# HAEMOPIETIC SYSTEM

## 5.1 INTRODUCTION

- The system of tissues and organs known as the **Haemopoietic system**, which includes the lymph nodes, spleen, bone marrow, and thymus, is responsible for producing the cellular components of blood.
- Blood is a type of specialized, fluid connective tissue that transports oxygen and nutrients to the cells and carries away carbon dioxide and other waste products.
- The body has **6 liters of blood in total.**
- It has a specific gravity of 1.055 and a pH of approximately 7.4, making it somewhat alkaline.
- Blood makes up around 8% of the total weight of the body.
- It always moves in a way that maintains a consistent environment.

## 5.2 FUNCTIONS OF BLOOD

1. **Transportation:** The digested nutrients such as glucose, vitamins, minerals, and proteins are absorbed into the blood through the capillary into the villi by the small intestine. The hormones secreted by endocrine glands are also transported by blood to the different organ and tissue.
2. **Provides oxygen to the cell:** Blood absorbs oxygen from the lungs and transport it to the different tissue and organ of the body.
3. **Protection:** WBCs protects against diseases by phagocytosis. It acts as a reservoir for substances like water and electrolytes etc.
4. **Regulation:** It regulates the pH and maintains water contents in the body.
5. **Homeostasis:** Homeostasis is defined as a self-regulating process by which a living organism can maintain internal stability while adjusting to changing external conditions. Blood helps in maintaining homeostasis in the body.

## 5.3 COMPOSITION OF BLOOD

Blood mainly composed of Plasma and formed elements (Erythrocytes, Leukocytes and Platelets).

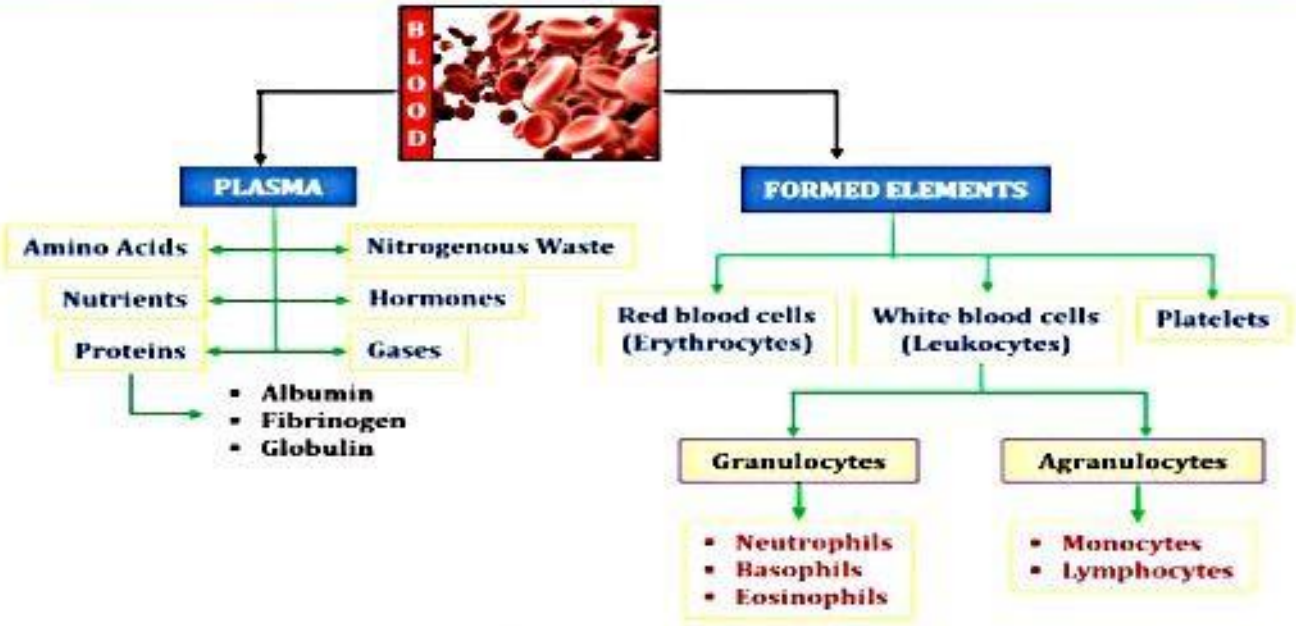



**Fig.5.1: Composition of Blood**

**5.3.1 Plasma:** Plasma is the yellowish liquid component of your blood that contributes to 55% of your blood's total volume.

