BLOOD
Hematology

The study of blood, blood-forming tissues, and their disorders.
Functions of Blood

- **Transportation**
  - oxygen and carbon dioxide
  - nutrients, hormones, metabolic wastes
  - heat

- **Regulation**
  - regulates pH through buffer systems
  - regulates body temperature
  - regulates osmotic pressure within cells

- **Protection**
  - clotting mechanisms to prevent blood loss
  - immunological function
Functions of Blood

- Transport of nutrients, gases, wastes, hormones, antibodies, enzymes, electrolytes, and heat.
Components of Blood

• Plasma - straw colored liquid component of blood
  – Water - 92%
  – Solutes including plasma proteins - 8%

• Formed Elements - Blood Cells
  – Erythrocytes
  – Leukocytes
  – Thrombocytes
Erythrocytes (RBCs)

- Make up more than 95% of formed elements
- Make up more than 40% of total blood volume
- Contain the oxygen carrying pigment hemoglobin which gives whole blood its red coloration
Anatomy of Erythrocytes

- Anucleated in the mature form
- Biconcave discs
- Flexible to squeeze through narrow capillaries
- Have no mitochondria or other organelles
- Each RBC contains about 280 million hemoglobin molecules for transporting oxygen and carbon dioxide
Erythrocytes and Hemoglobin

- Contain hemoglobin molecules
  - Globin - protein portion of molecule
  - Heme groups (4 heme groups per globin) non-protein portion of molecule which is responsible for RBC pigmentation
  - Composed of an iron (Fe++)
Erythrocyte & Hemoglobin
Leukocytes (WBCs)

- Main function is immunity
- Contains a nucleus
- Does not contain hemoglobin

Classification of WBCs
- Granular Leukocytes (Granulocytes)
  - Lobed nuclei and granules in the cytoplasm
- Agranular Leukocytes (Agranulocytes)
  - No cytoplasmic granules
Granulocytes

- **Neutrophils**
  - 55%-60% of WBCs
  - Phagocytic removal of foreign particles

- **Eosinophils**
  - 1%-4% of WBCs
  - Phagocytic removal of allergens

- **Basophils**
  - 0.5% or less of WBCs
  - Promotes inflammation by secreting histamines. Also secretes heparin.
Granulocyte
Neutrophil
Granulocyte
Eosinophil

19.T03c
Granulocyte
Basophils
Agranulocytes

- **Lymphocytes**
  - 25%-33% of WBCs
  - Produce antibodies for the removal of toxins and viruses

- **Monocytes**
  - 3%-8% of WBCs
  - Active phagocytic removal of large foreign particles and damaged cells
  - Eventually migrate out into tissues and become macrophages
Agranulocyte
Lymphocytes
Agranulocyte
Monocyte (Macrophage)
Thrombocytes (Platelets)

- Function in clotting and repair of slightly damaged blood vessels
- Actually fragments from the megakaryocytes that have become enclosed in pieces of the cell membrane
- 150,000 to 400,000 per cubic millimeter
- Life span of about 5 to 9 days
Hemostasis

- Refers to the mechanism by which bleeding is stopped
- Three Basic Processes
  - Vascular Spasms
  - Platelet Plug Formation
  - Coagulation (Clotting)
Vascular Spasm

- Contraction of the smooth muscles in the vascular walls of a damaged blood vessel
- Reflexes from pain receptors
Platelet Plug Formation

- **Platelet Adhesion** - platelets contact and stick to walls of damaged vessels
- **Platelet Release Reaction** - platelets extend projections and release content of their granules
- **Platelet Aggregation** - platelets gather in area of wound or injury
- **Eventually aggregation of platelets forms a platelet plug to stop bleeding**
Platelet Plug Formation

- Platelet Adhesion
- Platelet Plug Formation
- Platelet Aggregation
Coagulation (Clotting)

- Process of gel formation
- Blood remains a liquid if it remains within its vessels
- If removed it thickens and forms a gel
- Eventually the liquid will separate from the gel
- Forms a clot - a network of insoluble fibrin (protein fibers) in which blood formed elements are trapped
Coagulation

- Platelet
- Red blood cell
- Fibrin thread

SEM 15,000x

19.10
Coagulation Pathways

- Extrinsic Pathways
- Intrinsic Pathways
**Clotting Terms/Information**

- **Thrombus** – stationary clot within the blood vessel
- **Embolus** - clot, air bubble, fat, or piece of debris transported within the bloodstream (traveling thrombus)
Blood Typing (Grouping)

- Classified by genetically determined antigens located on the surface of erythrocytes
- More than 100 antigens can be detected on the surface of red blood cells
- Two Major Classification Systems
  - ABO Grouping
  - Rh Grouping
ABO Blood Typing

• Each parent contributes genes which determines the antigens (*agglutinogens*) or lack of antigens to their offspring
• O+ O forms the O blood type
• A + O and A + A forms the A blood type
• B + O and B + B forms the B blood type
• A + B forms the AB blood type
• Distribution of blood types varies among different races and ethnic backgrounds
ABO Blood Typing

