BIOLOGY 2402
Anatomy and Physiology Lecture

CHAPTER 19

THE CARDIOVASCULAR SYSTEM – THE BLOOD

THE CARDIOVASCULAR SYSTEM – THE BLOOD

(As cells become more differentiated, they become less capable of carrying on an independent existence)

Example: Specialized cells are less able to:

a. Protect themselves from extreme temperature, toxic chemicals, and changes in pH
b. Cannot seek food or devour whole bits of food;
c. Cannot move away from their own wastes, if firmly implanted in a tissue

Interstitial Fluid (also known as Intercellular or Tissue fluid) - bathes cells and carries out the above mentioned functions for them.

Extracellular fluid- composed of interstitial fluid.

* Blood plasma and lymph service the interstitial fluid, blood, plasma, and other fluids. All termed as fluids outside of cells.

* Blood and lymph, in turn service the interstitial fluids. (Picks oxygen from the lungs, nutrients from the gastrointestinal tract, and hormones from endocrine glands).

** Since the blood services all the tissues of the body it can be an important medium for the transport of disease-causing organisms (pathogens).

* Lymphatic System (a collection of lymphatic tissue and lymph vessels that contain a fluid called lymph) is the body's mechanism to protect itself from organisms.

** Internal environment of the human organism - composed of blood inside blood vessels, interstitial fluid around body cells, and lymph inside lymph vessels.

* Internal environment must be kept within normal physiological limits by a condition called homeostasis.

* **Cardiovascular system** - Composed of the blood, heart, and blood vessels.

Lymphatic system - Composed of the lymph, lymph vessels, and structures and organs containing lymphatic re-cycling capability of tissue (large numbers of white blood cells called lymphocytes).

* **Hematology** - The branch of science concerned with the study of blood, blood-forming tissues, and the disorders associated with them.

COMPARISON OF EXTRA CELLULAR FLUIDS

A. 1. Blood Plasma
2. Lymph
3. Interstitial Fluid (Intercellular fluid)

Are all similar in composition, but Plasma contains more protein. Principal chemical difference.

(Transfer of materials between blood and interstitial fluid occurs by **osmosis**, **diffusion**, and **filtration** across the endothelial cells.)

B. Interstitial fluid and Lymph also differ from Plasma in that they contain variable numbers of Leukocytes (white blood cells).

C. Like Plasma, Interstitial fluid and Lymph lack Erythrocytes (red blood cells) and platelets.

FUNCTIONS OF BLOOD

1. It transports:

   -Oxygen from the lungs to the cells of the body;
   - Carbon dioxide from the cells to the lungs;
   - Nutrients from gastrointestinal tract to the cells;
   - Waste products from cells;
   - Hormones from endocrine glands to the cells;
   - Heat from various cells.

2. It regulates:

   - pH through buffers
   - Normal body temperature through the heat-absorbing and coolant properties of its water content;
   - The water content of cells, principally through dissolved sodium ions (Na+) and proteins

3. It protects against:

   - Blood loss through the clotting mechanism;
   - Foreign microbes and toxins through certain white blood cells that are phagocytic or specialized proteins such as antibodies, interferon, and complement.

PHYSICAL CHARACTERISTICS OF BLOOD

1. Viscosity - 4.5 - 5.5 Thicker, heavier, and more viscous than water (viscosity of 1.0)

2. Temperature - 38 C (100.4 F) (Body temp. 37 C (98.6 F)

3. pH - 7.35 - 7.45 (Slightly alkaline, not acidic)

4. Salinity - 0.90% (Amount of salt (NaCl))

5. Total body weight - 8%

6. Volume - 5 - 6 liters for average male (1.5 gal.)
4 - 5 liters for average female (1.2 gal)

COMPONENTS OF BLOOD

Two components of blood:

(1) Formed Elements (Cells and Cell-like structures)
(2) Plasma (liquid containing dissolved substances)

Formed elements - Composed 45% of blood volume
Plasma - Composed 55% of blood volume

Whole blood is composed of two portions:

(a) Blood plasma (55%) - A water liquid containing dissolved substances.

(b) Formed element (45%) - Are cells and cell fragments.

PLASMA

Blood Plasma or Plasma (a straw-colored liquid) -- is what is left when the formed elements are removed from blood.

