Medical Biology

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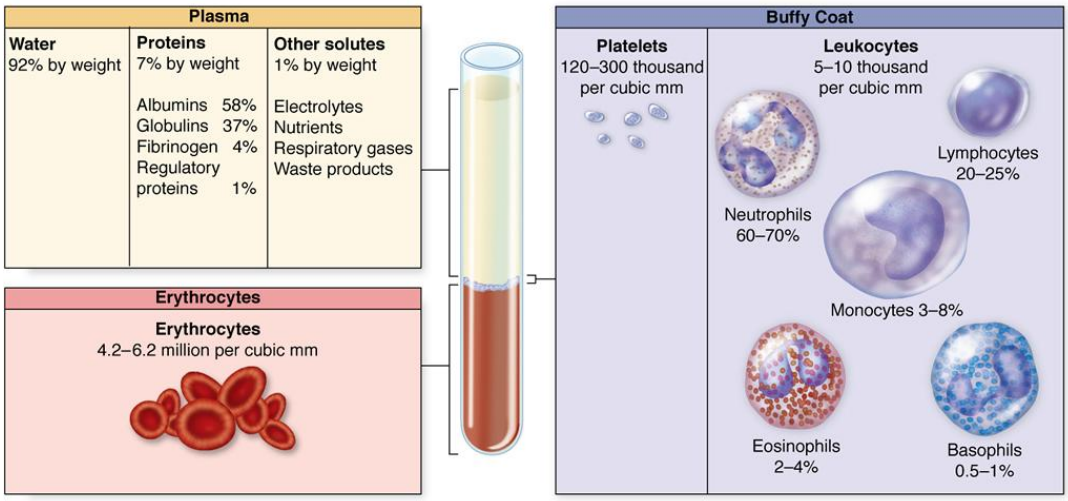
Blood

Blood is a fluid connective tissue consisting of cells suspended in a liquid fibrous matrix. The cells are called formed elements, and the liquid matrix is known as plasma. The formed elements consist of erythrocytes (red blood cells), leukocytes (white blood cells) and platelets. If blood is centrifuged, it divides into 3 portions:
(1) Plasma makes up roughly 55% (upper layer).
(2) Packed RBCs make up roughly 45% (lower layer).
(3) the buffy layer (containing WBCs and platelets) makes up <1% (middle layer).



The % of blood consisting of packed RBCs is known as the haematocrit. Blood's colour ranges from scarlet (oxygen-rich) to dark red (oxygen poor). Its viscosity is 5X that of water, due primarily to the presence of formed elements. Blood pH normally ranges from 7.35-7.45 (slightly alkaline). Blood temperature is typically 100°F. Typical blood volume is 4-5 L for females and 5-6 L for males.

Blood functions:
Blood has 3 main distribution functions:
(1) It carries O2 (from lungs) and nutrients (from GI tract and body stores) to all cells.
(2) It carries wastes from all cells to elimination sites (lungs for CO2; kidneys for nitrogenous wastes).
(3) It carries hormones from endocrine organs to target tissues.
Blood has 3 main regulatory functions:
(1) It regulates body T° by absorbing and distributing heat.
(2) It maintains body pH by virtue of its many buffers.
(3) It maintains adequate fluid volume in the body.
Blood has 2 main protective functions:
(1) It prevents blood loss by initiating clotting mechanisms in response to blood vessel damage.
(2) It prevents infection via WBCs and plasma immune proteins.

Plasma:

It is the straw-colour liquid part of blood. Blood plasma is about 55% of blood volume. 90% of plasma is water. Water acts as a solvent and suspending medium. Solutes dissolved in plasma include plasma proteins, nutrients, electrolytes, respiratory gases, hormones and wastes.
Three major types of plasma proteins are the **albumins, globulins,** and **fibrinogen.** Albumins are the most abundant plasma proteins and contribute most to plasma's osmotic pressure. They also combine with and help transport other organic molecules. The globulins are of three types called alpha, beta, and gamma globulins. Alpha and beta globulins also combine with and help transport substances in the blood such as hormones, cholesterol, and iron. Gamma globulins are also known as antibodies and are produced by plasma cells, not by the liver. Gamma globulins are important in fighting disease- causing pathogens. Fibrinogen is an inactive plasma protein. Once activated, fibrinogen forms a blood clot.

