Blood Composition

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Blood

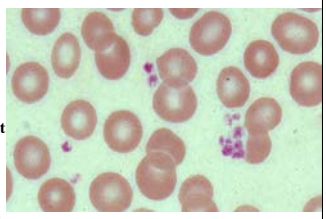
- By the end of the lesson you should be able to:
- State the composition of Blood
- State the function of red blood cells and plasma
- Explain the function of haemoglobin in the transport of oxygen
- State the function of macrophages and lymphocytes

Major Functions of Blood

- **The body contains 4 to 6 liters of blood with an average pH of 7.35 to 7.45.**

Functions include:

- **Transport Oxygen, Carbon Dioxide, Nutrients, Hormones, Heat, and Metabolic Wastes**
- **Regulation of pH, Body temperature, and water content of cells**
- **Protection against blood loss through clotting**
- **Protection against diseases through phagocytic white blood cells and antibodies**



Blood Functions: Distribution

- Blood transports:
  - Oxygen from the lungs and nutrients from the digestive tract
  - Metabolic wastes from cells to the lungs and kidneys for elimination
  - Hormones from endocrine glands to target organs

Blood Functions: Regulation

- Blood maintains:
  - Appropriate body temperature by absorbing and distributing heat to other parts of the body
  - Normal pH in body tissues using buffer systems
  - Adequate fluid volume in the circulatory system

Blood Functions: Protection

- Blood prevents blood loss by:
  - Activating plasma proteins and platelets
  - Initiating clot formation when a vessel is broken
- Blood prevents infection by:
  - Synthesizing and utilizing antibodies
  - Activating complement proteins
  - Activating WBCs to defend the body against foreign invaders

Physical Characteristics of Blood

- Average volume of blood:
  - 5–6 L for males; 4–5 L for females (Normovolemia)
  - Hypovolemia - low blood volume
  - Hypervolemia - high blood volume
- Viscosity (thickness) - 4 - 5 (where water = 1)
- The pH of blood is 7.35–7.45; x = 7.4
- Osmolarity = 300 mOsm or 0.3 Osm
  - This value reflects the concentration of solutes in the plasma
- Salinity = 0.85%
  - Reflects the concentration of NaCl in the blood
- Temperature is 38°C, slightly higher than "normal" body temperature
- Blood accounts for approximately 8% of body weight

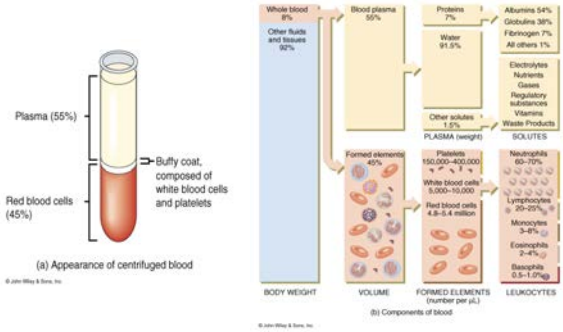
Composition of Blood

- Blood is the body's only fluid tissue (a connective tissue)
- 2 major components
  - Liquid = plasma (55%)
  - Formed elements (45%)
    - Erythrocytes, or red blood cells (RBCs)
    - Leukocytes, or white blood cells (WBCs)
    - Platelets - fragments of megakaryocytes in marrow

Components of Whole Blood

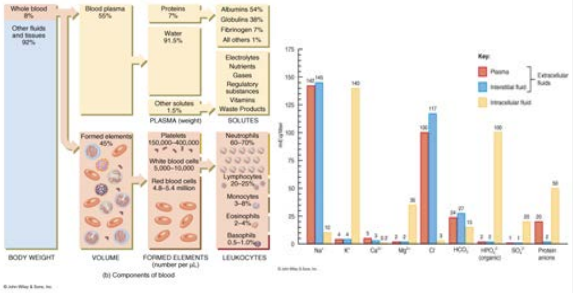
- Hematocrit
  - Males: 47% ± 5%
  - Females: 42% ± 5%

