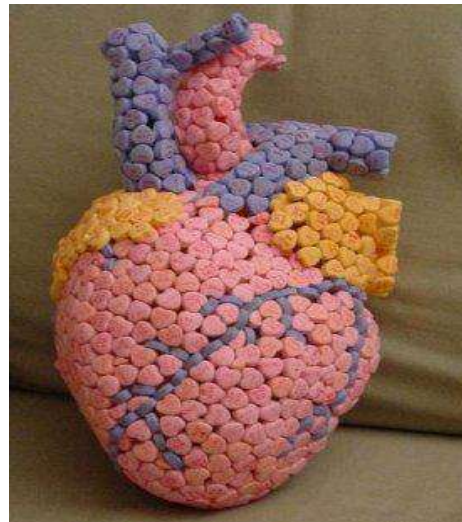




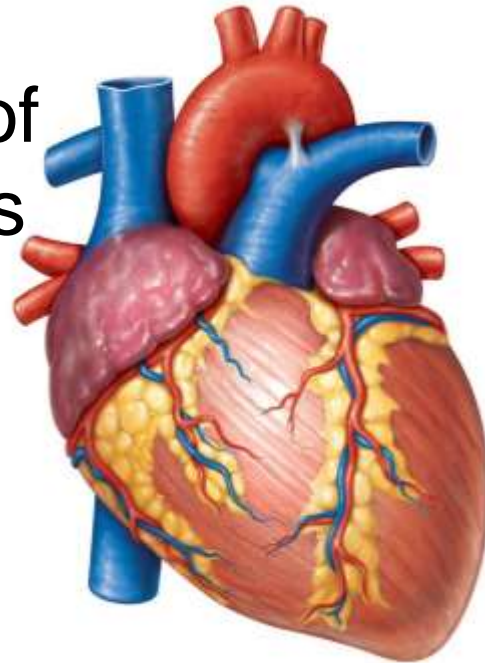
# CARDIOVASCULAR SYSTEM



*Oleksandr Kovalchuk*  
*ANATOM.UA*

# Cardiovascular System

- Main function:  
Transportation
  - Blood = transport of various substances
  - Heart = pump
  - Blood vessels = network of tubes



Humans have a closed circulatory system, typical of all vertebrates, in which blood is confined to vessels and is distinct from the interstitial fluid.

- The heart pumps blood into large vessels that branch into smaller ones leading into the organs.
- Materials are exchanged by diffusion between the blood and the interstitial fluid bathing the cells.

- Three Major Elements — Heart, Blood Vessels, & Blood

- 1. **The Heart** - cardiac muscle tissue

- highly interconnected cells

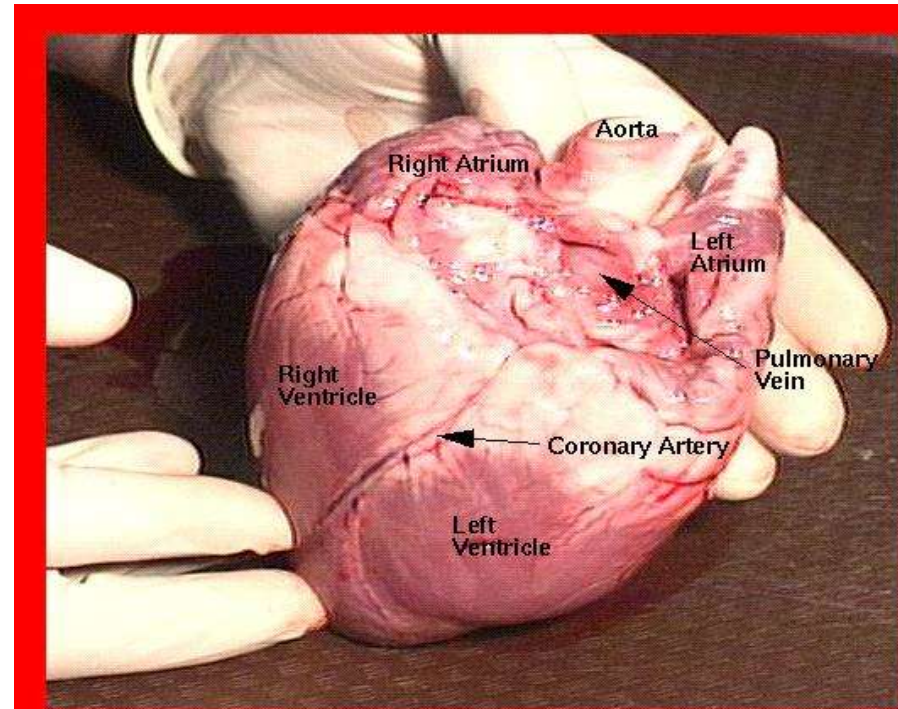
- four chambers

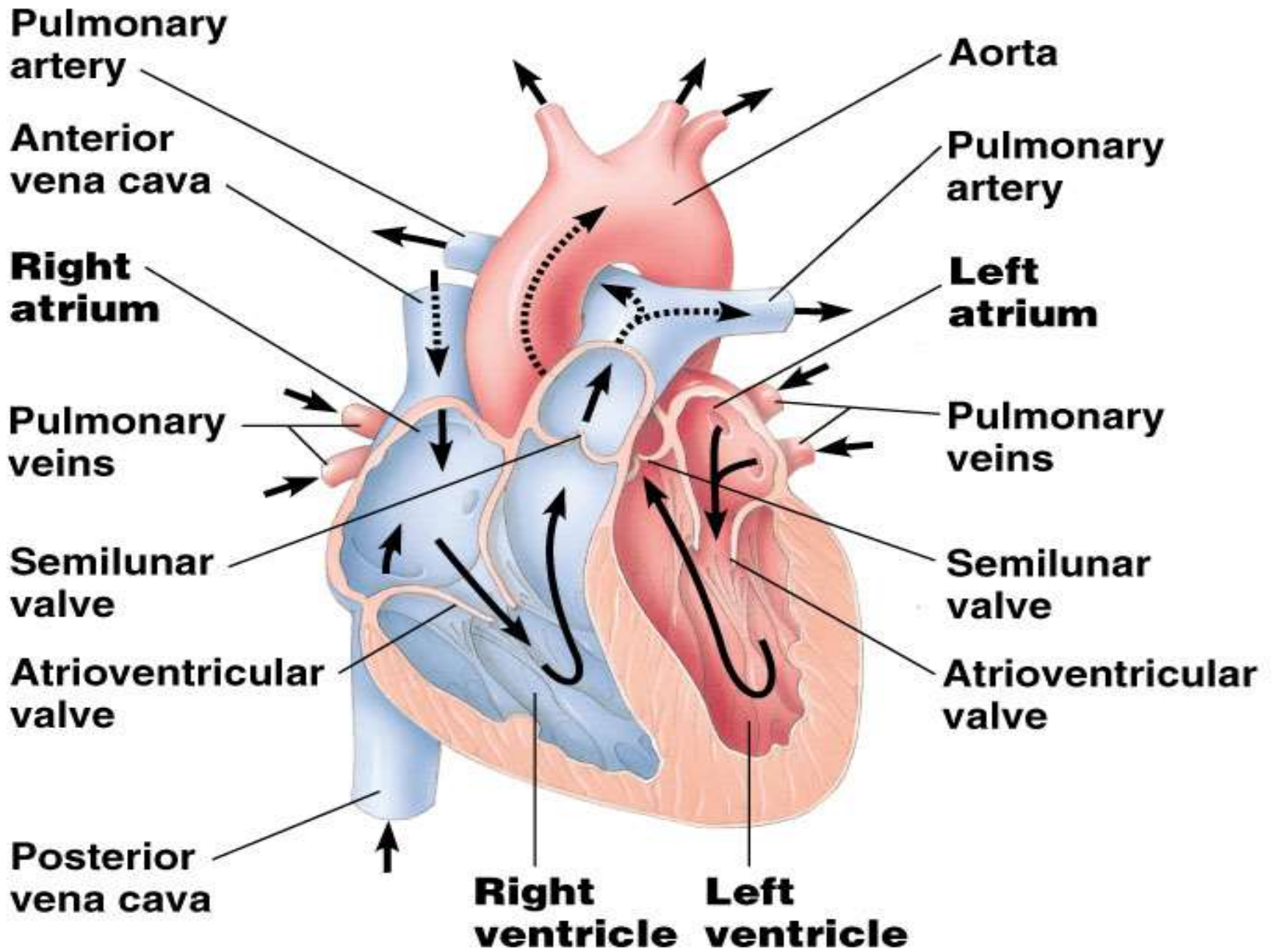
- Right atrium

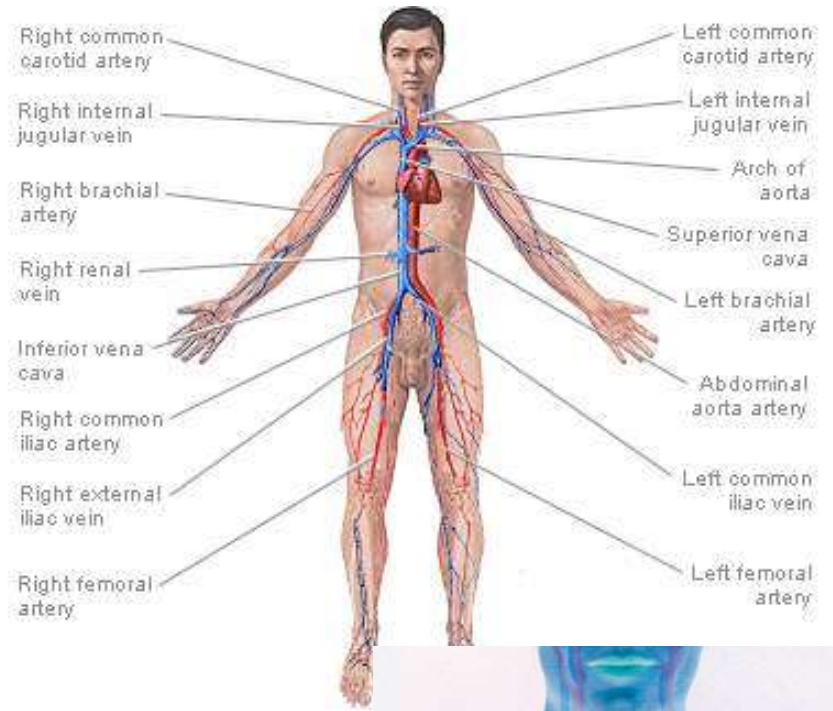
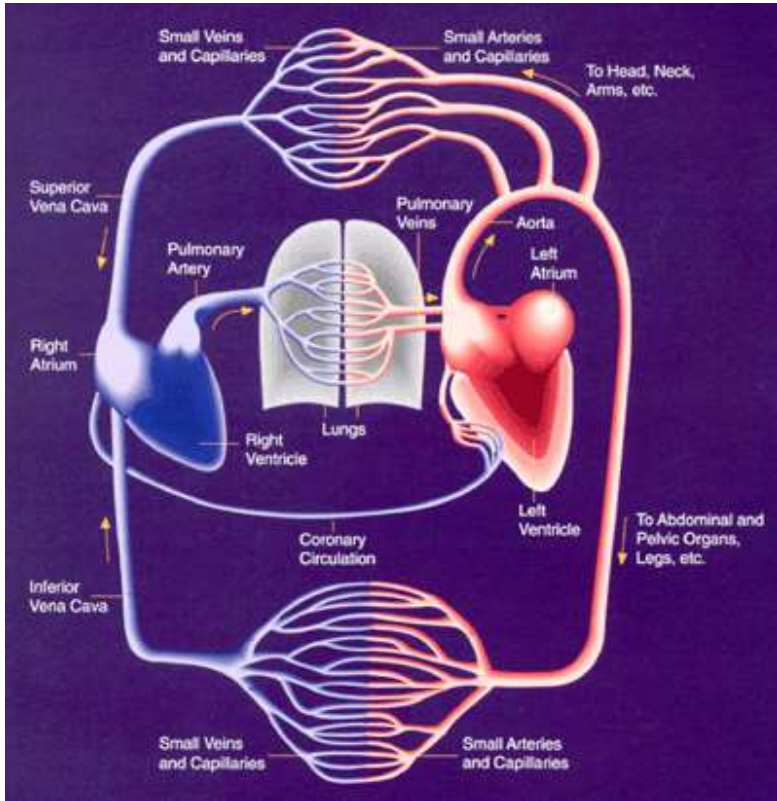
- Right ventricle

- Left atrium

- Left ventricle

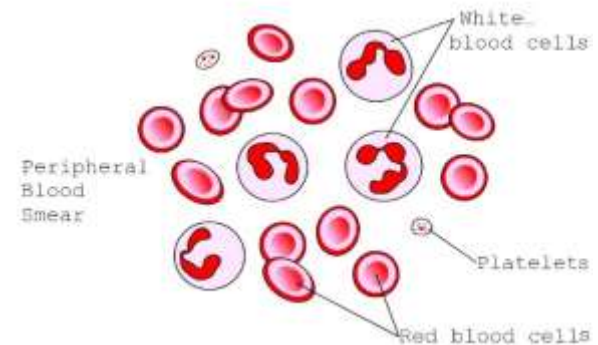
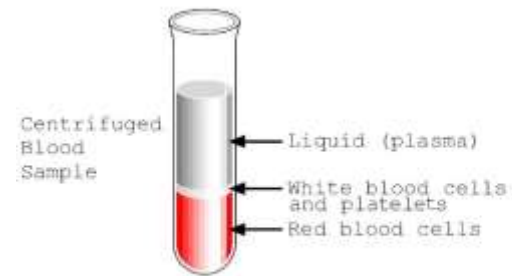






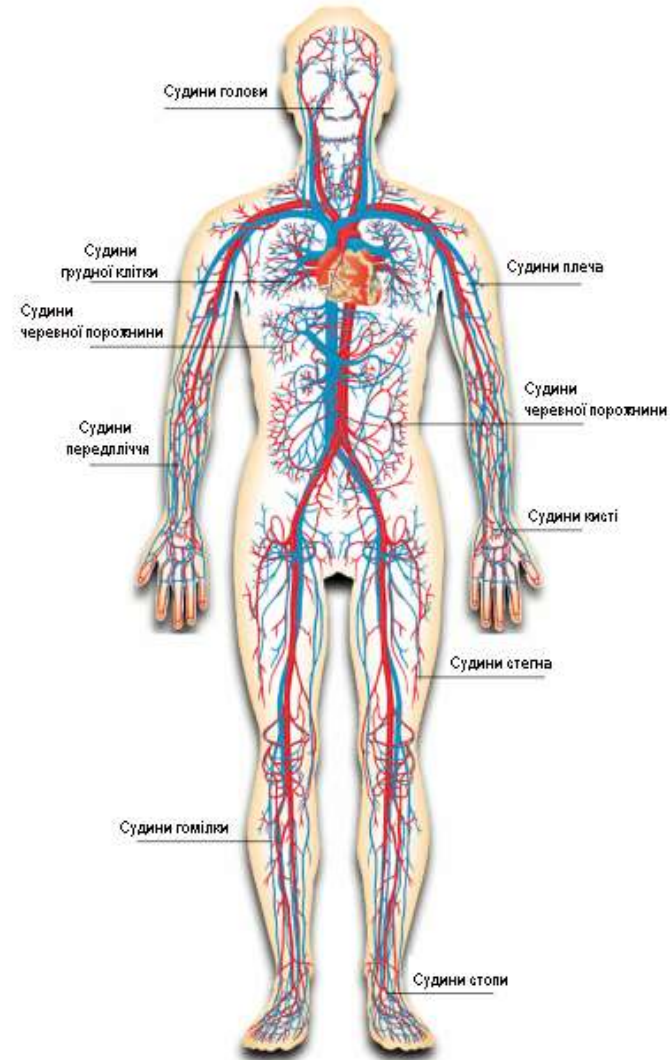
## ■ Blood

- Complex mixture of cells, water, and various proteins and sugars.
- Fifty-five percent is plasma (liquid).
- Forty-five percent is solid.

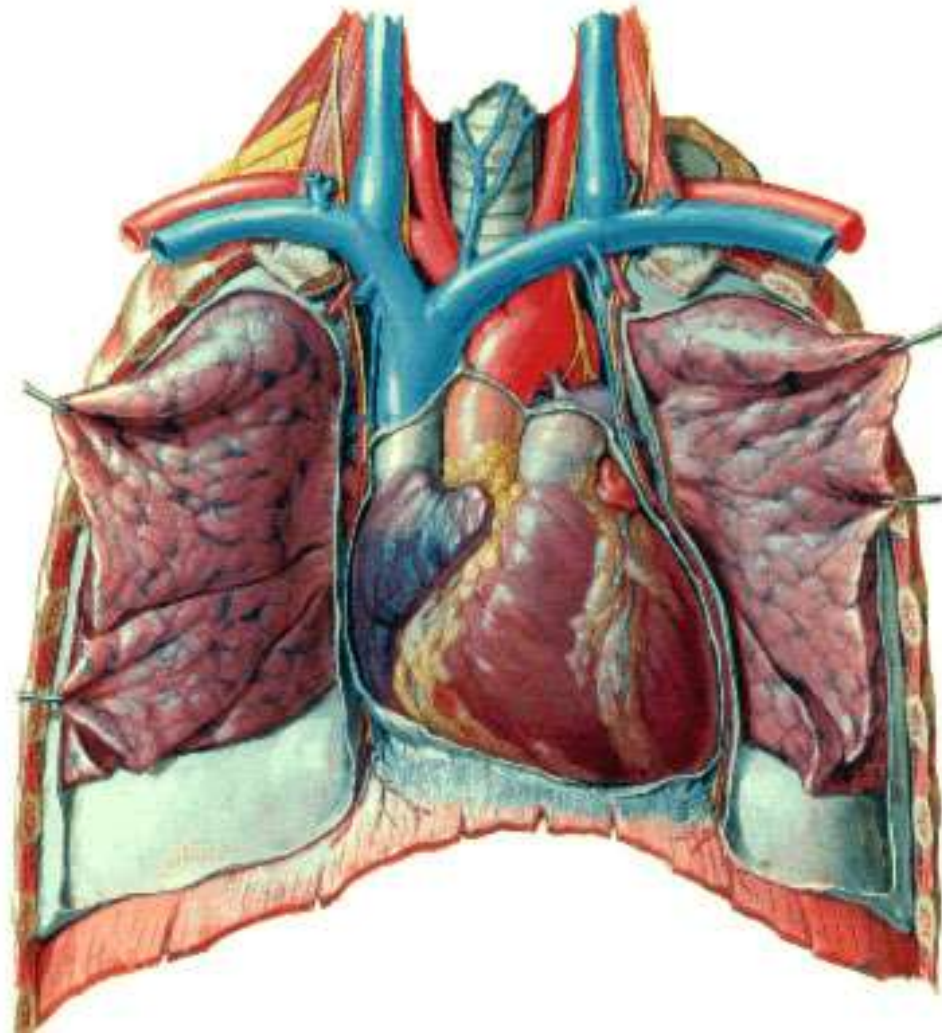


- Superior Vena Cava
- Right Atrium
- Tricuspid Valve
- Right Ventricle
- Pulmonary Semilunar Valve
- Lungs
- Pulmonary Vein
- Bicuspid Valve
- Left Ventricle
- Aortic Semilunar Valve
- Aorta
- *To the bodies organs & cells*

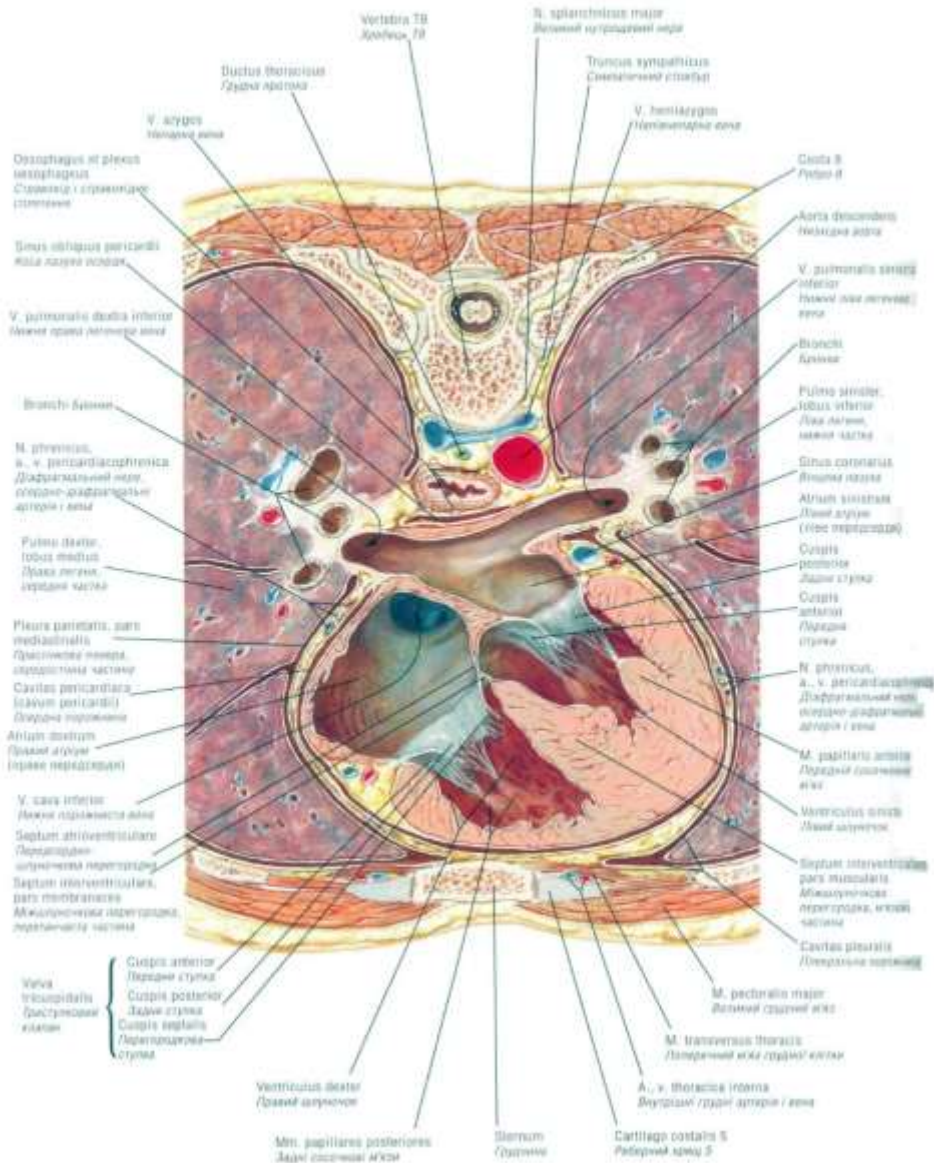
## Pathway of the blood



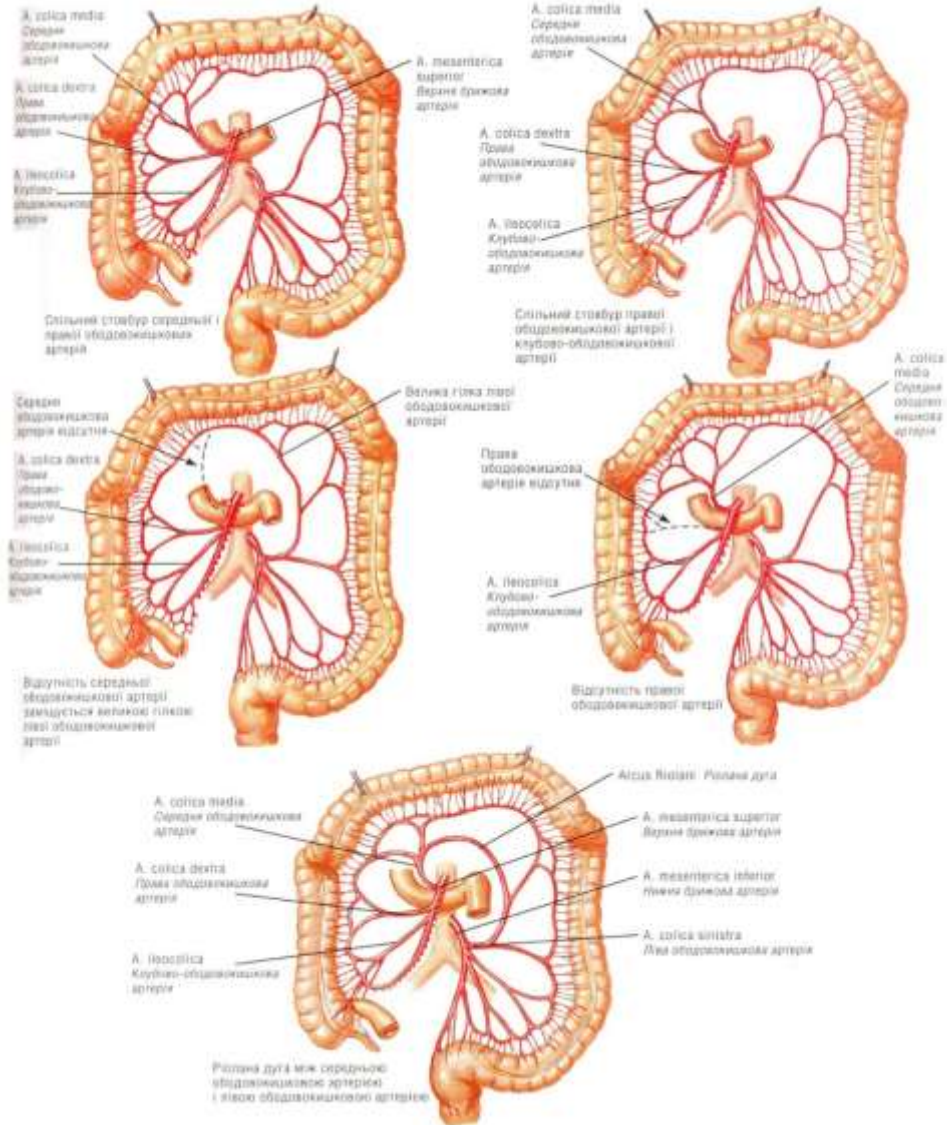




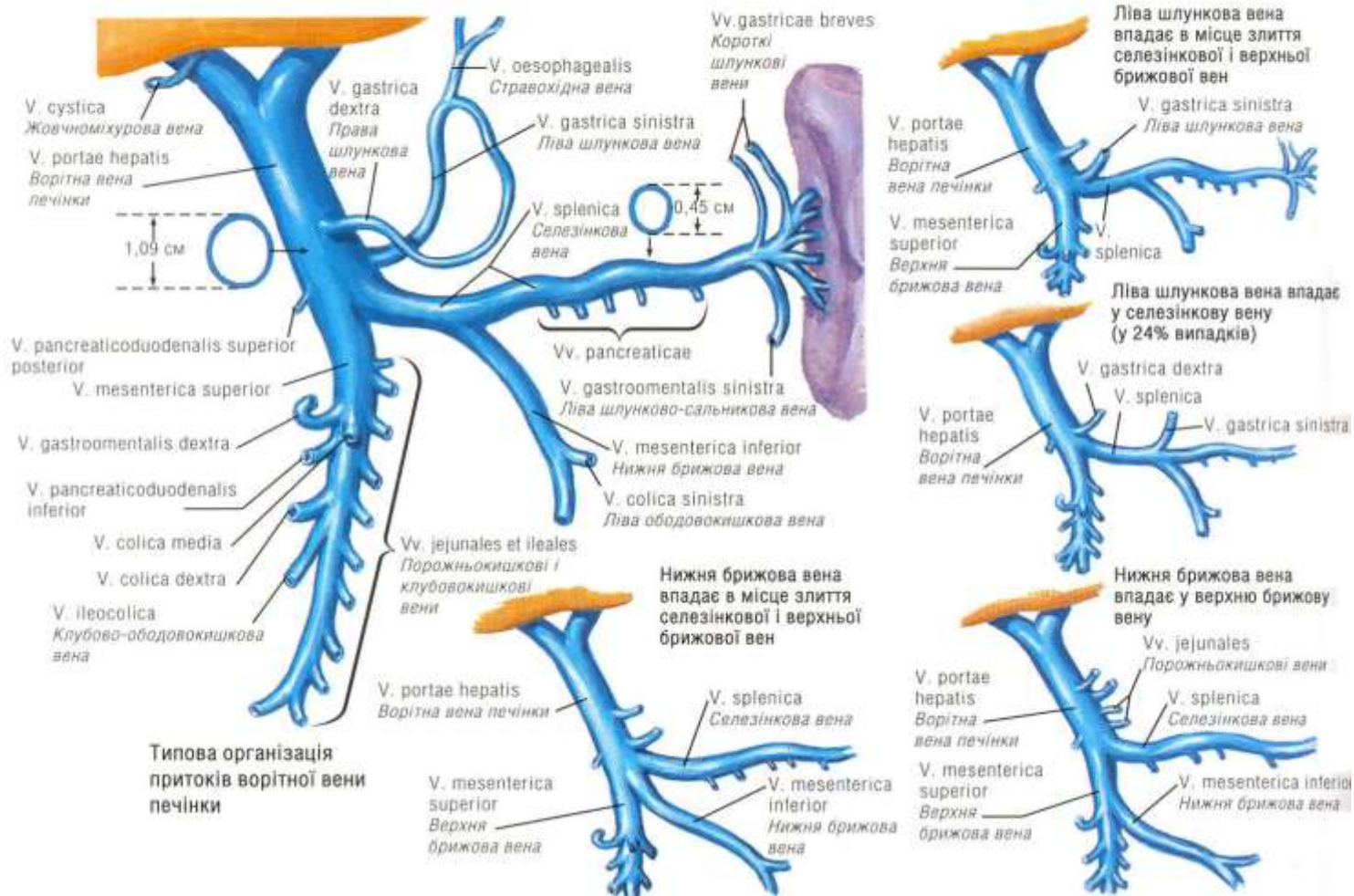
**Середостіння (mediastinum): горизонтальний переріз (вигляд зверху)**



Варіанти ободовишкових артерій (arteriae colicae)



## Варіанти ворітної вени печінки

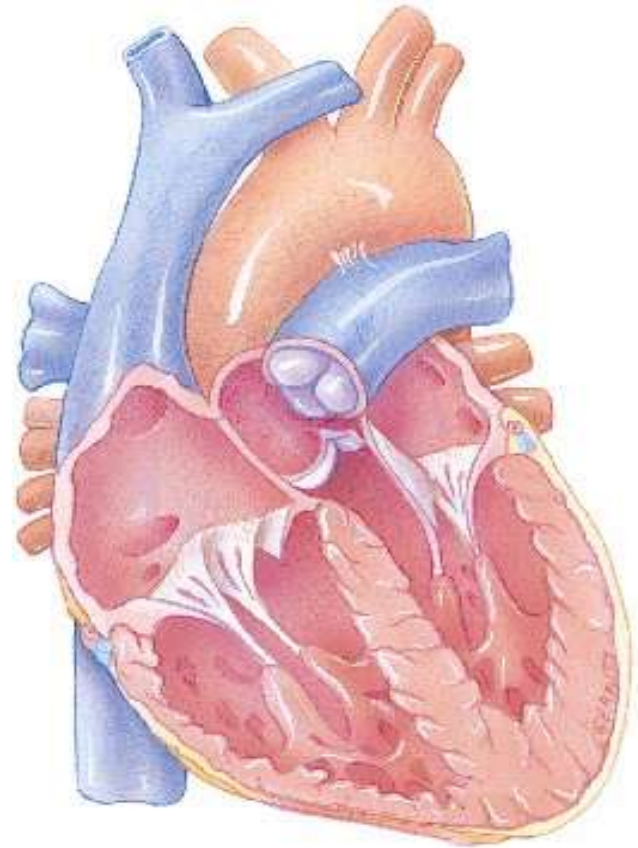


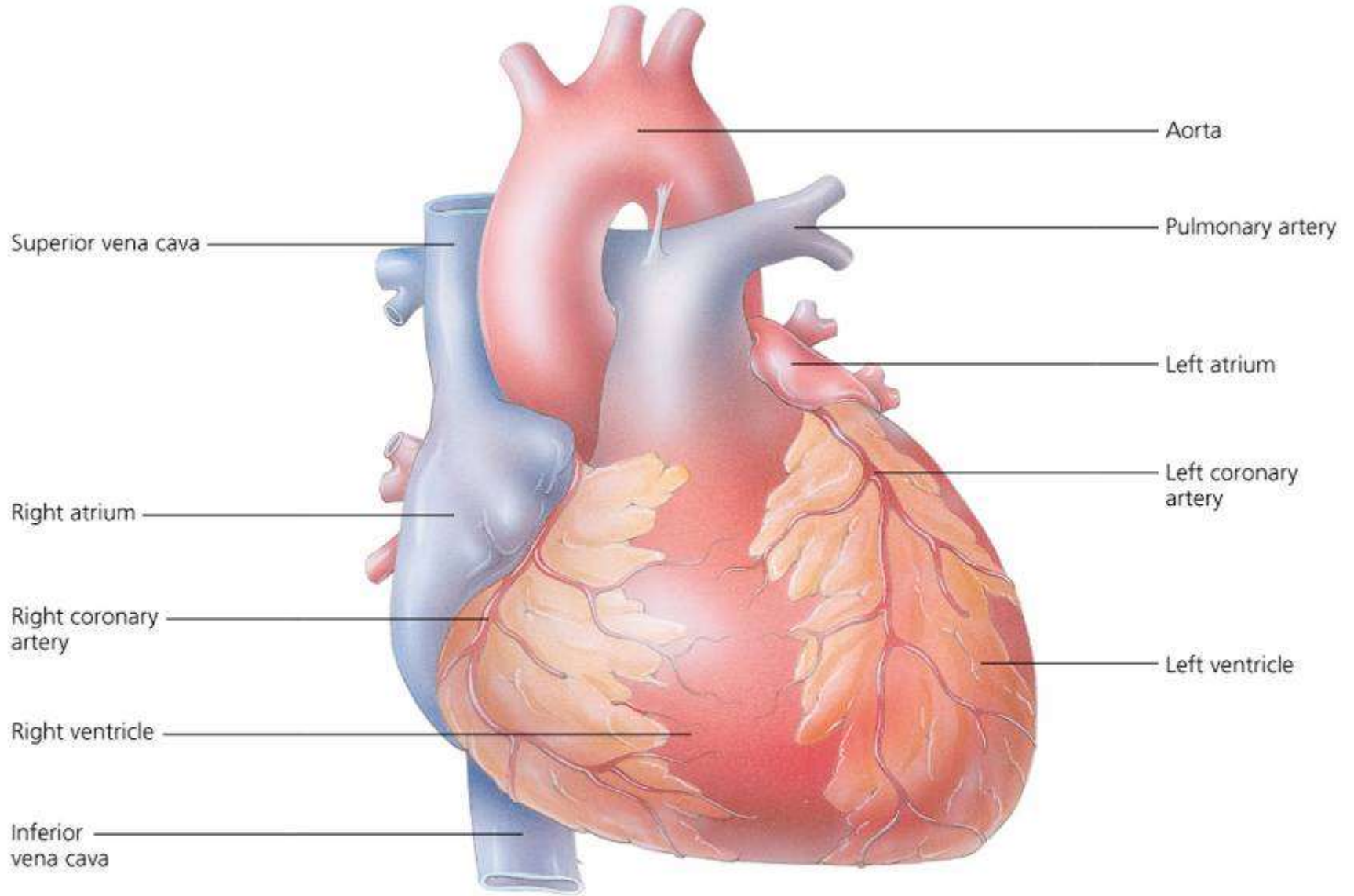


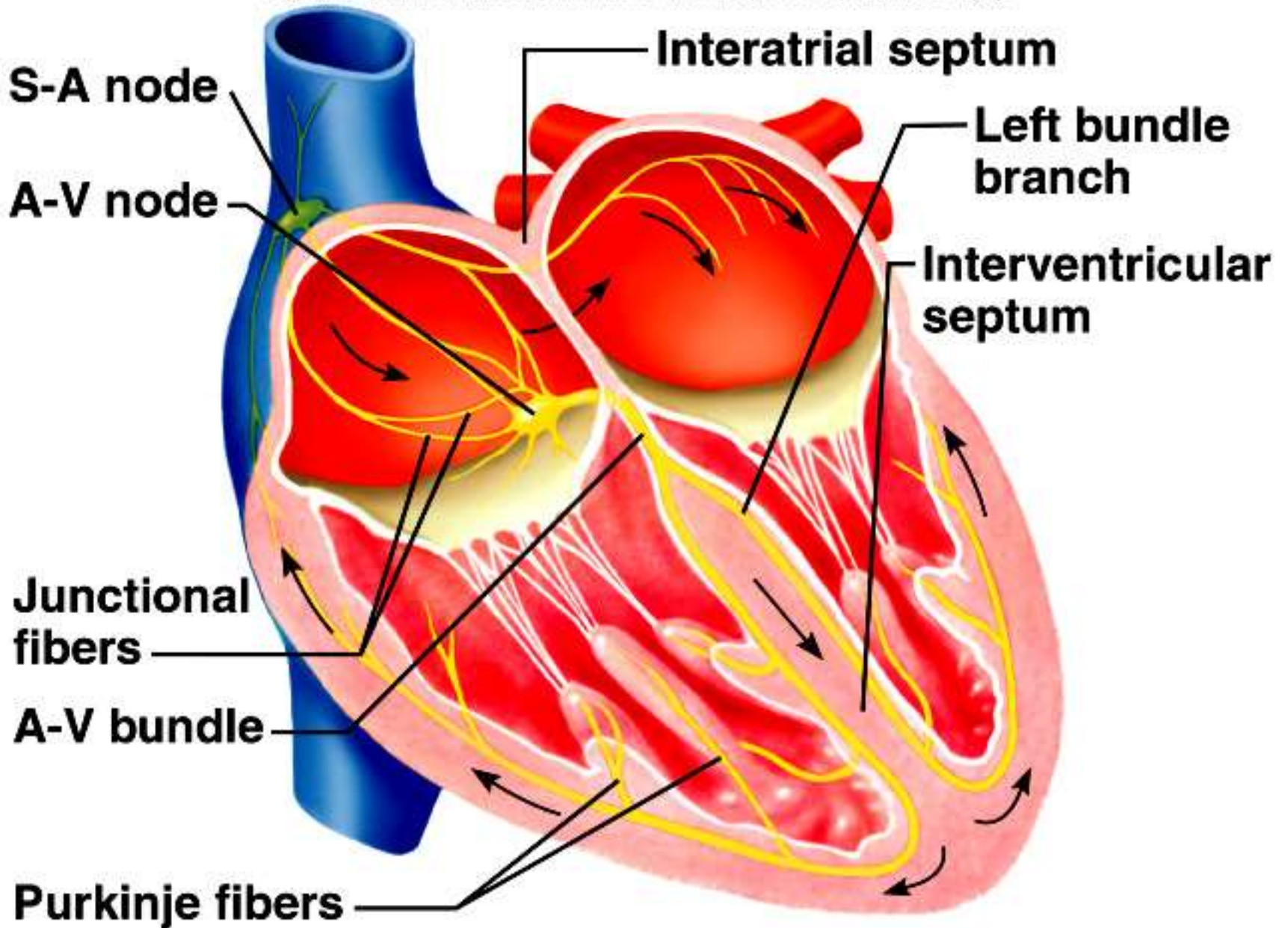
# The Cardiovascular System:

- 1) *cor*;
- 2) *vasa sanguinea*;
- 3) *vasa lymphatica*.

