Physiology of Blood

Blood is classified as a connective tissue because it consists of cells (RBCs and WBCs) and cell fragments (Platelets) surrounded by a liquid matrix (plasma). The cells and cell fragments are called formed elements and the liquid matrix is the plasma. The total blood volume in the average adult is approximately is 4-5L in females, and 5-6L in males.

Table (1): General Properties of Whole Blood

Fraction of body weight	**8%**
Volume /body weight	**80-85 ml/kg**
Mean temperature	**38 ℃**
PH	**7.35-7.45**
Viscosity (relative to water)	**Whole blood 4.5-5.5**
	Plasma 2.0
Osmolarity	**280-296 mOsm/L**
Mean salinity (mainly NaCl)	**0.9%**
Hematocrit (PCV)	**Female 37%-48%, Male 45%-52%**
Hemoglobin (Hb)	**Male 13-18 g/dl Female 12-16g/dl,**
Mean RBC count	**Female 4.8 million/mm^3, male 5.4 million/ mm^3**
Platelet count	**130000 – 360000/mm^3**
Total WBC count	**4000 – 11000/mm^3**

It was found that the highest number of cells within the blood returns to the RBCs, so the RBC count and hemoglobin concentration are very important clinical data because they determine the oxygen carrying capacity of the blood.

The three most common measurements used to estimate the oxygen carrying capacity are:

- Hematocrit value (PCV value)
- Hemoglobin concentration
- Total RBC count

These three values tend to be lower in women than in men, and the possible physiological reasons for this are:

1. Androgens in men stimulate RBC production, and thus men have higher levels than women
2. Women of reproductive age have periodic menstrual losses
3. Hematocrit is inversely proportional to the percentage of body fat. Fat percentage is higher in women than in men

Function of the Blood:

The function of the blood can be placed into three main categories and they are: ***transportation, regulation and protection.***

A- Transportation:

1. Blood carries oxygen from the lungs to other organs
2. It carries nutrients from the digestive system and storage depots to other organs
3. Blood carries CO2 from all organs and body tissues to the lungs for removal
4. It carries other waste products to the liver and kidneys for detoxification and removal
5. Blood carries hormones from the endocrine glands to their target cells
6. Blood carries metabolic heat from deep tissues to the body surface (Skin) for removal and helps to stabilize body temperature

B- Regulation:

1. Blood transfers water to and from the tissues, which helps to stabilize the water content of the cells
2. Many chemicals found in the blood act as buffers that help keep the blood´s PH within its normal limits (7.35 – 7.45) which is slightly alkaline
3. The osmotic composition of the blood is also critical for maintaining the normal fluid and electrolyte balance

C- Protection:

1. Blood plays several roles in inflammation
2. White blood cells destroy some micro-organisms and cancerous cells
3. Antibodies and complement proteins neutralize toxins or help to destroy micro-organisms
4. Platelets factors initiate clotting and minimize blood losses when blood vessels are damaged

Components of the Blood:

As mentioned previously blood consists of

- cells (RBCs and WBCs)
- cell fragments (Platelets)
- liquid matrix which is the plasma

Plasma and its constituents:

Plasma is a pale-yellow fluid accounting for slightly more than half of the total blood volume and consisting of approximately 91.5% - 92% of water and 8% of dissolved or suspended molecules. Plasma is considered a colloidal solution (means fine particles are suspended in a liquid and resistant to sedimentation or filtration).

1. **Water:** it enters the plasma from the digestive tract as ingested fluids, from interstitial fluids and as a by-product of metabolism. Excess water is removed from the plasma through the kidneys, lungs, intestinal tract and skin.
2. **Proteins:** it is the most abundant plasma solute; its concentration is about 6-9mg/dl. ***Plasma proteins play a variety of roles including clotting, defense and transport***

   The plasma proteins are classified into three main categories: (Albumin, Globulin and Fibrinogen)

   - **Albumin (60%):** the most abundant plasma proteins, ***because of their major role in viscosity and osmolarity, pathological changes in albumin concentration strongly influence blood pressure, flow and fluid balance.*** Albumin constitutes about 60% of plasma proteins, ***they are responsible for colloid osmotic pressure. Albumin transports lipids, hormones, calcium and other solutes and acts as a buffer for the pH of plasma.***

   - **Globulin (36%):** they are divided into Alpha (α) globulins, Beta (β) globulins and Gamma (ɣ) globulins

     1. Function of α-globulin:
        - Haptoglobin which transports hemoglobin released by dead erythrocytes
        - Ceruloplasmin transports copper
        - Prothrombin promotes blood clotting
        - The angiotensinogen which is activated to angiotensin I & II that play an important role in regulating salt balance in the body

2. Function of β-globulin:
   - Transferrin which transports iron
   - Complement proteins aid in destruction of toxins and pathogenic micro-organisms
3. ɣ-globulins which are antibodies that combat pathogens

- **Fibrinogen (4%):** is a key factor in blood clotting, forms fibrin which is the major component of blood clots.

  When the protein fibrinogen is removed from the plasma, the remaining fluid is called **serum**

  The liver produces all of the major plasma proteins except of ɣ-globulins which come from plasma cells that are descended from white blood cells called B-lymphocytes.

