Chapter 13 Outline

- Functions and Components of the Circulatory System
- Composition of Blood
- Structure of the Heart
- Cardiac Cycle and Heart Sounds
- Electrical Activity of the Heart and the ECG
- Blood Vessels
- Atherosclerosis and Cardiac Arrhythmias
- Lymphatic System

Functions of Blood

- Transportation
  - O₂, CO₂, metabolic wastes, nutrients, & hormones
- Regulation
  - helps regulate pH
  - helps regulate body temperature
  - Vasodilatation/vasoconstriction
  - helps regulate water content of cells by interactions with dissolved ions and proteins
- Protection from disease & loss of life

Plasma Proteins

- Constitute 7-9% of plasma
- 3 types of plasma proteins: albumins, globulins, and fibrinogen
  - Albumin accounts for 60-80%
    - Creates colloid osmotic pressure that draws H₂O from interstitial fluid into capillaries
  - Globulins:
    - Alpha & beta: prod. by liver - carry lipids (vitamins)
    - Gamma globulins: prod. by lymphocytes – are antibodies
  - Fibrinogen serves as clotting factor (vs. serum)
- Plasma regulation: Osmoreceptors in hypothalamus

Hemoglobin

- Globin protein consists of 4 polypeptide chains
  - 1 Heme (non-protein, C-H-N ring/polypeptide chain
  - Each heme has an iron ion (Fe) that can bond (reversibly) with 1 O₂ oxygen molecule
  - Each hemoglobin molecule can carry 4 O₂
  - Each RBC ~ 280 million hemoglobin molecules
  - 300 billion RBCs are produced each day

Leukocytes

- Have a nucleus, mitochondria, amoeboid locomotion
- Can squeeze through capillary walls (diapedesis)
  - Granular leukocytes: phagocytic, detoxify foreign substances, release heparin
  - Agranular leukocytes: Provide immune response, phagocytic

Platelets (thrombocytes)

- Lack nucleus
- Fragments of megakaryocytes from bone marrow
- Constitute most of mass of blood clots
- Release serotonin vasoconstricts vessels - reduce blood flow to clot area
- Secrete growth factors to maintain integrity of blood vessel wall
- Survive 5-9 days
- Stored in Spleen
Hematopoiesis (Erythropoiesis/Leukopoiesis)

- Stimulate by erythropoietin
- Stimulated by cytokines (autocrine regulators produced by immune system)

Cytokines

Terms to become familiar with:
- Agglutination – clumping of red blood cells in response to a reaction between an antibody and an antigen
- Antigens – a unique complex of self-molecules on cell surfaces. Foreign antigens (non-self) stimulate cells to produce antibodies
- Antibodies – proteins that react against a specific foreign antigen

Transfusion Reactions

- Type A blood (A antigens) make anti-B antigen antibodies
- Type B blood (B antigens) make anti-A antigen antibodies
- Type AB blood (A & B antigens) doesn’t have antibodies
- Type O (no antigens) has both anti-A & B antigen antibodies

Rh Blood Group

- The group includes several Rh antigens or factors
- Rh positive – presence of antigen D (or other Rh antigens)
- Rh negative – lack of these antigens
- erythroblastosisis fetaIis or hemolytic disease of the newborn

Rh-negative woman with Rh-positive fetus

Cells from Rh-positive fetus enter woman’s bloodstream

Woman becomes sensitized—Antibodies form to fight Rh-positive blood cells

In the next Rh-positive pregnancy, maternal antibodies attack fetal red blood cells

Anti-D antibodies not normally in blood – they form only in Rh- who are exposed to Rh+ blood

Type A blood

Type B blood

Type AB blood

Type O blood

Key
- Progenitor cells
- Erythroid cells
- Megakaryocytes
- Granulocytes/macrophages
- Hematopoietic stem cell
- Lymphoid stem cell
- T lymphocytes
- B lymphocytes
- NK cells
- Monocytes
- Thymocytes
- Cytokines
- Chemokines
- FGFs
- EGFs
- Insulin
- IGFs
- Thyroid hormones
- Glucocorticoids
- Mineralocorticoids
- Adrenocorticoids
- Sex hormones
- Vitamin D

