Elaine N. Marieb
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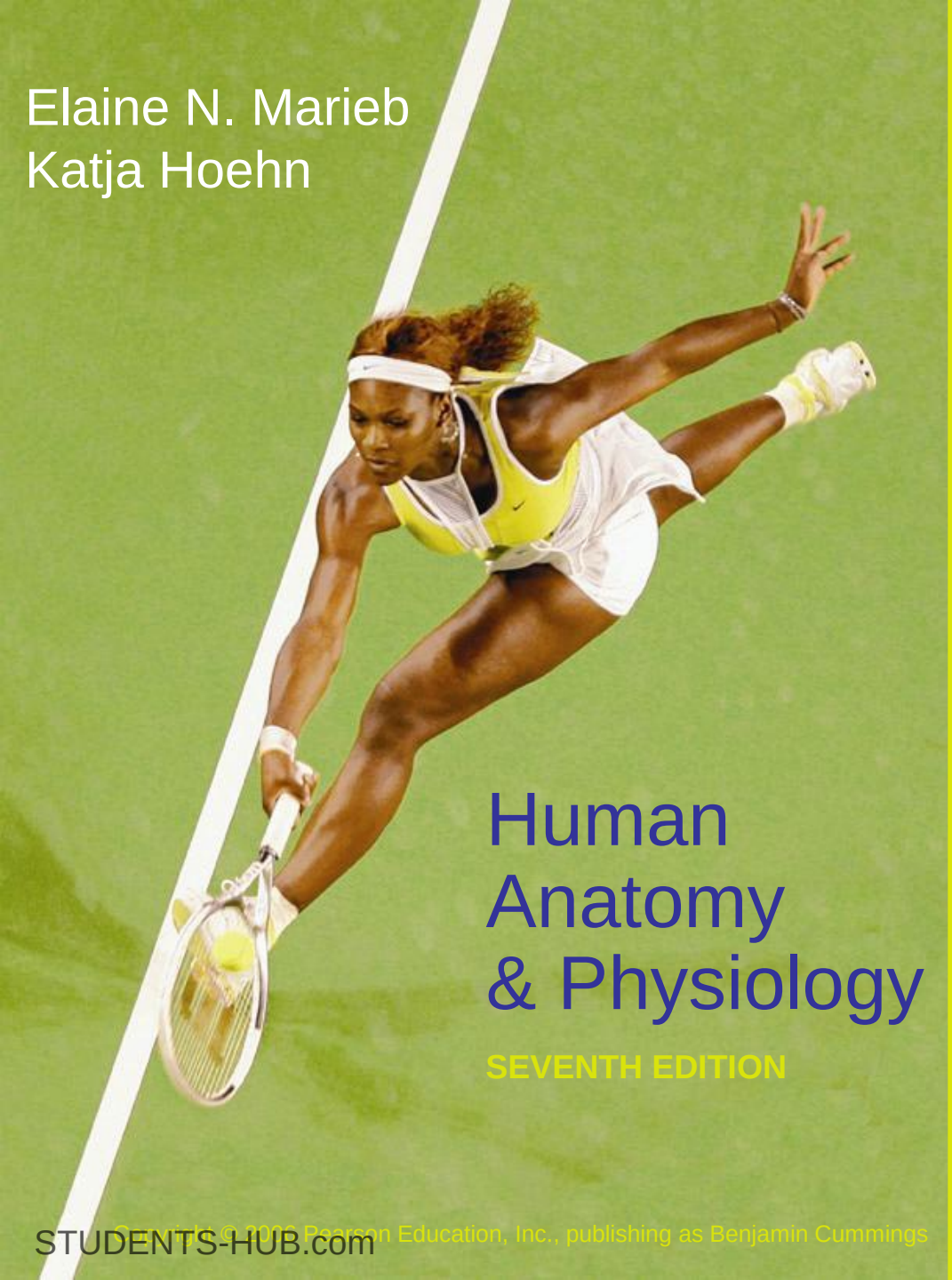


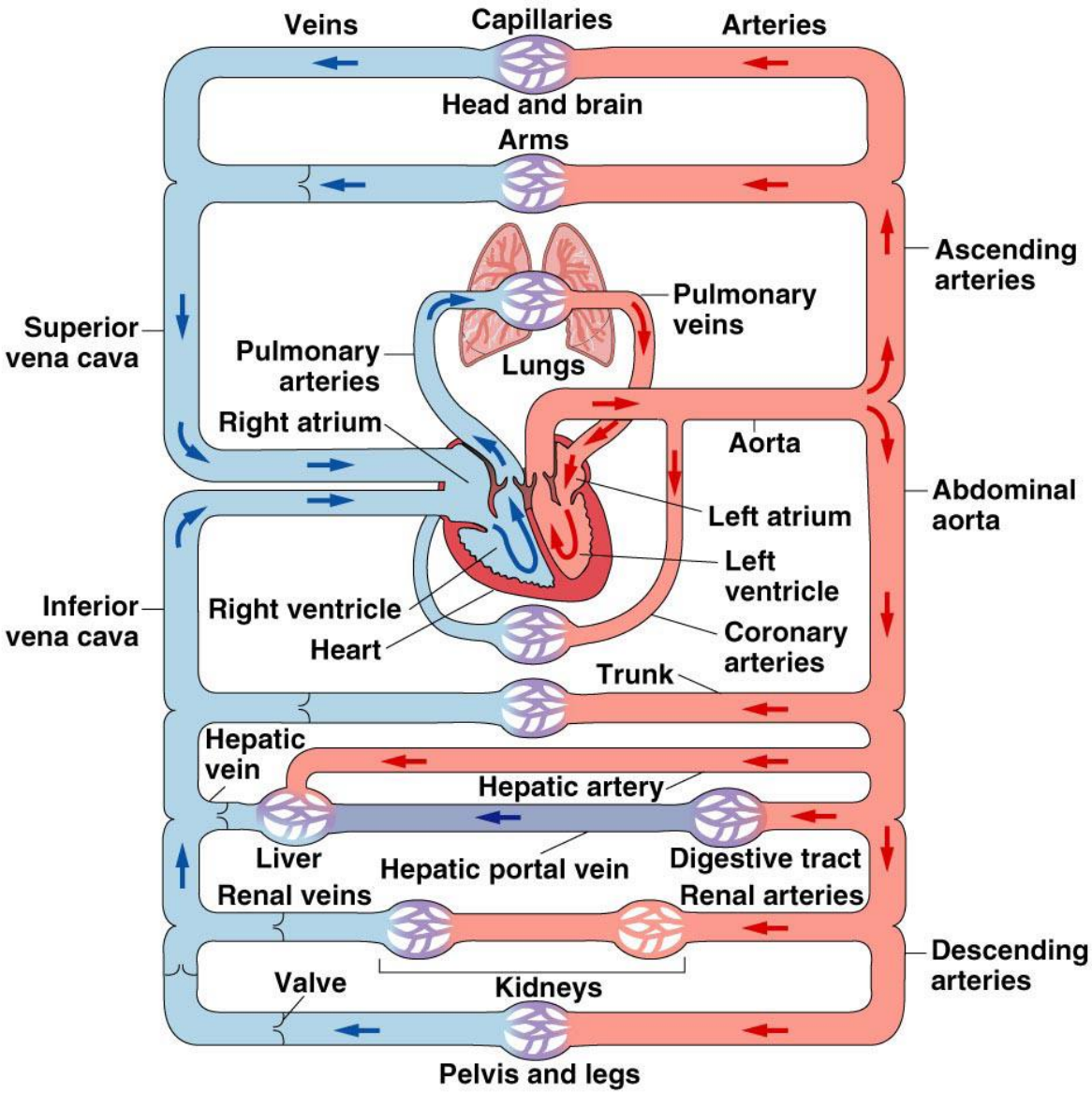
Human Anatomy & Physiology

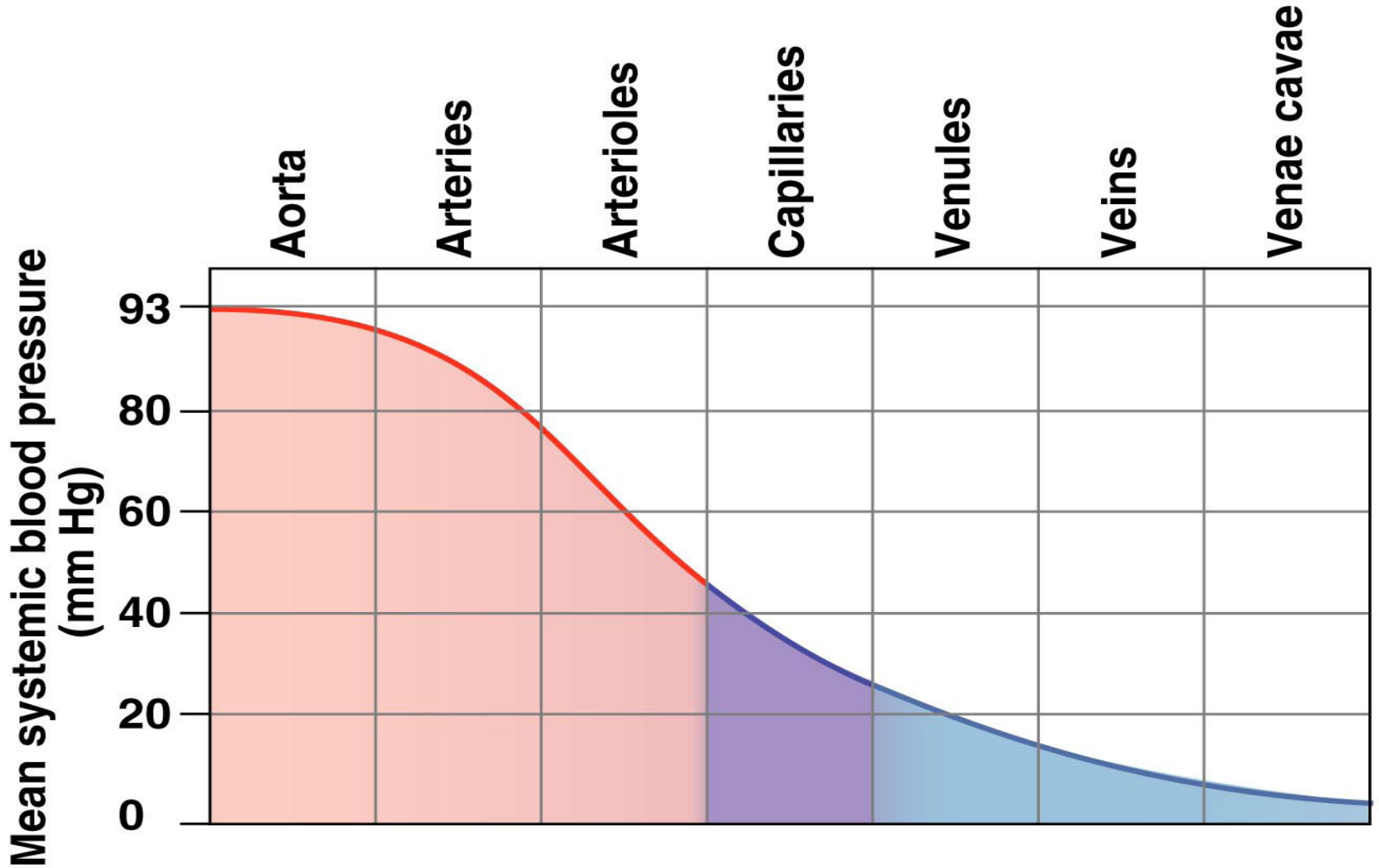
SEVENTH EDITION

PowerPoint® Lecture Slides
prepared by Vince Austin,
Bluegrass Technical
and Community College

CHAPTER 18 PART A

The Cardiovascular System: The Heart





Heart Anatomy

- Approximately the size of your fist
- Location
  - Superior surface of diaphragm
  - Left of the midline
  - Anterior to the vertebral column, posterior to the sternum

Coverings of the Heart: Anatomy

- **Pericardium** – a double-walled sac around the heart composed of:
  - A superficial fibrous pericardium
  - A deep two-layer serous pericardium
    - The parietal layer lines the internal surface of the fibrous pericardium
    - The visceral layer or **epicardium** lines the surface of the heart
    - They are separated by the fluid-filled pericardial cavity

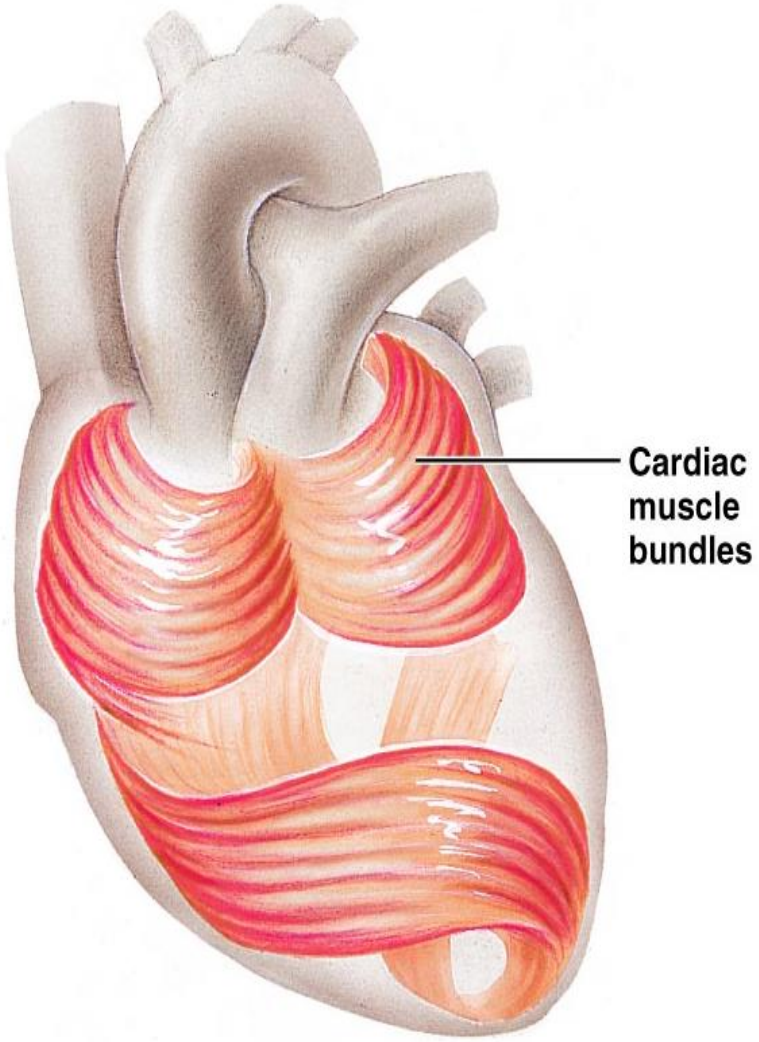
Coverings of the Heart: Physiology

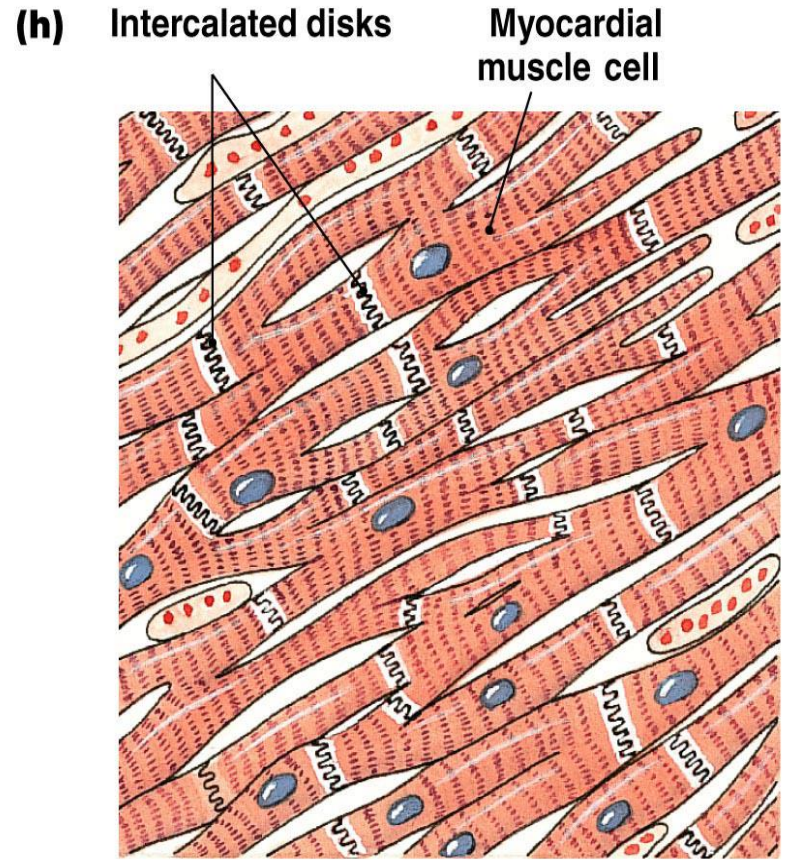
- The **pericardium**:
  - Protects and anchors the heart
  - Prevents overfilling of the heart with blood
  - Allows for the heart to work in a relatively friction-free environment

Heart Wall

- **Epicardium** – visceral layer of the serous pericardium
- **Myocardium** – cardiac muscle layer forming the bulk of the heart
- **Fibrous skeleton of the heart** – crisscrossing, interlacing layer of connective tissue
- **Endocardium** – endothelial layer of the inner myocardial surface

Cardiac Muscle Bundles





Myocardial muscle cells are branched, have a single nucleus, and are attached to each other by specialized junctions known as intercalated disks.