3. **Non-protein nitrogenous substances:**

   Blood plasma contains several important nitrogenous compounds in addition to protein like amino acids and nitrogenous wastes. ***The amino acids come from the digestion of dietary proteins or the catabolism of tissue proteins.***

   Nitrogenous wastes are toxic end products of catabolism. ***The most abundant is urea, a product of amino acid catabolism.*** Nitrogenous wastes are normally cleared from the blood and excreted by the kidneys at a rate that balances their rate of production. ***Nitrogenous wastes in addition to urea they include ammonia, creatine, creatinine, uric acid and bilirubin.***
4. **Nutrients:** they are absorbed from the digestive tract, and are transported by the blood plasma. ***They include: Glucose, amino acids, fats, cholesterol, phospholipids, vitamins and minerals.***

5. **Gases:** plasma transports some of the oxygen (O2) and carbon dioxide (CO2), carried by the blood. Plasma also contains an amount of dissolved nitrogen which becomes important in diving and aviation
6. **Regulatory substances:** like enzymes, produced by body cells to catalyze chemical reactions. Hormones produced by endocrine glands to regulate growth and development in the body
7. **Electrolytes:** ***like sodium, potassium, magnesium, calcium, chloride, bicarbonate, phosphate and sulfate. Sodium ions constitute about 90% of the plasma cations and account for more of the body´s osmolarity than any other solute.*** Sodium therefore has a major influence on blood volume and pressure; ***people with high blood pressure are advised to limit their sodium intake.*** Electrolyte concentrations are carefully regulated by the body and have stable concentrations in the plasma.

   Some components of the plasma come from several sources, such as liver, kidneys, intestines, endocrine glands and immune tissue such as spleen.

   Under normal conditions the intake of both water and solutes into the body equals the output, so that the total volumes in the body are maintained within a narrow range.

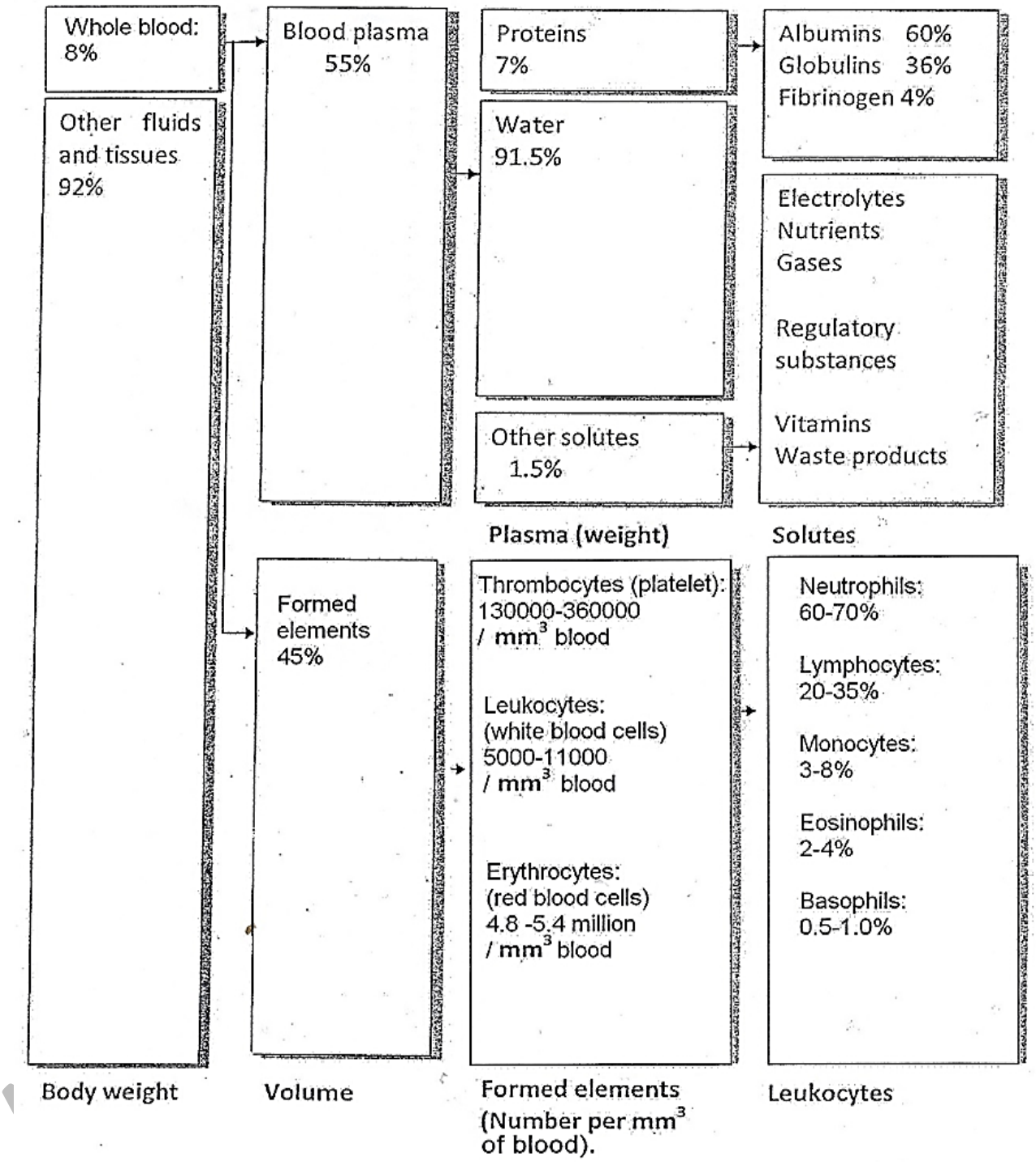

Figure (1): Components of Blood in Normal Adult