

3.The Circulatory System

A. Introduction

1. Circulatory system transports water, electrolytes, hormones, enzymes, antibodies, cell, gases and nutrients to all cells and carries away metabolic wastes to the kidneys, liver and skin, and carbon dioxide to the lungs.
2. Contributes to body defenses and the coagulation process and controls body temperature.
3. The lymphatic system is considered to be part of the circulatory system, the primary purpose of which is to circulate lymph fluid to and from the tissues and produce blood cells.

B. Blood

1. Composed of water, solutes and cells.
2. Normal adult volume approximately 5 quarts, 3 quarts (55%) plasma and 2 quarts (45%) of cells.
3. Plasma contains water, solutes and blood cells which are classified as red blood cells, white blood cells and platelets.
4. All blood cells develop from undifferentiated stem cells in the hematopoietic (blood forming) tissues, such as the bone marrow.
 - a. Stem cells are considered immature cells because they have not developed into their functional state.
 - b. As the stem cells mature, they differentiate into erythrocytes (red blood cells or RBCs), leukocytes (white blood cells or WBCs) and thrombocytes (platelets).
 - c. As they mature, the cells undergo changes in the nucleus and cytoplasm so that when they reach the circulating blood, they become fully mature and functional.
 - d. These changes are clearly visible using staining techniques and light microscopy.

C. Erythrocytes

1. RBCs measure about 7 um and, when circulating in the blood, do not have a nucleus.
2. During maturation in the bone marrow the RBCs lose their nucleus and simultaneously become biconcave discs.
3. Normal blood has approximately 4.5 to 5 million cells per cubic milliliter.
4. Life span is approximately 120 days.

5. The main component of the RBC is **hemoglobin** which binds to oxygen for transport to the tissues, then binds to CO₂ to be delivered to the lungs as a waste product. Hemoglobin gives blood its red color.
6. Millions of RBCs are continually being formed and destroyed daily and the bone marrow must have an adequate supply of amino acids, vitamin B complexes and minerals such as iron to maintain a normal blood supply.
7. Deficiencies of any of these substances or failure of the bone marrow to function properly may result in anemia.
8. The surface membrane of RBCs contain structures called antigens that designate the individual's blood type. It is vitally important that blood transfused into a patient never contain antigens to which the patient has antibodies as this will result in destruction of the transfused cells which can be rapidly fatal to the patient.

D. Leukocytes (White Blood Cells, WBCs)

1. WBCs number about 5,000 to 10,000 and are classified into cell lines which differ in color, size, shape, nuclear formation and function.
2. White cells are further divided into cell lines, one of which is the **granulocytes** which contain cytoplasmic granules and include the following cell types:
 - a. **Segmented neutrophils** aid in fighting infection with microorganisms through phagocytosis, ingest and destroy foreign organisms and materials.
 - b. **Eosinophils** are increased in allergies and parasitic infections.
 - c. **Basophils** release chemicals involved in hypersensitivity reactions.
2. Monocytes and lymphocytes are agranular cells.
 - a. **Monocytes** are phagocytic cells that function in destroying foreign organisms
 - b. **Lymphocytes**, which can live and multiply in the lymphatic system are the major components of the immune system.
 - 1) B cells produce antibodies.
 - 2) T cells attack foreign organisms directly and also process these for presentation to the B cells.
3. A commonly performed laboratory test is the "**differential**", in which a stained blood smear is examined and 100 WBCs are counted and differentiated according to cell type.
 - a. A high WBC count with an increase in granulocytes indicates a bacterial infection.
 - b. A high WBC count with predominantly immature WBCs present indicates leukemia.
 - c. A low WBC count with an increase in the lymphocytes indicates a viral infection.

E. Platelets

1. **Thrombocytes**, commonly called **platelets**, are much smaller than other blood cells and are actually fragments of megakaryocytes.

2. Normally there are 250,000 to 450,000 platelets/mm³.
3. Thrombocytes participate in blood clotting.
4. When vessels are damaged, the platelets release factors that are needed for the clotting reaction, the final result being a meshwork of these factors with the platelets to form a plug.
5. Blood clotting, or coagulation, is the final step in hemostasis, the prevention of blood loss.
6. Low platelets may cause a patient to have excessive bleeding or uncontrolled bleeding after an injury.

F. Difference Between Plasma and Serum

1. ***Plasma is the liquid portion of the blood without the cells.***
 - a. If a chemical agent or anticoagulant is added to prevent clotting, a blood sample can be separated by centrifugation into the cells and plasma.
 - b. *Plasma cannot clot* due to inactivation of certain vital necessary elements and *will contain all coagulation factors.*
 - c. Anticoagulated whole blood is required for all tests performed in the hematology department.
 - d. Plasma is required for all coagulation tests.
2. ***Serum is produced when blood is drawn into a non-additive tube and allowed to clot.***
 - a. The blood cells become meshed in a fibrin clot.
 - b. Serum contains essentially the same chemical constituents as plasma except that clotting factors have been used up to form the clot so *will have NO coagulation factors.*

G. Heart

1. The heart is a muscular organ responsible for the continuous pumping of blood through the vascular system.
2. It is about the size of a man's closed fist.
3. It contains four chambers: the right and left atrium, and the right and left ventricle.
4. Blood enters the heart through the right atrium and left atrium and leaves by way of the right and left ventricles.
 - a. Right atrium receives blood from superior vena cava and inferior vena cava.
 - b. Blood exits through the right ventricle to begin pulmonary circuit.

