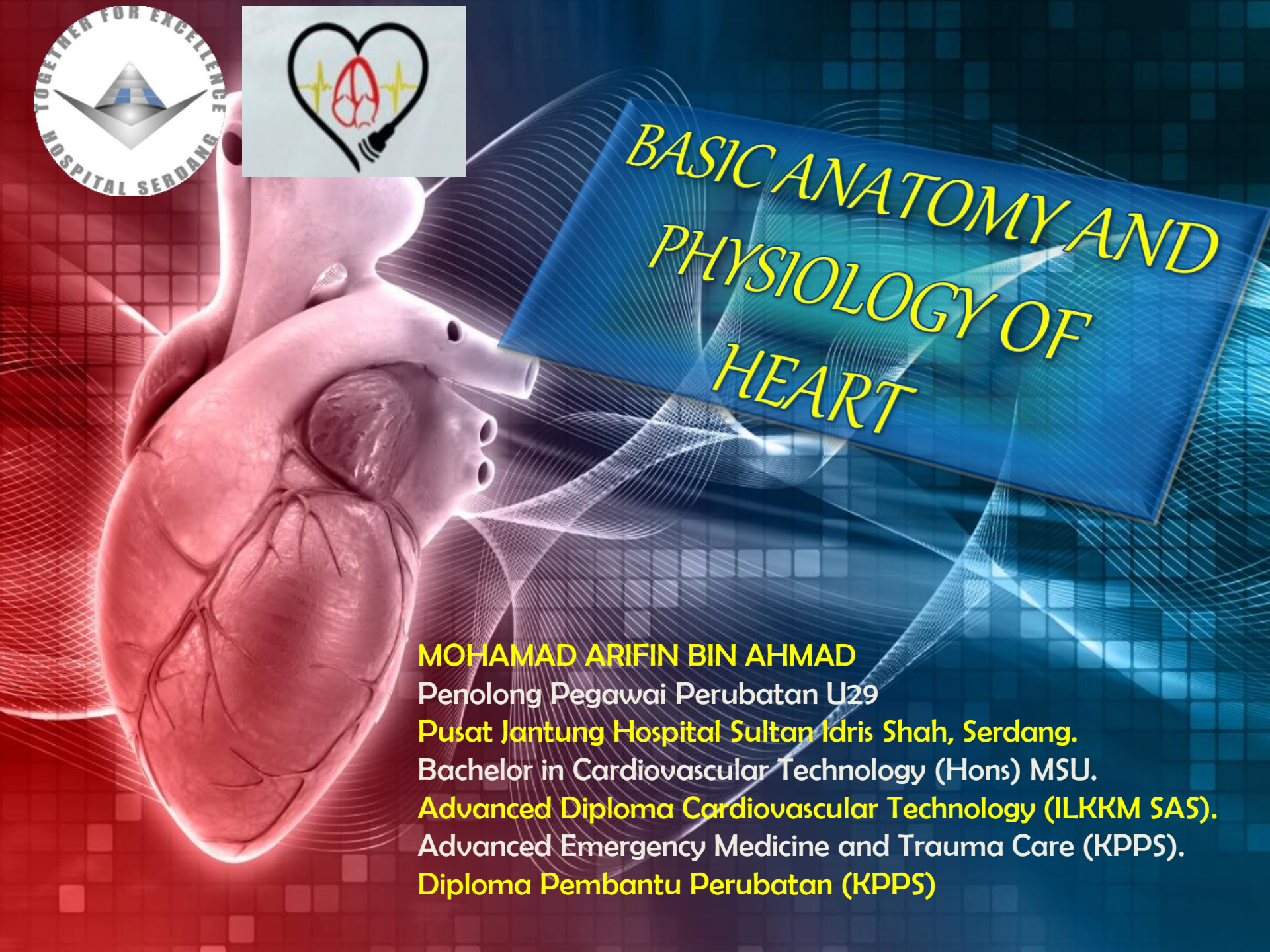

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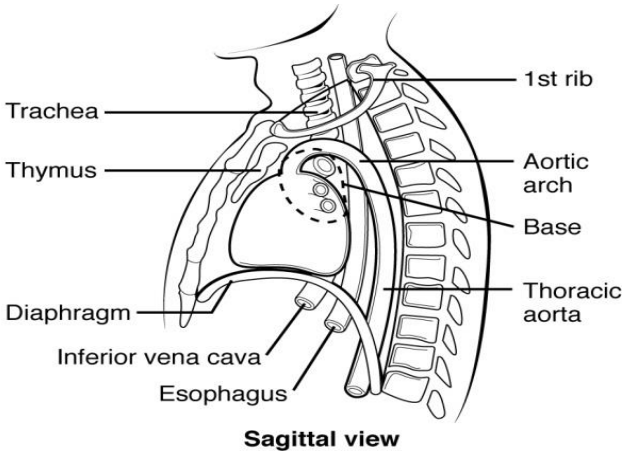
Table Of Contents

