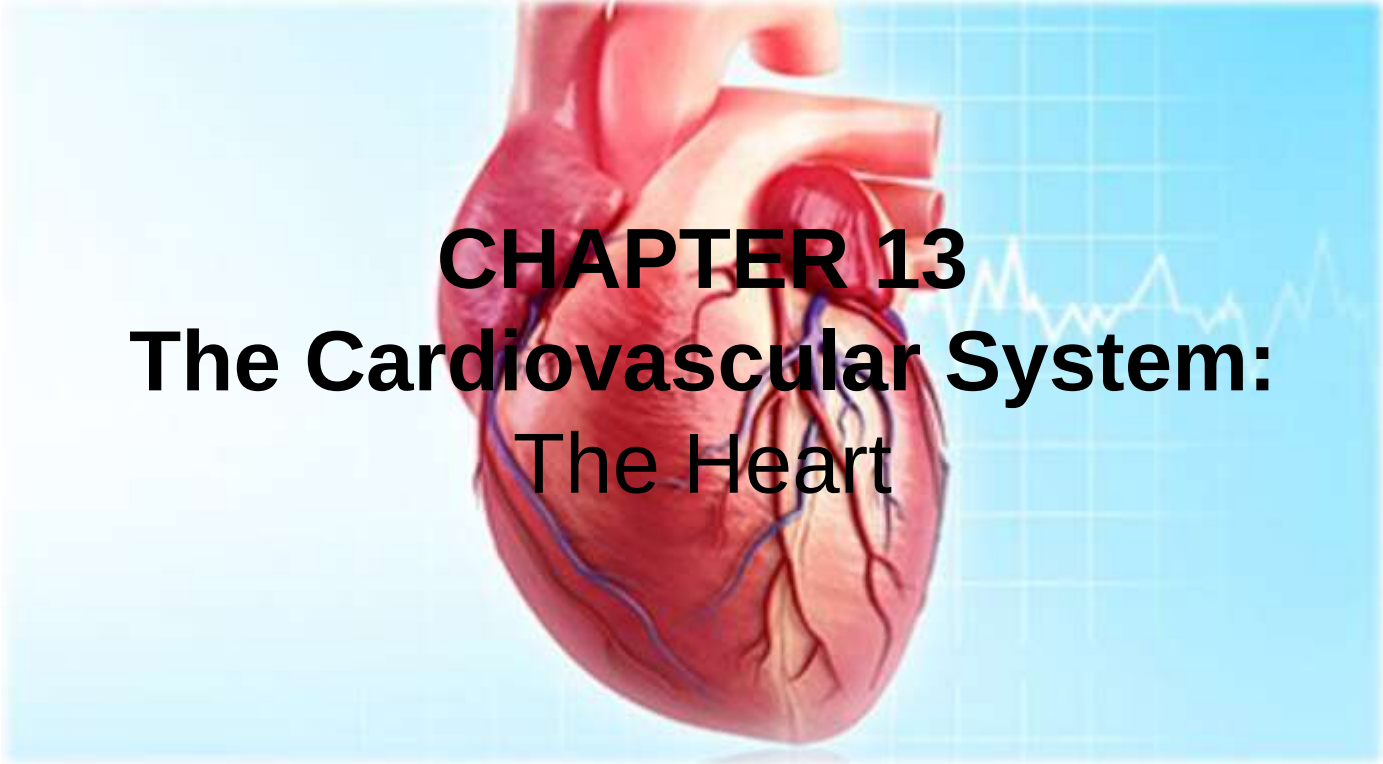




CHAPTER 13

The Cardiovascular System: The Heart

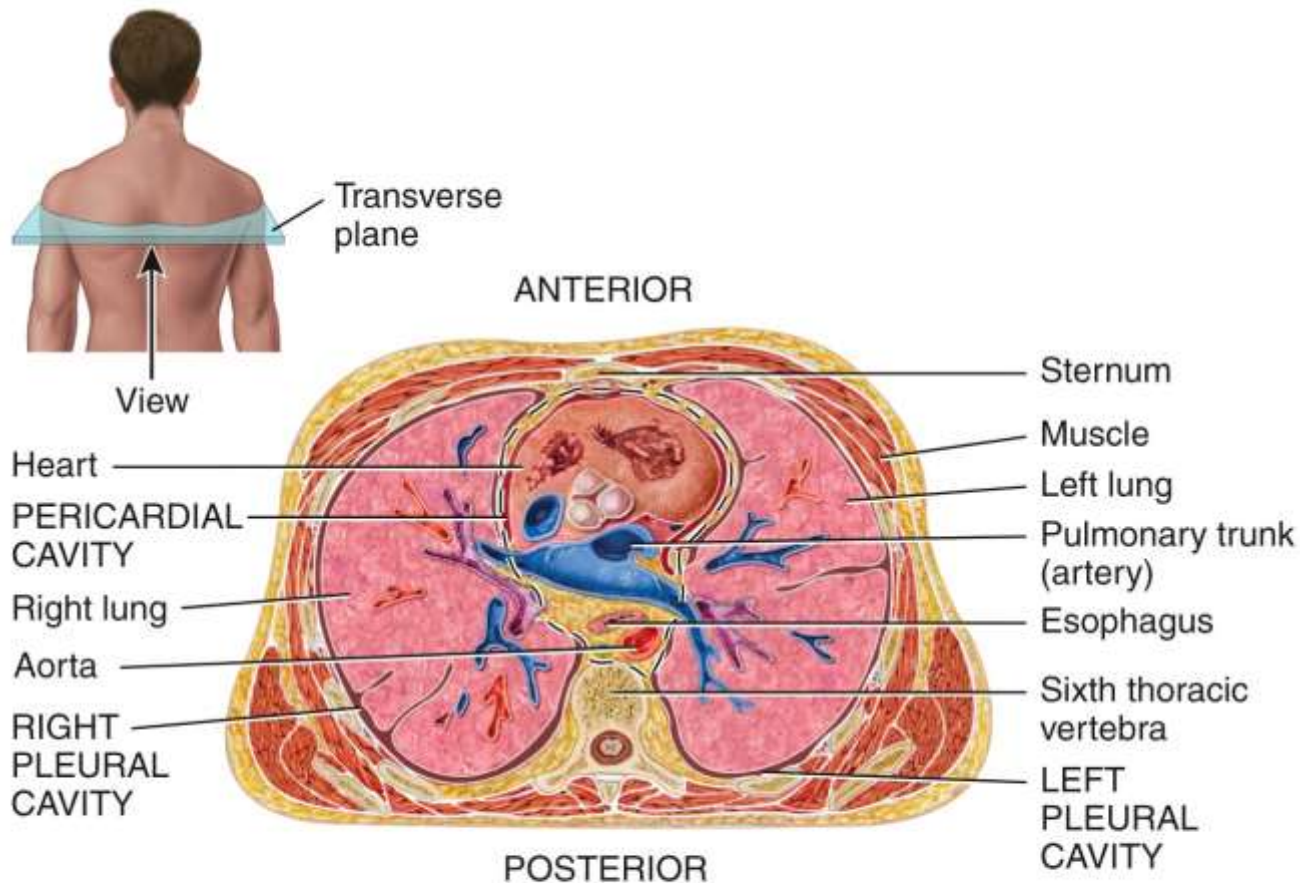
Introduction

- The heart
 - Beats about 100,000 times a day or 35 million times a year
 - Propels blood through approximately 120,000 km (75,000 mi) of vessels
 - Pumps about 5 liters of blood per minute
- Cardiology

Location and Surface Projection of the Heart

- Hollow, cone-shaped, and about the size of a closed fist
- Lies in the mediastinum
- Two-thirds of its mass is to the left of the midline
- Apex
- Base

Position of the Heart in the Mediastinum

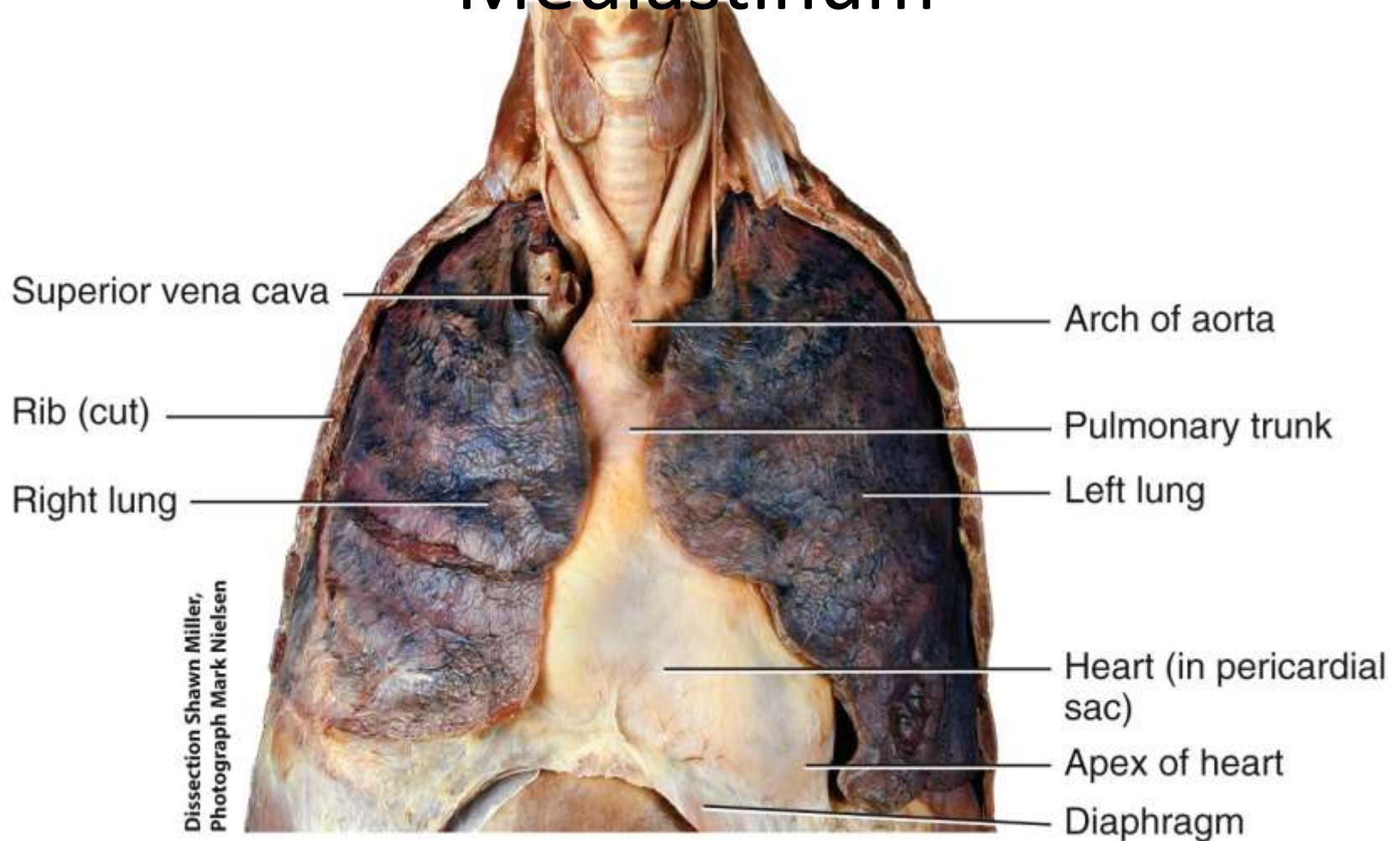


(a) Inferior view of transverse section of thoracic cavity showing the heart in the mediastinum

Location and Surface Projection of the Heart

- The surface projection is the outlined shape of an organ on the surface of the body.
- Anterior surface
- Inferior surface
- Right surface
- Left (pulmonary) surface

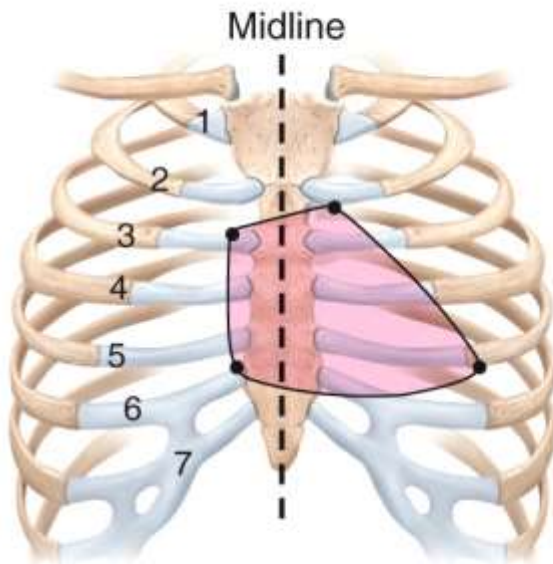
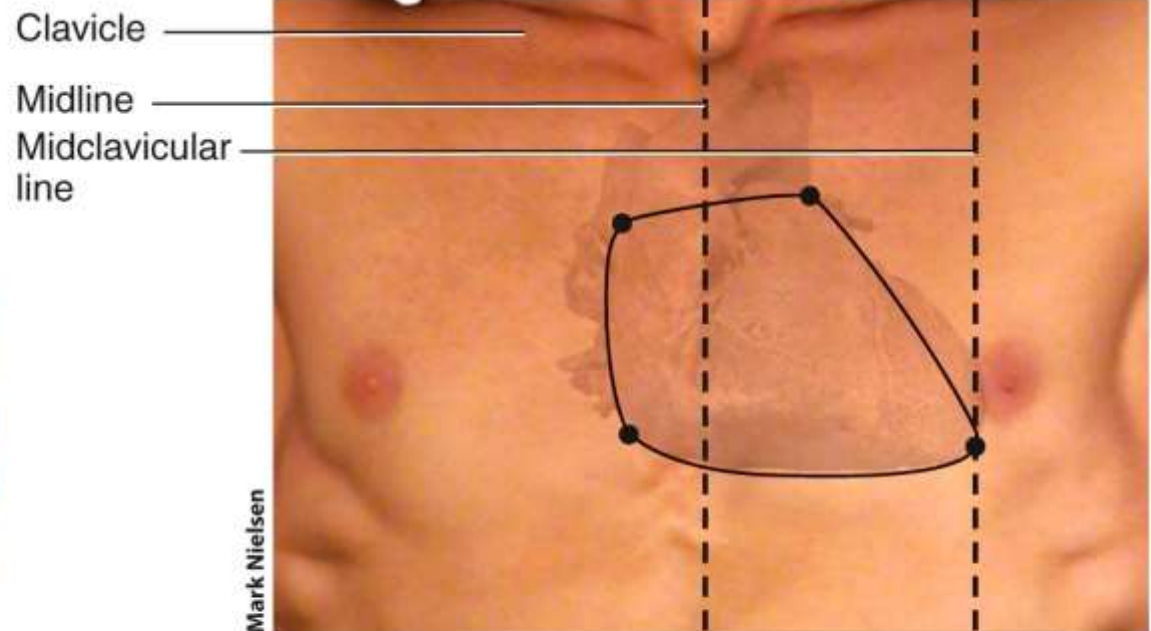
Position of the Heart in the Mediastinum



(c) Anterior view

Copyright © 2020, K. D. B. All rights reserved.

Position of the Heart in the Mediastinum



(d) Surface projection of the heart

Copyright © 2014 John Wiley & Sons, Inc. All rights reserved.

Clinical Connection

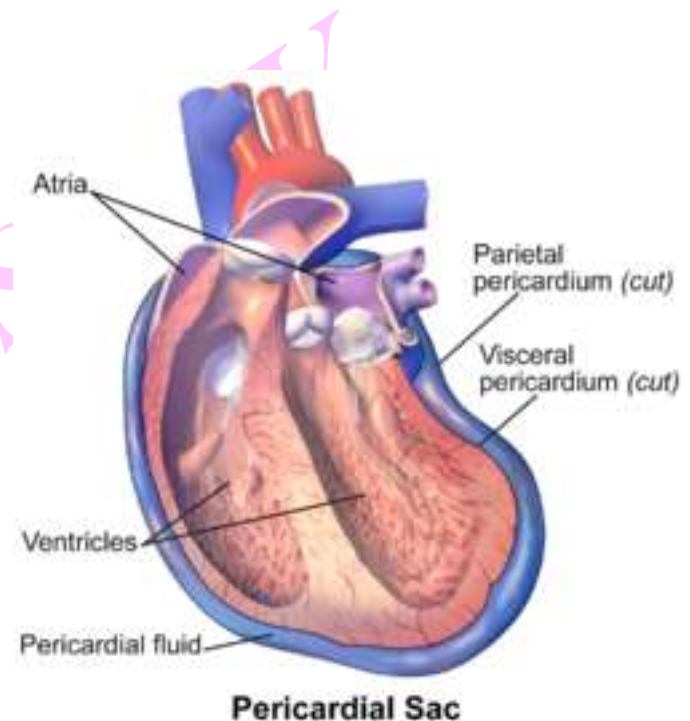
- Cardiopulmonary resuscitation (**CPR**): is an emergency procedure that combines chest compressions often with artificial ventilation in an effort to manually preserve intact brain function until further measures are taken to restore spontaneous blood circulation and breathing in a person who is in cardiac arrest

Structure and Function of the Heart

- **Pericardium:** is a double-walled sac containing the heart and the roots of the great vessels.

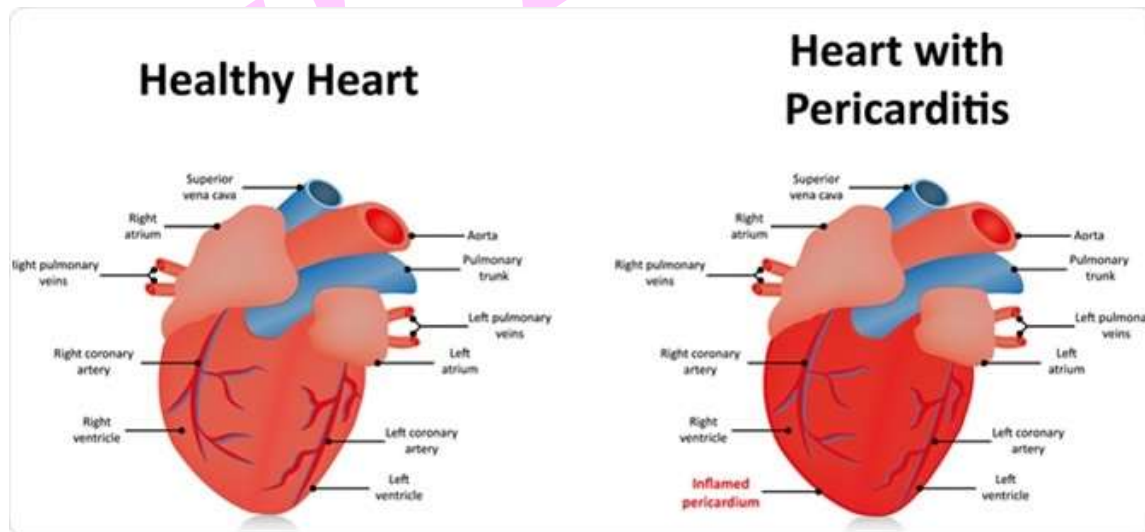
The pericardial sac has two layers, a serous layer and a fibrous layer. It encloses the pericardial cavity which contains pericardial fluid.

