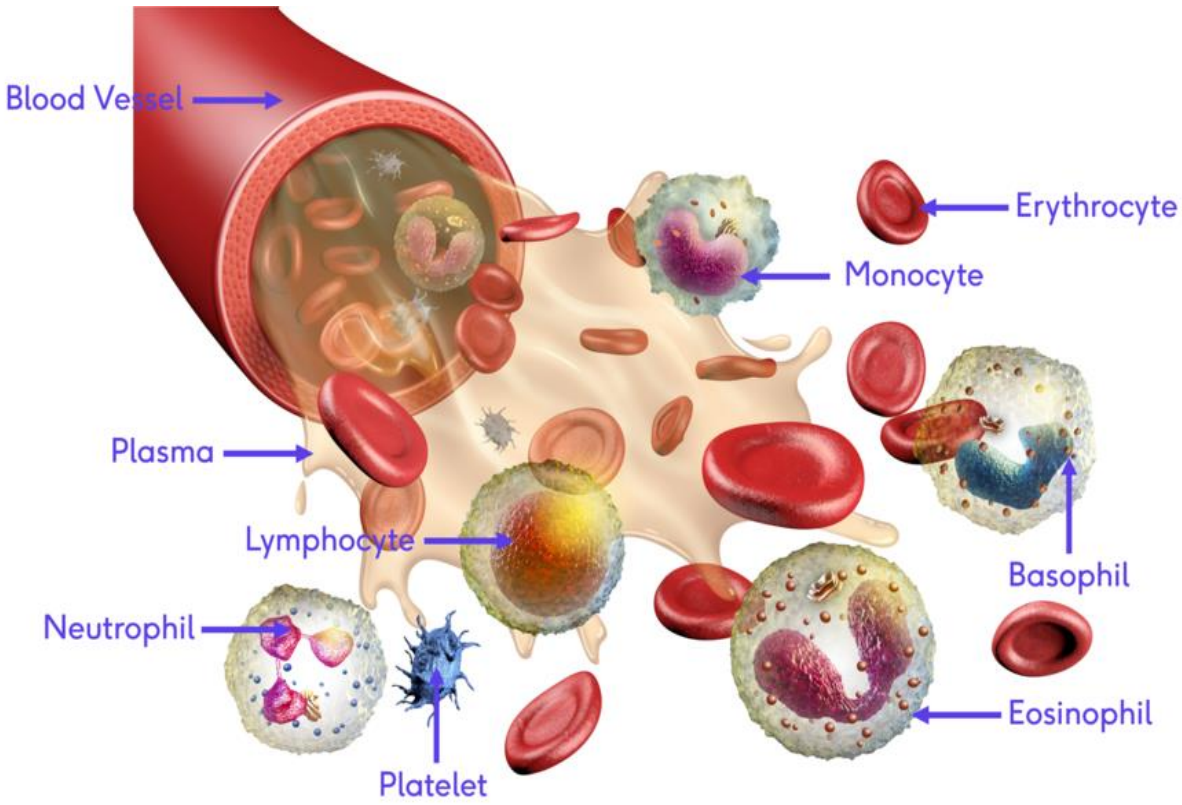
An Introduction to Blood Physiology and Blood Disorders

- Blood is critical for the transportation of nutrients, hormones, gases and wastes around the body.
- It also has important immunological functions.
- Blood is critical in the homeostatic regulation of pH, temperature and various other internal conditions. Blood is composed of plasma, platelets, leukocytes (White Blood Cells) and erythrocytes.

The adult human has from 4 to 5 litres of blood formed of cells and plasma circulating the body in vessels.

Plasma forms about 55% of the total blood volume.

- The other 45% comprises of a variety of different forms of cells.
- The total blood volume forms about 7 to 8 % of the total human weight in normal healthy adult.



Blood Plasma is a light – yellowish liquid. It acts as the base of the blood. It is composed of 91% of water and 9% solids such as coagulants, plasma proteins, electrolytes and immunoglobulins

In the embryonic stage blood plasma is formed from the mesenchymal cells. The albumin is formed first, followed by globulin and then other plasma proteins. In an adult, the reticuloendothelial cells in the liver are responsible for plasma production; this process is aided by bone marrow and spleen.