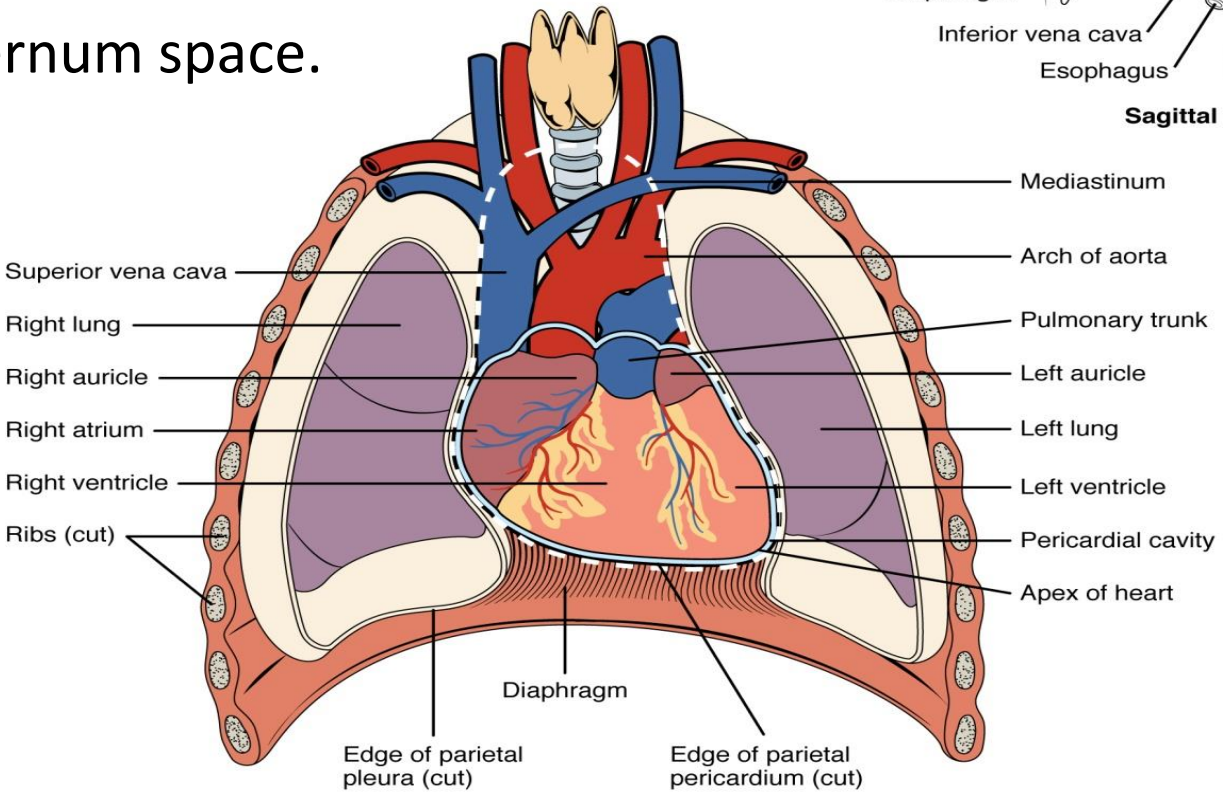
Interactive Info's

- If average rate of contraction is 75 beats per minute,
- A day will be approximately 108,000 times
- A year more than 39 million times
- For 75 year lifespan nearly 3,000,000,000 (3 billion times)
- Heart eject approximately 70 ml blood per contraction in a resting adult.
- 5.25 liters per minute.
- 14,000 liters per day.
- 10 million liters in a year of blood sent through roughly 60,000 miles of vessels.
- In order to understand how that happens, it is necessary to understand the anatomy and physiology of the heart.