- Fibrous pericardium
 - Serous pericardium
- Pericardial cavity



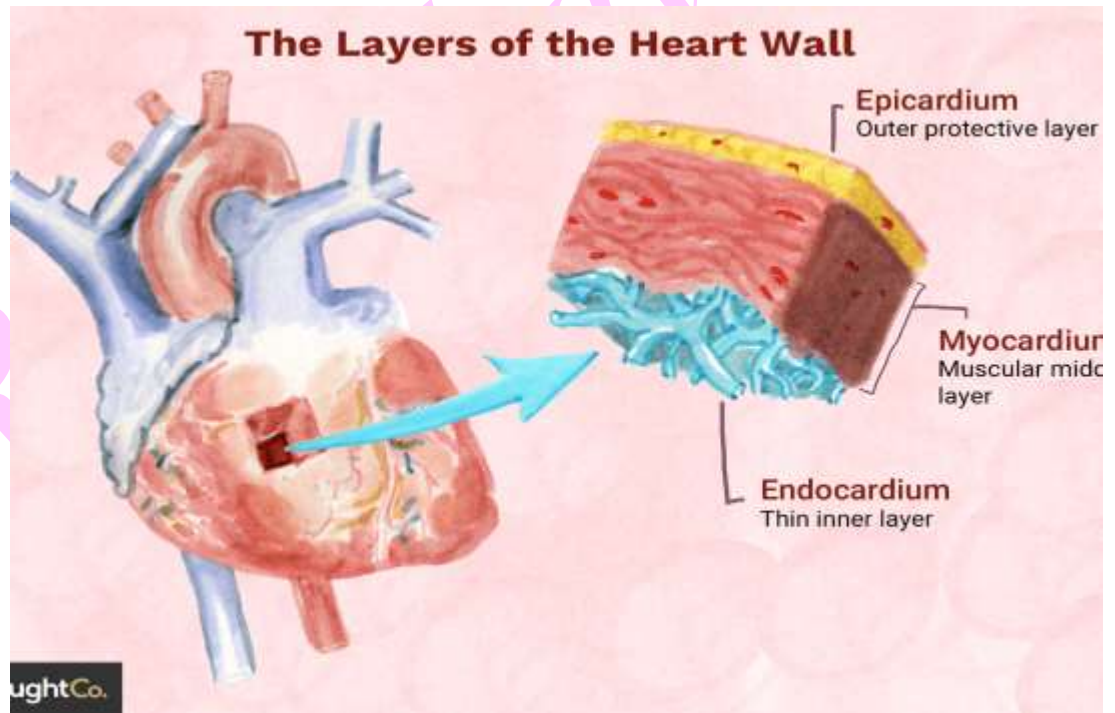
Clinical Connection

- **Pericarditis:** is swelling and irritation of the pericardium, the thin saclike membrane surrounding your heart. Pericarditis often causes chest pain and sometimes other symptoms. The sharp chest pain associated with pericarditis occurs when the irritated layers of the pericardium rub against each other

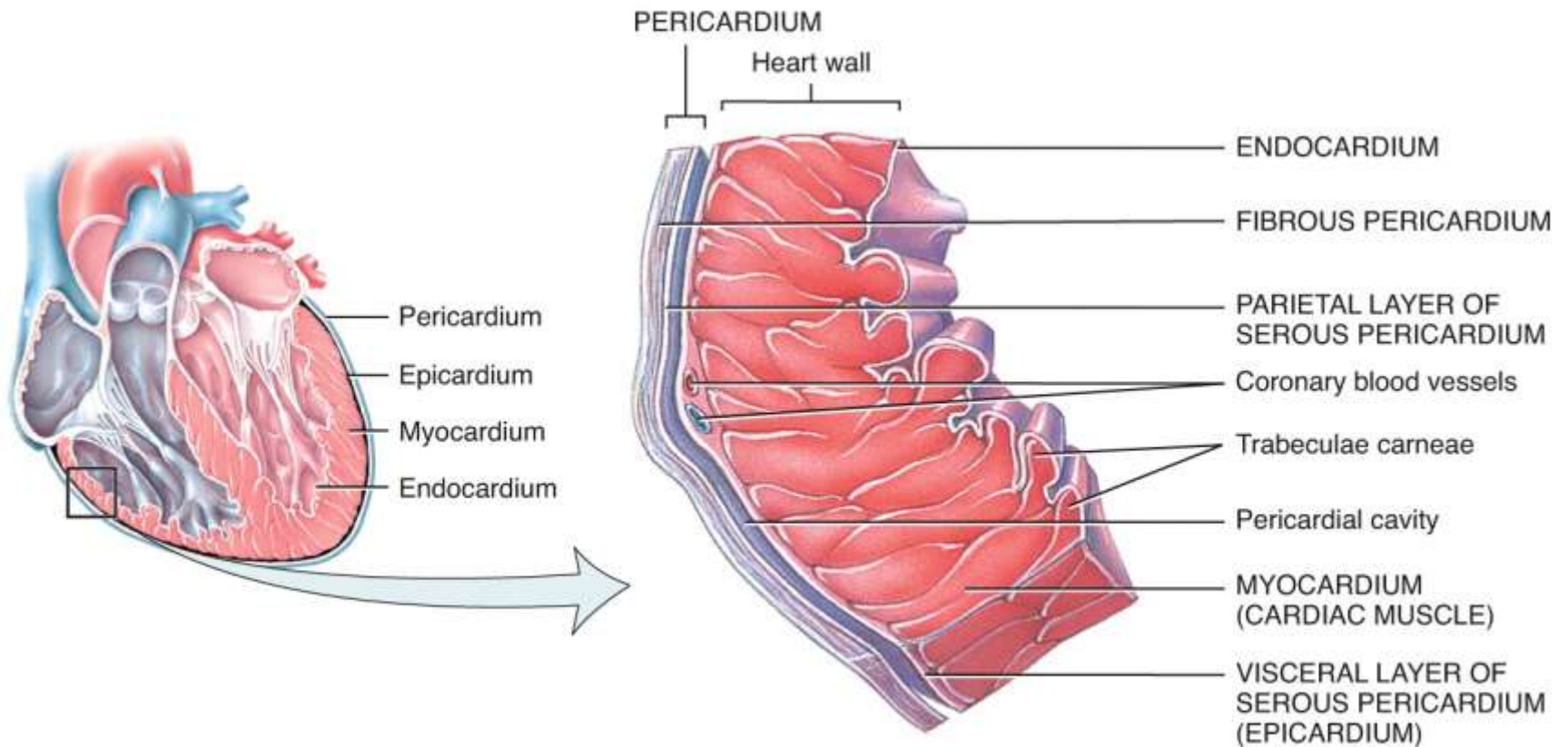


Layers of the Heart Wall

- Epicardium
- Myocardium
- Endocardium



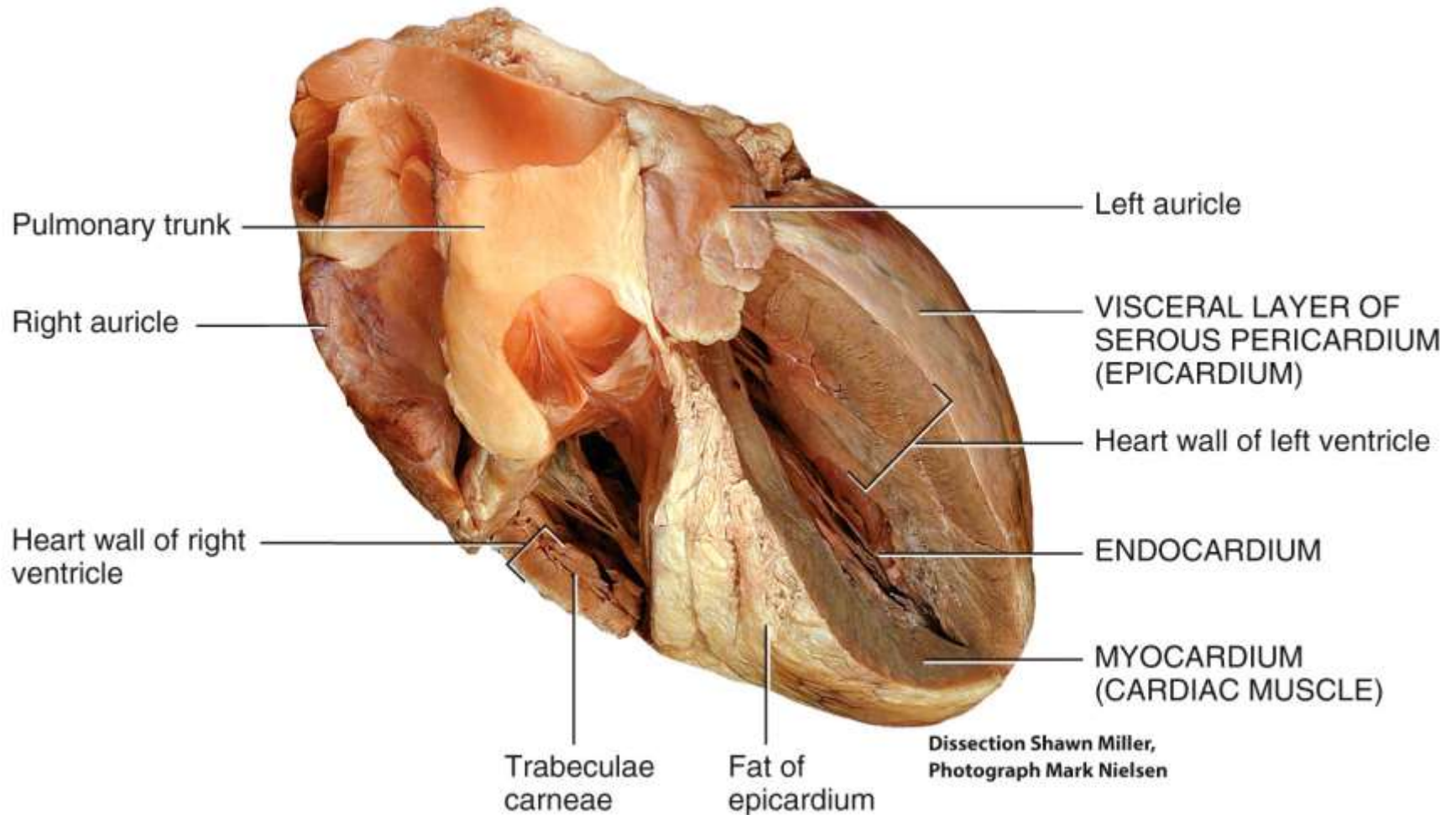
Pericardium and Heart Wall



(a) Portion of pericardium and right ventricular heart wall showing the divisions of the pericardium and layers of the heart wall

Copyright © 2014 John Wiley & Sons, Inc. All rights reserved.

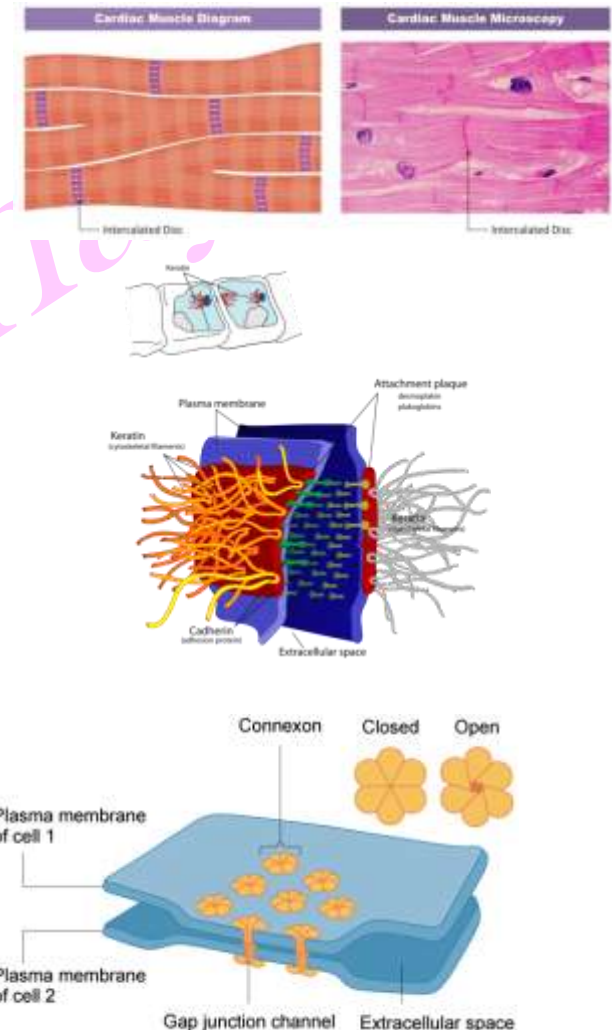
Pericardium and Heart Wall



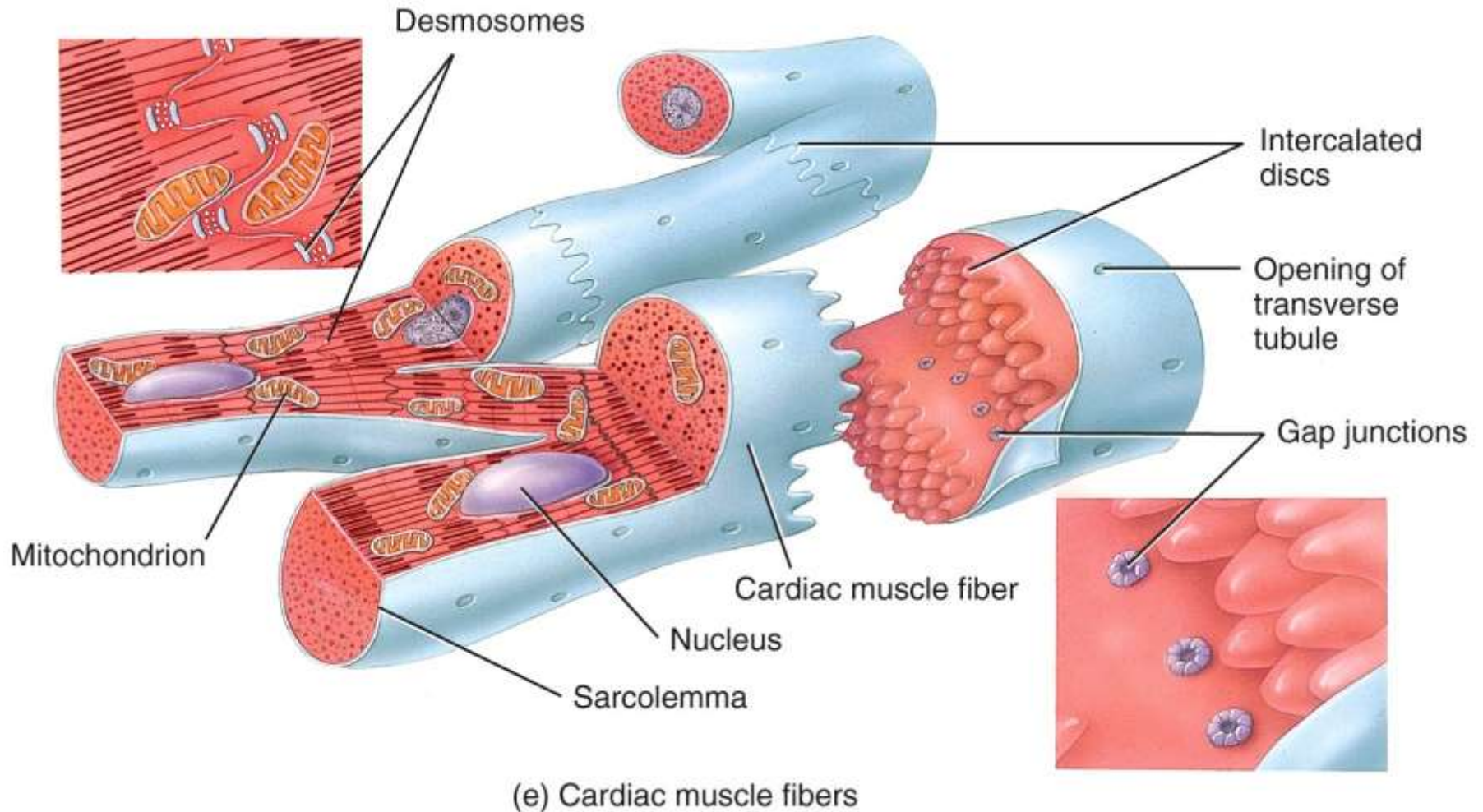
(b) Anterior view of layers of the heart wall

Structure and Function of the Heart

- **Cardiac muscle characteristics:**
 - **Intercalated discs:** are unique structural formations found between the myocardial cells of the heart. They play vital roles in bonding cardiac muscle cells together and in transmitting signals between cells.
 - **Desmosomes:** a structure by which two adjacent cells are attached, formed from protein plaques in the cell membranes linked by filaments.
 - **Gap junctions:** are a specialized intercellular connection between a multitude of animal cell-types. They directly connect the cytoplasm of two cells, which allows various molecules, ions and electrical impulses to directly pass through a regulated gate between cells.

