Essentials of Human Anatomy & Physiology

Seventh Edition

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# *Chapter 10*

# Blood

***Slides 10.1 – 10.31***

Lecture Slides in PowerPoint by Jerry L. Cook

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# Blood

- The only fluid tissue in the human body
- Classified as a connective tissue
  - Living cells = formed elements
  - Non-living matrix = plasma

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# Blood

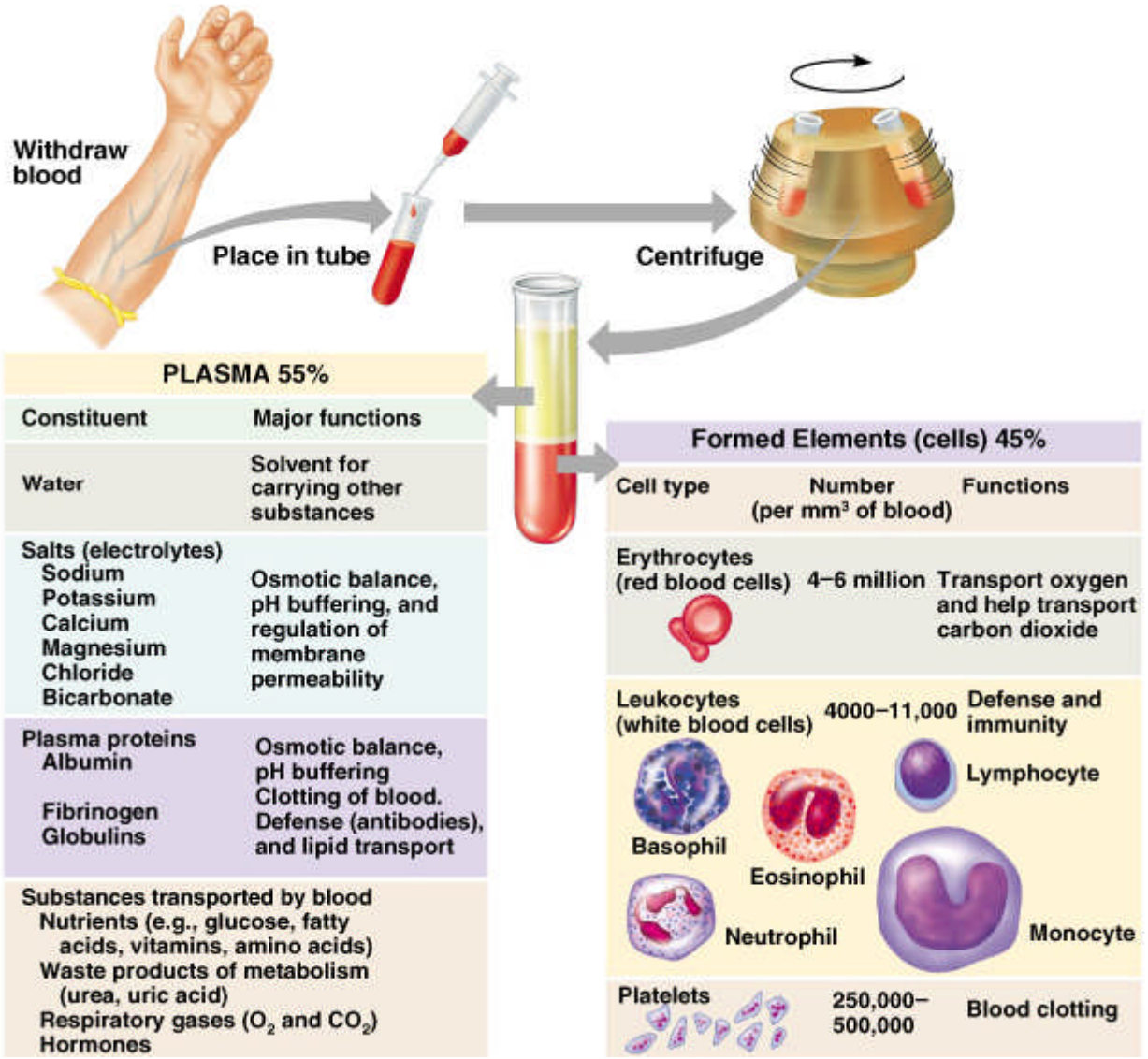


Figure 10.1

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# Physical Characteristics of Blood