Location

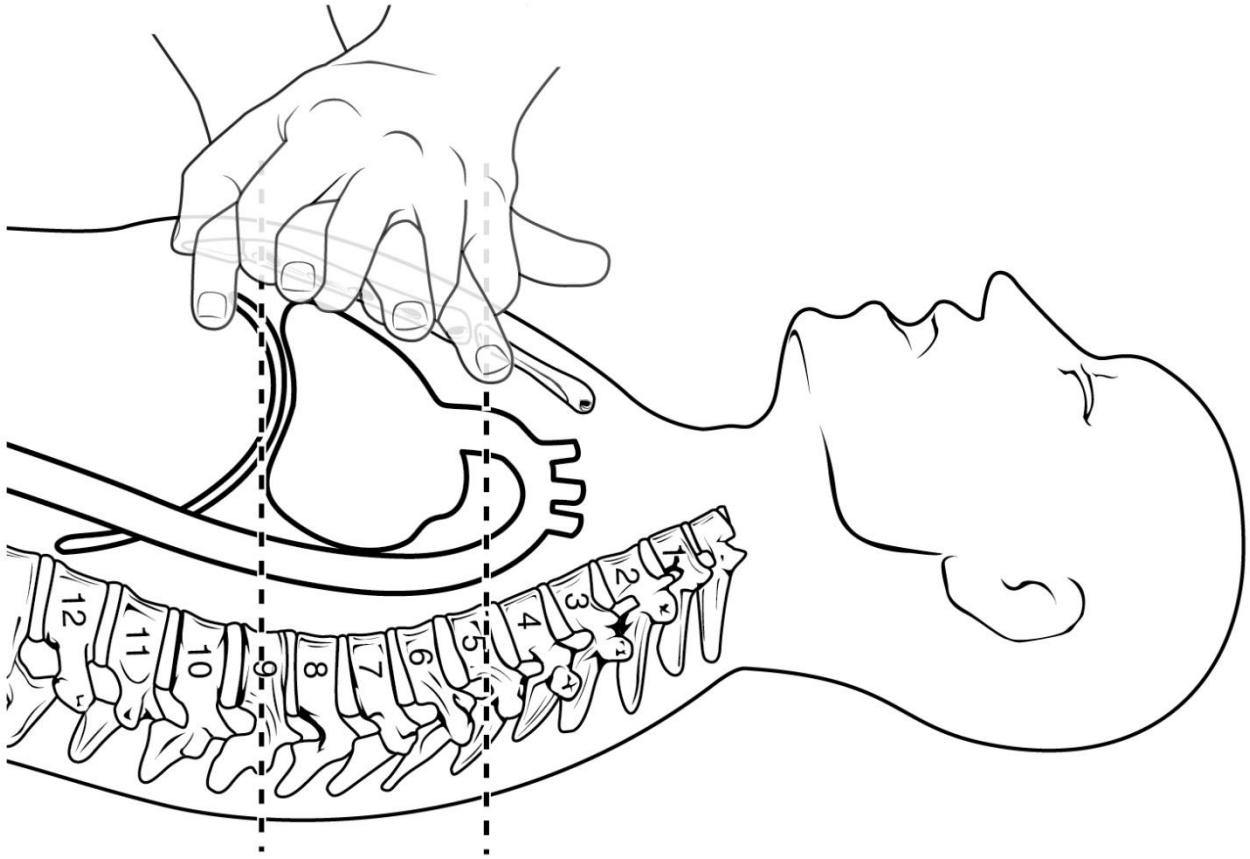
- Within thoracic cavity
- Medially between lungs in the mediasternum space.