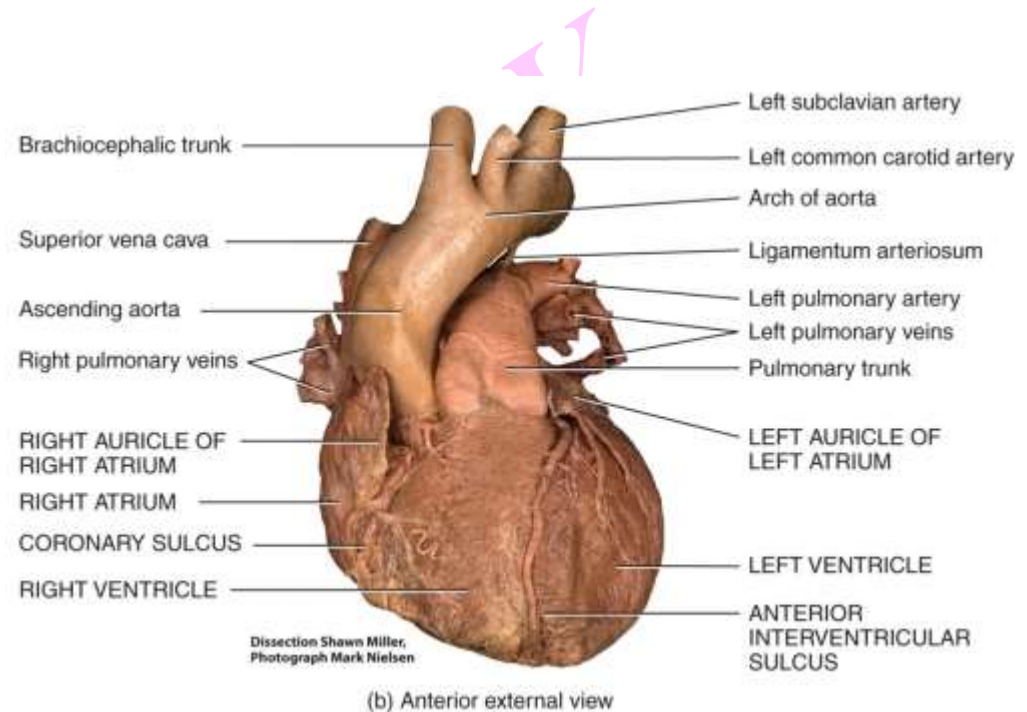


Pericardium and Heart Wall



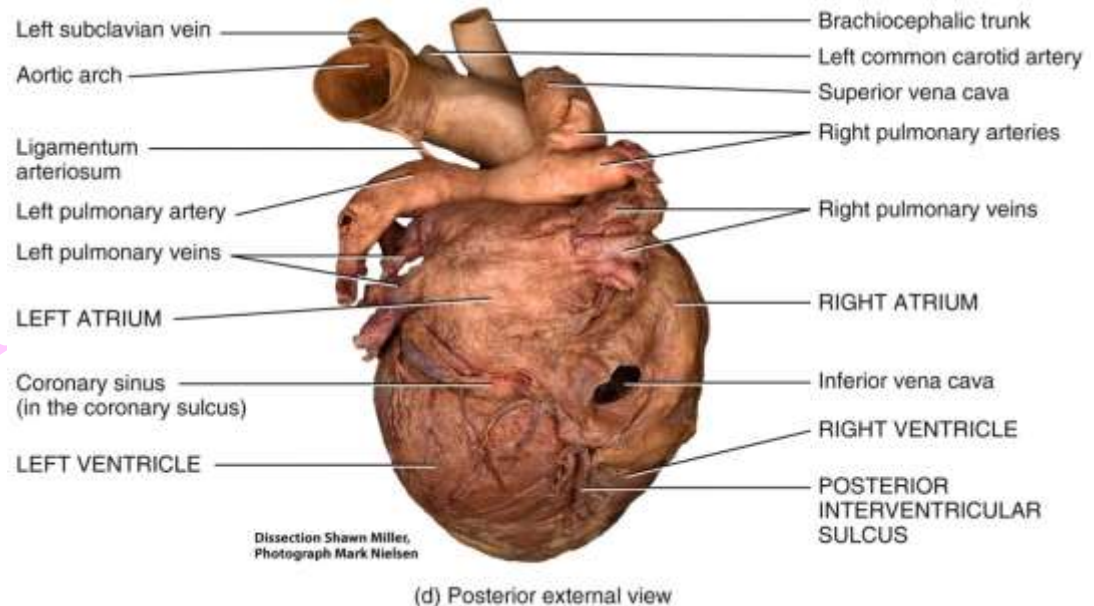
Chambers of the Heart

- Two superior chambers (atria)
- Two inferior chambers (ventricles)
- Pulmonary pump
- Systemic pump
- Auricles

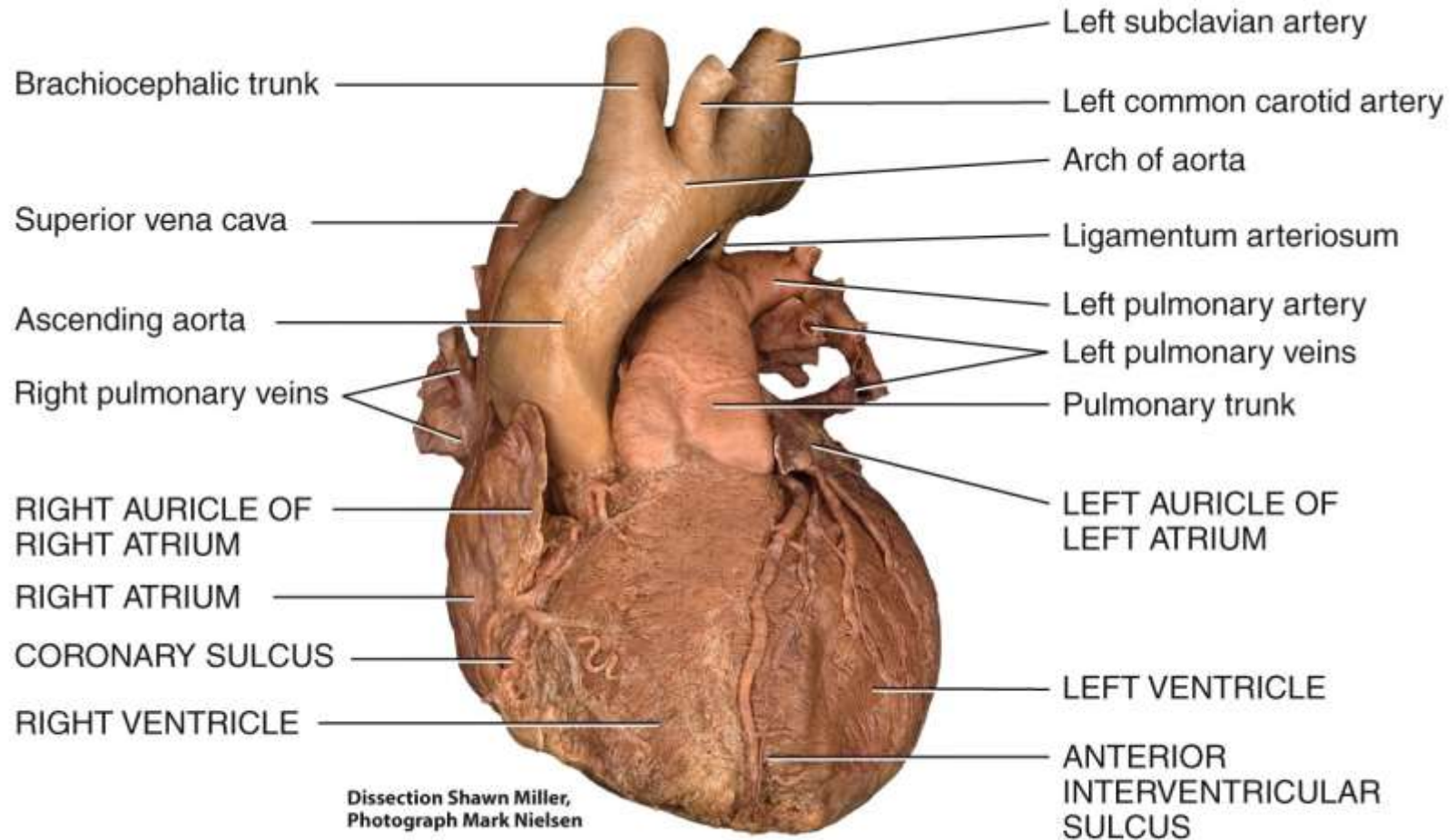


Chambers of the Heart

- The heart has three major surface markings, or grooves, called sulci.
 - Coronary sulcus
 - Anterior interventricular sulcus
 - Posterior interventricular sulcus



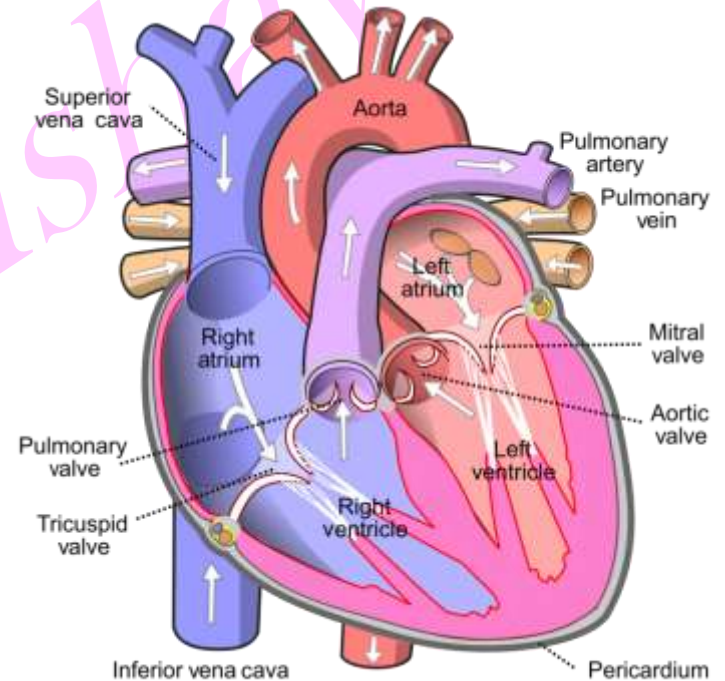
Structure of the Heart: Surface Features



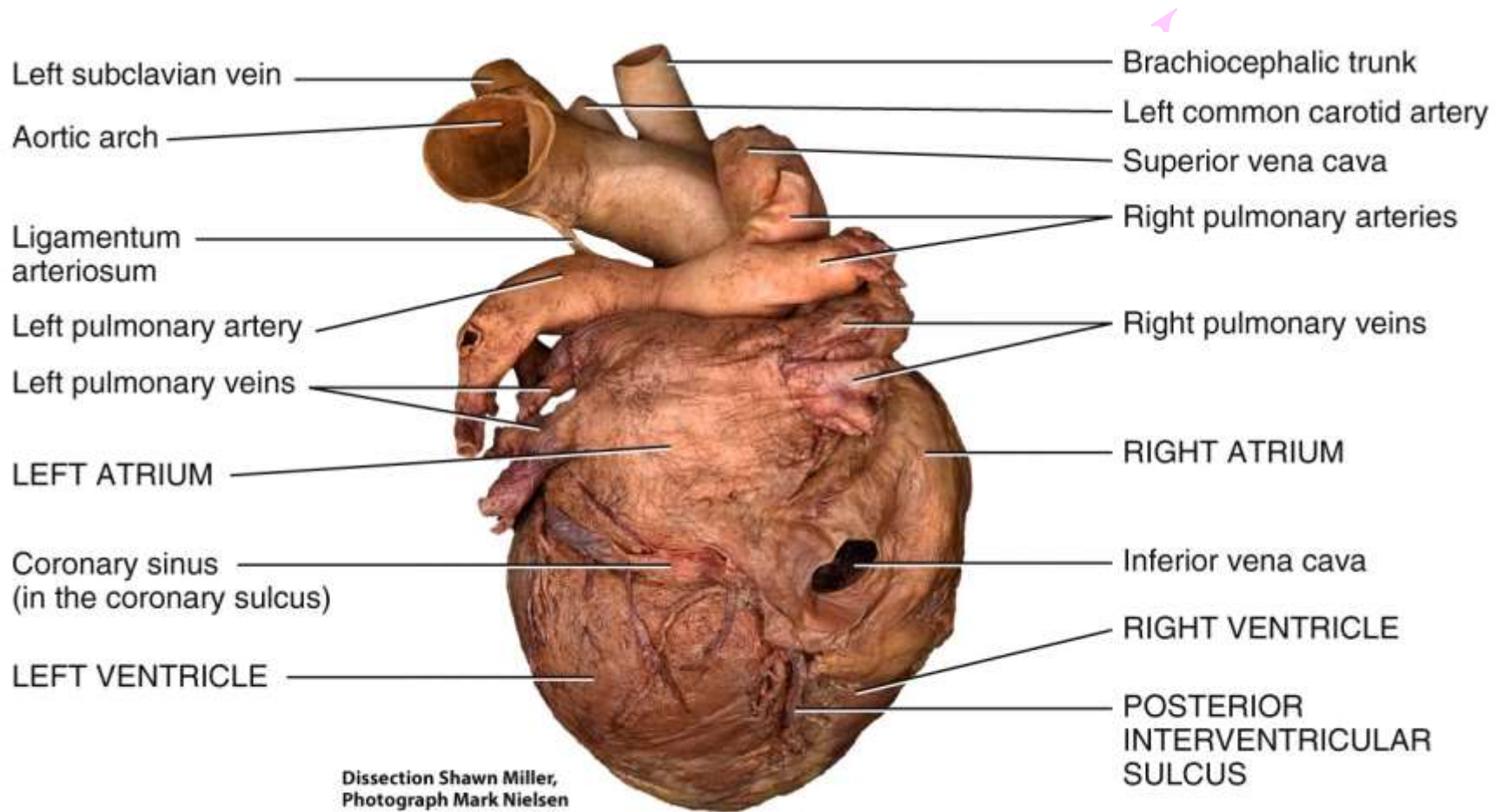
(b) Anterior external view

Right Atrium

- Receives deoxygenated blood from three veins:
 - Superior vena cava (SVC)
 - Inferior vena cava (IVC)
 - Coronary sinus



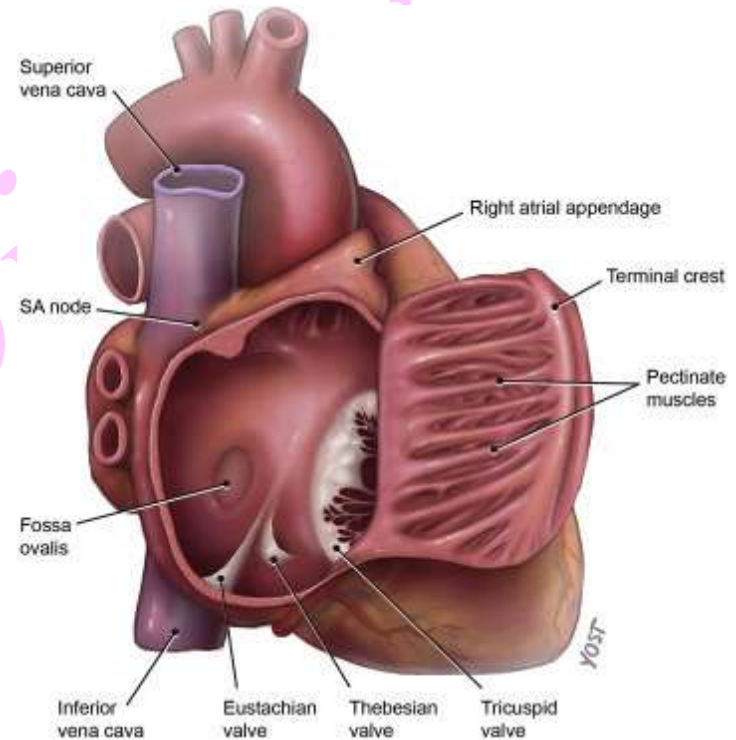
Structure of the Heart: Surface Features



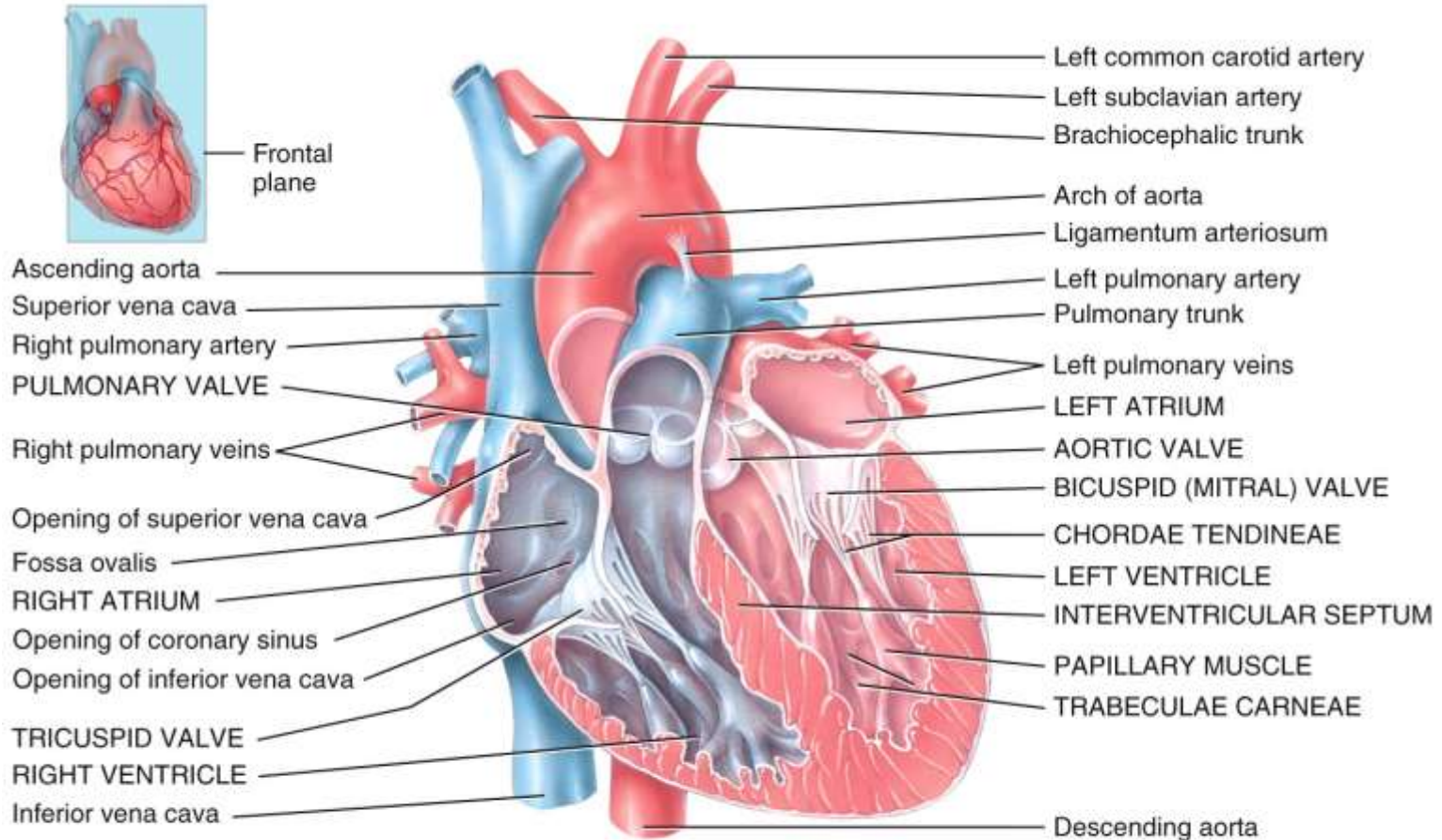
(d) Posterior external view

Right Atrium

- Pectinate muscles are internal muscular ridges on the atrial wall.
- Interatrial septum (wall)
- Fossa ovalis
- Tricuspid valve (or right atrioventricular valve)