- Plasma is necessary to help your body recover from injury, distribute nutrients, remove waste and prevent infection, while moving throughout your circulatory system.
- **"Serum"** is obtained from plasma after removing fibrinogen. (Serum = plasma - fibrinogen).
- In addition, it has 90–92 percent water that has the following chemicals dissolved in it.

➢ **Amino Acids:** Amino Acids are the organic compounds that combine to form proteins; hence they are referred to as the building components of proteins. These are necessary ingredients for the growth and development of human beings.

➢ **Nitrogenous waste:** Urea, creatinine and uric acid are the waste products of protein metabolism. These are formed in the liver and transported to kidney via blood for excretion.

➢ **Nutrients:** Once food is digested, it transforms into monosaccharides, amino acids, and fatty acids, which the body needs for heat production, energy production, material creation, and repair.

➢ **Hormones:** A hormone was thus defined as a compound that is produced in a secretory tissue and transported in the blood circulatory system to target tissues, where they induce functional changes.

➢ **Proteins:** Plasma proteins, that help maintain the colloidal osmotic

pressure at about 25 mm Hg. It is of the following types:

- ✓ **Albumin:** Albumin is a protein made by liver. Albumin enters the bloodstream and helps keep fluid from leaking out of the blood vessels into other tissues.
- ✓ **Fibrinogen:** Fibrinogen is a protein produced by the liver. This protein helps stop bleeding by helping blood clots to form.
- ✓ **Globulin:** Globulins are a group of proteins in blood that are made in liver by immune system. Globulins play an important role in liver function, blood clotting, and fighting infection.
- ➢ **Gases:** Oxygen, carbon dioxide and nitrogen are transported in the body through plasma. Oxygen and carbon dioxide are transported in combination with haemoglobin in red blood cells.

### 5.3.2 Formed Elements

There are mainly three types of cells as given below

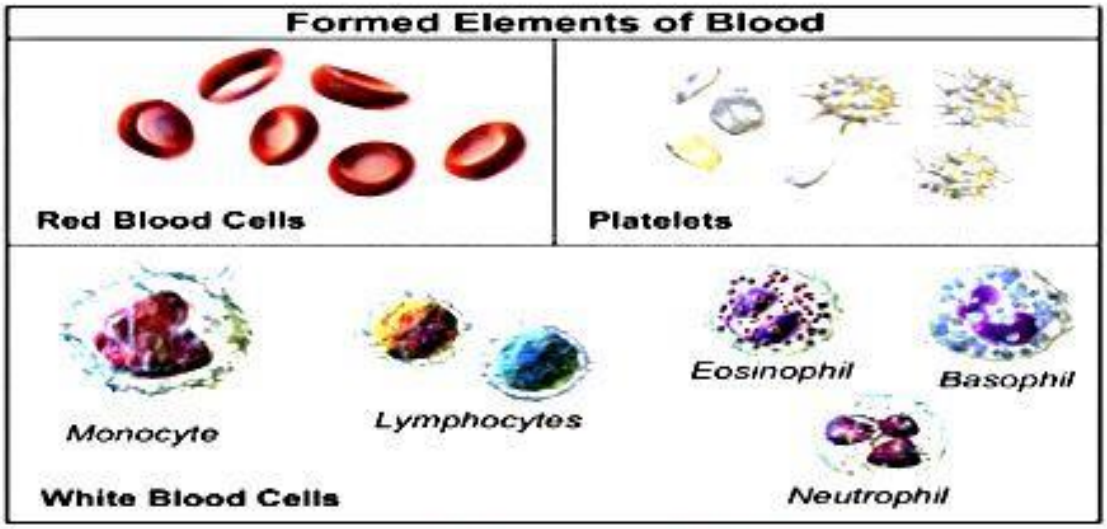



**Fig 5.2: Formed Element of Blood 1**

1. **Red Blood Cell or Erythrocytes:** Erythrocytes are circular, biconcave, non-nucleated disc shaped cell with a diameter of approximately 7.5 to 8.7 μm.

➢ **Characteristics**

- **The normal RBCs count** for adults, the usual range is generally 4.35 to 5.65 million red blood cells per microliter (mcL) of blood for men and 3.92 to 5.13 million red blood cells per mcL of blood for women.
- Red color of the red blood cell is due to the presence of the coloring pigment called **haemoglobin.**

- Average lifespan of RBC is about **120 days**. After the lifetime the senile (old) RBCs are destroyed in reticuloendothelial system.
- Spleen is called **'Graveyard of RBCs'.**

## ➢ Functions of Red Blood Cells

**Major function of RBCs is the transport of respiratory gases:**

### a. Transport of Oxygen from the Lungs to the Tissues

- Haemoglobin in RBC combines with oxygen to form oxyhaemoglobin.
- About 97% of oxygen is transported in blood in the form of oxyhemoglobin.

