Handbook of

Physiology

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Handbook of

PHYSIOLOGY

For students of Three year or Four year B.A. or B.Sc.
Interdisciplinary Course in Physiology

SEMESTER I, II & III

Under CCF curriculum

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SYLLABUS

Unit-I: Cells, Tissues, Systems, Organs of Human Body [10 Marks]
Cells in relation to human physiological functions, Cell organelles and their functions. Physiological system as a cluster of cells and tissues. Location and basic functions of major body-organs: Heart, Lung, Brain, Spinal cord, Liver, Stomach, Pancreas, Kidney, Digestive tract, Intestines, Sense organs, Reproductive organs [Use Models/Charts of different body organ systems & organs to observe anatomical position and structure.]

Unit-II: Biophysical and Biomolecular Phenomena [10 Marks]
Importance of major biophysical parameters in Physiology: Diffusion, Surface Tension, Absorption, Adsorption, pH, Buffer. Macro and Micronutrients and biomolecules involved in maintenance of human health: Definition with primary classifications, examples and functions of Carbohydrate, Protein, Lipids, Vitamins and enzymes.

Unit-III: Regulation and coordination of internal system [10 Marks]
Composition and functions of blood; functions of different blood cells. Composition and functions of Plasma proteins, hemoglobin molecule and anaemia. Exchange of respiratory gasses between lung and blood, and blood and tissue and their functions. Definition of hormone. Major secreting hormones and their important functions: Pituitary, Adrenal, Thyroid and Pancreas. Primary concept on Nerve fibers, Synapses, reflex action. Functional difference between central nervous system and peripheral nervous system.

Unit-IV: Applied Physiology [10 Marks]
Hematology: Definition, ABO and Rh Blood group system. Precautions of blood transfusion, Concept of Blood Bank. Microbiology and Immunology: Types of microbes, Beneficial and harmful bacteria with examples. Definition of Antigen and Antibody and Antibiotic and Vaccine with examples. Biotechnology: Outline concept and its modern applications. Basic concepts of Ergonomics and its importance in occupational health. Sports and Exercise Physiology: Physical fitness. Classification of sports, Basic concept of anthropometry. Application of statistics in biological science, Basic concept of population biology and Sample.

Unit-V: Common Diseases and Patho-physiological significance [10 Marks]:
Prevailing global communicable and non-communicable diseases, their primary causes and suggested measures: Influenza, Tuberculosis, Hepatitis, COVID-19, Diabetes mellitus, Haemophilia, Thalassaemia, COPD, Heart failure, Stroke, Hypothyroidism, Obesity. Pathophysiological tests, their normal range in the system and indicative diseases: TC, DC, ESR, Arneth Count, Fasting and Post-prandial blood sugar tests, Glycosylated haemoglobin, Bilirubin, Urea, Uric acid, Creatinine, SGOT, SGPT, Alkaline Phosphatase, Acid Phosphatase.

Unit-I: Cells, Tissues, Systems, Organs of Human Body

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1.1.Cell:

1.1.1.Cells in relation to human physiological functions: ***The structural and functional unit of human body is cell. This means human body is formed of cells and human physiology depends on the sum total action of all the cells present in body. Therefore the knowledge of cellular physiology is essential to understand the functions of different tissues, organs and systems in body.***

1.1.2.Cellular organelles and their functions: Every cell in human body contain almost all components of an eukaryotic cell and are listed in the table below:

	Location	Structure	Crucial functions
Cellular membrane or plasma membrane	Along the peripheral border of the cell and the organelles present inside it	Lipid bilayer with proteins embedded. Basic composition include **phospholipids, sphingolipids, glycolipids, cholesterol**, different proteins (transmembrane, peripheral and integral) including **glycoproteins.** There are specific regions in plasma membrane that are particularly rich in sphingolipids, cholesterol and different functional proteins endowing less fluidity in comparison to other regions of plasma membrane are called 'lipid rafts', representing functional domains of plasma membrane.	• Protection and formation of a hydrophobic layer to segregate ICF from ECF • Due to selective permeability only allows movement of few substances across it, which is aided by various **transporter proteins** present into plasma membrane • Plays crucial role in cellular signaling due to presence of various **receptor protein molecules**
Nucleus	Inside the cytoplasm	Surrounded by double membrane of lipid bilayer (called **nuclear envelope**), among which the outer membrane is continuous with the ER. Nuclear envelope contains pores which are very specific for transport of substances across it (known as **nuclear pore complexes**) The fluid inside nucleus (called **nucleoplasm**) contains chromosomes, nascent RNA transcripts, enzymes and regulator proteins. The DNA material along with packaging proteins (histones) form chromosomes; 22 pairs of autosomes and one pair of allosomes (XX or XY) or sex	• Packaging of genomic DNA into chromosomes • Synthesis of mRNA, rRNA, tRNA and many other types of RNA via **transcription**

		chromosomes are found. Chromosomes give a reticular arrangement called **nuclear reticulum** The genes for rRNA are continuously transcribed and the loci in chromosomes appear as dense structures known as **nucleolus**	
Centrosome	At the periphery of nucleus, adjacent to nuclear envelope	Contains two barrel shaped microtubule structures called **centrioles** which are surrounded by a cloud of amorphous substances (known as **centrosome matrix**)	• Acts as microtubule organizing centre for formation of spindle fibres during cell division
Ribosomes	Either bound to the surface of ER (**ER-bound ribosomes**) or free in cytoplasm (**cytoplasmic ribosomes**)	Does not have any envelope. Contains one large (60S) and one small (40S) subunit. Both of which is made up of ribosomal RNA and ribonucleoproteins (RNPs). Several rRNA in ribosome functions as ribozymes, *e.g.*, 28SrRNA acting as ***peptidyl transferase***. 18SrRNA in small subunit carry an evolutionary relic for eukaryotic origin	• Ribosome acts as a tool for synthesis of peptides, polypeptides and proteins hence is called **protein factory of cell** • ER-bound ribosomes synthesize proteins destined to be located on membrane, or to be exocytosed • Cytosolic ribosomes synthesize small soluble proteins which are to be transported inside various cellular organelles
Endoplasmic reticulum	Surround the nucleus and is widely distributed into cytoplasm which is finally continuous with plasma membrane	Ii is formed of a single lipid bilayer which is continuous with the outer membrane of nucleus. ER contains several enzymes for protein processing and other functions. The regions of endoplasmic reticulum (ER) that is involved in active synthesis and folding of protein has ribosomes embedded to its surface and are called **rough ER.** Other regions of ER which are involved in synthesis of lipids do not have ribosomes attached on the membrane and are called **smooth ER.** The breakdown products of ER which appear as small vesicles are called microsomes.	• Synthesis of proteins • **Post translational modifications** of proteins *e.g.*, protein folding, N-linked glycosylation, formation of disulfide linkage • Synthesis of membrane lipids, *e.g.*, phospholipid and cholesterol • Detoxification of xenobiotics • Storage of calcium • Carbohydrate metabolism
Golgi apparatus	Located near nucleus and ER	Has a definite single membrane and contains 5-8 flattened membrane bound sacks called **cisternae**	• Receives proteins from ER at CGN and carries out **post-translational modifications**, *e.g.*, N-

		The stacks of Golgi that is oriented towards ER are called **cis-face**, which along with small vesicles forms **cis-Golgi network** or **CGN** The stacks of Golgi that is oriented away from ER are called **trans-face**, which along with small vesicles forms **trans-Golgi network** or **TGN** Small vesicles that carry proteins from ER to Golgi helps in formation of large compartments of Golgi are known as dictyosomes.	linked and O-linked glycosylation, phosphorylation etc • **Protein modification** • Verification of proper three dimensional folding of proteins • **Protein sorting** and transport to various regions of cell • Modification and sorting of lipids • Metabolism of lipid and carbohydrate • Forms **acrosome** in sperm
Lysosome	Dispersed randomly into cytoplasm	Small single membrane bound vesicles Contains atleast 40 different types of proteolytic enzymes (**hydrolytic, EC-3 enzymes**), that act at acidic pH. Small primary lysosomes that contain inactive enzymes form secondary lysosomes when fused with vesicles containing truncated proteins, or endocytosed materials or worn out organelles. Digestion occurs within secondary lysosomes, and then shrinks to form telolysosomes.	• Digests truncated proteins, worn out organelles in a process called **autophagy [hence is also called suicidic bag]** • Digest endocytosed microbes and other toxic proteins that enter from outside – **heterophagy**.
Mitochondria	Dispersed randomly into cytoplasm	Is covered by double membrane of lipid bilayer. The outer membrane is leaky enough and permeable to many metabolites, however inner membrane is impermeable and compact due to presence of a special type of lipid called **cardiolipin**. Inner membrane is highly folded (folds are called **cristae**) contains all enzymes of respiratory chain and ATP synthase. Contains DNA (mtDNA), ribosome of prokaryotic origin which is used to synthesize few of the mitochondrial proteins	• Produces ATP, the energy currency of cell [**hence called power house of the cell**] • Plays a direct role in apoptosis • Regulates redox status of cell • Many metabolic pathways takes place into mitochondria • Play important role in cellular proliferation
Peroxisomes	Dispersed randomly into cytoplasm	Single membrane bound small round organelles containing important enzymes *i.e.*, **superoxide dismutases, peroxidases** and **catalases**	• Detoxification of superoxides and hydrogen peroxides
Glyoxysomes	Dispersed		• Glyoxylate cycle takes

	randomly into cytosol of cells of adipose tissue		place into glyoxysomes • Gluconeogenesis occurs
Cytoskeleton	Forms the backbone of the cell	Cytoskeleton has three components: **Microtubules:** Polymers of tubulin that forms long tubular shapes **Microfilaments:** Actins and myosins belong to this category. Actins are polymers for G-actins and myosins are formed of myosin monomers; both of which form filamentous structures **Intermediate filaments:** These are rope like structures formed of many elongated coiled-coil structures	• Together all the three cytoskeletal elements provide structural stability and shape to the cell. • The cytoskeleton helps to connect the components of extracellular matrix and cellular junctions to ensure stability • In addition, microtubules helps in transport of vesicles containing cell organelle and proteins • Microfilaments helps in changes in shape and functions as contractile elements • Intermediate filaments acts to bind cytoskeletal elements together

1.2.Physiological systems as clusters of cells and tissue:

Physiological system	Tissue	Most common cells
Cardiovascular system	**Cardiac muscle tissue:** • Junctional tissue: • Working tissue: **Blood vessels:** simple squamous epithelial tissue	**Junctional cardiac myocytes**: SA nodal fibers, internodal fibers, AV nodal fibers, fibers of bundle of His and Purkinje fibers; **Working cardiac myocytes** **Vascular endothelial cells** **Vascular smooth muscle cells**
Respiratory system	**Pulmonary tissue and respiratory tract:** Simple squamous epithelium, simple cuboidal epithelial tissue, ciliary columnar epithelial tissue, stratified squamous epithelial tissue, pseudostratified columnar epithelial tissue	**Type I and II glomus cells** **Clara cells** **Ciliated columnar and squamous epithelial cells** **Respiratory smooth muscle cells**
Digestive system	**Alimentary canal:** Ciliary columnar epithelial tissue, simple columnar epithelial tissue, stratified squamous epithelial tissue **Hepatic tissue:** non-parenchymal and parenchymal tissue **Pancreatic tissue:** Parenchymal tissue embedded with epithelial tissue	**Ciliated columnar and squamous epithelial cells** **Oxyntic cells** **Parietal cells** **I-cells** **Hepatocytes** **Kupffer cells**
Nervous system	**Brain tissue:** neural tissue and connective tissue **Spinal tissue:** neural tissue	**Neurons** **Glial cells** **Betz cell**

