**The Blood**

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**Overview of Blood Circulation**

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

**Composition of Blood**

* Blood is the body’s only fluid tissue
* It is composed of liquid plasma and formed elements
* Formed elements include:
* Erythrocytes, or red blood cells (RBCs)
* Leukocytes, or white blood cells (WBCs)
* Platelets
* Hematocrit – the percentage of RBCs out of the total blood volume
	+ Normal 47% male, 42% female



**Physical Characteristics and Volume**

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

**Functions of Blood**

* **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

**Functions of Blood: continued**

* **Regulation -** Blood maintains
* Appropriate body temperature by absorbing and distributing heat
* Normal pH in body tissues using buffer systems
* Adequate fluid volume in the circulatory system
* **Protection -** Blood prevents blood loss by
* Activating plasma proteins and platelets
* Initiating clot formation when a vessel is broken
* **Protection -** Blood prevents infection by:
* Synthesizing and utilizing antibodies
* Activating complement proteins
* Activating WBCs to defend the body against foreign invaders

**Blood Plasma**

* 55% of whole blood. Mostly water.
* Contains over 100 solutes, including:
* Proteins – albumin, globulins, clotting proteins, and others
* Nonprotein nitrogenous substances – lactic acid, urea, creatinine
* Organic nutrients – glucose, carbohydrates, amino acids
* Electrolytes – sodium, potassium, calcium, chloride, bicarbonate
* Respiratory gases – oxygen and carbon dioxide

**Formed Elements**

* 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 discs, anucleate, essentially no organelles
* Filled with hemoglobin (Hb), a protein that functions in gas transport
* Contain the plasma membrane protein that:
* Give erythrocytes their flexibility
* Allow them to change shape as necessary
* Structural characteristics contribute to its gas transport function
* Biconcave shape that has a huge surface area relative to volume
* Discounting water content, erythrocytes are more than 97% hemoglobin



**Typical Counts**

* 4,600,000 – 6,200,000 males
* 4,200,000 – 5,400,000 females
* 4,500,000 – 5,100,000 children

**Erythrocyte Function**

* Erythrocytes are dedicated to respiratory gas transport
* Each RBC contains approximately 300 million hemoglobin molecules
* In the systemic capillaries, hemoglobin gives up much of it’s oxygen
* In the pulmonary capillaries, RBCs pick up oxygen

**Production of Erythrocytes**

* Hematopoiesis – blood cell formation
* Hematopoiesis occurs in the red bone marrow of the:
* Axial skeleton and girdles
* Epiphyses of the humerus and femur



**Regulation of 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
* Erythropoietin (EPO) release by the kidneys is triggered by:
	+ Hypoxia due to decreased RBCs
	+ Decreased oxygen availability
	+ Increased tissue demand for oxygen



**Dietary Requirements of Erythropoiesis**

* 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

**Lifespan 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

**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

**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
	+ Lack of intrinsic factor needed for absorption of B12

**Anemia: Abnormal Hemoglobin**

* Sickle-cell anemia – results from a defective gene coding for an abnormal hemoglobin called hemoglobinS (HbS)
* This defect causes RBCs to become sickle-shaped in low oxygen situations

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**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

**Number of Leuckocytes** “Never Let Monkeys Eat Bananas”

* From the most to the least prevelent
	+ Neutrophils, Lymphocytes, Monocytes, Eosinophils, Basophils

**Neutrophils**

* Neutrophils are the most numerous WBC
* 50-70% of WBC population
* Attracted to sites of inflammation
* Neutrophils are our body’s bacteria slayers
* Are phagoctyic

**Lymphocytes**

* + - Account for 25% or more of WBCs



* Only a small number is found in the blood
* Most are found in lymph tissue
* Critical role in Immunity

**Monocytes**

* Monocytes account for 4–8% of leukocytes



* They are the largest leukocytes
* They leave the circulation, enter tissue, and

 differentiate into macrophages

* They have massive appetites
* Defends against chronic infections, viruses

 and parasites

**Eosinophils**

* Eosinophils account for 1–4% of WBCs



* Lead the body’s counterattack against

 parasitic worms

* Lessen the severity of allergies by

 phagocytizing immune complexes

**Basophils**

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* Account for 0.5% of WBCs
* Rarest of all WBC
* Releases histamine in inflammations
* Histamine – inflammatory chemical that acts as a

 vasodilator and attracts other WBCs (antihistamines

 counter this effect)

**Production of Leukocytes**

* Overproduction of WBC occurs in leukemia and infectious mononucleosis
* On the opposite end of the spectrum is Leukopenia, which is an abnormally low WBC count.
	+ Common with cancer medications and glucocorticoids
* Many hematopoietic hormones are used clinically to stimulate bone marrow

**Leukocytes Disorders: Leukemias**

* “White blood”
* Leukemia refers to cancerous conditions involving white blood cells
* In all leukemias, the bone marrow becomes almost totally occupied by cancerous WBC and immature WBC before flowing into the boodstream.
* Because other cells can be crowded out, severe anemia and bleeding problems occur.
* 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