- **Circulation** —  
pumping of  
blood through  
the entire body  
by the heart.

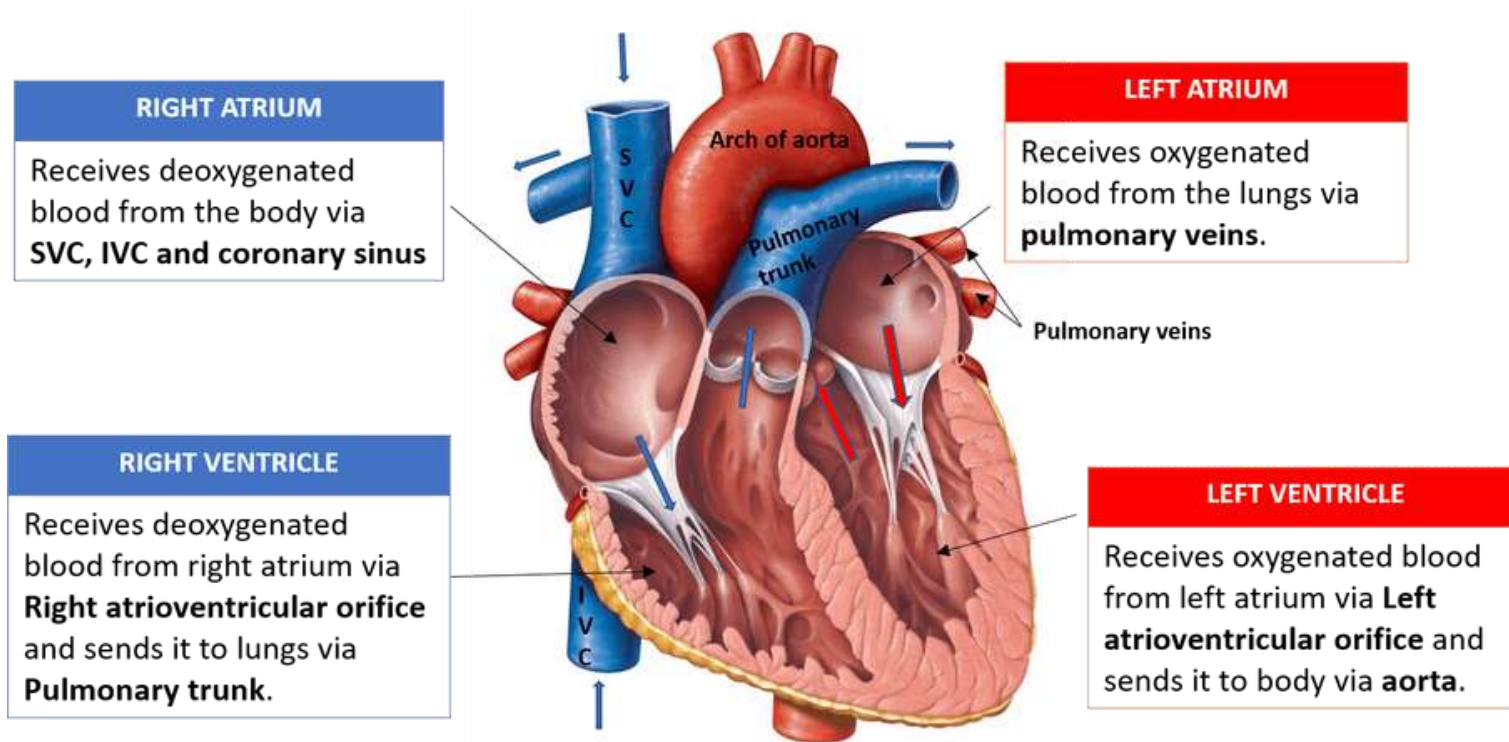




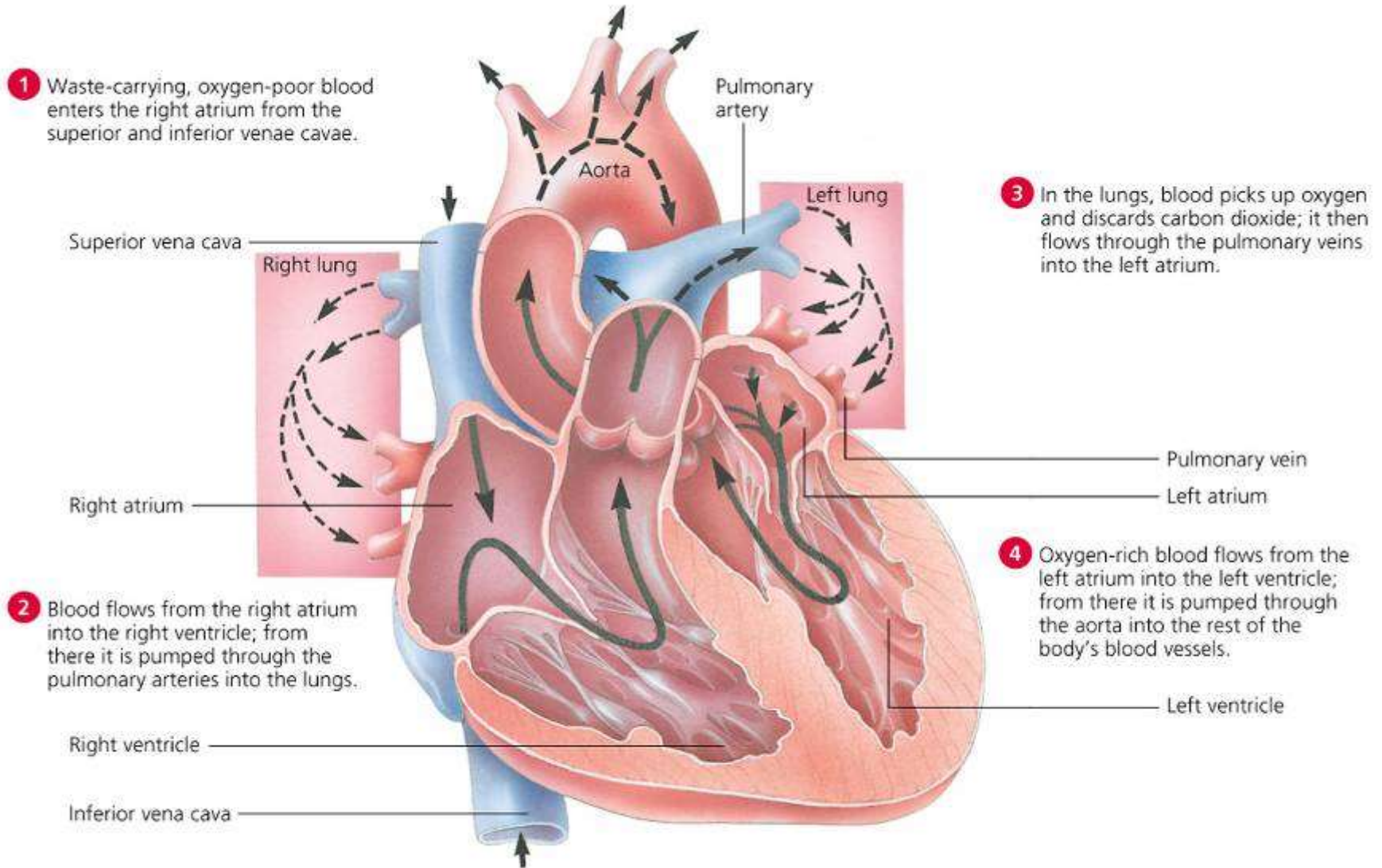


## Chambers of the heart:

Human heart is not a simple hollow pump. It has been divided by vertical septa into four chambers: two atria (right and left) and two ventricles (right and left). The atria lie superior to the ventricles. In anatomic position, the right atrium lies anterior to the left atrium and the right ventricle lies anterior to the left ventricle.



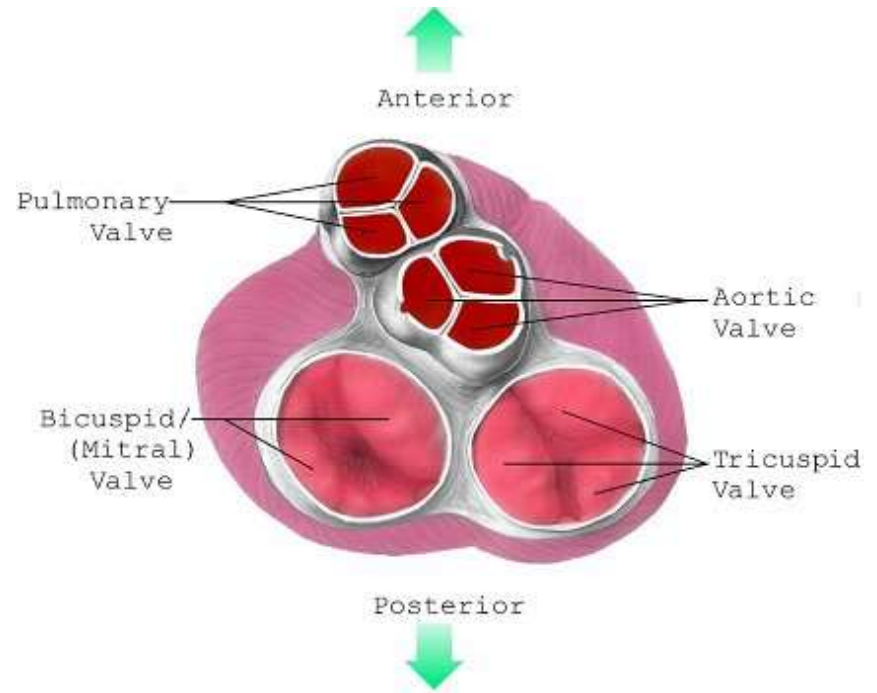




## ■ The Heart

- Covered by the pericardium.
- Has two sides with two chambers.
- Blood flows through the heart in one direction.
- Valves control the blood flow.
- The cardiac conduction system controls the electrical impulses that cause the heart to contract.

- **The Heart** (cont.)
  - Bicuspid (mitral) valve.
  - Tricuspid valve.
  - Pulmonary valve.
  - Aortic valve.



## ■ Circulation

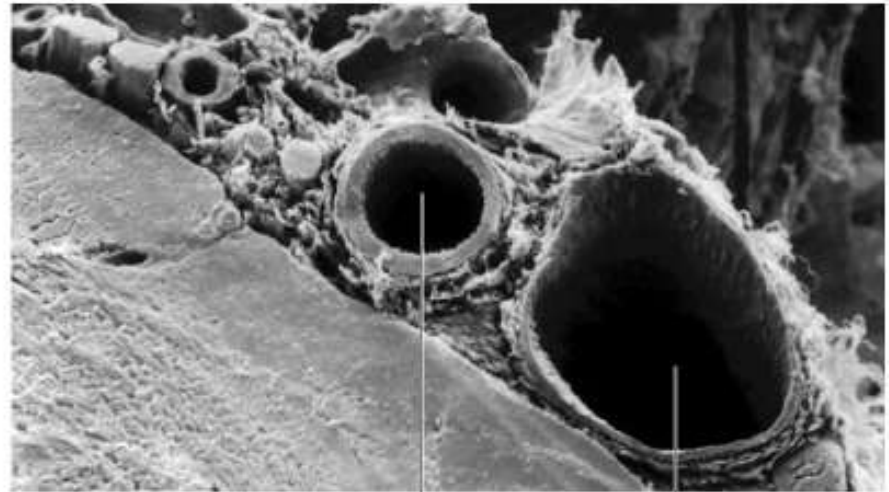
- **Coronary circulation** — the circulation of blood within the heart.
- **Pulmonary circulation** — the flow of blood between the heart and lungs.
- **Systemic circulation** — the flow of blood between the heart and the cells of the body.

# Classes of Blood Vessels

- **Arteries**
  - Carry blood *away* from heart
- **Arterioles**
  - Are smallest branches of arteries
- **Capillaries**
  - Are smallest blood vessels
  - Location of exchange between blood and interstitial fluid
- **Venules**
  - Collect blood from capillaries
- **Veins**
  - Return blood *to* heart

# Blood Vessels: The Vascular System

- Taking blood to the tissues and back
  - Arteries
  - Arterioles
  - Capillaries
  - Venules
  - Veins

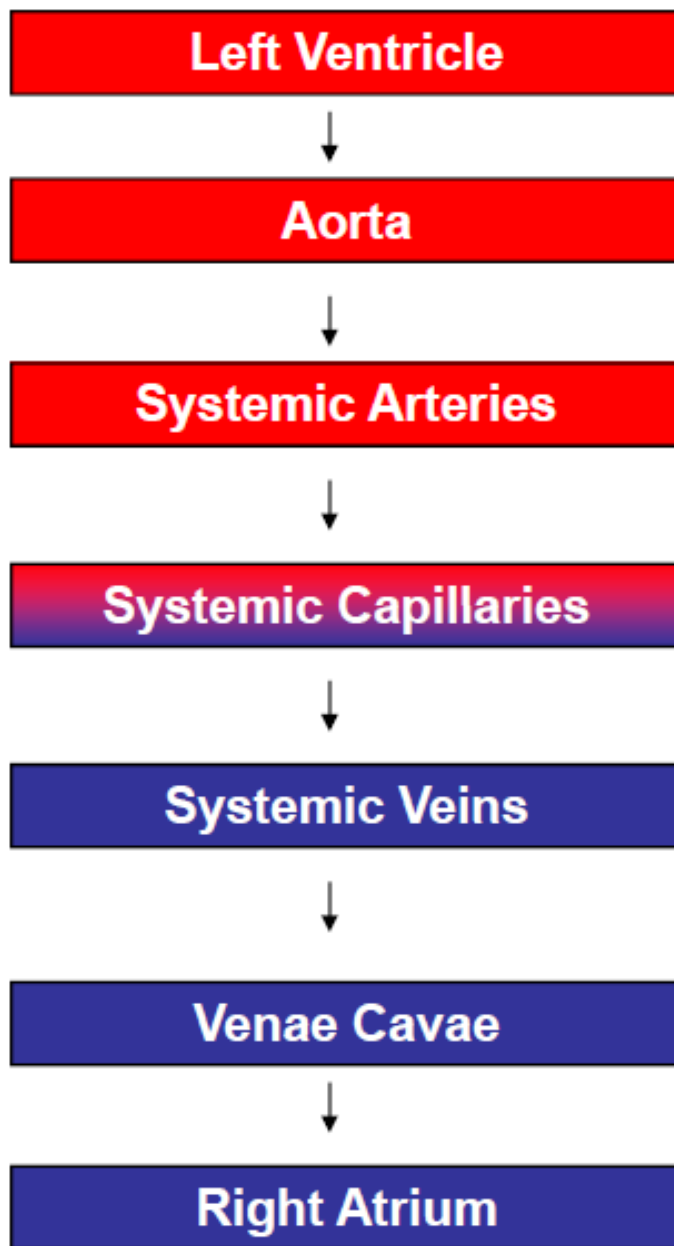


(a)

Artery

Vein

# *Systemic Circuit*



# The Vascular System

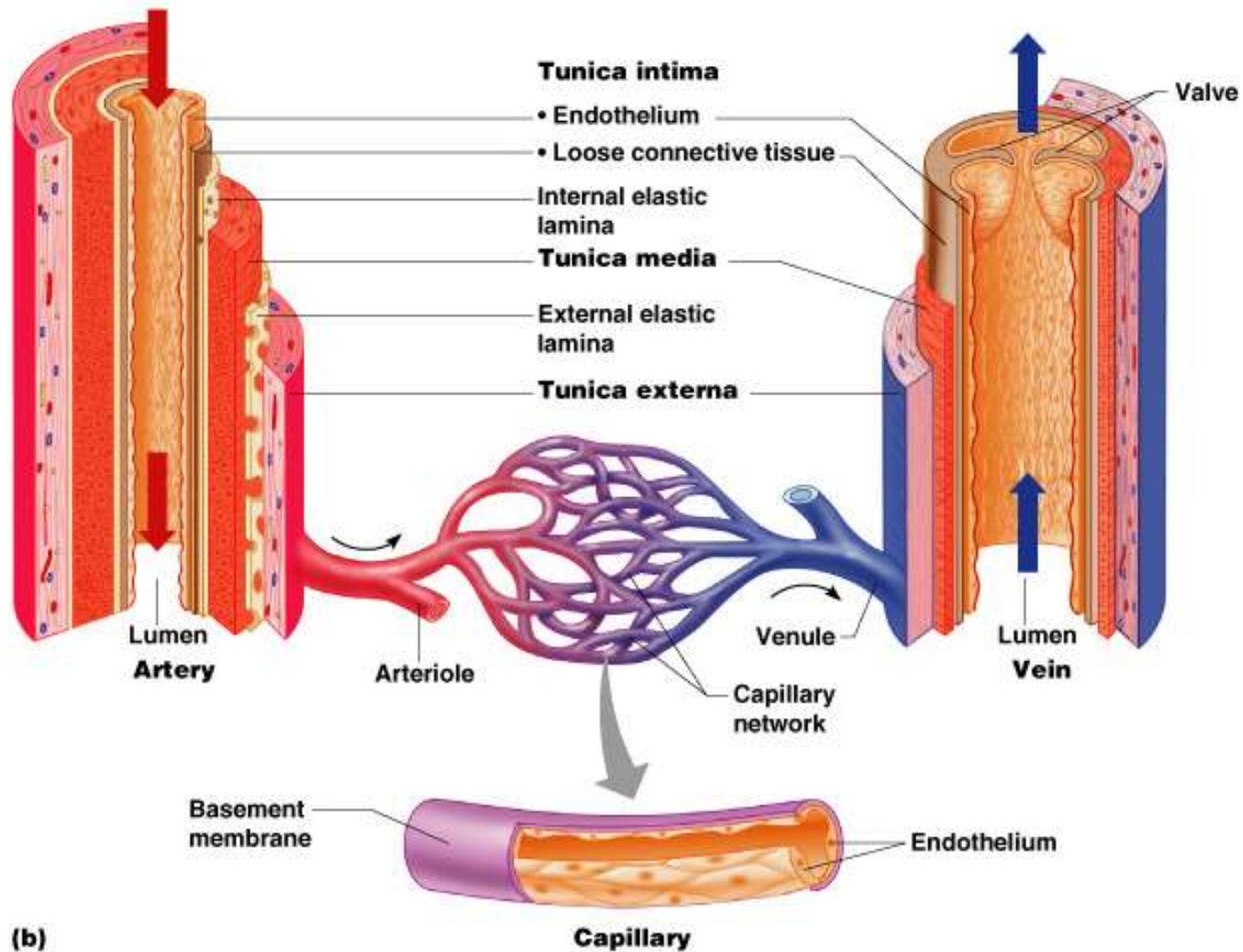
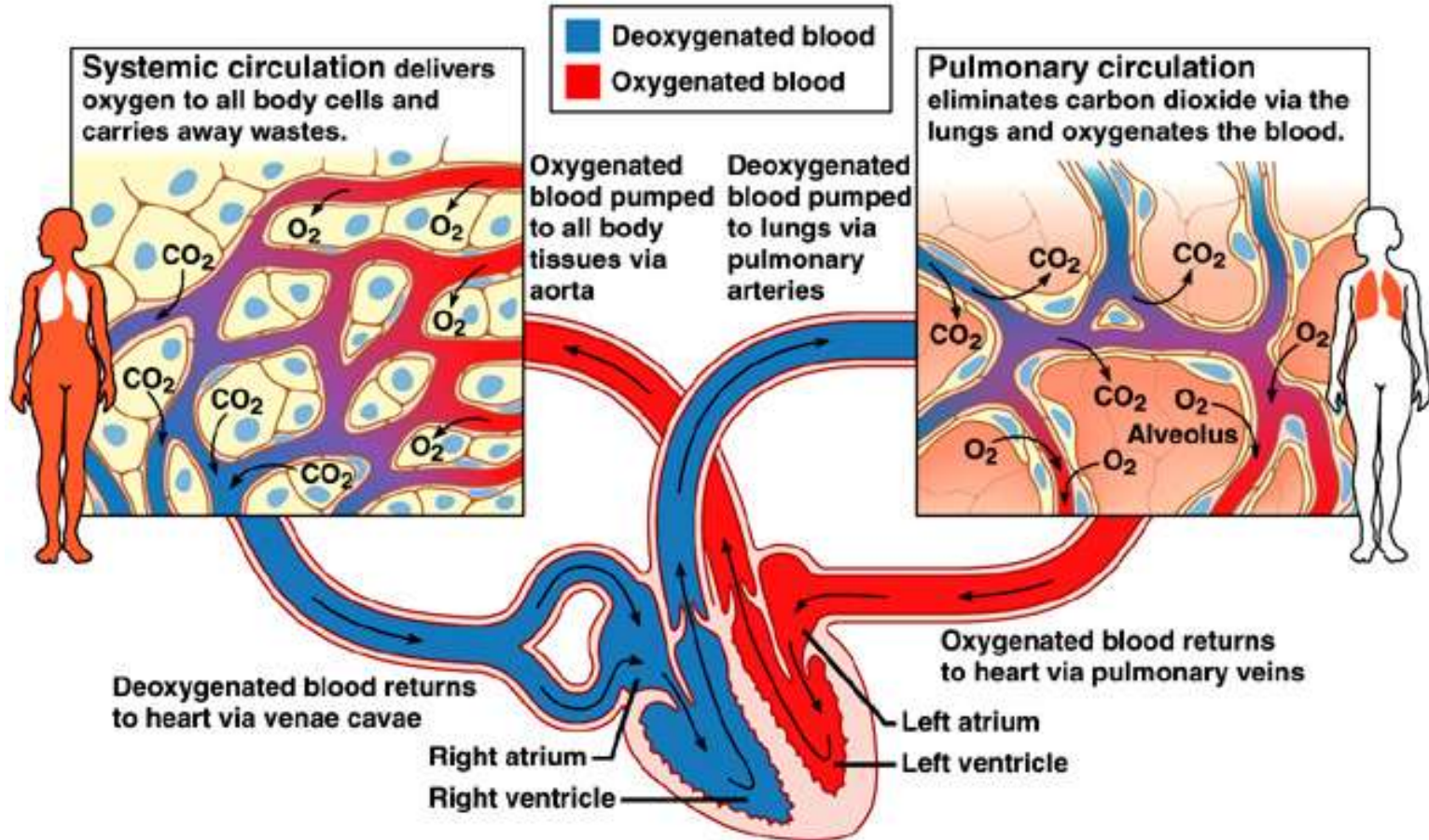


Figure 11.8b

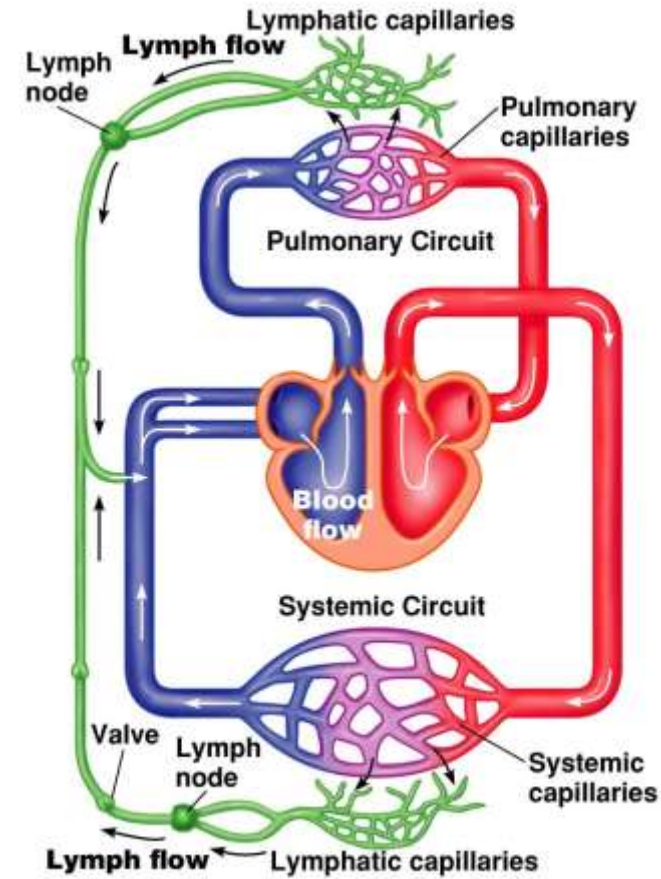




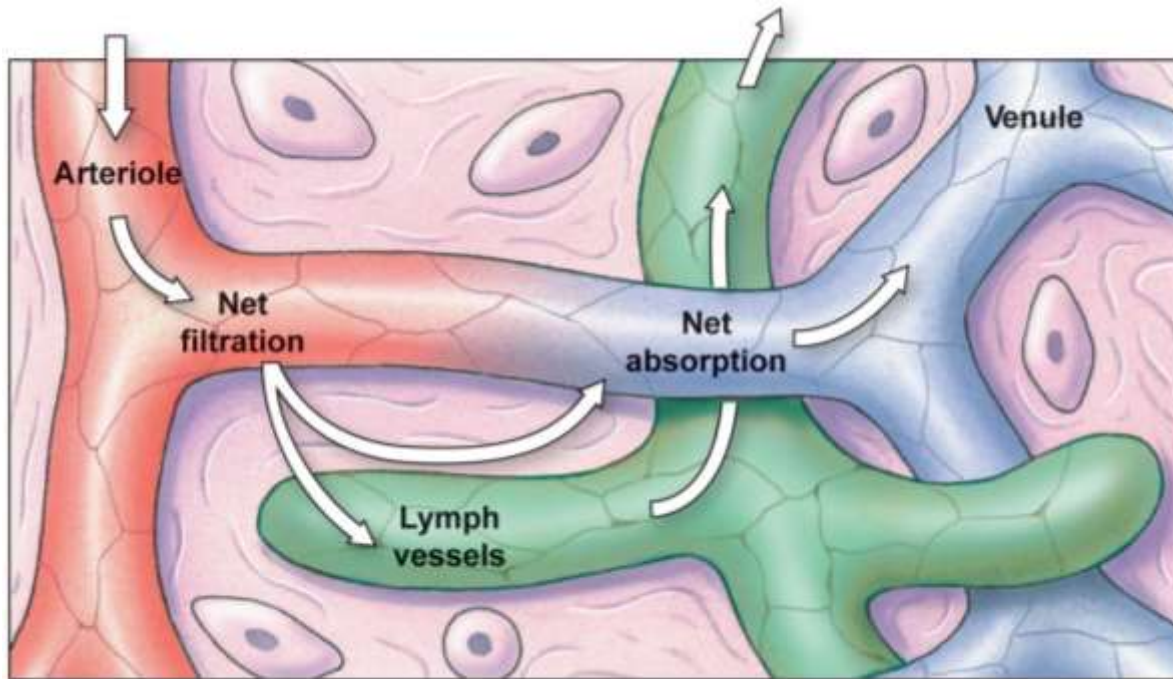
## The double pump

# Lymphatic circulation

- Driven by factors similar to venous circulation:
  - muscle activity
  - valves
  - respiration
- Lymph = plasma-proteins
- Lymphatic circulation collects fluid not reabsorbed by the capillaries
- Lymph is filtered in nodes before return to blood circulation

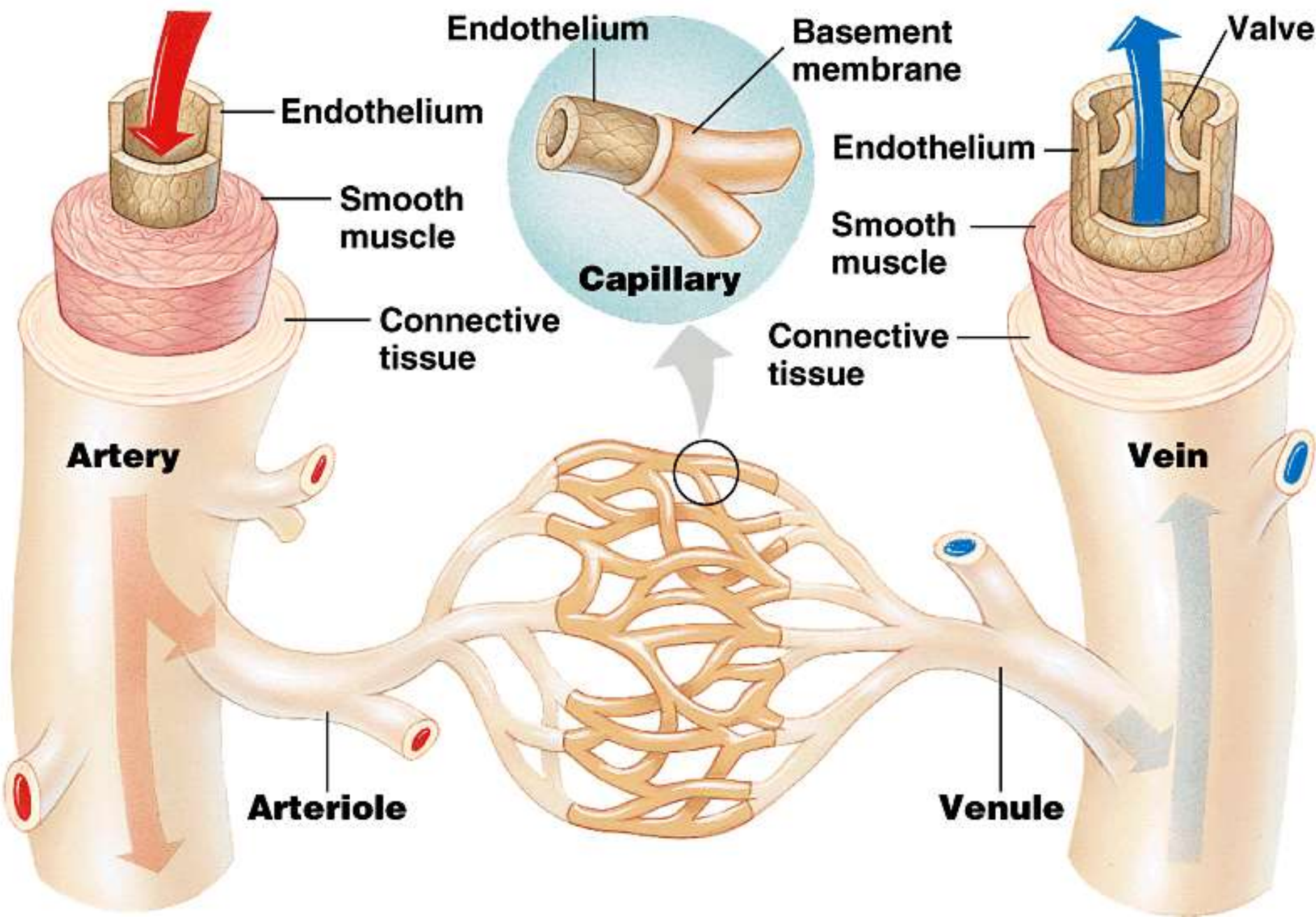


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(b) Relationship between capillaries and lymph vessels

- In most capillaries there is more [filtration than absorption](#)
- 90% the volume of fluid filtered out at the arterial end is absorbed back into the capillary at the venous end
  - the other 10% enters lymphatic vessels where it is returned back into circulation as the lymph vessels empty lymph fluid into blood at the right atrium



# Cardiorespiratory System

- Blood vessels
  - **Arteries** = vessels that carry blood away from the heart
  - **Veins** = vessels that carry blood to the heart
  - **Capillaries** = very small blood vessels that distribute blood to all parts of the body

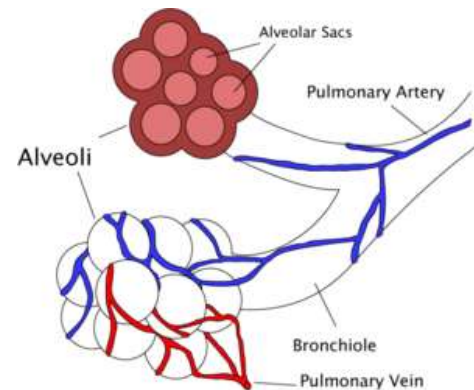
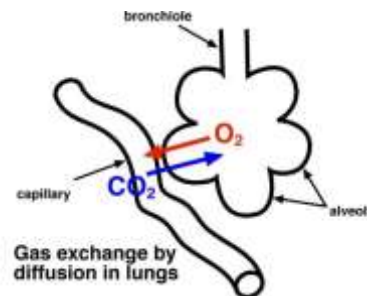
# Make Up of Blood Vessels: Arteries and Arterioles

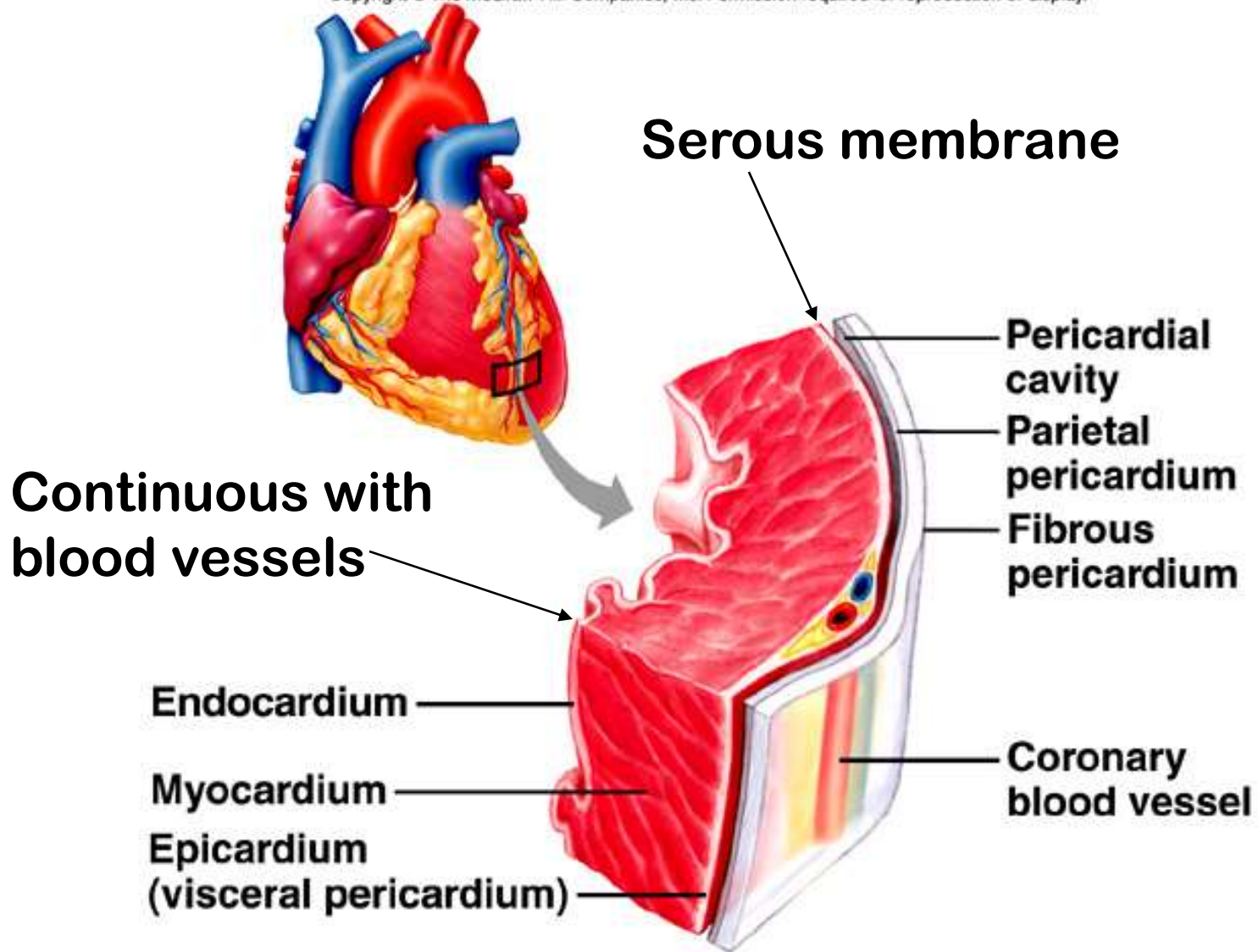
- Endothelium
- Elastic tissues
  - Rebounds
  - Evens flow
- Smooth muscles
- Fibrous tissue
  - Tough
  - Resists stretch

	Mean diameter	Mean wall thickness	Endothelium	Elastic tissue	Smooth muscle	Fibrous tissue	
Artery	4.0 mm	1.0 mm					
Arteriole	30.0 $\mu\text{m}$	6.0 $\mu\text{m}$					
Capillary	8.0 $\mu\text{m}$	0.5 $\mu\text{m}$					
Venule	20.0 $\mu\text{m}$	1.0 $\mu\text{m}$					
Vein	5.0 mm	0.5 mm					

# Gas Exchange

- Alveoli = tiny air sacs in the lungs through whose walls gases such as oxygen and carbon dioxide diffuse in and out of the blood
- Lungs expand and contract about 12—20 times a minute at rest

