Chapter 12
Blood
Introduction

A. Blood is a connective tissue
B. A complex mixture of cells, chemicals, and fluid
C. Transports substances throughout the body
D. Helps to maintain a stable internal environment
E. Includes:
   1. Red blood cells
   2. White blood cells
   3. Platelets
   4. Plasma
A. Blood Volume and Composition

1. An average-sized adult has a blood volume of about 5 liters (5.3 quarts).

2. **Hematocrit** (Ht): normally 45% cells and 55% plasma

3. **Plasma** is a mixture of:
   a) Water
   b) Amino acids
   c) Proteins
   d) Carbohydrates
   e) Lipids
   f) Vitamins
   g) Hormones
   h) Electrolytes
   i) Cellular wastes
Blood Cells

A. Red Blood Cells

1. Erythrocytes

   a) Biconcave disks

   b) Discard their nuclei during development so:
      1) Cannot reproduce
      2) Cannot produce proteins

   c) Contain one-third hemoglobin by volume
      1) Hemoglobin carries $O_2$
      2) When combined with $O_2$ oxyhemoglobin results (bright red)
      3) Deoxygenated blood (deoxyhemoglobin) is darker
1. Red Blood Cell Counts
   a) The typical red blood cell count is:
      a) 4,600,000-6,200,000 cells per mm$^3$ for males
      b) 4,200,000-5,400,000 cells per mm$^3$ for females
   b) The number of red blood cells is a measure of the blood's *oxygen-carrying capacity*
1. Red Blood Cell Production and Control
   a) In the embryo and fetus RBC production occurs in
      1) Yolk sac
      2) Liver
      3) Spleen
   b) After birth RBC production in red bone marrow
   c) Average life span of RBCs is 120 days
   d) The total number of RBCs remains relatively constant due to a negative feedback mechanism
      1) Detection of low $O_2$ in blood
      2) Erythropoietin is released from the kidneys and liver
      3) More RBCs produced
      4) $O_2$ carrying capacity of blood increases
Low blood oxygen

Liver → Kidney

Erythropoietin

Bloodstream

Increased oxygen-carrying capacity

Increased number of red cells

Red bone marrow

Release into bloodstream
Stimulation
Inhibition
1. Dietary Factors Affecting RBC Production

   a) *Vitamins* $B_{12}$ and *folic acid* are needed for DNA synthesis, so are necessary for the reproduction of all body cells

   b) Iron is needed for hemoglobin synthesis

   c) Deficiency in RBCs or quantity or hemoglobin is anemia
1. **Destruction of Red Blood Cells**

   a) **With age RBCs**
      1) Become increasingly fragile
      2) Are damaged by passing through narrow capillaries

   b) **Macrophages** in the liver and spleen phagocytize damaged red blood cells

   c) Hemoglobin is then converted into:
      1) *Heme* - an iron carrying porphyrin ring
      2) *Globin* - its protein carrier

   d) Heme is decomposed into
      1) Iron which is stored or recycled
      2) Biliverdin and bilirubin which are excreted in bile
1. Absorption of nutrients from food.
2. Blood transports absorbed nutrients.
3. Red blood cell production.
4. Red blood cells circulate for about 120 days.
5. Macrophage and damaged red blood cells.
8. Bilirubin and bile enter the small intestine.

Vitamin B12 and Folic acid are essential for red blood cell production.
A. **White Blood Cells**

1. Leukocytes help defend the body against disease
2. Formed from *hemocytoblasts* (hematopoietic stem cells)
3. Five types of WBCs are in circulating blood
   a) Distinguished by:
      a) Size
      b) Granular appearance of the cytoplasm
      c) Shape of the nucleus
      d) Staining characteristics
a) **Granular**

1) **Neutrophils**
   a. Red-staining fine cytoplasmic granules
   b. Multi-lobed nucleus
   c. 54-62% of leukocytes

2) **Eosinophils**
   a. Coarse granules that stain deep red
   b. Bilobed nucleus
   c. 1-3% of circulating leukocytes

3) **Basophils**
   a. Fewer granules that stain blue
   b. < 1% of leukocytes
a) **Agranular**

1. **Monocytes**
   a. Largest blood cells
   b. Variably-shaped nuclei
   c. 3-9% of circulating leukocytes

2. **Lymphocytes**
   a. Long-lived
   b. Large round nucleus
   c. 25-33% of circulating leukocytes
1. Functions of White Blood Cells
   a) Leukocytes can squeeze between cells lining walls of blood vessels by *diapedesis*
   b) Attack and remove bacteria and debris
      1) Neutrophils
         a. Phagocytic
      2) Eosinophils
         a. Moderate allergic reactions
         b. Defend against parasitic infections
      3) Basophils
         a. Migrate to damaged tissues
         b. Release histamine to promote inflammation
         c. Release heparin to inhibit blood clotting
1) Monocytes
   1) phagocytic
   2) engulf the larger particles

2) Lymphocytes
   a. major players in specific immune reactions
   b. Some produce antibodies
1. White Blood Cell Counts
   a) 1 mm$^3$ of blood typically contains 5,000 to 10,000 WBCs
   b) **Leukocytosis**
      1) Excess numbers of leukocytes
      2) Occurs after an infection
   c) **Leukopenia**
      1) Lowered number of leukocytes
      2) Occurs from a variety of conditions, including AIDS
   d) **Differential white blood cell counts**
      1) List the percentages of the types of leukocytes in a blood sample
      2) Can help pinpoint the nature of an illness, indicating whether it is caused by bacteria or viruses
A. Blood Platelets

