Animal physiology-lecture (3)

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Blood and Hematopoiesis

Blood is a circulating tissue composed of fluid plasma and cells (red blood cells, white blood cells, and platelets). **Anatomically**, blood is considered a connective tissue, due to its origin in the bones and its function:

1. Blood is the means and transport system of the body used in carrying elements (e.g. nutrition, waste, and heat) from one location in the body to another, by way of blood vessels.
2. Transport of respiratory gases.
3. Blood is also involved in maintaining homeostasis by acting as a medium for transferring heat to the skin and by acting as a buffer system for bodily pH.
4. Protects against blood loss through clotting, and against disease through phagocytic white blood cells and proteins such as antibodies, interferons, and complement.

Composition of the blood

Blood is composed of a **cellular portion**, called **formed elements** (erythrocytes, leukocytes, and platelets) function, respectively, in oxygen transport, immune defense, and blood clotting, and a **fluid portion**, called **plasma**.

Plasma is a straw-colored liquid consisting of water and dissolved solutes. The **major** solute of the plasma in terms of its concentration is Na^+. In addition to Na^+, plasma contains many other ions, as well as organic molecules such as metabolites, hormones, enzymes, antibodies, and other proteins. Plasma proteins constitute 7% to 9% of the plasma.

The formed elements of blood

Include **two** types of blood cells: **erythrocytes**, or red blood cells, and **leukocytes**, or white blood cells.

Red Blood Cells (Erythrocytes)

Erythrocytes are by far the more numerous of the two. A cubic millimeter of blood normally contains 5.1 million to 5.8 million erythrocytes in males and 4.3 million to 5.2 million erythrocytes in females. Erythrocytes are flattened, biconcave discs about 7μm in diameter and 2.2μm thick. Their unique shape relates to their function of transporting oxygen; it provides an increased surface area through which gas can diffuse. Erythrocytes lack nuclei and mitochondria (they obtain energy through anaerobic metabolism). Partly because of these deficiencies, erythrocytes have a relatively short circulating life span of only about 120 days. Each erythrocyte contains approximately 280 million hemoglobin molecules, which give blood its red color.

Each **hemoglobin** molecule consists of four protein chains called **globin**, each of which is bound to one **heme**, a red- pigmented molecule that contains iron. The iron group of heme is able to combine with oxygen in the lungs and release oxygen in the tissues. The heme iron is recycled from senescent (old) red blood cells in the liver and spleen. This iron travels in the blood to the bone marrow attached to a protein carrier called **transferrin**. This recycled heme iron supplies most of the body's need for iron.

A major function of RBCs, also known as **erythrocytes**, is to transport **hemoglobin**, which, in turn, carries oxygen from the lungs to the tissues. 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 thousand fold. The rapidity of this reaction makes it possible for the water of the blood to transport enormous quantities of CO_2 in the form of bicarbonate ion (HCO_3^-) from the tissues to the lungs, where it is reconverted to CO_2 and expelled into the atmosphere as a body waste product.

The hemoglobin in the cells is an excellent **acid-base buffer** (as is true of most proteins), so the RBCs are responsible for most of the acid-base buffering power of whole blood. RBC's are formed in the **myeloid tissue** or

most commonly known as **red bone marrow**, although when the body is under severe conditions the **yellow bone marrow**, which is also in the fatty places of the marrow in the body will also make RBC's. The formation of RBC's is called **erythropoiesis** (erythro= red; poiesis= formation).

White blood cells (leukocytes)

Leukocytes are also known as "WBC's". They are made in the bone marrow but they also divide in the blood and lymphatic systems. They are commonly amoeboid (cells that move or feed by means of temporary projections, called **pseudopods** (false feet), and escape the circulatory system through the capillary beds. **Leukocytes** differ from erythrocytes in several respects. Leukocytes contain nuclei that are somewhat segmented and are surrounded by electrons inside the membrane and mitochondria and can move in an amoeboid fashion. Because of their amoeboid ability, leukocytes can squeeze through pores in capillary walls and move to a site of infection, whereas erythrocytes usually remain confined within blood vessels. The movement of leukocytes through capillary walls is referred to as diapedesis or extravasation.

