Blood

- Sticky, opaque fluid with a metallic taste ($\text{Fe}^{2+}$)
- Varies from scarlet ($P_{O_2} = 100$) to dark red ($P_{O_2} = 40$)
- pH is between 7.35 and 7.45
- Average volume in an adult is 5 L (7% of body weight)
  - 2 L = blood cells (formed elements)
  - 3 L = plasma fluid portion of blood (ECF)
- Functions include:
  - Substance distribution
  - Body protection (clotting and immunity)
Components of Blood

Centrifugation separates blood based on density

- **Plasma** (least dense) ~58% of whole blood volume
  - 92% H₂O, 7% Proteins, 1% dissolved substances (organic molecules, ions, gasses)

- **Formed Elements** (cells)
  - **Buffy coat** (platelets and leukocytes (WBCs))
    - less than 1% of whole blood volume
  - **Erythrocytes** (red blood cells (RBCs)) (most dense)
    - 42% of whole blood volume
      - **Hematocrit** (Hct)
        - 1 μL = 1/1,000,000 L of blood contains:
          - 5,000,000 RBCs
          - 4,000 – 11,000 WBCs
          - 150,000 – 450,000 platelets
Erythrocytes (RBCs)

- **Biconcave** disc shape with a diameter of 7.5 $\mu$m,
- Very flexible
  - folds in order to move through some blood vessels that have a diameter **smaller** (5.0 $\mu$m) than the RBC
- Membranous “bags” filled with enzymes and Hb
  - no mitochondria (anaerobic fermentation only)
  - no nucleus or endoplasmic reticulum
  - no protein synthesis to make new enzymes, Hb or membrane components
  - leads to increased loss of membrane flexibility making older cells more fragile and prone to rupture
  - life span of an erythrocyte in circulation is ~120 days whereby they are removed by macrophages of the spleen and liver
Erythropoiesis

• In a healthy adult, the number of new RBCs entering circulation equals the number of old RBCs removed from circulation (approximately 2,500,000 per second)

• An increase in erythropoiesis is required during times of low oxygen content in blood (hypoxemia) due to:
  – decreased RBCs (anemia)
  – decreased oxygen availability (at high altitudes)
  – increased tissue demand for oxygen (exercising)

• The liver and kidneys secrete the hormone erythropoietin (epo) in response to hypoxemia
  – erythropoietin stimulates the differentiation of hemocytoblasts into erythrocytes
    • increases RBCs
    • increases the oxygen carrying ability of the blood
Hypoxemia (inadequate O₂ transport) → Sensed by liver and kidneys → Secretion of erythropoietin → Stimulation of red bone marrow → Increased O₂ transport → Increased RBC count → Accelerated erythropoiesis
Hemostasis

Bleeding stops in a 3 step process

• Vascular spasms
  – vasoconstriction of the damaged vessel temporarily decreases blood flow limiting blood loss

• Platelet plug formation
  – platelets in the vicinity of the injured blood vessel aggregate at the site of injury further limiting blood loss

• Coagulation
  – series of enzymatic reactions that activates blood proteins called clotting factors (procoagulants)
  – ends in the formation of fibrin (protein fiber mesh that stabilizes the platelet plug)
    • anticoagulants are substances that interfere with coagulation
1. Exposed collagen binds and activates platelets.
2. Release of platelet factors
3. Factors attract more platelets.
4. Platelets aggregate into platelet plug.

