Transport System of the Body:

Cell

External environment:

Nutrients
Waste

O<sub>2</sub> / Energy

Nutrients
Waste

CO<sub>2</sub> / Waste

Too Much Time

Cardiovascular System: Blood

Blood:
- Only fluid tissue in body (connective tissue)
- pH = 7.35 – 7.45 (slightly alkaline)
- Temp. slightly higher than body temp. (38°C / 100.4°F)
- ~ 8% body weight (♂ = 5-6 L; ♀ = 4-5 L)

Function ("River of Life"):
1) Distribution
   - Delivers oxygen / nutrients
   - Carries away metabolic wastes
   - Transports hormones
2) Regulation
   - Maintains body temperature / pH
   - Maintains fluid volumes
3) Protection
   - Prevents blood loss (e.g., clot formation)
   - Prevents infection (e.g., antibodies)

Blood Components:

A) Plasma

- Distributes materials / heat

Composition: (precisely maintained)

A) Water (~ 90%)

B) Protein (~ 8%)

C) Other solutes (~ 2% >100 different solutes present; Table 17.1)

- Organic nutrients (e.g., glucose)
- Nitrogenous waste (e.g., urea)
- Electrolytes (e.g., sodium)
- Respiratory gases (e.g., O<sub>2</sub>)
Blood Components:
B) Erythrocytes (red blood cells – RBCs)
- Small (~7 μm; biconcave (“cute”)
- Anucleate (lacking nucleus); few organelles
- Contain hemoglobin (O₂ / CO₂ transport protein)

Heme (O₂-binding pigment w/ iron) + Globin (protein)

Structure complements function
1) Small size and shape equates to large surface area / volume
2) 97% of cell volume is hemoglobin (~250 million hemoglobin)

Mass transport of respiratory gases
3) Lack mitochondria (don’t burn oxygen)

Efficient transport of respiratory gases

Erythropoiesis (red blood cell formation):
- ~2 million RBCs produced per second
- Formation occurs in red bone marrow

Entire process takes ~15 days

Erythropoiesis (red blood cell formation):
- Dietary requirements must be met for normal RBC formation

Iron: (hemoglobin synthesis)
- Stored in liver & spleen in protein iron complexes ferritin and hemosiderin

Vitamin B₁₂ and folic acid necessary for proper DNA synthesis

Free iron ions toxic!
- Acts as a catalyst for the formation of free radicals

Cardiovascular System – Blood

Blood Components:
B) Erythrocytes (red blood cells – RBCs)
- Regulated hormonally by erythropoietin
B) **Erythrocytes** (red blood cells – RBCs)

**Blood Components:**

- **Cardiovascular System – Blood**

**Pathophysiology:**

- **Anemia** (loss of oxygen carrying capacity of blood)
  - Decreased number of RBCs
  - Decreased hemoglobin content

**Destruction of Erythrocytes**

- “Old” RBCs engulfed by macrophages in spleen / liver
  - Lose flexibility
  - Iron salvages; stored for re-use
  - Heme group degraded to bilirubin
  - Bilirubin (yellow pigment)
    - Liver converts bilirubin to biliverdin
    - Biliverdin stored for re-use
  - Globins recycled to amino acids

**Jaundice:** Yellowing of skin due to bilirubin deposition

**Bilirubin** (captured by liver; released via gallbladder)
- **Urobilinogen** (metabolized in large intestine)
- **Stercobilin** (brown pigment)
  - Exits in feces

**Hemolysis**

- Hemorrhagic anemia (blood loss)
- Hemolytic anemia (RBC rupture)
- Aplastic anemia (red marrow destruction)

**Iron deficiency anemia** (inadequate intake of iron)
- Pernicious anemia (deficiency of vitamin B12)

**Microcytes**
- **Sickle-cell anemia** (genetic mutation – abnormal globin)

**Macrocytes**
- **Thalassemias** (genetic mutation – missing globin)

**EPO**
- Whole blood

**Polycythemia** increases blood viscosity, causing it to flow sluggishly

**Polycythemia vera** (bone marrow cancer)
- **Secondary polycythemia** (high altitude living)

**Leukocytes** (white blood cells – WBCs)

**Categories of Leukocytes:**

- **Granulocytes** (contain granules)
  1. Neutrophils (50 – 70%)
     - Small granules
     - Multi-lobed nucleus
     - Engulf bacteria / fungi
  2. Eosinophils (2 – 4%)
     - Large granules (lysosomes)
     - Bi-lobed nucleus
     - Kills parasitic worms
  3. Basophils (< 1%)
     - Large granules
     - U-shaped nucleus
     - Vasoconstriction / attracts WBCs

- **Agranulocytes** (lack granules)
  1. Lymphocytes (15 – 45%)
     - Large nucleus (spherical)
     - Function in immune response
  2. Monocytes (3 – 8%)
     - Largest of WBCs
     - Function as macrophages (differentiate in tissues)

**Lifespan** = hours – decades

**Lifespan** = hours – months
Cardiovascular System – Blood

Blood Components:

C) Leukocytes (white blood cells – WBCs)

Leukopoiesis (white blood cell formation):

- Lymphoid stem cell
  - Migrate to lymphoid tissue
  - Lymphoblast
  - Lymphocyte

- Myeloid stem cell
  - Myeloblast
  - Myelocyte
  - Eosinophilic myelocyte
  - Basophilic myelocyte
  - Neutrophilic myelocyte
  - Neutrophilic band cell
  - Eosinophilic band cell
  - Basophilic band cell

Hemopoiesis (red blood cell formation):

- Hemocytoblast
  - Megakaryoblast
  - Megakaryocyte
  - Thrombocytes

Blood Components:

D) Platelets (thrombocytes)

Thrombopoiesis (platelet formation):

