CHAPTER 20
CARDIOVASCULAR SYSTEM: The Heart

CHAPTER OVERVIEW: This chapter discusses the heart in detail. The location, structure, histology, cellular properties, and mechanism of contraction of the heart and cardiac muscle are discussed. The functions of the heart in relation to the entire cardiovascular system are considered. The events of the cardiac cycle, normal and abnormal heart sounds, and the regulation of the heart are described in detail. The role of the heart in homeostasis is discussed.

OUTLINE (four or five fifty-minute lectures):
Seeley, A&P, 5/e

<table>
<thead>
<tr>
<th>Chapt.</th>
<th>Topic Outline, Chapter 20</th>
<th>Figures &amp; Tables</th>
<th>Transparency Acetates</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>I. Size, Form and Location of the Heart, p. 608</td>
<td>Fig. 20.1, p. 608</td>
<td>TA-380</td>
</tr>
<tr>
<td></td>
<td>A. In the Thoracic Cavity</td>
<td>Fig. 20.2, pp.609</td>
<td>TA-381</td>
</tr>
<tr>
<td></td>
<td>1. Size of a Closed Fist</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Region of Mediastinum</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. Orientation</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Apex Inferior</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>2. Base Superior</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>II. Anatomy of the Heart, p. 610</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>A. Four Chambers</td>
<td>Fig. 20.3, p.610</td>
<td>TA-382</td>
</tr>
<tr>
<td></td>
<td>1. Fibrous Pericardium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Holds Heart in Place</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>b. Continuous with CT of Great Vessels &amp; Diaphragm</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>c. Outer Layer</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>2. Serous Pericardium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>a. Reduces Friction</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Components</td>
<td>Clinical Note, p.610</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1). Parietal Pericardium Lining</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Fibrous Pericardium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2). Visceral Pericardium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Covering Heart Itself</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>3). Pericardial Cavity with Pericardial Fluid</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B. Heart Wall</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Layers</td>
<td>Fig. 20.4, p.611</td>
<td>TA-383</td>
</tr>
<tr>
<td></td>
<td>a. Epicardium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Myocardium</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>c. Endocardium</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Special Structures</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>a. Musculi Pectinati</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>b. Crista Terminalis</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>c. Trabeculae Carneae</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>C. External Anatomy</td>
<td>Fig. 20.5a-c, p. 612</td>
<td>TA-384-385</td>
</tr>
</tbody>
</table>
1. **Atrial Auricles**
2. **Great Veins**
   a. Superior and Inferior Venae Cavae - R. Atrium
   b. Four Pulmonary Veins - L. Atrium
3. **Great Arteries**
   a. Pulmonary Trunk - L. Atrium
   b. Aorta - L. Ventricle
4. **Coronary Blood Supply**
   a. Landmarks
   1). Coronary Sulcus - Separates Atria from Ventricles
   2). Ant. & Post. Interventricular Grooves - Separate Ventricles
   b. Coronary Arteries
   1). Off Aorta to Supply Heart
   2). Left Coronary Artery
      a). Anterior Interventricular Artery
      b). Marginal Branch
      c). Circumflex Branch
   3). Right Coronary Artery & Posterior Interventricular Artery

4 **Heart Chambers and Valves**

1. Right and Left Atria
   a. Interatrial Septum
   b. Fossa Ovalis
2. Right and Left Ventricles
   a. Interventricular Septum
   b. Interventricular Grooves = Surface Landmark
3. Atrioventricular Valves
   a. Tricuspid Valve - Separates R. Atrium from R. Ventricle
   b. Bicuspid (or Mitral) Valve - Separates L. Atrium from L. Ventricle
   c. Structure of Atrioventricular Valves
      1). Valve Flaps (2 or 3)
      2). Chordae Tendineae
      3). Papillary Muscles
4. Semilunar Valves
   a. Aortic Semilunar Valve
   b. Pulmonary Semilunar Valve
   c. Three Valve Flaps
III. Route of Blood Flow Through the Heart, p. 617  
A. Double Pump  
B. Right Heart  
1. Heart to Lungs  
2. Through Pulmonary Trunk and Pulmonary Arteries  
3. Returned to Left Heart  
C. Left Heart  
1. Heart to Body  
2. Through Aorta  
3. Returned to Right Heart  