- **Type A**: Red blood cells have A antigen, plasma contains anti-B antibody.
- **Type B**: Red blood cells have B antigen, plasma contains anti-A antibody.
- **Type AB**: Red blood cells have both A and B antigens, plasma contains neither antibody.
- **Type O**: Red blood cells have neither A nor B antigen, plasma contains both anti-A and anti-B antibodies.
Blood Typing

Parents


Offspring

A, O  A, B, AB, B, O  A, B, AB

Parents

B, AB  B, O  A, B, AB  A, B, AB  B, O  A, B

Offspring

29 22
Rh Blood Grouping

- Based upon antigens (*agglutinogens*) located on the surface of erythrocytes
- Named because it was discovered from the blood of Rhesus monkeys
- Rh+ indicates people have Rh agglutinogens (D antigens)
- Rh- indicates people lack Rh agglutinogens
Rh Blood Groupings

- If an Rh- person receives blood from an Rh+ donor, the body will start to make Rh+ antibodies (agglutinins).
- If during a second transfusion, Rh+ blood is again given, the antibodies produced after receiving the first transfusion will cause hemolysis of the blood from the second transfusion which may result in death.
Blood Transfusions

• Person with type A blood
  – may receive blood from type A or O donor
  – may not receive type B or AB blood

• Person with type B blood
  – may receive blood from type B or O donor
  – may not receive type A or AB blood

• Person with type AB blood
  – may receive blood from type A, type B, or type O donors
  – (universal recipient)
Blood Transfusions

• Person with type O blood
  – May only receive blood from type O donors
  – May donate blood to all other blood types
  – (universal donors)
Hemolysis

- Rupturing of blood cells
- If blood types are not matched may have antigen - antibody reaction
- Could result in kidney damage
- Could result in death
- Must match blood between donor and recipient when performing blood transfusions
Anemia

- Reduced oxygen carrying capacity of the blood
- Nutritional Anemia - caused by dietary deficiency due to inadequate Iron, amino acids, or Vitamin B12 consumption
- Pernicious Anemia - anemia due to insufficient Hematopoiesis
- Hemorrhagic Anemia - anemia due to excessive loss of RBC’s due to bleeding
• Hemolytic Anemia - anemia due to premature rupture of RBC membrane spilling hemoglobin and other cellular contents into the plasma
  – hemoglobin defects
  – abnormal RBC enzymes
  – defects in RBC membrane
  – parasites - toxins
  – antibodies from incompatible blood

• Thalassemia - type of hereditary Hemolytic Anemia due to a defect in the production of hemoglobin
  – more prevalent in Mediterranean countries
• Aplastic Anemia - anemia due to the destruction or inhibition of Red Bone Marrow

• Sickle Cell Anemia - due to abnormal hemoglobin (S-shaped) that causes RBC to bend into a sickle shape
  – Cells rupture easily
  – Cells get caught in capillary beds and cut off blood supply to organs
  – Inherited condition due to faulty gene for hemoglobin production and formation
  – Many people with sickle cell trait (don’t have the disease but carriers of the gene) have greater resistance to malaria
Sickle Cell Anemia
Sickle Cell Determination

Hb^A/Hb^A = normal
Hb^A/Hb^B = carrier of sickle-cell disease
Hb^B/Hb^B = has sickle-cell disease
Blood Disorders and Homeostatic Imbalances

• Hemolytic Disease of the Newborn
• Also called Erythroblastosis Fetalis
• Only infants of Rh- mothers are at risk
• Rh incompatibility between mother and newborn infant
• Affects second or later children
• Treated preventatively by administration of the gamma globulin preparation RhoGAM after delivery, miscarriage, or abortion of first child
Hemolytic Disease of the Newborn
**Blood Disorders and Homeostatic Imbalances**

- Hemophilia - hereditary disorder of the coagulation process (blood will not clot) due to the lack of certain clotting factors in the blood (*Factor VIII*)
Leukemia

- Malignant disease of blood forming tissue
- Uncontrolled production and accumulation of immature WBC’s
- May prevent production of normal RBC’s
- May have an uncontrolled infection due to the abundance of immature or abnormal WBC’s that cannot fight infection or disease
Infectious Mononucleosis

- Contagious disease primarily affecting the lymph tissue but also effecting the blood
- Caused by the Epstein-Barr Virus (EBV)
- Occurs mainly in children and young adults
- Affects females 3 times more often
- Most commonly transmitted through oral contact
- Flu-like symptoms, chronic fatigue
Polycythemia

- A disorder where hematocrit is significantly elevated above normal values
- Results in increased blood viscosity and elevated blood pressure
- Can contribute to thrombosis and hemorrhaging
The LYMPHATIC System
Functions of the Lymphatic System

• Return fluid from the extracellular spaces to the bloodstream
• Protects the body from pathogenic microorganisms (defends the body against diseases)
• “Biological Filtering System”
Homeostasis and the Lymphatic System

