CHAPTER TWO:
Blood And Its Function
Blood

By the end of the lesson you should be able to:

- State the composition of Blood
- State the function of red blood cells, white blood cells and plasma
- State the function of haemoglobin in the transport of oxygen
- State the function of macrophages and lymphocytes
Blood

Blood is a specialized tissue consisting of several types of cells suspended in fluid medium called plasma.

- the average human has 5 litres of blood
- it is a transporting fluid
- it carries vital substances to all parts of the body
Blood

- Performs a wide range of functions.
Blood

- The only fluid tissue in the human body
- Taste, Odor, 5x thicker than water
- Classified as a connective tissue
  - Living cells = formed elements
  - Non-living matrix = plasma (90% water)
Physical Characteristics of Blood

Color range

- Oxygen-rich blood is scarlet red
- Oxygen-poor blood is dull red

- pH must remain between 7.35–7.45
- Slightly alkaline
- Blood temperature is slightly higher than body temperature
- 5-6 Liters or about 6 quarts /body
Figure 10.1

PLASMA 55%

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Major functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>Solvent for carrying other substances</td>
</tr>
<tr>
<td>Salts (electrolytes)</td>
<td>Osmotic balance, pH buffering, and regulation of membrane permeability</td>
</tr>
<tr>
<td>Sodium</td>
<td></td>
</tr>
<tr>
<td>Potassium</td>
<td></td>
</tr>
<tr>
<td>Calcium</td>
<td></td>
</tr>
<tr>
<td>Magnesium</td>
<td></td>
</tr>
<tr>
<td>Chloride</td>
<td></td>
</tr>
<tr>
<td>Bicarbonate</td>
<td></td>
</tr>
<tr>
<td>Plasma proteins</td>
<td>Osmotic balance, pH buffering, Clotting of blood.</td>
</tr>
<tr>
<td>Albumin</td>
<td>Defense (antibodies), and lipid transport</td>
</tr>
<tr>
<td>Fibrinogen</td>
<td></td>
</tr>
<tr>
<td>Globulins</td>
<td></td>
</tr>
<tr>
<td>Substances transported by blood</td>
<td>Nutrients (e.g., glucose, fatty acids, vitamins, amino acids)</td>
</tr>
<tr>
<td></td>
<td>Waste products of metabolism (urea, uric acid)</td>
</tr>
<tr>
<td></td>
<td>Respiratory gases (O₂ and CO₂)</td>
</tr>
</tbody>
</table>

Formed Elements (cells) 45%

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Number (per mm³ of blood)</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (red blood cells)</td>
<td>4–6 million</td>
<td>Transport oxygen and help transport carbon dioxide</td>
</tr>
<tr>
<td>Leukocytes (white blood cells)</td>
<td>4000–11,000</td>
<td>Defense and immunity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lymphocyte</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Basophil</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Eosinophil                                                                  1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Neutrophil                                                                  1</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Monocyte                                                                   1</td>
</tr>
<tr>
<td>Platelets</td>
<td>250,000–500,000</td>
<td>Blood clotting                                                              1</td>
</tr>
</tbody>
</table>
Human blood smear

X 500
Blood Plasma

- Composed of approximately 90 percent water
- Includes many dissolved substances
  - Nutrients, Salts (metal ions)
  - Respiratory gases
  - Hormones
  - Proteins, Waste products
Plasma Proteins

- Albumin – regulates osmotic pressure
- Clotting proteins – help to stem blood loss when a blood vessel is injured
- Antibodies – help protect the body from antigens
school blood plasma

- Plasma (55%)
- Red blood cells (44%) - Erythrocytes (5-6-million/ml)
- White blood cells - Leucocytes (5000/ml)
- Platelets
**Plasma (55%)**