Components of Normal Adult Blood

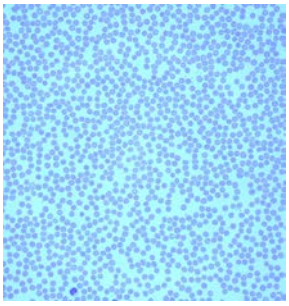


Measured via Hematocrit: female 38% to 46%, male 40% to 54%

Components of Normal Adult Blood

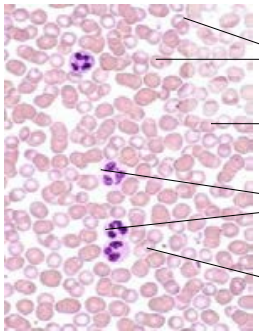


Human blood smear



X 500

skool blood plasma

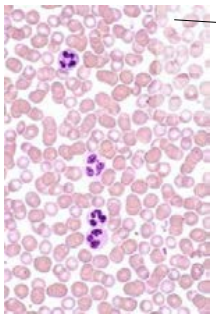


plasma (55%)
red blood cells
(5-6-million /ml)

white blood cells
(5000/ml)
platelets

Blood Plasma

- Blood plasma components:
  - Water = 90-92%
  - Proteins = 6-8%
    - Albumins; maintain osmotic pressure of the blood
    - Globulins
      - Alpha and beta globulins are used for transport purposes
      - Gamma globulins are the immunoglobulins (IgG, IgA, etc)
    - Fibrinogen; a clotting protein
  - Organic nutrients – glucose, carbohydrates, amino acids
  - Electrolytes – sodium, potassium, calcium, chloride, bicarbonate
  - Nonprotein nitrogenous substances – lactic acid, urea, creatinine
  - Respiratory gases – oxygen and carbon dioxide



Plasma

liquid part of blood

plasma transports:-

- soluble food molecules
- waste products
- hormones
- antibodies

Formed Elements

- Formed elements comprise 45% of blood
- Erythrocytes, leukocytes, and platelets make up the formed elements
  - Only WBCs are complete cells
  - RBCs have no nuclei or organelles, and platelets are just cell fragments
- Most formed elements survive in the bloodstream for only a few days
- Most blood cells do not divide but are renewed by cells in bone marrow

Erythrocytes (RBCs)

- Biconcave disc
  - Folding increases surface area (30% more surface area)
  - Plasma membrane contains *spectrin*
    - Give erythrocytes their flexibility
- Anucleate, no centrioles, no organelles
  - End result - no cell division
  - No mitochondria means they generate ATP *anaerobically*
    - Prevents consumption of O_2 being transported
- Filled with hemoglobin (Hb) - 97% of cell contents
  - Hb functions in gas transport
    - $Hb + O_2 \longleftrightarrow HbO_2$ (oxyhemoglobin)
- Most numerous of the formed elements
  - Females: 4.3–5.2 million cells/cubic millimeter
  - Males: 5.2–5.8 million cells/cubic millimeter

Erythrocytes (RBCs)

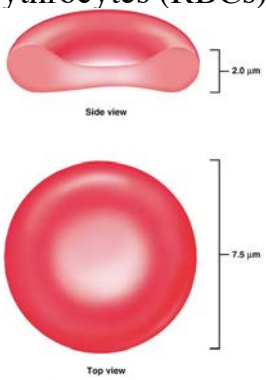
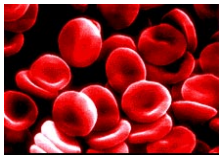


Figure 17.3

Red blood cells specialisations

1) **biconcave shape**



increases the surface area so more oxygen can be carried

2) **no nucleus**
→ extra space inside

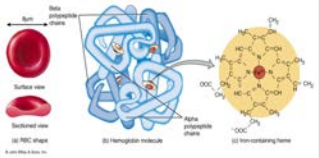
3) contain **haemoglobin**
→ the oxygen carrying molecule
→ 250million molecules / cell

Erythrocyte Function

- Erythrocytes are dedicated to respiratory gas transport
- Hemoglobin reversibly binds with oxygen and most oxygen in the blood is bound to hemoglobin
- Composition of hemoglobin
  - A protein called globin
    - made up of two alpha and two beta chains
  - A *heme* molecule
    - Each heme group bears an atom of iron, which can bind to one oxygen molecule
    - Each hemoglobin molecule thus can transport four molecules of oxygen

RBC Shape and the Structure of Hemoglobin

- **RBC's pass through capillary beds in single file.**
- **Hemoglobin is made of four polypeptides: Two Alpha and two Beta that contain a heme unit**
- **Each heme can carry an O2**
- **There are about 280 million hemoglobin molecules in each RBC**
- **Other molecules such as CO2 and NO are also carried by hemoglobin**



