The Cardiovascular System Part I: Heart
Outline of class lecture
After studying part I of this chapter you should be able to:
1. Describe the functions of the heart
2. Describe the location of the heart, the structures of the pericardium and the structures of the heart wall. Include an explanation of pericarditis and cardiac tamponade.
3. Describe the chambers of the heart including an explanation of the systemic and pulmonary circuits, the valves and major vessels of the heart, and course of blood flow through the heart.
4. Explain the cardiac cycle how the heart sounds (lub dup) are produced. In addition describe what a heart murmur is and their usual causes.
5. Describe the cause and treatments of coronary artery disorders.

Cardiovascular System: Heart
Chapter Overview
• General Information
• Functions
• Anatomy
• Electrical activity of the heart
• Cardiac cycle
• Clinical Applications

Heart: General Information
• At rest, the heart:
  • Pumps about 5 liters (1.3 gal) of blood per
  • Beats over 100,000 times a day to pump blood through ~60,000 miles of blood vessels
• Cardiology is the study of the heart and diseases associated with it.

Functions of the Heart
• Propels blood through the blood vessels to reach body cells
  – Generates blood pressure:
  – Regulates blood supply: Changes the rate and force of blood flow to match the changing metabolic needs of the tissues.

Heart Location
• Lies in the pericardial cavity located

Pericardium
• The pericardium is a fibrous membrane sac that encloses the heart.
  – Produces pericardial (serous) fluid within the pericardial cavity
    • Reduces friction between the beating heart and pericardial sac.

Disorders of the Pericardium
• Pericarditis:
  – Can result from infection, recent heart attack, damage due to radiation therapy for cancer
• Cardiac tamponade: Fluid accumulates in the
  – Since the heart relaxes passively it cannot fill with blood during relaxation due to the outside pressure
  – Causes: Rupture of the heart wall following myocardial infarct, rupture of blood vessels in the pericardium (tumor, trauma, etc.), and pericarditis.
Layers (3) of the Heart Wall
1. **Epicardium**: The serous membrane (visceral pericardium) that covers the outer surface of the heart
2. **Myocardium**: Middle layer - Muscular wall of the heart.
3. **Endocardium**:

   ![Anatomical diagram of the heart](image)

Chambers of the Heart
- Heart consists of 2 pumps connected in series. Each pump sends blood to a different circuit.
  - **Pulmonary circuit** runs between the heart and lungs
  - **System circuit** runs between the heart and body tissues
- Right side of the heart receives deoxygenated blood from the systemic circuit and pumps it thru the pulmonary circuit.
- Left side of the heart receives oxygenated blood from the pulmonary circuit and pumps it thru the systemic circuit

Atria
- Two superior chambers (right and left) are the receiving chambers of the heart.
  - Secretes a hormone called **Atrial Natriuretic Peptide (ANP)**, which functions to reduce blood volume and pressure – details discussed later.
  - **Interatrial septum**
  - **Fossa ovale** is a shallow depression in both sides of the interatrial septum. It is a remnant of the **foramen ovale** that allowed blood to pass from the pulmonary circuit to the systemic circuit (since the lungs were not fully developed nor being oxygenated) in the fetus.
Major Vessels of Atria
- **Right Atrium** receives deoxygenated blood from:
  - **Superior vena cava**: Blood returning from the arms, head and upper torso.
  - **Inferior vena cava**: Blood returning from the legs abdomen, and pelvis
  - **Coronary sinus**:

- **Left atrium** receives oxygenated blood from the **pulmonary veins** – returning blood from lungs.

Ventricles
- Two inferior chamber are

  - The ventricles receive blood from the atria and pump the blood out of the heart to the arterial system
    - **Right ventricle** pumps the blood thru the pulmonary **semilunar valve** into the **pulmonary trunk/artery** which carries the deoxygenated blood to the lungs
    - **Left ventricle** pumps the blood through the
      - Wall of left ventricle is larger (more muscular) than the right ventricle.
      - Greater musculature is necessary since this ventricle pumps the blood throughout the body.
      - Note: Both right and left ventricles chamber size is the same and pump the same volume of blood per beat

Heart Valves
- **Four valves** prevent backflow of blood in the heart.
  - Composed of dense irregular CT extending from the cardiac skeleton and lined with endocardium
- **Atroventricular (AV) valves**: Between the atria and ventricles
  - Prevent
    - **Tricuspid valve** has three flaps (cusps) and is located between the right atrium and right ventricle
    - **Bicuspid (mitral) valve** has two flaps and is
      - Both valves utilize **chordae tendineae** (strings of collagen) and **papillary muscles** for support to ensure there is no backflow of blood into the atria.
        - When blood is entering the ventricle, the valve is open, the chordae tendineae are slack and papillary muscles are relaxed. When the ventricle contracts, blood pushes the valve flaps towards the atria closing the valve. The papillary muscles contract and tighten the chordae tendineae to prevent the valve flaps from flipping up into the atrium
        - **Prolapse** is an abnormality of the valves - when the valves extend too far into the atrium and blood leaks through.
- **Semilunar (SL) valves**: Between the ventricles and the great vessels (pulmonary trunk and aorta)
  - Prevent
    - Each consists of 3 semilunar crescent-shaped cusps and do **not** have associated chordae tendineae or papillary muscles
    - **Pulmonary semilunar valve** is located between the pulmonary trunk and right ventricle.
    - **Aortic semilunar valve** is located
AV Valves and Blood Pressure
- The tricuspid valve is open when:
  - Rt Atrial pressure is _____________ than Rt Ventricular pressure.
- The bicuspid valve is open when:
  - Lt Atrial pressure is _____________ than Lt Ventricular pressure.
- The tricuspid valve is closed when:
  - Rt Atrial pressure is _____________ than Rt Ventricular pressure.
- The bicuspid valve is closed when:
  - Lt Atrial pressure is _____________ than Lt Ventricular pressure.