- Color range
  - Oxygen-rich blood is scarlet red
  - Oxygen-poor blood is dull red
- pH must remain between 7.35–7.45
- Blood temperature is slightly higher than body temperature

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# Blood Plasma

- Composed of approximately 90 percent water
- Includes many dissolved substances
  - Nutrients
  - Salts (metal ions)
  - Respiratory gases
  - Hormones
  - Proteins
  - Waste products

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# Plasma Proteins

- Albumin – regulates osmotic pressure
- Clotting proteins – help to stem blood loss when a blood vessel is injured
- Antibodies – help protect the body from antigens

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# Formed Elements

- Erythrocytes = red blood cells
- Leukocytes = white blood cells
- Platelets = cell fragments

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## Table 10.2 Characteristics of Formed Elements of the Blood

| Cell type | Occurrence in blood (per $mm^3$) | Cell anatomy* | Function |
|---|---|---|---|
| **Erythrocytes** (red blood cells, or RBCs)  | 4–6 million | Salmon-colored biconcave disks; anucleate; literally, sacs of hemoglobin; most organelles have been ejected | Transport oxygen bound to hemoglobin molecules; also transport small amount of carbon dioxide |
| **Leukocytes** (white blood cells, or WBCs) | 4000–11,000 | | |
| *Granulocytes* | | | |
| • Neutrophils  | 3000–7000 (40–70% of WBCs) | Cytoplasm stains pale pink and contains fine granules, which are difficult to see; deep purple nucleus consists of three to seven lobes connected by thin strands of nucleoplasm | Active phagocytes; number increases rapidly during short-term or acute infections |
| • Eosinophils  | 100–400 (1–4% of WBCs) | Red coarse cytoplasmic granules; figure-8 or bilobed nucleus stains blue-red | Kill parasitic worms; increase during allergy attacks; might phagocytize antigen-antibody complexes and inactivate some inflammatory chemicals |

*Appearance when stained with Wright'

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## Table 10.2 Characteristics of Formed Elements of the Blood

| Cell type | Occurrence in blood (per $mm^3$) | Cell anatomy* | Function |
|---|---|---|---|
| • Basophils  | 20–50 (0–1% of WBCs) | Cytoplasm has a few large blue-purple granules; U- or S-shaped nucleus with constrictions, stains dark blue | Granules contain histamine (vasodilator chemical), which is discharged at sites of inflammation |
| *Agranulocytes* | | | |
| • ymphocytes  | 1500–3000 (20–45% of WBCs) | Cytoplasm pale blue and appears as thin rim around nucleus; spherical (or slightly indented) dark purple-blue nucleus | Part of immune system; one group (B lymphocytes) produces antibodies; other group (T lymphocytes) involved in graft rejection, fighting tumors and viruses, and activating B lymphocytes |
| • Monocytes  | 100–700 (4–8% of WBCs) | Abundant gray-blue cytoplasm; dark blue-purple nucleus often kidney-shaped | Active phagocytes that become macrophages in the tissues; long-term "clean-up team"; increase in number during chronic infections such as tuberculosis |
| **Platelets** | 250,000–500,000 | Essentially irregularly shaped cell fragments; stain deep purple | Needed for normal blood clotting; initiate clotting cascade by clinging to broken area; help to control blood loss from broken blood vessels |

*Appearance when stained with Wright's

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# Erythrocytes (Red Blood Cells)

- The main function is to carry oxygen
- Anatomy of circulating erythrocytes
  - Biconcave disks
  - Essentially bags of hemoglobin
  - Anucleate (no nucleus)
  - Contain very few organelles
- Outnumber white blood cells 1000:1