Structure of Hemoglobin

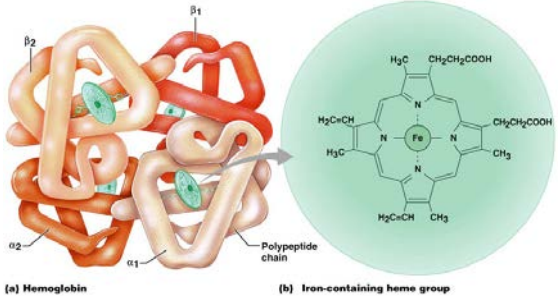


Figure 17.4

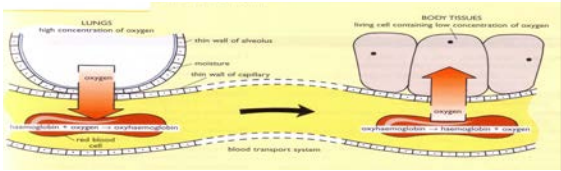
Haemoglobin

- **gives red blood cells their colour**
- **can carry up to 4 molecules of O_2**
- **associates and dissociates with O_2**
- **contains iron**

Hemoglobin

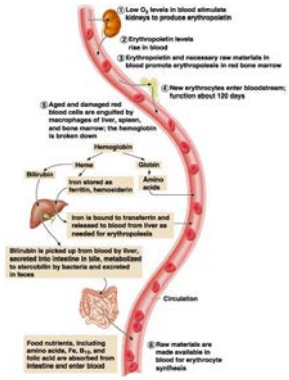
- Oxyhemoglobin – hemoglobin bound to oxygen
  - Oxygen loading takes place in the lungs
- Deoxyhemoglobin – hemoglobin after oxygen diffuses into tissues (reduced Hb)
- Carbaminohemoglobin – hemoglobin bound to carbon dioxide
  - Carbon dioxide loading takes place in the tissues

Function of Haemoglobin



When there is a high concentration of oxygen e.g in the alveoli haemoglobin combines with oxygen to form oxyhaemoglobin. When the blood reaches the tissue which have a low concentration of oxygen the haemoglobin dissociates with the oxygen and the oxygen is released into body tissues

Life Cycle of Red Blood Cells



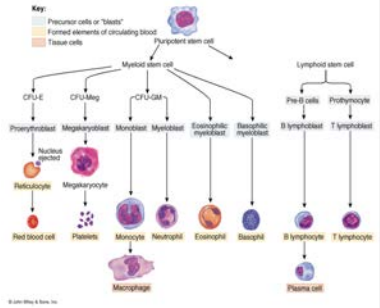
Formation of Blood cells - Hemopoiesis

Hormones:

RBC:
Erythropoietin

Platelets:
Thrombopoietin

WBC's: Colony-stimulating Factors (4)



Production of Erythrocytes

- Hematopoiesis – blood cell formation
  - Occurs in the red bone marrow (myeloid tissue)
    - Axial skeleton and girdles
    - Epiphyses of the humerus and femur
    - Marrow contains immature erythrocytes
    - Composed of reticular connective tissue
- Hemocytoblasts give rise to ALL formed elements
  - Lymphoid stem cells - give rise to lymphocytes
  - Myeloid stem cells - give rise to all other blood cells

Production of Erythrocytes: Erythropoiesis

- A hemocytoblast is transformed into a committed cell called the proerythroblast
- Proerythroblasts develop into early erythroblasts
- The developmental pathway consists of three phases
  - Phase 1 – ribosome synthesis in early erythroblasts
  - Phase 2 – hemoglobin accumulation in late erythroblasts and normoblasts
  - Phase 3 – ejection of the nucleus from normoblasts and formation of reticulocytes
- Reticulocytes then become mature erythrocytes
  - Reticulocytes make up about 1 -2 % of all circulating erythrocytes

Regulation and Requirements for Erythropoiesis

- Circulating erythrocytes – the number remains constant and reflects a balance between RBC production and destruction
  - Too few red blood cells leads to tissue hypoxia
  - Too many red blood cells causes undesirable blood viscosity
- Erythropoiesis is hormonally controlled and depends on adequate supplies of iron, amino acids, and B vitamins

