Blood

Functions

There are three major functions of blood:

1. Distribution

There are six distribution functions:

a. transports oxygen from the lungs to all the cells of the body

b. transports carbon dioxide from the body cells to the lungs

c. transports nutrients from the digestive organs to the body cells

d. transports metabolic waste products from the cells to the kidneys, lungs, and sweat glands for elimination

e. transports hormones from the endocrine tissues and organs to their target cells where they perform their functions

f. transports enzymes to various cells where they function in speeding up the rate of chemical reactions

2. Regulation

There are three regulation functions:

a. maintains normal body temperature through the absorption and distribution of body heat

b. maintains normal pH through the use of buffers

c. maintains fluid volume in the circulatory system and water content of cells through the movement of sodium ions

3. Protection

There are two protection functions:

a. prevents blood loss through clotting mechanisms

b. provides protection against bacteria, viruses, toxins, and other foreign substances through the production of white blood cells and antibodies
Blood is composed of two parts:

1. **formed elements**

There are three formed elements:

a. erythrocytes or red blood cells (RBCs)

b. leukocytes or white blood cells (WBCs)

c. platelets

2. **plasma** - The liquid or fluid portion of the blood which contains dissolved substances.

### Formed Elements

1. **Erythrocytes**

Erythrocytes are biconcave discs that have a nucleus when they are developing, but lack a nucleus when they are mature. They make up about 45% of the total blood volume and 33% of their weight is composed of hemoglobin.

The hemoglobin molecule consists of two portions:

a. **heme** - It is a red pigment which contains an iron atom. The iron atom has the ability to bond with oxygen and the function of the heme portion is to carry oxygen.

b. **globin** - It consists of four polypeptide chains and its function is to carry carbon dioxide. Each polypeptide chain is bonded to a heme group.

As the erythrocytes pass through the blood vessels in the lungs, oxygen is picked up by hemoglobin molecules and they are now referred to as oxyhemoglobin. Oxyhemoglobin is transported by the blood to the body tissues where the oxygen is released and used for cell processes. The molecules are now referred to as deoxyhemoglobin. Deoxyhemoglobin picks up carbon dioxide, which is a waste product of cells, and the molecules are now referred to as carbaminohemoglobin. The majority of carbon dioxide is converted into bicarbonate ions and transported by the plasma. Carbaminohemoglobin is transported by the blood to the lungs where the carbon dioxide is released.
Erythrocyte Production

The formation or production of erythrocytes is referred to as erythropoiesis. Erythropoiesis occurs in the red bone marrow of spongy bone located in the cranial bones, ribs, sternum, vertebrae, os coxa, and the proximal epiphyses of the humerus and femur.

In the red bone marrow there is a stem cell called the hemocytoblast which becomes a myeloid stem cell. The myeloid stem cell becomes a committed cell known as a proerythroblast. A committed cell is a cell which must develop along a specific pathway. The proerythroblast differentiates into an erythroblast in which ribosome synthesis and hemoglobin synthesis and accumulation occurs. When hemoglobin synthesis is at a maximum, the erythroblast becomes a normoblast. Within the normoblast the nucleus stops functioning, degenerates and is ejected from the cell. The cell membrane collapses inward forming a biconcave disc known as a reticulocyte. Reticulocytes leave the red bone marrow, enter the bloodstream and mature into erythrocytes.

The normal life span of an erythrocyte is between 100 and 120 days. They lose their flexibility, become rigid and fragile and many are trapped in the spleen and liver where they are ingested by macrophages ("big eaters"). The hemoglobin molecules are broken down into heme and globin. The heme portion decomposes into bilirubin which is a substance secreted in bile from the liver. The iron released from the heme portion combines with a protein and is transported by the blood to the red bone marrow where it is stored and later used to form new hemoglobin. The globin portion is broken down into amino acids and they are transported by the blood to various parts of the body.

Homeostasis is maintained between erythrocyte production and erythrocyte destruction by a hormone called erythropoietin. Erythropoietin is mainly produced by the kidneys and a small amount is produced by the liver. Some erythropoietin is also found circulating in the blood and lymph. When the level of oxygen in the blood decreases due to a decrease in the number of erythrocytes, kidney cells become oxygen-deficient and erythropoietin production increases. Erythropoietin is transported by the blood to the red bone marrow where it stimulates hemocytoblasts to begin their differentiation into erythrocytes.
2. Leukocytes

Leukocytes make up about 1% of the total blood volume and they function in protection against bacteria, viruses, parasites, tumor cells, toxins and other foreign substances. They differ from erythrocytes in that they contain a nucleus when they are mature.