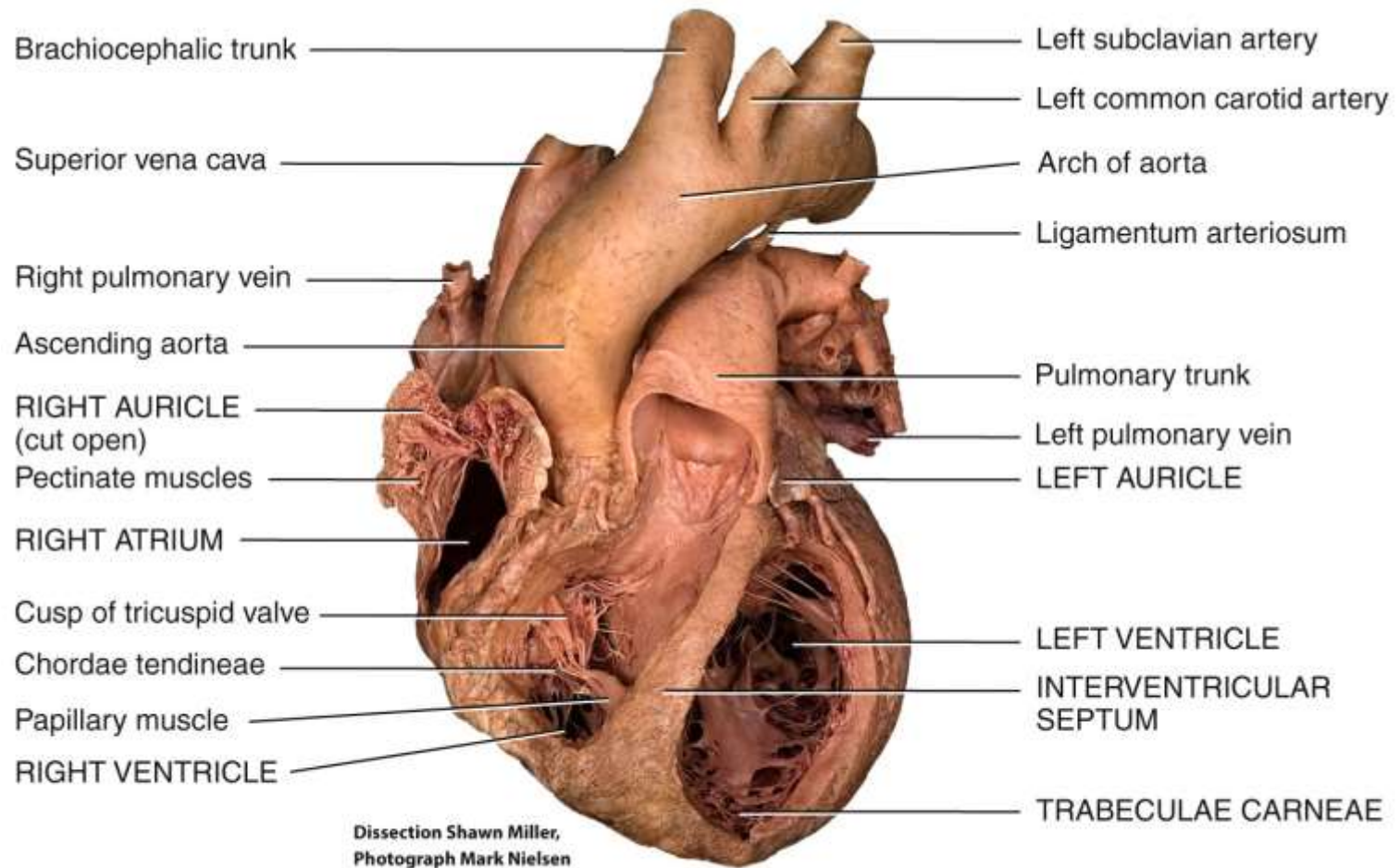


Structure of the Heart: Internal Anatomy



(a) Anterior view of frontal section showing internal anatomy

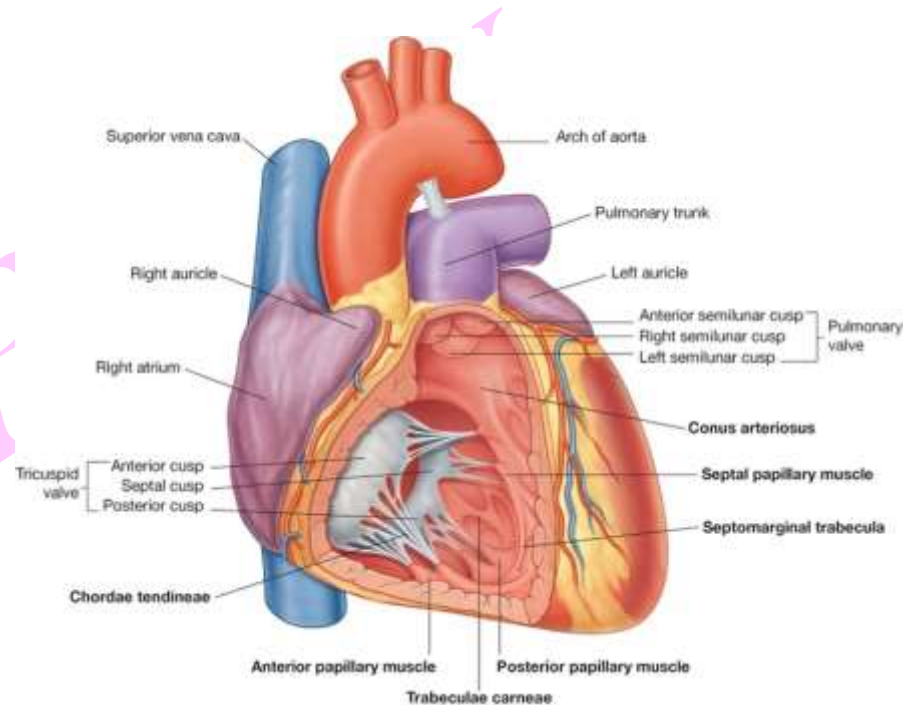
Structure of the Heart: Internal Anatomy



(b) Anterior view of partially sectioned heart

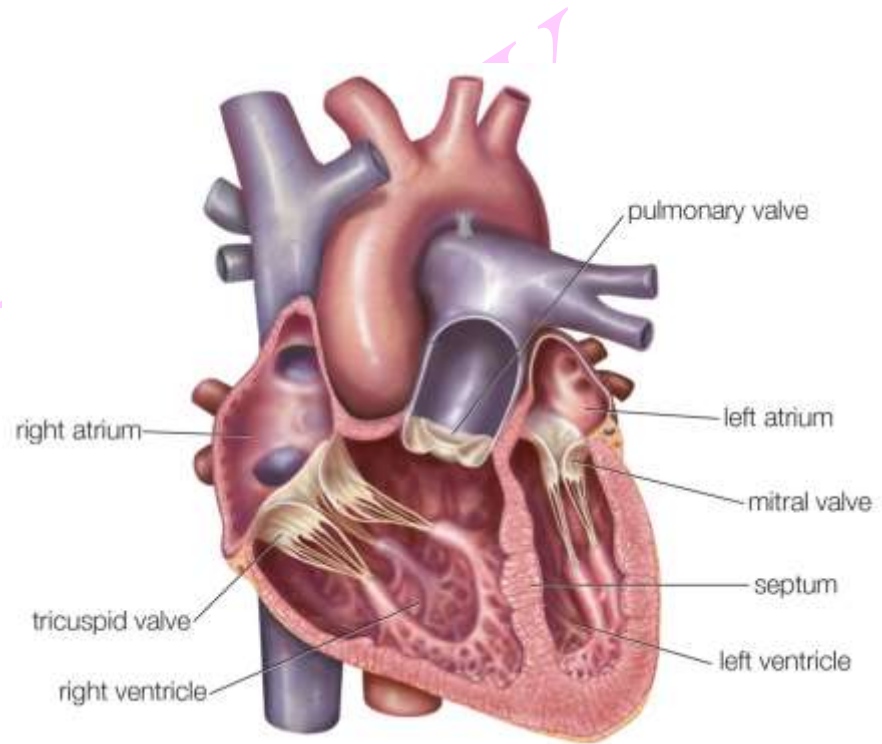
Right Ventricle

- Forms most of the anterior surface of heart
- Trabeculae carneae
- Chordae tendineae
- Interventricular septum
- Pulmonary valve
- Pulmonary trunk



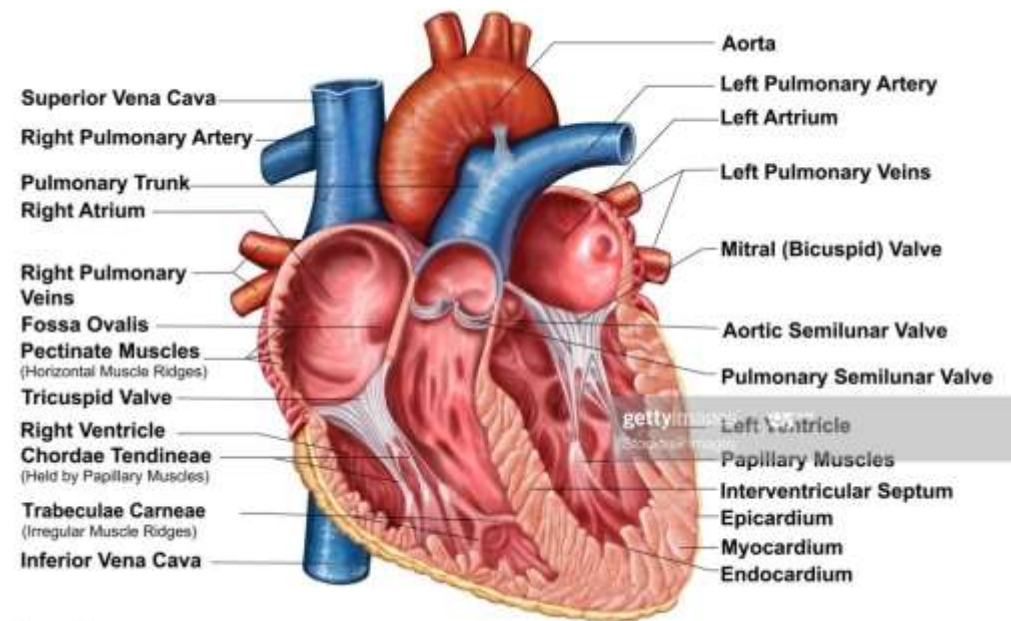
Left Atrium

- Forms most of the base of the heart
- Pulmonary veins (two from each lung)
- Bicuspid (mitral) valve
 - Also called left atrio-ventricular valve



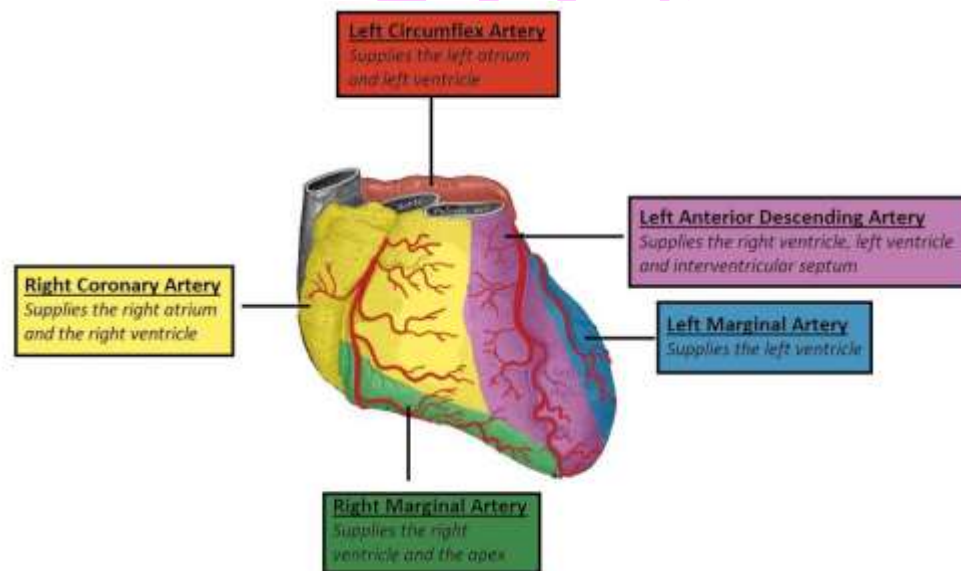
Left Ventricle

- Thickest part of the heart
- Contains trabeculae carneae and chordae tendineae
- Blood passes from the left ventricle into the aorta.



Left Ventricle

- Right and left coronary
- Rest of the blood passes into the arch of the aorta and descending aorta
- Ductus arteriosus



DUCTUS ARTERIOSUS

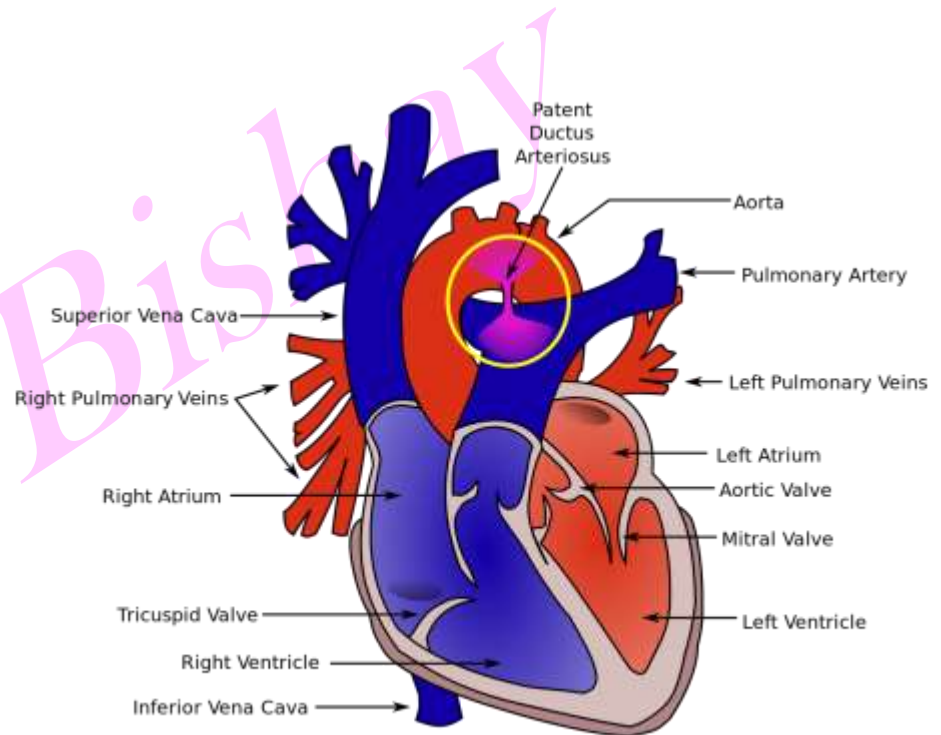
The **ductus arteriosus**, also called the **ductus Botalli**, is a blood vessel in the developing fetus connecting the trunk of the pulmonary artery to the proximal descending aorta. It allows most of the blood from the right ventricle to bypass the fetus's fluid-filled non-functioning lungs.

