

Cardiovascular System: Blood

I. The Formed Elements

- A. The blood, heart and blood vessels make up the C.V. system
 - 1. Designed to transport materials
 - 2. Blood contains nutrients and oxygen required by cells
 - 3. Must reach all parts of the body and all cells
 - 4. **Interstitial Fluid** bathes all cells, this is serviced by blood and lymph
 - 5. Blood carries the following:
 - a) O₂ from lungs
 - b) Hormones from the Endocrine Glands
 - c) Nutrients from G.I. tract
 - d) Enzymes from other areas of the body
 - e) Various chemicals
 - 6. Blood also transports wastes to the lungs, kidneys, and sweat glands
 - 7. Some substances are passed to the liver before excretion
 - 8. Other functions of blood include:
 - a) Regulate pH
 - b) Body Temperature
 - c) Protects blood loss by clotting
 - d) Destroys **Antigens** by phagocytosis
- B. The Formed Elements
 - 1. **Leukocytes**
 - a) Monomorphonuclear Leukocytes (AGRANULAR)
 - (1) Monocytes
 - (2) Lymphocytes
 - b) Polymorphonuclear Leukocytes (GRANULAR)
 - (1) Neutrophils
 - (2) Eosinophils
 - (3) Basophils
 - 2. **Erythrocytes**
 - 3. **Thrombocytes**

II. Blood Cells

- A. **Red Blood Cells (RBC) = Erythrocytes**
 - 1. Tiny, biconcave disks (increased surface area), 8 micrometers in diameter
 - 2. No organelles, can not divide
 - 3. Very little metabolism
 - 4. Possess anaerobic ATP synthesis
 - 5. Have a great capacity to carry O₂
 - 6. Consists of a membrane containing **hemoglobin**, which is loosely bound to oxygen.
 - a) oxyhemoglobin = bright red
 - b) Hemoglobin = protein (globin) + heme (iron)
 - 7. Structure of hemoglobin

- a) Four proteins called **Globins**
 - b) Four Non-proteins called **Heme**
 - c) Each heme is attached to a globin
8. Mature cells **lack nuclei** (i.e. are anucleate), leaving more room for hemoglobin/oxygen
9. Function of Hemoglobin
- (1) As cells pass through the lung, each iron component of hemoglobin attaches to it a molecule of O₂.
 - (2) This forms **Oxy-hemoglobin**
 - (3) This is transferred to other body cells
 - (4) At cells the O₂ is released
 - (5) The globin part attaches to some CO₂
 - (6) CO₂ transported back to lungs
 - (7) Most CO₂ carried by blood plasma
10. RBC Count (RCC) = the number of RBC's/mm³ blood.
- a) Average RCC = **4 million-6 million rbc's/mm³**
11. Average life-span = **120 days**
- a) Liver and spleen macrophages destroy worn RBC's
 - b) Hemoglobin is broken into globin and heme
 - c) Iron in Hg is recycled
 - d) Globins split into amino acids
 - e) Iron stored in liver in 2 forms:
 - (1) **Ferritin**: iron – protein
 - (2) **Hemosiderin**: very insoluble
 - f) Iron transported in the blood by **Transferrin**
 - g) Carries iron to bone marrow for new RBC production
 - h) Non-iron heme portion is converted:
 - (1) Biliverdin (green color)
 - (2) > Bilirubin (red color)
 - (3) > excreted in bile
 - i) In colon, bacteria convert bilirubin into urobilinogen, then into stercobilin, where it is eliminated as a brown pigment
12. Production (Erythropoiesis)
- a) In fetuses = yolk sac, liver, spleen
 - b) In adults = **red bone marrow**
 - c) Production – Destruction usually equal
 - d) Produced at about 1 -2 million per second
 - e) Homeostatic Mechanism of production control
 - (1) Reduced O₂ supply – **Hypoxia**
 - (2) If kidney or liver O₂ deficient they release – **Renal Erythropoietic Factor (REF)**
 - (3) REF converted to **Erythropoietin** (a hormone)
 - (4) This travels to bone marrow to stimulate production
 - f) B₁₂, folic acid, protein and iron are all needed
 - g) Intrinsic Factor in stomach allows B12 to be absorbed
 - h) **Hematocrit**: percent of blood made up of RBC's

(a) Males 40 – 54

(b) Females 38 – 46

13. Number normally remains stable.

a) Negative feedback mechanism involving the hormone **erythropoietin**, which is produced and secreted by special cells in the kidney and liver.