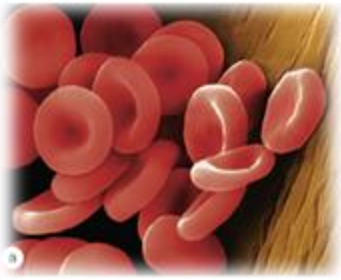
Blood cells:

The blood has 3 major formed elements:

1. Erythrocytes (RBC): function mainly to transport oxygen from the lung to the tissues.
2. Leukocytes (WBC): have a defensive role in destroying infective organisms such as bacteria & viruses as well as assisting in the removal of dead or damaged tissues.
3. Thrombocytes (platelets): are the first line of defense against any damage to blood vessels they adhere to the defect & share in the formation of blood clot.

Erythrocytes:

- These are rounded biconcave disks, bright red in color due to the presence of hemoglobin, their biconcave shape will maximize their surface area/ volume ratio so facilitate the gaseous exchange.
- RBCs are about 7.5 µm. in diameter, those RBCs with a diameter more than 9 µm. are called macrocytes, while those with a diameter less then 6µm. are called microcytes.
- RBC count in adult female is about 3.9-5.5 million/microliter, while in adult male it is about 4.1-6 million/microliter. Decrease in the number of RBC in the blood is associated with anemia, while the increase in number is called erythrocytosis or polycythemia.
- Haemoglobin (iron containing protein) is contained in abundance within RBCs. It reversibly binds and releases O2. In lungs, Hb binds O2 and is then oxyhaemoglobin, transport it to body tissue. Blood rich in oxyhaemoglobin are bright red (the arterial blood). In tissues, Hb releases O2 and is then deoxyhaemoglobin or reduced haemoglobin. Haemoglobin carrying CO2 which partly diffuse from the cells and tissues into the blood and carried to the lungs is known as carbaminohaemoglobin which gives venous blood its bluish colour.

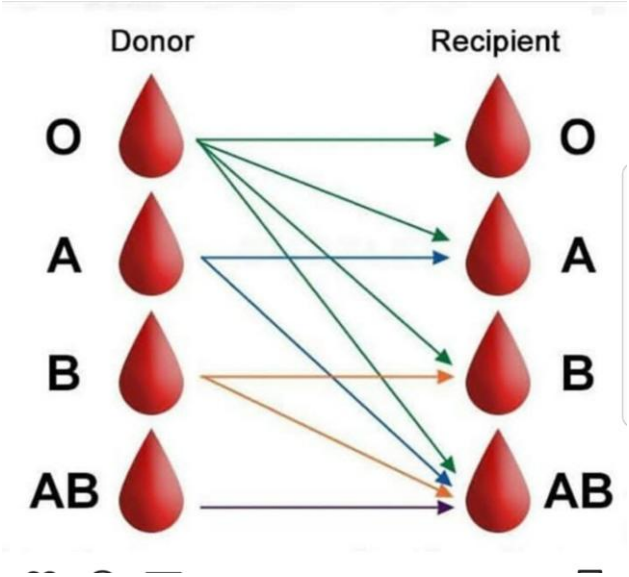


- RBCs have no nuclei as they are lost during the process of formation.
- These cells are highly flexible (deformable) so they can pass through the irregular and smallest capillaries.

- RBCs have a short life span of only 100-120 days in circulation, with aging RBCs become less deformable until they cannot pass through the splenic microcirculation and so they will be removed by phagocytosis.
- The extracellular surface of the RBC plasmalemma has specific inherited antigens and thus determine the blood group. The most notable of these are the A and B antigens, which determine the 4 blood groups, A, B, AB, and O.

ABO blood groups system

Blood groups	Antigen present in the surface of RBC	Antibodies present in the plasma
A	Antigens A	b
B	Antigens B	a
AB	Antigens A and B	Neither antibodies a nor b
O	Neither Antigen A nor B	Antibodies a and b

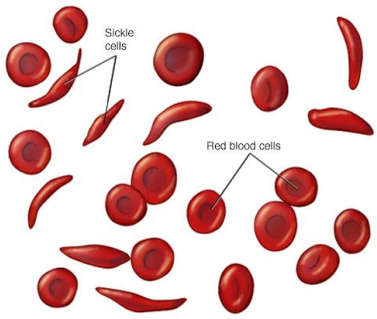


Disorders Involving Red Blood Cells

When there is an insufficient number of red blood cells or the cells do not have enough hemoglobin, the individual suffers from **anemia** and has a tired, run-down feeling. Iron, vitamin B12, and folic acid are necessary to produce red blood cells. ***Iron-deficiency anemia*** is the most common form. It results from inadequate intake of dietary iron, which causes insufficient hemoglobin synthesis. A lack of vitamin B12 causes ***pernicious anemia,*** in which stem-cell activity is reduced due to inadequate DNA production. Consequently, fewer red blood cells are produced. ***Folic-acid-deficiency anemia*** also leads to a reduced number of RBCs, particularly during pregnancy. Pregnant women should consult with their health-care provider about the need to increase their intake of folic acid, because a deficiency can lead to birth defects in the newborn.

