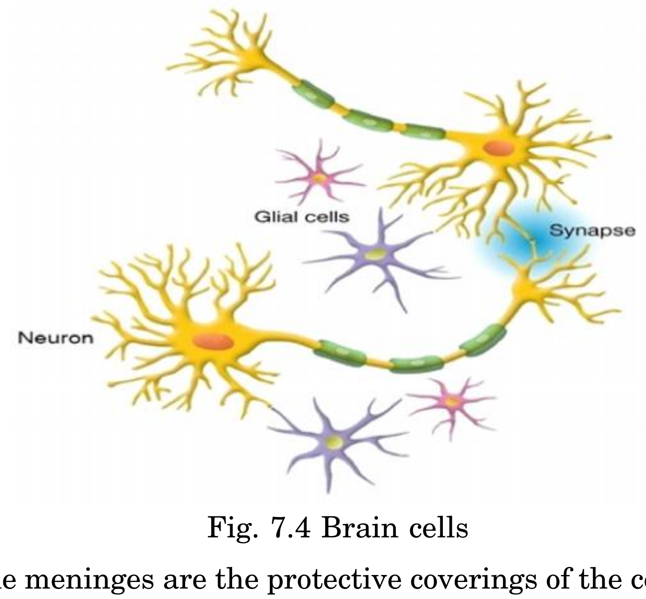


Fig. 7.4 Brain cells

Meninges : The meninges are the protective coverings of the central nervous system (CNS). They consist of three layers: the dura mater, arachnoid mater, and pia mater. (Fig. 7.5)

- **Dura mater-** The dura mater, which means "tough mother," is the thickest, toughest, and most superficial layer of meninges. Made of dense irregular connective tissue, it contains many tough collagen fibers and blood vessels. Dura mater protects the CNS from external damage, contains the cerebrospinal fluid that surrounds the CNS, and provides blood to the nervous tissue of the CNS.

- **Arachnoid mater-** The arachnoid mater, which means "spider-like mother," is much thinner and more delicate than the dura mater. It lines the inside of the dura mater and contains many thin fibers that connect it to the underlying pia mater. These fibers cross a fluid-filled space called the subarachnoid space between the arachnoid mater and the pia mater.
- *Pia mater.* The pia mater, which means "tender mother," is a thin and delicate layer of tissue that rests on the outside of the brain and spinal cord. Containing many blood vessels that feed the nervous tissue of the CNS, the pia mater penetrates into the valleys of the sulci and fissures of the brain as it covers the entire surface of the CNS.

The space between the arachnoid layer and the pia mater is called the subarachnoid space and it contains the cerebrospinal fluid.

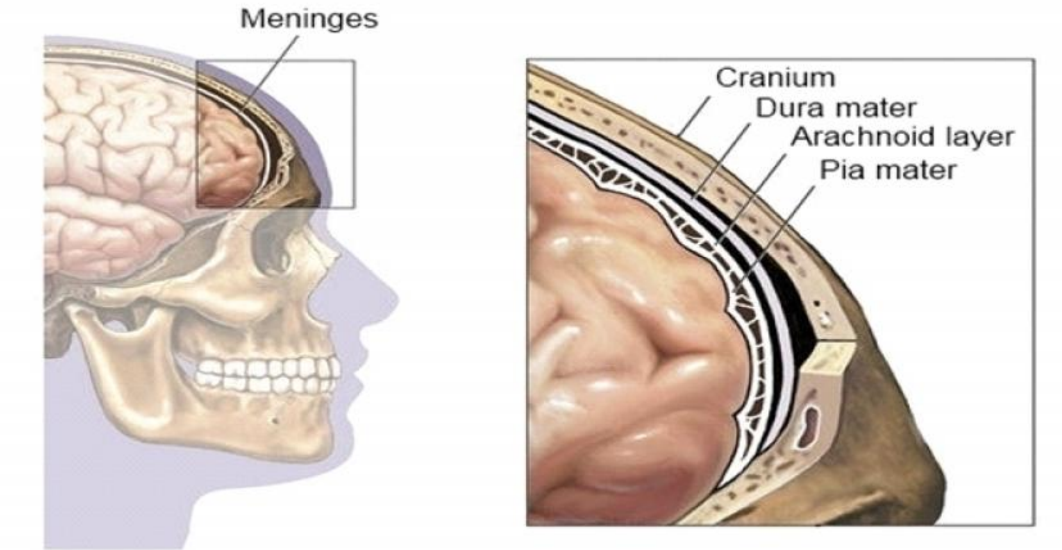


Fig.7.5 Meninges

Cerebrospinal Fluid (CSF) : CSF is a clear fluid that surrounds the brain and spinal cord, and helps to cushion these structures from injury. This fluid is constantly made by structures deep within the brain called the choroid plexus which is housed inside spaces within the brain called ventricles, after which it circulates through channels around the spinal cord and brain where is it finally reabsorbed. If the delicate balance between production and absorption of CSF is disrupted, then backup of this fluid within the system of ventricles can cause hydrocephalus.

Ventricles : Brain ventricles are a system of four cavities, which are connected by a series of tubes and holes and direct the flow of CSF within the brain. (Fig.7.6) These cavities are the lateral ventricles (right and left), which communicate with the third ventricle in the center of the brain through an opening called the interventricular foramen. This ventricle is connected to the fourth ventricle through a long tube called the Cerebral Aqueduct. CSF then exits the ventricular system through several holes in the wall of the fourth ventricle (median and lateral apertures) after which it flow around the brain and spinal cord.

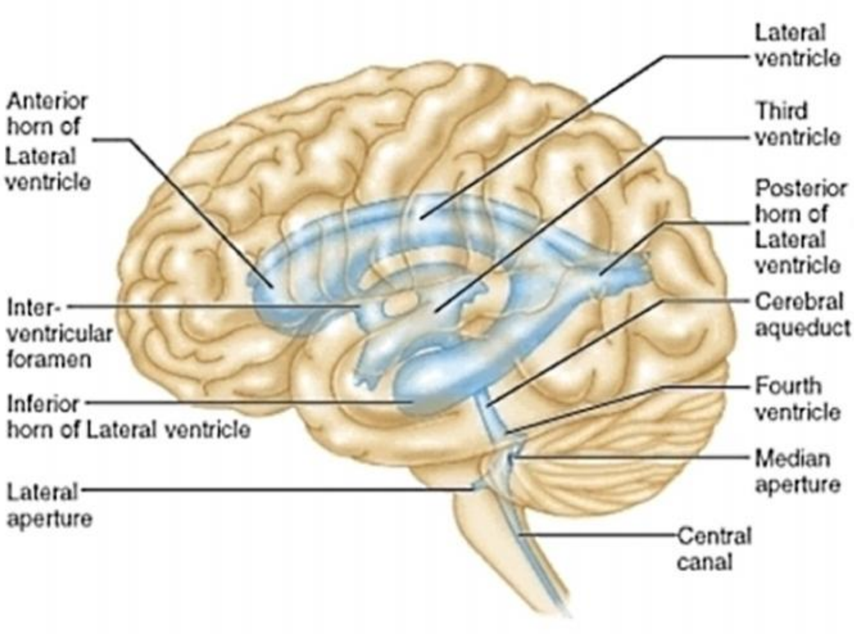


Fig.7.6 Ventricles of the brain

Brainstem : The brainstem is the lower extension of the brain which connects the brain to the spinal cord, and acts mainly as a relay station between the body and the brain. It also controls various other functions, such as wakefulness, sleep patterns, and attention; and is the source for ten of the twelve cranial nerves. It is made up of three structures: the midbrain, pons and medulla oblongata. The midbrain is inovolved in eye motion while the pons coordinates eye and facial movements, facial sensation, hearing, and balance. The medulla oblongata controls vegetative functions such as breathing, blood pressure, and heart rate as well as swallowing.

Thalamus : The thalamus is a structure that is located above the brainstem and it serves as a relay station for nearly all messages that travel from the cerebral cortex to the rest of the body/brain and vice versa. As such, problems within the thalamus can cause significant symptoms with regard to a variety of functions, including movement, sensation, and coordination. The thalamus also functions as an important component of the pathways within the brain that control pain sensation, attention, and wakefulness.

Cerebellum : (Fig.7.7) The cerebellum is located at the lower back of the brain beneath the occipital lobes and is separated from them by the tentorium. This part of the brain is responsible for maintaining balance and coordinating movements. Abnormalities in either side of the cerebellum produce symptoms on the same side of the body.

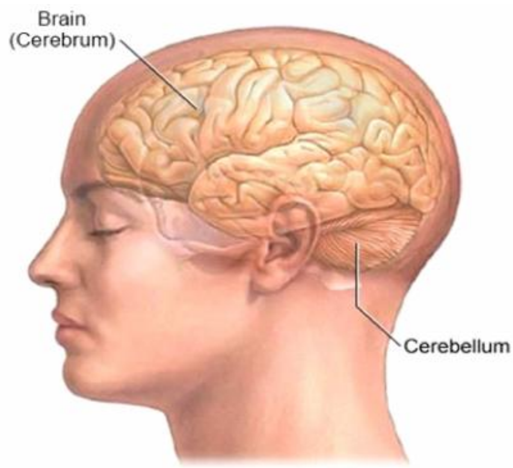


Fig.7.7 Cerebrum and cerebellum

Cerebrum : (Fig.7.7) The cerebrum forms the major portion of the brain, and is divided into the right and left cerebral hemispheres. These hemispheres are separated by a groove called the great longitudinal fissure and are joined at the bottom of this fissure by a struture called the corpus callosum which allows communication between the two sides of the brain. The surface of the cerebrum contains billions of neurons and glia that together form the cerebral cortex (brain surface), also known as "gray matter." The surface of the cerebral cortex appears wrinkled with small grooves that are called sulci and bulges between the grooves that are called gyri. Beneath the cerebral cortex are connecting fibers that interconnect the neurons and form a white-colored area called the "white matter."

Lobes : Several large grooves (fissures) separate each side of the brain into four distinct regions called lobes: frontal, temporal, parietal, and occipital. (Fig.7.8) Each hemisphere has one of each of these lobes, which generally control function on the opposite side of the body. The different portions of each lobe and the four different lobes communicate and function together through very complex relationships, but each one also has its own unique characteristics. The frontal lobes are responsible for voluntary movement, speech, intellectual and behavioral functions, memory, intelligence, concentration, temper and personality. The parietal lobe processes signals received from other areas of the brain (such as vision, hearing, motor, sensory and memory) and uses it to give meaning to objects. The occipital lobe is responsible for processing visual information. The temporal lobe is involved in visual memory and allows for recognition of objects and peoples' faces, as well as verbal memory which allows for remembering and understanding language.

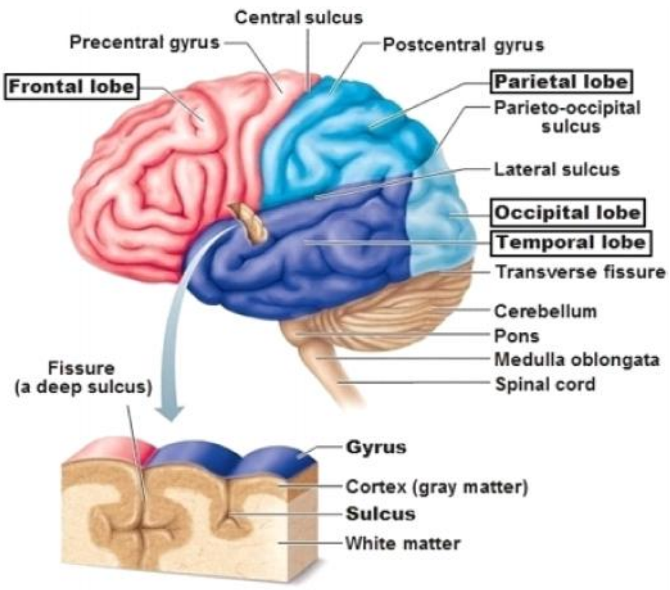


Fig.7.8 Lobes of brain

Hypothalamus : (Fig.7.9) The hypothalamus is a structure that communicates with the pituitary gland in order to manage hormone secretions as well as controlling functions such as eating, drinking, sexual behavior, sleep, body temperature, and emotions.

Pituitary Gland : The pituitary gland is a small structure that is attached to the base of the brain in an area called the sella turcica. (Fig.7.9) This gland controls the secretion of several hormones which regulate growth and development, function of various organs (kidneys, breasts, and uterus), and the function of other glands (thyroid gland, gonads, and the adrenal glands).

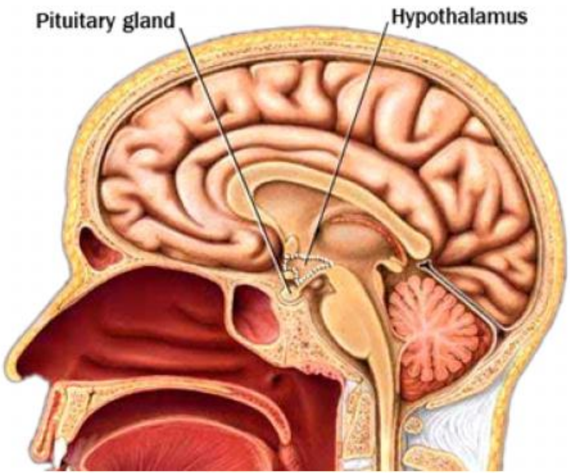


Fig.7.9 Hypothalamus and pituitary gland

Basal Ganglia : The basal ganglia are clusters of nerve cells around the thalamus which are heavily connected to the cells of the cerebral cortex. The basal ganglia are associated with a variety of functions, including voluntary movement, procedural learning, eye movements, and cognitive/emotional functions. The various components of the basal ganglia include caudate nucleus, putamen, globus pallidus, substantia nigra, and subthalamic nucleus. Diseases affecting these parts can cause a number of neurological conditions, including Parkinson's disease and Huntington's disease.

Spinal Cord-

The spinal cord is a long, thin, tubular bundle of neurons and support cells that extends from the bottom of the brain down to the space between the first and second lumbar vertebrae, and is housed and protected by the bony vertebral column. (Fig. 7.10) The spinal cord functions primarily in the transmission of signals between the brain and the rest of the body, allowing movement and sensation, but it also contains neural circuits that can control numerous reflexes independent of the brain.

General Structure : The spinal cord is divided into four different regions: the cervical, thoracic, lumbar and sacral regions The different cord regions can be visually distinguished from one another. Dorsal and ventral roots enter and leave the vertebral column respectively through intervertebral foramen at the vertebral segments corresponding to the spinal segment.

The length of the spinal cord is much shorter than the length of the bony spinal column, extending about 45 cm (18 inches). It is ovoid in shape and is enlarged in the cervical (neck) and lumbar (lower back) regions. Similar to the brain, the spinal cord is protected by three layers of tissue, called spinal meninges. The dura mater is the outermost layer, and it forms a tough protective coating. Between the dura mater and the surrounding bone of the vertebrae is a space called the epidural space, which is filled with fatty tissue and a network of blood vessels. The arachnoid mater is the middle protective layer. The space between the arachnoid and the underlying pia mater is called the subarachnoid space which contains cerebrospinal fluid (CSF). The medical procedure known as a lumbar puncture (or spinal tap) involves use of a needle to withdraw cerebrospinal fluid from the subarachnoid space, usually from the lumbar (lower back) region of the spine. The pia mater is the innermost protective layer. It is very delicate and it is tightly associated with the surface of the spinal cord.

In the upper part of the vertebral column, spinal nerves exit directly from the spinal cord, whereas in the lower part of the vertebral column nerves pass further down the column before exiting. The terminal portion of the spinal cord is called the conus medullaris. A collection of nerves, called the cauda equina, continues to travel in the spinal column below the level of the conus medullaris. The cauda equina forms as a result of the fact that the spinal cord stops growing in length at about age four, even though the vertebral column continues to lengthen until adulthood.

Three arteries provide blood supply to the spinal cord by running along its length. These are the two Posterior Spinal Arteries and the one Anterior Spinal Artery. These travel in the subarachnoid space and send branches into the spinal cord that communicate with branches from arteries on the other side.

Function: The spinal cord is divided into 33 different segments. At every segment, a pair of spinal nerves (right and left) exit the spinal cord and carry motor (movement) and sensory information. There are 8 pairs of cervical (neck) nerves named C1 through C8, 12 pairs of thoracic (upper back) nerves termed T1 through T12, 5 pairs of lumbar (lower back) nerves named L1 through L5, 5 pairs of sacral (pelvis) nerves numbered S1 through S5, and 3-4 pairs of coccygeal (tailbone) nerves.

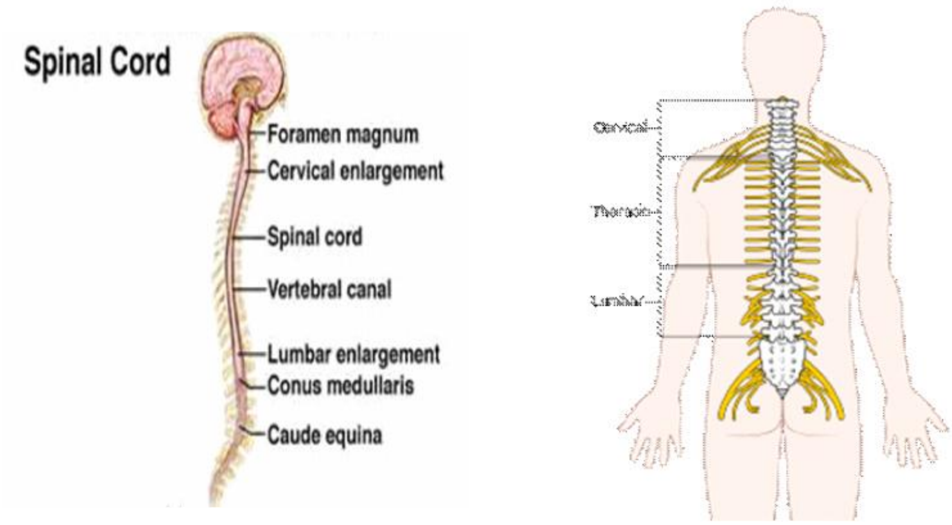


Fig. 7.10 Spinal cord

General Features

1. It carries sensory information (sensations) from the body and some from the head to the central nervous system (CNS) via afferent fibers, and it performs the initial processing of this information.

2. Motor neurons in the ventral horn project their axons into the periphery to innervate skeletal and smooth muscles that mediate voluntary and involuntary reflexes.

3. It contains neurons whose descending axons mediate autonomic control for most of the visceral functions.

4. It is of great clinical importance because it is a major site of traumatic injury and the locus for many disease processes.

Although the spinal cord constitutes only about 2% of the central nervous system (CNS), its functions are vital. Knowledge of spinal cord functional anatomy makes it possible to diagnose the nature and location of cord damage and many cord diseases.

