Lesson 10:

The Cardiovascular System

Key Concepts and Definitions:

- What three major structures make up the cardiovascular system?
- What are the functions of blood?
- Describe the specialized functions of a red blood cell and white blood cell.
- List the different types of white blood cells and briefly describe what each one does. What is the difference between the left and right side of the heart in regard to function. Review the anatomy of the heart. Print and label the blank heart provided, and offer a brief description about what each part of the heart does.
- Describe blood flow through the heart. What are the five main types of blood vessels?

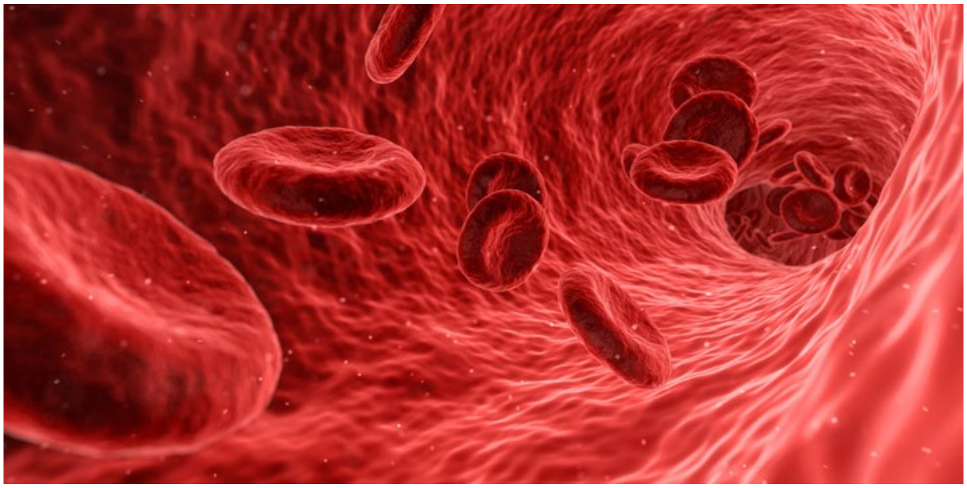
Our cardiovascular system greatly contributes to our homeostasis. Blood transports oxygen, carbon dioxide, nutrients, and hormones to and from our body's cells. It also helps regulate body pH and temperature, and provides excellent protection against disease through a process called phagocytosis, and the production of things called antibodies.

The cardiovascular system consists of three interrelated components. These are the blood, the heart, and the blood vessels.

Most cells that belong to a multicellular organism (such as you and I), cannot move around to obtain oxygen and nutrients or eliminate carbon dioxide and other wastes. Instead, these needs are met by two fluids, these being blood and interstitial fluid.

Blood is a liquid connective tissue that consists of cells surrounded by a liquid extracellular matrix. The extracellular matrix is called blood plasma, and it suspends various cells and cell fragments.

Interstitial fluid is the fluid that bathes body cells and is constantly renewed by the blood. Blood transports oxygen from the lungs and nutrients from the digestive system, which diffuse from the blood into the interstitial fluid and then into body cells. Carbon dioxide and other wastes move in the reverse direction, from body cells to interstitial fluid, to blood. Blood then transports the waste materials to various organs and channels of elimination such as the lungs, kidneys, and skin.



Blood has three general functions:

1. Transportation - Blood transports inhaled oxygen from the lungs to the cells of the body, and carbon dioxide from the body cells to the lungs for exhalation. It carries a variety of nutrients from the digestive system to body cells, and also hormones from the endocrine system to other body cells. Blood also transports heat and waste products to various organs for elimination from the body.
2. Regulation - Circulating blood helps to maintain homeostasis of all body fluids. Blood helps regulate pH through the use of buffer chemicals. It also helps adjust body temperature through the heat absorbing and coolant properties of water available in blood plasma and its variable rate of flow through the skin, where excess heat can be lost. In addition, the osmotic pressure of blood can influence the water content of cells, mainly through interactions of dissolved ions and proteins.
3. Protection - Blood can clot, which protects against its excessive loss from the cardiovascular system after an injury. In addition, its white blood cells protect against disease by carrying out a process called phagocytosis. Several types of blood proteins, including antibodies and interferons help protect against disease in a variety of ways.