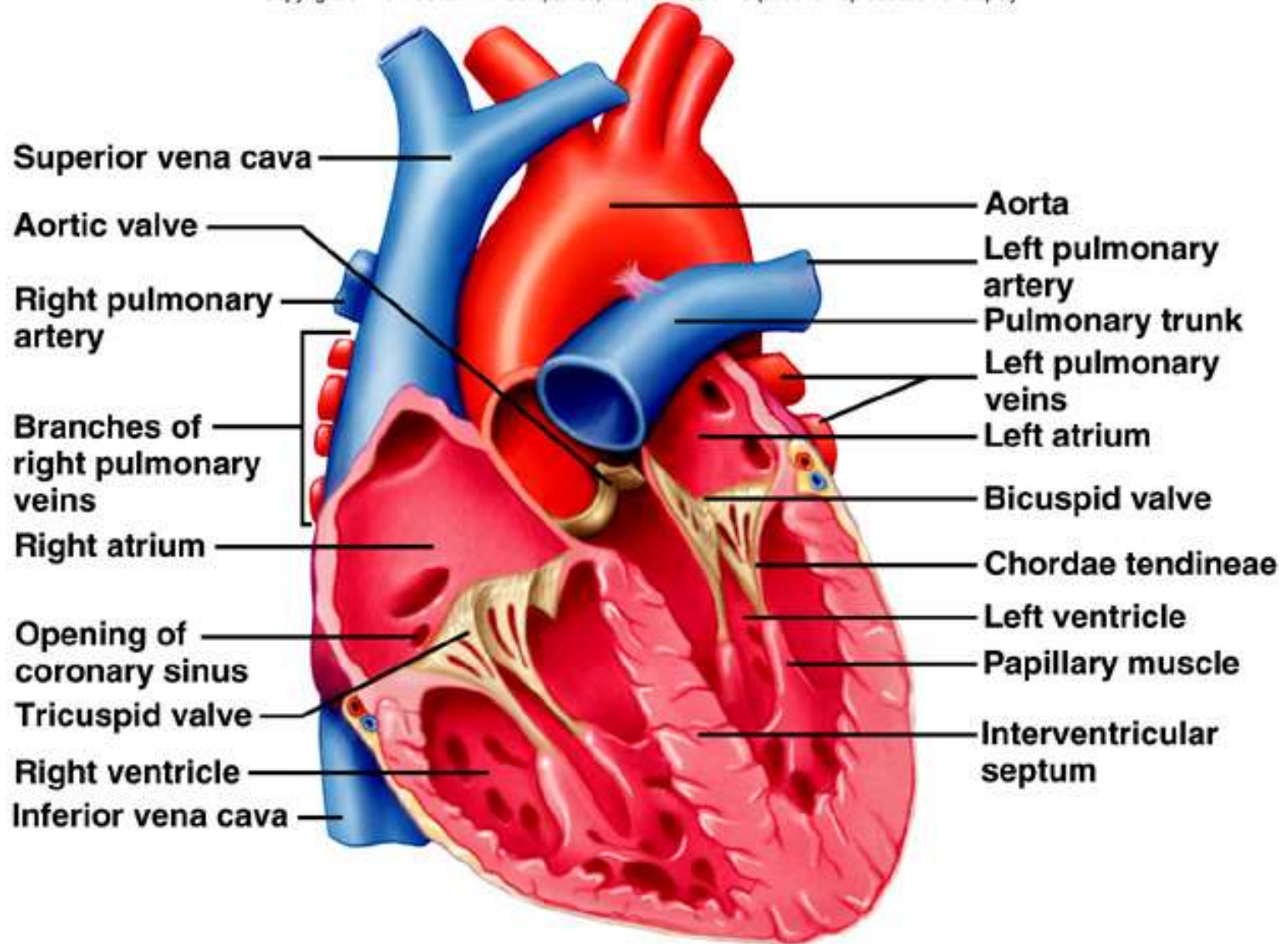






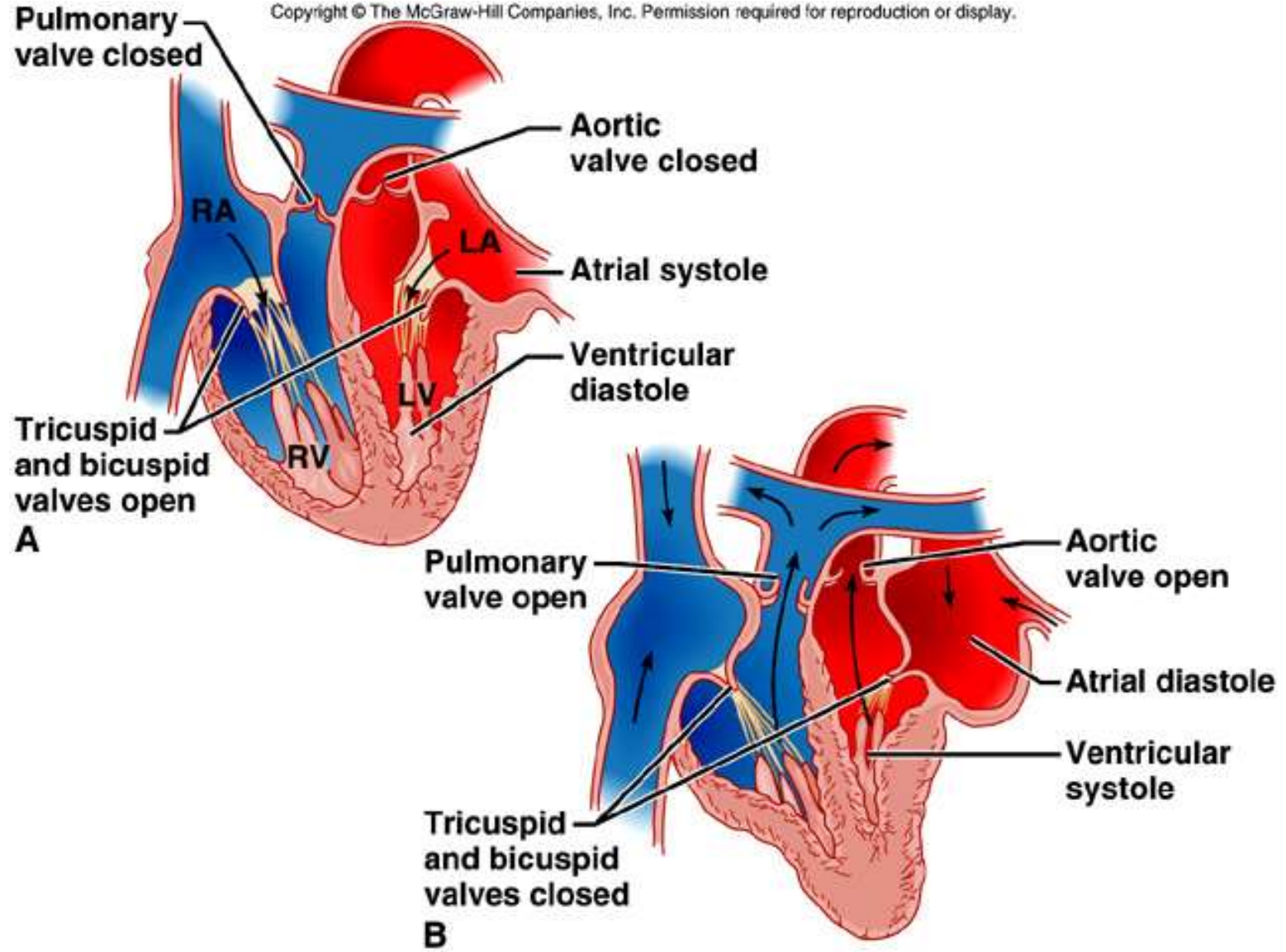
# Chambers of the heart; valves

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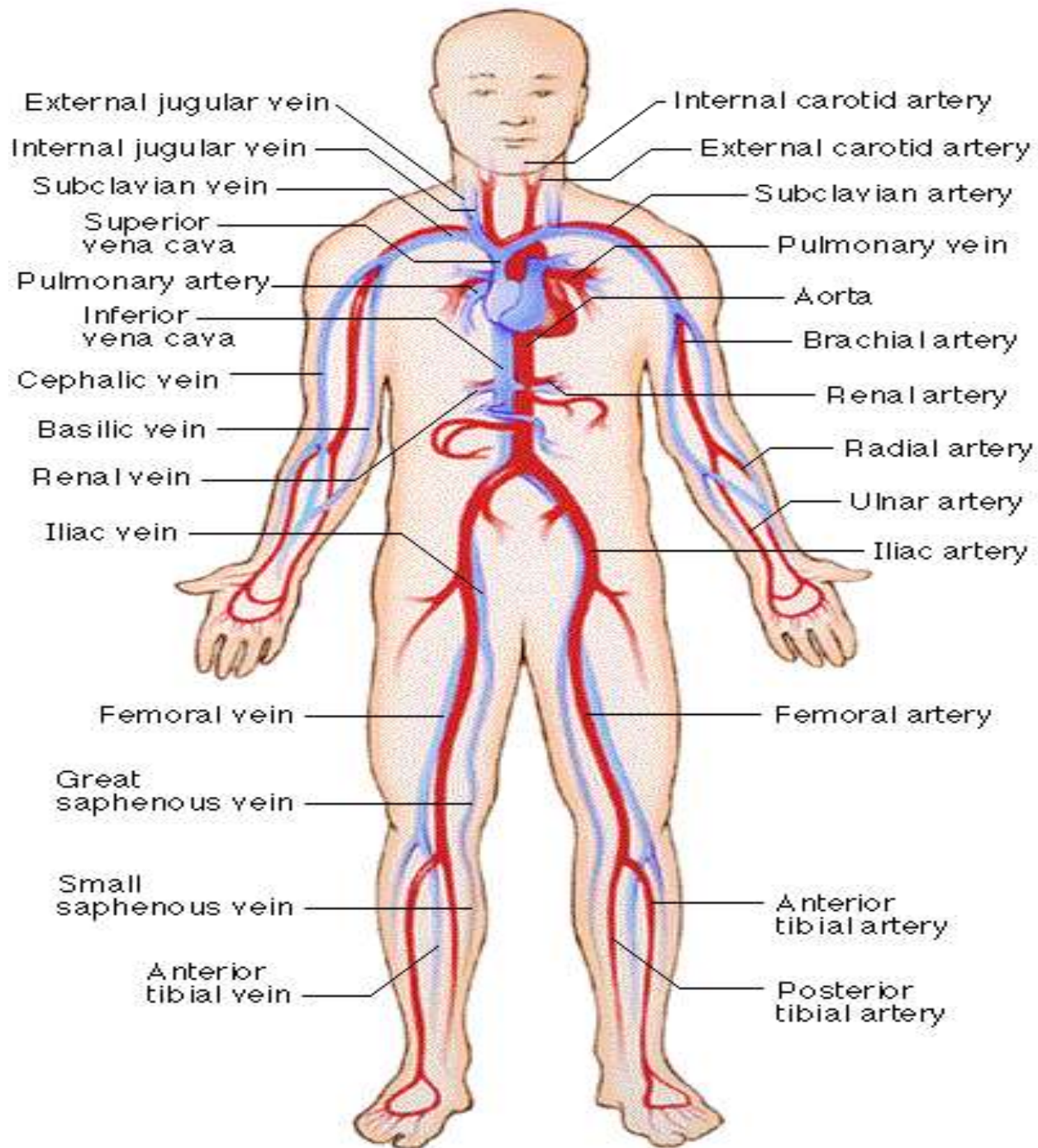
# Coordination of chamber contraction, relaxation

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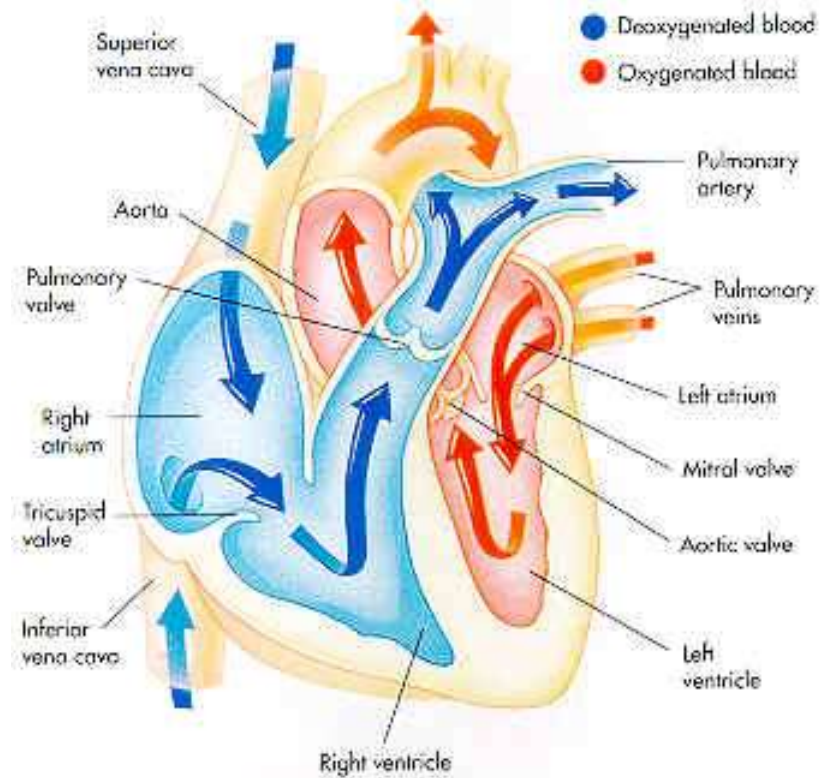
# Heart Anatomy

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

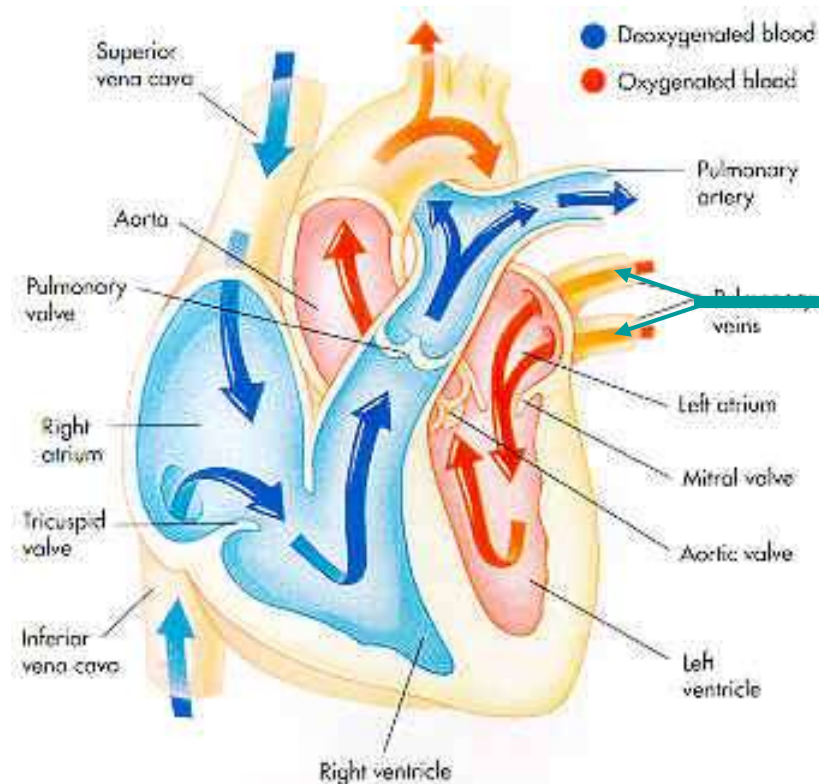


# The Heart

- The human heart has four chambers
  - Left and right ventricle
  - Left and right atrium
- The left side of the heart pumps oxygenated blood to the body while the right side of the heart pumps deoxygenated blood to the lungs where oxygen can be absorbed by the hemoglobin carrying red blood cells



**Path of Blood Through the Heart**  
 Figure 51-20

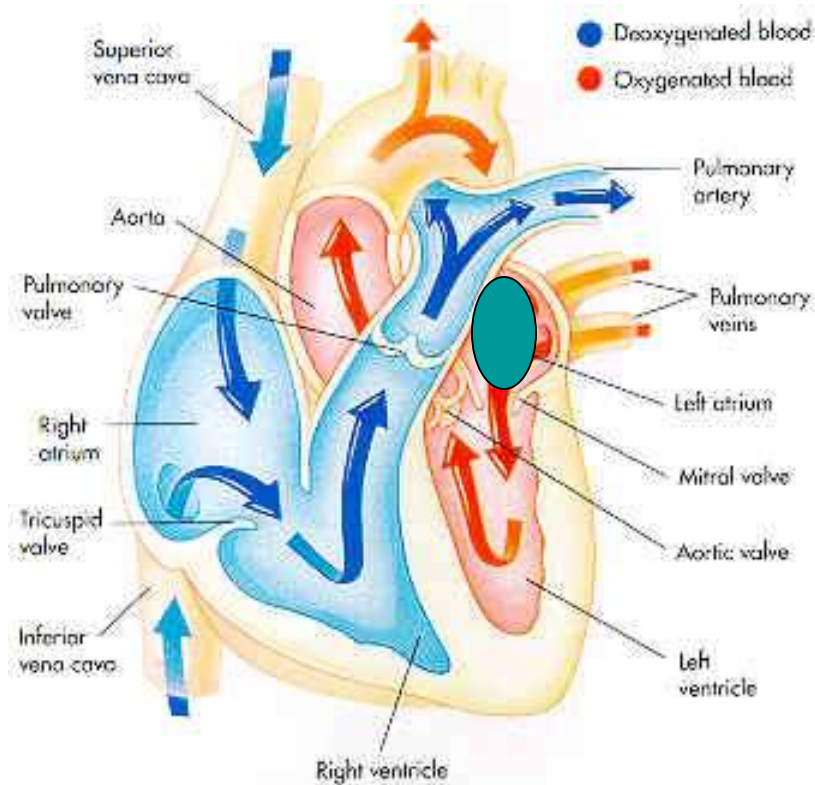


From lungs

Path of Blood Through the Heart  
Figure 51-20

After passing through the capillaries of the lungs, the blood which is now oxygenated returns to the heart in the pulmonary veins.

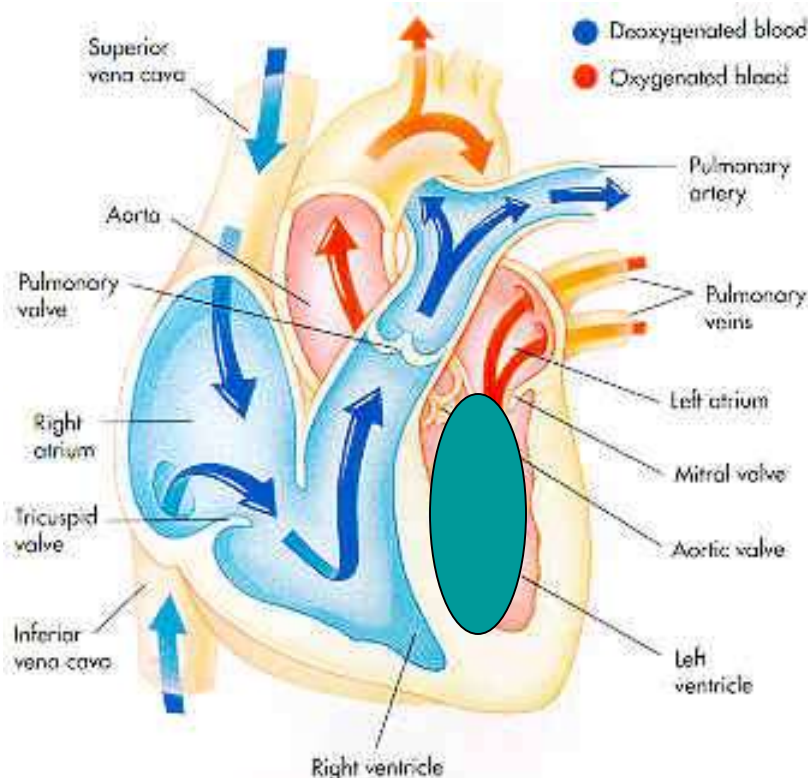
# The left atrium receives blood from the pulmonary vein.



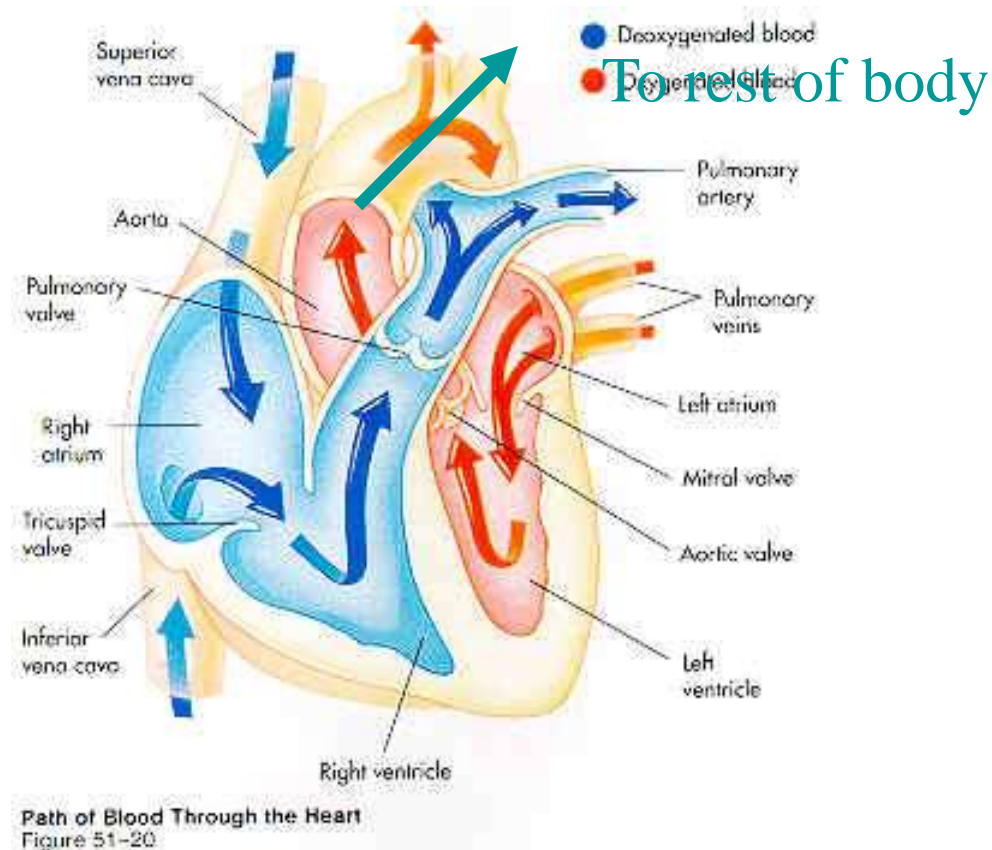
Path of Blood Through the Heart  
Figure 51-20



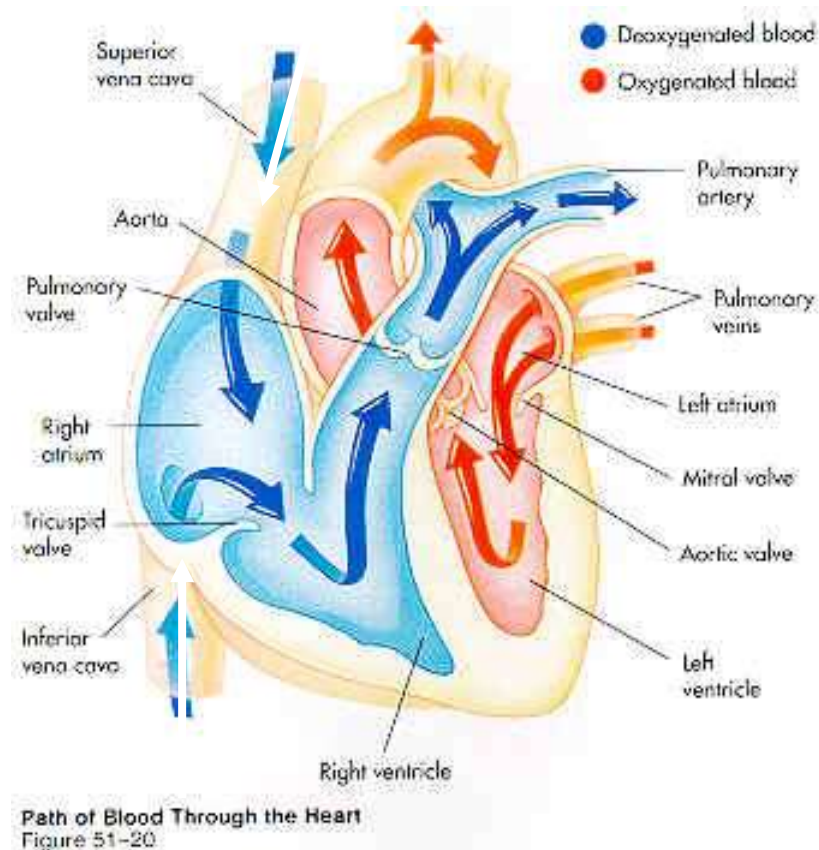
# Blood passes through the mitral valve into the left ventricle.



Path of Blood Through the Heart  
Figure 51-20

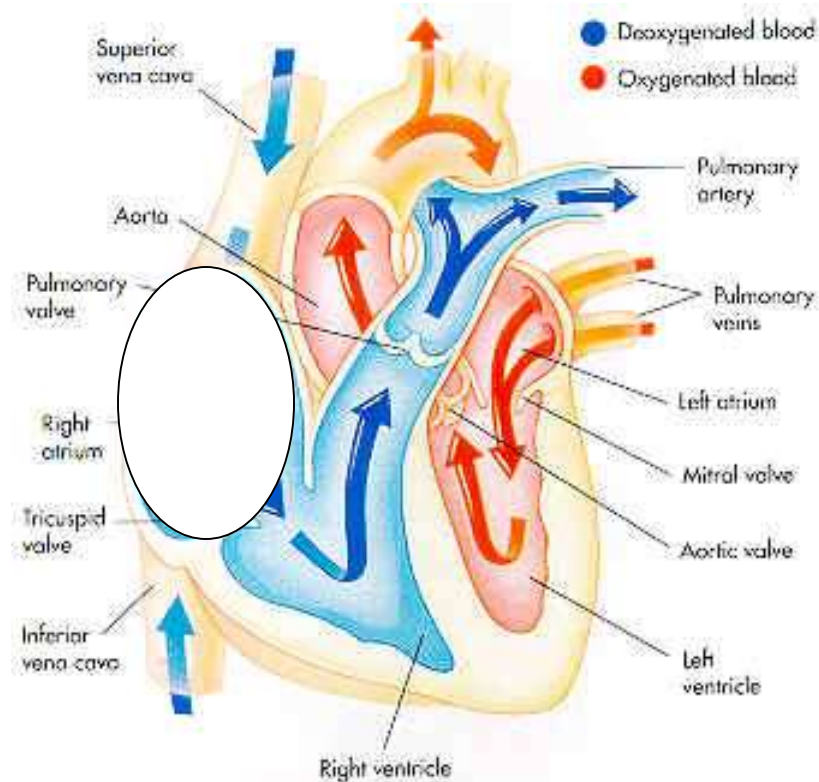


Contraction of the left ventricle pushes blood through the aortic semilunar valve into the aorta. Blood travels to all regions of the body where it feeds cells with oxygen picked up from the lungs and nutrients from the digestive tract.



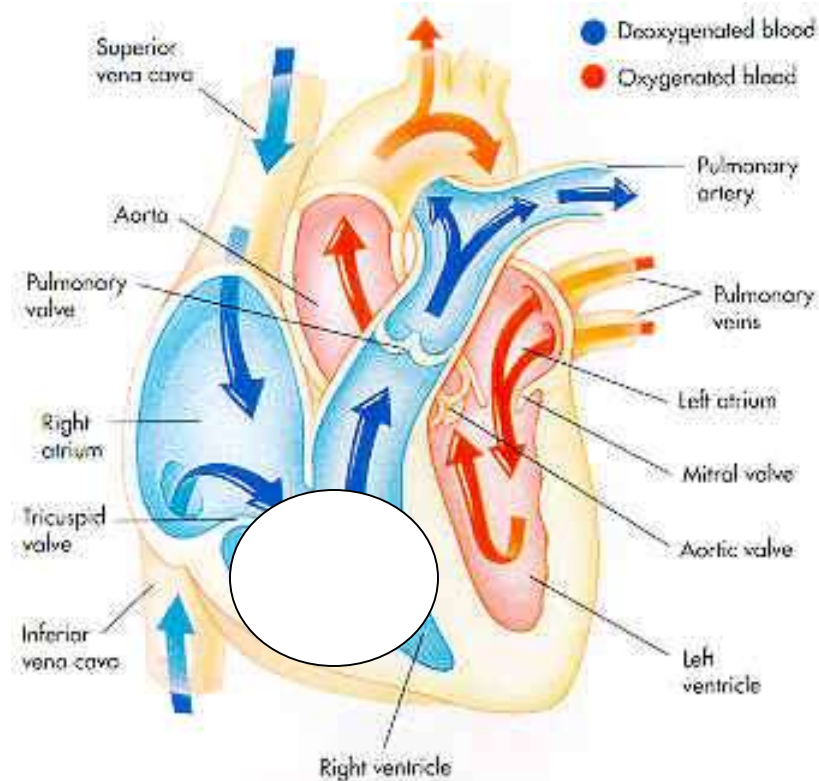
Deoxygenated blood returns from the rest of the body through the superior and inferior vena cava.

The right atrium receives the deoxygenated blood.

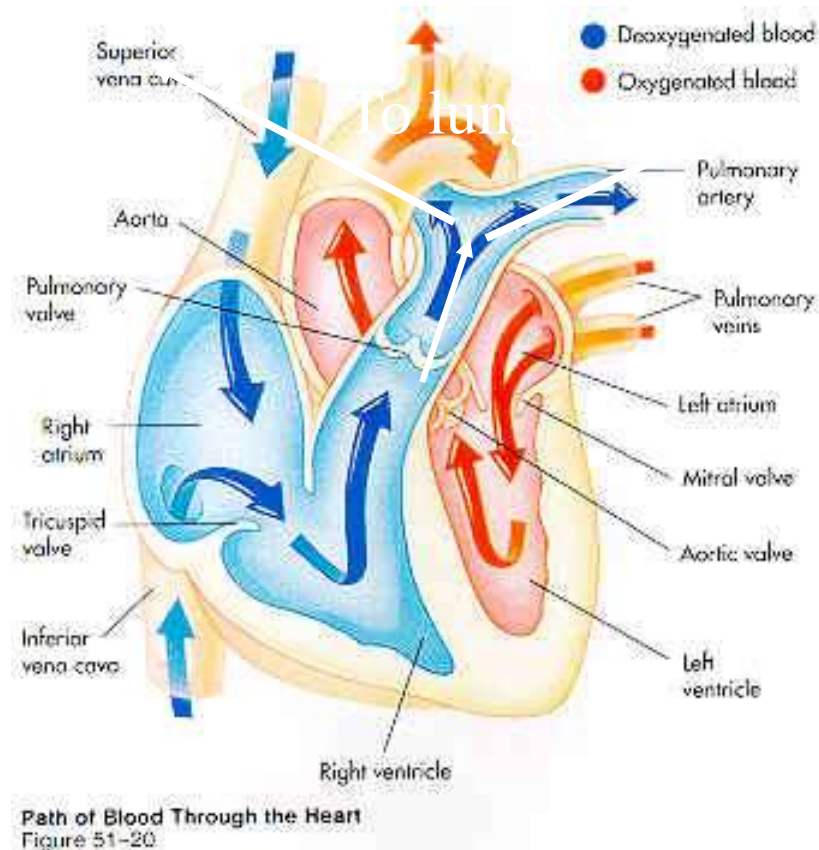


Path of Blood Through the Heart  
Figure 51-20

Blood then enters the right ventricle through the tricuspid valve.

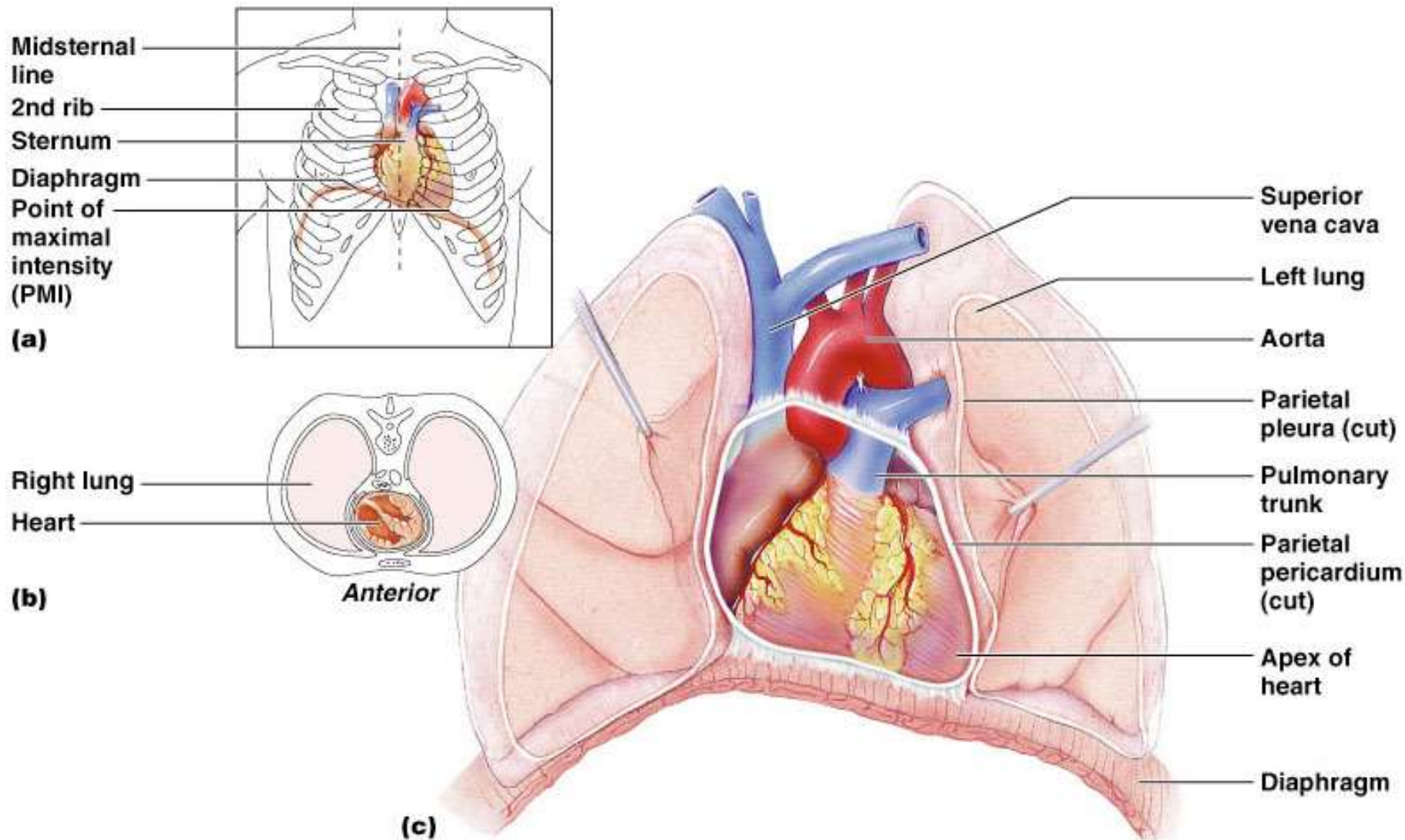


Path of Blood Through the Heart  
Figure 51-20

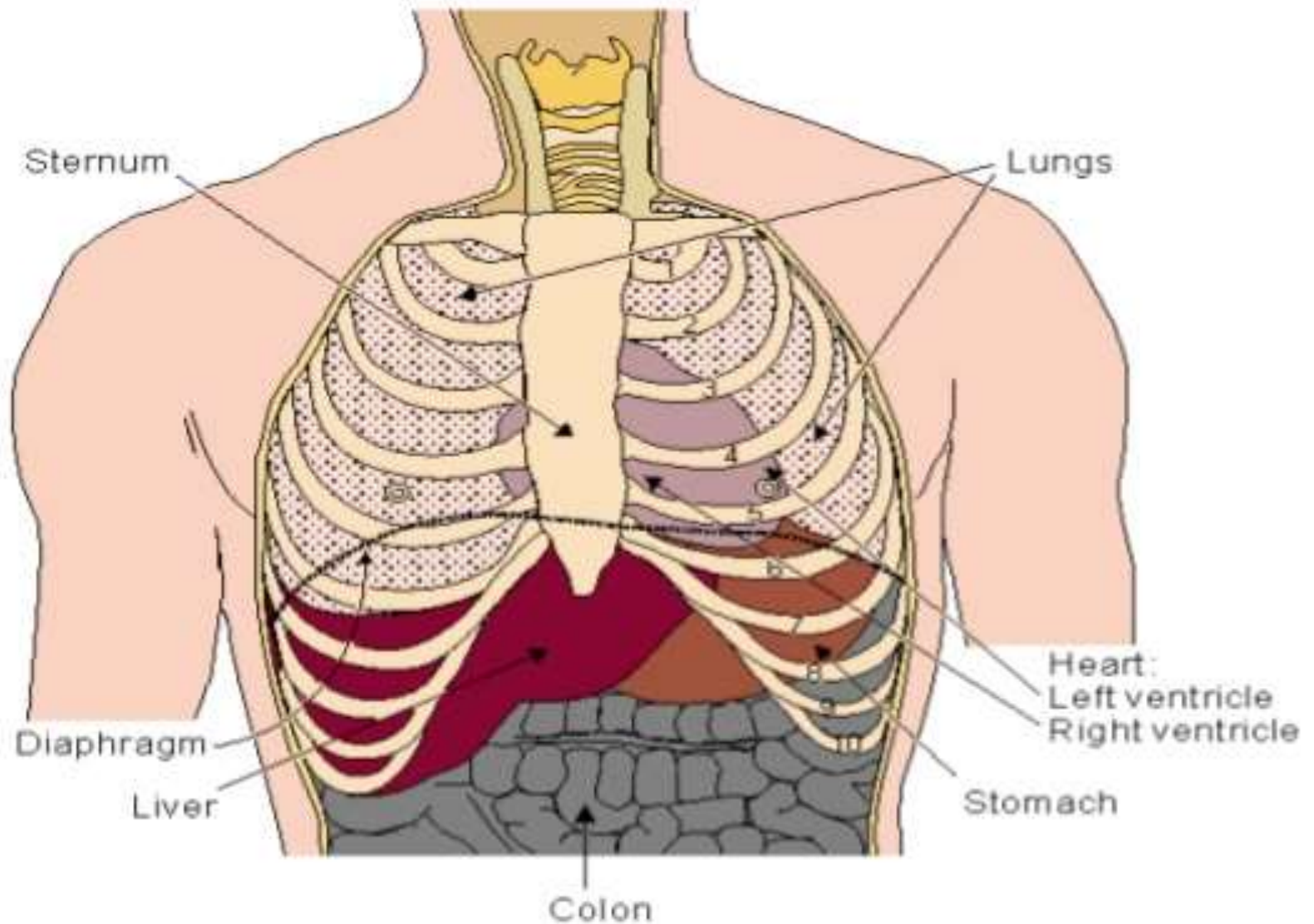


Contraction of the right ventricle pushes blood through the pulmonary semilunar valve into the pulmonary arteries in which it travels to the lungs.

