Chapter Four
The Cardiovascular System
Introduction

- Circulatory system is a transport system.
- Contributes to body defenses and the coagulation process and controls body temperature.
- The lymphatic system is considered to be part of the circulatory system, the primary purpose of which is to circulate lymph fluid.
## Box 4-1 Functions of the Blood

<table>
<thead>
<tr>
<th>Function</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation</td>
<td>Carry gases&lt;br&gt;Carry oxygen from the lungs to the tissues&lt;br&gt;Carry carbon dioxide from the tissues to the lungs&lt;br&gt;Transport waste products to sites such as the kidneys for excretion&lt;br&gt;Transport antibodies and white blood cells to defend against pathogenic microbes and viruses</td>
</tr>
<tr>
<td>Disbursement of nutrients</td>
<td>Distribute nutrients absorbed in the digestive tract to all organs of the body&lt;br&gt;Take nutrients released from fat, muscle, and tissues for use in other parts of the body</td>
</tr>
<tr>
<td>Regulation</td>
<td>Regulate the blood pH in all parts of the body&lt;br&gt;Regulate electrolyte balance to maintain a “steady state” condition&lt;br&gt;Control body temperature by redistribution of heat</td>
</tr>
<tr>
<td>Hemostasis</td>
<td>Restrict fluid loss when blood vessels are damaged&lt;br&gt;Formation of blood clots to prevent bleeding</td>
</tr>
</tbody>
</table>

Box 4.1: Functions of the blood
Blood

- All blood cells develop from undifferentiated stem cells
  - Stem cells are considered immature cells
  - As they mature, they differentiate into erythrocytes (red blood cells or RBCs), leukocytes (white blood cells or WBCs) and thrombocytes (platelets).
  - undergo changes in the nucleus and cytoplasm so that when they reach the circulating blood, they become fully mature and functional
# The Blood

## TABLE 4-1. Blood Cells

<table>
<thead>
<tr>
<th>CELLS</th>
<th>NUMBER/ SIZE</th>
<th>FUNCTION</th>
<th>FORMATION</th>
<th>DESTRUCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Erythrocytes (RBCs)</td>
<td>4.5–5.5 million/mm³; size 6–7 m</td>
<td>Transport $O_2$ and $CO_2$</td>
<td>Bone marrow</td>
<td>Fragmentation and removal in spleen, liver, and bone marrow; life span—120 days</td>
</tr>
<tr>
<td>Leukocytes (WBCs)</td>
<td>5000–9000/mm³; size 9–16 m</td>
<td>Defense</td>
<td>Granulocytes in bone marrow; nongranular WBCs in all lymphatic tissue</td>
<td>Removed in spleen, liver, bone marrow; life span—1 day to 1 year</td>
</tr>
<tr>
<td>Thrombocytes (platelets)</td>
<td>250,000–450,000/mm³; size 1–4 m</td>
<td>Clotting</td>
<td>Bone marrow</td>
<td>Removed in spleen; life span—9 to 12 days</td>
</tr>
</tbody>
</table>

*Abbreviations: RBCs, red blood cells; WBCs, white blood cells.*
Erythrocytes

- Red blood cells measure about 7 mm in diameter with a thickness of 2 mm.
- During maturation in the bone marrow, the RBCs lose their nucleus.
- Unique and flexible shape (biconcave disc) enables them to pass through very narrow capillaries and provides for maximum surface area to transfer oxygen and carbon dioxide.
- Normal blood has approximately 4.5 to 5 million cells per cubic milliliter.
- The life-span of RBCs is approximately 120 days in the circulating bloodstream.
Erythrocytes

- The main component of the RBC is **hemoglobin** which binds to oxygen for transport to the tissues, then binds to CO2 to be delivered to the lungs as a waste product.
- Hemoglobin gives blood its red color.
- Millions of RBCs are continually being formed and destroyed daily.
- Deficiencies may result in anemia.
- The surface membrane of RBCs contains structures called antigens that designate the individual's blood type.
The Blood

Figure 4.5  Human Blood Types

Type A
A antigen is present
(a)

Type B
B antigen is present
(b)

Type AB
A and B antigens are present
(c)

Type O
A or B antigens are not present
(d)
Leukocytes

- WBCs number about 5,000 to 10,000 and are classified into cell lines which differ in color size, shape, nuclear formation and function.
- White cells are further divided into cell lines, one of which is the granulocytes which contain cytoplasmic granules.
  - Segmented neutrophils
  - Eosinophils
  - Basophils
Leukocytes

- Monocytes and lymphocytes are agranular cells.
  
