**Blood**

**Overview of Blood Circulation**

1. Blood leaves the heart via arteries that branch repeatedly until they become capillaries
2. Oxygen (O2) and nutrients diffuse across capillary walls and enter tissues
3. Carbon dioxide (CO2) and wastes move from tissues into the blood
4. Oxygen-deficient blood leaves the capillaries and flows in veins to the heart
5. This blood flows to the lungs where it releases CO2 and picks up O2
6. The oxygen-rich blood returns to the heart

**Composition of Blood**

1. Blood is the body’s only fluid tissue
2. It is composed of:

* liquid plasma
* formed elements

1. Formed elements include:

* Erythrocytes, or red blood cells (RBCs)
* Leukocytes, or white blood cells (WBCs)
* Platelets

1. Hematocrit – the percentage of RBCs out of the total blood volume

**Physical Characteristics and Volume**

1. Blood is a sticky, opaque fluid with a metallic taste
2. Color varies from scarlet (oxygen-rich) to dark red (oxygen-poor)
3. The pH of blood is 7.35–7.45
4. Temperature is 38°C, slightly higher than “normal” body temperature
5. Blood accounts for approximately 8% of body weight
6. Average volume of blood is 5–6 L for males, and 4–5 L for females

**Functions of Blood**

    Blood performs a number of functions dealing with:

1. Substance distribution
2. Regulation of blood levels of particular substances
3. Body protection
4. **Distribution**
5. Blood transports:
6. Oxygen from the lungs and nutrients from the digestive tract
7. Metabolic wastes from cells to the lungs and kidneys for elimination
8. Hormones from endocrine glands to target organs
9. **Regulation**

      Blood maintains:

1. Appropriate body temperature by absorbing and distributing heat
2. Normal pH in body tissues using buffer systems
3. Adequate fluid volume in the circulatory system

**Protection**

  Blood prevents blood loss by:

1. Activating plasma proteins and platelets
2. Initiating clot formation when a vessel is broken

Blood prevents infection by:

1. Synthesizing and utilizing antibodies
2. Activating complement proteins
3. Activating WBCs to defend the body against foreign invaders

**Composition of blood**

Blood is classified as a connective tissue and consists of two main components:

1. Plasma, which is a clear extracellular fluid

2. Formed elements, which are made up of the blood cells and platelets

The formed elements are so named because they are enclosed in a plasma membrane and have a definite structure and shape. All formed elements are cells except for the platelets, which are tiny fragments of bone marrow cells.

**Formed elements are**:

•Erythrocytes, also known as red blood cells (RBCs)

•Leukocytes, also known as white blood cells (WBCs)

•Platelets

**ERYTHROCYTES (RBCS)**

* Biconcave discs, anucleate, essentially no organelles
* Filled with hemoglobin (Hb), a protein that functions in gas transport
* Contain the plasma membrane protein *spectrin* that:
* Gives erythrocytes their flexibility
* Allows them to change shape as necessary
* Erythrocytes are an example of the complementarity of structure and function
* Structural characteristics that contribute to its gas transport function are:
* Biconcave shape that has a huge surface area to volume ratio
* Discounting water content, erythrocytes are 97% hemoglobin
* ATP is generated anaerobically, so the erythrocytes do not consume the oxygenthey transport