**Platelets**

* Platelets are also known as thrombocytes
* They lack a nucleus and are roughly half the size of a RBC
* There are approximately 130,000 – 360,000 per cubic millimeter of blood
* They help repair damaged blood vessels by sticking to broken surfaces



**Hemostasis**

* “Stopping or halting bleeding”
* A series of reactions designed for stoppage of bleeding
* During hemostasis, three phases occur in rapid sequence
* Vascular spasms – immediate vasoconstriction in response to injury
* Platelet plug formation
* Coagulation (blood clotting)

**Vascular Spasm**

* The immediate response to blood vessel injury is constriction of the damaged vessel
* The spasm becomes more efficient as the amount of tissue damage increases
* A strong constricted artery can reduce blood loss for 20-30 minutes

**Platelet Plug Formation**

* They are fragments of very large cells
* They are essential for the clotting process that occurs when blood vessels are ruptured or the vessel lining is injured
* They stick to the damaged site forming a temporary plug
* Because they do not have a nucleus, they degenerate in about 10 days

**Coagulation or Blood Clotting**

* A set of reactions in which blood is transformed from a liquid to a gel
* Coagulation follows intrinsic and extrinsic pathways
* The process is very complicated involving 30 different structures

**Clot Retraction and Repair**

* Clot retraction – stabilization of the clot by squeezing serum from the fibrin strands
* Within 30-60 minutes the clot is stabilized by a platelet induced process
* Repair
* Platelet contains contractile proteins and they interact a lot like muscle cells
* Fibroblasts form a connective tissue patch

**Fibrinolysis**

* A clot is not a permanent solution to blood vessel injury
* Fibrinolysis removes uneeded clots when healing has occurred
* Without fibrinolysis, the blood vessels would gradually become completely blocked.

**Hemostasis Disorders**

* Thrombus – a clot that develops and persists in an unbroken blood vessel
* Thrombi can block circulation, resulting in tissue death
* Coronary thrombosis – thrombus in blood vessel of the heart
* Embolus – a thrombus freely floating in the blood stream
* Pulmonary emboli can impair the ability of the body to obtain oxygen
* Cerebral emboli can cause strokes



**Prevention of Undesirable Clots**

* Substances used to prevent undesirable clots include:
* Aspirin – an antiprostaglandin that inhibits thromboxane A2
* Heparin – an anticoagulant used clinically for pre- and postoperative cardiac care
* Warfarin – used for those prone to atrial fibrillation

**Blood Transfusions**

* Whole blood transfusions are used:
* When blood loss is substantial
* In treating thrombocytopenia
* The body can only compensate for so much blood loss
* Loss of 15-30% can cause weakness and pallor,
* Loss of more than 30% can be fatal

**Human Blood Groups**

* RBC membranes have glycoprotein antigens on their external surfaces
* These antigens are:
* Unique to the individual
* Recognized as foreign if transfused into another individual
* Presence or absence of these antigens is used to classify blood groups

**Blood Groups**

* Humans have 30 varieties of naturally occurring RBC antigens
* The antigens of the ABO and Rh blood groups cause vigorous transfusion reactions when they are improperly transfused

**ABO Blood Groups**

* The ABO blood groups consists of:
* Two antigens (A and B) on the surface of the RBCs
* Two antibodies in the plasma (anti-A and anti-B)
* An individual with ABO blood may have various types of antigens and spontaneously preformed antibodies
* Agglutinogens and their corresponding antibodies cannot be mixed without serious hemolytic reactions

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**Hemolytic Disease of the Newborn**

* Hemolytic disease of the newborn – Rh+ antibodies of a sensitized Rh– mother cross the placenta and attack and destroy the RBCs of an Rh+ baby
* Rh– mother becomes sensitized when Rh+ blood (from a previous pregnancy of an Rh+ baby or a Rh+ transfusion) causes her body to synthesis Rh+ antibodies
* The drug RhoGAM can prevent the Rh– mother from becoming sensitized
* Treatment of hemolytic disease of the newborn involves pre-birth transfusions and exchange transfusions after birth



**Transfusion Reactions**

* Transfusion reactions occur when mismatched blood is infused
* Donor’s cells are attacked by the recipient’s plasma agglutinins causing:
* Diminished oxygen-carrying capacity
* Clumped cells that impede blood flow
* Ruptured RBCs that release free hemoglobin into the bloodstream
* Circulating hemoglobin precipitates in the kidneys and causes renal failure



**The Big Picture: Blood and the Whole Body**

* Blood plasma transports substances, including heat, around the body, linking all body tissues together
	+ Substances can be transported between almost any two points in the body
* Blood tissue contains formed elements—blood cells and platelets
	+ RBCs assist in the transport of oxygen and carbon dioxide
	+ WBCs assist in the defense mechanisms of the whole body
	+ Platelets prevent loss of the fluid that constitutes the internal environment
* No organ or system of the body can maintain proper levels of nutrients, gases, or water without direct or indirect help from blood
	+ Other systems assist the blood
* Blood is useless unless it continues to transport, defend, and maintain balance



