The Cardiovascular System: The Heart

Objectives

Heart Anatomy

1. Describe the size, location, and orientation of the heart.
2. Identify structures of the pericardium.
3. Define the endocardium, myocardium, and epicardium.
4. Compare the function of the atria and the ventricles, and describe the difference between the function of the right and left ventricles.
5. Discuss the need for coronary circulation, and name the vessels that play a role in it.
6. Indicate the function and location of the atrioventricular valves and aortic and pulmonary valves.

Properties of Cardiac Muscle Fibers

7. Describe the microscopic anatomy and control of cardiac muscle cells, and compare to skeletal muscle cells.
8. Name the energetic requirements of cardiac muscle and how these requirements are met.

Heart Physiology

9. Describe the structures and activities of the intrinsic conduction system.
10. Draw a typical ECG. Label and define the three phases.
11. Discuss the cardiac cycle in terms of relative pressure in each set of chambers.
12. Explain the normal heart sounds and how the sounds relate to closure of specific valves and systole or diastole of the ventricles.
13. Define cardiac output, stroke volume, and heart rate. Calculate cardiac output and cardiac reserve.
14. List the factors that affect stroke volume of the heart.
15. Describe the effects of the divisions of the autonomic nervous system on the heart.

Developmental Aspects of the Heart

16. Describe the events of development of the heart from two separate tubes to a fin-ished structure.
17. Explain age-related changes that occur in the heart. Discuss possible changes in heart function due to these changes.

Suggested Lecture Outline

I. Heart Anatomy (pp. 678–689; Figs. 18.1–18.10)

A. Size, Location, and Orientation (p. 678; Fig. 18.1)
   1. The heart is the size of a fist and weighs 250–300 grams.
   2. The heart is found in mediastinum and two-thirds lies left of the midsternal line.
   3. The base is directed toward the right shoulder and the apex points toward the left hip.

B. Coverings of the Heart (p. 678; Fig. 18.2)
   1. The heart is enclosed in a doubled-walled sac called the pericardium.

2. Deep to pericardium is the serous pericardium.
3. The parietal pericardium lines the inside of the pericardium.
4. The visceral pericardium, or epicardium, covers the surface of the heart.

C. Layers of the Heart Wall (pp. 678–680; Fig. 18.3)
1. The myocardium is composed mainly of cardiac muscle and forms the bulk of the heart.
2. The endocardium lines the chambers of the heart.

D. Chambers and Associated Great Vessels (pp. 680–684; Fig. 18.4)
1. The right and left atria are the receiving chambers of the heart.
2. The right ventricle pumps blood into the pulmonary trunk; the left ventricle pumps blood into the aorta.

E. Pathway of Blood Through the Heart (pp. 684–685; Fig. 18.5)
1. The right side of the heart pumps blood into the pulmonary circuit; the left side of the heart pumps blood into the systemic circuit.

F. Coronary Circulation (pp. 685–686; Fig. 18.7)
1. The heart receives no nourishment from the blood as it passes through the chamber.
2. The coronary circulation provides the blood supply for the heart cells.
3. In a myocardial infarction, there is prolonged coronary blockage that leads to cell death.

G. Heart Valves (pp. 686–689; Figs. 18.8–18.10)
1. The tricuspid and bicuspid valves prevent backflow into the atria when the ventricles contract.
2. When the heart is relaxed the AV valves are open, and when the heart contracts the AV valves close.
3. The aortic and pulmonary valves are found in the major arteries leaving the heart. They prevent backflow of blood into the ventricles.
4. When the heart is relaxed the aortic and pulmonary valves are closed, and when the heart contracts they are open.

II. Properties of Cardiac Muscle Fibers (pp. 689–692; Figs. 18.11–18.12)

A. Microscopic Anatomy (pp. 689–690; Fig. 18.11)
1. Cardiac muscle is striated and contraction occurs via the sliding filament mechanism.
2. The cells are short, fat, branched, and interconnected by intercalated discs.

B. Mechanism and Events of Contraction (pp. 690–692; Fig. 18.12)
1. Some cardiac muscle cells are self-excitable.
2. The heart contracts as unit or not at all.
3. The heart’s absolute refractory period is longer than a skeletal muscle’s, preventing tetanic contractions.

C. Energy Requirements (p. 692)
1. The heart relies exclusively on aerobic respiration for its energy demands.
2. Cardiac muscle is capable of switching nutrient pathways to use whatever nutrient supply is available.

