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Simplified Anatomy and Physiology for Paramedical Students



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Foreword
Suresh K Sharma

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CHAPTER

4 Introduction to Cardiovascular System: Blood

INTRODUCTION

Blood is a specialized form of connective tissue, which circulates in a closed system of blood vessels and is composed of transparent fluid plasma in which different types of cells are suspended. The concentration of plasma in blood is about 55% and cells constitute about 45% of the blood volume.

The circulating blood consists of suspension of formed elements such as erythrocytes leukocytes, and platelets in a pale-yellow colored fluid called plasma. Blood is thicker and more viscous than water. The blood is alkaline in nature and having pH of 7.4 (normal ranges 7.35–7.5). In adults, the total volume of blood comprises about 80% of the total body weight. The total blood volume in average adults is 5–6 L in males and 4–5 L in females.

The study of blood, blood forming tissues, and their associated disorders is called hematology. The word (heme) comes from the Greek for blood.

COMPOSITION OF BLOOD

Blood contains plasma (straw-colored fluid) and cells. Plasma constitutes 91% of water and dissolved substance. Dissolved substances include protein 8% and salt 0.9% **(Fig. 4.1)**.

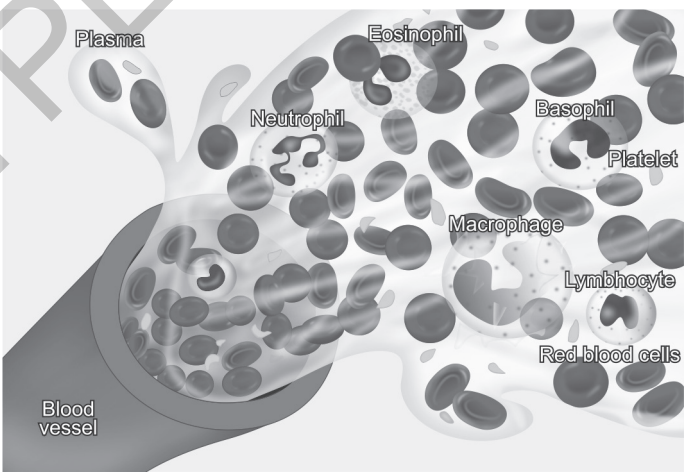

Fig. 4.1: Blood vessel containing cells.

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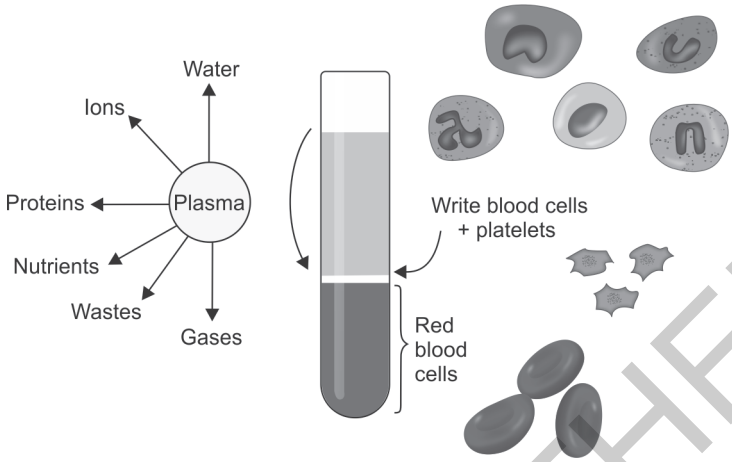

Fig. 4.2: Different cells of the blood.

Plasma contains the following (Fig. 4.2):

- **Nutrients:** Monosaccharides, amino acids, fatty acids, and vitamins from food.
- **Organic material:** Cholesterol, urea, uric acid, and creatinine.
- **Plasma proteins:** Albumin, globulin, and fibrinogen
- **Inorganic minerals:** Sodium chloride, copper, iodine, sodium, potassium, calcium, iron phosphorus, etc.
- Enzymes
- Hormones
- Antibodies
- Gases

Cellular content (formed elements) of blood contains the following:

- Leukocyte or white blood cells
- Erythrocytes or red blood cells
- Thrombocytes or platelets

The concentration of erythrocytes constitutes 95% of the cellular elements. Leukocytes and thrombocytes constitute for the remaining 5% of the volume of the cellular elements (**Figs. 4.3 and 4.4**).

