بسم الله الرحمن الرحيم

Physiology

﴿ وَقُل رَّبِّ أَدْخِلْنِي مُدْخَلَ صِدْقٍ وَأَخْرِجْنِي مُخْرَجَ صِدْقٍ وَاجْعَل لِّي مِن لَّدُنكَ سُلْطَانًا نَّصِيرًا ﴾

ربنا آتنا من لدنك رحمة وهيئ لنا من أمرنا رشدًا

MID | Lecture 1

Blood Introduction

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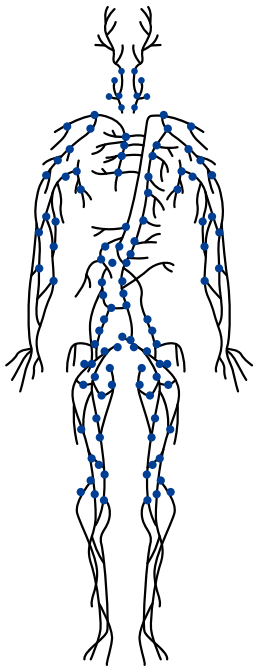
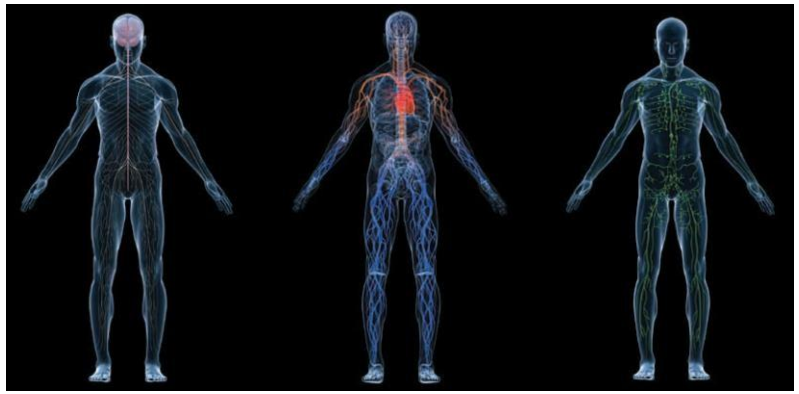


UNIT VI

Chapter 33

GUYTON AND HALL
TEXTBOOK OF MEDICAL PHYSIOLOGY



Introduction: Red Blood Cells, Anemia and Polycythemia

Ebaa M Alzayadneh, PhD

☞Learning Objectives

- Identify blood components (formed elements), their main characteristics and functions.
- Understand genesis of blood cells (hematopoiesis)
- Describe regulation red blood cells production
- Identify requirements for erythropoiesis
- Describe red blood cells cycle
- Define abnormalities of red blood cells

