Introduction to Cardiovascular System

- The Pulmonary Circuit
  - Carries blood to and from gas exchange surfaces of lungs

- The Systemic Circuit
  - Carries blood to and from the body

- Blood alternates between pulmonary circuit and systemic circuit
The Conducting System

- Heartbeat
  - A single contraction of the heart
  - The entire heart contracts in series
    - First the atria
    - Then the ventricles
The Conducting System

- A system of specialized cardiac muscle cells
  - Initiates and distributes electrical impulses that stimulate contraction

- Automaticity
  - Cardiac muscle tissue contracts automatically
The Conducting System

- Structures of the Conducting System
  - Sinoatrial (SA) node - wall of right atrium
  - Atrioventricular (AV) node - junction between atria and ventricles
  - Conducting cells - throughout myocardium
The Conducting System

- Conducting Cells
  - Interconnect SA and AV nodes
  - Distribute stimulus through myocardium
  - In the atrium
    - Internodal pathways
  - In the ventricles
    - AV bundle and the bundle branches

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The Conducting System

- **Heart Rate**
  - SA node generates 80–100 action potentials per minute
  - Parasympathetic stimulation slows heart rate
  - AV node generates 40–60 action potentials per minute
The Conducting System

- The Sinoatrial (SA) Node
  - In posterior wall of right atrium
  - Contains pacemaker cells
  - Connected to AV node by internodal pathways
  - Begins atrial activation (Step 1)
STEP 1

SA node activity and atrial activation begin.

Time = 0

Figure 20–13 Impulse Conduction through the Heart
The Conducting System

- The Atrioventricular (AV) Node
  - In floor of right atrium
  - Receives impulse from SA node (Step 2)
  - Delays impulse (Step 3)
  - Atrial contraction begins
STEP 2

Stimulus spreads across the atrial surfaces and reaches the AV node.

Elapsed time = 50 msec

Figure 20–13 Impulse Conduction through the Heart
There is a 100-msec delay at the AV node. Atrial contraction begins.

Elapsed time = 150 msec

Figure 20–13 Impulse Conduction through the Heart
The AV Bundle

- In the septum
- Carries impulse to left and right bundle branches
  - Which conduct to Purkinje fibers (Step 4)
- And to the moderator band
  - Which conducts to papillary muscles
The impulse travels along the interventricular septum within the AV bundle and the bundle branches to the Purkinje fibers and, via the moderator band, to the papillary muscles of the right ventricle.

Elapsed time = 175 msec
The Conducting System

- Purkinje Fibers
  - Distribute impulse through ventricles (Step 5)
  - Atrial contraction is completed
  - Ventricular contraction begins
The Impulse Conduction System

**STEP 5**

The impulse is distributed by Purkinje fibers and relayed throughout the ventricular myocardium. Atrial contraction is completed, and ventricular contraction begins.

Elapsed time = 225 msec

Figure 20–13 Impulse Conduction through the Heart
The Conducting System

- Abnormal Pacemaker Function
  - **Bradycardia**: abnormally slow heart rate
  - **Tachycardia**: abnormally fast heart rate
  - **Ectopic pacemaker**
    - Abnormal cells
    - Generate high rate of action potentials
    - Bypass conducting system
    - Disrupt ventricular contractions
The Conducting System

- Electrocardiogram (ECG or EKG)
  - A recording of electrical events in the heart
  - Obtained by electrodes at specific body locations
  - Abnormal patterns diagnose damage
The Conducting System

- Features of an ECG
  - P wave
    - Atria depolarize
  - QRS complex
    - Ventricles depolarize
  - T wave
    - Ventricles repolarize
The Conducting System

- Time Intervals Between ECG Waves
  - P–R interval
    - From start of atrial depolarization
    - To start of QRS complex
  - Q–T interval
    - From ventricular depolarization
    - To ventricular repolarization
The Conducting System

- **Contractile Cells**
  
  - Purkinje fibers distribute the stimulus to the contractile cells, which make up most of the muscle cells in the heart
Cardiac cycle = The period between the start of one heartbeat and the beginning of the next

- Includes both contraction and relaxation
The Conducting System

- The Cardiac Cycle
  - Begins with action potential at SA node
    - Transmitted through conducting system
    - Produces action potentials in cardiac muscle cells (contractile cells)
The Cardiac Cycle

- Phases of the Cardiac Cycle
  - Within any one chamber
    - **Systole** (contraction)
    - **Diastole** (relaxation)
The Cardiac Cycle

- Cardiac Cycle and Heart Rate
  - At 75 beats per minute
    - Cardiac cycle lasts about 800 msecs
  - When heart rate increases
    - All phases of cardiac cycle shorten, particularly diastole
Eight Steps in the Cardiac Cycle

1. **Atrial systole**
   - Atrial contraction begins
   - Right and left AV valves are open

2. **Atria eject blood into ventricles**
   - Filling ventricles

3. **Atrial systole ends**
   - AV valves close
   - Ventrices contain maximum blood volume
   - Known as end-diastolic volume (EDV)
The Cardiac Cycle

