Objectives
1. List the important components of blood
2. Describe the function of each component
3. Recognize the significance of the various blood types
4. Describe some disorders of the blood
5. Define the key words that relate to this chapter

Introduction
The body consists of active cells that need a continuous supply of nutrients and oxygen. Metabolic waste products need to be removed from the cells to maintain a stable cellular environment. Blood is the primary transport medium that is responsible for meeting these cellular demands. A central pump, the heart, provides the force to move the blood through a system of vessels that extend throughout the body. The average adult’s body has 8-10 pints of blood.

Blood
- Average adult body has 8-10 pints of blood
- Function of the blood
  a. Transport
     1. Transporting oxygen from the lungs to the tissues and carbon dioxide from the tissues to lungs
     2. Transporting nutrient molecules (glucose, amino acids, fatty acids and glycerol) from the small intestine or storage site to the cells of the body
     3. Transporting waste products (lactic acid, urea and creatinine) from the cells to kidneys and sweat glands for excretion
  b. Regulatory
     1. Regulates hormones and other chemicals that control the functioning of organs and systems
     2. Helps to regulate the body pH through buffers and amino acids that it carries; pH of blood is 7.4
     3. Regulates body temperature by circulating excess heat to the body surfaces and lungs
     4. Regulates the water content of cells through its dissolved sodium ion, thus playing a role in osmosis
  c. Protection
     1. Circulates antibodies and defensive cells to combat infection and disease
     2. Produces clots to prevent excessive loss of blood

Blood Composition
When a sample of blood is spun in a centrifuge, the cells and cell fragments are separated from the liquid part of the blood
- Plasma – liquid portion of blood without its cellular elements
- Serum – name given to plasma after a blood clot is formed
- Cellular elements (formed elements)
  a. Erythrocytes or red blood cells
  b. Leukocytes or white blood cells
  c. Thrombocytes or platelets

Blood Plasma
- Straw colored
- Comprises about 55% of the blood volume
Contains the following 6 substances
- **Water**
  - 92% of the total volume of plasma
    - Maintained by the kidneys and by water intake and output
- **Plasma proteins**
  - a. Fibrinogen – necessary for blood clotting and synthesized in the liver
  - b. Albumin – most abundant of all the plasma proteins produced in the liver and help to maintain the blood’s osmotic pressure and volume
  - c. Globulin – formed in the liver and the lymphatic system
    1. Gamma globulin helps synthesis of antibodies
    2. Prothrombin helps blood to coagulate with the aid of vitamin K
- **Nutrients** – glucose, fatty acids, cholesterol and amino acids absorbed from the digestive tract
- **Electrolytes** – most abundant electrolytes are sodium chloride and potassium chloride
- **Hormones, vitamins, and enzymes** – found in small amounts and help control chemical reactions in the body
- **Metabolic waste products** – all body cells are actively engaged in chemical reactions to maintain homeostasis and as a result waste products are formed and subsequently carried to various excretory organs

**Formation of Blood Cells**

**Red Blood Cells (RBCs)**

- **Hematopoiesis** is the formation of all blood cells
  - a. Occurs in the red bone marrow
  - b. Certain lymphatic tissue produces some white blood cells
    (i.e. spleen, tonsils and lymph nodes)
  - c. Develop from stem cells – undifferentiated precursor cells or hematocytoblasts
- **Erythropoiesis**
  - a. The manufacture of red blood cells (RBCs) occurs in the red bone marrow of essentially all bones
    1. Erythrocytes come from stem cells in the red bone marrow called hemocytoblasts
    2. As the hemocytoblast matures into an erythrocyte, it loses its nucleus and cytoplasmic organelles
    3. The hemocytoblast also becomes smaller, gains hemoglobin and develops a biconcave shape
  - b. RBCs live about 120 days
    - During this time they travel thousands of miles as they circulate throughout the body.
    - Normally the erythrocytes have a flexible cell membrane that allows them to bend and squeeze through the capillaries. As they age, however, their membrane loses its elasticity and becomes fragile. When they are defective or worn out, macrophages, which are phagocytic cells in the spleen and liver, remove them from circulation, and they are replaced by an equal number of new cells. Under typical conditions, more than 2 million erythrocytes are destroyed and replaced every second.
  - c. Process of development and breakdown
    - When RBCs are destroyed, the Hemoglobin is separated into its heme and globin components. The protein portion of the hemoglobin in the erythrocyte is broken down into its constituent amino acids, which are added to the supply of amino acids that are available in the body. The heme portion of the molecule is broken down into an iron compound and bilirubin, a yellow bile pigment. The liver then recycles the iron and sends it to the bone marrow for new hemoglobin. Bilirubin becomes part of the bile, which is secreted by the liver, and is carried in the bile duct to the small intestine.
  - d. Normal ranges **Red Blood Cells**
    1. Females 4.2 to 5.4 million/µl
    2. Males 4.5 to 6.2 million/µl
Hemoglobin