Source: pulmonary artery

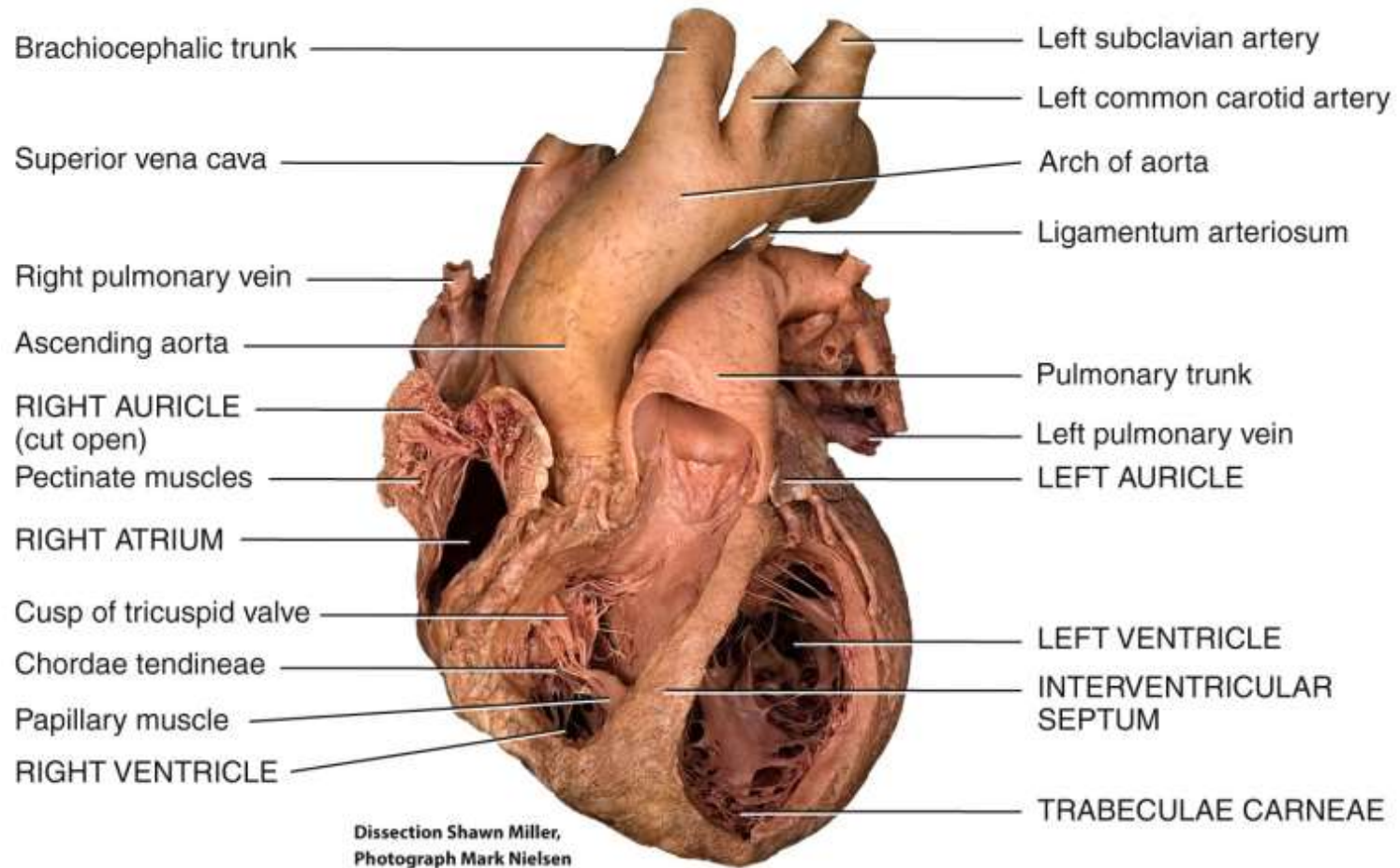
Branches: descending aorta

Vein: ductus venosus

System: Fetal circulation



Structure of the Heart: Internal Anatomy



(b) Anterior view of partially sectioned heart

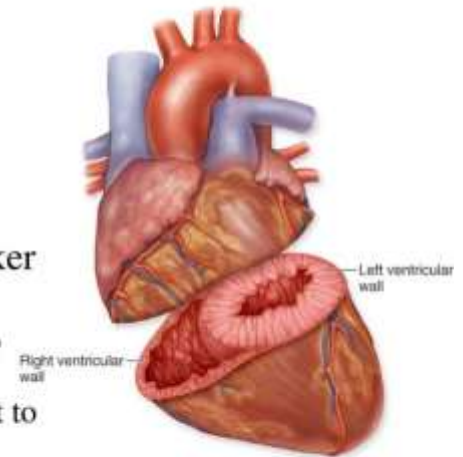
Myocardial Thickness and Function

- Atria characteristics
- Ventricle characteristics
- The myocardium is the thickest layer of the heart wall, with its thickness varying in different parts of the heart.

The myocardium of the left ventricle is the thickest, as this ventricle is responsible for generating the power needed to pump oxygenated blood from the heart to the rest of the body

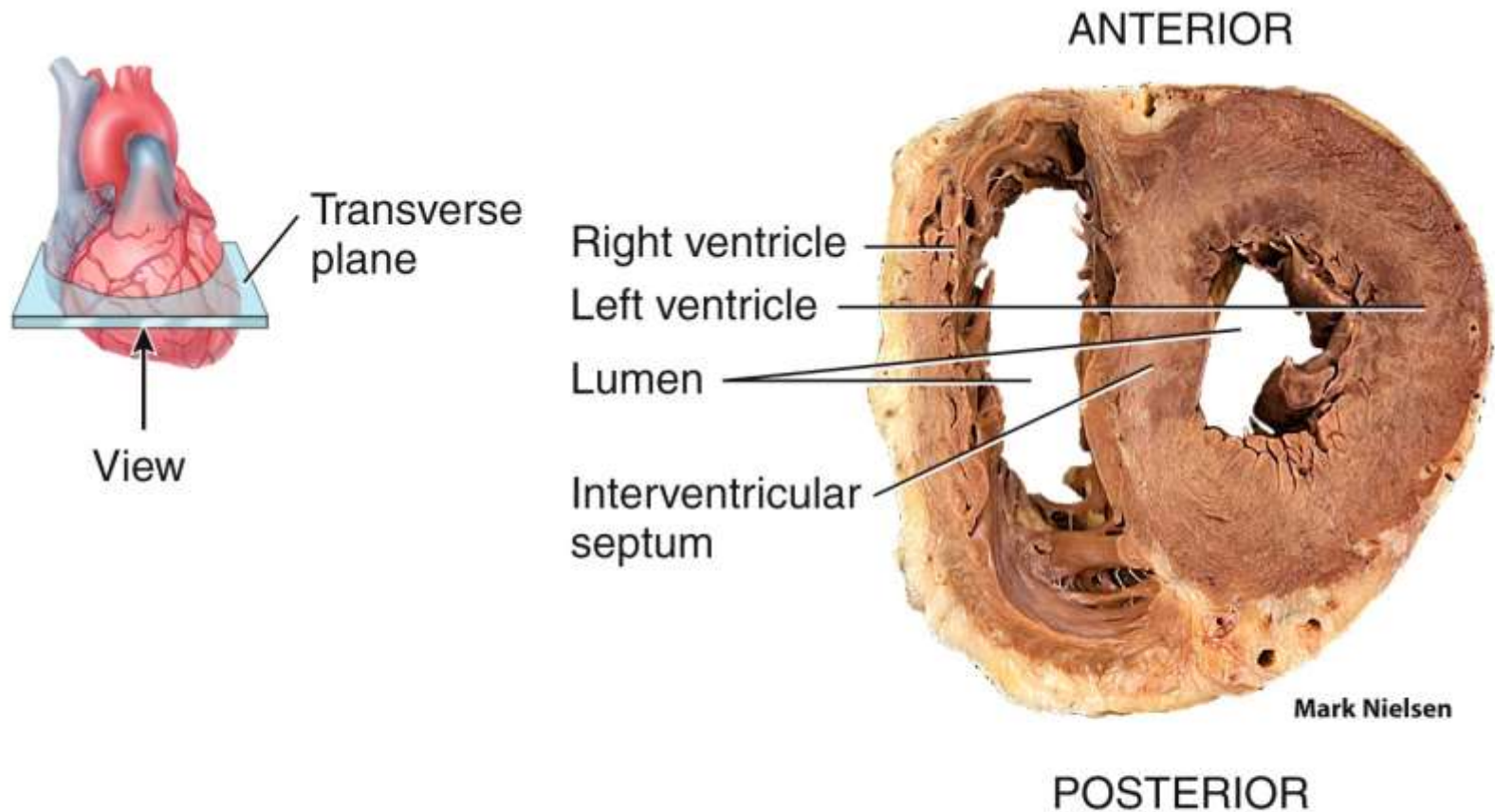
Myocardial Thickness and Function

- Thickness of myocardium varies according to the function of the chamber
- Atria are thin walled, deliver blood to adjacent ventricles
- Ventricle walls are much thicker and stronger
 - right ventricle supplies blood to the lungs (little flow resistance)
 - left ventricle wall is the thickest to supply systemic circulation



14-17

Structure of the Heart: Internal Anatomy

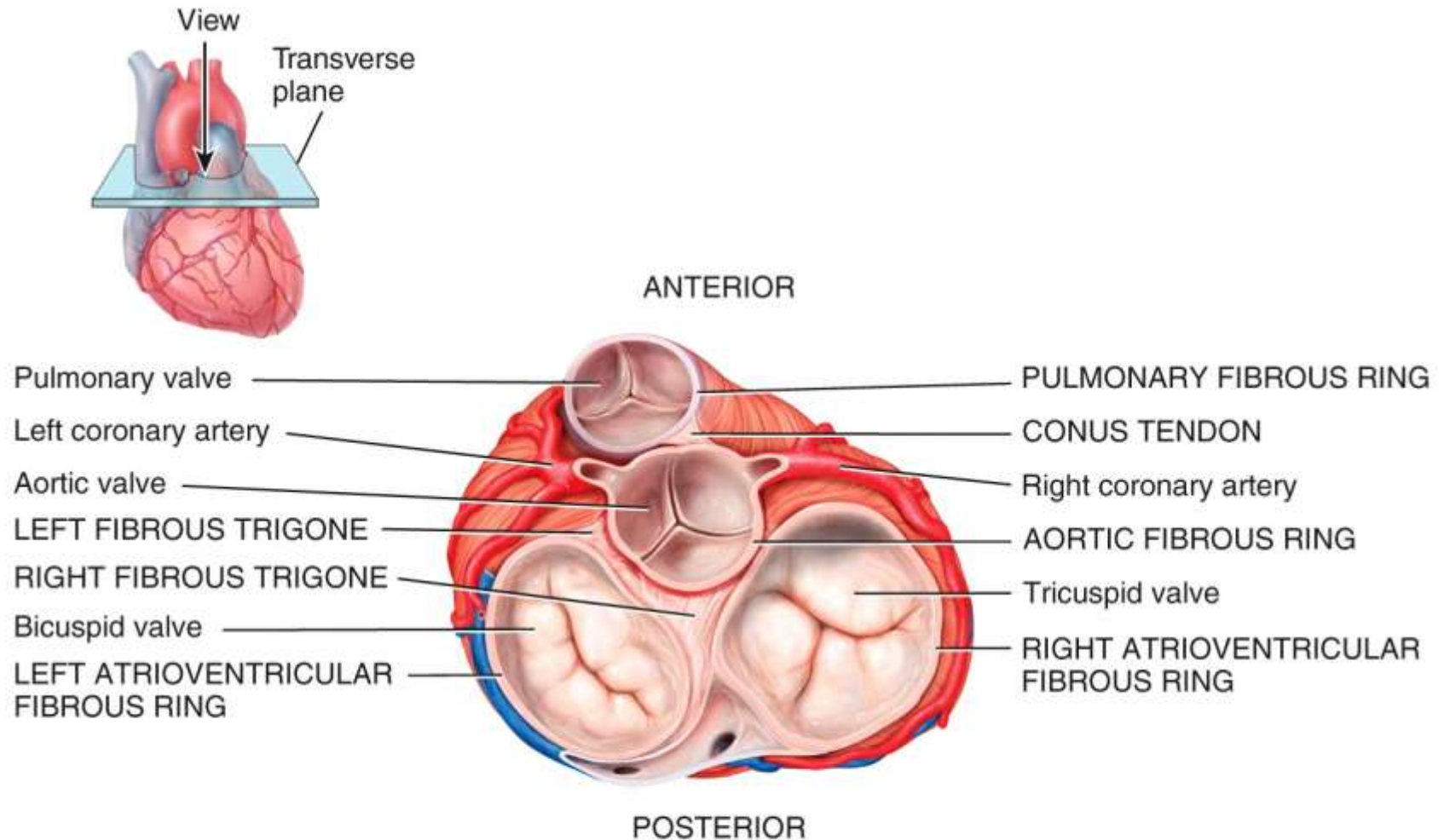


(c) Inferior view of transverse section showing differences in thickness of ventricular walls

Fibrous Skeleton of the Heart

- Four rings
 - Pulmonary fibrous ring
 - Aortic fibrous ring
 - Right atrioventricular fibrous ring
 - Left atrioventricular fibrous ring

Fibrous Skeleton of the Heart

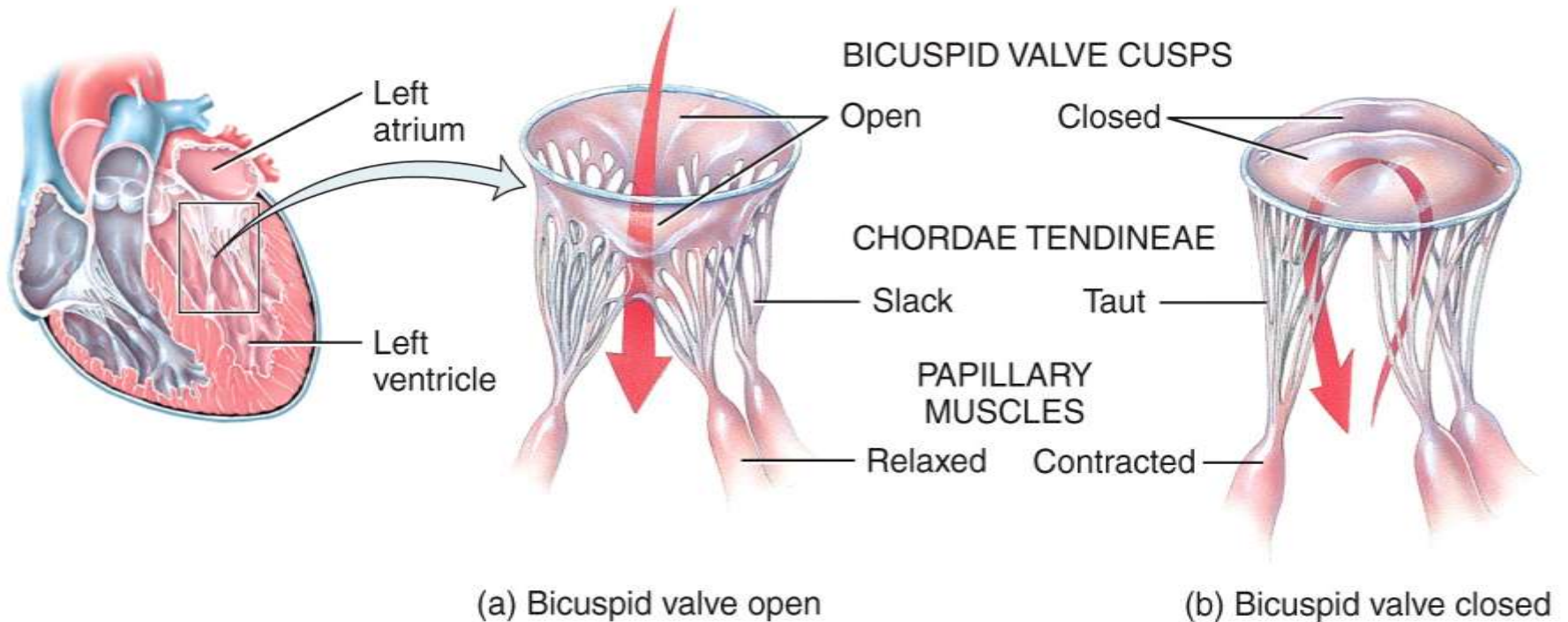


Superior view (the atria have been removed)

Atrioventricular Valves

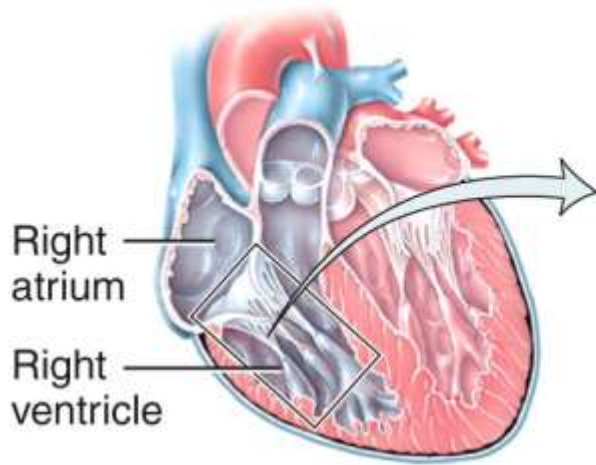
- There are four valves that prevent backflow of blood in the heart after blood passes through them.

Valves of the Heart

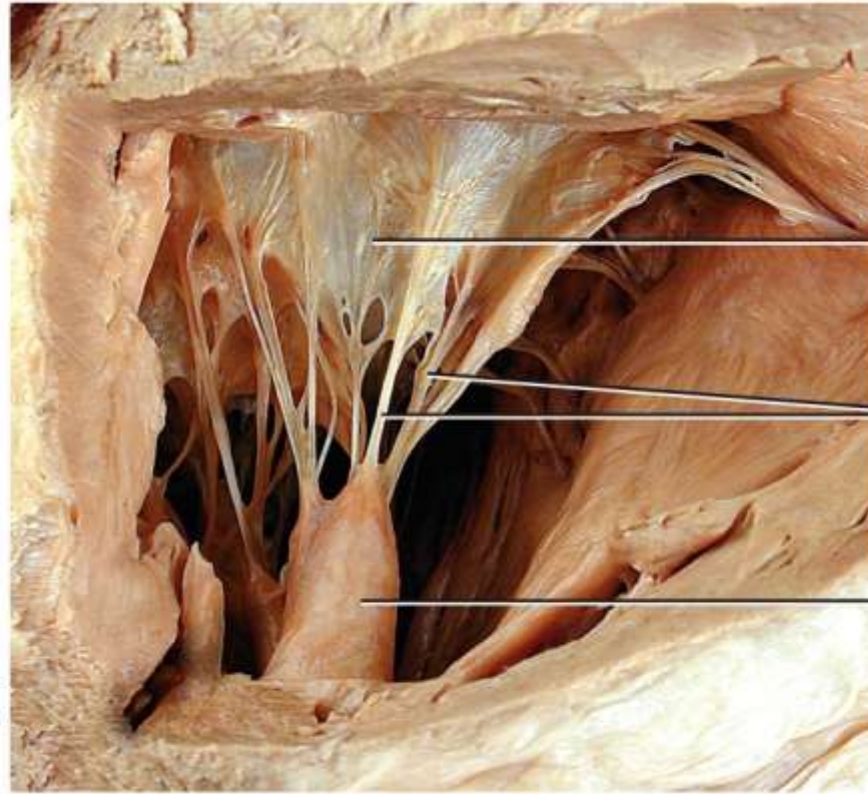


Copyright © 2014 John Wiley & Sons, Inc. All rights reserved.

