Cardiovascular System: Blood

- Physical characteristics
- Overall Functions
  - Components: structure and function
    - Plasma
    - Formed elements (rbc, wbc, platelets)
  - Hemostasis and blood clotting
  - Blood groups and typing
  - Capillary exchange and lymphatic capillaries
  - Disorders of the blood discussed throughout

Physical Characteristics of Blood

- Specialized connective tissue
- Quantity
  - 5-6 liters (1.5 gallons) in adult men
  - 4-5 liters in adult women
  - ~8% of our body weight
- Thick and sticky
  - Denser and more viscous than water
  - Opaque
  - Bright red in color (oxygen rich) or dark purple (oxygen poor)
- pH= 7.35 to 7.45

Overall Functions of Blood

- Transportation of all substances needed by the body
  - O₂ from lungs
  - Nutrients from digestive tract
  - Hormones from endocrine glands
  - Delivers wastes to kidneys and lungs for excretion
- Regulation of
  - Body temperature
  - Volume of water in the body
  - pH of body fluids
  - Defense
  - Protects against infection
  - Prevents blood loss by forming clots

Overall Components of Blood

- Plasma is the liquid component (55%)
  - Nonliving liquid matrix
    - 90-92% is water
  - 7-8% is proteins
  - 1% other molecules
- Formed elements (45%)
  - Living cells and cell fragments
    - Red blood cells (rbc or erythrocyte)-99%
    - White blood cells (wbc or leukocytes) <1%
    - Platelets <1%

Separating Blood into its Major Components

Components of Blood: Plasma

- Liquid portion of blood that functions as transport medium for blood cells, platelets and other substances (pale yellow when separated)

<table>
<thead>
<tr>
<th>Table 6.1 Blood Plasma Solutes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Plasma proteins</td>
</tr>
<tr>
<td>Inorganic ions (salts)</td>
</tr>
<tr>
<td>Gases</td>
</tr>
<tr>
<td>Organic nutrients</td>
</tr>
<tr>
<td>Nitrogenous waste products</td>
</tr>
<tr>
<td>Regulatory substances</td>
</tr>
</tbody>
</table>
Plasma Proteins
- **Albumins**
  - ~2/3 plasma proteins
  - Maintain water balance
  - Manufactured in liver
  - Transport lipid soluble substances
    - Bilirubin, fatty acids, penicillin
- **Globulins**
  - Some are antibodies that protect against disease
  - Transport some lipids including fats and cholesterol (HDL, LDL), fat soluble vitamins
- **Clotting proteins**
  - **Fibrinogen**

Formed Elements: Red Blood Cells (RBCs)
- AKA Erythrocytes or red corpuscles
- 99% of formed elements and major cause of viscosity
- 4-6 million per mm³ or one drop of blood
- 45% of total blood volume
- Structure
  - Small biconcave disks (flattened doughnut and sunken in middle)
  - Lack a nucleus when mature and have few organelles
  - Packed with hemoglobin (Hb)
- Function
  - Carry O₂ to all cells; carry away some CO₂ (~25%)
  - **FORM FITS FUNCTION**
    - Bend and squeeze through capillaries
    - Shape maximizes surface area
    - Built to transport O₂

Hemoglobin (Hb)
- Consists of 4 polypeptide chains
  - Each with an iron-containing heme group that binds O₂
  - Hb-O₂ called oxyhemoglobin and is bright red
  - Hb without O₂ called deoxyHb and is dark purple
  - >280 million Hb molecules in one RBC, 4 O₂ per Hb
- Functions best at about neutral pH and when O₂ concentration is high
  - Binds with greater affinity (~200X) to carbon monoxide (CO), making Hb unavailable for O₂ transport
  - CO poisoning can be fatal

Hematocrit: Percentage of RBCs in Blood
- Important measure of O₂ carrying capacity
- Normal range
  - 43-49% in men
  - 37-43% in women
- Low hematocrit
  - May signal anemia or other disorders of inadequate RBC production
- High hematocrit
  - Can thicken blood and increase risk of clots
  - Polycythemia - overproduction of RBC
  - Some shifts normal and temporary
    - Increases when stay at high altitude
    - Returns to normal when you return to normal altitude
    - Example of homeostatic regulation of blood oxygen
**Lifecycle of a RBC**
- Stem cell to mature RBC takes about a week
- Produced and destroyed at a rate of ~2 million/sec
- Life span around 120 days
  - ~3000 round trips a day
- Old and damaged RBCs are destroyed in liver and spleen by macrophages
  - Amino acid and iron parts are reused
  - Heme portion gets broken down by liver and converted to yellow pigment called bilirubin
  - Gets excreted with bile and contributes to color of feces and urine
  - Jaundice is accumulation of bilirubin in plasma
  - Yellowness of whites of eyes and skin
  - Breakdown of heme to bilirubin at site of a bruise contributes to yellowish tinge in skin