Semilunar Valves and Blood Pressure
- The pulmonary semilunar valve is open when:
  - Rt Ventricular pressure is _____________ than pulmonary trunk pressure.
- The pulmonary semilunar valve is closed when:
  - Rt Ventricular pressure is _____________ than pulmonary trunk pressure.
- The aortic semilunar valve is open when:
  - Lt Ventricular pressure is _____________ than aortic pressure.
- The aortic semilunar valve is closed when:
  - Lt Ventricular pressure is _____________ than aortic pressure.

An Incredibly Important Concept
Blood moves from one place to another because of a PRESSURE GRADIENT
- Blood flows from an area of

Cardiac Cycle
- The cardiac cycle comprises all the events associated with one heartbeat. There are two phases of the cardiac cycle. In the diastolic phase, the heart ventricles are relaxed and the heart fills with blood. In the systolic phase, the ventricles contract and pump blood to the arteries.
- **Systole:**
- **Diastole:** The relaxation phase of the heart

In a normal heart beat:
- The two atria contract (atrial systole) while the two ventricles relax (ventricular diastole). The contraction of the atria completes the filling of the ventricles with blood.
- Next, the two ventricles contract (ventricular systole) while the two atria relax (atrial diastole). Contraction of the ventricles causes the AV (atrioventricular) valves to close. When the increasing pressure in the ventricles exceeds the pressure in the pulmonary trunk and aorta, the SL (semilunar) valves are pushed open, and blood is ejected into the pulmonary trunk and aorta.
  - Amount of
    - Ventricles eject ~ 2/3 of their blood during their contraction – remaining blood (~1/3) is called the end-systolic volume.
    - As the ventricles relax (diastole) the pressure declines and the AV valves open, blood flows into the ventricles and fills them to approximately 80% of their volume before the atria contract.
    - At the end of ventricular diastole, the atria contract and force additional blood to flow into the ventricles to complete their filling
  - End-diastolic volume: Total amount of blood in the
Heart Sounds
- Sounds of the heart are due to the closing of the
  - The sounds are often verbalized as a “lub-dub”
- The “lub” or first sound, is produced as blood hits and closes the atrioventricular valves during the contraction of the ventricles.
- Closing of the semilunar valves produces the “dub” or second sound, when the pressure in the ventricles falls below the pressure in the arteries as the ventricles relax and blood hits and closes the semilunar valves.
- Listening to sounds in the chest to determine the condition of the heart and the lungs is called Auscultation.

Heart Valve Problems
- Heart valve diseases fall into two categories: Stenosis and Incompetence.
  - The Stenotic heart valve prevents the valve from opening fully, due to stiffened valve tissue.
    - Hence, there is more
      - Mitral stenosis – Mitral (bicuspid) valve becomes thickened and
        - Accumulation of blood in the Lt atrium causes an increase in left atrial and pulmonary vein pressure, resulting in pulmonary hypertension – the right ventricle hypertrophies to compensate
  - The Incompetent valves do not close all the way and blood regurgitates back through the valve.
    - May be due to damage to
Heart Murmurs

- **Heart murmurs** are abnormal heart sounds produced by abnormal patterns of blood flow in the heart; may be caused by:
  - **Defective heart valves** as seen in
    - May occur as a result of having **rheumatic fever**; antibodies made in response to the bacterial infection may damage the valves
  - **Septal Defects**
    - Are holes within the septal walls; usually are congenital and may occur either in the interatrial or interventricular septum.

Route of blood flow through the heart

Disorders of Coronary Arteries

- **Heart attack (myocardial infarction)** results when part of the coronary circulation becomes blocked and cardiac muscle cells die from lack of oxygen
  - Affected tissue then degenerates creating a
    - Degree of damage depends on where the blockage occurred along the coronary arteries
      - Blockage near the start of one of the coronary arteries can cause widespread damage and possibly stop the heart whereas blockage in a smaller artery will result in less of an infarct
Coronary artery blockage can result from:

- **Coronary atherosclerosis** which is the development of plaques (containing cholesterol and other lipids) that can narrow the artery lumen (opening) causing myocardial ischemia.
  - **Myocardial ischemia** can cause substernal pain which may be referred to the left shoulder and arm.
    - The pain is referred to as
  - Drugs such as nitroglycerin produce vasodilation, which improves circulation and thus relieves ischemia and pain
- **Thrombus**, or blood clot, is achieved via the aggregation of platelets and fibrin.
  - Thrombus formation in an intact blood vessel may completely cut-off blood flow.
  - Likely to
- **Embolus** is a blood clot transported in the blood and becoming logged in a blood vessel.
  - If a thrombus dislodges and becomes

- **Heparin** and **warfarin** are drugs used to inhibit the formation and growth of existing blood clots, thereby allowing the body to shrink and dissolve the blood clots through normal methods.

### Treatments for Coronary Artery Disorders

- **Angioplasty**: Small balloon is placed in a partially blocked coronary artery. The balloon is inflated, flattening the atherosclerotic deposits against the vessel wall and opening the blocked vessel. Balloon is removed leaving the vessel opened.
- Vessels can also be opened using a small coil called a **stent** which is left in place
- **Coronary bypass surgery** involves taking blood vessels from other parts of the patients body and using them to bypass obstructions in the coronary arteries