Valves of the Heart



Dissection Shawn Miller,
Photograph Mark Nielsen



Cusp of
tricuspid
valve

Chordae
tendineae

Papillary
muscle

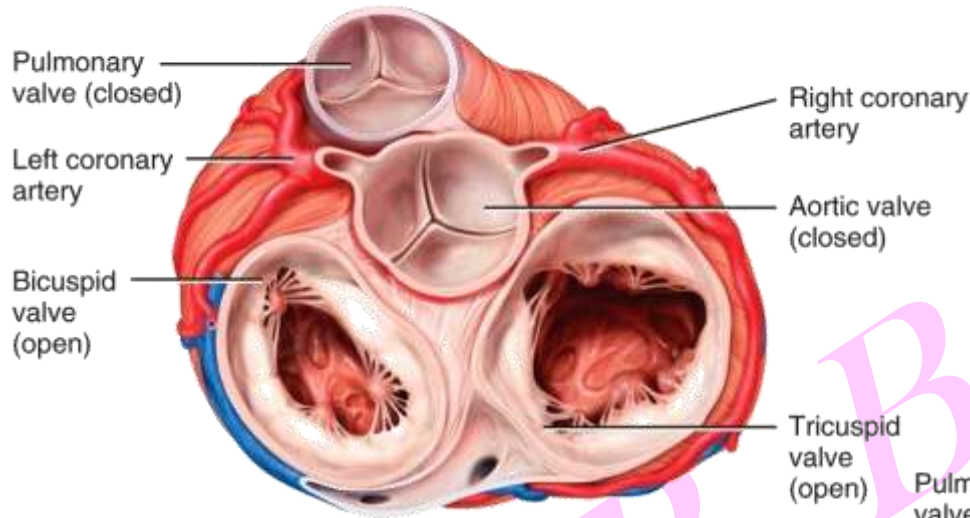
(c) Tricuspid valve open

Semilunar Valves

- Two semilunar (SL) valves
 - Allow ejection of blood from the ventricles
 - Prevent backflow of blood into the heart
- Pulmonary valve
- Aortic valve

Valves of the Heart

ANTERIOR

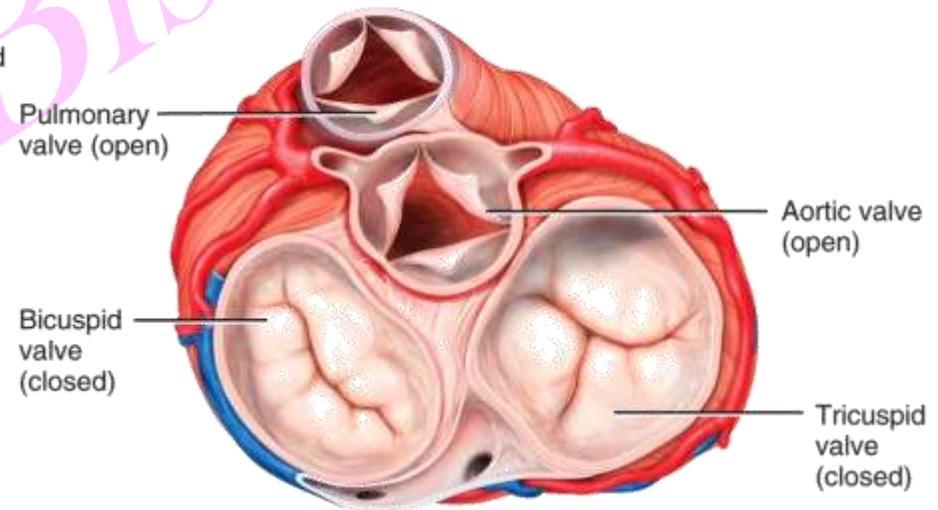


POSTERIOR

(d) Superior view with atria removed: pulmonary and aortic valves closed, bicuspid and tricuspid valves open

Copyright © 2014 John Wiley & Sons, Inc. All rights reserved.

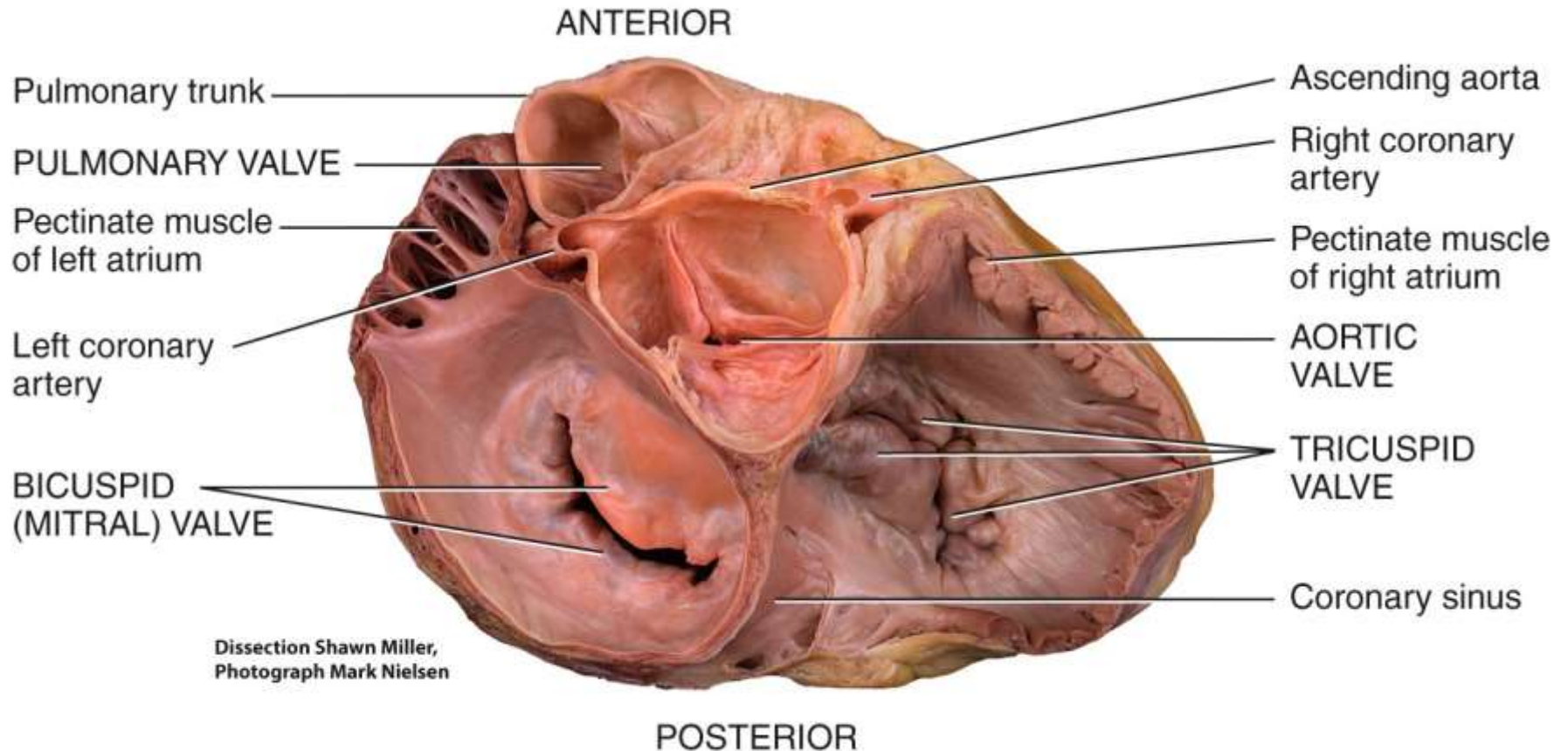
ANTERIOR



POSTERIOR

(e) Superior view with atria removed: pulmonary and aortic valves open, bicuspid and tricuspid valves closed

Valves of the Heart



(f) Superior view of atrioventricular and semilunar valves

Clinical Connection

- **Heart valve disorders**
 - **Stenosis:** Aortic stenosis is one of the most common and most serious valve disease problems. Aortic stenosis is a narrowing of the aortic valve opening. Aortic stenosis restricts the blood flow from the left ventricle to the aorta and may also affect the pressure in the left atrium
 - **Mitral valve prolapse (MVP):** Mitral valve prolapse (MVP) is a valvular heart disease characterized by the displacement of an abnormally thickened mitral valve leaflet into the left atrium during systole. It is the primary form of myxomatous degeneration of the valve.
 - **Aortic insufficiency:** (AI), also known as aortic regurgitation (AR), is the leaking of the aortic valve of the heart that causes blood to flow in the reverse direction during ventricular diastole, from the aorta into the left ventricle. As a consequence, the cardiac muscle is forced to work harder than normal.

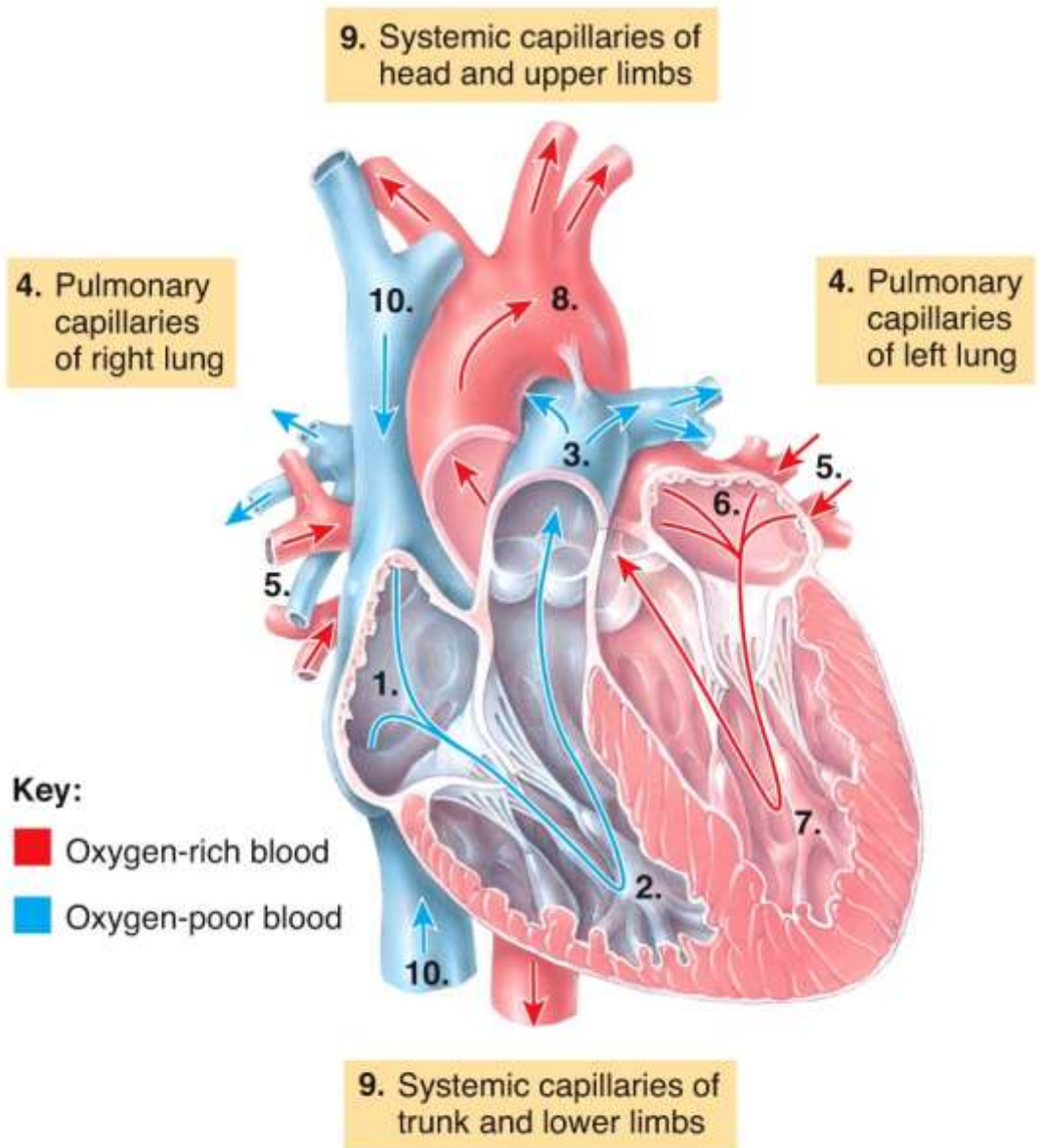
Circulation of Blood

- The heart pumps blood into two circuits arranged in series (connected end to end).
- Systemic circulation
 - The left ventricle pumps this blood into the aorta, which branches into systemic arteries.
 - **Arterioles**

Circulation of Blood

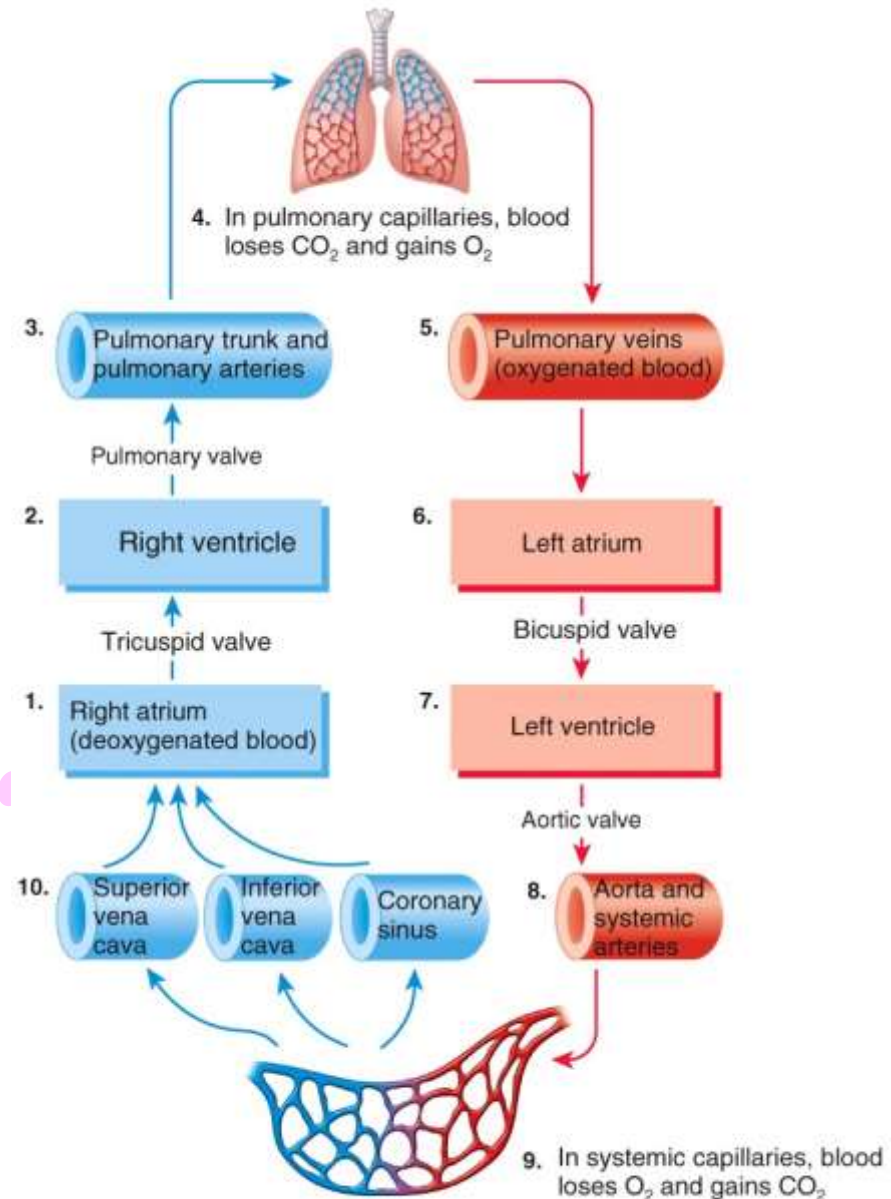
- Pulmonary circulation
 - Pulmonary capillaries
 - **Pulmonary veins**

Systemic and Pulmonary Circulations



(a) Path of blood flow through heart

Systemic and Pulmonary Circulations

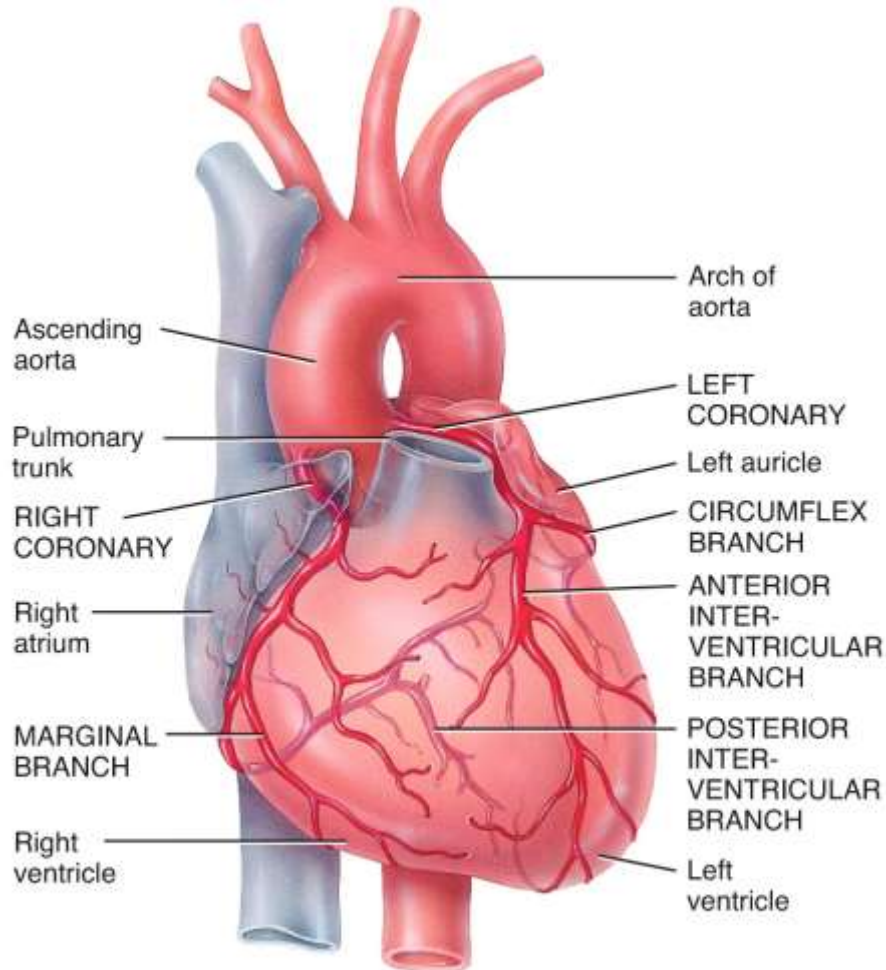


(b) Path of blood flow through systemic and pulmonary circulations

Coronary Circulation

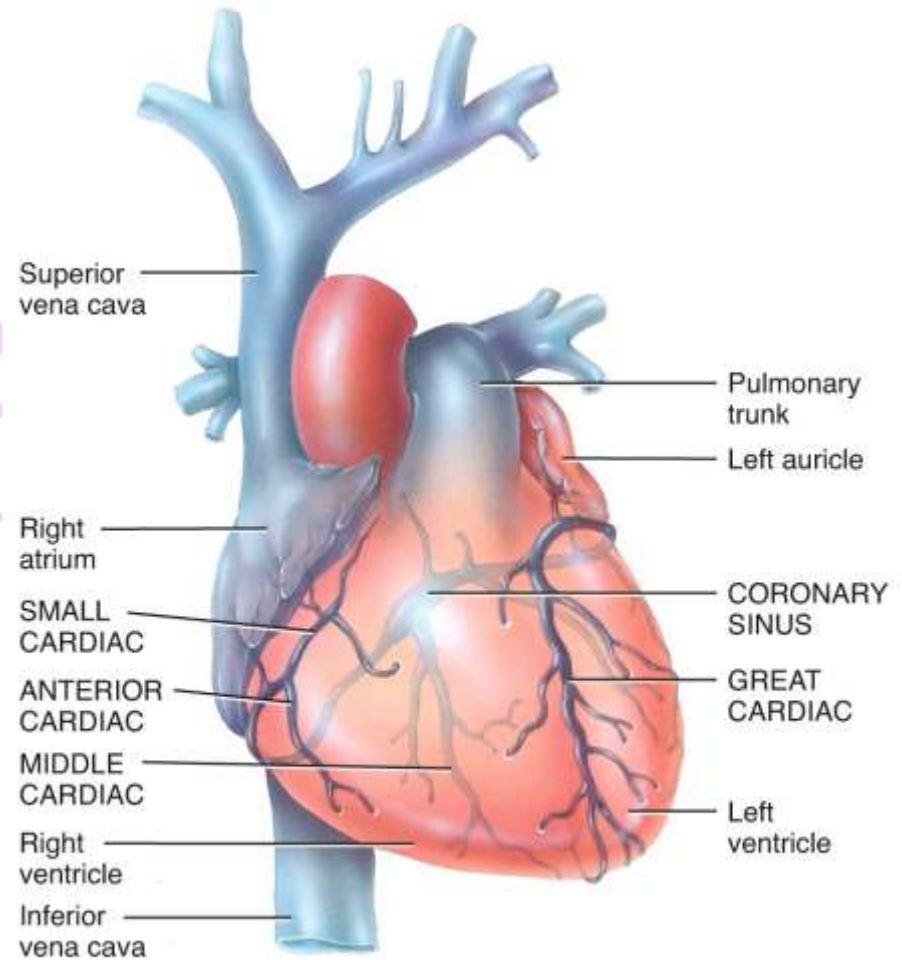
- Two coronary arteries
 - Left coronary artery
 - Anterior interventricular branch
 - Circumflex branch
 - Right coronary artery
 - Posterior interventricular branch
 - Marginal branch

