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HUMAN ANATOMY AND PHYSIOLOGY – I

UNIT 3

TOPIC :

- **Bodyfluids and blood**

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

Body Fluids

- Body fluids are the liquid substances found inside and outside the cells of the body that are essential for life processes. They help in transporting nutrients, removing waste, regulating temperature, lubricating organs, and maintaining internal balance (homeostasis).

Types of Body Fluids

Intracellular Fluid (ICF)

→ The intracellular fluid is the fluid that exists inside the cells. It constitutes approximately two-thirds of the total body fluid and plays a vital role in maintaining cell shape, internal environment, and metabolism.

Extracellular Fluid (ECF)

→ The extracellular fluid is the fluid found outside the cells, making up about one-third of the total body fluid. It is involved in transporting nutrients, hormones, and waste between cells and the bloodstream.

→ Divided into:

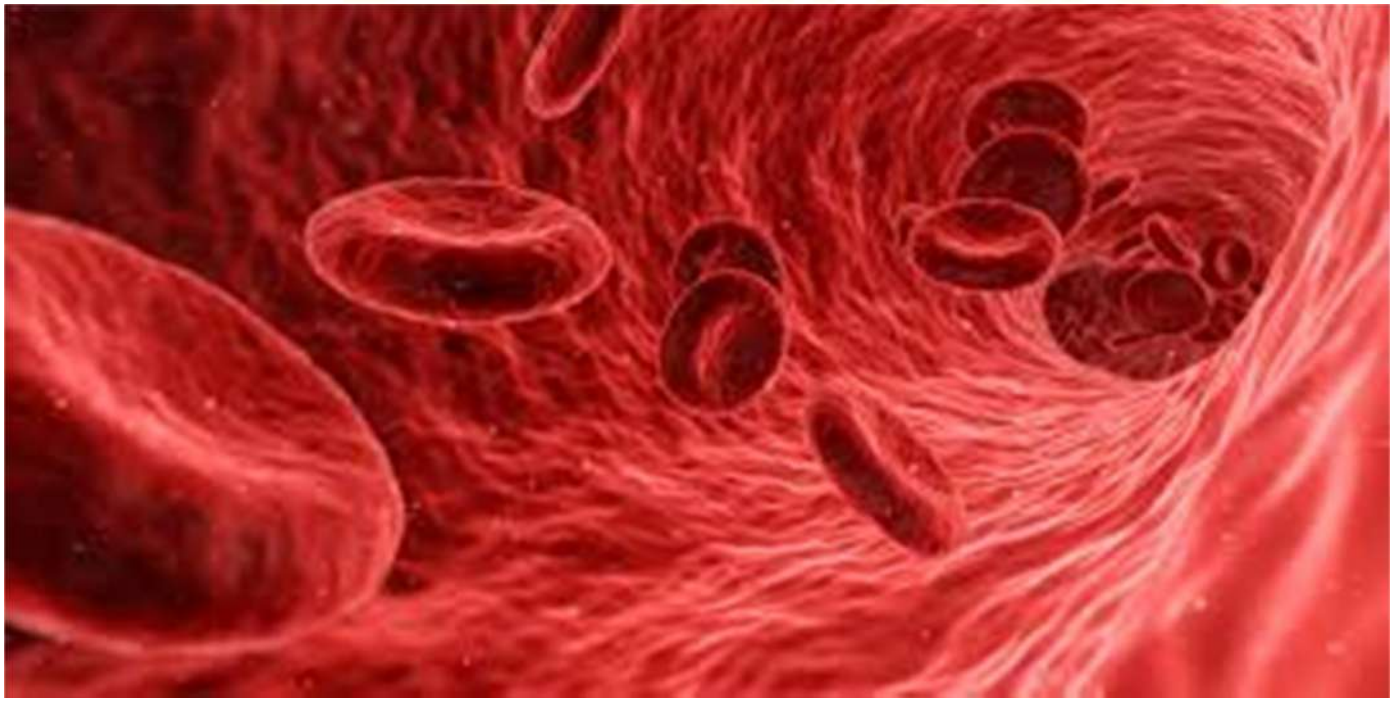
- Interstitial fluid (between tissue cells)
- Plasma (fluid part of blood)
- Lymph
- Cerebrospinal fluid (CSF)
- Synovial fluid (in joints)
- Aqueous humor (in eyes)

