

## I. Blood

### A. Functions

1. Transportation of waste and nutrients.
2. Temperature regulation.
3. Maintaining acid-base balance.
4. Protection
  - a. Blood clotting
  - b. Provides antibodies and white blood cells to defend against disease.

### B. Components of whole blood

#### 1. Plasma

- a. The fluid part of the blood.
- b. Consists of
  - i. 91% water
  - ii. 7% proteins (most are produced by the liver)
    - (a) **Albumins** help to maintain **blood osmotic pressure** which is important for exchange between capillaries and tissues.
    - (b) **Globulins** compose the **antibody** portion of the blood.
    - (c) **Fibrinogen** is a key clotting protein.
  - iii. 1.5% solutes
    - (a) Includes electrolytes, nutrients, gases, vitamins, hormones, enzymes and waste products.

#### 2. Formed elements

- a. The source of formed elements is **red bone marrow**.
  - i. Red bone marrow is located within the spaces of spongy bone.
  - ii. Primarily found in bones of the cranium, ribs, sternum, scapula, bodies of vertebrae, the pelvis and the proximal epiphysis of the humerus and femur.
  - iii. The red bone marrow contains **pluripotent stem cells** that have the ability to develop into several different types of cells.
  - iv. In response to specific hormones the pluripotent stem cells can generate either **myeloid** or **lymphoid stem cells**.
    - (a) In response to other hormones the myeloid stem cells can differentiate into red blood cells, platelets, eosinophils, basophils, neutrophils and monocytes.
    - (b) While lymphoid stem cells can differentiate into T & B lymphocytes.
- b. **Erythrocytes** (red blood cells, RBC)
  - i. RBC's are a biconcave disk (shape provides a greater surface area).
  - ii. Have no nucleus or other organelles.
  - iii. Filled with **hemoglobin** for the transport of oxygen, carbon dioxide and hydrogen ions.
    - (a) Composed of a **heme** portion containing iron and a **globin** portion composed of proteins.
    - (b) The hemoglobin carries oxygen from the lungs to the tissues.
    - (c) The tissues produce **H<sub>2</sub>O** (water) and **CO<sub>2</sub>** (carbon dioxide) as by-products of work.
      - (i) These two molecules can join together to form **H<sub>2</sub>CO<sub>3</sub>** (carbonic acid).

- (ii) Carbonic acid dissociates into  $\text{HCO}_3^-$  (bicarbonate ion) and  $\text{H}^+$  (hydrogen ion).
  - (iii) The hemoglobin carries the hydrogen ion up to the lungs as a waste product.
  - (iv) The bicarbonate ion travels in the blood plasma to buffer acids in the blood, helping to maintain blood pH.
- iv. There are approximately 5 million RBC's/microliter ( $\mu\text{L}$ ) of blood.
- v. RBC production
  - (a) Red blood cells have a lifespan of about 120 days so new cells are produced at a rate of 2 million per second.
  - (b) The formation of new RBC's is termed **erythropoiesis**.
  - (c) The stimulus for more RBC production is **hypoxia** (low blood oxygen).
  - (d) Hypoxia stimulates the production of **erythropoietin (EPO)** by the kidneys (+ the liver).
  - (e) EPO circulates through the blood to the red bone marrow where it stimulates myeloid stem cells to differentiate into new RBC's.
  - (f) An increase in the number of red blood cells reduces the hypoxia (negative feedback).
- vi. RBC life cycle
  - (a) Aged or damaged RBC's are phagocytized by macrophages in the spleen, liver and red bone marrow.
  - (b) The globin is broken down into amino acids to be reused.
  - (c) The iron is removed from the heme and is attached to a protein which is transported to red bone marrow for new hemoglobin synthesis or stored in the liver or spleen for reuse later.
  - (d) The rest of the heme molecule is converted into **biliverdin** then **bilirubin** which is transported via the blood to the liver.
  - (e) The liver secretes the bilirubin into bile.
- vii. **Anemia** is a condition in which the oxygen carrying capacity of the blood is reduced due to a deficiency of RBC's or hemoglobin.
  - (a) **Aplastic anemia** results from damage to red bone marrow via radiation, drugs, toxins, leukemia, etc.
  - (b) **Hemolytic anemia** results from diseases (sickle cell anemia, malaria) or outside agents (incompatible blood transfusion, dialysis) rupturing RBC's prematurely.
  - (c) **Iron deficiency anemia** results from inadequate iron intake or absorption or excessive loss of iron. This is the most **prevalent form of anemia**.
  - (d) **Pernicious anemia** results from the improper absorption of vitamin  $\text{B}_{12}$  for DNA synthesis.
- c. Leukocytes (white blood cells, WBC)
  - i. Function in combating microbes and preventing them from causing disease.
  - ii. Granular leukocytes
    - (a) Neutrophils
      - (i) The most common leukocyte.
      - (ii) Respond first to microbial invasion.