Coronary (Cardiac) Circulation



(a) Anterior view of coronary arteries

Copyright © 2014 John Wiley & Sons, Inc. All rights reserved.



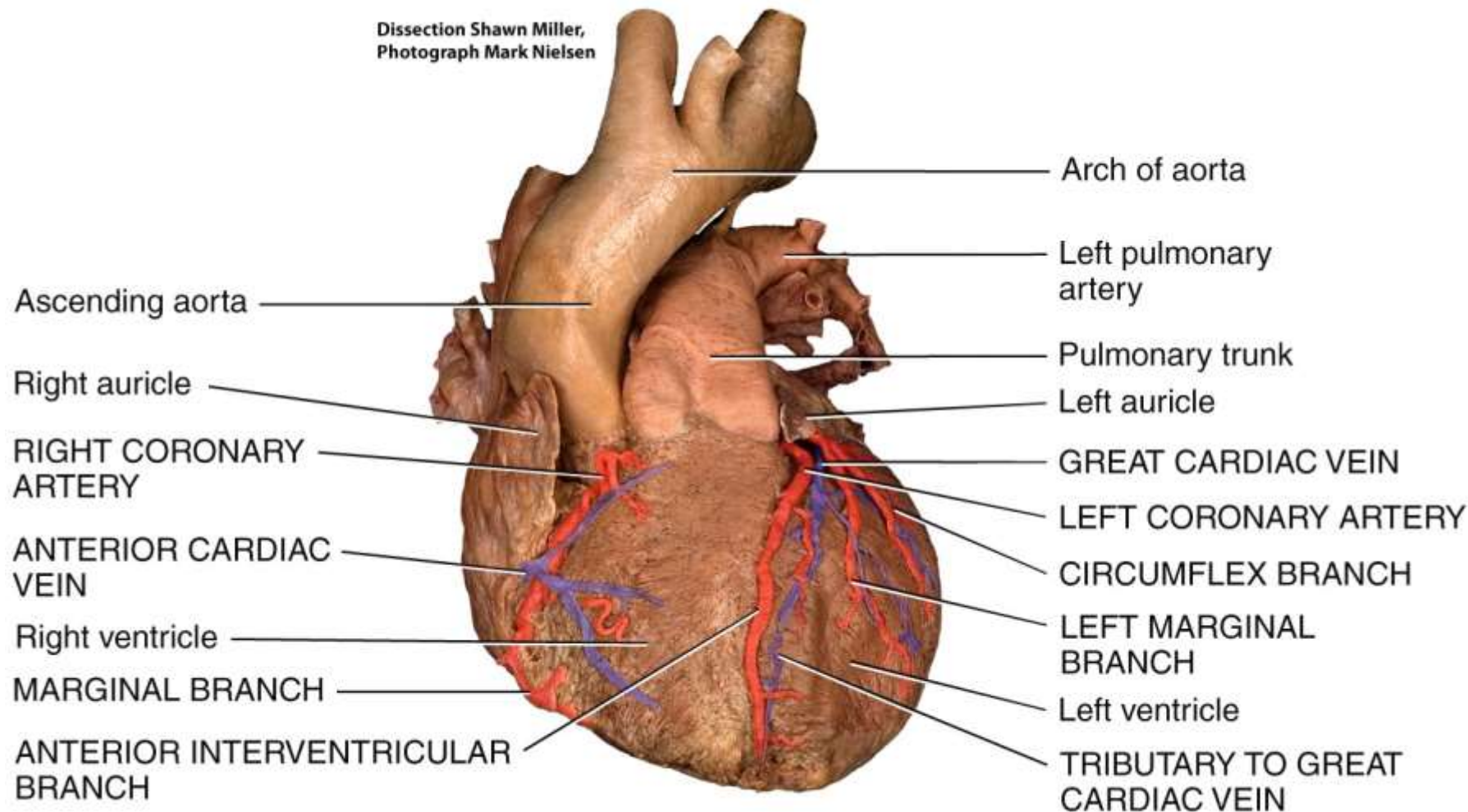
(b) Anterior view of coronary veins

Copyright © 2014 John Wiley & Sons, Inc. All rights reserved.

Copyright © 2020, R.Bishay. All rights reserved

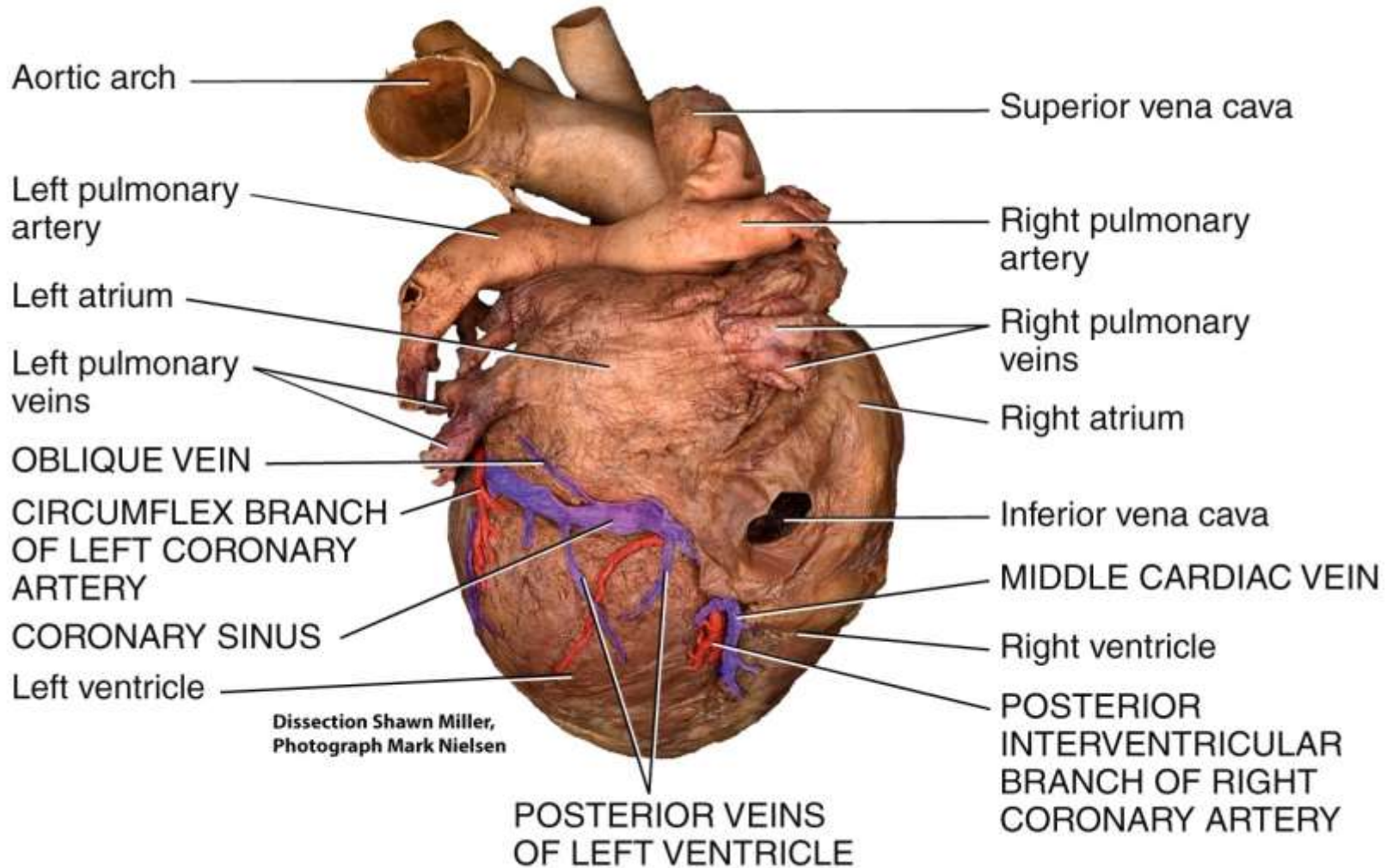
Coronary (Cardiac) Circulation

Dissection Shawn Miller,
Photograph Mark Nielsen



(c) Anterior view

Coronary (Cardiac) Circulation



(d) Posterior view

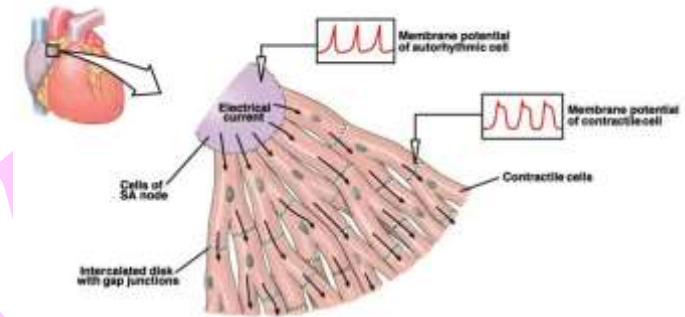
Clinical Connection

- **Myocardial ischemia and myocardial infarction:**

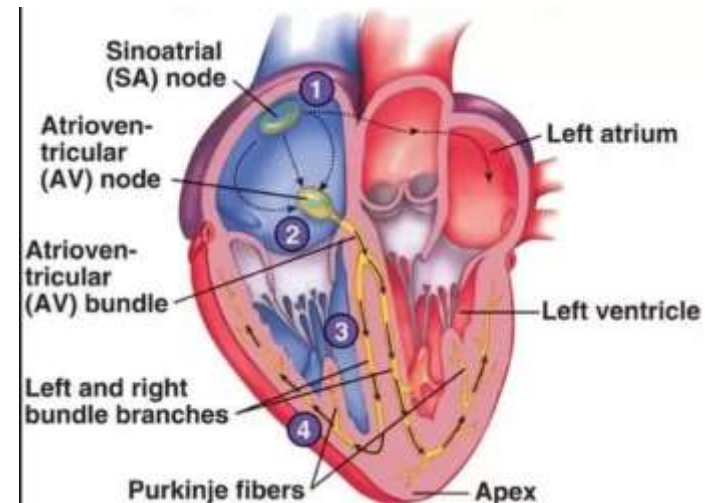
Cardiac ischemia refers to lack of blood flow and oxygen to the heart muscle. ... If ischemia is severe or lasts too long, it can cause a heart attack (myocardial infarction) and can lead to heart tissue death. In most cases, a temporary blood shortage to the heart causes the pain of angina pectoris

Cardiac Conduction System

- **Authorhythmic cells:** serve as a pacemaker to initiate the cardiac cycle (pumping cycle of the heart) and provide a conduction system to coordinate the contraction of muscle cells throughout the heart.
- **Pacemaker:** Sino-atrial node is called as the pacemaker of our heart. ...
The cardiac impulse originating from the SA node triggers a sequence of electrical events in the heart, thereby controlling the sequence of muscle contraction that pumps blood out of the heart.
- Cardiac conduction system



The heart's main pacemaker is in the sinoatrial node (SA node) where a group of autorhythmic cells are located at the junction of the vena cava and the right atrium



Cardiac Conduction

Interactions Animation

- [Cardiac Conduction](#)

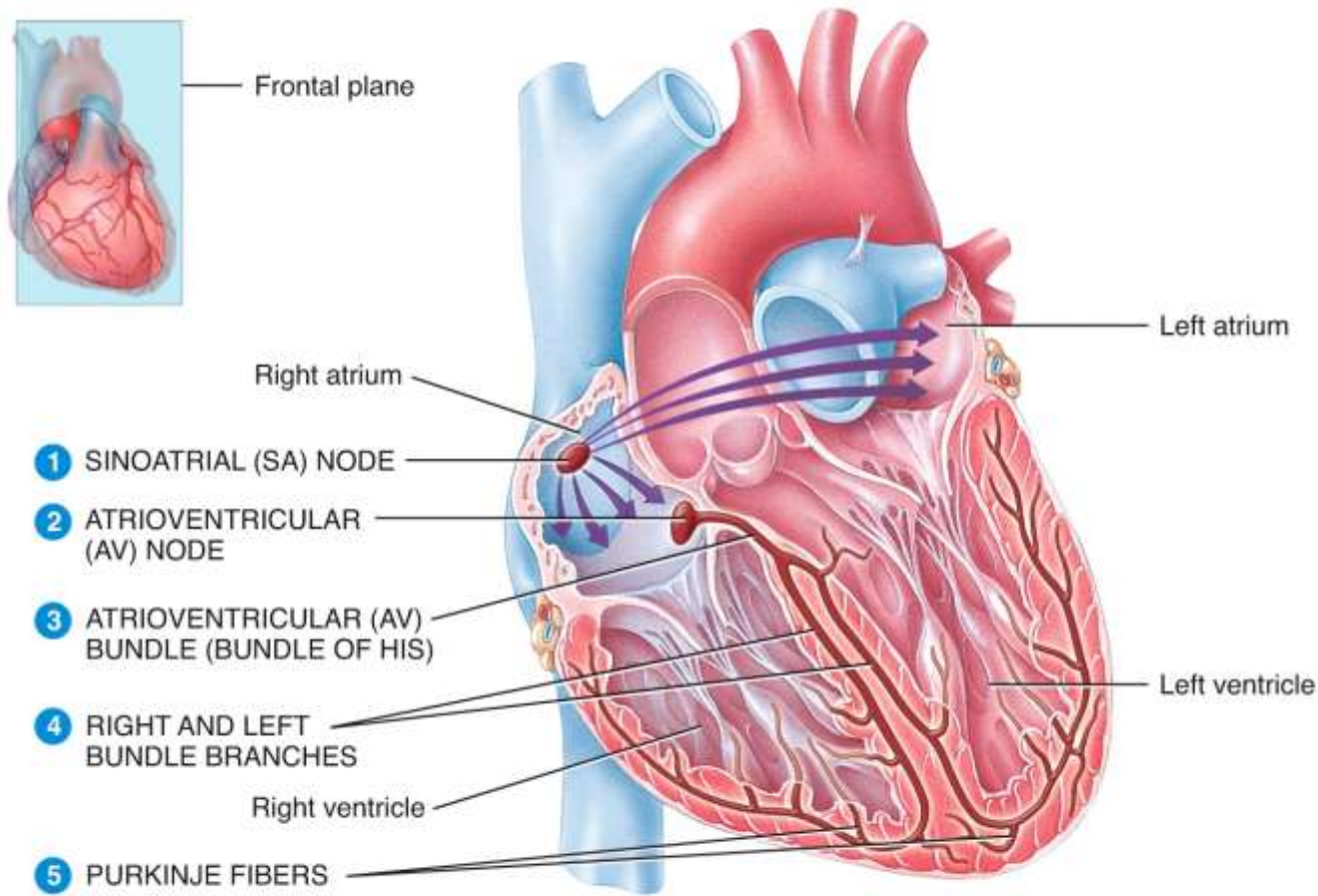
R. Bishay

You must be connected to the internet to run this animation.

