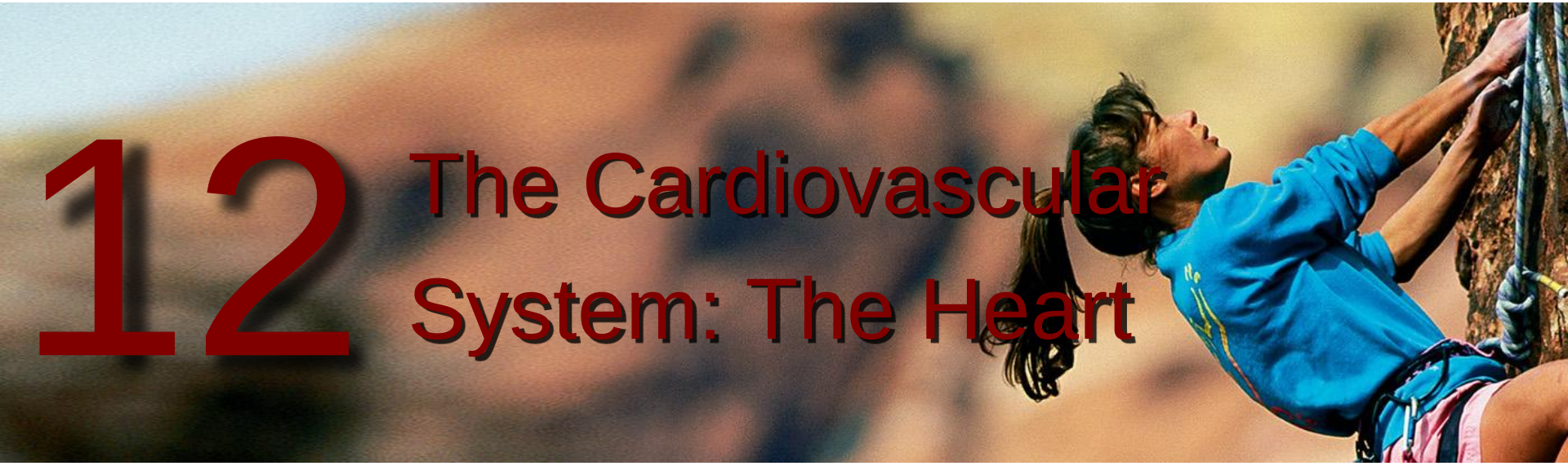
Essentials of Anatomy & Physiology, **4th Edition**

Martini / Bartholomew



12 The Cardiovascular System: The Heart

PowerPoint® Lecture Outlines
prepared by Alan Magid, Duke University

Slides 1 to 65

Heart's Place in the Circulation

Heart Pumps Blood into Two Circuits in Sequence

- *Pulmonary* circuit
  - To and from the lungs
- *Systemic* circuit
  - To and from the rest of the body

Heart's Place in the Circulation

Three Kinds of Blood Vessels

- *Arteries*
  - Carry blood *away* from heart and carry it to the capillaries
- *Capillaries*
  - Microscopic vessels where exchange between cells and blood takes place
- *Veins*
  - Receive blood from capillaries and carry it *back* to the heart

Heart's Place in the Circulation

Two Sets of Pumping Chambers in Heart

- Right *atrium*
  - Receives systemic blood
- Right *ventricle*
  - Pumps blood to lungs (pulmonary)
- Left *atrium*
  - Receives blood from lungs
- Left *ventricle*
  - Pumps blood to organ systems (systemic)

Heart's Place in the Circulation

Overview of the Cardiovascular System

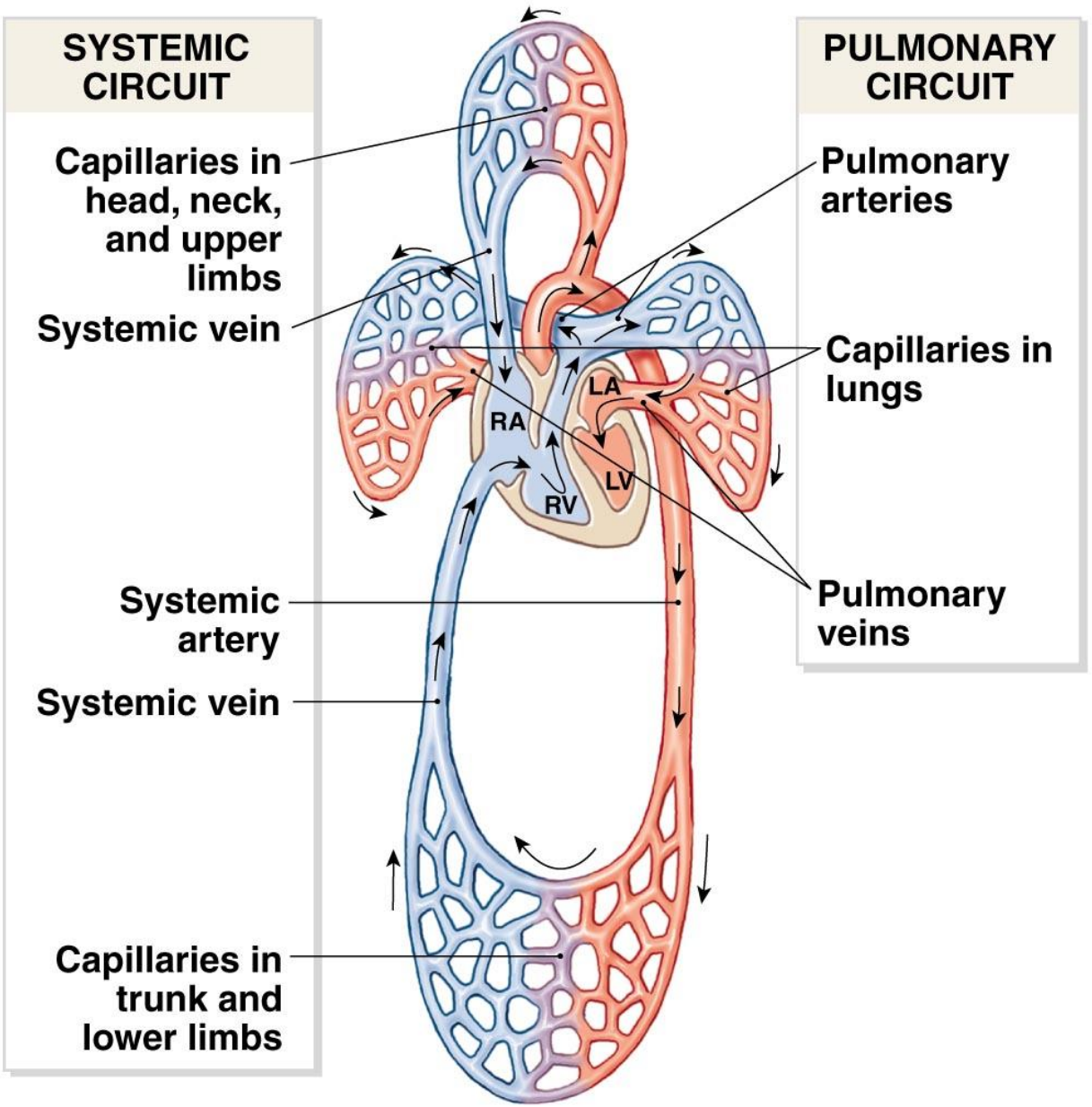


Figure 12-1

The Anatomy of the Heart

Pericardial Cavity

- Surrounds the heart
- Lined by *pericardium*
  - Two layers
  - *Visceral pericardium* (*epicardium*)
    - Covers heart surface
  - *Parietal pericardium*
    - Lines *pericardial sac* that surrounds heart

The Anatomy of the Heart

The Location of the Heart in the Thoracic Cavity

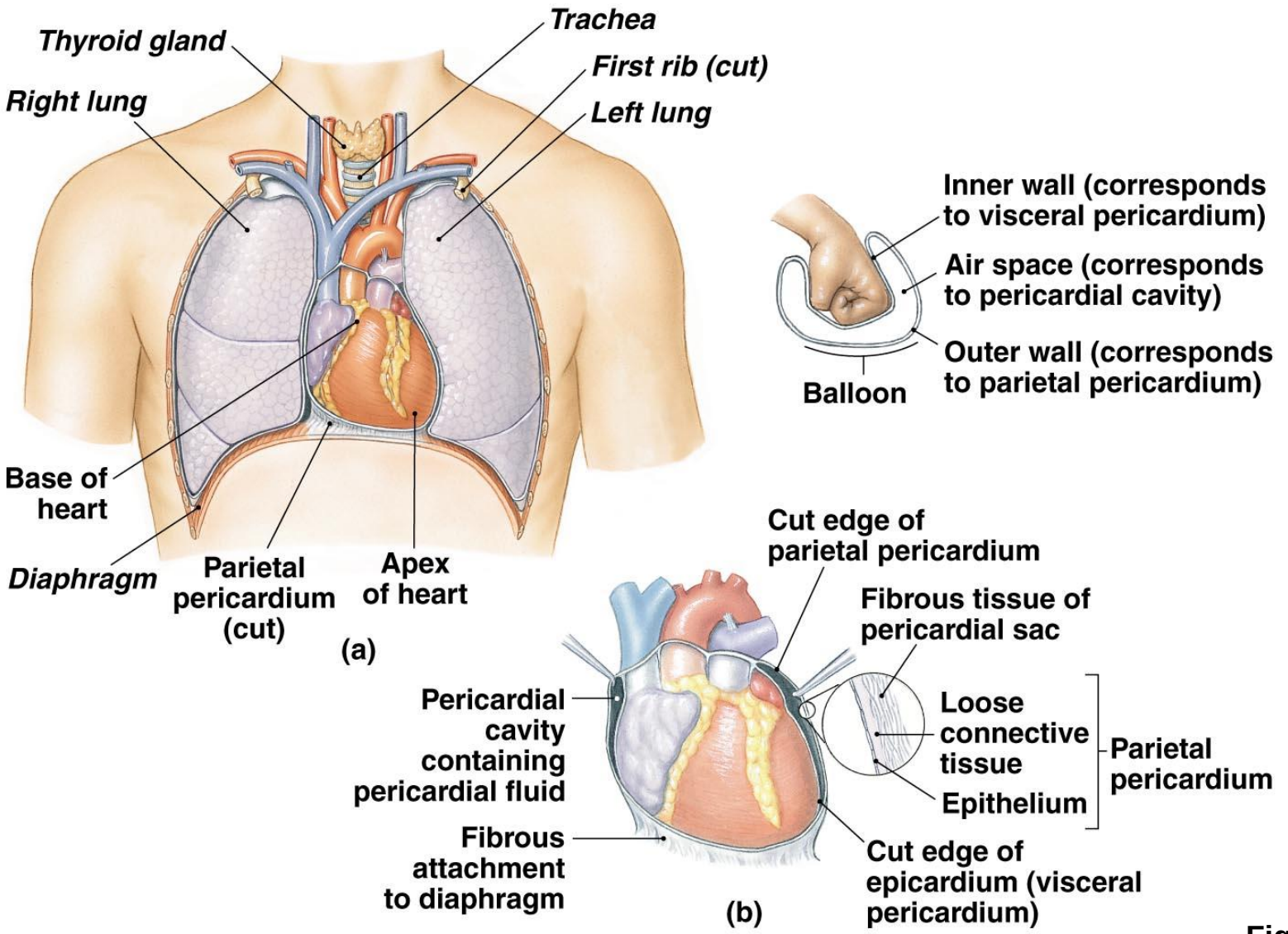


Figure 12-2

The Anatomy of the Heart

Surface Features of the Heart

- *Auricle*—Outer portion of atrium
- *Coronary sulcus*—Deep groove that marks boundary of atria and ventricles
- *Anterior interventricular sulcus*
- *Posterior interventricular sulcus*
  - Mark boundary between left and right ventricles
  - *Sulci* contain major cardiac blood vessels
  - Filled with protective fat