- Supports homeostasis by recycling fluids back into the bloodstream
- Defends the body against diseases which disrupt homeostasis
- “Biological Filtering”
The Lymphatic Network

- The flow of interstitial fluid from the extracellular spaces into the lymphatic network is primarily influenced by a pressure gradient.
- Once within the network the fluid is called lymph. A clear fluid with a high protein concentration.
- “Second Circulation”
The Lymphatic Network

Arrows show direction of flow of lymph and blood.
(a) Anterior view of principal components of lymphatic system
Structures of the Lymphatic Network

• Lymphatic Capillaries
  – Blind ended vessels where Lymph flow begins
  – Similar in structure to blood capillaries
  – Single layer of epithelial tissue

• Lymphatic Vessels
  – Larger continuations of the capillaries that carry Lymph toward the heart
  – Similar in structure to veins
  – Contain one-way valves
Lymphatic Capillaries
Lymphatic Trunk and Collecting Vessels

- Thoracic Duct (Large)
  - Main collecting duct for the lymphatic network
  - Drains lymph from the left side of the head, neck, thorax, and upper limb, and the entire body below the diaphragm

- Right Lymphatic Duct (Small)
  - Drains lymph from the right side of the head, neck, and thorax, and the right upper limb
Lymphatic Trunks
Movement of Lymph

- Flows by pressure gradients into lymphatic capillaries and into lymphatic vessels
- Moves toward the heart by the action of skeletal muscle pumps and respiratory muscle pumps
- Assisted by one-way valves
Skeletal Muscle Pump
Lymphatic Tissue Organs

- Lymph Nodes
- Spleen
- Thymus Gland
- Tonsils
- Red Bone Marrow
Lymph Nodes

- Small oval masses of lymphoid tissue
- Composed mainly of lymphocytes
- Concentrated in the neck, armpit, groin, and abdominal cavity
Structure of Lymph Nodes

- Kidney bean shaped (2.5 cm long)
- Receives afferent lymph vessels
  - Afferent - toward the structure
- Efferent lymph vessels carries lymph away from the hilus of the nodes
  - Efferent - away from the structure
- Surrounded by a fibrous capsule
- Internally - consists of clusters of lymphocytes called lymph nodules
- Outer region called the cortex
- Inner region called the medulla
Lymph Node Structures

Capsule
Subcapsular sinus
Trabecula
Trabecular sinus
Outer cortex
Germinal center in secondary lymphatic nodule
Inner cortex
Medullary sinus
Medulla

(b) Portion of a lymph node

LM 45x

22.06b
**Function of Lymph Nodes**

- As lymph flows through the nodes, lymphocytes and macrophages removes foreign particles and cleans the fluid.
- Substances removed include:
  - bacteria
  - viruses
  - toxins
Spleen

- Largest organ of the lymphatic system
- Located on the left side of the abdominal cavity just below the diaphragm
- Surrounded by a fibrous capsule
- Internally, consists of white pulp
  - Lymphocytes - Macrophages
- Also contains Red Pulp (venous sinuses)
- Large filter for removing foreign particles and old, worn out cells
- A major blood reservoir
Spleen

(a) Visceral surface

(b) Internal structure

(c) Portion of the spleen

- Splenic artery
- Splenic vein
- Gastric impression
- Colic impression
- Hilus
- Renal impression
- Splenic artery
- Splenic vein
- White pulp
- Red pulp: Venous sinus
- Splenic cord
- Central artery
- Trabecula
- Capsule

- Central artery
- Trabecula
- Capsule
- Red pulp
- White pulp
**Thymus Gland**

- Soft, bi-lobed structure located in the thoracic cavity (mediastinum)
- Located above the heart in infants
- Reduced size in adults
- Composed of lymphoid tissue
- Active during times of rapid development of the immune system
  - 6 months to 5 years of age
- In infants - site of T-Lymphocytes (T-Cells) maturation
Tonsils

- Located in the mouth and throat
- 3 pairs
  - palatine  - pharyngeal  - lingual
- Composed of lymphoid tissue
- White blood cells within the tissue destroy pathogens in the mouth and throat regions
Red Bone Marrow

- Located in the spongy bone tissue
- Site of hematopoiesis
  - production of all blood cells including lymphocytes
- Site of B-Lymphocyte maturation
Components of Immunity

• Antigens - foreign substances that stimulate the immune response
  – White blood cells recognize these as foreign

• Antibodies - proteins produced by cells that react with antigens by binding with them forming an antigen-antibody complex
  – Belong to a family of proteins known as Immunoglobins (Ig)
The Immune Response

- A response by the body to a specific foreign substance or invader
- Two Types of Response Mechanisms
- Cell Mediated Immunity - cells phagocytize the invading pathogen
- Antibody Mediated (Humoral) Immunity - antibodies of the body attack and destroy the invader
Lymphocytes