### b. Transport of Carbon Dioxide from the Tissues to the Lungs

- Haemoglobin combines with carbon dioxide and form carbhaemoglobin.
- About 30% of carbon dioxide is transported in this form.

## ➢ Development and Life Span of RBCs

Erythrocytes are formed in the bone marrow. They go through different stages of growth during the course of their about 120-day life cycle. The process of development of RBCs from haemocytoblasts takes about 7 days and is called as erythropoiesis.

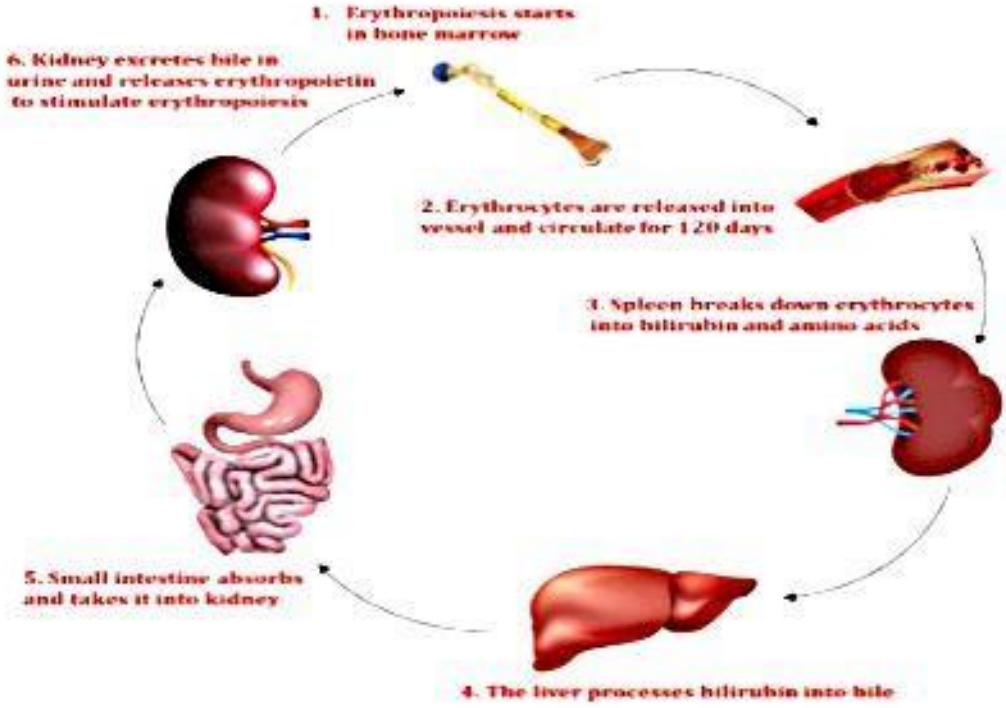



**Fig.5.3: Development and Life Span of RBCs**

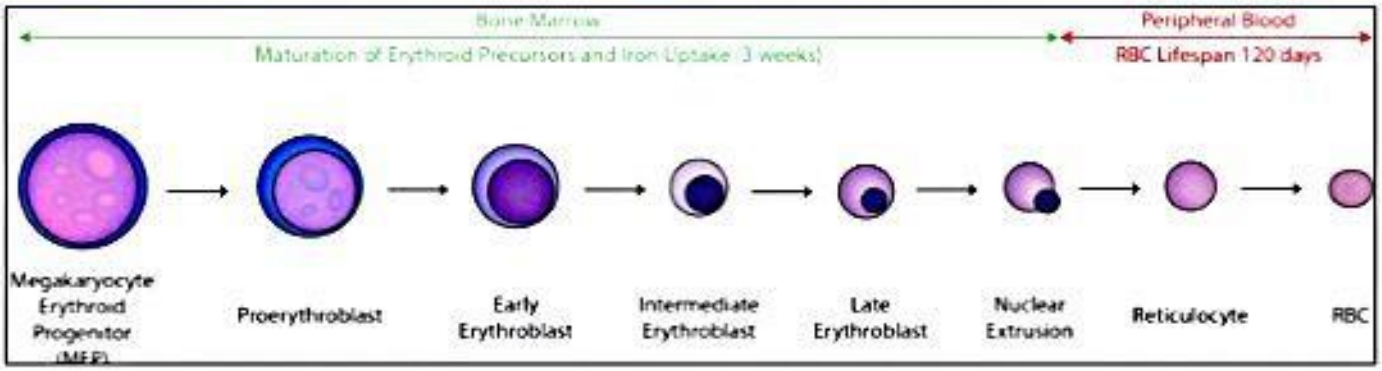



**Fig.5.4: Erythropoiesis**

- **Erythropoiesis is characterized by two main features:**

### i. Maturation of the cell

- ✓ The cell shrinks in size and loses its nucleus during this phase.
- ✓ The alterations are dependent on folic acid and vitamin $B_{12}$ levels.
- ✓ The presence of a glycoprotein known as intrinsic factor, which is secreted by parietal cells found in the stomach glands, is necessary for the absorption of vitamin $B_{12}$.
- ✓ Folic acid absorbed by cell in duodenum and jejunum where it undergoes change before entering the blood.
- ✓ The normal daily requirement of folic acid is 100-200 μm.

### ii. Formation of Haemoglobin inside the cell

- ✓ The two main components of hemoglobin synthesis are globin production and iron containg compound heme
- ✓ It is synthesized in developing erythrocytes in red bone marrow.

### ➢ Destruction of Erythrocytes

- The destruction of red blood cells is called **'Hemolysis'**. Red cells have an average life span of about 120 days after which they are cleared by-phagocytosis by reticuloendothelial macrophages due to accumulated changes during their life span.

### ➢ Destruction of Hemoglobin

- When red blood cells burst and release their hemoglobin, the hemoglobin isphagocytized almost immediately by macrophages in many parts of the body, butespecially by the Kupffer cells of the liver and macrophages of the spleen and bonemarrow.
- During the next few hours to days, the macrophages release iron from thehemoglobin and pass it back into the blood, to be carried by transferring either to thebone marrow for the production of new red