IV. Histology, p. 618  
A. Heart Skeleton  
1. Fibrous CT Rings Support Heart Valves  
2. Electrically Isolates Atria from Ventricles  
3. Point of Attachment of Cardiac Muscle  
5. B. Cardiac Muscle  
1. Striated, Branched, Uninucleate Cells  
2. Smooth Sarcoplasmic Reticulum  
   a. Less Organized than in Skeletal Muscle  
   b. T-tubule system Important  
3. Slow Onset of contraction - Related to Ca\(^{2+}\) Diffusion  
4. Primarily Aerobic Respiration - No O\(_2\) Debt Possible  
5. Functional Syncytium of Bundles or Sheets of Cells  
   a. Desmosomes  
   b. Gap Junctions  
6. C. Conducting System  
1. Structures  
   a. Sinoatrial Node (SA Node) - R. Atrium  
   b. Atrioventricular Node (AV Node) - R. Atrium  
   c. Atrioventricular Bundle  
   d. R & L Bundle Branches - Interventricular Septum  
   e. Purkinje Fibers - Large Diameter Cardiac Muscle Fibers  
2. Functions  
   a. SA Node with Spontaneous Action Potentials = Pacemaker  
   b. Depolarization Spreads from Node to Other Cardiac Cells  
   c. Atria Contract before Ventricles Depolarized  
      1). Preferred Depolarization Path to AV Node (0.04 sec.)
2). 0.11 sec. Delay at AV Node
d. Action Potentials along Bundles to Purkinje Fibers and Ventricular Fibers
e. Ventricular Contractions
   1). Apex to Base
   2). Wringing Action

V. Electrical Properties, p.620
   1. Resting Membrane Potentials (details Chapter 9)

8  A. Action Potentials
   1. Rapid Depolarization - Na\(^+\) Fast Channels Open
   2. Rapid Partial Repolarization
   3. Prolonged Slow Repolarization (Plateau Phase) - Slow Ca\(^{2+}\) Channels
   4. Final Rapid Depolarization - K\(^+\) Channels Open and Ca\(^{2+}\) Channels Close

9  B. Autorhythmicity of Cardiac Muscle
   1. Spontaneous Depolarizations
      a. Fastest in SA Node 70-80 Beats per min.
      b. Slow Channels
   2. Ectopic Foci

10 C. Refractory Period of Cardiac Muscle
    1. Extended Due to Plateau Phase
    2. Absolute Refractory Period Ensures Relaxation Nearly Complete Before Next Contraction
    3. Summation and Tetany Impossible

11 D. Electrocardiogram

12 VI. Cardiac Cycle, p. 625
   1. Repetitive Pattern of Pumping Action
A. Systole and Diastole

1. Atrial Systole and Diastole
   a. Period of Isovolumic Contraction
      1). After AV Valves Have Closed
      2). Before Semilunar Valves Have Opened
   b. Ejection Phase
      1). AV Valves Remain Closed
      2). Semilunar Valves Forced Open
   c. Early Diastole and Isovolumic Relaxation
      1). After Semilunar Valves have Closed
      2). Before Semilunar Valves have Opened

2. Ventricular Systole and Diastole
   a. Period of Isovolumic Contraction
      1). After AV Valves Have Closed
      2). Before Semilunar Valves Have Opened
   b. Ejection Phase
      1). AV Valves Remain Closed
      2). Semilunar Valves Forced Open
   c. Early Diastole and Isovolumic Relaxation
      1). After Semilunar Valves have Closed
      2). Before Semilunar Valves have Opened

3. Cardiac Output or Minute Volume
   a. End Diastolic Volume - End Systolic Volume = Stroke Volume
   b. Stroke Volume X Heart Rate = Cardiac Output or Minute volume
   c. Cardiac Reserve = Ability to Increase Cardiac Output
   d. Major Determinant of Arterial Blood Pressure (MABP = CO X PR, where PR Stands for Peripheral Resistance to Blood Flow)

B. Heart Sounds

1. First Heart Sound (Lubb)
   a. Vibrations Due to Closure of AV Valves
   b. Beginning of Ventricular Systole

2. Second Heart Sound (Dupp)
   a. Vibrations Due to Closure of Semilunar Valves
   b. Near End of Ventricular Systole

3. Third Heart Sound
   a. Normal, but Usually too Faint to be Heard
   b. Turbulent Flow of Blood from Atria to Ventricles
   c. Marks end of First Third of Ventricular Diastole

C. Aortic Pressure Curve

1. Peak Pressure During Ventricular Contraction
2. Incisura or Dicrotic Notch
a. Follows Closure of Aortic Semilunar Valve
b. Pressure Increase Caused by Elastic Recoil of Aorta