Hormonal Control of Erythropoiesis

- Erythropoietin (EPO) release by the kidneys is triggered by:
  - Hypoxia due to decreased RBCs
  - Decreased oxygen availability
  - Increased tissue demand for oxygen
- Enhanced erythropoiesis increases the:
  - RBC count in circulating blood
  - Oxygen carrying ability of the blood

Erythropoietin Mechanism

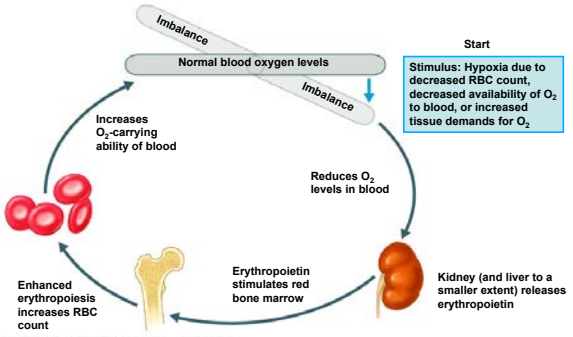
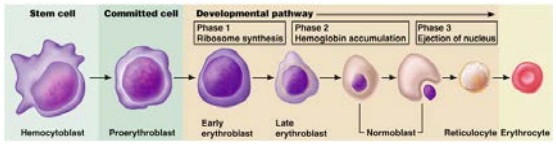


Figure 17.6

Dietary Requirements of Erythropoiesis

- Erythropoiesis requires:
  - Proteins, lipids, and carbohydrates
  - Iron, vitamin B_{12}, and folic acid
- The body stores iron in Hb (65%), the liver, spleen, and bone marrow
- Intracellular iron is stored in protein-iron complexes such as ferritin and hemosiderin
- Circulating iron is loosely bound to the transport protein transferrin

Production of Erythrocytes: Erythropoiesis



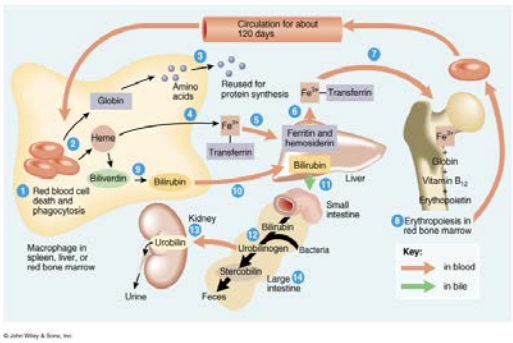
Fate and Destruction of Erythrocytes

- The life span of an erythrocyte is 100–120 days
  - Travels about 750 miles in that time (LA to Albuquerque)
- Old erythrocytes become rigid and fragile, and their hemoglobin begins to degenerate
- Dying erythrocytes are engulfed by macrophages
- Heme and globin are separated
  - Iron is removed from the heme and salvaged for reuse
    - Stored as hemosiderin or ferritin in tissues
    - Transported in plasma by beta-globulins as *transferrin*

Fate and Destruction of Erythrocytes

- Heme is degraded to a yellow pigment called bilirubin
  - Liver secretes bilirubin into the intestines as bile
  - Intestines metabolize bilirubin into urobilinogen
  - Urobilinogen leaves the body in feces, in a pigment called stercobilin
- Globin is metabolized into amino acids which are then released into the circulation

Formation and Destruction of RBC's



Erythrocyte Disorders

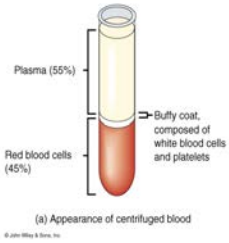
- Polycythemia
  - Abnormal excess of erythrocytes
    - Increases viscosity, decreases flow rate of blood
- Anemia – blood has abnormally low oxygen-carrying capacity
  - It is a symptom rather than a disease itself
  - Blood oxygen levels cannot support normal metabolism
  - Signs/symptoms include fatigue, paleness, shortness of breath, and chills

Abnormal Hematocrits

Polycythemia:
Increased RBC production.

Physiologic Polycythemia:
Increase in RBC production due to hypoxic tissues, like what occurs at high altitudes.