# Erythrocyte Function

## Erythrocytes are dedicated to respiratory gas transport

## Hemoglobin reversibly binds with oxygen and most oxygen in the blood is bound to hemoglobin

## Hemoglobin is composed of:

### The protein *globin*, made up of two alpha and two beta chains, each bound to a heme group

### Each heme group bears an atom of iron, which can bind one to oxygenmolecule

## Each hemoglobin molecule can transport four molecules of oxygen

# Hemoglobin (Hb)

## 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

# Production of Blood Cells

## Hematopoiesis – blood cell formation

## Hemopoiesis occurs in the red bone marrow of the:

### Axial skeleton and girdles

### Epiphyses of the humerus and femur

## Hemocytoblasts give rise to all formed elements

# 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

## 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 increases

# Erythropoiesis: Nutrient Requirements

## Erythropoiesis requires:

### Proteins, lipids, and carbohydrates

### Iron, vitamin B12, 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*

# Fate and Destruction of Erythrocytes

## The life span of an erythrocyte is 100–120 days

## Old erythrocytes become rigid and fragile, and their hemoglobin begins to degenerate

## Dying erythrocytes are engulfed by macrophages

## Heme and globin are separated and the iron is salvaged for reuse

# Fate of Hemoglobin

## Heme is degraded to a yellow pigment called *bilirubin*

## The liver secretes bilirubin into the intestines as bile

## The intestines metabolize it into urobilinogen

## This degraded pigment leaves the body in feces, in a pigment called *stercobilin*

## Globin is metabolized into amino acids and is released into the circulation

# Erythrocyte Disorders

## **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

# Anemia: Insufficient Erythrocytes

## Hemorrhagic anemia – result of acute or chronic loss of blood

## Hemolytic anemia – prematurely ruptured erythrocytes

## Aplastic anemia – destruction or inhibition of red bone marrow

# Anemia: Decreased Hemoglobin Content

## Iron-deficiency anemia results from:

### A secondary result of hemorrhagic anemia

### Inadequate intake of iron-containing foods

### Impaired iron absorption

## Pernicious anemia results from:

### Deficiency of vitamin B12

### Often caused by lack of intrinsic factor needed for absorption of B12

# 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 coding for an abnormal hemoglobin called *hemoglobin S* (HbS)

### HbS has a single amino acid substitution in the beta chain

### This defect causes RBCs to become sickle-shaped in low oxygen situations

# Polycythemia

## Polycythemia – excess RBCs that increase blood viscosity

## Three main polycythemias are:

### Polycythemia vera

### Secondary polycythemia

### Blood doping

# Leukocytes (WBCs)

## Leukocytes, the only blood components that are complete cells:

### Are less numerous than RBCs

### Make up 1% of the total blood volume

### Can leave capillaries via diapedesis

### Move through tissue spaces

## Leukocytosis – WBC count over 11,000 per cubic millimeter

### Normal response to bacterial or viral invasion

# Classification of Leukocytes: 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

# Neutrophils

## 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 bacterial slayers

# Eosinophils

## Eosinophils account for 1–4% of WBCs

### Have red-staining, bi-lobed nuclei connected via a broad band of nuclear material

### Have red to crimson (acidophilic) large, coarse, lysosome-like granules

### Lead the body’s counterattack against parasitic worms

### Lessen the severity of allergies by phagocytizing immune complexes

# Basophils

## Account for 0.5% of WBCs and:

### 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

# Agranulocytes

## Agranulocytes – lymphocytes and monocytes:

### Lack visible cytoplasmic granules

### Are similar structurally, but are functionally distinct and unrelated cell types

### Have spherical (lymphocytes) or kidney-shaped (monocytes) nuclei

# Lymphocytes

## Have large, dark-purple, circular nuclei with a thin rim of blue cytoplasm

## Found mostly enmeshed in lymphoid tissue (some circulate in the blood)

## There are two types of lymphocytes: T cells and B cells

### T cells function in the immune response

### B cells give rise to plasma cells, which produce antibodies

# Monocytes

## Monocytes account for 4–8% of leukocytes

### They are the largest leukocytes

### They have abundant pale-blue cytoplasms

### They have purple staining, U- or kidney-shaped nuclei

### They leave the circulation, enter tissue, and differentiate into macrophages

## Macrophages:

### Are highly mobile and actively phagocytic

### Activate lymphocytes to mount an immune response

# Production of Leukocytes

## Leukopoiesis is hormonally stimulated by two families of cytokines (hematopoetic 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

## Hemocytoblasts differentiate into myeloid stem cells and lymphoid stem cells

## Myeloid stem cells become myeloblasts or monoblasts

## Lymphoid stem cells become lymphoblasts

## Myeloblasts develop into eosinophils, neutrophils, and basophils

## Monoblasts develop into monocytes

## Lymphoblasts develop into lymphocytes

# Leukocyte Disorders: Leukemias

## Leukemia refer 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

## 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