Autoimmune hemolytic anemia causes the immune system to destroy the red blood cells faster than the body can replace them. This results in having too few RBCs. In hemolytic anemia, the rate of red blood cell destruction increases.

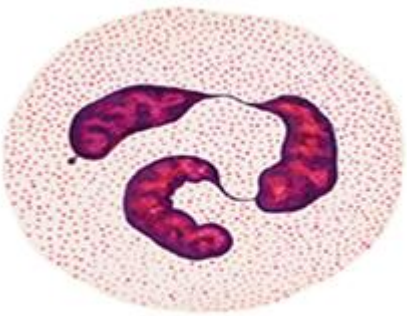
Sickle-cell anemia is a hereditary condition in which the individual has sickle-shaped red blood cells that tend to rupture as they pass through the narrow capillaries. The problem arises because the protein in two of the four chains making up hemoglobin is abnormal. The life expectancy of sickle shaped red blood cells is about 90 days instead of 120 days.



Leukocytes:

- Those are spherical cells that circulate in the blood until they migrate to the tissues. So, many functions of WBCs took place when they leave the circulation to enter the tissues.
- The no. of leukocytes (WBC) is much smaller than that of RBCs, in fact in a normal adult there are only between (6000-10,000) WBCs per µL of blood.
- According to the presence or absence of granules in their cytoplasm & according to the shape of the nucleus, the WBCs are classified into two groups:

1. Granulocytes: (polymorphonuclear leukocytes) because their cytoplasm contains prominent granules. They are Neutrophils, Eosinophils & Basophils.
2. Agranulocytes: (mononuclear leukocytes) they do not contain specific granules. They are Lymphocytes & Monocytes.



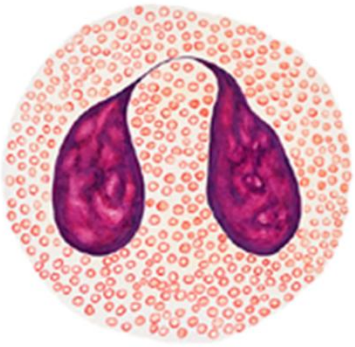
Neutrophilic granulocyte

Leukocytes are an important part of the defense mechanism against foreign materials, while they are circulating in the blood, they are spherical non motile cells, they leave the capillary by passing between the endothelial cells and they are normally found in the tissues.

Granulocytes:

❖ **Neutrophils:**

They constitute about 60-70% of the circulating leukocytes, their nucleus consists of 2-5 lobes (usually 3) linked together by fine chromatin thread. The cytoplasm of the neutrophils is filled with specific granules that are small.



Eosinophilic granulocyte

These cells circulate in the blood in a resting state but with appropriate activation they leave the blood and enter the tissues where they become highly mobile, phagocytic cells and their primary function is to ingest and destroy the invading organisms. Once neutrophils perform their function of killing microorganisms they die, resulting in the formation of **pus**, the accumulation of dead WBC with bacteria and tissue fluid.

❖ **Eosinophils:**

Are less numerous than neutrophils, they form only 2-4% of total WBC count. They have a characteristic bilobed nucleus. Their main feature is the presence of many large & elongated granules that are eosinophilic.

The number of eosinophils increase greatly in many types of parasitic infestations & the protection against the parasitic disease is one of their major functions. They also increase in allergic states.

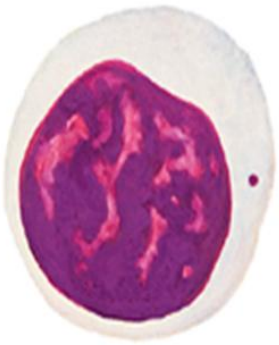
❖ **Basophils:**

Constitute less than 1% of the total WBC count, their nucleus is divided into irregular lobes, but this division is not so obvious and obscure by a cytoplasmic granule that are large and intensely basophilic, they are irregular in size & shape contain **histamine** (vasodilator) and **heparin** (anticoagulant). By migrating into connective tissues, basophils appear to transiently supplement the functions of mast cells. Like mast cells, basophils have surface receptors for immunoglobulin E (IgE) and secrete heparin and histamine in response to various antigens and allergens.

