The Islamic University, Najaf

College of Medical Techniques

Department of Radiology Techniques

Medical Physiology

First stage

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Lecture (2)

The Blood and its components

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Lecture Objectives

By the end of this lecture, the students should be able to:

1) Know the components of the blood.
2) Understand the functions of each component of the blood.
3) Explain how the RBCs produced.

Lecture Contents

- **The Blood**
  - Blood Components
    - Plasma
      - Plasma proteins
    - Serum
  - Erythrocytes or red blood cells (RBCs)
    - Shape and Size of Red Blood Cells
    - Concentration of Red Blood Cells in the Blood
    - Production of red blood cells
    - Areas of the Body that Produce RBCs
    - Stages of differentiation of RBCs
    - Erythropoietin regulates RBCs Production
    - The life span of RBCs is about 120 days

Blood

Blood, fluid that transports oxygen and nutrients to the cells and carries away carbon dioxide and other waste products. Technically, blood is a transport liquid pumped by the heart to all parts of the body, after which it is returned to the heart to repeat the process. Blood is both a tissue and a fluid. It is a tissue because it is a collection of similar specialized cells that serve particular functions. These cells are suspended in a liquid matrix (plasma), which makes the blood a fluid. If blood flow ceases, death will occur within minutes.

Blood Components

In human, blood is an opaque red fluid, denser and more viscous than water. The characteristic colour is imparted by **hemoglobin**, a unique iron-containing protein. Hemoglobin brightens in colour when saturated with oxygen (oxyhemoglobin) and darkens when oxygen is removed (deoxyhemoglobin). For this reason, the partially deoxygenated blood from a vein is darker than oxygenated blood from an artery.

The erythrocytes (red blood cells) constitute about 45% of the volume of the blood, while **The leukocytes (white blood cells) and thrombocytes (platelets)** constitute less than 1%. The fluid portion **(plasma)**, is a clear, slightly sticky, yellowish liquid. It serves as the liquid base for whole blood and constitute about 55% of the total blood volume.

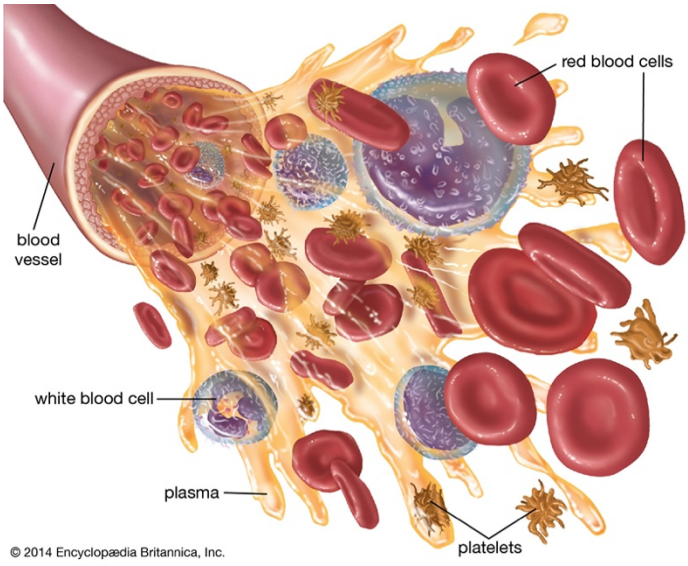

Figure 1: Reconstruction of a typical cell

The total amount of blood in humans varies with age, sex, weight, body type, and other factors, but in average for adults is about **60 millilitres per kilogram** of body weight, while the average young male has a plasma volume of about **35 millilitres** and a red cell volume of about **30 millilitres per kilogram** of body weight.

Plasma

The liquid portion of the blood, the plasma, is a complex solution containing 91% to 92% of water with normal pH of (7.40). The water of the plasma is freely exchangeable with that of body cells and other extracellular fluids and is available to maintain the normal state of hydration of all tissues. Plasma comprises of: **lipids, electrolytes, enzymes, sugar (glucose), hormones, vitamins, coagulants and plasma proteins**.