Figure 18.3

Right and Left Ventricles

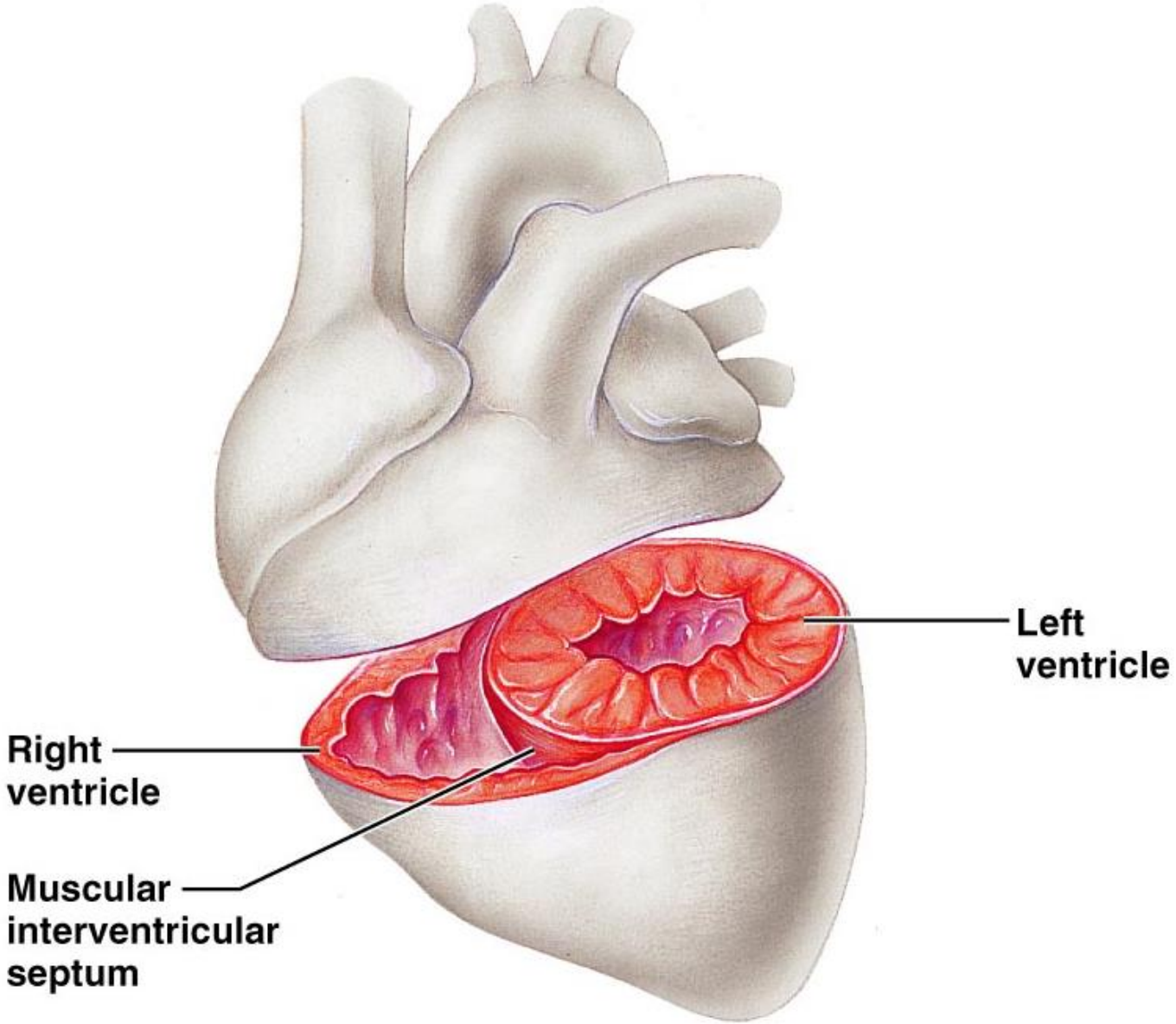
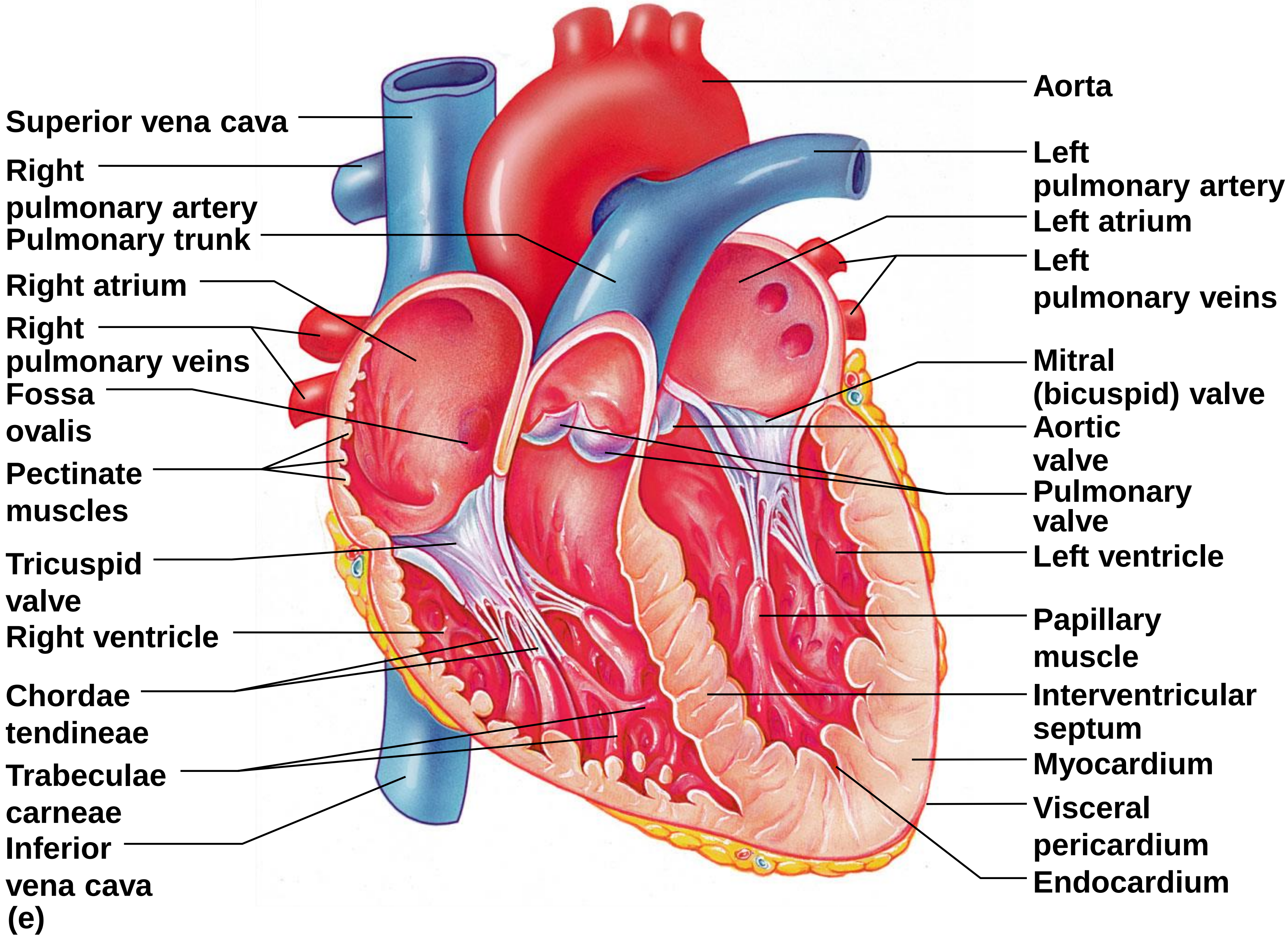


Figure 18.6



(e)

Figure 18.4e

Pathway of Blood Through the Heart and Lungs

- Superior and inferior vena cava → Right atrium → tricuspid valve → right ventricle
- Right ventricle → pulmonary semilunar valve → pulmonary arteries → lungs
- Lungs → pulmonary veins → left atrium
- Left atrium → bicuspid valve → left ventricle
- Left ventricle → aortic semilunar valve → aorta
- Aorta → systemic circulation

