BLOOD

Blood is a connective tissue made of living cells called formed elements suspended in a nonliving fluid matrix called plasma. Red blood cells normally account for about 45% of total volume known as hematocrit. White blood cells and platelets contribute less than 1% and plasma makes up the remaining 55%.

FUNCTIONS –
- Transportation – gases, nutrients, waste products, hormones
- Regulation – maintaining temperature, pH and fluid volume
- Protection – prevent blood loss and infection

PLASMA
1. Water – 90% of plasma; solvent for carrying substances and absorbing heat
2. Proteins – most are produced by the liver
   a. Albumins – maintains osmotic pressure
   b. Globulins – antibodies and lipid transport
   c. Fibrinogen – clotting of blood
3. Inorganic constituents (electrolytes - salts) – assist in osmotic balance, pH buffering, regulation of membrane permeability
4. Dissolved substances transported by the blood - nutrients, waste, gases, hormones

FORMED ELEMENTS
ERYTHROCYTES (RBC):
- Biconcave shaped cells that contain hemoglobin, an iron-bearing protein, to transport oxygen. A single RBC contain 250 million hemoglobin molecules, each capable of binding 4 molecules of O₂.
- How much O₂ can a single RBC carry? ____________
- Circulating RBC – 5 million per mm³ in a drop of blood.
- RBCs are anucleated and amitotic with a lifespan of ~120 days. Aged and damaged RBC are broken down in the spleen and the liver.
- Normal blood contains 14-18g in males & 12-16g in females per 100 ml of blood.
- Erythropoiesis occurs in red bone marrow where myeloid stem cells produce RBCs. Cells synthesize hemoglobin then eject the nucleus and mature. The rate of erythropoiesis is controlled by a hormone called erythropoietin. When blood levels of O₂ are low (hypoxia), kidney cells produce and release erythropoietin which stimulate stem cells in marrow to form RBCs. Vitamin B12, iron and Folic acid are needed for RBC production.

Anemia – decrease in the oxygen-carrying ability of the blood. It may result from a lower amount of RBC or abnormal hemoglobin.
Sickle cell anemia – genetic disorder resulting in abnormal hemoglobin that ruptures easily and forms clots in vessels
Polycythemia – abnormal increase in RBCs that may result from bone marrow cancer or response to living at high altitudes
LEUKOCYTES (WBC):

- Cells are crucial to body defense against disease. On average, there are ~4000-11000 WBCs/mm³. These cells contain nuclei and organelles.
- Cells are capable of moving in and out of blood vessels, a process called diapedesis. Cells can locate areas of tissue damage and infection by responding to chemicals that diffuse from damaged cells. This capability is called positive chemotaxis.
- When a bacterial or viral infection is detected, the body speeds up production of WBCs and this process is called leukocytosis. Myeloid and lymphoid stem cells produce the various WBCs.

<table>
<thead>
<tr>
<th>Granular WBC (produced from myeloid stem cells in red bone marrow)</th>
<th>Agranular WBC (produced in lymphoid stems cells in lymph tissue)</th>
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</thead>
<tbody>
<tr>
<td><strong>Neutrophils</strong> – active phagocytes; number increases rapidly during short-term or acute infections; most numerous</td>
<td><strong>Monocytes</strong> – active phagocytes that become macrophages to “clean-up”; increase during chronic infections</td>
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<td><strong>Eosinophils</strong> – mainly attacks parasites; increase during allergic attacks</td>
<td><strong>Lymphocytes</strong> – part of immune response; B lymphocytes produce antibodies &amp; T lymphocytes fight viruses, tumors and activate B lymphocytes</td>
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<td><strong>Basophils</strong> – release histamine (vasodilator) and heparin (anticoagulant) which is released at site of inflammation</td>
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Leukopenia – low WBC count; commonly caused by corticosteroids & anticancer drugs
Leukemia – bone marrow becomes cancerous; rapid production of WBC that are immature and incapable of carrying out normal functions.

PLATELETS (Thrombocytes):

- Platelets help initiate formation of blood clots to close breaks in damaged blood vessels. Coagulation of blood is called hemostasis. Hemostasis involves 3 phase: platelet plug formation (platelets accumulate), vascular spasm (platelets release serotonin which causes vessels to go into spasm to decrease blood loss), coagulation (platelets, enzymes, fibrinogen form clot)
- Myeloid stem cells in bone marrow form megakaryocytes. Megakaryocytes rupture and break off into thousands of anucleated platelet fragments. The hormone, thrombopoietin, accelerates the production of platelets which is triggered by damaged blood vessels.
- Platelets remain functional for 7-10 days. Normal platelet count is ~250,000/mm³.