The Anatomy of the Heart

The Surface Anatomy of the Heart

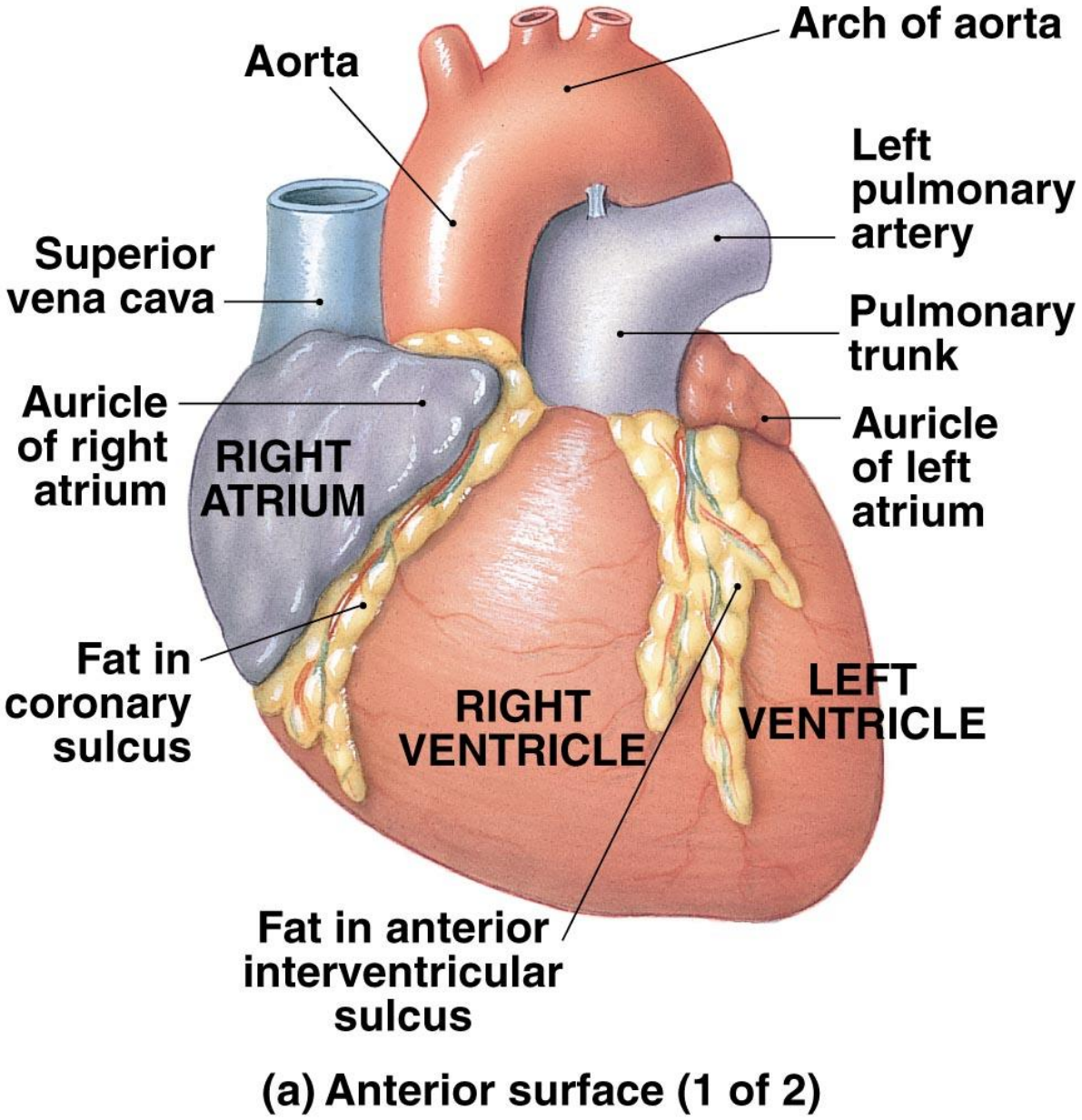


Figure 12-3(a)
1 of 2

The Anatomy of the Heart

The Surface Anatomy of the Heart

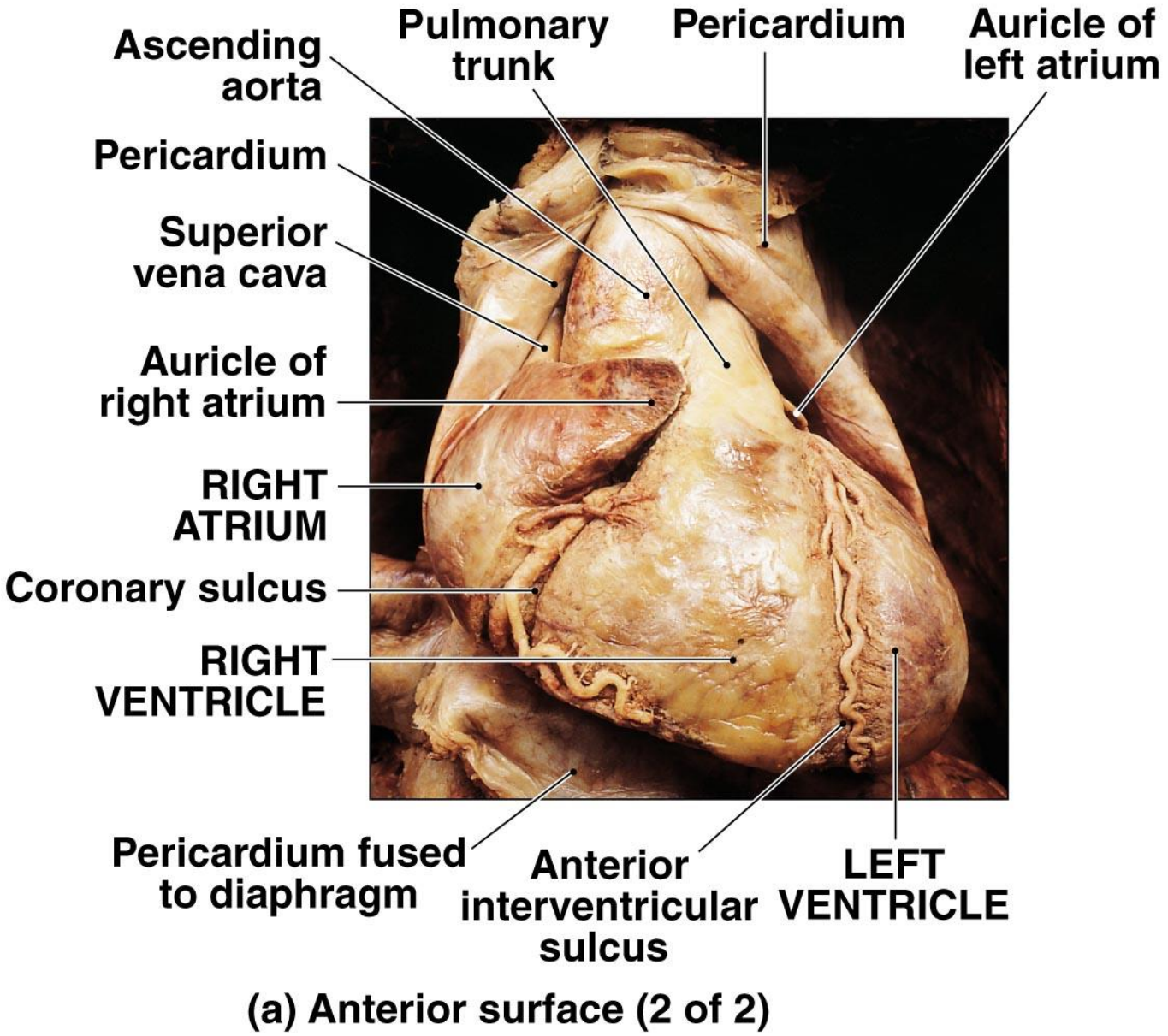


Figure 12-3(a) 2 of 2

The Anatomy of the Heart

The Surface Anatomy of the Heart

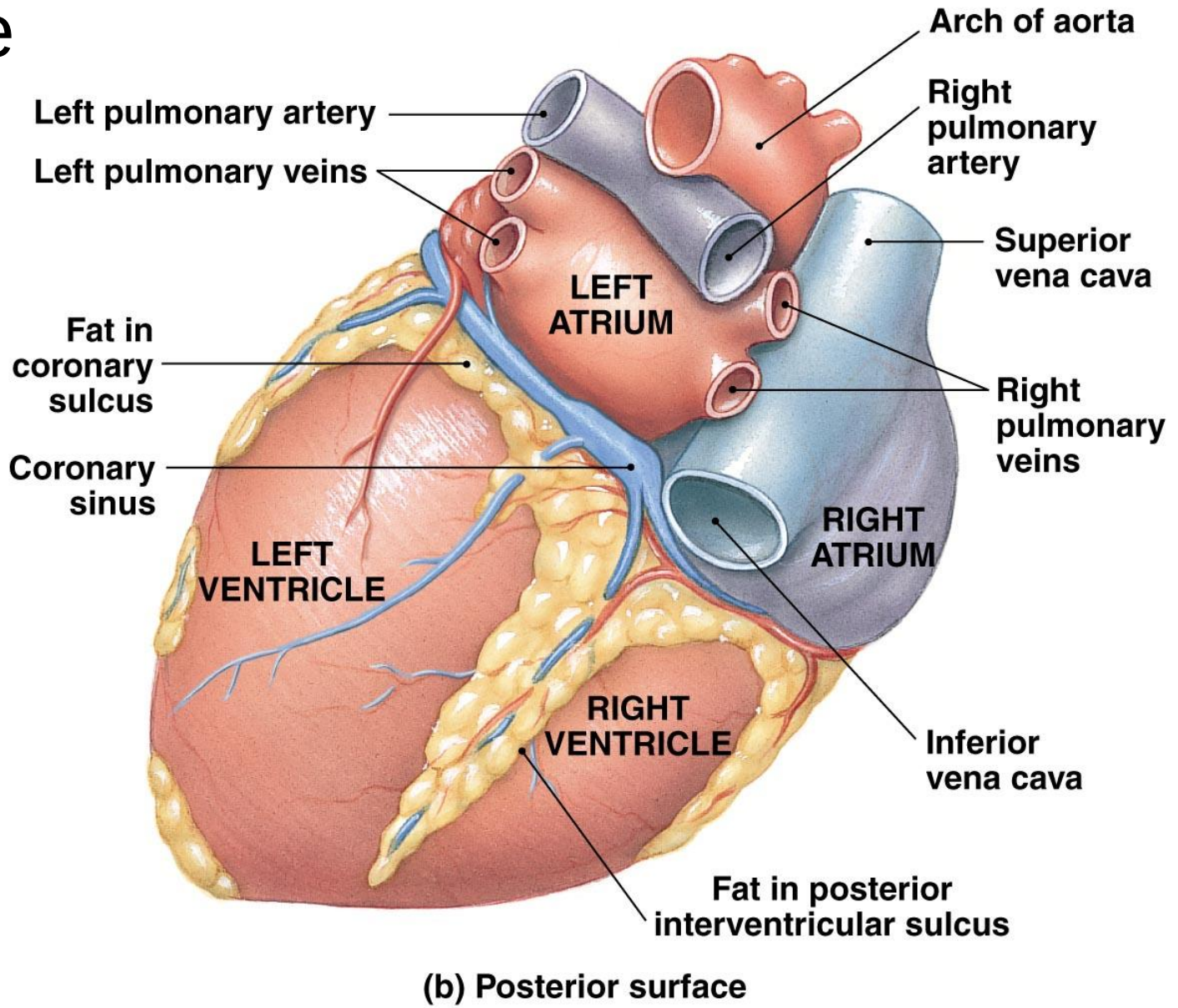


Figure 12-3(b)

The Anatomy of the Heart

The Heart Wall

- *Epicardium* (*visceral pericardium*)
  - Outermost layer
  - *Serous membrane*
- *Myocardium*
  - Middle layer
  - Thick muscle layer
- *Endocardium*
  - Inner lining of pumping chambers
  - Continuous with *endothelium*

The Anatomy of the Heart

The Heart Wall and Cardiac Muscle Tissue

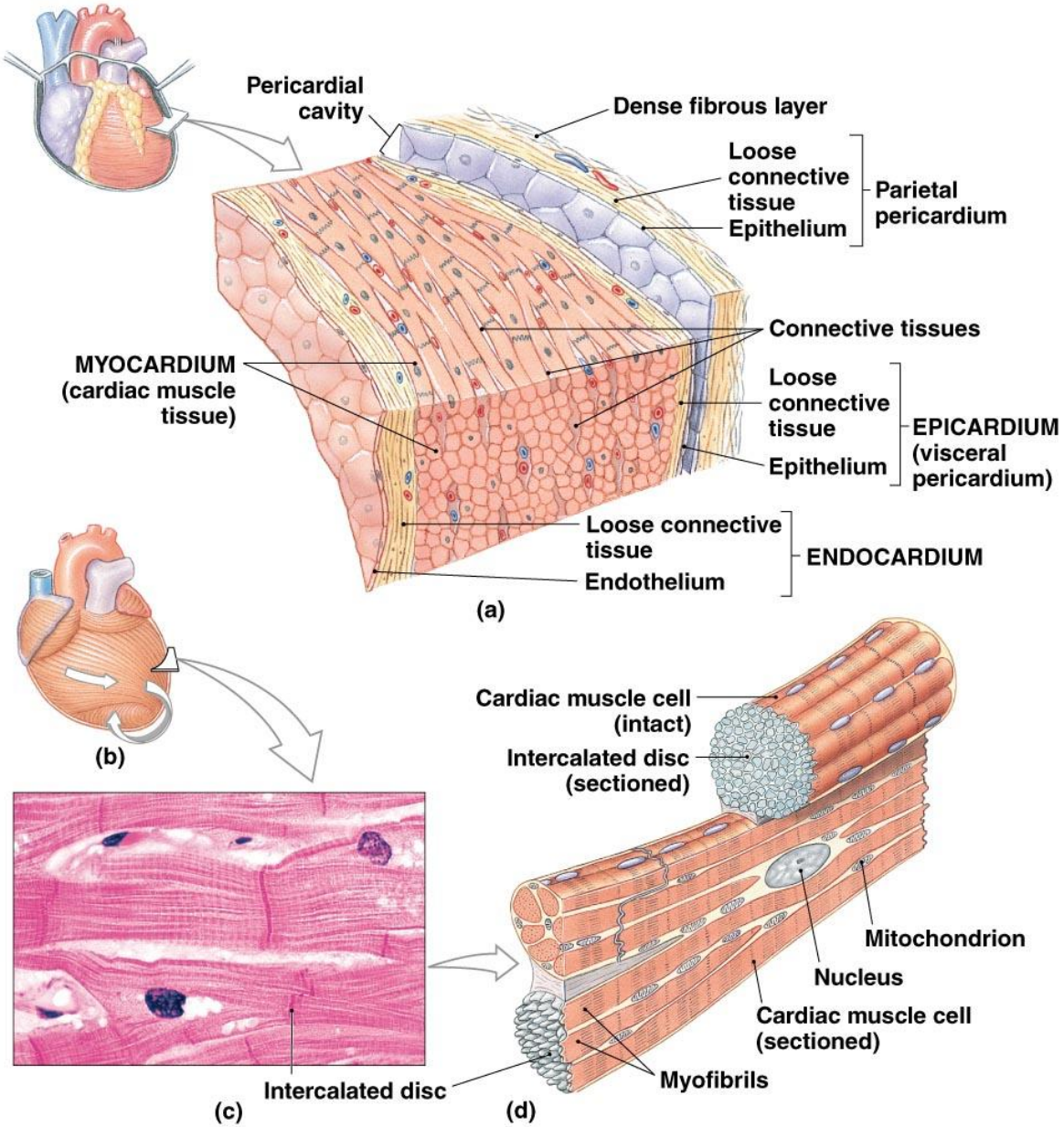


Figure 12-4

The Anatomy of the Heart

The Heart Wall and Cardiac Muscle Tissue

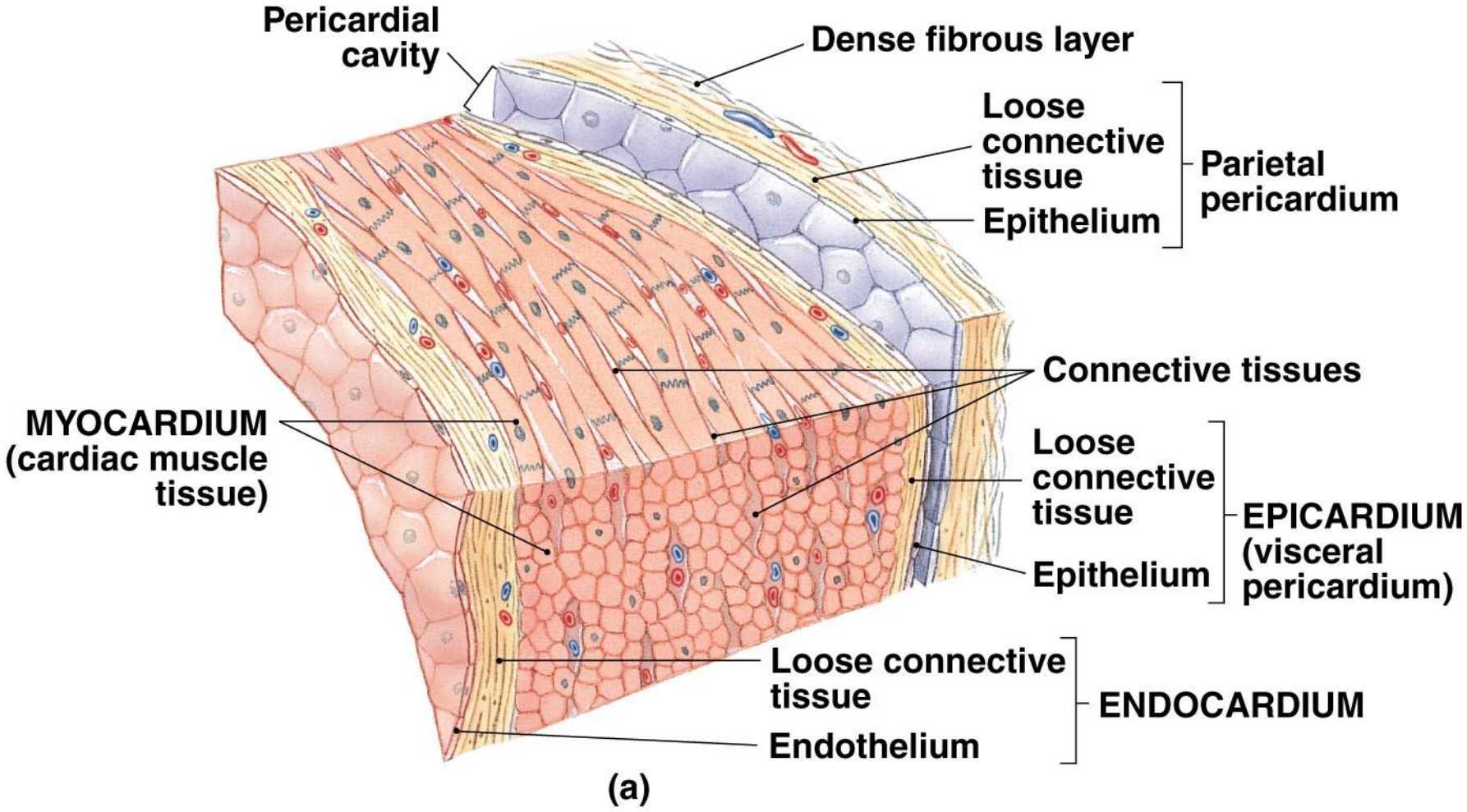


Figure 12-4(a)