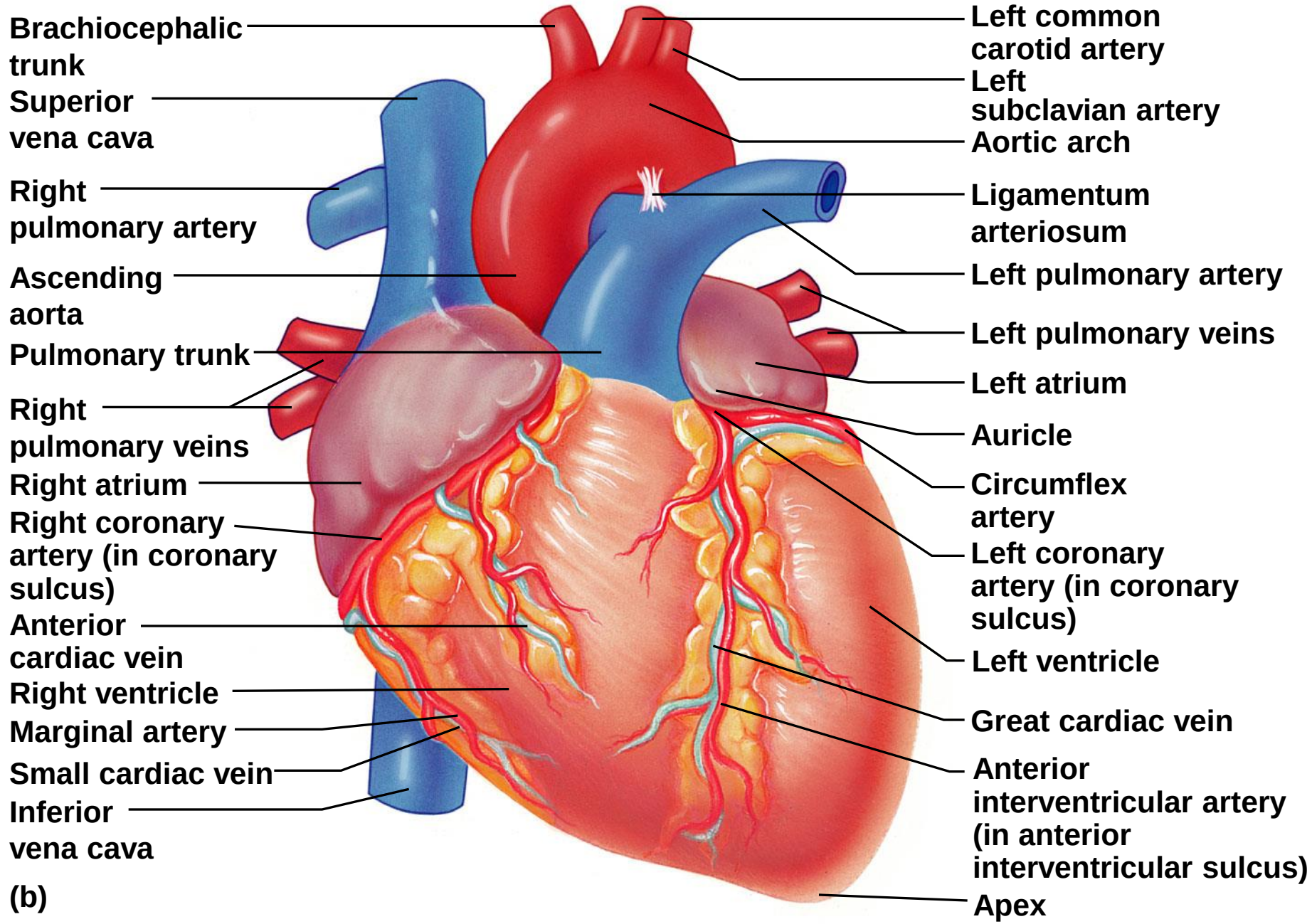


Figure 18.4b

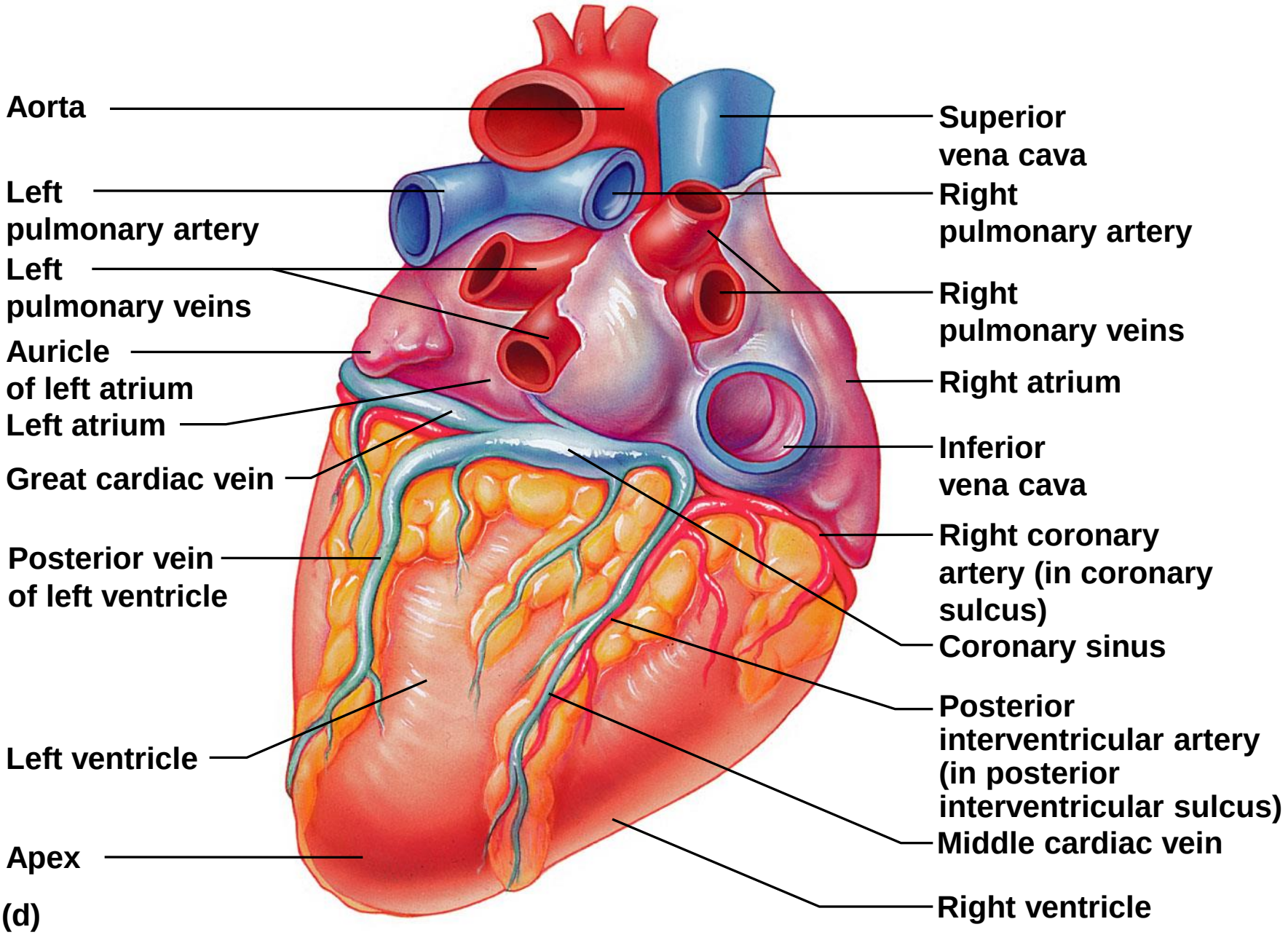


Figure 18.4d

Coronary Circulation

- Coronary circulation is the functional blood supply to the heart muscle itself
- Collateral routes ensure blood delivery to heart even if major vessels are occluded

Heart Valves

- Heart valves ensure unidirectional blood flow through the heart
- Atrioventricular (AV) valves lie between the atria and the ventricles
- AV valves prevent backflow into the atria when ventricles contract
- Chordae tendineae anchor AV valves to papillary muscles

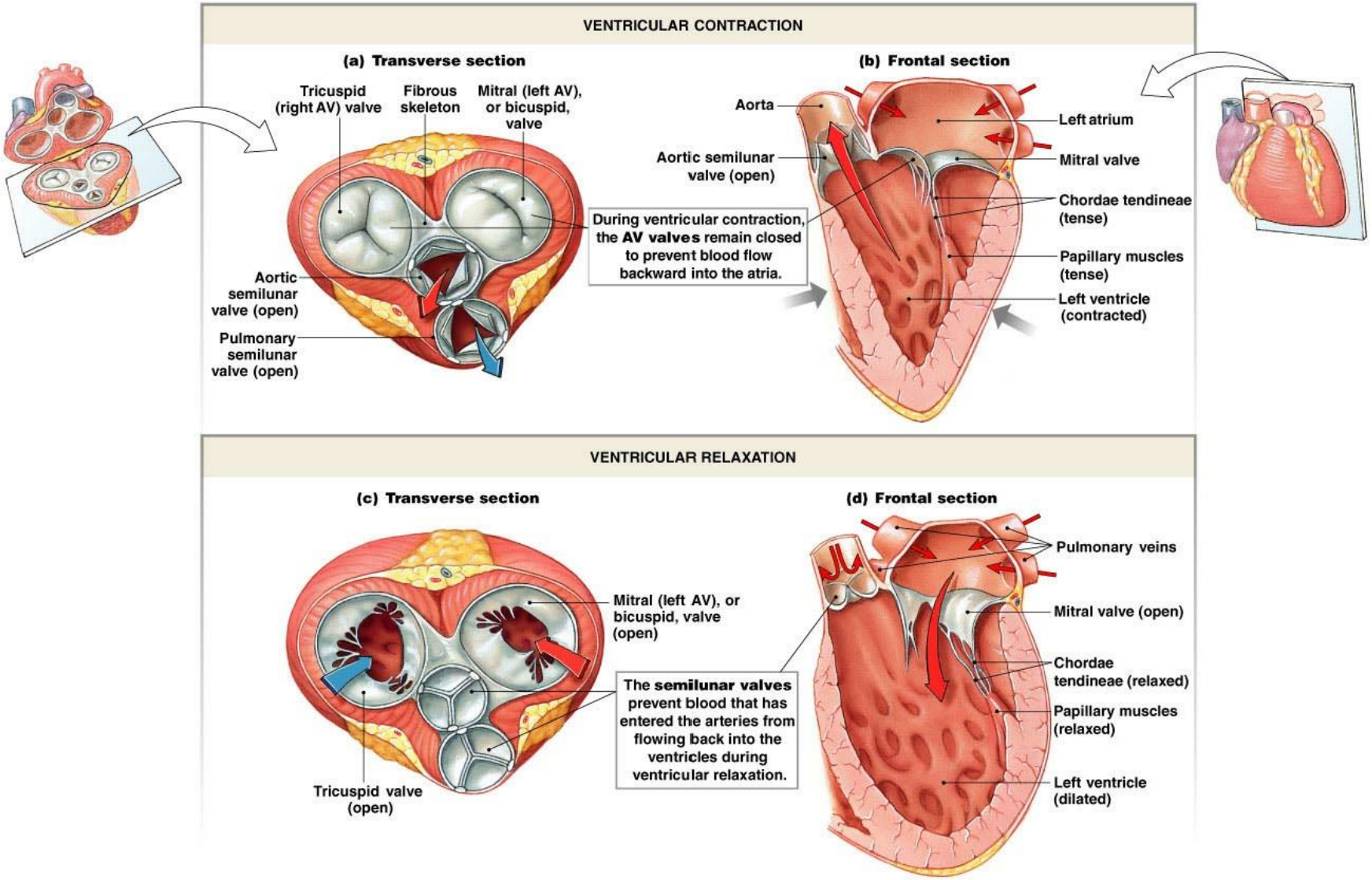


Figure 14-9 - Overview

Heart Valves

- Aortic semilunar valve lies between the left ventricle and the aorta
- Pulmonary semilunar valve lies between the right ventricle and pulmonary trunk
- Semilunar valves prevent backflow of blood into the ventricles

VENTRICULAR CONTRACTION

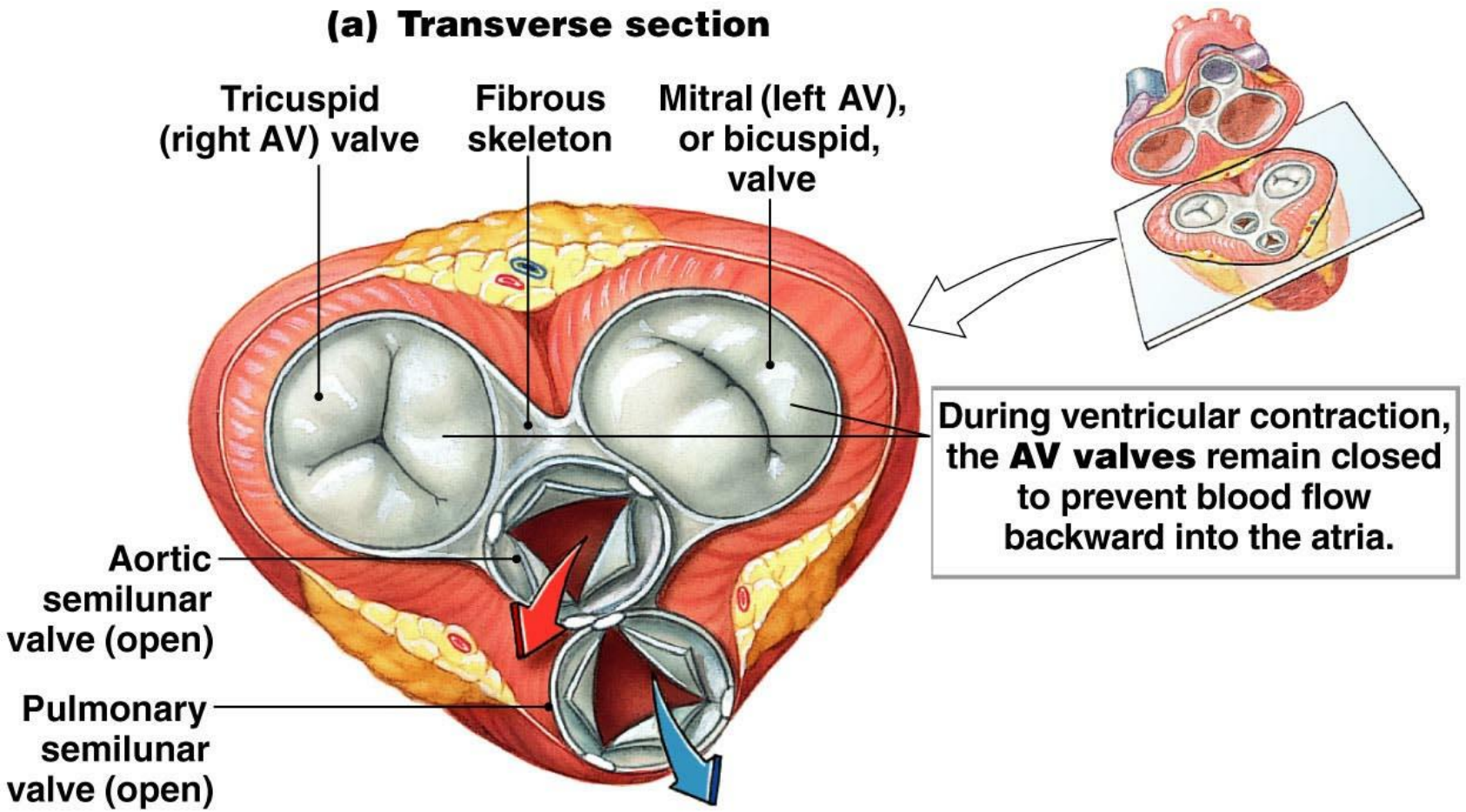
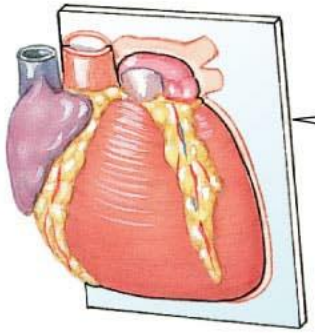


Figure 14-9a

VENTRICULAR CONTRACTION



(b) Frontal section

Aorta

Aortic semilunar valve (open)

During ventricular contraction, the **AV valves** remain closed to prevent blood flow backward into the atria.

Left atrium

Mitral valve

Chordae tendineae (tense)

Papillary muscles (tense)

Left ventricle (contracted)

Figure 14-9b

Heart Valves

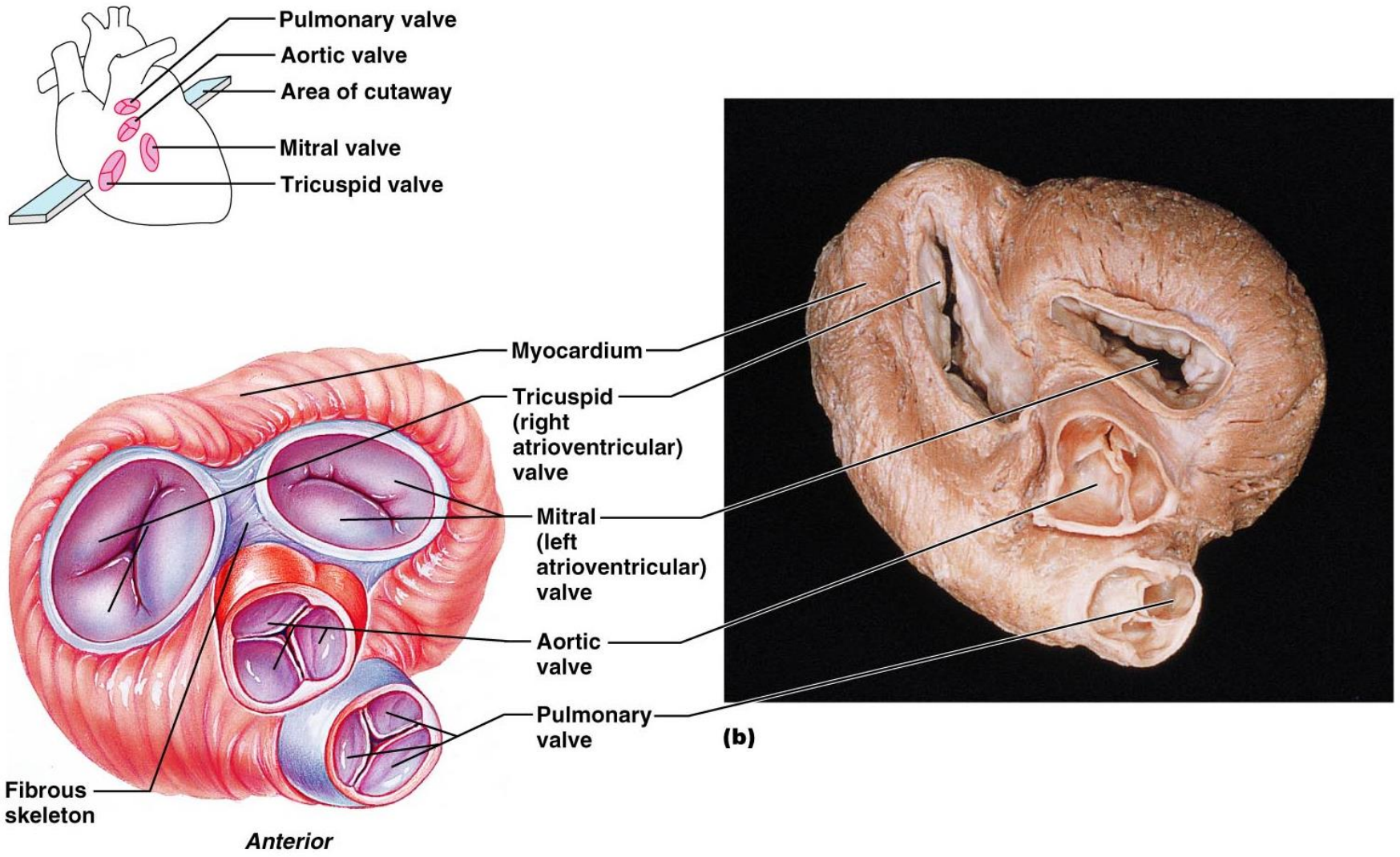
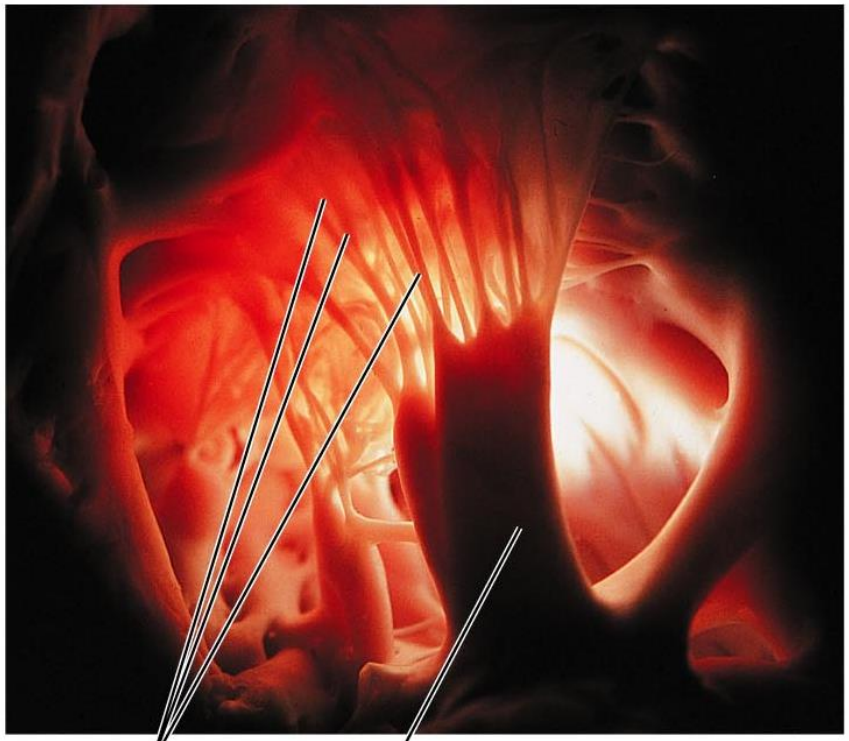