Functions of Blood Plasma

Blood Plasma has various vital functions:

1. Coagulation- Plasma contains fibrinogen and pro-coagulants such as thrombin and factor x
2. Immune Defense- Plasma has Immunoglobulins (antibodies) that play a role in the body's immunological defence process
3. Maintenance of osmotic pressure- The presence of plasma proteins such as Albumin which is vital for maintaining a balance of fluid, called oncotic pressure, in the blood (maintained at around 25 mmHg).
4. Acid-base balance- Plasma proteins helps in acid-base balance through buffering action.
5. Transportation of Nutrients- Nutrients such as glucose, amino acids, liquids and vitamins are transported in the blood plasma from the digestive system to different body parts.
6. Transportation of Respiratory Gases. Oxygen is carried to the body from the lungs and carbon dioxide back to the lungs for excretion.
7. Transportation of Hormones.
8. Excretion- Waste products from cellular metabolism are carried within the plasma and excreted via the kidneys, lungs and skin
9. Temperature Regulation

The erythrocyte sedimentation rate (ESR) is used as a diagnostic tool. As fibrinogen increases in acute inflammatory conditions, the ESR will also increase.

Erythrocytes (RBCs)

Erythrocytes (known as Red Blood Cells (RBCs) are biconcave discoidal cells. RBCs lack a nucleus, contain haemoglobin (the red iron-rich protein that carries O2) and are surrounded by a membrane of lipids and proteins. The normal healthy adult produces 119 million red blood cells per second. It forms 44% of the total blood volume and a single RBC cell is sized 0.000007 m. They are produced by red bone marrow via a process called erythropoiesis.[9]

Functions of Erythrocytes

A single Erythrocyte cell lives only for 120 days and in that duration, it performs successive roles

1. Oxygen delivery from the lungs to the peripheral tissues.
2. Collect CO2 from peripheral cells and return it to the lungs.

RBCs contain haemoglobin with ferrous heme (Fe) which has an affinity for oxygen. When it arrives at deoxygenated cells the Fe looses its affinity for O2 (due to decreased partial pressure of O2 and low PH).

Leucocytes (WBCs)

Leucocytes are the cellular component of the blood that are also known as white blood cells (WBCs). WBCs have a nucleus and lack hemoglobin. WBCs form 1% of the total blood volume in healthy adults.[5] They are considered to be an important part of the immune system. The leucocytes are produced in the bone marrow in a process called Hematopoiesis and normal WBCs count ranged between 4,000 and 10,000 cells/µl.

Types and Function of Leucocytes

There are several types of WBCs such as Neutrophils, Eosinophils, Basophils, Lymphocytes (B and T) and Monocytes

Neutrophils

Neutrophils are WBCs that are released from the bone marrow. They represent 50% of total WBCs count. Around 100 billion of the Neutrophils cells are produced every day and they are considered to be the first immune system cells. They are the major pathogen-fighting immune cells that migrate to sites of infection and then identify and kill bacteria and viruses. Neutrophils also send signals to alert other immune system cells.[13]

Monocytes

Monocytes represent 5 to 12 % of the total WBCs count. They are considered to be the "garbage trucks" of the immune system and play an important function in cleaning dead cells and tissue regeneration.

Eosinophils

Eosinophils represent less than 5% of the total WBCs. They are found in large amounts in the digestive system. Eosinophils play an important role in dealing with invading bacteria and parasites, such as worms.

Basophils

Basophils represent 1% of the total WBCs count. These cells play a role in asthma. They stimulate histamine release, leading to the inflammation and bronchoconstriction that occurs in asthma.

Lymphocytes

Lymphocytes produce antibodies that give immunity to the body if the body is exposed to the same infection again. It consists of two types of cells, T cells which have an invading function and B cells, which in contrast to other WBCs, are responsible for humoral