Polycythemia Vera:
genetic mutation in the hemocytoblastic cell line that increases RBC production.
Hematocrit values can reach 70%



Polycythemia

- Polycythemia – excess RBCs that increase blood viscosity
- Three main polycythemias are:
  - Polycythemia vera
  - Secondary polycythemia
  - Blood doping

Changes in hemoglobin

- **Anemia:** A deficiency of RBCs, which can be caused by either too rapid loss or slow production.
  - **Blood loss Anemia:** Due to hemorrhage, plasma is replaced in 1-3 days, but, RBC replacement takes longer.
  - **Microcytic Hypochromic Anemia:** Low levels of hemoglobin in RBCs due to chronic blood,Inadequate intake of iron-containing foods,Impaired iron absorption resulting in low Fe3+ levels in newly produced RBCs.
  - **Aplastic Anemia:** Decreased RBC production in bone marrow due to chemical, drug, or radiation exposure.
  - **Pernicious Anemia:** Chronic illness caused by impaired absorption of Vitamin B-12 because of a lack of intrinsic factor (IF) in gastric secretions**.** Vitamin B12, in turn, is necessary for the formation of red blood cells.

Changes in Hemoglobin

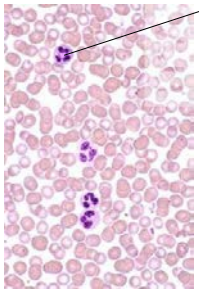
- **Hemolytic Anemia:** Different abnormalities of RBCs that make RBCs fragile and rupture easily.
  - **Hereditary Spherocytosis**: RBC develop as small spherical cells rather than being biconcave. These spherical cells easily rupture by slight compression.
  - **Sickle-cell Anemia**: Genetic mutation causing abnormal beta chains. When this hemoglobin is exposed to low O2 concentrations, it precipitates into long crystals that cause the cells to become sickle-shaped.

Anemia: Abnormal Hemoglobin

- Thalassemias – absent or faulty globin chain in hemoglobin
  - Erythrocytes are thin, delicate, and deficient in hemoglobin
- Sickle-cell anemia – results from a defective gene
  - Codes for an abnormal hemoglobin called hemoglobin S (HbS)
  - This defect causes RBCs to become sickle-shaped in low oxygen situations

Leukocytes (WBCs)

- Leukocytes, the only blood components that are complete cells:
  - 4,800 - 10,000/cubic millimeter
  - Protect the body from infectious microorganisms
  - Can leave capillaries via diapedesis
  - Move through tissue spaces (amoeboid motion)
  - Many are phagocytic (possess numerous lysosomes)
- Two major types of leukocytes
  - Granulocytes: Neutrophils, Eosinophils, Basophils
  - Agranulocytes: Monocytes, Lymphyocytes
- Leukocytosis – WBC count over 11,000/mm^3
  - Normal response to bacterial or viral invasion
- Leukopenia - a decrease in WBC count below 4,800/mm^3
- Leukemia - a cancer of WBC



White blood cells

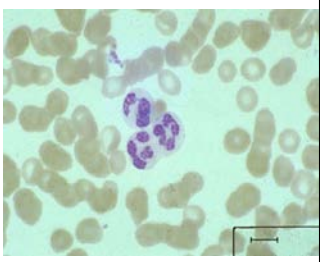
- the bodies "**defence**"
- part of the immune system
- much **larger** than RBCs
- far **fewer**
- have a nucleus
- 4000-13000 per mm^3
- 2 types phagocytes and lymphocytes

Granulocytes: Neutrophils
(Polymorphonuclear leukocytes)

- Account for 65-75% of total WBC's
- Neutrophils have two types of granules that:
  - Take up both acidic and basic dyes
  - Give the cytoplasm a lilac color
  - Contain peroxidases, hydrolytic enzymes, and defensins (antibiotic-like proteins)
- Neutrophils are our body's bacteria slayers
- AKA "polys" or PMN's (polymorphonuclear)

WBC Anatomy and Function Neutrophil

- **Make up 60 to 70% of WBC's**
- **10 –12 um. In diameter**
- **Nucleus 2-5 lobes (increase with cell age)**
- **Fine granular cytoplasm**
- **Phagocytic cells the engulf bacteria**
- **Increase: stress, burns, bacterial infections**
- **Decrease: Radiation exposure, B12 deficiency**



Granulocytes

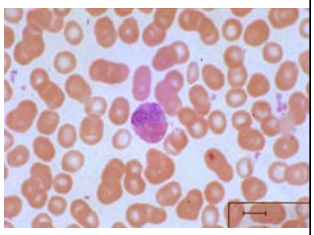
- Granulocytes – neutrophils, eosinophils, and basophils
  - Contain cytoplasmic granules that stain specifically (acidic, basic, or both) with Wright's stain
  - Are larger and usually shorter-lived than RBCs
  - Have lobed nuclei
  - Are all phagocytic cells