Nerves-

Nerves are bundles of axons in the peripheral nervous system (PNS) that act as information highways to carry signals between the brain and spinal cord and the rest of the body. Each axon (Fig. 7.11) is wrapped in a connective tissue sheath called the endoneurium. Individual axons of the nerve are bundled into groups of axons called fascicles, wrapped in a sheath of connective tissue called the perineurium. Finally, many fascicles are wrapped together in another layer of connective tissue called the epineurium to form a whole nerve. The wrapping of nerves with connective tissue helps to protect the axons and to increase the speed of their communication within the body.

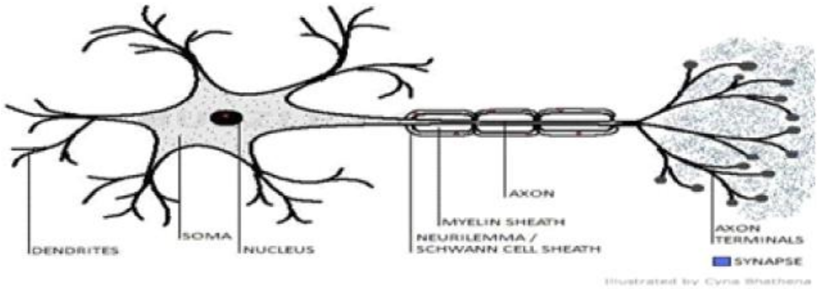


Fig. 7.11 Axon

- **Afferent, Efferent, and Mixed Nerves-** Some of the nerves in the body are specialized for carrying information in only one direction, similar to a one-way street. Nerves that carry information from sensory receptors to the central nervous system only are called afferent nerves. Other neurons, known as efferent nerves, carry signals only from the central nervous system to effectors such as muscles and glands. Finally, some nerves are mixed nerves that contain both afferent and efferent axons. Mixed nerves function like 2-way streets where afferent axons act as lanes heading toward the central nervous system and efferent axons act as lanes heading away from the central nervous system.

- **Cranial Nerves :** (Fig.7.12) Extending from the inferior side of the brain are 12 pairs of cranial nerves. Each cranial nerve pair is identified by a Roman numeral 1 to 12 based upon its location along the anterior-posterior axis of the brain. Each nerve also has a descriptive name (e.g. olfactory, optic, etc.) that identifies its function or location. The cranial nerves provide a direct connection to the brain for the special sense organs, muscles of the head, neck, and shoulders, the heart, and the GI tract.

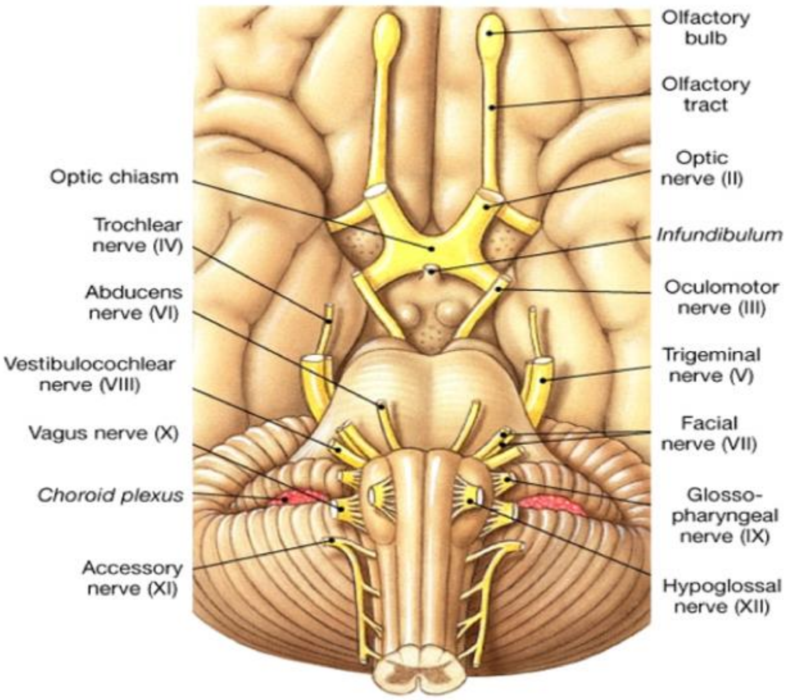


Fig.7.12 Cranial nerves

Cranial nerve I (Olfactory nerve): Smell

Cranial nerve II (Optic nerve): Vision

Cranial nerve III (Oculomotor nerve): Eye movements and opening of the eyelid

Cranial nerve IV (Trochlear nerve): Eye movements

Cranial nerve V (Trigeminal nerve): Facial sensation and jaw movement

Cranial nerve VI (Abducens nerve): Eye movements

Cranial nerve VII (Facial nerve): Eyelid closing, facial expression and taste sensation

Cranial nerve VIII (Vestibulocochlear nerve): Hearing and sense of balance

Cranial nerve IX (Glossopharyngeal nerve): Taste sensation and swallowing

Cranial nerve X (Vagus nerve): Heart rate, swallowing, and taste sensation

Cranial nerve XI (Spinal accessory nerve): Control of neck and shoulder muscles

Cranial nerve XII (Hypoglossal nerve) : Tongue movement

- **Spinal Nerves-** (Fig.7.13) Extending from the left and right sides of the spinal cord are 31 pairs of spinal nerves. The spinal nerves are mixed nerves that carry both sensory and motor signals between the spinal cord and specific regions of the body. The 31 spinal nerves are split into 5 groups named for the 5 regions of the vertebral column. Thus, there are 8 pairs of cervical nerves, 12 pairs of thoracic nerves, 5 pairs of lumbar nerves, 5 pairs of sacral nerves, and 1 pair of coccygeal nerves. Each spinal nerve exits from the spinal cord through the intervertebral foramen between a pair of vertebrae or between the C1 vertebra and the occipital bone of the skull.

C1-C6: Neck flexion

C1-T1: Neck extension

C3-C5: Diaphragm

C5-C6: Shoulder movement and elbow flexion

C6-C8: Elbow and wrist extension

C7-T1: Wrist flexion

C8-T1: Hand movement

T1-T6: Trunk muscles above the waist

T7-L1: Abdominal muscles

L1-L4: Thigh flexion

L2-L4: Thigh adduction (movement toward the body)

L4-S1: Thigh abduction (movement away from the body)

L2-L4: Leg extension at the knee

L5-S2: Leg extension at the hip

L4-S2: Leg flexion at the knee

L4-S1: Foot dorsiflexion (move upward) and toe extension

L5-S2: Foot plantarflexion (move downward) and toe flexion

The spinal nerves also provide sensation to the skin in an organized manner as depicted in diagram below.

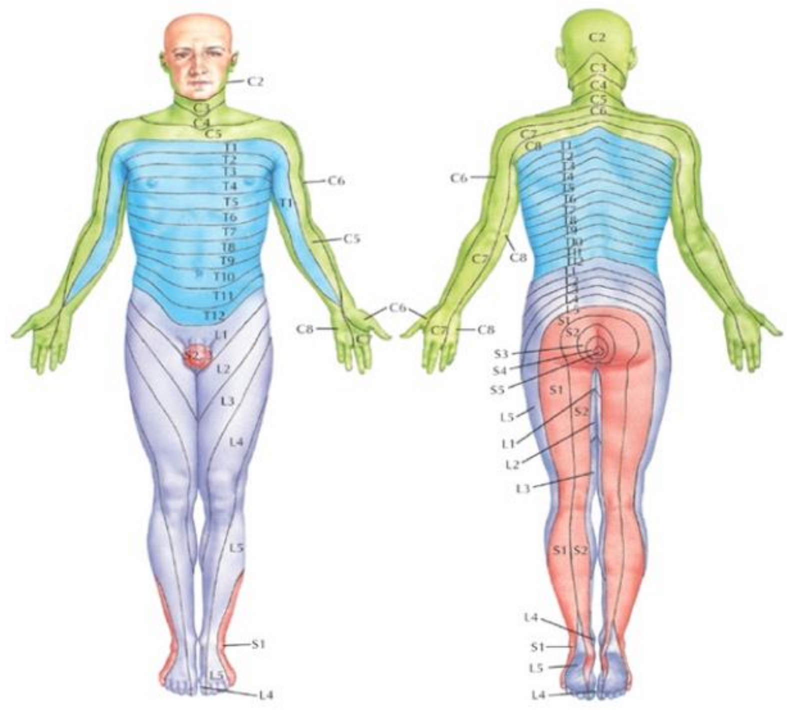


Fig.7.13 Spinal nerves

Pineal Gland : (Fig.7.14) The pineal gland is an outgrowth from the back portion of the third ventricle, and has some role in sexual maturation, although the exact function of the pineal gland in humans is unclear.

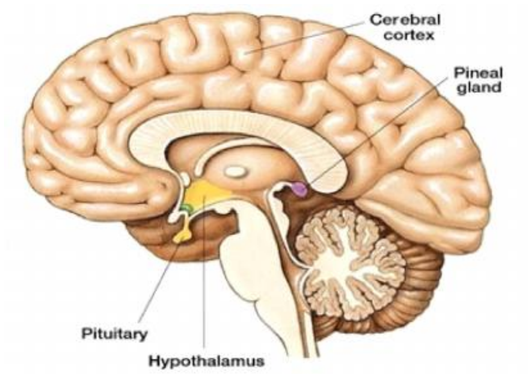


Fig.7.14 Location of pineal gland

7.2 Physiology of Nervous System

Functions of the Nervous System-

The nervous system has 3 main functions:

i) sensory,

ii) integration

iii) motor.

(i) **Sensory-** The sensory function of the nervous system involves collecting information from sensory receptors that monitor the body's internal and external conditions. These signals are then passed on to the central nervous system (CNS) for further processing by afferent neurons (and nerves).

(ii) **Integration-** The process of integration is the processing of the many sensory signals that are passed into the CNS at any given time. These signals are evaluated, compared, used for decision making, discarded or committed to memory as deemed appropriate. Integration takes place in the gray matter of the brain and spinal cord and is performed by interneurons. Many interneurons work together to form complex networks that provide this processing power.

iii) **Motor-** Once the networks of interneurons in the CNS evaluate sensory information and decide on an action, they stimulate efferent neurons. Efferent neurons (also called motor neurons) carry signals from the gray matter of the CNS through the nerves of the peripheral nervous system to effector cells. The effector may be smooth, cardiac, or skeletal muscle tissue or glandular tissue. The effector then releases a hormone moves a part of the body to respond to the stimul

Reflexes-

Reflexes are fast, involuntary responses to stimuli. The most well known reflex is the patellar reflex, which is checked when a physicians taps on a patient's knee during a physical examination. Reflexes are integrated in the gray matter of the spinal cord or in the brain stem. Reflexes allow the body to respond to stimuli very quickly by sending responses to effectors before the nerve signals reach the conscious parts of the brain. This explains why people shall often pull their hands away from a hot object before they realize they are in pain.

Functions of the Cranial Nerves-

Each of the 12 cranial nerves has a specific function within the nervous system.

- The **olfactory nerve** (I) carries scent information to the brain from the olfactory epithelium in the roof of the nasal cavity.
- The **optic nerve** (II) carries visual information from the eyes to the brain.
- **Oculomotor, trochlear, and abducens** nerves (III, IV, and VI) all work together to allow the brain to control the movement and focus of the eyes.
- The **trigeminal nerve** (V) carries sensations from the face and innervates the muscles of mastication.
- The **facial nerve** (VII) innervates the muscles of the face to make facial expressions and carries taste information from the anterior 2/3 of the tongue.
- The **vestibulocochlear nerve** (VIII) conducts auditory and balance information from the ears to the brain.
- The **glossopharyngeal nerve** (IX) carries taste information from the posterior 1/3 of the tongue and assists in swallowing.
- The **vagus nerve** (X), sometimes called the wandering nerve due to the fact that it innervates many different areas, "wanders" through the head, neck, and torso. It carries information about the condition of the vital organs to the brain, delivers motor signals to control speech and delivers parasympathetic signals to many organs.
- The **accessory nerve** (XI) controls the movements of the shoulders and neck.
- The **hypoglossal** nerve (XII) moves the tongue for speech and swallowing

Sensory Physiology-

All sensory receptors can be classified by their structure and by the type of stimulus that they detect. Structurally, there are 3 classes of sensory receptors: free nerve endings, encapsulated nerve endings, and specialized cells. Free nerve endings are simply free dendrites at the end of a neuron that extend into a tissue. Pain, heat, and cold are all sensed through free nerve endings. An encapsulated nerve ending is a free nerve ending wrapped in a round capsule of connective tissue. When the capsule is deformed by touch or pressure, the neuron is stimulated to send signals to the CNS. Specialized cells detect stimuli from the 5 special senses: vision, hearing, balance, smell, and taste. Each of the special senses has its own unique sensory cells—such as rods and cones in the retina to detect light for the sense of vision.

Glossary

- **Autonomic System :** deals with the visceral organs, like the heart, stomach, gland, and the intestines
- **Axon :** the part of the neuron that conducts nerve impulses
- **Central Nervous System (CNS) :** the system that includes the brain and the spinal cord
- **Cerebellum :** part of the brain that is located posterior to the medulla oblongata and pons, coordinates skeletal muscles to produce smooth, graceful motions
- **Cerebrospinal Fluid (CSF) :** acts a shock absorber for the central nervous system, protecting the brain and spinal cord from injury; it also has a high glucose content which serves as a nutritional factor
- **Cerebrum** motor control, learning, speech, somatic sensory functions, vision, hearing and more.
- **Dendrites :** short pieces that come off of the cell body that receive the signals from sensory receptors and other neurons
- **Longitudinal Sulcus :** separates the cerebrum in to the right and left hemispheres
- **Medulla** control center for respiratory, cardiovascular and digestive functions.
- **Myelin :** a fatty substance that surrounds and insulates the nerve fibers and facilitates the conduction of the nerve impulse transmissions
- **Multiple Sclerosis (MS) :** disease that affects the CNS by causing hardening and scaring of the myelin
- **Peripheral Nervous System (PNS) :** a way of communication from the central nervous system to the rest of the body by nerve impulses that regulate the functions of the human body
- **Pons** control centers for respiration and inhibitory functions.
- **Postganglionic Cells :** have their cell bodies in the ganglia and send their axons to target organs or glands
- **Sensory Receptor :** structure that can find any kind of change in it's surroundings or environment
- **Somatic Nervous System (SNS) :** the part of the peripheral nervous system associated with the voluntary control of body movements through the action of skeletal muscles, and also reception of external stimuli
- **Synapses :** the gap between two neurons; new synapses lead to learning
- **Afferent :** Carrying toward.
- **Anterior :** The front, as opposed to the posterior.
- **Basal ganglia :** A region of the base of the brain that consists of three clusters of neuron
- **Blood pressure :** The blood pressure is the pressure of the blood within the arteries
- **Brain :** The portion of the central nervous system that is located within the skull

- **Brainstem :** The lowest part of the brain which merges with the spinal cord
- **Cauda equina :** A bundle of spinal nerve roots that arise from the end of the spinal cord.
- **Cell :** The basic structural and functional unit of any living thing.
- **Cerebellum :** The portion of the brain that is in the back of the head,
- **Cerebral :** Of or pertaining to the cerebrum or the brain.
- **Cerebral cortex :** A thin mantle of gray matter
- **Cerebral hemispheres :** The two halves of the cerebrum, the largest part of the brain.
- **Cerebrospinal fluid :** A watery fluid that is continuously produced and absorbed and that fl...
- **Cerebrum :** The largest part of the brain. It is divided into two hemispheres, or halves.
- **Cervical :** Having to do with any kind of neck, including the neck
- **Coccygeal :** Referring to the coccyx, the small tail-like bone at the bottom of the spine,
- **Cortex :** The outer layer of any organ.
- **Cortical :** Having to do with the cortex, the outer layer of an organ.
- **Cranial :** 1. Pertaining to the cranium or skull. 2. Toward the head.
- **Cranial nerves :** The nerves of the brain, which emerge from or enter the skull
- **Dura :** The outermost, toughest, and most fibrous of the three membranes (meninges) covering.
- **Efferent :** Carrying away.
- **Fornix :** In anatomy, any vault like or arched structure, such as the fornix cerebri
- **Frontal :** In anatomy, pertaining to the forehead.
- **Gland :** A group of cells that secrete a substance for use in the body.
- **Globus :** A word straight from the Latin, meaning (not unexpectedly) a globe or sphere.
- **Gray matter :** The cortex of the brain, which contains nerve cell bodies.
- **Gyrus :** A convolution on the surface of a cerebral hemisphere caused by the infolding of th...
- **Heart rate :** The number of heartbeats per unit of time, usually per minute.
- **Hippocampus :** An area deep in the forebrain that helps regulate emotion, learning, and memory
- **Hypothalamus :** The area of the brain that secretes substances that influence pituitary and other endocrines
- **Involuntary :** Done other than in accordance with the conscious shall of the individual.
- **Lobe :** Part of an organ that appears to be separate in some way from the rest.
- **Medulla :** The innermost part.
- **Medulla oblongata :** The base of the brain, which is formed by the enlarged top of the spinal cord

- **Metabolism :** The whole range of biochemical processes that occur within a living organism
- **Motor :** Something that produces or refers to motion.
- **Muscle :** Muscle is the tissue of the body which primarily functions as a source of power.
- **Myelin :** The fatty substance that covers and protects nerves.
- **Nerve :** A bundle of fibers that uses electrical and chemical signals to transmit
- **Nerve cell :** See: Neuron.
- **Neuron :** A nerve cell that receives and sends electrical signals over long distances within.
- **Occipital :** 1. Pertaining to the occiput, the back of head. 2. Located...
- **Optic nerve :** The optic nerve connects the eye to the brain.
- **Paralysis :** Loss of voluntary movement (motor function).
- **Parietal :** meaning "belonging to the wall"
- **Peripheral :** Situated away from the center, as opposed to centrally located.
- **Peripheral nervous system :** The portion of the nervous system that is outside the brain
- **Pituitary gland :** The main endocrine gland. It is a small structure in the head.
- **Pons :** A specific section of the brain formed by the rounded prominence on the front surface
- **Posterior :** The back or behind, as opposed to the anterior.
- **Reflex :** An involuntary reaction.
- **Sacral :** Referring to the sacrum.
- **Sclerosis :** Localized hardening of skin. Sclerosis is generally caused by underlying diseas.
- **Sensation :** In medicine and physiology, sensation refers to the registration of an incoming.
- **Sensory :** Relating to sensation, to the perception of a stimulus,
- **Spinal cord :** The major column of nerve tissue that is connected to the brain
- **Stress :** In a medical or biological context stress is a physical, mental, or emotional fact.
- **Striatum :** Part of the basal ganglia of the brain.
- **Subarachnoid :** Literally, beneath the arachnoid, the middle of three membranes
- **Sulci :** The plural of sulcus.
- **Taste :** A perception that results from stimulation of a gustatory nerve.
- **Temporal :** Pertaining to time, limited in time, temporary, or transient.
- **Temporal lobe :** The lobe of the cerebral hemisphere located down on the side
- **Vital :** Necessary to maintain life. For example, breathing is a vital function.
- **Voluntary :** Done in accordance with the conscious shall of the individual.