III. Heart Physiology (pp. 692–705; Figs. 18.13–18.23)

A. Electrical Events (pp. 692–697; Figs. 18.13–18.18)

1. Intrinsic conduction system is made up of specialized cardiac cells that initiate and distribute impulses, ensuring that the heart depolarizes in an orderly fashion.
2. The autorhythmic cells have an unstable resting potential, called pacemaker potentials, that continuously depolarizes.
3. Impulses pass through the autorhythmic cardiac cells in the following order: sinoatrial node, atrioventricular node, atrioventricular bundle, right and left bundle branches, and Purkinje fibers.
4. The autonomic nervous system modifies the heartbeat: the sympathetic center increases rate and depth of the heartbeat, and the parasympathetic center slows the heartbeat.
5. An electrocardiograph monitors and amplifies the electrical signals of the heart and records it as an electrocardiogram (ECG).

B. Heart Sounds (pp. 697–698; Fig. 18.19)
   1. Normal
      a. The first heart sound, lub, corresponds to closure of the AV valves, and occurs during ventricular systole.
      b. The second heart sound, dup, corresponds to the closure of the aortic and pulmonary valves, and occurs during ventricular diastole.
   2. Abnormal
      a. Heart murmurs are extraneous heart sounds due to turbulent backflow of blood through a valve that does not close tightly.

C. Mechanical Events: The Cardiac Cycle (pp. 698–700; Fig. 18.20)
   1. Systole is the contractile phase of the cardiac cycle and diastole is the relaxation phase of the cardiac cycle.
   2. Cardiac Cycle
      a. Ventricular Filling: Mid-to-Late Diastole
      b. Ventricular Systole
      c. Isovolumetric Relaxation: Early Diastole

D. Cardiac Output (pp. 700–705; Figs. 18.21–18.23)
   1. Cardiac output is defined as the amount of blood pumped out of a ventricle per beat, and is calculated as the product of stroke volume and heart rate.
   2. Regulation of Stroke Volume
      a. Preload: the Frank-Starling law of the heart states that the critical factor controlling stroke volume is the degree of stretch of cardiac muscle cells immediately before they contract.
      b. Contractility: contractile strength increases if there is an increase in cytoplasmic calcium ion concentration.
      c. Afterload: ventricular pressure that must be overcome before blood can be ejected from the heart.
   3. Regulation of Heart Rate
      a. Sympathetic stimulation of pacemaker cells increases heart rate and contractility, while parasympathetic inhibition of cardiac pacemaker cells decreases heart rate.
      b. Epinephrine, thyroxine, and calcium influence heart rate.
      c. Age, gender, exercise, and body temperature all influence heart rate.
   4. Homeostatic Imbalance of Cardiac Output
      a. Congestive heart failure occurs when the pumping efficiency of the heart is so low that blood circulation cannot meet tissue needs.

b. Pulmonary congestion occurs when one side of the heart fails, resulting in pulmonary edema.

IV. Developmental Aspects of the Heart (pp. 705–709; Figs. 18.24–18.25)

A. Embryological Development (pp. 705–708; Figs. 18.24–18.25)
   1. The heart begins as a pair of endothelial tubes that fuse to make a single heart tube with four bulges representing the four chambers.
   2. The foramen ovale is an opening in the interatrial septum that allows blood returning to the pulmonary circuit to be directed into the atrium of the systemic circuit.
   3. The ductus arteriosus is a vessel extending between the pulmonary trunk to the aortic arch that allows blood in the pulmonary trunk to be shunted to the aorta.

B. Aging Aspects of the Heart (pp. 708–709)
   1. Sclerosis and thickening of the valve flaps occurs over time, in response to constant pressure of the blood against the valve flaps.
   2. Decline in cardiac reserve occurs due to a decline in efficiency of sympathetic stimulation.
   3. Fibrosis of cardiac muscle may occur in the nodes of the intrinsic conduction system, resulting in arrhythmias.
   4. Atherosclerosis is the gradual deposit of fatty plaques in the walls of the systemic vessels.

Cross References

Additional information on topics covered in Chapter 18 can be found in the chapters listed below.

