Composition of Blood

- Blood = Plasma + Formed elements.
- Plasma is the ground substance of blood.
  - Slightly higher density than water.
  - Contains dissolved proteins, some dissolved gases.
  - Formed elements consist of blood cells (red & white), and cell fragments (platelets).
- Red blood cells (erythrocytes) transport O₂ & CO₂.
- White blood cells act as part of the immune system.
- Platelets are membrane-enclosed structures, filled with cytoplasm, and are crucial to the blood clotting mechanism.

Plasma: 46 – 64%.
- Water (92%)
- Proteins (7%)
  - Albumin (60%).
  - Globulins (35%).
  - Fibrinogen (4%).
  - Regulatory proteins (<1%).
- Other solutes (1%).
  - Electrolytes.
  - Organic nutrients.
  - Organic wastes.
- Formed elements (37-54%)
  - Red blood cells (99.9%).
  - White blood cells.
    - Neutrophils
    - Eosinophils.
    - Basophils.
    - Lymphocytes
    - Monocytes
  - Platelets
Plasma

- Very similar in composition to interstitial fluid, except that plasma contains more dissolved proteins and gases.
- Approx. 7g dissolved proteins per 100 cc of plasma (5X concentration in interstitial fluid).
- Large size of proteins prevents transport across capillary wall.
- Types of proteins:
  - Albumins (major portion of proteins).
  - Globulins include immunoglobulins (antibodies) and transport proteins.
    - Lipoproteins are globulins that bind to lipids and transport these to peripheral tissues.
  - Fibrinogens are components of the blood clotting system.
    - Change to fibrin (insoluble strands of protein fiber) that make up the mesh of a blood clot.
- Serum: plasma without dissolved proteins.

Formed Elements

- Erythrocytes make up the majority of formed elements (99.9%).
- 1 ml of blood contains approximately 5 X 10^6 erythrocytes.
- Hematocrit = % of erythrocytes / unit volume.
  - Normal hematocrit: 40-54% in men; 37-47 % in women.
- Structure of erythrocyte:
  - Biconcave disk shaped.
  - Lack of various cellular organelles including mitochondria, ribosomes and nucleus.
  - Energy obtained from glucose in surrounding fluids.
- Erythrocyte lasts up to 120 days in circulation.
Hemoglobin

- Erythrocyte consists of a cell membrane and cytoplasm.
- Cytoplasm is roughly 2/3 water and 1/3 proteins.
- Predominant protein is hemoglobin (Hb).
- Hb allows red blood cell to transport O₂ and CO₂ (also provides red color of blood).
- Four globular protein subunits combine to form complete Hb molecule.
- A pigment molecule (heme) provides attachment sites for O₂.
- CO₂ attaches onto globin portion of the Hb molecule.
- Both O₂ and CO₂ are easily attached and detached (allows diffusion-based transport to occur).

Red Blood Cell Recycling

- Once RBC’s reach unusable point, they either rupture (mechanical stresses) or are consumed by phagocytes.
- Ruptured elements are small enough to pass through kidneys and eliminated in urine.
- Most RBC’s are engulfed and processed by circulating phagocytes.
  - Globular proteins are disassembled into component amino acids.
  - Heme molecules have iron ion stripped and released into blood stream.
  - Developing RBC’s in the bone marrow absorb these amino acids and iron ions.
Red Blood Cell Formation

- Erythropoiesis occurs in myeloid tissue (marrow) of the adult.
- Major production centers in the vertebrae, sternum, ribs, skull, scapulae, pelvis and in humerus and femur.
- Immature blood cells (erythroblasts) actively synthesize hemoglobin.
- Erythroblast sheds nucleus after approx. 4 days to become a reticulocyte.
- Reticulocyte enters blood circulation and transforms to mature RBC’s within 1 day.