Assignments/Test

Q. Choose the correct answer and rewrite the sentences.

1. The function of the central nervous system is

   A. to receive, process and interpret incoming information

   B. to send out messages to muscles

   C. to send out messages to glands and organs

   D. all of the above

2. The peripheral nervous system-

   A. is made up of the brain and spinal cord

   B. handles the central nervous system's input and output

   C. depends exclusively on sensory neurons

   D. depends exclusively on motor neurons

3. The _______ nervous system is part of the peripheral nervous system.

   A. somatic

   B. sympathetic

   C. autonomic

   D. all of the above

4. One function of the somatic nervous system is to

   A. carry information from the senses to the CNS and from the CNS to the skeletal muscles

   B. carry information to the glands and organs

   C. control the sympathetic and parasympathetic nervous systems

   D. process information in the brain

5. The sympathetic nervous system handles ________ responses, while the parasympathetic nervous system governs _______ responses.

   A. voluntary; involuntary

   B. involuntary; voluntary

   C. arousal; relaxing

   D. sensory; motor

6. The autonomic nervous system is involved with

   A. voluntary responses

   B. the nerves connected to the senses and skeletal muscles

   C. involuntary responses such as the regulation of blood vessels and glands

   D. only sensory nerves

7. Neurons -

   A. are the basic units of the nervous system.

   B. are held in place by glial cells.

   C. transmit electrical messages throughout the nervous system.

   D. are characterized by all of the above.

8. The three main parts of the neuron are the

A. dendrites, cell body and axon.

B. axon, dendrites and synapse.

C. synapse, impulse and cleft.

D. myelin sheath, dendrites and synapse.

9. The ______ receive messages from other neurons, while the ______ carry messages on to other neurons or to muscle or gland cells.

A. cell bodies; dendrites

B. dendrites; axons

C. axons; dendrites

D. myelin sheaths; cell bodies

10. What occurs at the synapse?

A. The electrical charge jumps from the synaptic end bulb across the synaptic cleft to the dendrites of the next neuron.

B. The axon terminals contact the dendrites of the next neuron and neurotransmitters are transferred.

C. Synaptic vesicles in the synaptic end bulb release neurotransmitters into the synaptic cleft, and they lock into receptor sites of receiving dendrites.

D. Scientists are studying the process because the exact mechanism is unknown.

UNIT 8- URINARY SYSTEM

Objectives - At the end of this lesson you shall be able to-

- Describe the organs of urinary system
- Describe the structure of urinary system
- Describe the functions of urinary organs
- Describe the process of formation of urine, urination
- State the hormones and their functions produced by kidneys
- State the regulation of concentration and volume of urine
- State the urologic diseases

Introduction : The urinary system consists of the kidneys, ureters, urinary bladder, and urethra. (Fig. 8.1) Adrenal glands are superior to the kidneys as like a cap on kidney. The kidneys filter the blood to remove wastes and produce urine. The ureters, urinary bladder, and urethra together form the urinary tract, which acts as a plumbing system to drain urine from the kidneys, store it, and then release it during urination. Besides filtering and eliminating wastes from the body, the urinary system also maintains the homeostasis of water, ions, pH, blood pressure, calcium.

8.1 Urinary System Anatomy:

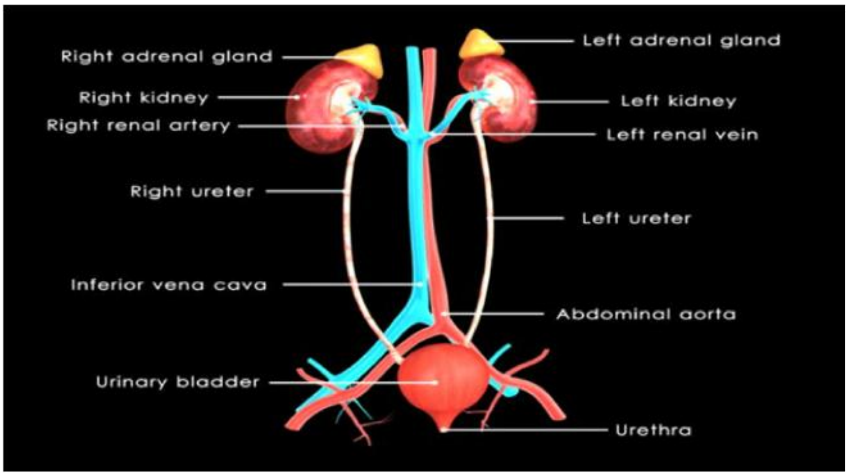


Fig. 8.1 Urinary system

Kidneys-The kidneys are a pair of bean-shaped organs found along the posterior wall of the abdominal cavity. The left kidney is located slightly higher than the right kidney because the right side of the liver is much larger than the left side. The kidneys, unlike the other organs of the abdominal cavity, are located posterior to the peritoneum and touch the muscles of the back. The kidneys are surrounded by a layer of adipose that holds them in place and protects them from physical damage. The kidneys filter metabolic wastes, excess ions, and chemicals from the blood to form urine.

Structure of kidney

The indentation on the concave side of the kidney, known as the renal hilus, provides a space for the renal artery, renal vein, and ureter to enter the kidney.

A thin layer of fibrous connective tissue forms the renal capsule surrounding each kidney. The renal capsule provides a stiff outer shell to maintain the shape of the soft inner tissues.

Deep to the renal capsule is the soft, dense, vascular renal cortex. (Fig.8.2) Seven cone-shaped renal pyramids form the renal medulla deep to the renal cortex. The renal pyramids are aligned with their bases facing outward toward the renal cortex and their apexes point inward toward the center of the kidney.

Each apex connects to a minor calyx, a small hollow tube that collects urine. The minor calyces merge to form 3 larger major calyces, which further merge to form the hollow renal pelvis at the center of the kidney. The renal pelvis exits the kidney at the renal hilus, where urine drains into the ureter.

Blood Supply

1. The renal arteries branch directly from the abdominal aorta and enter the kidneys through the renal hilus.
2. Inside our kidneys, the renal arteries diverge into the smaller afferent arterioles of the kidneys.
3. Each afferent arteriole carries blood into the renal cortex, where it separates into a bundle of capillaries known as a glomerulus.
4. From the glomerulus, the blood recollects into smaller efferent arterioles that descend into the renal medulla.
5. The efferent arterioles separate into the peritubular capillaries that surround the renal tubules.
6. Next, the peritubular capillaries merge to form veins that merge again to form the large renal vein.
7. Finally, the renal vein exits the kidney and joins with the inferior vena cava, which carries blood back to the heart.

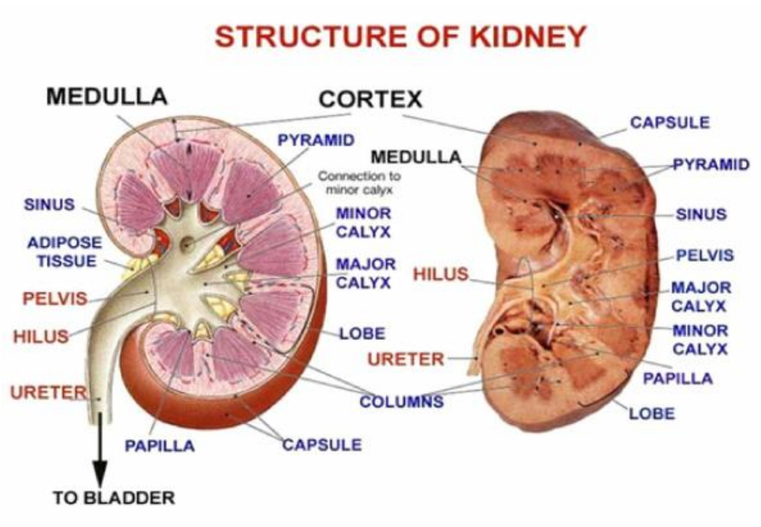


Fig.8.2 Structure of kidney

Ureters- The ureters are a pair of tubes that carry urine from the kidneys to the urinary bladder. The ureters are about 10 to 12 inches long and run on the left and right sides of the body parallel to the vertebral column. Gravity and peristalsis of smooth muscle tissue in the walls of the ureters move urine toward the urinary bladder. The ends of the ureters extend slightly into the urinary bladder and are sealed at the point of entry to the bladder by the ureterovesical valves. These valves prevent urine from flowing back towards the kidneys.

Urinary Bladder-The urinary bladder is a sac-like hollow organ used for the storage of urine. The urinary bladder is located along the body's midline at the inferior end of the pelvis. Urine entering the urinary bladder from the ureters slowly fills the hollow space of the bladder and stretches its elastic walls. The walls of the bladder allow it to stretch to hold anywhere from 600 to 800 milliliters of urine.

Urethra-The urethra is the tube through which urine passes from the bladder to the exterior of the body. The female urethra is around 2 inches long and ends inferior to the clitoris and superior to the vaginal opening. In males, the urethra is around 8 to 10 inches long and ends at the tip of the penis. The urethra is also an organ of the male reproductive system as it carries sperm out of the body through the penis.

The flow of urine through the urethra is controlled by the internal and external urethral sphincter muscles. The internal urethral sphincter is made of smooth muscle and opens involuntarily when the bladder reaches a certain set level of distention. The opening of the internal sphincter results in the sensation of needing to urinate. The external urethral sphincter is made of skeletal muscle and may be opened to allow urine to pass through the urethra or may be held closed to delay urination.

8.2- Functions of Urinary Organs-Kidney, Ureters

Functions of the Urinary System-

There are several functions of the Urinary System:

- Removal of waste product from the body (mainly urea and uric acid)
- Regulation of electrolyte balance (e.g. sodium, potassium and calcium)
- Storage and Excretion of Wastes
- Regulation of acid-base homeostasis
- Controlling blood volume and maintaining blood pressure
- Production of Hormones- The kidneys produce and interact with several hormones that are involved in the control of systems outside of the urinary system such as

(i) **Calcitriol-** Calcitriol is the active form of vitamin D in the human body. ii) Erythropoietin- Erythropoietin, also known as EPO, is a hormone that is produced by the kidneys to stimulate the production of red blood cells.

(iii) **Renin-** Renin is not a hormone itself, but an enzyme that the kidneys produce to start the renin-angiotensin system (RAS). The RAS increases blood volume and blood pressure in response to low blood pressure, blood loss, or dehydration.

(iv) **Angiotensin II-** stimulates several processes, including stimulating the adrenal cortex to produce the hormone aldosterone. Aldosterone then changes the function of the kidneys to increase the reabsorption of water and sodium ions into the blood, increasing blood volume and raising blood pressure.

8.3 Formation of of Urine -

- Average urine production in adult humans is about 1 – 2 L per day, depending on state of hydration, activity level, environmental factors, weight, and the individual's health.
- Producing too much or too little urine needs medical attention. Polyuria is a condition of excessive production of urine (> 2.5 L/day), oliguria when < 400 mL are produced, and anuria one of < 100 ml per day.

Urine is formed as per following steps-(Fig.8.3)

1. The first step in urine formation is the filtration of blood in the kidneys. In a healthy human the kidney receives between 12 and 30% of cardiac output, but it averages about 20% or about 1.25 L/min.

2. **The basic structural and functional unit of the kidney is the nephron.** Its chief function is to regulate the concentration of water and soluble substances like sodium salts by filtering the blood, reabsorbing what is needed and excreting the rest as urine.

3. In the first part of the nephron, the renal corpuscle blood is being filtrated from the circulatory system into the nephron.

4. A pressure difference between forces the filtrate from the blood across the filtration membrane. The filtrate includes water, small molecules and ions that easily pass through the filtration membrane. However larger molecules such as proteins and blood cells are prevented from passing through the filtration membrane.

5. The amount of filtrate produced every minute is called the glomerular filtration rate or GFR and amounts to a staggering 180 litres per day. About 99% of this filtrate is then reabsorbed as it passes through the nephron and the remaining 1% becomes urine.

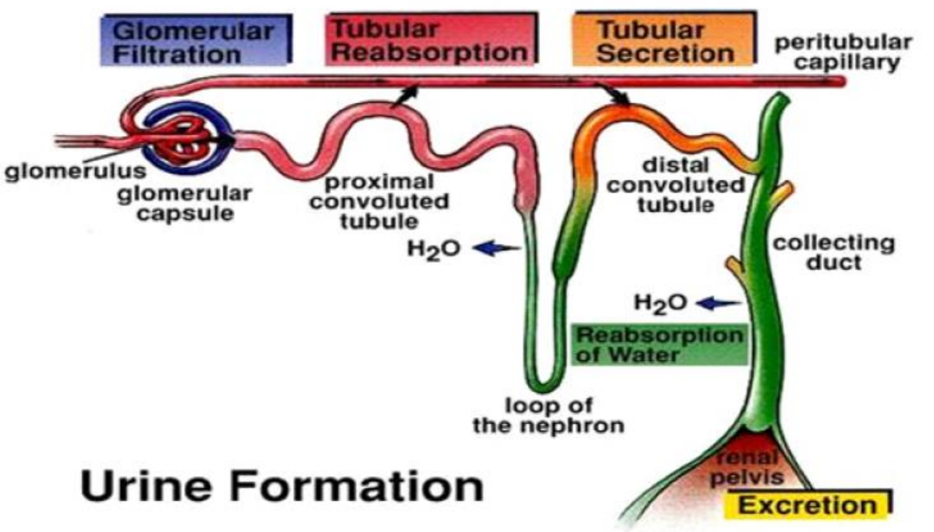


Fig.8.3 Diagrammatic representation of Urine formation

Regulation of concentration and volume-

The urinary system is regulated by the endocrine system by hormones such as antidiuretic hormone, aldosterone and parathyroid hormone.

- The urinary system is under influence of the blood pressure, nervous system and endocrine system.
- Antidiuretic hormone (ADH), is a neurohypophysial hormone found in most mammals.
- Its two primary functions are to retain water in the body and to constrict blood vessels. Vasopressin regulates the body's retention of water by acting to increase water absorption in the collecting ducts of the kidney nephron.
- Vasopressin increases water permeability of the kidney's collecting duct and distal convoluted tubule by inducing translocation of aquaporin-CD water channels in the kidney nephron collecting duct plasma membrane.

Urine movement-

- Urine moves from the nephrons collecting duct system to the minor calyx and then the major calyx before entering the renal pelvis, a funnel-like dilated proximal part of the ureter within the kidney.

- The major function of the renal pelvis is to act as a funnel for urine flowing to the ureter.
- From here the urine flows through the ureters to the bladder, where it is stored until urination takes place.

Urination- Urination is the process of releasing urine from the urinary bladder through the urethra and out of the body. The process of urination begins when the muscles of the urethral sphincters relax, allowing urine to pass through the urethra. At the same time that the sphincters relax, the smooth muscle in the walls of the urinary bladder contract to expel urine from the bladder.

- Urination is the ejection of urine from the urinary bladder through the urethra to the outside of the body.
- In healthy humans (and many other animals), the process of urination is under voluntary control.
- In infants, some elderly individuals, and those with neurological injury, urination may occur as an involuntary reflex.
- Physiologically, micturition involves coordination between the central, autonomic, and somatic nervous systems. Brain centers that regulate urination include the pontine micturition center, periaqueductal gray, and the cerebral cortex.
- In male urine is ejected through the penis, and in female through the vulva.
- Urination may be delayed as long as the bladder does not exceed its maximum volume, but increasing nerve signals lead to greater discomfort and desire to urinate

Urologic diseases-

- Urologic diseases can involve congenital or acquired dysfunction of the urinary system.
- Kidney diseases are normally investigated and treated by nephrologists, while the specialty of urology deals with problems in the other organs. Gynecologists may deal with problems of incontinence in women.
- Diseases of other bodily systems also have a direct effect on urogenital function. For instance it has been shown that protein released by the kidneys in diabetes mellitus sensitises the kidney to the damaging effects of hypertension.
- Diabetes also can have a direct effect in urination due to peripheral neuropathies which occur in some individuals with poorly controlled diabetes.

Glossary

- Antidiuretic: lessening or decreasing of urine production or an agent that decreases the release of urine.
- Catheterisation: a catheter is a tube that can be inserted into a body cavity, duct or vessel. Catheters thereby allow drainage or injection of fluids or access by surgical instruments. The process of inserting a catheter is catheterization. In most uses a catheter is a thin, flexible tube: a "soft" catheter; in some uses, it is a larger, solid tube: a "hard" catheter.
- Dehydration: condition resulting from excessive loss of body fluid.

- Diabetes: a general term for a disease characterized by the beginning stages and onset of renal failure. It is derived from the Greek word diabaínein, that literally means "passing through," or "siphon", a reference to one of diabetes' major symptoms—excessive urine production.
- Diuresis: secretion and passage of large amounts of urine.
- Diuretic: increasing of urine production, or an agent that increases the production of urine.
- Erythropoietin: hormone that stimulates stem cells in the bone marrow to produce red blood cells
- Fibrous Capsule: the kidney's loose connective tissue
- Glomerulus: capillary tuft that receives its blood supply from an afferent arteriole of the renal circulation.
- Gluconeogenesis: the cycle of producing a glucose form fat or protein; preformed by the kidney in times of long fasting, initially gluconeogenesis is preformed by the liver
- Loop of Henle/ Nephron Loop: u-shaped tube that consists of a descending limb and ascending limb; primary role is to concentrate the salt in the interstitium, the tissue surrounding the loop
- Medullary Pyramids or Renal Pyramids: the cone shaped masses in the kidney
- Micturition: another name for excretions
- Nephron: basic structural and functional unit of the kidney; chief function is to regulate water and soluble substances by filtering the blood, reabsorbing what is needed and excreting the rest as urine
- Renal Calculi: kidney stones, solid crystals of dissolved minerals in urine found inside the kidneys
- Renal Cortex: outer portion of the kidney
- Renal Lobe: each pyramid together with the associated overlying cortex
- Renal Pelvis: a central space, or cavity that transmits urine to the urinary bladder via the ureter
- Renin: hormone released by kidneys when blood pressure falls
- TURP: transurethral resection of the prostate. During TURP, an instrument is inserted up the urethra to remove the section of the prostate that is blocking urine flow. This is most commonly caused by benign prostatic hyperplasia (BPH). A TURP usually requires hospitalization and is done using a general or spinal anesthetic. It is now the most common surgery used to remove part of an enlarged prostate.
- Urethra: a muscular tube that connects the bladder with the outside of the body
- Ureters: two tubes that drain urine from the kidneys to the bladder
- Urine: liquid produced by the kidneys, collected in the bladder and excreted through the urethra
- Urinary Bladder: a hollow, muscular and distensible or elastic organ that sits on the pelvic floor
- Urinary System: a group of organs in the body concerned with filtering out excess fluid and other substances from the bloodstream

Assignments/Test

Multiple choice questions-

1. Direct control of water excretion in the kidneys is controlled by

A) Anti-diuretic hormone

B) The medulla oblongata

C) Blood plasma

D) Sodium amounts in the blood

2. Nephrons

A) Eliminate wastes from the body

B) Regulate blood volume and pressure

C) Control levels of electrolytes and metabolites

D) Regulate blood pH

E) All of the above

3. Which part of the Nephron removes water, ions and nutrients from the blood?

A) vasa recta

B) loop of Henle

C) proximal convuluted tubule

D) peritubular capillaries

E) glomerulus

4. Kidneys have a direct effect on which of the following

A) Blood pressure

B) How much water a person excretes

C) Total blood volume

D) pH

E) all of the above

5. What happens in tubular excretion?

A) urine bonds are formed between the wastes

B) wastes are diffused from the tubule

C) wastes move into the distal convoluted tubule from the blood

D) blood pressure forces wastes away from the kidney

6. The function of the loop of the nephron in the process of urine formation is:

A) reabsorption of water

B) production of filtrate

C) reabsorption of solutes

D) secretion of solutes

Q. Answer the following.

1. What are the functions of kidney?
2. Write an anatomy of urinary system.
3. Write the process of urination.
4. Write the structure of kidney.
5. Write the hormones secreted by kidney with their functions.