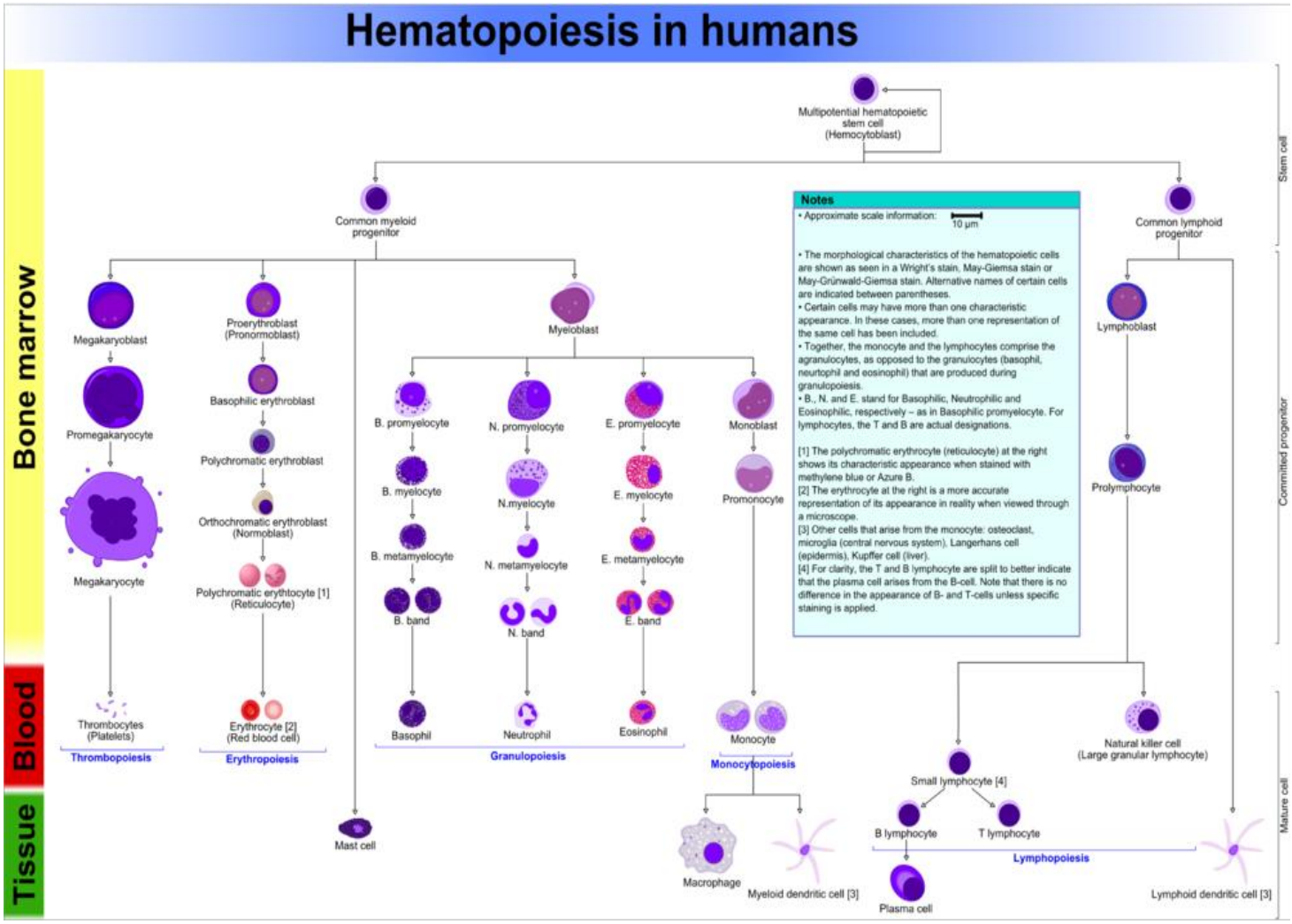
immunity ie immunity associated with circulating antibodies, in contradistinction to cellular immunity[17]. These cells play an important role in developing a lot of the current vaccines.[18]

Pathophysiology of Leucocytes

Elevated WBCs counts can indicate a variety of conditions. Infection, inflammation, trauma, pregnancy, asthma, allergy, cancers such as leukaemia and even aggressive exercises can result in elevated WBCs.

On the other hand, low WBCs counts can indicate severe infections, bone marrow damage, autoimmune diseases (e.g. Systemic Lupus Erythematosus SLE) and splenic sequestration.

Hematopoiesis



Hematopoiesis (blood cell formation), occurs in red bone marrow ie myeloid tissue.