*(Serum is plasma minus its clotting proteins)

Constituents of Plasma

1. Water - 91.5%
2. Solutes - 1.5%
3. Proteins - 7%
   -Albumins
   - Globulins
   - Fibrinogen
   (Most plasma proteins are synthesized by the liver).
4. Wastes - Urea, uric acid, creatine, bilirubin, ammonium salts
5. Nutrients - amino acids (from protein), glucose (from carbohydrate), fatty acids and glycerol
6. Regulatory Substances - Enzymes (by cells) and Hormones (by glands)
7. Gases - O_2, C_2, N_2, (has no known function in the body)
8. Electrolytes - Inorganic salts, Cations - Na^+, K^+, Ca^{2+}, Mg^{2+}; Anions- Cl^-, HPO_4^{2-}, SO_4^{2-} (helps maintain osmatic pressure and serve as essential minerals)

FORMED ELEMENTS

1. Erythrocytes (Red blood cells)
2. Leukocytes (White blood cells)

   a. Granular leukocytes (granulocytes)
      Neutrophils
      Eosinophils
      Basophils

   b. Agranular leukocytes (agranulocytes)
      Lymphocytes (T cells,B cells and Natural killer cells)
      Monocytes

3. Thrombocytes (Platelets)

PRODUCTION OF FORMED ELEMENTS

Hemopoiesis or Hematopoiesis - Is the process by which blood cells are formed.

(a) Embryonic and Fetal Life - The yolk sac, liver, spleen, thymus gland, lymph nodes, and bone marrow all participate at various times in producing the formed elements.

(b) Adult - The red bone marrow (myeloid tissue) in the proximal epiphyses of the humerus and femur; flat bones of the cranium, sternum, ribs, vertebral, and pelvis; and lymphoid tissue.

Stem cells – Are located in the red bone marrow. All the formed elements of the blood are derived from a single population of stem cells.

Hematopoises – Stem Cells give rise to the cell lines that produce the formed elements:

(1) **Proerythroblasts** (rubriblasts)- form mature Erythrocytes
(2) **Myeloblasts** - form mature Neutrophils, Eosinophils, and Basophils.
(3) **Monoblasts** - form mature Monocytes.
(4) **Lymphoblasts**- form mature Lymphocytes.
(5) **Megakaryoblasts** - form mature Thrombocytes (Platelets).

ERYTHROCYTES (RED BLOOD CELLS)

Erythrocytes or Red Blood Cells (RBCs) are more than 99% of the formed elements in blood.

Red blood cells are about 700 times more numerous than white blood cells and 17 times more numerous than platelets in the blood.

Healthy adult male has about 5.4 million red blood cell/cubic millimeter (mm^3).

Healthy adult female has about 4.8 million per cubic millimeter (mm^3).

(There are about 50 mm^3 in a drop of blood)

RBC Anatomy (Structure):

(Are flexible and can squeeze through marrow capillaries.)

- Appear as biconcave discs, with a diameter of 7-8 um.
- Lack nucleus and other organelles and can neither reproduce nor carry on extensive metabolic activities.
- Contain hemoglobin (oxygen carrying pigment)

*(Hemoglobin, which constitutes about 33% of the cell weight, is responsible for the red color of blood).

Normal values for hemoglobin:

Infants -	14 to 20g/100 ml of blood
Adult females-	12 to 15g/100 ml of blood
Adult males-	14 to 16.5g/100 ml of blood

After phagocytosis of RBC's by macrophages, hemoglobin is recycled.

RBC Physiology (Functions):

-Transport oxygen and carbon dioxide.
(Hemoglobin in erythrocytes combines with oxygen to form **Oxyhemoglobin**, without oxygen is called **Deoxyhemoglobin**, and with carbon dioxide to form **Carbaminohemoglobin**, and then transports them through blood vessels).

RBC has no nucleus, all their internal space is available for oxygen transport.

(A hemoglobin molecule consist of protein called **globin**, composed of four

polypeptide chains, and four nonprotein pigments called **hemes**, each of which contains iron (as FE^{2+}) that can combine reversibly with an oxygen molecule).

RBC lack mitochondrial and generate ATP anabolically (without oxygen), thereby do not consume any of the oxygen that they transport.

Life History of the Red Blood Cells:

-Red blood cells live about 120 days. (Due to wear and tear as they squeeze through capillaries).

Without nucleus and other organelles, RBC cannot synthesize new components to replace damaged ones.