Figure 18.8a, b

Heart Valves



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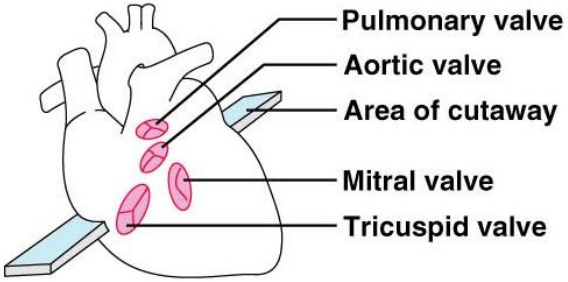
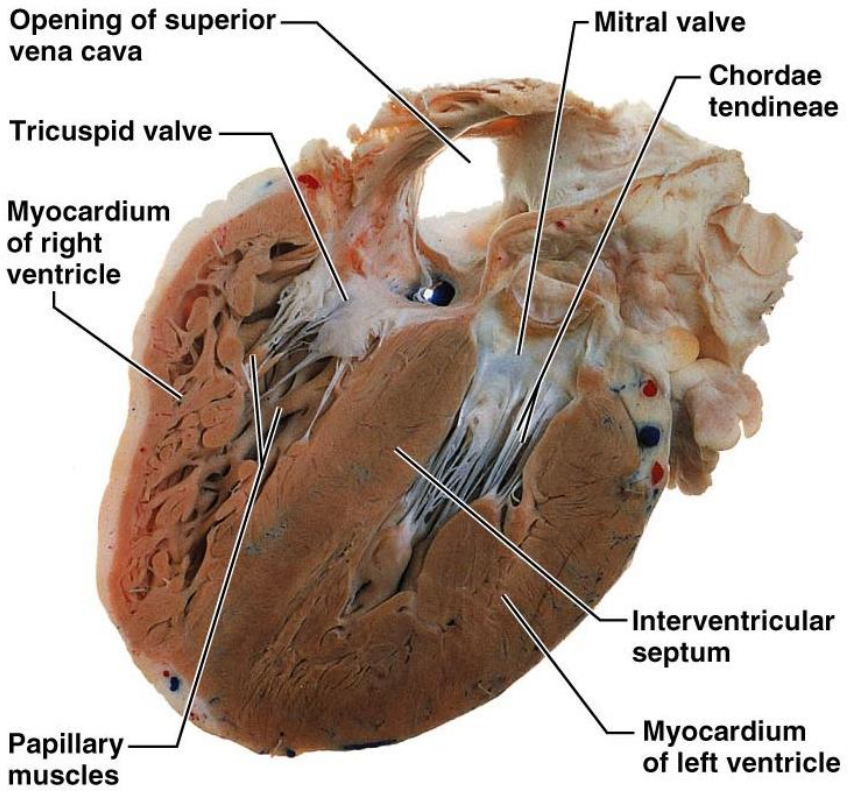




(d)

Figure 18.8c,d

VENTRICULAR RELAXATION

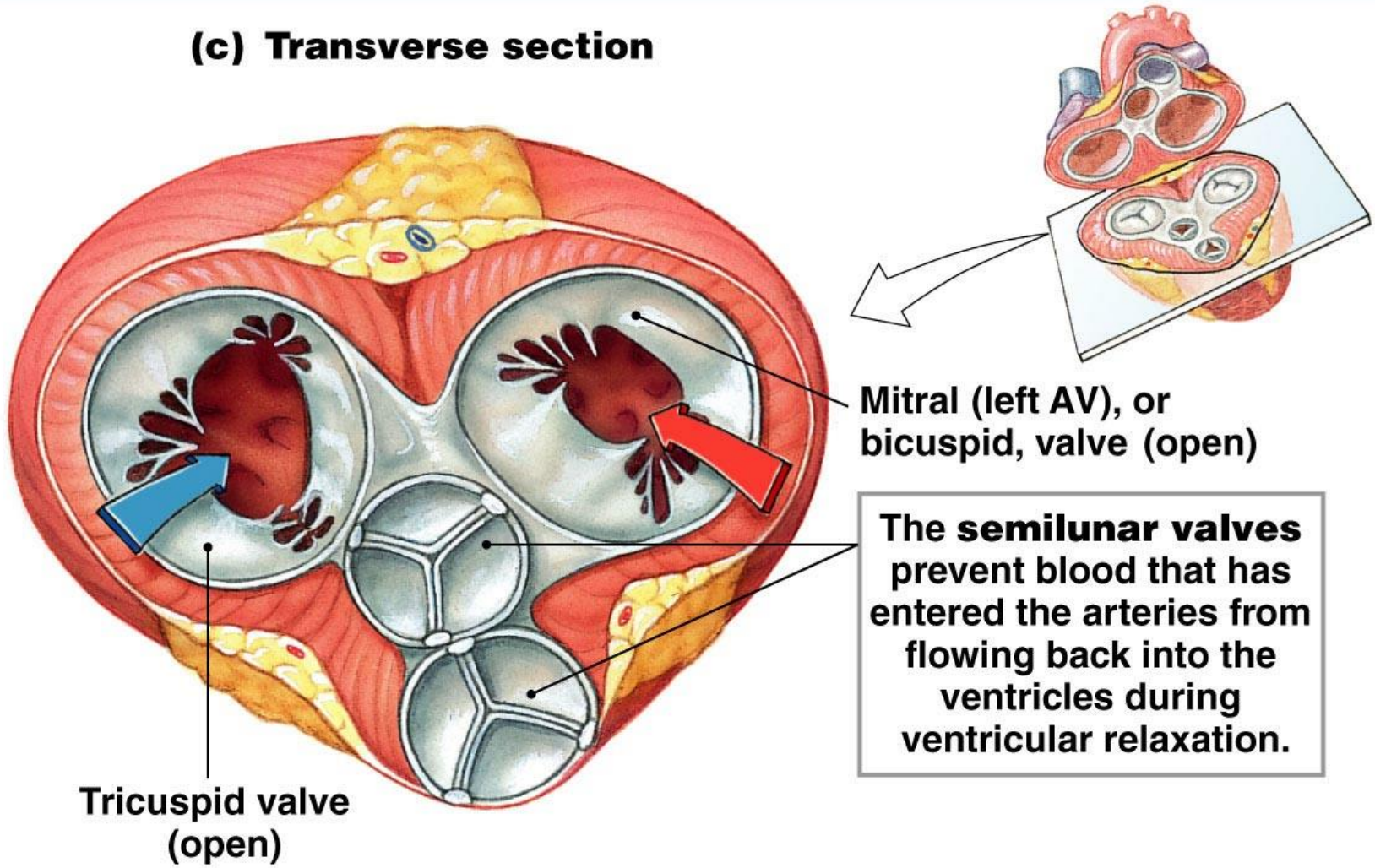


Figure 14-9c

VENTRICULAR RELAXATION

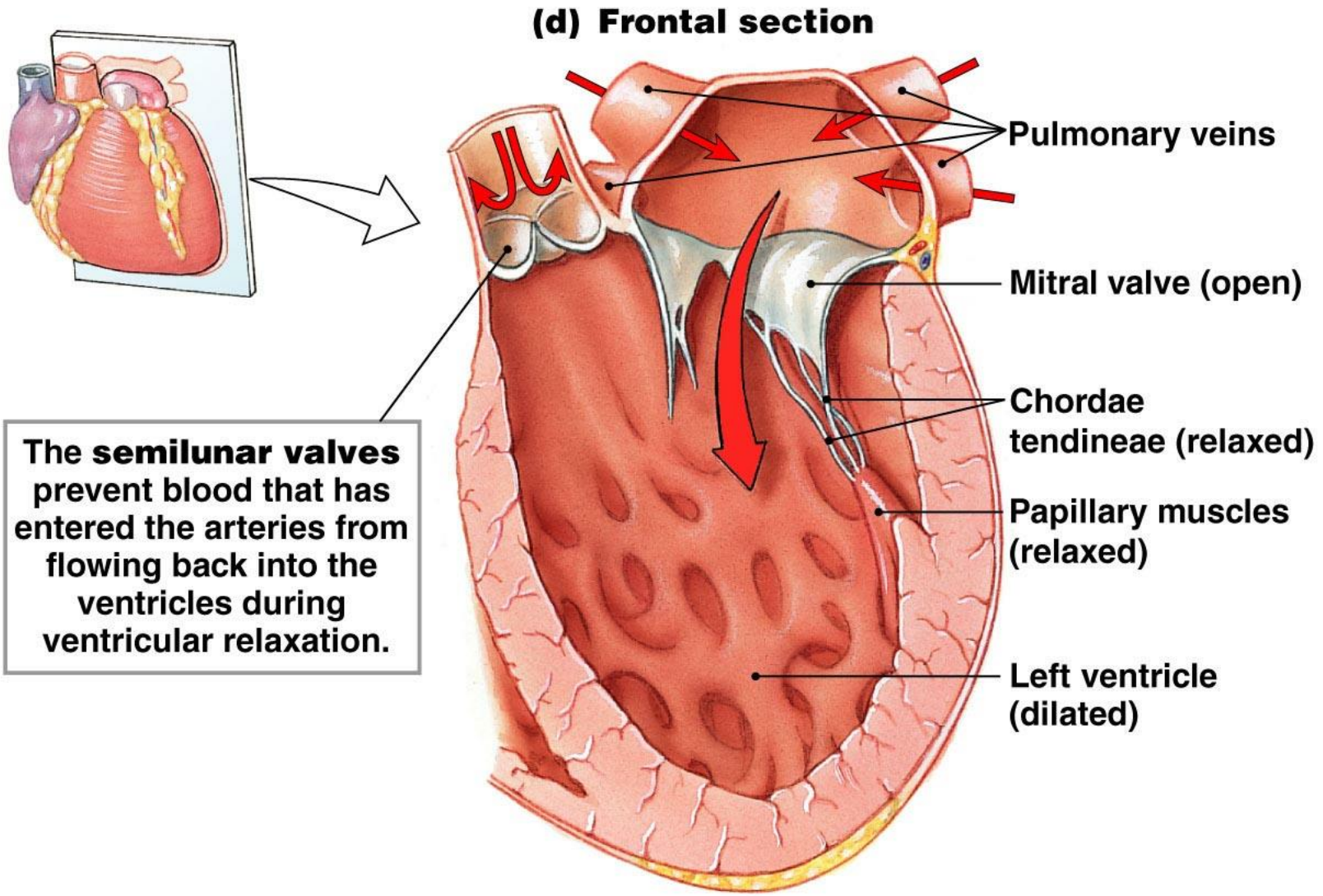


Figure 14-9d

Microscopic Anatomy of Heart Muscle

- Cardiac muscle is striated, short, fat, branched, and interconnected
- The connective tissue endomysium acts as both tendon and insertion
- Intercalated discs anchor cardiac cells together and allow free passage of ions
- Heart muscle behaves as a functional syncytium