- Plasma is yellowish fluid in blood.
- Blood plasma – main transport medium
- Water (90%)
- Ions
- Plasma proteins (albumin, Fibrinogen, Immunoglobulins)
- Hormones
- Dissolved substances (Nutrients), waste products, respiratory gaseous
<table>
<thead>
<tr>
<th>Substance transported by plasma</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Salts</strong>&lt;br&gt;a. Sodium ion (Na⁺), potassium ion (K⁺), and chloride ion (Cl⁻)&lt;br&gt;b. Calcium ion (Ca²⁺)</td>
<td>• Osmotic balance conduction of nerve impulses&lt;br&gt;• Blood clotting</td>
</tr>
<tr>
<td><strong>Products of digestion</strong>&lt;br&gt;Glucose, amino acids, fatty acids, and glycerol</td>
<td>• Nourishment of cells</td>
</tr>
<tr>
<td><strong>Vitamins</strong></td>
<td>• Regulation of cell functions</td>
</tr>
<tr>
<td><strong>Soluble proteins</strong>&lt;br&gt;a. Fibrinogen and protrombin&lt;br&gt;b. Albumin&lt;br&gt;c. Antibodies</td>
<td>• Blood clotting&lt;br&gt;• Osmotic balance&lt;br&gt;• Immunity</td>
</tr>
<tr>
<td><strong>Enzymes</strong></td>
<td>• Catalyse chemical reactions</td>
</tr>
<tr>
<td><strong>Waste products</strong>&lt;br&gt;Urea, carbon dioxide,</td>
<td>• None, they are removed by excretion</td>
</tr>
<tr>
<td><strong>Hormones</strong>&lt;br&gt;a. Insulin&lt;br&gt;b. Aldosterone</td>
<td>• Lowers blood glucose concentration&lt;br&gt;• Regulates concentration of sodium and potassium ions in the blood.</td>
</tr>
</tbody>
</table>
Formed Elements

- Erythrocytes = red blood cells
- Leukocytes = white blood cells
- Platelets = cell fragments
<table>
<thead>
<tr>
<th>Cell type</th>
<th>Occurrence in blood (per mm³)</th>
<th>Cell anatomy*</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Erythrocytes</strong> (red blood cells, or RBCs)</td>
<td>4–6 million</td>
<td>Salmon-colored biconcave disks; anucleate; literally, sacks of hemoglobin; most organelles have been ejected</td>
<td>Transport oxygen bound to hemoglobin molecules; also transport small amount of carbon dioxide</td>
</tr>
<tr>
<td><strong>Leukocytes</strong> (white blood cells, or WBCs)</td>
<td>4000–11,000</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Granulocytes</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>- Neutrophils</td>
<td>3000–7000 (40–70% of WBCs)</td>
<td>Cytoplasm stains pale pink and contains fine granules, which are difficult to see; deep purple nucleus consists of three to seven lobes connected by thin strands of nucleoplasm</td>
<td>Active phagocytes; number increases rapidly during short-term or acute infections</td>
</tr>
<tr>
<td>- Eosinophils</td>
<td>100–400 (1–4% of WBCs)</td>
<td>Red coarse cytoplasmic granules; figure-8 or bilobed nucleus stains blue-red</td>
<td>Kill parasitic worms; increase during allergy attacks; might phagocytize antigen-antibody complexes and inactivate some inflammatory chemicals</td>
</tr>
<tr>
<td>Cell type</td>
<td>Occurrence in blood (per mm(^3))</td>
<td>Cell anatomy*</td>
<td>Function</td>
</tr>
<tr>
<td>-------------</td>
<td>------------------------------------</td>
<td>---------------</td>
<td>--------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Basophils</td>
<td>20–50 (0–1% of WBCs)</td>
<td>Cytoplasm has a few large blue-purple granules; U- or S-shaped nucleus with constrictions, stains dark blue</td>
<td>Granules contain histamine (vasodilator chemical), which is discharged at sites of inflammation</td>
</tr>
<tr>
<td>Agranulocytes</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphocytes</td>
<td>1500–3000 (20–45% of WBCs)</td>
<td>Cytoplasm pale blue and appears as thin rim around nucleus; spherical (or slightly indented) dark purple-blue nucleus</td>
<td>Part of immune system; one group (B lymphocytes) produces antibodies; other group (T lymphocytes) involved in graft rejection, fighting tumors and viruses, and activating B lymphocytes</td>
</tr>
<tr>
<td>Monocytes</td>
<td>100–700 (4–8% of WBCs)</td>
<td>Abundant gray-blue cytoplasm; dark blue-purple nucleus often kidney-shaped</td>
<td>Active phagocytes that become macrophages in the tissues; long-term “clean-up team”; increase in number during chronic infections such as tuberculosis</td>
</tr>
<tr>
<td>Platelets</td>
<td>250,000–500,000</td>
<td>Essentially irregularly shaped cell fragments; stain deep purple</td>
<td>Needed for normal blood clotting; initiate clotting cascade by clinging to broken area; help to control blood loss from broken blood vessels</td>
</tr>
</tbody>
</table>