Formation and destruction of red blood cells and recycling of hemoglobin components:

(Worn-out red blood cells removed from circulation and destroyed by fixed phagocytic macrophages in the spleen and liver and breakdown products are recycled as follows):

1. Macrophages in the spleen, liver, or red bone marrow phagocytize worn-out red blood cells.
2. The globin and heme portions of hemoglobin are split apart.
3. Globin is broken into amino acids, which can be
4. Reused to synthesize other proteins.
5. Iron removed from the heme portion
6. Associates with a plasma protein called **transferrin**, which transports iron in the bloodstream.
7. In muscle fibers, liver cells, and moacrophages of the spleen and liver, iron detaches from transferrin and attaches to ion-storage protein called **ferritin** and **hemosiderin**.
8. Upon rellease from a storage site or absorption from the gastrointestinal tract, iron attaches to transferrin.
9. It is then transported to bone marrow, where RBC precursors take it up through receptor-mediated endocytosis
10. For use in production of new hemoglobin molecules.

11. Erythropoiesis in red bone marrow results in the production of red blood cells, which enter the circulation.
!2. At the same time, the non-iron portion of heme is converted to **biliverdin**, a green pigment, and then into
13. **Bilirubin**, an orange pigment.
14. Bilirubin enters the blood and is transported to the liver.
15. Within the liver, bilirubin is secreted by liver cells into bile, which passes into the small intestine.
16. In the large intestine bacteria convert bilirudin into **urobilinogen**.
17. Some uroblinogen is absorbed back into the blood, converted to **urobilin**, a yellow pigment, and excreted in urine.
18. Most urobilinogen is eliminated in feces in the form of a brown pigment called **stercobilin**, which gives feces their characteristic color.

Note: **Jaundice** is a yellowish staining of the skin and sclerae caused by a buildup of bile pigments in the circulation and interstitial spaces.

Production of RBCs:

Erythropoiesis is the process by which erythrocytes are formed.

(Note that RBC in blood lack nucleus or other organelles)

(From the Stem Cell, **Proerythroblast** gives rise to an **Early (Basophilic) erythroblast** which then develops into an **Intermediate (polychromatophilic) erythroblast**, which developes into **Late erythroblasts**, to **Reticulocyte**, and then to **Erythrocytes**).

Normoblast is a nucleated red blood cell found in red marrow, but rarely found in blood.

Anemia - a lower than normal number of RBC's or quality of hemoglobin, or circulatory problems that reduce blood flow to tissues.

Hypoxia- cellular oxygen deficiency.

*Normally erythropoiesis(process of erythrocyte formation) and red blood cell destruction proceed at the same pace.

Negative Feedback Regulation of Erythropoiesis (red blood formation)

--If the oxygen-carrying capacity of the blood falls because erythropoiesis is not keeping up with RCB destruction, a negative feedback system steps up erythrocyte production.

LEUKOCYTES (White Blood Cells)

WBC Anatomy and Types

- Have a nucleus (unlike RBC)
- Do not contain hemoglobin (unlike RBC)

Two major groups of leucocytes:

1) **Granular leucocytes (granulocytes)**
   a. Neutrophils
   b. Eosinophils
   c. Basophils

2) **Agranular leucocytes (agranulocytes)**
   a. Lymphocytes
   b. Monocytes

Granular leukocytes (granulocytes) have conspicuous granules in the cytoplasm that can be seen under light microscope.

Agranular leukocytes (agranulocytes) do not have cytoplasmic granules that can be seen under a light microscope, owing to their small size and poor staining qualities.

(Just as red blood cells have surface proteins, so do white blood cells and all other nucleated cells in the body).

*(These proteins, called **MHC (Major Histocompatibility)** antigens, are unique for each person (except for identical twins) and can be used for identify marker).

** Blood is merely a conduit (natural channel) for monocytes, which migrate out into the tissues, enlarge, and differentiate into **macrophages**.

Two Types of Macrophages:

1. **Fixed macrophages** reside in a particular tissue (alveolar macrophages, spleen macrophages, etc.)

2. **Wandering (free) macrophages** roam the tissue and gather at sites of infection or inflammation.

WBC Physiology (Functions)

In healthy body, some WBCs, especially **lymphocytes**, can live for several months or years, but most live only a few days.

During a period of infection, phagocytic WBCs may live only a few hours.