Microscopic Anatomy of Cardiac Muscle

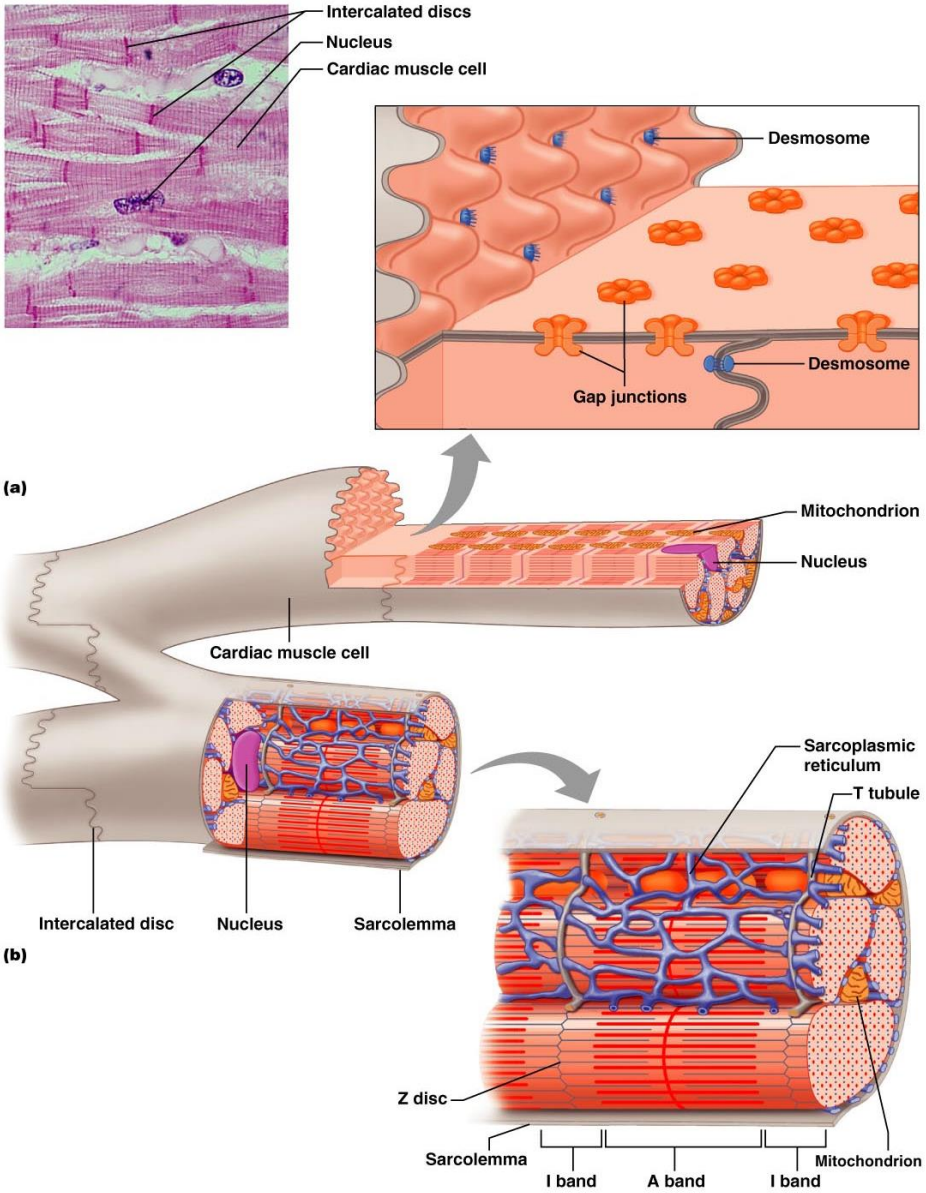


Figure 18.11

Cardiac Muscle Contraction

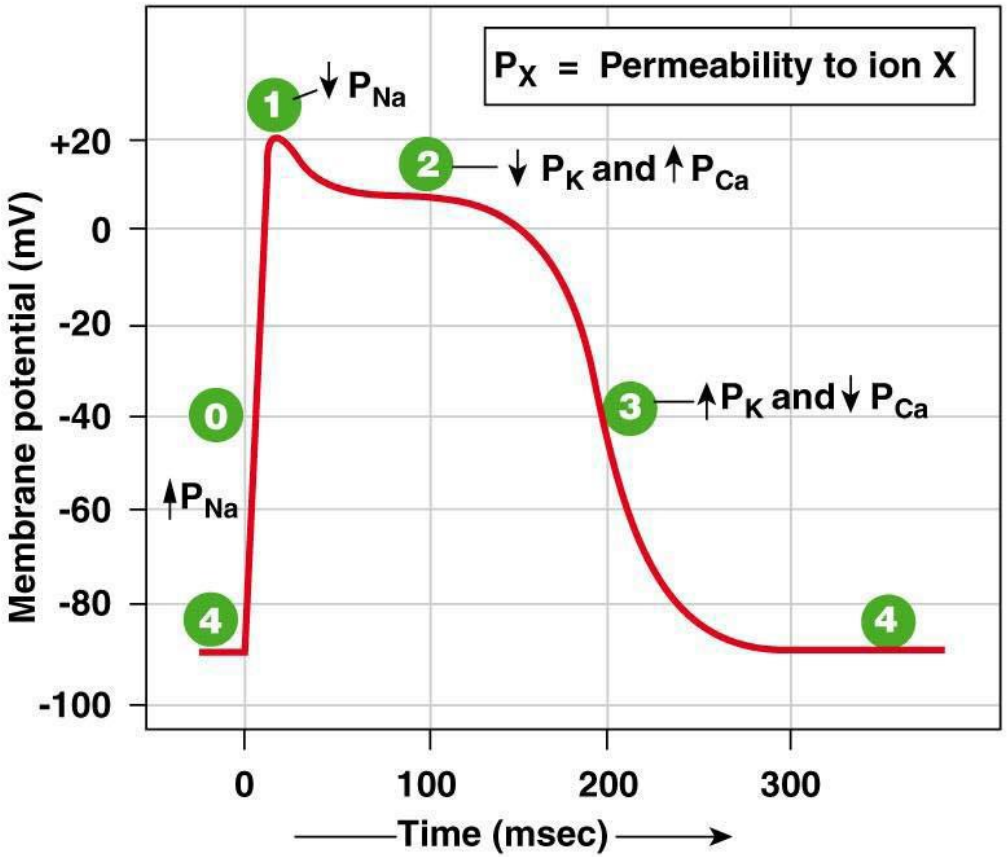
- Heart muscle:
  - Is stimulated by nerves and is self-excitable (automaticity)
  - Contracts as a unit
  - Has a long (250 ms) absolute refractory period
- Cardiac muscle contraction is similar to skeletal muscle contraction

Two Types of Cardiac Muscle

1.Myocardial Contractile cells:

- The Action Potentials are similar to those of neurons and skeletal muscles.
- The rapid depolarization phase of the AP is due to Na+ entry, steep repolarization phase is due to K+ leaving the cell.
- There is a lengthening of the AP due to Ca2+ entry

Myocardial Contractile Cells



Phase	Membrane channels
0	Na^+ channels open
1	Na^+ channels close
2	Ca^{2+} channels open; fast K^+ channels close
3	Ca^{2+} channels close; slow K^+ channels open
4	Resting potential

Action Potential of a Myocardial contractile cell

Phase 4: Resting membrane potential -90mV

Phase 0: depolarization. A wave of depolarization move to the contractile cell through gap junctions, membrane potential become more positive. Voltage-gated Na+ channels open.

Phase1: initial repolarization. Na+ close, cell begin to repolarize as K+ leaves through open K+ channel.

Phase 2: the Plateau. Results from two events: decrease in K+ permeability and increase in Ca2+ permeability.

Phase 3: rapid repolarization. The plateau ends when Ca2+ channels close and K+ permeability increase once more

Heart Physiology: Intrinsic Conduction System

2. Myocardial Autorhythmic cells: Initiate action potentials

- Have unstable resting potentials called pacemaker potentials
- Use calcium influx (rather than sodium) for rising phase of the action potential

Pacemaker and Action Potentials of the Heart

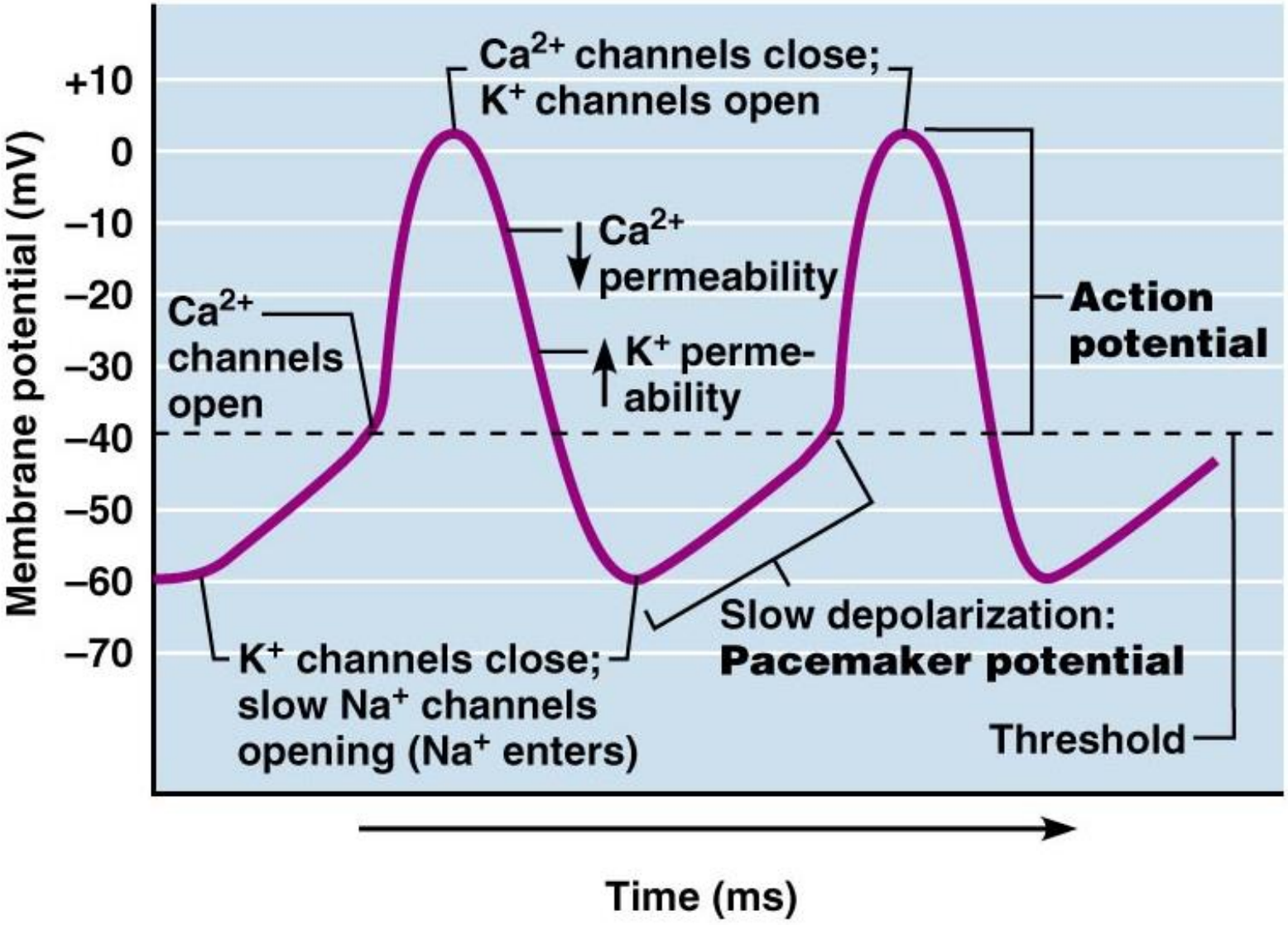


Figure 18.13

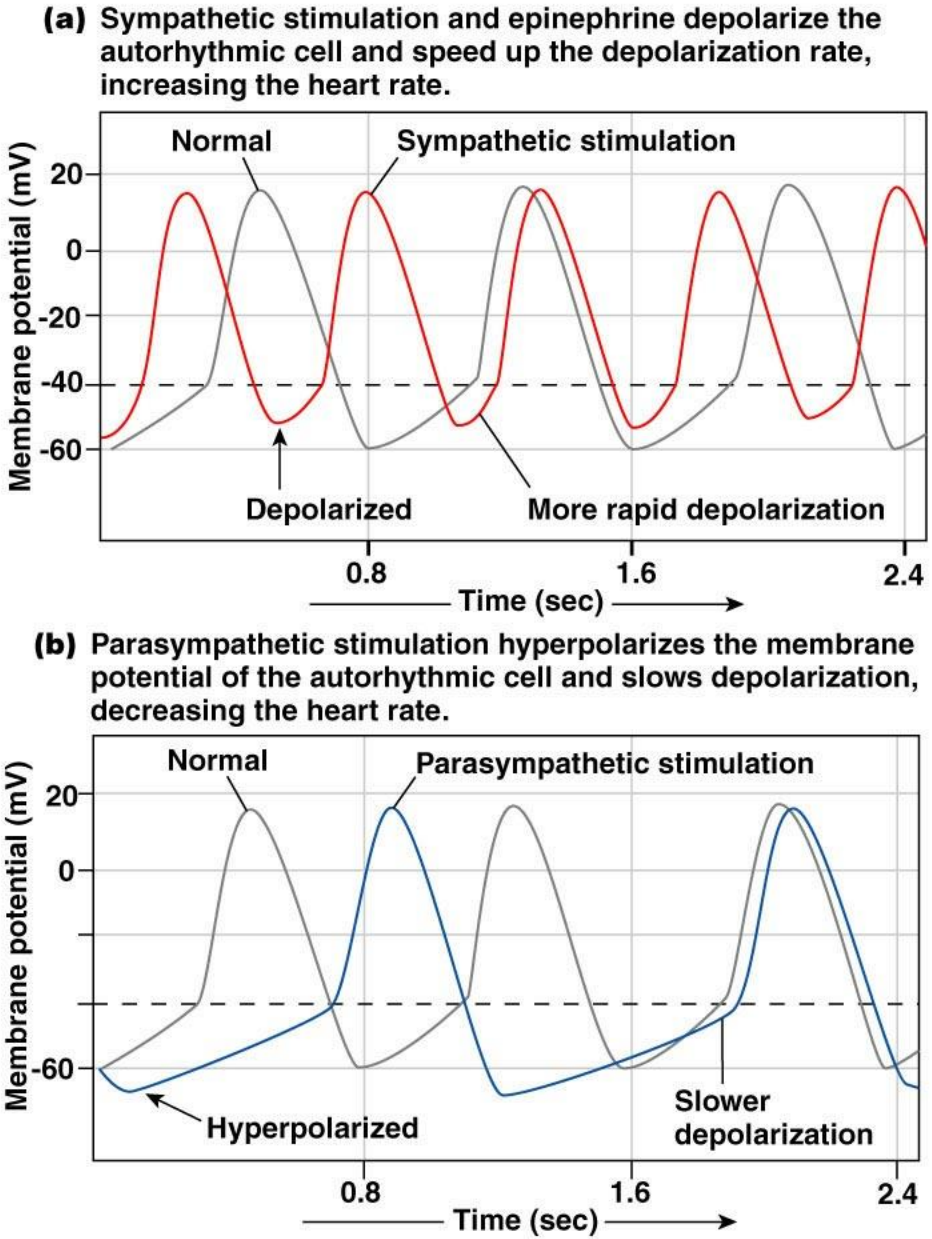
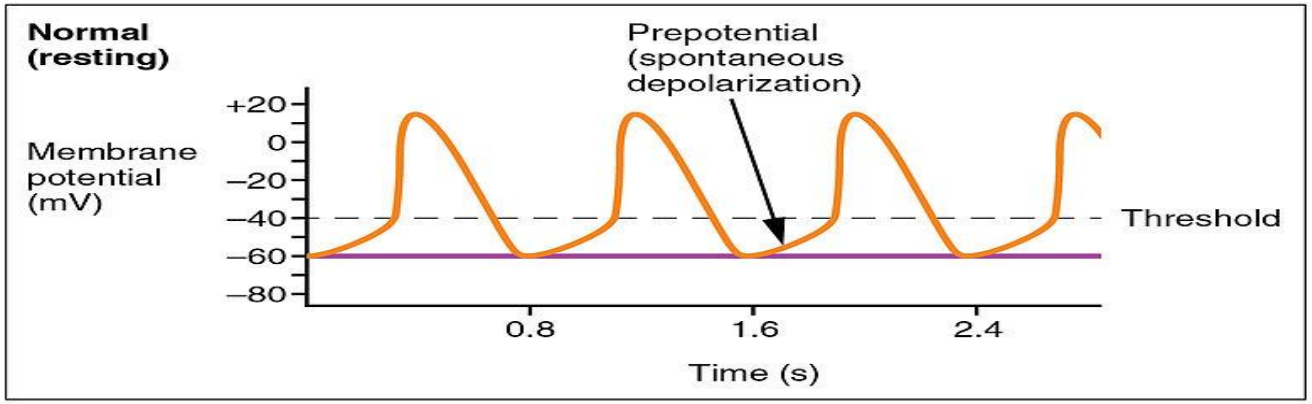
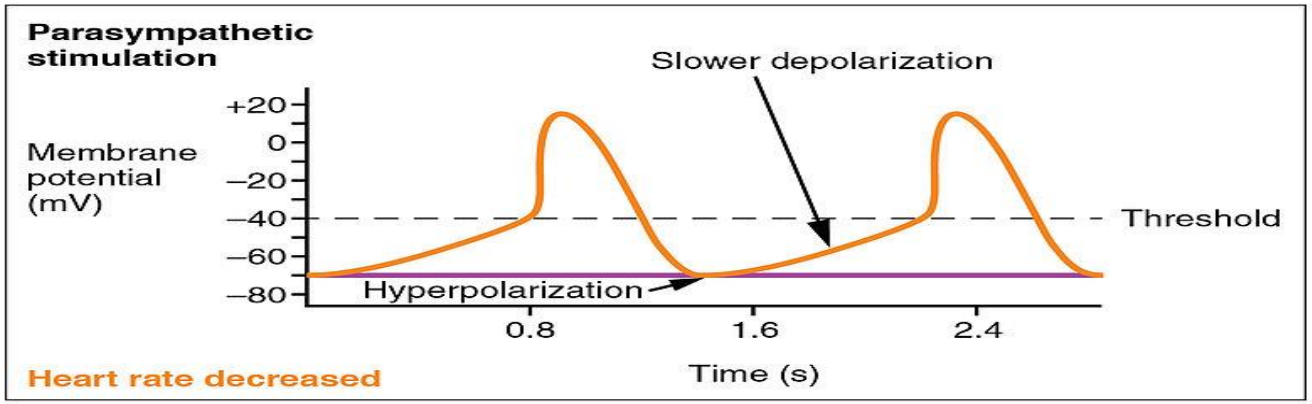
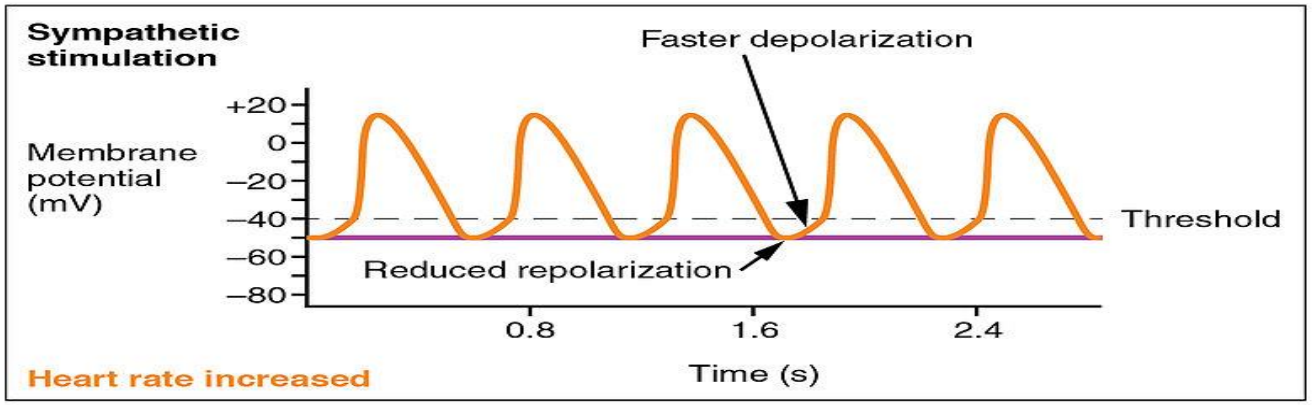