1. Chapter 1: Ventral body cavity; mediastinum
2. Chapter 3: Cell junctions
3. Chapter 4: Serous membranes; cardiac muscle; squamous epithelium; collagen
4. Chapter 9: Sliding filament mechanisms
5. Chapter 11: Membrane potential
6. Chapter 12: Medullary control of cardiac rate
7. Chapter 13: Vagus nerve
8. Chapter 14: Neurotransmitters and cardiac rate; general sympathetic and parasympathetic function
9. Chapter 19: Atherosclerosis; hydrostatic pressure and fluid movement; cardiac output and regulation of blood pressure; vasomotor centers and control of blood pressure; function of baroreceptors and chemoreceptors in blood pressure control; blood volume and pressure control; blood flow to the heart
10. Chapter 22: Function of pulmonary arteries and veins
11. Chapter 28: Fetal circulation and modifications that occur during birth

Laboratory Correlations

1. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Cat and Fetal Pig Versions.* Eighth Edition Updates. Benjamin Cummings, 2006.

   Exercise 30: Anatomy of the Heart

   Exercise 31: Conduction System of the Heart and Electrocardiography
2. Marieb, E. N. *Human Anatomy & Physiology Laboratory Manual: Main Version.* Seventh Edition Update. Benjamin Cummings, 2006.

   Exercise 30: Anatomy of the Heart

Exercise 31: Conduction System of the Heart and Electrocardiography

Histology Slides for the Life Sciences

Available through Benjamin Cummings, an imprint of Pearson Education, Inc. To order, contact your local Benjamin Cummings sales representative.

Slide 30 Cardiac Muscle Tissue, Heart.

Lecture Hints

1. Point out that the visceral layer of the pericardium (epicardium) is the same as the outermost layer of the heart wall.
2. Display a single diagram of both pericardium and heart wall so that students get an overall perspective of construction.
3. Clearly distinguish between atrium and auricle.
4. Point out that blood flow through the right and left side of the heart occurs simultaneously, and that the direction of flow in both sides progresses from atrium to ventricle, with both sides of the heart pumping the same volume of blood.
5. Describe the construction differences between the atrioventricular valves and the semilunar valves, and why the construction of each type of valve works best in its location. Stress that the valves are not rigid structures, but flimsy.
6. Compare ion movement, depolarization, and repolarization in cardiac muscle to that of skeletal muscle. Emphasize why a long repolarization phase is important to cardiac muscle function.
7. Emphasize that the pacemaker cells are cardiac muscle cells, just modified so that they spontaneously depolarize.
8. Clearly distinguish between the basic rate set by the conduction system of the heart and the acceleratory or inhibitory controls (sympathetic and parasympathetic) set by the medulla.
9. Emphasize that the ECG is the measurement of the total electrical activity of the heart at the surface of the body. Students often wonder why the ECG does not look like an action potential.
10. When discussing ventricular systole and diastole, reinforce the definitions of root words so that students can think critically about meanings rather than memorize terminology, e.g., isovolumetric means “same volume.”
11. Stress the relationship between pressure changes in the heart chambers and flow of blood through the heart. The concepts of pressure gradients and flow are often new to students.
12. Note that while the ventricles have both a passive and active phase to filling, the atria only fill passively.
13. Relate the heart sounds to specific points in the discussion of the cardiac cycle, so that students integrate these ideas.
14. Clearly differentiate between preload as a function of mechanical stretch, and contractility as a function of strength of stimulation of contraction.
15. Discuss the importance of most blood volume bypassing fetal lungs, and the role of the foramen ovale and ductus arteriosus. Stress the significance of the closure of these structures after birth.

Activities/Demonstrations

1. Audio-visual materials listed under Multimedia in the Classroom and Lab.

2. Play a recording of normal and abnormal heart sounds to accompany your presentation of valve function and malfunction. (“Interpreting Heart Sounds” is available on free loan from local chapters of the American Heart Association.)
3. Obtain tracings of normal and abnormal ECGs. Determine what is malfunctioning with the cardiac conduction system to yield the abnormal tracings.
4. Record the heart rates of student volunteers as they stand quietly and run in place for a few minutes. Using a standard stroke volume, calculate the change in cardiac output.
5. Use heart models and dissected specimens to show the anatomy of the heart and its position within the chest cavity.
6. Using dissected animal specimens, compare fetal heart structures with adult structures.