		Purkinje cells
Reproductive system	**Testicular tissue:** Simple cuboidal epithelial tissue, simple columnar epithelial tissue, pseduostratified columnar epithelial tissue **Ovarian tissue:** Simple cuboidal epithelial tissue, ciliary columnar epithelial tissue, simple columnar epithelial tissue, stratified squamous epithelial tissue (keratinized and non-keratinized)	**Primordial germ cells** **Sertoli cells** **Spermatocytes and sperm** **Follicular cells** **Granulosa cells** **Oocyte and ovum**
Excretory system	**Renal tissue:** Simple cuboidal epithelium, simple squamous epithelial tissue, transitional epithelial tissue, stratified squamous epithelial tissue **Dermal and epidermal tissue:** Stratified squamous epithelial tissue, glandular epithelial tissue	**Macula densa cells** **Mesangial cells** **Juxtaglomerular cells** **Cuboidal and squamous epithelial cells**

1.3.Location and functions of major organs in body:

Name of the organ	Location	Functions
Heart	**At the middle of chest being slightly behind and to the left of the thoracic cage**	• Generate the force to circulate blood through various blood vessels • Has some endocrine functions as well
Lung	**Into the thoracic cavity above the diaphragm**	• Site for gaseous exchange • Helps in excretion • Regulation of acid base balance
Brain	**At top of the neck inside a bony skull box called cranium**	• Centre for all motor functions and most of the sensory functions • Regulates learning and memory functions • Regulates the autonomic functions of several organs and systems • Regulates emotional behaviours • Regulates sleep and wakefulness cycle
Spinal cord	**Inside the spinal column made up of 33 bones called vertebrae**	• Regulation of reflexes • Sensory and motor pathways extend through spinal cord
Liver	**Upper right hand portion of abdominal cavity**	• Is the home for almost all metabolic pathways and synthesis of various biochemical substances • Synthesizes various proteins, most importantly the plasma proteins • Detoxification of xenobiotic substances
Stomach	**Upper left hand portion of abdominal cavity**	• Breakdown of foodstuff and digestion of protein occurs here • Secretes HCl which helps in protection against harmful microorganisms
Pancreas	**Upper middle portion of abdominal cavity**	• Secretes pancreatic juice rich in several digestive enzymes • Site for synthesis of insulin and glucagon which regulates blood sugar level
Kidney	**Below the rib cage at the middle back region**	• Regulation of water and electrolyte balance • Major excretory functions in body • Reabsorption
Digestive tract	**Extends from oral cavity to the**	• Digestion of biomacromolecules in

	intestines	foodstuff • Regulation of absorption of vitamins, mineral and several organic and inorganic substances in diet • Excretion
Small intestine	**Into lower abdominal cavity beneath stomach**	Major site for absorption
Large intestine	**Lower abdominal cavity and at the periphery of small intestine**	Absorption, secretion and excretion
Eye	**At the frontal side of face above nose inside a bony socket called orbit**	• Visual sensation, and perception of depth • Black and white and colour vision
Ear	**On both sides of head**	• Auditory sensation • Maintenance of body balance
Nose	**Middle of the head**	Sensation of smell (olfaction)
Tongue	**From hyoid bone to the floor of the mouth**	• Sensation of taste (gustation) • Preliminary role in digestion
Testes	**Inside an external sac like structure called scrotum**	• Secretion of male sex hormones testosterone and DHT • Formation of male gamete spermatozoa
Ovary	**Lower abdomen**	• Secretion of female sex hormones, such as estrogen, progesterone etc • Regulation of menstrual cycle • Formation of female gamete ovum

Unit-II: Biophysical and Biomolecular Phenomena

Diffusion: Physiological importance
Surface Tension: Physiological importance
Absorption: Physiological importance
Adsorption: Physiological importance
pH and physiological buffer systems
Macro and Micronutrients and biomolecules involved in maintenance of human health
Carbohydrates: Definition, example, functions and primary classifications
Proteins: Definition, example, functions and primary classifications
Lipids: Definition, example, functions and primary classifications
Enzymes: Definition, example, functions and primary classifications
Vitamins: Definition, example, functions and primary classifications

2.1.Diffusion:

2.1.1.Definition: ***Diffusion is the tendency of particles to spread uniformly in every possible direction in a solution or free space.*** This type of movement of the particles is considered to be random and cannot be prevented.

2.1.2.Physiological importance: Diffusion is a basic biophysical principle among many other biological phenomena and its biological significance is also widespread.

i) Membrane transport: Although plasma membrane has a semipermeable nature and most of the transport mechanism imparts special transport proteins or channels, few substances which are mostly lipid soluble molecules, *e.g.*, steroids, thyroid hormones, lipid soluble gases, few drugs can move across the plasma membrane through simple diffusion process. Even in case of many specialized transporter channels ions are transported through diffusion along their electrochemical gradient.

ii) Ionic transport and electrical activities in neurons: Facilitated diffusion of various ions, *e.g.*, Na^+, K^+ along their electrochemical gradients across the plasma membrane of neurons in CNS, PNS and ANS helps in generation of propagated electrical activities in form of action potential.

iii) Ionic transport and muscular activities: Facilitated diffusion of various ions such as Na^+, K^+ along their electrochemical gradients across the plasma membrane of skeletal and cardiac muscles helps in generation of action potential and results in Ca^{2+} influx which ultimately results in contraction of skeletal and cardiac muscles.

iv) Respiratory exchange of gases: Perhaps the most common example of basic principles of diffusion in physiology is exchange of respiratory gases, *e.g.*, O_2 and CO_2 across the tissue cells, erythrocytes, endothelial cells of capillary wall and alveolar cells. Exchange of respiratory gases occurs between blood and tissue in periphery and in lung exchange occurs between blood and alveoli. Diffusion of O_2 ad CO_2 occurs in reverse directions which follow the principles of diffusion. Pressure and concentration gradient of O_2 favours its diffusion from lung to blood and then from blood to tissues. In case of CO_2 its concentration is highest in tissues and therefore the diffusion of CO_2 occurs from tissues to blood and then from blood into the lung.

v) Intestinal absorption: Absorption of carbohydrates, lipids, vitamins and minerals across the intestinal epithelia occurs through diffusion along their concentration gradient.

vi) Renal reabsorption: Reabsorption of urea in the renal tubules is a classic example of diffusion in kidneys.

2.2.Surface tension:

2.2.1.Definition: ***It is an inward force acting perpendicularly on the surface layer of a liquid that tend to pull all surface molecules towards the interior of the liquid mass.*** Surface tension contracts the liquid surface to a minimum area and keeps it in a state of tension like a stretched membrane.

2.2.2.Physiological importance: Surface tension has important physiological role in body:

i) Emulsifying action of bile salts: Bile salts lower the surface tension of fat droplets in duodenum this makes the surface of large fat droplets to form stable emulsion in water which helps in absorption of fat.

ii) Lung compliance: Lung compliance or the stretchability of lungs depends on the surface tension of alveoli, which is adjusted by the lung surfactants (a group of amphipathic molecules).

2.3.Absorption:

2.3.1.Definition: ***It is a physicochemical phenomenon in which organic or inorganic substances, and fluid are assimilated into cells or across tissues and organs***.

2.3.2.Physiological importance: Absorption has several physiological importance such as - absorption of metabolites from GI tract, absorption and reabsorption of water in GI tract and renal tubules etc.

2.4.Adsorption:

2.4.1.Definition: ***It is a physicochemical phenomenon in which one substance (adsorbate) is concentrated on the surface of another substance (adsorbent).*** It is a reversible, exothermic phenomenon with a dynamic equilibrium, and the reversal of adsorption is known as desorption.

2.4.2.Physiological importance: Surface tension has important physiological role in body:

i) Transport in plasma: Various mineral ions, carbohydrates, lipids etc are transported in plasma being adsorbed on the surface of colloidal plasma proteins.

ii) Enzyme catalyzed reactions: Formation of enzyme substrate complexes sometimes include chemisorption of substrates on the surface of enzymes. Chemisorption holds substrates on enzymes for sufficient time, which allows substrate to undergo desired chemical changes.

2.5.pH and buffer:

2.5.1. Definition of pH and buffer: ***By definition pH (power or potential of hydrogen) of any solution is the negative logarithmic value of hydrogen ion concentration.*** As per the formula, pH = -log $[H^+]$, which indicates a rise in $[H^+]$ or a rise in acidity is reflected as a decrease in pH value; on contrary a decreased $[H^+]$ or a rise in alkalinity is reflected as a rise in pH value. The range of pH is 0.0 to 14.0 because of the dissociation constant of water being 10^{-7}.

Buffer is a solution that resists change of its pH when acid or alkali is added to an extent. Buffer is classified into two groups – ***acid buffer*** and ***alkaline buffer***. An acid buffer is formed when a weak acid is in mixture with its conjugate base and alkaline buffer is formed when a weak base is in mixture with its conjugate acid. Some important buffer systems present in our body are – ***bicarbonate buffer***, ***phosphate buffer***, ***protein buffer*** and ***hemoglobin buffer***.

2.5.2.Physiological importance: The pH of most of the body fluids including plasma is maintained at a range between 6.8-7.4. This pH range is particularly important for enzymatic actions (as because for most of the enzymes the *optimum pH range* lies between 6.8-7.2), also it is important for ionic

transport, maintenance of electrolyte balance etc. The buffer systems present in plasma and other body fluids plays crucial role in maintenance of pH.

2.6.Carbohydrates:

2.6.1.Definition: ***Carbohydrates are those biomolecules that contain hydrated carbons, carry two or more alcoholic -OH groups, and one or more carbonyl carbon within an aldehyde or ketone group***. Carbohydrates and their hydrolytic products are chemically either *polyhydroxyaldehydes* or *polyhydroxyketones*, *e.g.*, glucose, fructose, galactose etc.

2.6.2.Functions: Carbohydrates are primary source of energy among all our major biomacromolecules. However, they may have several other physiological functions.

- Production of energy, *e.g.*, glucose, trehalose, glycogen and starch etc.
- Maintenance of cellular and extracellular structures– cellulose, chitin, hyaluronic acid and chondroitin sulphate, constituents of genetic materials, *e.g.*, ribose and deoxyribose.
- Metabolic products of some carbohydrates are used for synthesis of fatty acids and some amino acids. Carbohydrates also serve as nutreints, *e.g.*, lactose in milk.
- Diverse functions as conjugates of lipids (***glycolipids***) and proteins (***glycoproteins***), antibiotics, *e.g.*, streptomycin etc.