The Anatomy of the Heart

The Heart Wall and Cardiac Muscle Tissue

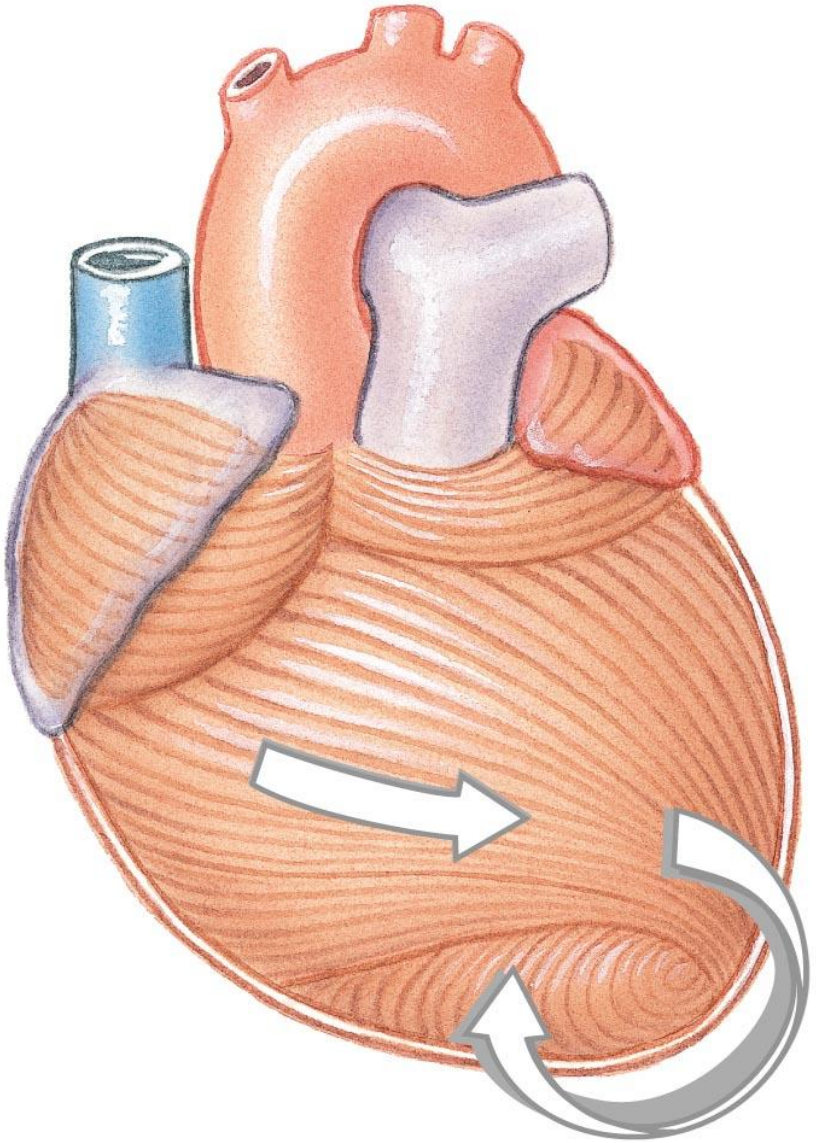
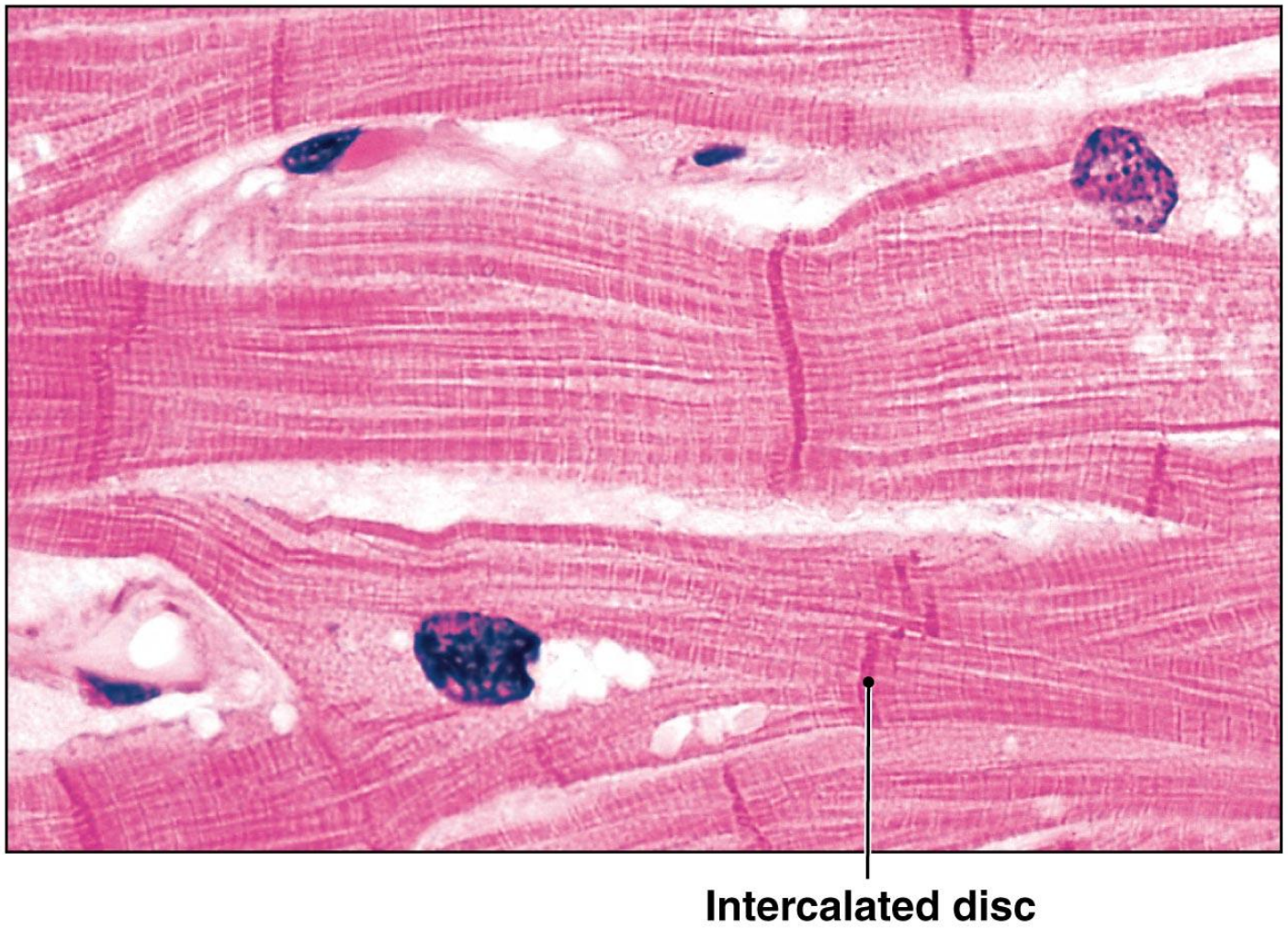


Figure 12-4(b)

(b)

The Anatomy of the Heart

The Heart Wall and Cardiac Muscle Tissue



(c)

Figure 12-4(c)

The Anatomy of the Heart

The Heart Wall and Cardiac Muscle Tissue

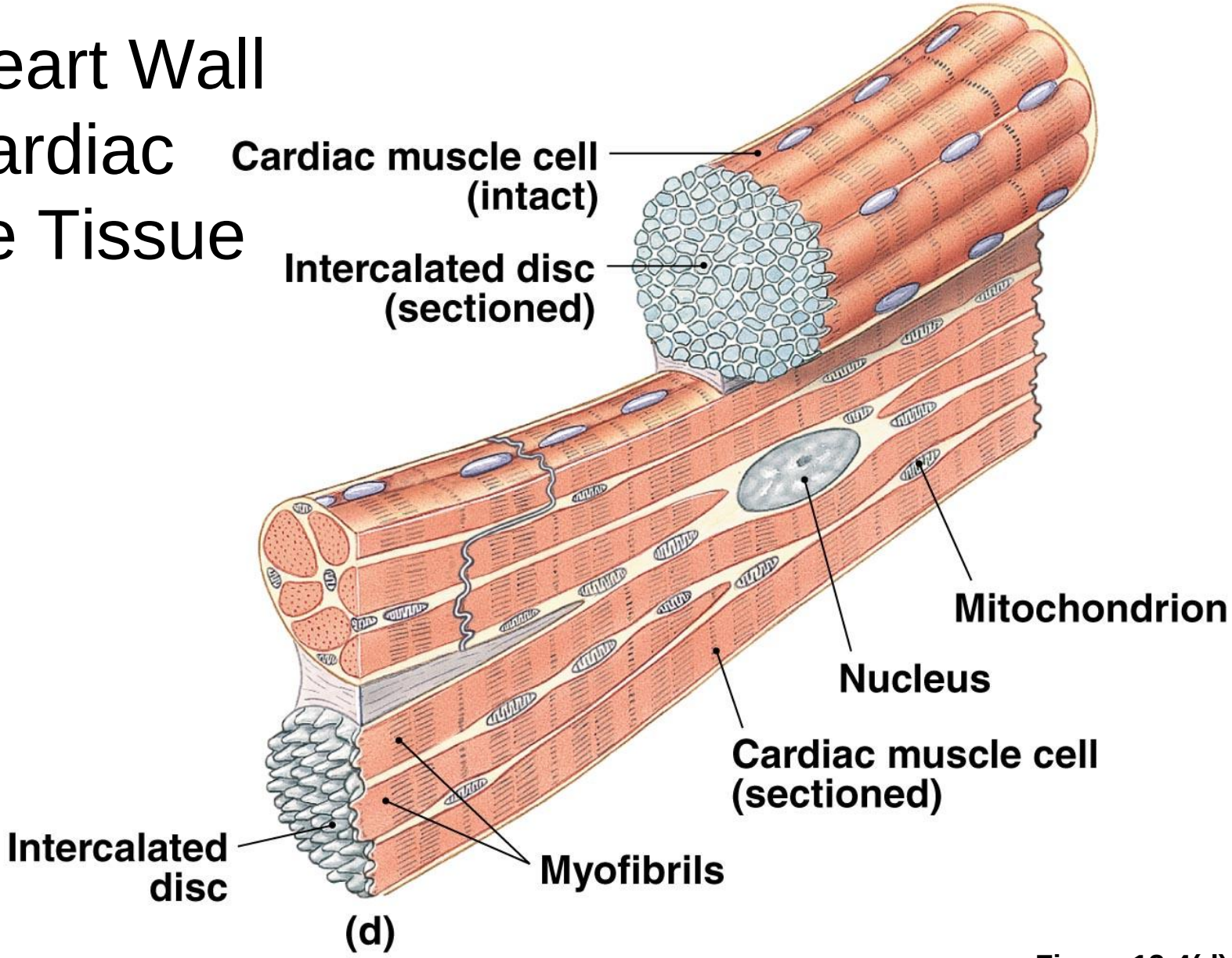


Figure 12-4(d)

The Anatomy of the Heart

Cardiac Muscle Cells

- Shorter than skeletal muscle fibers
- Have single nucleus
- Have striations (sarcomere organization)
- Depend on aerobic metabolism
- Connected by *intercalated discs*
  - *Desmosomes* transmit tension
  - *Gap junctions* transmit action potential

The Anatomy of the Heart

Internal Anatomy and Organization

- *Interatrial septum*
  - Separates atria
- *Interventricular septum*
  - Separates ventricles
- *Atrioventricular valves*
  - Located between atrium and ventricle
  - Ensure one-way flow from atrium to ventricle

The Anatomy of the Heart

Blood Flow in the Heart

- *Superior* and *inferior venae cavae*
  - Large veins carry systemic blood to right atrium
- Right atrium sends blood to right ventricle
  - Flows through right AV valve
    - Bounded by three *cusps* (*tricuspid* valve)
    - Cusps anchored by *chordae tendinae*
    - Chordae attached to *papillary muscles*

The Anatomy of the Heart

Blood Flow in the Heart (cont'd)

- Right ventricle pumps blood through *pulmonary semilunar valve*
  - Enters *pulmonary trunk*
  - Flows to lungs through right, left pulmonary arteries where it picks up oxygen
- Pulmonary veins carry blood to left atrium
- Left atrium sends blood to left ventricle
  - Enters through left AV valve (*bicuspid* or *mitral*)
- Left ventricle pumps blood to aorta
  - Through aortic semilunar valve to systems

The Anatomy of the Heart

The Sectional Anatomy of the Heart

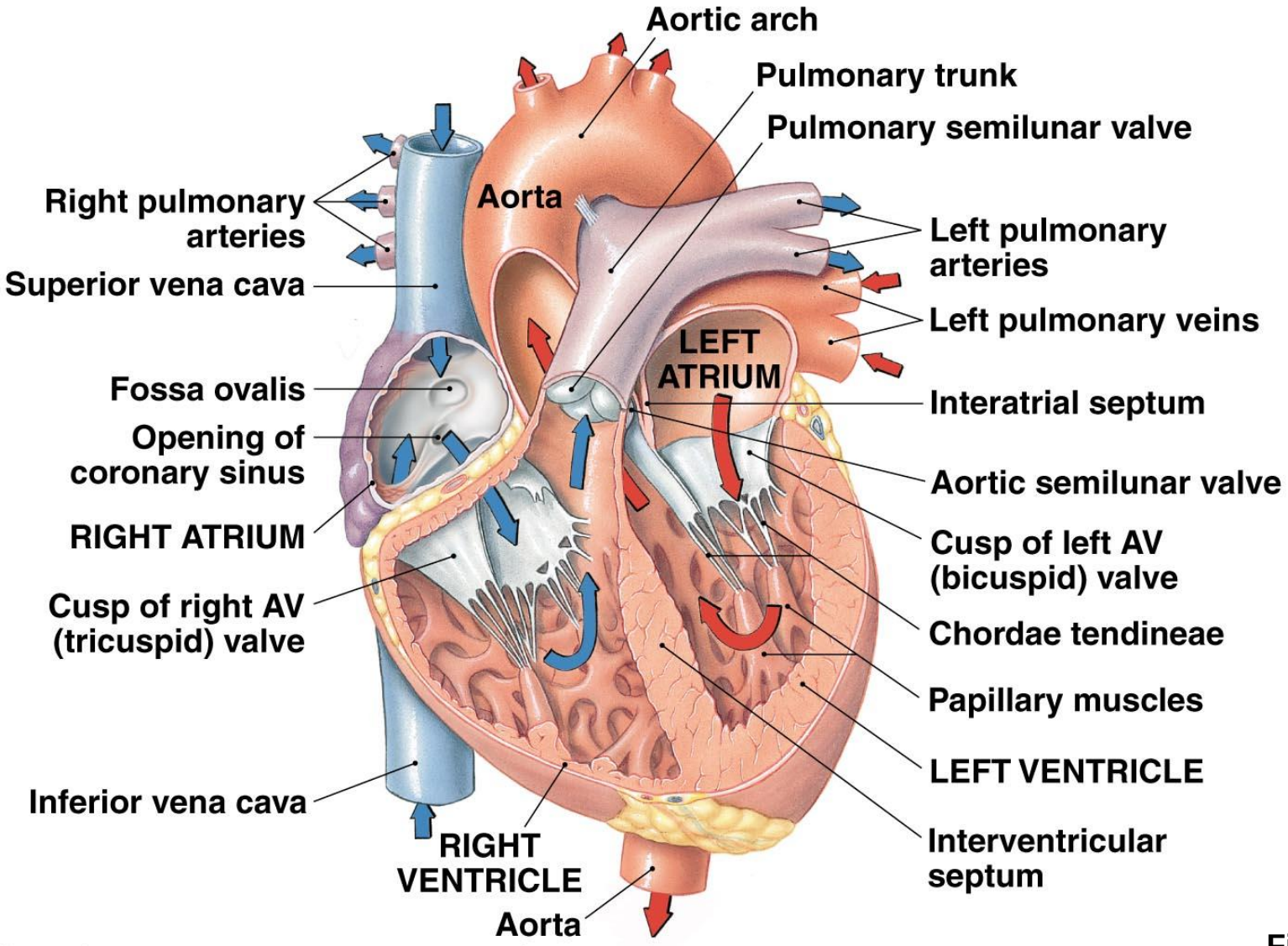


Figure 12-5

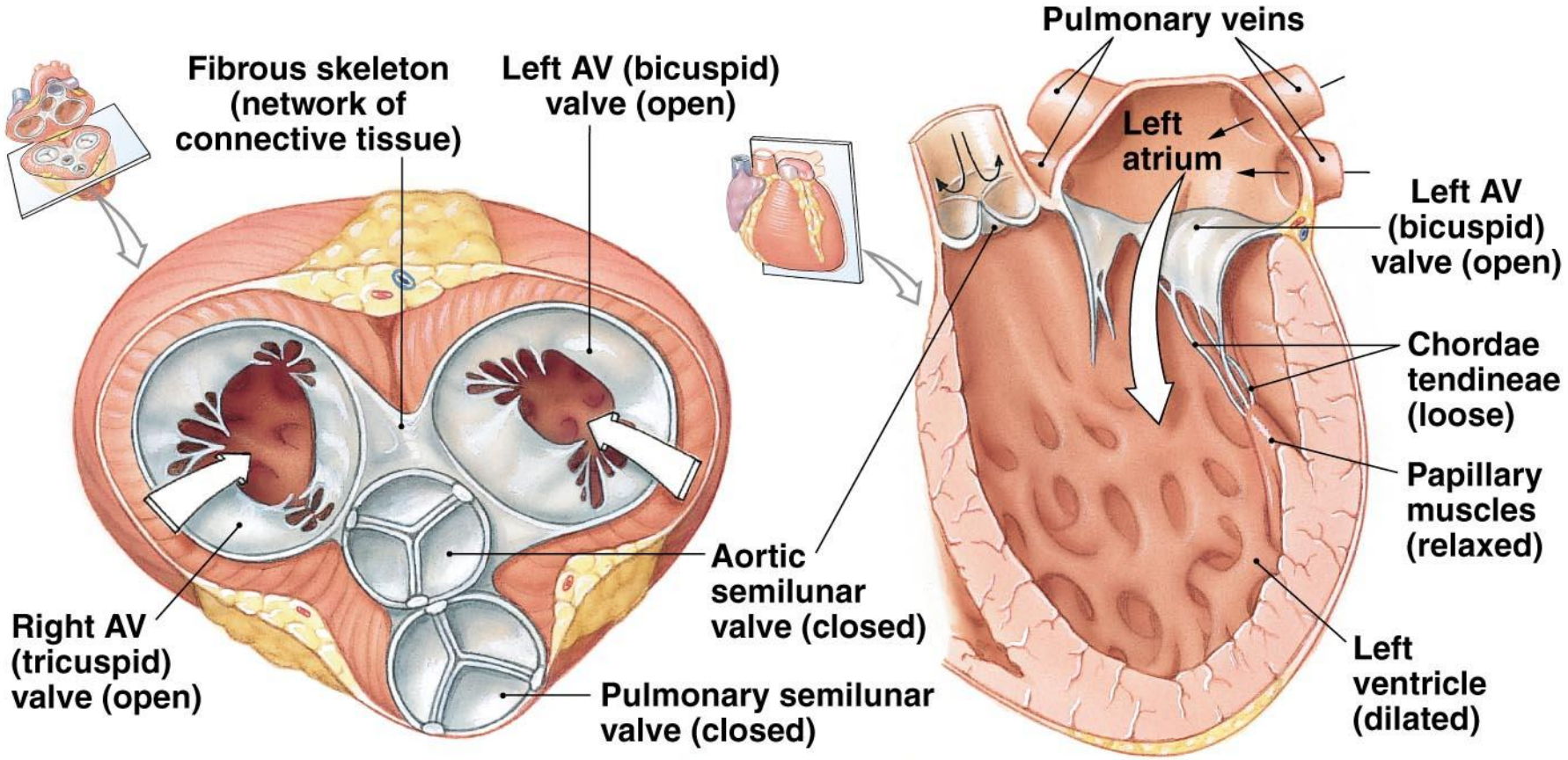
The Anatomy of the Heart

Functional Anatomy of the Heart

- Left ventricular myocardium much thicker than right
  - Reflects functional difference in load
- Valves ensure one-way flow of blood
  - Prevent backward flow (*regurgitation*)
- Fibrous skeleton supports valves and muscle cells