*Appearance when stained with Wright*
Red blood cells (erythrocytes) (RBCs)

- transport oxygen
- specialised to do this

Also carry some $CO_2$
Erythrocytes

- Biconcave disc
- Does not have nucleus & mitochondria
- Small, about 7.5 μm in diameter
- TSA/V is ↑
- Elastic membrane (enable it to squeeze easily into the tiniest blood capillaries)
- Packed with haemoglobin
- Haemoglobin – protein pigment – haem group – ion atom
Erythrocytes

- Lifespan – 120 days
- Destroyed – liver & spleen
- Manufactured – bone marrow of long bones, ribs, skull & vertebrae
Erythrocytes

1) **biconcave shape**
   - increases the surface area so more oxygen can be carried
   - Flexible and allows it to squeeze through blood capillary

2) **no nucleus**
   - extra space inside

3) contain **haemoglobin**
   - the oxygen carrying molecule
   - 250 million molecules / cell
Erythrocytes (Red Blood Cells)

- The main function is to carry oxygen
- Anatomy of circulating erythrocytes
  - Biconcave disks
  - Essentially bags of hemoglobin
  - Anucleate (no nucleus)
  - Contain very few organelles
- Outnumber white blood cells 1000:1
Hemoglobin

- Iron-containing protein
- Binds strongly, but reversibly, to oxygen
- Each hemoglobin molecule has four oxygen binding sites
- Each erythrocyte has 250 million hemoglobin molecules
Haemoglobin

- Is the iron containing pigment
- Gives red blood cells their colour
- Can carry up to 4 molecules of $O_2$
- Associates and dissociates with $O_2$
- Contains iron
When there is a high concentration of oxygen e.g. in the alveoli, haemoglobin combines with oxygen to form oxyhaemoglobin. When the blood reaches the tissue which have a low concentration of oxygen the haemoglobin dissociates with the oxygen and the oxygen is released into body tissues.
- 98% oxygen carried the blood as oxyhaemoglobin while remaining 2% dissolved in plasma.
- Carbaminohaemoglobin (HbCO₂)
Leucocytes

- Colourless
- Have nucleus & mitochondria
- Irregular in shape
- Less than 1%
- Larger than RBC
- Made – stem cells in the bone marrow and lymph nodes
- Fight infection
Leucocytes

- Activities – interstitial fluid
- Squeeze through the pores in bc
- Can be divided into two group
- Granulocytes (Neutrophils, Eosinophils, Basophils)
- Agranulocytes (Lymphocytes, monocytes)
Leukocytes (White Blood Cells)

- Crucial in the body’s defense against disease
- These are complete cells, with a nucleus and organelles
- Able to move into and out of blood vessels (diapedesis)
- Can respond to chemicals released by damaged tissues
Leukocyte Levels in the Blood

- Normal levels = 4,000 to 11,000 cells/ml

- Abnormal leukocyte levels
  - Leukocytosis
    - Above 11,000 leukocytes/ml
    - Generally indicates an infection
  - Leukopenia
    - Abnormally low leukocyte level
    - Commonly caused by certain drugs
Types of Leukocytes

- **Granulocytes**
  - Granules in their cytoplasm can be stained
  - Include neutrophils, eosinophils, and basophils
Types of Leukocytes

- **Agranulocytes**
  - Lack visible cytoplasmic granules
  - Include lymphocytes and monocytes

Figure 10.4
Granulocytes

- Neutrophils
  - Multilobed nucleus with fine granules
  - Act as phagocytes at active sites of infection

- Eosinophils
  - Large brick-red cytoplasmic granules
  - Found in response to allergies and parasitic worms
Granulocytes

- Basophils
  - Have histamine-containing granules
  - Initiate inflammation
Agranulocytes

- Lymphocytes
  - Nucleus fills most of the cell
  - Play an important role in the immune response