blood cells or to the liver and othertissues for storage in the form of ferritin.

- The porphyrin portion of the hemoglobin molecule is converted by the macrophages, through a series of stages, into the bile pigment bilirubin, which is released into the blood and later removed from the body by secretion through the liver into the bile.

2. **White Blood Cell or Leukocytes:** White blood cells, also called leucocytes, detect and deal with infections or foreign molecules that enter the body.

- White blood cells will produce antibodies to fight the infection and help with other immune responses.
- The name **"White Blood Cell"** derives from the physical appearance of a blood sample after centrifugation. White cells are found in the buffy coat, a thin, typically white layer of nucleated cells between the sedimented red blood cells and the blood plasma.
- One cubic millimeter of blood contains 7000 to 8000 WBC.
- These are formed in bone marrow.
- Their life span depends on the body need so they have life span of months or even years.

➢ **Functions of WBC**

These are the cells of the immune system that are involved in protecting the body against both infectious disease and foreign invaders.

Other functions are

- **Scavenging:** It act as cellular scavengers by ingesting dying and invading bacterial cells, but they recognize and refuse to eat their own kind.
- **Pus formation:** Pus is the buildup of fluid, living and dead white blood cells, dead tissue, and bacteria or other foreign substances. White blood cells (WBCs) move through the walls of the blood vessels into the area of the infection and collect in the damaged tissue. During this process, pus forms.
- **Phagocytosis:** Phagocytes are a type of white blood cell that use phagocytosis to engulf bacteria, foreign particles, and dying cells to protect the body.
- **Inflammation:** They circulate in the blood and mount inflammatory

and cellular responses to injury or pathogens.

- **Antibodies formation:** White blood cells release chemicals that break the organism down and destroy it. Other white blood cells, called lymphocytes, target attacks in another way, by making antibodies.