Critical Thinking/Discussion Topics

1. Relate the functioning of the heart to the functioning of a water pump. Include problems associated with low blood pressure going to the heart and high pressure leaving the heart.
2. Discuss the signs of impending heart attack.
3. Compare the significance of ventricular fibrillation as opposed to atrial fibrillation.
4. Discuss the role of cardiac muscle in ejecting blood from the ventricles as opposed to ejecting blood from the atria.
5. How would heart function change if cells of the AV node depolarized at a faster rate than SA node cells?
6. What would happen to the heart (and the rest of the body) over a period of time if a partial blockage of the aortic semilunar valve occurred?
7. Discuss the symptoms and potential problems in a person with mitral valve prolapse.
8. Examine the action of digoxin as a therapy for heart murmurs.
9. Identify long-term stress and its role in hypertensive disorders of the heart.

Library Research Topics

1. Research the role of antihypertensive drugs on the action of the heart.
2. Study the alternatives to coronary bypass operations.
3. Investigate the known effects of street drugs on heart activity.
4. Research the effect of smoking on the heart and its function.
5. Examine the criteria used for heart transplants and their success rate.
6. Research the effect of exercise on heart function.
7. Identify the use of pacemakers and what specific problems they are designed to correct.
8. Explore the status of artificial hearts or external heart pumps. Identify advances and problems.
9. Study fetal heart defects and outline advances in treatment.
10. Research the diagnostic tests done to measure heart health, and what they are designed to show.

Multimedia in the Classroom and Lab

Online Resources for Students

The following shows the organization of the Chapter Guide page in both the Anatomy & Physiology Place and MyA&P™. The Chapter Guide organizes all the chapter-specific online media resources for Chapter 18 in one convenient location, with e-book links to each section of the textbook. Please note that both sites also give you access to other general A&P resources, like InterActive Physiology®*, PhysioEx 6.0™, Anatomy 360°, Flashcards, a Glossary, a Histology Tutorial, and much more.*

Objectives

Section 18.1 Heart Anatomy (pp. 678–689)

InterActive Physiology®: Anatomy Review: The Heart

Art Labeling Activity: Gross Anatomy of the Heart, External View (Fig. 18.4b, p. 681)

Art Labeling Activity: Gross Anatomy of the Heart, Internal View (Fig. 18.4e, p. 683)

Memory: The Structure of the Heart

Section 18.2 Properties of Cardiac Muscle Fibers (pp. 689–692)

InterActive Physiology®: Cardiac Action Potential

Section 18.3 Heart Physiology (pp. 692–705)

InterActive Physiology®: Intrinsic Conduction System

InterActive Physiology®: Cardiac Cycle

InterActive Physiology®: Cardiac Output

PhysioEx: Frog Cardiovascular Physiology

Case Study: Coronary Stenosis

Case Study: Cardiac Arrhythmia

Memory: The Cardiovascular System

Activity: Sequence of Excitation of the Heart

Section 18.4 Developmental Aspects of the Heart (pp. 705–709)

Chapter Summary

Self-Study Quizzes

Art Labeling Quiz

Matching Quiz

Multiple-Choice Quiz (Level I)

Multiple-Choice Quiz (Level II)

True-False Quiz

Crossword Puzzles

Crossword Puzzle 18.1

Crossword Puzzle 18.2

Media

See Guide to Audio-Visual Resources in Appendix A for key to AV distributors.

Video

1. *The Circulatory System: Two Hearts That Beat as One* (FHS; 28 min., 1989). From *The Living Body* series, this program describes the structure and functioning of the heart.
2. *Diagnosing Heart Disease* (FHS; 18 min., 1994). Discusses heart disease, the warning signs of heart attack, electrocardiograms, and cardio-catheterization. Helps students visualize the various tests used in the diagnosis of heart problems.
3. *Heart Attack* (FHS; 50 min., 2000). From *The Body Invaders* series, this program looks at the causes, symptoms, and treatment of atherosclerosis.

4. *Heart Valves: Repairing the Heart* (FHS; 19 min.). Discusses the symptoms and treatment of aortic valve stenosis. Covers the functions of angioplasty, the uses of a pacemaker, and an implantable defibrillator.
5. *The Human Cardiovascular System: The Heart Videotape* (BC; 25 min., 1995). A sheep heart is utilized to illustrate structure and function of the heart, along with dissected human specimen and the cadaver to show the heart coronary and great vessels. Excellent for a laboratory demonstration as a supplement to dissection.
6. *Pumping Life—The Heart and Circulatory System* (WNS; 20 min.). Explains the structure and function of the heart. Uses animation and live action. Discusses heart problems and the importance of preventive maintenance.