- (iii) Phagocytize microbes and release the enzyme lysozyme to destroy bacteria.
- (b) Basophils
  - (i) Involved in inflammatory and allergic reactions.
  - (ii) Secrete heparin (prevents blood clotting) and histamine (inflammation).
- (c) Mast cells
  - (i) Phagocytes that are similar to basophils.
  - (ii) Found in connective tissue and tend to congregate beneath epithelial surfaces along blood vessels.
- (d) Eosinophils
  - (i) Secrete antihistamines that help lessen an allergic reaction.
  - (ii) Attack parasitic worms.
- iii. Agranular leukocytes
  - (a) Monocytes
    - (i) The largest phagocytes in circulation.
    - (ii) Monocytes can leave circulation to enter tissues where they are now referred to as macrophages.
  - (b) Lymphocytes
    - (i) Play a crucial role in immunity which will be covered later.
    - (ii) Develop from lymphoid stem cells.
    - (iii) T lymphocytes
      - Act directly against virus-infected cells and tumor cells.
    - (iv) B lymphocytes
      - Give rise to plasma cells which produce antibodies.
    - (v) Natural killer cells
      - Attack infectious microbes and tumor cells.
- iv. Abnormalities in the number of white blood cells.
  - (a) **Leukocytosis**
    - (i) A normal increase in the number of white blood cells in response to stresses such as invading microbes, surgery, strenuous exercise and anesthesia.
    - (ii) Usually indicates inflammation or infection.
  - (b) **Leukopenia**
    - (i) An abnormally low level of white blood cells.
    - (ii) Associated with viral diseases (HIV), poisoning and excessive irradiation.
- d. Platelets (thrombocytes)
  - i. Are anucleated fragments of huge cells called **megakaryocytes** (develop from myeloid stem cells).
  - ii. Platelets contain vesicles filled with chemicals that promote blood clotting.
  - iii. When vessel damage occurs platelets aggregate together to form a **platelet plug** at the site of injury to stop blood loss.

### C. Hemostasis

1. The slowing and/or stopping of blood flow.
2. Includes 3 mechanisms

- a. **Vascular spasm**
    - i. When a blood vessel is damaged the smooth muscle in the wall of the vessel contracts narrowing the opening of the blood vessel and reducing blood loss.
  - b. **Platelet plug formation**
    - i. When vessel damage occurs platelets adhere to the exposed connective tissue of the vessel wall.
    - ii. After adhering, platelets aggregate together forming a platelet plug and release the chemicals stored within their vesicles.
    - iii. These chemicals help to activate other platelets causing them to add to the platelet plug.
      - (a) Other chemicals are released that maintain the vascular spasm.
  - c. **Clotting**
    - i. A multi-step process in which various clotting factors activate each other.
    - ii. Can be initiated by tissue damage (**extrinsic pathway**) or damage to a vessel wall (**intrinsic pathway**).
    - iii. This damage stimulates the formation of **prothrombinase (prothromin activator)**.
    - iv. **Prothrombinase** converts **prothrombin** (a clotting protein formed by the liver if vitamin K is present) into the enzyme **thrombin**.
    - v. **Thrombin** interacts with **fibrinogen** (also produced by the liver) converting it into **fibrin**, the actual clotting material.
    - vi. **Fibrin** forms long threads that insinuate within and surrounds the initial platelet plug.
  - 3. Clot retraction
    - a. Once the clot is formed the fibrin threads gradually contract pulling the damaged edges of the tissue together.
    - b. This prevents further damage and allows for repair processes to begin.
  - 4. Dissolution of a blood clot.
    - a. The blood protein **plasminogen** is incorporated into a clot as it is formed.
    - b. **Tissue plasminogen activator (TPA)**, released by the walls of blood vessels, reacts with the **plasminogen** and converts it into **plasmin**.
    - c. **Plasmin** is an enzyme which digests fibrin threads.
  - 5. Abnormal clot formation
    - a. **Thrombus**
      - i. A clot formed in an unbroken blood vessel.
      - ii. May block the vessels in which it forms.
    - b. **Embolus**
      - i. A clot that moves from its site of formation.
      - ii. Can become lodged somewhere where the vessel narrows resulting in pulmonary embolism, heart attack or strokes.
- D. Blood types
- 1. ABO blood groups
    - a. The blood types A, B, AB and O are determined by whether or not a certain glycoprotein (**antigen**) is present on the surface of red blood cells.
      - i. An individual with the type A antigen on the surface of their red blood cell will be categorized as having type A blood.

- ii. If the B antigen is present they will have blood type B.
    - iii. If both the A and B antigens are present they will have blood type AB.
    - iv. If neither antigen A or antigen B are present they will have blood type O.
  - b. In addition to the antigens on the red blood cells, the blood plasma of an individual may contain an antibody that does not correspond to the blood type of that individual.
    - i. For example, an individual with blood type A (has A antigens) will have B antibodies in their blood plasma.
    - ii. An individual with blood type B will have A antibodies.
    - iii. An individual with blood type AB will have no antibodies.
    - iv. An individual with blood type O will have both A and B antibodies in their blood plasma.
  - c. If a given cell type is exposed to a matching antibody (blood type A is exposed to an A antibody) the blood cells will agglutinate (clump) and **hemolysis** of the RBC's occurs.
  - d. In a transfusion involving mismatched blood the concern revolves around the donor cells being agglutinated by the recipients antibodies.
    - i. Although the recipient would also be receiving antibodies from the donor that would agglutinate the recipient's cells, the antibodies are so diluted in the recipient's plasma they aren't concentrated enough to agglutinate the recipient's red blood cells.
- 2. RH system
  - a. In addition to the A and B antigens, red blood cells can also have an RH antigen.
    - i. If the RH antigen is present on red blood cells they are designated RH positive.
    - ii. If the RH antigen is not present they are designated RH negative.
  - b. Under normal circumstances an individual with RH negative blood will not be born with RH antibodies in their plasma.
    - i. However, exposure to RH positive blood will stimulate the immune system to make anti-RH antibodies that remain in the blood.