- Monocytes
  - Largest of the white blood cells
  - Function as macrophages
  - Important in fighting chronic infection
<table>
<thead>
<tr>
<th>Type of leucocytes</th>
<th>Characteristic</th>
<th>Abundance (per mm$^3$ of blood)</th>
<th>Function</th>
</tr>
</thead>
</table>
| Neutrophils (62%)  | • Irregularly lobed nucleus.  
                   • Granules in the cytoplasm remain **unstained** when treated with Leishman’s stain. | 4000 - 6000 | Phagocytosis of bacteria. |
| Eosinophils (2%)   | • Nucleus with two lobes.  
                   • Granules in the cytoplasm **stain red** when treated with Leishman’s stain. | 100 - 400 | • Amount increases in people with **allergic conditions** such as asthma.  
                   • Possess anti-histamine properties. |
| Basophils (0.5%)   | • Nucleus with two lobes or is S-shaped.  
                   • Granules in the cytoplasm **stain blue** with Leishman’s stain. | 25 - 200 | • Produce **heparin** (anti-clotting protein) which helps to prevent blood clotting.  
                   • Secrete **histamine** which is involved in inflammation of damaged tissues and allergic reactions. |
<table>
<thead>
<tr>
<th>Lymphocytes (32%)</th>
<th>Monocytes (4%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>- The smallest type of leucocyte.</td>
<td>- The largest type of leucocyte.</td>
</tr>
<tr>
<td>- Rounded nucleus with little cytoplasm.</td>
<td>- Large bean-shaped nucleus.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Provide specific immunity, for example, production of antibodies.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>- Phagocytosis of bacteria.</td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1500 – 2700</td>
</tr>
<tr>
<td></td>
<td>100 – 700</td>
</tr>
</tbody>
</table>
Which of the following descriptions is true about human leucocytes?

<table>
<thead>
<tr>
<th>Leucocyte</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>A Basophil</td>
<td>A granular leucocyte that is involved in blood clotting.</td>
</tr>
<tr>
<td>B Eosinophil</td>
<td>A non-granular leucocyte that kills parasitic worms.</td>
</tr>
<tr>
<td>C Lymphocyte</td>
<td>A granular leucocyte that produces antibodies.</td>
</tr>
<tr>
<td>D Monocyte</td>
<td>A non-granular leucocyte that destroys pathogen by phagocytosis.</td>
</tr>
</tbody>
</table>
Monocytes
White blood cells

- The bodies “defence”
- Part of the immune system
- Much larger than RBCs
- Far fewer
- Have a nucleus
- 4000-13000 per mm$^3$
- 2 types monocytes and lymphocytes
Other important jobs of the white blood cells:

- They produce **antibodies** which can recognise and fight bacteria
- They produce **antitoxins** which neutralise the toxins (poisons) that bacteria produce, which make us feel ill
Lymphocyte
Lymphocytes
Provide a specific immune response to infectious diseases.

There are 2 types:
- T-cells
- B-cells

They produce antibodies.
Platelets

- Derived from ruptured multinucleate cells (megakaryocytes)
- Needed for the clotting process
- Normal platelet count $= 300,000/mm^3$
Platelets

- Fragments of large cells from the bone marrow
- Does not have nucleus
- Blood clotting
Platelets

if you get cut:-

- platelets produce tiny fibrin threads
- these form a web-like mesh that traps blood cells.
- these harden forming a clot, or "scab."
- 150,000 to 400,000 per mm$^3$
Can you?

- State the composition of Blood
- State the function of red blood cells and plasma
- Explain the function of haemoglobin in the transport of oxygen
- State the function of macrophages and lymphocytes
Hematopoiesis – Blood Cell Formation

- Occurs in red bone marrow
- All blood cells are derived from a common stem cell (hemocytoblast)
Fate of Erythrocytes

- Unable to divide, grow, or synthesize proteins
- Wear out in 100 to 120 days
- When worn out, are eliminated by phagocytes in the spleen or liver
- Lost cells are replaced by division of stem cells
Hemostasis

- Stoppage of blood flow
- Result of a break in a blood vessel
- Hemostasis involves three phases
  - Platelet plug formation
  - Vascular spasms
  - Coagulation
1. Vessel damage, blood loss
2. Vascular spasm.
3. Platelet plug forms
4. Coagulation
Platelet Plug Formation

- Collagen fibers are exposed by a break in a blood vessel
- Platelets become “sticky” and cling to fibers
- Anchored platelets release chemicals to attract more platelets
- Platelets pile up to form a platelet plug
Vascular Spasms

- Anchored platelets release serotonin
- Serotonin causes blood vessel muscles to spasm
- Spasms narrow the blood vessel, decreasing blood loss
Coagulation

- Injured tissues release thromboplastin
- \( PF_3 \) (a phospholipid) interacts with thromboplastin, blood protein clotting factors, and calcium ions to trigger a clotting cascade
- Prothrombin activator converts prothrombin to thrombin (an enzyme)
Coagulation, cont.