2.6.3.Classification: Carbohydrates are classified into four groups, *i.e.*, monosaccharides, disaccharides, oligosaccharides and polysaccharides.

i) ***Monosaccharides:*** These are the simplest unit of carbohydrates *i.e.*, cannot be hydrolysed further into smaller carbohydrate molecules. Most of the monosaccharides have a general formula – $\mathbf{C_nH_{2n}O_n}$ and in animals all monosaccharides bear 3-7 carbon atoms.

ii) ***Disaccharides:*** These are produced by formation of ***glycosidic linkages*** between two sugar moieties, *e.g.*, sucrose, lactose, maltose and trehalose.

iii) ***Oligosaccharides:*** These are larger molecules composed of 3-10 units of monosaccharides joined together via formation of ***glycosidic linkages***. Often the oligosaccharyl units are ligated to specific proteins to form ***glycoproteins*** through ***O-linked*** or ***N-linked glycosidic linkages.***

iv) ***Polysaccharides:*** These are large molecules that contain more than 10 monosaccharide units and are often branched chain molecules, *e.g.*, starch, glycogen, inulin etc. Polysaccharides are often classified as homoglycans and heteroglycans. ***Homoglycans contain similar type of sugars, whereas heteroglycans contain different other sugars or their derivatives***.

2.7.Proteins:

2.7.1.Definition: ***Proteins are macromolecules made up of amino acids; more precisely are polymers of L-α-amino acids joined together by peptide linkages.*** All naturally occurring proteins in animals mostly contain L-amino acids instead of D-amino acids.

2.7.2.Functions: Although it is quite difficult to gist all the functions of this most important biomolecule in our body, the major functions are:

- Structural stability of a cell as a component of plasma membrane and cytoskeleton.
- Regulation of membrane transport and Formation of various cellular organelles
- Most of the enzymes of our metabolic pathways are proteins; hence synthesis of all other biomolecules and their metabolism depends on various proteins functioning as enzymes.
- Formation of various cellular organelles
- Few proteins may act as hormones, *e.g.*, *insulin*, *anti-diuretic hormone*, *growth hormone* etc.

- Few of the proteins may act as receptors of hormones, neurotransmitters and several other biomolecule; hence helps in cellular signaling.
- Proteins make the extracellular matrix outside of cells to keep them in a stable microenvironment.
- Proteins mediate cell-to-cell communication.
- Proteins help in formation of cellular junctions.

2.7.3.Classification: Proteins are broadly classified into simple proteins, conjugated proteins and derived proteins.

i) Simple proteins: Contain only amino acids; no other non-protein part is present, *e.g.*, ***protamines*** (***smallest and simplest among all proteins***), histones, albumins, globulins, ***prolamines*** (***proline rich proteins***), ***scleroproteins*** (***fibrous animal proteins, such as keratins, collagens, elastins, chondroitins***).

ii) Conjugated proteins: These are complexes of simple proteins that carry non-protein part. The protein part is called ***apo-protein***. Conjugated proteins have been classified as-

- *a) Chromoproteins:* Carry a chromophore as non-protein part, *e.g.*, hemoglobin carrying heme as a pigment.
- *b) Metalloproteins:* Bound to metal ions, *e.g.*, carbonic anhydrases contain Zn^{2+}
- *c) Nucleoproteins:* Contains small nucleic acids (DNA or RNA) as prosthetic group, *e.g.*, ribonucleoproteins of ribosomes
- *d) Phosphoproteins:* Carry a phosphoric acid as non-protein part, *e.g.*, casein and ovovitellin
- *e) Lipoproteins:* Here the non-protein part is triacylglycerol, phospholipids, sphingolipids, fatty acid or cholesterol, *e.g.*, VLDL, LDL, HDL, IDL etc.
- *f) Glycoproteins:* Attached with carbohydrates as non-protein part (quantity of carbohydrate is less than 4%), *e.g.*, immunoglobulins, TSH, FSH etc.
- *g) Mucoproteins:* Attached with carbohydrates as non-protein part (quantity of carbohydrate is more than 4%).

iii) Derived proteins: These are produced from natural proteins due to physical and chemical modifications.

2.8.Lipids:

2.8.1.Definition: ***Lipids are esters of fatty acids with alcohol.*** In many cases lipids may also contain phosphoric acid, nitrogenous bases and carbohydrates. These are heterogeneous group of organic substances found both in animals and plants.

2.8.2.Functions: The major functions of lipids in body are:

- Acts as chemical messengers for cell signaling pathways.
- Acts as a component of plasma membrane and membrane for may intracellular organelles.
- Has cushioning functions for various large organs in our body.
- Plays a very important role in inflammatory responses and hypersensitivity reactions (namingly the type I hypersensitivity reaction also known as ***allergy***).

2.8.3.Classification: Lipids are broadly classified into three different groups, *e.g.*, simple lipids, compound lipids and derived lipids.

i) Simple lipids: These are esters of fatty acids with alcohols, and classified into neutral fat and wax.
a) Neutral fats or glycerides: These are esters of fatty acids with glycerol. According to the number of fatty acids attached to the glycerol, there are three types of glycerides –

- *Monoacylglycerol:* Contains only one molecule of fatty acid esterified to the glycerol.
- *Diacylglycerol:* Contains two fatty acid molecules esterified to the glycerol.

- *Triacylglycerol:* Contains three molecules of fatty acids esterified to glycerol. ***Triacylglycerols are also known as fats, and oils are those fats that remain in liquid state at room temperature***.

b) Waxes: These are esters of long-chain fatty acids with higher monohydroxy long chain aliphatic alcohols. These esters are usually found in solid form. Examples include myricyl palmitate which is an ester of myricyl alcohol and palmitic acid found in bee wax. Cholesteryl esters and vitamin D esters are also examples of waxes.

2. Compound lipids: When fats contain other groups in addition to the alcohol and fatty acids, are called compound lipids. There are also different types of compound lipids –

a) Phospholipids: These are substituted forms of fats that contain phosphoric acid, and other groups like choline, ethanolamine, inositol, serine, or diphosphatidyl glycerol.
b) Glycolipids: These are compounds of lipids with carbohydrate moieties, along with an amino alcohol sphingosine. Glycolipid does not contain phosphates as in case of phospholipids, *e.g.*, cerebrosides and gangliosides.
c) Sulfolipids: These are also substituted forms of lipids that contain sulphate groups.
d) Proteolipids: These are compounds of lipids with amino acids.
e) Lipoproteins: These are basically large compound of lipids with large proteins *e.g.*, VLDL, LDL, IDL and HDL.

3. Derived lipids: These are basically hydrolytic end products of compound lipids as well as simple lipids. Although these are derived forms of lipids they retain all other general properties of lipids, *e.g.*, diacylglyerols, monoacylglycerols, fatty acids, and glycerols.

2.9.Enzymes:

2.9.1.Definition: ***Enzymes are biocatalysts, synthesized by living cells as large proteins, which can catalyze specific thermodynamically possible non-spontaneous biochemical reactions both inside and outside of the cell via catalyzing changes in various covalent bonds of their substrates.*** Most of the enzymes are biochemically protein in nature with high molecular weight; however few RNA molecules may also act as enzymes, which are known as ***ribozymes***. Enzymes are synthesized by living cells as inactive large molecules, known as ***zymogens*** or ***pro-enzymes***. Zymogens are subsequently cleaved to release the additional parts from both C-terminal and N-terminal regions to get the final active form of enzyme molecules

2.9.2.Functions: Enzymes play important role in catalyzing non-spontaneous reactions in biological systems; however, few of the major functions of enzymes in survival of cell are:

- Synthesis of proteins by peptidyl transferase and synthesis of fatty acid by fatty acid synthase.
- Breakdown of carbohydrates, lipids and proteins to produce energy.
- Oxido-reductases in mitochondrial electron transport chain helps in formation of ATP.

2.9.3.Classifications: Enzyme commission in the year 1999 classified enzymes on basis of mode of action:

- **EC-1 or *Oxidoreductases*:** Group of enzymes which are involved in oxidation and reduction of their substrates, ***e.g. alcohol dehydrogenases.***
- **EC-2 or *Transferases*:** Group of enzymes which catalyze transfer of a specific group from one substrate to another substrate, ***e.g. alanine transaminases (AST).***
- **EC-3 or *Hydrolases*:** Group of enzymes which bring about hydrolysis of their substrates, ***e.g. pepsin.***

- **EC-4 or *Lyases*:** Group of enzymes which facilitates removal of small fractions from large molecules of their substrates, ***e.g. fumarases.***
- **EC-5 or *Isomerases*:** Group of enzymes which are involved in isomerization of their substrates, ***e.g. phosphohexose isomerases.***
- **EC-6 or *Ligases*:** Group of enzymes which are involved in joining of two of their substrates, ***e.g. DNA ligases.***

[Recently in the year 2018, Enzyme Commission added another class of enzymes which is ***translocase*** designated as **EC-7**]

2.10. Vitamins:

2.10.1. Definition: ***Vitamins are essential organic substances which are required for various physiological functions in small quantities.*** Some of the vitamins are plant based, *i.e.*, taken in daily diet and some are synthesized within our body.

2.10.2. Classifications, source, function and deficiency symptoms:

Group I: Fat soluble vitamins			
Name	**Source**	**Functions**	**Deficiency symptoms**
Vitamin A *(Retinol)*	Cod liver oil, milk, butter, cheese, egg-yolk, tomatoes, carrots, green-yellow vegetables	Vision, growth, differentiation, male fertility	Xerophthalmia, decreased sperm count, immuno – suppression
Vitamin D *(Cholecal-ciferol)*	Cod liver oil, oily flesh of fishes, milk and egg-yolk, hydrogenated vegetable fats.	Bone mineralization, Ca^{2+} and PO_4^{3-} absorption	Ricketsae Osteomalacia
Vitamin E *(Tocopherol)*	Peanut oil, maize oil, sunflower oil, soyabean oil; peanuts, almonds, sweet potato, lettuce	Works as an antioxidant, anticancer effect, prevention of muscular dystrophy,	Muscular dystrophy, testicular atrophy, axonal dystrophy
Vitamin K *(Phylloqui-none)*	Spring (collard) greens, spinach, and Brussels sprouts, soybean, and olive oils	Helps in blood coagulation and oxidative phosphorylation	Fatal hemorrhagic diseases
Group II: Water soluble vitamins			
Vitamin B_1 *(Thiamin)*	Pork, meat, and fish potatoes, whole-grain cereals	Acts as a co-enzyme for TCA cycle, and PPP enzymes	Chronic peripheral neuritis, beriberi, Wernicke-Korsakoff's syndrome
Vitamin B_2 *(Riboflavin)*	Milk, dairy products, eggs, meat and fish	Helps in metabolism, prevention of oxidative stress	Cheilosis, angular stomatitis, seborrheic dermatitis
Vitamin B_3 *(Niacin)*	Yeast, liver, meat, fish, prawns, legumes, peanuts, cereals	Precursor of NAD^+, NADH and NADPH	Pellagra
Vitamin B_5 *(Pantothenic acid)*	Beef, poultry, sea-food, mushroom, avocado, potatoes, broccoli	Energy metabolism, synthesis of fatty acids and cholesterol	Paraesthesia
Vitamin B_6 *(Pyridoxine)*	Pork, poultry, fish, soybeans, peanut	Erythropoiesis, Na^+ and K^+ balance	Peripheral neuropathy
Vitamin B_7 *(Biotin)*	Yeasts, marmite, liver, egg yolk, peanuts, tomatoes, milk	Fatty acid synthesis and breakdown of amino acids, hair growth	Dermatitis, enteritis, hair loss

Vitamin B_9 *(Folic acid)*	Liver, many fruits and vegetables	Erythrocyte maturation, cell division and DNA synthesis	Vitamin deficiency megaloblastic anemia and birth defects
Vitamin B_{12} *(Cobalamin)*	Gut bacteria, fish, meat, poultry eggs, dairy products	Erythropoiesis, myelinogenesis	Vitamin deficiency megaloblastic anemia and aciduria
Vitamin C *(Ascorbic acid)*	Citrus fruits and many vegetables	Antioxidant effect, collagen synthesis, dopamine formation, erythrocyte maturation	Scurvy, anemia

Unit-III: Regulation and coordination of internal system

Composition and functions of blood; functions of different blood cells.
Composition and functions of plasma proteins, hemoglobin molecule and anaemia
Exchange of respiratory gasses between lung and blood, and blood and tissue and their functions.
Definition of hormone.
Major secreting hormones and their important functions: Pituitary, Adrenal, Thyroid and Pancreas.
Primary concept on Nerve fibers, Synapses, reflex action.
Functional difference between central nervous system and peripheral nervous system.