Thrombus – floating clot
Embolus – stationary clot
Thrombocytopenia – insufficient number of circulating platelets; can result from bone marrow cancer, radiation, certain drugs, vitamin K deficiency or liver failure
Hemophilia – genetic disorder resulting form a lack of any of the factors needed for clotting

The ABO Blood System

<table>
<thead>
<tr>
<th>Blood Type (genotype)</th>
<th>Type A (AA, AO)</th>
<th>Type B (BB, BO)</th>
<th>Type AB (AB)</th>
<th>Type O (OO)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red Blood Cell Surface Proteins (phenotype)</td>
<td>A agglutinogens only</td>
<td>B agglutinogens only</td>
<td>A and B agglutinogens</td>
<td>No agglutinogens</td>
</tr>
<tr>
<td>Plasma Antibodies (phenotype)</td>
<td>a agglutinin only</td>
<td>b agglutinin only</td>
<td>None</td>
<td>a and b agglutinin</td>
</tr>
</tbody>
</table>
The major function of the cardiovascular system is transportation, using the blood to carry oxygen, nutrients, cellular wastes, hormones and other substances vital for body homeostasis to and from the cells. The heart is enclosed within the mediastinum, the middle cavity of the thorax. The apex is toward the left and rests on the diaphragm, at the 5th intercostal space. The base is toward the right and lies beneath the 2nd rib. The heart begins as a tube that is beating and pumping blood by the 4th week of embryonic development.

**Membranes & Layers of the Heart**

- **Pericardium** – this double-walled sac encloses the heart. The superficial fibrous pericardium and parietal pericardium protects and anchors heart to surrounding structures such as the diaphragm and sternum. The visceral pericardium lines the external surface of the heart; fluid between the parietal and visceral layers reduces friction.
- **Epicardium** – outer layer of heart.
- **Myocardium** – thick bundles of cardiac muscle.
- **Endocardium** – endothelium that lines the heart chambers and the blood vessels entering and leaving the heart.

**Heart Anatomy**

- 4 hollow chambers lined with endocardium – two atria (superior) & two ventricles (inferior).
- Interventricular & Interatrial septum – separates the left and right side.
- Atrioventricular (AV) valves – between the atrium & the ventricles; prevents back flow into atrium.....right AV valve is a tricuspid and left AV valve is a bicuspid (mitral valve).
- Semilunar (SL) valves (tricuspids) – between an artery & a ventricle; Aortic SL valve – between the aorta and left ventricle.....Pulmonary SL valve – between the pulmonary artery and right ventricle.
- Superior & Inferior Vena Cava – vessels that returns blood to the heart from the body.
- Pulmonary Arteries (Trunk) – pulmonary trunk splits into right and left pulmonary arteries.
- Pulmonary Veins – returns oxygenated blood from lungs.
- Aorta – vessel that delivers blood to the body.
- Chordae tendinae – anchor the AV valves to the papillary muscles protruding from the walls of ventricles.
- Coronary arteries – arteries branch from the base of the aorta to oxygenate and nourish the myocardium.
- Coronary veins – veins drain the blood from the myocardium into enlarged vessel on the back of the heart called the coronary sinus which empties into the right atrium.
Pathway of Blood –
1. Deoxygenated blood enters the right atrium from the superior & inferior vena cava
2. Blood moves through the AV valves into the right ventricle (SL valve is closed)…when filled, the AV valve closes and the pulmonary SL valve opens….the right ventricle contracts pushing the blood into the pulmonary arteries
3. Pulmonary arteries carry blood to lungs to pick up O₂ & release CO₂ in the capillaries ---- O₂ rich blood returns to heart and enters the left atrium
4. Blood moves through AV mitral valve into left ventricle (SL valve is closed)…when filled, the AV valve closes and the aortic SL valve opens….the left ventricle contracts pushing the blood into the aorta to carry blood to the rest of the body

Pulmonary Circuit – circulation of blood from the right side of the heart to the lungs and back to the left side of heart

Systemic Circuit – circulation of blood from the left side of the heart through the body tissues and back to the right side of the heart
Cardiac Cycle (complete heartbeat = .8 secs)
1. During relaxation phase (diastole), blood returning from the large veins flows into atria. AV valves are open and SL valves are closed.
2. A brief period of atrial systole (contraction) forces blood out of the atria into the ventricles.
3. As pressure rises in ventricles, the AV valves close (lub) and the SL valves are forced open. The ventricles contract (systole) pushing blood into the pulmonary arteries and aorta.
4. Atria relax (diastole), then ventricles begin to relax and SL valves close (dub). AV valves open and the cycle continues.

