CHAPTER 17

Blood
• What are the functions of the following components of blood:

1. Plasma
2. White Blood Cells (WBCs)
3. Platelets
4. Red Blood Cells (RBCs)
Blood Composition

- Blood: a fluid connective tissue composed of
  - Plasma
  - Formed elements
    - Erythrocytes (red blood cells, or RBCs)
    - Leukocytes (white blood cells, or WBCs)
    - Platelets
Blood Composition

- Hematocrit
  - Percent of blood volume that is RBCs
  - 47% ± 5% for males
  - 42% ± 5% for females
1. Withdraw blood and place in tube.
2. Centrifuge the blood sample.

**Plasma**
- 55% of whole blood
- Least dense component

**Buffy coat**
- Leukocytes and platelets
- <1% of whole blood

**Erythrocytes**
- 45% of whole blood
- Most dense component
Physical Characteristics and Volume

- Sticky, opaque fluid
- Color scarlet to dark red
- pH 7.35–7.45
- 38°C
- ~8% of body weight
- Average volume: 5–6 L for males, and 4–5 L for females
Functions of Blood

1. Distribution of

- $O_2$ and nutrients to body cells
- Metabolic wastes to the lungs and kidneys for elimination
- Hormones from endocrine organs to target organs
Functions of Blood

2. Regulation of

- Body temperature by absorbing and distributing heat
- Normal pH using buffers
- Adequate fluid volume in the circulatory system
Functions of Blood

3. Protection against
   - Blood loss
     - Plasma proteins and platelets initiate clot formation
   - Infection
     - Antibodies
     - Complement proteins
     - WBCs defend against foreign invaders
Blood Plasma

- 90% water
- Proteins are mostly produced by the liver
  - 60% albumin
  - 36% globulins
  - 4% fibrinogen
Blood Plasma

• Nitrogenous by-products of metabolism—lactic acid, urea, creatinine
• Nutrients—glucose, carbohydrates, amino acids
• Electrolytes—Na⁺, K⁺, Ca²⁺, Cl⁻, HCO₃⁻
• Respiratory gases—O₂ and CO₂
• Hormones
Formed Elements

• Only WBCs are complete cells
• RBCs have no nuclei or organelles
• Platelets are cell fragments
• Most formed elements survive in the bloodstream for only a few days
• Most blood cells originate in bone marrow and do not divide
Erythrocytes

• Biconcave discs, anucleate, essentially no organelles
• Filled with hemoglobin (Hb) for gas transport
• Contain the plasma membrane protein spectrin and other proteins
  • Provide flexibility to change shape as necessary
• Are the major factor contributing to blood viscosity
Erythrocytes

• Structural characteristics contribute to gas transport
  • Biconcave shape—huge surface area relative to volume
  • >97% hemoglobin (not counting water)
  • No mitochondria; ATP production is anaerobic; no O$_2$ is used in generation of ATP
• A superb example of complementarity of structure and function!
Erythrocyte Function

• RBCs are dedicated to respiratory gas transport

• Hemoglobin binds reversibly with oxygen
Erythrocyte Function

• Hemoglobin structure
  • Protein globin: two alpha and two beta chains
  • Heme pigment bonded to each globin chain
• Iron atom in each heme can bind to one $O_2$
• Each Hb molecule can transport four $O_2$
(a) Hemoglobin consists of globin (two alpha and two beta polypeptide chains) and four heme groups.

(b) Iron-containing heme pigment.
Hemoglobin (Hb)

- $O_2$ loading in the lungs
  - Produces oxyhemoglobin (ruby red)

- $O_2$ unloading in the tissues
  - Produces deoxyhemoglobin or reduced hemoglobin (dark red)

- $CO_2$ loading in the tissues
  - Produces carbaminohemoglobin (carries 20% of $CO_2$ in the blood)
Hematopoiesis

- Hematopoiesis (hemopoiesis): blood cell formation
  - Occurs in red bone marrow of axial skeleton, girdles and proximal epiphyses of humerus and femur
Hematopoiesis

• Hemocytoblasts (hematopoietic stem cells)
  • Give rise to all formed elements
  • Hormones and growth factors push the cell toward a specific pathway of blood cell development