The Components of Blood:

Our blood has two main components:

1. Blood plasma - a watery liquid extracellular matrix that contains dissolved substances.
2. Formed elements - consisting of cells and cell fragments.

Blood is about 55% blood plasma and about 45% formed elements. Normally, more than 99% of the formed elements are cells named for their red color - we know them as red blood cells. In contrast, pale, colorless white blood cells and platelets occupy less than 1% of the formed elements.

BLOOD PLASMA:

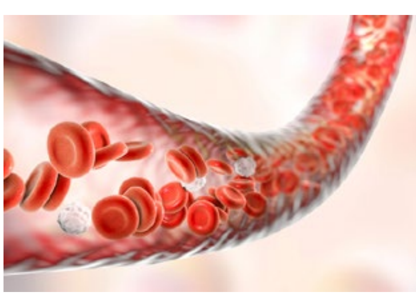
When the formed elements are removed from blood, a yellow, straw-colored liquid emerges called blood plasma. Blood plasma is about 91.5% water and 8.5% solutes, most of which are a variety of proteins. Some of the proteins in blood plasma are also found elsewhere in the body, but those confined to blood are called blood plasma proteins.

Hepatocytes (liver cells) synthesize most of the blood plasma proteins, which include albumins, globulins, and fibrinogen. These blood plasma proteins are also called antibodies (or immunoglobulins). They are produced during certain immune responses. Foreign substances (antigens) such as bacteria and viruses stimulate the production of millions of different antibodies. An antibody binds specifically to the antigen that stimulated its production and thus disables the invading antigen.

Besides proteins, other solutes in blood plasma include electrolytes, nutrients, regulatory substances such as enzymes and hormones, gases, and waste products such as urea, uric acid, creatinine, ammonia, and bilirubin.

FORMED ELEMENTS:

The formed elements of the blood include three main components: red blood cells, white blood cells, and platelets. Red blood cells (RBCs), also known as erythrocytes, transport oxygen from the lungs to the body cells and deliver carbon dioxide from body cells to the lungs. White blood cells (WBCs), also known as leukocytes, protect the body from invading pathogens and other foreign substances. It is good to know that there are several types of WBCs: neutrophils, basophils, eosinophils, monocytes, and lymphocytes. Each type of WBC contributes in its own way to the body's defense mechanisms.



Platelets, the final type of formed element, are fragments of cells that do not have a nucleus. Among other actions, they release chemicals that promote blood clotting when blood vessels are damaged.

How Blood Cells are Formed:

Although some WBCs have a lifetime measured in years, most formed elements of the blood last only hours, days, or weeks, and must be replaced continually. Negative feedback systems regulate the total number of RBCs and platelets in circulation, and their numbers normally remain steady. The abundance of the different types of WBCs however, varies in response to the potential for invading pathogens and other foreign or perceived antigens.

The process by which the formed elements of blood develop is called hematopoiesis. Before birth, this process first occurs in the umbilical cord of the embryo and later in the liver, spleen, thymus, and lymph nodes of the fetus. Red bone barrow becomes the primary site during the last three months before birth and then continues throughout life as the main source of blood cell production.

Red bone marrow is a connective tissue located in the microscopic spaces of spongy bone tissue. It is mostly present in the bones of the axial skeleton, pectoral and pelvic girdle, and the end portions of the humerus and femur bones.

Within the bone marrow, all blood cells originate from a single type of unspecialized cell called a stem cell. When a stem cell divides, it first becomes an immature red blood cell, white blood cell, or platelet-producing cell. The immature cell then divides, matures further, and ultimately becomes a mature red blood cell, white blood cell, or platelet.

The rate of blood cell production is controlled by the body's needs. Certain conditions may trigger additional production of blood cells. When the oxygen content of body tissues is low or the number of red blood cells decreases, the kidneys produce and release erythropoietin, a hormone that stimulates the bone marrow to produce more red blood cells. The bone marrow produces and releases more white blood cells in response to infections. It produces and releases more platelets in response to bleeding.