- Lumen of blood vessel
- Intact endothelium
- Prevents platelet adhesion
- Releases prostacyclin and NO
- Exposed collagen in damaged blood vessel wall
- Smooth muscle cells
- Collagen subendothelial layer
Damage to wall of blood vessel

Collagen exposed

Platelets adhere and release platelet factors

Platelets aggregate into loose platelet plug

Vasoconstriction

Coagulation cascade

Thrombin formation

Converts fibrinogen to fibrin

Temporary hemostasis

Clot: reinforced platelet plug

Fibrin slowly dissolved by plasmin

Clot dissolves

Cell growth and tissue repair

Intact blood vessel wall
Leukocytes (WBCs)

- Primary cells for the **immune system** response that functions to protect the body from **foreign antigens** (substances that trigger an immune response)
  - pathogen
    - disease producing biological agent
  - allergen
    - substance that causes an allergic reaction
- Exit blood vessels functioning extravascularly where they live within tissues for a few hours to many months
- Leukocytes found in blood in the following proportions:
  - 60% Neutrophils
  - 30% Lymphocytes
  - 8% Monocytes
  - 2% Eosinophils
  - 0.4% Basophils
Antibodies

- Antibodies are secreted into the blood by B lymphocytes in response to a pathogen recognize and bind to foreign **antigens**
  - Y-shaped protein molecules which enable them to bind to 2 antigens simultaneously
- When an antibody binds to foreign antigen it causes **agglutination**
  - clumping of cells, held together by antibodies as observed in a blood transfusion reaction
  - antigens are then typically destroyed by T lymphocytes
ABO Blood Groups

- Human blood types are determined by the presence or absence of 2 types of antigenic glycoproteins in the membrane of RBCs
  - ABO blood group antigens
    - A antigen
    - B antigen
  - Rh antigen
    - Someone with the Rh antigen on the RBCs is positive
    - Someone without the Rh antigen on the RBCs is negative
<table>
<thead>
<tr>
<th>Blood type</th>
<th>Antigen on red blood cell</th>
<th>Antibodies in plasma</th>
</tr>
</thead>
<tbody>
<tr>
<td>O</td>
<td>No A or B antigens</td>
<td>“Anti-A” and “anti-B”</td>
</tr>
<tr>
<td>A</td>
<td>A antigens</td>
<td>“Anti-B”</td>
</tr>
<tr>
<td>B</td>
<td>B antigens</td>
<td>“Anti-A”</td>
</tr>
<tr>
<td>AB</td>
<td>A and B antigens</td>
<td>None to A or B</td>
</tr>
</tbody>
</table>
ABO Blood Groups

• Problems with transfusions arise because plasma normally contains antibodies to the ABO antigens.
• People make antibodies to the RBC antigens that they do NOT possess.
  • Type A has anti-B antibodies.
  • Type B has anti-A antibodies.
  • Type AB has no antibodies in the plasma.
  • Type O has both anti-A and anti-B antibodies.

• Rh positive blood does NOT have anti-Rh antibodies in their plasma.
• Rh negative blood has anti-Rh antibodies in their plasma.
Transfusion Compatibilities

To determine if a transfusion is compatible, compare the antigens of the donor with the antibodies of the recipient. If they match, then the transfusion will harm the recipient.

<table>
<thead>
<tr>
<th>Blood Type</th>
<th>receive from</th>
<th>donate to</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A, O</td>
<td>A, AB</td>
</tr>
<tr>
<td>B</td>
<td>B, O</td>
<td>B, AB</td>
</tr>
<tr>
<td>AB</td>
<td>A, B, AB, O</td>
<td>AB</td>
</tr>
<tr>
<td></td>
<td>universal recipient</td>
<td></td>
</tr>
<tr>
<td>O</td>
<td>O</td>
<td>A, B, AB, O</td>
</tr>
<tr>
<td></td>
<td>universal donor</td>
<td></td>
</tr>
<tr>
<td>Rh⁺</td>
<td>Rh⁻, Rh⁺</td>
<td>Rh⁺</td>
</tr>
<tr>
<td>Rh⁻</td>
<td>Rh⁻</td>
<td>Rh⁻, Rh⁺</td>
</tr>
</tbody>
</table>
Blood from type A donor

Type B (anti-A) recipient

Donor RBCs agglutinated by recipient plasma

Agglutinated RBCs block small vessels