WBCs are far less numerous than red blood cells, about 5000-10,000 cells per cubic millimeter (mm^3) of blood.

***RBCs therefore outnumber white blood cells about 700:1.

Leukocytosis refers to an increase in the number of WBCs.

Leukopenia refers to an abnormally low level of white blood cells (below $5000/mm^3$).

(Because skin and mucous membranes of the body are continuously

exposed to microbes and their toxins, some of these microbes can invade deeper tissues to cause disease).

The General Function of White Blood Cells (WBCs) is to combat these pathogens (microbes and their toxins) by **phagocytosis** or **immune responses**.

***Neutrophils
***Monocytes

(Are both actively phagocytotic - they can ingest bacteria and dispose of dead matter).

Granulocytes (neutrophils, eosinophils, and basophils) and **Monocytes** (an agranulocyte) leave the bloodstream to fight injury or infection, but never return.

Lymphocytes (an agranulocyte) continually recirculate from blood to interstitial spaces of tissues to lymphatic fluid and back to blood.

Emigration is the process by which WBCs leave the bloodstream:

(i) in which they slow down,
(ii) roll along the endothelium,
(iii) sticking, and
(iv) then squeeze between endothelial cells.

Chemotaxis is a phenomenon by which several different chemicals released by microbes and inflamed tissues attract phagocytes.

-**Neutrophils** respond to tissue destruction by bacteria most quickly among other WBCs. Act as first line of defense.

Are most common type of white blood cells in the blood.

Contain several destructive chemicals:
(1) **Lysozymes** - destroys several bacteria

(2) **Strong oxidants** (superoxid anion (O_2^-), hydrogen peroxide (H_2O_2), and hypochlorite anion (Ocl^-))
(3) **Defensins**, proteins that exhibit a broad range of antibiotic activity against bacteria, fungi, and viruses.

Monocytes take longer to reach a site of infection than neutrophils.

Are typically the largest of the white blood cells
(1) Arrive in larger number and destroy more microbes.
(2) Upon arrival, enlarge and differentiate into **wandering macrophages** which clean up cellular debris and microbes following infection.

Eosinophils are believed to release enzymes (histaminase) that combat the effects of histamine and other mediators of inflammation in allergic reaction.

Basophils are also believed to be involved in inflammatory and allergic reaction.

Lymphocytes are involved in the production of antibodies (Immunity- antibody- antigen reactions)

*Antibodies are special proteins that inactivate antigens.

*Antigens are substances that will stimulate the production of antibodies and are capable of reacting specifically with the antibody.

Major Types of Lymphocytes:

(1) **B Cells** - are particularly effective in destroying bacteria and inactivating their toxins.

(2) **T Cells** - attack viruses, fungi, transplanted cells, cancer cells, and some bacteria.

(3) **Natural killer cells** - attack a wide variety of infectious microbes and certain spontaneously arising tumor cells.

***An increase in the number of circulating WBCs usually indicates inflammation or infection.

Percentage of each type of White Blood Cells in a Normal Differential White Blood Count:

Neutrophils	60% - 70%
Lymphocytes	20% - 30%
Monocytes	2% – 8%
Eosinophils	1% – 4%
Basophils	0.5% -1%

WBCs	**HIGH COUNT**	**LOW COUNT**
Neutrophil	Bacteria infection, Burns, Stress, or Inflammation	Radiation, Certain drugs Vit B_{12} deficiency, Systemic lupus erythematosus
Eosinophil	Allergic reaction Parasitic infection Autoimmune disease Adrenal insufficiency	Certain drugs, Stress, Cushing syndrome
Basophil	Allergic responses Leukemia, Cancer, Hypothyroidism	Pregnancy, Ovulation, Hyperthyroidism
Lymphocyte	Viral infection, Immune diseases, Leukemia	Prolonged severe illness, High steroid level,
Lymphocyte	Viral infection	Immunosuppression

Monocyte	Fungal infection Tuberculosis (TB) Leukemia Chronic disease	Rarely occur.

PLATELETS

Structure:
- Are round or oval discs
- Without a nucleus
- Average from 2 to 4 um in diameter

Functions:

-Repair slightly damaged blood vessels.
- Initiate a chain of reaction that results in blood clotting.

Life Span and Number:

- Have a short life span (5-9 days).
- Between 250,00 and 400, 000 present in each cubic millimeter (mm^3) of blood.