3.1.Blood:

"Blood is a fluid connective tissue". It is a tissue because it is composed of numerous different type of cells; fluid because cells in this tissue are flowing continuously through different regions of body. It is a connective tissue because it is continues to flow from periphery to deep down into various organs and other tissues into body, connecting them with each other.

Salient features:

- Blood is slightly alkaline (pH ranges between 7.38-7.42; or 7.4 in average) in chemical nature.
- It is red in colour due to presence of hemoglobin rich RBCs.
- The characteristic odour of the fresh blood is due to presence of some amino acids *e.g., butyric acid, caproic acid*.
- The specific gravity of blood is 1.055 to 1.060 at 15°C (298K) temperature.
- It tastes salty due to presence of NaCl (0.9%, 0.9 g/dl).
- Blood is fluid in nature and has a viscosity of 36-54 *mpoise*.
- Blood has a high specific heat and high conductivity of heat.

3.1.1.Composition: About 55% of blood volume is composed of plasma, and 45% is composed of cells and platelets. The ratio of plasma to cell appears to be 55:45; this is referred to as ***haematocrit value***.

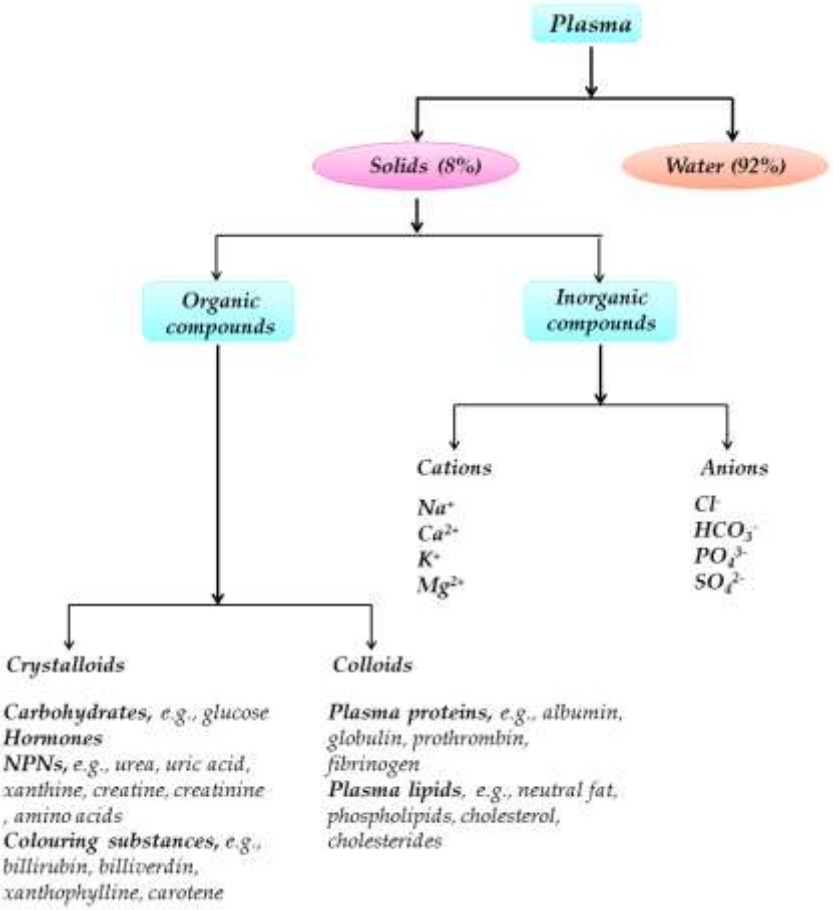
3.1.1.1.Cellular components: Among the 45% of hematocrit, the total value represents erythrocytes. WBCs and platelets which constitute a minimal proportion are found at the buffy coat at the junction between the red mass bottom and the clear plasma above.

Blood cell	Precursor cell	Site of formation	Functions
Erythrocytes	Proerythroblast	Bone marrow	Transport of blood gases
Leucocytes			
Eosinophil	Eosinophiloblast	Bone marrow	Prevent allergic reactions
Neutrophil	Myeloblast	Bone marrow	Phagocytosis, clearing of debris and inflammation
Basophil	Basophiloblast	Bone marrow	Mounts allergic reactions; however limits spread of allergy at late phases
Lymphocyte	Lymphoid progenitor cells	Lymphoid organs	Play crucial role in cell mediated immunity and humoral immunity
Monocyte	Monoblast	Bone marrow	Phagocytosis, formation of macrophages
Platelets	Megakaryocyte	Bone marrow	Plays central role in blood coagulation

3.1.1.2.Composition of plasma: Water constitutes around 92% of plasma present in our blood. The rest 8% contains inorganic ions and organic substances.

i) ***Inorganic ions:*** They play important role in blood to maintain blood pressure, functionalities of excitable tissues, enzymatic activities etc.

ii) ***Organic substances:*** The organic substances being carried by the blood is also required for diverse functions, *e.g.*, nutrition, transport of materials both biologically important and waste materials, transport of hormones, and medicine as well as some drugs.



Among the organic substances the largest fraction among colloidal materials is constituted by plasma proteins. We have four principal plasma proteins in our blood, *e.g.*, albumin, globulin, fibrinogen and prothrombin.

Plasma protein	Source and structure	Functions
Albumin		• Responsible for most of the colloidal osmotic tension of blood (70-80%). • Transports billirubin, hormones and drugs etc.
Globulin		• Plays crucial role in immune system • Transports iron, copper, heme, lipid • Most of the coagulation factors in blood are globulins
Fibrinogen		Plays crucial role in blood coagulation
Prothrombin		Regulates the entire process of hemostasis

3.1.2.Hemoglobin: Hemoglobin is a conjugated globular protein which is present abundantly into erythrocytes or RBCs. It has an ability to combine with gases like O_2 and CO_2 both. Each individual RBC contain 200-300 million molecules of hemoglobin, among which 65% is synthesized during nucleated stage and only 35% is synthesized during reticulocyte stage. Its normal value is 13.5 to 18.0 g/dl in male and 11.4 to 16.0 g/dl in female.

Structure: Hemoglobins have a molecular weight of 65,450 making it a large oligomeric, allosteric, conjugated glycoprotein with four polypeptide chains joined by non-covalent bonds. It contains heme as prosthetic group. Heme is a compound of iron (Fe) with porphyrin, a complex compound with a '*tetra-pyrrole*' structure (pentagonal rings containing N). Each of the hemoglobin molecules consists of four globin chains, which vary greatly among different types of hemoglobins. Each of the α-globin chains are composed of 141 amino acids and each of the β-chains are composed of 146 amino acids.

Type of hemoglobin	Globin chain composition	Stages at which are detectable
Embryonic (Hb-E)	$\alpha_2\varepsilon_2$	Embryo (<8 weeks)
Fetal Hb (Hb-F)	$\alpha_2\gamma_2$	Fetus (3-9 months)
Adult Hb major (Hb-A$_1$)	$\alpha_2\beta_2$	Adults (from birth)
Adult Hb minor (Hb-A$_2$)	$\alpha_2\delta_2$	Adults (from birth)
Hb-A$_3$	$\alpha_2\beta_2$	Adults (from birth)
Glycosylated Hb (Hb-A$_{1C}$)	$\alpha_2\beta_2$	Adults during hyperglycemia or diabetes mellitus

Compounds and derivatives of hemoglobin:

- ***Hematin compounds:*** Hematins are formed due to reaction of acid and alkalies with adult hemoglobin, and are therefore referred as - ***acid hematin*** and ***alkaline hematin***.
- ***Hemin compounds:*** These are also known as ***hematin hydrochloride*** which is formed from boiling of oxy-Hb with NaCl and glacial acetic acids.
- ***Hematoidin compounds:*** These are breakdown products of Hb in body.
- ***Oxyhemoglobin compounds:*** These are compounds of hemoglobin with oxygen. The iron remains in ferrous state (Fe^{2+}).
- ***Carbamino hemoglobin compounds:*** These are compounds of hemoglobin with carbon dioxide. It is formed by union of CO_2 with the globin chains of Hb.
- ***Carboxyhemoglobin compounds:*** These are compounds of hemoglobin with carbon monoxide instead of oxygen.
- ***Methemoglobin compounds:*** These are derivatives of Hb in which Fe is in ferric state and methemoglobin is the true oxidation product of Hb. Methemoglobin cannot bind O_2.
- ***Nitrosyl compounds:*** These are compounds of hemoglobin with nitric oxide (NO) instead of O_2. It is formed in nitric oxide poisoning.

3.1.3.Anaemia: Anemia refers to a the physiological condition where the hemoglobin content goes below the normal. Anaemia may occur when RBC count or the hematocrit value is decreased.

Cardinal signs of anemia: Anaemia may occur due to many different reasons, and are classified accordingly; however there are few signs which are in common for all kind of anaemia:

i) A decrease in partial pressure of oxygen (PO_2) in blood
ii) Breathing problem (dyspnea)
iii) Decreased muscular activity and muscular weakness (early onset fatigue)
iv) Decreased CNS functions (headache, vertigo, lack of concentration)
v) Rise in heart rate, stroke volume, cardiac output leading to *hypertension* (elevated blood pressure)
vi) Increased rate of erythropoiesis

Types of anaemia: Anaemia can be classified on the basis of etiology as follows:

Type of anaemia	Reason	Salient features
Iron deficiency anaemia	Dietary deficiency of iron, decreased absorption of iron	**General signs of anemia +** Deformation of epithelial mucosa Atrophy of taste buds

		Ulceration of mouth (**stomatitis**) Spoon shaped nail (**koilonychia**) **RBCs are microcytic.**
Vitamin deficiency anaemia	Deficiency of folic acid (B_9) and/or cyanocobalamin (B_{12})	**General signs of anemia +** Presence of large precursors of RBCs (megaloblasts) into the blood Diarrhoea Skin lesions Difficulty in walking **RBCs are macrocytic.**
Pernicious anaemia	Autoimmune destruction of gastric parietal cells	**General signs of anemia +** Gastritis and gastric atrophy Peripheral neuropathy Atherosclerosis Thrombosis **RBCs are macrocytic.**
Aplastic anaemia	Damaged red bone marrow due to radiation, toxins and chemical substances	**General signs of anemia** **RBCs are normocytic.**
Sickle cell anaemia	Mutation in β-globin gene leading to formation of abnormal hemoglobin (Hb-S)	**General signs of anemia +** Presence of highly fragile **sickle** shaped RBCs in blood **RBCs are normocytic.**
Hemolytic anaemia	Liver failure, infections, drugs (penicillin, antimalarial drugs and sulfa drugs), lead poisoning, presence of isoagglutinins like anti Rh factor	**General signs of anemia** **RBCs are normocytic.**
Hemorrhagic anaemia	Blood loss due to accident or cut, internal hemorrhage	**General signs of anemia +** Iron deficiency **RBCs are normocytic.**

3.2.Transport of blood gases:

Exchange of respiratory gases (O_2 and CO_2) takes place between the alveoli of lungs and the blood, blood and the tissue. Gaseous exchange occurs through ***bulk flow diffusion***.