They are different from red cells in the fact that they are usually larger in size 10-14 micrometers in diameter. White blood cells do not contain hemoglobin which in turn makes them translucent. Many times in diagrams or pictures white blood cells are represented in a blue color, mainly because blue is the color of the stain used to see the cells. White blood cells are almost invisible under the microscope unless they are stained; therefore, they are classified according to their staining properties. Those leukocytes that have granules in their cytoplasm are called granular leukocytes; those without clearly visible granules are called a granular (or no granular) leukocyte.

The stain used to identify white blood cells is usually a mixture of a pink-to-red stain called **eosin** and a blue-to purple stain (methylene blue), which is called a "**basic** stain." Granular leukocytes with pink-staining granules are therefore called **eosinophils**. Eosinophils are chemo toxic and kill parasites.

And they make up 2-4% of granular cells. Those with blue-staining granules are called **basophils**. Basophils store and synthesize histamine which is important in allergic reactions. They enter the tissues and become "**mast cells**" which help blood flow to injured tissues by the release of histamine. Basophils make up 0-1% of granular cells. Those with granules that have little affinity for either stain are **neutrophils**. Neutrophils are the first to act when there is an infection and are also the most abundant type of leukocyte. Neutrophils fight bacteria and viruses by **phagocytosis** which means they engulf pathogens that may cause infection. The life span of a neutrophil is only about 12-48 hours. They accounting for 50% to 70% of the leukocytes in the blood. Immature neutrophils have sausage-shaped nuclei and are called **band cells**.

There are **two** types of agranular leukocytes: **lymphocytes** and **monocytes**. Lymphocytes are usually the second most numerous type of leukocyte; they are small cells with round nuclei and little cytoplasm. There are two **Lymphocytes**: the **B-** and **T-** cell. B and T Lymphocytes make up 20-30% of a granular cells: **B-Lymphocytes** produce antibodies that find and mark pathogens for destruction. **T-Lymphocytes** kill anything that they deem abnormal to the body. **Monocytes**, by contrast, are the largest of the leukocytes and generally have kidney- or horseshoe-shaped nuclei. In addition to these two cell types, there are smaller numbers of plasma cells, which are derived from lymphocytes. Monocytes are responsible for rallying the cells to defend the body. Monocytes carry out phagocytosis and are also called macrophages. Monocytes make up 2-8% of a granular cell.

Platelets

Platelets, also called **thrombocytes**, are the smallest of the formed elements and are membrane-bound cell fragments. Platelets have no nucleus, they are between one to two micrometers in diameter. Less than 1% of whole blood consists of platelets. They result from fragmentation of large cells called **Megakaryocytes** (which are cells derived from stem cells in the bone marrow). Platelets are produced at a rate of 200 billion per day. Their

production is regulated by the hormone called **Thrombopoietin**. The circulating life of a platelet is 8-10 days. The sticky surface of the platelet allows them to accumulate at the site of broken blood vessels to form a clot. This aids in the process of hemostasis ("blood stopping").

Blood Types

Based on the presence or absence of antigen and antibodies, human blood is classified into 4 groups A, B, AB, and O.
The A group contains antigen A and antibody B.
The B group contains antigen B and antibody A.
The AB group contains both antigens A and B and no antibodies.
The O group contains no antigen and both antibodies A and B.
The ABO blood group is inherited by a set of multiple alleles.

Presence of a particular factor is denoted by Rh factor discovered by Weiner from the rabbits immunized with the blood of the *Macaca rhesus* monkey.

Hematopoiesis

Blood cells are constantly formed (figure 1) through a process called **hematopoiesis**. The hematopoietic stem cells—those that give rise to blood cells—originate in the yolk sac of the human embryo and then migrate in sequence to regions around the aorta, to the placenta, and then to the liver of a fetus. The liver is the major hematopoietic organ of the fetus, but then the stem cells migrate to the bone marrow and the liver ceases to be a source of blood cell production shortly after birth. Scientists estimate that the hematopoietic tissue of the bone marrow produces about 500 billion cells each day. The hematopoietic stem cells form a population of relatively undifferentiated, multipotent adult stem cells that give rise to all of the specialized blood cells. The hematopoietic stem cells are self-renewing, duplicating themselves by mitosis so that the parent stem cell population will not become depleted as individual stem cells differentiate into the mature blood cells. The term erythropoiesis **refers** to the formation of erythrocytes,

and leukopoiesis to the formation of leukocytes. These processes occur in **two** classes of tissues after birth, **myeloid** and **lymphoid**.