UNIT 9- REPRODUCTIVE SYSTEM

Objectives-

At the end of this lesson you shall be able to-

- State the organs of female and male reproductive system
- Describe the anatomy and physiology of female and male reproductive system
- Define menstrual cycle
- State phases of menstrual cycle.
- Describe ovulation, spermatogenesis

9.1 Anatomy of Female Reproductive System

Parts of female reproductive system-

External genital organs- (Fig.9.1)

Although a woman's external genitals are commonly referred to as the "vagina," the vagina is actually one of several parts that create that section of a woman's body. Collectively, these parts are called the vulva. Rich with nerves, the vulva can provide sexual pleasure when properly stimulated.

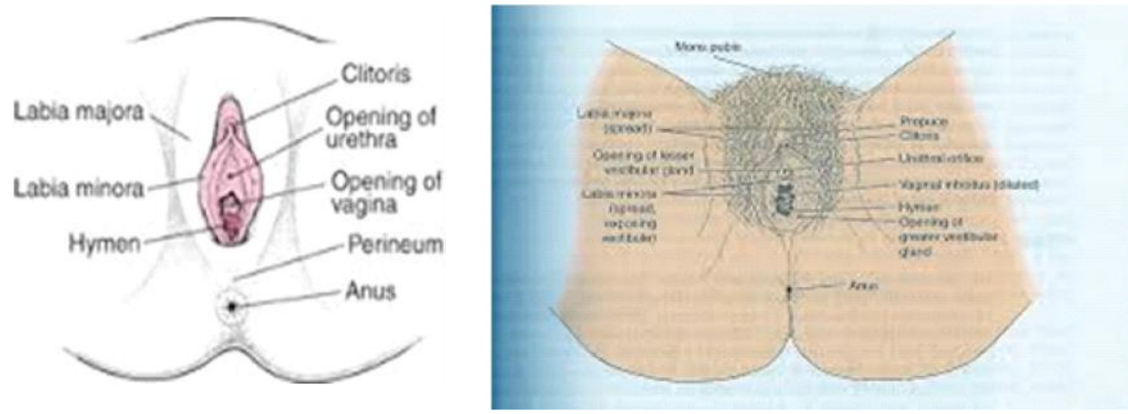


Fig.9.1 External female genital organs

- Vagina -The vagina is muscular tube about three inches long that ends the birth canal. This is where a man's penis enters the woman during sexual intercourse. The vaginal opening is visible from the outside, but it is protected by the labia when a woman stands and during most activities.
- Labia majora-The labia majora are two folds of skin that extend from the front of the vaginal opening to the back of it. The outer surfaces of the folds have darker-colored skin and stronger hairs, while the inner folds are smoother. The labia majora join to form the cleft shape of the female genitals. This is also known as the pudendal cleft or the cleft of Venus, after the Roman goddess of love.
- Labia minora-Between the labia majora are the labia minora, two folds of skin that also extend down from the clitoris and around the vaginal opening. These vary in size from woman to woman. They are joined together by a small fold of skin known as the fourchette, or "little fork." This can be torn during childbirth or during acts of sexual violence, and doctors often use sutures to repair it.
- Clitoris-The clitoris is a crucial element for sexual arousal in most women. This small sexual organ at the top of the vagina at the junction of the labia minora appears outside the folds of skin like a small pink button.

During sexual stimulation, the clitoris functions much like a man's penis in that it becomes erect thanks to signals from the brain. The shaft under the skin has erectile tissue, which becomes engorged with increased blood flow. The clitoris is a very sensitive area when stimulated. Most women cannot achieve orgasm without direct stimulation to the clitoris.

- **Urethra -** The outer female genitals also include the urethra. Located between the vaginal opening and the frontal connection of the labia minora, the urethral opening is where a woman expels urine from her body.

Internal genital organs-(Fig.9.2)

- **Ovaries -** They are a pair of glands about the size and shape of almonds located on the left and right side of pelvic cavity .lateral to the superior portion of uterus .Ovaries produce female sex harmones such as estrogen and progesterone as well as ova ,the female gametes .Ova are produced from oocyte cells that slowly develop throughout the women's early life and reach maturity after puberty. Each month during ovulation a mature ovum is released The ovum travels from the ovary to the fallopian tube, where it may be fertilized before reaching the uterus .

- **Fallopian tube -** They are a pair of muscular tube that extend from the left and right superior corners of the uterus to the edge of the ovaries .The fallopian tubes end in a funnel –shaped structure called the infundibulum ,which is covered with a small projection called fimbriae .They pick up released ova and carry them into the infundibulum for transport to the uterus .The inside of each fallopian tube is covered in cilia that work with smooth muscle of the tube to carry the ovum to the uterus .

- **Uterus -** The uterus is a hollow ,muscular pear shaped organ located posterior and superior to the urinary bladder .Connected to the two fallopian tube on its superior end and to the vagina on its inferior end ,the uterus is also known as womb as it surrounds the developing fetus during pregnancy .The inner lining of the uterus ,known as the endometrium provides support to the embryo during early development .the visceral muscles of the uterus contract during childbirth to push the fetus through the birth canal.

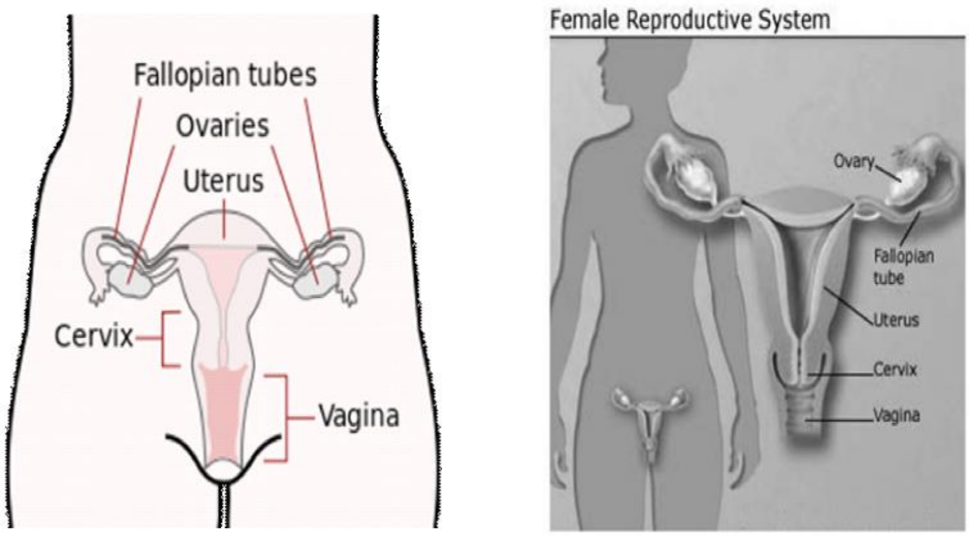


Fig.9.2 Diagram of female reproductive system

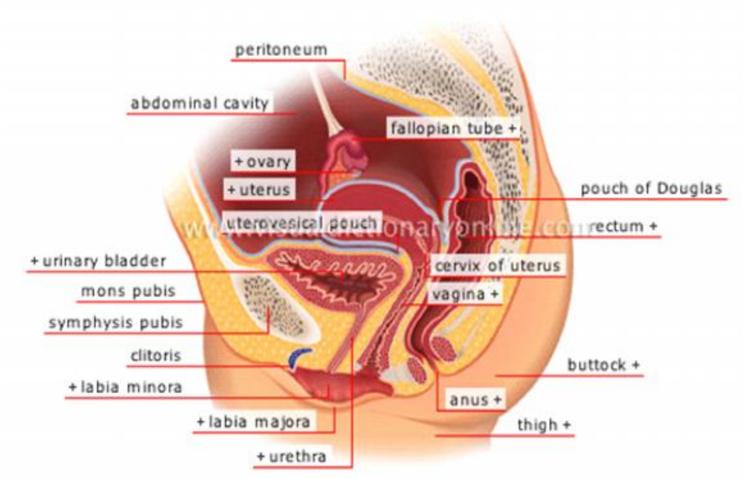


Fig.9.3 Internal and external parts of female reproductive system

Breast and Mammary Glands - The breasts are specialized organs of the female body that contain mammary glands, milk ducts and adipose tissue. (Fig.9.4)The two breasts are located on the left and right sides of the thoracic region of the body in the center of each breast is a highly pigmented nipple that releases milk when stimulated, the areolas a thickened highly pigmented bang of the skin that surrounds the nipple, protects the underlying tissue during breast feeding. The mammary glands are a special type of sudoriferous glands that have been modified to produce milk to feed infants .Within each breast 15 to20 clusters of mammary glands become active during pregnancy and remain active until milk is no longer needed .The milk passes through the milk ducts on its way to the nipple, where it exits the body.

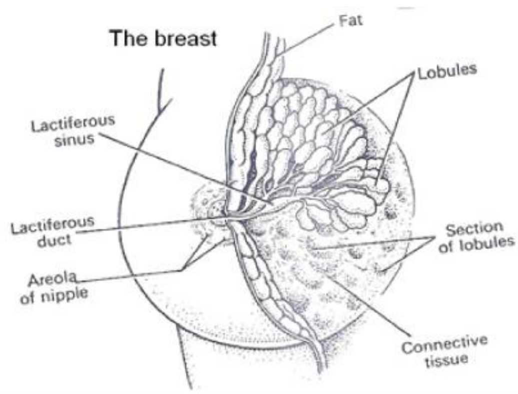


Fig.9.4 Breast and its internal structure

Blood supply- Uterine artery and ovarian artery arises from internal pudendal artery.

Venous drainage – Uterine and ovarian vein which form plexus.

Nerve supply – Pelvic plexus of the nerve contains symphathetic and parasymphathetic nerve supply.

9.2 Physiology of female reproductive system

1. The reproductive cycle - This is a process of producing an ovum and readying the uterus to receive a fertilized ovum to begin pregnancy .If an ovum produced is not fertilized and implanted in the uterine wall ,the reproductive cycle resets itself through menstruation. The entire reproductive cycle takes about 28 days on an average, but may be as short as 24 days or as long as 36days in some women.

2. **Oogenesis and ovulation -** Under the influence of follicle stimulating hormone (F.H.S.) and Luteinizing hormone (L.H.) the ovaries produce a mature ovum in a process known as ovulation .By about 14 days into the reproductive cycle an oocyte reaches

maturity and is released as an ovum .Although the ovaries begin to mature many oocytes each month, usually only one ovum per cycle is released.

3. **Fertilization –** Once the mature ovum is released from ovary ,the fimbria catch the egg and direct it down the fallopian tube to the uterus It takes about a week for the ovum to travel to the uterus .If the sperm are able to reach and penetrate the ovum ,the ovum becomes fertilized zygote containing a full complement of DNA. After a two week period of rapid division known as the germinal period of development, the zygote forms an embryo. The embryo will then implant itself into the uterine wall and develop there during pregnancy.

4. **Menstruation -**While the ovum matures and travels through the fallopian tube, the endometrium grows and develops in preparation for the embryo .If the ovum is not fertilized in time or if it fails to implant into the endometrium the arteries of the uterus constrict to cut of blood flow to the endometrium .The lack of blood flow causes cell death in the endometrium and the eventual shedding of tissue in a process known as menstruation. In normal menstrual cycle, this shedding begins around day 28 and continues into the first few days of the new reproductive cycle.

5. **Pregnancy –** If the ovum is fertilized by the sperm cell, the fertilized embryo will implant itself into the endometrium and begin to form an amniotic cavity, umbilical cord and placenta .For the first 8 weeks ,the embryo will develop almost all of the tissue and organs present in the adult before entering the fetal period of development during weeks 9 through 38 .During the fetal period , the fetus grows large and more complex until it is ready to be born .

6. **Lactation-** lactation is the production and release of milk to feed an infant. The production of milk begins prior to birth under the control of the hormone prolactin. Prolactin is produced in response to the suckling of an infant on the nipple ,so milk is produced as long as active breast feeding occurs .As soon as the infant is weaned ,prolactin and milk production end soon after . The release of milk by the nipple is known as 'milk letdown reflex' and is controlled by the hormone Oxytocin. Oxytocin is also produced in response to infant suckling so that milk is only released when as infant is actively feeding.

9.3 –Physiology of Menstruation

Definitions:

- Menstrual cycle-Towards the end of puberty, girls begin to release ova as a part of a monthly period called female reproductive cycle or menstrual cycle.
- Menarche-The first onset of menstruation is called as menarche.
- Menopause - Menopause is the physiological cessation of menstrual cycle associated with advancing age.

Phases of menstrual cycle (Total cycle 28 days) - (Fig.9.5)

1) Phase I – Menstrual period 5days .Surface epithelium is stripped off the lining of the uterus and bleeding occurs.(0-5)days blood loss 50 to 60 ml.

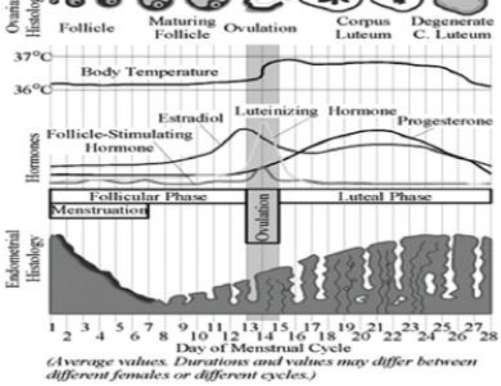


Fig.9.5 Phases of menstrual cycle

2) Phase II – Post menstrual phase (stage of repair)

Proliferation of mucosa of endothelium (6 to 9days)

3) Phase III – Ovulation (13-14days). Maturation and release of ovum .

4) Phase IV - Secretary Phase (14 to 28 days). Formation of corpus leuteum, prepare the bed for pregnancy.

9.4 Anatomy of male reproductive system

- External genital organs
- Internal genital organs

External genital organs –

Penis

Scrotum

Internal genital organs –

Epididymis
Vas deferens
Accessory gland
Seminal vesicles
Prostate gland
Bulbourethral glands

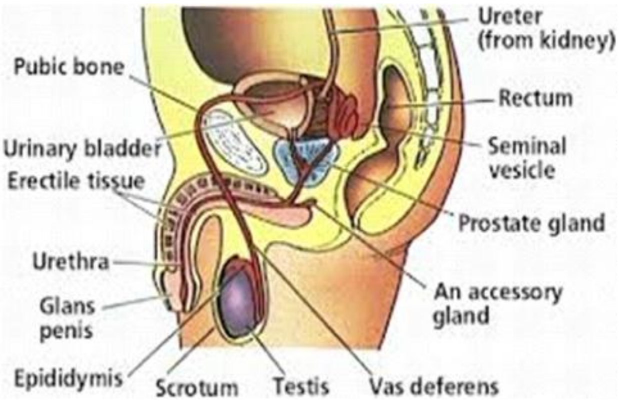


Fig.9.6 Male reproductive system

1. **Penis –** The penis is the male copulatory organ .It has a long shaft and an enlarged bulbous shaped tip called the glans penis which supports and is protected by foreskin .When the male becomes sexually aroused thepenis becomes erect and ready for sexual activity .Erection occurs because sinuses within ther erectile tissue of the penis become filled with blood. The arteries of the penis are dilated while the veins are passively compressed so that the blood from erectile tissue of the penis are dilated while the veins are passively compressed so that blood flows into the erectile cartilage under pressure.

2. **Scrotum-** The scrotum is a pouch-like structure that hangs behind the penis. It holds and protects the testes. It also contains numerous nerves and blood vessels. During the times of lower temperatures , the Cremaster muscle contracts and pulls the scrotum closer to the body, while the Dartos muscle gives a wrinkled appearance; when the temperature increases the Cremaster and Dartos muscles relaxes to bring down the scrotum away from the body and remove the wrinkles respectively.The scrotum the scrotum remains connected to the abdomen or pelvic cavity by the inguinal canal. (The spermatic cord, formed from spermatic artery, vein and nerve bond together with connected tissue passes into the testis through the inguinal canal.)

Internal genital organs-

Epididymis- The epididymis, a whitish mass of tightly coiled tubes cupped against the testicles, acts as a maturation and storage of for sperm before they pass into the vas deferens that carry sperm to the ampullary gland and prostatic ducts.

Vas deferens- The vas deferens, also known as the sperm duct, is a thin tube approximately 30 centimeters (0.98 feet) long that starts from the pelvic cavity.

Accessory glands- Three accessory glands provide fluids that lubricate the duct system and nourish the sperm cells. They are the seminal vesicles, the prostate gland, and the bulbourethral glands (Cowper glands).

Seminal vesicles- Seminal vesicles are sac-like structures attached to the vas deferens at one side of the bladder. They produce a sticky, yellowish fluid that contains fructose. This fluid provides sperm cells energy and aids there mobility. 70% of the semen is its secretion.

Prostate gland- The prostate gland surrounds the ejaculatory ducts at the base of male urethra, just below the bladder. The prostate gland is responsible for the proof semen, a liquid mixture of sperm cells prostate fluid and seminal fluid. This gland is also responsible for making semen milky in appearance by mixing calcium to the semen coming from seminal vesicle (semen coming from the seminal vesicle is yellowish in colour); the semen remains cloudy and clumpy until the prostatic profibrinolysin is formed into fibrinolysin and lysis of the fibrinogen from the seminal vesicle fluids occurs.

Bulbourethral glands- The bulbourethral glands, or Cowper's glands, are pea-sized structures located on the sides of the urethra just below the prostate gland. These glands produce a clear, slippery fluid that empties directly into the urethra. This fluid serves to lubricate the urethra and to neutralize any acidity that may be present due to residual drops of urine in the urethra.