**RBC Production is Regulated by a Hormone**
- Can increase production 10-fold to ~20 million cells/sec

**Blood Doping**
- Any method of increasing the number of RBC’s to increase athletic performance
  - Epogen can be injected into a person months prior to an athletic event OR
  - Blood is drawn, stored, then returned to the body
  - Increases O₂ carrying capacity of blood
  - Makes blood more viscous and heart has to pump harder
    - After exercise dehydration can concentrate blood more
    - Increases risk of clots, high blood pressure, heart attack, stroke

**Anemia**
- General term for a decrease in the O₂ carrying capacity of blood
  - Lower than normal number of RBC
  - Lower than normal hemoglobin content in RBC
  - Symptoms include
    - Fatigue, pale skin, headaches, dizziness, difficulty breathing
    - Iron, folic acid (B vitamin), and Vitamin B12 are necessary for production of RBCs
    - Some women may become slightly anemic because of heavy menstrual flow

**Types of Anemia**
- Iron deficiency anemia - insufficient iron results in less Hb per RBC, most common form
- Folic acid anemia - folic acid deficiency
- Pernicious anemia - deficiency of B12 absorption by GI tract
- Aplastic anemia - bone marrow does not produce enough stem cells
- Hemorrhagic anemia caused by extreme blood loss
- Sickle-cell anemia - RBCs are sickle-shaped (abnormal Hb) when O₂ concentration is low
  - Shape makes it harder to travel through small vessels and encourages early destruction and clotting
- Hemolysis is the rupturing of RBC
  - Hemolytic disease of the newborn

**Formed Elements: White blood cells (WBC)**
- AKA leukocytes
  - Functions
    - Defend the body against disease
    - Remove wastes, toxins, and damaged or abnormal cells
- Produced in bone marrow and arise from stem cells
- Make up less than 1% of formed elements AND we couldn’t live without them
  - Only about 7000 per drop blood (5000-11,000)
- Five types of WBCs in two categories
  - Granular leukocytes or granulocytes
  - Agranular leukocytes or agranulocytes
Characteristics of WBC

- Larger than RBCs
- More diverse in structure and function
- Have a nucleus and organelles but no Hb
- Are translucent so need to be stained to be seen
- Most have life span even shorter than RBCs
  - Granular leukocytes live a few hours to 12 days
  - Agranular leukocytes live months to many years
- Liver and spleen destroy worn out WBC
- Not confined to bloodstream and can move to site of infection, inflammation, or tissue damage

WBC Movement

- Capable of exiting and re-entering a blood vessel
- Move to the site of infection or tissue damage
- Amoeboid movement

WBC: Granulocytes

- Neutrophils: stain neutral
  - Are the first to respond to an infection and engulf microorganisms by phagocytosis
- Eosinophils: stain red or pink
  - Defend against parasitic worms (tapeworms, hookworms, etc.) by surrounding and blasting them with digestive enzymes
  - Release chemicals that are involved in allergic reactions
  - Lessen their severity
- Basophils: stain blue
  - Most rare of WBC
  - Release histamines
    - Initiates inflammatory response
    - Attract other WBC to injured area
    - Associated with allergic reactions (dilate blood vessels and constrict airways)

WBC: Agranulocytes

- Monocytes
  - Are the largest of WBC and have U-shaped nuclei
  - Filter out of bloodstream and take up residence in body tissues
  - Become larger macrophages that phagocytize pathogens, old or abnormal cells, and cellular debris
  - Stimulate other WBC to defend the body
- Lymphocytes
  - Make up about 30% of WBC
  - Spherical nucleus that almost fills the cell
  - Two types
    - B lymphocytes - give rise to plasma cells that make antibodies
    - T lymphocytes - attack damaged or diseased cells
Disorders of WBCs

- Leukocytosis - increase in number of WBCs
  - Normal when body is invaded by bacteria, viruses, or other foreign substances
  - Abnormal - infectious mononucleosis, leukemia
- Infectious mononucleosis – viral disease caused by Epstein-Barr virus (EBV)
  - Infects monocytes resulting in an increase and abnormal appearance
  - Symptoms include fatigue, sore throat, fever, chills, and swollen lymph nodes
- Leukemia – a group of cancers of WBCs that results in their uncontrolled multiplication
- Leukopenia – decrease in number of WBCs
  - Can be caused by certain drugs, like chemotherapeutic agents