Functions of Body Fluids :

- Transport of oxygen, carbon dioxide, nutrients, and waste.
- Regulation of body temperature.
- Lubrication of joints and organs (e.g., synovial fluid, pleural fluid).
- Shock absorption (e.g., CSF protects the brain).
- Maintains acid-base balance and electrolyte balance.
- Supports cellular functions and chemical reactions.

Blood

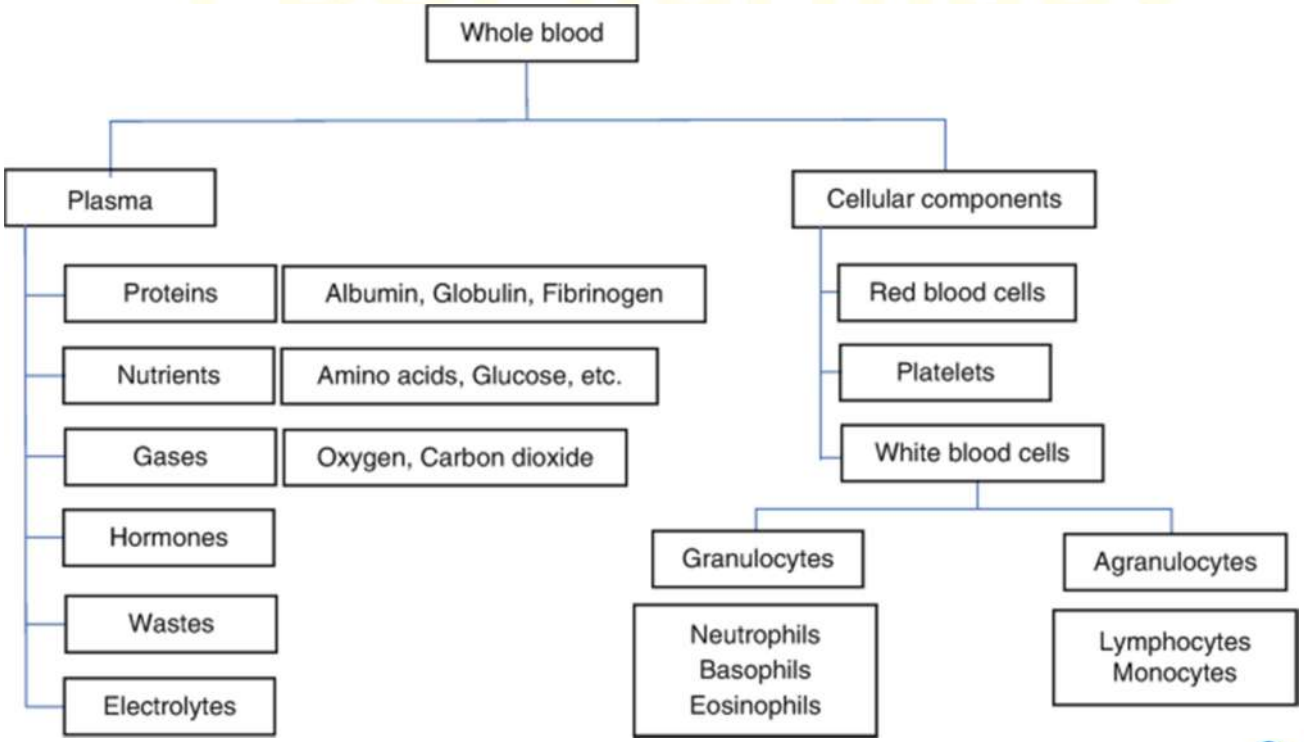
- Blood is a connective tissue that plays a vital role to carry various life processes and protects the body against diseases
- Haematology is the branch of medical science concerned with the study of blood, blood-forming tissues, and blood disorders.
- The system of organs and tissues, including the bone marrow, spleen, thymus and lymph nodes, involved in the production of cellular blood components is known as haematopoietic system.