FUNCTIONS OF BLOOD

- **Respiration:** Transportation of oxygen from lungs to tissues and carbon dioxide from tissues to lungs.
- **Coagulation of blood:** It contains factors of clotting mechanism, preventing blood loss from ruptured blood vessels.
- **Excretion:** Transport of metabolic wastes to the lungs, kidneys, intestine, and skin for removal.
- **Nutrition:** Transport nutrient materials such as fatty acids, monosaccharides, and amino acids from GI tract to tissues and waste materials to excretory organs such as kidneys.

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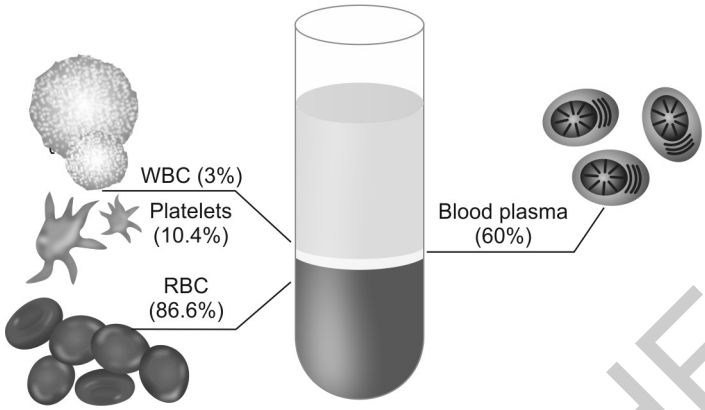

Fig. 4.3: Cellular content of blood.

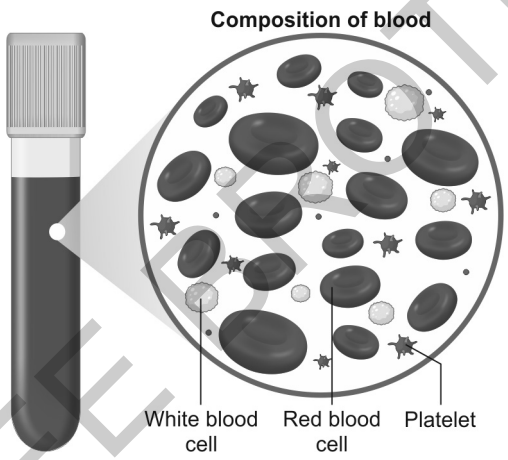

Fig. 4.4: Composition of blood.

- Transport hormones from glands to the organs.
- Maintain a normal acid-base balance of the body.
- Regulation of water balance.
- Regulation of body temperature.
- Transportation of metabolites.
- Defense against infection by the white cells and the antibodies.

CELLULAR ELEMENTS OF THE BLOOD

Red Blood Corpuscles (RBC) or Erythrocytes

Erythrocytes **(erythros: red and cytos: cell)** are the most numerous of the blood elements that have been formed. They are non-nucleated cells that are spherical, biconcave, disc shaped. RBC contains a pigment of hemoglobin that is able to bind with oxygen and release it during its circulation to the tissues of the body. Carbon dioxide is then absorbed by the red cells from the tissues

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and taken to the lungs to be exhaled. The standard range is between 4 and 5.5 lakhs per cubic millimeter.

Red blood cells are produced in the long bones, flat, and irregular bones of the red bone marrow. RBCs' lifetime is roughly 120 days.

Erythropoiesis

The process of development of RBCs is called erythropoiesis. According to the monophyletic theory, the various cells concerned in normoblasts erythropoiesis are hemocytoblast, proerythroblast, early normoblast, intermediate normoblast, late normoblast, reticulocyte, and mature RBC.