Production:

Hemopoietic stem cell -- Megakaryoblast -- Platelets

- Produced in red bone marrow.

HEMOSTASIS

Differs from Homeostasis (constant internal environment)

Hemostasis - The stoppage of bleeding.

Three Basic Mechanisms to Prevent Blood Loss

1) Vascular spasm
2) Platelet plug formation
3) Blood coagulation (clotting)

Vascular Spasm

The smooth muscles of a blood vessel wall contracts to stop bleeding.

Reduces blood loss for several minutes to several hours, during which time the other hemostatic mechanisms can go into operation.

Platelet Plug Formation

Involves the clumping of platelets to stop bleeding.

Two Types of Granules Present in the Cytoplasm:

(1) **Alpha granules** contain clotting factors and platelet-derived growth factor (PDGF).

(2) **Dense granules** contain ADP, ATP, Ca^{2+}, Serotonin, and enzyme that produce Thromboxane A2.

Platelet Plug Formation Occurs as Follows:

(1) **Platelet Adhesion** - A process by which platelets attach together.

(2) **Platelet Release Reaction** - As a result of adhesion, platelets become activated and liberate contents of their granules.

Serotonin and thromboxane A2 function as vasoconstrictors, causing contraction of vascullar smooth muscle, which decreases blood flow through the injured vessel.

(3) **Platelet aggregation** - Release of ADP makes other platelets in the area to sticky, and the stickyness cause them to adhere to others.

Platelet Plug - The accumulation and attachment of large numbers of platelets.

Clotting (Coagulation)

In the vessels, blood maintains its liquid state.

Outside the body, it thickens and forms a gel.

The gel eventually separates from the liquid.
Serum - the straw-colored liquid --is simply plasma minus its clotting proteins.

Coagulation - is the process of clotting or gel formation.

Thrombosis - results if blood clots too easily -- clotting in a unbroken blood vessels.

Hemorrhage - results if blood takes too long to clot.

Coagulation Factors - are various chemicals involved in clotting.

Three Basic Stages of Blood Clotting

(1) Formation of prothrombinase (prothrombin activator). Initiated by either the extrinsic or the intrinsic pathway or both.

(2) Conversion of prothrombin (a plasma protein formed by the liver) into the enzyme thrombin by prothrombinase.

(3) Conversion of soluble fibrinogen (another plasma protein

formed in the liver) into soluble fibrin by thrombin.

Fibrin forms the threads of the clot.

1. **Formation of Prothrombinase** (Stage 1)

Two mechanisms are involved: (a) extrinsic, and (b) intrinsic pathways.

(a) **Extrinsic Pathway** (Outside blood vessels):

Has fewer steps than intrinsic pathway

Occurs rapidly, within matter of seconds if trauma is severe.

Tissue Factor (TF) leaks into the blood from cells outside (extrinsic to) blood vessels and initiates the formation of prothroombinase.

Activates **clotting factor VII**, which activates **factor X**.

Activated **factor X** combines with **factor V** in the presence of **calcium ions (Ca^{2+})** to form the active enzym **prothrombinase**.

(b) **Intrinsic Pathway** (Within the blood vessel):

More complex than the extrinsic pathway.

Occurs more slowly, usually requiring several minutes.

Activators are in direct contact with blood or contained within (intrinsic to) the blood; outside tissue damage is not needed.

Factor XII is activated by contact with **collagen** from damaged endothelial.

Factor XII activates **factor IX**. (Activated **factor VII** from extrinsic pathway also can activate **factor IX**).

Activated **factor IX** joins with **factor VIII** and **platelet phospholipids** to activate **factor X**.

Activated **factor X** combines with **factor V** and **Ca^{2+}**(as cofactor) to form the active enzyme **prothrombinase** as in extrinsic pathway,

2. **Common Pathway** (Stages 2 and 3)

In the **second stage**, **prothrombinase** and **Ca^{2+}** catalyze the conversion of **prothrombin** to **thrombin**.

In the **third stage**, **thrombin**, in the presence of **Ca^{2+}**, converts **fibrinogen**, which is soluble, to **loose fibrin threads**, which are insoluble.

(How clotting is controlled: Fibrin has the ability to absorb and inactivate up to 90% of the thrombin formed from prothrombin. This helps stop the spread of thrombin into the blood and thus limits spread of the clot beyond the site of damage).