Properties of Blood

- Color – Bright red (oxygenated) and dark red (deoxygenated).
- Volume – 5–6 L in males, 4–5 L in females.
- Viscosity – 3 to 5 times more viscous than water.
- pH – Slightly alkaline, between 7.35 and 7.45.
- Temperature – Approximately 38°C (100.4°F).
- Buffering Capacity – Maintains pH using buffers like bicarbonate and hemoglobin.
- Ionic Composition – Contains Na^+, K^+, Ca^{2+}, Cl^-, HCO_3^- for cellular functions.
- Coagulability – Capable of clotting through platelets and clotting factors.
- O_2 and CO_2 Transport – Carries oxygen via hemoglobin and CO_2 as bicarbonate.

Composition of Blood



Plasma (About 55%)

→ Plasma is the straw-colored, liquid part of blood that holds the blood cells in suspension and helps in the transport of nutrients, hormones, and waste products.

Components of Plasma

- **Water (90–92%)**
  - Acts as a solvent and medium for transport.
- **Plasma Proteins (6–8%)**
  - **Albumin**: Maintains osmotic pressure and transports substances.
  - **Globulin**: Includes antibodies for immune defense.
  - **Fibrinogen**: Helps in blood clotting.
- **Electrolytes**
  - Sodium (Na^+), Potassium (K^+), Chloride (Cl^-), Bicarbonate (HCO_3^-)
  - Maintain pH and electrolyte balance.
- **Nutrients**
  - Glucose, amino acids, lipids, and vitamins.
- **Hormones and Enzymes**
  - Transported from endocrine glands to target organs.
- **Waste Products**
  - Urea, creatinine, uric acid — excreted by kidneys.

Cellular Components

Red Blood Cells (Erythrocytes)

- RBCs are discotic-shaped cells constituting 99% of the blood and carrying haemoglobin molecules.

Function of RBCs

- Oxygen Transporter
- Release of ATP and Vessel Dilation

White Blood Cells (Leukocytes)

- WBCs fight against external organisms. They are described according to their characteristics, morphology, and staining property.
- They are granulocytes and agranulocytes corresponding to the presence or absence of granules (lysosomes)

Types of Leukocytes

Granular Leukocytes or Granulocytes: The granulocyte refers to three types of WBCs.

1. Neutrophils,
2. Eosinophils,
3. Basophils

Functions of WBCs are:

→ Phagocytosis
→ Antibody Formation
→ Fibroblasts Formation
→ Trephones Synthesis
→ Heparin Secretion
→ Antihistamine Function

Platelets (Thrombocytes)

➲ They are very small , non nucleated dics of diameter 2-4 um, obtained from cytoplasm of megakaryocytes in red bone marrow . Its constituents promote blood clotting leading to haemostasis (Stop bleeding)

Functions of Platelets

- ♦ Vasoconstriction
- ♦ Platelet plug formation
- ♦ Coagulation (Blood Clotting)
- ♦ Fibrinolysis

Functions of Blood

1. Transport Function

- Carries **oxygen** from lungs to tissues (via hemoglobin in RBCs)
- Transports **carbon dioxide** from tissues to lungs
- Delivers **nutrients** from digestive tract to cells
- Carries **hormones** from endocrine glands to target organs
- Removes **metabolic waste** products to kidneys, lungs, and skin

2. Protective Function

- **WBCs** destroy pathogens (bacteria, viruses)
- **Antibodies** (produced by B cells) neutralize toxins
- **Platelets and fibrinogen** help in **blood clotting** to prevent blood loss

3. Regulatory Function

- Regulates **body temperature** by distributing heat
- Maintains **pH balance** through buffer systems (e.g., bicarbonate)
- Maintains **osmotic balance** and **fluid volume** through plasma proteins
- Distributes **water and electrolytes** to maintain homeostasis

Haemopoeisis

→ Hemopoiesis (also spelled hematopoiesis) is the biological process by which new blood cells are formed from stem cells in the bone marrow. It includes the production of red blood cells (RBCs), white blood cells (WBCs), and platelets.