Plasma proteins

- **Serum albumin** the major plasma protein, it is relatively small molecule, the principal function of which is to retain water in the bloodstream by its osmotic effect. Serum albumin also serves as a nonspecific carrier protein.
- **Fibrinogen** the main protein that participate in the clotting of the blood.
- **Immunoglobulins or antibodies** produced in response to a specific foreign substance, or antigen to help in fighting the infections.
- **Transporting proteins** many proteins are involved in highly specific ways with the transport function of the blood such as hemoglobin-binding protein (haptoglobin) transport the free hemoglobin to the reticuloendothelial system during hemolysis (breakdown) of red cells occur.

Serum

If whole blood is allowed to clot and the clot removed, the remaining fluid is called **Serum**. Human blood serum contains essentially the same composition as plasma, except that its fibrinogen and clotting factors II, V, VIII has been removed.

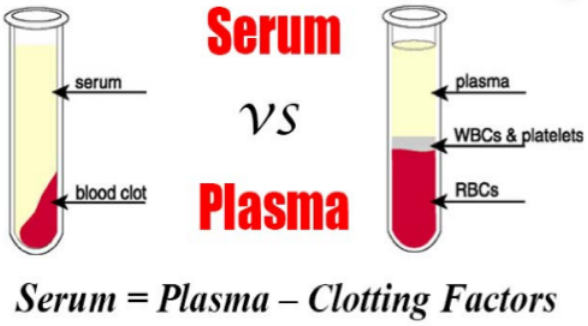

Figure 2: Difference between serum and plasma

Erythrocytes or red blood cells (RBCs)

Erythrocytes are the most abundant cells of the blood and are necessary for the delivery of oxygen to the tissues. The major function of RBCs is to transport hemoglobin, which, in turn, carries oxygen from the lungs to the tissues. In human, hemoglobin must remain inside RBCs to effectively perform its functions.

The RBCs have other functions besides transport of hemoglobin. For instance, they contain a large quantity of **carbonic anhydrase**, an enzyme that catalyzes the reversible reaction between carbon dioxide (CO_2) and water to form carbonic acid (H_2CO_3), increasing the rate of this reaction several thousandfold. The rapidity of this reaction makes it possible for the water of the blood to transport enormous quantities of CO2 in the form of bicarbonate ion (HCO_3-) from the tissues to the lungs, where it is reconverted to CO2 and expelled into the atmosphere as a body waste product. The hemoglobin in the cells is an excellent acid-base buffer, so the RBCs are responsible for most of the acid-base buffering power of whole blood.

Shape and Size of Red Blood Cells

Normal RBCs, are biconcave disks having a mean diameter of about 7.8 micrometers and a thickness of 2.5 micrometers at the thickest point and 1

micrometer or less in the center. The average volume of the RBC is 90 to 95 cubic micrometers. The shapes of RBCs can change as the cells squeeze through capillaries. Actually, the RBC is a "bag" that can be deformed into almost any shape.

Concentration of Red Blood Cells in the Blood

In healthy men, the average number of RBCs per cubic millimeter is 5,200,000 (±300,000); in women, it is 4,700,000 (±300,000). Persons living at high altitudes have greater numbers of RBCs.

Production of red blood cells

Areas of the Body that Produce RBCs.

In the early weeks of embryonic life, primitive, nucleated RBCs are produced in the **yolk sac**. During the middle trimester of gestation, the **liver** is the main organ for production of RBCs, but reasonable numbers are also produced in the **spleen** and **lymph nodes**. Then, during the last month of gestation and after birth, RBCs are produced exclusively in the **bone marrow**.