Cardiac Conduction System

- Sinoatrial (SA) node
- Atrioventricular (AV) node
- The nervous system and certain hormones can alter the pace of contractions, but the nervous system does not initiate contractions.
- Electrocardiogram (ECG or EKG)

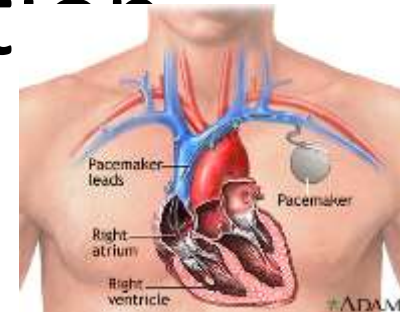
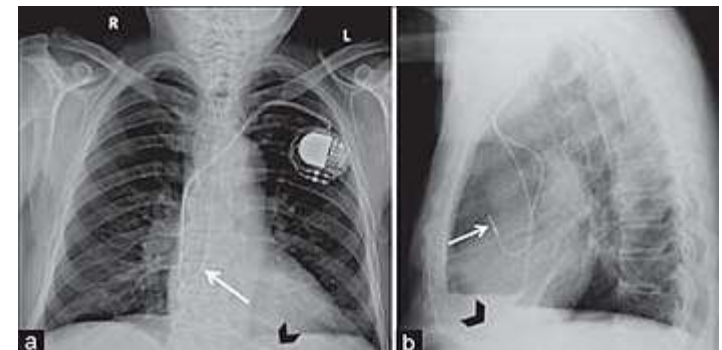
The Conduction System of the Heart and a Normal Electrocardiogram



(a) Anterior view of frontal section

Clinical Connections

- **Artificial pacemakers:** A device that uses electrical impulses to regulate the heart rhythm or reproduce it. An internal pacemaker is one in which the electrodes to the heart, the electronic circuitry, and the power supply are all implanted internally, within the body
- Pacemaker batteries last between 5 and 15 years (average 6 to 7 years), depending on how active the pacemaker is. Your doctor will replace the generator along with the battery before the battery starts to run down



Cardiac Conduction System

- Electrocardiogram (ECG or EKG): is a test that measures the electrical activity of the heartbeat. With each beat, an electrical impulse (or “wave”) travels through the heart. This wave causes the muscle to squeeze and pump blood from the heart.
 - Membrane potential
 - Polarization
 - Depolarization
 - Repolarization
 - Action potential (or impulse)
 - P wave
 - QRS wave
 - T wave

Cardiac Cycle

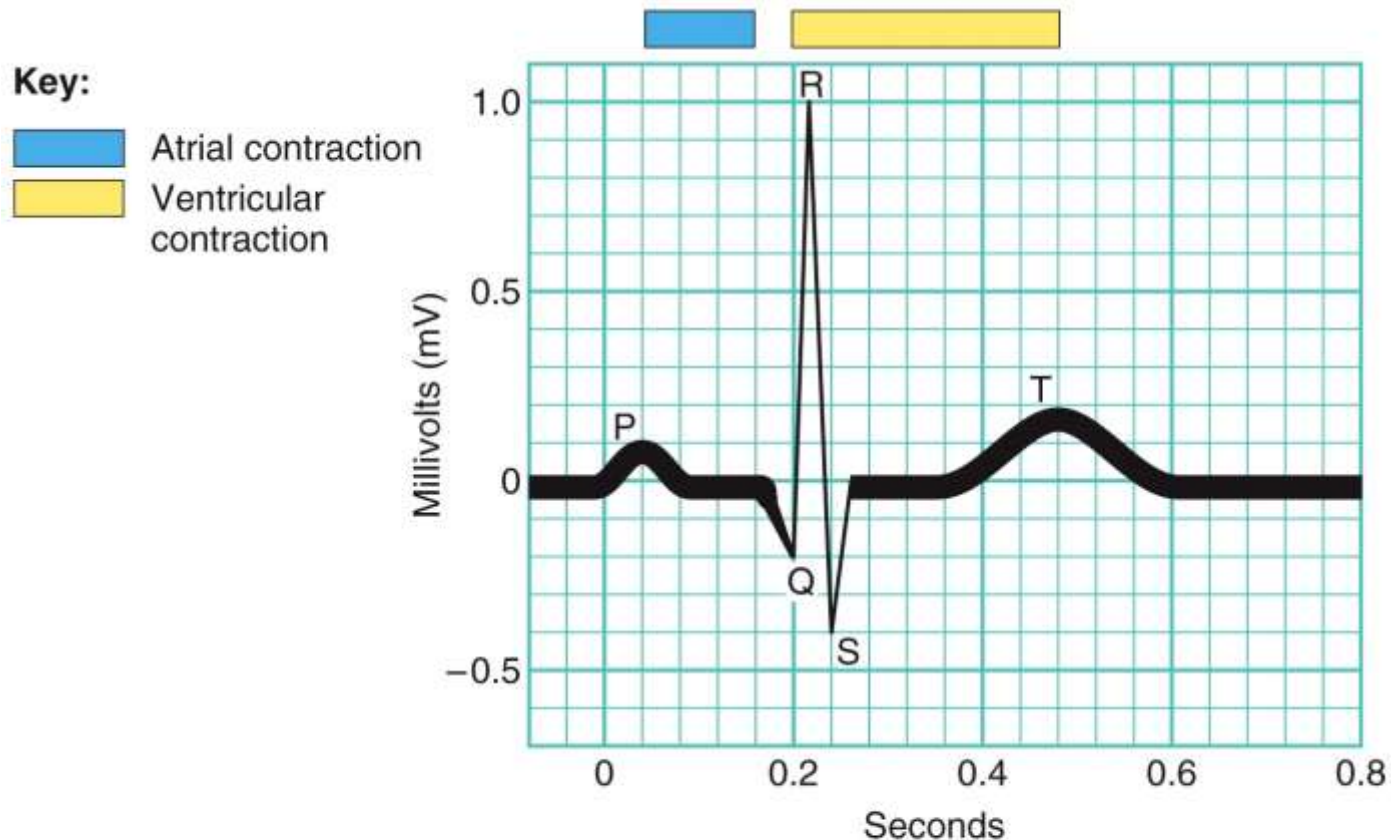
Interactions Animation

- [Cardiac Cycle](#)

R. Bishay

You must be connected to the internet to run this animation.

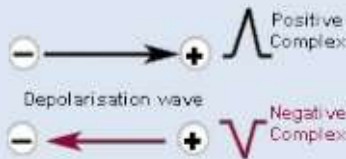
The Conduction System of the Heart and a Normal Electrocardiogram



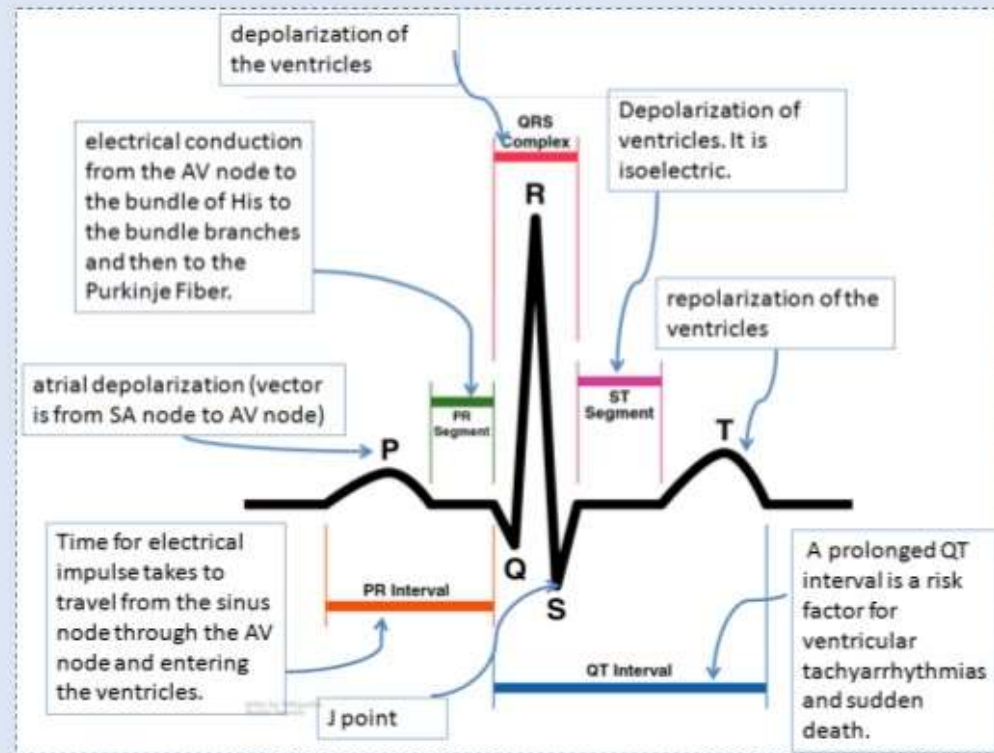
(b) Waves associated with a normal electrocardiogram of a single heartbeat

The Conduction System of the Heart and a Normal Electrocardiogram

Understanding ECG Waveform



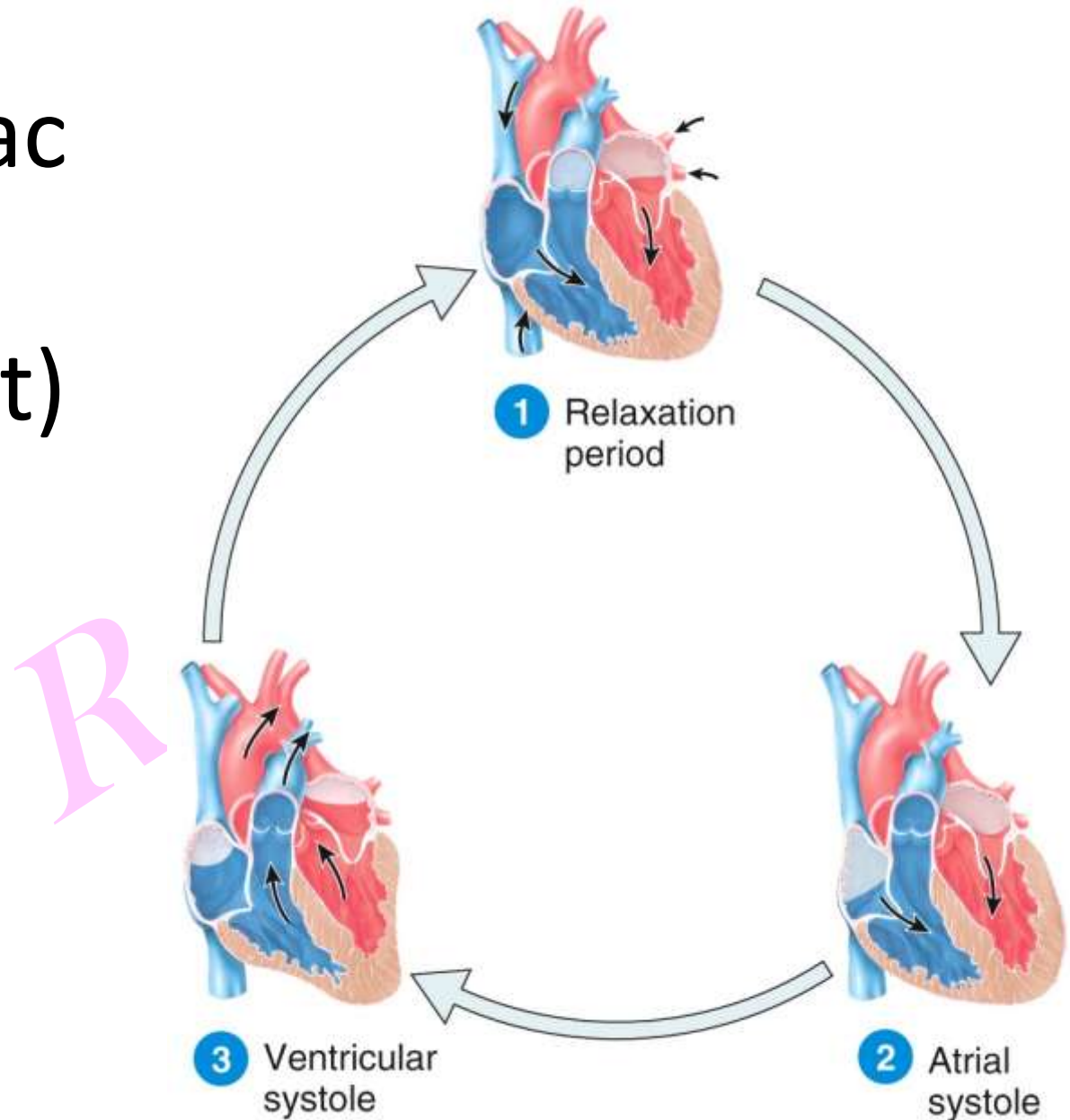
If a wavefront of depolarization travels towards the positive electrode, a positive-going deflection will result. If the waveform travels away from the positive electrode, a negative going deflection will be seen.



Cardiac Cycle (Heartbeat)

- A single cardiac cycle consists of all the events associated with one heartbeat.
- Normally the atria contract while the ventricles relax and vice versa.
- **Systole:** period of contraction of the ventricles of the heart that occurs between the first and second heart sounds of the cardiac cycle (the sequence of events in a single heart beat). Systole causes the ejection of blood into the aorta and pulmonary trunk.
- **Diastole:** in the cardiac cycle, period of relaxation of the heart muscle, accompanied by the filling of the chambers with blood. ...
Ventricular diastole again occurs after the blood has been ejected (during ventricular systole) into the aorta and pulmonary artery.

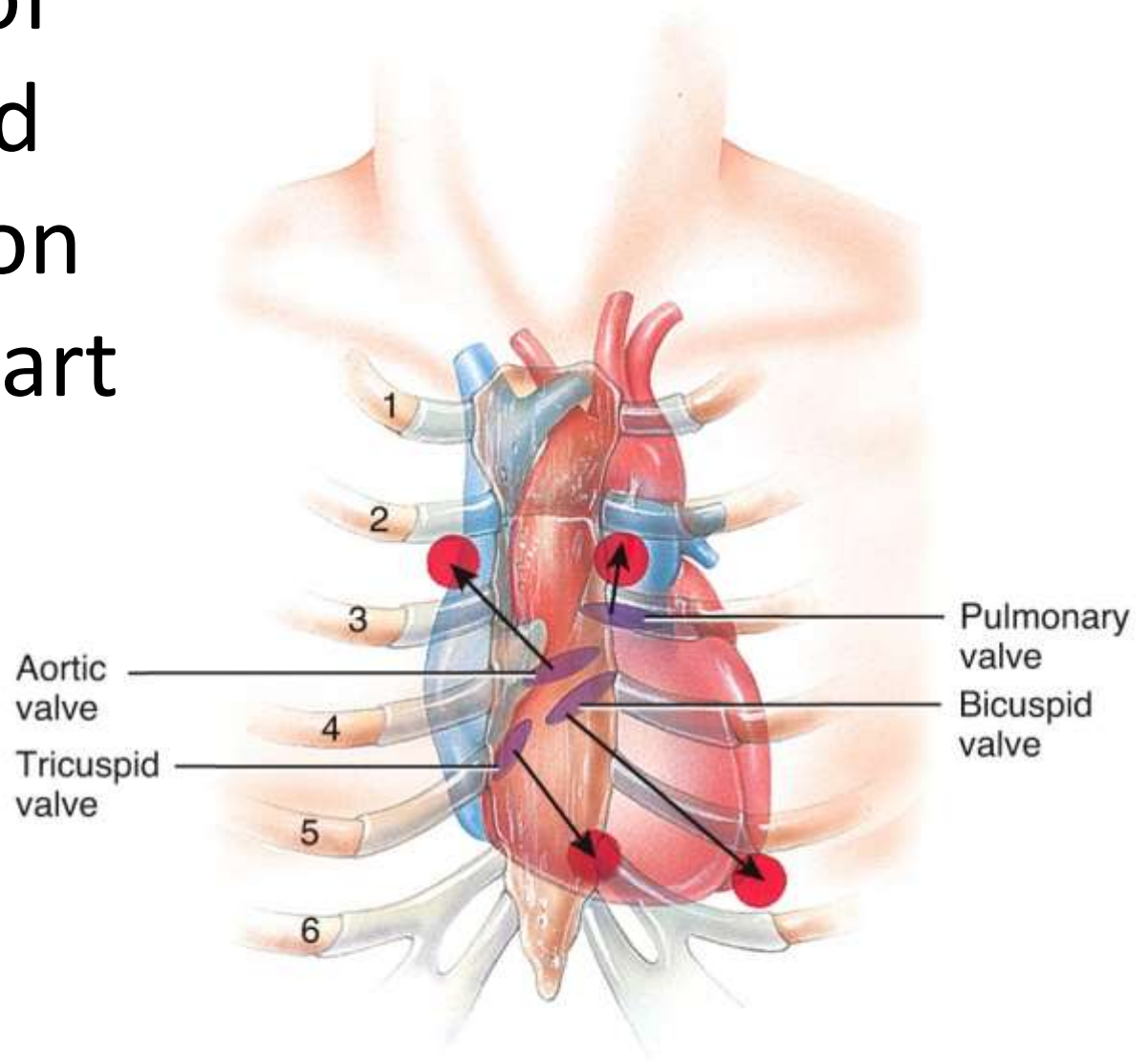
The Cardiac Cycle (Heartbeat)



Heart Sounds

- Auscultation
- First sound (S1), or lubb
- Second sound (S2), or dupp
- The sounds are best heard over the chest at areas slightly away from the actual location of the valves.
- **The “lub” is the first heart sound**, commonly termed S1, and is caused by turbulence caused by the closure of mitral and tricuspid valves at the start of systole.
- **The second sound,” dub” or S2**, is caused by the closure of aortic and pulmonic valves, marking the end of systole.

Location of Valves and Auscultation Sites for Heart Sounds



Anterior view of heart valve locations and auscultation sites

Clinical Connection

- **Heart murmur:** are sounds during your heartbeat cycle — such as whooshing or swishing — made by turbulent blood in or near your heart. These sounds can be heard with a stethoscope. A normal heartbeat makes two sounds like "lubb-dupp" (sometimes described as "lub-DUP"), which are the sounds of your heart valves closing

Exercise and the Heart

- Aerobic exercise improves cardiovascular fitness.
- Prolonged training increases maximal cardiac output.
- Stroke volume:(SV) is the volume of blood in millilitres ejected from the each ventricle due to the contraction of the heart muscle which compresses these ventricles
- Exercise helps reduce blood pressure, anxiety, and depression; control weight; and increases the ability to dissolve blood clots.

Cardiac Output

Interactions Animation

- [Cardiac Output](#)

R. Bishay

You must be connected to the internet to run this animation.

Clinical Connections

- **Coronary artery disease (CAD)**
 - *Risk factors for CAD:*
- Age. Simply getting older increases your risk of damaged and narrowed arteries.
- Sex. Men are generally at greater risk of coronary artery disease. ...
- Family history. ...
- Smoking. ...
- High blood pressure. ...
- High blood cholesterol levels. ...
- Diabetes. ...
- Overweight or obesity.
 - Development of atherosclerotic plaques: Patho-physiology
 - Diagnosis of CAD: Internal medicine
 - Treatment of CAD: Pharmacology

Development of the Heart

- **Mesoderm**
- Cardiogenic area
- Endocardial tubes
- Primitive heart tube
- Endocardial cushions
- Atrioventricular canal

Development of the Heart