5. *The right side of the heart is responsible for pumping **oxygen poor** blood to the lungs to pick up oxygen.*
6. *The left side of the heart is responsible for pumping the **oxygen rich** blood to all parts of the body.*
7. A muscular wall called the septum divides the right and left sides of the heart.
8. The pulmonary veins bring oxygen rich blood and the vena cava brings oxygen poor blood.
9. Valves in the heart control the flow, if a valve malfunctions, blood flows backwards causing a heart murmur.
10. The heart beats about 60 to 80 times per minute and is measured by feeling the pulse.

H. The Vessels and Circulation

1. Blood circulates throughout the body within a closed system through blood vessels.
2. Blood vessels are tube-like structures capable of expanding and contracting and consist of three types: arteries, veins and capillaries.
3. *Arteries* carry highly oxygenated blood away from the heart.
 - a. Arteries branch into smaller vessels called *arterioles*.
 - b. Arteries have thick walls composed of three layers because the blood is under pressure from the contraction of the ventricles.
 - c. The only artery that is *not oxygenated* is the *pulmonary artery*, which carry blood from the right side of the heart to the lungs for oxygenation.
 - d. Because it is full of oxygen, normal arterial blood is bright, cherry red in color.
 - e. The largest artery in the body is the *aorta*.
 - f. *Arteries have a pulse.*
4. Blood flows from the arterial system into the smallest of the blood vessels, the *capillaries*.
 - a. Capillaries are microscopic vessels composed of a single layer of endothelial cells which may be so small in places that the RBCs pass through single file.
 - b. Through the walls of the capillaries, exchanges take place between the bloodstream and the tissues, oxygen is released and carbon dioxide is absorbed by the blood.
 - c. Capillaries return the oxygen poor blood to the smallest of the veins, *venules*.
 - d. Blood in the capillaries is a mixture of both venous and arterial blood.

5. **Veins** are responsible for returning blood to the heart.
 - a. Veins carry deoxygenated blood.
 - b. The only vein that **carries oxygenated** blood is the **pulmonary vein**, which carries oxygenated blood from the lungs back to the heart.
 - c. The walls composed of three layers but are thinner than arteries because the blood is under less pressure.
 - d. Because venous blood is oxygen poor, it is much darker in color than normal arterial blood.
 - e. The largest vein in the body is the **vena cava**.
 - f. The longest vein in the body is the **great saphenous** vein in the leg.
6. In summary, blood is oxygenated in the lungs, the arteries carry the oxygen rich blood through arterioles then to the smallest branches called capillaries. Blood goes from the capillaries into the venules to the veins to be returned back to the heart.

I. Hemostasis and Coagulation

1. Hemostasis is the process by which the body stops the leakage of blood from the vascular system after an injury.
 - a. It includes the process that leads to clot formation as well as clot dissolution.
 - b. If an injury occurs to a blood vessel, the hemostatic process is set in motion to repair the injury.
2. This **hemostatic process**, also called **coagulation**, proceeds in four steps - MEMORIZE.
 - a. **Vasoconstriction** caused the damaged vessel to constrict (narrow) to decrease the flow of blood to the injured areas.
 - b. **Platelet plug formation** - injury to the blood vessel exposes protein material in the basement membrane of the vessel.
 - 1) Contact with this material causes the platelets to degranulate and stick to one another (platelet aggregation).
 - 2) The aggregated platelets then adhere to the injured area (platelet adhesion) to form a "platelet plug".
 - 3) Normal platelet plug formation depends on an adequate number of functional platelets in the blood, and blood vessel integrity.
 - 4) For some injuries, such as a needle stick, this is all that is needed to heal the injury, but for larger injuries the process continues.

- c. ***Fibrin clot formation*** involves the complex interaction of a series of ***coagulation factors***.
 - 1) More than a dozen clotting factors present in the blood plasma are needed for clotting to occur.
 - 2) The final reaction in clot formation involves the conversion of a precursor factor into fibrin, which forms a meshwork, trapping cells and platelets in an insoluble fibrin clot also known as the hemostatic plug.
 - d. ***Fibrinolysis*** involves the ultimate removal or dissolution of the fibrin clot once healing has occurred.
 - 1) A substance called plasmin breaks the fibrin into small fragments called ***fibrin degradation products*** (FDP), which are removed by phagocytic cells lining the reticuloendothelial system.
 - 2) The clot must degenerate. Clots that break loose may lodge in the brain causing a stroke.
3. The coagulation process is divided into two systems, intrinsic and extrinsic.
- a. All coagulation factors required for the ***intrinsic system are contained in the blood***.
 - b. The extrinsic factors are stimulated when tissue damage occurs.

J. Diagnostic Assessment of the Circulatory System

- 1. Blood
 - a. CBC including indices (MCV, MCH, MCHC) - lavender
 - b. Hemoglobin and/or Hematocrit (H&H) -lavender
 - c. differential - lavender
 - d. eosinophil count - lavender
 - e. ESR- lavender or black
 - f. Ferritin - red
 - g. Iron and total iron binding capacity (TIBC) - red
 - h. bone marrow
- 2. Heart
 - a. ABG
 - b. AST
 - c. CK and CK isoenzymes
 - d. Electrolytes - Na, K, CO₂ and Cl
 - e. LDH
 - f. Triglycerides
 - g. cholesterol

3. Blood Vessels
 - a. cholesterol
 - b. triglycerides
 - c. coagulation tests (see next)

4. Coagulation
 - a. Prothrombin time (PT)
 - b. Partial thromboplastin time (PTT)
 - c. Fibrinogen
 - d. Fibrin degradation products (FDP)
 - e. Platelet count
 - f. Factor assays
 - g. Bleeding time