Red Blood Cells:

Red blood cells, also known as erythrocytes, contain the oxygen-carrying protein hemoglobin, which gives blood its red colour. A healthy adult male has about 5. 4 million red blood cells per microliter of blood, and a healthy adult female has about 48 million. In order to maintain normal numbers of red blood cells, new mature cells must enter the circulatory system at the rate of at least 2 million per second, a pace that balances the equally high rate of normal red blood cell destruction.

An increase in the number of WBCs above 10,000 per microliter is a normal protective response to stresses such as microbes, strenuous exercise, anesthesia, and surgery. An abnormally low level of white blood cells (less that 5, 000 per microliter) is called leukopenia. It is never beneficial, and may be caused by more serious issues such as radiation, and certain chemotherapy drugs and agents.

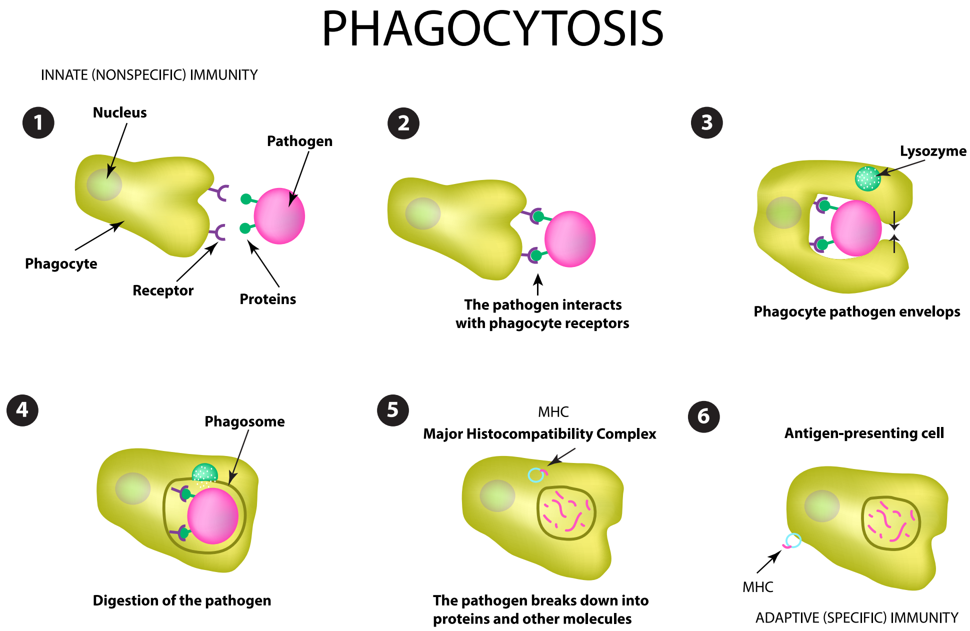
The skin and mucous membranes of the body are continuously exposed to a variety of microbes and their toxins. Some of these microbes can invade deeper tissues to cause disease. Once pathogens (microbes) enter the body, the general function of white blood cells is to combat them by means of an immune response, also known as phagocytosis. To accomplish this, many WBCs leave the blood stream and collect at sites of infection or inflammation. Once granular leukocytes and monocytes leave the bloodstream to fight injury or infection, they never return to it. Lymphocytes, in contrast, continually recirculate through the blood and into interstitial spaces of tissues to lymph plasma and back to blood.

Only about 2% of the total lymphocyte population is circulating in the blood stream at any given time. The rest is in the lymph plasma and organs such as the skin, lungs, lymph nodes, and spleen. Red blood cells are contained within the bloodstream, but in contrast, white blood cells leave the bloodstream by a process known as emigration (or diapedesis). During this process they roll along the endothelium, stick to it, and then squeeze between endothelial cells where molecules known as adhesion molecules help WBCs stick to the endothelial tissue.

When it comes to immune responses (phagocytosis), neutrophils and macrophages are most active as they dispose of dead matter. There are also several different chemicals released by microbes that attract phagocytes. This is a process called chemotaxis.