- **Hemocytoblast:** A large cell with a diameter of 18–24 microns, two or more nucleoli and agranular cytoplasm.
- **Proerythroblast:** Agranular cytoplasm, 14–19 microns in diameter, large round nucleus.
- **Early normoblast:** Agranular cytoplasm 11–17 microns in diameter, large nucleus but without nucleoli,
- **Intermediate normoblast:** Cell with diameter of 10–14 microns, nucleus smaller than that of the precursor, bluish red cytoplasm.
- **Late normoblast:** Cell with diameter of 7–10 microns, red cytoplasm (fully hemoglobinized)
- **Reticulocyte:** A non-nucleated cell, the size of a mature or slightly larger erythrocyte.
- **Mature erythrocyte:** Non-nucleated 7.2 microns in diameter, biconcave disc, cytoplasm uniformly red with a faint central Pallor **(Fig. 4.5)**.

Hemoglobin

Hemoglobin is a conjugated protein that acts as a vehicle for oxygen and carbon dioxide transport. It is composed of four protein chains, two alpha chains and

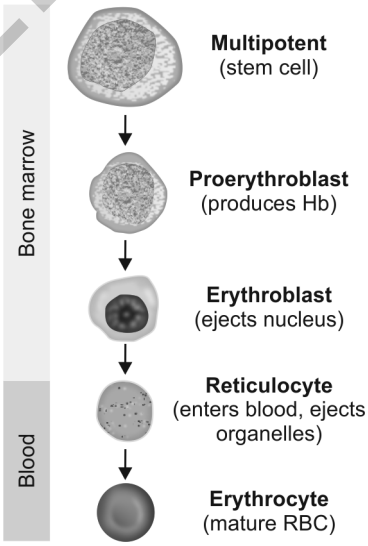

Fig. 4.5: Matuaration of RBCs.

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two beta chains, each with a ring-like heme group containing an iron atom. Oxygen binds reversibly to these iron atoms and is transported through blood. Hemoglobin is responsible for the red color of the blood. Its structure consists of four subunits, typically a tetramer of alpha 2 beta 2, each containing a heme moiety in the ferrous state with iron. There are 141 amino acid residues in each alpha chain, and in each beta chains there are 146 residues. A normal adult male contains 14–16 g of hemoglobin per hundred mL of blood and a normal female contains 12–16 g per hundred mL of blood **(Fig. 4.6)**.

The functions of hemoglobin are:

- Transport of Oxygen and Carbon dioxide in the body.
- Maintenance of acid-base balance
- Source of formation of Bilirubin

Hemolysis

The lifespan of RBC is about 120 days and their breakdown is carried out by phagocytic reticuloendothelial cells. This process is called **hemolysis.** Spleen, liver, and bone marrow are the major sites for hemolysis.

White Blood Cells or Leukocytes

White blood cells (WBCs), also called leukocytes, are the cells which actively participate in the immune system. They are involved in protecting the body against both infectious disease and foreign invaders. There are about 6,000–10,000 (every 8,000) WBCs per cubic millimeter in blood of an adult. The cytoplasm of WBCs contains nuclei and some have granules in their cytoplasm.

Classification of WBCs

They are classified into:

1. Granulocytes or polymorphonuclear leukocytes are classified as follow:
   a. *Neutrophils (polymorphs):* **Normal range: 2,500–6,000 per cubic mm**. They form the largest percentage of WBC approximately 42–60% of

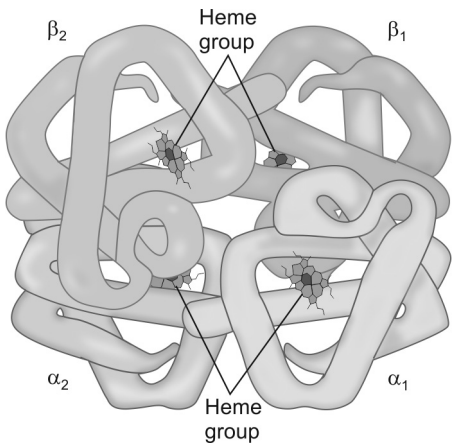

Fig. 4.6: Structure of hemoglobin.

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the total WBCs. Neutrophils play a major role in the mechanism of defense. Their diameter varies from 10 to 12 μm in size. In their nucleus, there are 2–5 lobes that stain violet purple. Light pink stains in the cytoplasm with pinkish granules. In acute bacterial infections, the number increases **(Fig. 4.7)**.