Blood supply

1. Testicular artery and testicular vein
2. Nerve supply symphathetic and parasymphathetic plexus

9.5 Physiology of Male Reproductive System:

- The entire male reproductive system is dependent on hormones, which are chemicals that regulate the activity of many different types of cells or organs.
- The primary hormones involved in the male reproductive system are follicle-stimulating hormone, luteinizing hormone, and testosterone.
- Follicle-stimulating hormone is necessary for sperm production (spermatogenesis), and luteinizing hormone stimulates the production of testosterone, which is also needed to make sperm.
- Testosterone is responsible for the development of male characteristics, including muscle mass and strength, fat distribution, bone mass, facial hair growth, voice change, and sex drive.

9.6 Spermatogenesis:

The cells that line the walls of the seminiferous tubules are collectively called spermatogenic cells. Those cells nearest the basement membrane are called spermatogonia. These cells are stem cells—that is, they are capable of continuous division and remain undifferentiated, never maturing into specialized cells. Extending from the spermatogonia toward the lumen of the tubule are cells at various levels of maturity, with the most mature cells—the sperm—facing the lumen.

Spermatogenesis begins at puberty within the seminiferous tubules of the testes. The spermatogonia, each of which contains 46 chromosomes, divide by mitosis repeatedly and differentiate to produce primary spermatocytes (still diploid cells with 46 chromosomes each). The primary spermatocytes begin meiosis. During the first meiotic division (meiosis I, or the reduction division), each primary spermatocyte divides into two secondary spermatocytes, each with 23 chromosomes (haploid cells). During the second meiotic division (meiosis II, or the equatorial division), each secondary spermatocyte divides again, producing a total of four spermatids. Each spermatid still contains 23 chromosomes, but these chromosomes consist of only one chromatid (rather than the normal two chromatids).

Spermiogenesis describes the development of spermatids into mature sperm (sperm cells, or spermatozoa). At the end of this process, each sperm cell bears the following structures:

- The head of the sperm contains the haploid nucleus with 23 chromosomes. At the tip of the sperm head is the acrosome, a lysosome containing enzymes that are used to penetrate the egg. The acrosome originates from Golgi body vesicles that fuse to form a single lysosome.
- The midpiece is the first part of the tail. Mitochondria spiral around the midpiece and produce energy (ATP) used to generate the whiplike movements of the tail that propel the sperm.
- The tail is a **flagellum** consisting of the typical 9 + 2 microtubule array.

Hormonal regulation of spermatogenesis

The production of sperm is regulated by hormones, as shown in Figure 2:

- The hypothalamus begins secreting gonadotropin releasing hormone (GnRH) at puberty.
- GnRH stimulates the anterior pituitary to secrete follicle stimulating hormone (FSH) and luteinizing hormone (LH).
- LH stimulates the interstitial cells in the testes to produce testosterone and other male sex hormones (androgens). (In males, LH is also called interstitial cell stimulating hormone, or ICSH.)
- Testosterone produces the following effects:
- Testosterone stimulates the final stages of sperm development in the nearby seminiferous tubules. It accumulates in these tissues because testosterone and FSH act together to stimulate sustentacular cells to release androgen-binding protein (ABP). ABP holds testosterone in these cells.
- Testosterone entering the blood circulates throughout the body, where it stimulates activity in the prostate gland, seminal vesicles, and various other target tissues.
- Testosterone and other androgens stimulate the development of secondary sex characteristics, those characteristics not directly involved in reproduction. These include the distribution of muscle and fat typical in adult males, various body hair (facial and pubic hair, for example), and deepening of the voice.

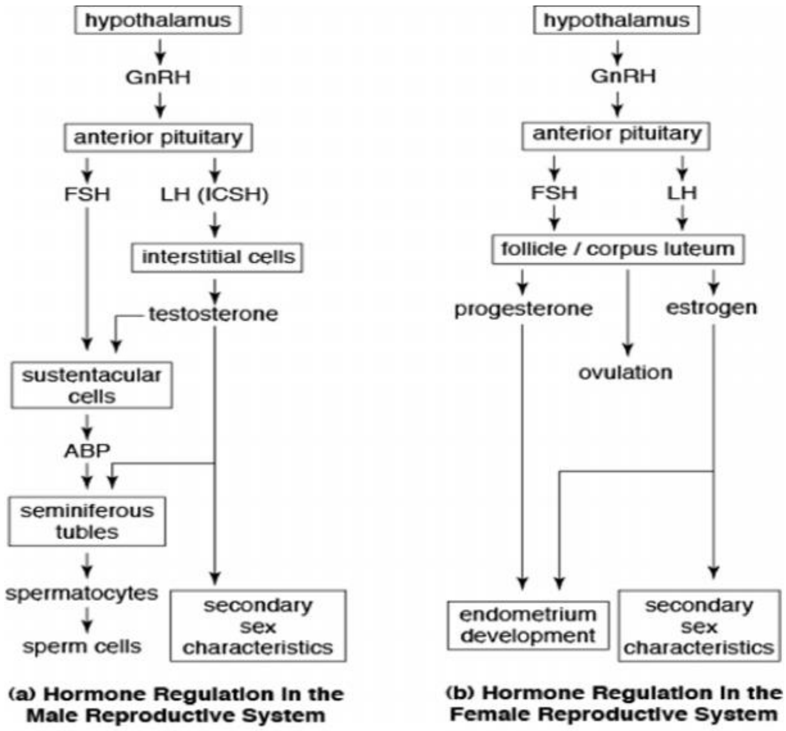


Fig.9.7 Processes of hormone regulation in the male and female reproductive systems.

Levels of testosterone are regulated by a negative-feedback mechanism with the hypothalamus. When the hypothalamus detects excessive amounts of testosterone in the blood, it reduces its secretion of GnRH. In response, the anterior pituitary reduces its production of LH and FSH, which results in a decrease in the production of testosterone by interstitial cells. GnRH secretion is also inhibited by inhibin, a hormone secreted by sustentacular cells in response to excessive levels of sperm production.

Glossary

- **Ovary**- Female genital gland that produces eggs and the sex hormones estrogen and progesterone.
- **Uterus**- Hollow muscular organ receiving the egg and, once fertilized, enabling its development and expulsion at the end of pregnancy.
- **Labia minora**- Mucous folds of the vulva located between the labia majora.
- **Labia majora**- Thick cutaneous hairy folds of the vulva protecting the vaginal orifice.
- **Vagina**- Muscular canal located between the neck of the uterus and the vulva enabling copulation.
- **Broad ligament of uterus**- Peritoneal fold connecting the lateral edge of the uterus to the abdominal cavity wall.
- Ampulla of fallopian tube- Widened section of the fallopian tube located between the infundibulum and the isthmus.
- **Infundibulum of fallopian tube**- Largely flat section of the fallopian tube through which the egg enters.Isthmus of fallopian tube- Narrow section of the fallopian tube opening into the uterus.

- **Fallopian tubes**- Canals transporting the egg from the ovary to the uterus; fertilization of the egg by the spermatozoon generally takes place in the upper part of the tube.
- **Vulva**- external female genital organ which consists mainly the labia and the clitoris

Assignments/Tests

Multiple choice questions-

1. A muscular tube that transports sperm-filled semen.

   A. vagina

   B. Fallopian tube

   C. vas deferens

2. A fluid that contains millions of sperm.

   A. amniotic

   B. urine

   C. semen

3. A chemical or hormone produced by the testes that causes bodily changes during male puberty.

   A. estrogen

   B. progesterone

   C. Testosterone

4. A set of coiled tubes that connect to the vas deferens.

   A. Fallopian tubes

   B. epididymis

   C. urethra

5. A process in which sperm laden semen leaves the male body.

   A. ovulation

   B. gestation

   C. ejaculation

6. Tiny male cell that unites with the female ovum to form a fertilized egg or zygote.

   A. sperm

   B. testes

   C. scrotum

7. These are responsible for carrying sperm filled semen from the male to the female's vagina.

   A. penis and urethra

   B. gonads

   C. testicles

8. A gland that makes some of the parts of semen.

   A. ovary

   B. scrotum

   C. prostate

9. A major male sex organ that produces and stores sperm.

A. prostate

B. testicle

C. ovary

10. The sac that holds the testes.

A. scrotum

B. placenta

C. vas deferens

11. When menstruation ends in middle age.

A. menopause

B. gestation

C. implantation

12. The fleshy outer part of the female reproductive system where the opening to the vagina is located.

A. uterus

B. ovary

C. vulva

13. Also called the mammary gland, two of these are located at the chest level and produce milk for the newborn baby.

A. breast

B. ovary

C. cervix

14. These are the major female sex organs that produce ova or eggs.

A. ovary/ovaries

B. testes/testicles

C. gametes

15. A sac shaped like an upside down pear with a thick lining and muscles in the pelvic area where a fertilized egg or zygote comes to grow into a baby. Also called the womb.

A. vagina

B. cervix

C. uterus

16. The tiny female sex cell that unites with a male sperm to form a zygote or fertilized egg.

A. ovary

B. ovum

C. gonad

17. Also called the birth canal, this is a muscular passageway from the cervix to the outside of the female's body.

A. vagina

B. uterus

C. Fallopian tube

18. The opening to the uterus.

    A. vagina

    B. ovary

    C. cervix

19. This connects the ovary to the uterus.

    A. vagina

    B. cervix

    C. Fallopian tube

20. The shedding of the lining of the uterus along with some blood once a month. Also called a monthly period is

    A. gestation

    B. conception

    C. menstruation

Q. Answer the following.

1. Describe the male reproductive system.
2. Describe the female reproductive system.
3. Draw and label the male reproductive system.
4. Draw and label the female reproductive system.
5. Write the structure of breast.
6. Write the phases in menstrual cycle.

UNIT 10- ENDOCRINE SYSTEM

Objectives- At the end of this lesson you shall be able to-

- State the definition of endocrine, hormone and target organ
- State the names of various endocrines
- State the anatomy of various endocrinal glands
- State the hormones and their functions of individual endocrines
- State the endocrine system vs. nervous system function
- State the properties of hormones
- State how the regulation of hormones take place
- State the classes of hormones

Introduction:

Endocrinal glands are ductless glands that secrete hormones into the blood. Hormones are substances secreted by the endocrine glands and collected by the circulation that act to produce effects upon specific organs and tissues. Hormones are effectors of the endocrine system.

Target organs, target tissues and target cells are those specific organs, tissues and cells upon which each hormone acts and produces its effects. Hormones selectively act upon their targets due to specific receptor proteins present in these targets.

The endocrine system includes all of the glands of the body and the hormones produced by those glands. The glands are controlled directly by stimulation from the nervous system as well as by chemical receptors in the blood and hormones produced by other glands.

By regulating the functions of organs in the body, these glands help to maintain the body's homeostasis. Cellular metabolism, reproduction, sexual development, sugar and mineral homeostasis, heart rate, and digestion are among the many processes regulated by the actions of hormones.?

Endocrines in the human body are-(Fig. 10.1)

- Hypothalamus
- Pituitary gland
- Pineal gland
- Thyroid
- Parathyroid
- Pancreas
- Adrenal gland
- Testis (In males)
- Ovary (In females)

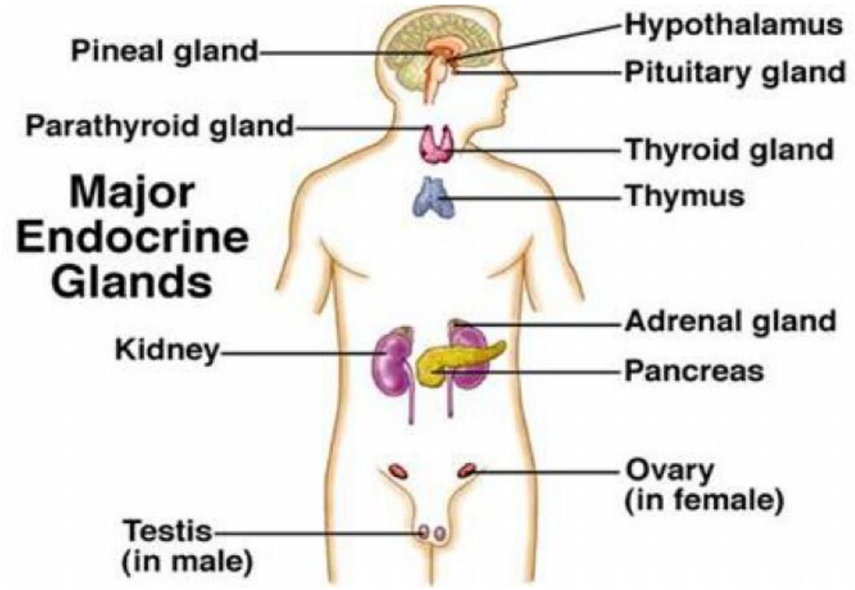


Fig. 10.1 Endocrine glands in the human body

10.1 Anatomy of the Endocrine System and Functions of Hormones

1. Hypothalamus- (Fig.10.2 and Fig.10.3)

The hypothalamus is a part of the brain located superior and anterior to the brain stem and inferior to the thalamus. It serves many different functions in the nervous system, and is also responsible for the direct control of the endocrine system through the pituitary gland. The hypothalamus contains special cells called neurosecretory cells—neurons that secrete hormones :

- Thyrotropin-releasing hormone (TRH)
- Growth hormone-releasing hormone (GHRH)
- Growth hormone-inhibiting hormone (GHIH)
- Gonadotropin-releasing hormone (GnRH)
- Corticotropin- releasing hormone (CRH)
- Oxytocin
- Antidiuretic hormone (ADH)

All of the releasing and inhibiting hormones affect the function of the anterior pituitary gland. TRH stimulates the anterior pituitary gland to release thyroid-stimulating hormone. GHRH and GHIH work to regulate the release of growth hormone—GHRH stimulates growth hormone release, GHIH inhibits its release. GnRH stimulates the release of follicle stimulating hormone and luteinizing hormone while CRH stimulates the release of adrenocorticotropic hormone. The last two hormones—oxytocin and antidiuretic hormone—are produced by the hypothalamus and transported to the posterior pituitary, where they are stored and later released.

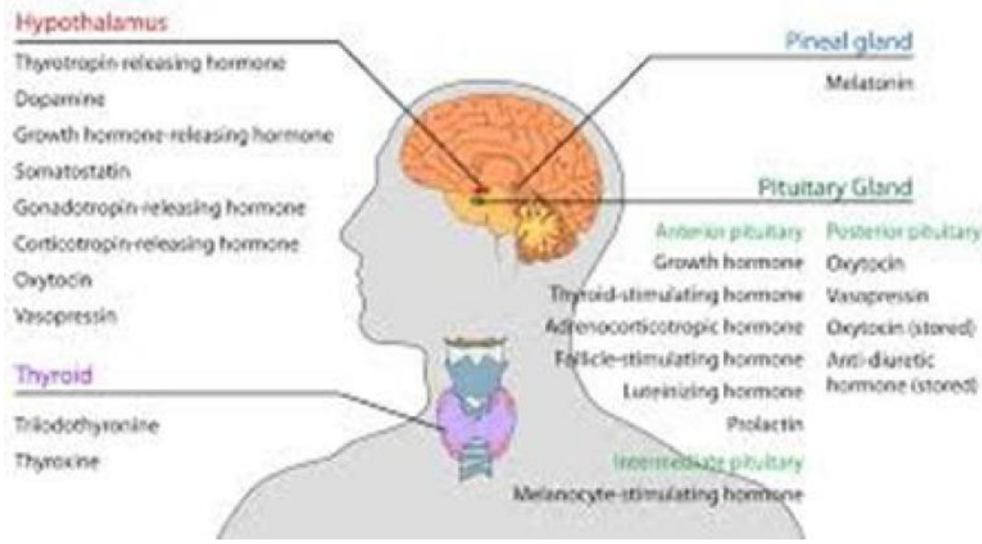


Fig.10.2 Endocrines in and above the neck and their hormones

10.2. Pituitary Gland- (Fig.10.2 and Fig.10.3)

The pituitary gland, also known as the hypophysis, is a small pea-sized lump of tissue connected to the inferior portion of the hypothalamus of the brain. Many blood vessels surround the pituitary gland to carry the hormones it releases throughout the body. Situated in a small depression in the sphenoid bone called the sella turcica, the pituitary gland is actually made of 2 completely separate structures: the posterior and anterior pituitary glands.

1. Posterior Pituitary: The posterior pituitary gland is actually not glandular tissue at all, but nervous tissue instead. The posterior pituitary is a small extension of the hypothalamus through which the axons of some of the neurosecretory cells of the hypothalamus extend. These neurosecretory cells create 2 hormones in the hypothalamus that are stored and released by the posterior pituitary:

• Oxytocin triggers uterine contractions during childbirth and the release of milk during breastfeeding.

• Antidiuretic hormone (ADH) prevents water loss in the body by increasing the re-uptake of water in the kidneys and reducing blood flow to sweat glands.

2. Anterior Pituitary: The anterior pituitary gland is the true glandular part of the pituitary gland. The function of the anterior pituitary gland is controlled by the releasing and inhibiting hormones of the hypothalamus. The anterior pituitary produces 6 important hormones:

• Thyroid stimulating hormone (TSH), as its name suggests, is a tropic hormone responsible for the stimulation of the thyroid gland.

• Adrenocorticotropic hormone (ACTH) stimulates the adrenal cortex, the outer part of the adrenal gland, to produce its hormones.

• Follicle stimulating hormone (FSH) stimulates the follicle cells of the gonads to produce gametes—ova in females and sperm in males.

• Luteinizing hormone (LH) stimulates the gonads to produce the sex hormones—estrogens in females and testosterone in males.

• Human growth hormone (HGH) affects many target cells throughout the body by stimulating their growth, repair, and reproduction.

• Prolactin (PRL) has many effects on the body, chief of which is that it stimulates the mammary glands of the breast to produce milk.

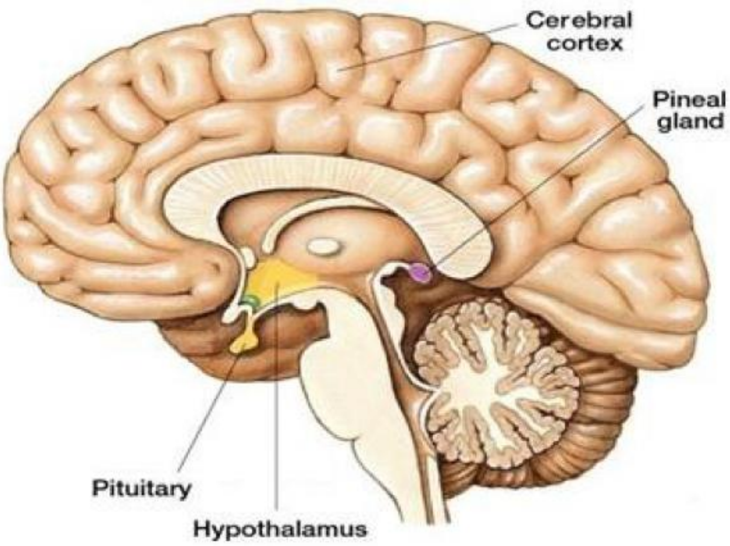


Fig.10.3 Locations of hypothalamus, pineal gland and pituitary gland

10.3. Thyroid Gland- (Fig.10.4)

The thyroid gland is a butterfly-shaped gland located at the base of the neck and wrapped around the lateral sides of the trachea. The thyroid gland produces 3 major hormones:

- Calcitonin
- Triiodothyronine (T3)
- Thyroxine (T4)

Calcitonin is released when calcium ion levels in the blood rise above a certain set point. Calcitonin functions to reduce the concentration of calcium ions in the blood by aiding the absorption of calcium into the matrix of bones. The hormones T3 and T4 work together to regulate the body's metabolic rate. Increased levels of T3 and T4 lead to increased cellular activity and energy usage in the body.