## Types of White Blood Cell

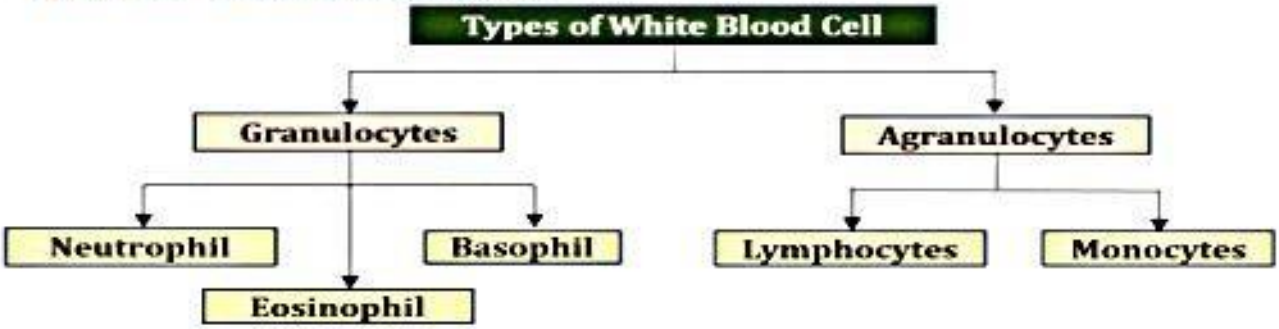



**Fig.5.5: Types of White Blood Cell**

### a. Granulocytes

- Granulocytes are a type of white blood cell that has small granules inside them. These granules contain proteins.
- Granulopoiesis is the term used to describe the process of granulocyte production.
- They differentiate into three forms during development, following a common path from myeloblast to myelocyte.
- Its nuclei are multilobed. Their name is a representation of the dyes they absorb when stained in a lab.
- It is of the following types:

#### i. Neutrophils

- These contain very fine cytoplasmic granules.
- Neutrophils are also called polymorph nuclear (MN) having variety of nuclear shapes.
- They play roles in the destruction or inhibition of the growth of bacteria by release of chemical.

#### ii. Eosinophils

- These have large granules and a prominent nucleus that is divided into two lobes.
- They function in the destruction of allergens and inflammatory chemicals, and release enzymes that disable parasites.

#### iii. Basophils

- They have a pale nucleus that is usually hidden by granules.

- They secrete histamine causing dilation of the blood vessels, and also secrete heparin which is an anticoagulant that promotes mobility of other WBCs by preventing clotting.

### b. Agranulocytes

- It does not contain granules in the cytoplasm.
- It is having large nucleus.
- It is of the following types:
- Lymphocytes are a type of immune cell usually classified as small, medium or large.
- Medium and large lymphocytes are generally seen mainly in fibrous connective tissue and only occasionally in the circulation bloodstream.

#### i. Lymphocytes

- Lymphocytes destroys cancer cells, cells infected by viruses, and foreign invading cells.
- Antigens are of the following types:
  - ✓ Pollen from flowers and plants
  - ✓ Fungi
  - ✓ Bacteria
  - ✓ Few large molecules drug

#### ii. Monocytes

- They are the largest of the formed elements.
- Their cytoplasm is abundant and clear.
- These function by activating other immune cells.
- They differentiate into macrophages, which are large phagocytic cells, and digest pathogens, dead neutrophils, and the debris of dead cells.
- It also consists of interleukin, that has following functions
  - ✓ It stimulates the production of globulin by the liver.
  - ✓ It enhances the production of activated T-lymphocytes.
  - ✓ It increases body temperature by acting on the hypothalamus.

### 3. Platelets

- Platelets are cell fragments smaller in size than RBCs and WBCs.
- Nucleus is absent in platelets.
- Platelets are also called Thrombocytes. The stimulus to formation of platelets is a substance called as thrombopoietin.
- Random shaped 2 – 4 micron size. The life span of platelet is 8-11 days.

- Normal platelet count is 1,50,000 – 4,00,000 per drop of blood.

➢ **Function of Platelets**

- **Clot Retraction** - Cytoplasm of platelets contains the contractile proteins, namely actin, myosin and thrombosthenin, which are responsible for clot retraction.
- **Prevention of blood loss (Haemostasis)** - Platelets accelerate the haemostasis by three ways:
  - ✓ Platelets secrete 5-HT, which causes the constriction of blood vessels.
  - ✓ Due to the adhesive property, the platelets seal the damage in blood vessels like capillaries.
  - ✓ By formation of temporary plug, the platelets seal the damage in blood vessels.
- **Repair of Ruptured Blood Vessel** - Platelet-derived growth factor (PDGF) formed in cytoplasm of platelets is useful for the repair of the endothelium and other structures of the ruptured blood vessels.
- **Defense Mechanism** - By the property of agglutination, platelets encircle the foreign bodies and destroy them.

## 5.4 BLOOD CLOTTING

- Blood clotting, or coagulation, is the process by which blood changes from a liquid to a gel, forming a blood clot. It potentially results in hemostasis, the cessation of blood loss from a damaged vessel, followed by repair.
- The substances which are necessary for clotting are normal present in blood but in inactive form. They are known as procoagulants which are activated (during injury) and clot is formed.