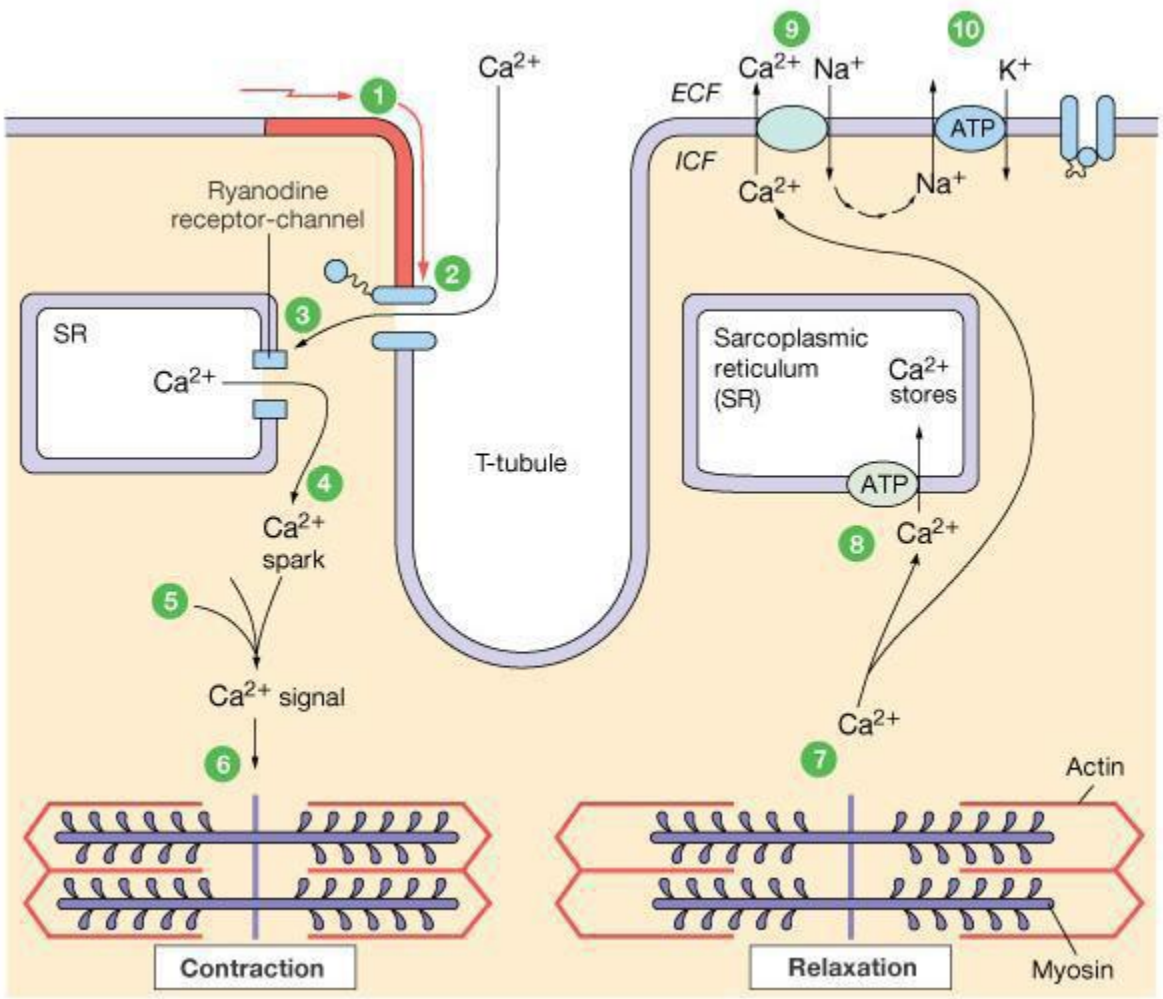
Figure 14-16 - Overview







Excitation-contraction coupling and relaxation in cardiac muscle



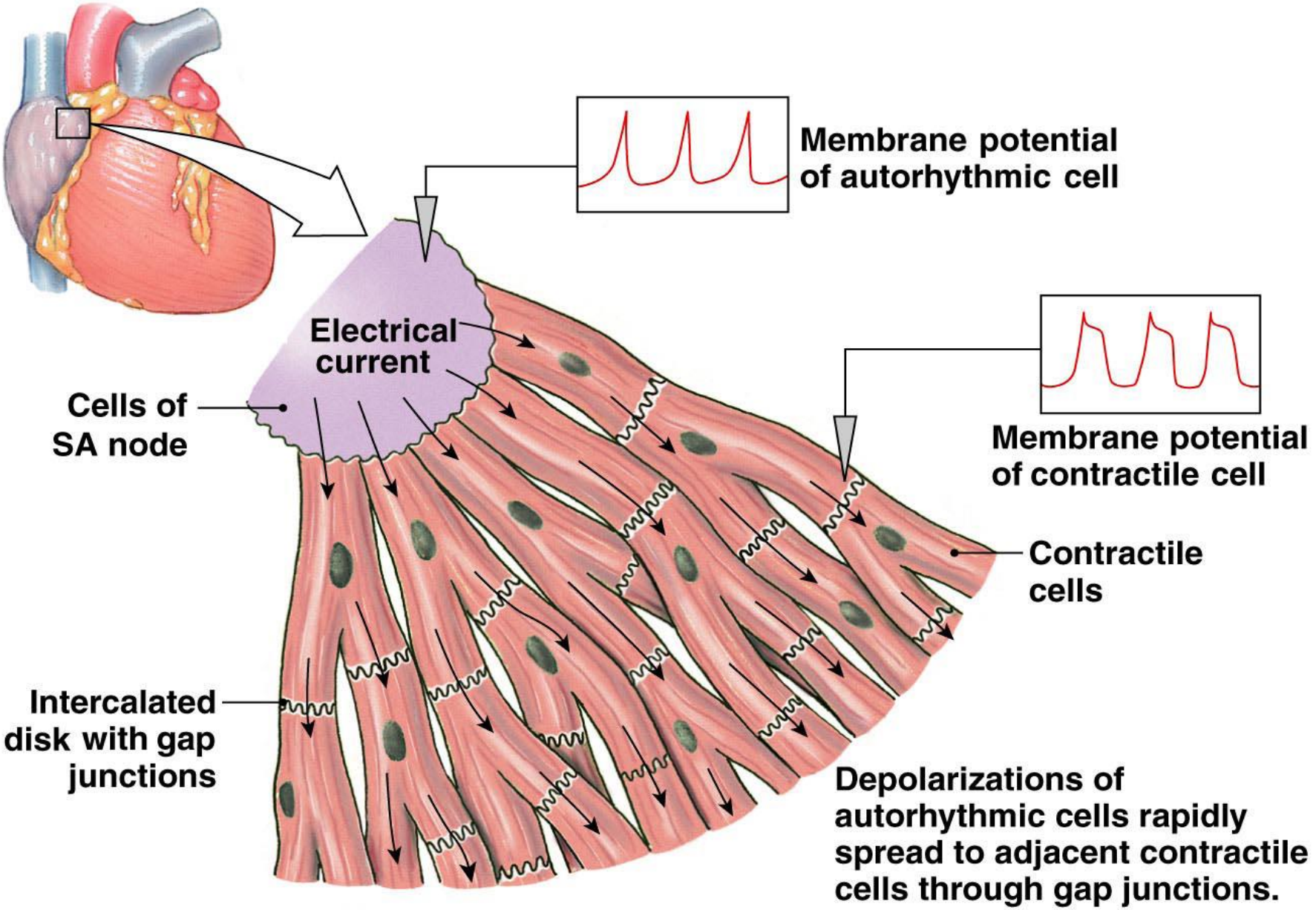
1. Action potential enters from adjacent cell.
2. Voltage-gated Ca^{2+} channels open. Ca^{2+} enters cell.
3. Ca^{2+} induces Ca^{2+} release through ryanodine receptor-channels (RyR).
4. Local release causes Ca^{2+} spark.
5. Summed Ca^{2+} sparks create a Ca^{2+} signal.
6. Ca^{2+} ions bind to troponin to initiate contraction.
7. Relaxation occurs when Ca^{2+} unbinds from troponin.
8. Ca^{2+} is pumped back into the sarcoplasmic reticulum for storage.
9. Ca^{2+} is exchanged with Na^{+}.
10. Na^{+} gradient is maintained by the Na^{+}-K^{+}-ATPase.

Heart Physiology: Sequence of Excitation

- Sinoatrial (SA) node generates impulses about 75 times/minute
- Atrioventricular (AV) node delays the impulse approximately 0.1 second
- Impulse passes from atria to ventricles via the atrioventricular bundle (bundle of His)

Heart Physiology: Sequence of Excitation

- AV bundle splits into two pathways in the interventricular septum (bundle branches)
  - Bundle branches carry the impulse toward the apex of the heart
- Purkinje fibers carry the impulse to the heart apex and ventricular walls
- Purkinje fibers are specialized conducting cells that transmit electrical signals very rapidly.
- The electrical signal for contraction begins when SA node fires an AP and depolarization spreads to adjacent cells through gap junction