Formed Elements: Platelets

- AKA thrombocytes
- Disk shaped cell fragments NOT actual cells
- Fragments are from precursor cells called megakaryocytes in the red bone marrow
- Produced at a rate of 200 billion per day
- 150,000 to 300,000 per mm³ (drop of blood)
- Life span 5 to 10 days
- Important in the process of blood clotting or coagulation

Hemostasis: Stopping Blood Loss

- Vessel damage occurs
- Formation of platelet plug - platelets swell and stick together to seal a ruptured vessel
  - Platelets produce a chemical that attracts more platelets
  - Aspirin prevents formation of this chemical
- Formation of a blood clot or coagulation - blood changes from liquid to gel
  - Prothrombin activator is released from damaged vessel, platelets, and surrounding tissues
  - A series of chemical reactions produces fibrin strands
  - Fibrin strands, blood cells, and platelets form a meshwork sealing the damaged vessel
- Clot contracts and pulls damaged edges together, further sealing the opening

Blood Clotting Disorders

- Even if one of the factors needed for clotting is lacking the process is slowed or blocked
  - Vitamin K and Ca²⁺ also necessary
- Thrombocytopenia – low platelet count that can result in the inability of blood to clot
  - Viral infections, anemia, leukemia, exposure to radiation, exposure to certain drugs...
- Thromboembolism – when a clot forms and breaks off from its site of origin and plugs another vessel
- Hemophilia – inherited clotting disorder due to a deficiency in one or more clotting factors
  - Treatment involves restoring missing clotting factors
  - Bleeding episodes controlled with transfusions

Blood Loss and Blood Transfusion

- 15% blood loss
  - Pallor (pale skin color) and weakness
- Loss of 30% or more strains body’s ability to maintain blood pressure and oxygenate tissues
  - Need blood transfusion – transfer of blood from one individual into another individual
  - Can lead to severe shock followed by death if not replaced
  - Shock is a state in which blood flow to the tissues of the body is inadequate to sustain life
Donating Blood

- Donating blood is a safe and sterile procedure
- You will donate about a pint of blood
- You will replace the plasma in a few hours and the cells in a few weeks
- A few people may feel dizzy afterwards so sit down, eat a snack and drink some water
- Your blood will at least be tested for syphilis, HIV antibodies and hepatitis and if any of them come back positive you will be notified
- Your blood can help save many lives
- You should not give blood if:
  - You have ever had hepatitis, malaria or been treated for syphilis or gonorrhea within 12 months
  - If you are at risk for having HIV or have AIDS

Blood Groups and Blood Types

- Human blood is classified into different blood types
  - Determined by the presence or absence of proteins on surface of RBCs
  - Named by the antigen found on the surface of the cell
    - ABO blood groups and Rh factors
- Some background and definitions
  - Antigen (generate against) - proteins in cell membranes that body recognizes as self
  - Antibodies (against the body) - proteins that mount attack against foreign cells or antigens
  - Agglutination - clumping
  - Transfusion reaction - any adverse effect of a blood transfusion

TABLE 11.2 Transfusion Incompatibilities among Blood Types

<table>
<thead>
<tr>
<th>Blood Types</th>
<th>Antibody on Red Blood Cells</th>
<th>Antibody in Plasma</th>
<th>Blood Type (RBC) That Can Be Blooded in Transfusions</th>
<th>Incidence of Blood Types in Canada (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>A</td>
<td>A, B</td>
<td>A, B</td>
<td>0.5%</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>A, B</td>
<td>B, O</td>
<td>0.2%</td>
</tr>
<tr>
<td>AB</td>
<td>A and B</td>
<td>A, B</td>
<td>A, B</td>
<td>0.5%</td>
</tr>
<tr>
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Blood Typing

- Anti-A
- Anti-B
- Anti-Rh

Rh Factor

- Common blood group that is also inherited
  - Name comes from the beginning letters of the Rhesus monkey where the antigen was first discovered
  - Rh-positive blood—protein antigen found on the surface of the RBC
  - Rh-negative blood—absence of this protein antigen on the surface of the RBC
  - Rh-positive is most common
  - Rh antibodies only develop in a person after they are exposed to the Rh factor from another’s blood
  - Usually occurs between a Rh+ fetus and Rh- mother
Prevention of Hemolytic Disease of the Newborn

- Rh- women are given an injection of anti-Rh antibodies no later than 72 hours after birth to an Rh+ baby
- These antibodies attack the Rh antibodies formed by the mother
- Injection repeated if an Rh- mother has another Rh+ baby in later pregnancies

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</tr>
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<td>Eosinophils</td>
</tr>
<tr>
<td>Monocytes</td>
</tr>
<tr>
<td>Neutrophils</td>
</tr>
<tr>
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