- White blood cells involved in the immune response
- Development and Maturation
  - Originate in the red bone marrow
  - Mature in the thymus gland (T-Cells)
  - Mature in the bone marrow and Peyer’s patches (B-Cells)
- Immunocompetence
  - The programming of lymphocytes to distinguish and identify cells as either self or non-self cells
Cell Mediated Immunity - CMI

• Involves T-Cell function of all cell lines
• Initiated when a macrophage identifies an antigen in the body, phagocytizes it, processes it, and presents it to the T-Helper cell.
**T-Cells**

- Undergoes development in the thymus gland and then migrates to the lymphoid tissue
- Once in lymphoid tissue, binds to specific antigens and develop into different cell lines
- Different T-Cell Lines:
  - Killer T-Cells
  - Helper T-Cells
  - Suppressor T-Cells
  - Memory T-Cells
**Killer T-Cells**  
*(Cytolytic or Cytotoxic T-Cells)*

- Produce lymphotoxins which rupture non-self cells
- Especially good a destroying virus infected cells, cancer cells, and foreign cells
Killer T-Cells
(Cytolytic T-Cells)

• Identification
• Produces
Lymphotoxins
• Phagocytosis
Helper T-Cells

• Stimulate the defense activities of other lymphocytes
• Attract neutrophils and monocytes to the area of intrusion
• Enhances the ability of macrophages to ingest and destroy non-self cells
• Stimulates Killer T-Cells production
• Stimulates B-Cell production
• Orchestrates the defensive symphony of the body
Suppressor T-Cells

• Modulates the reaction of other lymphocytes inhibiting their activity
• Slows down and eventually stops the defense mechanisms
Memory T-Cells

- Stores information about a specific antigen for the next encounter
T Cell Phagocytosis and Processing

1. Phagocytosis or endocytosis of antigen
2. Antigen-presenting cell (APC)
3. Antigen-endosome
4. Digestion of antigen into peptide fragments
5. Vesicle containing peptide fragments and MHC-II molecules fuse
6. Peptide fragments bind to MHC-II molecules
7. Vesicle undergoes exocytosis and antigen–MHC-II complexes are inserted into plasma membrane

APCs present exogenous antigens in association with MHC-II molecules.
Antibody Mediated Immunity or Humoral Immunity

• Involves B-Cell function:
  – Plasma cell produce antibodies
  – Memory B-Cells storage of information

• Initiated when a macrophage identifies an antigen in the body, phagocytizes it, processes it and presents it to the T-helper cell.
B Cells

- Undergo development in the red bone marrow or Peyer’s patches and then migrate to the lymphoid tissue
- Once they bind to an antigen they develop into one of two different cell lines
- Plasma Cells - synthesize and release antibodies
- Memory B-Cells - stores information about the specific antigen for the next encounter
Humoral Immunity

- B Cell
  - Phagocytosis
  - Activation (processing)
  - Antibody Production
The Immune Response

[Diagram showing various stages of the immune response, including the interaction between T cells, B cells, and antigen presentation.]

CELL-MEDIATED IMMUNE RESPONSES
Directed against intracellular pathogens, such as viruses, some cancer cells, and tissue transplants

ANTIBODY-MEDIATED IMMUNE RESPONSES
Directed against extracellular pathogens, such as bacteria.
Acquired Immunity

- The ability to develop immunity after initial exposure to a particular type of antigen
- 4 different mechanisms of developing immunity.
  - Naturally Acquired Active Immunity
  - Naturally Acquired Passive Immunity
  - Artificially Acquired Active Immunity
  - Artificially Acquired Passive Immunity
Naturally Acquired Active Immunity

- Immunity as a result of previous exposure to pathogens under natural conditions
- Examples:
  - measles
  - chicken pox
  - influenza
Naturally Acquired Passive Immunity

- Immunity caused by the transfer of antibodies from one person to another
- Transfer of antibodies from a mother to infant during fetal development
- Transfer of antibodies from mother to infant during breast feeding
- Examples:
  - polio
  - rubella
  - diphtheria
Artificially Acquired Passive Immunity

- immunity induced by the introduction of antibodies from an animal or another person
- antibodies are injected in an active state and therefore provide protection against disease causing agents immediately
  - snake anti-venoms - rabies
  - hepatitis - tetanus
- very effective but very short lived
Artificially Acquired Active Immunity

- immunity acquired by artificial introduction of a vaccine
- administered by injection or orally
  - diphtheria - tetanus - pertussis (DPT)
  - measles - mumps - rubella (MMR)
- may be long lasting or lifelong
  - measles - polio
- preferred method of stimulating the immune response
Immunization

The ability of the immune system to respond and activate the immune response quickly during repeated exposure to infectious disease.
**Vaccine**

- A suspension of parts of microorganisms, inactivated whole microorganisms, or inactivated toxins
- Administered to induce an immune response
- When later exposed to the active form of the disease, the individual already has the antibodies to fight against it
- Common Vaccines:
  - chicken pox
  - hepatitis A/B
  - measles
  - mumps
  - polio
  - flu
  - tetanus
AIDS Acquired Immunodeficiency Syndrome

• A disease caused by a virus (HIV)
  – Human Immunodeficiency Virus
• Destroys T-Cells (Helper)
• Results in fatal immunodeficiency
• Victim dies from infection by another opportunistic disease
  – pneumonia  – Kaposi’s sarcoma
  – dementia    – AIDS Wasting Syndrome
AIDS (Cont.)