The Anatomy of the Heart

The Valves of the Heart

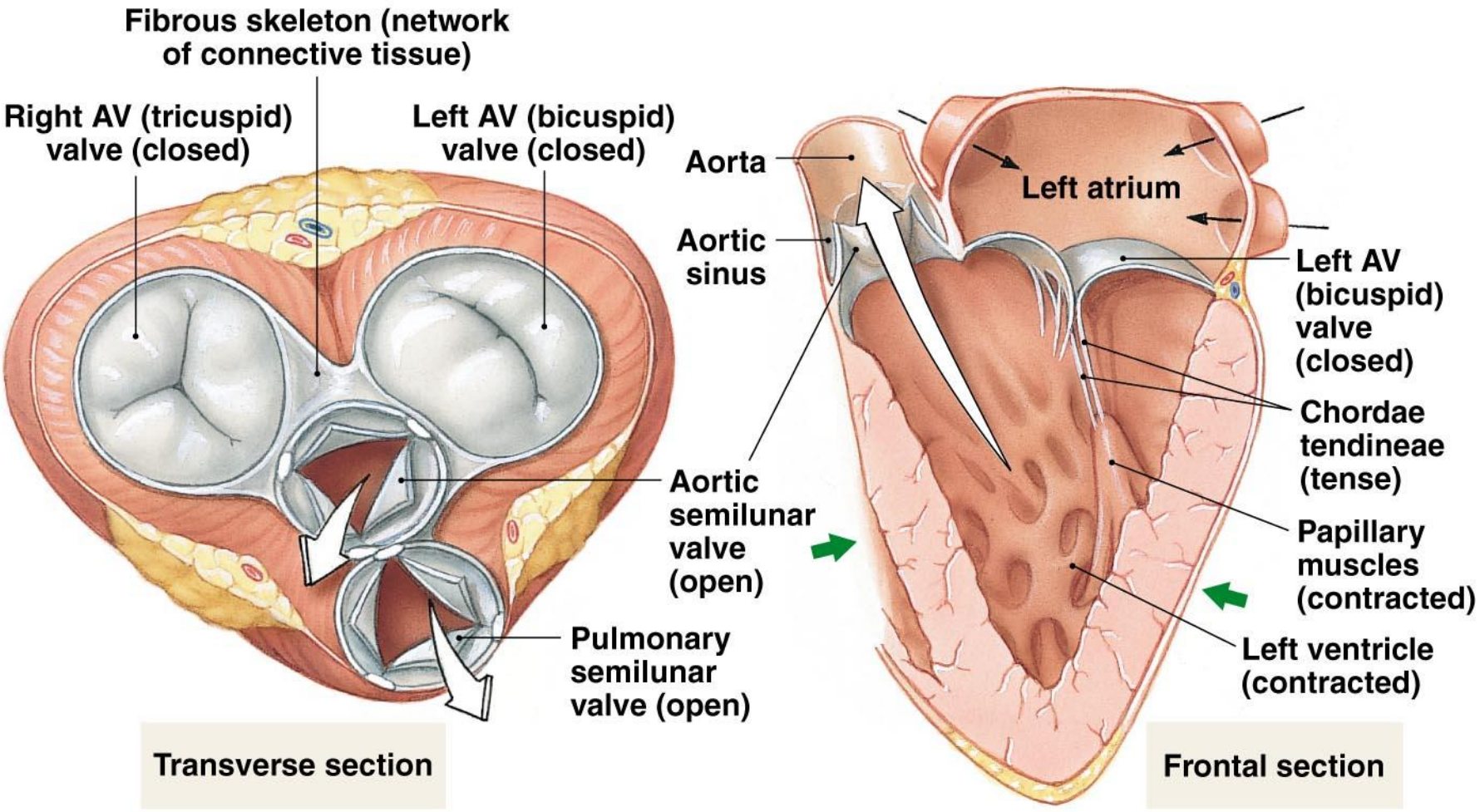


(a) Relaxed ventricles

Figure 12-6(a)

The Anatomy of the Heart

The Valves of the Heart



(b) Contracting ventricles

PLAY The Heart: Anatomy

Figure 12-6(b)

The Anatomy of the Heart

Key Note

The heart has four chambers, the right atrium and ventricle with the pulmonary circuit and left atrium and ventricle with the systemic circuit. The left ventricle's greater workload makes it more massive than the right, but the two pump equal amounts of blood. AV valves prevent backflow from the ventricles into the atria, and semilunar valves prevent backflow from the outflow vessels into the ventricles.

The Anatomy of the Heart

The Blood Supply to the Heart

- *Coronary circulation* meets heavy demands of myocardium for oxygen, nutrients
- *Coronary arteries* (right, left) branch from *aorta* base
- *Anastomoses* (arterial interconnections) ensure constant blood supply
- Drainage is to right atrium
  - Great, middle cardiac veins drain capillaries
  - Empty into *coronary sinus*

The Anatomy of the Heart

The Coronary Circulation

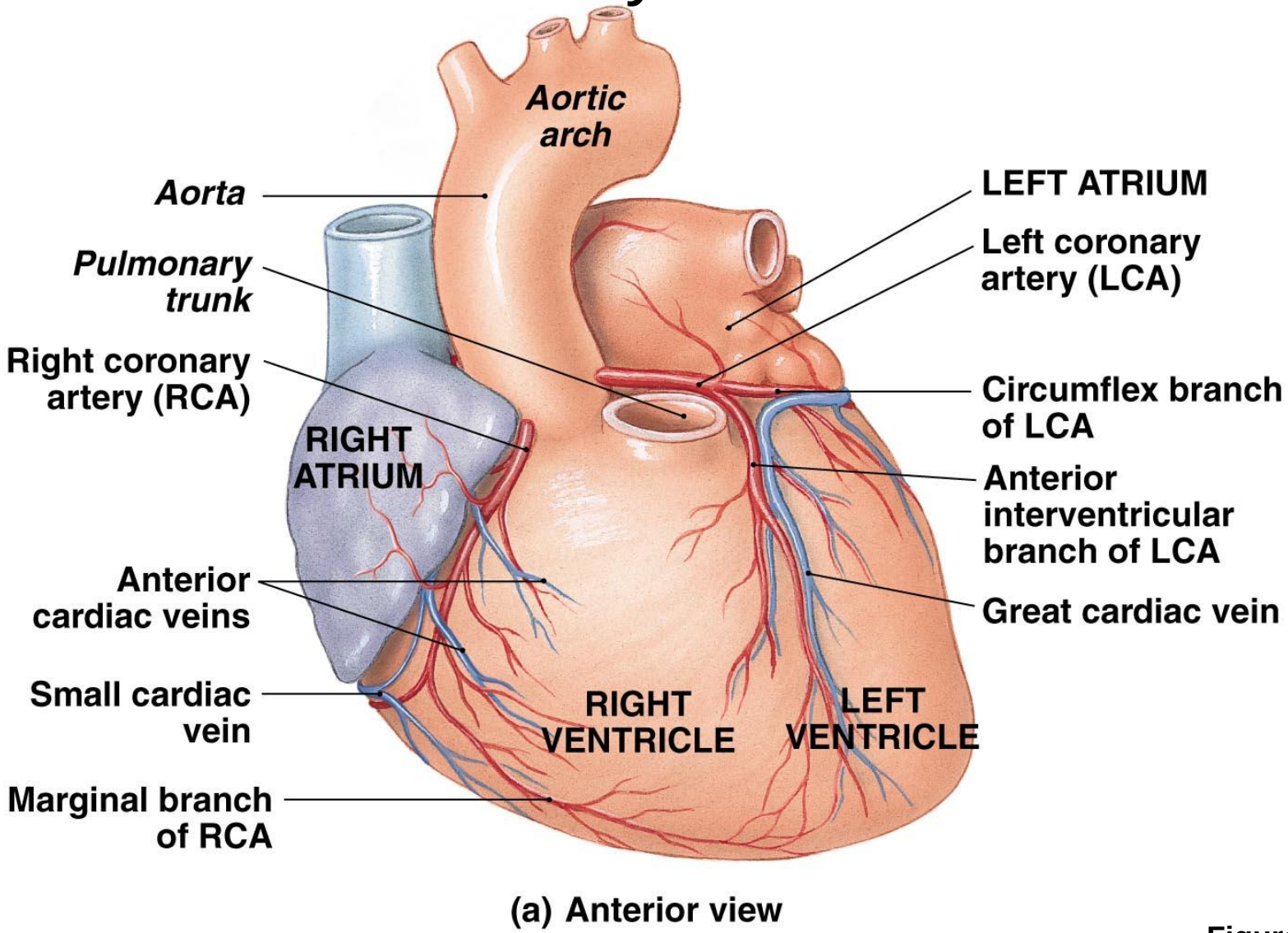


Figure 12-7(a)

The Anatomy of the Heart

The Coronary Circulation

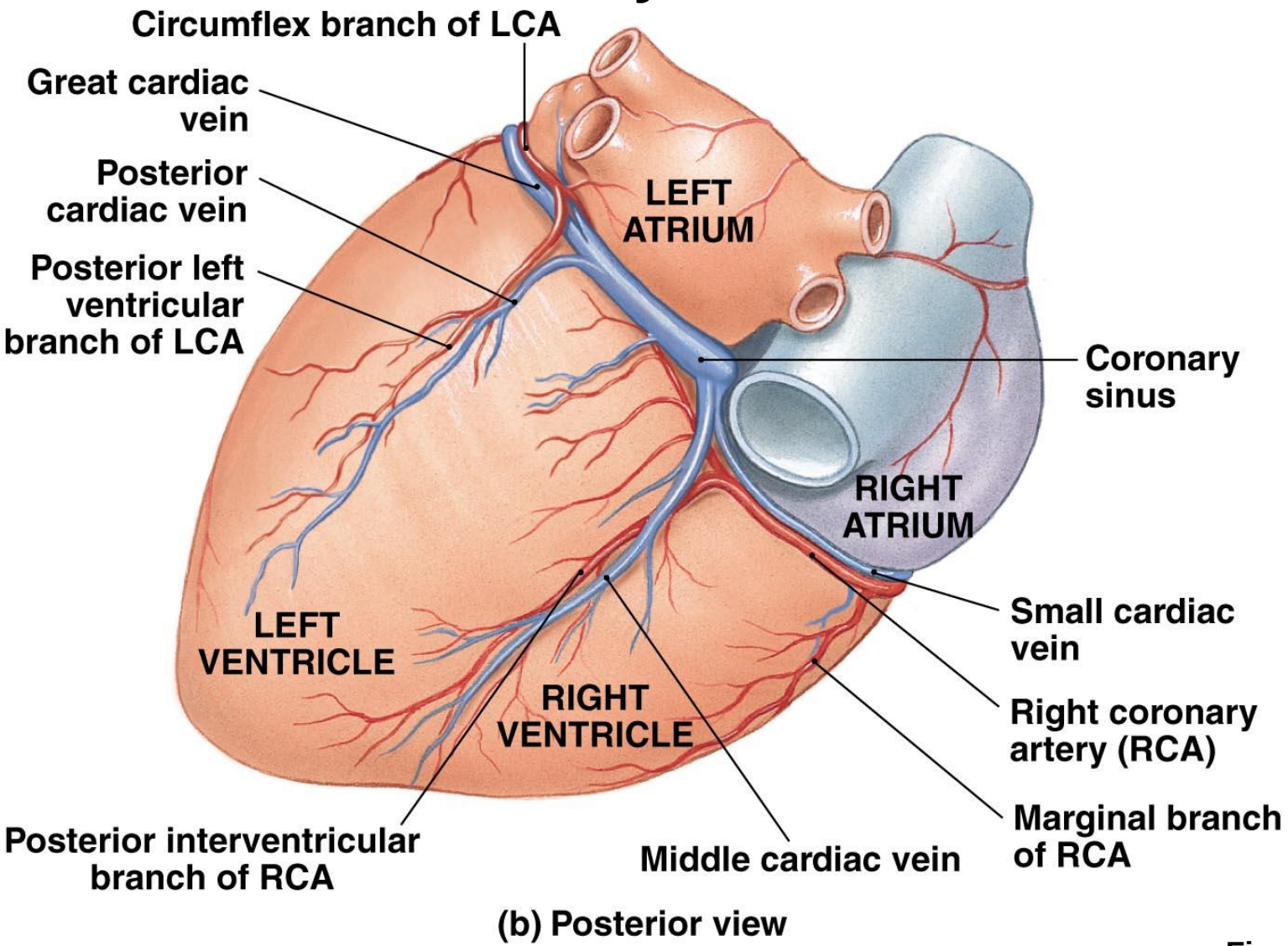


Figure 12-7(b)

The Heartbeat

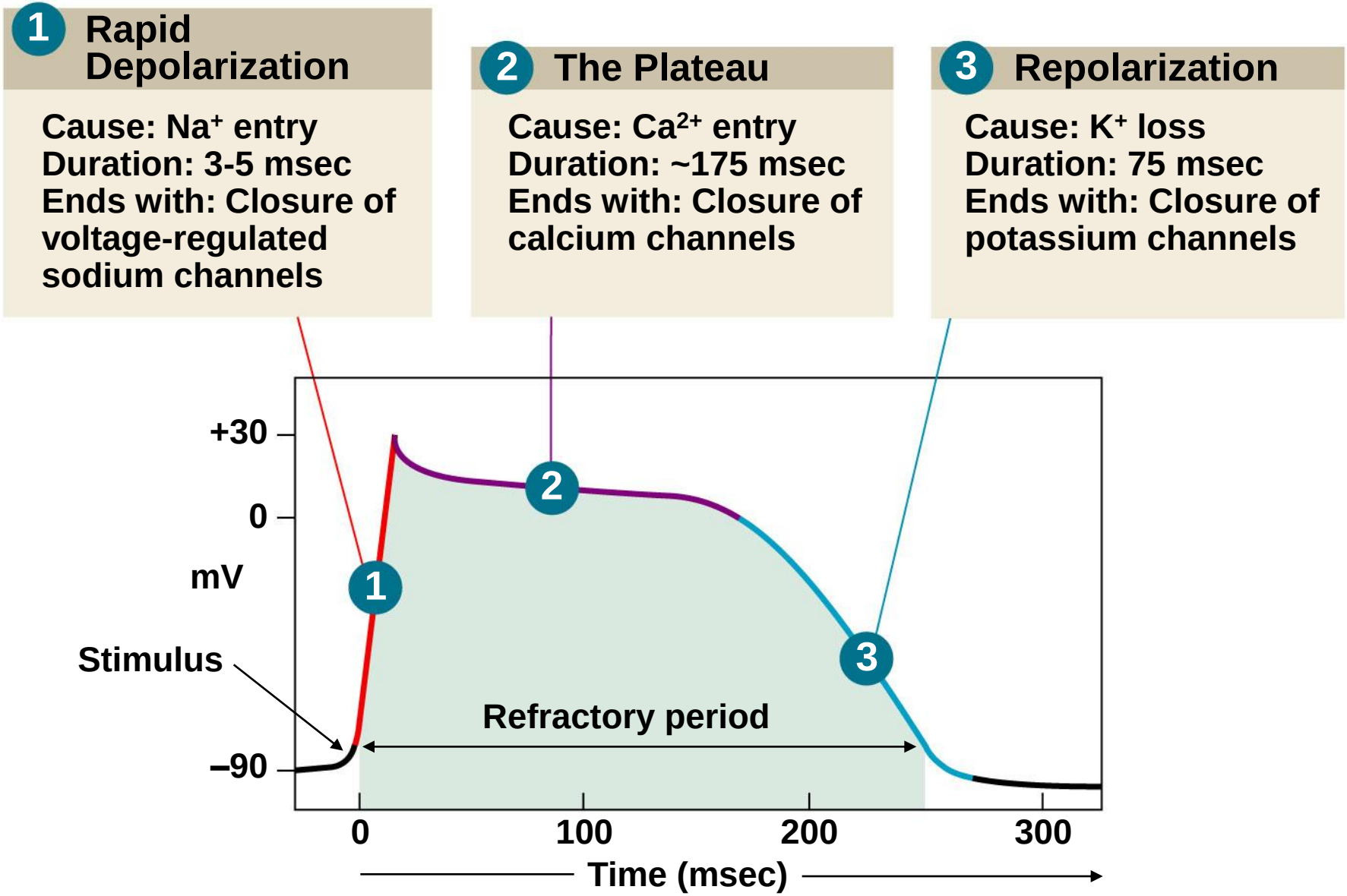
Heartbeat Needs two Types of Cardiac Cells