Functions of Blood

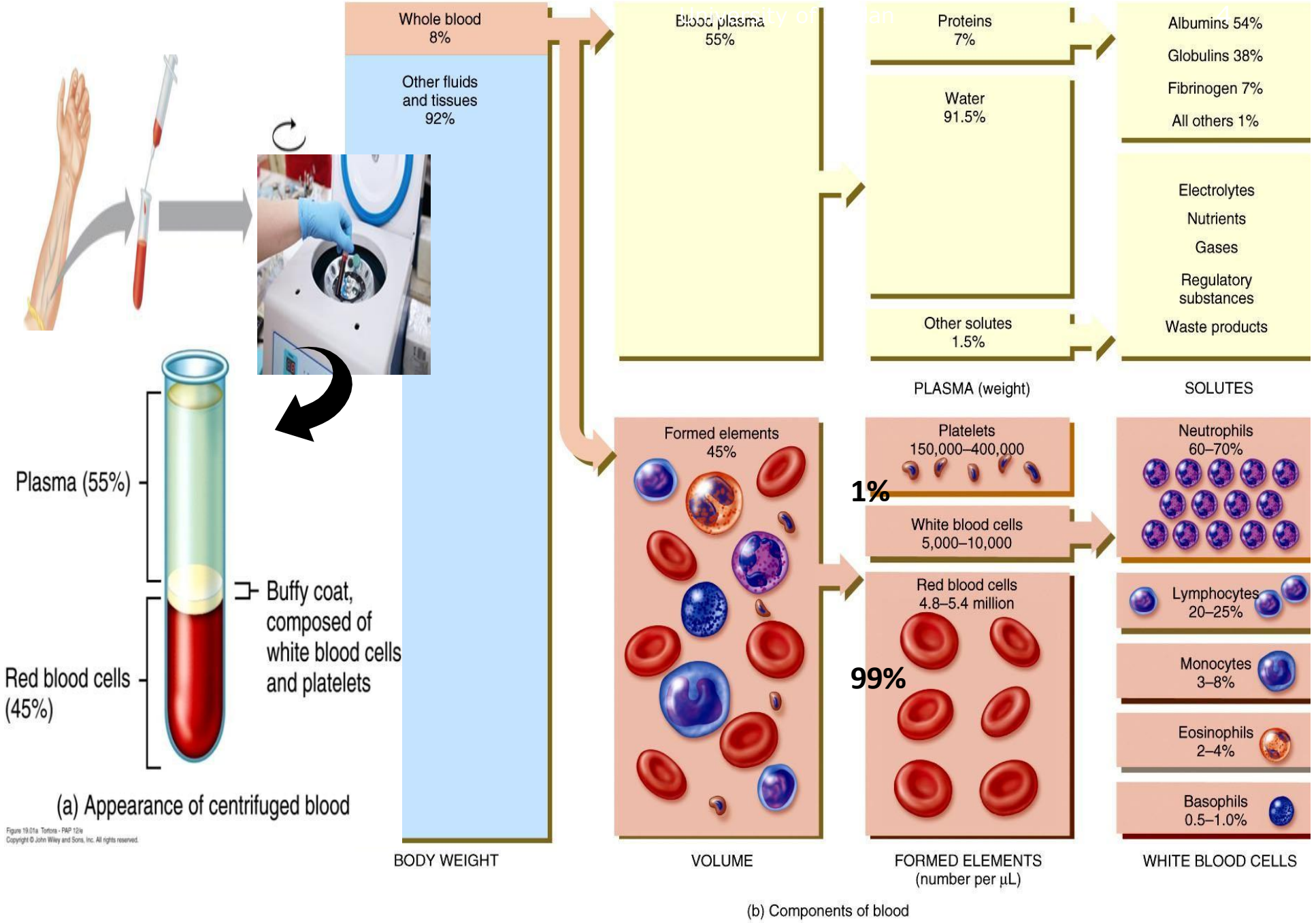
- Transportation of:
  - O_2 by hemoglobin in RBCs
  - CO_2 from cells to the lungs for elimination
  - Nutrients to body tissues
  - Wastes to organs that deal with wastes such as the liver and the kidney
  - Hormones to their target organs

Functions of Blood

- Regulation of:
  - pH: Blood contains **buffers** that resist changes in pH. Proteins, such as **Hemoglobin, in red blood cells act as buffers** by **accepting or donating H^+ ions**.
    - pH must remain within a narrow range because **enzymes require an optimal pH** to function normally. **Deviations** cause **acid–base disorders**.
  - Temperature: Blood vessels near the skin **dilate in response to heat** (**vasodilation**) and **constrict in cold** (**vasoconstriction**) to **regulate body temperature**.
  - Blood Pressure: Results from the **force exerted by circulating blood** against the **walls of blood vessels**. **Blood volume is directly proportional to BP** — as blood volume increases, BP also rises.
  - Osmotic Pressure: Blood **proteins**, mainly **albumin**, exert oncotic pressure that **pulls fluid back into the capillaries**, helping maintain **fluid balance**.
  - Volume

Functions of Blood

- Protection:
  - Clotting: In case of **injury**, blood initiates a **coagulation mechanism** involving **platelets**, which **aggregate and help stop bleeding**.
  - Immune: Protection against microbes.
  - Proteins: Some **blood proteins act as carriers**, **safely transporting potentially harmful substances** through the bloodstream.