# Heart Anatomy



# TOPOGRAPHY AND SYNTOPY OF HEART

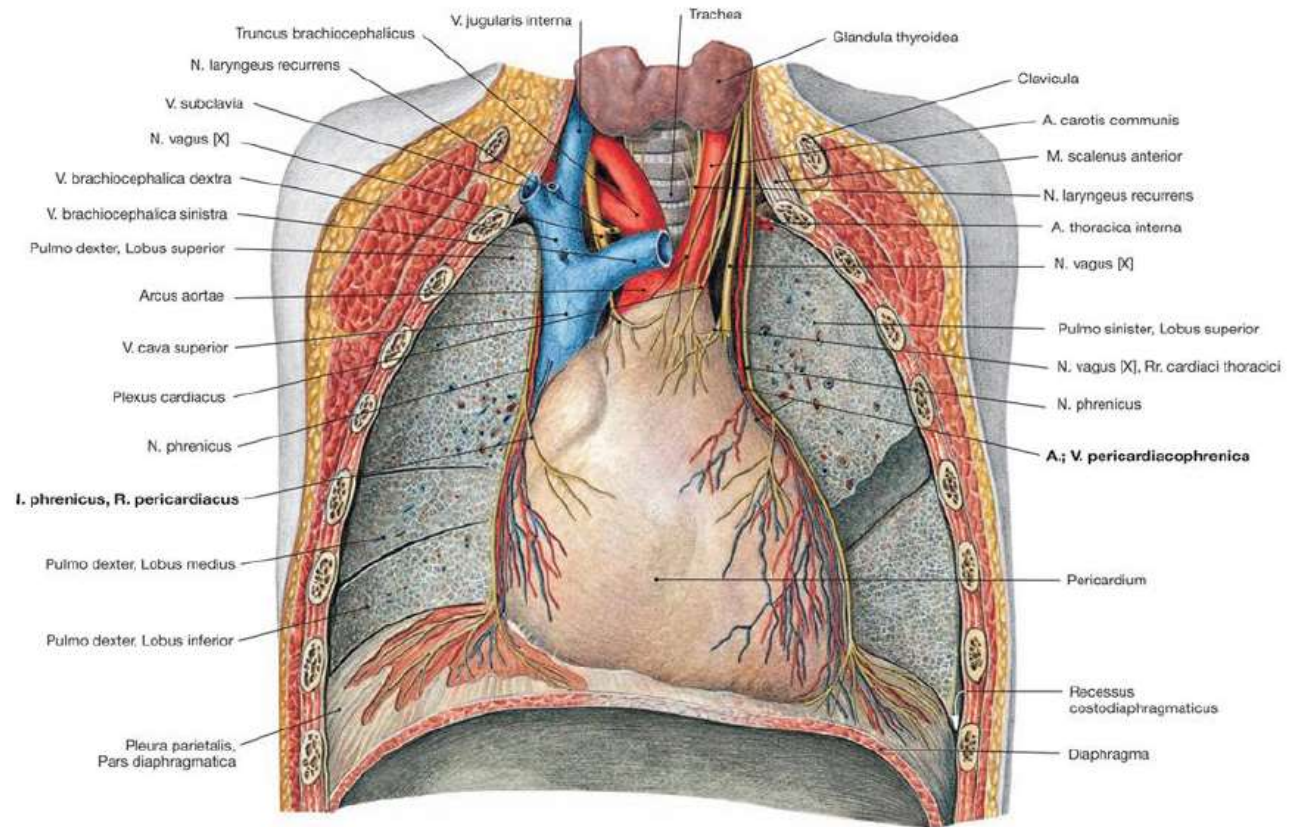




# Mediastinum

## Middle

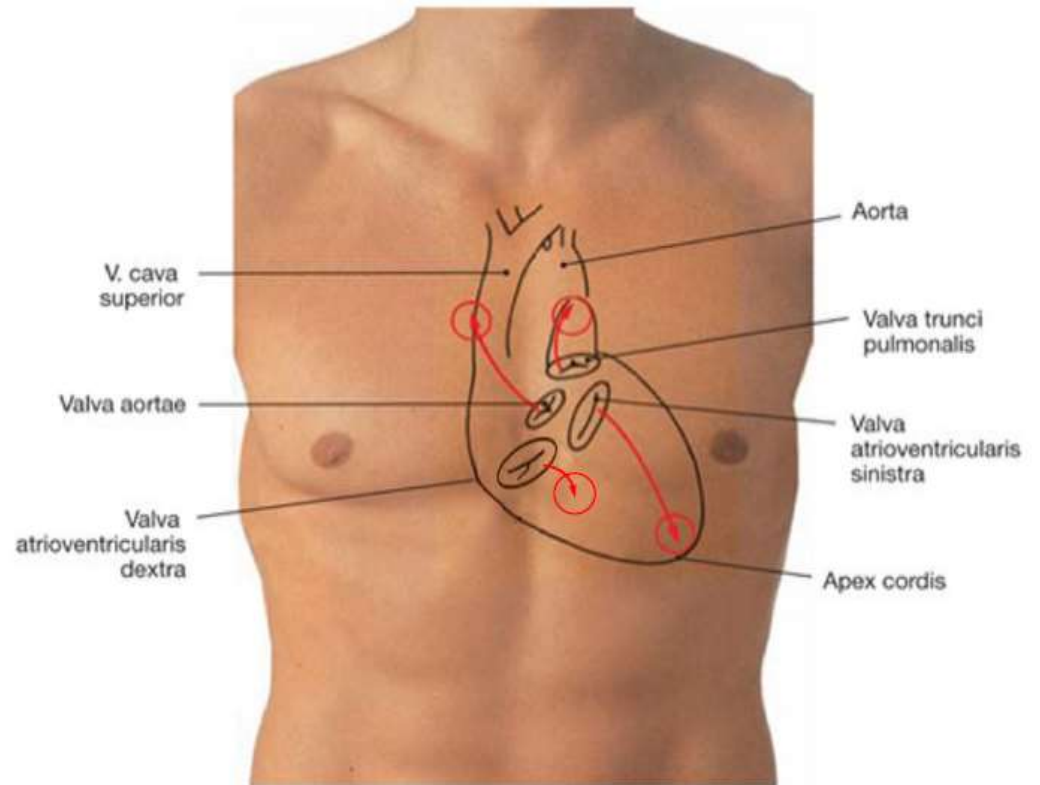
- Pericardium
- Heart
- Great vessels

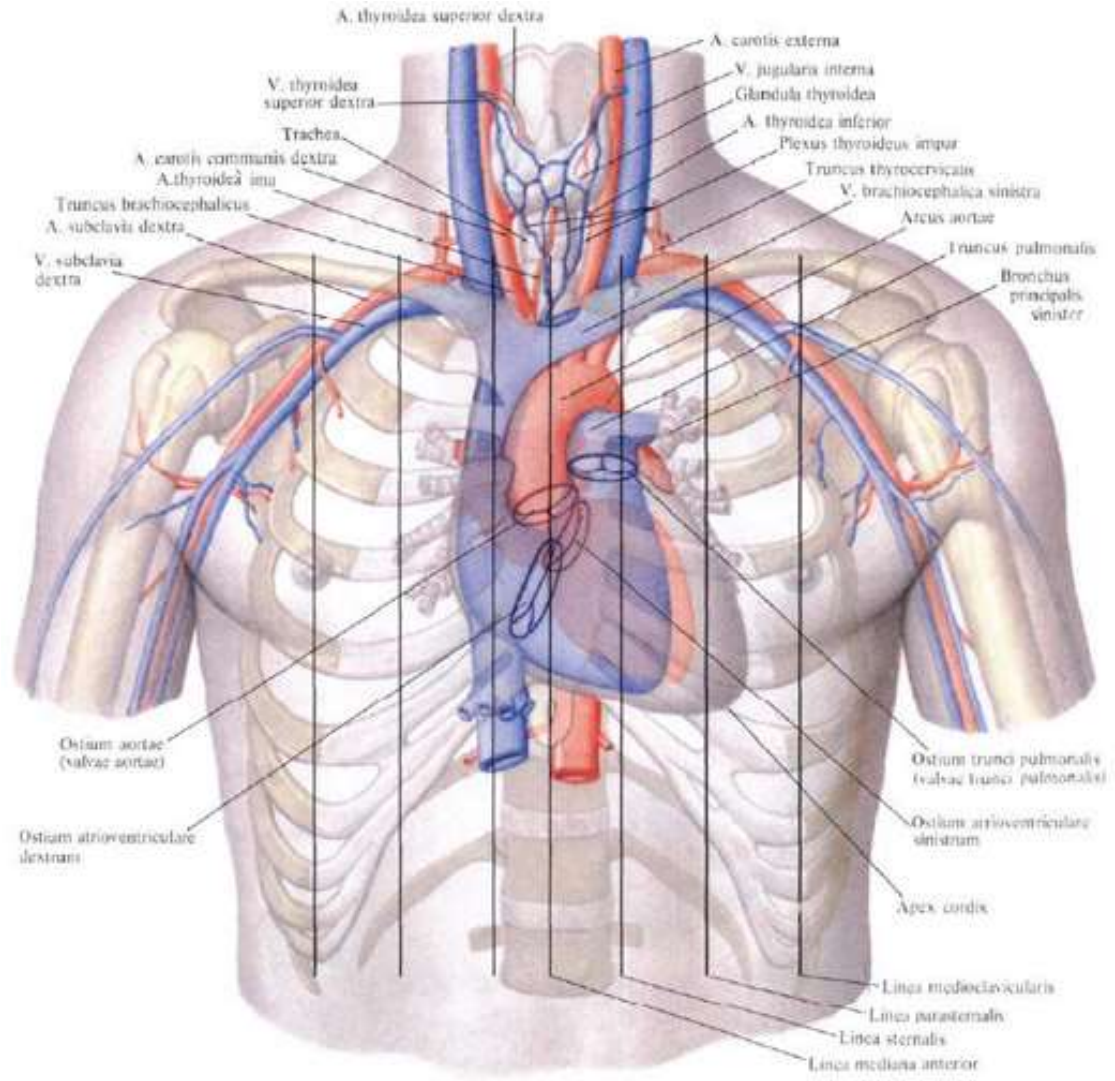


## Middle mediastinum

Topography of heart and auscultation points

- Aortic valve:  
Right 2nd intercostal space
- Pulmonary valve:  
Left 2nd intercostal space
- Right AV valve:  
Left 4th intercostal space
- Left AV valve:  
Left 5th intercostal space





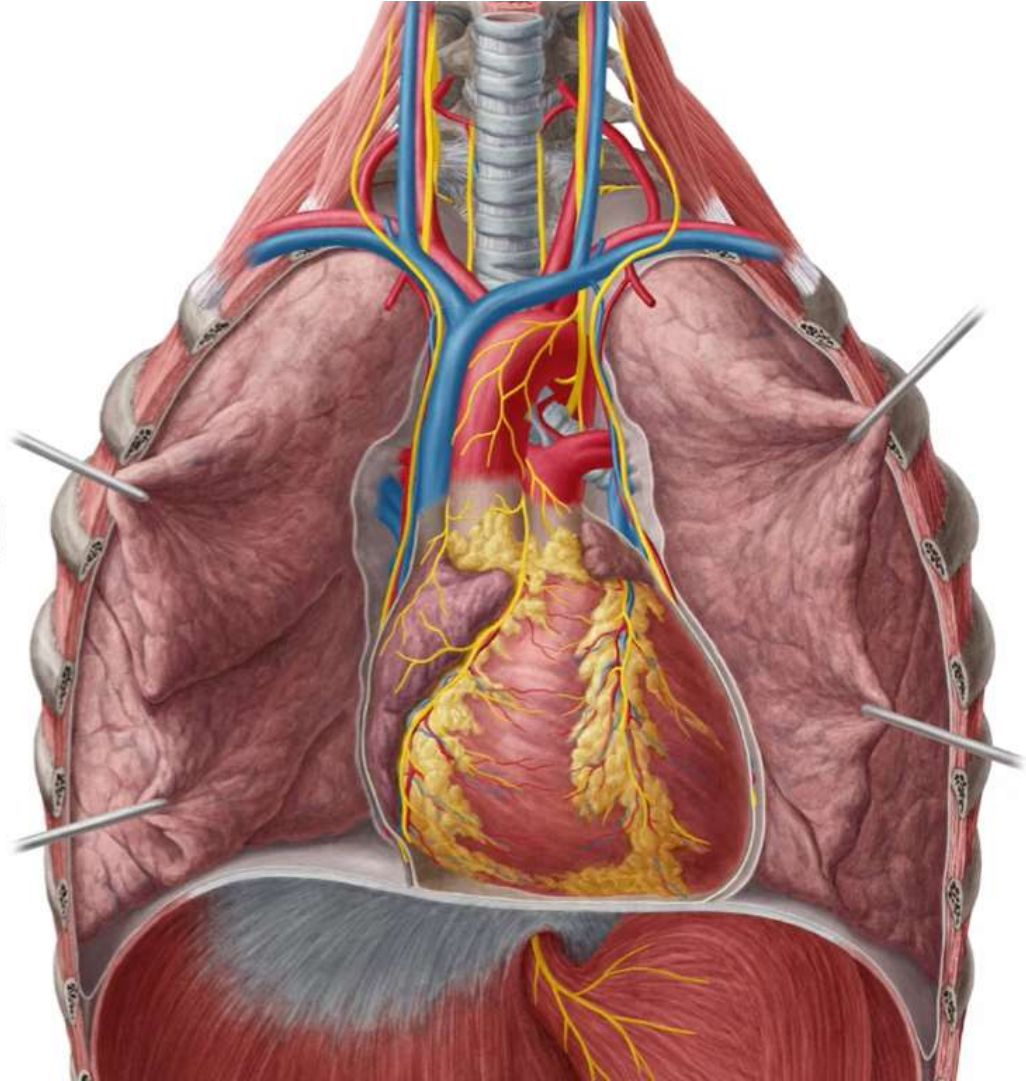
Cardiac circulatory system function:

**Pulmonary circuit:**

Carries the deoxygenated blood into the lungs.

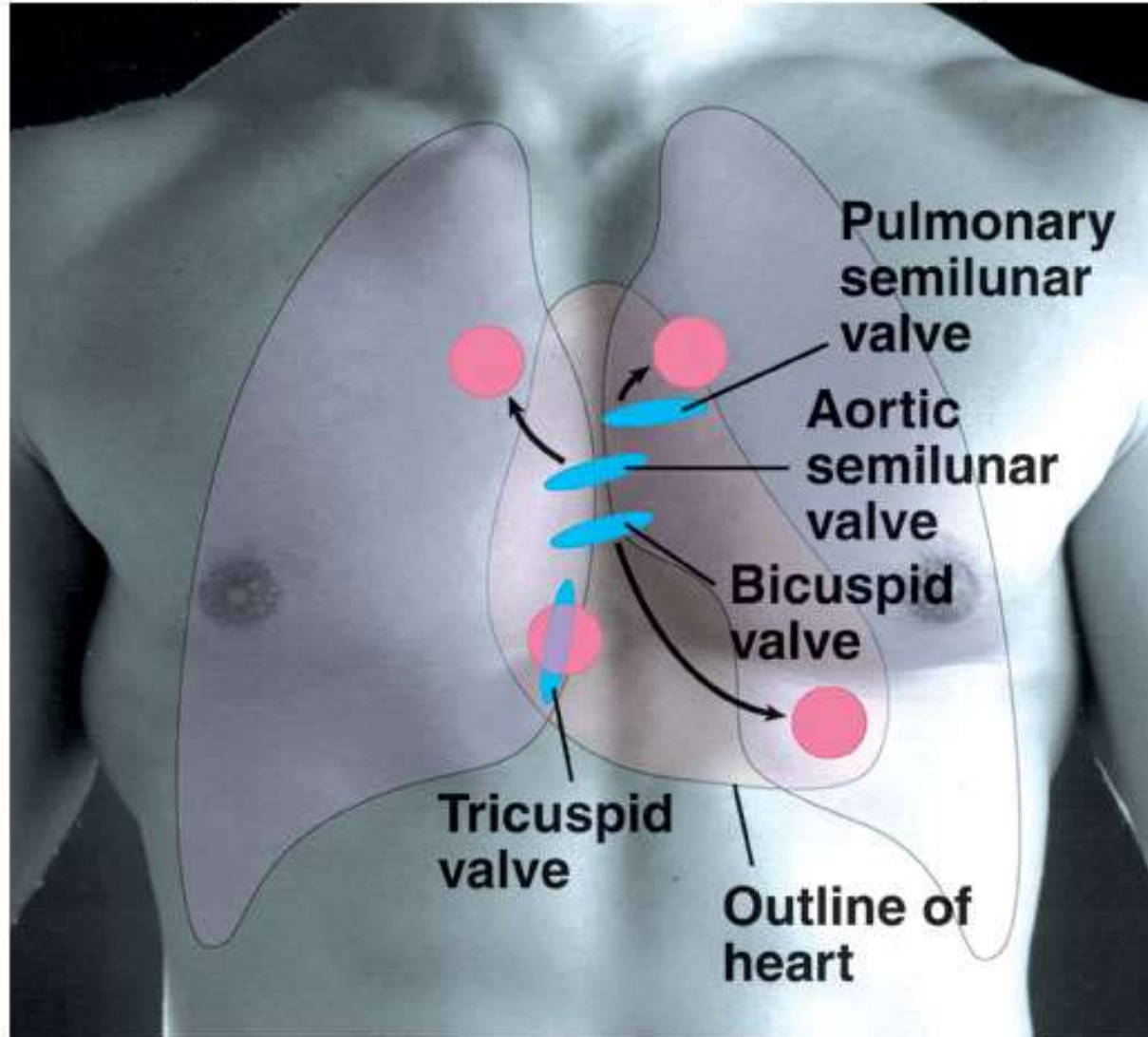
**Systemic circuit:**

Delivers the oxygenated blood to the tissues.



# Location of Heart Valves

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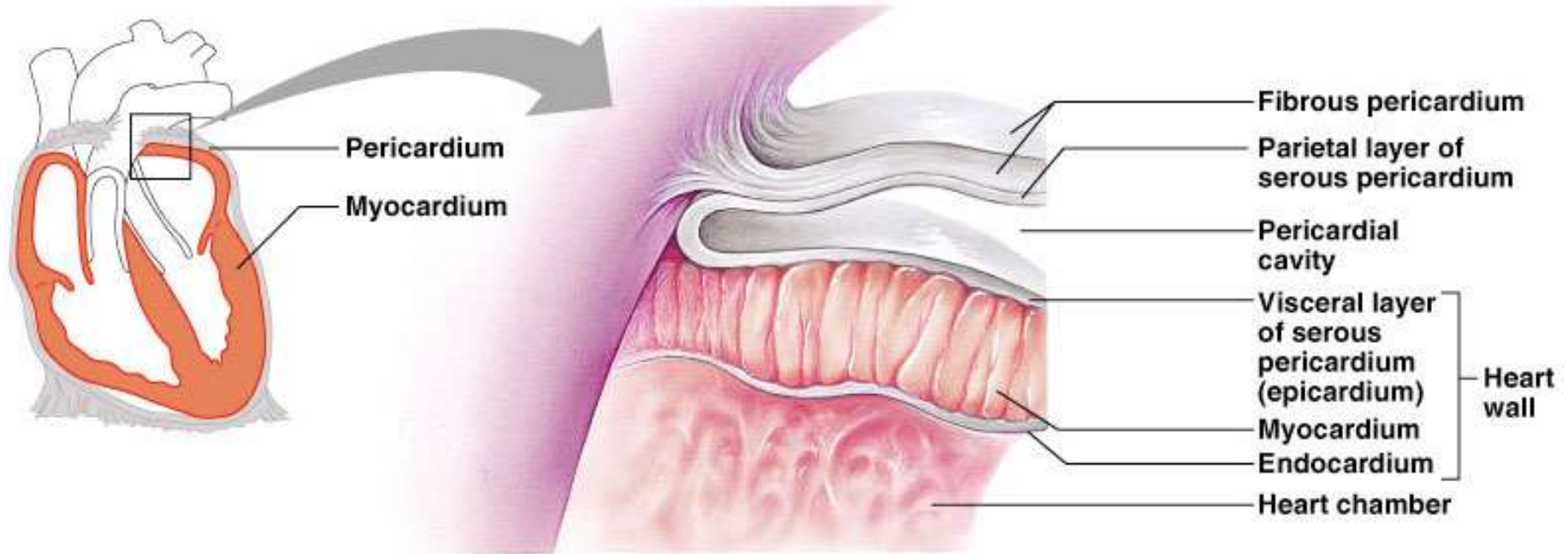
# Coverings of the Heart: Anatomy

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

# Coverings of the Heart

- The Function of 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

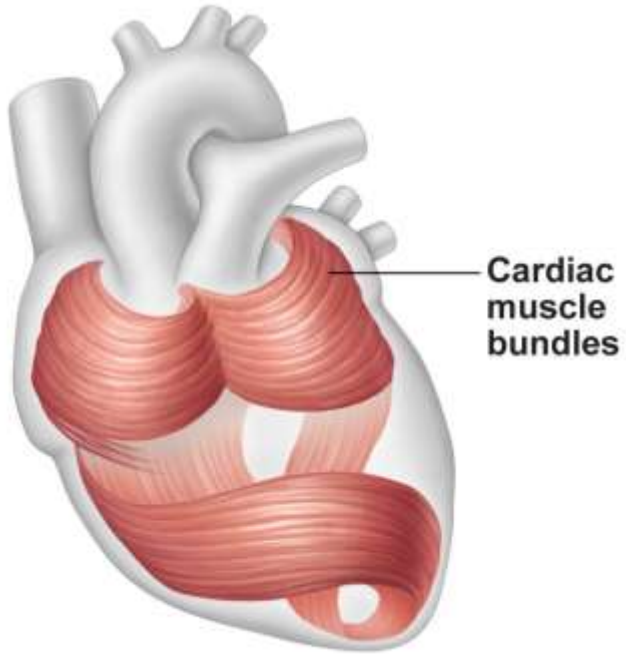
# Pericardial Layers of the Heart



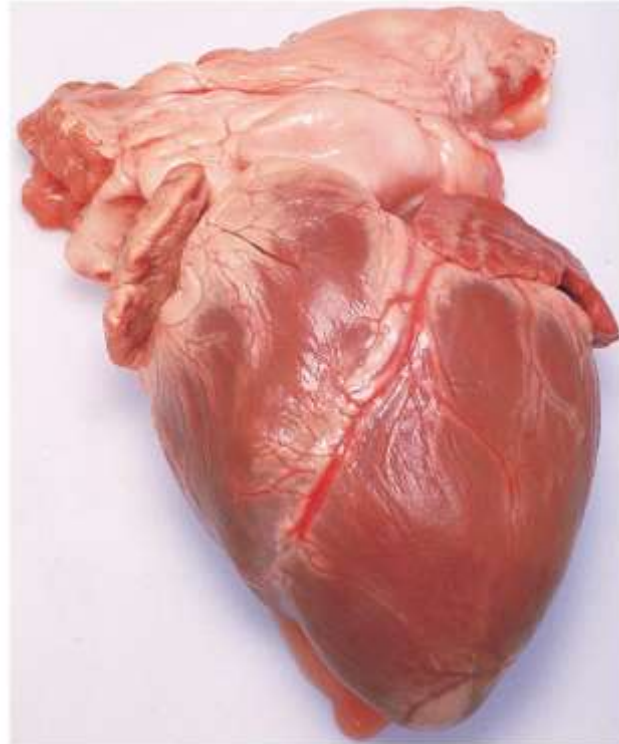


# Heart Wall

- 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



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# External Heart: Major Vessels of the Heart (Anterior View)

---

- Vessels **returning blood to the heart** include:
  1. Superior and inferior **venae cavae**
  2. Right and left **pulmonary veins**
  
- Vessels conveying **blood away from the heart** include:
  1. **Pulmonary trunk**, which splits into right and left pulmonary arteries
  2. Ascending **aorta** (three branches) –
    - a. **Brachiocephalic**
    - b. **Left common carotid**
    - c. **Subclavian arteries**



# External Heart: Vessels that Supply/ Drain the Heart (Anterior View)

---

- **Arteries** — right and left coronary (in atrioventricular groove), marginal, circumflex, and anterior interventricular arteries
- **Veins** — small cardiac, anterior cardiac, and great cardiac veins

# External Heart: Anterior View

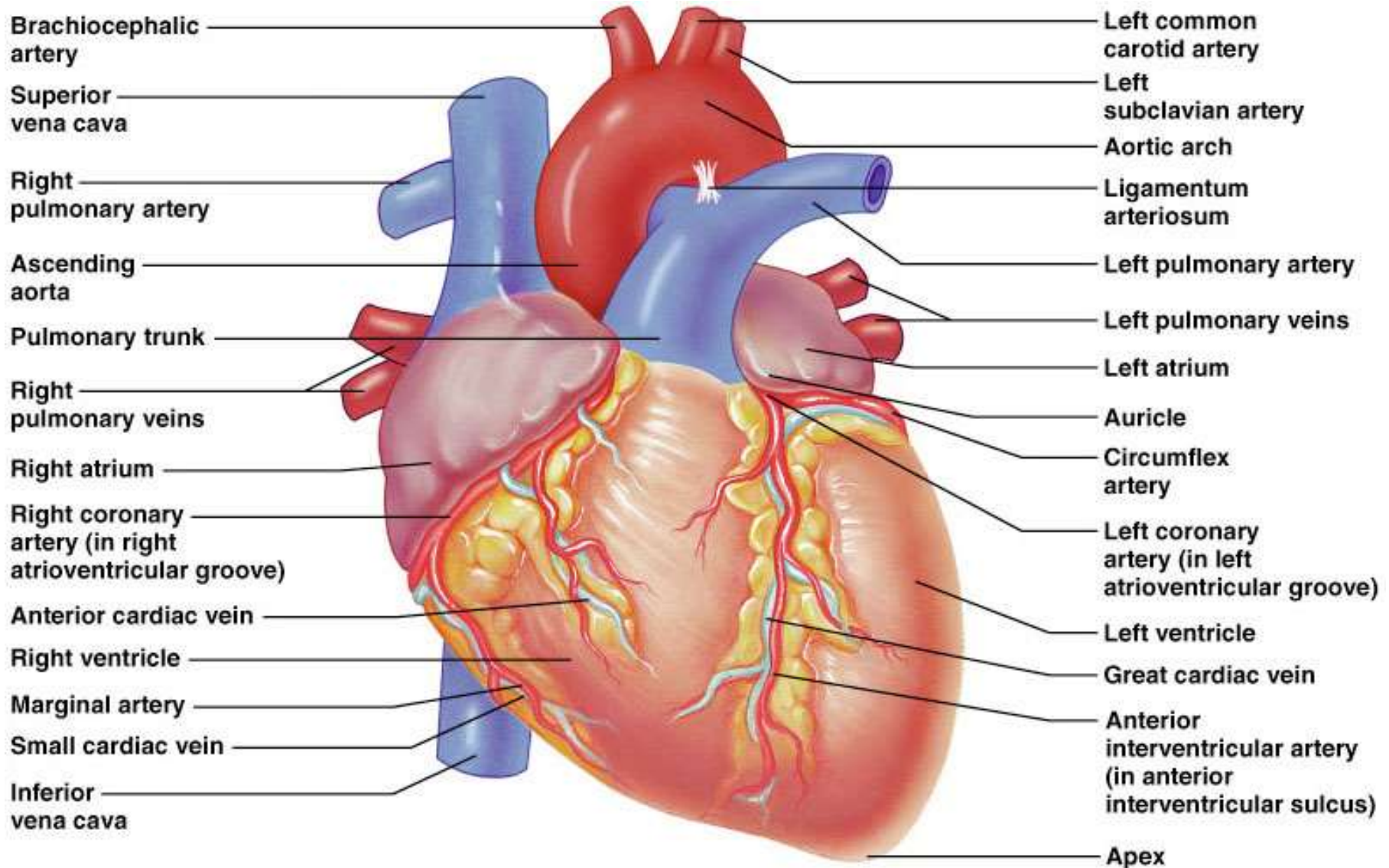
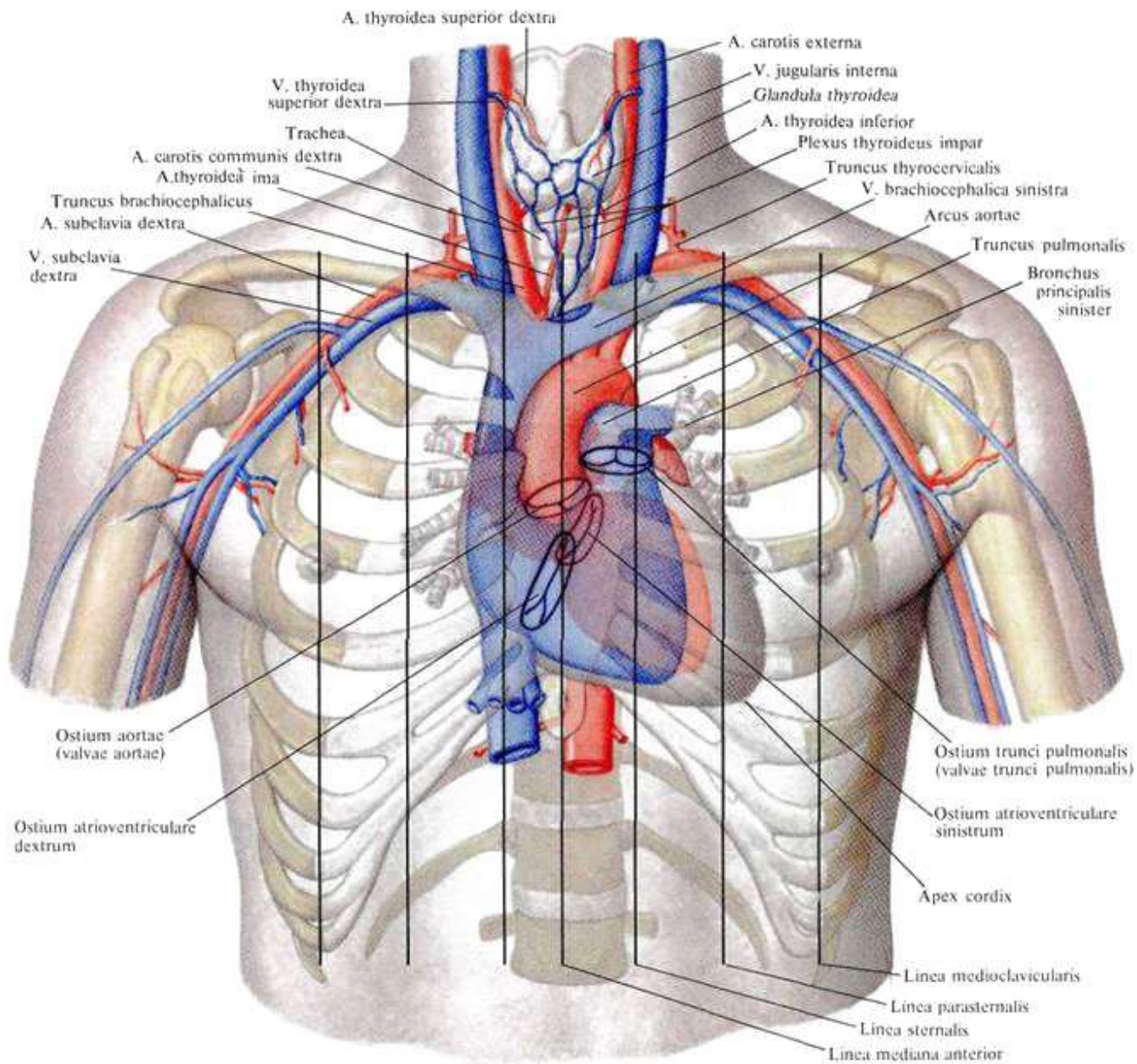


Figure 18.4b

# External Heart: Major Vessels of the Heart (Posterior View)

---

- Vessels returning blood to the heart include:
  1. Right and left pulmonary veins
  2. Superior and inferior venae cavae
- Vessels conveying blood away from the heart include:
  1. Aorta
  2. Right and left pulmonary arteries



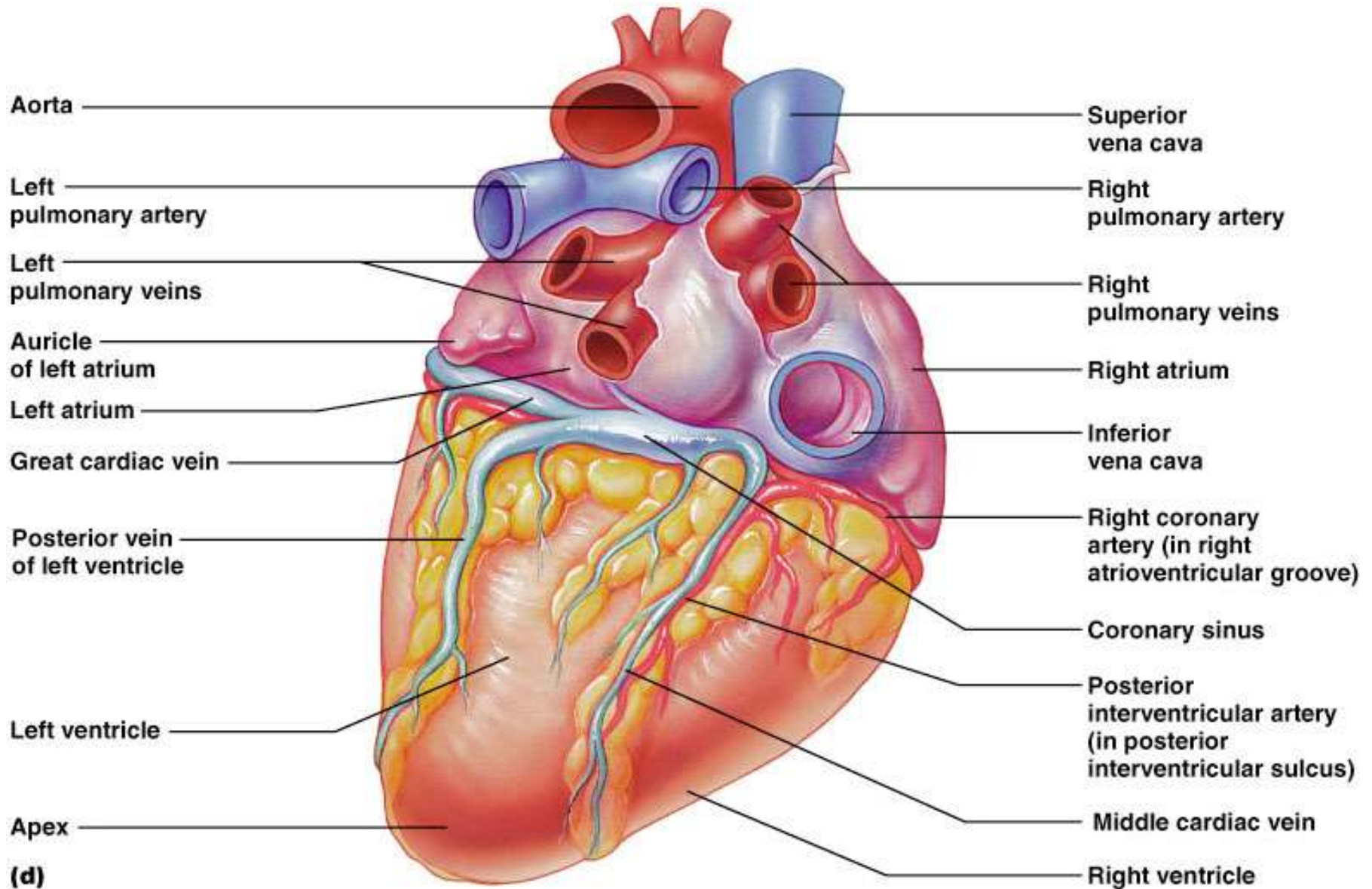


# External Heart: Vessels that Supply/ Drain the Heart (Posterior View)

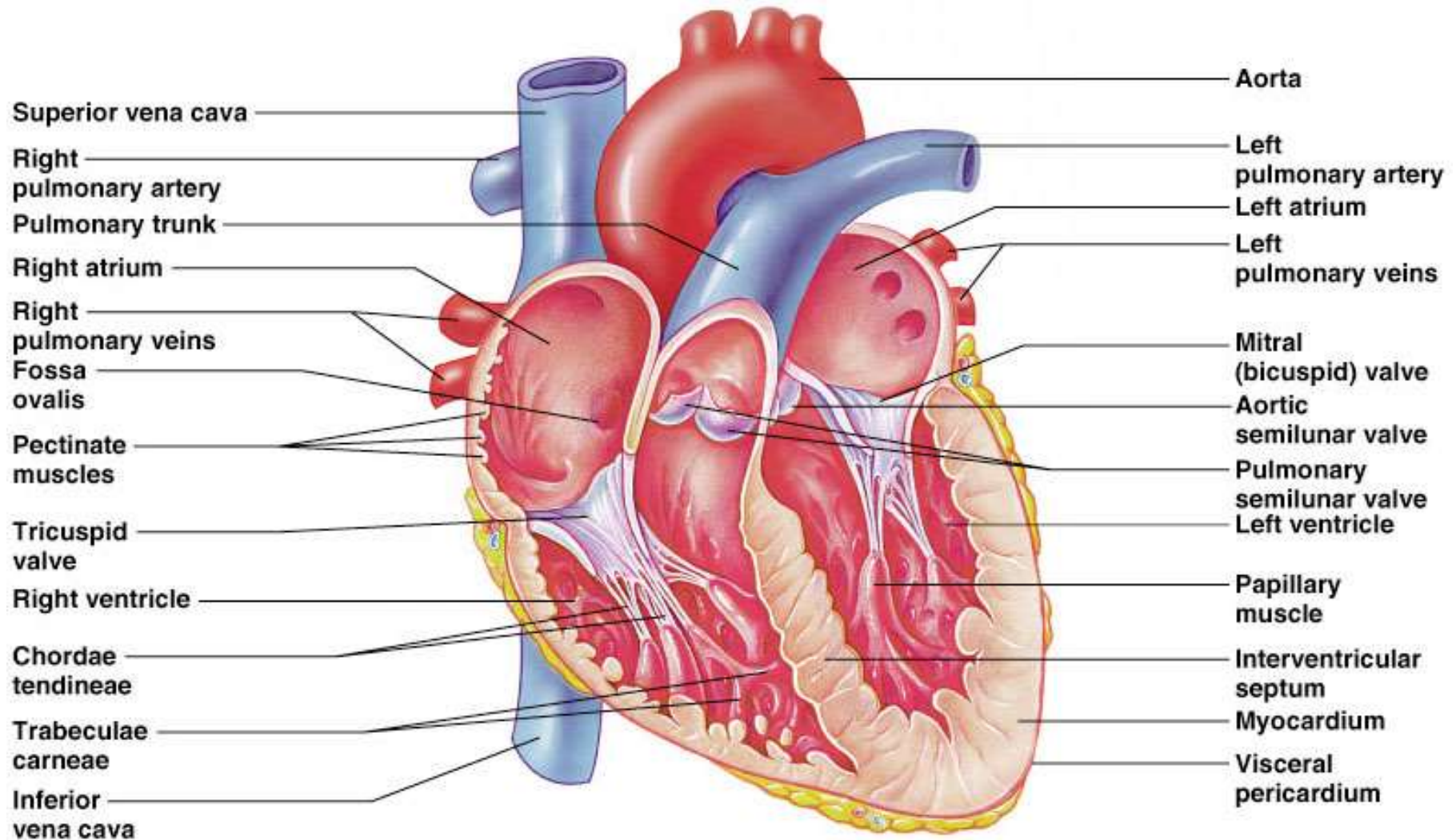
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- **Arteries** — right coronary artery (in atrioventricular groove) and the posterior interventricular artery (in interventricular groove)
- **Veins** — great cardiac vein, posterior vein to left ventricle, coronary sinus, and middle cardiac vein