Leukocytes travel through the blood and leave the blood vessels through spaces between the cells that form the walls of the capillaries. The process is referred to as diapedesis. The leukocytes move through the tissues by amoeboid motion to areas of infection or tissue damage. They are drawn to the areas of infection or tissue damage by toxins or chemicals released by the damaged tissue and the response is referred to as chemotaxis (movement toward chemicals).

There are two major groups of leukocytes based on the shape of their nucleus and the characteristics of their cytoplasm.

1. Granulocytes - They have lobed nuclei and they contain granules in their cytoplasm.

There are three types of granulocytes:

a. neutrophils - They are the most numerous of the leukocytes. The nucleus has 3 to 6 lobes and the cytoplasm contains many fine granules. Many of the granules function as lysosomes. Other granules contain antibiotic-like proteins called defensins. Neutrophils function as phagocytes which ingest and destroy bacteria and some fungi at the sites of inflammation.

b. eosinophils - They are about the same size as neutrophils. The nucleus is bi-lobed and the cytoplasm contains many large, coarse granules which function as lysosomes. Eosinophils function in destroying parasitic worms such as flatworms and roundworms, destroying antigen-antibody or immune complexes, and in the inactivation of chemicals that cause inflammation of allergic reactions.

c. basophils - They are the least numerous of the leukocytes. The nucleus is S or U-shaped and the cytoplasm contains a few large, coarse granules. The granules contain histamine which causes inflammation, dilates blood vessels, and attracts other white blood cells to the area of infection.
2. **Agranulocytes** - They have a large nucleus and no visible granules in their cytoplasm.

There are two types of agranulocytes:

a. **lymphocytes** - They are about the same size or slightly larger than erythrocytes. The nucleus is large, round or slightly indented and surrounded by a thin area of cytoplasm.

There are two types of lymphocytes:

1. **T lymphocytes** - They function in an immune response by attacking and destroying virus-infected cells and tumor cells.

2. **B lymphocytes** - They form **plasma cells** in response to **antigens** (foreign substances) that enter the body. The plasma cells then produce antibodies that inactivate the antigens.

b. **monocytes** - They are the largest of the leukocytes and the nucleus is U or kidney-shaped. When monocytes enter tissues, they become **macrophages** ("big eaters") which engulf bacteria and viruses and clean up cellular debris following an infection.

**Leukocyte Production**

Formation of leukocytes is called leukopoiesis and it is regulated by a group of hormones called **colony stimulating factors** (CSF's). Both granulocytes and agranulocytes are formed in the red bone marrow. **Granulocytes** mature in the red bone marrow, **lymphocytes** mature in lymphatic tissue and organs, and **monocytes** mature in the tissues.

Leukopoiesis begins with hemocytoblasts. The hemocytoblasts may either become a myeloid stem cell or a lymphoid stem cell depending on the hormone present. If a myeloid stem cell forms, it may become either a myeloblast or a monoblast. Myeloblasts and monoblasts are committed cells and must follow a specific pathway of development. A myeloblast differentiates into a promyelocyte. Promyelocytes may follow one of three pathways and a characteristic nucleus and granules form. The promyelocyte becomes a myelocyte which produces an eosinophil, a neutrophil, or a basophil.

If a monoblast was formed, it differentiates into a promonocyte which then becomes a monocyte.

A lymphoid stem cell produces a committed cell called a lymphoblast. Lymphoblasts differentiate into **prolymphocytes** which become **T** or **B lymphocytes**.
Platelets

Platelets function in blood clotting and they consist of small cytoplasmic fragments which contain granules. Formation of platelets is called thrombopoiesis and is regulated by the hormone thrombopoietin.

Thrombopoiesis begins with hemocytoblasts which form cells called megakaryoblasts. Mitosis (division of the nucleus) occurs repeatedly in the megakaryoblast, but cytoplasmic division does not occur. The cells formed are multi-nucleated and are called promegakaryocytes. When mitotic divisions end, the cell becomes known as a megakaryocyte. Within the megakaryocyte membranes begin to form which divides the cell into numerous compartments. The megakaryocyte ruptures, forming cytoplasmic fragments called platelets or thrombocytes.