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Rh Blood Group
Intact Blood Vessel

Intact blood vessel:
- Endothelium
- Connective tissue (collagen)
- Proteins (capable of activating platelets)

1. Endothelium keeps blood away from connective tissue (chemicals could activate platelets)
2. Endothelium releases Prostoglandin (PG1) & Nitric Oxide:
   1. Vasodilators
   2. Inhibit platelet aggregation
   3. CD39 enzyme (endothelium) breaks down ADP to AMP

Damage to wall of blood vessel

- Tissue factor exposed
- Clot: reinforced platelet plug
- Collagen exposed
- Platelets aggregate into platelet plug
- Temporary hemostasis
- Cell growth and tissue repair
- Vasoconstriction
- Platelets adhere and release platelet factors
- Thrombin
- Formation of coagulation cascade
- Converts fibrinogen to fibrin

Overview of Hemostasis – 3 major steps

Vasoconstriction
- Step 1: endothelial cells of damaged vessel
- Releases vasoconstrictive paracines

Platelet Plug Formation – step 2

Coagulation – Step 3

Coagulation (clotting) – last and most effective defense against bleeding
- Converts a platelet plug into a clot
  - Insoluble network fibrin threads

2 pathways ways to make Fibrin – Both use a number of

- Intrinsic (contact) pathway – exposure of plasma to collagen (or other negatively charged surface, e.g., test tube)
  - i.e., Damage to tissue exposes collagen
  - Activates plasma protein Factor XII (Protease)
  - Activates other clotting Factors
  - Fibrinogen turns to Fibrin!!!!!!!

- Extrinsic pathway:
  - Tissue Factor III (aka tissue thromboplastin) released by damaged tissues begin cascade
  - Activates other clotting Factors
  - Fibrinogen turns to Fibrin!!!!!!!
Overview of Hemostasis and Tissue Repair

- Damage to wall of blood vessel
- Tissue factor exposed
- Clot: reinforced platelet plug
- Fibrin slowly dissolved by plasmin
- Collagen exposed
- Platelets aggregate into loose platelet plug
- Temporary hemostasis
- Cell growth and tissue repair

Cardiac Cycle

- Is repeating pattern of contraction and relaxation of heart
- Systole refers to contraction phase
- Diastole refers to relaxation phase
- Atria contract simultaneously; ventricles follow 0.1-0.2 sec later

- Stroke volume: amount of blood ejected from 1 ventricles during systole (~ 70 mL)

EDV – ESV = Stroke Volume

Structure of Heart

- Heart has 4 chambers
  - 2 atria receive blood from venous system
  - 2 ventricles pump blood to arteries
  - Pulmonary and systemic systems

Coagulation and Fibrinolysis

- Coagulation
  - Thrombin
  - Fibrinogen
  - Plasminogen
  - tPA (tissue plasminogen activator)
- Fibrinolyis
  - Fibrin polymer
  - Fibrin

Coagulation and fibrinolysis:

- Clot retraction occurs within 30 minutes
- Platelet-derived growth factor secreted by platelets and endothelial cells
  - Mitotic stimulant for fibroblasts and smooth muscle cells

Cardiac Cycle

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Electrical Activity of Heart

- Myocardial cells are short, branched, and interconnected by gap junctions.
- Entire muscle that forms a chamber is called a **myocardium**.
- Remember action potentials originating in any cardiac cell are transmitted to all others:
- Chambers separated by nonconductive tissue.

SA Node Pacemaker

- SA node functions as pacemaker.
  - Depolarizes spontaneously (autorythmic cells).
  - Pacemaker Potential.