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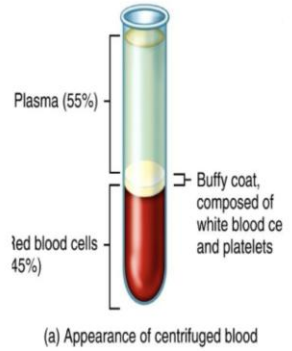
Composition and Separation of Blood Components



(a) Appearance of centrifuged blood

- The Composition of Blood:
  - Blood is drawn by **puncturing a vein**, a process known as **venipuncture (phlebotomy)**.
  - The **blood sample is centrifuged before clotting**, separating its components by **density** into **three layers**:
  - Bottom layer (≈45%) – **Red blood cells (RBCs)**, which have the **highest density**.
  - Middle thin whitish layer – **White blood cells (leukocytes)** and **platelets**, together with **RBCs** known as the **formed elements**.
  - Top yellowish layer (≈55%) – **Plasma**, a **clear fluid** that makes up most of the blood volume.
  - If **clotting occurs**, some **plasma components** such as **fibrinogen** become **trapped in the clot**, and the remaining fluid is called **serum**.
  - **Serum = Plasma – (fibrinogen + clotting factors).**

Composition and Separation of Blood Components:

- **Plasma:**
  1. **Water (≈91.5%)**
  2. **Proteins (≈7%) –**
     - **Albumins (≈54%)**
     - **Globulins (≈38%)**
     - **Fibrinogen (≈7%)**
  3. **Other Solutes:**
     - **Gases:** O_2, CO_2, NO
     - **Electrolytes:** Mainly Na^+ and Cl^-
     - **Nutrients:** Glucose, amino acids, lipids
     - **Regulatory Substances:** Hormones, enzymes
     - **Waste Products:** Urea, uric acid, ammonia

- **Formed Elements:**
  1. **Red Blood Cells (RBCs) – ≈99%** of formed elements
  2. **Platelets – Cell fragments**, not complete cells, involved in **clotting**
  3. **White Blood Cells (WBCs / Leukocytes):**
     - **Neutrophils:** 60–70% (*predominant under normal conditions*)
     - **Lymphocytes:** 20–25%
     - **Monocytes:** 3–8%
     - **Eosinophils:** 2–4%
     - **Basophils:** 0.5–1%