Software

1. *A.D.A.M.® InterActive Anatomy® 4.0* (see p. 9 of this guide for full listing).
2. *A.D.A.M.® MediaPro* (see p. 9 of this guide for full listing).
3. *A.D.A.M.® Anatomy Practice* (see p. 86 of this guide for full listing).
4. *Bodyworks* (see p. 9 of this guide for full listing).
5. *LOGAL Explorer™: Cardiovascular System™ CD-ROM* (RIL; Win/Mac). This program illustrates the role the heart plays in the function of the human body. Investigates the heart as well as its function, the effect of drugs, cardiac fitness, and various heart disorders.
6. *InterActive Physiology® 9-System Suite CD-ROM: Cardiovascular System* (BC; Win/Mac 2006). Presents topics related to heart and blood vessel physiology, such as blood pressure, cardiac output, intrinsic conduction system, cardiac action potential, and cardiac cycle.
7. *The Ultimate Human Body* (see p. 9 of this guide for full listing).

Lecture Enhancement Material

To view thumbnails of all of the illustrations for Chapter 18, see Appendix B.

Transparencies Index/Media Manager

Figure 18.1	Location of the heart in the mediastinum.
Figure 18.2	The pericardial layers and layers of the heart wall.
Figure 18.3	The circular and spiral arrangement of cardiac muscle bundles in the myocardium of the heart.
Figure 18.4	Gross anatomy of the heart.
Figure 18.5	The systemic and pulmonary circuits.
Figure 18.6	Anatomical differences in right and left ventricles.
Figure 18.7	Coronary circulation.
Figure 18.8	Heart valves.
Figure 18.9	The atrioventricular valves.
Figure 18.10	The semilunar valves.
Figure 18.11	Microscopic anatomy of cardiac muscle.
Figure 18.12	Changes in membrane potential and permeability during action potentials of contractile cardiac muscle cells.
Figure 18.13	Pacemaker and action potentials of autorhythmic cells of the heart.
Figure 18.14	Cardiac intrinsic conduction system and action potential succession during one heartbeat.
Figure 18.15	Autonomic innervation of the heart.

Figure 18.16 An electrocardiogram tracing (lead I).
Figure 18.17 The sequence of excitation of the heart related to the deflection waves of an ECG tracing.
Figure 18.18 Normal and abnormal ECG tracings.
Figure 18.19 Areas of the thoracic surface where the heart sounds can be best detected.
Figure 18.20 Summary of events during the cardiac cycle.
Figure 18.21 Preload and afterload influence stroke volume.
Figure 18.22 Mechanism by which norepinephrine influences heart contractility.
Figure 18.23 Factors involved in regulation of cardiac output.
Figure 18.24 Development of the human heart during week 4.
Figure 18.25 Three examples of congenital heart defects.
A Closer Look Heart Boosters, Retreads, and Replacements

Answers to End-of-Chapter Questions

Multiple Choice and Matching Question answers appear in Appendix G of the main text.

Short Answer Essay Questions

10. The heart is enclosed within the mediastinum. It lies anterior to the vertebral column and posterior to the sternum. It tips slightly to the left. (p. 678)
11. The pericardium has two layers, a fibrous and a serous layer. The outer fibrous layer is a fibrous connective tissue that protects the heart and anchors it to surrounding structures. The inner serous layer (squamous epithelial cells) lines the fibrous layer as the parietal serous pericardium and at the base of the heart continues over the heart surface as the visceral serous pericardium. The visceral serous pericardium is the outermost layer of the heart wall, i.e., the epicardium. (p. 678)
12. Blood that enters the right atrium on its way to the left atrium is in the pulmonary circuit. The path is as follows: right atrium, right ventricle, pulmonary trunk, right and left pulmonary arteries, lungs, pulmonary veins, left atrium. This circuit is called the pulmonary circuit. (p. 684)
13. a. The coronary arteries are actively delivering blood to the myocardium when the heart is relaxed. The coronary vessels are compressed and ineffective in blood delivery when the ventricles are contracting. (pp. 685–686)
    b. The major branches of the coronary arteries and the areas they serve are as follows. The left coronary artery runs toward the left side of the heart and divides into the anterior interventricular artery and the circumflex artery. The anterior interventricular artery supplies blood to the interventricular septum and anterior walls of both ventricles, and the circumflex artery serves the left atrium and the posterior walls of the left ventricle. The right coronary artery splits to the right side of the heart, where it divides into the marginal artery and the posterior interventricular artery. The marginal artery serves the myocardium of the lateral part of the right side of the heart and the posterior interventricular artery, which runs to the heart apex and supplies the posterior ventricular walls. (pp. 685–686)
14. A longer refractory period of cardiac muscle is desirable because it prevents the heart from going into prolonged or tetanic contractions which would stop its pumping action. (p. 691)
15. a. The elements of the intrinsic conduction system of the heart, beginning with the pacemaker, are: the SA node or pacemaker, AV node, AV bundle, right and left bundle branches, and Purkinje fibers. (p. 693)
    b. This system functions to initiate and distribute impulses throughout the heart so that the myocardium depolarizes and contracts in an orderly, sequential manner from atria to ventricles. (p. 694)