Stages of differentiation of RBCs

The first cell that can be identified as belonging to the RBC series is the **proerythroblast**, shown at the starting point in **Figure 3**. Under appropriate stimulation, large numbers of these cells are formed from the stem cells. Once the proerythroblast has been formed, it divides multiple times, eventually forming many mature RBCs. The first-generation cells are called **basophil erythroblasts** because they stain with basic dyes; the cell at this time has accumulated very little hemoglobin. In the succeeding generations, as shown in **Figure 3**, the cells become

filled with hemoglobin to a concentration of about 34%, the nucleus condenses to a small size, and its final remnant is absorbed or extruded from the cell.

At the same time, the endoplasmic reticulum is also reabsorbed. The cell at this stage is called a **reticulocyte** because it still contains a small amount of basophilic material,

consisting of remnants of the Golgi apparatus, mitochondria, and a few other cytoplasmic organelles. During this reticulocyte stage, the cells pass from the bone marrow into the blood capillaries by diapedesis (squeezing through the pores of the capillary membrane).

The remaining basophilic material in the reticulocyte normally disappears within 1 to 2 days, and the cell is then a **mature erythrocyte**. Because of the short life of the reticulocytes, their concentration among all the RBCs is normally less than 1%.

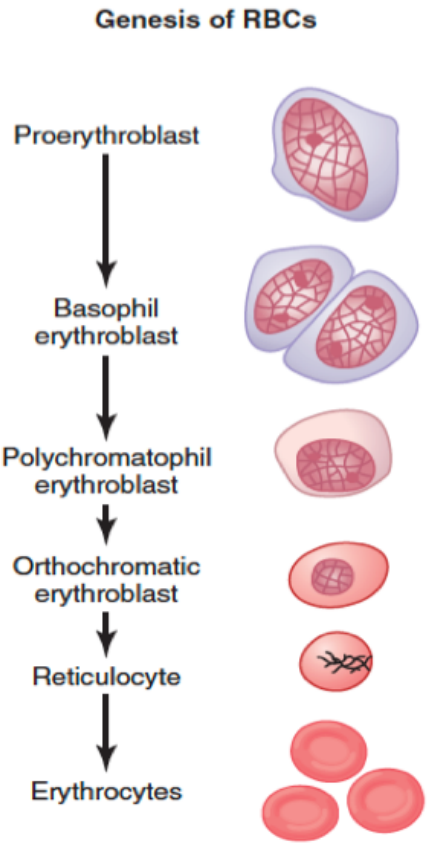

Figure 3: Genesis of RBCs

Erythropoietin regulates RBCs Production

Conditions that decrease the quantity of oxygen transported to the tissues (hypoxia) ordinarily increase the rate of RBC production.

The principal stimulus for RBC production in low oxygen states is a circulating hormone called **erythropoietin**, a glycoprotein with a molecular weight of about

34,000. In the absence of erythropoietin, hypoxia has little or no effect to stimulate RBC production.

Vitamin B12 and folic acid are especially important for final maturation of the RBCs. Therefore, deficiency of either vitamin B12 or folic acid causes maturation failure in the process of erythropoiesis.

The life span of RBCs is about 120 days

When RBCs are delivered from the bone marrow into the circulatory system, they normally circulate an average of **120 days** before being destroyed. Even though mature RBCs do not have a nucleus, mitochondria, or endoplasmic reticulum, they do have cytoplasmic enzymes that are capable of metabolizing glucose and forming small amounts of adenosine triphosphate (ATP). Even so, the metabolic systems of old RBCs become progressively less active and the cells become more and more fragile, presumably because their life processes wear out.

Once the RBC membrane becomes fragile, the cell ruptures during passage through some tight spot of the circulation. Many of the RBCs self-destruct in the spleen, where they squeeze through the red pulp of the spleen. There, the spaces between the structural trabeculae of the red pulp, through which most of the cells must pass, are only 3 micrometers wide, in comparison with the 8-micrometer diameter of the RBC. When the spleen is removed, the number of old abnormal RBCs circulating in the blood increases considerably.