Granulocytes: Eosinophils

- Eosinophils account for 1–4% of WBCs
  - Have red-staining, bilobed nuclei
  - Have red to crimson granules
  - Function:
    - Lead the body's counterattack against parasitic infections
    - Lessen the severity of allergies by phagocytizing immune complexes (ending allergic reactions)

WBC Anatomy and Function Eosinophil

- **Make up 2-4% of WBC's**
- **10 –12 um in diameter**
- **Nucleus 2–3 lobed**
- **Cytoplasm filled with large red granules**
- **Combat histamines in allergic reactions**
- **Phagocytic on antigen/antibody complexes**
- **Destroy certain parasitic worms**
- **Increase: allergic reactions, parasitic infections, autoimmune disease**

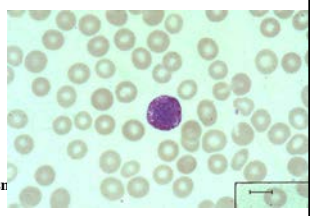


Granulocytes: Basophils

- Account for 0.5-1% of all WBCs
  - Have U- or S-shaped nuclei with two or three conspicuous constrictions
  - Are functionally similar to mast cells
  - Have large, purplish-black (basophilic) granules that contain histamine
    - Histamine – inflammatory chemical that acts as a vasodilator and attracts other WBCs (antihistamines counter this effect)

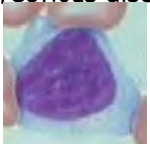
WBC Anatomy and Function Basophil

- **Make up .5 to 1% of WBC's**
- **8- 10 um in diameter**
- **Cytoplasm filled with large deep blue-purple granules**
- **Liberate heparin and histamines during allergic reactions**
- **Intensify inflammatory response**
- **Increase: Allergic reactions, leukemia, cancers, hypothyroidism**
- **Decrease: Pregnancy, ovulation, stress, hyperthyroidism**



Lymphocytes

Provide a **specific immune response** to infectious diseases.

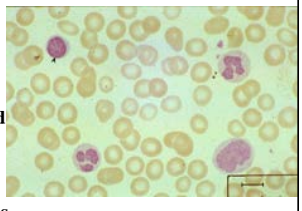


There are 2 types: -
- T-cells
- B-cells

They produce **antibodies**.

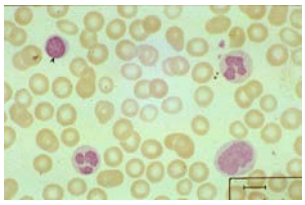
WBC Anatomy and Function Lymphocytes

- **Make up 20 to 25% WBC's**
- **Small: 6-9 um in diameter**
  Large: 10-14 um
- **Nucleus is round or slightly indented**
- **Cytoplasm forms rim around nucleus**
- **B cells produce antibodies**
- **T cells attack viruses, cancer cells, and transplanted tissues**
- **Natural killer cells attack infectious microbes and tumor cells**

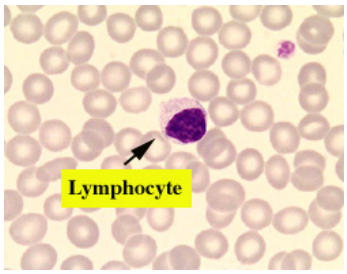


WBC Anatomy and Function Lymphocytes

- **Increase: Viral infections and some leukemias**
- **Decrease: Prolonged illness, immunosuppression**



Lymphocyte



Agranulocytes: Lymphocytes

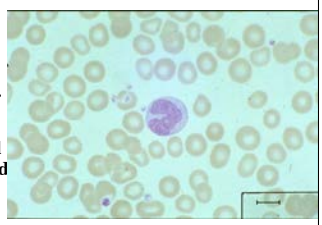
- Account for 20-25% or more of WBCs and:
  - Have large, dark-purple, circular nuclei with a thin rim of blue cytoplasm
  - Are found mostly enmeshed in lymphoid tissue (some circulate in the blood)
- Most important cells of the immune system
- There are two types of lymphocytes: T cells and B cells
  - T cells - attack foreign cells directly
  - B cells give rise to plasma cells, which produce antibodies