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# Hemoglobin

- Iron-containing protein
- Binds strongly, but reversibly, to oxygen
- Each hemoglobin molecule has four oxygen binding sites
- Each erythrocyte has 250 million hemoglobin molecules

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# Leukocytes (White Blood Cells)

- Crucial in the body's defense against disease
- These are complete cells, with a nucleus and organelles
- Able to move into and out of blood vessels (diapedesis)
- Can move by ameboid motion
- Can respond to chemicals released by damaged tissues

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# Leukocyte Levels in the Blood

- Normal levels are between 4,000 and 11,000 cells per millimeter
- Abnormal leukocyte levels
  - Leukocytosis
    - Above 11,000 leukocytes/ml
    - Generally indicates an infection
  - Leukopenia
    - Abnormally low leukocyte level
    - Commonly caused by certain drugs

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# Types of Leukocytes

- Granulocytes
  - Granules in their cytoplasm can be stained
  - Include neutrophils, eosinophils, and basophils

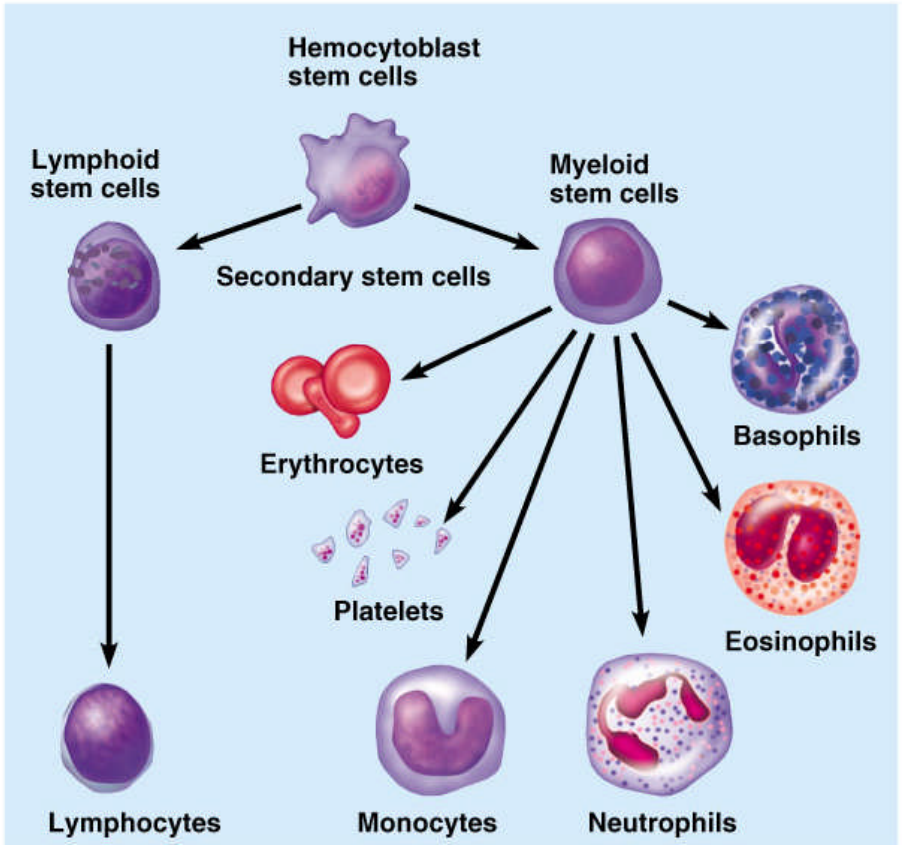


Figure 10.4

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# Types of Leukocytes

- Agranulocytes
  - Lack visible cytoplasmic granules
  - Include lymphocytes and monocytes