• New blood cells enter blood sinusoids
Erythropoiesis

- Erythropoiesis: red blood cell production
  - A hemocytoblast is transformed into a proerythroblast
  - Proerythroblasts develop into early erythroblasts
Erythropoiesis

- Phases in development
  1. Ribosome synthesis
  2. Hemoglobin accumulation
  3. Ejection of the nucleus and formation of reticulocytes
- Reticulocytes then become mature erythrocytes
Figure 17.5

Stem cell  

Hemocytoblast  

Committed cell  

Proerythroblast  

Developmental pathway  

Phase 1  
Ribosome synthesis  

Phase 2  
Hemoglobin accumulation  

Phase 3  
Ejection of nucleus  

Early erythroblast  

Late erythroblast  

Normoblast  

Reticulocyte  

Erythrocyte
Regulation of Erythropoiesis

• Too few RBCs leads to tissue hypoxia
• Too many RBCs increases blood viscosity
• Balance between RBC production and destruction depends on
  • Hormonal controls
  • Adequate supplies of iron, amino acids, and B vitamins
Hormonal Control of Erythropoiesis

• Erythropoietin (EPO)
  • Direct stimulus for erythropoiesis
  • Released by the kidneys in response to hypoxia
Hormonal Control of Erythropoiesis

• Causes of hypoxia
  • Hemorrhage or increased RBC destruction reduces RBC numbers
  • Insufficient hemoglobin (e.g., iron deficiency)
  • Reduced availability of $O_2$ (e.g., high altitudes)
Hormonal Control of Erythropoiesis

• Effects of EPO (Erythropoietin)
  • More rapid maturation of committed bone marrow cells
  • Increased circulating reticulocyte count in 1–2 days
• Testosterone also enhances EPO production, resulting in higher RBC counts in males
Figure 17.6

**Homeostasis:** Normal blood oxygen levels

1. **Stimulus:** Hypoxia (low blood \(O_2\)-carrying ability) due to
   - Decreased RBC count
   - Decreased amount of hemoglobin
   - Decreased availability of \(O_2\)

2. **Kidney** (and liver to a smaller extent) releases erythropoietin.

3. Erythropoietin stimulates red bone marrow.

4. Enhanced erythropoiesis increases RBC count.

5. \(O_2\)-carrying ability of blood increases.

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Homeostasis: Normal blood oxygen levels

1 Stimulus: Hypoxia (low blood O₂-carrying ability) due to
- Decreased RBC count
- Decreased amount of hemoglobin
- Decreased availability of O₂
Homeostasis: Normal blood oxygen levels

1. **Stimulus:** Hypoxia (low blood $O_2$-carrying ability) due to
   - Decreased RBC count
   - Decreased amount of hemoglobin
   - Decreased availability of $O_2$

2. Kidney (and liver to a smaller extent) releases erythropoietin.
Kidney (and liver to a smaller extent) releases erythropoietin. Erythropoietin stimulates red bone marrow.

Stimulus:
Hypoxia (low blood $O_2$-carrying ability) due to
- Decreased RBC count
- Decreased amount of hemoglobin
- Decreased availability of $O_2$

IMBALANCE

Homeostasis: Normal blood oxygen levels

IMBALANCE

Kidney (and liver to a smaller extent) releases erythropoietin.

Figure 17.6, step 3
Kidney (and liver to a smaller extent) releases erythropoietin. Erythropoietin stimulates red bone marrow. Enhanced erythropoiesis increases RBC count.

**Stimulus:** Hypoxia (low blood $O_2$-carrying ability) due to
- Decreased RBC count
- Decreased amount of hemoglobin
- Decreased availability of $O_2$

**Homeostasis:** Normal blood oxygen levels

2. Kidney (and liver to a smaller extent) releases erythropoietin.

3. Erythropoietin stimulates red bone marrow.

4. Enhanced erythropoiesis increases RBC count.

Figure 17.6, step 4
Kidney (and liver to a smaller extent) releases erythropoietin. Erythropoietin stimulates red bone marrow. Enhanced erythropoiesis increases RBC count. $O_2^-$-carrying ability of blood increases.