    - Monocytes
    - Lymphocytes

- A commonly performed laboratory test is the "differential"
  
    - A high WBC count with an increase in granulocytes indicates a bacterial infection
    - A high WBC count with predominantly immature WBCs present indicates leukemia
    - A low WBC count with an increase in the lymphocytes indicates a viral infection.
The Blood

Figure 4.6 Human Blood Cells

- Neutrophil
- Eosinophil
- Basophil
- Monocyte
- Lymphocyte
- Red blood cells
- Platelets
Platelets

- **Thrombocytes**, commonly called platelets, are much smaller than other blood cells and are actually fragments of megakaryocytes.
- Normally there are 250,000 to 450,000 platelets/mm³.
- Life span is 9–12 days.
- Thrombocytes participate in blood clotting.
- When vessels are damaged, the platelets release factors that are needed for the clotting reaction.
- Blood clotting, or coagulation, is the final step in hemostasis, the prevention of blood loss.
- Low platelets may cause a patient to have excessive bleeding or uncontrolled bleeding after an injury.
Plasma

- If a chemical agent or anticoagulant is added to prevent clotting, a blood sample can be separated by centrifugation into the cells and plasma.

- Plasma cannot clot due to inactivation of certain vital necessary elements and will contain all coagulation factors.

- Anticoagulated whole blood is required for all tests performed in the hematology department.

- Plasma is required for all coagulation tests.
Serum

- Serum is produced when blood is drawn into a non-additive tube and allowed to clot.
  - The blood cells become meshed in a fibrin clot.
  - Serum contains essentially the same chemical constituents as plasma except that clotting factors have been used up to form the clot so will have NO coagulation factors.
Figure 4.7 Centrifuged Blood Specimens With and Without Anticoagulant, Respectively
Blood is slightly basic with a pH of 7.35.
Figure 4.1 Superficial Anatomy of the Heart
The Heart

- The human heart is a muscular organ about the size of a man’s closed fist.
- The heart contains four chambers and is located slightly left of the midline in the thoracic cavity.
- The two atria are separated by the interatrial septum (wall), and the interventricular septum divides the two ventricles.
- Heart valves are positioned between each atrium and ventricle so that blood can flow in one direction only, thereby preventing backflow.
- Blood flow through the heart
The Heart

- The heart is a muscular organ responsible for the continuous pumping of blood through the vascular system.
- It is about the size of a man's closed fist.
- It contains four chambers: the right and left atrium, and the right and left ventricle.
The Heart

- Blood enters the heart through the right atrium and left atrium and leaves by way of the right and left ventricles.
  - Right atrium receives blood from superior vena cava and inferior vena cava.
  - Blood exits through the right ventricle to begin pulmonary circuit.
The Heart

Figure 4.2  Sectional Anatomy of the Heart
The Heart

- The right side of the heart is responsible for pumping oxygen poor blood to the lungs to pick up oxygen.

- The left side of the heart is responsible for pumping the oxygen rich blood to all parts of the body.

- A muscular wall called the septum divides the right and left sides of the heart.
The Heart

Figure 4.3 The Pulmonary Circuit
The Heart

- The pulmonary veins bring oxygen rich blood and the vena cava brings oxygen poor blood.
- Valves in the heart control the flow, if a valve malfunctions, blood flows backwards causing a heart murmur.
- The heart beats about 60 to 80 times per minute and is measured by feeling the pulse.
The Vessels and Circulation

• Blood circulates throughout the body within a closed system through blood vessels.
• Blood vessels are tube-like structures capable of expanding and contracting and consist of three types: arteries, veins and capillaries.
Arteries

- **Arteries** carry highly oxygenated blood away from the heart.
  - Arteries branch into smaller vessels called **arterioles**.
  - Arteries have thick walls composed of three layers because the blood is under pressure.
  - The only artery that is not oxygenated is the **pulmonary artery**, which carry blood from the right side of the heart to the lungs for oxygenation.
The Vessels and Circulation

Figure 4.9 The Arterial System
Arteries

• The only artery that is not oxygenated is the pulmonary artery, which carry blood from the right side of the heart to the lungs for oxygenation.

• Full of oxygen, normal arterial blood is bright, cherry red in color.

• The largest artery in the body is the aorta.

• Arteries have a pulse.
The Vessels and Circulation

**Capillaries:** Thin walls permit exchange of blood and fluids from surrounding tissues. They are so small in diameter that only one RBC can pass through at a time.