Monocytes

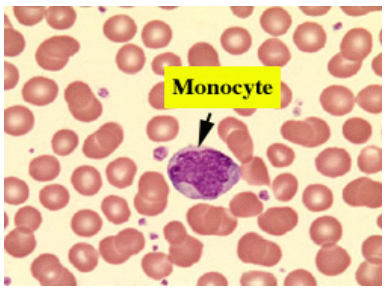
- Monocytes account for 3–7% of leukocytes
  - They are the largest leukocytes
  - They have purple-staining, U- or kidney-shaped nuclei
  - They leave the circulation, enter tissue, and differentiate into macrophages

WBC Anatomy and Function Monocytes

- **Make up 3-8 % of WBC's**
- **12 – 20 um in diameter**
- **Nucleus is kidney-shaped**
- **Cytoplasm is non-granular**
- **Phagocytic cells**
- **Increase: Viral and fungal infections, tuberculosis, and some leukemias**
- **Decrease: Bone marrow depression, treatment with cortisol**



Monocytes



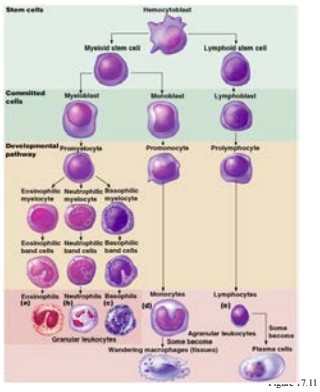
Production of Leukocytes

- Leukopoiesis is hormonally stimulated by two families of cytokines (hematopoietic factors) – interleukins and colony-stimulating factors (CSFs)
  - Interleukins are numbered (e.g., IL-1, IL-2), whereas CSFs are named for the WBCs they stimulate (e.g., granulocyte-CSF stimulates granulocytes)
- Macrophages and T cells are the most important sources of cytokines
- Many hematopoietic hormones are used clinically to stimulate bone marrow

Formation of Leukocytes

- All leukocytes originate from hemocytoblasts
  - The mother of all blood stem cells
- Hemocytoblasts differentiate into *myeloid* stem cells and *lymphoid* stem cells
  - Myeloid stem cells become myeloblasts or monoblasts
    - Granulocytes form from myeloblasts
    - Monoblasts enlarge and form monocytes
  - Lymphoid stem cells become lymphoblasts
    - Lymphoblasts develop into lymphocytes

Formation of Leukocytes



Leukocytes Disorders: Leukemias

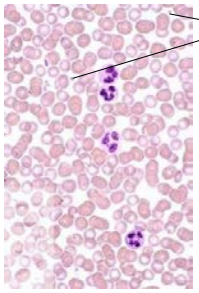
- Leukemia refers to cancerous conditions involving white blood cells
- Leukemias are named according to the abnormal white blood cells involved
  - Myelocytic leukemia – involves myeloblasts
  - Lymphocytic leukemia – involves lymphocytes
- Acute leukemia involves blast-type cells and primarily affects children
- Chronic leukemia is more prevalent in older people

Leukemia

- Immature white blood cells are found in the bloodstream in all leukemias
- Bone marrow becomes totally occupied with cancerous leukocytes
- Severe anemia ensues due to excess production of WBC' s
- The white blood cells produced, though numerous, are not functional
- Death is caused by internal hemorrhage and overwhelming infections
- Treatments include irradiation, antileukemic drugs, and bone marrow transplants

Platelets

- Platelets are fragments of megakaryocytes
- Their granules contain serotonin, Ca^{2+}, enzymes, ADP, and platelet-derived growth factor (PDGF)
- Platelets function in the clotting mechanism by forming a temporary plug that helps seal breaks in blood vessels
- Platelets not involved in clotting are kept inactive by Nitric Oxide (NO) and prostaglandins



Platelets

if you get cut:-

- platelets produce tiny fibrin threads
- these form a web-like mesh that traps blood cells.
- these harden forming a clot, or "scab."
- 150,000 to 400,000 per mm^3

Platelet Anatomy and Function

- **Disc-shaped 2 – 4 um in diameter**
- **150,000 to 400,000 per uL of blood**
- **Alpha Granules: contain clotting factors, platelet-derived growth factor**
- **Dense Granules: contain ADP, ATP, Ca2+, serotonin, and fibrin-stabilizing factor**