Need for Vitamin K

Normal clotting depends on adequate vitamin K in the body.

Although vitamin K is not involved in actual clot formation, it is required for the synthesis of four clotting factors by liver cells: (Factors II (prothroombin), VII, IX, and X).

Vitamin K is normally produced by bacteria in the large intestine.

Clot Retraction and Repair

Clot retraction is the consolidation or tightening of the fibrin clot.

During retraction, some serum escapes between the fibrin threads, but the formed elements in blood remain trapped in the fibrin thrads.

Fibrinolysis

Fibrinolytic system provides checks and balances so that clotting does not get out of hand.

Also dissolves clots at a site of damage once the damage is repaired.

Fibrinolysis is the dissolution of a clot.

Hemostatic Control Mechanism

Intravascular Clotting

Despite the anticogulating and fibrinolytic mechanisms, blood clots sometimes from within the cardiovascular system.

(1) May be initiated by roughened endothelial surface of a blood vessel as a result of atherosclerosis, truma, or infection.

(2) May also form when blood flows too slowly (stasis), allowing clotting factors to accumulate locally in high concentration to initiate coagulation.

Thrombosis - Clotting in an unbroken blood vessel (usually a vein).

Thrombus - Clot itself.

Embolus - A blood clot, bubble of air, fat from broken bones, or a piece of debris transported by the bloodstream.

Pulmonary embolism - Condition that results when embolus lodges in the lungs.

GROUPING (TYPING) OF BLOOD

Surface of erythrocytes contain some glycoproteins and glycolipds that can act as antigens.

Antegens (**Isoantegens** or **Agglutinogens**) are normal components of one person's RBC plasma membrane that can trigger damaging antigen-antibody respponse in other people.

Two Major Blood Group Classification: (based on the presence or absence of various isoantigens):

I. ABO
II. Rh

(Other groups are the Lewis, Kell, Kidd, and Duffy systems).

I. ABO Blood Group

ABO blood grouping is based on two glycolipid isoantigens called A and B.

Type A - Individuals whose erythrocytes (Red blood cells) displays only antegen A

Type B - Individuals whose erythrocytes (Red blood cells) displays only antigen B

Type AB - Individuals who displays both A and B

Type O - Those who displays neither A or B

Most people's blood plasma contains naturally occurring antibodies called **Isoantibodies or Agglutinins** that will react with A or B antigens if the two are mixed.

These are:

(a) Anti-A antibody
(b) Anti-B antibody

*You do not have **isoantibodies or agglutinins** that react with the **isoantigens or agglutinogens** of your own erythrocytes, but most likely you do have an isoantibodies for any isoantegens you RBC's lack.

*--Results in incompatible blood transfusion.

When antigen-antibody complexes form in the body, they activate plasma proteins if the complement family.

Complement molecules poke holes in the donated RBC's causing them to burst and release hemoglobin into the plasma -- a reaction called **Hemolysis**.

* The liberated hemoglobin may cause kidney damage.

Agglutination - clumping of microorganisms or blood corpuscles; typically an antigen-antibody reaction - that is visible to the naked eye.

(Results in an incompatible blood transfusion)

*(Agglutinated cells can block blood vessels and may lead to kidney or brain damage and death, and the liberated hemoglobin (Due to hemolysis)

may also cause kidney damage.)

*Universal recipients - Individuals with type AB blood - Do not have any a or b agglutinins in their plasma, they can theoretically receive blood from donors of all four blood types; there are no agglutinins to attack donated erythrocytes.

***Universal donors** - Individuals with type O blood - have no A or B agglutinogens on their erythrocytes, they can theoritcally donate blood to recipients of all four blood types.

II. **Rh Blood Group**

(Rh system of blood classification is so named because it was first worked out in the blood of the (Rhesus Monkey).

Rh^+ - Individuals whose erythrocytes have the Rh agglutinogens (Antigen) 85% whites; 88% blacks.

Rh^- - Those who lack Rh agglutinogens 15% whites; 12% blacks.

* (Under normal circumstances, human plasma does not contain anti-Rh agglutinins. However, if an Rh^- person receives Rh^+ blood, the body starts to make anti-Rh agglutinins that will remain in the blood. If a second transfusion of Rh^+ blood is given later, the previously formed anti-Rh agglutinins will react against the donated blood and a severe reaction may occur.)