# External Heart: Posterior View



# Gross Anatomy of Heart: Frontal Section



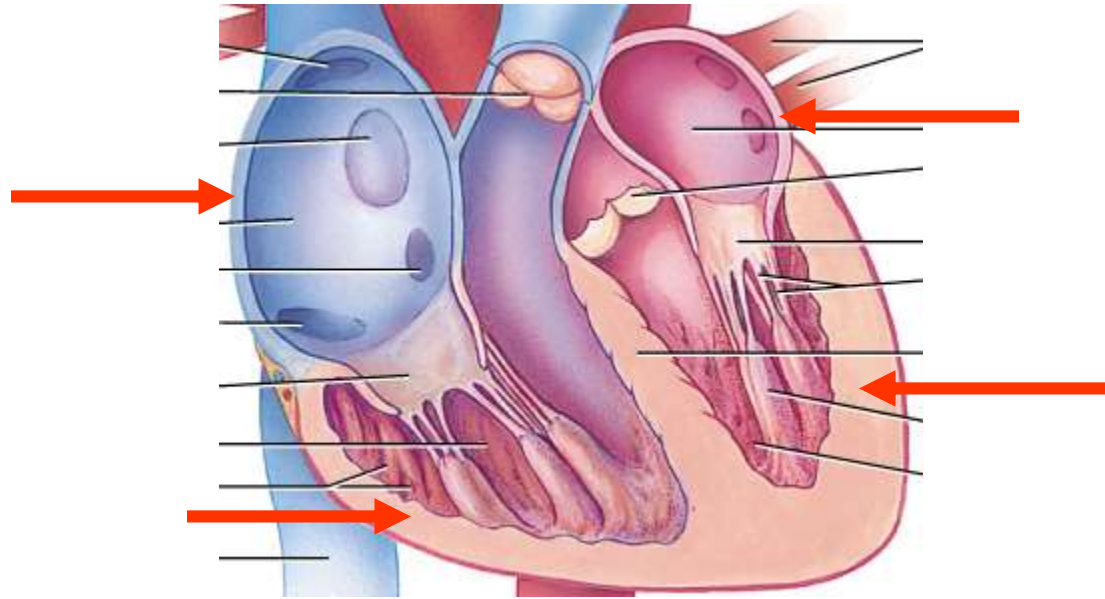
# Atria of the Heart

- Atria are the **receiving chambers** of the heart
- Each atrium has a protruding auricle
- **Pectinate muscles** mark atrial walls
- **Blood enters right atria from superior and inferior venae cavae and coronary sinus**
- Blood enters left atria **from pulmonary veins**

# Ventricles of the Heart

- Ventricles are the **discharging chambers** of the heart
- **Papillary muscles and trabeculae carneae** mark ventricular walls
- **Right ventricle pumps blood into the pulmonary trunk**
- **Left ventricle pumps blood into the aorta**

# Myocardial Thickness and Function



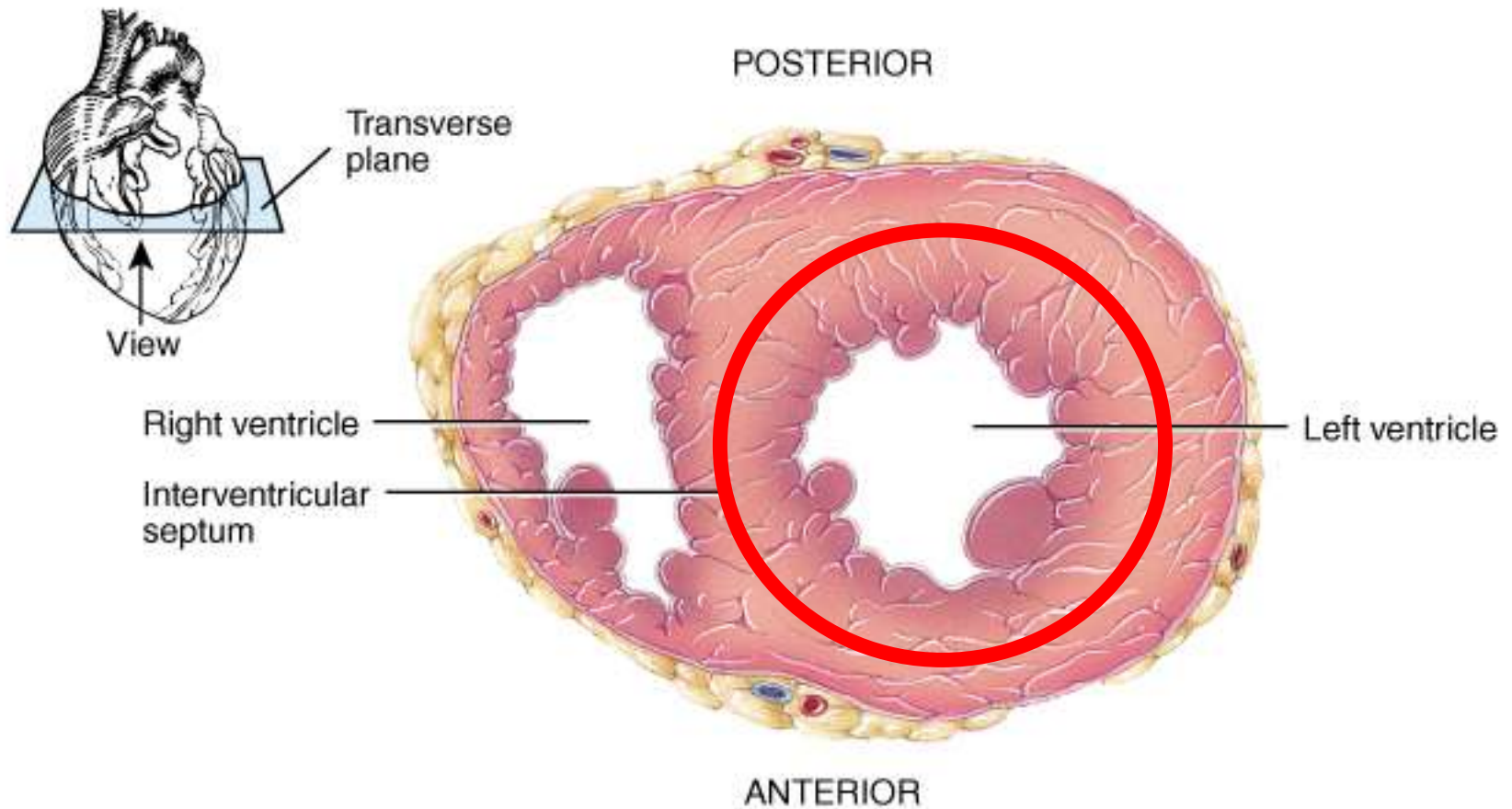
Thickness of myocardium varies according to the function of the chamber

Atria are thin walled, deliver blood to adjacent ventricles

Ventricle walls are much thicker and stronger

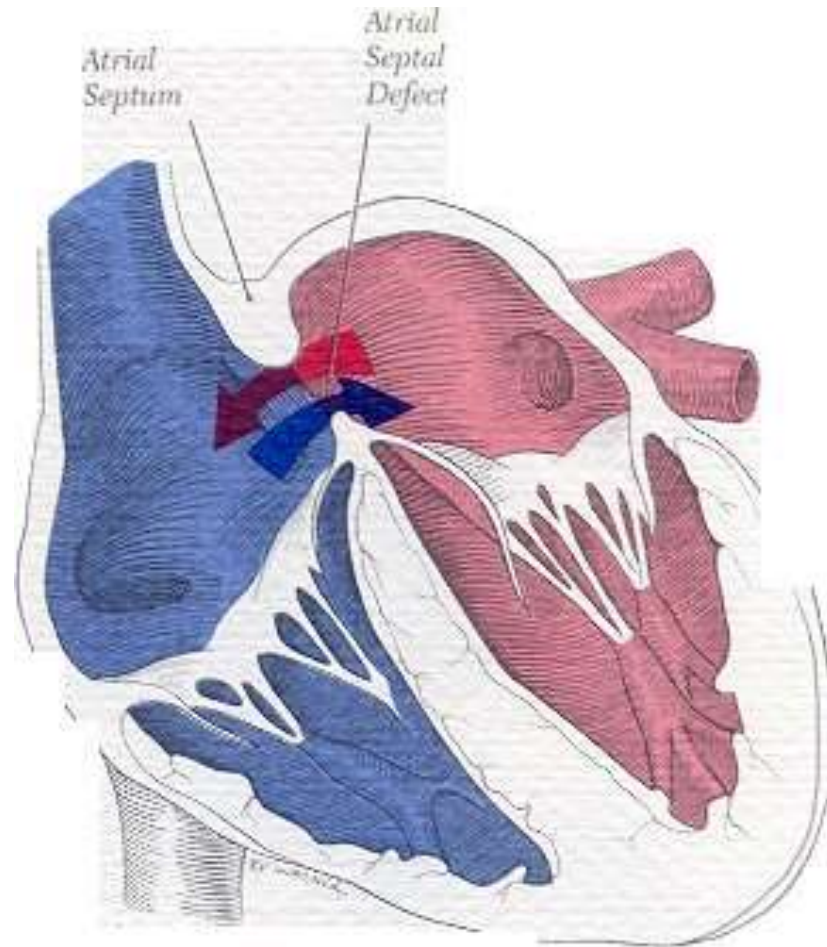
- right ventricle supplies blood to the lungs (little flow resistance)
- **left ventricle wall is the thickest to supply systemic circulation**

# Thickness of Cardiac Walls



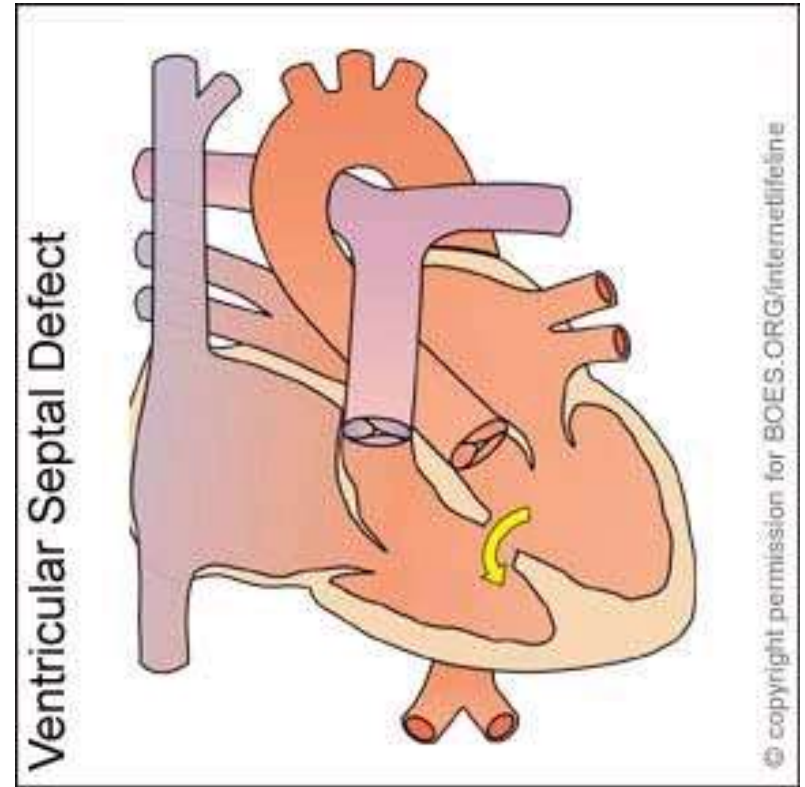
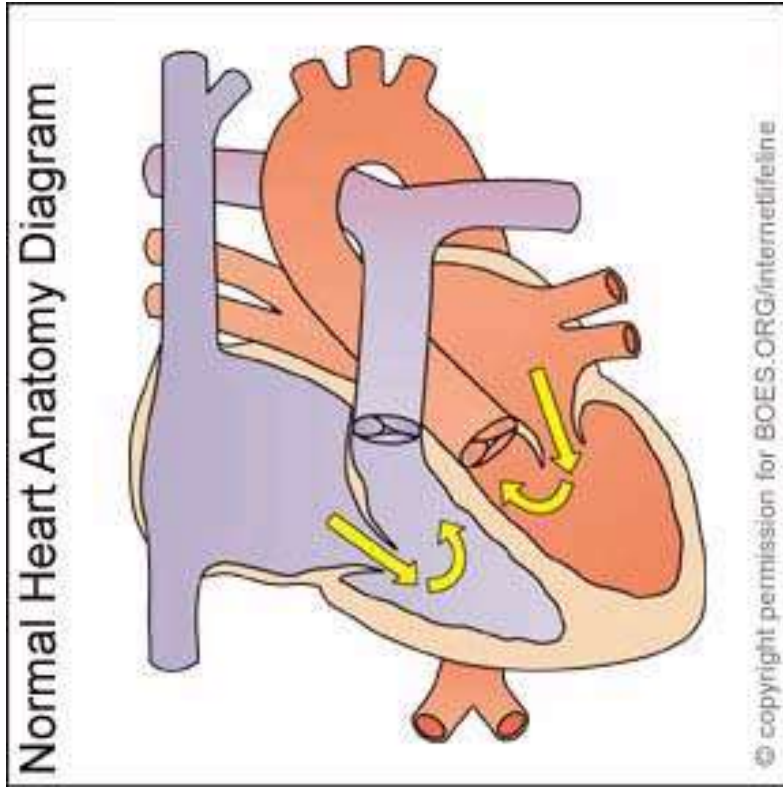
Myocardium of left ventricle is much thicker than the right.

# Atrial Septal Defect





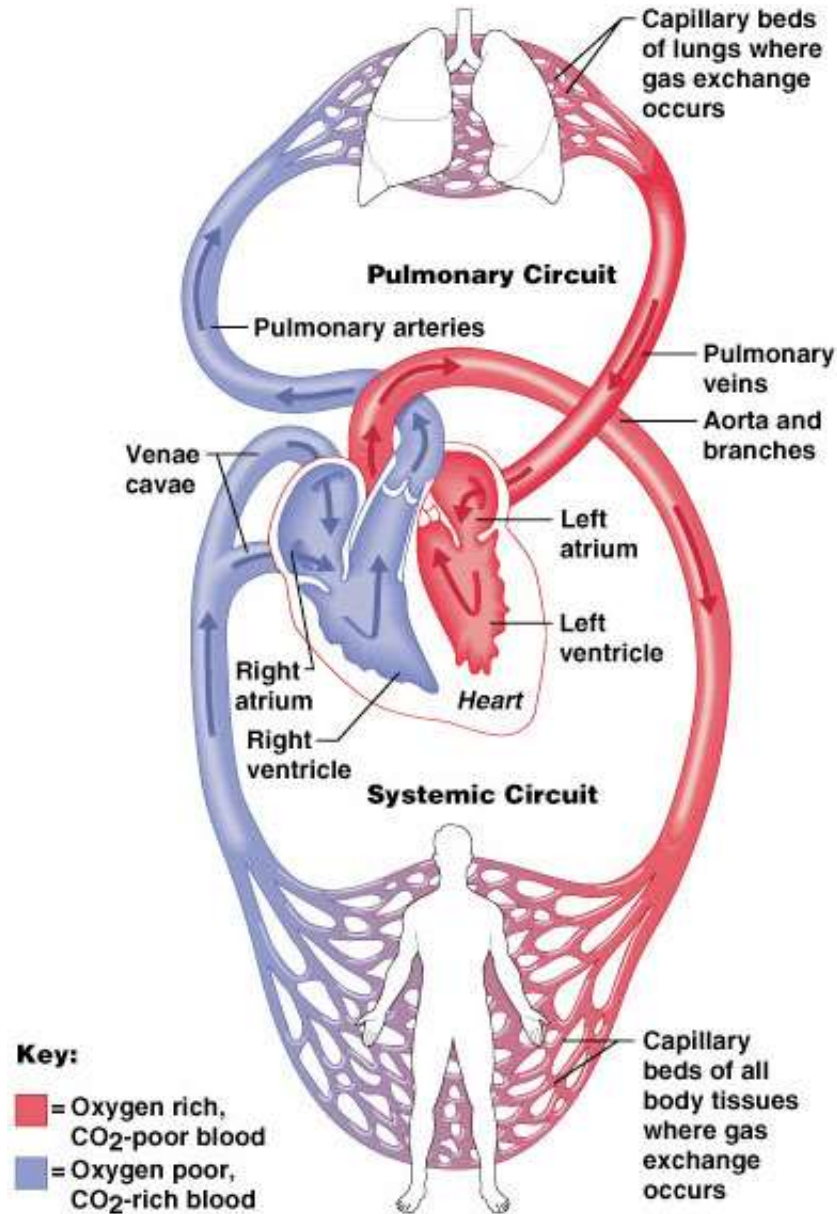
# Ventricular Septal Defect



# Pathway of Blood Through the Heart and Lungs

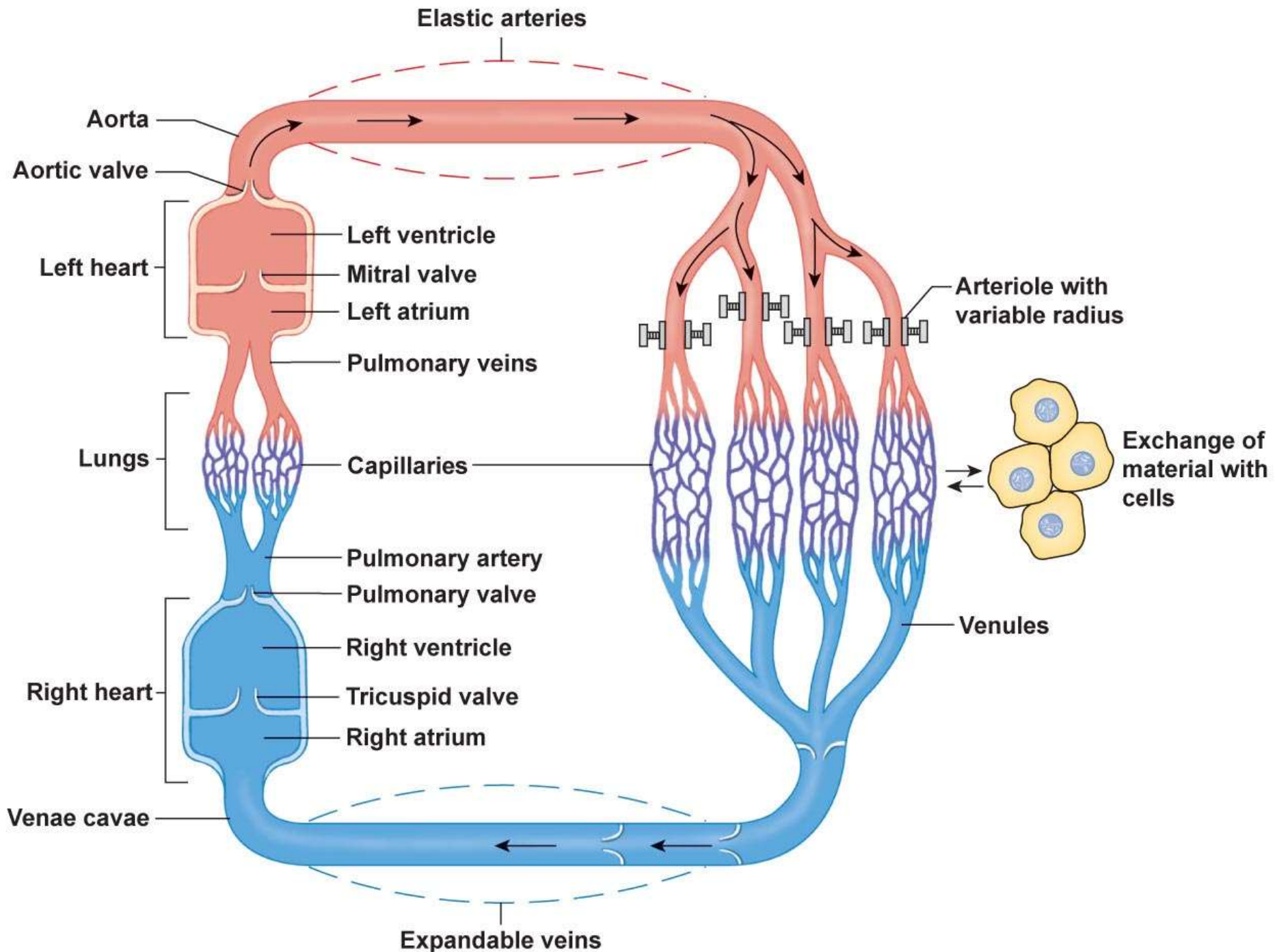
- Right atrium → tricuspid valve → right ventricle
- Right ventricle → pulmonary semilunar valve → pulmonary arteries → lungs
- Lungs → pulmonary veins → left atrium
- Left atrium → bicuspid valve → left ventricle
- Left ventricle → aortic semilunar valve → aorta
- Aorta → systemic circulation

# Pathway of Blood Through the Heart and Lungs

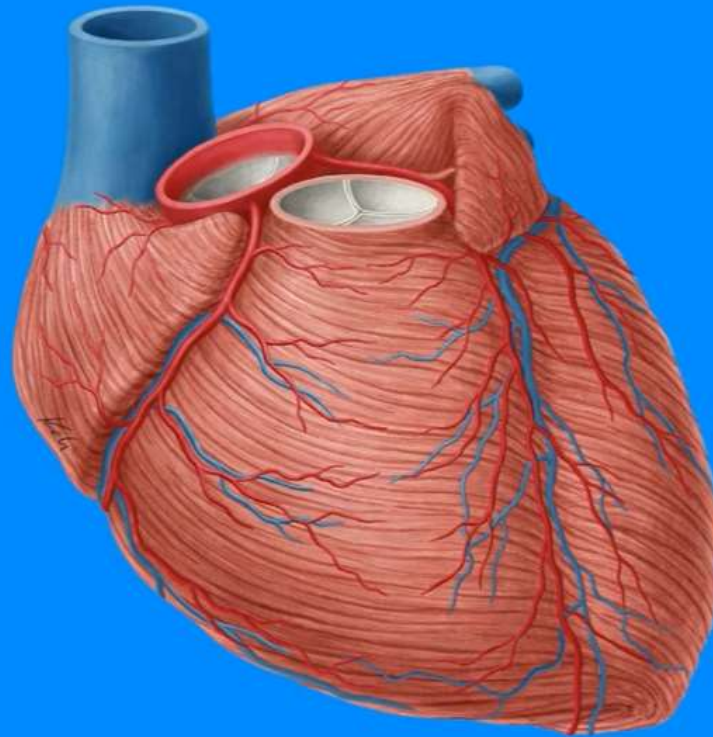


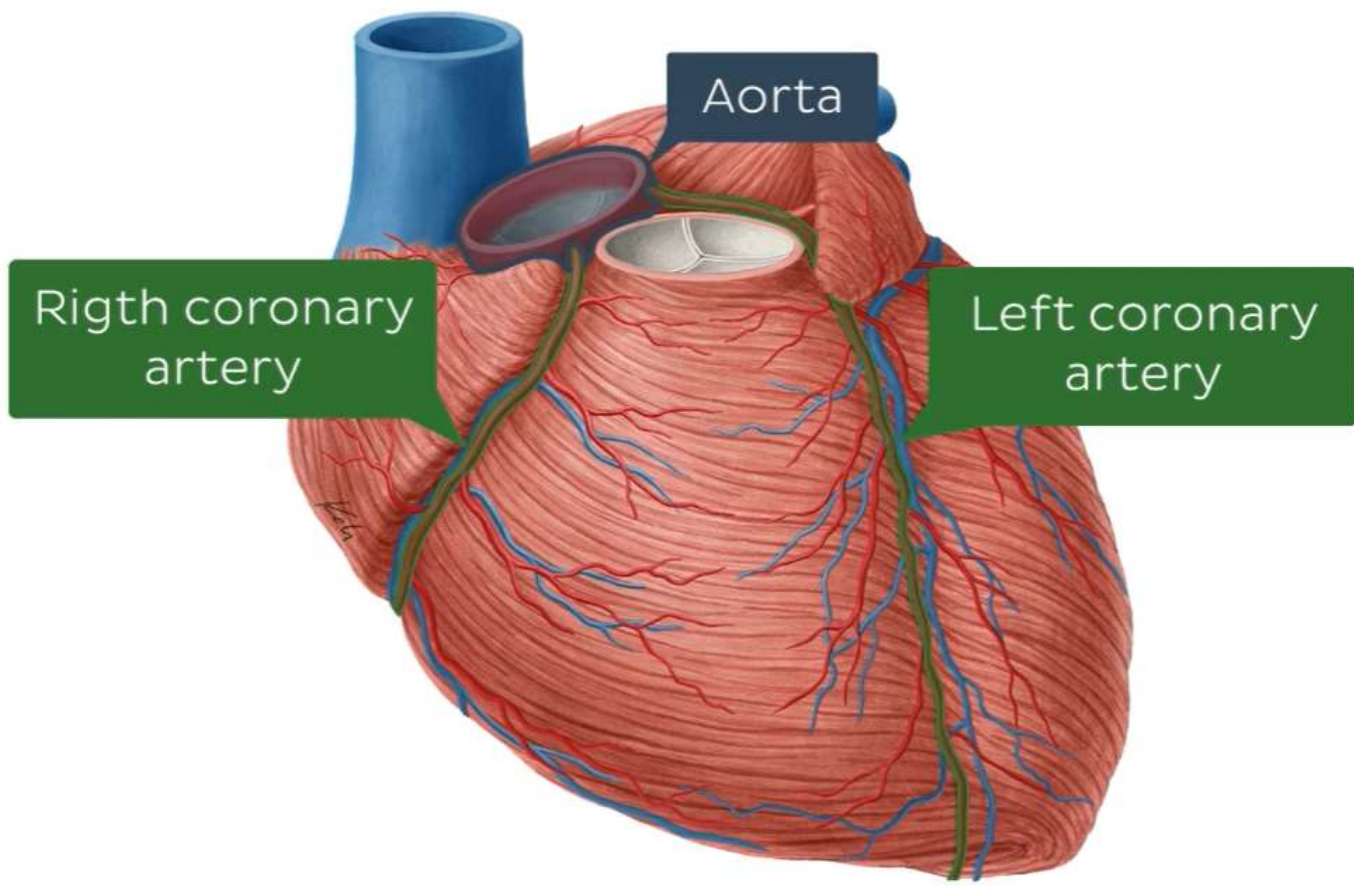
# Vascular System

- The heart can be thought of 2 separate pumps
  - from the right ventricle, blood is pumped at a low pressure to the lungs and then back to the left atria
  - from the left ventricle, blood is pumped at a high pressure to the rest of the body and then back to the right atria
- There are 3 main types of vessels that carry blood around the body
  - Arteries** and **arterioles** (small arteries)
    - carry blood away from the heart
  - Capillaries**
    - allow for exchange of materials between the blood and the cells of the body
  - Veins** and **venules** (small veins)
    - carry blood back to the heart



# Coronary circulation

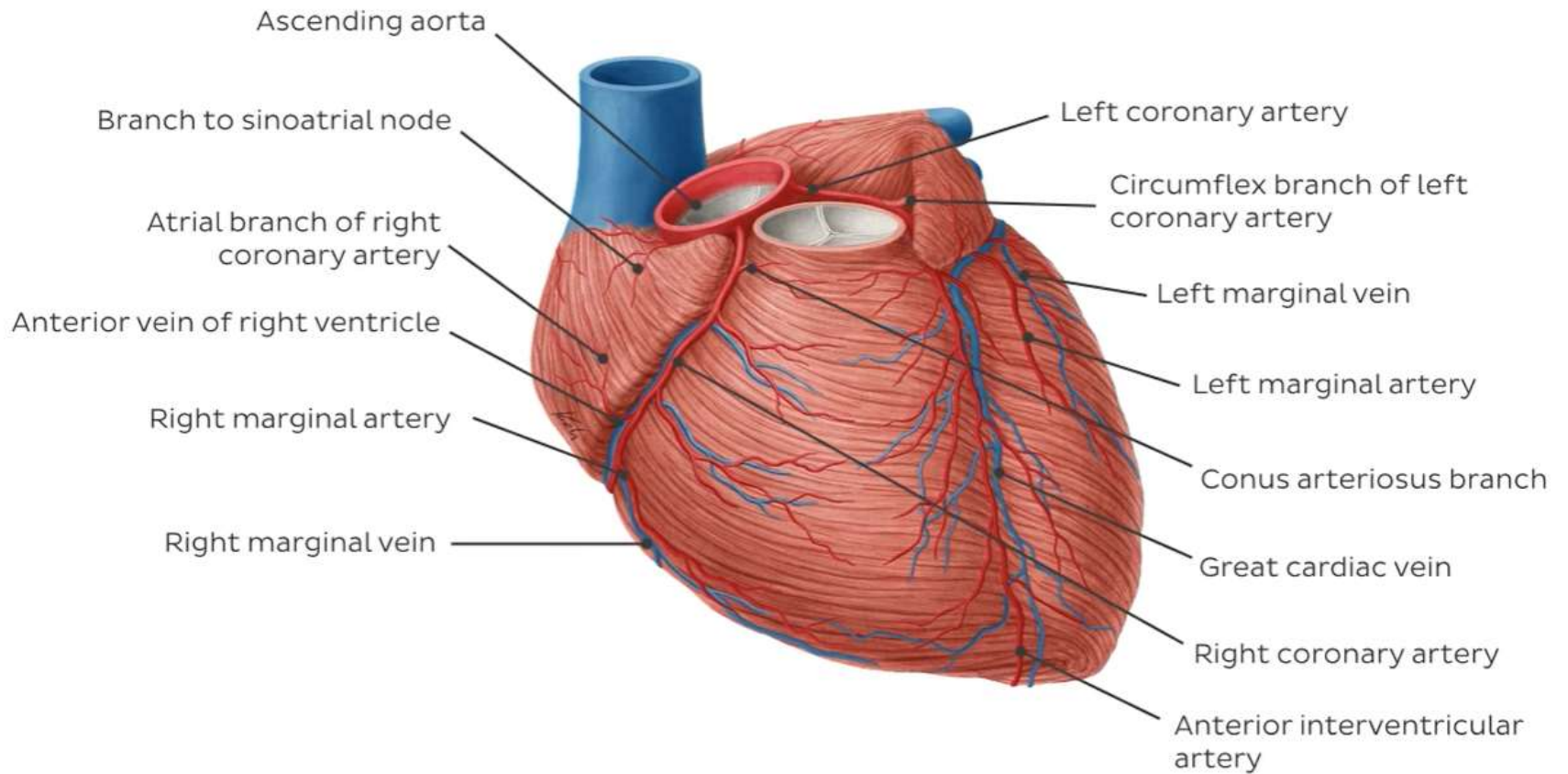




Aorta

Rigth coronary artery

Left coronary artery

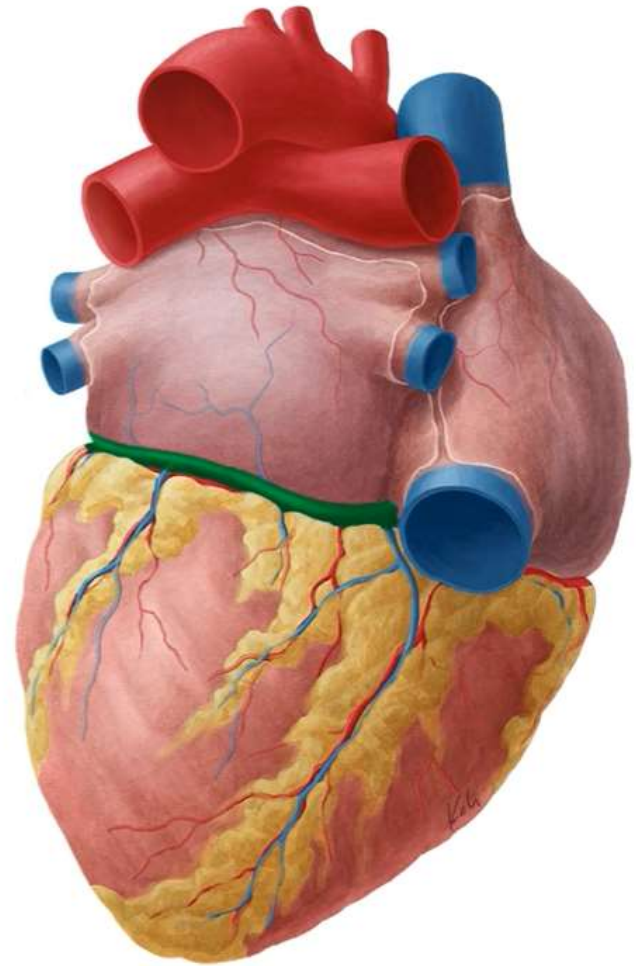
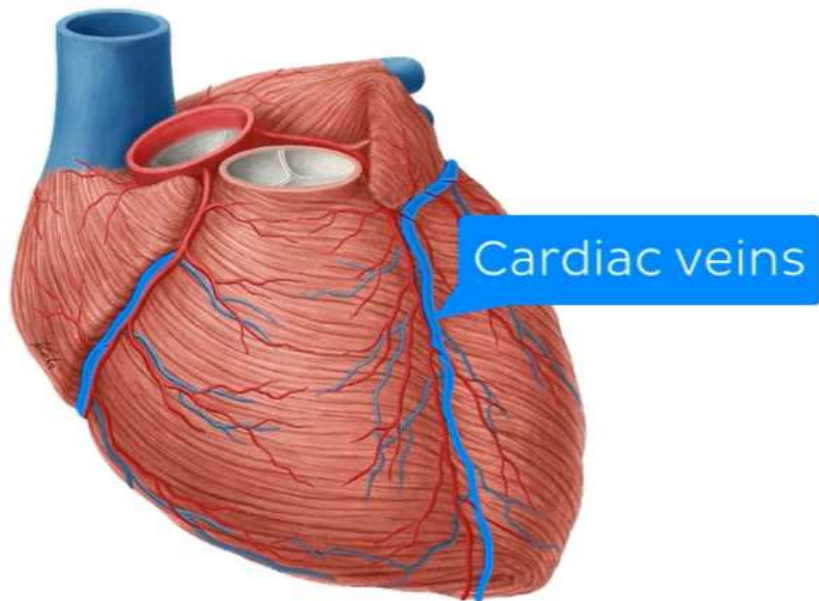