- Erythrocytes contain a red pigment called hemoglobin
- Made of protein molecule called globin and an iron compound called heme
- Function of RBCs
  - Helps to transport oxygen to the tissues and some carbon dioxide away from the tissues
    a. Oxyhemoglobin – oxygen carrying erythrocytes
    b. Carbaminohemoglobin – occurs when erythrocytes release oxygen into tissues and pick up carbon dioxide.
      o The carbon dioxide that is formed in the cells is picked up by the plasma as a bicarbonate; which is responsible for the dark, reddish-blue color characteristic of venous blood
- Normal ranges
  a. Females 12-16 g/100ml
  b. Males 14-18 g/100ml
- Hemolysis – a rupture or bursting of the red blood cell which sometimes occurs as a result of a blood transfusion reaction or other disease processes

White Blood Cells (WBCs)

- Called leukocytes
  o Larger than erythrocytes but fewer in number and are manufactured in both red bone marrow and lymphatic tissue
- Natural defense against injury and disease
  This is achieved through:
    a. Phagocytosis and destruction of bacteria
    b. Synthesis of antibody molecules
    c. “Cleaning up” of cellular remnants at the site of inflammation
    d. Walling off of the infected area

Even though leukocytes are considered to be blood cells, they do most of their work in the tissues; they use the blood as a transport medium

- Types of leukocytes
  o Because WBCs are clear and colorless*, they must be stained first with an appropriate dye usually Wright’s stain before they can be identified under the microscope.
    *lack of hemoglobin gives the cell a whitish appearance
  o Classification is due to the presence of cytoplasmic granules, nuclear structure and reactions to stains (Table 12-3 pg. 245)
    1. Granulocytes
      o Cells develop granules in the cytoplasm
      o Made in red bone marrow from cells called myeloblasts
      o Most granulocytes live only a few days
    2. Agranulocytes
      o Those that do not have granules
      o Lifespan ranges from a few days to several years
- Diapedesis
  o Process that allows leukocytes to move through the capillary walls into the tissue spaces which provides a defense against organisms that cause disease
- Normal ranges
  o Average 3,200 to 9,800/µl

Types of WBCs – Granulocytes

- Made from cells called myeloblasts
- Three types
  a. Neutrophils
    1. Phagocytize bacteria with lysosomal enzymes
       Phagocytosis is a process that surrounds, engulfs and digests harmful bacteria
2. Most common type of leukocyte
   b. Eosinophils
      1. Phagocytize the remains of antibody-antigen reactions
      2. Increase in number in allergic conditions (neutralize histamine), malaria and parasite or worm infestations
   c. Basophils
      1. Activated during an allergic reaction or inflammation
      2. Produce histamine, a vasodilator that increases blood flow to damaged tissues, and heparin, an anticoagulant that inhibits blood clot formation

Types of WBCs – Agranulocytes
   • Lymphocytes
      a. Subdivided into:
         1. B-lymphocytes – synthesized in the bone marrow
         2. T-lymphocytes – synthesized in the thymus gland
      b. Help the body by synthesizing and releasing antibody molecules and by protecting against the formation of cancer cells
   • Monocytes
      a. Formed in bone marrow and the spleen
      b. Assist in phagocytosis
      c. During inflammation, they help to wall off and isolate the infected area

