Functions of Blood

- transportation of critical substances
  - CO₂, O₂, nutrients, metabolic wastes, heat, hormones
- regulation of pH, body temperature, and fluid balance
- protection from disease and blood loss
  - clotting
  - immune system

Characteristics of Blood

- more viscous than water – increases work of heart
- adhesive due to platelets (thrombocytes)
- temperature of blood = 37°C; pH = 7.40
- blood volume
  - 5 liters in 70 kg male
  - regulated by aldosterone, ADH, ANF, and other hormones
Components of Blood

- Hematocrit = percent of blood that is formed elements
  - erythrocytes
  - leukocytes
  - thrombocytes
- Blood without formed elements is plasma
- Plasma without proteins is serum
Components of Blood

- Formed elements typically 48% in males, 42% in females
- differs due to blood loss at menstruation
- living at altitude increases hematocrit
- erythropoietin (EPO) used as (banned) performance enhancement for aerobic sports
Erythrocytes

- Red blood cells = 25 trillion in body; turnover of 3 million per second
- Transport O$_2$ and some CO$_2$
- 8 micron diameter biconcave discs
  - Maximizes surface area
  - Membrane is flexible enough to squeeze into capillaries (5 micron diameter)
- Live in blood for 120 days: no nucleus to repair cell when damaged

Erythrocytes

- Each erythrocyte contains 280 million molecules of hemoglobin
- Each hemoglobin consists of four proteins bound to each other (2 alpha, 2 beta “chains”)
  - Each protein contains a heme group near its center
  - Each heme group contains an iron molecule at its center
  - The iron molecule is what binds O$_2$
Hemoglobin

- hemoglobin releases $O_2$ when in environment that is low in $O_2$ (becoming deoxyhemoglobin), holds $O_2$ tight when in environment that is high in $O_2$ (becoming oxyhemoglobin)
  - when one $O_2$ is bound, the protein undergoes a conformational change (twists into a slightly different shape)
  - when one protein changes conformation, the others also are forced into a conformational change, since they are linked to each other

- this makes it more likely that $O_2$ will bind to the second, third, and fourth iron molecules
- this is called “positive cooperativity,” since the binding of one $O_2$ to iron makes it easier for the other three irons to bind $O_2$
  - from a practical standpoint, at any given time in a hemoglobin molecule, either all four irons will have $O_2$ bound, or none of them will
Hematopoiesis

- Formation of new red blood cells
- all RBC and WBC come from same multipotent stem cells
- RBC: reticulocyte has lost its nucleus and squeezes between endothelial cells of capillaries of red bone marrow

Erythropoiesis

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Erythropoiesis

- negative feedback regulation of RBC formation
  - sensed variable: hypoxia (low O₂ concentration) or low blood flow, especially in kidneys
  - erythropoietin (EPO) released by variety of tissues, but mainly by kidney
  - EPO stimulates erythropoiesis in bone marrow
Destruction of Erythrocytes

- Macrophages break down hemoglobin, recycling amino acids and iron.
- Rest of heme converted to biliverdin (green) and then bilirubin (yellow).
- Bilirubin is transported to liver on albumin (a plasma protein), and excreted in bile.
  - If bile ducts are blocked, bilirubin builds up in plasma, and yellow tints appear on skin and eyes (jaundice).
- Ultimately excreted in urine (urobilins make urine yellow) and feces (stercobilins and urobilins make feces brown).
Erythrocyte Disorders

- Thalassemia – defective hemoglobin production, growth and development problems if severe enough
- Sickle cell anemia – defective beta chain, cell forms sickle shape when oxygen is released, sticks in capillaries

Erythrocyte Disorders

- Anemias
  - hemorrhagic anemia – from severe bleeding
  - aplastic anemia – bone marrow defective
  - iron deficiency anemia – low iron
  - pernicious anemia – low vitamin B12 (needed for erythropoiesis) or intrinsic factor (required for B12 absorption)
Blood Typing

- **ABO system**
  - based on proteins on surface of erythrocyte (antigens), with antibody proteins in plasma
  - cross reactions cause agglutinations (clumping), which are basis of simple blood typing tests

- Rh+: has Rh antigen on RBC surface
- Normally, a person does not have Rh antibodies in plasma (whether they are Rh+ or Rh-)
- if Rh- person gets Rh+ transfusion, Rh antibodies develop, and NEXT transfusion of Rh+ blood is major problem due to agglutination
  - erythroblastosis fetalis (hemolytic disease of the newborn)
Leukocytes (white blood cells)

- Protect body against microorganisms and diseased body cells, remove dead cells and debris
- Granulocytes: cytoplasm contains large granules; have multi-lobed nuclei
  - Three distinctive types: neutrophils, basophils, eosinophils
- Agranulocytes: cytoplasm contains small granules and nuclei that are not lobed
  - Two distinctive types: lymphocytes and monocytes
Hematopoiesis

Leukocytes (white blood cells):

- Neutrophils – recent infection (bacterial)
- Basophils – allergic reactions (release histamine and heparin, for vasodilation and anti-coagulation, respectively)
- Eosinophils – allergic reactions, bacterial infections, parasites
- Monocytes – later infection (viral or fungal)
- Lymphocytes (T cells, B cells, NK cells) – viral or bacterial infection, diseased body cells (cancer)
Leukocytes (white blood cells)

- function of phagocytes (can engulf pathogens – neutrophils, eosinophils, and especially monocytes are phagocytes)
  - margination: phagocyte adheres to blood vessel wall (endothelium displays protein flags to which the phagocyte sticks)
  - emigration: endothelium displays selectins to attract WBC

Leukocytes (white blood cells)

- function of phagocytes (cont.)
  - chemotaxis: attraction of phagocytes by release of chemical stimuli from pathogens or damaged tissues
  - destruction of bacteria by lysozymes (digestive enzymes), strong oxidants (think of hydrogen peroxide), and defensins (proteins that can kill a variety of pathogens)
Thrombocytes (Platelets)

- involved in hemostasis (stoppage of bleeding)
  - NOTE: read book for details
  - vascular spasm: arterioles constrict to limit blood loss, endothelial cells become sticky
  - platelet plug formation
    - platelets aggregate
    - form plug coagulation
    - clot formed
1. Platelet adhesion occurs when von Willebrand factor contacts collagen and platelets.

2. The platelet release reaction results in the release of ADP, thromboxanes, and other chemicals that activate other platelets.

3. Platelet aggregation occurs when fibronogen receptors on activated platelets bind to fibronogen, connecting the platelets to one another. A platelet plug is formed by the accumulating mass of platelets.