Plasma

Plasma is the liquid portion of the blood and makes up about 55% of the total blood volume. About 90% of plasma is water and the remaining portion is dissolved substances. The most abundant dissolved substances are proteins. Other dissolved substances include nutrients, hormones, respiratory gases, ions, and cellular waste products.

Hemostasis

Hemostasis is the stopping of bleeding and it involves three stages.

1. vascular spasms - When a blood vessel is damaged, the smooth muscle in the wall of the vessel contracts immediately and reduces blood flow to the area.

2. platelet plug formation - When a blood vessel is damaged, platelets adhere to the exposed collagen fibers. The platelets enlarge, become irregularly shaped and form spiked processes. The granules in the platelets begin to break down and some release serotonin which enhances vascular spasms. Other granules release adenosine diphosphate (ADP) which causes more platelets to accumulate and release their contents. The result is the formation of a loose-fitting platelet plug.

3. coagulation or blood clotting - Coagulation is a complex process and involves substances called coagulants which may be found in the platelets or in the plasma.
There are two pathways of coagulation:

a. intrinsic pathway - It occurs when platelets clump together on the collagen fibers, break down and release platelet coagulation factors (PFs) into the plasma.

b. extrinsic pathway - It occurs when a blood vessel and the surrounding tissue are damaged. The damaged tissue cells release a lipoprotein called tissue thromboplastin.

In both pathways, after a series of reactions, Factor X is formed and four stages occur:

1. In the intrinsic pathway, Factor X combines with calcium, Factor V, and platelet coagulation factor 3 (PF3). In the extrinsic pathway, Factor X combines with calcium, Factor V, and tissue thromboplastin. The result of both pathways is the formation of prothrombin activator.

2. Prothrombin activator converts the plasma protein, prothrombin into an enzyme called thrombin.

3. Thrombin converts a plasma protein, fibrinogen into a protein called fibrin. Fibrin consists of protein threads which form a network in which platelets accumulate. The result is the formation of a gel-like clot which traps more platelets and blood cells.

4. Thrombin also activates Factor XIII (fibrin stabilizing factor). Factor XIII tightens the fibrin strands which strengthens and stabilizes the clot. Contractile proteins in the platelets pull the fibrin strands closer together and the process is referred to as clot retraction. During clot retraction, a straw-colored liquid called serum is formed. Serum is plasma minus the coagulating proteins.

When the blood vessel has healed, the clot dissolves and the process is referred to as fibrinolysis. At the beginning of clotting, a plasma protein called plasminogen is incorporated into the clot. Plasminogen remains inactive until healing occurs. Enzymes then activate plasminogen to form plasmin, a protein-digesting enzyme, which dissolves the clot.

Blood Groups

On the surface of the plasma membrane of erythrocytes there are genetically determined proteins, or antigens, specifically called agglutinogens. In the plasma there are antibodies specifically called agglutinins. Agglutinins act against foreign agglutinogens, causing the blood to clump or agglutinate.
Blood groups are divided based on the presence or absence of agglutinogens.

There are two major blood groups in humans:

1. ABO Blood Group

   The ABO blood group is based on the presence or absence of two agglutinogens known as A and B on the surface of the plasma membrane of the erythrocytes.

   A person with type A blood has agglutinogen A
   A person with type B blood has agglutinogen B
   A person with type AB blood has both agglutinogens A and B
   A person with type O blood has neither agglutinogen A nor B

   Around the age of two months, agglutinins form in the plasma. The agglutinins are known as anti-A and anti-B.

   A person with type A blood has agglutinin anti-B
   A person with type B blood has agglutinin anti-A
   A person with type AB blood has neither agglutinin anti-A nor anti-B
   A person with type O blood has both agglutinin anti-A and anti-B

   A person with type O blood is referred to as a universal donor and can give blood to a person of any of the four blood types. A person with type AB blood is referred to as a universal recipient and can receive blood of any of the four types.

2. Rh Blood Group

   The Rh blood group is based on the presence or absence of eight agglutinogens known as Rh factors. If any one of the Rh factors is present, the person is referred to as being Rh positive (Rh\(^+\)) and they do not have anti-Rh in their plasma. If none of the Rh factors is present, the person is Rh negative (Rh\(^-\)) and they have anti-Rh in their plasma.