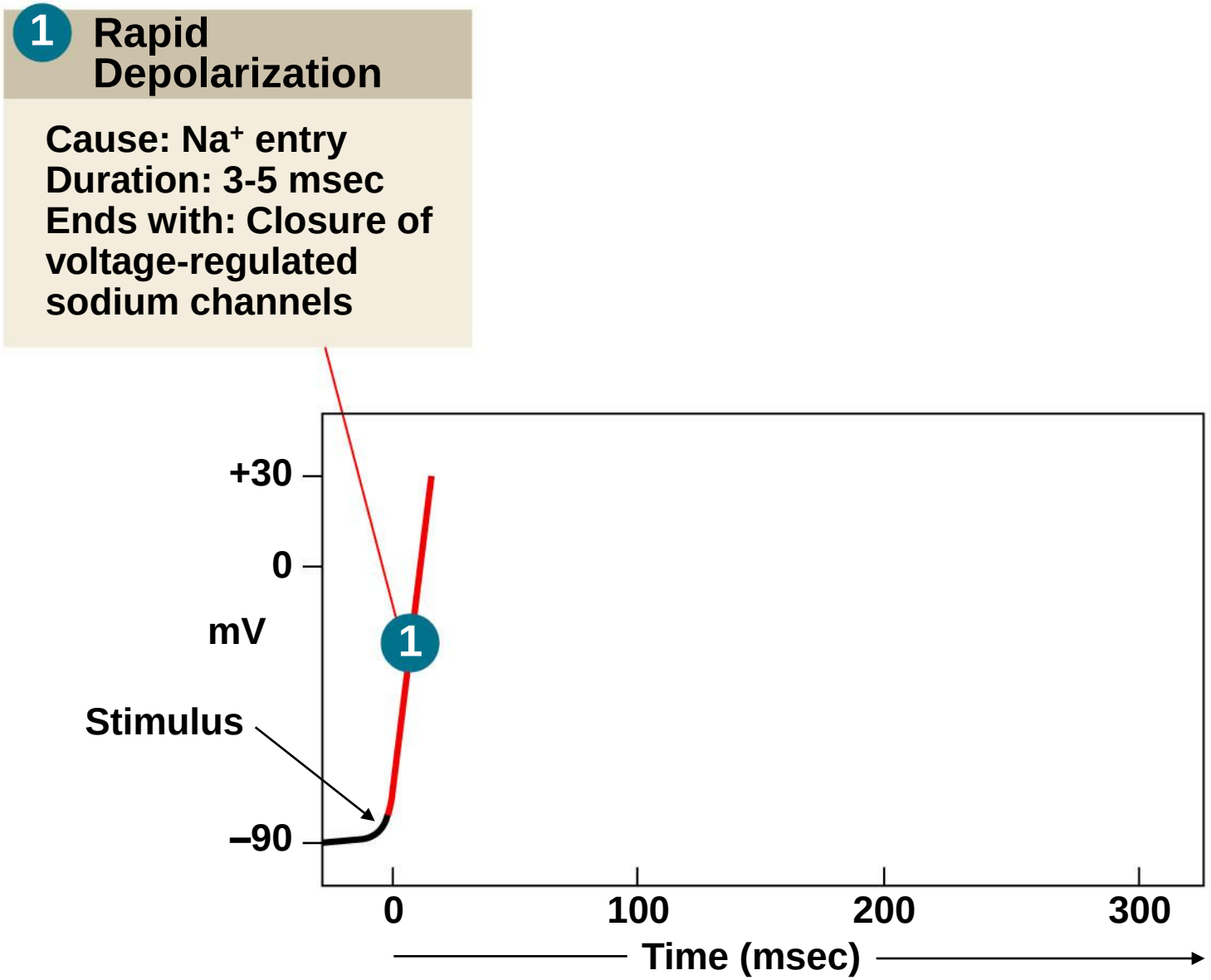
- Contractile cells
  - Provide the pumping action
- Cells of the *conducting system*
  - Generate and spread the action potential

The Heartbeat

Differences between Cardiac and Skeletal Muscle Cells

- Cardiac action potential has long *plateau phase*
- Cardiac muscle has long, slow twitch
- Cardiac muscle has long *refractory period*
  - Can't be *tetanized*





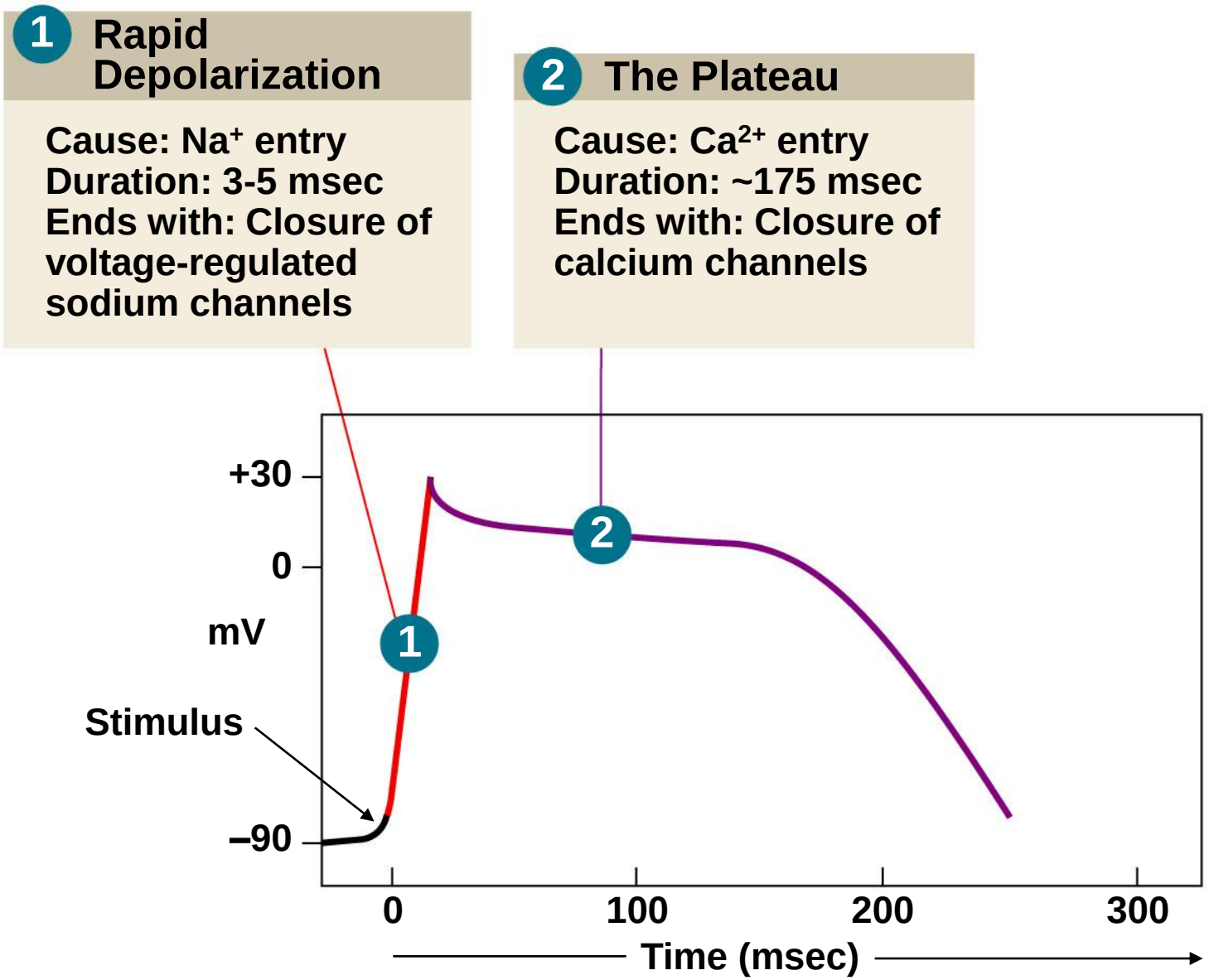


Figure 12-8(a)
3 of 5

1 Rapid Depolarization

Cause: Na^+ entry
Duration: 3-5 msec
Ends with: Closure of voltage-regulated sodium channels

2 The Plateau

Cause: Ca^{2+} entry
Duration: ~175 msec
Ends with: Closure of calcium channels

3 Repolarization

Cause: K^+ loss
Duration: 75 msec
Ends with: Closure of potassium channels

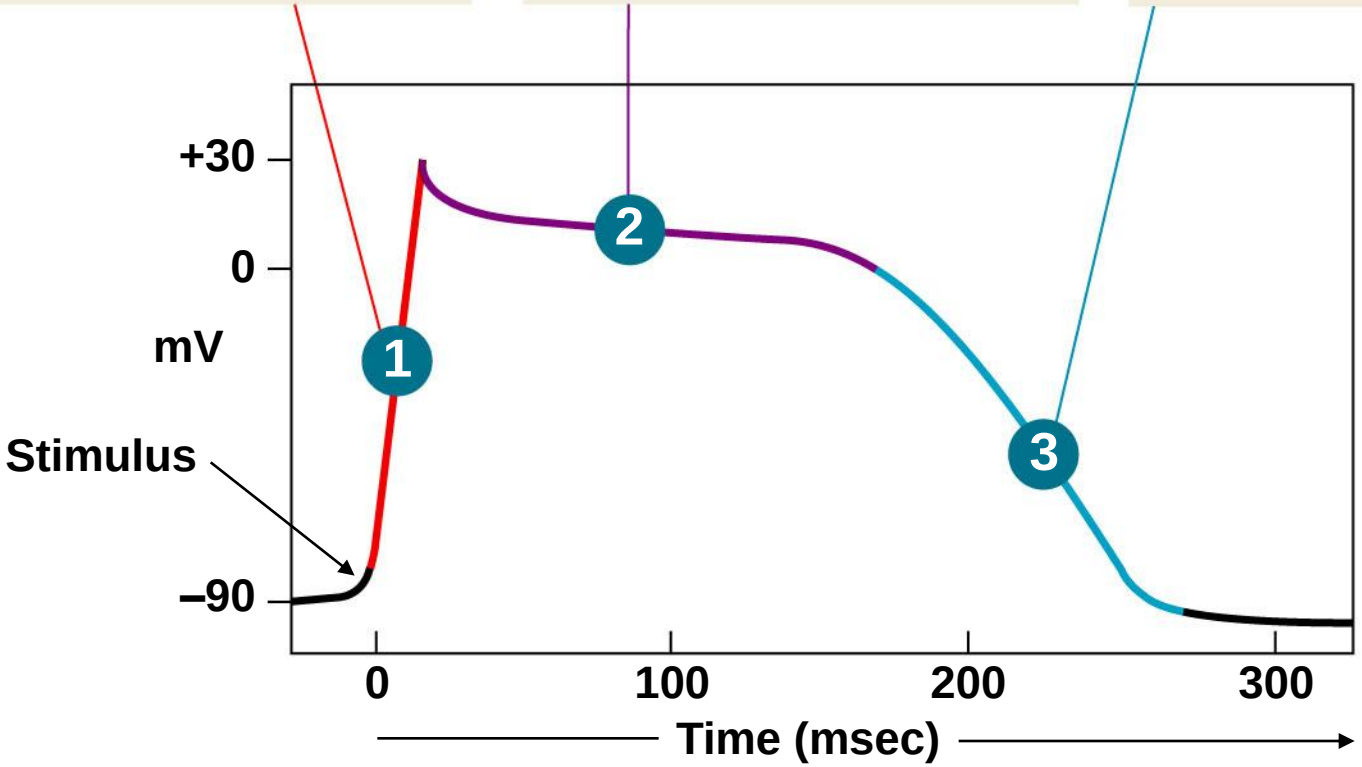


Figure 12-8(a)
4 of 5

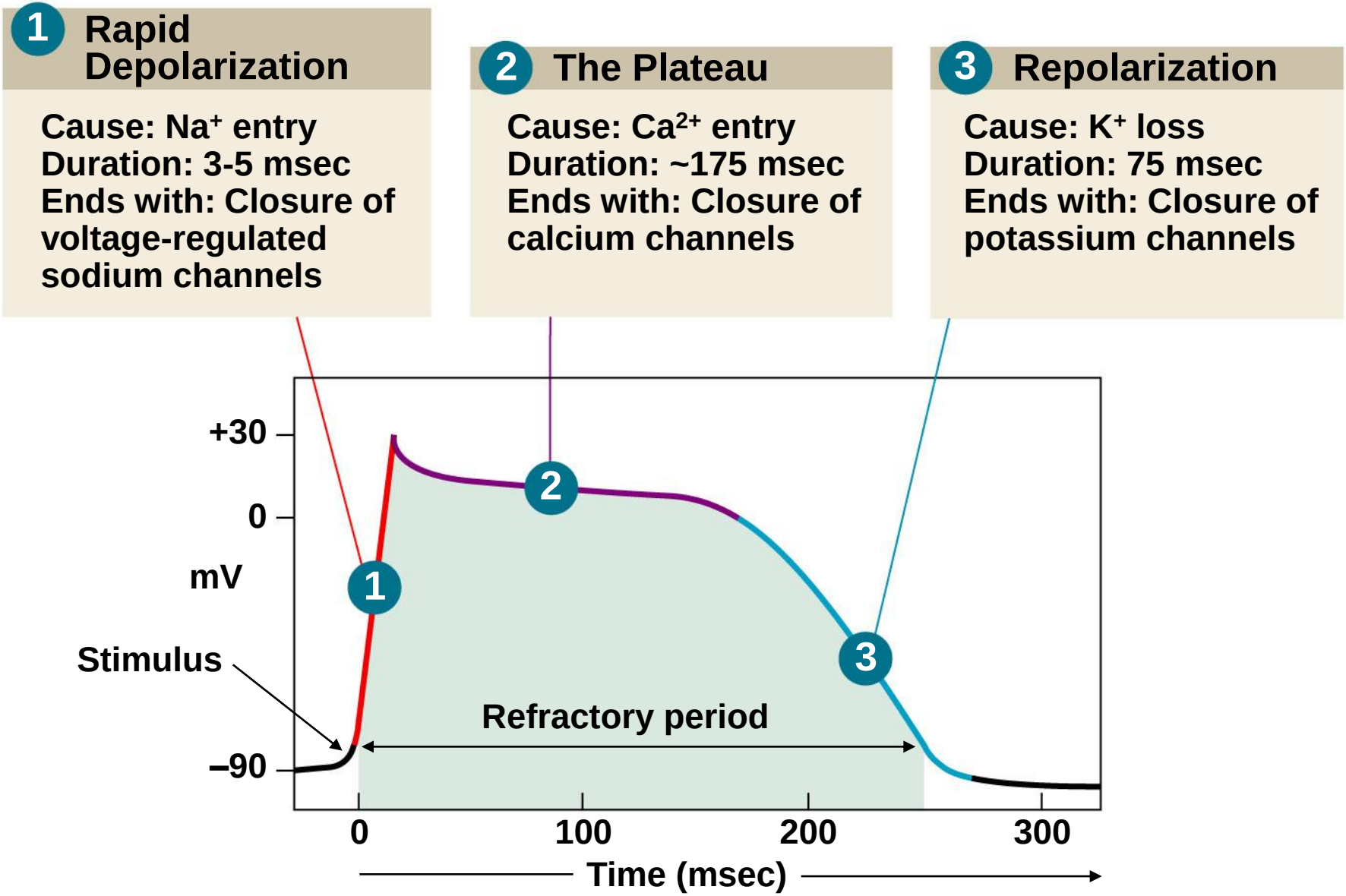


Figure 12-8(a)
5 of 5

The Heartbeat

Action Potentials and Muscle Cell Contraction in Skeletal and Cardiac Muscle

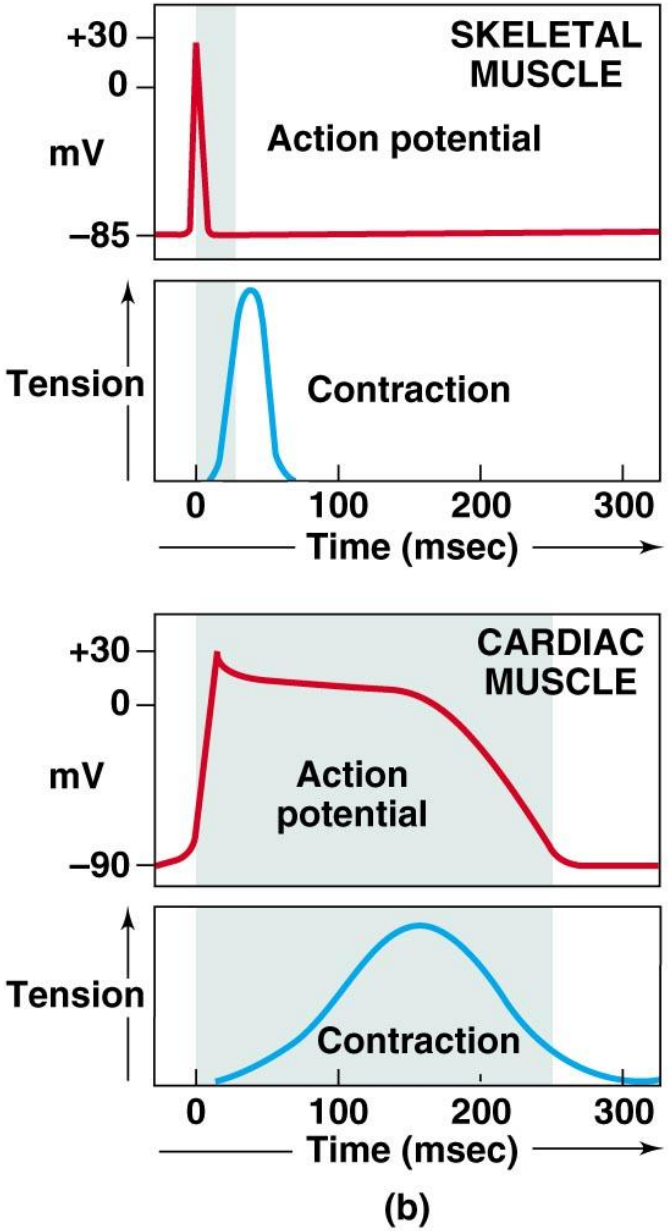


Figure 12-8(b)