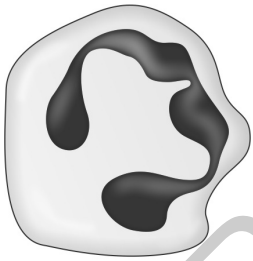

Fig. 4.7: Image of neutrophil.

b. *Eosinophils (Acidophils):* **Normal range: 40–400/μL.** These cells are slightly larger than neutrophils (12–14 μm). There are several wide, round/oval orange-pink granules in the cytoplasm of eosinophils. Allergic reactions such as asthma, food, and drug sensitivities are growing. The normal number of eosinophils is 2–4% of the total WBCs **(Fig. 4.8)**.

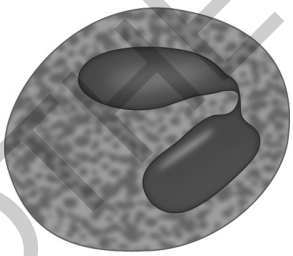

Fig. 4.8: Image of eosinophil.

c. *Basophils:* The basophils are the rarest of the white blood cells. They are difficult to find in human blood because they constitute only 0.5–1% of total number of leukocytes. The nucleus is kidney-shaped or lobulated. They excrete two chemicals that aid in the body's defenses—histamine and heparin **(Fig. 4.9)**.

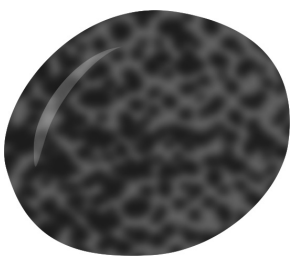

Fig. 4.9: Image of basophil.

2. **Agranular leukocytes:** They are divided into the following:
   a. *Lymphocytes:* It measures about 15–20 microns. They are associated with the body's defense mechanism. Lymphocytes are characterized by having a deeply stained nucleus and a comparatively small amount of cytoplasm. They are around 20–25%. Lymphocytosis is seen in viral infections, particularly in children (**Fig. 4.10**).

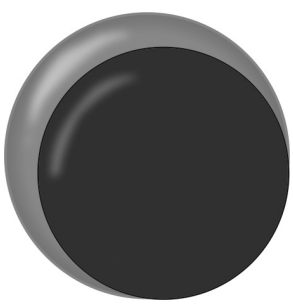

Fig. 4.10: Image of lymphocytes.

They are of two types:
      i. Small lymphocyte: Equal in size to mature erythrocyte or smaller, around nucleus filing the cells, can be pale blue cytoplasm containing Azure granules.
      ii. Large lymphocyte: It measures 10–40 microns, nuclear is large and around, cytoplasm containing azure granules.
   b. *Monocytes:* **Normal range: 700–1500/μL**. Monocytes range from 14 to 18 μm in diameter and are the largest WBCs. They have a centrally

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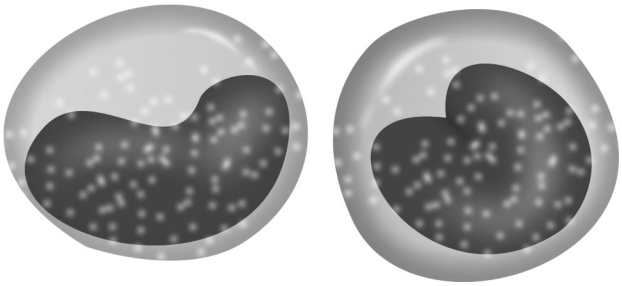

Fig. 4.11: Image of monocytes.

located nucleus that stains pale violet. They are around 3–8% wide and "horseshoe" shaped. Their cytoplasm stains are light greyish blue and contain dust-like granules of reddish blue and a few clear vacuoles. They circulate in the blood and are strongly phagocytic and motile. Monocytosis is seen in bacterial infections (e.g., tuberculosis) and protozoan infections **(Fig. 4.11)**.

Platelets or Thrombocytes

They are small non-nucleated disc-shaped cells derived from megakaryocyte in red bone marrow. Platelets, also called thrombocytes (**thromb + cyte, "blood clot cell"),** are a component of blood whose function is to stop bleeding by clumping and clotting blood vessel injuries.
Normal range: 150,000–400,000/µL.

BLOOD GROUP

The blood group was found by Karl Landsteiner. The blood group system of ABO is used to categorize human beings' blood.