Eight Steps in the Cardiac Cycle

4. **Ventricular systole**
   - Isovolumetric ventricular contraction
   - Pressure in ventricles rises
   - AV valves shut

5. **Ventricular ejection**
   - Semilunar valves open
   - Blood flows into pulmonary and aortic trunks
   - Stroke volume (SV) = 60% of end-diastolic volume
The Cardiac Cycle

Eight Steps in the Cardiac Cycle

6. **Ventricular pressure falls**
   - Semilunar valves close
   - Ventricles contain end-systolic volume (ESV), about 40% of end-diastolic volume

7. **Ventricular diastole**
   - Ventricular pressure is higher than atrial pressure
   - All heart valves are closed
   - Ventricles relax (isovolumetric relaxation)
Eight Steps in the Cardiac Cycle

8. **Atrial pressure is higher than ventricular pressure**
   - AV valves open
   - Passive atrial filling
   - Passive ventricular filling
   - Cardiac cycle ends
The Cardiac Cycle

- Blood Pressure
  - In any chamber
    - Rises during systole
    - Falls during diastole
  - Blood flows from high to low pressure
    - Controlled by timing of contractions
    - Directed by one-way valves
The Cardiac Cycle

- **Heart Sounds**
  - **$S_1$**
    - Loud sounds
    - Produced by AV valves
  - **$S_2$**
    - Loud sounds
    - Produced by semilunar valves
  - **$S_3$, $S_4$**
    - Soft sounds
    - Blood flow into ventricles and atrial contraction
The Cardiac Cycle
Locating the assessment points

1. Aortic area—second intercostal space, right sternal border
2. Pulmonic area—second intercostal space, left sternal border
3. Erb’s point—third intercostal space, left sternal border
4. Tricuspid area—fourth (or fifth) intercostal space, left sternal border
5. Mitral area or apex—fifth intercostal space, left midclavicular line
The Cardiac Cycle

- Heart Murmur
  - Sounds produced by regurgitation through valves
Cardiodynamics

- The movement and force generated by cardiac contractions
  - End-diastolic volume (EDV)
  - End-systolic volume (ESV)
  - Stroke volume (SV)
    - SV = EDV – ESV
  - Cardiac output (CO)
    - The volume pumped by left ventricle in 1 minute
Cardiodynamics

- Cardiac Output
- \( \text{CO} = \text{HR} \times \text{SV} \)
- \( \text{CO} = \) cardiac output (mL/min)
- \( \text{HR} = \) heart rate (beats/min)
- \( \text{SV} = \) stroke volume (mL/beat)
Factors Affecting Cardiac Output

- Cardiac output
  - Adjusted by changes in heart rate or stroke volume
- Heart rate
  - Adjusted by autonomic nervous system or hormones
- Stroke volume
  - Adjusted by changing EDV or ESV
Cardiodynamics

- Atrial Reflex
  - Also called Bainbridge reflex
  - Adjusts heart rate in response to venous return
  - Stretch receptors in right atrium
    - Trigger increase in heart rate
    - Through increased sympathetic activity
Hormonal Effects on Heart Rate

- Increase heart rate (by sympathetic stimulation of SA node)
  - Epinephrine (E)
  - Norepinephrine (NE)
  - Thyroid hormone
Factors Affecting the Stroke Volume

The EDV: amount of blood a ventricle contains at the end of diastole

- **Filling time:**
  - duration of ventricular diastole

- **Venous return:**
  - rate of blood flow during ventricular diastole
Cardiodynamics

- The EDV and Stroke Volume
  - At rest
    - EDV is low
    - Myocardium stretches less
    - Stroke volume is low
  - With exercise
    - EDV increases
    - Myocardium stretches more
    - Stroke volume increases
Cardiodynamics

- The **Frank–Starling Principle**
  - As EDV increases, stroke volume increases

- Physical Limits
  - Ventricular expansion is limited by
    - Myocardial connective tissue
    - The cardiac (fibrous) skeleton
    - The pericardial sac
Cardiodynamics

- End-Systolic Volume (ESV)
  - The amount of blood that remains in the ventricle at the end of ventricular systole is the ESV
Cardiodynamics

- **Afterload**
  - Is increased by any factor that restricts arterial blood flow
  - As afterload increases, stroke volume decreases
Cardiodynamics

- Heart Rate Control Factors
  - Autonomic nervous system
    - Sympathetic and parasympathetic
  - Circulating hormones
  - Venous return and stretch receptors
Cardiodynamics

- **Stroke Volume Control Factors**
  - **EDV**
    - Filling time
    - Rate of venous return
  - **ESV**
    - Preload
    - Contractility
    - Afterload
Cardiac Reserve
- The difference between resting and maximal cardiac output
Cardiodynamics

- The Heart and Cardiovascular System
  - Cardiovascular regulation
    - Ensures adequate circulation to body tissues
  - Cardiovascular centers
    - Control heart and peripheral blood vessels
  - Cardiovascular system responds to
    - Changing activity patterns
    - Circulatory emergencies