The Heartbeat

The Conducting System

- Initiates and spreads electrical impulses in heart
- Two types of cells
  - *Nodal cells*
    - *Pacemaker cells*
      - Reach threshold first
      - Set heart rate
  - *Conducting cells*
    - Distributes stimuli to myocardium

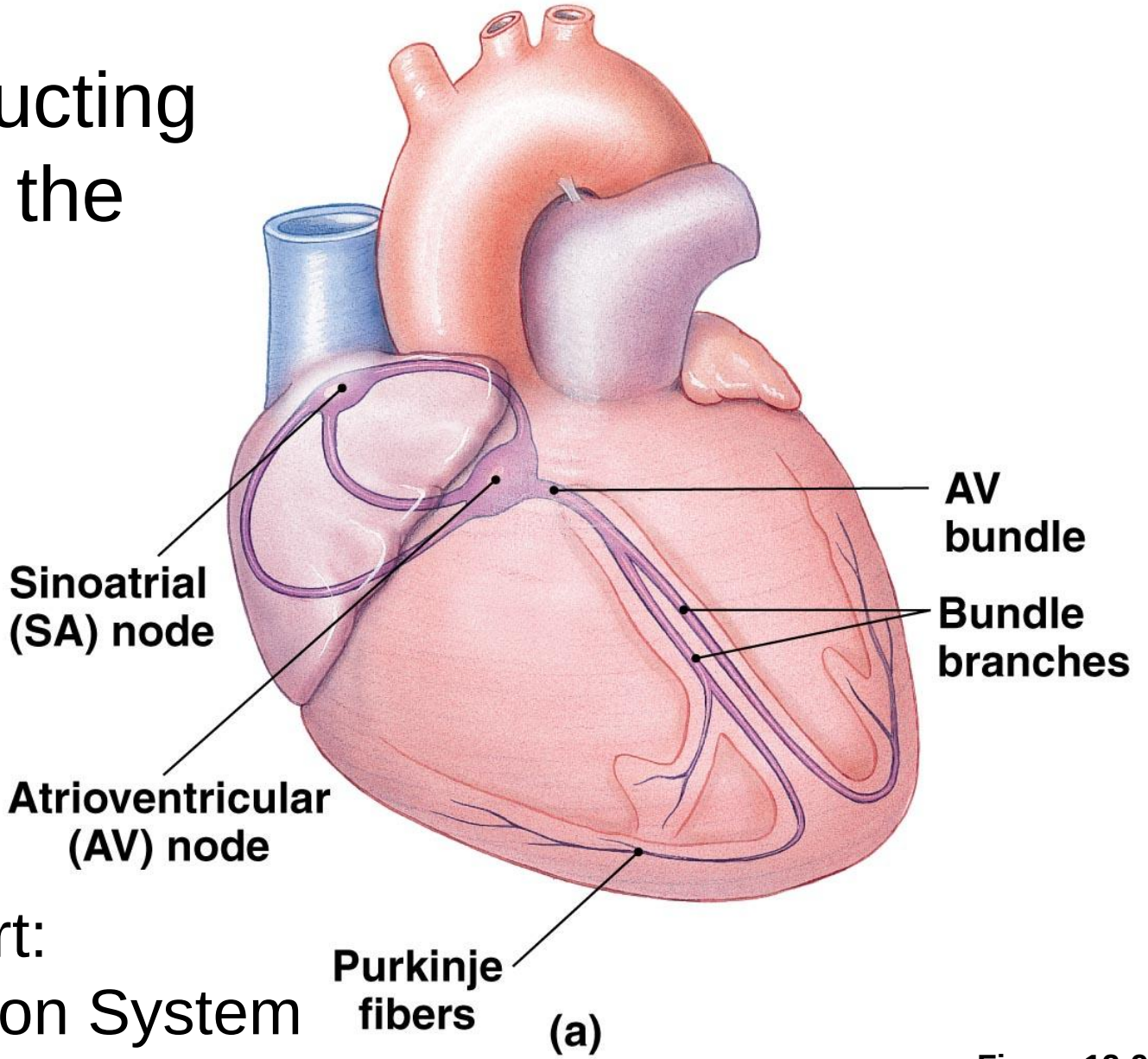
The Heartbeat

The Conducting System (cont'd)

- Heart is *self-exciting*
  - Pacemaker cells establish heart rate
    - Normal pacemaker is *sinoatrial* (SA) *node*
  - Impulse spreads from SA node:
    - Across atria
    - To *atrioventricular* (AV) *node*
    - To AV bundle and bundle branches
    - Via *Purkinje fibers* to ventricles

The Heartbeat

The Conducting System of the Heart



PLAY The Heart: Conduction System

Figure 12-9(a)

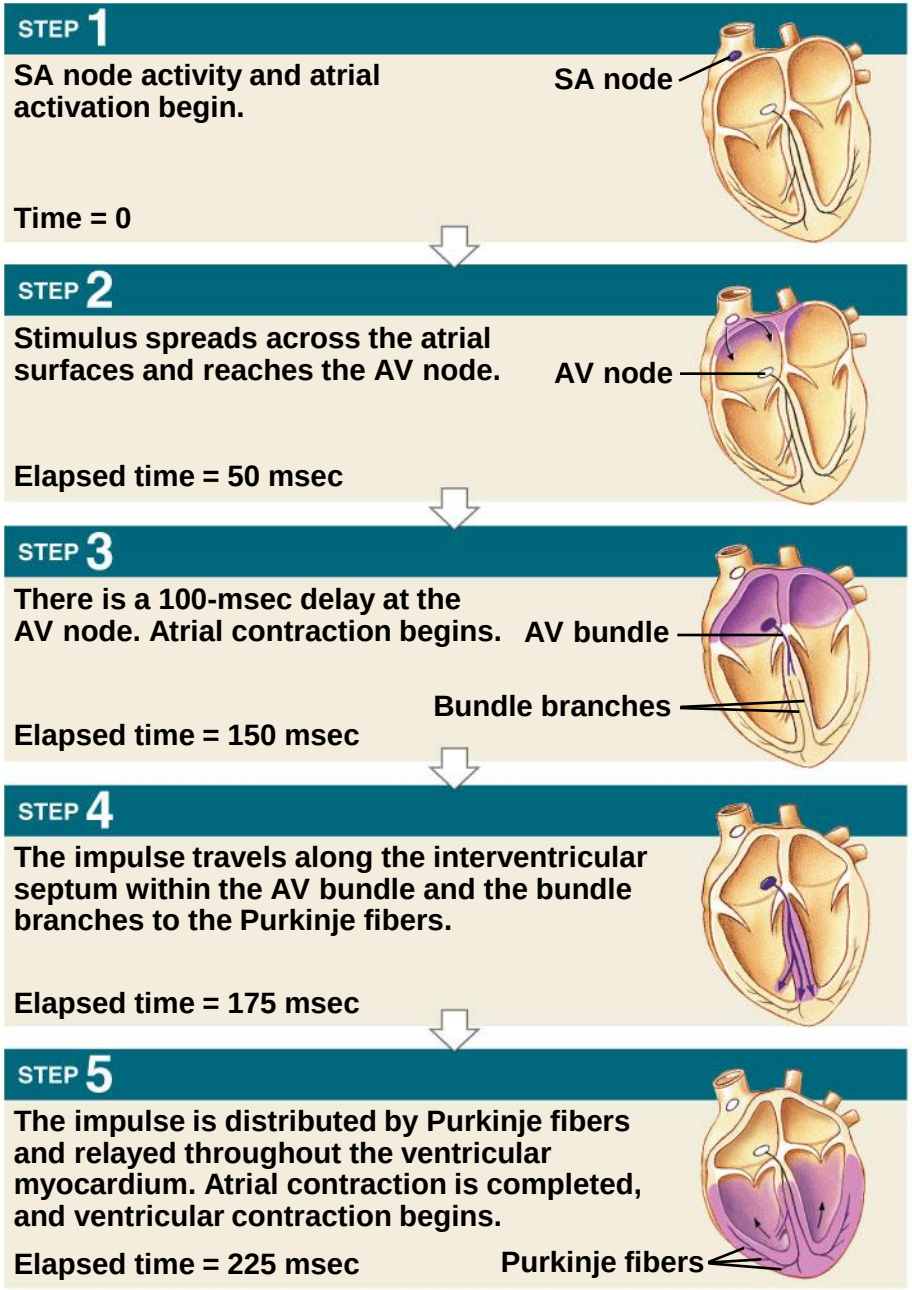


Figure 12-9(b)
1 of 6

STEP 1

SA node activity and atrial activation begin.