There are glycoproteins on the surface of the red cell and glycolipids that function as antigen. They are called blood group antigens. These antigens are present as antigen.

It can be present on the surface or protrude from the red cell's membrane. An immune reaction may take place, if introduced into a person who lacks the antigen.

An individual who donates blood is a donor. A recipient is a person who collects blood. If the donation of blood does not match that of the recipient, after transfusion, the incompatibility results in agglutination and lysis of donated red blood cells. This can lead to extreme disease and can cause death.

The antigens and a corresponding antibody in each blood group are shown in **Table 4.1**.

Rhesus System

The Rhesus factor is present on RBCs membranes. Individuals who have rhesus on their RBC are rhesus-positive (Rh +ve) and those who lack Rh antigen are designated as rhesus negative (Rh –ve). If a Rh-positive blood is given to

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TABLE 4.1: Antigens and corresponding antibodies.

Group	*Antigen*	*Antibody*
A	A	B
B	B	A
AB	AB	None
O	None	Anti A, Anti B

a Rh-negative person, no immediate reaction occurs. But during a second transfusion, the Rh negative person develops Anti-Rh agglutinin, which leads to agglutination of the reaction.

Erythroblastosis Fetalis

In this condition the fetus of Rh-negative mother and Rh-positive father is Rh positive. This may lead to serious complications as Rh antigen will travel from the fetus to Mother's blood. When these antibodies reach the fetus, they produce severe hemolytic reactions, which may lead to death of the fetus.

Clotting of Blood (Coagulation of Blood)

When a blood vessel is damaged bleeding occurs. Loss of blood is stopped by a formation of blood clot. Blood clotting is a defense mechanism of the body and prevents loss of blood from the site of injury. The formation of blood clot depends upon 12 factors.

Nomenclature for blood coagulation factors:

- **Factor I:** Fibrinogen
- **Factor II:** Prothrombin
- **Factor III:** Thromboplastin
- **Factor IV:** Calcium
- **Factor V:** Labile factor
- **Factor VI:** Unassigned
- **Factor VII:** Stable factor
- **Factor VIII:** Antihemophilic factor
- **Factor IX:** Christmas factor
- Factor V and VII are required for conversion of damaged tissue into thromboplastin. Factor VIII is an antihemophilic factor. Absence of Factor VIII leads to disease called hemophilia.

DISORDERS OF BLOOD

Anemia

Anemia is a state of decreased red cell mass of blood leading to decreased oxygen carrying capacity of the body. Red cell indices are useful in classifying anemia.

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TABLE 4.2: Classification of anemia.	
Category	***Anemia***
Microcytic	Iron deficiency anemia, sideroblastic anemia, thalassemia
Macrocytic	Aplastic anemia vitamin B_{12} deficiency anemia
Normocytic	Hemolytic anemia and bone marrow suppression

Clinical features of anemia: There is usually shortness of breath (particularly on exercise), weakness, lethargy, palpitation, and headaches. In older subjects, symptoms of cardiac failure, angina pectoris, or intermittent claudication or confusion may be present.

Anemia can also be classified based on the size of the red blood cells and amount of hemoglobin in each cell **(Table 4.2)**.

Iron Deficiency Anemia

Incidence: This is the most prevalent type of anemia found globally and in India. It is seen in all age groups, but it is more common in age-bearing females and in infants.

Cause: Iron is one of the most common elements in the crust of the earth, yet iron shortages are the most common cause of anemia. This is because the body has a restricted capacity to absorb iron and excess iron loss is regular due to bleeding. It is caused by iron deficiency, which is necessary for normal hemoglobin production.

Megaloblastic Anemia

These are a group of disorders with abnormally large red cells due to faculty DNA synthesis and nuclear cytoplasmic asynchrony, resulting in anemia.

Cause: Vitamin B_{12}, or cobalamin and folic acid, are necessary for normal DNA synthesis. Megaloblastic anemia occurs due to one or both of these vitamins being deficient.

Pathogenesis: There is a deficiency in DNA synthesis in megaloblastic anemia, although RNA synthesis remains unimpaired. Due to hemoglobin being synthesized in excess during the delay, there is impaired cell division. As a consequence, erythroid precursors are formed as a result of this enlargement. All proliferating cells are affected by these changes.