**Stimulus:** Hypoxia (low blood $O_2$-carrying ability) due to
- Decreased RBC count
- Decreased amount of hemoglobin
- Decreased availability of $O_2$

**Homeostasis:** Normal blood oxygen levels

**IMBALANCE**

2) Kidney (and liver to a smaller extent) releases erythropoietin.

3) Erythropoietin stimulates red bone marrow.

4) Enhanced erythropoiesis increases RBC count.

5) $O_2^-$-carrying ability of blood increases.
Dietary Requirements for Erythropoiesis

• Nutrients—amino acids, lipids, and carbohydrates

• Iron
  • Stored in Hb (65%), the liver, spleen, and bone marrow
  • Stored in cells as ferritin and hemosiderin
  • Transported loosely bound to the protein transferrin

• Vitamin $\text{B}_{12}$ and folic acid—necessary for DNA synthesis for cell division
Fate and Destruction of Erythrocytes

• Life span: 100–120 days
• Old RBCs become fragile, and Hb begins to degenerate
• Macrophages engulf dying RBCs in the spleen
Fate and Destruction of Erythrocytes

• Heme and globin are separated
  • Iron is salvaged for reuse
  • Heme is degraded to yellow the pigment bilirubin
• Liver secretes bilirubin (in bile)) into the intestines
• Degraded pigment leaves the body in feces as stercobilin
• Globin is metabolized into amino acids
1. Low O$_2$ levels in blood stimulate kidneys to produce erythropoietin.
2. Erythropoietin levels rise in blood.
3. Erythropoietin and necessary raw materials in blood promote erythropoiesis in red bone marrow.
4. New erythrocytes enter bloodstream; function about 120 days.
5. Aged and damaged red blood cells are engulfed by macrophages of liver, spleen, and bone marrow; the hemoglobin is broken down.

- Hemoglobin
- Heme
- Globin
- Iron stored as ferritin, hemosiderin
- Amino acids
- Iron is bound to transferrin and released to blood from liver as needed for erythropoiesis.

- Bilirubin is picked up from blood by liver, secreted into intestine in bile, metabolized to stercobilin by bacteria, and excreted in feces.

- Food nutrients, including amino acids, Fe, B$_{12}$, and folic acid, are absorbed from intestine and enter blood.

- Raw materials are made available in blood for erythrocyte synthesis.

Figure 17.7
Low O2 levels in blood stimulate kidneys to produce erythropoietin.
1. Low O2 levels in blood stimulate kidneys to produce erythropoietin.
2. Erythropoietin levels rise in blood.
1. Low O₂ levels in blood stimulate kidneys to produce erythropoietin.

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Aged and damaged red blood cells are engulfed by macrophages of liver, spleen, and bone marrow; the hemoglobin is broken down.

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6) Raw materials are made available in blood for erythrocyte synthesis.

- Hemoglobin
  - Hem
  - Globin
  - Amino acids
  - Iron stored as ferritin, hemosiderin

- Bilirubin is picked up from blood by liver, secreted into intestine in bile, metabolized to stercobilin by bacteria, and excreted in feces.

- Iron is bound to transferrin and released to blood from liver as needed for erythropoiesis.

- Circulation

- Food nutrients, including amino acids, Fe, B12, and folic acid, are absorbed from intestine and enter blood.
Low $O_2$ levels in blood stimulate kidneys to produce erythropoietin.

Erythropoietin levels rise in blood.

Erythropoietin and necessary raw materials in blood promote erythropoiesis in red bone marrow.

Aged and damaged red blood cells are engulfed by macrophages of liver, spleen, and bone marrow; the hemoglobin is broken down.

New erythrocytes enter bloodstream; function about 120 days.

Food nutrients, including amino acids, Fe, $B_{12}$, and folic acid, are absorbed from intestine and enter blood.

Raw materials are made available in blood for erythrocyte synthesis.