Inflammation
   • Occurs when living tissue is damaged in any way
   • Signs and symptoms
      a. Redness
      b. Local heat
      c. Swelling
      d. Pain
   • The inflammatory process Figure 12-2 pg. 246
      a. Mast cell is irritated causing histamine to be released
         1. Increases blood flow and capillary permeability to the injury
         2. The damaged area is walled off as a result of the clotting action of fibrinogen on the damaged tissue and macrophage (cell that removes dead organisms and foreign substances by phagocytosis) action
      b. Cellular response
         1. Neutrophils and monocytes are stimulated
         2. Neutrophils move quickly into damaged area by diapedesis
         3. Neutrophils begin phagocytosis of the pathogenic microorganisms
         4. Neutrophil death and pus formation
            o Pus is a combination of dead tissue, dead and living bacteria, dead leukocytes and blood plasma
         5. Macrophage invasion and cleanup
      c. Vascular response
         1. Vasodilation which leads to hyperemia (increased blood to an area)
            o Capillaries bulge causing redness and heat
         2. Vascular permeability endothelial cells spread apart
         3. Blood serum and white blood cells leak into tissue causing swelling
         4. Increased edema in the tissues puts pressure on nerves causing severe pain
         5. Area is protected, causing loss of function
Thrombocytes (Blood Platelets)
Smallest of the solid components of blood; thrombocytes are not cells but fragments of the megakaryocytes cytoplasm
- Function in the initiation of the blood-clotting process
  a. When a blood vessel is damaged, the platelets are stimulated to produce sticky projecting structures, allowing them to stick to the collagen fibers
  b. This reaction occurs countless times, creating a “platelet plug” to stop the bleeding
  c. Platelets secrete a chemical called serotonin (serotonin) which causes the blood vessel to spasm and narrow and a decrease in blood loss until the clot forms
- Normal ranges
  o 250,000 to 450,00 per cubic millimeter of blood
Old platelets eventually disintegrate in the bone marrow

Coagulation  Figure 12-3 pg. 248
Blood clotting or coagulation is a complicated and essential process which depends in large part on thrombocytes
- Injury leads to release of serotonin and thromboplastin
  a. Thromboplastin is a complex substance that can only cause coagulation if calcium ions and prothrombin are present
  b. Prothrombin is a plasma protein synthesized in the liver
- Prothrombin converts to thrombin
  o Thromboplastin and calcium ions act as enzymes in a reaction that converts prothrombin into thrombin
- Fibrinogen converts to fibrin
  o Thrombin acts as an enzyme, changing fibrinogen a plasma protein into fibrin
- Clot
  o The fibrin threads layer themselves over the cut, creating a fine, mesh-like network that entraps the red blood cells, platelets and plasma creating a blood clot
- Clotting time norms
  o The clotting time for humans is form 5 to 15 minutes

Blood Types
There are four major groups or types of blood: A, B, AB and O
- Types
  a. A
  b. B
  c. AB
  d. O
- Antigens and antibodies
  a. ABO blood groups are based on the presence of absence of certain antigens on the surface of the RBC membrane
  b. These antigens, A and B, are inherited; consequently, blood types are also inherited
    1. Type A blood has type A antigen
    2. Type B blood has type B antigen
    3. Type AB blood has both A and B antigens
    4. Type O blood has neither type A nor type B antigens
  c. Certain blood antibodies develop in the plasma shortly after birth
    1. Type A blood develops B antibodies
    2. Type B blood develops A antibodies
    3. Type AB blood develops neither A or B antibodies
    4. Type O blood develops both A and B antibodies

Test known as type and crossmatch is done before receiving a blood transfusion to determine blood type
• **Agglutination**
  a. Antibodies react with the antigens of the same type, causing the red blood cells to clump together
  b. The clumping of blood, a process known as agglutination clogs the blood vessels, impeding circulation which could cause death
  c. Example: Type B blood could not receive Type A blood because the Antigen B would clump with the B Antibodies of Type A blood

• **Rh factors**
  a. Human red blood cells, in addition to containing antigens A and B, also contain the Rh antigen
    1. People possessing the Rh factor are said to be Rh positive
      o About 85% of North Americans
    2. People without the Rh factor are Rh negative
      o About 15% of North Americans
  b. Normally, neither Rh+ nor Rh- individuals have Rh antibodies
    1. If an Rh- person is exposed to Rh+ blood, either through a blood transfusion or by transfer of blood between a mother and fetus, the Rh- individual develops Rh antibodies
    2. If that individual is exposed to Rh+ blood a second time, a transfusion reaction results (agglutination)
    3. RHO Gam, a special preparation of immune globin, is given to Rh- mothers with Rh+ fetus’s within 72 hours after delivery of each baby
      o Antibodies in RHO Gam destroy any Rh+ cells of the baby’s which may have entered the mother’s bloodstream
      o Prevents the mother’s immune system from producing Rh antibodies

• **Recipient and donor matching**
  Table 12-4 pg. 249
  a. When transfusions are given, it is necessary to match both the Rh type and the ABO type
  b. Universal recipient
    1. Type AB+
    2. May receive any type of blood