3.2.1.Transport of oxygen: Transport of O_2 occurs from atmospheric air into tissues in three stages:

i) Diffusion of oxygen from atmospheric air into alveoli: Partial pressure of oxygen in the atmospheric air is 159 mm Hg and in the alveoli, it is 104 mm Hg. Because of from atmospheric air into the alveoli.

ii) Diffusion of oxygen from alveoli into blood: Partial pressure of oxygen in the pulmonary capillary is 40 mm Hg and in the alveoli, it is 104 mm Hg. Pressure gradient is 64 mm Hg. It facilitates the diffusion of oxygen from alveoli into the blood.

iii) Transport of oxygen from blood into tissues: Oxygen is transported from alveoli to the tissue by blood in two forms:

- *As physical solution:* Oxygen dissolves in water of plasma and is transported in this ***physical form.*** Amount of oxygen transported in this way is very negligible *i.e.*, only 0.3 ml/100 ml of plasma.
- *In combination with hemoglobin:* Oxygen combines with hemoglobin in blood and is transported as ***oxyhemoglobin.*** Transport of oxygen in this form is important because, maximum amount (97%) of oxygen is transported by this method.

Salient features of oxygen transport:

- Oxygen combines with hemoglobin only as a physical combination. It is only **oxygenation** and not **oxidation.**
- Oxygen can be readily released from hemoglobin when it is needed partial pressure of oxygen in the blood is more. Hemoglobin gives out oxygen whenever the partial pressure of oxygen in the blood is less.
- Oxygen combines with the iron (Fe^{2+}) in heme part of hemoglobin.
- Each molecule of hemoglobin contains 4 atoms of iron.
- One gram of hemoglobin combines with 1.34 ml of oxygen.
- ***Increase in partial pressure of carbon dioxide helps in extraction of oxygen from the oxyhemoglobin*** (***Bohr effect***).
- Presence of ***2,3-bisphosphoglycerate*** (***2,3-BPG***) in RBC also helps in extraction of oxygen from oxyhemoglobin.
- CO binds to the heme group of the hemoglobin molecule at the same site as O_2 with 200 times greater affinity and thus decreases O_2 transport.

3.2.2.Transport of carbon dioxide: Transport of CO_2 occurs from tissues into atmospheric air

i) Transport of carbon dioxide from tissues into blood: Carbon dioxide produced into tissues as a byproduct of TCA cycle, hence is highly concentrated into tissue. CO_2 diffuses easily from tissue cells into plasma by passive diffusion and is transported by the blood into two forms:

- *As physical solution:* Only 3 ml/100 ml of plasma of carbon dioxide is transported as dissolved state. It is about 7% of total carbon dioxide in the blood.
- *As bicarbonate:* About 63% of carbon dioxide is transported as bicarbonate. From plasma, carbon dioxide enters the RBCs. In the RBCs, carbon dioxide combines with water to form carbonic acid by ***carbonic anhydrases***. Carbonic acid is very unstable and readily dissociates into bicarbonate and hydrogen ions. Bicarbonates are transported as sodium bicarbonate into plasma.

ii) Diffusion of carbon dioxide from blood into alveoli: Partial pressure of carbon dioxide in alveoli is 40 mm Hg whereas in the blood it is 46 mm Hg hence diffuses from blood into the alveoli.

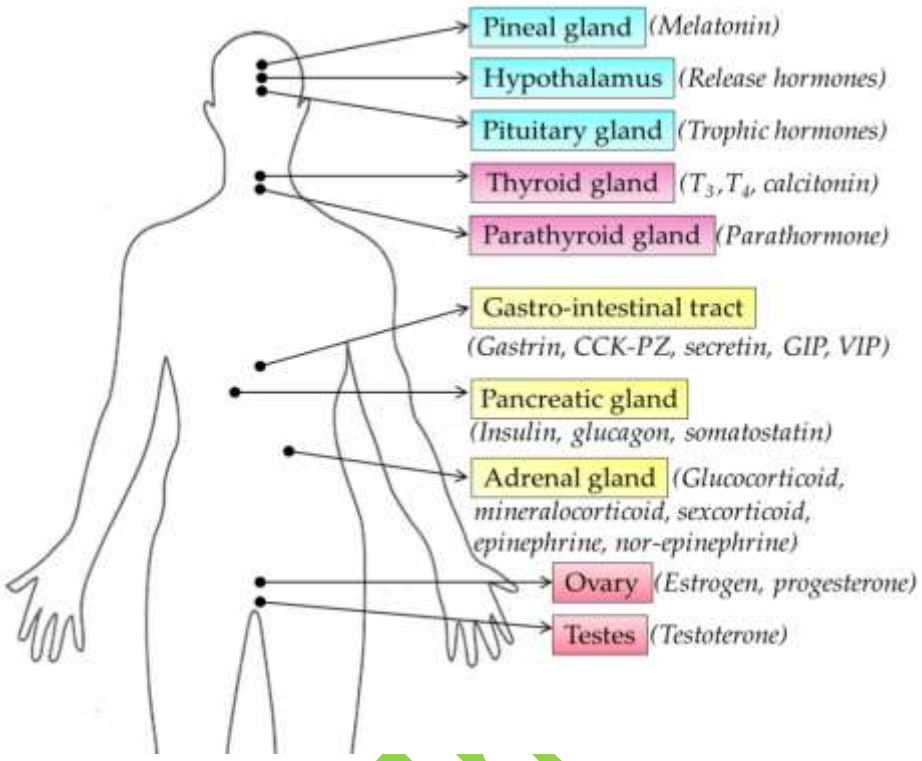
iii) Diffusion of carbon dioxide from alveoli into atmospheric air: In atmospheric air, partial pressure of carbon dioxide is very insignificant and is only about 0.3 mm Hg whereas, in the alveoli, it is 40 mm Hg. So, carbon dioxide enters passes to atmosphere from alveoli easily.

Salient features of carbon dioxide transport:

- Most of the CO_2 transported from tissues via plasma in form of HCO_3^- which comes out of the RBCs in via ***chloride shift***.
- Near the lungs HCO_3^- again enters into RBCs via ***reverse chloride shift*** to form CO_2 again.
- ***Oxygenation of hemoglobin helps in transport of carbon dioxide.*** It was first described by ***John Scott Haldane*** in 1860, hence is known as ***Haldane effect***.

3.3.Hormones and their important functions:

3.3.1.Definition: ***Hormones are chemical substances synthesized and secreted from specific cells or tissues (endocrine glands), which act on their specific receptors located at their target cells, and alters various physiological functions like metabolism, homeostasis etc. Hormones*** are chemical substances synthesized and secreted from specific cells or tissues (***endocrine glands***). When hormone released by an endocrine gland acts on same gland or nearby gland, it is called ***paracrine secretion***. If hormones are acting on neighboring cells then it is a ***juxtacrine secretion*** and if acting on the same cell from which it has been secretion then it is termed ***autocrine secretion***.



3.3.2.Pituitary hormones: Pituitary is known as '*master gland*' for its control over major endocrine glands in our body. The control of pituitary over many other endocrine glands is established by the hormones released from anterior part of pituitary, which are known as ***'stimulating hormones'***. However, there is another part of CNS, hypothalamus, controls secretion of stimulating hormones by pituitary, hence is known as '*master of master gland*' and the hormones released from hypothalamus that control secretion of stimulating hormones are known as ***'release hormones'*.**

Release hormone secreted from hypothalamus	**Target cell on anterior pituitary**	**Stimulating hormone secreted from anterior pituitary**	**Target gland**	**Final bioactive hormone**	**Hormonal axis**
GHRH	Somatotrophs	**GH**	Liver	**Somatomedins**	Hypothalamo-hypophysial hepatic axis
Soamtostatin	Somatotrophs	**GH** (decreased)	-	-	-
	Thyrotrophs	**TSH** (decreased)	-	-	-
TRH	Thyrotrophs	**TSH**	Thyroid	**T_1, T_2, T_3, RT_3,T_4**	Hypothalamo-hypophysial thyroid axis
	Mammotrophs	**PRL**	Mammary gland	-	-
Dopamine	Mammotrophs	**PRL** (decreased)	-	-	-
GnRH	Gonadotrophs	**FSH, LH**	Gonads (ovary or testes)	**Estrogen, progesterone, testosterone**	Hypothalamo-hypophysial gonadal axis
CRH	Corticotrophs	**ACTH**	Adrenal gland	**Glucocorticoid Mineralocorticoid Sex corticoids**	Hypothalamo-hypophysial adrenal axis

***GHRH:** *growth hormone release hormone*; **GH:** *growth hormone*; **TRH:** *thyroid release hormone*; **TSH:** *thyroid stimulating hormone*; **PRL:** *prolactin*; **GnRH:** *gonadotropin release hormone*; **FSH:** *follicle stimulating hormone*; **LH:** *leutinizing hormone*; **CRH:** *corticotropin release hormone*; **ACTH:** *adrenocorticotrophic hormone.*

Since hypothalamus is a part of CNS, it has no glandular secretory cells, rather it contains neurons. Hence the *release hormones* from hypothalamus are actually synthesized and secreted by neurons, and are known as ***neurohormones***. The neurons of hypothlamus that synthesize and secrete neurohormones are called ***neurosecretory neurons***. Posterior pituitary has no glandular cells hence do not synthesize hormones; however neurosecretory neurons from *supraoptic nucleus* and *paraventricular nucleus* of hypothalamus extend from hypothalamus through posterior pituitary and secretes two important neurohormones; such two neurohormones are said to be posterior pituitary hormones, *i.e.*, **ADH** or **AVP** and **oxytocin**.

Part of the hypothalamus	Name of hormone	Physiological function	Associated diseases
Supraoptic nucleus	**ADH or AVP**	Regulation of body fluid osmolality, regulation of blood pressure	**Diabetes insipidus** (at low ADH); **ADH excess syndrome** (at high ADH)
Paraventricular nucleus	**Oxytocin**	Regulation of parturition and milk ejection	

***ADH:** *anti-diuretic hormone*; **AVP:** *arginine vasopressin*

3.3.3.Adrenal hormones: It is so called because of its anatomical location; adrenal gland is small gland adjacent to the renal tissue kidney. The cortical and medullary parts of adrenal gland synthesize and secrete few physiologically important hormones.