(1) Chemoreceptors in kidney and liver detect low blood oxygen,

(2) Erythropoietin is released from kidney and liver into circulation,

(3) Erythropoietin targets red bone marrow, stimulating erythropoiesis.

14. Comprise 99% of blood cells.

B. White Blood Cells (WBC) = Leukocytes

Leukocytes function to control disease:

1. Most only live a few days (except lymphocytes)
2. Possess nuclei and have no hemoglobin
3. WBC have human leukocyte associated antigens
4. Unique for each person – except in ID-TWINS
5. Leukocytes are divided into two major groups; granulocytes and agranulocytes

6. Granulocytes

a) Neutrophils

(1) Most abundant WBC = 54% - 62%

(2) Polymorphonucleocytes (**PMN**)

(3) **Phagocytosis** of foreign particles (disease organisms & debris)

(4) First to respond to infection

(5) Increased in acute bacterial infections

(6) Release enzyme Lysozyme

b) Eosinophils

(1) 1-3% of total WBC's

(2) Kill parasites and are responsible for **allergic reactions**

(3) Increased during parasitic infections (tapeworm, hookworm)

(4) Release histamine during allergic reactions

(5) Antigen – antibody complexes

c) Basophils

(1) <1% of total WBC's

(2) Release **heparin** which inhibits blood clotting

(3) Release **histamine**, a vasodilator helpful of inflammatory responses (increases blood flow to damaged tissue)

(4) Involved in allergic reactions

- (5) May leave bloodstream and develop into **mast cells** (antibodies attach and cause mast cell to burst, releasing allergy mediators).

7. **Agranulocytes**

a) **Monocytes**

- (1) 3-9% of total WBC's
- (2) Found in large numbers at infection site
- (3) **Phagocytic**, clean up cellular debris
- (4) largest wbc, 12-20 microns
- (5) In blood = phagocyte; In tissues = macrophage
- (6) Increased during typhoid fever, malaria, mononucleosis
- (7) Take longer to reach infection

b) **Lymphocytes**

- (1) 25-33% of total WBC's;
- (2) live for several months to years;
- (3) range in size from large (10-14 μ) to small (6-9 μ)
- (4) produce **antibodies** that act against specific foreign substances (immunity);
- (5) increased during TB, whooping cough, viral infections, tissue rejection reactions, and tumors

8. Average WBC count (WCC) = **5,000-10,000 wbc's / mm³ blood**;

a) Number of wbc's increases during infections;

- (1) leukocytosis = WCC > 10,000;
- (2) leucopenia = WCC < 5,000;

9. **Differential WCC** indicates % of each particular leukocyte;

10. **Diapedesis** = process by which leukocytes move through blood vessel walls to enter tissues;

11. **Leukemia** = abnormal (uncontrolled) production of specific types of immature leukocytes (see below).

C. **Platelets = thrombocytes**

1. Fragments of giant cells called megakaryocytes;
2. Normal count = **130,000-360,000 platelets/mm³ blood**;
3. Function = **blood clotting** (will be discussed in more detail later)

D. **Origin of the Formed Elements**

1. Formed in red marrow by a process called HEMATOPOESIS
2. Takes place in humerus, femur, sternum, ribs, vertebrae, pelvis, lymph tissues
3. RBC's, platelets and granular leukocytes are produced in red marrow
4. Agranular leukocytes arise from red marrow, spleen, tonsils, and lymph nodes
5. All cells originate from **Hemocytoblasts**

ALL BLOOD CELLS ARE FORMED FROM THE SAME LARGE PRIMITIVE CELL CALLED A HEMOCYTOBLAST.

Appendix to Part D: Origin of the Formed Elements

1. Hematopoiesis: Blood Cell Manufacture
2. Occurs in 2 types of tissues:
 - a. myeloid tissue found in red marrow
 - b. lymphoid tissue
3. Red marrow found in humerus, femur, ribs, sternum, and diploe of cranium
4. Lymphoid tissue found in spleen, tonsils, lymph nodes, thymus.
5. The granular leukocytes are produced in the myeloid tissues as well as the erythrocytes and platelets.
6. The monocytes are produced in the spleen and red marrow.
7. The lymphocytes are produced in the lymphoid tissues.

III. **BLOOD PLASMA** Blood plasma is clear, yellow liquid, composed of proteins, nutrients, gases, electrolytes, and many more substances.