16. See Figure 18.16. The P wave results from impulse conduction from the SA node through the atria. The QRS complex results from ventricular depolarization and precedes ventricular contraction. Its shape reveals the different size of the two ventricles and the time required for each to depolarize. The T wave is caused by ventricular repolarization. (p. 696)
17. The cardiac cycle includes all events associated with the flow of blood through the heart during one complete heartbeat. One cycle includes a period of ventricular filling (mid-to-late diastole at the end of which atrial systole occurs), ventricular systole, and isovolumetric relaxation (early diastole). (p. 698)
18. Cardiac output is the amount of blood pumped out by each ventricle in one minute. It can be calculated by the following equation: cardiac output = heart rate X stroke volume. (p. 700)
19. The Frank-Starling Law explains that the critical factor controlling stroke volume is the degree of stretch of the cardiac muscle cells just before they contract. The important factor in the stretching of cardiac muscle is the amount of blood returning to the heart and distending its ventricles. (pp. 700–701)
20. In a fetus, the common function of the foramen ovale and the ductus arteriosus is to allow blood to bypass the pulmonary circulation. If these shunts remain patent after birth, the opening prevents adequate gas exchange, O_2 loading and CO_2 unloading, in the pulmonary circulation. (pp. 706–707)

Critical Thinking and Clinical Application Questions

1. Cardiac tamponade is compression of the heart due to accumulation of blood or inflammatory fluid in the pericardial sac. Such compression reduces the ability of the heart to beat and act as an effective pump, leading to inadequate blood delivery (which results in ischemia and cyanosis), and ultimately cardiogenic shock. (p. 678)
2. a. To auscultate the aortic valve, place the stethoscope over the second intercostal space at the right sternal margin. To auscultate the mitral valve, place the stethoscope over the heart apex, in the fifth intercostal space in line with the middle of the clavicle. (p. 697)
   b. These abnormal sounds would be heard most clearly during ventricular diastole for the aortic valve and during atrial systole for the mitral valve. (pp. 697–698)
   c. An incompetent valve has a swishing sound after the valve has supposedly closed. A stenosed valve has a high-pitched sound when blood is being forced through its constricted opening during systole just before valve closure. (p. 698)
3. Failure of the left ventricle (which pumps blood to the body) can result in chest pain due to dying or dead ischemic cardiac cells; pale, cold skin due to lack of circulation of blood from blocked ventricular contraction; and moist sounds in the lower lungs due to high pressure and pooling of blood in the pulmonary circulation because of nonfunction of the left ventricle. (pp. 704–705)
4. Oxygen-deficient blood returning from the systemic circulation to the right heart will pass repeatedly around the systemic circuit, while oxygenated blood returned from the lungs is continually recycled through the pulmonary circuit. (p. 681)
5. Gabriel, being a user of an injectable drug, probably was infected by a bacteria-contaminated (“dirty”) needle used to administer heroin. (p. 709)
6. The synonyms are as follows: (a) coronary sulcus, (b) right AV valve, (c) left AV or mitral valve, and (d) bundle of His. (pp. 681, 686, 693)

Suggested Readings

Anversa, P. and Nadal-Ginard, B. “Myocyte Renewal and Ventricular Remodelling.” *Nature* 415 (6868) (Jan. 2002): 240–243.

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