Agranulocytes:

❖ **Lymphocytes:**

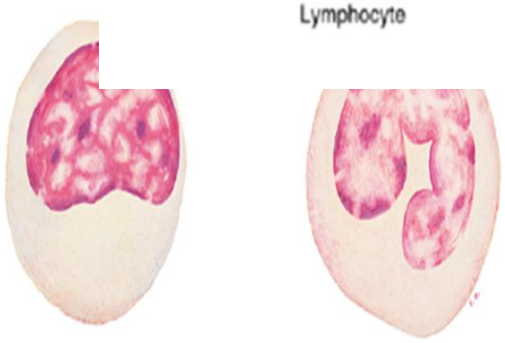
Lymphocytes make up 20-25% of WBCs. They are groups of spherical cells with similar morphological characters. They have an ovoid nucleus, the cytoplasm of the cell is scanty and can be seen as a thin rim around the nucleus. Major classes include B lymphocytes, helper and cytotoxic T lymphocytes (CD4+ and CD8+, respectively), and natural killer (NK) cells. These and other types of lymphocytes have diverse roles in immune defenses against invading microorganisms and certain parasites or abnormal cells.



Lymphocyte

The B cells produce antibodies that are used to attack invading bacteria, viruses, and toxins. The T cells destroy the body's own cells that have themselves been taken over by viruses or become cancerous.

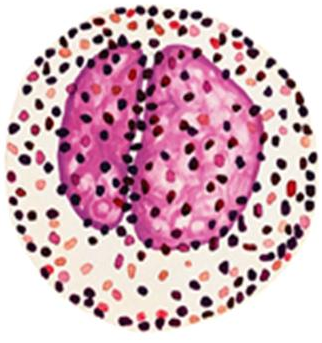
Activation of B lymphocytes after an immune response to a foreign particle leads to their differentiation into plasma cells. Those cells are large cells with eccentric rounded nucleus, and they are responsible for active synthesis of immunoglobulins. Plasma cells are seen in a small population in lymphoid organs.



Monocyte Monocyte

❖ **Monocytes:**

They are the largest of leukocytes. They constitute 3-8% of the white blood cells. They are spherical cells with oval or kidney shaped nucleus which are often placed eccentrically. Their cytoplasm is basophilic. Monocytes can live in the blood for 8 hours, after which they move into the connective tissue, where they may remain for a few months or longer. Blood monocytes are the precursor cells of tissue macrophages and other cells of the mononuclear



