Chapter 06
Lecture Outline

See separate PowerPoint slides for all figures and tables pre-inserted into PowerPoint without notes.
Cardiovascular System: Blood
Points to ponder

• What type of tissue is blood and what are its components?
• What is found in plasma?
• Name the three formed elements in blood and their functions.
• How does the structure of red blood cells relate to their function?
• Describe the structure and function of each white blood cell.
• What are disorders of red blood cells, white blood cells, and platelets?
• What do you need to know before donating blood?
• What are antigens and antibodies?
• How are ABO blood types determined?
• What blood types are compatible for blood transfusions?
• What is the Rh factor and how is this important to pregnancy?
• How does the cardiovascular system interact with other systems to maintain homeostasis?
Circulatory System Components

- Heart
- Blood vessels
- Blood
Three Primary Functions of the Blood

• Transportation
  – Nutrients, waste, hormones

• Regulation
  – Temperature, water volume, pH

• Defense
  – Against infections and bleeding
Figure 7.1

Food and water intake

Oxygen intake

Elimination of carbon dioxide

The Human Body

Respiratory system

Nutrients, salt, water

$O_2$  $CO_2$

Water, salts, metabolic waste

Circulatory system

Metabolic waste

Transport to and from all cells

Elimination of food residues, metabolic wastes

Digestive system

Elaboration of excess water, salts, metabolic wastes

Urinary system

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Blood components

Measurement: hematocrit
Males → 41-53%
Females → 31-46%

a) Whole blood.
b) Blood after being spun in centrifuge.
c) A table-top centrifuge.
Plasma 55% → 91% water and 9% ions & plasma proteins

<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>Ions (blood 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</td>
</tr>
<tr>
<td>Albumin</td>
<td>Clotting</td>
</tr>
<tr>
<td>Fibrinogen</td>
<td>Defense</td>
</tr>
<tr>
<td>Immunoglobulins (antibodies)</td>
<td></td>
</tr>
<tr>
<td>Substances transported by blood</td>
<td>Nutrients</td>
</tr>
<tr>
<td>Respiratory gases</td>
<td>Waste products</td>
</tr>
<tr>
<td>Hormones</td>
<td></td>
</tr>
</tbody>
</table>

Separated blood elements
### Cellular elements 45%

<table>
<thead>
<tr>
<th>Cell type</th>
<th>Number per µL (mm³) of blood</th>
<th>Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leukocytes (white blood cells)</td>
<td>5,000–10,000</td>
<td>Defense and immunity</td>
</tr>
<tr>
<td>Basophils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lymphocytes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Eosinophils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutrophils</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monocytes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Platelets</td>
<td>250,000–400,000</td>
<td>Blood clotting</td>
</tr>
<tr>
<td>Erythrocytes (red blood cells)</td>
<td>5–6 million</td>
<td>Transport of O₂ and some CO₂</td>
</tr>
</tbody>
</table>

- **Separated blood elements**
- **Erythrocytes (red blood cells)**: 5–6 million
- **Platelets**: 250,000–400,000
- **Leukocytes (white blood cells)**: 5,000–10,000
- **Basophils**, **Lymphocytes**, **Eosinophils**, **Neutrophils**, **Monocytes**

- **Functions**:
  - Defence and immunity
  - Blood clotting
  - Transport of O₂ and some CO₂
Where do the formed elements come from and what are they?
Red Blood Cells

• Functions: transport $O_2$ and $CO_2$ & buffer
• Measurements: hematocrit
  • hemoglobin
    » males $\rightarrow$ 13.5-17.5 g/dL
    » Female $\rightarrow$ 12 - 16 g/dL
• Life span: 120 days
Figure 6.4  Response of the kidneys to a decrease in blood oxygen concentration.

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Erythropoietin

O₂-sensitive cells in kidneys respond to a decline in O₂ availability by increasing erythropoietin production.

Increased number of RBCs returns O₂ availability to normal.

Erythropoietin stimulates increased RBC production by stem cells in bone marrow.
What is blood doping?

- It is any method of increasing the number of RBCs to increase athletic performance.
- It allows more efficient delivery of oxygen and reduces fatigue.
- EPO is injected into a person months prior to an athletic event.
- It is thought to be able to cause death due to thickening of blood that leads to a heart attack.
Stem cells are located in red bone marrow.

Stem cells multiply and become specialized.