Hemoglobin

Amino acids

Iron is bound to transferrin and released to blood from liver as needed for erythropoiesis.
Erythrocyte Disorders

• Anemia: blood has abnormally low $O_2$-carrying capacity
  • A sign rather than a disease itself
  • Blood $O_2$ levels cannot support normal metabolism
  • Accompanied by fatigue, paleness, shortness of breath, and chills
Causes of Anemia

1. Insufficient erythrocytes
   - Hemorrhagic anemia: acute or chronic loss of blood
   - Hemolytic anemia: RBCs rupture prematurely
   - Aplastic anemia: destruction or inhibition of red bone marrow
Causes of Anemia

2. Low hemoglobin content
   - Iron-deficiency anemia
     - Secondary result of hemorrhagic anemia or
     - Inadequate intake of iron-containing foods or
     - Impaired iron absorption
Causes of Anemia

- Pernicious anemia
  - Deficiency of vitamin $B_{12}$
  - Lack of intrinsic factor needed for absorption of $B_{12}$
  - Treated by intramuscular injection of $B_{12}$ or application of Nascobal
3. Abnormal hemoglobin
   - Thalassemias
     - Absent or faulty globin chain
     - RBCs are thin, delicate, and deficient in hemoglobin
Causes of Anemia

• Sickle-cell anemia
  • Defective gene codes for abnormal hemoglobin (HbS)
  • Causes RBCs to become sickle shaped in low-oxygen situations
(a) Normal erythrocyte has normal hemoglobin amino acid sequence in the beta chain.

(b) Sickled erythrocyte results from a single amino acid change in the beta chain of hemoglobin.
Erythrocyte Disorders

• Polycythemia: excess of RBCs that increase blood viscosity

• Results from:
  • Polycythemia vera—bone marrow cancer
  • Secondary polycythemia—when less $O_2$ is available (high altitude) or when EPO production increases
  • Blood doping
Leukocytes

• Make up <1% of total blood volume
• Can leave capillaries via diapedesis
• Move through tissue spaces by ameboid motion and positive chemotaxis
• Leukocytosis: WBC count over 11,000/mm³
  • Normal response to bacterial or viral invasion
Figure 17.9

**Differential WBC count**

(All total 4800 – 10,800/l)

- **Granulocytes**
  - Neutrophils (50 – 70%)
  - Eosinophils (2 – 4%)
  - Basophils (0.5 – 1%)

- **Agranulocyte**
  - Lymphocytes (25 – 45%)
  - Monocytes (3 – 8%)
Granulocytes

- Granulocytes: neutrophils, eosinophils, and basophils
  - Cytoplasmic granules stain specifically with Wright’s stain
  - Larger and shorter-lived than RBCs
  - Lobed nuclei
  - Phagocytic
Neutrophils

• Most numerous WBCs
• Polymorphonuclear leukocytes (PMNs)
• Fine granules take up both acidic and basic dyes
• Give the cytoplasm a lilac color
• Granules contain hydrolytic enzymes or defensins
• Very phagocytic—“bacteria slayers”
Eosinophils

- Red-staining, bilobed nuclei
- Red to crimson (acidophilic) coarse, lysosome-like granules
- Digest parasitic worms that are too large to be phagocytized
- Modulators of the immune response
Basophils

- Rarest WBCs
- Large, purplish-black (basophilic) granules contain histamine
  - Histamine: an inflammatory chemical that acts as a vasodilator and attracts other WBCs to inflamed sites
- Are functionally similar to mast cells
(a) **Neutrophil;**
multilobed nucleus

(b) **Eosinophil;**
bilobed nucleus, red cytoplasmic granules

(c) **Basophil;**
bilobed nucleus, purplish-black cytoplasmic granules
Agranulocytes

- Agranulocytes: lymphocytes and monocytes
  - Lack visible cytoplasmic granules
  - Have spherical or kidney-shaped nuclei
Lymphocytes

• Large, dark-purple, circular nuclei with a thin rim of blue cytoplasm

• Mostly in lymphoid tissue; few circulate in the blood

• Crucial to immunity
Lymphocytes

• Two types
  • T cells act against virus-infected cells and tumor cells
  • B cells give rise to plasma cells, which produce antibodies
Monocytes

• The largest leukocytes
• Abundant pale-blue cytoplasm
• Dark purple-staining, U- or kidney-shaped nuclei
Monocytes

- Leave circulation, enter tissues, and differentiate into macrophages
  - Actively phagocytic cells; crucial against viruses, intracellular bacterial parasites, and chronic infections
- Activate lymphocytes to mount an immune response
(d) Small lymphocyte; large spherical nucleus