Or

→ Hematopoiesis is the production of all of the cellular components of blood and blood plasma. It occurs within the hematopoietic system, which includes organs and tissues such as the bone marrow, liver, and spleen. Simply, hematopoiesis is the process through which the body manufactures blood cells.

- Haemo / Hemo Means Blood Cells
- Poeisis Means Formation / Development

→ Around 250 billion (25 x1010 new RBCs, 20 billion (20 x109) new WBCs, and 25 billion (20 x109) platelets are required for replacing the aged or dead cells each day.

→ Formation of blood cells (RBCs, WBCs, platelets) is termed as haemopoiesis or haematopoiesis and the tissues involved in this process are known as haematopoietic tissue.

Types of Blood Cells Formed in Hemopoiesis:

1. **Erythropoiesis** – Formation of red blood cells
2. **Leukopoiesis** – Formation of white blood cells
    - **Granulopoiesis** – Neutrophils, eosinophils, basophils
    - **Lymphopoiesis** – Lymphocytes
    - **Monocytopoiesis** – Monocytes
3. **Thrombopoiesis** – Formation of platelets (from megakaryocytes)

Formation of Haemoglobin

→ Haemoglobin (Hb) is a respiratory pigment present in RBCs and giving them their red colour. It is conjugated protein having 4% heme (Fe^{+2} and porphyrin) and 96% globin protein. It is synthesised within the immature erythrocytes during erythropoiesis, in the red bone marrow.

Chemical Structure of Hemoglobin:

Hemoglobin is composed of :

- 4 globin chains (protein parts)
  - 2 alpha (α) chains
  - 2 beta (β) chains (in adult HbA)
- 4 heme groups (iron-containing pigment)
  - Each heme contains 1 ferrous ion (Fe^{2+}) that binds to 1 oxygen molecule

Thus, 1 molecule of hemoglobin can carry 4 molecules of oxygen.

Normal Level of Haemoglobin in Human Body

The age, sex, altitude, exercise, excitement and adrenaline level affects the Hb level in the blood.

- Normal haemoglobin level in males is 14- 17gm/100 ml,
- Normal haemoglobin level in females is 12- 15gm/100 ml), and
- Normal haemoglobin level in newly born babies is 14.5-18.5. gm/ 100 ml

Anaemia

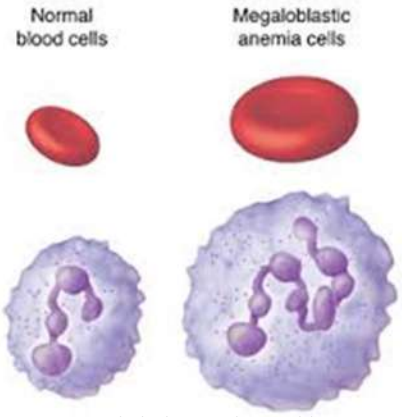
- Anemia is a condition in which there is a decrease in the number of red blood cells (RBCs), hemoglobin concentration, or hematocrit in the blood, leading to reduced oxygen delivery to tissues.
  It is diagnosed when hemoglobin levels fall below normal physiological values for age, sex, or physiological status (e.g., pregnancy).