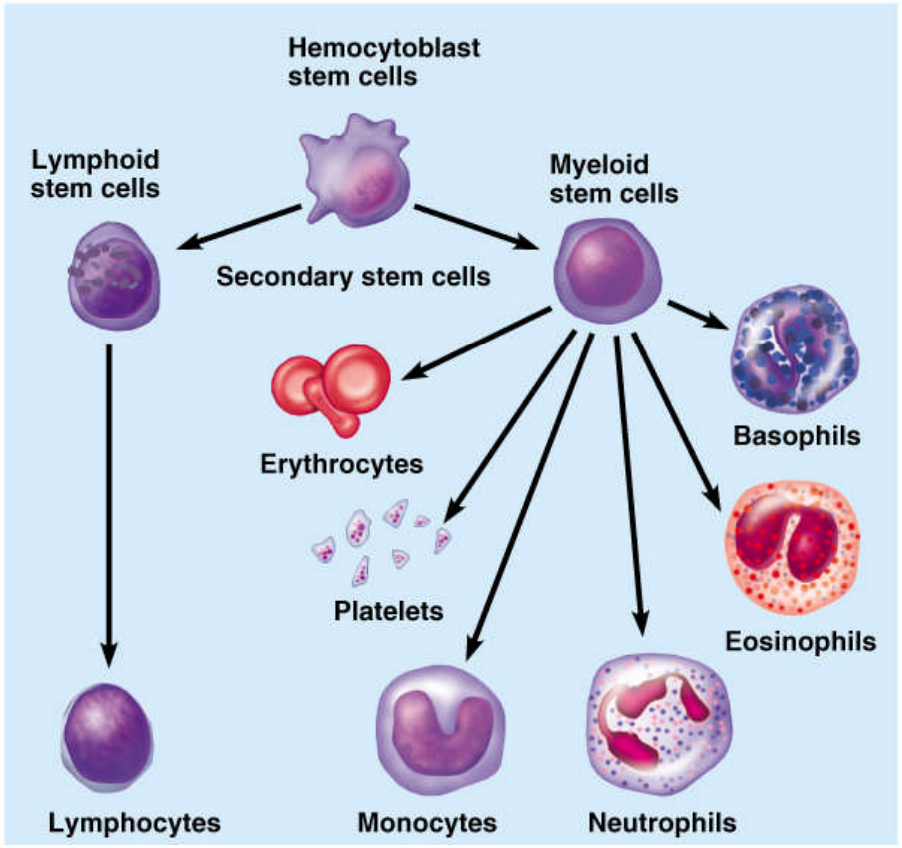


Figure 10.4

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# Granulocytes

- Neutrophils
  - Multilobed nucleus with fine granules
  - Act as phagocytes at active sites of infection
- Eosinophils
  - Large brick-red cytoplasmic granules
  - Found in repsonse to allergies and parasitic worms

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# Granulocytes

- Basophils
  - Have histamine-containing granules
  - Initiate inflammation

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# Agranulocytes

- Lymphocytes
  - Nucleus fills most of the cell
  - Play an important role in the immune response
- Monocytes
  - Largest of the white blood cells
  - Function as macrophages
  - Important in fighting chronic infection

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# Platelets

- Derived from ruptured multinucleate cells (megakaryocytes)
- Needed for the clotting process
- Normal platelet count = 300,000/$mm^3$

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# Hematopoiesis

- Blood cell formation
- Occurs in red bone marrow
- All blood cells are derived from a common stem cell (hemocytoblast)
- Hemocytoblast differentiation
  - Lymphoid stem cell produces lymphocytes
  - Myeloid stem cell produces other formed elements

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# Fate of Erythrocytes

- Unable to divide, grow, or synthesize proteins
- Wear out in 100 to 120 days
- When worn out, are eliminated by phagocytes in the spleen or liver
- Lost cells are replaced by division of hemocytoblasts

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# Control of Erythrocyte Production

- Rate is controlled by a hormone (erythropoietin)
- Kidneys produce most erythropoietin as a response to reduced oxygen levels in the blood
- Homeostasis is maintained by negative feedback from blood oxygen levels