(e) Monocyte; kidney-shaped nucleus
<table>
<thead>
<tr>
<th>CELL TYPE</th>
<th>ILLUSTRATION</th>
<th>DESCRIPTION*</th>
<th>CELLS/µL (mm³) OF BLOOD</th>
<th>DURATION OF DEVELOPMENT (D) AND LIFE SPAN (LS)</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (red</td>
<td><img src="image1.png" alt="Illustration" /></td>
<td>Biconcave, anucleate disc; salmon-colored; diameter 7–8 µm</td>
<td>4–6 million</td>
<td>D: about 15 days LS: 100–120 days</td>
<td>Transport oxygen and carbon dioxide</td>
</tr>
<tr>
<td>blood cells, RBCs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leukocytes (white</td>
<td><img src="image2.png" alt="Illustration" /></td>
<td>Spherical, nucleated cells</td>
<td>4800–10,800</td>
<td></td>
<td></td>
</tr>
<tr>
<td>blood cells, WBCs)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Granulocytes</td>
<td><img src="image3.png" alt="Illustration" /></td>
<td>Nucleus multilobed; inconspicuous cytoplasmic granules; diameter 10–12 µm</td>
<td>3000–7000</td>
<td>D: about 14 days LS: 6 hours to a few days</td>
<td>Phagocytize bacteria</td>
</tr>
<tr>
<td>Neutrophil</td>
<td><img src="image4.png" alt="Illustration" /></td>
<td>Nucleus bilobed; red cytoplasmic granules; diameter 10–14 µm</td>
<td>100–400</td>
<td>D: about 14 days LS: about 5 days</td>
<td>Kill parasitic worms; complex role in allergy and asthma</td>
</tr>
<tr>
<td>Eosinophil</td>
<td><img src="image5.png" alt="Illustration" /></td>
<td>Nucleus bilobed; large purplish-black cytoplasmic granules; diameter 10–14 µm</td>
<td>20–50</td>
<td>D: 1–7 days LS: a few hours to a few days</td>
<td>Release histamine and other mediators of inflammation; contain heparin, an anticoagulant</td>
</tr>
</tbody>
</table>

* Appearance when stained with Wright's stain.
**TABLE 17.2** Summary of Formed Elements of the Blood

<table>
<thead>
<tr>
<th>CELL TYPE</th>
<th>ILLUSTRATION</th>
<th>DESCRIPTION*</th>
<th>CELLS/µL (mm³) OF BLOOD</th>
<th>DURATION OF DEVELOPMENT (D) AND LIFE SPAN (LS)</th>
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</thead>
<tbody>
<tr>
<td>Agranulocytes</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Lymphocyte</td>
<td></td>
<td>Nucleus spherical or indented; pale blue cytoplasm; diameter 5–17 µm</td>
<td>1500–3000</td>
<td>D: days to weeks LS: hours to years</td>
<td>Mount immune response by direct cell attack or via antibodies</td>
</tr>
<tr>
<td>• Monocyte</td>
<td></td>
<td>Nucleus U or kidney shaped; gray-blue cytoplasm; diameter 14–24 µm</td>
<td>100–700</td>
<td>D: 2–3 days LS: months</td>
<td>Phagocytosis; develop into macrophages in the tissues</td>
</tr>
<tr>
<td>Platelets</td>
<td></td>
<td>Discoid cytoplasmic fragments containing granules; stain deep purple; diameter 2–4 µm</td>
<td>150,000–400,000</td>
<td>D: 4–5 days LS: 5–10 days</td>
<td>Seal small tears in blood vessels; instrumental in blood clotting</td>
</tr>
</tbody>
</table>

* Appearance when stained with Wright’s stain.
Warm Up 4/14

Describe the function and composition of blood. Name all of the major cell types!
Leukopoiesis

• Production of WBCs

• Stimulated by chemical messengers from bone marrow and mature WBCs
  • Interleukins (e.g., IL-1, IL-2)
  • Colony-stimulating factors (CSFs) named for the WBC type they stimulate (e.g., granulocyte-CSF stimulates granulocytes)

• All leukocytes originate from hemocytoblasts
Figure 17.11

Stem cells
- Hemocytoblast
- Myeloid stem cell
- Lymphoid stem cell

Committed cells
- Myeloblast
- Myeloblast
- Myeloblast
- Monoblast
- Lymphoblast

Developmental pathway
- Promyelocyte
  - Eosinophilic myelocyte
    - Eosinophilic band cells
  - Basophilic myelocyte
    - Basophilic band cells
  - Neutrophilic myelocyte
    - Neutrophilic band cells
- Promonocyte
  - Monocytes
    - Eosinophils (a)
    - Basophils (b)
    - Neutrophils (c)
  - Lymphocytes (e)
- Granular leukocytes
- Agranular leukocytes

Some become
Leukocyte Disorders

• Leukopenia
  • Abnormally low WBC count—drug induced

• Leukemias
  • Cancerous conditions involving WBCs
  • Named according to the abnormal WBC clone involved
  • Myelocytic leukemia involves myeloblasts
  • Lymphocytic leukemia involves lymphocytes

• Acute leukemia involves blast-type cells and primarily affects children

• Chronic leukemia is more prevalent in older people
Leukemia

- Bone marrow totally occupied with cancerous leukocytes
- Immature nonfunctional WBCs in the bloodstream
- Death caused by internal hemorrhage and overwhelming infections
- Treatments include irradiation, antileukemic drugs, and stem cell transplants
Platelets

• Small fragments of megakaryocytes
• Formation is regulated by thrombopoietin
• Blue-staining outer region, purple granules
• Form a temporary platelet plug that helps seal breaks in blood vessels
Figure 17.12

Stem cell

Developmental pathway

Hemocytoblast

Megakaryoblast

Promegakaryocyte

Megakaryocyte

Platelets
Hemostasis

- Fast series of reactions for stoppage of bleeding
  1. Vascular spasm
  2. Platelet plug formation
  3. Coagulation (blood clotting)
Vascular Spasm

• Vasoconstriction of damaged blood vessel

• Triggers
  • Direct injury
  • Chemicals released by endothelial cells and platelets
  • Pain reflexes
Platelet Plug Formation

• Positive feedback cycle
  • At site of blood vessel injury, platelets
    • Stick to exposed collagen fibers with the help of von Willebrand factor, a plasma protein
    • Swell, become spiked and sticky, and release chemical messengers
      • ADP causes more platelets to stick and release their contents
      • Serotonin and thromboxane A$_2$ enhance vascular spasm and more platelet aggregation
Figure 17.13

Step 1 Vascular spasm

- Smooth muscle contracts, causing vasoconstriction.

Step 2 Platelet plug formation

- Injury to lining of vessel exposes collagen fibers;
  - Platelets adhere.
  - Platelets release chemicals that make nearby platelets sticky; platelet plug forms.

Step 3 Coagulation

- Fibrin forms a mesh that traps red blood cells and platelets, forming the clot.
Coagulation

• A set of reactions in which blood is transformed from a liquid to a gel
• Reinforces the platelet plug with fibrin threads
Transfusions

• Whole-blood transfusions are used when blood loss is substantial
• Packed red cells (plasma removed) are used to restore oxygen-carrying capacity
• Transfusion of incompatible blood can be fatal
Human Blood Groups

• RBC membranes bear 30 types glycoprotein antigens that are
  • Perceived as foreign if transfused blood is mismatched
  • Unique to each individual
  • Promoters of agglutination and are called agglutinogens
• Presence or absence of each antigen is used to classify blood cells into different groups
Blood Groups

• Humans have 30 varieties of naturally occurring RBC antigens

• Antigens of the ABO and Rh blood groups cause vigorous transfusion reactions

• Other blood groups (MNS, Duffy, Kell, and Lewis) are usually weak agglutinogens
ABO Blood Groups

• Types A, B, AB, and O

• Based on the presence or absence of two agglutinogens (A and B) on the surface of the RBCs

• Blood may contain anti-A or anti-B antibodies (agglutinins) that act against transfused RBCs with ABO antigens not normally present

• Anti-A or anti-B form in the blood at about 2 months of age
**TABLE 17.4** ABO Blood Groups

<table>
<thead>
<tr>
<th>BLOOD GROUP</th>
<th>WHITE</th>
<th>BLACK</th>
<th>ASIAN</th>
<th>NATIVE AMERICAN</th>
<th>RBC ANTIGENS (AGGLUTINOGENS)</th>
<th>PLASMA ANTIBODIES (AGGLUTININS)</th>
<th>BLOOD THAT CAN BE RECEIVED</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>4</td>
<td>4</td>
<td>5</td>
<td>&lt;1</td>
<td>A</td>
<td>None</td>
<td>A, B, AB, O (Universal recipient)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>B</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>11</td>
<td>20</td>
<td>27</td>
<td>4</td>
<td>B</td>
<td>Anti-A (a)</td>
<td>B, O</td>
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<td></td>
<td></td>
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<tr>
<td>A</td>
<td>40</td>
<td>27</td>
<td>28</td>
<td>16</td>
<td>A</td>
<td>Anti-B (b)</td>
<td>A, O</td>
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</tr>
<tr>
<td>O</td>
<td>45</td>
<td>49</td>
<td>40</td>
<td>79</td>
<td>None</td>
<td>Anti-A (a) Anti-B (b)</td>
<td>O (Universal donor)</td>
</tr>
</tbody>
</table>

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Rh Blood Groups

• There are 45 different Rh agglutinogens (Rh factors)
• C, D, and E are most common
• Rh$^+$ indicates presence of D
Rh Blood Groups

• Anti-Rh antibodies are not spontaneously formed in Rh\(^-\) individuals
• Anti-Rh antibodies form if an Rh\(^-\) individual receives Rh\(^+\) blood
• A second exposure to Rh\(^+\) blood will result in a typical transfusion reaction
Transfusion Reactions

- Occur if mismatched blood is infused
- Donor’s cells
  - Are attacked by the recipient’s plasma agglutinins
  - Agglutinate and clog small vessels
  - Rupture and release free hemoglobin into the bloodstream
- Result in
  - Diminished oxygen-carrying capacity
  - Hemoglobin in kidney tubules and renal failure
Blood Typing

• When serum containing anti-A or anti-B agglutinins is added to blood, agglutination will occur between the agglutinin and the corresponding agglutinogens

• Positive reactions indicate agglutination
### ABO Blood Typing

<table>
<thead>
<tr>
<th>Blood Type Being Tested</th>
<th>RBC Agglutinogens</th>
<th>Serum Reaction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Anti-A</td>
</tr>
<tr>
<td>AB</td>
<td>A and B</td>
<td>+</td>
</tr>
<tr>
<td>B</td>
<td>B</td>
<td>-</td>
</tr>
<tr>
<td>A</td>
<td>A</td>
<td>+</td>
</tr>
<tr>
<td>O</td>
<td>None</td>
<td>-</td>
</tr>
</tbody>
</table>
**Blood being tested**

**Type AB** (contains agglutinogens A and B; agglutinates with both sera)

**Type A** (contains agglutinogen A; agglutinates with anti-A)

**Type B** (contains agglutinogen B; agglutinates with anti-B)

**Type O** (contains no agglutinogens; does not agglutinate with either serum)
Restoring Blood Volume

• Death from shock may result from low blood volume

• Volume must be replaced immediately with
  
  • Normal saline or multiple-electrolyte solution that mimics plasma electrolyte composition
  
  • Plasma expanders (e.g., purified human serum albumin, hetastarch, and dextran)
    
    • Mimic osmotic properties of albumin
    
    • More expensive and may cause significant complications
Diagnostic Blood Tests

• Hematocrit
• Blood glucose tests
• Microscopic examination reveals variations in size and shape of RBCs, indications of anemias
Diagnostic Blood Tests

- Differential WBC count
- Prothrombin time and platelet counts assess hemostasis
- SMAC, a blood chemistry profile
- Complete blood count (CBC)
Heart Anatomy / Physiology
Whiteboard Review

- Label the interior and exterior anatomy of the heart
- Describe and show the pathway of blood through the heart
- Describe and show the 5 steps of excitation (challenge: correlate each step with the 3 waves of an ECG)
- Describe and show the 3 phases of the cardiac cycle
- What is the difference in function of the atrium and ventricles?
- What is the difference between pulmonary, systemic, and coronary circulation?
- Label and describe the function of the 4 valves in our heart.