Cardiac Intrinsic Conduction

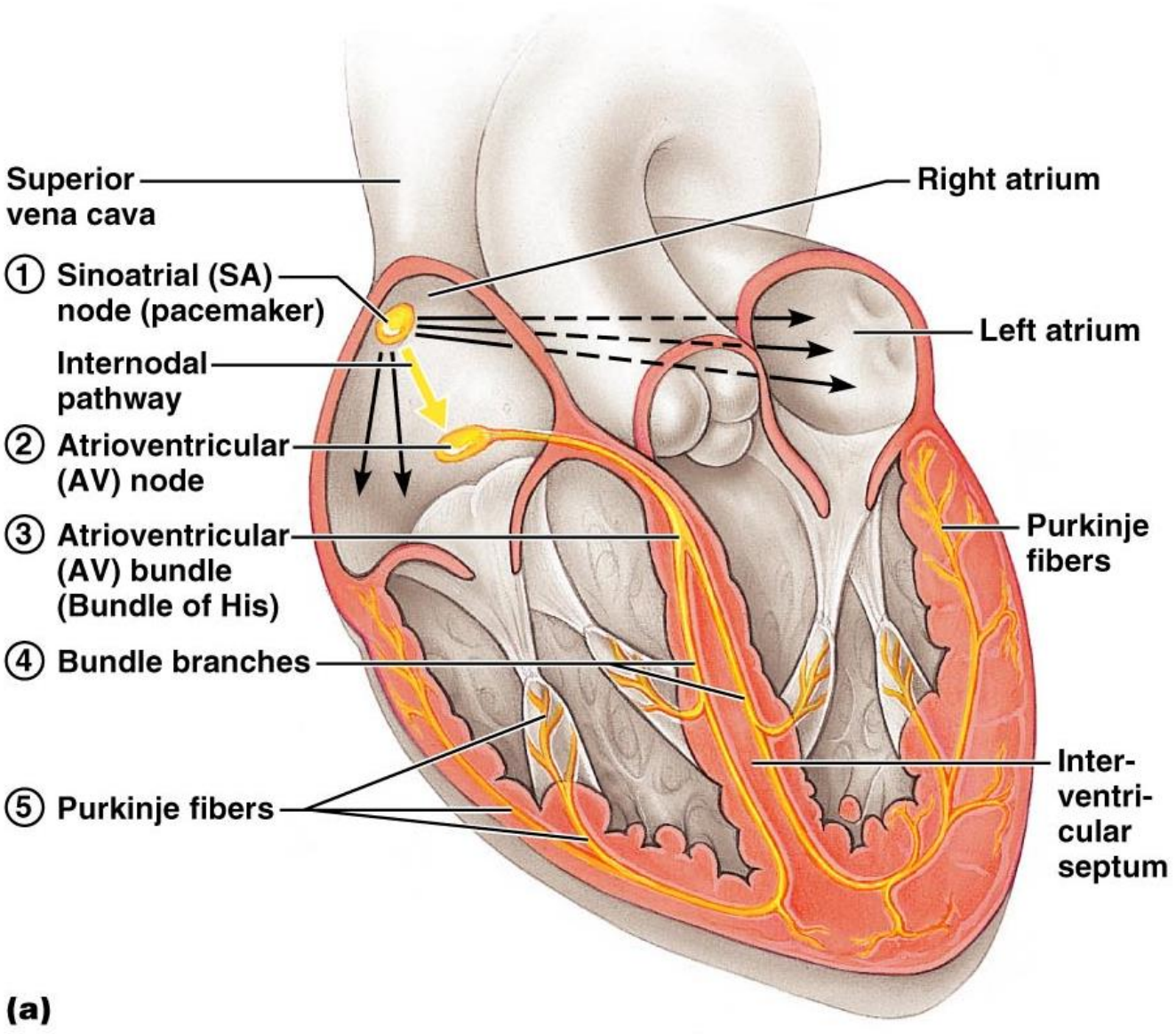


Figure 18.14a

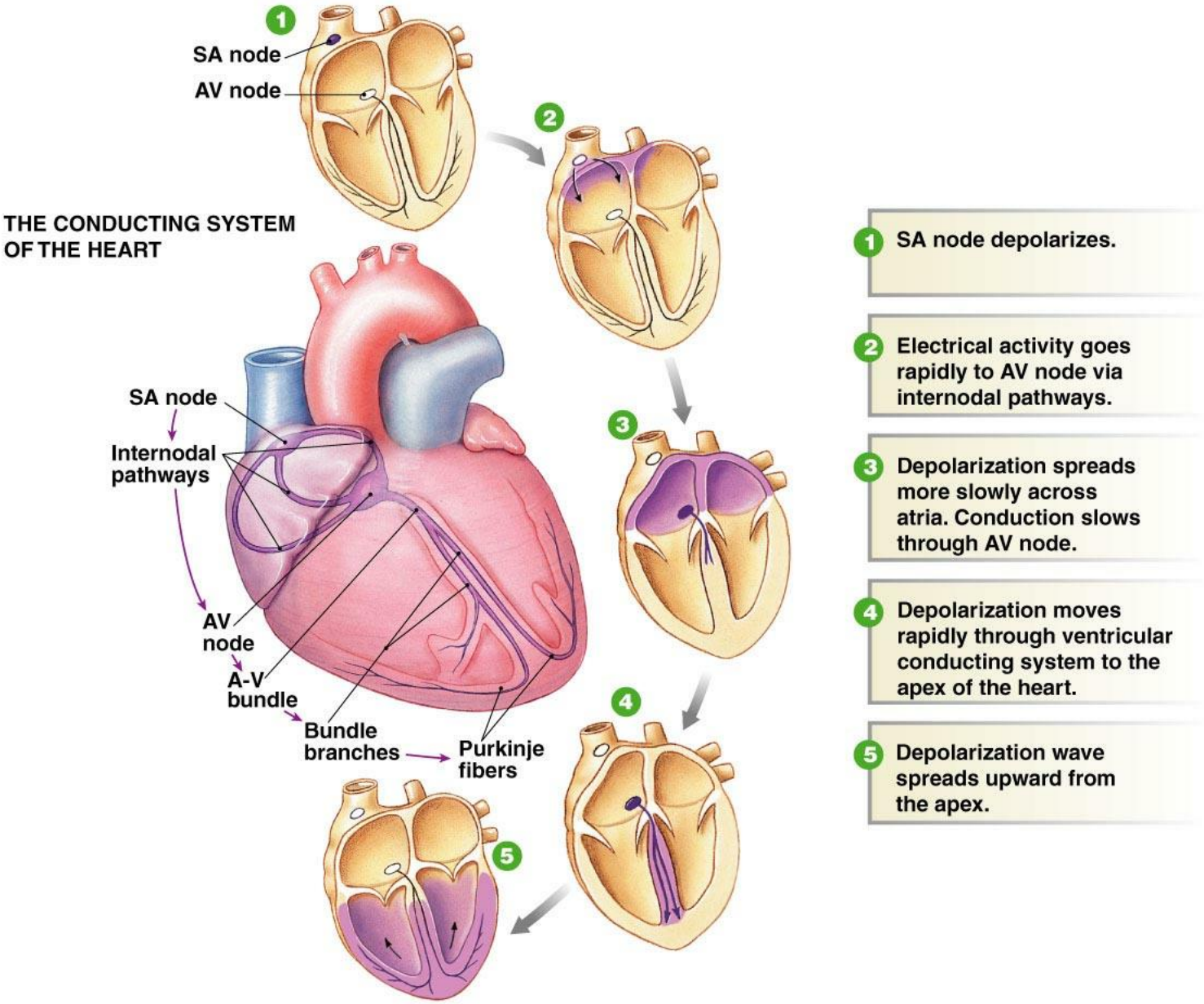


Figure 14-18

Electrocardiography

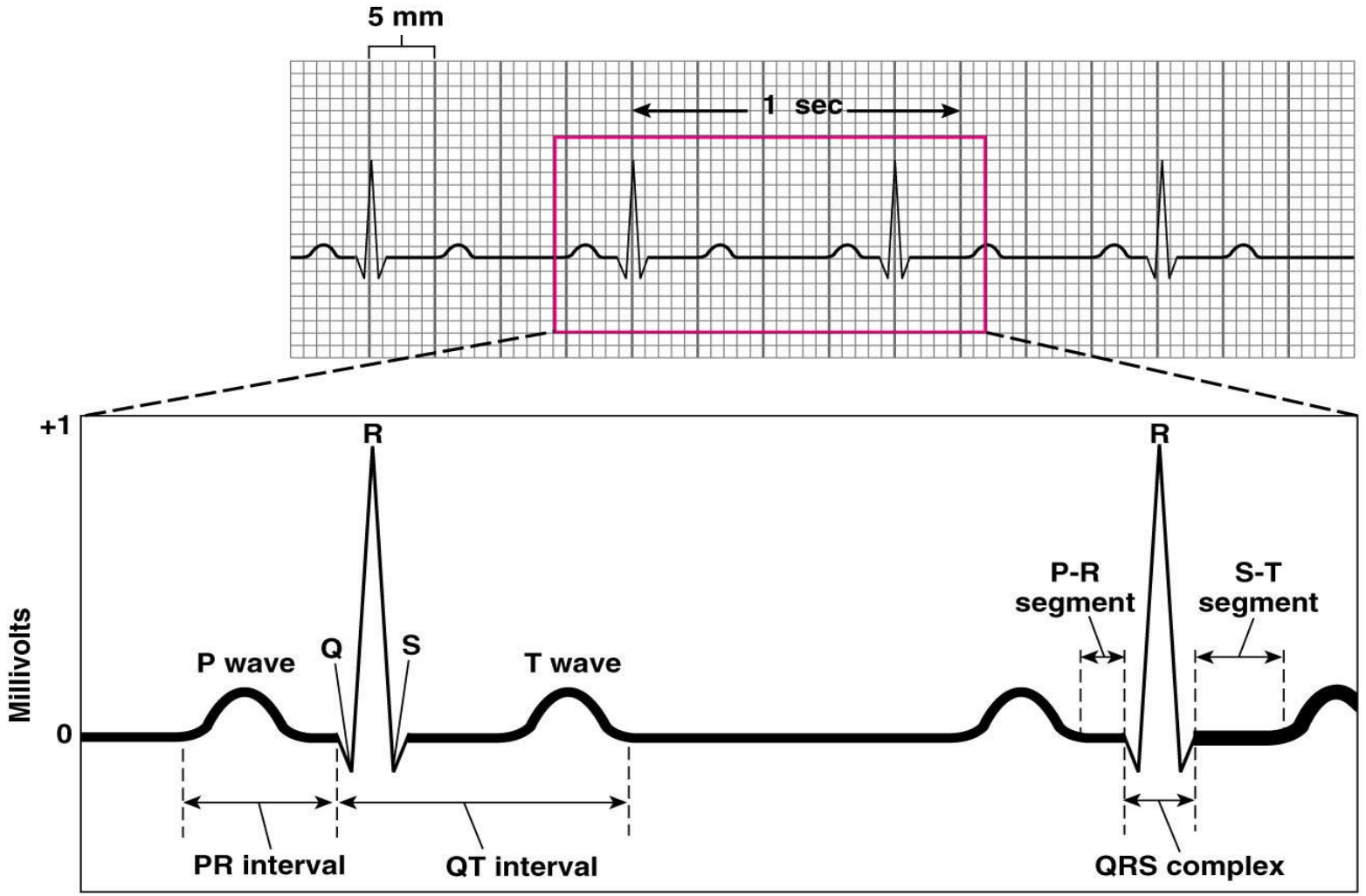


Figure 18.16

Heart Excitation Related to ECG

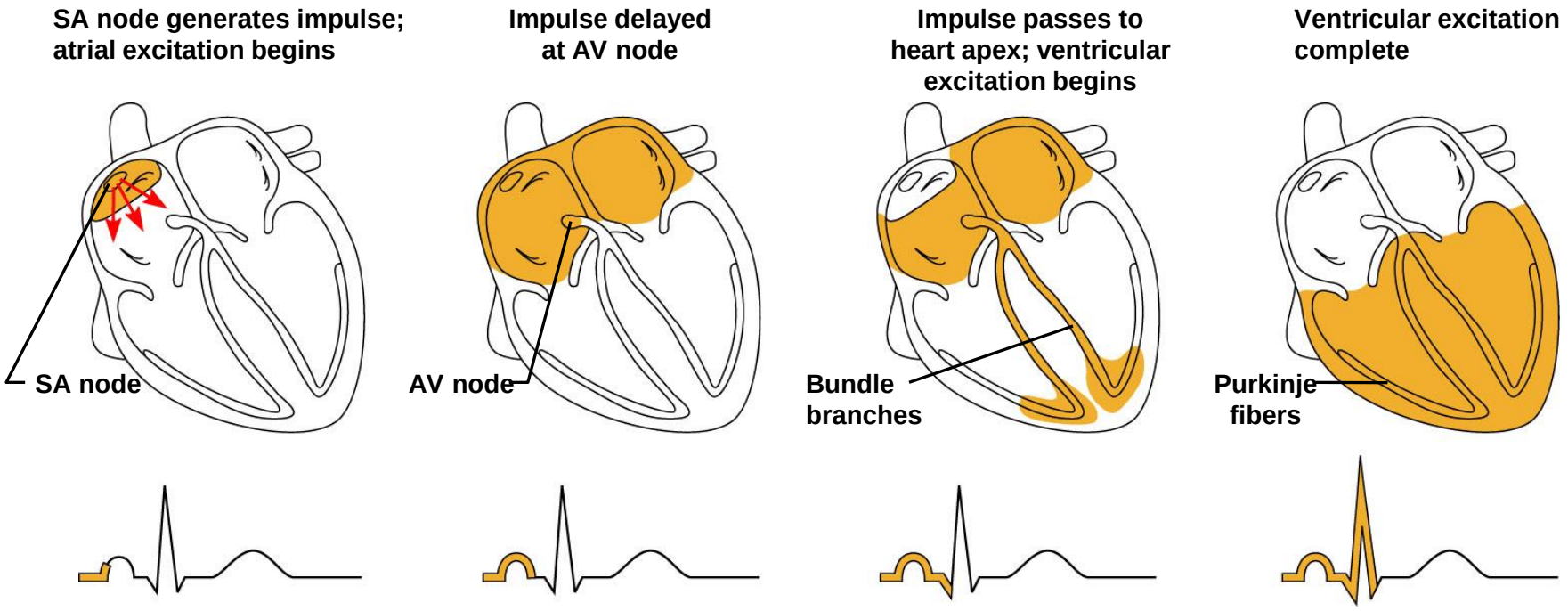
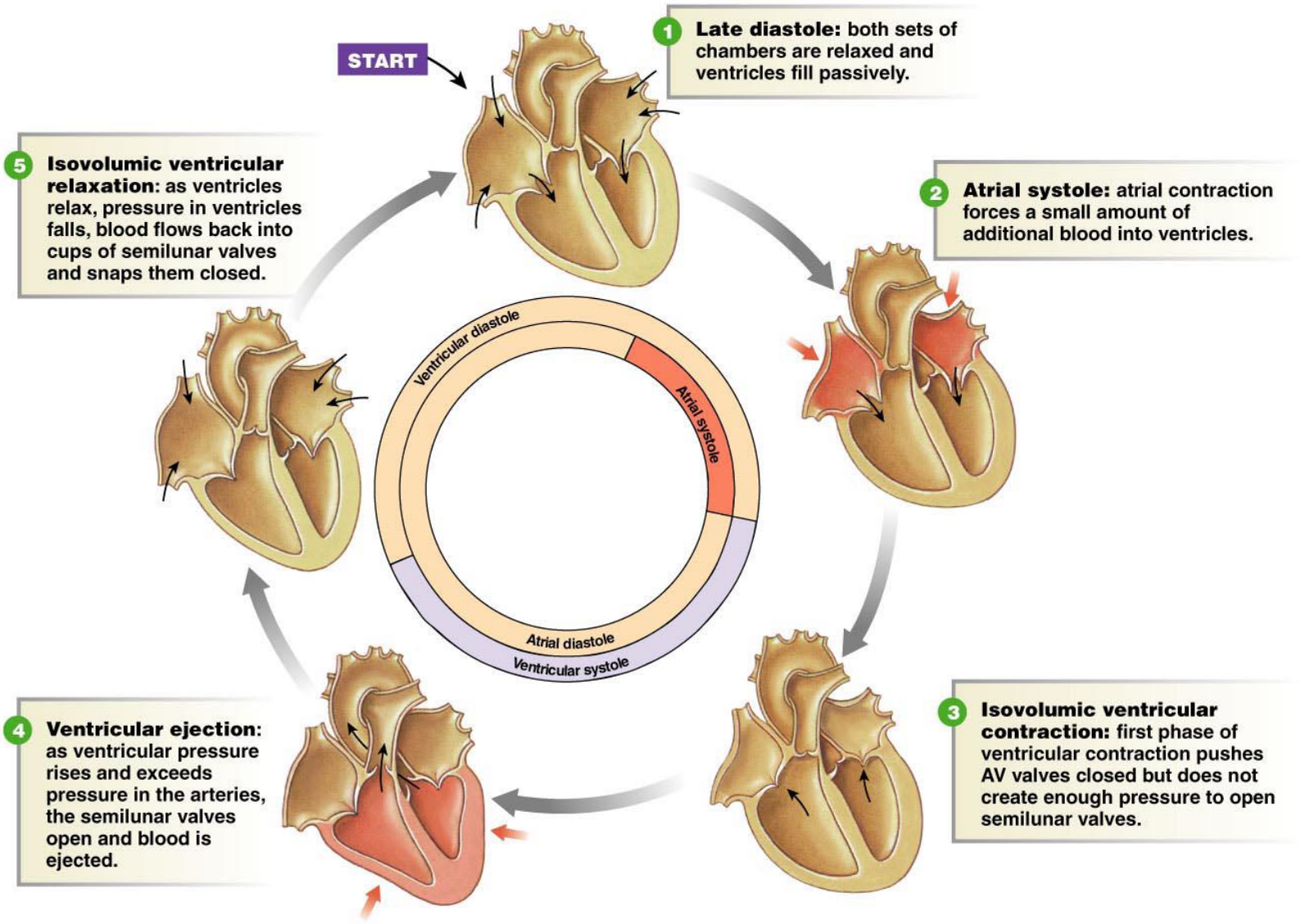


Figure 18.17

Electrocardiography

- Electrical activity is recorded by electrocardiogram (ECG)
- P wave corresponds to depolarization of SA node
- QRS complex corresponds to ventricular depolarization
- T wave corresponds to ventricular repolarization
- Atrial repolarization record is masked by the larger QRS complex