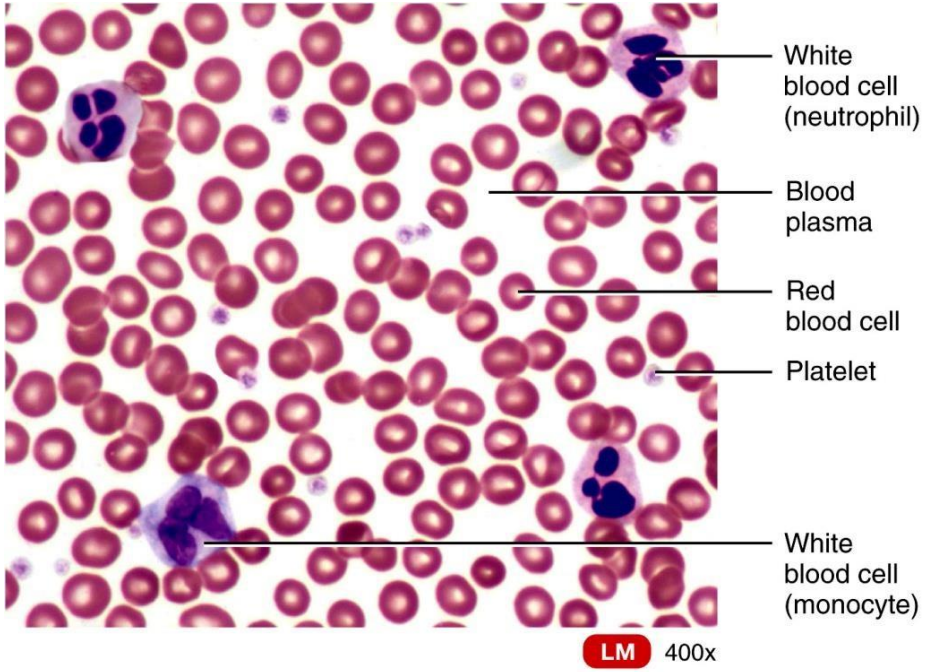
Blood Physical Characteristics

- 38℃
- Viscous sticky
- Alkaline pH (7.35-7.45)
- Color depends on O_2 (bright-dark) red
- 20% of ECF, 8% by weight
- Blood volume: 5-6 males, 4-5 females | Depends largely on body size
- The volume of blood is regulated hormonally by:
  - **RAAS (Renin–Angiotensin–Aldosterone System):** Increases blood volume and pressure by promoting sodium and water retention.
  - **ADH (Antidiuretic Hormone):** Prevents water loss by increasing water reabsorption in the kidneys.
  - **ANP (Atrial Natriuretic Peptide):** Decreases blood volume and pressure by promoting sodium and water excretion.

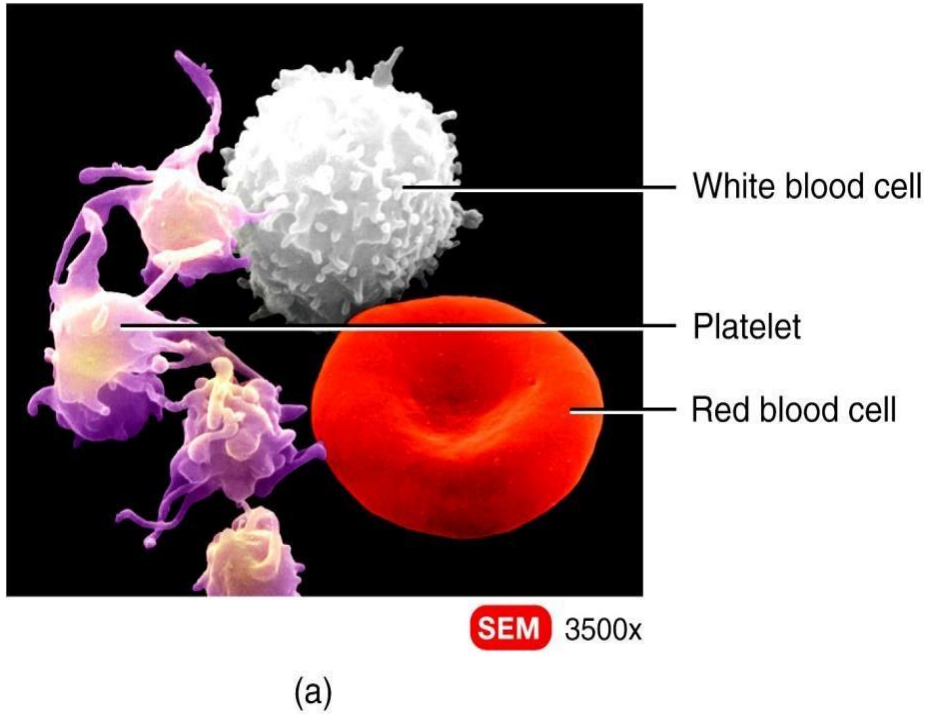
Question: Are all blood sampling tubes the same? And procedures.

- Blood Collection Tubes:
  - ➢Venipuncture
  - ➢Finger or heel stick
  - ➢Arterial stick
- Tubes differ based on the **additives** they contain.
- Some tubes are **plain (without additives)**, while others contain **anticoagulants** such as **EDTA** or **heparin** to **prevent coagulation**.
- The **choice of tube** depends on the **type of blood test** being performed:
  A. To obtain **serum**, use a **plain tube** (no additives).
  B. To obtain **plasma**, use a tube containing an **anticoagulant** to **prevent clotting**