Regulation of Erythropoiesis

- Myeloid tissue must receive adequate amounts of nutrients (iron, vitamins – B₁₂, B₆, folic acid – amino acids).
- Erythropoietin → hormone that stimulates RBC production.
- Can increase RBC production X10 (30 million/sec).
Red Blood Cell Type

- Antigen molecules (agglutinogens) are present on the surface of each erythrocyte.
- Characteristics of these molecules depend on genetics.
- Three important and common antigens denoted by A, B, Rh.
- All erythrocytes for any one individual have same antigens on surface.
  - Type A = blood with A-antigen only.
  - Type B = blood with B-antigen only.
  - Type O = neither A or B.
  - Type AB = blood with both A and B.
- Presence of absence of the Rh antigen is denoted by + or -, ie, AB+ (A+B+Rh), AB- (A+B)
- Blood matching needs to be performed to prevent immune system from attacking foreign antigens.

White Blood Cells

- WBC’s (leukocytes) lack hemoglobin (no reddish coloration) and contain nuclei.
- Leukocytes do not circulate for long periods of time (leave circulatory system in response to immune response triggers).
- Characteristics of leukocytes:
  - Capable of ameboid movement (cytoplasmic extensions).
  - Diapedesis or “squeezing” through the space between endothelial cells to leave circulation.
  - Attraction to specific chemical stimuli (positive chemotaxis).
  - Phagocytosis or “eating” of old cells.
- Functions of leukocytes:
  - Defense against pathogens.
  - Removal of toxins.
  - Recycling of damaged cells.
Types of Leukocytes

- Neutrophils (50-70%).
  - Active phagocytes; arrive first at injury site.
  - Specialize in attacking and digesting bacteria.
- Eosinophils (2-4%).
  - Phagocytes; attracted to foreign compounds.
- Basophils (< 1%)
  - Migrate into site of injury and release heparin and histamine.
- Monocytes (2-8%)
  - Very active phagocytes; attract fibroblasts to injury site.
- Lymphocytes (20-30%)
  - Primary cells of the lymphatic system (small fraction found in blood).
  - Different types of lymphocytes that act as part of specific immune responses.

Platelets

- Large cells known as megakaryocytes located in bone marrow continuously shed cytoplasmic membrane-enclosed packets.
- These fragments are known as platelets (or thrombocytes).
- Extremely important in the blood clotting process.
- Platelets are replaced constantly (life span is roughly 10 – 12 days).
What would be the effects of a decrease in plasma proteins?
- Decrease in plasma osmotic pressure.
- Decreased ability to clot & fight infections.
- Transport of insoluble substances may be affected.

How would dehydration affect a person’s hematocrit?
- Dehydration → less H2O in the body → increase in RBC concentration → increased hematocrit
- You move from sea level to high altitude. What would happen to levels of RBC’s in your body?
- High altitude → less O2 → increase in EPO release → increases RBC production.
- Which type of white blood cell would you expect to find in greatest numbers in an infected cut?
- Infected cut → bacterial contamination → expect to find large #’s of neutrophils since these consume bacteria.
- Which cell type would you expect to find in elevated numbers in a person producing large amounts of circulating antibodies to combat a virus?
- Lymphocytes since these produce specific anti-bodies.
- A sample of bone marrow has fewer than normal # of megakaryocytes. What body process would be affected by this?
- Blood clotting since fewer #’s of platelets will be produced.
Hemostasis

- Prevents excessive blood loss through walls of damaged blood vessels.
- Consists of 3 steps:
  - Vascular phase (1 – 3 seconds after injury)
    - Vasoconstriction occurs
  - Platelet phase (1 – 3 seconds after injury)
    - Platelets converge onto site
  - Coagulation phase (15 seconds – minutes after)
    - Creates a blood clot at the local site of injury to seal off damaged portion of blood wall.

The Blood Clotting Process

- Clotting cannot occur unless several “factors” are present within the blood.
- Most of these are proteins, which act as enzymes that accelerate other processes → this is the coagulation cascade.
- Two pathways exist:
  - Extrinsic pathway is faster and is initiated first.
  - Intrinsic pathway is slower and is initiated to reinforce the initial clot.
The Blood Clotting Process

[Diagram showing the blood clotting process with various components and pathways labeled.]