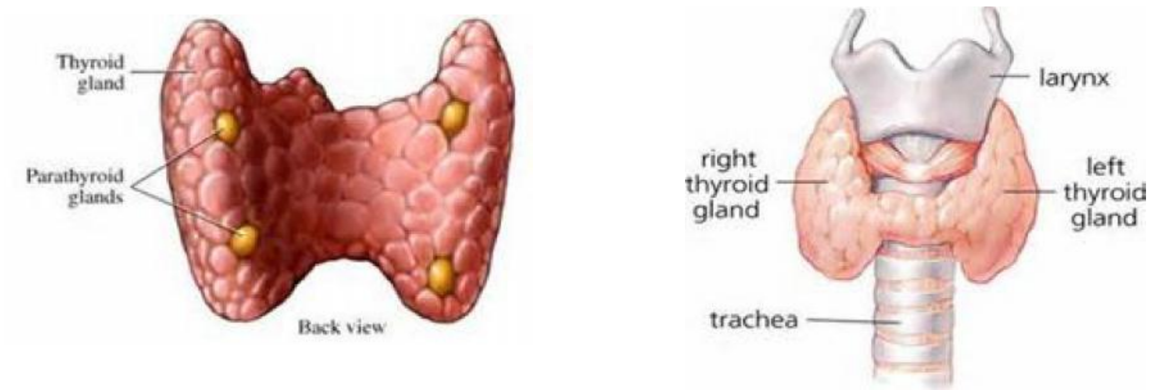


Fig.10.4 Thyroid gland and parathyroid gland

10.4 Parathyroid Glands-

The parathyroid glands are 4 small masses of glandular tissue found on the posterior side of the thyroid gland. (Fig.10.4) The parathyroid glands produce the hormone parathyroid hormone (PTH), which is involved in calcium ion homeostasis. PTH is released from the parathyroid glands when calcium ion levels in the blood drop below a set point. PTH stimulates the osteoclasts to break down the calcium containing bone matrix to release free calcium ions into the bloodstream. PTH also triggers the kidneys to return calcium ions filtered out of the blood back to the bloodstream so that it is conserved.

10.5 Adrenal Glands-

The adrenal glands are a pair of roughly triangular glands found immediately superior to the kidneys. So they are also called as suprarenal glands. (Fig.10.5)

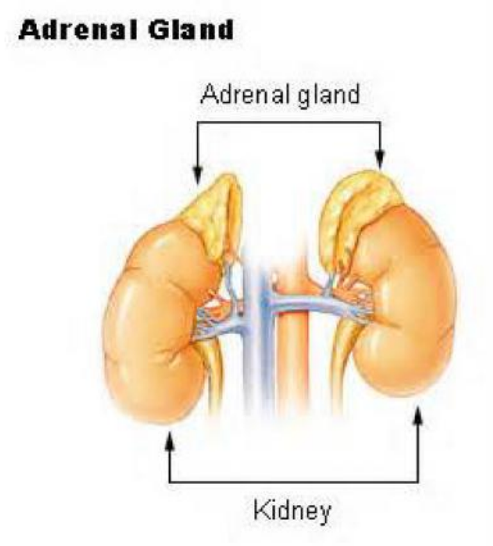


Fig.10.5 Adrenal gland

The adrenal glands are each made of 2 distinct layers, each with their own unique functions:

i) The outer adrenal cortex

ii) Inner adrenal medulla.

• Adrenal cortex: The adrenal cortex produces many cortical hormones in 3 classes: glucocorticoids, mineralocorticoids, and androgens.

1. Glucocorticoids have many diverse functions, including the breakdown of proteins and lipids to produce glucose. Glucocorticoids also function to reduce inflammation and immune response.

2. Mineralocorticoids, as their name suggests, are a group of hormones that help to regulate the concentration of mineral ions in the body.

3. Androgens, such as testosterone, are produced at low levels in the adrenal cortex to regulate the growth and activity of cells that are receptive to male hormones. In adult males, the amount of androgens produced by the testes is many times greater than the amount produced by the adrenal cortex, leading to the appearance of male secondary sex characteristics.

• Adrenal medulla: The adrenal medulla produces the hormones epinephrine and norepinephrine under stimulation by the sympathetic division of the autonomic nervous system. Both of these hormones help to increase the flow of blood to the brain and muscles to improve the "fight-or-flight" response to stress. These hormones also work to increase heart rate, breathing rate, and blood pressure while decreasing the flow of blood to and function of organs that are not involved in responding to emergencies.

10.6 Testis

The gonads—ovaries in females and testes in males—are responsible for producing the sex hormones of the body. These sex hormones determine the secondary sex characteristics of adult females and adult males.

• Testes: The testes are a pair of ellipsoid organs found in the scrotum of males that produce the androgen testosterone in males after the start of puberty. Testosterone has effects on many parts of the body, including the muscles, bones, sex organs, and hair follicles. This hormone causes growth and increases in strength of the bones and muscles, including the accelerated growth of long bones during adolescence. During puberty, testosterone controls the growth and development of the sex organs and body hair of males, including pubic, chest, and facial hair. In men who have inherited genes for baldness testosterone triggers the onset of androgenic alopecia, commonly known as male pattern baldness.

10.7 **Ovaries** : The ovaries are a pair of almond-shaped glands located in the pelvic body cavity lateral and superior to the uterus in females. The ovaries produce the female sex hormones progesterone and estrogens. Progesterone is most active in females during ovulation and pregnancy where it maintains appropriate conditions in the human body to support a developing fetus. Estrogens are a group of related hormones that function as the primary female sex hormones. The release of estrogen during puberty triggers the development of female secondary sex characteristics such as uterine development, breast development, and the growth of pubic hair. Estrogen also triggers the increased growth of bones during adolescence that lead to adult height and proportions.

10.8-Pancreas

The pancreas is a large gland located in the abdominal cavity just inferior and posterior to the stomach. (Fig.10.6) The pancreas is considered to be a heterocrine gland as it contains both endocrine and exocrine tissue. The endocrine cells of the pancreas make up just about 1% of the total mass of the pancreas and are found in small groups throughout the pancreas called islets of Langerhans. Within these islets are 2 types of cells—alpha and beta cells. The alpha cells produce the hormone glucagon, which is responsible for raising blood glucose levels. Glucagon triggers muscle and liver cells to break down the polysaccharide glycogen to release glucose into the bloodstream. The beta cells produce the hormone insulin, which is responsible for lowering blood glucose levels after a meal. Insulin triggers the absorption of glucose from the blood into cells, where it is added to glycogen molecules for storage.

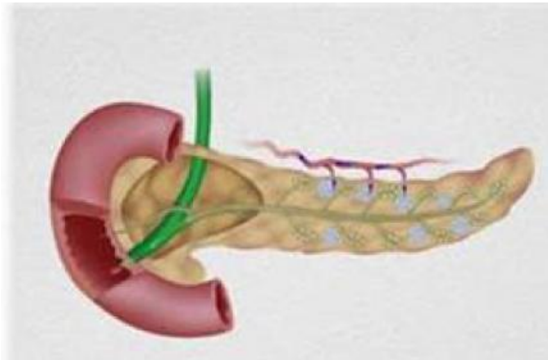


Fig. 10.6 Pancreas

10.9 Pineal Gland-

The pineal gland is a small pinecone-shaped mass of glandular tissue found just posterior to the thalamus of the brain. The pineal gland produces the hormone melatonin that helps to regulate the human sleep-wake cycle known as the circadian rhythm. The activity of the pineal gland is inhibited by stimulation from the photoreceptors of the retina. This light sensitivity causes melatonin to be produced only in low light or darkness. Increased melatonin production causes humans to feel drowsy at nighttime when the pineal gland is active.

10.10 Thymus-

The thymus is a soft, triangular-shaped organ found in the chest posterior to the sternum. The thymus produces hormones called thymosins that help to train and develop T-lymphocytes during fetal development and childhood. The T-lymphocytes produced in the thymus go on to protect the body from pathogens throughout a person's entire life.

The thymus becomes inactive during puberty and is slowly replaced by adipose tissue throughout a person’s life.

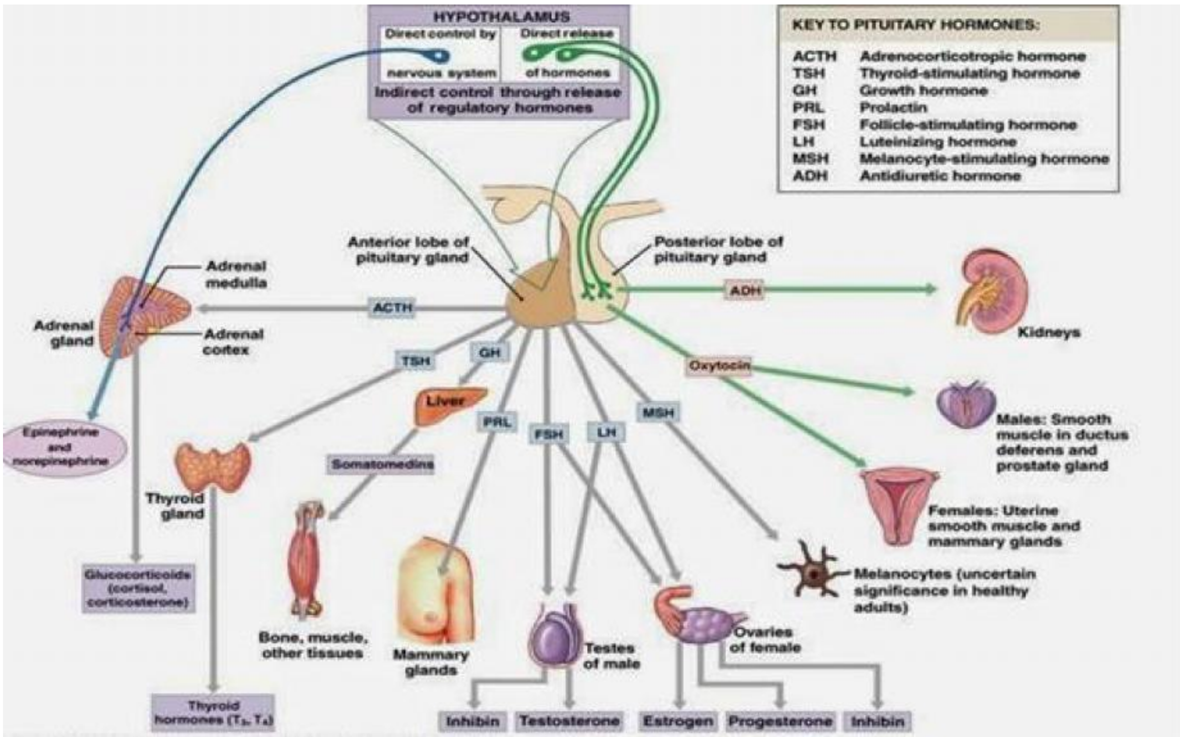


Fig. 10.7 Diagrammatic representation of all hormones and their functions

Endocrine System vs. Nervous System Function

The endocrine system works alongside of the nervous system to form the control systems of the body. The nervous system provides a very fast and narrowly targeted system to turn on specific glands and muscles throughout the body. The endocrine system, on the other hand, is much slower acting, but has very widespread, long lasting, and powerful effects. Hormones are distributed by glands through the bloodstream to the entire body, affecting any cell with a receptor for a particular hormone. Most hormones affect cells in several organs or throughout the entire body, leading to many diverse and powerful responses.

Properties of Hormones-

• Once hormones have been produced by glands; they are distributed through the body via the bloodstream.

• As hormones travel through the body, they pass through cells or along the plasma membranes of cells until they encounter a receptor for that particular hormone.

• Hormones can only affect target cells that have the appropriate receptors. This property of hormones is known as specificity. Hormone specificity explains how each hormone can have specific effects in widespread parts of the body.

• Many hormones produced by the endocrine system are classified as tropic hormones. A tropic hormone is a hormone that is able to trigger the release of another hormone in another gland. Tropic hormones provide a pathway of control for hormone production as well as a way for glands to be controlled in distant regions of the body.

• Many of the hormones produced by the pituitary gland, such as TSH, ACTH, and FSH are tropic hormones.

• Some hormones are proteins, like insulin, glucagon and ADH, others are derived from proteins (modified amino acids), like adrenaline and noradrenaline, other are steroids, like the corticosteroids and estrogen.

Hormonal Regulation-The levels of hormones in the body can be regulated by several factors.(Fig.10.7)

• The nervous system can control hormone levels through the action of the hypothalamus and its releasing and inhibiting hormones. For example, TRH produced by the hypothalamus stimulates the anterior pituitary to produce TSH.

• Tropic hormones provide another level of control for the release of hormones. For example, TSH is a tropic hormone that stimulates the thyroid gland to produce T3 and T4.

• Nutrition can also control the levels of hormones in the body. For example, the thyroid hormones T3 and T4 require 3 or 4 iodine atoms, respectively, to be produced. In people lacking iodine in their diet, they shall fail to produce sufficient levels of thyroid hormones to maintain a healthy metabolic rate.

• Finally, the number of receptors present in cells can be varied by cells in response to hormones. Cells that are exposed to high levels of hormones for extended periods of time can begin to reduce the number of receptors that they produce, leading to reduced hormonal control of the cell.

Classes of Hormones-

Hormones are classified into 2 categories depending on their chemical make-up and solubility: water-soluble and lipid-soluble hormones. Each of these classes of hormones has specific mechanisms for their function that dictate how they affect their target cells.

• **Water-soluble hormones** : Water-soluble hormones include insulin, epinephrine, HGH, and oxytocin. As their name indicates, these hormones are soluble in water. Water-soluble hormones are unable to pass through the phospholipid bilayer of the plasma membrane and are therefore dependent upon receptor molecules on the surface of cells. When a water-soluble hormone binds to a receptor molecule on the surface of a cell, it triggers a reaction inside of the cell. This reaction may change a factor inside of the cell such as the permeability of the membrane or the activation of another molecule..

• **Lipid-soluble hormones** : Lipid-soluble hormones include the steroid hormones such as testosterone, estrogens, glucocorticoids, and mineralocorticoids. Because they are soluble in lipids, these hormones are able to pass directly through the phospholipid bilayer of the plasma membrane and bind directly to receptors inside the cell nucleus. Lipid-soluble hormones are able to directly control the function of a cell from these receptors, often triggering the transcription of particular genes in the DNA to produce "messenger RNAs (mRNAs)" that are used to make proteins that affect the cell's growth and function.

Glossary

Adrenal cortex : The outer portion of the adrenal gland located on top of each kidney.

Adrenal gland : A small gland located on top of the kidney.

Adrenal medulla : The inner portion of adrenal gland.

Adrenaline : A stress hormone produced within the adrenal gland that quickens the heart beat

Anatomy : The study of human or animal form, by observation or examination of the living being

Anterior : The front, as opposed to the posterior. The anterior surface of the heart is tow...

Brain : The portion of the central nervous system that is located within the skull.

Calcium : A mineral found mainly in the hard part of bones, where it is stored.

Cortex : The outer layer of any organ.

Cortisol : A metabolite of the primary stress hormone cortisone. Endocrine: Pertaining to hormones and the glands that make and secrete them into the blood

Endocrinology : The study of the medical aspects of hormones,

Enzymes : Proteins that act as a catalysts in mediating and speeding a specific chemical reactions

Estrogen : A female steroid hormone that is produced by the ovaries and, in lesser amounts,

Exocrine : Pertaining to the secretion of a substance out through a duct.

Gland : A group of cells that secrete a substance for use in the body.

Glucose : The simple sugar that is the chief source of energy.

Growth hormone : A hormone made in the pituitary gland that stimulates the release of anoth...

Heart rate : The number of heartbeats per unit of time, usually per minute

Hormone : A chemical substance produced in the body that controls and regulates the activities of the body

Hypothalamus : The area of the brain that secretes substances that influence pituitary and other endocrines

Hypothyroid : Deficiency of thyroid hormone which is normally made by the thyroid gland

Immune : Protected against infection, usually by the presence of antibodies.

Insulin : A natural hormone made by the pancreas that controls the level of the sugar

Kidney : One of a pair of organs located in the right and left side of the abdomen. Luteinizing hormone: A gonadotropin (a hormone that affects the function of the sex organs)

Luteinizing hormone-releasing hormone : A hormone that controls sex hormones in men and women

Medulla : The innermost part

Melatonin : A hormone that is produced by the pineal gland

Menstruation : The periodic blood that flows as a discharge from the uterus.

Metabolism : The whole range of biochemical processes that occur within a living organism.

Muscle : Muscle is the tissue of the body which primarily functions as a source of power.

Neck : The part of the body joining the head to the shoulders.

Organ : A relatively independent part of the body that carries out one or more special function

Oxytocin : A hormone made in the brain that plays a role in childbirth and lactation

Pancreas : A spongy, tube-shaped organ that is about 6 inches long and is located in the abdomen

Parathyroid gland : A gland that regulates calcium, located behind the thyroid gland in the neck

Parathyroid hormone : Parathormone.

Pineal gland : A small gland that is located near the center of the brain. Pituitary: As an adjective, pertaining to the pituitary gland or its hormonal secretions

Pituitary gland : The main endocrine gland. It is a small structure in the head.

Posterior : The back or behind, as opposed to the anterior.

Posterior pituitary : The back portion of the pituitary,

Pregnancy : The state of carrying a developing embryo or fetus within the female body.

Progesterone : A female hormone,

Prolactin : A hormone secreted by the pituitary gland that stimulates lactation (milk production)

Scrotum : The pouch of skin that contains the testes, epididymides, and lower portions of testis

Somatostatin : A hormone that is widely distributed throughout the body,

Sperm : A sperm is the male "gamete" or sex cell. It combines with the female for fertilization.

Steroid : One of a large group of chemical substances classified by a specific carbon structure

Stomach : The digestive organ that is located in the upper abdomen, under the ribs.

Stress : In a medical or biological context stress is a physical, mental, or emotional fact

Testes : Plural of testis.

Testosterone : A 'male hormone', sex hormone produced by the testes Thyroid gland: A gland that makes and stores hormones that help regulate the heart rate,

Thyroid hormones : Chemical substances made by the thyroid gland, TSH: Thyroid stimulating hormone.