Formed Elements of Blood

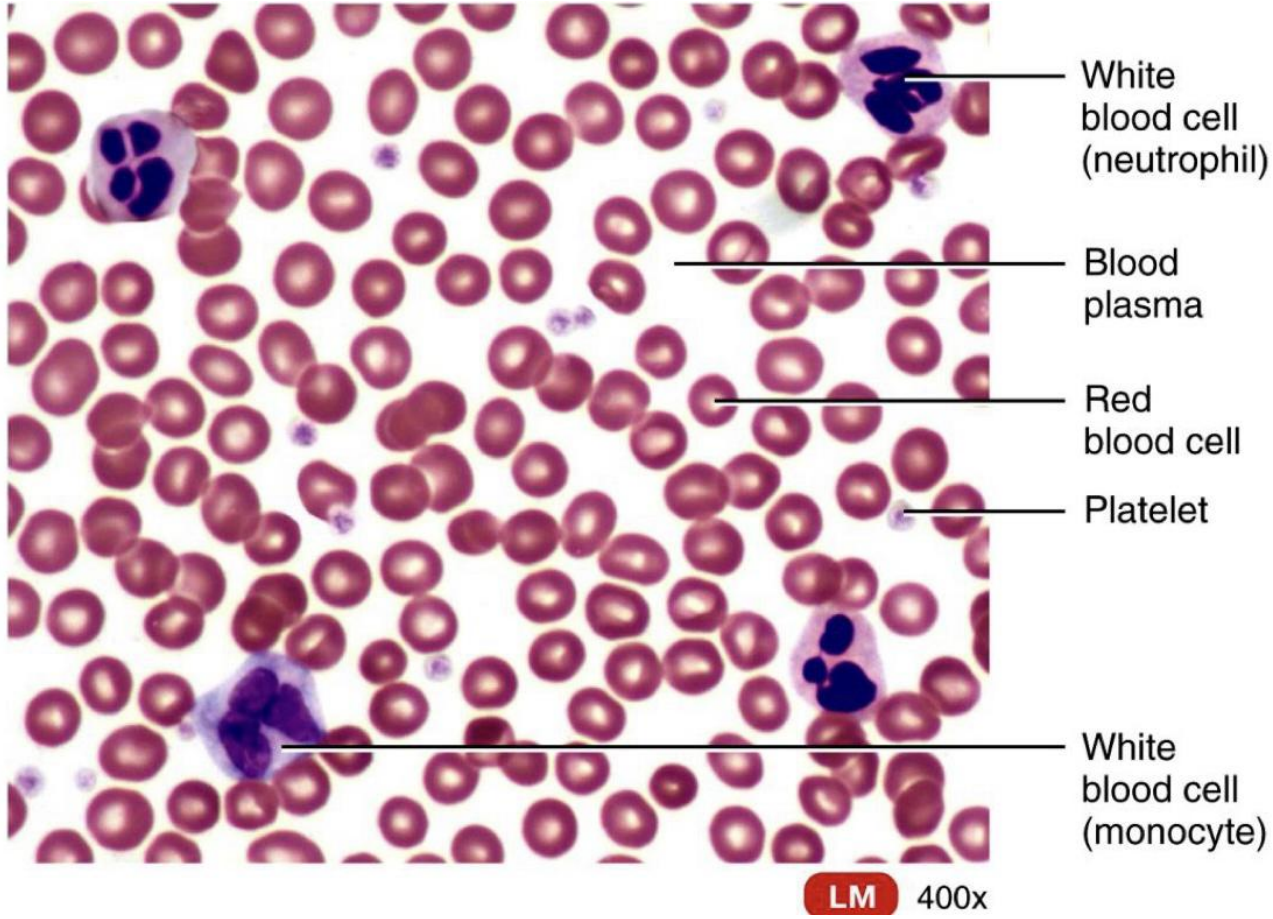


Blood : a liquid connective tissue, Extracellular matrix is plasma, cells are suspended.



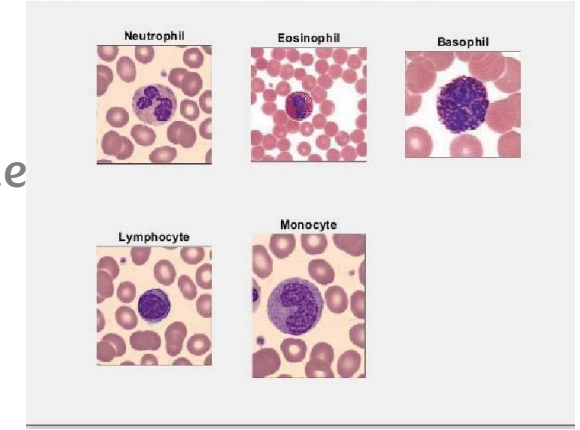
Interstitial fluid: part of ECF renewed by blood

Formed Elements of Blood RBCs , WBCs and platelets



- **Observation under the Light Microscope:**
- The **most abundant cells** seen are **red blood cells (RBCs)**.
- The **small fragments** present are **platelets**.
- The **larger cells with distinct nuclear shapes** are **white blood cells (WBCs):**
  - **Monocytes** – have a **kidney-shaped nucleus**.
  - **Neutrophils** – have a **multilobed (polymorphonuclear) nucleus**.
  - **Lymphocytes** – have a **large nucleus that occupies most of the cell**.