### 5.4.1 Mechanism of blood clotting

- **Blood clotting mainly involves three mechanisms**

1. **Vasoconstriction:** When platelets come into contact with a blood vessel that has been injured, they cause the surface to become sticky and attach to the damaged wall. As soon as a blood artery is ruptured, the smooth muscle in its wall's contracts. For a while, this reaction slows blood loss while the other haemostatic processes active.
2. **Platelet Plug Formation:** When blood platelets encounter a damaged

blood vessel, they form a "platelet plug" to help to close the gap in the broken blood vessel. (The key stages of this process are called platelet adhesion, platelet release reaction, and platelet aggregation)

3. **Blood clotting or Coagulation-** It is the process in which blood loses its fluidity and become a jelly like mass few minutes after it is shed out or collected in a container. It results in hemostasis, the cessation of blood loss from a damaged vessel, followed by repair.

## 5.4.2 Stages of Blood Clotting

### Stage 1: Formation of Prothrombin Activator

- Blood clotting commences with the formation of a substance called prothrombin activator, which converts prothrombin into thrombin.
- Its formation is initiated by substances produced either within the blood or outside the blood.
- Thus, formation of prothrombin activator occurs through two pathways:

1. **Intrinsic pathway:** This is initiated by liquid blood making contact with a foreign surface, i. e. something that is not part of the body.
2. **Extrinsic pathway:** This is initiated by liquid blood making contact with damage tissue.

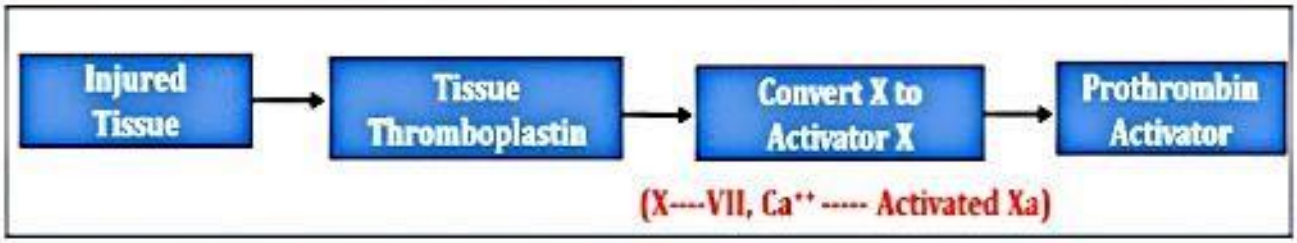



**Fig.5.6: Formation of Prothrombin Activator**

- Both the intrinsic and the extrinsic systems involve interactions between coagulation factors.
- These coagulation factors have individual names but are often referred to by a standardized set of Roman Numerals, e.g. Factor VIII (anti - hemophilic factor), Factor IX (Christmas factor).

**Table 5.1: Blood Clotting Factors**

| CLOTTING FACTORS | |
|---|---|
| Factor | Name of clotting factor |
| Factor I | Fibrinogen |
| Factor II | Prothrombin |

| | |
|---|---|
| Factor III | Tissue Thromboplastin |
| Factor IV | $Ca^{+}$ ion |
| Factor V | Labile factor |
| Factor VII | Stable factor |
| Factor VIII | Antihemophilic Factor |
| Factor IX | Plasma thromboplastin component (PTC) |
| Factor X | Stuart-Prower factor |
| Factor XI | Plasma Thromboplastin antecedent (PTA) |
| Factor XII | Hageman factor |
| Factor XIII | Fibrin stabilizing factor (Fibrinase) |

### Stage 2: Conversion of Prothrombin into Thrombin

- Blood clotting is all about thrombin formation.
- Once thrombin is formed, it definitely leads to clot formation.
- Prothrombinase (formed in stage 1) converts prothrombin, which is a plasma protein that is formed in the liver, into the enzyme thrombin.

### Stage 3: Conversion of Fibrinogen (Soluble) into Fibrin (Insoluble)

- The final stage of blood clotting involves the conversion of fibrinogen into fibrin by thrombin. Thrombin converts inactive fibrinogen into activated fibrinogen. Activated fibrinogen is called fibrin monomer.
- Fibrin is insoluble and forms the threads that bind the clot. Fibrin monomer polymerizes and form loosely arranged strands of fibrin.
- Loose strands are modified into dense and tight fibrin threads by fibrin-stabilizing factor (factor XIII) in the presence of calcium ions.
- All the tight fibrin threads are aggregated to form a meshwork of stable clot.