Time = 0

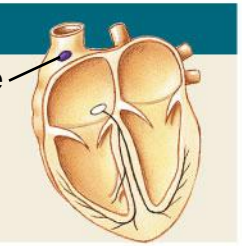


Figure 12-9(b)
2 of 6

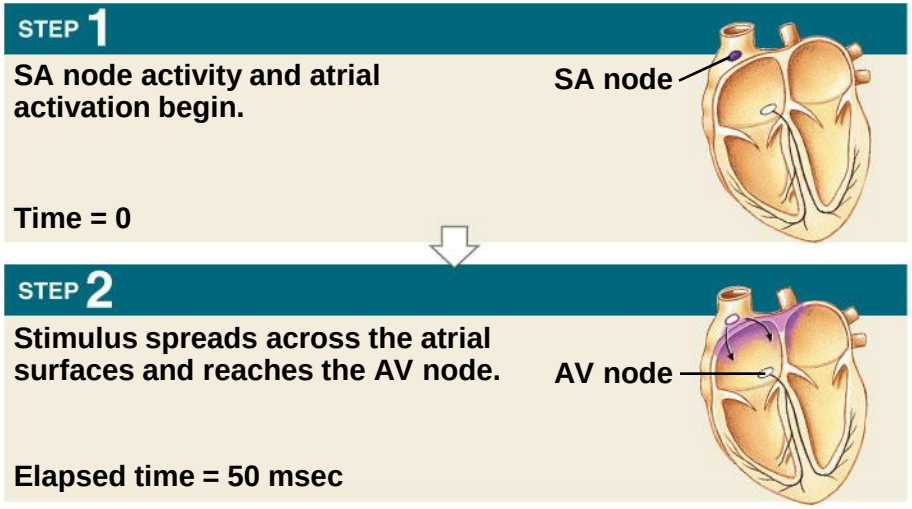


Figure 12-9(b)
3 of 6

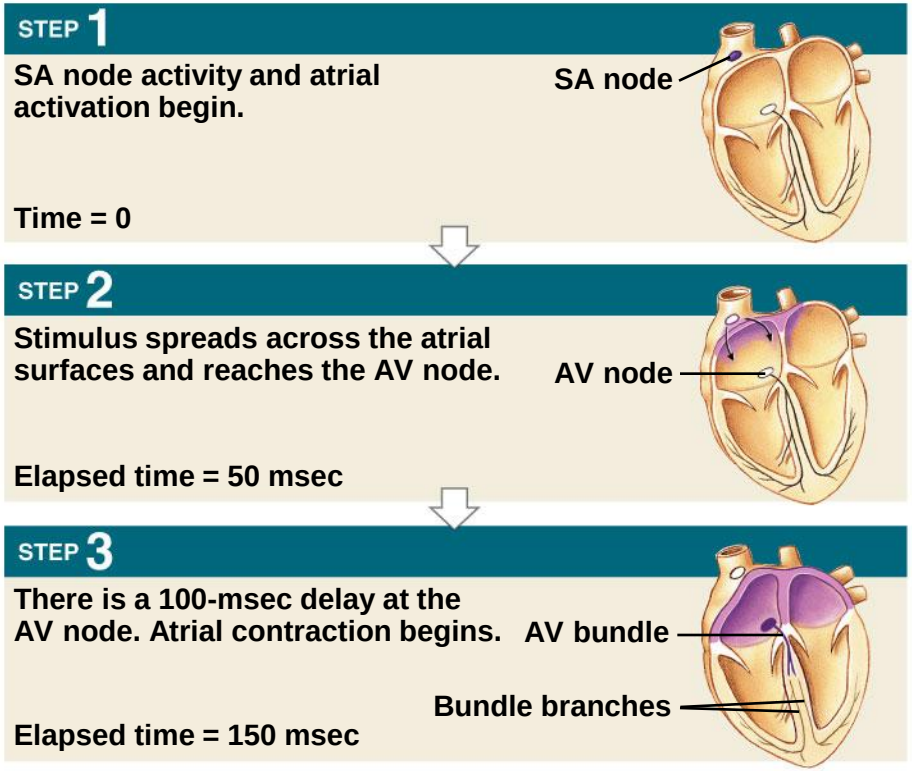


Figure 12-9(b)
4 of 6

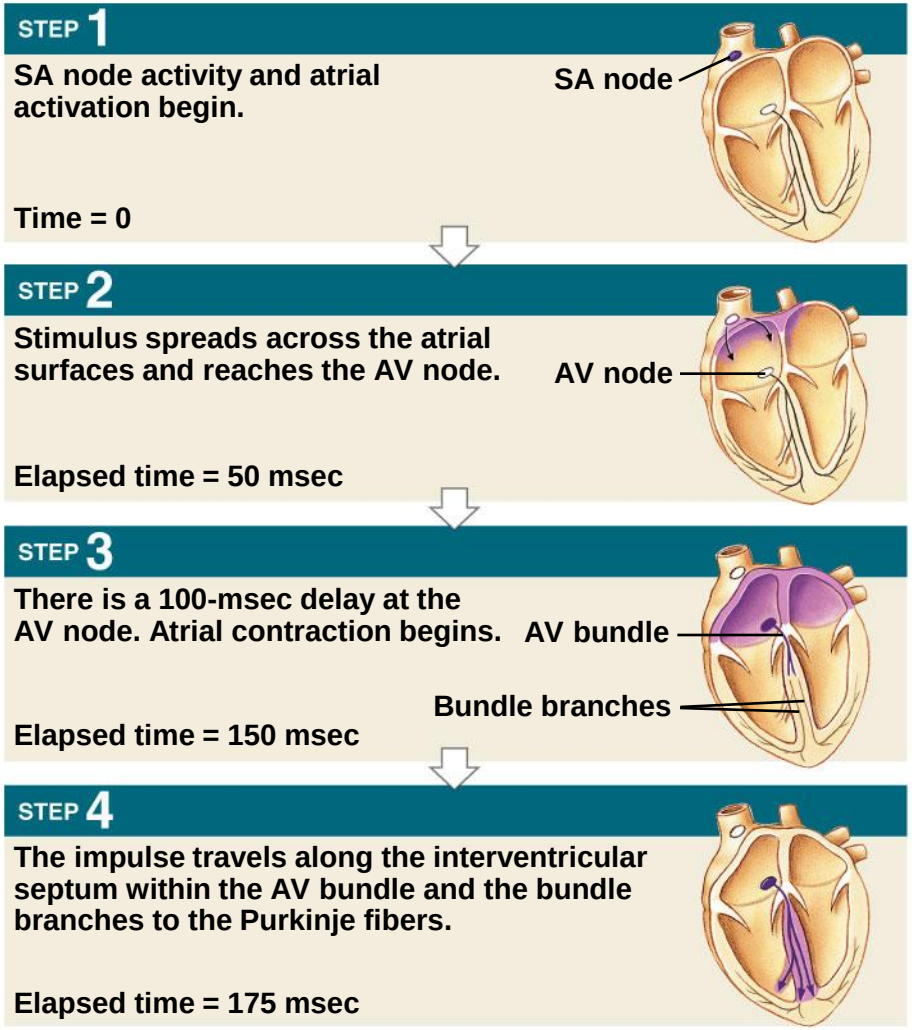


Figure 12-9(b)
5 of 6

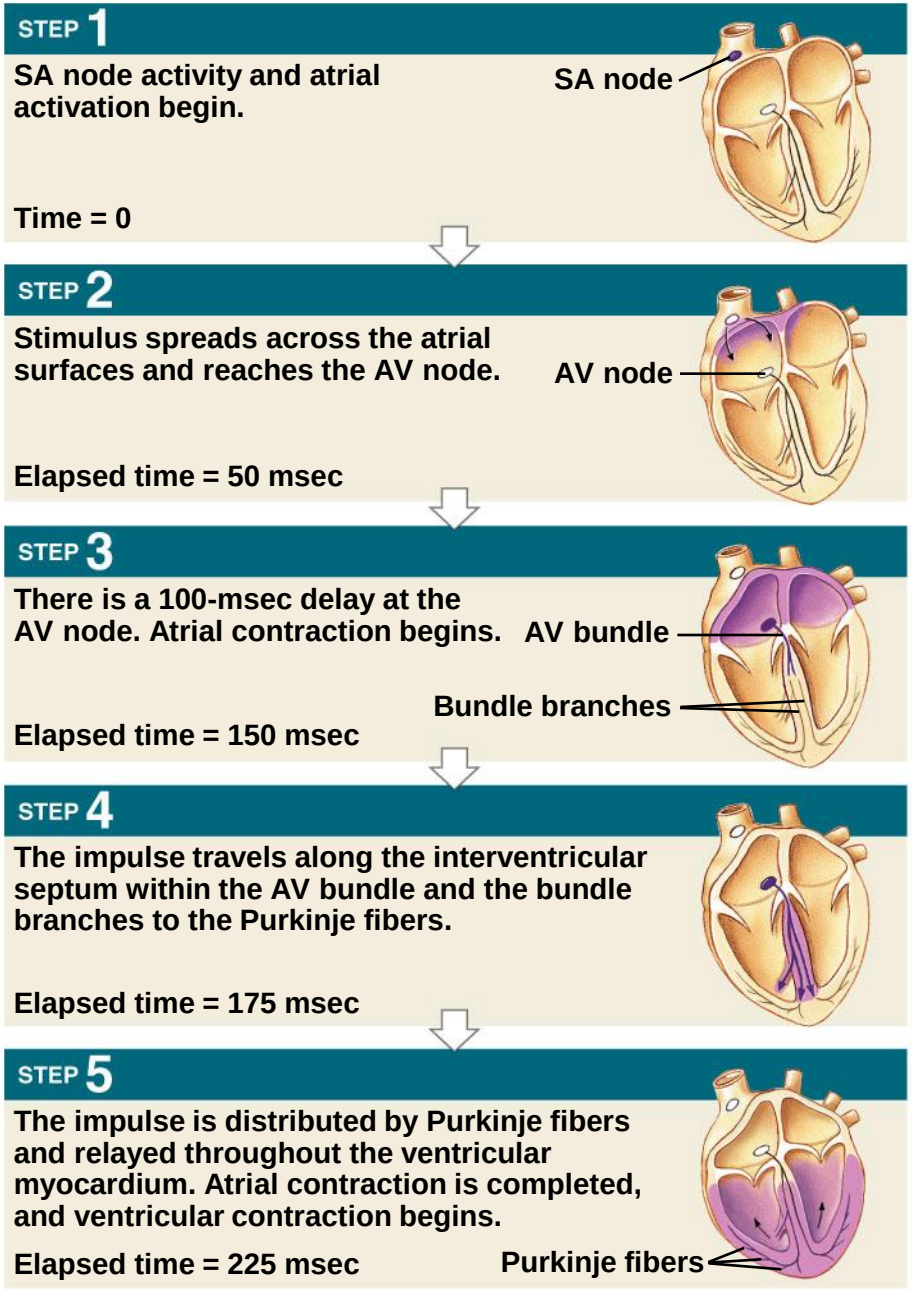


Figure 12-9(b)
6 of 6

The Heartbeat

The Electrocardiogram (ECG or EKG)

- A recording of the electrical activity of the heart
- Three main components
  - *P wave*
    - Atrial depolarization
  - *QRS complex*
    - Ventricular depolarization
  - *T wave*
    - Ventricular repolarization

The Heartbeat

An Electrocardiogram

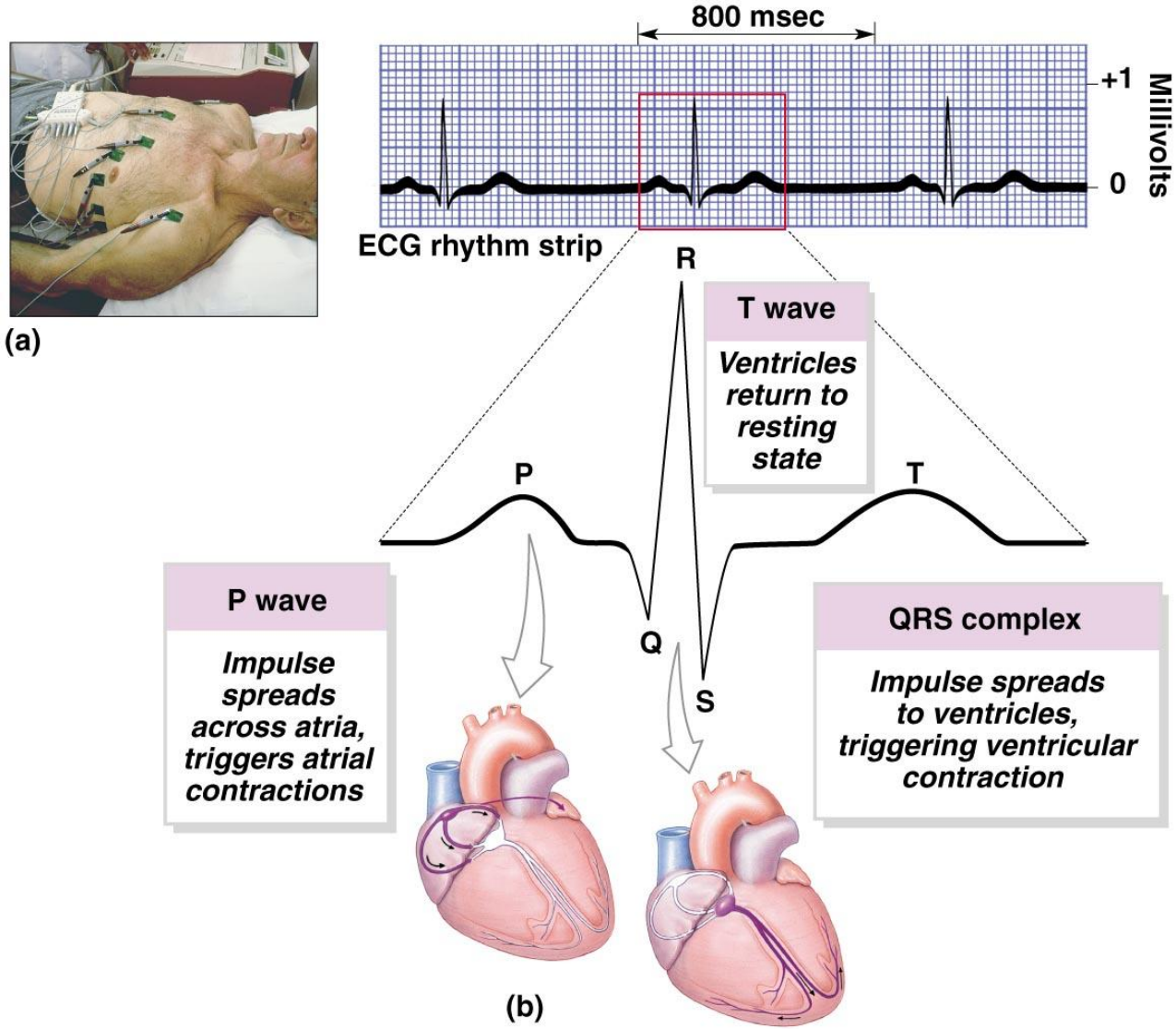


Figure 12-10

The Heartbeat

Key Note

The heart rate is established by the SA node, as modified by autonomic activity, hormones, ions, etc. From there, the stimulus is conducted through the atrium to the AV node, the AV bundle, the bundle branches, and Purkinje fibers to the ventricular myocardium. The ECG shows the electrical events associated with the heartbeat.

The Heartbeat

The Cardiac Cycle

- Two phases in cardiac cycle
  - *Systole*
    - Contraction phase
    - Both ventricles simultaneously
  - *Diastole*
    - Relaxation phase