• **Universal donors**
  a. Type O Rh-
  b. May donate to all types of blood

**Blood Norms**

Tests have been devised to use physiological blood norms in diagnosing and following the course of certain diseases

• **Bleeding time** – 1 to 3 minutes
• **Coagulation time** – 5 to 15 minutes
• **Hemoglobin count**
  a. Female 12 to 16 gm/dl
  b. Male 14 to 18 gm/dl
• **Platelet count** – 150,000 to 350,000/mm³
• **Prothrombin time**
  a. 9.5 to 11 seconds
  b. Dosage of medication is based on clotting times
• **Sedimentation rate**
  a. Time required for erythrocytes to settle to the bottom of an upright tube at room temperature
  b. Elevated ESR indicates whether disease is present and is valuable in observing the progression of inflammatory conditions
  c. Female 0 to 20 mm/hour
  d. Male 0 to 10 mm/hour
Red blood cell count
  a. Female 4.2 to 5.4 million/µl
  b. Male 4.5 to 6.2 million/µl
White blood cell count – 3,200 to 9,800/µl
Cholesterol level – below 200 mg/dl

Disorders of the Blood
• Anemia
  a. A deficiency in the number and/or percentage of RBCs and the amount of hemoglobin in the blood
  b. Characterized by varying degrees of dyspnea, pallor, palpitation and fatigue
• Iron-deficiency anemia
  a. Caused by a deficiency of adequate amounts of iron in the diet
  b. Alleviate condition by ingestion of iron supplements and green, leafy vegetables that contain the mineral iron
• Pernicious anemia
  a. Deficiency of vitamin B12 and/or lack of the intrinsic factor necessary for the absorption and utilization of vitamin B12
  b. Characterized by dyspnea, pallor and fatigue as well as specific neurologic changes
• Aplastic anemia
  o Disease caused by the suppression of the bone marrow
• Sickle cell anemia
  a. Chronic blood disease inherited form both parents
  b. Causes RBCs to form in the abnormal crescent shape
  c. Most prevalent in African-Americans
• Cooley’s anemia (Thalassemia)
  a. Blood disease caused by a defect in hemoglobin formation
  b. There is no natural way for the body to eliminate iron leading to “iron overload” and organ failure
• Polycythemia
  a. A condition in which too many RBCs are formed
  b. Treat with phlebotomy or drug therapy
• Embolism
  o Where a foreign substance (air, clot, cancer cells, fat, bacterial clumps) or embolus is carried by the bloodstream until it reaches an artery too small for passage
• Thrombosis
  o Formation of a blood clot or thrombus in a blood vessel caused by unusually slow blood circulation, immobility or decrease in mobility
• Hematoma
  o Localized clotted mass of blood found in an organ, tissue or space caused by a traumatic injury
• Hemophilia
  o Hereditary disease in which the blood clots slowly or abnormally
• Thombocytopenia
  o Blood disease in which there is a decrease in the number of platelets resulting in blood that will not clot properly
• Leukemia
  o Cancerous or malignant condition in which there is a great increase in the number of white blood cells which replace the erythrocytes, thus interfering with the transport of oxygen to the tissues and hinder the synthesis of new red blood cells from bone marrow
• Septicemia
  o Describes the presence of pathogenic (disease-producing) organisms or toxins in the blood
• Multiple myeloma
  o Condition where plasma cells or B-lymphocytes multiply abnormally in the bone marrow, causing weakness in the bone leading to pathologic fractures and bone pain

Bone Marrow Transplants
• A procedure that transplants healthy bone marrow into a patient whose bone marrow is not functioning properly
• Used to treat leukemia, aplastic anemia, sickle cell anemia and to replace the bone marrow and restore normal function after high doses of radiation that are given to treat malignancies
• Different types of bone marrow transplants:
  a. Autologous bone marrow transplant
     o The donor is the patient him/herself
  b. Allogenic bone marrow transplant
     o Donor shares the same genetic type as the patient
       1. Identical twin
       2. Parent
       3. Unrelated
       4. Umbilical cord

• Bone marrow transplant procedure
  a. High doses of chemotherapy or radiation are included in the preparation to effectively treat a malignancy and make room in the bone marrow for new cells to grow
     o Therapy is called ablative because it stops the process of blood cell production and the marrow becomes empty
  b. Marrow transplant is administered through a central venous catheter
  c. The stem cells find their way into the bone marrow and reproduce healthy new cells

• Engraftment
  o Period of time following the transplant
  o Marrow begins reproducing new blood cells, usually between the 15 and 30th day