Among WBCs, neutrophils respond most quickly to tissue destruction by microbes. After engulfing a pathogen during phagocytosis, a neutrophil unleashes several chemicals to destroy the pathogen. These chemicals include the enzyme lysozyme, which destroys certain bacteria, and strong oxides such as superoxide anion, hydrogen peroxide, and hypochlorite anion which is similar to household bleach. Neutrophils also contain defensins, proteins that exhibit a broad range of antibiotic activity against bacteria and fungi.

Within a neutrophil, vesicles containing defensins merge with phagosomes containing microbes.



Eosinophils leave the capillaries and enter tissue fluid. They are believed to release enzymes, such as histaminase, that combat the effects of histamine and other substances involved in inflammation during allergic reactions. Eosinophils also release complexes that are effective against certain parasitic worms. A high eosinophil count often indicates an allergic condition or a parasitic infection.

At sites of inflammation, basophils leave capillaries, enter tissues, and release granules that contain heparin, histamine, and serotonin. These substances intensify the inflammatory response and are involved in hypersensitivity (allergic) reactions. Basophils are similar in function to mast cells, connective tissue cells that originate from multipotent stem cells in red bone marrow. Like basophils, mast cells release substances involved in inflammation, including heparin, histamine, and proteases. Mast cells are widely dispersed in the body, particularly in connective tissues of the skin, and mucous membranes of the respiratory and digestive canal.

Lymphocytes are the main soldier in lymphoid system battles. Mostly lymphocytes continually move along lymphoid tissues, lymph plasma, and blood, spending only a few hours at a time in blood. Thus, only a small proportion of the total lymphocytes are present in the blood at any given time. There are three main types of lymphocytes:

1. B Cells
2. T Cells
3. Natural Killer Cells

B cells are particularly effective in destroying microbes and inactivating their toxins. T cells attack infected body cells and tumor cells and are responsible for the rejection of some transplanted organs. Generally, immune responses carried out by both B cells and T cells help combat infection and provide protection against some diseases.

Natural killer cells attack a wide variety of infected body cells and certain tumors. In contrast to all of these various cells, monocytes take longer to reach a site of infection than neutrophils, but they arrive in larger numbers and destroy more microbes. On their arrival, monocytes enlarge and differentiate into wandering macrophages, which clean up cellular debris and microbes by phagocytosis after an infection is over.

Platelets:

Platelets are tiny blood cells that help your body form clots to stop bleeding. If one of your blood vessels gets damaged, it sends out signals to the platelets. The platelets then rush to the site of damage and form a plug (clot) to fix the damage. The process of spreading across the surface of a damaged blood vessel to stop bleeding is called adhesion. This is because when platelets get to the site of the injury, they grow sticky tentacles that help them stick (adhere) to one another. They also send out chemical signals to attract more platelets. The additional platelets pile onto the clot in a process called aggregation.

Platelets have a short life span, normally just 5 to 9 days. Aged and dead platelets are removed by fixed macrophages in the spleen and liver.

The Heart:

Your heart is an incredible and complex muscle. It contributes to homeostasis of the body by pumping blood through blood vessels to the various tissues of the body and to deliver oxygen and nutrients, and also to remove waste products.

As you have already learned in the previous portion of this chapter, the cardiovascular system consists of blood, the heart, and blood vessels. We have already had a look at the composition and function of blood, but in this section, we will explore the pump that circulates it through the body - the heart. For blood to reach body cells, and exchange materials with them, it must be pumped continuously by the heart through the vast scape of the body's blood vessels.

The heart beats about 100,000 times every day, which adds up to about 35 million beats in a year, and approximately 2.5 billion times in your average life span.

The left side of the heart pumps blood through an estimated 100, 000 km (60, 000 miles) of blood vessels, which is equivalent to traveling around the earth's equator about three times. In contrast, the right side of the heart pumps blood through the lungs, enabling blood to pick up oxygen and unload carbon dioxide.

In this next section we will seek to explore the structures of the heart and the tremendously unique properties which allow this muscle to pump for a lifetime without rest.