Uterus : A hollow, pear-shaped organ that is located in a woman's lower abdomen,

Vasopressin : A relatively small (peptide) molecule that is released by the pituitary gland

ASSIGNMENTS/TEST

Q. Answer the following.

1. Where is the thyroid gland located?
2. What is the function of the thyroid?
3. What is the thyroid shaped the most like?
4. Write an anatomy of pituitary gland.
5. What are the hormones secreted by pituitary gland?
6. Where is the pituitary gland located?
7. Write a note on 'sella turcica'.

8. Write the classification of hormones.

9. What are the hormones secreted by hypothalamus gland?

10. What are the hormones secreted by adrenal gland?

11. What is the difference between the endocrine gland and the exocrine gland?

12. Why the endocrine system is considered one of the integrative systems of the body? What is the other physiological system that also has this function?

13. What are hormones?

14. What are target organs of the hormones?

15. How does the circulatory system participate in the functioning of the endocrine system?

16. Are hormones only proteins?

17. What are the main endocrine glands of the human body?

18. What is the pineal gland?

19. What is the osseous cavity where the pituitary gland is located?

20. What are the main divisions of the hypophysis? What are their functions?

21. What is the relation between the hypothalamus and the hypophysis?

22. What are the hormones secreted by the adenohypophysis? What are their respective functions?

23. What is the relation between the thyroid and the hypophysis?

24. What are the target tissues and target organs of each adenohypophyseal hormone?

25. What are the hormones secreted by the neurohypophysis? What are their respective functions?

26. Which are the target organs and target tissues of the posterior pituitory?

Multiple choice questions-

Q. Choose the correct answer and rewrite the sentence.

1. Bodily chemical messengers that send messages from one set of cells to another, affecting changes.

A. hormones

B. nephrons

C. alveoli

2. This controls how quickly the body uses energy, makes proteins and controls how sensitive the body should be to other hormones.

A. adrenal gland

B. hypothalamus

C. thyroid

3. This affects wake/sleep patterns and seasonal functions.

A. pineal

B. adrenal

C. thyroid

4. This links the nervous system to the endocrine system via the pituitary gland.

A. thalamus

B. hypothalamus

C. adrenal

5. The master gland that controls many bodily functions.

A. thalamus

B. hypothalamus

C. pituitary

6. These glands control the amount of calcium in the blood and bones.

A. pituitary

B. parathyroid

C. thyroid

7. A group of cells that gives off or secretes chemicals.

A. artery

B. vein

C. gland

8. These release hormones in conjunction with stress.

A. adrenal

B. pituitary

C. thyroid

9. This is the hormone secreted by pancreas.

A. Insulin

B. Calcitonin

C. oxytocin

10. These glands are above the kidney.

A. adrenal

B. pituitary

C. thyroid

UNIT 11- SENSORY ORGANS

Objectives- At the end of this lesson you shall be able to-

- Describe the anatomy of the ear
- State the physiology of hearing
- State the structure and functions of an eye
- Describe the anatomy of the Lacrimal apparatus
- State the physiology of vision
- Describe the anatomy of the skin
- Describe the functions of the skin
- State the structure and functions of tongue
- State the structure of nose and name the paranasal sinuses
- State the role of nose in smelling

11.1 Structure and Functions of Eye :

Anatomy of Eye-

- The eyeball, which is an elongated sphere about 2.5 cm in diameter, has three layers, or coats (Fig. 11.1):

i) the sclera,

ii) the choroid and

iii) the retina. Only the retina contains photoreceptors for light energy.

- The outer layer, the sclera, is white and fibrous except for the cornea, which is made of transparent collagen fibers.
- The cornea is the window of the eye.
- The middle, thin, darkly pigmented layer, the choroid, is vascular and absorbs stray light rays that photoreceptors have not absorbed.
- Toward the front, the choroid becomes the donut-shaped iris.
- The iris regulates the size of the pupil, a hole in the center of the iris through which light enters the eyeball. The color of the iris (and therefore the color of your eyes) correlates with its pigmentation. Heavily pigmented eyes are brown, while lightly pigmented eyes are green or blue.
- Behind the iris, the choroid thickens and forms the circular ciliary body. The ciliary body contains the ciliary muscle, which controls the shape of the lens for near and far vision.
- The lens, attached to the ciliary body by ligaments, divides the eye into two compartments; the one in front of the lens is the anterior compartment, and the one behind the lens is the posterior compartment.
- The anterior compartment is filled with a clear, watery fluid called the aqueous humor. A small amount of aqueous humor is continually produced each day.
- The third layer of the eye, the retina, is located in the posterior compartment, which is filled with a clear, gelatinous material called the vitreous humor.
- The retina contains photoreceptors called rod cells and cone cells. The rods are very sensitive to light, but they do not see color; therefore, at night or in a darkened room, we see only shades of gray.
- The cones, which require bright light, are sensitive to different wavelengths of light, and therefore we have the ability to distinguish colors.

• The retina has a very special region called the fovea centralis where cone cells are densely packed. Light is normally focused on the fovea when we look directly at an object. This is helpful because vision is most acute in the fovea centralis.

• Sensory fibers from the retina form the optic nerve, which takes nerve impulses to the brain.

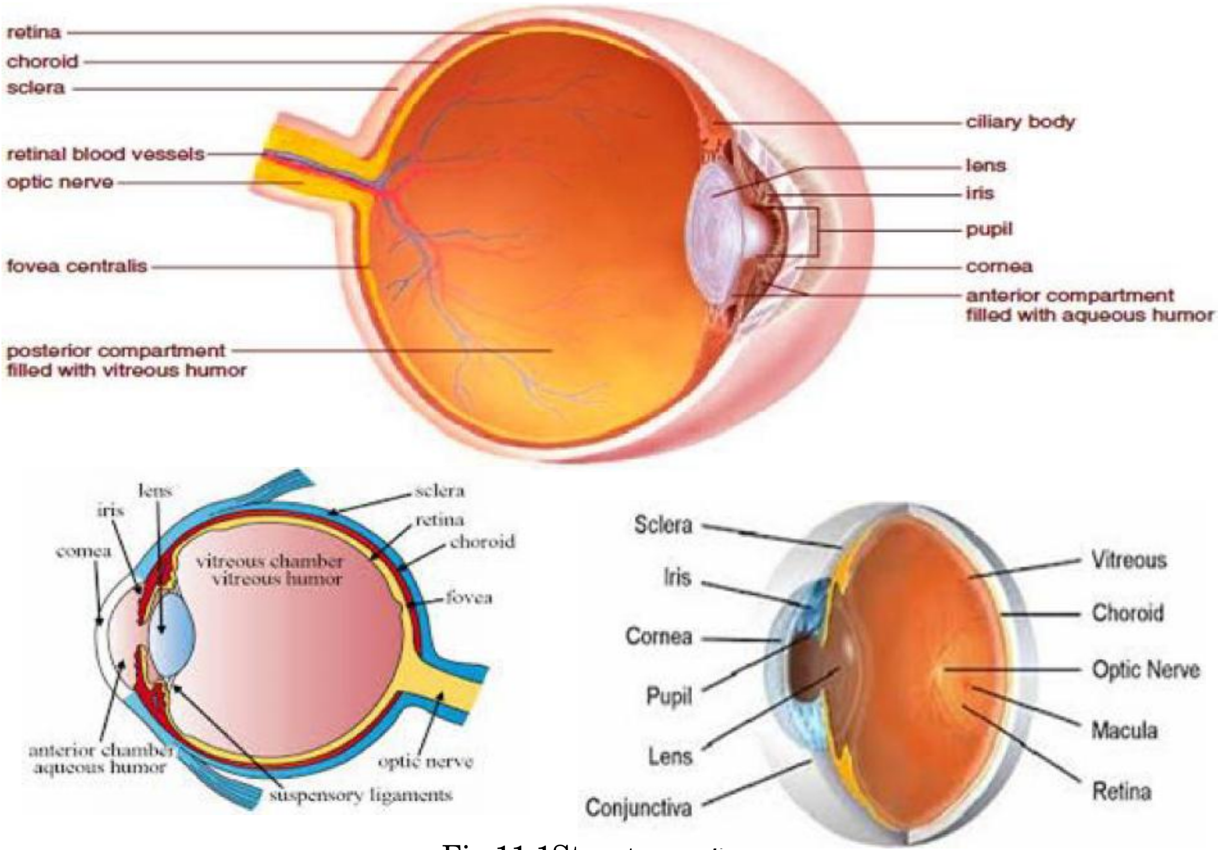


Fig.11.1Structure of eye

The lacrimal apparatus is the physiologic system containing the orbital structures for tear production and drainage.

It consists of:

• The lacrimal gland, which secretes the tears, and its excretory ducts, which convey the fluid to the surface of the eye;

• The lacrimal canaliculi, the lacrimal sac, and the nasolacrimal duct, by which the fluid is conveyed into the cavity of the nose, emptying anterioinferiorly to the inferior nasal conchae from the nasolacrimal duct.

• The nerve supply of lacrimal apparatus done by carotid plexus of nerves along artery internal and external sympathetically but parasympathetic from lacrimal nucleus of the facial nerve.

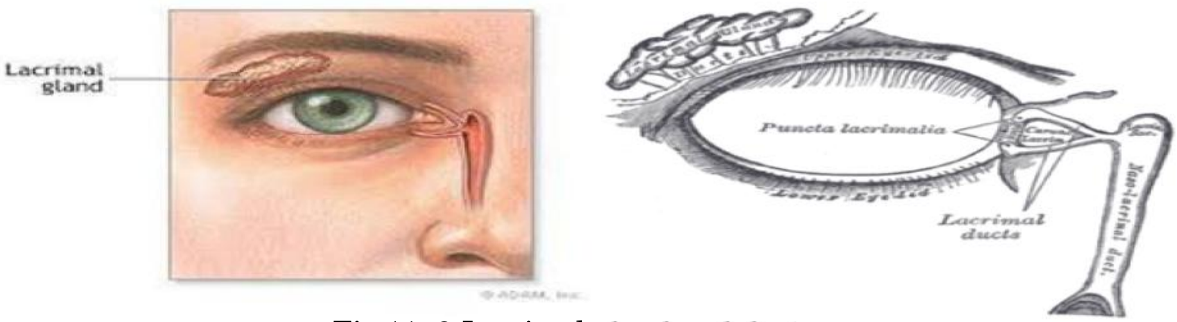


Fig.11. 2 Lacrimal gland and ducts

Physiology of vision-

• Rods and cones generate nerve impulses in the retinas of the eyes that travel along the optic nerves to the optic chiasma, where they partially cross over.

• The sensory organs for vision - the eyes - are at the front of the head, but areas of the brain at the back and sides provide the actual visual sense.

• Mixed impulses from both eyes pass through the optic tracts to the striate cortex at the back of the brain and end in the temporal lobe area so that right and left halves of the visual field merge.

• When light rays reach the retina (the film of the eye's camera), light energy is converted into electrical nerve signals. Crisscrossed with blood vessels, the retina has three layers of microscopically thin nerve cells.

• Nearest to the lens is a layer of ganglion cells, then a layer of bipolar cells and finally the photoreceptors. It is the photoreceptors that actually process the packets of light energy or photons that impact on the retina, so light must pass through the ganglions and bipolar cells to get to others.

• There are two types of photoreceptor cells, which, because of their shapes, are called rods and cones. Rods are sensitive enough to respond to a single photon, the basic unit of light, but together they create only one coarse, gray image, which is just adequate for seeing in poor light.

• Fine detail and color come from the cones, but they need a lot more light and work best in broad daylight. Inside the human eye, there are eighteen times more rods than cones. These are arranged in such a way as to produce the best possible combination of night and day vision.

11.2 Structure and Functions of Ear

Structure of an ear-

Three major regions make up the ear: the outer ear, middle ear, and inner ear. (Fig.11.3) The outer ear consists of the exterior structures of the ear, the auricle and external auditory canal. Visible on the exterior of the head is the auricle, the external part of the ear that extends from the head.

Anatomical System

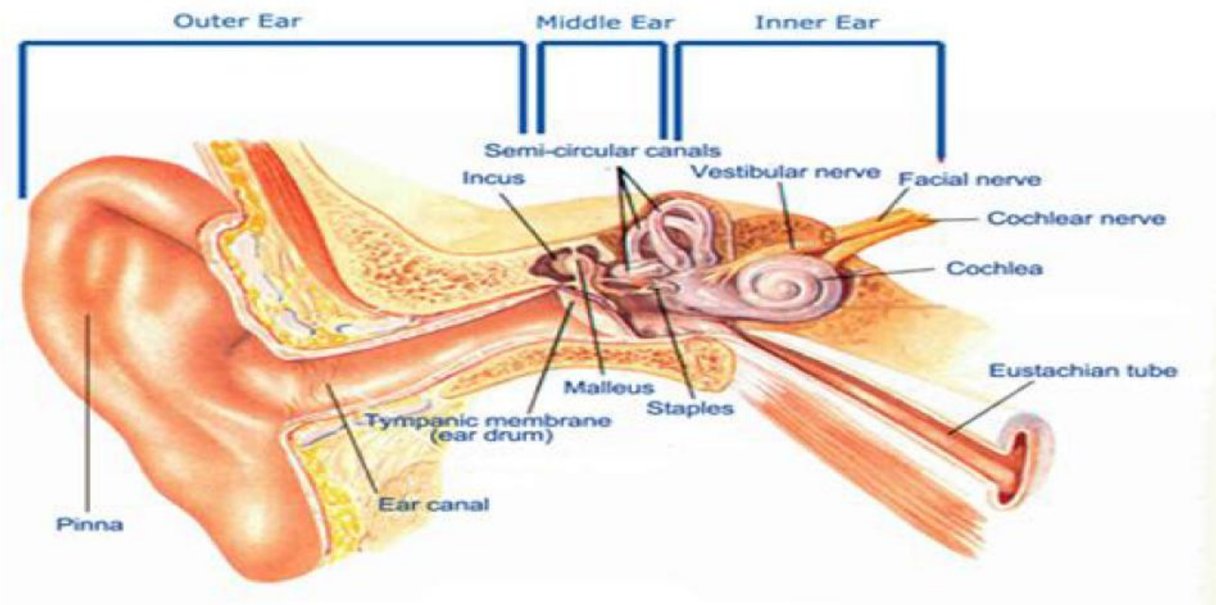


Fig.11.3 structure of the ear

[The auricle is made of elastic cartilage and adipose tissue covered with skin. It is a flexible organ whose curves help to conduct sounds into the other structures of the ear. In the center of the auricle is the external auditory canal, a tube that conducts sound through the body's exterior and skull and into the middle ear.

The middle ear begins at the end of the external auditory canal with the tympanic membrane, or eardrum. The eardrum is a thin, circular membrane spanning the interior of the auditory canal. It vibrates in response to sound waves.

Beyond the eardrum, the middle ear opens into a larger, air-filled cavity containing the three tiny bones known as the auditory ossicles. The auditory ossicles vibrate with the eardrum and conduct sounds through the middle ear to the inner ear. A small tube known as the auditory or Eustachian tube attaches the middle ear to the throat and allows the air pressure inside the middle ear to equalize with the atmospheric pressure.

The inner ear is the final section of the ear. It receives vibrations from the outer and middle ear; converts these vibrations into nerve impulses; and conducts nerve impulses to the brain. Within the inner ear is the cochlea, a spiral organ that contains many delicate hair cells for detecting vibrations. The cochlea acts as the functional sensory receptor of the ear. Nerve fibers from the vestibulocochlear nerve attach to the cochlea to transmit auditory signals to the brain.

Also found within the inner ear are the two equilibrium-detecting structures of the ear: the vestibule and the semicircular canals. The vestibule - a small, hollow region next to the cochlea - contains otolithic membranes that detect static equilibrium. Three fluid-filled, oval semicircular canals extend from the side of the vestibule opposite the cochlea to detect dynamic equilibrium. Each semicircular canal is aligned with a plane of the body – anterior/posterior, superior/inferior, and left/right – to detect movement in that plane.

Functions of an ear-

- The ear is a group of sensory organs in the head that collaborate to produce the sense of hearing. Together these organs perform the amazing function of converting sound waves in air into electrical signals to transmit to the brain.

- The ear also contains several special structures that produce the body's sense of equilibrium, or balance.

Physiology of Hearing-

- Hearing occurs in the ear when the auricle conducts sound waves into the auditory canal and on to the tympanic membrane.

- The tympanic membrane acts like a microphone by converting the sound waves into movements of the membrane, which in turn moves the malleus.

- The malleus taps on the incus and the incus, in turn, taps on the stapes to conduct the sound as bony vibrations to the inner ear.

- Tiny muscles attached to the ossicles contract or relax to attenuate the volume of sounds passing through the middle ear.

- The stapes pushes on a small hole in the cochlea known as the oval window, which in turn creates tiny ripples in the endolymph liquid filling the cochlea.

- These ripples are detected by hair cells inside the cochlea that are arranged within the spiral to each detect a specific frequency of sound. Each hair cell is connected to a neuron from the cochlear branch of the vestibulocochlear nerve that transmits auditory information to the brain.

Physiology of Equilibrium-

Static equilibrium - the sense of which direction gravity is pulling on the body - is detected by the otolithic membranes in the vestibule of the inner ear. Small calcium carbonate crystals embedded in a gel matrix on the surface of the otolithic membrane are pulled down by gravity and bend hair cells embedded in the membrane. The bending of these hair cells indicates which direction is down, and the nerves send this information to the brain through the vestibular branch of the vestibulocochlear nerve. As the head or body moves to a new position relative to the force of gravity, the otolithic membrane adjusts its position and sends new information to the brain.

Dynamic equilibrium - the sense of rotational motion of the body - is detected by the semicircular canals of the vestibule. Each semicircular canal is filled with a liquid endolymph, which can freely pass through the canal. The base of the canal contains a gelatinous structure known as the cupula, which contains hair cells to detect movements of the cupula. When the fluid in a semicircular canal moves, it pushes on the cupula and stimulates the hair cells. The bending of these hair cells indicates which direction the head or body is moving, and the nerves send this information to the brain through the vestibular branch of the vestibulocochlear nerve.

11.3 Structure and Functions of Skin

Structure of skin- (Fig 11.4)

• The skin is by far the largest organ of the human body, weighing about 10 pounds (4.5 kg) and measuring about 20 square feet (2 square meters) in surface area.

• The skin consists of two distinct layers: the epidermis and the dermis. Each layer is made of distinct tissues and performs distinct functions to support the body.

• A third layer of tissue under the skin, known as the hypodermis or subcutaneous layer is not truly part of the skin itself but connects the skin loosely to the underlying muscles and bones that make up the deeper tissues of the body.