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# Control of Erythrocyte Production

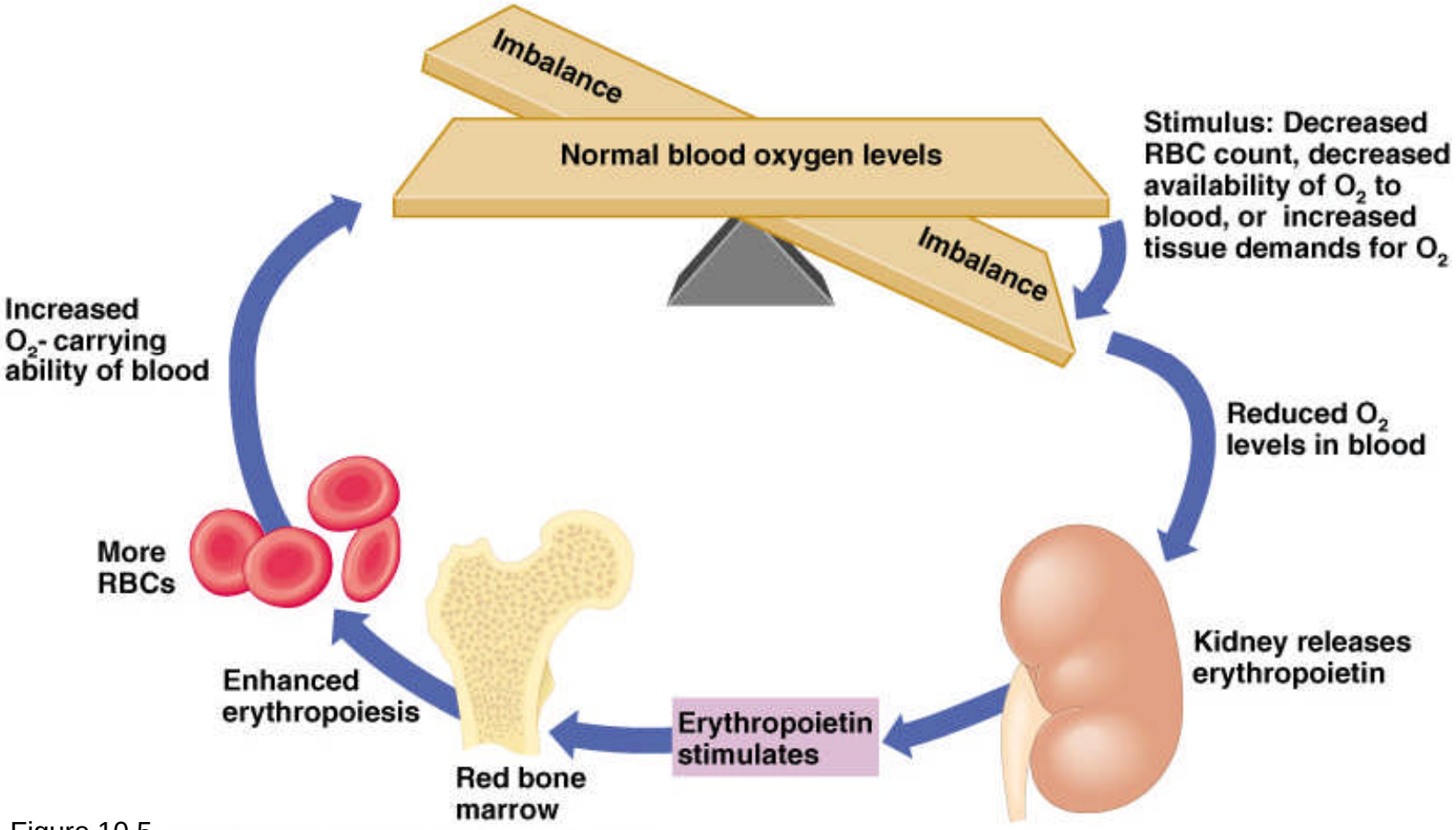


Figure 10.5

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# Hemostasis

- Stoppage of blood flow
- Result of a break in a blood vessel
- Hemostasis involves three phases
  - Platelet plug formation
  - Vascular spasms
  - Coagulation