Mature blood cells include:
- Erythrocyte (red blood cell)
- Neutrophil
- Eosinophil
- Basophil
- Monocyte
- Lymphocyte
- Megakaryocyte
- Platelets

Granular leukocytes include:
- Neutrophil
- Eosinophil

Agranular leukocytes include:
- Basophil
- Monocyte
- Lymphocyte

Pluripotent cells:
- Erythroblast
- Myeloblast
- Monoblast
- Lymphoblast
- Megakaryoblast
White Blood Cells

• Functions
  – Protection from infection
  – Regulation of the inflammatory reaction
Granular Leukocytes

- **Neutrophils**
  - 60% of circulating wBCs
  - First on the scene to fight infection by engulfing microorganisms

- **Eosinophils**
  - 2 – 4% of circulating wBCs
  - Defend against large parasites (worms)
  - Moderate severity of allergic reactions

- **Basophils**
  - 0.5% of circulating wBCs
  - Histamine in granules – role in inflammation
Agranular Leukocytes

- **Monocytes**
  - 5%
  - Leave the blood and transform into macrophages

- **Lymphocytes**
  - 30%
  - Two types
    - B lymphocytes $\rightarrow$ antibodies
    - T lymphocytes $\rightarrow$ specific immune response
Platelets

- Small cell fragments derived from megakaryocytes
- Important role in hemostasis

Clotting factors from:
- Platelets
- Damaged cells
- Plasma (factors include calcium, vitamin K)

Enzymatic cascade:
- Prothrombin
- Thrombin
- Fibrinogen
- Fibrin

Fibrin clot formation

Collagen fibers
Platelet plug
Fibrin clot
Hemostasis

- Three stages
  - **Vascular spasm**: constriction of blood vessels to reduce blood flow
  - **Platelet plug formation**: sealing of the ruptured blood vessel
  - **Coagulation**: formation of a blood clot
    - Complicated series of reactions
    - Fibrinogen $\rightarrow$ Fibrin

- Bleeding disorder
  - Hemophilia
## ABO Blood Type

<table>
<thead>
<tr>
<th>Type A</th>
<th>Type B</th>
<th>Type AB</th>
<th>Type O</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antigen A</td>
<td>Antigen B</td>
<td>Antigens A and B</td>
<td>Neither A nor B</td>
</tr>
<tr>
<td>Red blood cells</td>
<td>B</td>
<td>A</td>
<td>Neither A nor B</td>
</tr>
<tr>
<td>Plasma antibodies</td>
<td>B</td>
<td>A</td>
<td>A and B</td>
</tr>
</tbody>
</table>

### Incidences:
- **U.S. Caucasians**
  - Type A: 40%
  - Type B: 10%
  - Type AB: 5%
  - Type O: 45%

- **U.S. African Americans**
  - Type A: 27%
  - Type B: 20%
  - Type AB: 4%
  - Type O: 49%

- **Native Americans**
  - Type A: 8%
  - Type B: 1%
  - Type AB: 0%
  - Type O: 91%
Blood being tested | Antibodies
---|---
Type A (Contains antigen A) | Anti-A | Anti-B
Type B (Contains antigen B) |  | 
Type AB (Contains antigens A and B) |  | 
Type O (Contains neither A nor B antigens) |  | 

Agglutinated blood
a) When an Rh positive man fathers a child by an Rh negative woman, the fetus may inherit the Rh positive antigen.
During pregnancy or more commonly at childbirth, a small amount of fetal blood enters the mother's circulation.

Figure 7.13b
c) Over the next several weeks the woman develops antibodies and an immune memory against the Rh antigen.
d) When the woman becomes pregnant with her second Rh positive child, her immune system quickly produces antibodies that attack the fetus’ red blood cells.
Blood donation
• **Anemia**: reduction in oxygen-carrying capacity due to inadequate number of red blood cells or inadequate hemoglobin
  – **Iron-deficiency anemia**: caused by inadequate intake or malabsorption of dietary iron
  – **Hemorrhagic anemia**: caused by blood loss
  – **Pernicious anemia**: caused by Vitamin B12 deficiency
  – **Hemolytic anemia**: caused by destruction of red blood cells
Blood Disorders – White Blood Cells

• **Leukemia**
  – Forms of cancer due to proliferation of white blood cells

• **Multiple myeloma**
  – Form of cancer involving the proliferation of plasma cells in the bone marrow

• **Mononucleosis**
  – Contagious Epstein-Barr virus infection of lymphocytes
Blood Disorders

• **Septicemia** (blood poisoning)
  – Bacteria proliferating in blood, overwhelming body’s defenses

• **Thrombocytopenia**
  – Reduction in platelet number
  – Unusual bruising and bleeding