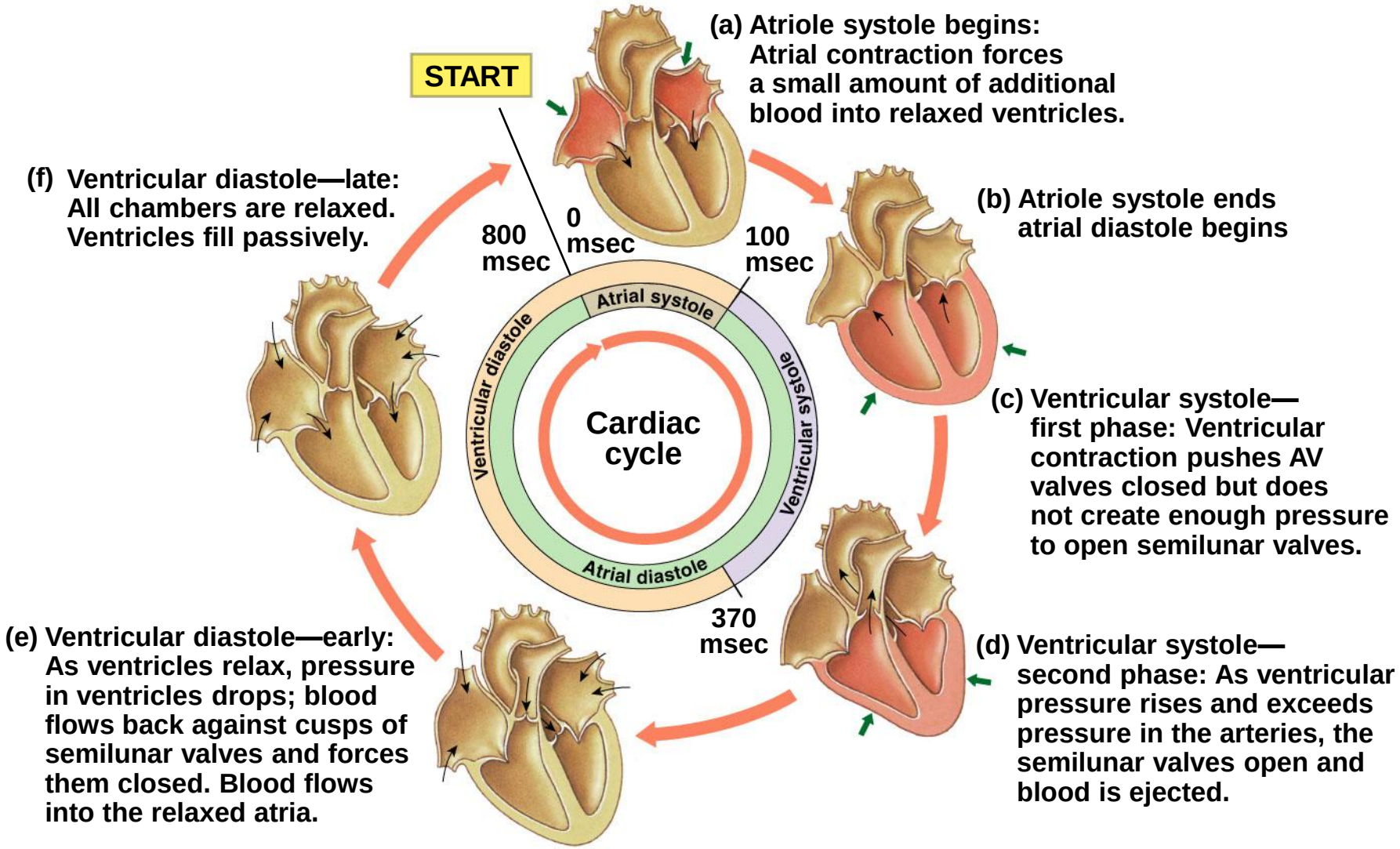


Figure 12-11
1 of 6

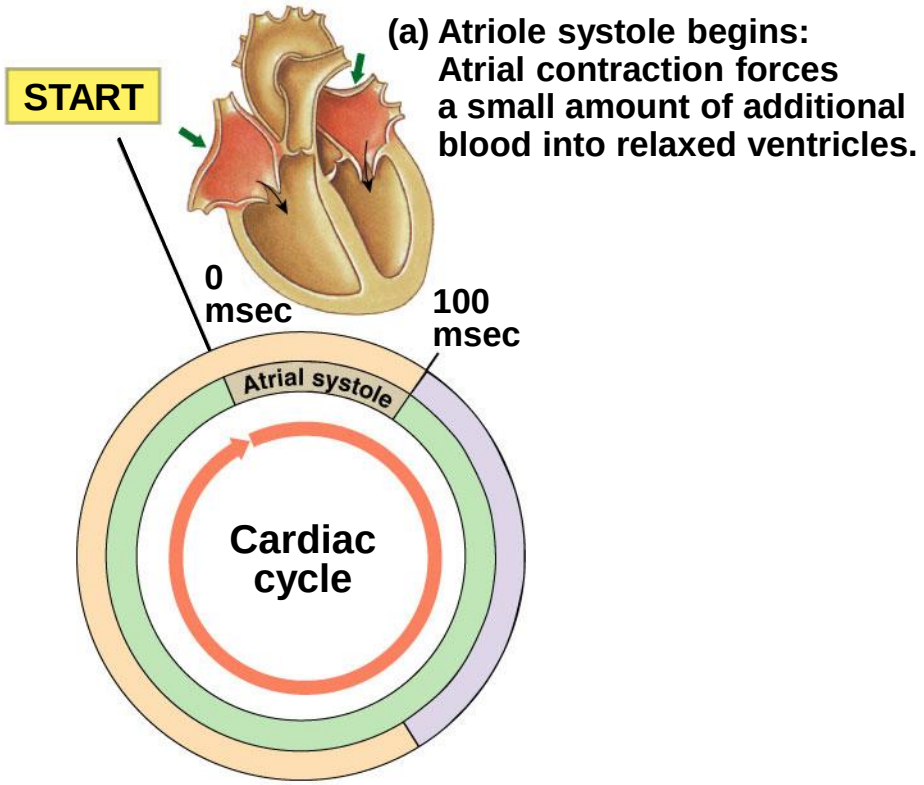


Figure 12-11
2 of 6

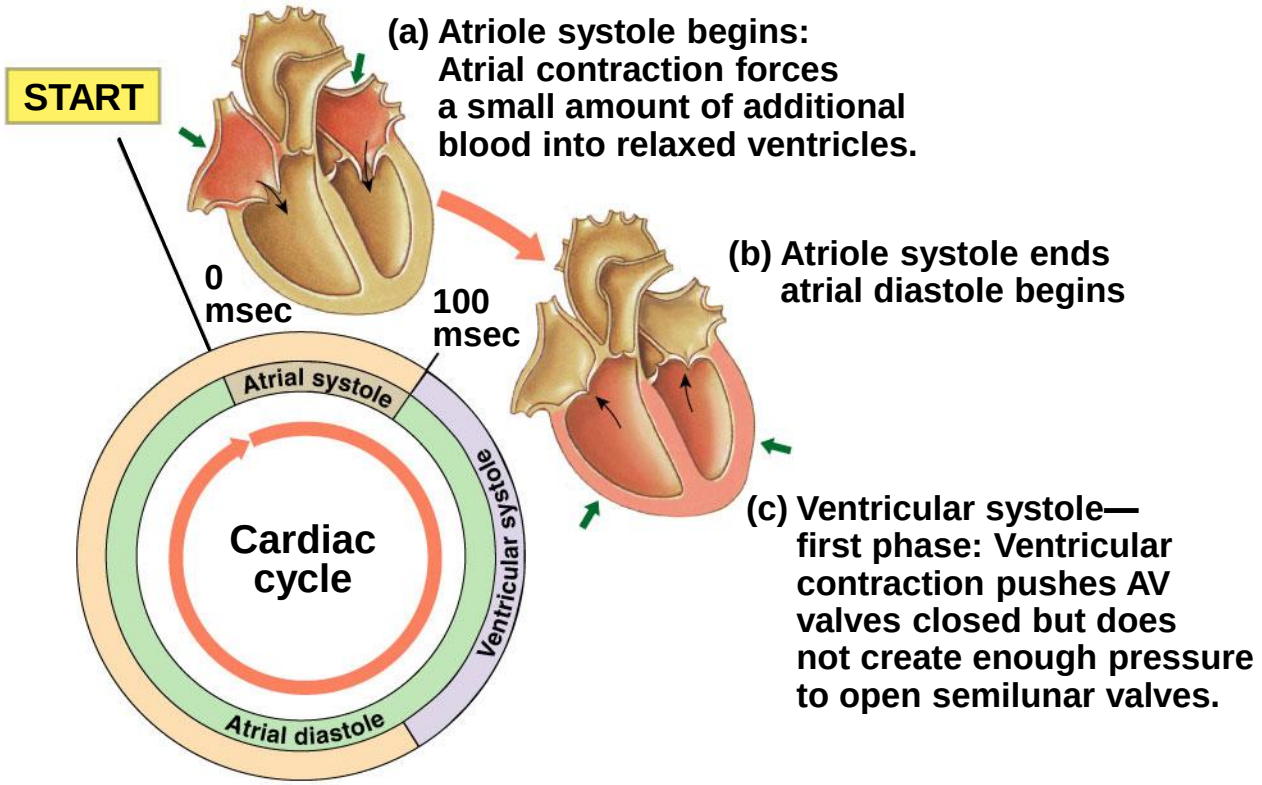


Figure 12-11
3 of 6

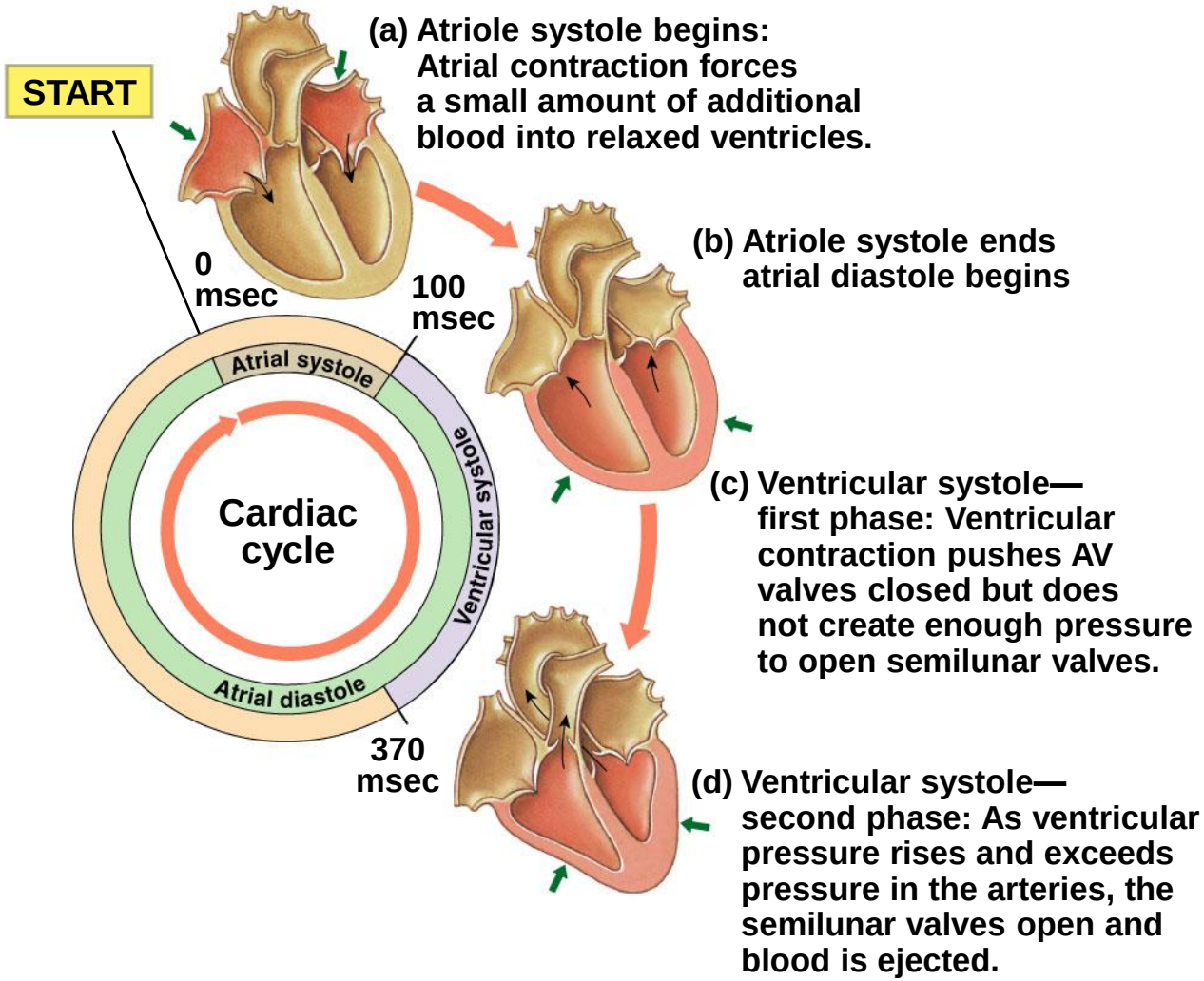


Figure 12-11
4 of 6

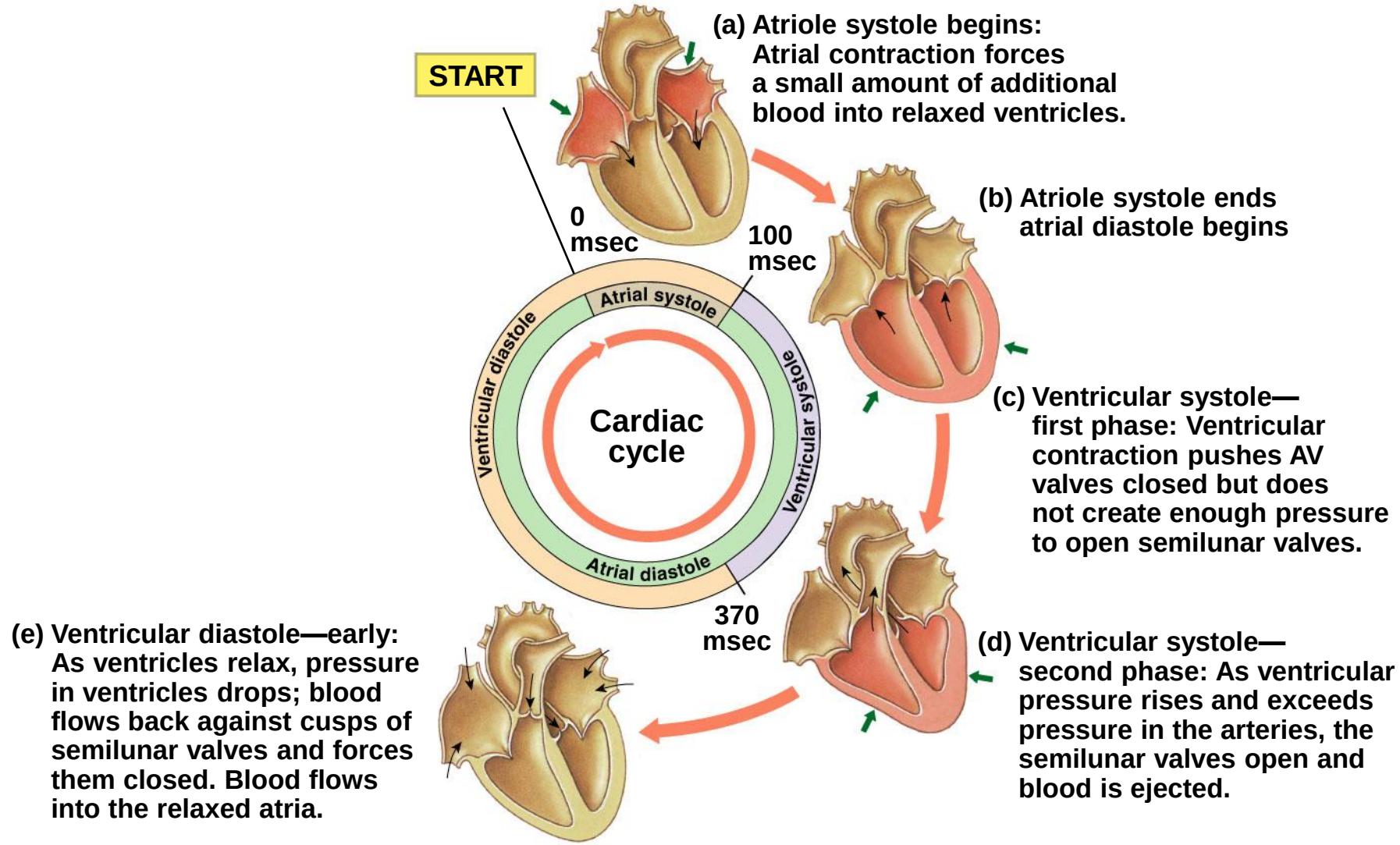


Figure 12-11
5 of 6

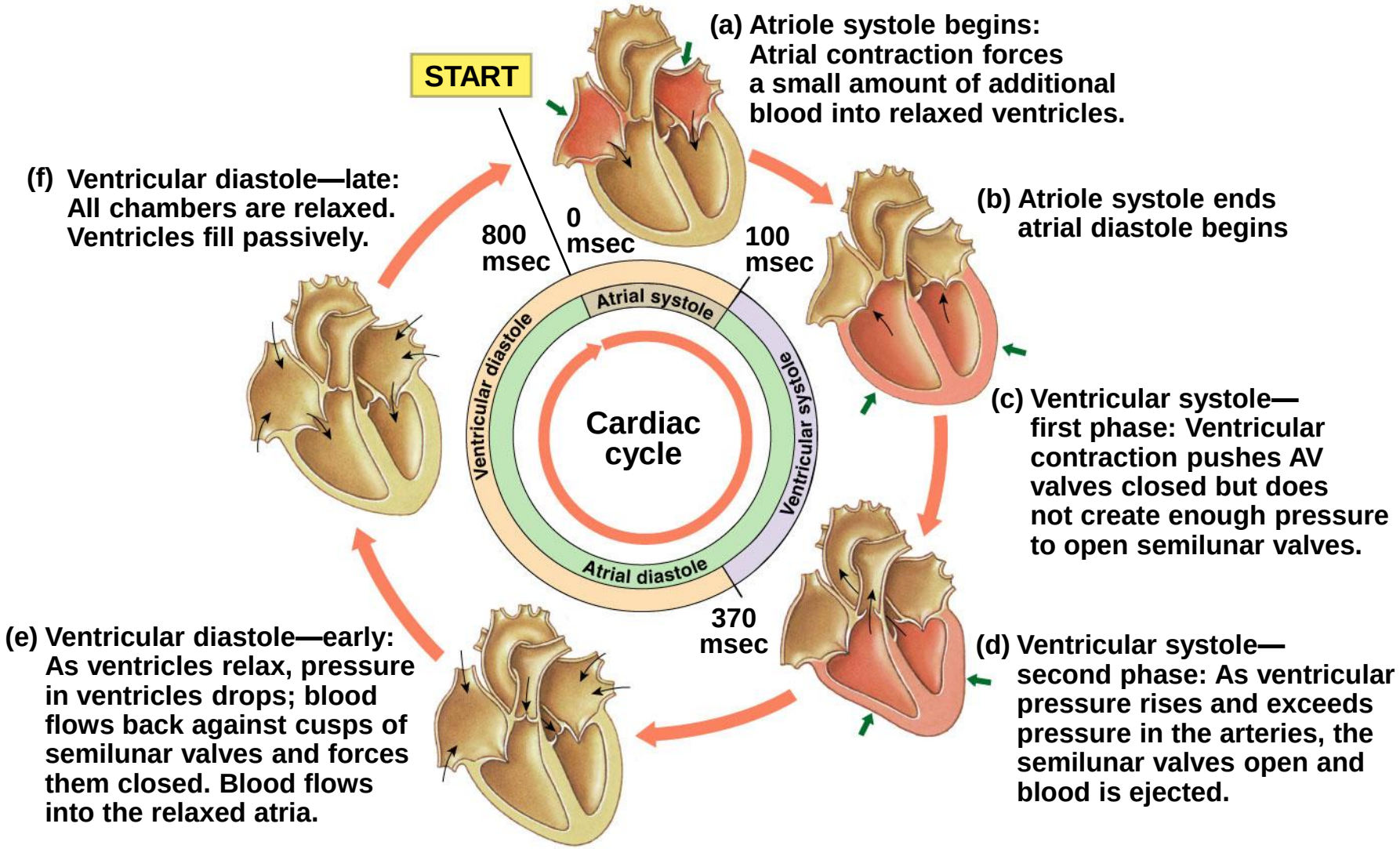


Figure 12-11
6 of 6

The Heartbeat

Heart Sounds

- Generated by *closing* of valves
- Two main heart sounds
  - First sound (*lubb*)
    - Closing of AV valve
  - Second sound (*dupp*)
    - Closing of aortic valve
- Indicate start/stop of systole
- Heard with *stethoscope*

Heart Dynamics

Some Essential Definitions

- *Heart dynamics*—Movements and forces generated during cardiac contraction
- *Stroke volume*—Amount of blood pumped in a single beat
- *Cardiac output*—Amount of blood pumped each minute

Heart Dynamics

Factors Controlling Cardiac Output

- Blood volume reflexes
- Autonomic innervation
  - Heart rate effects
  - Stroke volume effects
- Hormones

Heart Dynamics

Blood Volume Reflexes

- Stimulated by changes in *venous return*
  - VR is amount of blood *entering* heart
- *Atrial reflex*
  - Speeds up heart rate
  - Triggered by stretching wall of right atrium
- *Frank-Starling principle*
  - Increases ventricular output
  - Triggered by stretching wall of ventricles

Heart Dynamics

Autonomic Control of the Heart

- Parasympathetic innervation
  - Releases acetylcholine (ACh)
  - Lowers heart rate and stroke volume
- Sympathetic innervation
  - Releases norepinephrine (NE)
  - Raises heart rate and stroke volume

Heart Dynamics

Autonomic Innervation of the Heart

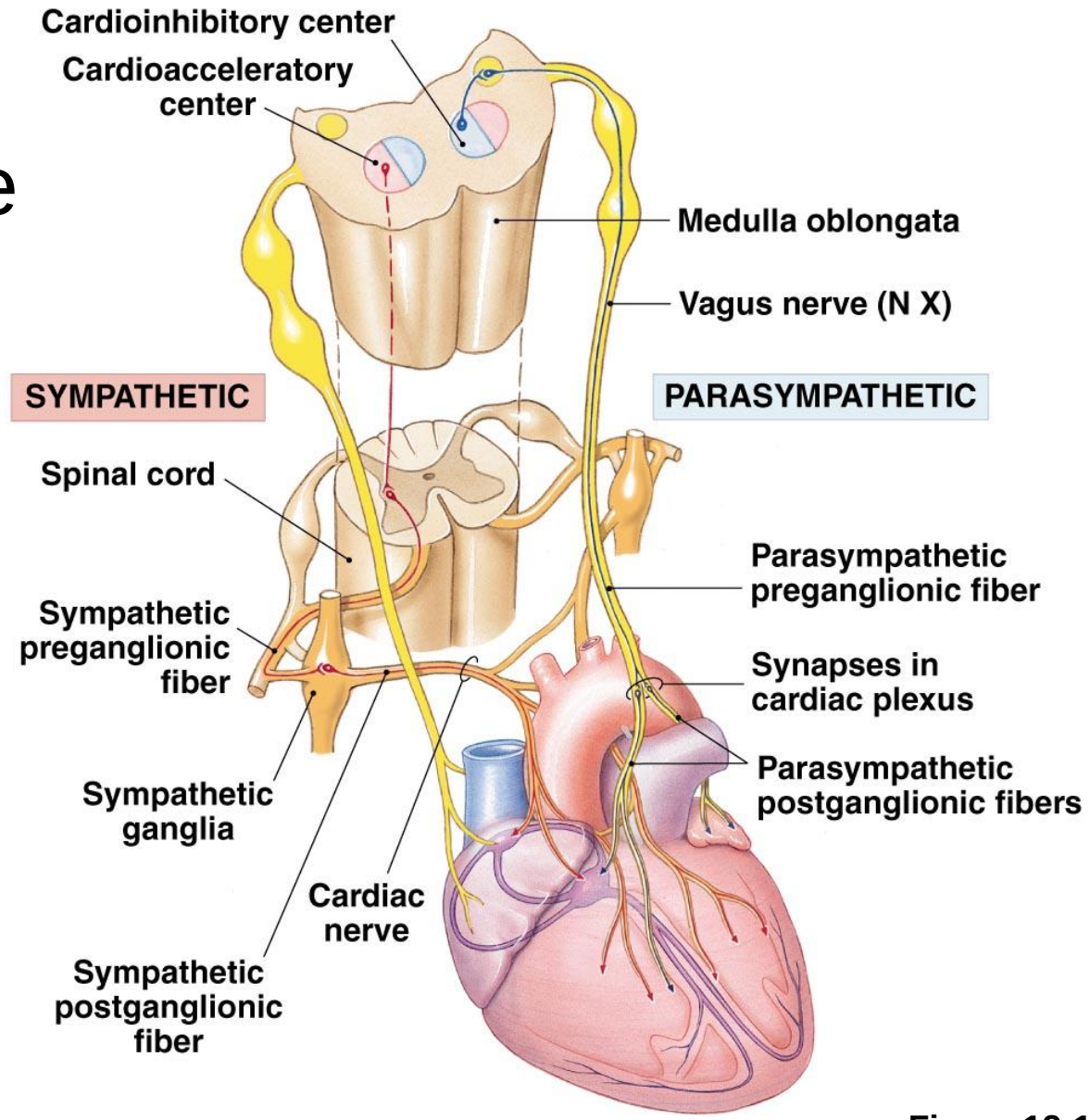


Figure 12-12

Heart Dynamics

Hormone Effects on Cardiac Output

- Adrenal medulla hormones
  - Epinephrine, norepinephrine released
  - Heart rate and stroke volume increased
- Other hormones that increase output
  - Thyroid hormones
  - Glucagon

Heart Dynamics

CNS Control of the Heart

- Basic control in *medulla oblongata*
  - *Cardioacceleratory center*
    - Activation of sympathetic neurons
  - *Cardioinhibitory center*
    - Governing of parasympathetic neurons
  - Other inputs
    - Higher centers
    - Blood pressure sensors
    - Oxygen, carbon dioxide sensors

Heart Dynamics

Key Note

Cardiac output is the amount of blood pumped by the left ventricle each minute. It is adjusted moment-to-moment by the ANS, and by circulating hormones, changes in blood volume and in venous return. A healthy person can increase cardiac output by three-fold to five-fold.