**Veins:** Thinner walls than arteries so they are more likely to collapse when blood is withdrawn.

**Arteries:** Thicker walls (Tunica externa) than veins; resist the strong pressure of blood being pushed through.

Figure 4.11 Comparison of Arteries, Veins, and Capillaries
Capillaries

- Blood flows from the arterial system into the smallest of the blood vessels, the **capillaries**.
  - Capillaries are microscopic vessels composed of a single layer of endothelial cells.
  - Oxygen is released and carbon dioxide is absorbed by the blood.
  - Capillaries return the oxygen poor blood to the smallest of the veins, **venules**.
  - Blood in the capillaries is a mixture of both venous and arterial blood.
Figure 4.4 Exchange of gases in Systemic and Pulmonary Capillaries
The Vessels and Circulation

Figure 4.17 Capillary Bed
Capillaries

- Capillary bleeding is occurs slowly and evenly because of the smaller size of the vessels and the low pressure within the vessels.
- Capillary bleeding is usually considered minor and is easily controlled with slight pressure or sometimes bleeding stops without intervention.
The Vessels and Circulation

Click on the image above to see an animation showing capillary pressure.
The Vessels and Circulation

Figure 4.10 Venous System
Veins

- **Veins** are responsible for returning blood to the heart.
  - Veins carry deoxygenated blood
  - The only vein that carries **oxygenated** blood is the **pulmonary vein**, which carries oxygenated blood from the lungs back to the heart.
  - The walls composed of three layers but are thinner than arteries because the blood is under less pressure.
Veins

• Because venous blood is oxygen poor, it is much darker in color than normal arterial blood.

• The largest vein in the body is the *vena cava*.

• The longest vein in the body is the *great saphenous* vein in the leg.
The Vessels and Circulation

Figure 4.13 Venous System of the Upper Torso and Arm
The Vessels and Circulation

Figure 4.14  Major Arm Veins
The Vessels and Circulation

Figure 4.15 Variations in Venous Patterns
Figure 4.16 Major Leg Veins

1. Femoral vein
2. Greater saphenous vein
3. Popliteal vein
4. Lesser saphenous vein
Figure 4.12  Plaque Build-Up Causing Partial Blockage of the Artery
Summary

- In summary, blood is oxygenated in the lungs, the arteries carry the oxygen rich blood through arterioles then to the smallest branches called capillaries. Blood goes from the capillaries into the venules to the veins to be returned back to the heart.
Hemostasis and Coagulation

Hemostasis

- Hemostasis is the maintenance of circulating blood in the liquid state and retention of blood in the vascular system by preventing blood loss.
Hemostasis and Coagulation

• Hemostasis is the process by which the body stops the leakage of blood from the vascular system after an injury.
  – It includes the process that leads to clot formation as well as clot dissolution.
  – If an injury occurs to a blood vessel, the hemostatic process is set in motion to repair the injury.
Hemostasis and Coagulation

- This hemostatic process, also called coagulation, proceeds in four steps – MEMORIZE.
  - Vasoconstriction
  - Platelet plug formation
  - Fibrin clot formation
  - Fibrinolysis
Hemostasis and Coagulation

Figure 4.18 Steps in the clotting response
Coagulation Issues that Impact Phlebotomy

- Divided into two systems: intrinsic and extrinsic.
- When a phlebotomist discovers or anticipates bleeding, it is important to use standard precautions, including gloves, to avoid exposure of the skin and mucous membranes.
- Drugs such as heparin and Coumadin (warfarin), suppress clotting factors.
- Clotting factors are not produced by the body.
- Disseminated intravascular coagulation (DIC), emboli, thrombi, etc.
Laboratory Tests of the Cardiovascular System

- The number of RBCs, their morphological traits, and their hemoglobin content can be determined from an anticoagulated blood specimen in the clinical hematology laboratory.
- Platelets and WBCs can be assessed on the basis of number and morphological features.
- Platelet function, as well as each coagulation factor, can be measured from anticoagulated blood specimens in the coagulation section of the clinical hematology laboratory.
Diagnostic Assessment of the Circulatory System

- Blood
  - CBC including indices (MCV, MCH, MCHC) – lavender
  - Hemoglobin and/or Hematocrit (H&H) – lavender
  - differential – lavender
  - eosinophil count – lavender
  - ESR – lavender or black
  - Ferritin – red
  - Iron and total iron binding capacity (TIBC) – red
  - bone marrow
Diagnostic Assessment of the Circulatory System