[(a) Rh^+ father (b) Rh^- mother and Rh^+ fetus]

(b) -If an Rh^- female is impregnated by an Rh^+ male and fetus is Rh^+ agglutinogens may enter the material blood via the placenta during delivery.

(c) Upon exposure to the fetal Rh^+ agglutinogens, the mother will make anti-Rh agglutinins.

(d) If the female becomes pregnant again, her ant-Rh agglutinins will cross the placenta into the fetal blood.

* If the fetus is Rh^+, hemolytic disease of the newborn will result (erythroblastosis fetalis).

DIAGNOSTIC BLOOD TESTS

Type and Crossmatch

To prevent transfusion reactions the blood is typed, and a **crossmatch** is made.

Blood typing determines the ABO and Rh blood groups of the blood sample.

Process:
(1) Blood cells are separated from the serum.
(2) Cells are tested with known antibodies to determine the type of antigen on the cell surface.

Note: If a patient's blood cells agglutinate when mixed with anti-A antibodies but do not agglutinate when mixed with anti-B antibodies, it's concluded that the cells have type A antigen.

Complete Blood Count

Complete Blood Count (CBC) – Is an analysis of the blood that provides much information. Consists of a red blood count, hemoglobin and hematocrit measurements, a white blood count, and a differential white blood count.

Red Blood Count (RBC)

Normal range for a **red blood count (RBC)** is the number (expressed in millions) of red blood cells per microliter of blood.

Male – 4.6-6.2 million/ul of blood.
Female – 4.2-5.4 million/ul of blood.

Erythrocytosis – Is an overabundance of red blood cells.

Hemoglobin Measurement – Determines the amount of hemoglobin to a given volume of blood, usually expressed as grams of hemoglobin per 100 ml of blood.

Hematocrit Measurement – The percentage of total blood volume composed of red blood cells is the hematocrit.

White Blood Count (WBC) – Measures the total number of white blood cells in the blood.

Normally 5000-10000 white blood cells are present in each microliter of blood.

Leukopenia – Is a lower-than-normal WBC and can indicate depression or destruction of the red marrow by radiation, drugs, tumor, or deficiency of vitamin B12 or folate.

Leukocytosis – Is an abnormally high WBC.

Leukemia (A cancer of red marrow) – Often results in leukocytosis, but the white blood cells have abnormal structure and function. Bacterial infections also can cause leukocytosis.

Differential White Blood Count

Differential white blood count – determines the percentage of each of the five kinds of white blood cells in the WBC.

Normally Neutrophils count for 60%-70%; Lymhocytes, 20%-30%;

Monocytes, 2%-8%; Eosinophils, 1%-4%; and Basophils, 0.5%-1%.

CLINICAL FOCUS – DISORDERS OF THE BLOOD

1. Anemia - Is a decreased erythrocyte count or hemoglobin deficiency.

   * Anemia is a sign, not a diagnosis.

   Kinds of Anemia

   a) Nutritional Anemia arises from an inadequate diet, one that provides insufficient amount of iron, the necessary amino acids, or vitamin B_{12}.
   b) Pernicious Anemia is the insufficient production of erythrocytes resulting from an inability of the body to produce intrinsic (glycoprotein) factor. As a result, the person cannot absorb Vit. $B_{12.}$
   c) Hemorrhagic Anemia an excessive loss of erythrocytes through bleeding.

   d) Hemolytic Anemia premature destruction of erythrocytes (red blood cells). (If erythrocytes cell membranes rupture prematurely, the cells remain as "ghosts", and their hemoglobin pour out into the plasma.

   e) Aplastic Anemia destruction or inhibition of the red bone marrow.

   f) Sickle-Cell Anemia (SCA) abnormal kind of hemoglobin.

2. Polycythemia is an abnormal increase in the number of erythrocytes.

3. Infectious Mononucleosis (IM) is a contagious disease that primarily

affects lymphoid tissue. It is characterized by an elevated white blood cell count, with an abnormally high percentage of lymphocytes. Caused by Epstein-Barr virus (EBV).

4. Chronic fatigue syndrome is characterized by extreme fatigue for at least six months and the absence of known diseases that might produce similar symptoms. Among the symptoms are sore throat, headache, muscular aches, fever and chills, fatigue, joint pain, and neurological defects.

5. Leukemia is a malignant disease of blood forming tissues characterized by the uncontrolled productions of white blood cells that interferes with normal clotting and vital body activities.