A. **Contents:**

1. 55% of blood is plasma, 45% consists of cells
2. Plasma is 90% water, 7-9% protein plus assorted salts, vitamins, glucose, gasses, hormones, etc

B. **Water:**

1. 91.5%
2. Functions as solvent, in transport, temperature regulation, and serves as site of metabolic reactions.

C. **Plasma Proteins:**

1. 7%
2. All produced in the liver.
3. Three types of proteins are present:
 - a) **albumin;**
 - (1) maintains osmotic pressure of cells (0.9%) and
 - (2) transports fatty acids
 - (3) produced by liver
 - (4) provides viscosity -needed for blood pressure
 - b) **globulins** - Alpha, beta, gamma;
 - (1) Alpha and Beta transport fats and fat sol. Vitamins
 - (2) Gamma antibodies are produced by lymphocytes
 - c) **fibrinogen;**
 - (1) assists in blood clotting
 - (2) Blood plasma minus fibrinogen is serum

D. **Plasma Nutrients:**

1. amino acids
2. monosaccharides (i.e. glucose)

3. lipoproteins

E. Plasma Wastes:

1. urea (amino acid metabolism)
2. uric acid (nucleotide metabolism)
3. creatinine (creatine metabolism)
4. creatine (CP to recycle ADP to ATP in muscle & brain)
5. bilirubin (hemoglobin metabolism)

F. Plasma Gases:

1. oxygen (needed for cellular respiration)
2. carbon dioxide (produced by cell respiration)
3. nitrogen (use unknown)

G. Plasma Electrolytes:

1. include sodium, potassium, calcium, magnesium, chloride, bicarbonate, phosphate, and sulphate
2. Maintain osmotic pressure, Resting Membrane Potential, and pH

H. Regulatory Substances:

1. enzymes
2. hormones

IV. HEMOSTASIS = stoppage of bleeding from a blood vessel

A. 3 steps involved:

1. Blood vessel spasm (vessel walls constrict)
2. Platelet plug formation
 - a) platelets also release the hormone **serotonin** which causes further vasoconstriction of the vessel
3. **blood coagulation** = formation of a blood clot;
 - a) complex cascade of events (positive feedback mechanism);
 - b) requires calcium ions;
 - c) Final step = fibrinogen → **fibrin**.
 - d) See scanning electron micrograph,

B. Fibrinolytic System

1. Fibrinolytic system provides checks and balances so that blood clotting does not go awry
2. Fibrinolytic substances include:
 - a) tissue plasminogen activator (TPA):
 - (1) naturally produced
 - (2) Also injected quickly after MI to dissolve coronary thrombus.
 - b) Heparin is an anticoagulant:
 - (1) naturally produced by basophiles and mast cells;

- (2) Also used a pharmacologic agent extracted from lung tissues of animals;
- (3) Used during open heart surgery and hemodialysis.
- c) Warfarin (Coumadin) is another anticoagulant:
 - (1) given to patients prone to thrombosis;
 - (2) slower acting than heparin.

VI. Antigen – Antibody Reactions

- A. **Antibody** productions: proteins that inactivate **Antigens**
- B. Antigens are proteins that can cause an immune response
- C. Antigens make up the structure of viruses and bacterial membranes
- D. **Toxins** released by bacteria are antigens

VII. BLOOD GROUPS/TRANSFUSIONS

A. Significance

- 1. There are **antigens** present on the cell membrane surface of our erythrocytes (red blood cells).
- 2. Our plasma contains substances called **antibodies** that are produced against non-self antigens.
- 3. If the RBC antigen (donor) and plasma antibody (recipient) are the same, the serious condition of **hemolysis** (bursting) of RBC's will occur.
- 4. In the laboratory, this situation can be simulated, however the result is termed **agglutination** = clumping of red blood cells.

B. Blood types:

- 1. Inherited trait
- 2. Determined by the antigens on a person's RBC's
- 3. 4 types: A, B, AB, O
 - a) Type A blood = antigen A on RBC's
 - b) Type B blood = antigen B on RBC's
 - c) Type AB blood = both antigen A & B on RBC's
 - d) Type O = neither A or B antigen on RBC's

C. **Antibodies** in plasma: (See above figure)

- 1. Shortly after birth, we spontaneously develop antibodies against RBC antigens, that our not our own.
- 2. Antibodies formed include:
 - a) Persons with Type A blood, develop Anti-B antibodies;
 - b) Persons with Type B blood, develop Anti-A antibodies;
 - c) Persons with Type AB blood, do not develop either Anti-A or Anti-B antibodies;
 - d) Persons with Type O blood, develop both Anti-A and Anti-B antibodies.