Cardiac Cycle



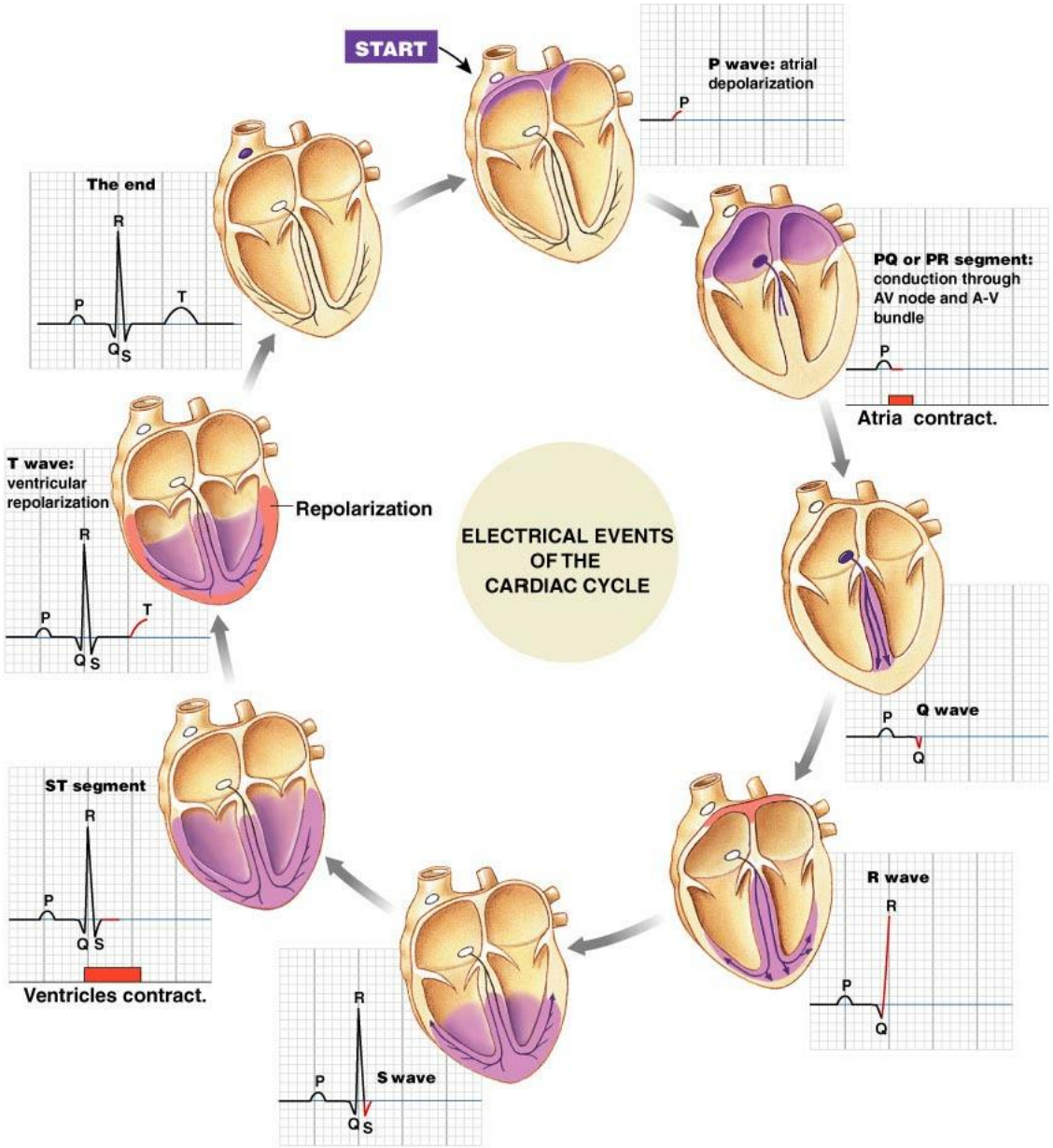


Figure 14-21 - Overview (1 of 9)

Cardiac Output (CO) and Reserve

- CO is the amount of blood pumped by each ventricle in one minute
- CO is the product of heart rate (HR) and stroke volume (SV)
- HR is the number of heart beats per minute
- SV is the amount of blood pumped out by a ventricle with each beat
- Cardiac reserve is the difference between resting and maximal CO

Cardiac Output:

- Resting HR for fetus (140-160 b/m)
- Male's HR(64-72 b/m)
- Female's HR (72-80 b/m)
- CO (ml/min) = HR (75 beats/min) x SV (70 ml/beat)
- CO = 5250 ml/min (5.25 L/min)

Heart Contractility and Norepinephrine

- Sympathetic stimulation releases norepinephrine and initiates a cyclic AMP second-messenger system

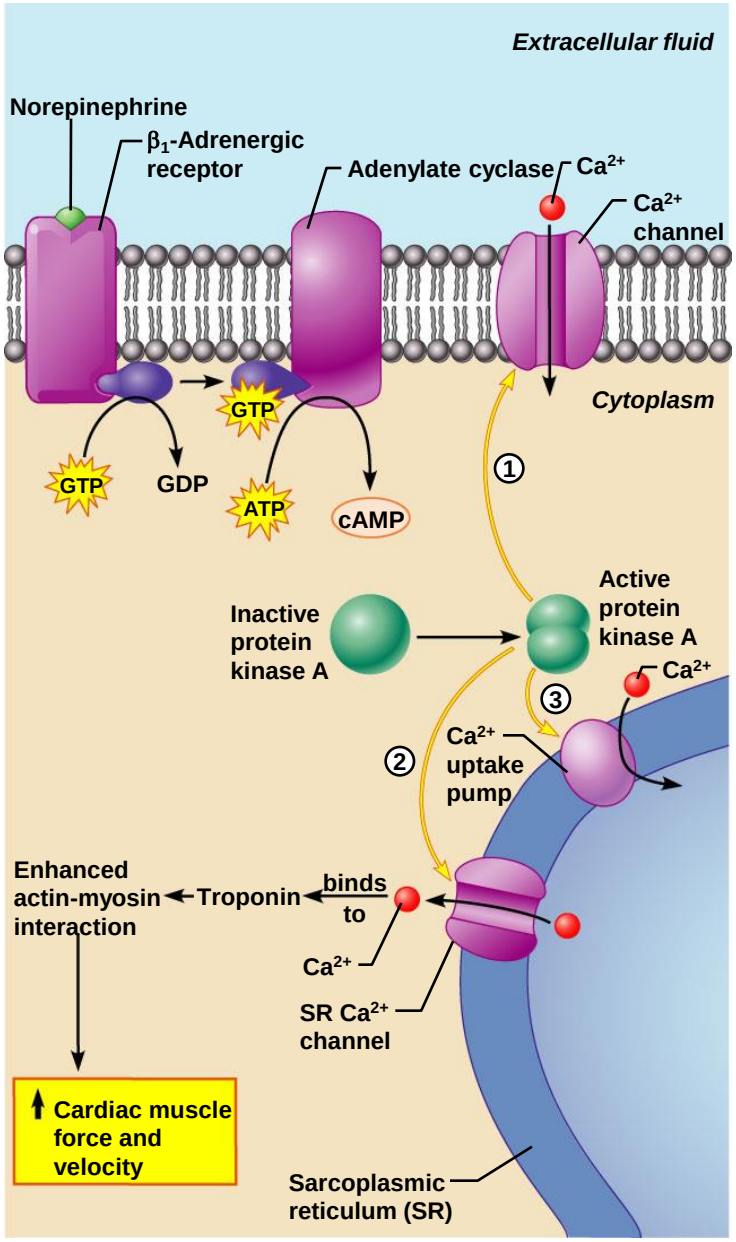


Figure 18.22

Regulation of Heart Rate: Autonomic Nervous System

- Sympathetic nervous system (SNS) stimulation is activated by stress, anxiety, excitement, or exercise
- Parasympathetic nervous system (PNS) stimulation is mediated by acetylcholine and opposes the SNS
- PNS dominates the autonomic stimulation, slowing heart rate and causing vagal tone

Chemical Regulation of the Heart

- The hormones epinephrine and thyroxine increase heart rate
- Intra- and extracellular ion concentrations must be maintained for normal heart function

Congestive Heart Failure (CHF)

- Congestive heart failure (CHF) is caused by:
- When the pumping efficiency of the heart is depressed so that circulation is inadequate to meet tissue needs, CHF occurs.
- Coronary atherosclerosis
- Persistent high blood pressure
- Multiple myocardial infarcts
- Dilated cardiomyopathy (DCM)

CHF

- If the left heart fails, pulmonary congestion occurs the right heart continues to propel blood to
- the lungs, but the left side is unable to eject the returning blood into the systemic circulation.
- As blood vessels within the lungs becomes swollen with blood, the pressure within them increase,
- and fluid leaks from the circulation into the lungs, causing Pulmonary edema. If untreated the
- person suffocates.
- If the right side of the heart fails, peripheral congestion occurs as blood backs up in the
- systemic circulation. Edema occur in the feet, ankle, and fingers become swollen and puffy.

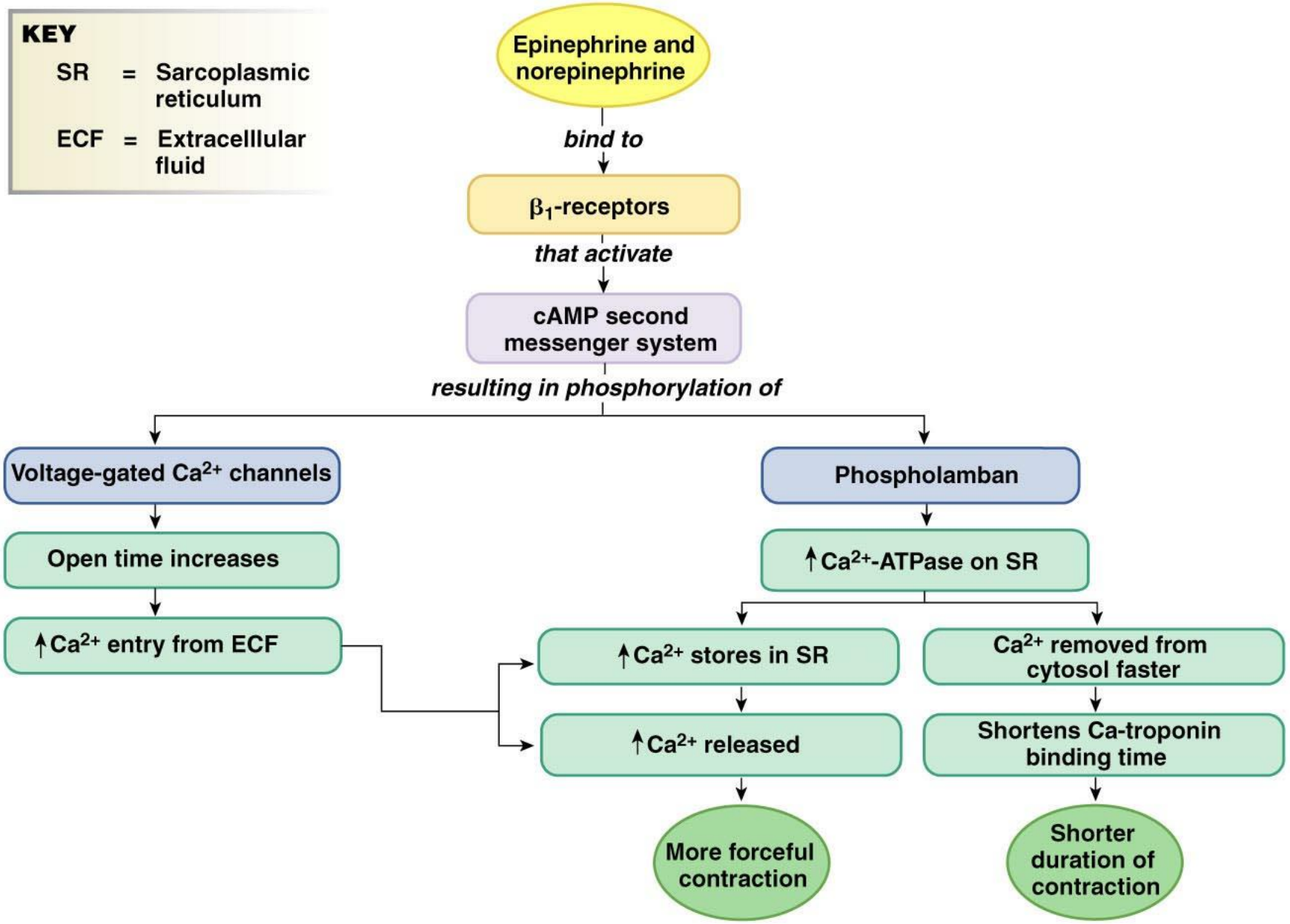


Figure 14-30

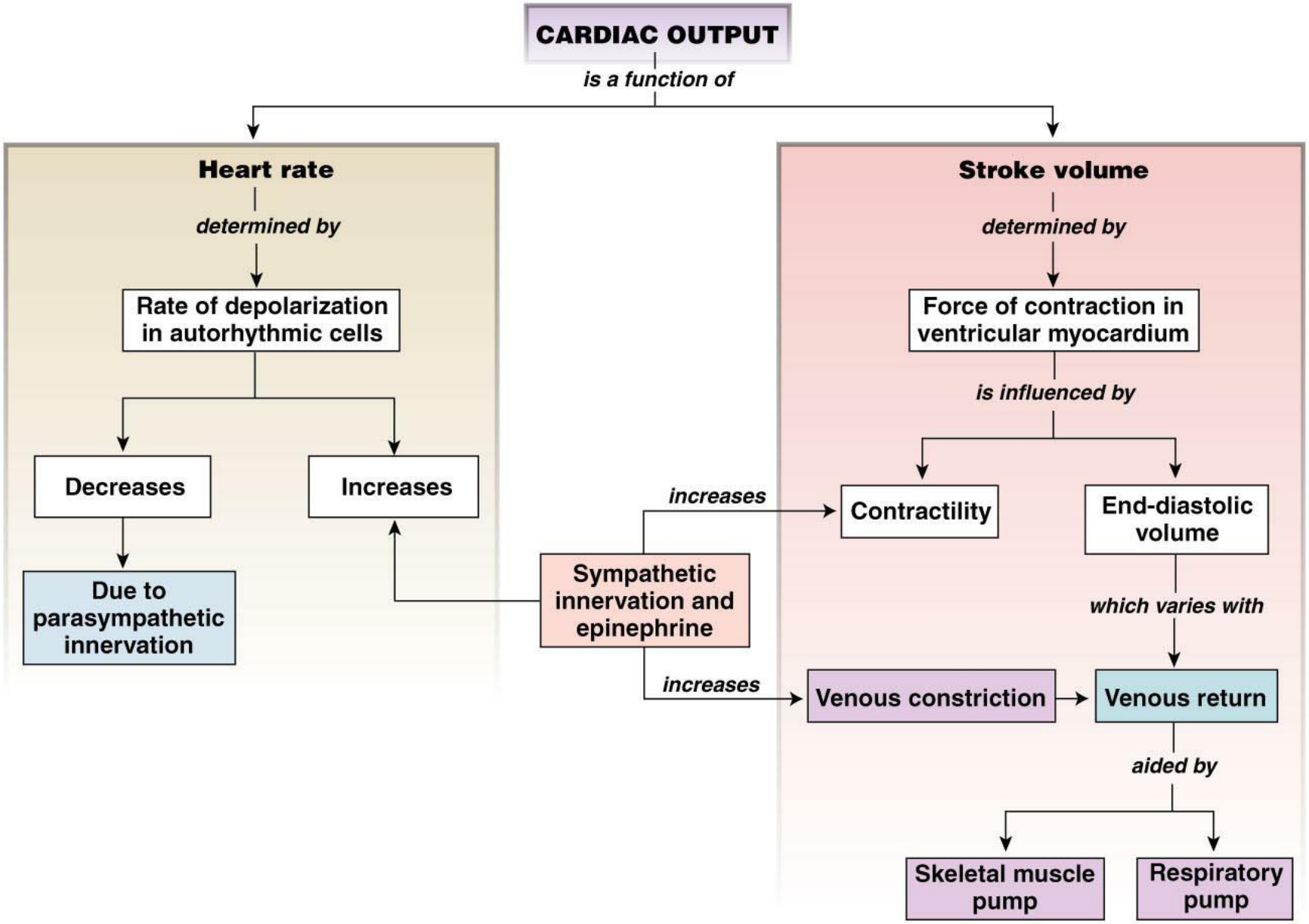


Figure 14-31