Types of Anemia

Iron Deficiency Anemia

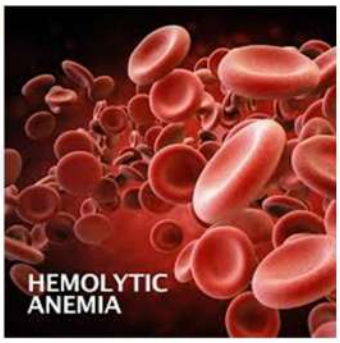
- Iron deficiency anemia is the most common type of anemia worldwide. It occurs when the body lacks enough iron to produce adequate hemoglobin, the protein in red blood cells responsible for oxygen transport. This results in the formation of microcytic (small-sized) and hypochromic (pale) red blood cells.
- The major causes include chronic blood loss (such as from menstruation, ulcers, or hemorrhoids), poor dietary intake, increased requirements during pregnancy or childhood, and malabsorption syndromes like celiac disease.

Megaloblastic anemia



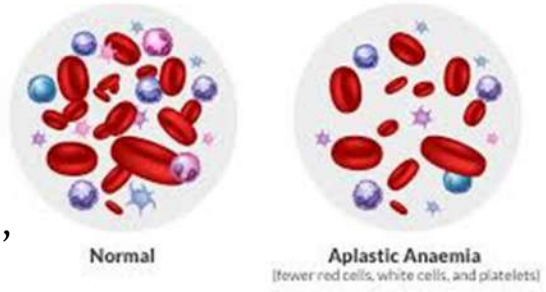
- Megaloblastic anemia is caused by impaired DNA synthesis due to deficiency of vitamin B12 or folic acid. This results in the production of large, immature, and dysfunctional red blood cells known as megaloblasts. The anemia is macrocytic, meaning red blood cells are larger than normal.
- Common causes include poor dietary intake (especially in strict vegetarians), malabsorption (as in pernicious anemia or gastrointestinal surgeries), chronic alcoholism, and increased needs during pregnancy. Clinical symptoms include fatigue, pallor, glossitis (red, inflamed tongue), gastrointestinal discomfort, and in vitamin B12 deficiency, neurological symptoms such as numbness, tingling, and memory loss.

Hemolytic Anemia



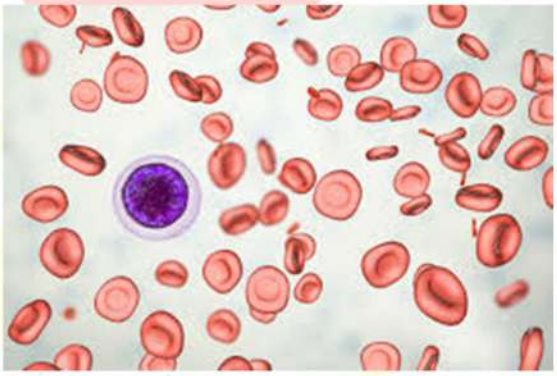
- Hemolytic anemia occurs when red blood cells are destroyed faster than they can be produced. This leads to a decreased number of circulating RBCs and reduced oxygen-carrying capacity of the blood. It can be either inherited or acquired.
- Inherited forms include sickle cell anemia, thalassemia, and hereditary spherocytosis. Acquired causes include autoimmune disorders, certain medications, infections (like malaria), or mechanical damage (e.g., artificial heart valves). Symptoms commonly include fatigue, jaundice (due to increased bilirubin from RBC breakdown), dark-colored urine, pallor, and in severe cases, an enlarged spleen (splenomegaly).

Aplastic Anemia



- Aplastic anemia is a serious condition where the bone marrow fails to produce enough red blood cells, white blood cells, and platelets.
  This results in a condition called pancytopenia. It is a potentially life-threatening disorder.
- Causes include exposure to radiation, certain chemicals (like benzene), drugs (such as chloramphenicol or chemotherapy agents), viral infections (hepatitis, Epstein-Barr virus), and autoimmune conditions.

Anemia of Chronic Disease



- Anemia of chronic disease (also called anemia of inflammation) is commonly seen in patients with long-standing infections, chronic inflammatory diseases (like rheumatoid arthritis), kidney disease, or cancers. It results from the body's inability to use stored iron properly and impaired red blood cell production.
- The cause is multifactorial, including poor iron utilization, reduced erythropoietin production (especially in chronic kidney disease), and shortened RBC lifespan. Patients often have mild to moderate anemia with symptoms such as weakness, tiredness, and pallor, but they may also show signs of the underlying disease.