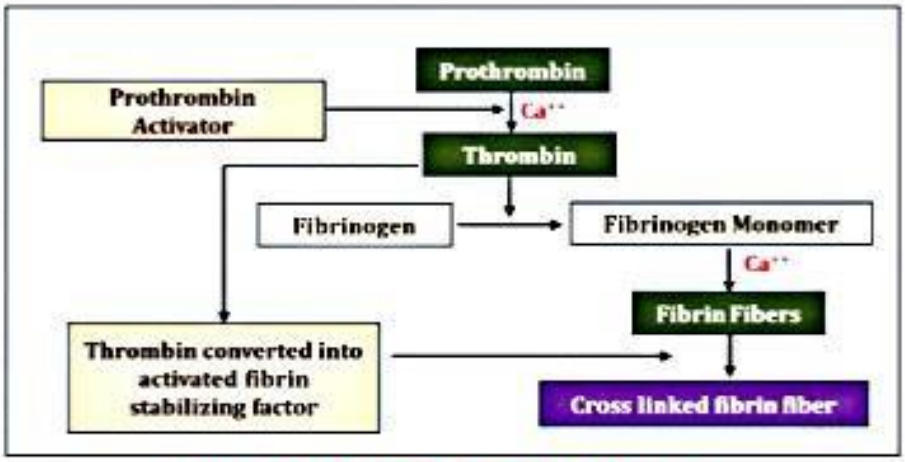



**Fig.5.7: Formation of fibrin**

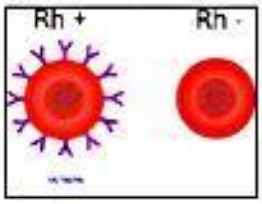
## 5.5 BLOOD GROUP

- Blood group is discovered by the **Austrian Scientist Karl Landsteiner**, in 1901.

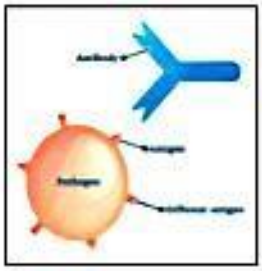
- He was honoured with Nobel Prize in 1930 for this discovery.

### 5.5.1 Blood Group Systems

- These two blood group systems are the most important ones that are determined before blood transfusions.




- There are four main blood groups types - **A, B, AB and O**. Blood group is determined by the genes you inherit from your parents.
- Each group can be either **Rh positive or Rh negative**, which means in total there are eight main blood groups.
- The blood group is identified by **antibodies** and **antigens** in the blood



- Antibodies are proteins found in plasma. They're part of your body's natural defences. They recognise foreign substances, such as germs, and alert your immune system, which destroys them.
- Antigens are protein molecules found on the surface of red blood cells.

### 5.5.2 Importance of Blood Grouping

- Blood Grouping helps prevent reactions when someone gets a blood transfusion.
- It is used in preventing haemolytic disease (Rh incompatibility between mother and foetus).
- It is also used in paternity disputes (to determine the father).
- It is used in medicolegal cases.

### 5.5.3 ABO System

Based on the presence or absence of antigen A and antigen B, blood is divided into four groups:

- **Blood group A –** It has A antigens on the red blood cells with anti-B antibodies in the plasma
- **Blood group B –** It has B antigens with anti-A antibodies
- **Blood group O-** It has no antigens, but both anti-A and anti-B antibodies in the plasma.
- **Blood group AB-** It has both A and B antigens, but no antibodies in the plasma.

**Table 5.2: ABO System of Blood Group**

| BLOOD TYPE | ANTIGEN ON RBC | ANTIBODY IN PLASMA | CAN DONATE TO | CAN RECEIVE FROM |
|---|---|---|---|---|
| A | A | Anti-B | A, AB | A, O |
| B | B | Anti-A | B, AB | B, O |
| AB | A and B | None | AB | A, B, AB, O |
| O | None (zero) | Anti-A &Anti-B | A, B, AB, O | O |

## 5.6 DISORDER OF BLOOD

- Bleeding disorders are a group of conditions in which there is a problem with the body's blood clotting process.
- These disorders can lead to heavy and prolonged bleeding after an injury or surgery.
- The various disorders of blood are

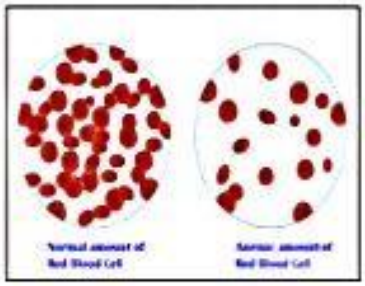
### 1. Disorder of Red Blood Cell

The disorder of Red Blood Cell includes anemia and polycythemia-

a. **Anemia:** Anemia is a condition in which the body does not have enough healthy red blood cells. Hence, there is decrease in oxygen carrying capacity of blood.