Part of the adrenal gland	Name of hormone	Physiological function	Associated diseases
Adrenal cortex	**Glucocorticoid**	Regulation of carbohydrate, fat, protein and mineral metabolism; resistance of stress	**Cushing syndrome** (at high glucocorticoid); **Addison's disease** (at low glucocorticoid)
	Mineralocorticoid (or aldosterone)	Regulation of Na^+, K^+, and H^+ Raises blood pressure by reabsorption of Na^+	**Hyperaldosteronism** (at high aldosterone); **Addison's disease** (at low aldosterone)
	Sexcorticoid	Regulation of sexual functions	**Adrenogenital syndrome** (at high sexcorticoid); **Addison's disease** (at low sexcorticoid)
Adrenal medulla	**Epinephrine or adrenaline**	Plays crucial role in oxygen consumption, carbohydrate and fat metabolism, increases RBC count, increases heart rate and contractility of heart, increases systolic blood pressure	-
	Norepinephrine or noradrenaline	Regulates metabolism, functionality of heart, acts as a potent vasoconstrictor, increases both SBP and DBP	-

3.3.4.Thyroid hormones: Thyroid gland is a bilobed glandular organ that remains connected to the pharynx by a thyroglossal duct, lying over the trachea at a position just below cricoid cartilage. The functional units of thyroid gland are thyroid follicles, each of which consists of cuboidal epithelium arranged in a single layer surronding a lumen that contains colloid material.

The follicular cells are source of ***thyroid hormone biosynthesis*** and the so called *clear cells* (*C cells*) present within follicular wall and extracellular spaces in between the follicles are source of ***calcitonin*** or ***thyrocalcitonin***.

Wolf-Chaikoff effect is a phenomena in which dietary excess in iron leads to hyperthyroidism.

Cell of thyroid gland	Name of hormone	Physiological function	Associated diseases
Follicular cells	**Thyroid hormones**	Thermogenic action and regulation of body temperature, helps in growth and development	**Hypothyroidism** with **Myxedema** and **Cretinism** (at low thyroid hormone level); **hyperthyroidism** (at high thyroid hormone level)
Parafollicular or Clear (C)-cells	**Thyrocalcitonin**	Prevents hypercalcemia, helps in mineralization of bone,	**Osteopenia** (at low thyrocalcitonin)

3.3.5.Pancreatic hormones: It is so called because of its anatomical location; adrenal gland is small gland adjacent to the renal tissue kidney. The cortical and medullary parts of adrenal gland synthesize and secrete few physiologically important hormones.

Cell of pancreas	Name of hormone	Physiological function	Associated diseases
α-cells	**Glucagon**	Increases blood sugar level, gluconeogenesis, adipose tissue lipolysis, ketogenesis	**Hypoglycemia** (at low glucagon); **hyperglycemia** (at high glucagon)
β-cells	**Insulin**	Decreases blood sugar level, increases protein synthesis, adipose tissue lipogenesis	**Hyperglycemia** and **diabetes mellitus** (at low insulin); **hyperinsulinism** (at high insulin)
δ-cells	**Somatostatin**	Inhibits synthesis of insulin and glucagon	-

3.4.Nervous system:

3.4.1.Neurons, nerve fibers and nerves: ***A neuron is the structural and functional unit of nerves and nervous system***. There are about 10^{11} neurons in the central nervous system.

Structure of neurons:

A neuron has three basic parts, *i.e.*, cell body known as soma, and two types of extended parts called dendrons and axons.

a) Cell body or soma: The cell body of a neuron is composed of following structural elements –

i) Cell membrane: This encloses the cytosol of neurons.

ii) Nucleus: This large, spherical or ovoid structure contains nucleoli and bar bodies.

iii) Nissl granules: These are basically ribonulceoproteins found in cell body and dendrons and are involved in synthesis of proteins and probably involved in conduction of nerve impulses.

iv) Neurofibrils: These are thin filament like structures that passes through cell body, are extended from dendrons to the axon and are formed of microfilaments.

v) Mitochondria: These are rod shaped organelles that are involved in synthesis of ATP.

vi) Inclusion bodies: Contains melanin, secretory materials and metallic copper, and are stained by lipochrome and lipofuchsin.

vii) Centrosomes: Only found in neurons of embryonic stage.

Apart from these, all protein synthesizing organelles are found in soma, *e.g.*, ***ribosomes***, ***Golgi apparatus*** and ***endoplasmic reticulum***.

b) Dendrons and dendrites: These processes are usually numerous in numbers, but may also be just a single in few cases. These carry nerve impulses from preceding neuron to soma of the next neuron in form of ***electrotonic potential*** (not in form of ***action potential***).

c) Axons: Axons are long processes of cell body which arise from the axon hillock. Many of the axons in peripheral nervous system are covered by ***myelin sheath*** (lipid rich layer) made up from ***Schwann cells*** (in PNS) or ***glial cells*** (in CNS). The axons are formed of a tube like structure surrounded by the cell membrane of cell bodies, called ***axolemma***, and its interior is continuous with cytoplasm of cell body which is called ***axoplasm***. The axons divide to form axon terminals, which are enclosed with knob like structures at the tip. Axons carry nerve impulses from the cell body towards another neuron in the form of an *action potential* generated in the initial segment of the axon as the threshold potential is lowest in this part.

The axon filament of one neuron is called a ***nerve fiber;*** on the other hand a bunch of nerve fibers from multiple neurons is called a ***nerve*** or ***tract***. If nerve fibers are unmyelinated the bunch is called ***nerve;*** on contrary if nerve fibers are myelinated the bunch is called ***tract***.

3.4.2.Synapses: ***A synapse is a specialized structure formed at the junction of neuroneuronal junctions (where the preceding neuron ends and the other neuron starts) through which the information in form of a nerve impulse travels from one neuron to another neuron.*** Under electron microscope it is seen that pre-synaptic fibres end in an expanded terminal called – ***synaptic knob***. The synaptic knob and soma each has an intact membrane. The membrane of synaptic knob from preceding neuron is called ***pre-synaptic membrane***, and the membrane of next neuron is called ***post-synaptic membrane***. The synaptic knobs are separated from post-synaptic region by cleft like structures having a width of approximately 200 Å. There are many parallel intersynaptic filaments of about 50 Å that crosses the synaptic cleft – ***canaliculi***. These filaments are fixed at both ends. In case of post-synaptic region there is a web of canaliculi implanted on the post-synaptic membrane that are extended at a considerable distance in post-synaptic cytoplasm. The pre-synaptic region (or synaptic knob) contains many mitochondria which probably takes part in synthesis of neurotransmitters. The pre-synaptic region also contains some vesicles (***synaptic vesicles***) filled up with neurotransmitters. These vesicles are more concentrated near the ***synaptic cleft***. Post-synaptic membrane contains specific receptors for neurotransmitters.

Synaptic transmission:

When an action potential arrives at the pre-synaptic region traveling down the *synaptic knob* it depolarizes the pre-synaptic membrane. This local depolarization opens up ***voltage gated Ca^{2+} channels*** present on the pre-synaptic membrane. Since $[Ca^{2+}]$ is high in ECF, Ca^{2+} rushes inside the synaptic knob as soon as the AP is arrive, down its concentration gradient.

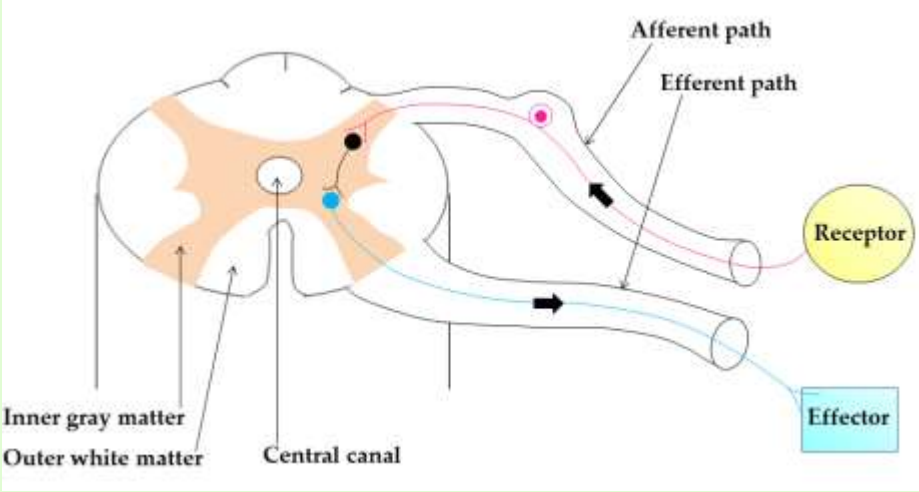
This Ca^{2+} is pre-requisite for fusion of synaptic vesicles containing neurotransmitters with the pre-synaptic membrane, which is followed by discharge of neurotransmitters from synaptic vesicles. Exocytosis of the synaptic vesicles releases neurotransmitters within the *synaptic cleft* which diffuse towards post-synaptic region to bind their specific molecular receptors. Binding of neurotransmitters with their specific receptors on postsynaptic membrane may lead to –

- Either *rapid depolarisation*, thereby generating an action potential which travels down the post-synaptic membrane, and is called ***excitatory post-synaptic potentiation*** (***EPSP***). EPSP is seen in case of ***excitatory neurotransmitters***, *e.g.*, ***acetylcholine, glutamate*** etc.
- Or, hyperpolarisation of membrane so that membrane potential becomes more negative and action potential is not generated which inhibits propagation of nerve impulse. Hence it is also called ***inhibitory post-synaptic potentiation*** (***IPSP***) and seen in case of ***inhibitory neurotransmitters*** such as ***GABA, glycine*** etc.

3.4.3.Reflex action: The term '*reflex*' refers to an involuntary effector response due to application of a sensory stimulus. ***A reflex action is an autonomic and reproducible effector response to a sensory stimulus with the involvement of central nervous system (CNS).***

Reflex arc:

Reflex arc refers to the path through which a reflex action takes place. A reflex arc is composed of – a ***receptor***, the ***afferent path***, a ***centre***, the ***efferent path***, the junction with target organ and the ***effector*** organ.



a) *Receptor:* It receives sensory stimulus and converts (or transduce) it into ***generator potential***, thus producing nerve impulse in the sensory nerve connected to it.
b) *Afferent path:* It is made up of sensory nerves. It helps in conduction of nerve impulses to the reflex centre in form of action potential.
c) *Reflex centre:* It conceives the synapse through which the nerve impulse is transmitted to motor nerves.
d) *Efferent path:* It is made up of motor nerves. It helps in conduction of nerve impulse to the effector organ in the form of ***action potential***.
e) *Junction with the effector organ:* It is the part through which efferent impulses goes to the effector organ. In case of myoneural junction it is transmitted in form of an ***end plate potential*** and in other cases it is transmitted in form of ***graded potential***.
f) *Effector organ:* It is the organ which shows the reflex action. It may be either a group of muscle fibers or a gland which shows reflex action by contraction or secretion respectively.

3.4.4.Difference between central nervous system and peripheral nervous system:

	Central nervous system	Peripheral nervous system
Extent and major components	Brain, brainstem and spinal cord constitute the central nervous system	On the other hand the nerves that originate from brain and spinal cord
Covering	The CNS is enclosed with a special connective tissue – *meninges*	There is no such definite coverings
Myelination	Neurons are usually unmyelinated ; however in few cases oligodendroglia may form protective covering around the axons	Neurons are myelinated by Schwann cells
Speed of impulse conduction	Conduction of nerve impulse occurs at low to moderate speed	Conduction of nerve impulse occurs at high speed

Unit-IV: Applied Physiology

Hematology: Definition, ABO and Rh Blood group system. Precautions of blood transfusion, Concept of Blood Bank.
Microbiology and Immunology: Types of microbes, Beneficial and harmful bacteria with examples. Definition of Antigen and Antibody and Antibiotic and Vaccine with examples.
Biotechnology: Outline concept and its modern applications.
Basic concepts of Ergonomics and its importance in occupational health.
Sports and Exercise Physiology: Physical fitness. Classification of sports, Basic concept of anthropometry.
Application of statistics in biological science: Basic concept of population biology and Sample.