- Thrombin joins fibrinogen proteins into hair-like fibrin
- Fibrin forms a meshwork (the basis for a clot)
Blood Clotting

- Blood usually clots within 3 to 6 minutes
- The clot remains as endothelium regenerates
- The clot is broken down after tissue repair
Undesirable Clotting

- Thrombus
  - A clot in an unbroken blood vessel
  - Can be deadly in areas like the heart

- Embolus
  - A thrombus that breaks away and floats freely in the bloodstream
  - Can later clog vessels in critical areas such as the brain
Bleeding Disorders

- Thrombocytopenia (caused by viruses, medications or post-bone CA treatment)
  - Platelet deficiency
  - Even normal movements can cause bleeding from small blood vessels that require platelets for clotting
- Hemophilia
  - Hereditary bleeding disorder
  - Normal clotting factors are missing
Blood Groups and Transfusions

- Large losses of blood have serious consequences
  - Loss of 15 to 30 percent causes weakness
  - Loss of over 30 percent causes shock, which can be fatal

- Transfusions are the only way to replace blood quickly

- Transfused blood must be of the same blood group
Human Blood Groups

- Blood contains genetically determined proteins
- A foreign protein (antigen) may be attacked by the immune system
- Blood is “typed” by using antibodies that will cause blood with certain proteins to clump (agglutination)
Human Blood Groups

- There are over 30 common red blood cell antigens
- The most vigorous transfusion reactions are caused by ABO and Rh blood group antigens
ABO Blood Groups

- Based on the presence or absence of two antigens
  - Type A
  - Type B
- The lack of these antigens is called type O
Blood Types Determine Blood Compatibility

<table>
<thead>
<tr>
<th>Blood Type</th>
<th>Red Blood Cells</th>
<th>Plasma Antibodies</th>
<th>Incidences:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type A</td>
<td>Antigen A</td>
<td>B</td>
<td>U.S. Caucasian: 40%</td>
</tr>
<tr>
<td>Type B</td>
<td>Antigen B</td>
<td>A</td>
<td>U.S. African-American: 27%</td>
</tr>
<tr>
<td>Type AB</td>
<td>Antigens A and B</td>
<td>Neither A nor B</td>
<td>Native Americans: 8%</td>
</tr>
<tr>
<td>Type O</td>
<td>Neither A nor B</td>
<td>A and B</td>
<td></td>
</tr>
</tbody>
</table>

- **Type A**: Antigen A
- **Type B**: Antigen B
- **Type AB**: Antigens A and B
- **Type O**: Neither A nor B antigens
ABO Blood Groups

- The presence of both A and B is called type AB
- The presence of either A or B is called types A and B, respectively
Rh Blood Groups

- Named because of the presence or absence of one of eight Rh antigens (agglutinogen D)
- Most Americans are Rh\(^+\)
- Problems can occur in mixing Rh\(^+\) blood into a body with Rh\(^-\) blood
How Rh sensitization occurs.

1. Rh-negative woman with Rh-positive fetus
2. Cells from Rh-positive fetus enter mother’s bloodstream
3. Woman becomes sensitized—antibodies (⊕) form to fight Rh-positive blood cells
4. In the next Rh-positive pregnancy, antibodies attack fetal blood cells
Rh Dangers During Pregnancy

- Danger is only when the mother is Rh\(^{-}\) and the father is Rh\(^{+}\), and the child inherits the Rh\(^{+}\) factor
Rh Dangers During Pregnancy

- The mismatch of an Rh− mother carrying an Rh+ baby can cause problems for the unborn child
  - The first pregnancy usually proceeds without problems
  - The immune system is sensitized after the first pregnancy
  - In a second pregnancy, the mother’s immune system produces antibodies to attack the Rh+ blood (hemolytic disease of the newborn)
Blood Typing

- Blood samples are mixed with anti-A and anti-B serum
- Coagulation or no coagulation leads to determining blood type
- Typing for ABO and Rh factors is done in the same manner
- Cross matching – testing for agglutination of donor RBCs by the recipient’s serum, and vice versa