- Myeloid stem cell
- Hemocytoblast
- Megakaryoblast
- Megakaryocyte
- Platelets

Hemostasis (‘stoppage of bleeding’):

- Series of fast, localized reactions to halt blood loss

Phase 1:
- Vascular spasm

Phase 2:
- Platelet plug formation
  - Vasoconstriction of damaged vessel
  - Temporarily seals vessel break (positive feedback loop)

Phase 3:
- Coagulation (blood clotting)

Blood converted from liquid to gel (3–6 minutes)

- Requires clotting factors (procoagulants)

Pathophysiology:

Leukemia:

- Uncontrolled proliferation of WBCs (leukocytes)

- Named according to abnormal cell line involved

Acute leukemia:
- Derived from blast-type cells
- Rapid advancement
- Often observed in children

Chronic leukemia:
- Derived from later cell stages
- Slow advancement
- Often observed in elderly

Symptoms:

- Anemia / bleeding problems
- Fever / weight loss
- Frequent infections

Treatment:

- Irradiation
- Chemotherapy
- Bone marrow transplant

Lymphocytic leukemia

Mononucleosis:

- Excessive number of agranulocytes

- Epstein-Barr virus

- Often associated with infectious mononucleosis

- May involve acute lymphoblastic leukemia

- Often observed in children

- Frequent infections

- Bone marrow transplant

Leukemia:

- Uncontrolled proliferation of WBCs (leukocytes)

- Derived from blast-type cells

- Rapid advancement

- Often observed in children

- Frequent infections

- Bone marrow transplant

Myelocytic leukemia

- Derived from later cell stages

- Slow advancement

- Often observed in elderly

- Bone marrow transplant

- Excessive number of agranulocytes

- Epstein-Barr virus

- Often associated with infectious mononucleosis

- May involve acute lymphoblastic leukemia

- Often observed in children

- Frequent infections

- Bone marrow transplant
Hemostasis (‘stoppage of bleeding’): Series of fast, localized reactions to halt blood loss

**Cardiovascular System – Blood**

**Step 1:** Formation of prothrombin activator

<table>
<thead>
<tr>
<th>Factor Number</th>
<th>Factor Name</th>
<th>Nature</th>
<th>Source</th>
<th>Pathway</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>Fibrogen</td>
<td>Plasma-protein</td>
<td>Liver</td>
<td>Common pathway</td>
<td>converted to fibrin; part of coagulation cascade of blood</td>
</tr>
<tr>
<td>II</td>
<td>Prothrombin</td>
<td>Plasma-protein</td>
<td>Liver</td>
<td>Common pathway</td>
<td>converted to thrombin; part of coagulation cascade of blood</td>
</tr>
<tr>
<td>III</td>
<td>Thromboplastin (PF)</td>
<td>Plasma protein</td>
<td>Platelets</td>
<td>Initiation of coagulation cascade of blood</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Calcium ions</td>
<td>Inorganic ion</td>
<td>Plasma</td>
<td>Needed for activity of some of the other coagulation factors</td>
<td></td>
</tr>
<tr>
<td>V</td>
<td>Proaccelerin</td>
<td>Plasma-protein</td>
<td>Liver, plasma</td>
<td>Common pathway</td>
<td></td>
</tr>
<tr>
<td>VII</td>
<td>Proconvertin</td>
<td>Plasma-protein</td>
<td>Liver, plasma</td>
<td>Intrinsic pathway</td>
<td>activates factors IX, X, XI, XII</td>
</tr>
<tr>
<td>VIII</td>
<td>Calcium ions</td>
<td>Inorganic ion</td>
<td>Plasma</td>
<td>Required for activity of some of the other coagulation factors</td>
<td></td>
</tr>
<tr>
<td>IX</td>
<td>Factor VIII</td>
<td>Plasma-protein</td>
<td>Liver</td>
<td>Required for activity of some of the other coagulation factors</td>
<td></td>
</tr>
<tr>
<td>X</td>
<td>Factor IX</td>
<td>Plasma-protein</td>
<td>Liver</td>
<td>Required for activity of some of the other coagulation factors</td>
<td></td>
</tr>
<tr>
<td>XI</td>
<td>Factor XI</td>
<td>Plasma-protein</td>
<td>Liver</td>
<td>Required for activity of some of the other coagulation factors</td>
<td></td>
</tr>
<tr>
<td>XII</td>
<td>Factor XII</td>
<td>Plasma-protein</td>
<td>Liver</td>
<td>Required for activity of some of the other coagulation factors</td>
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<tr>
<td>XIII</td>
<td>Factor XIII</td>
<td>Plasma-protein</td>
<td>Liver, plasma</td>
<td>Required for activity of some of the other coagulation factors</td>
<td></td>
</tr>
</tbody>
</table>

**Step 2:** Formation of thrombin

**Step 3:** Formation of fibrin mesh

**Clot Retraction / Repair:**

- Released by platelets; stimulates smooth muscle cells and fibroblasts to divide and rebuild vessel wall

**Fibrinolysis:**

- Process of removing clot once healing has occurred

**Disorders of Hemostasis:**

**Thromboembolic Disorders**

- Thrombus: A clot develops in an unbroken blood vessel
- Embolus: A free-floating clot in the bloodstream (may lead to embolism)

**Bleeding Disorders**

- Hemophilia A: Factor VIII deficiency
- Hemophilia B: Factor IX deficiency
- Petechiae: Small purplish spots on the skin
- Thrombocytopenia: Deficiency in platelets

**Anticoagulants:**

- Factors that inhibit clotting (e.g., heparin)

**Symptoms:**

- Prolonged bleeding
- Disabled / painful joints

**Treatment:**

- Plasma transfusions
- Injection of clotting factor(s)