- Erythrocyte production and the formation of leukocytes and platelets is stimulated by hormones. Red blood cells live for around four months and then they break down and parts are reused to make new blood cells.

The haemocystoblast forms two types of descendants:

1. Lymphoid stem cell, which produces lymphocytes
2. Myeloid stem cell, which can produce all other classes of formed elements.

Formation of Red Blood Cells (the entire developmental process from haemocystoblast to mature RBC takes 3 to 5 days).

- Anucleate - RBCs are unable to synthesize proteins, grow, or divide.
- Life span - RBCs become more rigid and begin to fragment, or fall apart, in 100 to 120 days.
- Lost RBCs - Replaced more or less continuously by the division of haemocystoblasts in the red bone marrow.
- Immature RBCs - Developing RBCs divide many times and then begin synthesizing huge amounts of haemoglobin.
- Reticulocyte - When enough haemoglobin has been accumulated, the nucleus and most organelles are ejected and the cell collapses inward; the resulting in young RBC (ie reticulocyte) because it still contains some rough endoplasmic reticulum (ER).
- Mature erythrocytes - Within 2 days of release, they have rejected the remaining ER and have become fully functioning erythrocytes.
- Erythropoietin. The rate of erythrocyte production is controlled by a hormone called erythropoietin; normally a small amount of erythropoietin circulates in the blood at all times, and red blood cells are formed at a fairly constant rate.
- Control of RBC production. An important point to remember is that it is not the relative number of RBCs in the blood that controls RBC production; control is based on their ability to transport enough oxygen to meet the body's demands.

Formation of White Blood Cells and Platelets

- In the human adult, the bone marrow produces 60–70 percent of the white cells (i.e., the granulocytes), and all of the platelets.
- The lymphatic tissues, particularly the thymus, the spleen, and the lymph nodes, produce the lymphocytes (comprising 20–30 percent of the white cells).
- The reticuloendothelial tissues of the spleen, liver, lymph nodes, and other organs produce the monocytes (4–8 percent of the white cells).
- The platelets, which are small cellular fragments rather than complete cells, are formed from bits of the cytoplasm of the giant cells (megakaryocytes) of the bone marrow.
- Colony-stimulating factors and interleukins: prompt red bone marrow to turn out leukocytes and marshal up an army of WBCs to ward off attacks by enhancing the ability of mature leukocytes to protect the body.
- Thrombopoietin (a hormone): accelerates the production of platelets, but little is known about how that process is regulated.
- **Blood Disorders**. There are many conditions of/or affecting the human hematologic system i.e the biological system that includes plasma, platelets,

leukocytes, and erythrocytes, the major components of blood and the bone marrow. This list is an example of disorders:

- Sickle Cell Anemia
- Anaemia of Chronic Disease
- Acute Lymphoblastic Leukemia
- Acute Myeloid Leukemia
- Multiple Myeloma
- Aplastic Anaemia
- Erythrocytosis
- Iron Deficiency and vitamin B12 Anemia
- Leucocytosis
- Leucopenia

Erythrocytes Disorders:

Also known as red blood cell and iron disorders. These disorders are manifested by a failure of O2 transportation from the lungs to various body tissues.

iron deficiency anaemia , Congenital sideroblastic anaemia, Megaloblastic anaemia (including pernicious anaemia), Iron deficiency anaemia , Hemolytic anaemia and Sickle Cell Anemia. Thalassemia, Hemolytic disease of the newborn, Spherocytosis and Hemochromatosis[25] are other erythrocyte disorders that can occur.

Leukocytes Disorders:

Leukocytes disorders are also known as white blood cells disorders. WBCs can either increase in number, decrease in number or malfunction. The most common WBCs disorders are found with the neutrophils and lymphocytes. Disorders of monocytes and eosinophils are less common. Basophil disorders are very rare

WBCs disorders characteristic of low WBC counts includes neutropenia, Disorders characteristic of high WBC counts include Eosinophilia and Neutrophilia[26].

Sinuses, lung and ear infections, skin abscesses, mouth sores, periodontal disease and invasive fungal infection are the most common symptoms of leucocyte disorders

Bleeding Disorders:

When some coagulates found in the plasma are malfunctioned it will lead to bleeding disorders such as haemophilia and von Willebrand disease.