1. Blood **platelets** are fragments of **megakaryocytes**

2. Help repair damaged blood vessels by adhering to their broken edges

3. Normal counts vary from 130,000 to 360,000 platelets per mm$^3$
Blood Plasma

A. Plasma

1. Clear, straw-colored fluid portion of the blood
2. Mostly water (~90%)
3. Contains a variety of substances
4. Transports
   a) Nutrients
   b) Gases
5. Regulates fluid and electrolyte balance
6. Maintains a favorable pH
A. **Plasma Proteins**

1. Most abundant dissolved substances in plasma ($\sim 7\%$)
2. Not used for energy
1. Fall into three groups:
   a) Albumins
      1) ~ 60% of plasma proteins
      2) help maintain osmotic pressure of the blood

   b) Globulins
      1) ~ 36% of plasma proteins
      2) Designated as alpha, beta, and gamma globulins
         a. *Alpha* and *beta globulins* function in transporting lipids and fat-soluble vitamins
         b. *Gamma globulins* are a type of antibody

   c) Fibrinogen
      1) ~ 4% of plasma proteins
      2) plays a primary role in blood coagulation
A. Nutrients and Gases

1. The most important blood gases are
   a) Oxygen \((\text{O}_2)\)
   b) Carbon dioxide \((\text{CO}_2)\)

2. Plasma *nutrients* include
   a) Amino acids
   b) Monosaccharides
   c) Nucleotides
   d) Lipids
      1) Not soluble in the water of the plasma
      2) Surrounded by protein molecules for transport through the bloodstream as *lipoproteins*
a) Lipoproteins are classified based on their densities
   1) Density reflects composition
   2) Types of lipoproteins include:
      a. HDL – high density
      b. LDL – low density
      c. VLDL – very low density
      d. Chylomicrons
A. **Nonprotein Nitrogenous Substances**

1. generally include amino acids, urea, and uric acid
   
   a) Urea and uric acid are the by-products of protein and nucleic acid catabolism
A. Plasma Electrolytes

1. Are absorbed by the intestines or are by-products of cellular metabolism

2. Include
   a) Sodium \((Na^+)\)
   b) Potassium \((K^+)\)
   c) Calcium \((Ca^{2+})\)
   d) Magnesium \((Mg^{2+})\)
   e) Chloride \((Cl^-)\)
   f) Bicarbonate \((HCO_3^-)\)
   g) Phosphate \((PO_4^{3-})\)
   h) Sulfate \((SO_4^{2-})\)

3. Some are important in maintaining
   a) Osmotic pressure
   b) pH
Hemostasis

A. Hemostasis

1. Stoppage of bleeding
2. Follows injury to a vessel
3. Three steps:
   a) Blood vessel spasm
      1) Cutting a blood vessel causes the muscle in its walls to contract in a reflex (vasospasm)
      2) Lasts only a few minutes
      3) Long enough to initiate the second and third steps of hemostasis
a) Platelet plug formation

1) Platelets stick to the exposed edges of damaged blood vessels, forming a net with spiny processes protruding from their membranes

2) A platelet plug is most effective on a small vessel
1 Break in vessel wall

2 Blood escaping through break

3 Platelets adhere to each other, to end of broken vessel, and to exposed collagen

4 Platelet plug helps control blood loss
a) **Blood coagulation**

1) Most effective means of hemostasis
2) Very complex process involving *clotting factors*
3) Damaged tissues release *tissue thromboplastin*
4) *Thromboplastin* activates the first in a series of factors
5) Leads to production of *prothrombin activator*
6) *Prothrombin activator* converts *prothrombin* in the plasma into *thrombin*
7) Thrombin catalyzes a reaction that converts soluble fibrinogen into net-like insoluble fibrin
8) *Fibrin* causes the blood cells to catch
1) The amount of prothrombin activator formed is proportional to the amount of tissue damage.
2) Once a blood clot forms, it promotes still more clotting through a positive feedback system.
3) After a clot forms, fibroblasts invade the area and produce fibers throughout the clots.
4) A clot that forms abnormally in a vessel is a thrombus.
5) A thrombus that dislodges is an embolus.
Blood Groups and Transfusions

A. After mixed success with transfusions, scientists determined that blood

1. was of different types
2. only certain combinations were compatible
A. Antigens and Antibodies

1. Clumping of red blood cells following transfusion is called **agglutination**

2. Agglutination is due to the interaction of **antigens** on the surfaces of RBCs with **antibodies** carried in the plasma

3. Only a few of the antigens on RBCs produce transfusion reactions
   1. ABO group
   2. Rh group
A. ABO Blood Group

1. **Type A blood**
   a) A antigens on RBCs
   b) anti-B antibodies in the plasma

2. **Type B blood**
   a) B antigens on RBCs
   b) anti-A antibodies in the plasma

3. **Type AB blood**
   a) Both A and B antigens on RBCs
   b) No antibodies in the plasma
1. Type O blood
   a) Neither antigen
   b) Both antibodies in the plasma
2. Adverse transfusion reactions
   a) Due to the agglutination of RBCs
   b) Avoided by preventing the mixing of blood that contains matching antigens and antibodies
A. Rh Blood Group

1. Named after the rhesus monkey

2. Rh factor surface protein
   a) Present on RBCs then blood is Rh positive
   b) Absent on RBCs then blood is Rh negative
   c) No corresponding antibodies in the plasma
   d) If a person with Rh-negative blood is transfused with Rh-positive antibodies for the Rh factor will develop in the plasma

3. Erythroblastosis fetalis
   a) develops in Rh-positive fetuses of Rh-negative mothers
   b) can now be prevented
Rh-negative woman and Rh-positive man conceive a child.

Rh-negative woman with Rh-positive fetus.

Cells from Rh-positive fetus enter woman’s bloodstream.

Woman becomes sensitized—antibodies (⁺) form to fight Rh-positive blood cells.

In the next Rh-positive pregnancy, maternal antibodies attack fetal red blood cells.