Extra image to see the lymphocyte



Interstitial Fluid and Blood Interaction:

- The **interstitial fluid** interacts with **blood** through continuous **exchange and transport processes**.
- It is **constantly renewed and modified** by substances from the **blood plasma**.
- At the same time, **a portion of the interstitial fluid returns to the bloodstream**, maintaining a **dynamic equilibrium** between the two main components of the **extracellular fluid (ECF):**
  - Blood plasma
  - Interstitial fluid

Functions of Red Blood Cells (Erythrocytes)

- Carry hemoglobin, bearing O_2 to the tissues
- Contain carbonic anhydrase, which catalyzes the reaction:

$$CO_2 + H_2O \rightarrow H_2CO_3$$

- Allows large amounts of CO_2 to be carried in solution as HCO_3^-
- Hemoglobin is an excellent acid-base buffer, by donating or accepting **H^+**.

CO_2 Transport via Bicarbonate (HCO_3^-):

1. Once produced, **carbonic acid (H_2CO_3) dissociates** into **H^+** and **bicarbonate (HCO_3^-)**.
2. **HCO_3^-** serves as the **main form of CO_2 transport** in the blood.
3. The **conversion of CO_2 to HCO_3^-** occurs **inside red blood cells** through the enzyme **carbonic anhydrase**.
4. **HCO_3^-** then **moves out of RBCs in exchange for Cl^- ions**, a process called the **chloride shift**.
5. In the **pulmonary capillaries**, **HCO_3^- reenters the RBCs**, **recombines with H^+** to form **H_2CO_3**, which is then **converted back into CO_2 and H_2O**.
6. The **CO_2 is exhaled through the lungs**.

RBC Size and Shape

- Biconcave discs: The **biconcave shape** results from a redundant **plasma membrane** and the **absence of a nucleus**. This unique shape, together with the **flexible membrane**, **increases the deformability** and flexibility of red blood cells. It allows them to **squeeze through very narrow capillaries** without rupturing.
- Mean 7.8 (diameter) x 2.5 microns (thickest) or x 1 micron (center)
- Average volume 90-95 micrometers^3
- **Question:** Why is **hemoglobin** contained inside **red blood cells (RBCs)** rather than circulating freely in the plasma?
  - **Answer:** If hemoglobin were free in the plasma, it could **leak into the interstitial space**, causing a **significant loss of hemoglobin**. Moreover, **free hemoglobin** would be **filtered out by the kidneys**, leading to **hemoglobin loss in urine** and possible **kidney damage**.

RBC Count and Indices

- Men: 5,200,000 (± 300,000)/mm^3
- Women: 4,700,000 (± 300,000)/mm^3
  - RBC counts can be increased at higher altitudes because the atmosphere contains **less oxygen**. To **compensate for reduced oxygen availability**, the body **stimulates increased RBC production.**
- 2 million/sec production
- RBC indices:
  - MCV (Mean cell volume) 90 ± 9 fl = 10^{-15} L
  - MCH (Mean Cell Hgb) 32 ± 2 pg
  - MCHC (Mean cell Hgb conc) 33 ± 3%
  - RDW CV 11.6-14.6%
    - It measures **how much the sizes of red blood cells vary**. Normally, the **variation should be minimal.**
  - (SD of MCV/MCV) 39-46 fL

Physiology Quiz 1

For any feedback, scan the code or click on it.

Corrections from previous versions:

Versions	Slide # and Place of Error	Before Correction	After Correction
V0 → V1	Slide 8	Together known as formed elements	Together with **RBCs** known as formed elements
V1 → V2			