SLE221: Systems Physiology Lecture Notes

Topic 1: Haematology

Blood

Blood is the transport medium of the body, the liquid inside blood vessels that is pumped around the body by the action of the heart. 8% of the weight of a human body is blood, each of us has approximately 5L made up of 2L of blood cells and 3L of plasma. Blood makes up one quarter of the extracellular fluid. Total blood volume is pumped around the body in 1 min, this is cardiac output.

- The composition is 55% plasma and 45% cellular elements (haematocrit).
- pH of arterial blood is 7.35-7.45
- Temperature is 38°C

Overall Functions of Blood

Acts as the main transport medium because it carries oxygen and carbon dioxide between lungs and tissues, nutrients, waste products (like urea) and hormones and vitamins from production sites to target organs.

It also acts as a buffer to maintain acid/base balance, controls temperature through vasodilation/vasoconstriction of blood vessels and defends against pathogens and toxins with white blood cells, antibodies and T lymphocytes.

What is Plasma?

Plasma is the yellow coloured liquid component of blood, the largest proportion of blood. Plasma and interstitial fluids are extracellular fluids that exchange water and salts rapidly. Only small amount of the smallest plasma protein (albumin) leak out of the blood vessels to be in the interstitial fluid. Functions:

- Transport medium
- Role in acid/base balance
- Heat absorption
- Colloid osmotic pressure of plasma proteins holds water in blood, maintaining blood volume.
- Plasma proteins have a role in blood clotting.

Plasma is 90% water, and the remainder is solutes, proteins in colloid dispersion and substances carried in plasma by proteins. Solutes include salts, water soluble nutrients and waste products, gases and water soluble hormones.

The most abundant plasma electrolytes are Na^+ and Cl^- (determine blood osmotic pressure), HCO_3^- (important in buffering), Ca^{2+} (roles in hormone and neurotransmitter release, blood clotting and contraction of all muscle).

Organic plasma components include glucose, amino acids, lipids, vitamins and hormones. Also has waste products such as urea and bilirubin (responsible for yellow colour of plasma). The term ‘serum’ means the fluid left of plasma once the plasma proteins have been removed.

Proteins in Colloid Dispersion

Plasma proteins make up 6-8% of plasma and are albumins (most abundant - 60%), globulins and fibrinogen. They're mostly large in size and retained within blood vessels, attracting water into the bloodstream- essential for maintaining blood volume. Also prevents changes in pH.

Cellular Elements in Blood

- *RBC (erythrocytes):* Cell which have lost their nucleus
- *WBC (leukocytes):* Have a nucleus
- *Platelets (thrombocytes):* Fragments of cells

RBC (erythrocytes)

Most numerous cells in blood. Biconcave discs with no nuclei (can't divide), flexible. Cell shape creates large surface area for diffusion of O_2 across the membrane, and thinness enables O_2 to diffuse rapidly between the exterior and innermost regions of the cell. 8um diameter; 2um thick. The cell has a specialised actin cytoskeleton anchored under the cell membrane. Contractile actin allows the membrane to be flexible and return to its original shape. 120 day lifespan, formed in red marrow and dedicated to respiratory gas transport due to containing haemoglobin.

Each Hb contains 4 protein globin chains with 1 unit of haem each. It appears red when oxygenated and blue when deoxygenated. Haem is an iron containing pigment that binds O_2, so 1 Hb can bind 4 oxygen molecules. O_2 is poorly soluble in plasma, and 98.5% is bound to Hb.

- **Males**: 14-18g/ 100ml
- **Females**: 12-16g/ 100ml

The primary role of Hb is to carry O_2, but it also combines with CO_2, acidic hydrogen-ion portion (H^+) of ionised carbonic acid, carbon monoxide and nitric oxide. Carries 98.5% of oxygen, while the other 1.5% is dissolved in blood.

RBCs contain an enzyme called carbonic anhydrase that catalyses the conversion of CO_2 to bicarbonate ions (HCO_3^-), the primary form in which CO_2 is carried in the blood. Bicarbonate is a major pH buffer.

Glycolytic enzymes in erythrocytes generate energy to fuel active transport mechanisms involved in maintaining ionic concentrations within the cell. They rely on glycolysis for ATP formation.

Haematocrit

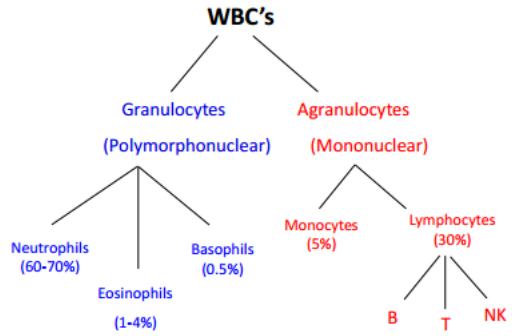
Haematocrit is the percentage of blood occupied by the RBC, on average 42% (females) and 45% (males).

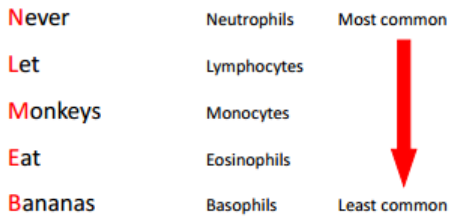
RBC Count

Using a haemocytometer:

- **Females:** 4.3-5.3 million RBC per microlitre
- **Males:** 5.1-5.8 million RBC per microlitre

1ml of blood contains about 5000 million RBC, so if blood volume is 5L, then total RBC= 25 million-million.





White Blood Cells (Leukocytes)

Manufactured in red bone marrow, but lack Hb so appear white. They have different structures and functions that are highly variable in number and work mostly outside the blood vessels. They are the mobile units of the body's immune system. There 3 major tasks are to:

- Destroy bacteria and viruses and defend against invaders
- Find and destroy cancer cells arising in the body
- Remove dead or injured cells 'clean-up crew'

WBCs are attracted into interstitial spaces by bacterial toxins, cell debris and foreign bodies. They leave the circulation by squeezing between endothelial cells with amoeba like movements (diapedesis). WBC count is around 7 million per ml of blood. Normally they are outnumbered 1000:1 by RBCs.

A person with leukaemia might have 500 million WBCs per ml of blood. It is a cancerous condition involving uncontrolled proliferation of WBC, yet there is inadequate defence capabilities against foreign invasion because the WBCs are immature/abnormal and can't perform normal functions.

Neutrophils

Neutrophils are granulocytes that are polymorphs and have an affinity for stains. They are phagocytic specialists, essentially suicide bombers- they release their granules (neutrophil extracellular traps or NETs) into the ECF to trap and kill bacteria extracellularly.

Their function is to work in tissues to engulf and ingest bacteria by releasing lysosomal enzymes. Very important in inflammatory responses and scavenge to clean up debris. They usually circulate for 6-8 hrs, and elevated levels of circulating neutrophils indicate a bacterial infection. Pus is neutrophils, or remnants of.

Eosinophil

Eosinophils are polymorphic granulocytes that contain granules and have an affinity for the red stain eosin.

Their function is associated with responses to allergies (eg. Hayfever and asthma) and also internal parasite infections, particularly intestinal worms. They are also phagocytic, elevated levels are associated with allergic conditions.

Basophil

Basophils are also polymorphic granulocytes containing granules, and they have an affinity for blue stain. They are least numerous and most poorly understood. Structurally and functionally, they are similar to mast cells (never circulate but are dispersed through body tissues). They circulate for <1 day and survive 3-4 days.