4.1.Hematology:

Hematology is the study of etiology, symptoms and treatment of diseases associated with blood.

4.1.1.Blood grouping systems: To date more than twenty different blood group systems have been introduced since the discovery of first blood group system (*i.e.*, ABO system) by Karl Landsteiner in year 1900.

ABO system of blood grouping: According to Karl Landsteiner we have four groups in this system depending on the presence or absence of a specific membrane bound antigen on the surface of RBCs.

Blood group	Antigen	Antibody
A group	A antigen	Anti B or β antibody
B group	B antigen	Anti A or α antibody
AB group	Both A and B antigen	None
O group	None	Both α and β antibody

The blood group antigens, A and B antigens are surface glycoproteins of RBCs that are produced from a basic precursor substance (**H-substance** or **H-antigen**) by the enzyme ***N-acetyl galactosmainyl transferase*** (for formation of **A-antigen**) and ***galactosyl transferase*** (for formation of **B-antigen**). Both of these A and B antigens have compatible antibodies that agglutinate them (***hemagglutination***), known as ***α*** and ***β-antibodies***, which belong to ***IgM class of antibodies***. Now, the rule is a person who carries RBCs with a specific antigen in blood do not contain antibody for the same, *i.e.*, A-group person carries A-antigen hence do not carry α-antibody, rather contain β-antibody; on the other hand a person deficient in the A or B antigen must carry the compatible antibody. This is known as ***Landsteiner's law***.

Rh system: The antigen of this group was first discovered in Rhesus monkeys hence is called ***Rh-antigen*** (***D-antigen***). Later it was also detected in human and was compiled with ABO system for determination of blood group. The peculiarity of this Rh antigen is that it has no known naturally occurring antibody against it, however if introduced into a Rh negative person it can generate Rh antibody against it which is known as anti-D antibody. Compilation of ABO system and Rh system gives eight blood groups, *e.g.*, A+, A-, B+, B-, AB+, AB-, O+ and O-. Among these groups AB+ and AB- is known as ***universal recipient*** because it has no antibody, on the other hand O- is claimed to be ***universal donor***, because it has no antigen.

4.1.2.Blood transfusion: Blood transfusion is the process of transferring blood or blood components from one person (the donor) into the bloodstream of another person (the recipient). Transfusion is

done as a ***life-saving procedure*** to replace blood cells or blood products lost through bleeding. Blood transfusion is essential in following conditions:

i) Anaemia
ii) Hemorrhage
iii) Trauma
iv) Burns
v) Surgery

Precautions for blood transfusion: ***Autologous blood transfusion*** is the collection and reinfusion of patient's own blood. It is also called ***self-blood donation.*** The conventional transfusion of blood that is collected from persons other than the patient is called ***allogeneic*** or ***heterologous blood transfusion.***

a) Precautions to be taken before the transfusion of blood:

i) Donor must be healthy, without any diseases like sexually transmitted diseases (STDS) such as syphilis and viral diseases *e.g.*, hepatitis, AIDS.
ii) Only compatible blood must be transfused
iii) Both matching and cross-matching must be done
iv) Rh compatibility must be confirmed.

b) Precautions to be taken while transfusing blood:

i) Apparatus for transfusion must be sterile
ii) Temperature of blood to be transfused must be same as the body temperature
iii) Transfusion of blood must be slow. The sudden rapid infusion of blood into the body increases the load on the heart, resulting in many complications.

4.1.3.Blood bank: Blood collected from a person can be preserved for a long time, and the process of preservation of blood is called ***blood banking***. For preservation in future transfusion blood is mixed with either ***acid-citrate-dextrose*** (**ACD**) buffer or ***citrate-phosphate-dextrose-adenine*** (**CPDA**) buffer. Stored blood is not suitable for transfusion of WBCs or platelets, hence is solely preserved for RBCs.

4.2.Microbiology and Immunology:

4.2.1.Types of microbes: Microorganisms are classified into two groups, *i.e.*, ***acellular*** and ***cellular***.

a) **Acellular microorganisms:** Acellular microorganisms are further classified into two groups- ***viruses*** and ***prions***.

i) *Viruses:* These are infectious microorganisms that behave as inert entities outside of a host cell, however are capable of replicate faster inside of a host cell.
ii) *Prions:* These are not complete organisms, rather are proteinaceous infectious substances.

b) **Cellular microorganisms:** Cellular microorganisms are classified into ***prokarya and eukarya.***

i) *Prokarya:* These are non-nucleated microorganisms, which are classified into:

- *Archea:*
- *Actinobacteria:*
- *Cyanobacteria:*
- *Eubacteria:*

ii) *Eukarya:* These are microorganisms that contain well developed nucleus, *i.e.*, nucleus with nuclear membrane which are classified into:

- ***Microalgae:***
- ***Microfungi:***
- ***Protozoa:***

4.2.2.Beneficial and harmful bacteria: Not all bacteria are harmful, some are beneficial as well. Beneficial bacteria that offer us many advantages include *Lactobacillus acidophilus*, *Bifidobacteria bifidum*, *Streptococcus thermophilus* etc. Harmful bacteria on the other hand produce serious diseases, such as *Vibrio cholerae*, *Salmonella typhi*, *Bordatella pertussis* etc.

4.2.3.Antibodies: ***These are glycoproteins synthesized and secreted by plasma cells (differentiated form of B-lymphocytes) that exists as monomer, dimer, trimer or pentamer of immunoglobulin units which interacts with specific soluble or membrane bound antigen and participates in several immunological reactions, such as precipitation, agglutination, opsonization, cytolysis etc.*** Antibodies are classified into five classes based on their light chain and heavy chain composition:

	Light chain	Heavy chain	% in plasma	Mode of action
IgA	κ, λ	α_1, α_2	12%	Precipitation
IgD	κ, λ	Δ	1%	Receptor of antigens
IgE	κ, λ	E	0.001%	Anaphylactic reaction
IgG	κ, λ	γ_1, γ_2, γ_3, γ_4	80%	Precipitation, opsonization, lytic reaction, antitoxic effects
IgM	κ, λ	μ_1, μ_2	7%	Agglutination and lytic reaction

4.2.4.Antigens: ***Antigens refer to a wide variety of molecules which are usually foreign to the body (self-antigens are also present) and can mount immune response of varying degrees on being introduced to the body***. Biochemically an antigen may be a carbohydrate or protein or lipid and even a nucleic acid in nature. It should also be noted that the whole structure of an antigenic substance may not be capable of showing antigenic properties; in such cases relatively small fractions of those large molecules show antigenic properties, which are known as ***epitopes***. On the other hand the part of an immunoglobulin molecule that interacts with an antigen is called ***paratope***.

4.2.5.Antibiotics: ***Antibiotics are organic antibacterial substances isolated from microbes that are capable of killing or inhibiting the growth of other bacteria***. Examples include *penicillin and its derivatives*, *vancomycin*, *carbapenem*, *imipenem* and *cephalosporins*.

4.2.6.Vaccines: ***A vaccine is a mixture of a particular antigen or part of a microorganism with complete or incomplete Freund's adjuvant that helps to build up adaptive immunity in body prior to an infection to combat various diseases.*** Examples include polio vaccine, pox vaccine etc.

4.3.Biotechnology and its applications:

Biotechnology is an applied branch of science that bridges biological science with modern technology as an integrated approach of both.

Applications: The knowledge of biotechnology is applied in a vast area of today's world –

i) To improve quality and quantity of crops in agriculture
ii) Gene mapping and human genome project
iii) Bioremediation technologies to combat environmental pollution
iv) Cloning of genes and large scale production of proteins
v) Bioinformatics tools provide better understanding about unknown proteins, protein-protein interactions and many more in field of research and analysis.

4.4.Ergonomics and its importance in occupational health:

Ergonomics *(Greek 'ergon' means energy and 'nomos' means number)* ***refers to the branch of science that deals with human interaction with different elements in a particular environment and profession. Ergonomics helps to design tools for optimizing human well-being and human performance in a particular environment.*** Ergonomics has profound importance in occupational health:

i) Design the workplace to optimize human performance, *i.e.*, design of chair, computer table, working table and everything.
ii) The occupational therapists in industry provide an ergonomic assessment that specifically define a problem, formulate goals based on the needs and identifies individualized interventions to correct the problem.
iii) Helps to prevent musculo-skeletal disorders (MSD) among the workers.

4.5.Sports and exercise physiology:

4.5.1.Physical fitness: ***Physical fitness in sports and exercise physiology refers to a set of attributes that provide an individual with the abilities to perform physical activity.*** The components of physical activity are – speed, endurance, strength, flexibility and agility.

4.5.2.Classification of sports: In context to physiology different types of sports has been classified into nine groups based on the variation in ***static*** and ***dynamic component*** intensity. The static component is measured in form of ***maximum voluntary contraction*** or **MVC**, which represents the muscular strength and dynamic component is measured as ***VO_{2max}***, the maximal oxygen consumption during a sport activity. The nine groups are –

i) **Low MVC-Low VO_{2max} group:** Billiard, Golf, Bowling, Cricket
ii) **Low MVC-Moderate VO_{2max} group:** Baseball, Table tennis, Volleyball
iii) **Low MVC-High VO_{2max} group:** Badminton, Soccer, Long tennis
iv) **Moderate MVC-Low VO_{2max} group:** Archery, Diving, Motorcycling
v) **Moderate MVC-Moderate VO_{2max} group:** Rugby, Jumping, Sprinting
vi) **Moderate MVC-High VO_{2max} group:** Basketball, Swimming
vii) **High MVC-Low VO_{2max} group:** Weightlifting, Gymnastics, Judo
viii) **High MVC-Moderate VO_{2max} group:** Wrestling, Snowboarding, Skateboarding
ix) **High MVC-High VO_{2max} group:** Boxing, Rowing, Cycling

4.5.3.Basic components of anthropometry: Anthropometry is the quantitative study of dimensions with respect to the human body. Anthropometric data provide information about health and development status, nutritional status, risk of diseases etc. The basic components of anthropometry are – ***body weight, body height, skin fold thickness, arm span, knee height, sitting height, chest circumference, waist hip ratio*** etc. All these basic anthropometric measurements can be combined with each other or with other informations to calculate various anthropometric indices such as-

i) ***BMI or body mass index***: Weight/Height^2 in kg/m^2
ii) ***Ponderal index:*** (Weight/Height^3) x 100 in kg/m^3
iii) ***Fat mass index:*** Fat mass/Height^2 in kg/m^2
iv) ***Fat free mass index:*** Lean body mass/Height^2 in kg/m^2

4.6.Biostatistics:

Biostatistics is the branch of biological science that study methodology for collection, systematic analysis, interpretation and presentation of biological data obtained from experiment. Biostatistics is applied to draw conclusions and to establish hypothesis regarding various biological phenomenon.