Blood coagulation

- Blood coagulation (or blood clotting) is the process by which blood from its liquid state changes to a gel-like consistency.
- A host defence mechanism known as haemostasis is a complex process which blocks the bleeding from a damaged vessel.
- Platelet adherence and aggregation to macromolecules in the sub-endothelial tissues forms a primary haemostaticplug.
- Activating plasma coagulation factors by platelets lead to the generation of a fibrin clot that builds up the platelet aggregate.
- Shedding of platelet aggregate and fibrin clots occurs when the wound starts healing.

Factors of Blood Clotting

- Factor I - fibrinogen
- Factor II - prothrombin
- Factor III - tissue thromboplastin (tissue factor)
- Factor IV - ionized calcium (Ca++)
- Factor V - labile factor or proaccelerin
- Factor VI - unassigned
- Factor VII - stable factor or proconvertin
- Factor VIII - antihemophilic factor
- Factor IX - plasma thromboplastin component, Christmas factor
- Factor X - Stuart-Prower factor
- Factor XI - plasma thromboplastin antecedent
- Factor XII - Hageman factor
- Factor XIII - fibrin-stabilizing factor

Mechanism of Blood Coagulation

The process of coagulation is a cascade of enzyme catalysed reactions wherein the activation of one factor leads to the activation of another factor and so on.

The three main steps of the blood coagulation cascade are as follows:

i. Formation of prothrombin activator
ii. Conversion of prothrombin to thrombin
iii. Conversion of fibrinogen into fibrin

1. Formation of prothrombin activator

→ The formation of a prothrombin activator is the first step in the blood coagulation cascade of secondary haemostasis. It is done by two pathways, viz. extrinsic pathway and intrinsic pathway.

Extrinsic Pathway

- It is also known as the tissue factor pathway. It is a shorter pathway. The tissue factors or tissue thromboplastins are released from the damaged vascular wall. The tissue factor activates the factor VII to VIIa. Then the factor VIIa activates the factor X to Xa in the presence of Ca2+.

Intrinsic Pathway

- It is the longer pathway of secondary haemostasis. It begins with the exposure of blood to the collagen from the underlying damaged endothelium. This activates the plasma factor XII to XIIa.
- XIIa is a serine protease, it activates the factor XI to XIa. The XIa then activates the factor IX to IXa in the presence of Ca2+ ions.
- The factor IXa in the presence of factor VIIIa, Ca2+ and phospholipids activate the factor X to Xa.

Common Pathway

- ♦ The factor Xa, factor V, phospholipids and calcium ions form the prothrombin activator. This is the start of the common pathway of both extrinsic and intrinsic pathways leading to coagulation.

2. Conversion of prothrombin to thrombin

→ Prothrombin or factor II is a plasma protein and is the inactive form of the enzyme thrombin. Vitamin K is required for the synthesis of prothrombin in the liver. The prothrombin activator formed above converts prothrombin to thrombin. Thrombin is a proteolytic enzyme. It also stimulates its own formation, i.e. the conversion of prothrombin to thrombin. It promotes the formation of a prothrombin activator by activating factors VIII, V and XIII.

3. Conversion of fibrinogen into fibrin

→ Fibrinogen or factor I is converted to fibrin by thrombin. Thrombin forms fibrin monomers that polymerise to form long fibrin threads. These are stabilised by the factor XIII or fibrin stabilising factor. The fibrin stabilising factor is activated by thrombin to form factor XIIIa. The activated fibrin stabilising factor (XIIIa) forms cross-linking between fibrin threads in the presence of Ca2+ and stabilises the fibrin meshwork. The fibrin mesh traps the formed elements to form a solid mass called a clot.