Myeloid tissue is the red bone marrow of the long bones, ribs, sternum, pelvis, bodies of the vertebrae, and portions of the skull. **Lymphoid** tissue includes the lymph nodes, tonsils, spleen, and thymus. The bone marrow produces all of the different types of blood cells; the lymphoid tissue produces lymphocytes derived from cells that originated in the bone marrow. As the cells become differentiated during erythropoiesis and leukopoiesis, they develop membrane receptors for chemical signals that cause further development along particular lines.

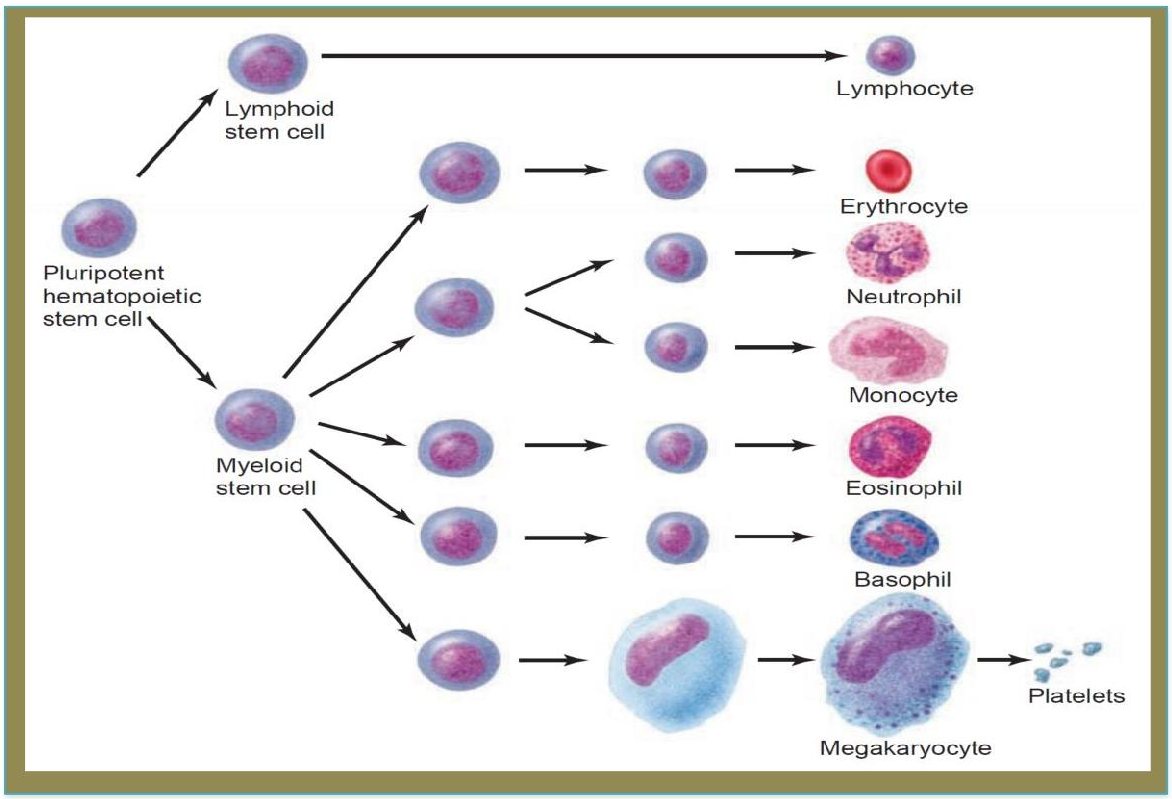

Figure 1: Production of blood cells by the bone marrow.