Coronary sinus

Latin

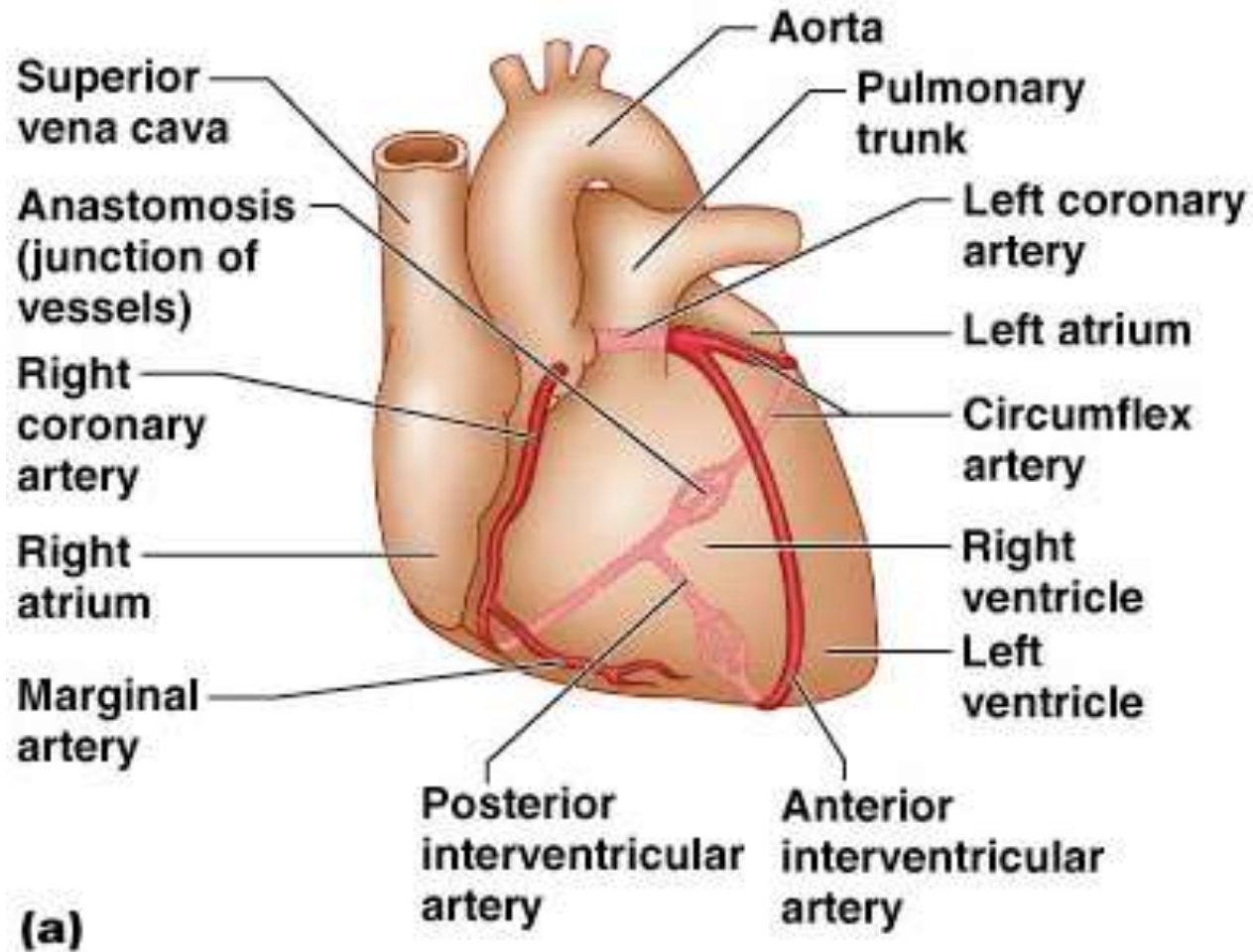
Sinus coronarius



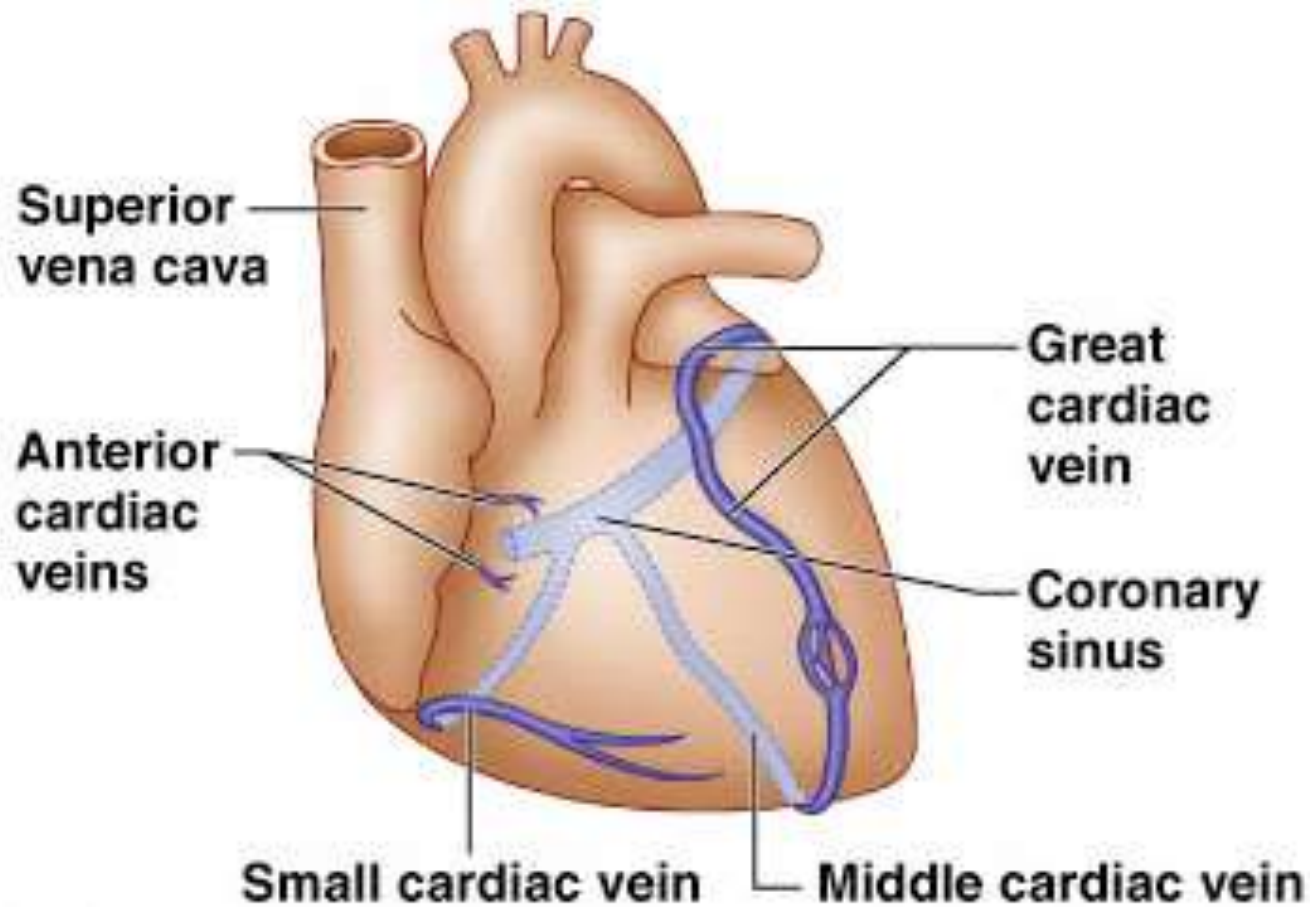
# Coronary Circulation

- 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

# Coronary Circulation: Arterial Supply



# Coronary Circulation: Venous Supply



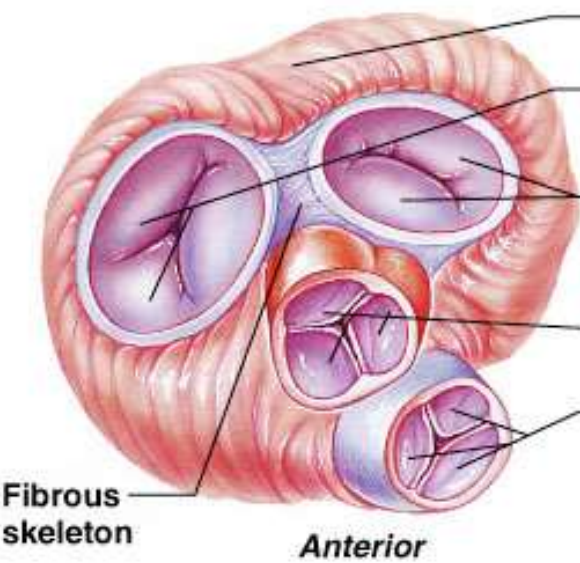
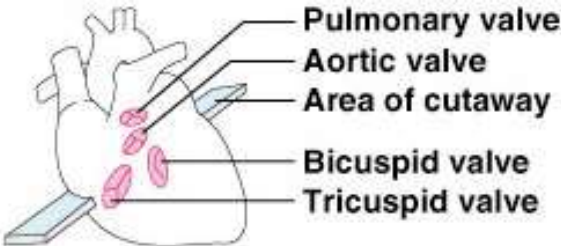
# Heart Valves

- 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**

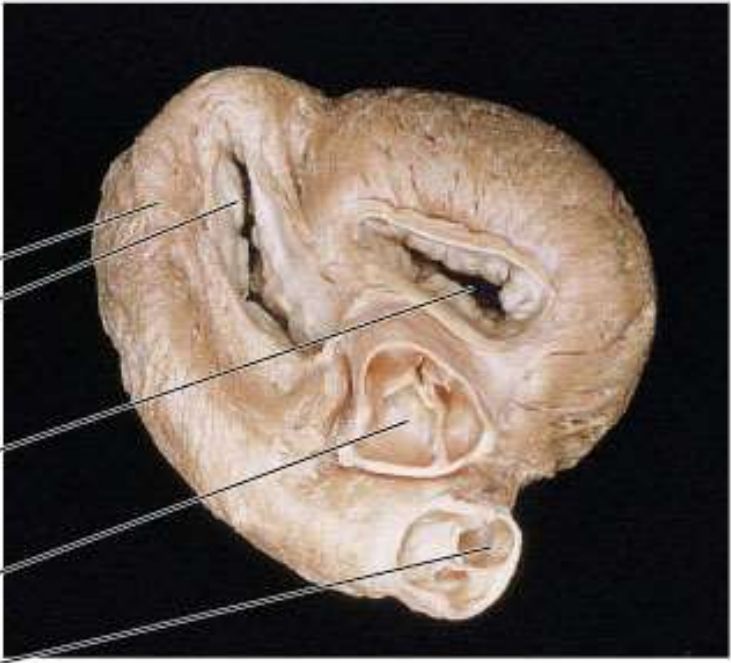
# Heart Valves

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

# Heart Valves



- Myocardium
- Tricuspid valve (right atrioventricular)
- Bicuspid (mitral) valve (left atrioventricular)
- Aortic semilunar valve
- Pulmonary semilunar valve

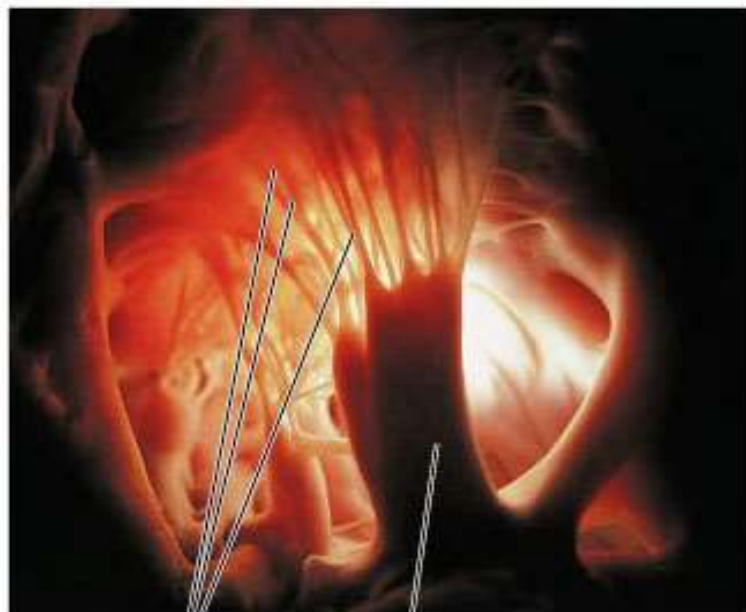


(a)

(b)

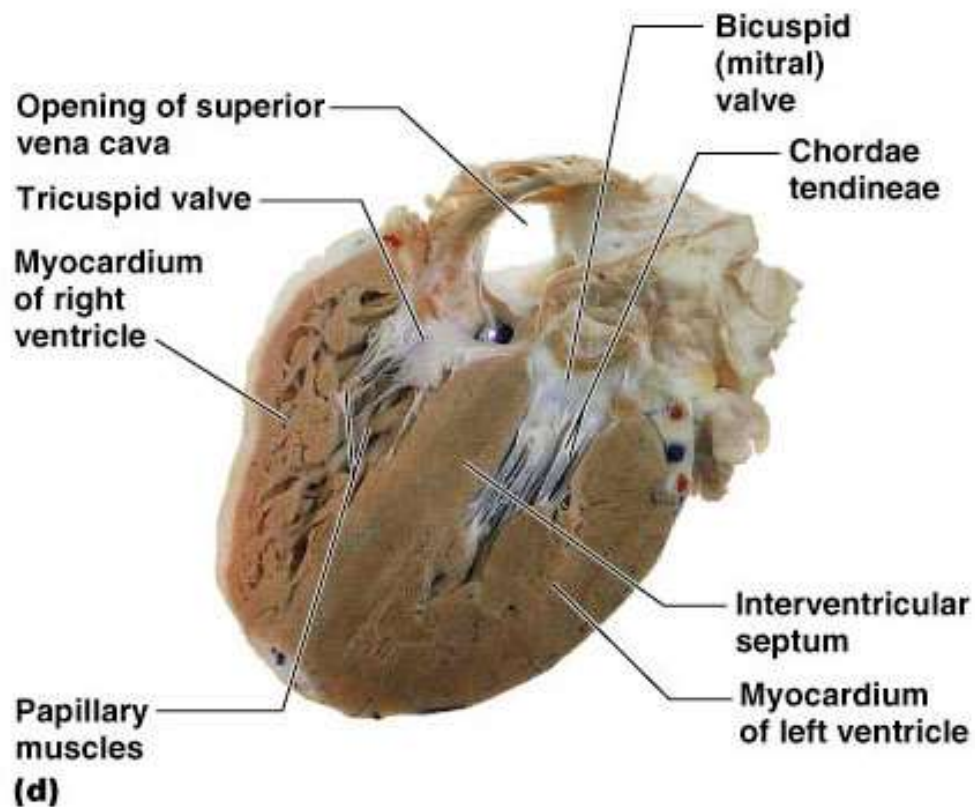
Figure 18.8a, b

# Heart Valves



Chordae tendineae attached to tricuspid valve flap  
(c)

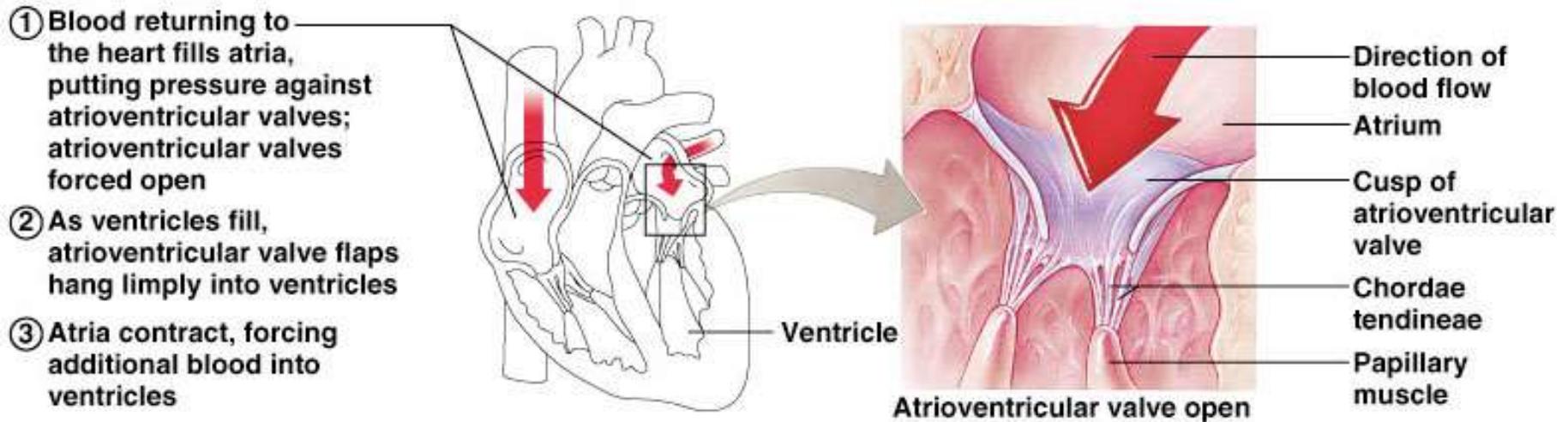
Papillary muscle



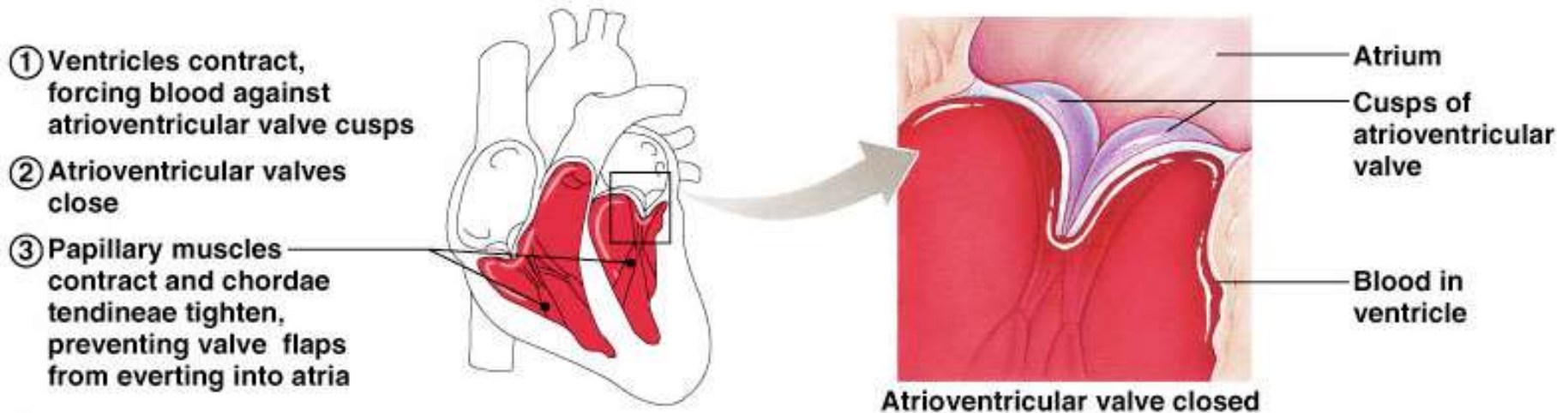
Papillary muscles  
(d)



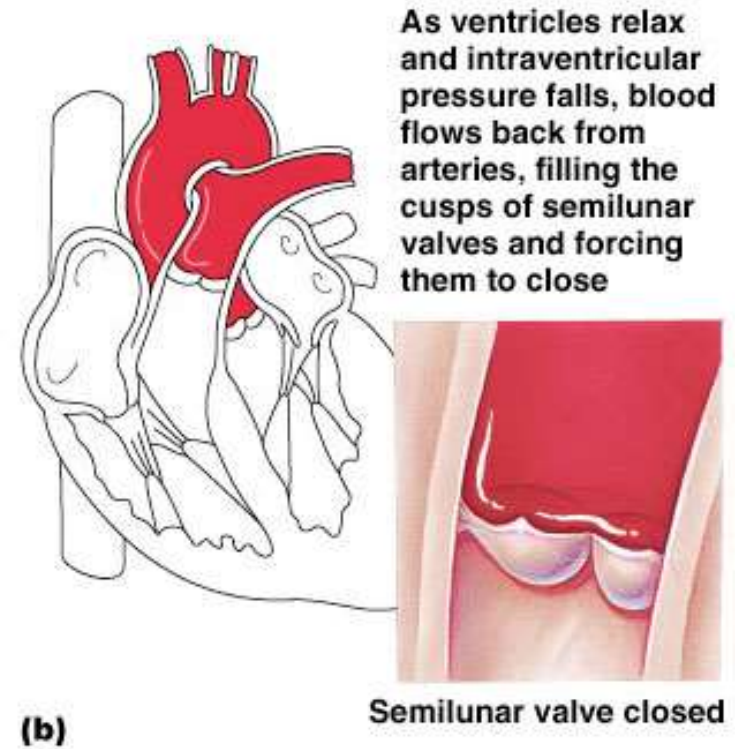
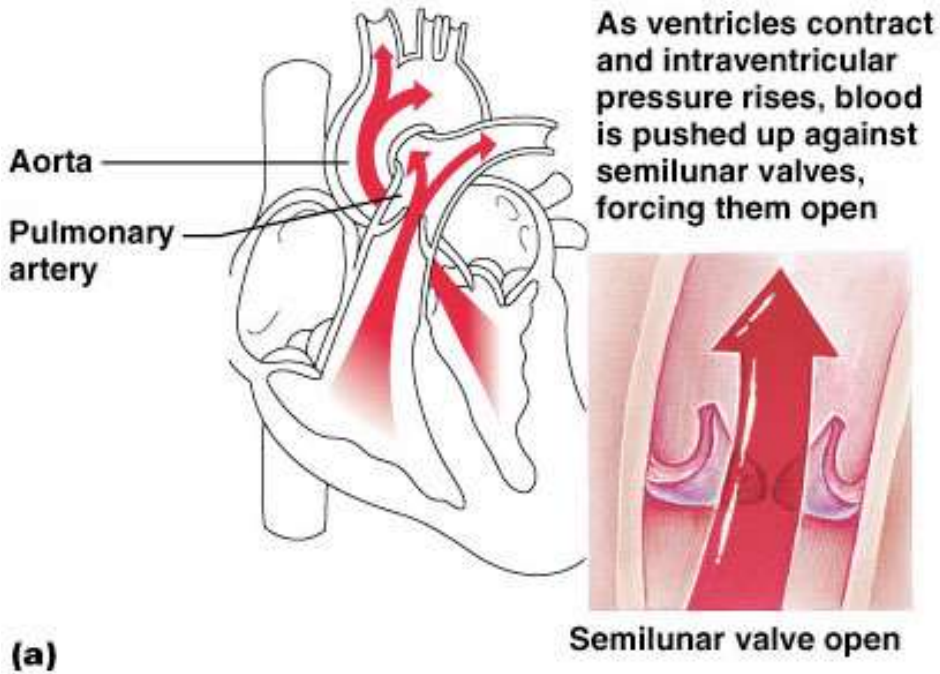
# Atrioventricular Valve Function



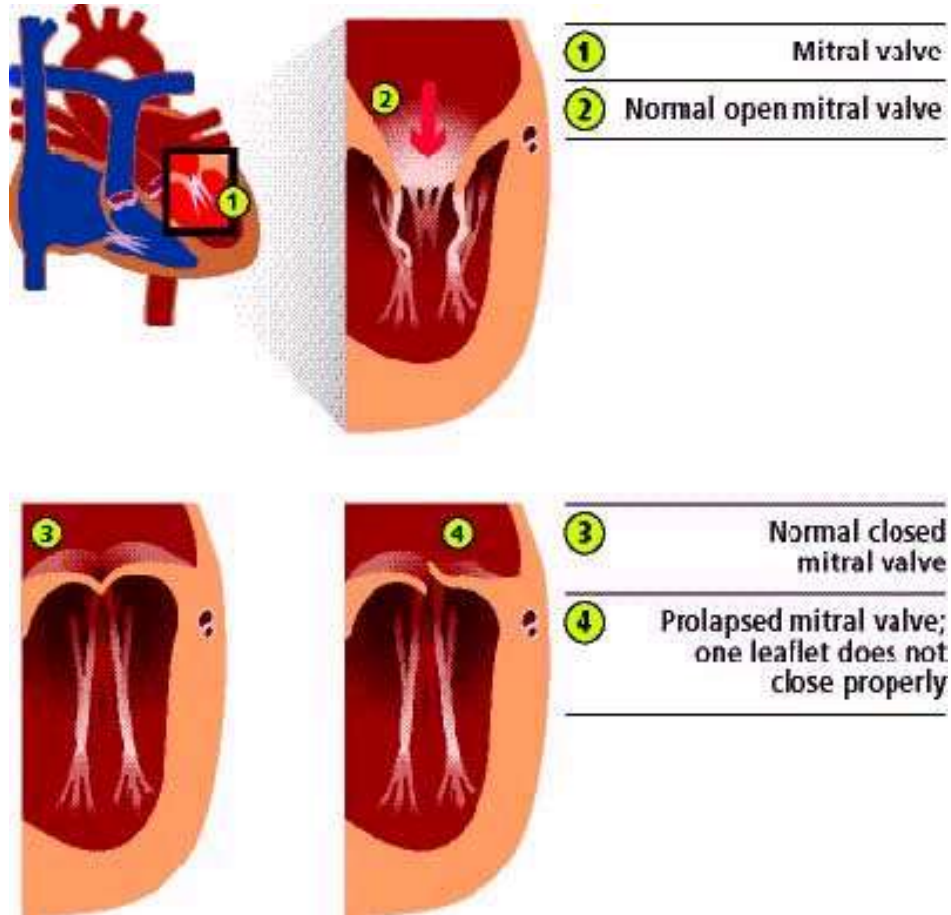
(a)



# Semilunar Valve Function



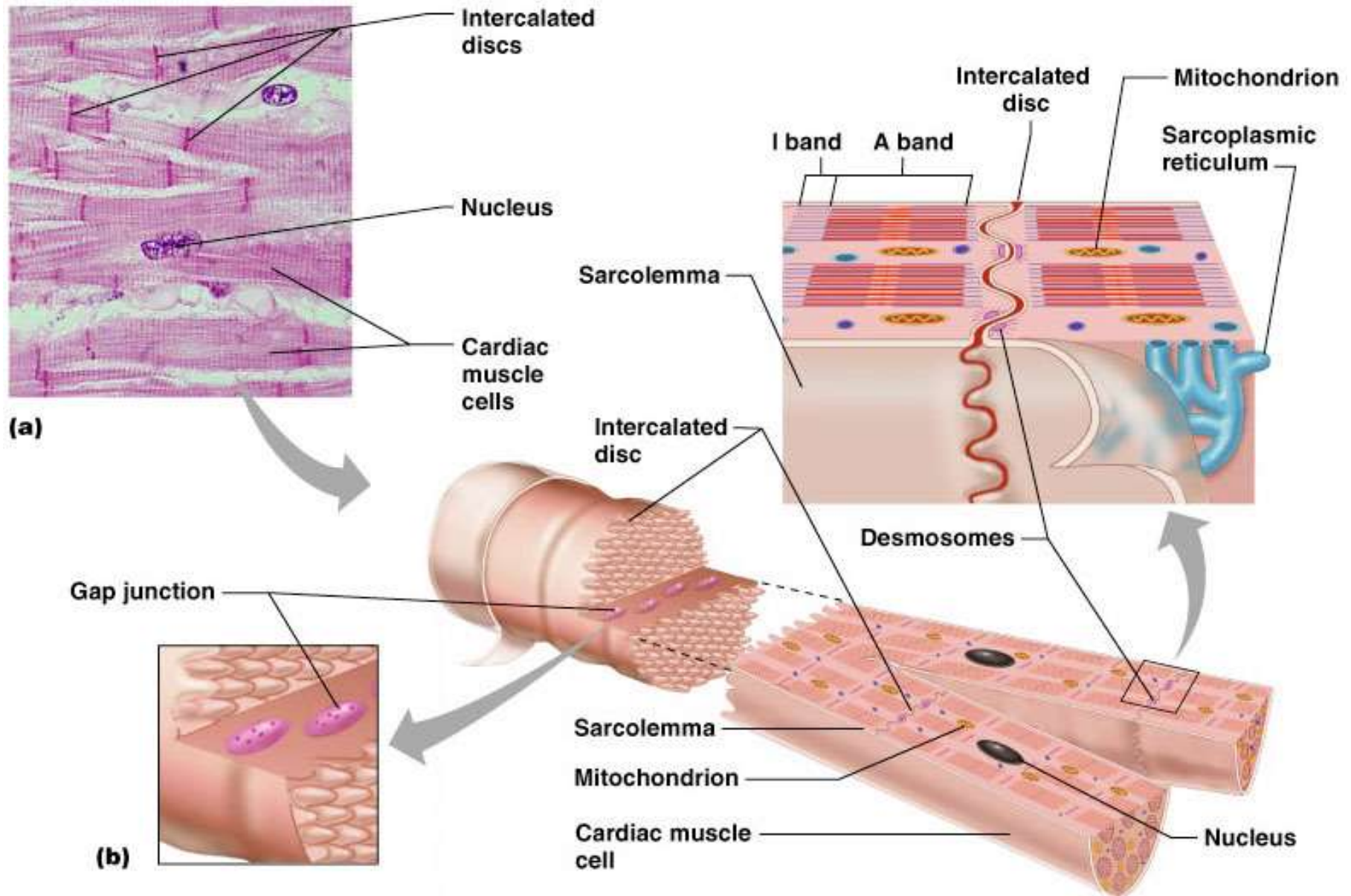
# Mitral Valve Prolapse



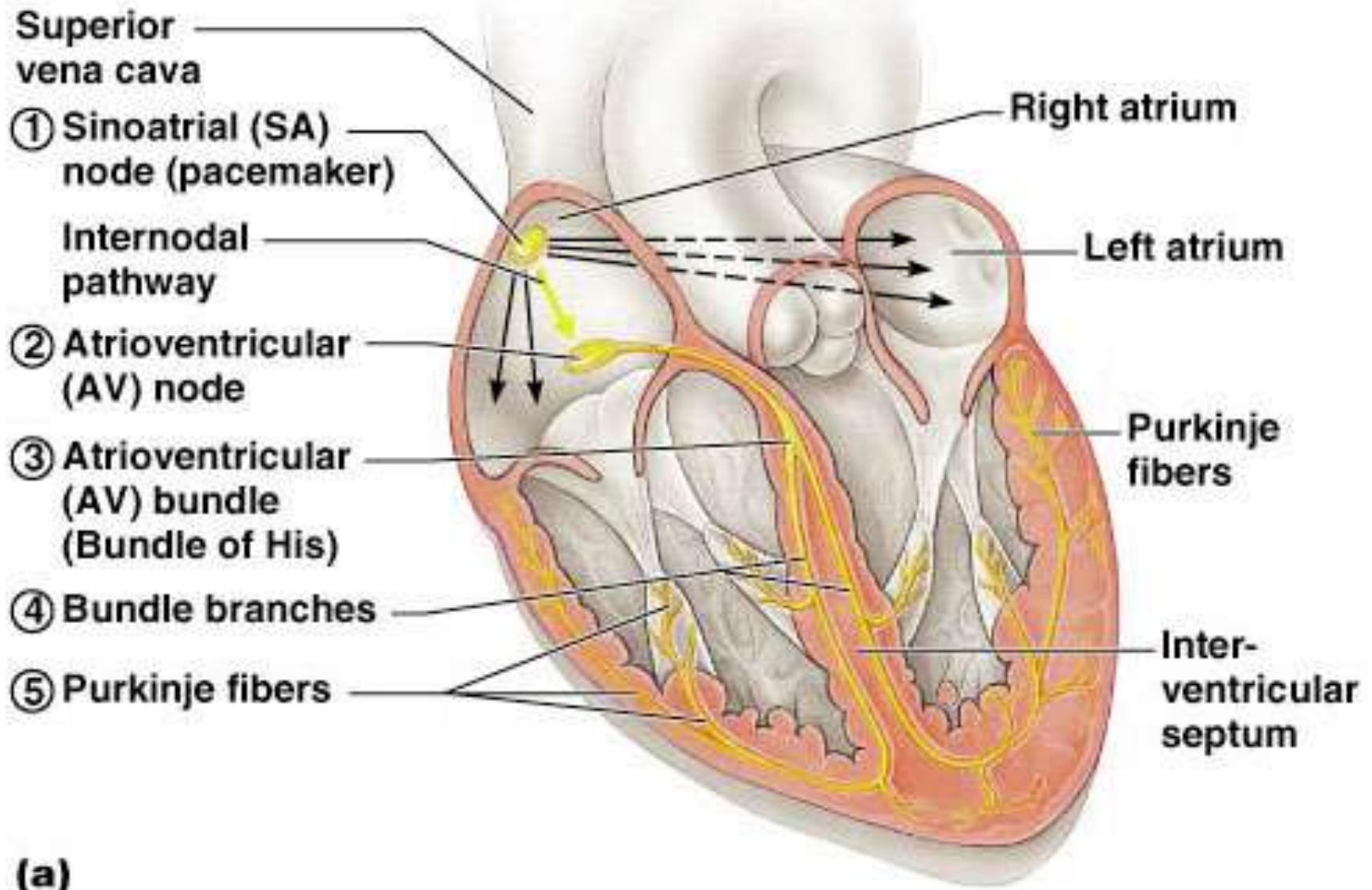
# Microscopic Anatomy of Heart Muscle

- 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

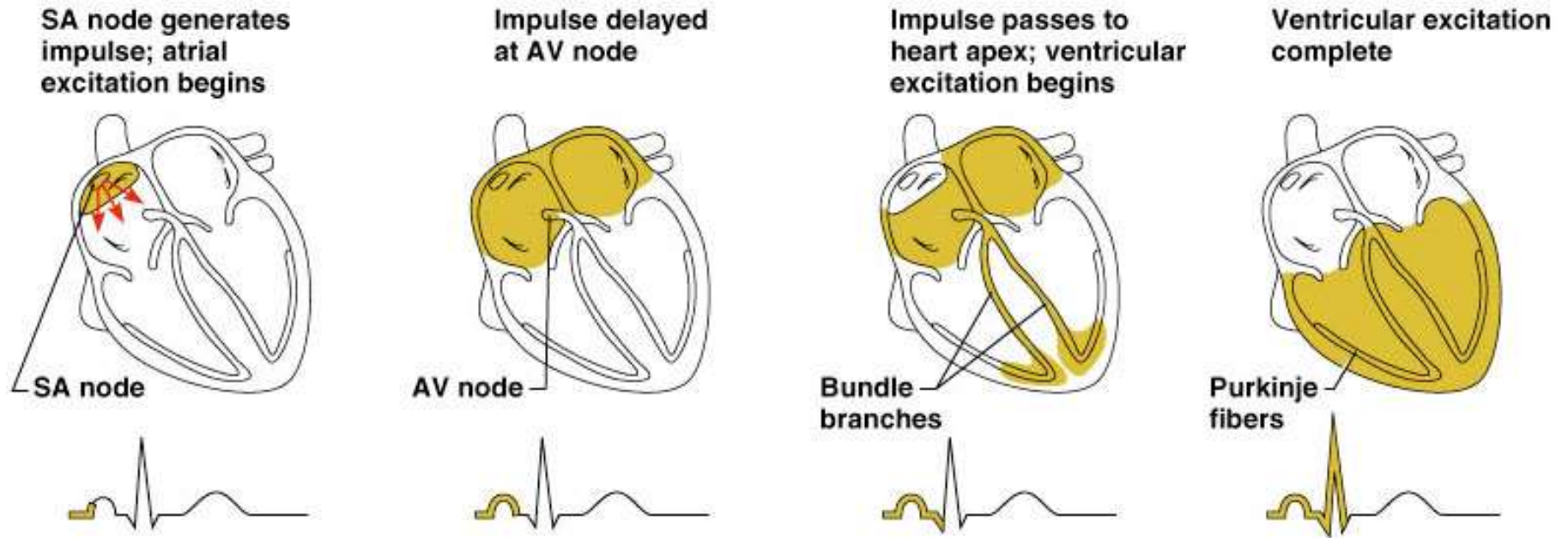
# Microscopic Anatomy of Heart Muscle



# Heart Physiology: Sequence of Excitation

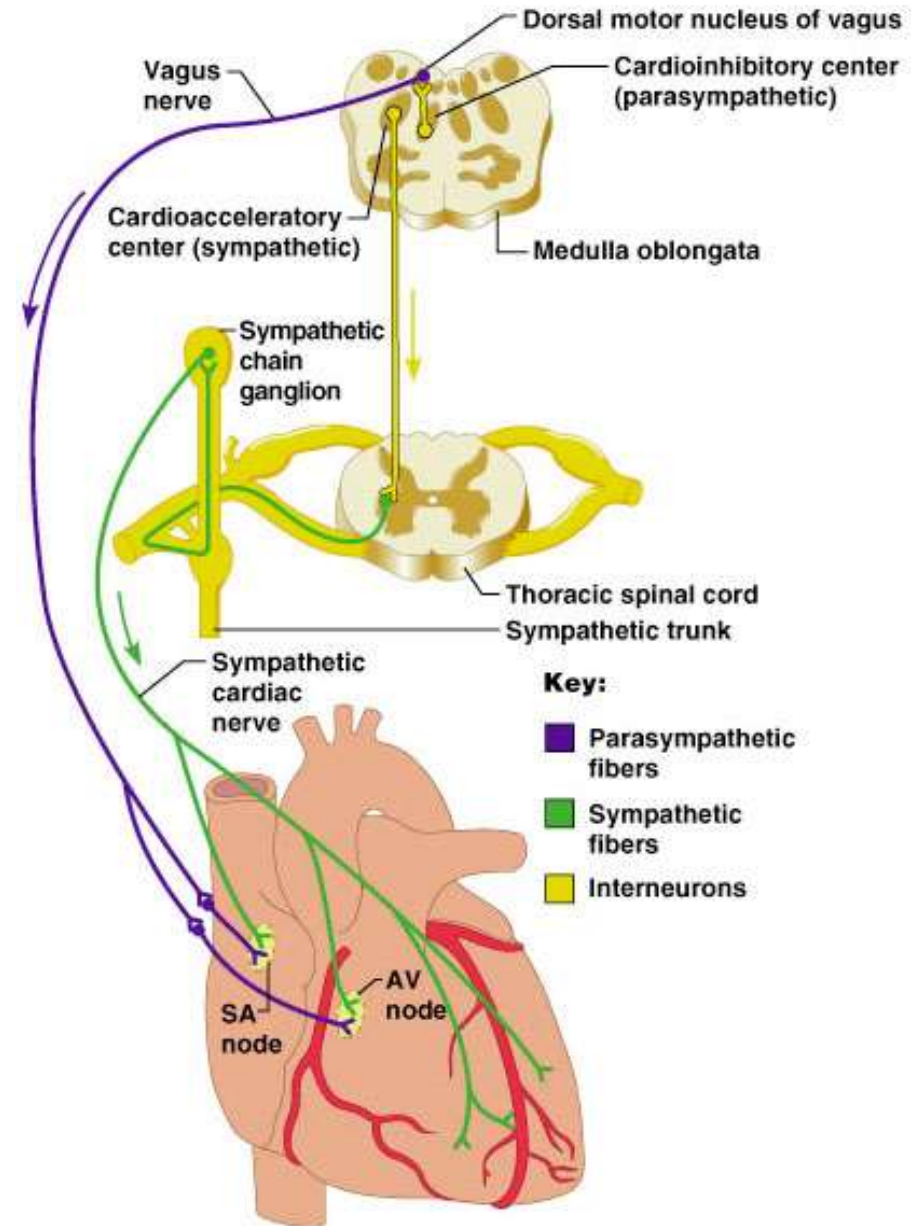


# Heart Excitation Related to ECG



# Extrinsic Innervation of the Heart

- Heart is **stimulated** by the **sympathetic cardioacceleratory center**
- Heart is **inhibited** by the **parasympathetic cardioinhibitory center**