4.6.1.Population and sample: In statistics population refers to ***a large widespread group or a huge number of individuals, cases or events that can be expressed as variables under investigation in an experiment, test or survey.*** Population is categorized into two types ***infinite population*** (*a population in which all members cannot be counted*) and ***finite population*** (*a limited population in which all members can be precisely counted*). On the other hand sample refers to ***a relatively small group or members (individuals, cases, events etc) chosen from a large population for a particular study, experiment which represents entire population***.

4.6.2.Parameter and statistic: ***In statistics a parameter is a numerical value or index of all scores of a variable,*** *e.g.,* mean, median, mode**.** On the other hand ***statistic refers to summary value or numerical index that has been worked out from the scores of a variable estimating the parameter of the population***, *e.g.,* standard deviation standard error etc.

Unit-V: Common Diseases and Patho-physiological significance

Prevailing global communicable and non-communicable diseases, their primary causes and suggested measures: Influenza, Tuberculosis, Hepatitis, COVID-19, Diabetes mellitus, Haemophilia, Thalassaemia, COPD, Heart failure, Stroke, Hypothyroidism, Obesity. Pathophysiological tests, their normal range in the system and indicative diseases: TC, DC, ESR, Arneth Count, Fasting and Post-prandial blood sugar tests, Glycosylated haemoglobin, Bilirubin, Urea, Uric acid, Creatinine, SGOT, SGPT, Alkaline Phosphatase, Acid Phosphatase.

5.1.Communicable and non-communicable diseases:

Diseases are categorized into communicable and non-communicable classes. ***A communicable disease is that which is transmitted from one person to another.*** Diseases which are caused by pathogens belong to this category, *e.g.*, HIV-AIDS, influenza, tuberculosis etc.

On the other hand ***diseases which are caused by unhealthy lifestyles, genetics and environmental factors does not spread from one individual to another, hence are called non-communicable diseases.*** Examples include obesity, cancer, COPD.

Disease	Type of disease	Primary causes	Disease prevention
Influenza	Communicable, infectious (viral) disease(***unpredictable sudden epidemics)*** that affect lung and airways	Influenza viruses (*e.g.*, **H_3N_2, H_1N_1, H_2N_2, H_5N_1**)	• Social distancing • Maintenance of hand hygiene and standard of sanitization • Cough etiquette • Use of protective barriers • Vaccination
Tuberculosis	Communicable, infectious (bacterial) disease that affect lung and airways	***Mycobacterium tuberculosis***	• Maintenance of general hygiene, *i.e.*, use of surgical masks and sanitization • Good ventilation • Use of anti-TB drugs, such as rifampin, pyrazinamide, ethambutol
Hepatitis	Communicable, infectious (viral) disease that affect liver leading to hepatic inflammation	Hepatitis viruses (**hepatitis A, hepatitis B, hepatitis C, hepatitis D, and hepatitis E**)	• Safe drinking water supplies • Good standard of sanitization • Maintenance of food hygiene • Vaccination
COVID-19	Communicable, infectious (viral) disease that affects lung and airways, gut	SARS-CoV-2 viruses (**α, β, γ, δ, κ, μ and λ**)	• Social distancing • Maintenance of hand hygiene and standard of sanitization • Use of surgical masks • Vaccination
Diabetes mellitus	Non-communicable disease that affects a number of organs and body parts in a non-specific way	**Type I DM:** Autoimmune destruction of β-cells of pancreas **Type II DM:** Insulin resistance due to overweight and obesity and other factors including environmental influence	• Maintenance of body weight (BMI between 21-23 kg/m^2) • Physical activity and exercise • Less consumption of refined carbohydrates, high-saturated fat • Increased consumption of MUFA and PUFA and complex carbohydrates like dietary fibres (green leafy vegetables, fruits, pulses, fenugreek seeds

			are good sources of dietary fibres) • **Human Insulin injection**
Haemophilia	Non-communicable disease that affects blood coagulation system leading to life threatening conditions	**Hemophilia A:** Deficiency of factor VIII **Hemophilia B:** Deficiency of factor IX **Hemophilia C:** Deficiency of factor XI	• Replacement of clotting factors which are deficient • Clinical approach that aims to treat prolonged bleeding and associated bone and muscle damage via medicine
Thalassaemia	Non-communicable disease that affects synthesis of hemoglobin	**α thalassaemia major:** Decreased synthesis of α-chain **α thalassaemia minor:** α-chain synthesis is slightly affected **β thalassaemia major:** Decreased synthesis of α-chain **β thalassaemia minor:** β-chain synthesis is slightly affected	• Blood transfusion • Folic acid supplementation • Stem cell therapy • Bone marrow transplant • Gene therapy
COPD	Non-communicable disease that affects lung and airways (chronic inflammation in respiratory tract and emphysema)	Indoor and outdoor air pollution, **CO poisoning**, bacterial infection (pneumonia)	• Improved ventilation • Use of modern fuels to prevent air pollution • Use of non-conventional energy sources, such as solar cooker, wind energy, biogas plants etc. • Use of antibiotics in case of infection and chronic inflammation
Heart failure	Non-communicable disease that affects cardiovascular health		• Use of diuretics • Use of drugs like β-blockers, SGLT2i, ARNIs, MRAs • Use of left ventricular assist device - a pacemaker • Heart transplantation • Changes in lifestyle
Stroke	Non-communicable disease that affects brain, heart	**Ischemic stroke:** Due to blockade of an artery **Hemorrhagic stroke:** Due to bleeding **Transient ischemic stroke:** Due to temporary blockade of small blood vessels	• Use of tissue plasminogen activator (tPA) • Acupuncture therapy • Yoga • Herbal supplements to improve neurological functions • Changes in lifestyle

		Brain-stem stroke: Due reduced blood supply to the brain stem **Cryptogenic stroke:** Due to unknown reason	
Hypothyroidism	Non-communicable disease that affects synthesis of thyroid hormone		• Consumption of levothyroxine • Low intake of sugar and dairy products • Low consumption of processed food • Vitamin B_{12} supplementation • Selenium supplementation
Obesity	Non-communicable disease that severely impacts cardiovascular and respiratory health	Physical inactivity, unhealthy food, overeating, harmful consumption of alcohol	• Changes in lifestyle • Increased physical activity and exercise • Strict dietary routine • Less consumption of junk food, avoidance of tobacco and alcohol • Body weight and BMI monitoring

5.2.Pathophysiological tests:

Various pathophysiological tests are conducted in pathological laboratories in order to find out presence of acute and chronic diseases based on assessment of some common parameters, *i.e.*, hematological parameters, quantity of biochemical substances in blood, urine, feces etc.

	Normal range	Physiological variation	Indicative diseases
TC	**Total RBC count:** 5-6 million/mm^3 blood	Rise in RBC count: **Polycythemia**	Thrombosis, peptic ulcer, myelofibrosis, acute leukaemia, myelosplastic syndrome
		Decrease in RBC count: **Anaemia**	Iron deficiency, bone marrow disorder, vitamin deficiency, iron deficiency, dengue, hemolytic disorders, hemorrhage
	Total WBC count: 4500-11,000 /mm^3 blood	Rise in WBC count: **Leucocytosis**	Chronic and acute infections, inflammation, leukaemia
		Decrease in WBC count: **Leucopenia**	-
DC	**Neutrophil:** 60-70%	Rise in neutrophil: **Neutrophilia**	Myocardial infarction, tissue injury, any kind of chronic inflammation
		Decrease in neutrophil: **Neutropenia**	Measles, typhoid
	Eosinophil: 1-4%	Rise in eosinophil: **Eosinophilia**	Allergy, parasitic infection
		Decrease in eosinophil: **Eosinopenia**	Bacterial infection
	Basophil: 0-1%	Rise in basophil: **Basophilia**	Allergy, chicken pox, influenza, ulcerative colitis
	Monocyte: 5-10%	Rise in monocyte: **Monocytosis**	Hodgkin's disease, Crohn's disease, rheumatoid arthritis, syphilis
	Lymphocyte: 25-30%	Rise in lymphocyte: **Lymphocytosis**	Tuberculosis, measles, chicken pox and various chronic infections

		Decrease in lymphocyte: **Lymphopenia**	HIV-AIDS
ESR	***Wintrobe tube method*** **Male:** 0 to 9 mm/hr **Female:** 0 to 15 mm/hr	High ESR	ESR increases in inflammation, multiple myeloma, hyperfibrinogenemia, tuberculosis, anaemia, malignant tumors, rheumatoid arthritis and systemic lupus erythematosus (SLE), rheumatic fever and liver diseases.
		Low ESR	ESR decreases in allergy, sickle cell anemia, polycythemia vera, leucocytosis. hypofibrinogenemia and severe leucocytosis
Arneth count	2-3 lobes/ neutrophil	High lobe number: **Older neutrophil**	Uraemia, Vitamin B_{12} deficiency
		Low lobe number: **Younger neutrophil**	-
Fasting blood-sugar	70-110 mg/dl	110-150 mg/dl: **Glucose tolerance** 150-180 mg/dl: **Hyperglycemia** >180mg/dl: **Glucosuria**	Rises in hyperglycemia, hypoinsulinism and diabetes mellitus
		<70 mg/dl: **Hypoglycemia**	Decreases in hypoglycemia, hyperinsulinism
Post-prandial blood-sugar	<140 mg/dl		Rises in hyperglycemia, hypoinsulinism and diabetes mellitus Decreases in hypoglycemia, hyperinsulinism
Glycosylated hemoglobin	4-8%		Rises in persistent hyperglycemia and diabetes mellitus
Billirubin	**Total:** 0.2-1.0 mg/dl **Conjugated:** <0.2 mg/ dl	Rise in billirubin: **Hyperbillirubinemia**	Rises in biliary obstruction, hemolytic anaemia, jaundice
Urea (serum/urine)	20-40 mg/dl	Rise in urea: **Uraemia**	Rises in diabetic coma, thyrotoxicosis, fever, acute glomerulonephritis, nephrosclerosis, polycystic kidney, enlargement of prostate
		Decrease in urea: **Hypouraemia**	Decreases in hepatitis, myxoedema, acidosis
Uric acid (serum)	**Male:** 3.5-7 mg/dl **Female:** 3-6 mg/dl	Rise in uric acid: **Hyperuricemia**	Rises in gout, leukaemia, eclampsia, polycythemia and febrile conditions
Creatinine	60-125 µmol/litre of serum	Rise in urea: **Hypercreatininemia**	Rises in nephritis and other renal diseases
SGOT	8-20 IU/litre		Rises in myocardial infarction, hepatocellular damage
SGPT	**Male:** 13-35 IU/litre **Female:** 10-30 IU/litre		Rises in infective hepatitis, liver cirrhosis, hepatic malignancy,
Serum alkaline phosphatase	40-125 IU/litre		Rise in bone diseases, ricketsae, osteomalacia, osteoblastoma, bone metastasis, Paget's disease, hyperparathyroidism, chronic obstructive jaundice, cholestasis, gall stone, viral hepatitis and liver cirrhosis
Serum acid phosphatase	2.5-12 IU/litre		Rises in prostate cancer

***TC:** *total count*; **DC:** *differential count*; **ESR:** *erythrocyte sedimentation rate*; **SGOT:** *serum glutamate-oxaloacetate transaminase*; **SGPT:** *serum glutamate pyruvate transaminase*