Aplastic Anemia

Definition: Aplastic anemia is a condition in which red cells, white cells, and platelets are not produced by the bone marrow, resulting in PANCYTOPENIA.

Etiology: Bone marrow failure may be: (1) Congenital or inherited-called Fanconi anemia (2) Secondary to drugs, toxins, chemicals, exposure to radiation, or postspecific viral infections (3) Idiopathic, if the cause is unknown.

Clinical characteristics: The patient has symptoms of anemia (fatigue, breathlessness, pallor) because red cells are not produced by the marrow. Since normal WBC production is impaired, he/she may also have repeated

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and severe infections. Because of thrombocytopenia, the patient might also have bleeding symptoms.

Hemolytic Anemia

It is due to increased red blood cell destruction. It occurs because of mechanical injury to red blood cells or malarial infection due to hereditary disorders.

Polycythemia (Erythrocytosis)

There is an abnormal increase in the number of red blood cells in this condition. Changes include an increase in hemoglobin above 17.5 g/dL in adult males and 15.5 g/dL in females, usually with an associated increase in the number of red cells (**above 6.0 × 1012/L in males and 5.5 × 1012/L in females and hematocrit in females).**

Disorders of WBC

- Leukopenia is a condition in which WBCs are reduced below normal that is less than 4,000 per cubic mm of blood.
- **Agranulocytosis:** Acute condition there is a great reduction in number of polymorphonuclear leukocytes.
- **Leukopenia:** Decrease in the number of white blood cells in the blood.
- **Leukocytosis:** Abnormal circulating leukocytes pathological conditions.
- **Leukemia:** It is a cancerous condition characterized by an overproduction of white blood cells.

Disorders of Platelets

Thrombocytopenia: Decrease in the number of platelet count, which results in petechial hemorrhage, increase in bleeding time, and defect in retraction of clot.

Disorders of Clotting

Hemophilia: This condition occurs due to the absence of factor VIII (and antihemophilic factor)

Thrombosis: International clotting of blood is called thrombosis. It may occur due to roughening and blood vessels, which may lead to deep vein thrombosis.

SUMMARY

- Blood is a specialized form of connective tissue, which circulates in a closed system of blood vessels and is composed of transparent fluid plasma in which different types of cells are suspended.
- Blood is alkaline in nature pH of 7.4 (normal ranges 7.35–7.5).
- Blood contains plasma (straw-colored fluid) and cells.

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- Plasma constitute:
  - Water: 91%
  - Dissolved substances
    - Protein: 8%
    - Salts: 0.9%
- Cellular content (formed elements) of blood:
  - Leukocyte or white blood cells
  - Erythrocytes or red blood cells
  - Thrombocytes or platelets
- **Functions of blood are:** (1) Respiration: Transporting oxygen from lungs to tissues and carbon dioxide from tissues to lungs, (2) Coagulation of blood, (3) Excretion: transport of metabolic wastes to the lungs, kidneys, intestine, and skin for removal, (4) Nutrition, (5) Transport hormones, (6) Maintain a normal acid-base balance of the body, (7) Regulation of water balance, (8) Regulation of body temperature, (9) Transport of metabolites, (10) Defense against infection.
- **Erythropoiesis:** The process of development of RBCs is called erythropoiesis.
- **Hemoglobin:** It is a conjugated protein that serves as a vehicle for transportation of oxygen and carbon dioxide.
- **The functions of hemoglobin are:** (1) Transport of oxygen and carbon dioxide in the body, (2) Maintenance of acid-base balance, (3) Source of formation of bilirubin.
- **Classification of WBCs:** (1) Granulocytes or polymorphonuclear leukocytes—again classified as follows: Neutrophils (polymorphs), Eosinophils (acidophils) and Basophils, (2) Agranular leukocytes—they are divided into the following: Lymphocytes and Monocytes.
- **Platelets or thrombocytes:** They are small non-nucleated disc-shaped cells derived from megakaryocyte in red bone marrow, are a component of blood whose function is to stop bleeding by clumping and clotting blood vessel injuries.
- **Blood group:** The antigens and a corresponding antibody in each blood group are as follows:

Group	*Antigen*	*Antibody*
A	A	B
B	B	A
AB	AB	None
O	None	Anti-A, Anti-B

- **Anemia:** Anemia is a state of decreased red cell mass of blood leading to decreased oxygen carrying capacity of body. Red cell indices are useful in classifying anemia.
- **Clotting of blood (coagulation of blood):** Blood clotting is a defense mechanism of the body and prevents loss of blood from the site of injury. The formation of blood clot depends upon 12 factors. Nomenclature for blood coagulation factors is described as:
  - Factor I: Fibrinogen
  - Factor II: Prothrombin
  - Factor III: Thromboplastin
  - Factor IV: Calcium

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- Factor V: Labile factor
- Factor VI: Unassigned
- Factor VII: Stable factor
- Factor VIII: Antihemophilic factor
- Factor IX: Christmas factor
- Factor V and VII are required for conversion of damaged tissue into thromboplastin.
- Factor VIII is an antihemophilic factor. Absence of Factor VIII leads to disease called hemophilia.

- Leukopenia is a condition in which WBCs are reduced below normal that is less than 4,000 per cubic mm of blood.
- **Agranulocytosis:** Acute condition, there is a great reduction in number of polymorphonuclear leukocytes.
- **Leukocytosis:** Abnormal circulating leukocytes pathological conditions.
- **Leukemia:** It is a cancerous condition characterized by an overproduction of white blood cells.
- **Thrombocytopenia:** Decrease in the number of platelet count, which results in petechial hemorrhage, increase in bleeding time, and defect in retraction of clot.
- **Hemophilia:** This condition occurs due to the absence of factor VIII (and antihemophilic factor)
- **Thrombosis:** International clothing of blood is called thrombosis. It may occur due to roughening and blood vessels, which may lead to death.

GLOSSARY

1. **Agglutination:** The clumping of red blood cells on the surface of the cells as a result of antibodies bound to antigens.
2. **Antibodies:** These are the proteins that the body creates to recognize antigens and neutralize or kill them. Antibodies provide bodies with a significant protection against any foreign microorganism—causing disease.
3. **Antigens:** Molecules that provide blood or other tissue cells with a particular signature or identity. In addition to bacteria and viruses, antigens are present on the surface of blood and other tissue cells.
4. Amino acids are organic compounds that are protein building blocks. There are 20 amino acids of various kinds.
5. **Bacteria:** It is a simple single-sided microscopic organism lacking chlorophyll and a membrane around its nuclei. By mitosis, it reproduces. Many bacterial organisms are parasites of humans and other plants and animals.
6. **Enzymes:** It is a biological catalyst that speeds up chemical responses. The molecules upon which **enzymes** may act are called substrates, and the **enzyme** converts the substrates into different molecules known as products.
7. **Hormones:** Substances formed by specialized cells (usually proteins) that can move to other parts of the body where they influence chemical reactions and control different cellular functions. For example, with insulin.
8. **Albumin:** It is the liver's most abundant plasma protein. Different substances are transported by albumin, including bilirubin, fatty acids, metals, ions, and hormones.

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9. **Blood:** It is a liquid connective tissue made up of erythrocytes, leukocytes, and platelets and a plasma—called extracellular fluid matrix.
10. **Fibrinogen:** This is a plasma protein that is formed in the liver and is involved in blood coagulation.
11. **Lipids:** It is a water-insoluble macro biomolecule soluble in nonpolar solvents including fats, waxes, oils, hormones, etc.
12. **Plasma:** It is a liquid straw-colored medium in the blood that carries red cells, white cells, platelets, etc. Much of the volume of the blood consists of plasma.

LONG ANSWER TYPE QUESTIONS

1. **Discuss in detail about the composition of blood and blood group system.**
2. **What is hemopoiesis? Discuss in detail disorders of blood.**

SHORT ANSWER TYPE QUESTIONS

1. **Give a brief account of RBCs.**
2. **What is blood coagulation.**
3. **What is plasma protein.**