- Heart
  - ABG
  - AST
  - CK and CK isoenzymes
  - Electrolytes – Na, K, CO2 and Cl
  - LDH
  - Triglycerides
  - cholesterol
Diagnostic Assessment of the Circulatory System

- Blood Vessels
  - Cholesterol
  - Triglycerides
  - coagulation tests (see next)
Diagnostic Assessment of the Circulatory System

- Coagulation
  - Prothrombin time (PT)
  - Partial thromboplastin time (PTT)
  - Fibrinogen
  - Fibrin degradation products (FDP)
  - Platelet count
  - Factor assays
  - Bleeding time
### Laboratory Tests of the Cardiovascular System

#### Table 4.3  Common Blood Chemistries and Examples of Disorders Associated with Abnormal Results

<table>
<thead>
<tr>
<th>Test</th>
<th>Abbreviation</th>
<th>Normal Range</th>
<th>Examples of Possible Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkaline phosphatase</td>
<td>ALP</td>
<td>30.0–115.0 U/L</td>
<td>Liver disease, bone disease,</td>
</tr>
<tr>
<td>Blood urea nitrogen</td>
<td>BUN</td>
<td>8.0–25.0 mg/dL</td>
<td>Kidney disease, dehydration,</td>
</tr>
<tr>
<td>Calcium</td>
<td>CA</td>
<td>8.5–10.5 mg/dL</td>
<td>Hypercalcemia, bone metastasis,</td>
</tr>
<tr>
<td>Cholesterol</td>
<td>CHOL</td>
<td>120–200 mg/dL</td>
<td>Atherosclerosis, nephrosis, obstructive jaundice</td>
</tr>
<tr>
<td>Creatinine</td>
<td>Creat</td>
<td>0.4–1.6 mg/dL</td>
<td>Chronic nephritis, muscle disease, obstruction of urinary tract</td>
</tr>
<tr>
<td>Globulin</td>
<td>Glob</td>
<td>1.0–3.5 g/dL</td>
<td>Bacteremia, rheumatoid arthritis, hepatic carcinoma</td>
</tr>
<tr>
<td>Glucose fasting blood sugar</td>
<td>FBS</td>
<td>70.0–110.0 mg/100 mL</td>
<td>Diabetes mellitus, excess insulin</td>
</tr>
<tr>
<td>Two-hour postprandial</td>
<td>2-hr FPG</td>
<td>&lt;140 mg/dL</td>
<td>Diabetic syndrome, brain damage</td>
</tr>
<tr>
<td>Lactic acid</td>
<td>LDH</td>
<td>100–220 mU/mL</td>
<td>Acute MI, acute leukemia, hepatitis</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
<td>3.5–5.5 mg/dL</td>
<td>Renal failure, acidosis, cell damage</td>
</tr>
<tr>
<td>Serum glutamic-</td>
<td>SGOT</td>
<td>0–41 U/mL</td>
<td>Mit, liver disease, pancreatitis</td>
</tr>
<tr>
<td>serum oxaloctic acid</td>
<td>SGPT</td>
<td>0–45 U/mL</td>
<td>Active cirrhosis, pancreatitis, obstructive jaundice</td>
</tr>
<tr>
<td>Sodium</td>
<td>NA</td>
<td>135–146 mg/dL</td>
<td>Diabetes insipidus, coma, Glueck syndrome</td>
</tr>
<tr>
<td>Free thyroxine</td>
<td>T4</td>
<td>1.3–3.0 mg/dL</td>
<td>Thyrotoxicosis, hyperthyroidism,</td>
</tr>
<tr>
<td>Total bilirubin</td>
<td>TB</td>
<td>0–1.2 mg/dL</td>
<td>Liver disease, hemolytic anemia, lupus erythematosus</td>
</tr>
<tr>
<td>Triglycerides</td>
<td>TRIG</td>
<td>40–170 mg/dL</td>
<td>Liver disease, atherosclerosis, pancreatitis</td>
</tr>
<tr>
<td>Uric acid</td>
<td>UA</td>
<td>2.2–6.0 mg/dL</td>
<td>Renal failure, gout, leukemia, oxaloplasma</td>
</tr>
</tbody>
</table>

GL = gastrointestinal, CA = carcinoma, malignant tumor, MI = myocardial infarction
Laboratory Tests of the Cardiovascular System

- Bone marrow can be stained and studied microscopically in the hematology laboratory for the detection of abnormal numbers and morphological characteristics of blood cells.
- Tests for blood types and cross-matches for donor blood are done in an immunohematology, a transfusion, or a blood banking laboratory.