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# Platelet Plug Formation

- Collagen fibers are exposed by a break in a blood vessel
- Platelets become “sticky” and cling to fibers
- Anchored platelets release chemicals to attract more platelets
- Platelets pile up to form a platelet plug

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# Vascular Spasms

- Anchored platelets release serotonin
- Serotonin causes blood vessel muscles to spasm
- Spasms narrow the blood vessel, decreasing blood loss

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# Coagulation

- Injured tissues release thromboplastin
- $PF_3$ (a phospholipid) interacts with thromboplastin, blood protein clotting factors, and calcium ions to trigger a clotting cascade
- Prothrombin activator converts prothrombin to thrombin (an enzyme)

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# Coagulation

- Thrombin joins fibrinogen proteins into hair-like fibrin
- Fibrin forms a meshwork (the basis for a clot)

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# Blood Clotting

- Blood usually clots within 3 to 6 minutes
- The clot remains as endothelium regenerates
- The clot is broken down after tissue repair

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# Undesirable Clotting

- Thrombus
  - A clot in an unbroken blood vessel
  - Can be deadly in areas like the heart
- Embolus
  - A thrombus that breaks away and floats freely in the bloodstream
  - Can later clog vessels in critical areas such as the brain

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# Bleeding Disorders

- Thrombocytopenia
  - Platelet deficiency
  - Even normal movements can cause bleeding from small blood vessels that require platelets for clotting
- Hemophilia
  - Hereditary bleeding disorder
  - Normal clotting factors are missing

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# Blood Groups and Transfusions

- Large losses of blood have serious consequences
  - Loss of 15 to 30 percent causes weakness
  - Loss of over 30 percent causes shock, which can be fatal
- Transfusions are the only way to replace blood quickly
- Transfused blood must be of the same blood group

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# Human Blood Groups

- Blood contains genetically determined proteins
- A foreign protein (antigen) may be attacked by the immune system
- Blood is “typed” by using antibodies that will cause blood with certain proteins to clump (agglutination)

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# Human Blood Groups

- There are over 30 common red blood cell antigens
- The most vigorous transfusion reactions are caused by ABO and Rh blood group antigens

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# ABO Blood Groups

- Based on the presence or absence of two antigens
  - Type A
  - Type B
- The lack of these antigens is called type O

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# ABO Blood Groups

- The presence of both A and B is called type AB
- The presence of either A or B is called types A and B, respectively

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# Rh Blood Groups

- Named because of the presence or absence of one of eight Rh antigens (agglutinogen D)
- Most Americans are $Rh^+$
- Problems can occur in mixing $Rh^+$ blood into a body with $Rh^-$ blood

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# Rh Dangers During Pregnancy

- Danger is only when the mother is $Rh^-$ and the father is $Rh^+$, and the child inherits the $Rh^+$ factor

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# Rh Dangers During Pregnancy

- The mismatch of an $Rh^-$ mother carrying an $Rh^+$ baby can cause problems for the unborn child
  - The first pregnancy usually proceeds without problems
  - The immune system is sensitized after the first pregnancy
  - In a second pregnancy, the mother's immune system produces antibodies to attack the $Rh^+$ blood (hemolytic disease of the newborn)

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# Blood Typing

- Blood samples are mixed with anti-A and anti-B serum
- Coagulation or no coagulation leads to determining blood type
- Typing for ABO and Rh factors is done in the same manner
- Cross matching – testing for agglutination of donor RBCs by the recipient's serum, and vice versa

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# Developmental Aspects of Blood

- Sites of blood cell formation
  - The fetal liver and spleen are early sites of blood cell formation
  - Bone marrow takes over hematopoiesis by the seventh month
- Fetal hemoglobin differs from hemoglobin produced after birth

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