• The epidermis is made of four to five layers of epithelial tissue that constantly grows from the inside out and replaces most of its cells every few weeks.

i) The deepest layer of the epidermis is the stratum basale (stratum germinativum), a layer of stem cells that produce all of the keratinocytes, or skin cells, in the epidermis. If this layer is destroyed in a particular region, the epidermis cannot regrow and is replaced by scar tissue. Melanocytes found in this layer produce the pigment melanin to give the skin its coloration and protect the body from ultraviolet radiation. Special touch sensitive cells known as Merkel cells are also present in the stratum basale to detect the shape and texture of objects touched by the skin.

ii) Superficial to the stratum basale is a thicker layer of epidermis known as the stratum spinosum, or spiny layer. Young keratinocytes are pushed into this layer from the reproduction of stem cells in the stratum basale. In the stratum spinosum, these keratinocytes begin to fill with keratin and form spiny connections between cells known as desmosomes. Desmosomes hold the cells together tightly while keratin fills the cells and gives the skin its strength and water resistance.

iii) The next layer, the stratum granulosum, is a thin layer featuring granular keratinocytes that have been pushed out of the stratum spinosum. The granular appearance of keratinocytes is due to keratin and other chemicals accumulating inside the cells. Keratinocytes in the stratum granulosum also secrete lamellar granules, a waterproof substance that prevents water from leaking out of the body's tissues or leaking into the body from the external environment.

iv) Beyond the stratum granulosum the keratinocytes are cut off from their blood supply and begin to die, resulting in layers of dead keratinocytes on the body's exterior.

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In the thick skin on the soles of the feet and palms of the hands the stratum lucidum is a thin, transparent layer of dead keratinocytes lying superficial to the stratum granulosum. The outermost layer is the stratum corneum, a thick layer of dead, flattened, keratin-filled keratinocytes that protect the underlying tissues. Dead keratinocytes slough off from the exterior surface of the stratum corneum only to be replaced by new cells emerging from the deeper layers.

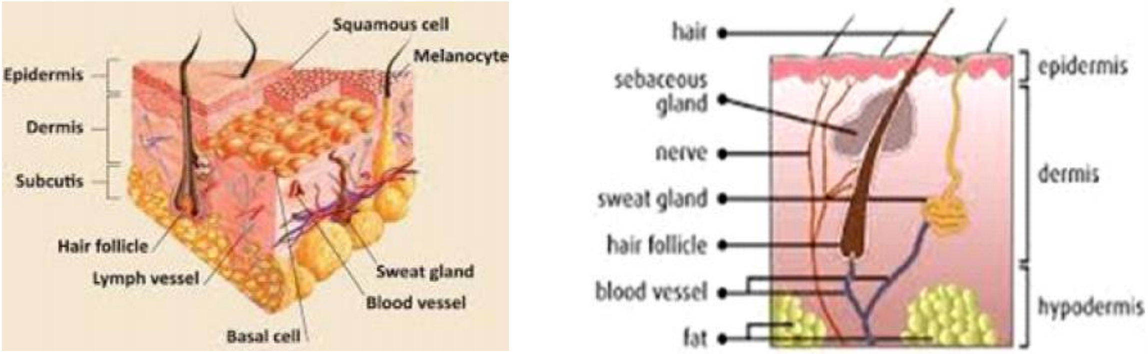

Fig 11.4 Structure of skin

• Deep to the epidermis are the connective tissues of the dermis. Two major regions make up the dermis: the papillary layer (stratum papillarosum) and the reticular layer (stratum reticulosum).

i) The papillary layer is the most superficial layer of the dermis; it contacts the epidermis. Between the epidermis and dermis it forms an undulating border that is rich in blood vessels and nervous tissue. These nervous and vascular tissues support the epidermis while the undulations, known as dermal papillae, increase the surface area of this border region.

ii) The reticular layer makes up the majority of the skin's thickness and is primarily made of dense irregular fibrous connective tissue. A thick web of collagen (the strongest protein found in nature) and elastin fibers makes up the dense irregular connective tissue and provides great strength and elasticity to the dermis. Many arterioles and venules also pass through the reticular layer to provide blood flow to the superficial tissues of the papillary layer and epidermis.

• Deep to the dermis is the subcutaneous layer, also known as the hypodermis. The subcutaneous layer contains mostly loose connective tissues such as adipose and areolar connective tissue. These tissues store energy as triglycerides; provide insulation to the underlying tissues; and loosely connect the skin to the body. This loose connection increases the flexibility of the body, especially at the joints where a large range of motion is extremely important.

Functions of skin-Being the largest and most superficial organ of the body, the skin provides many important functions to the body.

• The skin acts as the primary barrier to keep materials from passing into and out of the body. This barrier function prevents pathogens and toxins from entering the body and keeps vital fluids locked in the body's tissues.

• The skin also protects the underlying tissues from UV radiation, extreme temperatures, and friction. Its high capacity for replacing itself results in the skin being able to sustain significant environmental damage and then quickly heal to resume its function.

• A dense network of nerves provides the skin with the ability to sense touch, pain, temperature and pressure from the external environment. Even the blood vessels in the dermis function in the regulation of body temperature by controlling how much hot blood passes near the body's surface or is kept in deeper tissues.

• It forms the outer covering for the entire body and protects the internal tissues from the external environment.

• Hairs growing out of the skin help to shade and insulate parts of the body to protect them from the environment.

• Nails reinforce the fingertips and can be used for scratching. A variety of exocrine glands also add function to the skin through their secretions.

• Sudoriferous (sweat) glands help maintain the body's temperature homeostasis through evaporative cooling.

• Sebaceous glands help to lubricate and hydrate the skin while making it more waterproof.

• Finally, ceruminous glands produce earwax to protect the ear canals from pathogens and environmental pollutants.

11.4 TONGUE & TASTE-

Structure of tongue-

• The tongue is made up of muscles covered by mucous membranes. These muscles are attached to the lower jaw and to the hyoid bone, which is located just above the larynx and anchors the muscles of the tongue (it is the only bone in the body that doesn't touch any other bone).

• The muscle fibers are heavily supplied with nerves, so it can manipulate food in the mouth and place it between the teeth for chewing - without being bitten in the process.

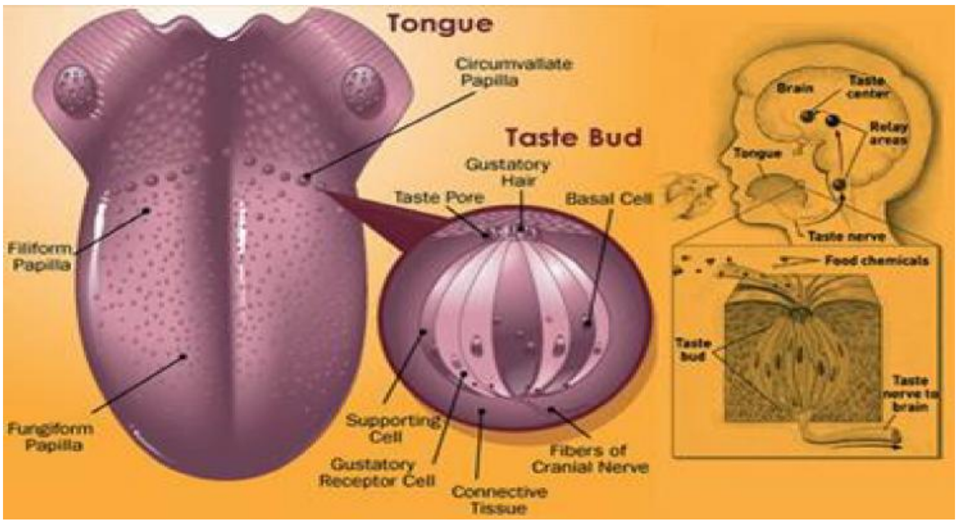

Fig.11.5 structure of a tongue

• On the surface of the tongue are special areas that detect the flavor of food. These begin with very small nodules, called papillae (Fig.11.5) that form the top surface of the tongue and give it its rough texture.

• Between the papillae at the sides and base of the tongue are small, bulblike structures that are sensory organs, called taste buds, which enable us to enjoy the sensations of flavor and warn us when food is unfit to eat.

There are four types of these taste receptors:

(1) Sweet, as produced by table sugar;

(2) sour, as produced by vinegar;

(3) Salty, as produced by table salt; and

(4) Bitter, as produced by caffeine or quinine.

Each of these taste receptors is most highly concentrated in certain regions of the tongue's surface. (Fig.11.6)

• Sweet receptors are mostly on the tip of the tongue (noted in a child's preference to lick a candy sucker rather than chew it).

• Sour receptors occur primarily along the sides of the tongue and are stimulated mainly by acids.

• Salt receptors are most common in the tip and upper front portion of the tongue. They are stimulated mainly by inorganic salts.

• Bitter receptors are located toward the back of the tongue. They are stimulated by a variety of chemical substances, most of which are organic compounds, although some inorganic salts of magnesium and calcium produce bitter sensations too.

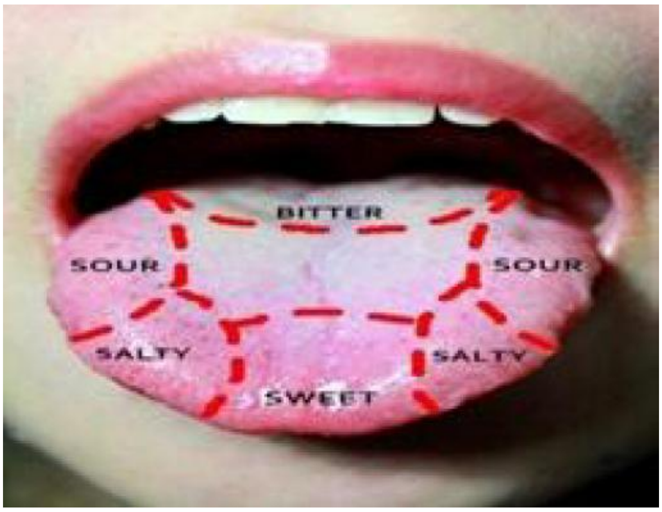

Fig.11.6 Taste receptors on tongue

Babies have many more of these taste buds than an adult, and they have these almost everywhere in the mouth, including the cheeks. Perhaps it is for this reason that adults enjoy more flavors than babies, who dislike bitter tastes and prefer bland food. The average adult has about 9,000 taste buds on each surface of the tongue, roof of the mouth, and throat.

Functions of Tongue-

• Taste

• The tongue also aids in the formation of sound of speech

• Coordinates its movements to aid in swallowing.

11.5 Nose, Sinuses and Smell-

Structure-

• Smell is often considered the least important of all the senses, but it may be one of the oldest, and probably acts on the subconscious more than the other senses. The walls of the nasal cavity enable both these functions.

• A limited portion of the nose and nasal cavity is further dedicated to the sense of smell, through its olfactory organs.(Fig.11.7) These olfactory sense organs are located beneath the bridge of the nose atop the nasal cavity. These organs, the olfactory membranes, are to be found in two clefts there and can be identified as a small grey or yellow patch of tissue.

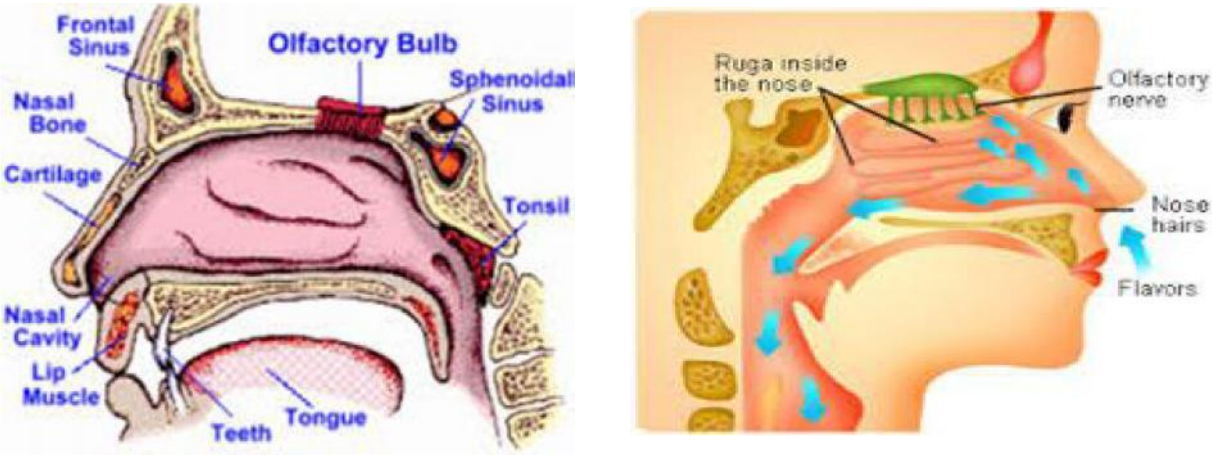

Fig. Fig.11.7 Structure of nose

Of course, we always smell something, and most airflow passes through the nose during normal breathing. This allows a limited fraction of the inhaled air to reach the olfactory clefts, yet is sufficient to trigger an olfactory response. Even more effective is when a person forcefully sniffs at an odor, quickly drawing air into the nose. The increased speed alters the direction of airflow, drawing more of the scent toward the sensors of the olfactory clefts.

Paranasal sinuses- The sinuses of the face, sometimes called the paranasal sinuses, are air pockets within the bones of the skull located behind and beside the nose, cheeks, and eye sockets.(Fig.11.8) They are four in no. and named as follows-

i) Frontal sinus

ii) Ethmoid sinus

iii) Sphenoid sinus

iv) Maxillary sinus

The roles played by the sinuses within the head are debated. However, there is little doubt about the role of scents in human behavior. The human nose can remember 50,000 different smells, and the body is provided with glands to produce specific odors, many of which appear to be associated with sexual attraction and excitement, and others that have considerable significance as well. The bond between a baby and its mother is thought to be tightened by a form of scent imprinting.

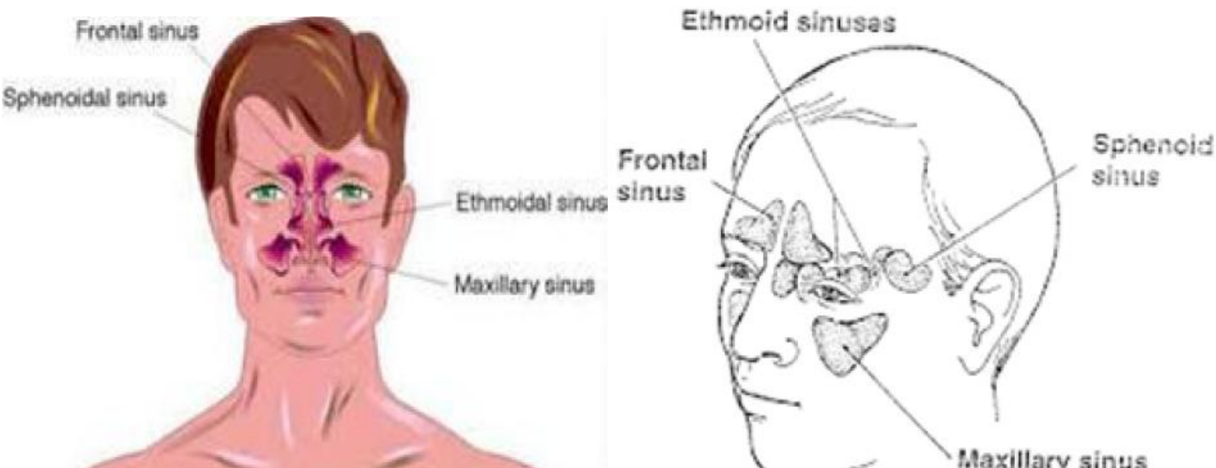

Fig.11.8 Paranasal sinuses

Functions of Nose-

• The nose is concerned with filtering and providing a passage for air on its way to the lungs.

• In particular, the nasal conchae are filled with mucosal respiratory membranes coated in cilia-tiny hair-like cells that act to move waves of mucus toward the throat. These protections trap inhaled bacteria, dirt, viruses, and chemical particles in the mucus. The cilia and swallowing action then serve to sweep the allergens and infectious agents into the back of and down the throat for destruction (digestion) in the stomach.

Glossary

Anosmia: Lack of olfaction, or a loss of the sense of smell

Auditory Canal : Tube from the auditory meatus or opening of the ear to the tympanic membrane

Auditory Tube : Either of the paired tubes connecting the middle ears to the nasopharynx; equalizes air pressure on the two sides of the eardrum

Chemoreception : Physiological response of a sense organ to a chemical stimulus

Choroid : Vascular layer of the eye lying between the retina and the sclera

Circumvallate papillae : Papillae that are present on the back of the oral part of the tongue

Cochlea : Is concerned with hearing, resembling a shell of a snail

Dysosmia : When things smell differently than they should

Equilibrium : Sense of balance

Extraocular muscles : Six muscles that control eye movements: lateral rectus, medial rectus, inferior rectus, superior rectus, inferior oblique and superior oblique

Filiform papillae : Thin, longer papillae that don't contain taste buds but are the most numerous

Foliate papillae : Ridges and grooves towards the posterior part of the tongue

Fungiform papillae : These are present mostly at the apex (tip) of the tongue-slightly mushroom shaped

Gustation : The sense of taste

Hair Cell : Mechanosensors for hearing, columnar cells each with a bundle of 100-200 specialized cilia at the top

Haptic : From the Greek Haphe, means pertaining to the sense of touch

Hyposmia : Decreased ability to smell

Inner Ear : Innermost part of the ear, contains the cochlea, vestibule and semi-circular canals

Middle Ear : Air Filled Cavity behind the Ear Drum, includes most of the ear Drum and ear Bones

Nasopharynx : Nasal part of the pharynx that lies behind the nose and above the level of the soft palate

Olfaction : The sense of smell

Otitis Media : An inflammation of the middle ear

Outer Ear : External portion of the ear, includes the auricle, ear canal and surface of the ear drum

Oval Window : Fenestra that has the base of the stapes attached to it

Papilla : Specialized epithelial cells that are small projections on the top of the tongue

Perception : The brain's interpretation of a sensation

Photoreceptors : Specialized type of neuron found in the eye's retina that is capable of phototransduction

Pinna : Auricle of the ear

Retina : Thin layer of neural cells that lines the back of the eyeball of vertebrates and some cephalopods

Round Window : Fenestra leading into the cochlea

Sclera : White outer coating of the eye- gives the eye its shape and helps to protect the delicate inner parts

Semicircular Canals : Certain canals of the inner ear

Sensation : Occurs when nerve impulses arrive in the brain

Sensory adaptation : A decrease in response to stimuli

Stapes : One of the small bones in the tympanum of the ear; the stirrups bone

Tactition : The sense of pressure perception, generally in the skin

Tympanic Membrane : The membrane in the ear that vibrates to produce sound

Assignments/Test

Q. Answer the following.

1. Write the structure of tongue.
2. What are the functions of tongue?
3. What are the functions of ear?
4. Write the physiology of hearing.
5. Write the physiology of equilibrium.
6. Draw and label the eyeball.
7. Describe the structure of an eyeball.
8. Describe the physiology of vision.
9. What are the functions of skin?
10. Describe the structure of skin.
11. Write a note on 'paranasal sinuses'.

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