Blood

OUTLINE:

- Functions of Blood
- Composition of Blood
- Blood Cell Disorders
- Blood Types
- Blood Clotting
Functions of Blood

- Transportation
- Protection
- Regulation
  - pH
  - Temperature
Composition of Blood

- Plasma: liquid that makes up about 55% of blood
  - Composition of plasma
    - About 93% water
    - 7% consists of dissolved substances: ions, dissolved gases, hormones, plasma proteins, and waste products
- Formed elements
  - Cellular components of blood
  - Make up about 45% of blood
Figure 11.1 *Separation of blood into its major components.*

- **Whole blood**
  - Plasma is a medium for transporting materials in the blood.

- **55%**
  - The formed elements consist of red blood cells, white blood cells, and platelets.

- **45%**
  - Red blood cells transport oxygen.
  - Platelets are cell fragments essential to blood clotting.
  - White blood cells defend the body against disease.
Plasma proteins

- Help balance water flow between blood and cells

General categories

- Albumins
  - Important for blood’s water-balancing ability

- Globulins
  - Transport lipids and fat-soluble vitamins
  - Some are antibodies

- Clotting proteins
  - Example: fibrinogen
Formed Elements and Platelets

- Stem cells within red bone marrow give rise to the formed elements
  - Platelets
  - White blood cells
  - Red blood cells
- Platelets
  - Sometimes called thrombocytes
  - Fragments of larger precursor cells called megakaryocytes
  - Essential to blood clotting
Figure 11.2 All formed elements originate in the red bone marrow.

Stem cells are undifferentiated cells in the red bone marrow that give rise to all the formed elements.

Stem cells divide and become specialized.

Mature formed elements are specialized for specific functions.

Red blood cells (erythrocytes)

Granulocytes
- Neutrophil
- Eosinophil
- Basophil

Agranulocytes
- Monocyte
- Lymphocyte

Platelets

Megakaryoblast
- Megakaryocyte

Monoblast
- Lymphoblast

Myeloblast
- Erythroblast

Stem cell

Nucleus lost
### Table 11.1 The Formed Elements of Blood

<table>
<thead>
<tr>
<th>Type of Formed Element</th>
<th>Cell Function</th>
<th>Description</th>
<th>No. of Cells/mm²</th>
<th>Life Span</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Platelets</strong></td>
<td></td>
<td>Play role in blood clotting</td>
<td>250,000–500,000</td>
<td>5–10 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Fragments of a megakaryocyte: small, purple-stained granules in cytoplasm</td>
<td></td>
<td></td>
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<tr>
<td><strong>White Blood Cells (WBCs; leukocytes)</strong></td>
<td></td>
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<td></td>
</tr>
<tr>
<td><strong>Granulocytes</strong></td>
<td></td>
<td>Consume bacteria by phagocytosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Neutrophils</td>
<td></td>
<td>Multilobed nucleus, clear-staining cytoplasm, inconspicuous granules</td>
<td>3000–7000</td>
<td>6–72 hours</td>
</tr>
<tr>
<td>Eosinophils</td>
<td></td>
<td>Large, pink-staining granules in cytoplasm, bilobed nucleus</td>
<td>100–400</td>
<td>8–12 days</td>
</tr>
<tr>
<td>Basophils</td>
<td></td>
<td>Large, purple-staining cytoplasmic granules; bilobed nucleus</td>
<td>20–50</td>
<td>3–72 hours</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Release histamine, which attracts white blood cells to the site of inflammation and widens blood vessels</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Agranulocytes</strong></td>
<td></td>
<td>Consume dead cells, and cell parts by phagocytosis</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Monocytes</td>
<td></td>
<td>Gray-blue cytoplasm with no granules; U-shaped nucleus</td>
<td>100–700</td>
<td>Several months</td>
</tr>
<tr>
<td>Lymphocytes</td>
<td></td>
<td>Round nucleus that almost fills the cell</td>
<td>1500–3000</td>
<td>Many years</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Attack damaged or diseased cells or disease-causing organisms; produce antibodies</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Red Blood Cells (RBCs; erythrocytes)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Transport oxygen and carbon dioxide</td>
<td>4–6 million</td>
<td>About 120 days</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Biconcave disk, no nucleus</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
White Blood Cells and Defense Against Disease

- Also called leukocytes (leuko: white, cytes: cells)
- Have a nucleus
- One type is produced in lymph nodes and other lymphoid tissue
White Blood Cells and Defense Against Disease