**Symptoms** – Breathlessness, tiredness, loss of appetite and pallor of skin.

➢ The different types of anemia are



i. **Iron deficiency anemia** - Iron deficiency anemia is due to insufficient iron. Without enough iron, the body can't produce enough of a substance in red blood cells that enables them to carry oxygen (hemoglobin). It occurs due to low dietary intake and reduction in absorption of food.

ii. **Thalassemia** - Thalassemia is an inherited (i.e., passed from parents to children through genes) blood disorder caused when the body doesn't make enough of a protein called hemoglobin, that leads to reduction in oxygen carrying capacity of blood.

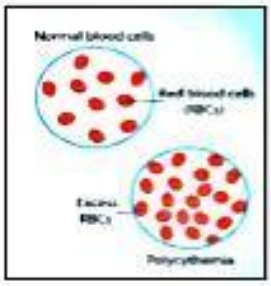
iii. **Megaloblastic anemia** - Megaloblastic anemia is a form of macrocytic anemia. Macrocytic anemia is a blood disorder that causes bone marrow

to make abnormally large red blood cells. It occurs due to deficiency of vitamin $B_{12}$ and folic acid. Due to this, maturation of red blood cell does not occur.

iv. **Hemolytic anemia** - Hemolytic anemia is a disorder in which red blood cells are destroyed faster than they can be made. The destruction of red blood cells is called hemolysis. It occurs due to hereditary disorder, mechanical injury to red blood cell and infections like malaria.

v. **Aplastic anemia** - Aplastic anemia occurs when your bone marrow doesn't make enough red and white blood cells, and platelets.

b. **Polycythemia:** Polycythemia is a blood disorder occurring when there are too many red blood cells, which carry oxygen from the lungs through the blood stream to the rest of the body. The excess red blood cells cause the blood to increase in volume and thicken, keeping it from flowing easily.




## 2. Disorder of White Blood Cell

The disorder of white blood cell includes leukocytosis and leucopenia.

a. **Leukocytosis:** Leukocytosis is an elevation in the absolute WBC count (>10,000 cells/μL).It is of the following types

i. **Neutrophilia** - Neutrophilia is defined as a higher neutrophil count in the blood than the normal reference range of absolute neutrophil count. Neutrophilia can be seen in infections, inflammation, and/or neoplastic processes.

ii. **Eosinophilia** - Eosinophilia is an increase in the number of eosinophils in the blood, occurring in response to some allergens, drugs, and parasites.

iii. **Leukaemia** - Leukaemia is a malignant progressive disease in which the bone marrow and other blood-forming organs produce increased numbers of immature or abnormal leucocytes. These suppress the production of normal blood cells, leading to anaemia.

b. **Leucopenia:** Leukopenia is a reduction in the WBC count (<3500 cells/μL). It is produced by infections and some drugs.

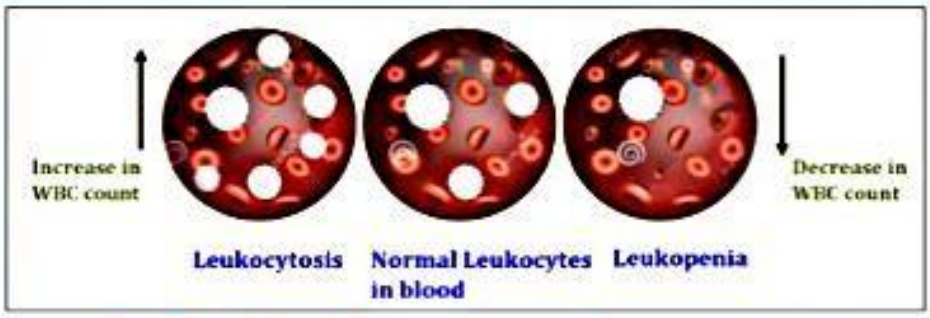



**Fig. 5.8: Leukocytosis and Leucopenia**

## 3. Disorder of platelets

The disorder of platelet includes thrombocytopenia.

**Thrombocytopenia:** Thrombocytopenia is the deficiency of platelets in the blood. This causes bleeding into the tissues, bruising, and slow blood clotting after injury.

## 4. Disorder of clotting

The disorder of clotting includes haemophilia and thrombosis.

a. **Haemophilia:** Haemophilia is a medical condition in which the ability of the blood to clot is severely reduced, causing the sufferer to bleed severely from even a slight injury. The condition is typically caused by a hereditary lack of a coagulation factor, most often factor VIII.

b. **Thrombosis:** Thrombosis is a blood clot within blood vessels that limits the flow of blood. Complications of thrombosis can be life-threatening, such as a stroke or heart attack.