• A person who is HIV positive is considered a carrier of AIDS
• Blood test to detect for HIV antibodies
• 6 month dormancy period between exposure until you test positive for HIV
• May be HIV positive but not actually develop AIDS until many years later
  – Years ago - positive test - 6 months to 2 - 3 years until you developed AIDS
  – Now - proper treatment - can live for more than 20 years after you have tested positive
• Difference between HIV+ and AIDS
  - T-Cell count below 200
    • normally 800 - 1500
  - Two or more opportunistic diseases present
• Once diagnosed with AIDS, death usually occurs within 2 - 3 years
  - This is changing rapidly due to improved drug therapies and lifestyle modifications once diagnosed with the disease
AIDS - Mechanisms

- Selectively destroys Helper T-Cells
- May also destroy other leukocytes after the initial dormant period
- Results in suppressed cell mediated immunity
Transmission and Prevention of AIDS

• spread through the transmission of blood, semen, or vaginal fluids from an infected person to one who is not infected
  – unprotected sexual intercourse
    • homosexual or heterosexual
  – sharing intravenous drug needles
  – infected blood transfusions
  – mother to child during childbirth
  – mother to child during breast feeding
AIDS

• NO vaccine or drug is 100% effective in curing AIDS
• Ways to guarantee you won’t get AIDS

• DON’T Use Intravenous DRUGS

• ABSTINENCE From Sexual Intercourse (Mutual Monogamy)
Measles

- A highly communicable disease characterized by fever, general malaise, sneezing, nasal congestion, brassy cough, conjunctivitis, spots on the buccal mucosa, and maculopapular eruptions over the entire body
- Caused by the Rubeola virus
Mumps

- An acute, contagious, febrile disease characterized by inflammation of the parotid and other salivary glands.
- Greatest complication -- infertility
Rubella

• An acute infectious disease resembling both scarlet fever and measles but differing from them in that it has a short course, slight fever, and is free from sequelae.

• Also known as *German Measles*
Tetanus

- An acute infectious disease due to the toxin *Clostridium Tetani* growing anaerobically at the site of the injury. May cause lockjaw and muscle paralysis.
THE CARDIOVASCULAR SYSTEM
Functions of the Heart

- PUMPS Blood
  - Transports Oxygen and Nutrients
  - Removes Carbon Dioxide and Metabolic Wastes
  - Thermoregulation
  - Immunological Function
  - Clotting Mechanisms
The Heart

- Hollow, muscular organ
- Beats over 100,000 times a day
- Pumps 7,000 liters (1835 gallons) of blood per day
- Pumps blood through 60,000 miles of blood vessels in the circulatory system
The Heart
Location of the Heart

- Located in the center of the thoracic cavity (mediastinum) with 2/3 of the heart’s mass lying to the left of the midline of the body
- About the size of your fist
(a) Inferior view of transverse section of thoracic cavity showing the heart in the mediastinum

(b) Anterior view of the heart in the mediastinum
Pericardium

- Fibrous connective tissue covering that surrounds the heart
- Fibrous Pericardium - outer layer of the pericardium
  - Anchors the heart to the mediastinum
- Serous Pericardium
  - Inner, thinner, more delicate double layered membrane surrounding the heart
    - Parietal Layer
    - Visceral Layer (Epicardium)
Pericardium

(b) Simplified relationship of the serous pericardium to the heart

20.02b
The Heart Wall

- Epicardium - the outermost layer of the heart wall (actually continuous with the visceral layer of the serous pericardium)
- Myocardium - middle layer of the heart muscle
  - Makes up the bulk of the heart muscle
- Endocardium - thin layer of endothelial connective tissue that lines the inside of the myocardium
Heart Tissue Layers

(a) Portion of pericardium and right ventricular heart wall showing the divisions of the pericardium and layers of the heart wall
Chambers of the Heart

• Collecting Chambers
  – Atria
    • Right Atrium
    • Left Atrium

• Pumping Chambers
  – Ventricles
    • Right Ventricle
    • Left Ventricle
Ventricular Myocardium and Chambers

(c) Inferior view of transverse section showing differences in thickness of ventricular walls.
Vessels of the Heart

- Inferior Vena Cava
- Superior Vena Cava
- Pulmonary Artery
- Pulmonary Veins
- Aorta
  - Ascending Aorta
  - Arch of the Aorta
  - Descending Aorta
Heart Structures
Heart Structures

- Brachiocephalic trunk
- Superior vena cava
- Ascending aorta
- Right auricle of right atrium
- Right ventricle
- Left subclavian artery
- Left common carotid artery
- Arch of aorta
- Left pulmonary artery
- Ligamentum arteriosum
- Pulmonary trunk
- Left auricle of left atrium
- Anterior interventricular sulcus
- Left ventricle

(b) Anterior external view showing surface features
Heart Structures

(c) Posterior external view showing surface features
Heart Valves

• Atrioventricular Valves
  – Tricuspid Valve
  – Bicuspid Valve (Mitral Valve)

• Semilunar Valves
  – Pulmonary Semilunar Valve
  – Aortic Semilunar Valve
Heart Valves

- Pulmonary valve
- Left coronary artery
- Aortic valve
- LEFT FIBROUS TRIGONE
- RIGHT FIBROUS TRIGONE
- Bicuspid valve
- LEFT ATRIOVENTRICULAR FIBROUS RING

Superior view (the atria have been removed)

20.05
Heart Valves

(e) Superior view of atrioventricular and semilunar valves

20.06e
Internal Cardiac Structures

- Atrial Septum  (Inter-Atrial Septum)
- Ventricular Septum  
  (Inter-Ventricular Septum)
- Chordae Tendineae
- Papillary Muscles
- Trabeculae Carne
Atrioventricular Valves

(a) Bicuspid valve open
(b) Bicuspid valve closed
Internal Cardiac Structures
Internal Cardiac Structures

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- Strachiocephalic veins
- Superior vena cava
- Right auricle
- Right atrium
- Cusp of tricuspid valve
- Chordae tendinæ
- Pectinate muscles
- Papillary muscle
- Right ventricle

- Left common cardinal artery
- Left subclavian artery
- Arch of aorta
- Ascending aorta
- Pulmonary trunk
- Left auricle
- Trabeculae carneæ
- Left ventricle
- Interventricular septum

(b) Anterior view of partially sectioned heart showing internal anatomy

20.04b
Circulation Pathways

(a) Systemic and pulmonary circulations
20.07a
Circulation Pathways

1. Right atrium (deoxygenated blood)
2. Tricuspid valve
3. Right ventricle
4. Pulmonary valve
5. Pulmonary trunk and pulmonary arteries
6. Left atrium
7. Left ventricle
8. Aortic valve
9. In systemic capillaries, blood loses O₂ and gains CO₂
10. Superior vena cava, Inferior vena cava, Coronary arteries

4. In pulmonary capillaries, blood loses CO₂ and gains O₂.

(b) Diagram of blood flow

20.07g
Blood Flow Through the Heart

- Opening and closing of the heart valves
  - Controlled by pressure changes in the heart chambers
- Contraction and relaxation of the myocardium
  - Controlled by the cardiac conduction system
Heart Valves
Opening and Closing

(c) Superior view with atria removed: pulmonary and aortic valves closed, bicuspid and tricuspid valves open
(d) Superior view with atria removed: pulmonary and aortic valves open, bicuspid and tricuspid valves closed
Conduction System of the Heart

- Self-Excitability - the ability to generate its own action potential (Autorhythmicity)
- Innervated by the autonomic nervous system
  - Influences heart rate
  - Does not initiate contraction
- Composed of specialized heart muscle cells that can generate and distribute impulses that causes contraction
Myocardial Cell
Specialized Structures
Heart Muscle Cell

(b) Arrangement of components in a cardiac muscle fiber

Sarcomere
Heart Conduction System
Structures

- **SA Node (Sinoatrial Node)**
  - Pacemaker of the Heart
  - Compact mass of specialized cells located in the right atrial wall just below the superior vena cava
- **AV Node (Atrioventricular Node)**
- **Atrioventricular (AV) Bundle (Bundle of HIS)**
- **Right and Left Bundle Branches**
- **Purkinje Fibers**
Typical EKG Tracing

Key:
- Blue: Atrial contraction
- Yellow: Ventricular contraction
- S-T segment
- P-Q interval
- Q-T interval

Lab 20.12
Electrocardiogram (EKG)

- Recordings of electrical changes that accompany a cardiac cycle
- P Wave - small upward deflection
  - Electrical Event - Atrial Depolarization
  - Mechanical Event - Atrial Contraction
- QRS Complex - small downward, large upward, large downward, and slight upward deflection on EKG
  - Electrical Event - Ventricular Depolarization
  - Mechanical Event - Ventricular Contraction
Electrocardiogram (EKG)

- T Wave - upward dome shaped deflection on the EKG
  - Electrical Event - Ventricular Repolarization
  - Mechanical Event - Ventricular Relaxation
- Atrial Repolarization
- Obscured by the QRS Complex
  - Occurs during the same time as ventricular contraction
The Cardiac Cycle

- All events associated with one heartbeat
- Normal cardiac cycle:
  - Two atria contract while the two ventricles relax
  - Two ventricles contract while the two atrias relax
- Systole - contraction phase
- Diastole - relaxation phase
Phases of the Cardiac Cycle

- **EDV - End Diastolic Volume** - the amount of blood that enters a heart ventricle from the atria during diastole (relaxation of the ventricles)

- **Ventricular Systole - contraction of the ventricles**
  - **Isovolumetric Contraction** - a brief period of time when the ventricles are contracting but both the atrioventricular and semilunar valves remain closed.
Phases of the Cardiac Cycle

- Relaxation Period - the end of the heartbeat when the ventricles are starting to relax
  - Isovolumetric Relaxation - the short period of time in which both the atrioventricular and semilunar valves are closed
- Ventricular Filling - period of time when the ventricles are filling with blood and expanding
Phases of the Cardiac Cycle

- ESV - End Systolic Volume - the amount of blood still left in the ventricle after systole (contraction of the ventricles)

- Stroke Volume - the amount of blood ejected from the left ventricle during each heartbeat (systole) EDV - ESV - SV

- Heart Rate - the number of times the heart beats or completes a full cycle of events each minute
  - normally 60 - 100 beats per minute
Wigger’s Diagram
Heart Sounds

- Auscultation - the process of listening for sounds
- Heart makes 4 sounds - 2 of which can be heard with a stethoscope
- Lubb - sound generated by blood swirling or turbulence after closing of the Atrioventricular valves
- Dupp - sound generated by blood swirling or turbulence after closing of the Semilunar valves
Heart Auscultation Sites

(b) Anterior view of heart valve locations and auscultation sites

20.15b
Cardiac Output

- Measurement that indicates how well and how hard the heart is working
- The amount of blood pumped out of the left ventricle each minute
- Function of heart rate X stroke volume
- CO - HR X SV
  - Resting C.O. is about 5 liters per minute
  - 75 bpm x 70 ml/beat - 5250 ml/min
  - During strenuous exercise can have a C.O. of between 25 to 30 Liters per minute
Blood Vessels

- Aorta
- Arteries
- Arterioles
- Capillaries
- Venules
- Veins
- Superior and Inferior Vena Cava
Blood Vessels

(d) Transverse section through an artery

(e) Red blood cells passing through a capillary
Arteries

- Blood vessels that carry blood away from the heart and to other tissues
- Lumen - the hollow center section of an artery through which the blood flows
- Elastic Arteries
  - Large arteries that conduct blood from the heart to the medium sized muscular arteries
- Muscular (Distributing) Arteries
  - Medium sized arteries that distribute blood to various parts of the body
Elastic Arteries

- Windkessel Vessels
Tissue Layers of Arteries

- **Tunica Interna (Intima)** - the inner lining of an artery
  - Made up of endothelial tissue
- **Tunica Media** - the middle layer of tissue in an artery
  - Usually the thickest layer of tissue
  - Made up of elastic fibers and smooth muscle tissue
- **Tunica Externa (Adventitia)** - the outermost layer of an artery
  - Made up of elastic and collagen fibers
Tissue Layers of Blood Vessels
• Arterioles - small, almost microscopic arteries that deliver blood to capillaries

• Capillaries - microscopic vessels that connect arterioles to venules
  - Found close to almost every cell in the body
  - Supplies nutrients and oxygen to tissues
  - Removes metabolic waste products from tissues
  - Composed of a single layer of tissue with no tunica media or tunica externa
  - Single layer of endothelial cells and a basement membrane
Capillary Beds
Types of Capillaries

(a) Continuous capillary formed by endothelial cells
(b) Fenestrated capillary

- Intracapillary vesicles
- Basement membrane
- Nucleus of endothelial cell
- Lumen
- Interstitial cell

(c) Sinusoid

- Incomplete basement membrane
- Nucleus of endothelial cell
- Lumen
- Interstitial cell
• Venules - microscopic blood vessels that leave the capillaries and drain into veins
• Veins - blood vessels that return blood from body tissues to the heart
  – Same three layers of tissues as arteries
  – Vary in thickness much more than arteries
  – Have one-way valves in them to prevent back flow of blood
Veins

- Valves to direct blood flow back toward the heart
Venous Return

- Volume of blood flowing back to the heart from the systemic veins
- Pressure Difference between the right atrium and the venous system
- Skeletal Muscle Pump (Milking)
  - the contraction of skeletal muscles forces the blood in the veins of those muscles back toward the heart
- Respiratory Pump - changes in the volumes and pressures of the abdominal and thoracic cavity during breathing forces blood back to the heart
Skeletal Muscle Pump

Proximal valve
Distal valve
Brachial Pulse
Radial Pulse
Femoral Pulse
Popliteal Pulse
Dorsal Pedalis Pulse
Factors Influencing Blood Pressure

- **BP = C.O. X TPR**
  - C.O. - Cardiac Output
    - HR (Heart Rate)
    - SV (Stroke Volume)
  - TPR - Total Peripheral Resistance
    - Blood Vessel Diameter
      - Vasoconstriction
      - Vasodilation
    - Blood Vessel Length
    - Blood Viscosity
Influence of Blood Pressure

- Increased blood volume
- Skeletal muscle pump
- Respiratory pump
- Vasoconstriction

Decreased parasympathetic impulses
Increased sympathetic impulses and hormones from adrenal medulla
Increased venous return

Increased heart rate (HR)
Increased stroke volume (SV)

Increased blood viscosity
Increased total blood vessel length
Decreased blood vessel radius (vasoconstriction)

Increased cardiac output (CO)

Increased systemic vascular resistance (SVR)

Increased mean arterial blood pressure (MABP)
Blood Pressure through the Vascular System
Homeostasis and blood pressure regulation
Factors Effecting Blood Flow

- Cardiac Output - HR X SV

- Blood Pressure - the pressure exerted by blood on the walls of blood vessels

- TPR - Total Peripheral Resistance
  - opposition to blood flow through the vessels due to friction between the blood and the vessel walls
    - blood viscosity
    - total blood vessel length (1 mile per pound)
    - radius of blood vessel

- Capillary Exchange - exchange of substances between the blood and cells
Pulmonary Circulation

- All the circulatory vessels that carry deoxygenated blood from the right ventricle, to the lungs for re-oxygenation, and back to the left atrium of the heart
Systemic Circulation

- Circulatory routes of arteries and arterioles that carry oxygenated blood from the left ventricle to the systemic capillaries of the body’s organs and return deoxygenated blood back to the right atrium through the venules and veins
Disorders and Homeostatic Imbalances of the Cardiovascular and Circulatory System
Aneurysm

- A weakening in the wall of an artery or vein that can bulge outward or herniate
- Caused by atherosclerosis, syphilis, congenital vessel defects, and trauma
- If untreated may eventually grow large and rupture causing severe pain, shock, and eventually death
- Can be repaired surgically by inserting a dacron graft over the weakened area
Arteriosclerosis

• Hardening of the arteries related to age and other disease processes.
Atherosclerosis

- The process by which fatty deposits (usually plaque) are deposited on the walls of the coronary arteries
- Usually enhanced by diets high in saturated fats and cholesterol
Atherosclerosis

(a) Normal artery
(b) Obstructed artery
Cerebral Vascular Accident (CVA) - Stroke

- A general term most commonly applied to cerebral vascular conditions that accompany either ischemic or hemorrhagic lesions.
- These conditions are usually secondary to atherosclerotic disease, hypertension, or a combination of both.
Coronary Artery Disease

- #1 cause of death for middle aged men and post menopausal women in the United States
- Over 500,000 deaths annually
- Heart muscle receives inadequate blood and oxygen because of occlusion of coronary arteries
Etiology of CAD

- Cardiovascular Disease Risk Factors
- Lesion Develops
  - Smoking
  - Hypertension
  - Diabetes
- Plaque Build Up ---> Atherosclerosis
  - accelerated by Hyperlipidemia
- Occlusion of Coronary Artery
- Ischemia
- Hypoxia
- Necrosis
- Myocardial Infarction (M.I.)
CAD Interventions

- CABG
  - Coronary
  - Artery
  - Bypass
  - Graft
- PTCA
  - Percutaneous
  - Transluminal
  - Coronary
  - Angioplasty
- Stent
- Drug Therapy
Cardiovascular Disease Risk Factors

• Uncontrollable Risk Factors
  – Age  - Gender  - Heredity  - Race

• Primary Risk Factors
  – Smoking  - Lack of Exercise
  – Hypertension  - Hyperlipidemia
  – Diabetes  - Obesity

• Secondary (Contributing) Risk Factors
  – Stress  - Nutritional Status
Hypertension

• High blood pressure
• Can lead to:
  – Stroke
  – CAD - atherosclerosis
  – cardiomegaly - cardiomyopathy
  – Congestive Heart Failure (CHF)
Determination of Hypertension

- **Diastolic Pressure**
  - Mild 90 - 104 mm Hg
  - Moderate 105 - 114 mm Hg
  - Severe > 115 mm Hg

- **Systolic Pressure** - not usually related to hypertension unless systolic reading is consistently above 140 mm Hg
Classification of Hypertension

- Essential Hypertension
  - no known cause
  - over 90% of all known cases
  - idiopathic Hypertension

- Secondary Hypertension
  - high blood pressure brought about by some other pathological condition such as renal or endocrine disease
Etiology of Essential Hypertension

• Genetic component
• Lack of exercise
• Obesity
• Poor nutritional status
• High alcohol consumption
• High sodium intake
• Stress
Treatment of Hypertension

- Weight Control
- Exercise
- Sodium Restriction in Diet
- Modify Drinking Habits
- Dietary Modifications
- Stress Management
- Drug Therapy
Hypertension

Occurs when a genetically susceptible individual is subjected to environmental factors such as high sodium intake, stress, poor nutritional and alcohol consumption habits, and lack of exercise, the conditions are established for the development of hypertension.
Myocardial Infarction (M.I.)

- Heart attack
- Heart muscle cell death
- A condition caused by partial or complete occlusion of one or more of the coronary arteries