Conducting Tissues of Heart

- **SA node** functions as pacemaker.
  - Depolarizes spontaneously (autorythmic cells).
  - Pacemaker Potential.

Electrical Conduction in the Heart

- SA node depolarizes.
- Electrical activity goes rapidly to AV node via internodal pathways.
- Conduction slows through AV node.
- Depolarization wave spreads upward from the apex.

**SA Node Pacemaker Potentials**

- Action potential.
- HCN channels = hyperpolarization activated cyclic nucleotide channels – channels open in response to hyperpolarization.
- Na+ moves in.
- Cell contracts.
Action Potential in Myocardial Cells

- Action potential of a cardiac contractile cell

Excitation-Contraction Coupling

- Depolarization of myocardial cells opens V-gated Ca\(^{2+}\) channels in sarcolemma
- This depolarization opens V-gated and Ca\(^{2+}\) release channels in SR (calcium-induced-calcium-release)
- Ca\(^{2+}\) binds to troponin and stimulates contraction (as in skeletal muscle)
- During repolarization Ca\(^{2+}\) pumped out of cell and into SR

Cardiac Muscle (Myocardium)

- Ca\(^{+}\) induced Ca\(^{+}\) release

Refractory Periods

Electrocardiogram (ECG or EKG)

- Composite of all action potentials/amplified/recorded
- Recording of electrical activity of heart conducted thru ions in body to surface

- P wave
  - SA node fires, atria depolarize and contract
  - atrial systole begins 100 msec after SA signal

- QRS complex
  - ventricular depolarization
  - complex shape of spike due to different thickness and shape of the two ventricles

- ST segment - ventricular systole
  - plateau in myocardial action potential

- T wave
  - ventricular repolarization and relaxation
Electrical Activity of Cardiac Cycle

Figure 14-21 (9 of 9)

P wave: atrial depolarization
Q wave: ventricular depolarization
R wave: ventricular contract
S wave: ventricular repolarization

PQ or PR segment: conduction through AV node and AV bundle

Veins
- Valves
- Skeletal muscular pumps
- Diaphragm

Cholesterol and Lipoproteins
- Lipids & cholesterol carried in blood by plasma lipoproteins
- LDLs: produced in liver
- Many organs cells have receptors for lipoproteins
- Cell engulfs it
- Liver removes LDLs this way
- HDLs take cholesterol to liver

Atherosclerosis
- Plaques form in response to damage done to the endothelium of a blood vessel.
- Caused by:
  - Damage or "insult" to endothelium
  - Smoking, high blood pressure, diabetes, high cholesterol

LDL and Plaque
- The development of atherosclerotic plaques
Ischemic Heart Disease

- **Ischemia**: blood supply to tissue is deficient
- Causes increased lactic acid from anaerobic metabolism
- Is most commonly due to atherosclerosis in coronary arteries
- Often accompanied by **angina pectoris** (chest pain)

Arrhythmias Detected on ECG

- **Arrhythmias** are abnormal heart rhythms
- Heart rate <60/min is **bradycardia**; >100/min is **tachycardia**

Arrhythmias Detected on ECG

- In **flutter**, contraction rates can be 200-300/min
- In **fibrillation**, contraction of myocardial cells is uncoordinated and pumping ineffective
  - **Ventricular fibrillation** is life-threatening
  - **Electrical defibrillation** resynchronizes heart by depolarizing all cells at same time

Lymphatic System

- 3 basic functions:
  1. Transports interstitial fluid (**lymph**) back to blood
  2. Transports fat from small intestine to blood
  3. Provides immunological defenses against pathogens
- **Lymphatic capillaries**
  - Very porous, absorb proteins, microorganisms, fat

Lymphatic System

- Lymph nodes filter lymph before returning it to R. & L. subclavian veins via **thoracic duct** or **right lymphatic duct**
- Nodes contain lymphocytes and phagocytic cells that remove pathogens
- Tonsils, spleen, thymus (lymphoid organs)