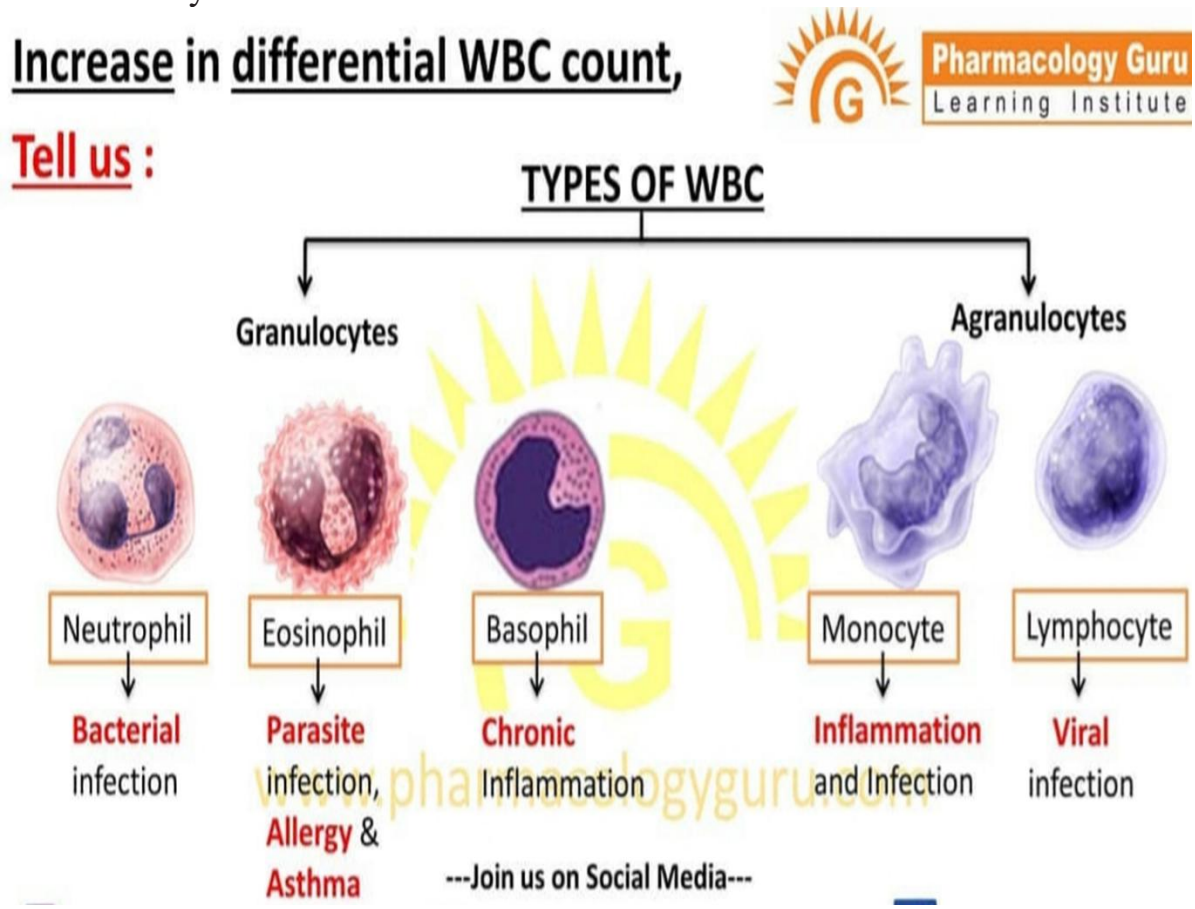
Basophilic granulocyte

phagocytic system such as kupffer cells in the liver, pulmonary and alveolar macrophages.

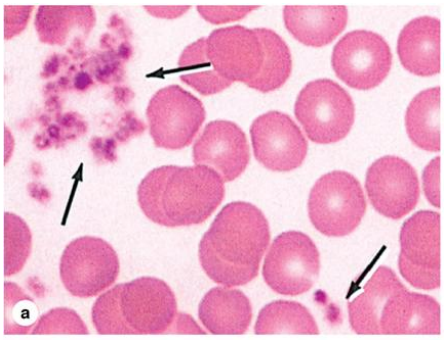
Clinical notes:

Increased numbers of white cells appear in the peripheral blood in a variety of disorders and provide a useful clue to underlying disease. For example:

1. An increase in circulating neutrophils in bacterial infections (neutrophilia).
2. An increase in circulating eosinophil in parasitic infestations and some allergies and in asthma (eosinophilia).
3. An increase in circulating lymphocytes in certain viral infections (lymphocytosis).
4. An increase in circulating basophils indicates the presence of chronic inflammation.
5. Increase in monocyte levels indicates inflammation and infection.



Platelets (thrombocytes):



Are non-nucleated, small, disklike cells formed from fragmentation of a giant cell in the bone marrow called megakaryocytes. Platelets will promote blood clotting & help in repairing gaps in the wall of blood vessels. Their count is 150- 400 $\times 10^3/mm^3$. They have a life span of only 10 days. The role of platelets in controlling blood loss (hemorrhage) and wound healing is as follows:

■■ **Primary aggregation:** Disruptions in the microvascular endothelium, which are very common, allow the platelet to form a **platelet plug** to stop bleeding.
■■ **Secondary aggregation:** Platelets in the plug increase the size of the plug.
■■ **Blood coagulation:** During platelet aggregation, **fibrinogen** from plasma, **von Willebrand factor** and other proteins released from the damaged endothelium, and platelet promote the sequential interaction (cascade) of plasma proteins, giving rise to a **fibrin** polymer that forms a three-dimensional network of fibers trapping RBCs and more platelets to form a **blood clot**, or **thrombus**.
■■ **Clot retraction:** The clot initially bulges into the blood vessel lumen, but soon contracts slightly.
■■ **Clot removal:** Protected by the clot, the endothelium and surrounding tunic are restored by new tissue, and the clot is then removed, mainly dissolved by the proteolytic enzyme **plasmin**, which is formed continuously through the local action of **plasminogen activators** from the endothelium on **plasminogen** from plasma.

Disorders related to platelets:
There are lots of different groups of disorders affecting the platelets:
Thrombocythaemia – where there are too many platelets in circulation.
Thrombocytopenia – where there are too few platelets in circulation.
Dysfunction disorders – where there are the correct number of platelets in circulation, but they do not work properly.
All of these disorders mean that the clotting process is disrupted so lead to abnormal clot formation and bleeding.