# Electrocardiography

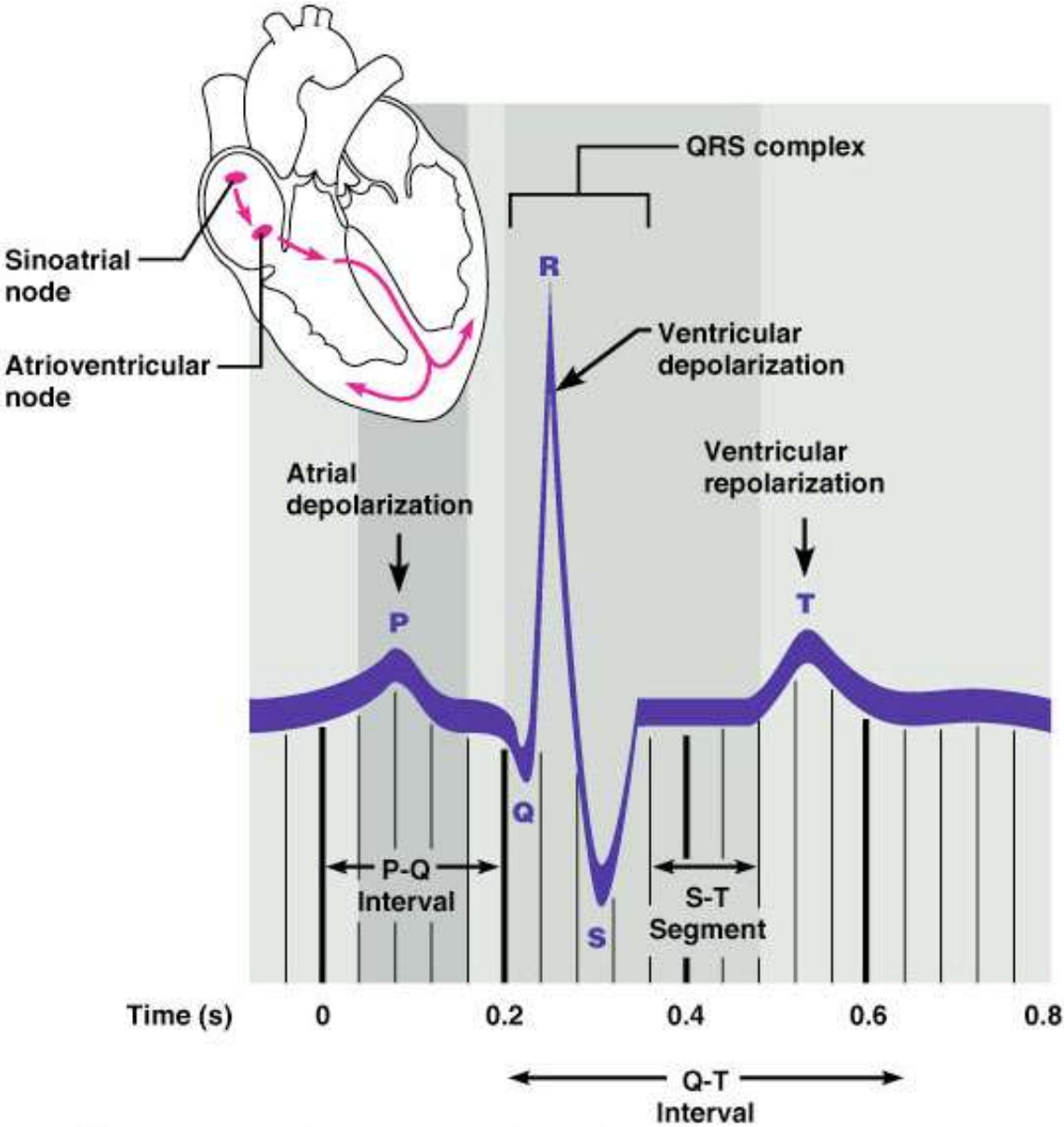


Figure 18.16

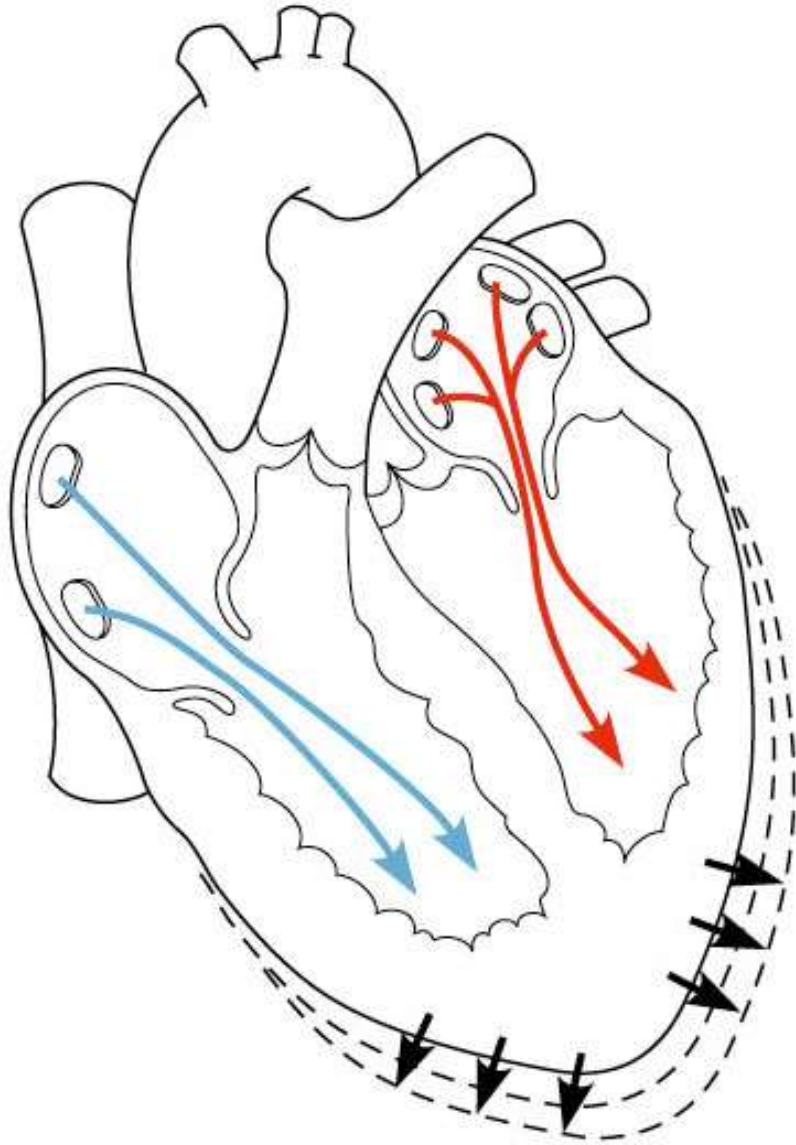
# Cardiac Cycle

- Cardiac cycle refers to all events associated with blood flow through the heart
  - **Systole** — contraction of heart muscle
  - **Diastole** — relaxation of heart muscle

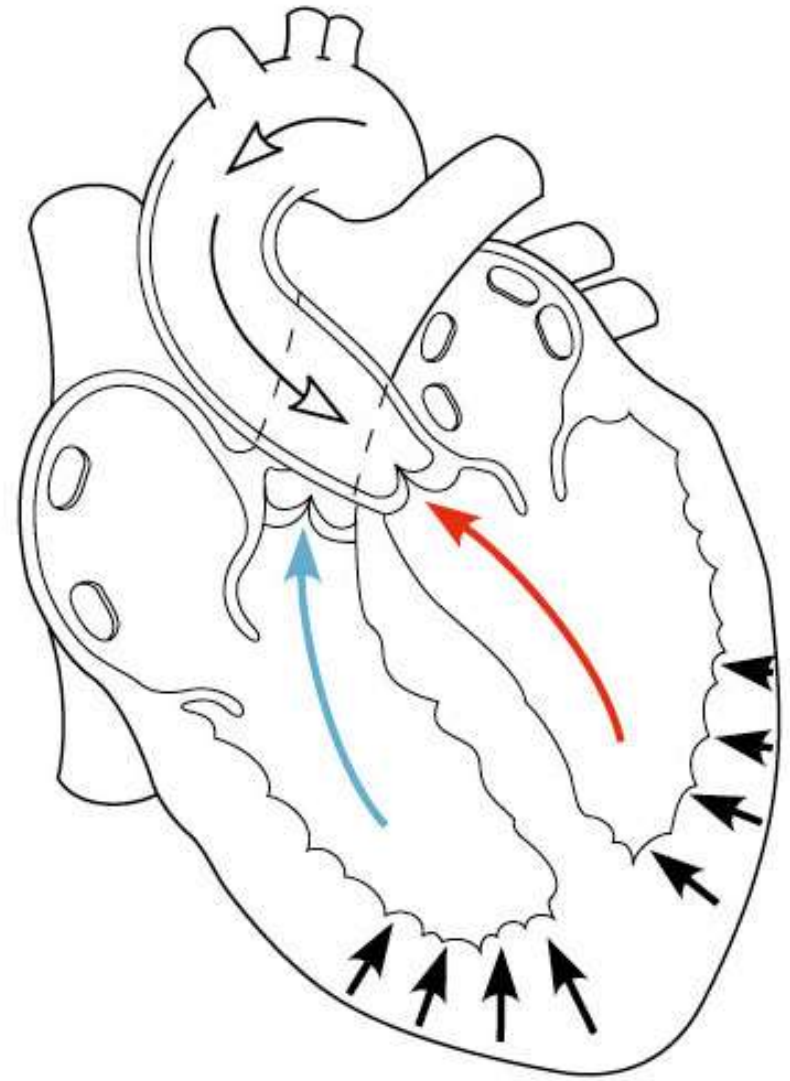
# Phases of the Cardiac Cycle

- Ventricular filling — mid-to-late diastole
  - Heart blood pressure is low as blood enters atria (passively) and flows into ventricles
  - AV valves are open, then atrial systole occurs

# Preload and Afterload



**(a) Preload**



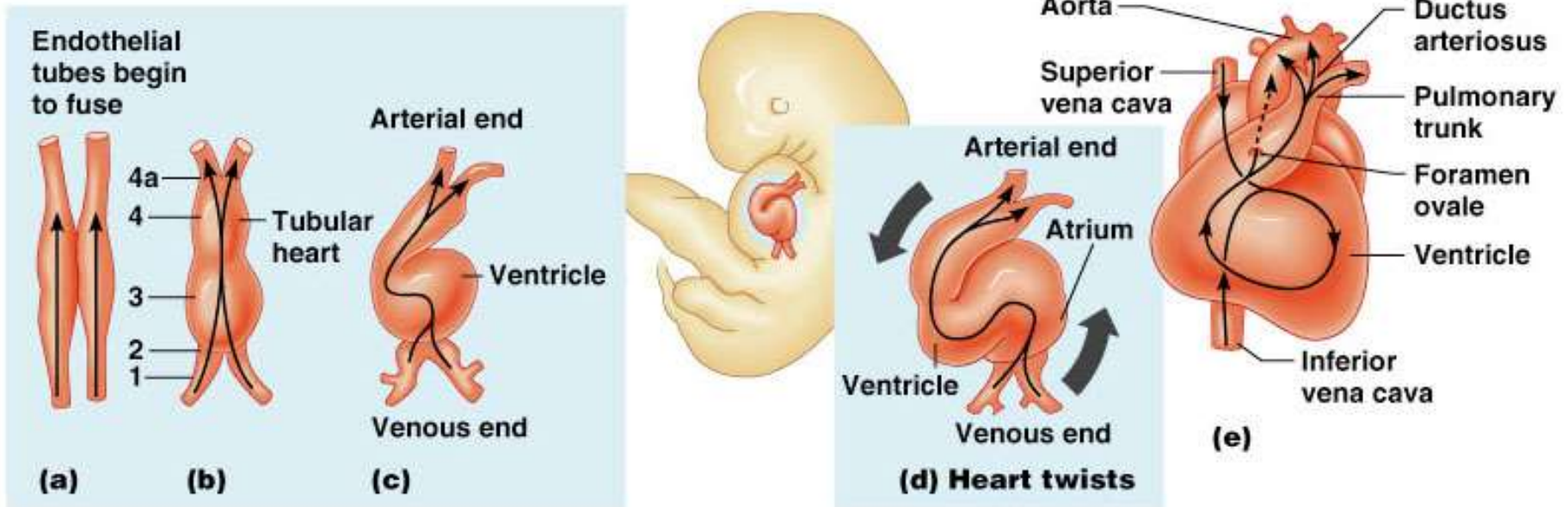
**(b) Afterload**

# 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
    - If the Vagus Nerve was cut, the heart would lose its tone. Thus, increasing the heart rate by 25 beats per minute.

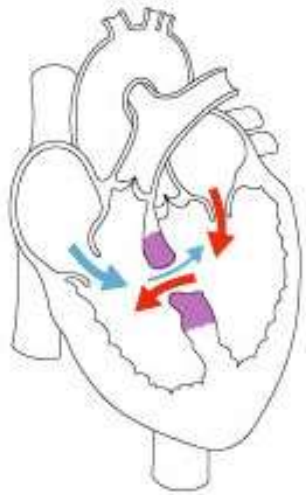
# Developmental Aspects of the Heart



# Developmental Aspects of the Heart

- Fetal heart structures that bypass pulmonary circulation
  - Foramen ovale connects the two atria
  - Ductus arteriosus connects pulmonary trunk and the aorta

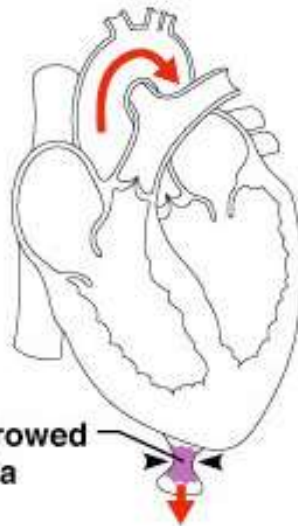
# Examples of Congenital Heart Defects



Occurs in about 1 in every 500 births

## (a) Ventricular septal defect.

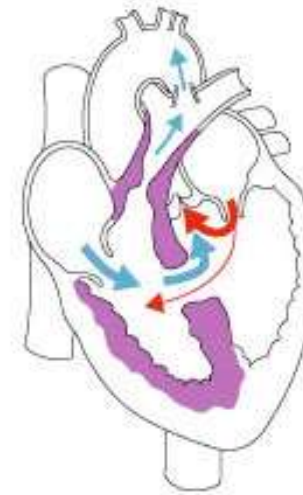
The superior part of the inter-ventricular septum fails to form; thus, blood mixes between the two ventricles, but because the left ventricle is stronger, more blood is shunted from left to right.



Occurs in about 1 in every 1500 births

## (b) Coarctation of the aorta.

A part of the aorta is narrowed, increasing the workload on the left ventricle.



Occurs in about 1 in every 2000 births

## (c) Tetralogy of Fallot.

Multiple defects (*tetra* = four): Pulmonary trunk too narrow and pulmonary valve stenosed, resulting in a hypertrophied right ventricle; ventricular septal defect; aorta opens from both ventricles; wall of right ventricle thickened from overwork.

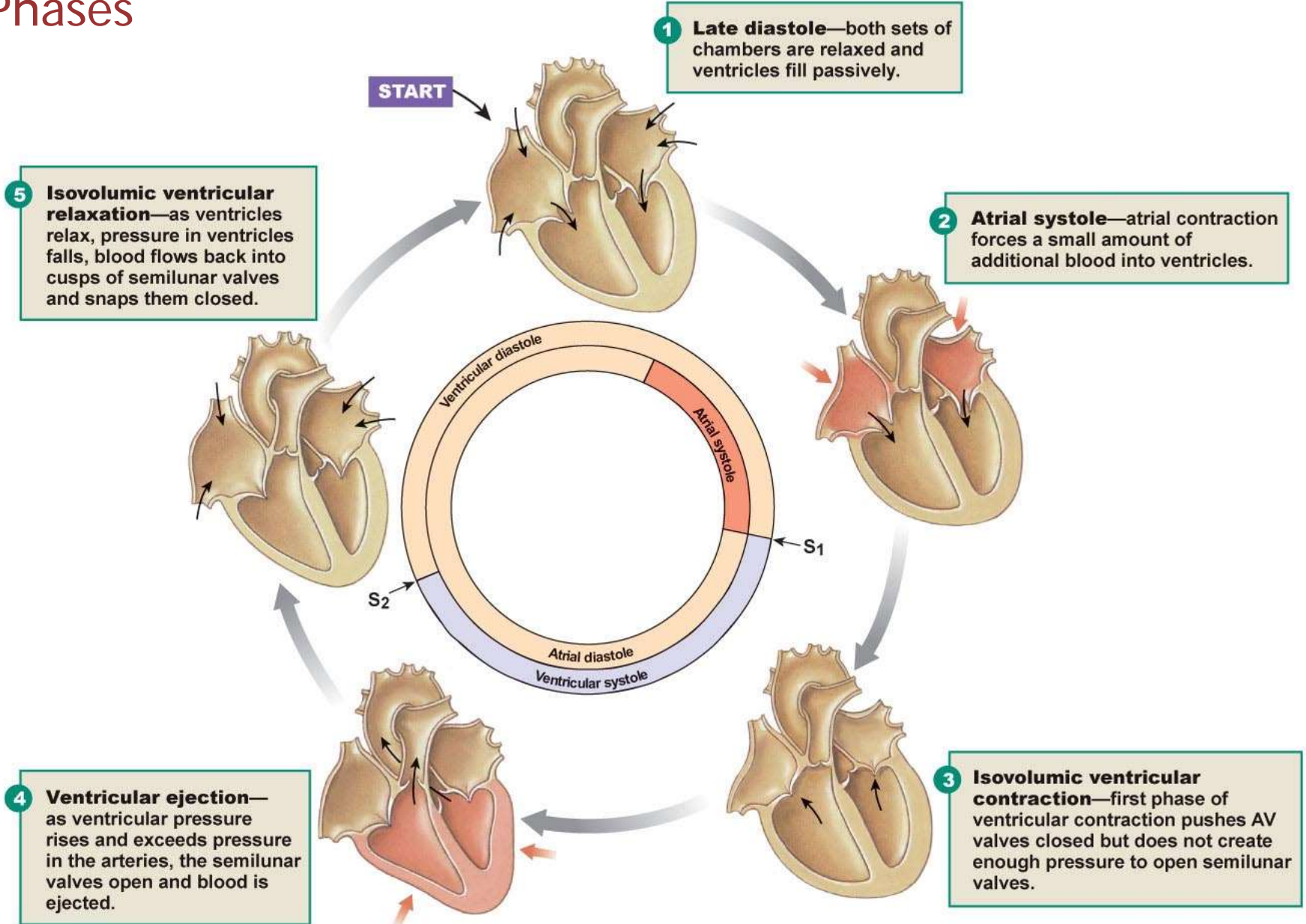


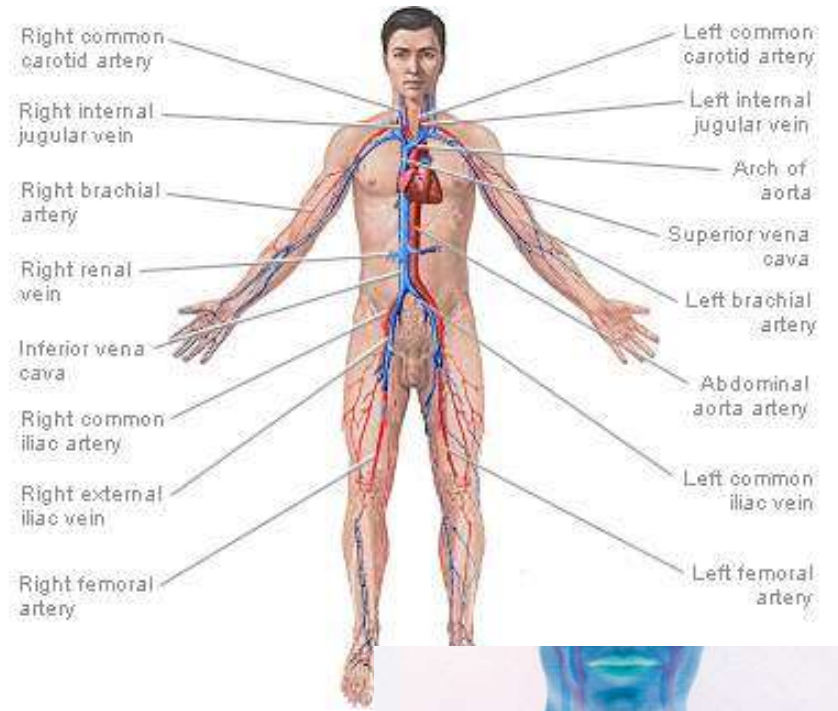
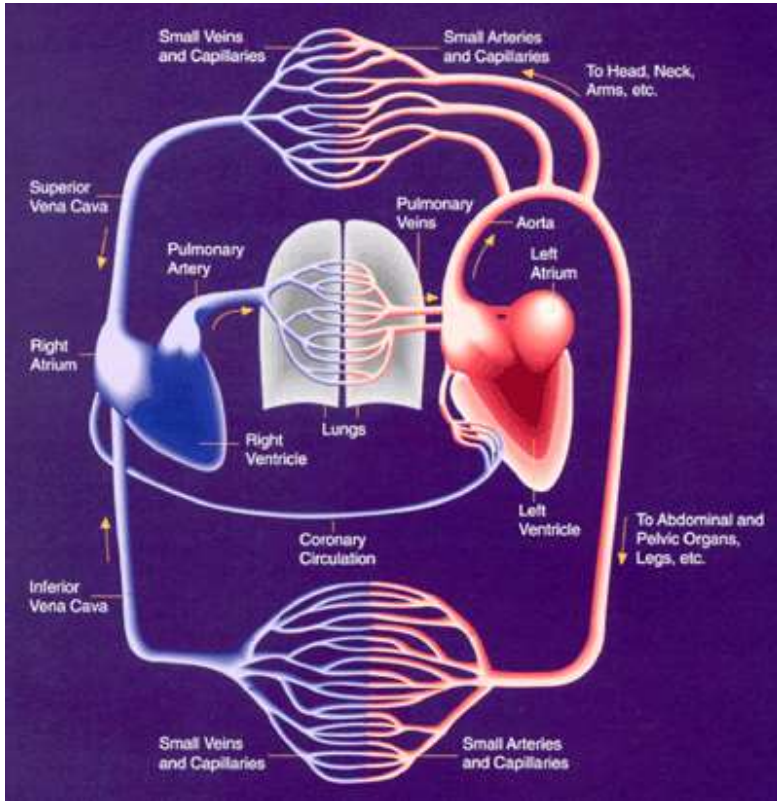
# Artificial Heart



# Cardiac Cycle

## Phases





# Monitoring Your Heart Rate (Palpation Methods)

- Carotid artery in the neck
- Radial artery in the wrist

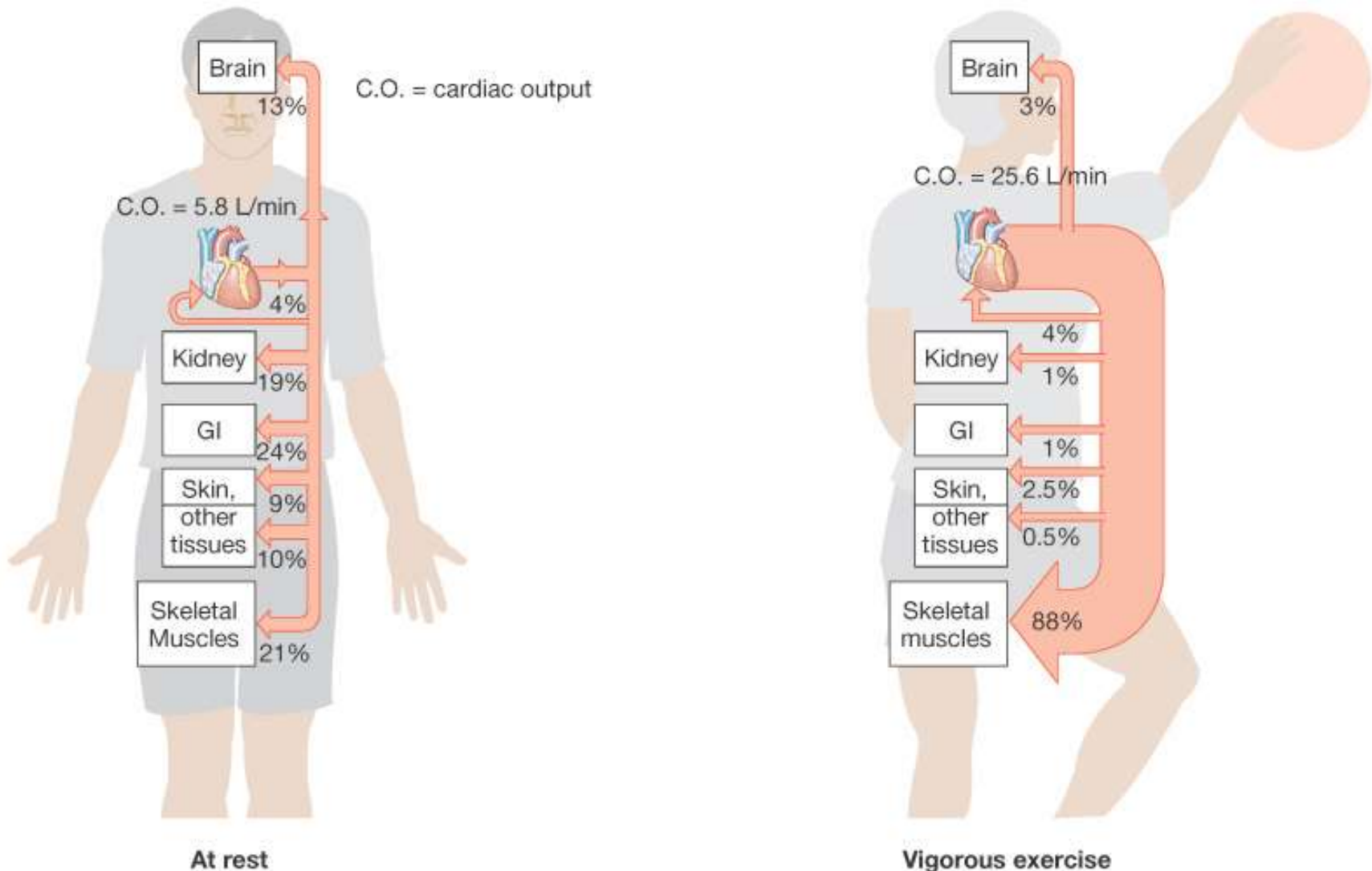


- Count beats for 10 seconds and multiply the result by 6 to get rate in beats per minute

# Monitoring Your Heart Rate (Auscultation Method)

- Place the bell of the stethoscope over the third intercostals space (i.e., the space between two adjoining ribs) to the left of the sternum (breast bone). (Or to the left of the sternum just above the nipple line).

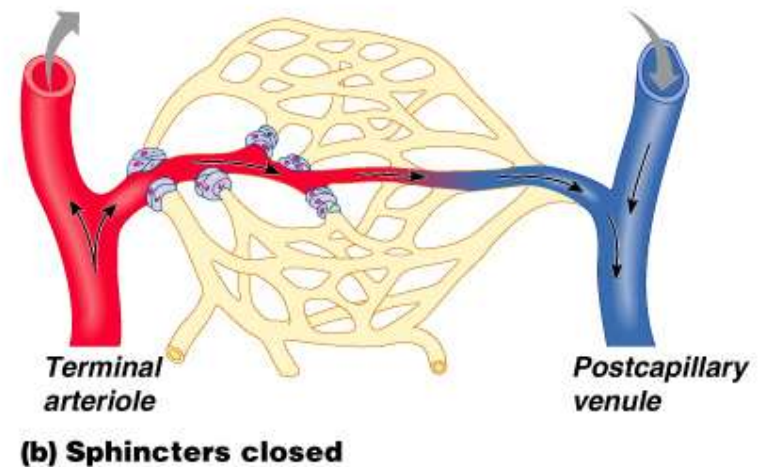
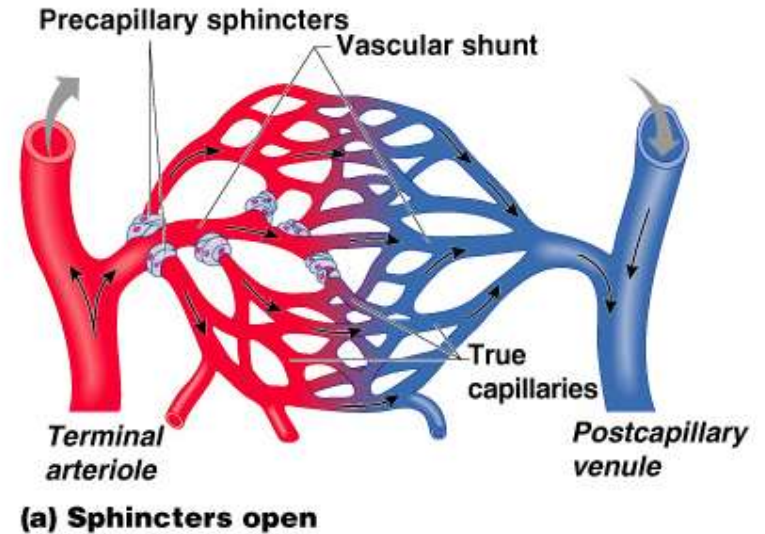
# Cardiovascular Response to Exercise



Distribution of cardiac output at rest and during exercise

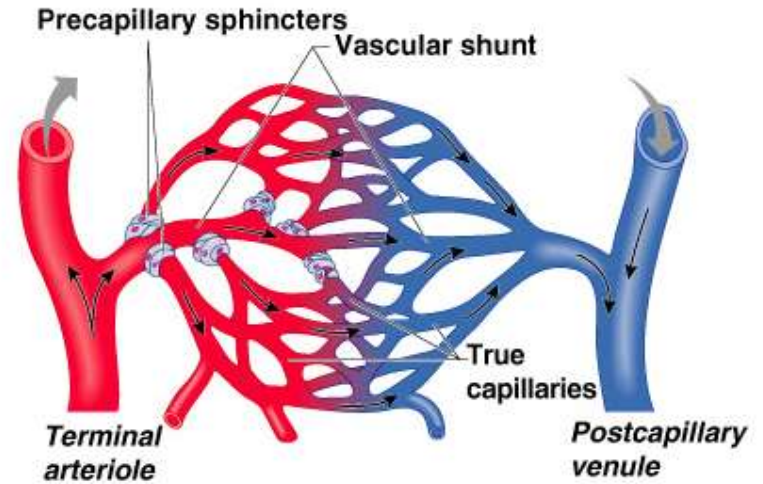
# Capillary Beds

- Capillary beds consist of two types of vessels
  - Vascular shunt — directly connects an arteriole to a venule

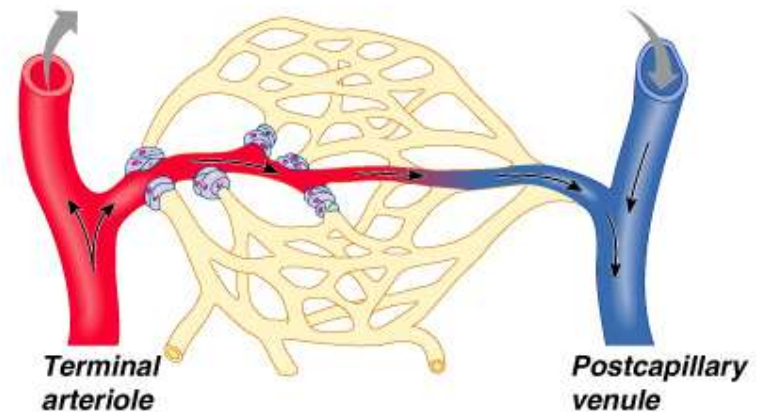


# Capillary Beds

- True capillaries — exchange vessels
  - Oxygen and nutrients cross to cells
  - Carbon dioxide and metabolic waste products cross into blood



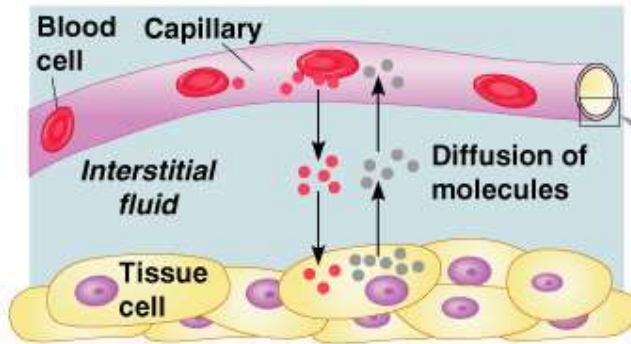
**(a) Sphincters open**



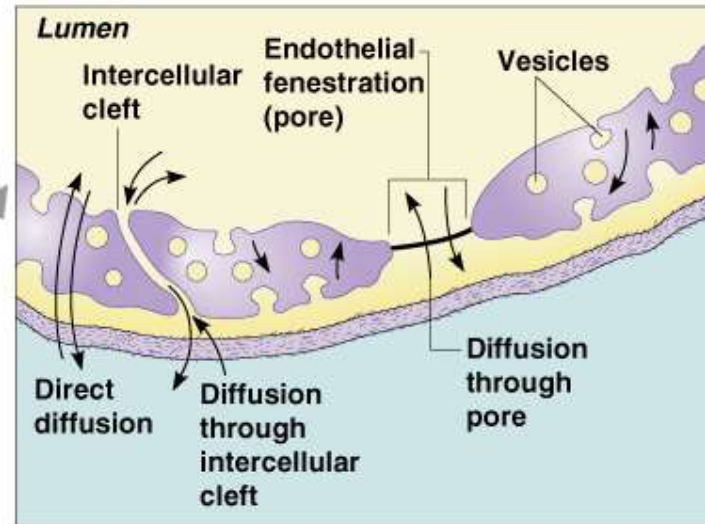
**(b) Sphincters closed**



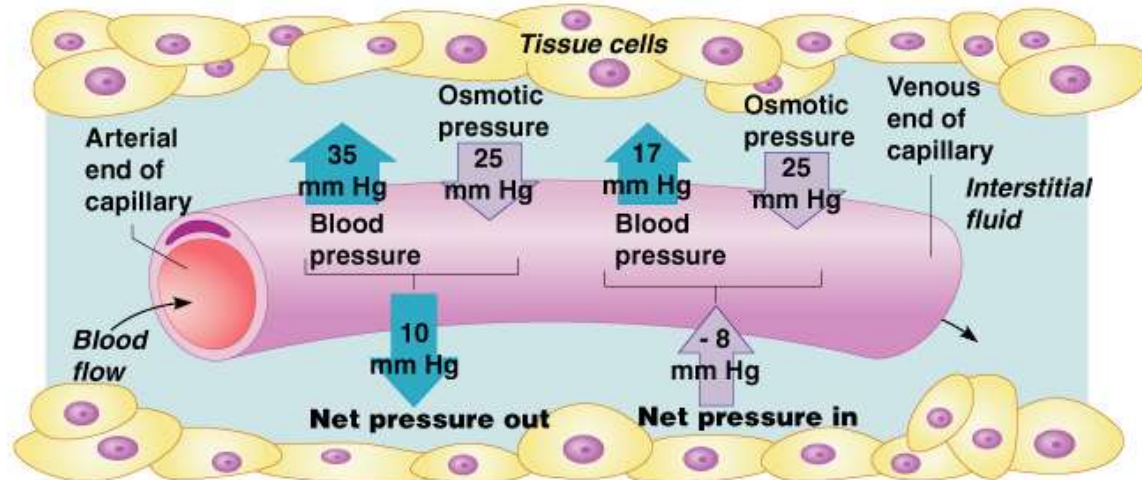
# Diffusion at Capillary Beds



(a)