- **General functions**
  - Remove wastes, toxins, and damaged and abnormal cells
  - Help defend the body against disease
    - Can leave the circulatory system and move to the site of infection or tissue damage
    - Some are capable of phagocytosis
Figure 11.3 White blood cells can squeeze between the cells that form the wall of a capillary.
White Blood Cells and Defense Against Disease

- Two groups based on the presence or absence of granules in the cytoplasm
  - **Granulocytes (possess granules)**
    - Classified based on how they stain
      - Neutrophils do not stain
      - Basophils stain purple
      - Eosinophils stain pink
  - **Agranulocytes (lack visible granules)**
Granulocytes

- Neutrophils (most abundant of the WBCs)
  - Engulf microbes by phagocytosis, thus curbing the spread of infection
  - Component of pus (liquid associated with infection):
    - Dead neutrophils, bacteria and cellular debris
Granulocytes

- **Eosinophils**
  - Defend against parasitic worms
  - Lessen the severity of allergies

- **Basophils**
  - Release histamine that attracts other white blood cells and causes the blood vessels to dilate
  - Also play a role in some allergic reactions
Agranulocytes

- Monocytes
  - Largest of the formed elements
  - Develop into macrophages: phagocytic cells that engulf invading microbes, dead cells, and cellular debris

- Lymphocytes
  - B lymphocytes
  - T lymphocytes
Agranulocytes

- **B lymphocytes**
  - Give rise to plasma cells, which produce antibodies
    - Antibodies are proteins that recognize specific molecules (antigens) on the surface of invading microbes or other foreign cells
- **T lymphocytes**
  - Specialized white blood cells
  - Kills cells not recognized as coming from the body, or cells that are cancerous
Red Blood Cells and Transport of Oxygen

- Also called erythrocytes
- Transport oxygen to the cells
- Carry about 23% of the blood’s total carbon dioxide
- Shaped like biconcave disks and are very flexible
- No nucleus when mature
- Contain hemoglobin
Figure 11.4 *Red blood cells.*
Red Blood Cells and Hemoglobin

- Oxygen-binding pigment in RBCs

- Structure
  - Each molecule has four subunits
  - Each subunit has a polypeptide chain and a heme group
  - The iron ion of the heme group binds to oxygen
Red Blood Cells and Hemoglobin

- Oxyhemoglobin: hemoglobin bound with oxygen
- Hemoglobin has a much greater affinity for carbon monoxide than for oxygen
  - Odorless and tasteless
  - An insidious poison
Figure 11.5 *The structure of hemoglobin.*

Each hemoglobin molecule consists of four polypeptide chains (globins).

Each polypeptide chain contains a heme group with an iron atom that binds to oxygen.

Oxygen molecules bind to hemoglobin.

Oxygen molecules are released.

Each hemoglobin molecule can carry up to four molecules of oxygen.
Life Cycle of Red Blood Cells

- Produced in the red bone marrow
- Live about 120 days
- Undergo phagocytosis in the liver and spleen
  - Hemoglobin is degraded into its protein component (globin) and heme component
    - The iron from the heme is sent to the bone marrow for recycling
    - The remaining portions of heme are degraded to bilirubin, which the liver releases in bile
Life Cycle of Red Blood Cells

- Production of red blood cells
  - Regulated by a negative feedback mechanism
  - Production typically matches destruction
  - In the case of blood loss, the rate of RBC production is increased
    - Kidney cells sense reduced oxygen and produce the hormone erythropoietin
    - Erythropoietin stimulates the red bone marrow to produce more RBCs
    - The increased oxygen-carrying capacity of the blood inhibits production of erythropoietin
Figure 11.6 *The production of red blood cells.*

- Decreased oxygen delivery to tissues
- A decreased oxygen delivery to the kidney stimulates the kidney to release erythropoietin.
- Inhibits erythropoietin release
- Increases erythropoietin release
- Increased oxygen delivery to tissues
- Erythropoietin stimulates the red bone marrow to produce more red blood cells.
- More red blood cells

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Disorders of Red Blood Cells

- Anemia
  - The blood’s ability to carry oxygen is reduced
  - Can result from too little hemoglobin, too few red blood cells, or both
  - Symptoms include fatigue, headaches, dizziness, paleness, breathlessness, and heart palpitations

- Types of anemias
  - Iron-deficiency anemia
  - Hemolytic anemia: sickle-cell anemia
  - Pernicious anemia
Disorders of Red Blood Cells

- Anemia (cont’d)
  - Iron-deficiency anemia (most common form, leads to inadequate hemoglobin production)
  - Causes:
    - A diet that contains too little iron
    - An inability to absorb iron
    - Blood loss
Disorders of Red Blood Cells

- Anemia (cont’d)
  - Hemolytic anemia: when red blood cell destruction exceeds production
    - Causes:
      - Infections
      - Defects in the membranes of RBCs
      - Transfusion of mismatched blood
      - Hemoglobin abnormalities
Disorders of Red Blood Cells

- Anemia (cont’d)
  - Sickle-cell anemia
    - An example of a hemolytic anemia
    - Caused by abnormal hemoglobin
      - RBCs form a sickle shape when the blood’s oxygen content is low
    - Results in RBCs that are fragile and rupture easily, clogging small blood vessels and promoting clot formation
Disorders of Red Blood Cells

- Anemia (cont’d)
  - Pernicious anemia
    - Occurs when there is insufficient production of red blood cells
    - Production of RBCs depends on vitamin $B_{12}$
      - Intrinsic factor produced by the stomach lining helps the small intestine absorb vitamin $B_{12}$ from the diet
      - Caused by failure to produce intrinsic factor, which makes impossible the absorption of vitamin $B_{12}$
Disorders of White Blood Cells

- Infectious mononucleosis
  - Viral disease of the lymphocytes caused by the Epstein-Barr virus
  - Symptoms include fever, headache, sore throat, and swollen lymph nodes
  - There is no treatment
Disorders of White Blood Cells

- Leukemia
  - A cancer of the WBCs that causes the number of WBCs to greatly increase
  - These abnormal cells take over the bone marrow, preventing the development of normal RBCs, WBCs, and platelets
  - Symptoms include anemia and inadequate clotting and body defense mechanisms
  - Treatment typically involves radiation therapy, chemotherapy, and transfusions
    - Bone marrow transplants can help
Blood Types

- Named by the antigen (protein) found on the surface of RBCs
  - Type A has only the A antigen
  - Type B has only the B antigen
  - Type AB has both A and B antigens
  - Type O has neither A nor B antigens

- Agglutination (clumping)
  - Occurs when someone’s antibodies contact a foreign cell
  - This response can be used to determine blood type
Blood Types

All cells, including red blood cells, have antigens on their plasma membranes that allow the body to recognize “self” from “foreign” cells. This tutorial describes the antigens that determine blood type and explains the importance of knowing an individual’s blood type before giving and receiving blood.

Press "PLAY" to begin Animation.
## Table 11.2 Transfusion Relationships among Blood Types

<table>
<thead>
<tr>
<th>Blood Types</th>
<th>Antigens on Red Blood Cells</th>
<th>Antibodies in Plasma</th>
<th>Blood Types (RBCs) That Can Be Received in Transfusions</th>
<th>Incidence of Blood Type in United States</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>Anti-B</td>
<td>A, O</td>
<td>Caucasian, 40%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>African American, 26%</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Asian, 27.3%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Hispanic 31%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Native American, 8%</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>Anti-A</td>
<td>B, O</td>
<td>Caucasian, 11%</td>
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<tr>
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<td></td>
<td></td>
<td>African American, 19%</td>
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<td></td>
<td></td>
<td>Asian, 25.5%</td>
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<td></td>
<td></td>
<td>Hispanic 10%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Native American, 1%</td>
</tr>
<tr>
<td>AB</td>
<td>A and B</td>
<td>None</td>
<td>A, B, AB, O</td>
<td>Caucasian, 4%</td>
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<td></td>
<td></td>
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<td></td>
<td>African American, 4%</td>
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<td></td>
<td></td>
<td>Asian, 7.1%</td>
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<tr>
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<td></td>
<td></td>
<td></td>
<td>Hispanic 2.2%</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>Native American, 0%</td>
</tr>
<tr>
<td>O</td>
<td>None</td>
<td>Anti-A, Anti-B</td>
<td>O</td>
<td>Caucasian, 45%</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td>African American, 51%</td>
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<td></td>
<td>Asian, 40%</td>
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<tr>
<td></td>
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<td></td>
<td></td>
<td>Hispanic 57%</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Native American, 91%</td>
</tr>
</tbody>
</table>
Rh Factor

- First discovered on the rhesus macaque (*Macaca mulatta*), also called the rhesus monkey
  - Another important antigen
  - Individuals who have Rh antigens on their RBCs are Rh-positive
  - Individuals who lack Rh antigens on their RBCs are Rh-negative
  - An Rh-negative person will not form anti-Rh antibodies unless he or she has been exposed to the Rh antigen
    - Transfusion
    - Having given birth to an Rh-positive baby
Figure 11.7 Blood typing.

(a) Agglutination relationship among blood types

Blood type

O^+

A^-

B^+

AB^-

(b) Diagrams showing no agglutination (top) and agglutination (bottom)

(c) Diagrams of antigens and antibodies with no agglutination and with agglutination

No agglutination

Antigen A

Antibody to B

Agglutination

Antigen A

Antibody to A
Rh Factor

- Hemolytic disease of the newborn
  - Anti-Rh antibodies can develop in the mother
  - They can cross the placenta, destroying the Rh-positive fetus’s RBCs
  - The baby may die or be very anemic

- RhoGAM
  - A serum containing antibodies against the Rh antigens
  - Given to an Rh-negative mother to destroy any Rh-positive fetal cells in her circulation and thereby prevent her production of anti-Rh antibodies
Figure 11.8 *Rh incompatibility.*

**An Rh⁺ man and an Rh⁻ woman could have an Rh⁺ baby.**

**First pregnancy: At birth some of the Rh⁺ blood of the fetus may enter the mother’s circulation.**

**After delivery: The mother forms anti-Rh antibodies over the next few months.**

**Second pregnancy with an Rh⁺ fetus: Anti-Rh antibodies may pass into the fetus’s blood, causing its blood cells to burst.**
Blood Clotting

- Steps that occur once a blood vessel is cut
  - The vessel constricts
  - Platelets form a plug that seals the leak
    - Platelets cling to collagen and produce a chemical that attracts more platelets
    - Note: aspirin prevents the formation of this chemical and therefore inhibits clot formation
  - Formation of a blood clot
Blood Clotting

The key events in clot formation are:

- Clotting factors are released from injured tissue and platelets
- These factors convert an inactive blood protein to prothrombin activator
- Prothrombin activator converts prothrombin (a plasma protein produced by the liver) to thrombin, an active form
- Thrombin causes fibrinogen (another plasma protein produced by the liver) to form long strands of fibrin
- Fibrin strands form a web that traps blood cells and forms a clot
- When the wound has healed, the enzyme plasmin, formed from plasminogen, digests the fibrin strands of the clot
Figure 11.9 Selected steps in the blood-clotting process.

**Step 1:** Injured cells in the walls of the vessels and platelets release clotting factors.

**Step 2:** Clotting factors convert an inactive blood protein to prothrombin activator.

**Step 3:** Prothrombin activator converts prothrombin to thrombin.

**Step 4:** Thrombin converts fibrinogen to fibrin.

**Step 5:** The fibrin network traps red blood cells and platelets, forming a blood clot.
Blood Clotting

- If even one of the clotting factors is lacking, the process can be slowed or completely blocked

- Vitamin K is needed to synthesize prothrombin in the liver

  - Clotting does not occur without it

  - Two sources of vitamin K are diet and intestinal bacteria (which can be killed by antibiotic therapy)
Blood Clotting

- Disorders
  - Hemophilia
    - Inherited condition characterized by excessive bleeding
    - Caused by faulty gene involved in the production of clotting factors
    - Treatment involves restoration of the missing clotting factor
Blood Clotting

- Disorders (cont’d)
  - Formation of unnecessary blood clots can have immediate health consequences
    - Clots can disrupt blood flow and cause heart attack or stroke
    - A clot that continues to circulate is called an embolus
    - A clot that lodges in an unbroken blood vessel is called a thrombus
Blood

Blood serves many important functions in the body, including the transport of nutrients and waste products to and from cells as well as defense against disease. This tutorial explores the liquid and cellular elements that constitute blood and their main roles in the body.

Press "PLAY" to begin Animation.
You Should Now Be Able To:

- Describe the functions of blood
- Describe the formation of blood
- Know the composition of blood:
  - Plasma
  - Platelets
  - White blood cells
  - Red blood cells
- Know the main blood cell disorders
- Know the blood types and Rh factor
- Understand blood clotting and blood clotting disorders