Blood Group

- A blood type or blood group is the classification of blood on the basis of the presence or absence of inherited antigens (proteins, carbohydrates, glycoprotein, or glycolipids) on the surface of RBCs.
- Understanding of blood is significant for the following practices :
- Blood grouping is essential for both donor and receiver for successful blood transfusion
- Blood grouping is important to resolve paternity disputes and medico legal cases
- It is significant in diagnosis of some blood grouping related diseases and conseguences.

Depending on the type of antigens present or absent on the membrane of RBCs, various blood grouping system are follow :

I. Classical ABO blood grouping system,
II. Rhesus (Rh) blood grouping system,
III. MNS blood grouping system, and
IV. P blood grouping system.

First two are major blood grouping systems and are more prevalent in the population and cause severe transfusion reaction, while the last two are minor blood grouping systems found in small proportion of the population and produce minute transfusion reactions.

ABO Blood Group

→ ABO blood group is based on A and B antigens on the RBCs surface. This system classifies blood on the basis of antigens located on the surface of RBCs and circulating antibodies in plasma. Combination of proteins and their antibodies form four types of blood:

- Type A: It consists of protein A and antibodies for protein B.

- Type B: It consists of protein B and antibodies for protein A.
- Type AB: It consists of proteins A and B but no antibodies.
- Type O: It does not consist of any proteins but have both A and B antibodies.

→ Thus, type AB blood group is universal receiver and can receive any blood type; whereas type O blood group is universal donor and can donate blood to anyone.

Rh Blood Group

→ It was first detected in Rhesus monkey. Sometimes Surface antigens of RBCs have the Rh factor. 97% Indian population have Rh positive (i.e. presence of Rh antigens) else have Rh negative blood group.

Importance of Blood Grouping

1) In blood transfusion;
2) Haemolytic disease of newborn;
3) Paternity dispute;
4) Medicolegal issues;
5) Susceptibility to various diseases (blood group O peptic ulcer blood group A -gastric ulcer);
6) Immunology, genetics, anthropology
7) To identify criminals.

Blood Transfusion

→ Blood transfusion is the process of transferring whole blood or blood components (such as red blood cells, plasma, or platelets) from a donor to a recipient through intravenous (IV) administration, typically used to replace lost components of the blood.

→ It becomes essential in condition like Anaemia, Trauma, Burns and Surgery.

- Donar : A Person who donates the blood.
- Recipient : A Person who receives the blood.

Significance of Blood Transfusion

- Blood loss
- Acute Poisoning
- Blood Diseases
- Hemolytic Diseases

Disorders of Blood

There are many disorder and blood related diseases.

→ **Anemia :** Anemia is a condition characterized by a decrease in the number of red blood cells (RBCs) or hemoglobin concentration, leading to reduced oxygen-carrying capacity of blood.

→ **Leukemia :** Leukemia is a malignant cancer of white blood cells originating in the bone marrow, causing uncontrolled proliferation of abnormal WBCs.

→ **Thrombocytopenia :** Thrombocytopenia is a condition where there is a low platelet count, increasing the risk of bleeding and bruising.

→ **Polycythemia Vera :** Polycythemia vera is a rare blood cancer in which the bone marrow produces excess RBCs, leading to thickened blood and increased risk of clotting.

Reticulo endothelial System (RES)

- ❖ It is also called as macrophage system or the mononuclear phagocyte system.
- ❖ It is a network of cells located throughout the body that help to filter out dead and toxic particles and also work to identity foreign substances in both the blood and tissues.
- ❖ It is part of the immune system of human body and consists of phagocytic cells. .
- ❖ It is closely related to lymphatic system because the two are independent structurally and functionally.
- ❖ This system is made up of highly phagocytic cells which are widely distributed in the body

Functions

- ✓ Phagocytosis : Bacterial, dead cells, foreign particles is the basic component of immune system, and it also helps the lymphocytes.
- ✓ Indirect immune function : Processing and presenting antigen to lymphocytes.
- ✓ Breakdown of aging RBC.
- ✓ Storage and circulation of iron.