VII Regulation of the Heart, p. 632

A. Intrinsic Regulation

1. Venous Return Determines End Diastolic Volume and Preload
2. Starling's Law of the Heart
   a. Stretch of Cardiac Muscle Produces Stronger Contractions
   b. Increased Venous Return Leads to Greater Cardiac Output
3. Afterload = Pressure Needed to Move Blood into the Aorta

B. Extrinsic Regulation

1. Cardioregulatory Center and Chemoreceptors in Medulla Oblongata
2. Parasympathetic Control
   a. Vagus Nerve
   b. Decreases Heart Rate and (Small) Decrease in Force; up to 20% Decrease in Cardiac Output
   c. Acetylcholine
      1). Hyperpolarization
      2). Opens Ligand Gated K⁺ Channels
3. Sympathetic Control
   a. Cardiac Nerves
   b. Increases Heart Rate and Contractility; up to 100% Increase in Cardiac Output
   c. Norepinephrine
      1). Hypopolarization
      2). β-Adrenergic Activation of cAMP Second Messenger System
4. Hormonal Control
   a. Epinephrine and Norepinephrine in Blood from Adrenal Medulla
   b. Longer Lasting than Neural Stimulation
   c. Increases Heart Rate and Force of Contraction

16, 17 VIII. Heart and Homeostasis, 634

A. Effect of Blood Pressure

1. Baroreceptor Reflex
   a. Stretch Receptors in Internal Carotid Artery and Aorta
   b. Sympathetic Fibers from
Cardioacceleratory Center  
c. Parasympathetic Fibers from  
Cardioinhibitory Center  
d. Increased BP Increases  
Parasympathetic Activity and Decreases  
Sympathetic Activity  
e. Decreased BP Increases Sympathetic  
Activity and Decreases Parasympathetic  
Activity  

![Fig. 20.22, p.635](image)

B. Effect of pH, Carbon Dioxide, and Oxygen  
1. Central Chemoreceptors Sensitive to  
Decreased pH and Increased CO₂ in Medulla  
Oblongata  
2. Peripheral Chemoreceptors Sensitive to  
Decreased O₂ in Aorta and Carotid Bodies;  
More Important in Regulation of Respiration  
and Blood Vessel Constriction  

C. Effect of Extracellular Ion Concentrations  
1. K⁺, Ca²⁺, and Na⁺ and Effects on Membrane  
Potentials  
2. K⁺ Heart Block  

D. Effect of Body Temperature  

IX. Systems Pathology, p. 640  

![Fig. 20.23, p.636](image)  
TA-401

IMPORTANT CONSIDERATIONS: Four major topic areas covered above are: basic anatomy of  
the heart, histology and electrical properties of cardiac muscle, the cardiac cycle, and the regulation  
of the heart and its relation to homeostasis. Being familiar with the pattern of circulation of blood through  
the heart and the cardiovascular system is of special importance to those students planning on careers  
in the health related professions. There are pharmacological implications for clinical practice in  
knowing where the blood goes after leaving the site of administration of therapeutic agents.  
Autorhythmicity and the plateau of the action potential give trouble to students who did not get a solid  
grasp of the ideas associated with membrane potentials when they were presented in Chapter 9. Some  
backtracking may be necessary to ensure that students do get these concepts, since they are  
fundamental to understanding the control mechanisms regulating cardiac function.  
The pressure relationships which are so important to a clear understanding of the cardiac cycle are not  
necessarily familiar to the student. Students may need to be helped to see that it is the pressure  
difference and not the cardiac muscle itself that maintains the flow of blood through the cardiovascular  
system. Another common misconception that students may have is that the heart contracts and  
immediately ejects blood. Be sure that they understand that initially both the atrioventricular valves  
and the semilunar valves are closed, until the pressure on the blood is sufficient to force the semilunar  
valves open and eject the blood.  
Understanding of the extrinsic regulatory mechanisms require remembering the discussions on the  
parasympathetic and sympathetic divisions of the autonomic nervous system covered in Chapter 16.  
Students should be encouraged to review this material if they cannot remember it.  
Students should be able to predict (and explain) changes in heart rate and/or force of contraction that  
follow changes in any of the following: blood pressure, pH, oxygen content of the blood, carbon  
dioxide content of the blood, body temperature, and/or extracellular concentrations of important ions  
(sodium, potassium, calcium, chloride).
SEE INSTRUCTOR'S MANUAL AND COURSE SOLUTIONS MANUAL FOR ADDITIONAL RESOURCES.