MULTIPLE CHOICE QUESTIONS

1. **Which of the following statements about blood is true?**
   a. Blood is about 20% water.
   b. Blood is slightly more acidic than water.
   c. Blood is slightly more viscous than water.
   d. Blood is slightly more salty than sea water.
2. **Which of the following statements about albumin is true?**
   a. It is the most abundant plasma protein.
   b. It is produced by specialized leukocytes called plasma cells.
   c. It draws water out of the blood vessels and into the body's tissues.
   d. None of the above
3. **Which of the following plasma proteins is not produced by the liver?**
   a. Fibrinogen
   b. Alpha globulin
   c. Immunoglobulin
   d. Beta globulin
4. **What is the average life-span of RBCs?**
   a. 8–10 days
   b. 120 days
   c. 1 years
   d. 3 years
5. **What is the main function of neutrophil?**
   a. Liberate heparin
   b. It has opposite effect to histamine
   c. Destroys bacteria with lymphocytes
   d. Blood clotting

ANSWERS KEY

1. c **2.** a **3.** c **4.** b **5.** c

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ATLAS

Identify and label the diagrams.

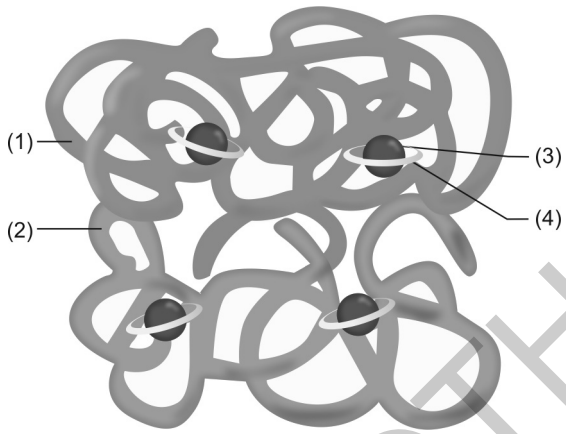

Fig. 1: Hemoglobin.

1. _____
2. _____
3. _____
4. _____

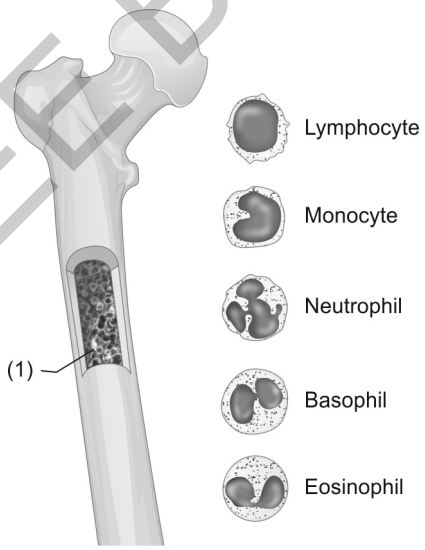

Fig. 2: Long bone.

1. _____

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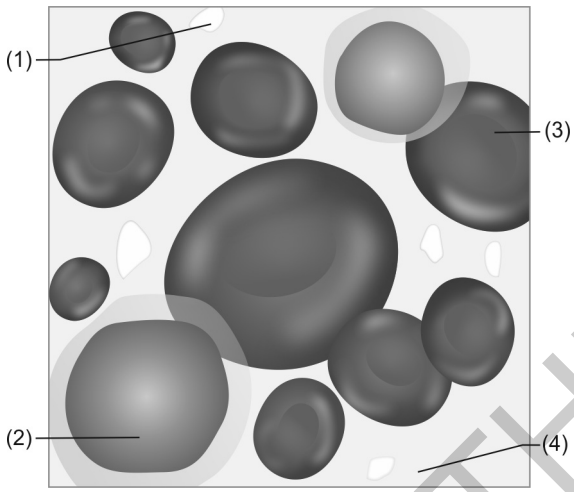

Fig. 3: Component of blood.

1. _____
2. _____
3. _____
4. _____

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Simplified Anatomy and Physiology
for Paramedical Students

The book contains the topic as per the Indian Paramedical Council syllabus. Anatomy and physiology is the backbone of general foundation course (GFC). The basics of anatomy and physiology are applied all around in medical, paramedical and nursing discipline. Therefore, it is pivotal to learn the concepts well. *Simplified Anatomy and Physiology for Paramedical Students* is written in view to provide the comprehensive information about the human anatomy and physiological process in easy language. The book has practice questions which will help the students to prepare for their examination.

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Printed in India

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ISBN 978-93-5465-780-1

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