REGULATION of heart – two systems act to regulate heart activity:
1. Autonomic Nervous System (ANS) – decrease or increase the heart rate depending on which division is activated (sympathetic or parasympathetic)
2. Intrinsic conduction system (nodal system) – built into the heart tissue and sets cardiac rhythm. The system causes heart muscle depolarization in one direction from the atria to the ventricles. It enforces a contraction rate of approximately 75 beats per minute on the heart.
   - Sinoatrial (SA) node (pacemaker) – located in right atrium; it starts each heartbeat and sets the pace for the whole heart. SA node triggers the impulse to spread across the atria to the AV node and the atria contract pushing blood into ventricles.
   - Atrioventricular (AV) node – at the junction of the atria and ventricles; AV node receives impulse....impulse is briefly delayed to give the atria time to finish contracting. Then AV node sends impulse over the ventricles (AV bundle, bundle branches, Purkinje fibers) causing the ventricles to contract.
**Blood Vessels**

**Arteries** carry blood away from heart. Arteries branch into smaller arteries and eventually into **arterioles**, which feed into **capillaries**. Capillaries drain into **venules**, which eventually turn into **veins** that return blood to the heart. Veins have valves to prevent back flow.

The walls of vessels have 3 tunics. **Tunica intima** lines the lumen and forms a slick surface that decreases friction as blood flows through the lumen. **Tunica media** constricts or dilates to change the diameter of the vessel. **Tunica externa** supports and protects the vessel.
**Arterial Pulse** – the alternating expansion and recoil of an artery that occurs with each beat of the left ventricle creates a pressure wave – a pulse – that travels through the entire arterial system. Normally, pulse rate (pressure surges/min) equals heart rate (beats/min) ---- average 70 beats/min. Body sites where the pulse is easily palpated can also be compressed to stop the blood flow into distal tissues during hemorrhage --- they are called pressure points.

**Cardiac Output** – the amount of blood pumped out by each ventricle in 1 minute. It is a product of heart rate and stroke volume. **Stroke volume** is the volume of blood pumped out by each ventricle with each heartbeat. **Heart rate** is the number of beats per minute. For example if: HR (75 beats/min) x SV (70 mL/beat) = CO (5250 mL/min). Since the normal adult blood volume is about 5000 ml, the entire blood supply passes through the body once each minute.

The critical factor controlling stroke volume is how much the cardiac muscle cells are stretched prior to contraction. The venous return, amount of blood entering heart and distending its ventricles, determines the extent of stretching. When stroke volume declines, cardiac output is maintained by faster heartbeat. Heart rate is modified by the ANS, various chemicals, hormones and ions. Age, gender, exercise and body temperature influence heart rate.

- **Tachycardia** – rapid heart rate over 100 beats/min
- **Bradycardia** – slower heart rate lower than 60 beats/min

**Blood Pressure** – the pressure that blood exerts against the inner walls of the blood vessels. When ventricles contract, they force blood into arteries that expand as the blood is pushed into them. The high pressure forces the blood to continually move into areas where pressure is lower and eventually back to the heart.

- Use a sphygmomanometer to measure blood pressure: systolic (ventricle contraction) & diastolic (ventricle relaxation). Normal blood pressure is 120/80 (S/D).
- Blood pressure is directly related to cardiac output and peripheral resistance, the amount of friction the blood encounters as it flows through the vessels. Several factors influence pressure: ANS, kidney functions, temperature, chemicals (drugs), diet…..these factors can alter the viscosity of blood, the elasticity of vessels and the amount of blood.

- **Hypotension** – low blood pressure; systolic below 100 mm Hg
- **Hypertension** – high blood pressure; sustained 140/90 mm Hg

**Valvular Stenosis** – valve flaps become stiff; often because of repeated bacterial infections of endocardium (endocarditis)

**Angina Pectoris** – chest pain due to lack of oxygen to myocardium

**Myocardial Infarction** – heart attack due to prolonged lack of oxygen

**Heart block** – damage to AV nodes can partially or totally release control of the SA node resulting in the ventricles beating at their own rate which is slower

**Ischemia** – lack of adequate blood supply to the heart muscle may lead to fibrillation – a rapid uncoordinated shuddering of the heart muscle; can result in heart attack

**Murmur** – abnormal or unusual heart sounds

**Congestive heart failure** – heart is ‘worn-out’ due to age, hypertensive heart disease or another pathological process that weakens the heart

**Atherosclerosis** – clogging of the coronary vessels with fatty buildup