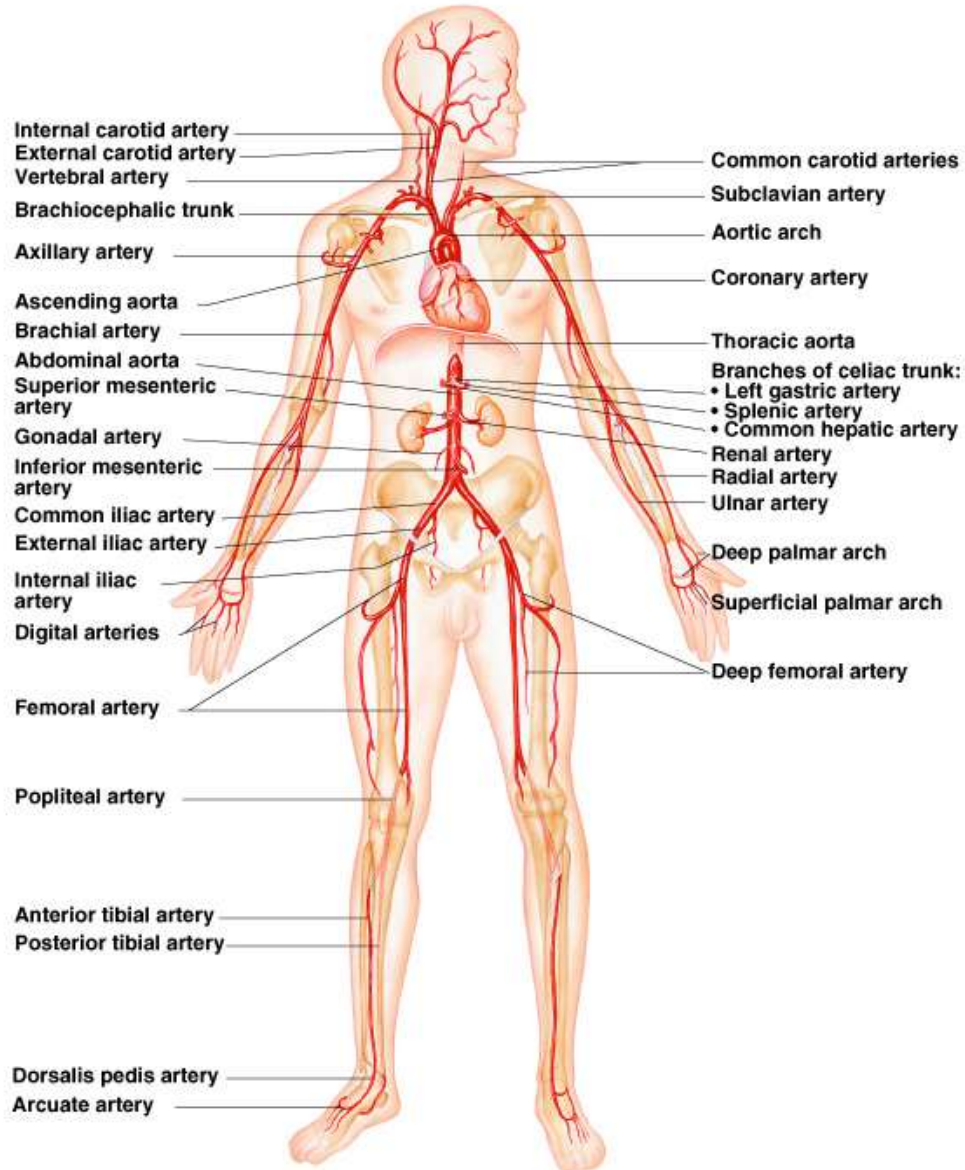


(b)

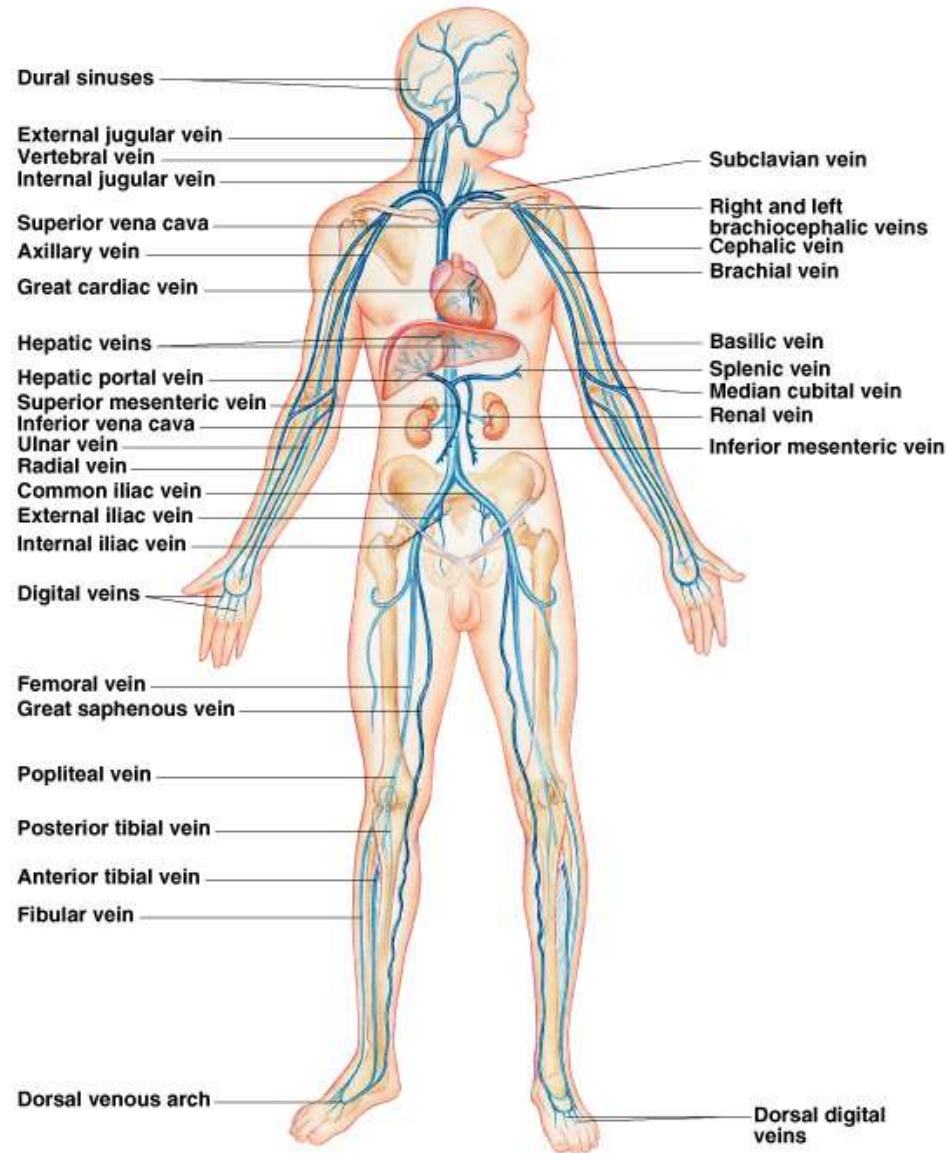


(c)

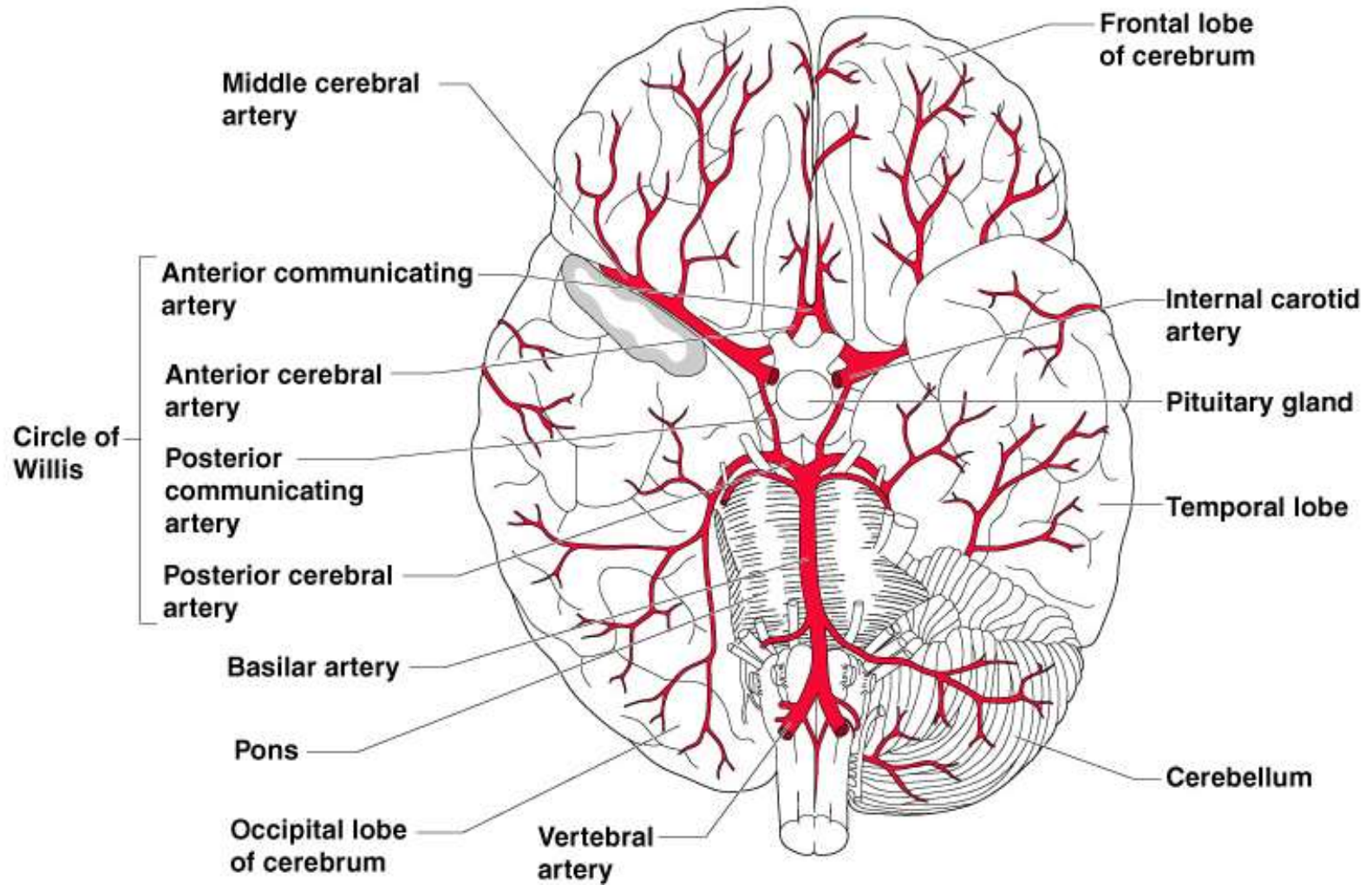
# Major Arteries of Systemic



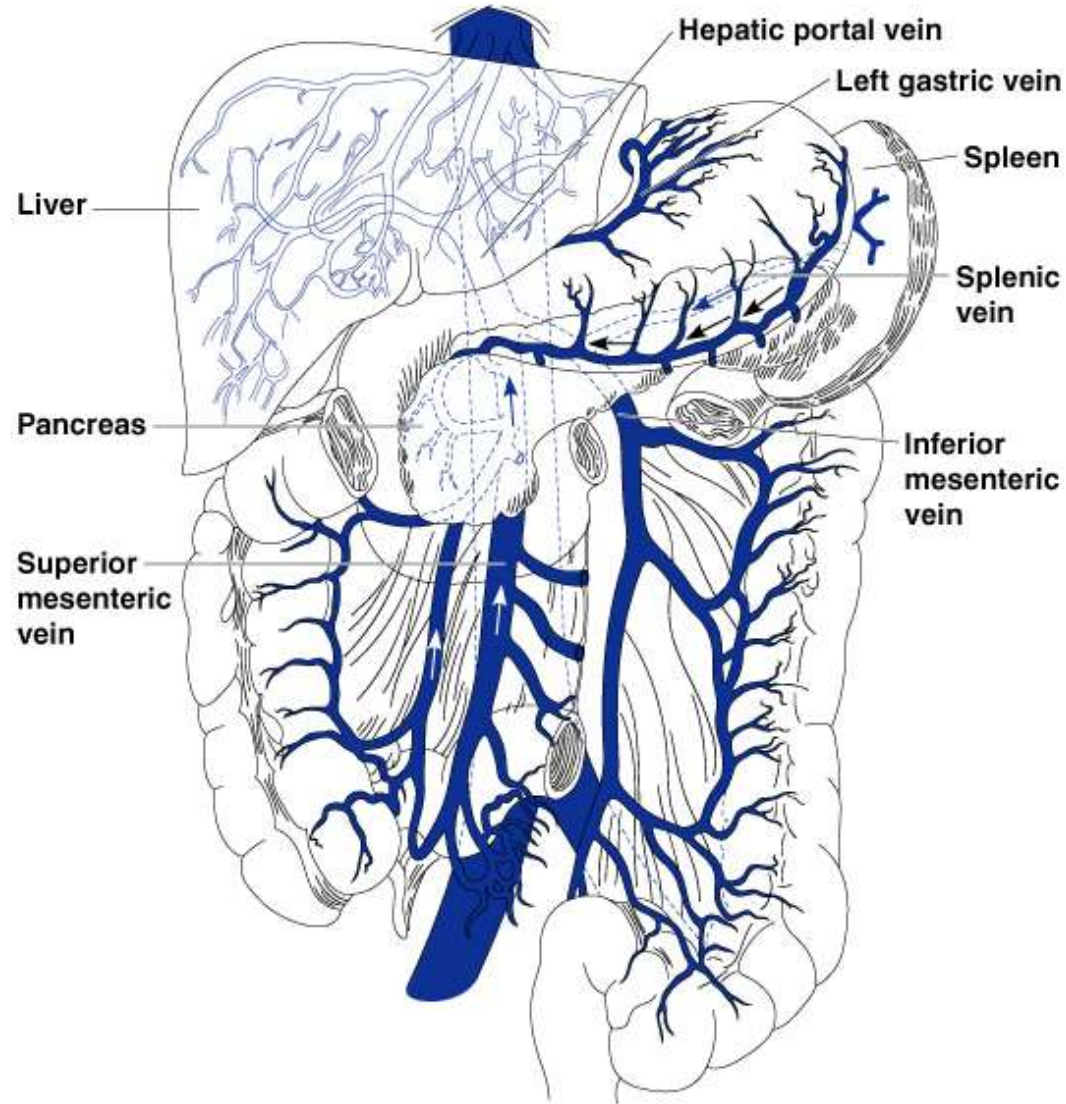
# Major Veins of Systemic



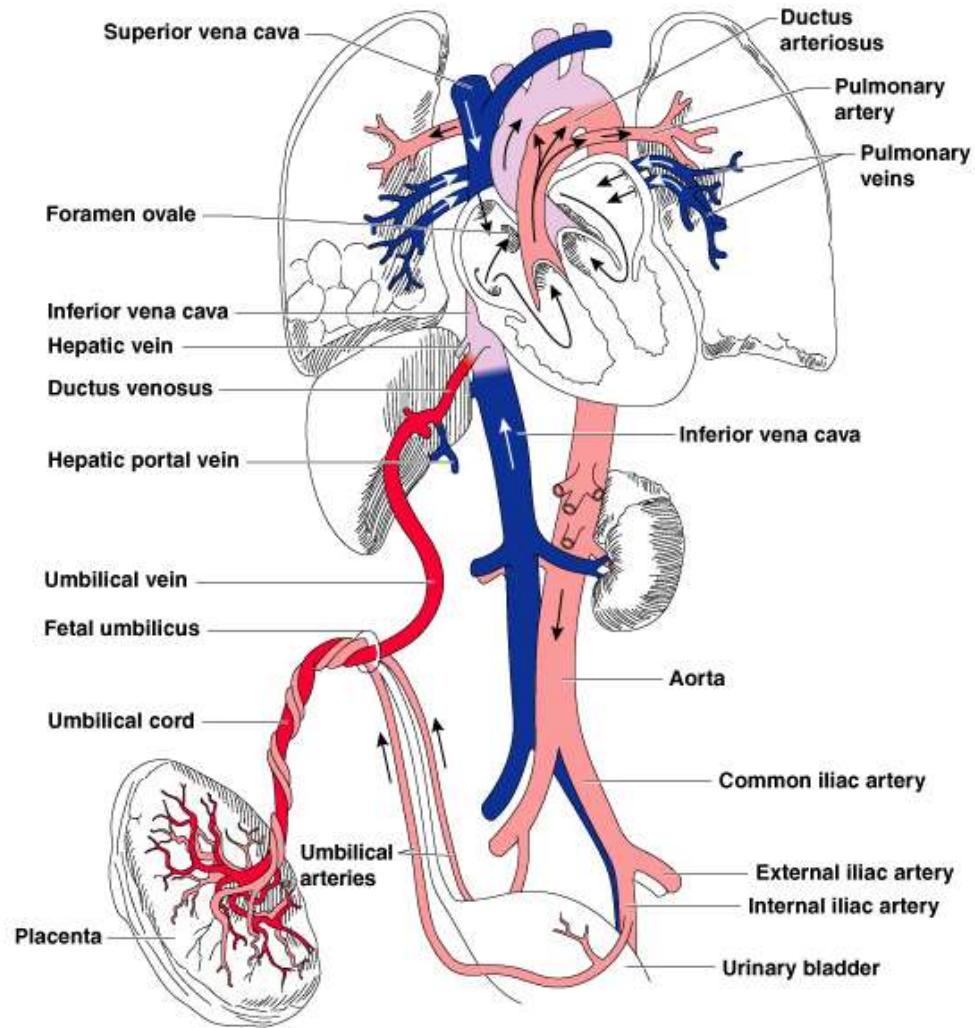
# Arterial Supply of the Brain



# Hepatic Portal Circulation



# Circulation to the Fetus

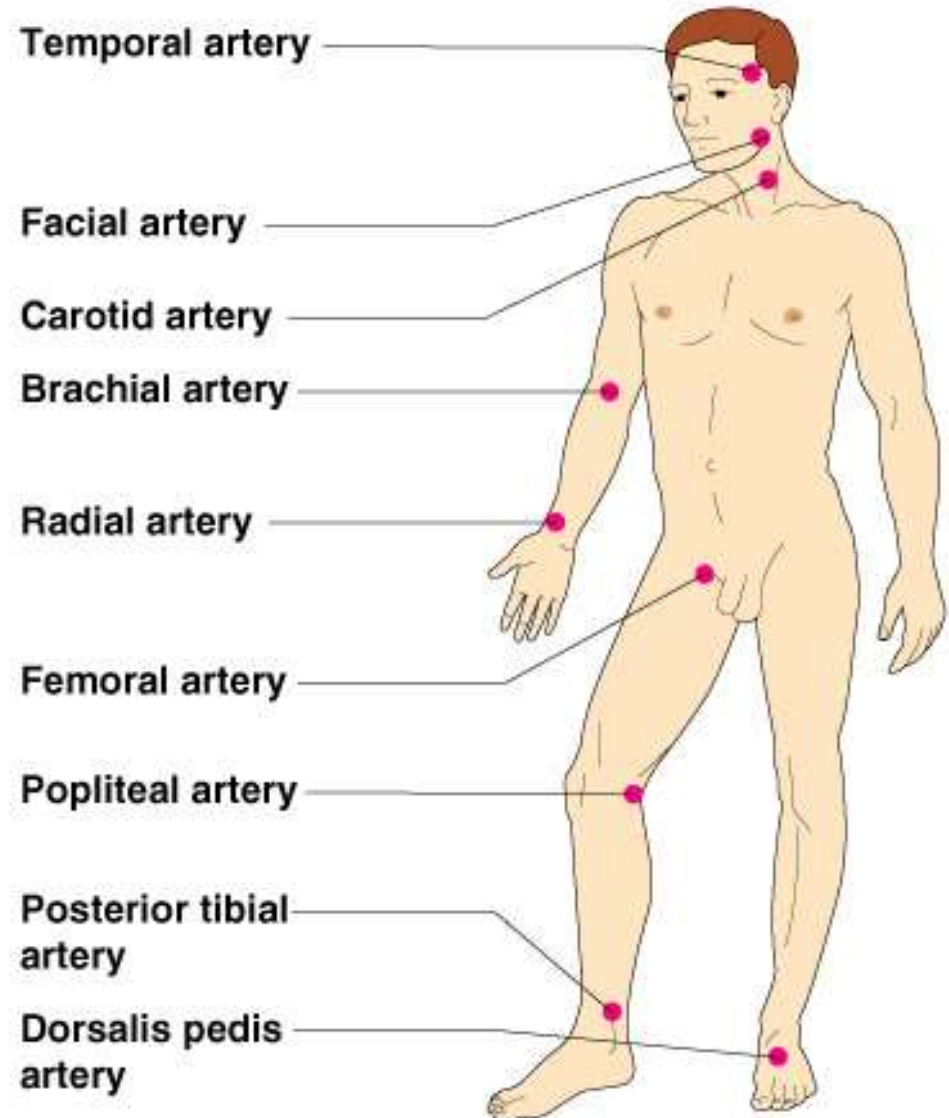


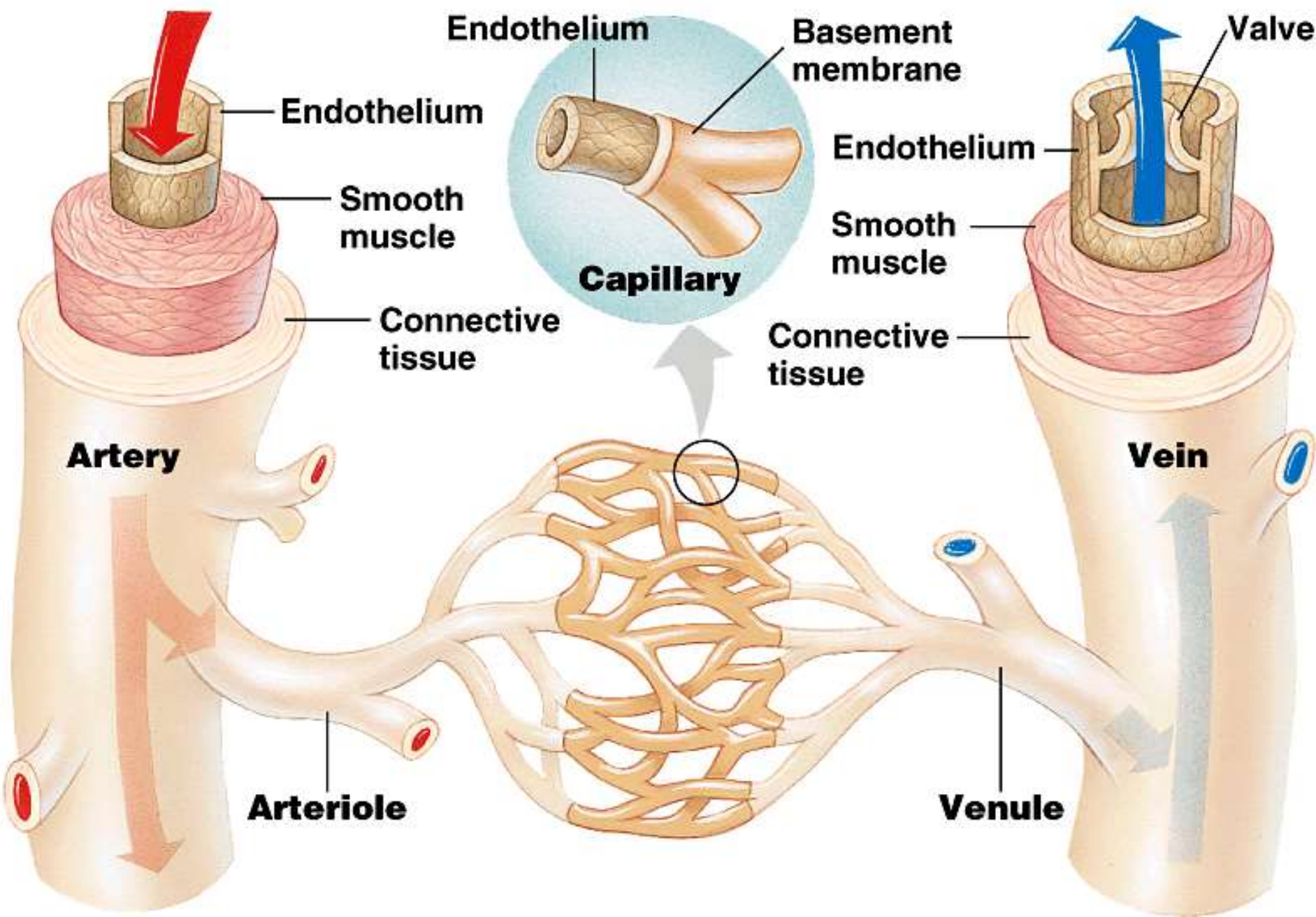
**KEY:**

- High oxygenation
- Moderate oxygenation
- Low oxygenation
- Very low oxygenation

# Pulse

- Pulse – pressure wave of blood
- Monitored at “pressure points” where pulse is easily palpated

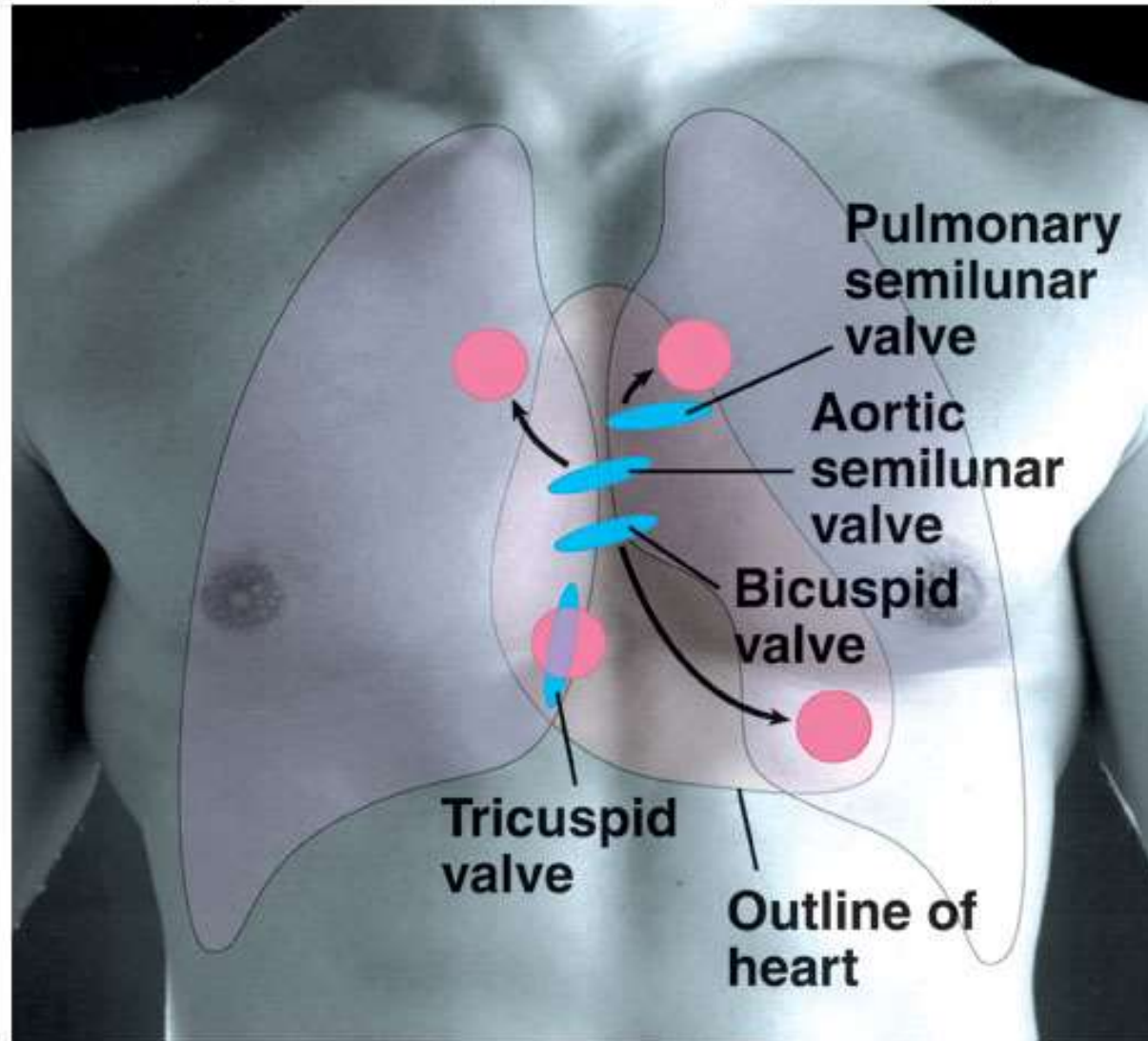






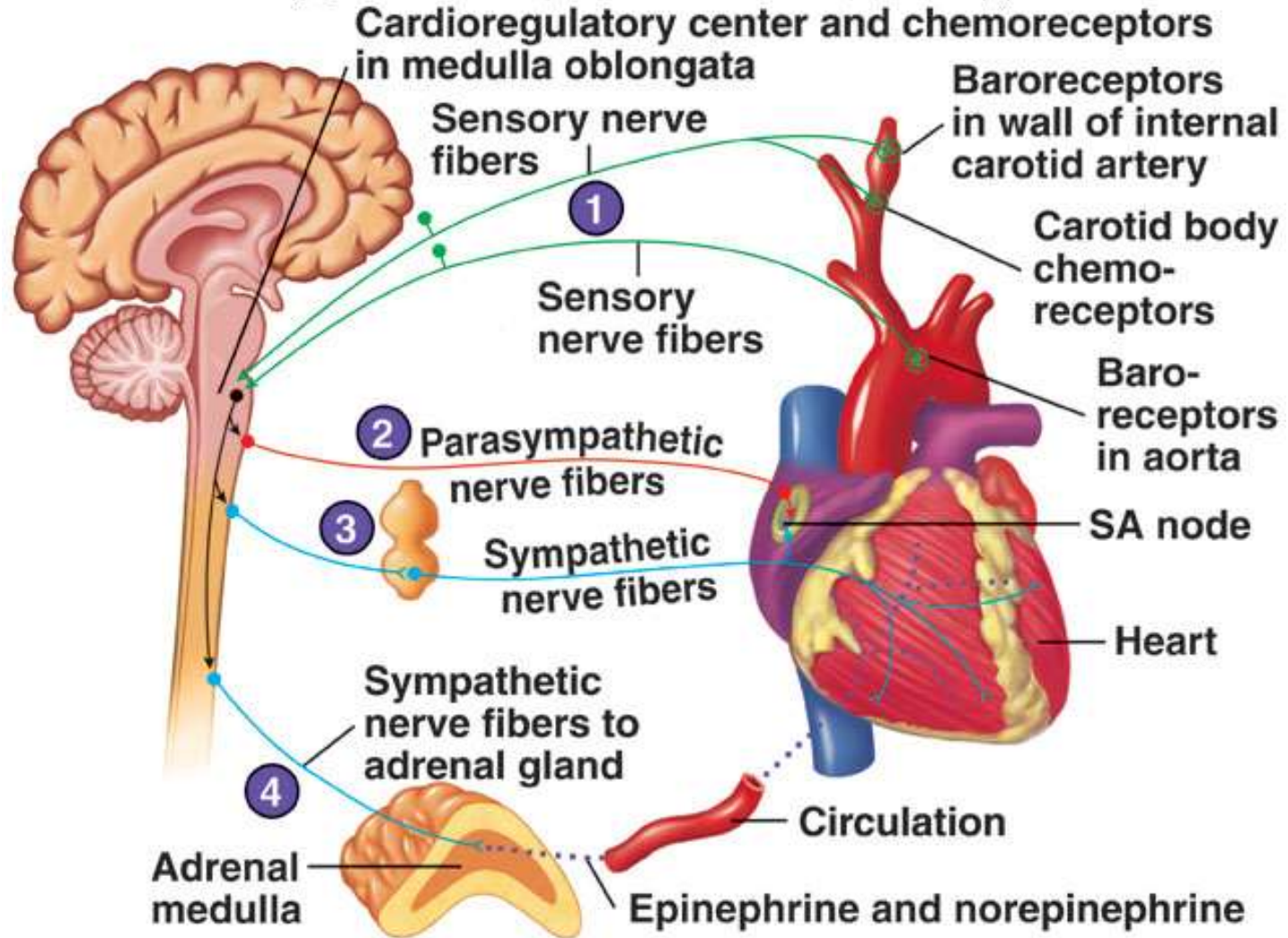
# Location of Heart Valves

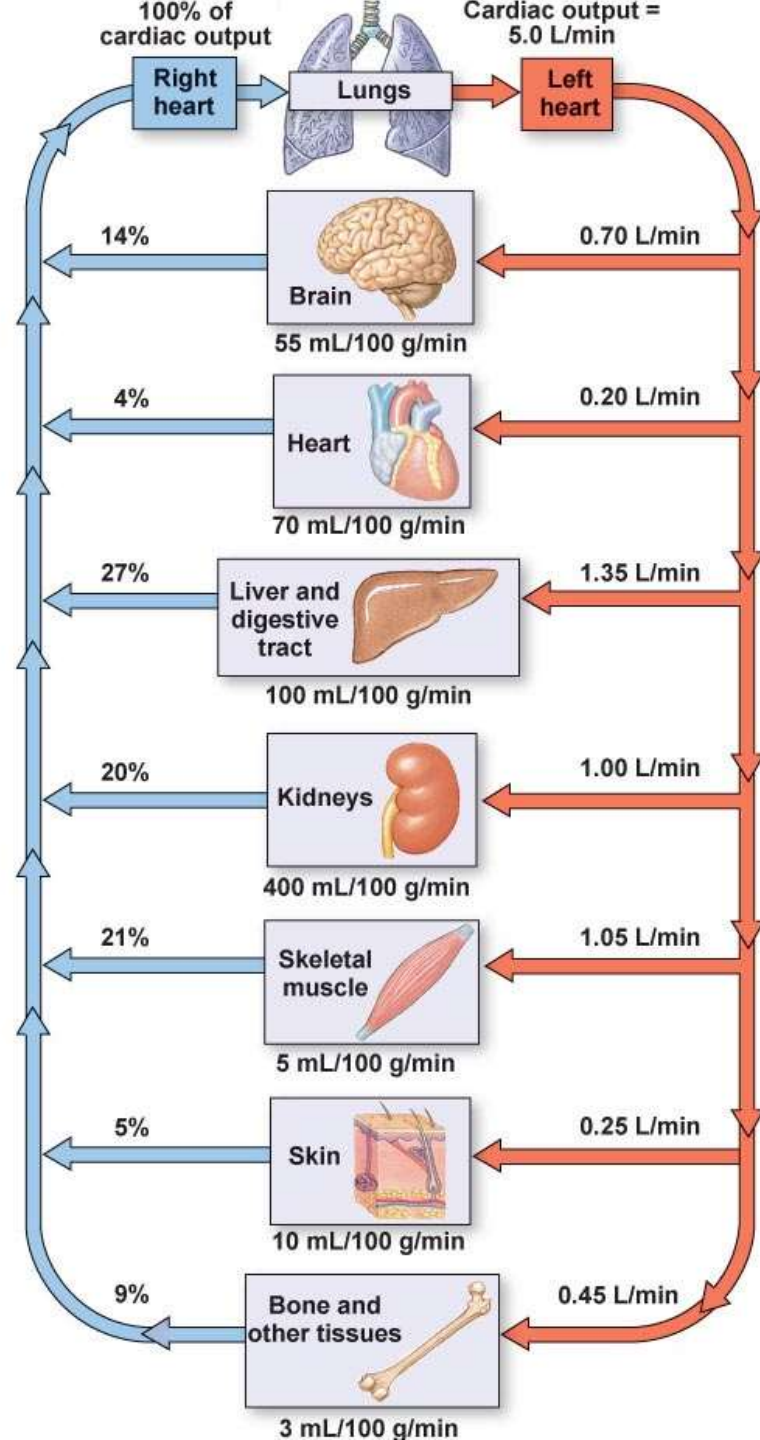
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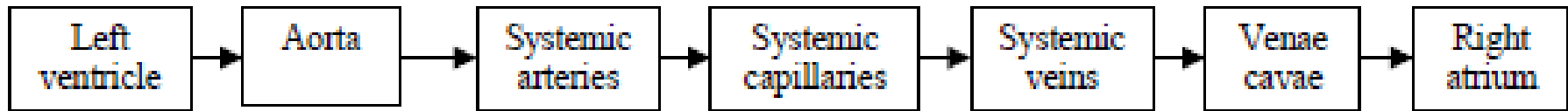
# Baroreceptor and Chemoreceptor Reflexes

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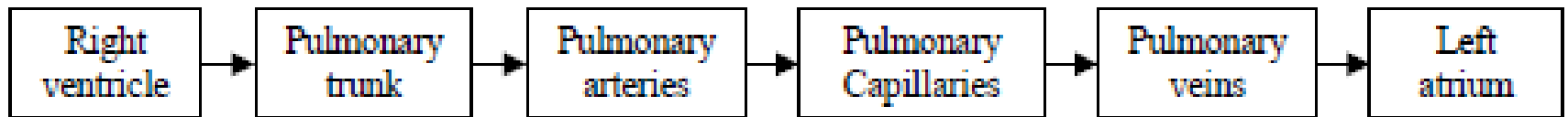




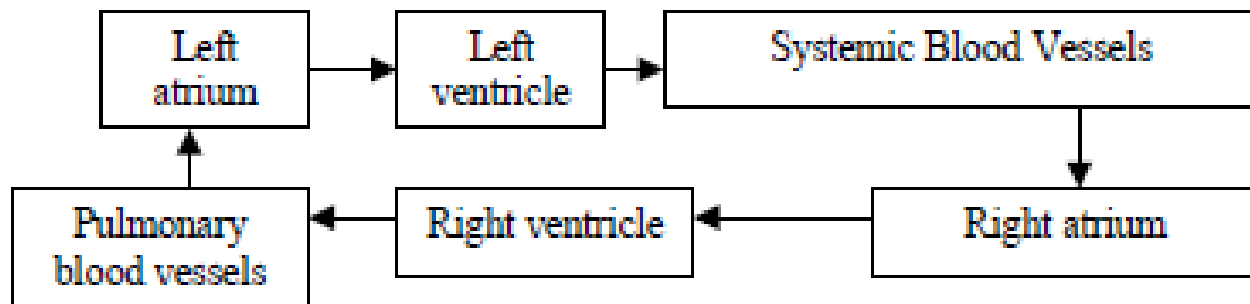
Systemic circuit:



Pulmonary circuit:



If we combine the 2 circuits, note that we have 2 pumps in series:



The heart has its own network of blood vessels (known as the coronary circuit). It's necessary b/c the heart requires a prodigious amount of oxygen and nutrients, and little oxygen and/or nutrients from blood within the chambers can diffuse thru the thick myocardium. The basic pathway of blood is:

