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**
  - Percent of blood volume that is RBCs
  - 47% ± 5% for males
  - 42% ± 5% for females

- **Blood**: Withdraw blood and place in tube.
- **Centrifuge the blood sample.**
Physical Characteristics and Volume

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

Functions of Blood

1. Distribution of
   - O₂ and nutrients to body cells
   - Metabolic wastes to the lungs and kidneys for elimination
   - Hormones from endocrine organs to target organs

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

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
  - 60% albumin
  - 36% globulins
  - 4% fibrinogen

Blood Plasma

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

Formed Elements

- Only ________s are complete cells
- RBCs have no nuclei or organelles
- Platelets are cell ____________________
- Most formed elements survive in the bloodstream for only a few ________
- Most blood cells originate in bone marrow and do not divide
**Erythrocytes**

- Biconcave discs, anucleate, essentially no
- 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

**Erythrocyte Function**

- RBCs are dedicated to respiratory gas
- Hemoglobin binds reversibly with oxygen

**Figure 17.3**

- Side view (cut)
- Top view
  - 2.5 µm
  - 7.5 µm

**Erythrocytes**

- Structural characteristics contribute to gas
  - Biconcave shape—huge surface area relative to volume
  - >97% hemoglobin (not counting water)
  - No mitochondria; ATP production is anaerobic; no O₂ is used in generation of ATP
- A superb example of complementarity of
Erythrocyte Function

• Hemoglobin structure
  – Protein globin: two alpha and two beta chains
  – Heme pigment bonded to each globin chain
• ______________ atom in each heme can bind to one O\(_2\) molecule
• Each Hb molecule can transport four O\(_2\)

__________ (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
  – 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 ______________________
  - Hormones and growth factors push the cell toward a specific pathway of blood cell development
- New blood cells enter blood sinusoids

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
Regulation of Erythropoiesis

• Too few RBCs leads to tissue ________________
• Too many RBCs increases blood viscosity
• Balance between RBC production and destruction depends on
  — ____________________ controls
  — Adequate supplies of ____________, amino acids, and B vitamins

Hormonal Control of Erythropoiesis

• Erythropoietin (EPO)
  — Direct stimulus for erythropoiesis
  — Released by the ________________ in response to hypoxia

Hormonal Control of Erythropoiesis

• Causes of ________________
  — Hemorrhage or increased RBC destruction reduces RBC numbers
  — Insufficient hemoglobin (e.g., iron deficiency)
  — Reduced availability of _______ (e.g., high altitudes)

Hormonal Control of Erythropoiesis

• Effects of EPO
  — More rapid maturation of committed bone marrow cells
  — Increased circulating reticulocyte count in 1–2 days
  — ____________________ also enhances EPO production, resulting in higher RBC counts in males
3/23/15

Figure 17.6

Kidney (and liver to a smaller extent) releases erythropoietin. Erythropoietin stimulates red bone marrow. Enhanced erythropoiesis increases RBC count. Oxygen carrying ability of blood increases.

Enhanced erythropoiesis increases RBC count.

Homeostasis: Normal blood oxygen levels

Stimulus: Hypoxia (low blood O₂ carrying ability) due to
• Decreased RBC count
• Decreased amount of hemoglobin
• Decreased availability of O₂

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 B₁₂ and folic acid—necessary for DNA synthesis

Fate and Destruction of Erythrocytes

• Life span: ____________ days
• Old RBCs become fragile, and Hb begins to degenerate
• Macrophages engulf dying RBCs in the spleen

Dietary Requirements for Erythropoiesis

• Heme and globin are separated
  – Iron is salvaged for ____________
  – 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 ____________

Fate and Destruction of Erythrocytes
Figure 17.7 Low O$_2$ levels in blood stimulate kidneys to produce erythropoietin.

1. Erythropoietin levels rise in blood.
2. Erythropoietin and necessary raw materials in blood promote erythropoiesis in red bone marrow.
3. Aged and damaged red blood cells are engulfed by macrophages of liver, spleen, and bone marrow; the hemoglobin is broken down.
4. Raw materials are made available in blood for erythrocyte synthesis.
5. New erythrocytes enter bloodstream; function about 120 days.

Erythrocyte Disorders
- _________________: 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 _______________
   - 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 ________________ content
   - Iron-deficiency anemia
     - Secondary result of hemorrhagic anemia or
     - Inadequate intake of iron-containing foods or
     - Impaired iron absorption
Causes of Anemia

- __________ anemia
  - Deficiency of vitamin B₁₂
  - Lack of intrinsic factor needed for absorption of B₁₂
  - Treated by intramuscular injection of B₁₂ or application of Nascobal

3. __________ hemoglobin
- Thalassemias
  - Absent or faulty globin chain
  - RBCs are thin, delicate, and deficient in hemoglobin
Erythrocyte Disorders

- ________________: 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