CPR Life-sustaining Technique

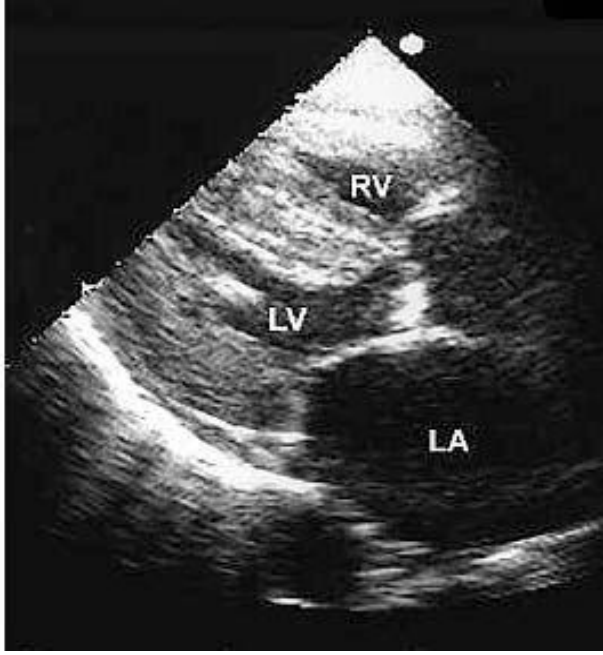
- If the heart should stop, CPR can maintain the flow of blood until the heart resumes beating.
- By applying pressure to the sternum, the blood within the heart will be squeezed out of the heart and into the circulation.
- Proper positioning of the hands on the sternum to perform CPR would be between the lines at T4 and T9.

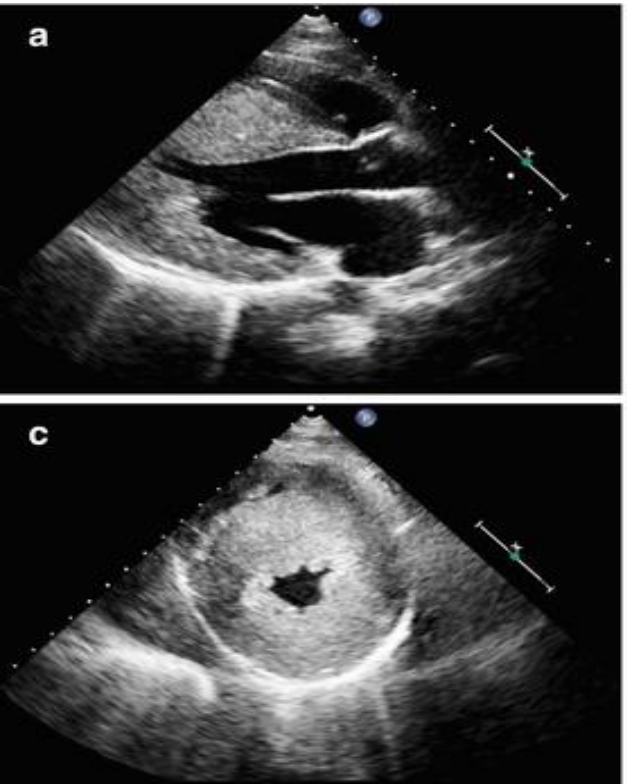


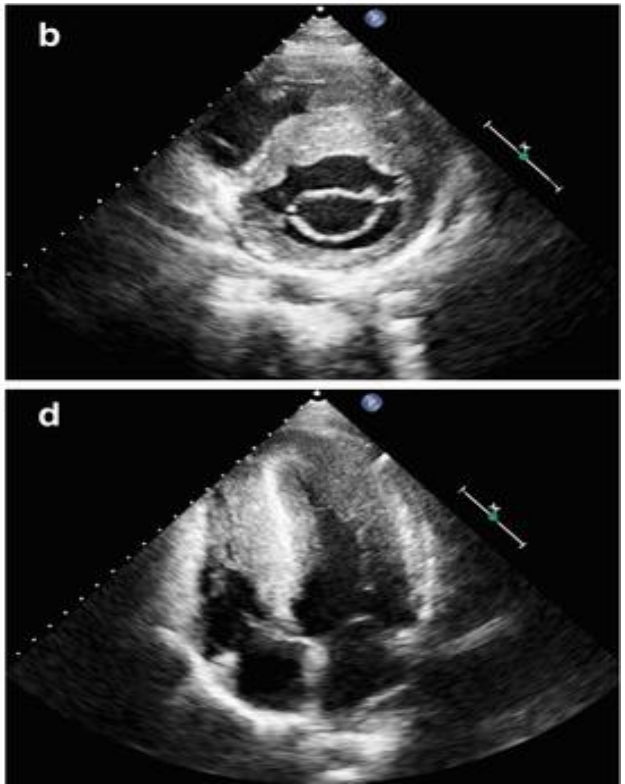
Shape and Size

- Similar to a pinecone
- Approximately the size of your fist (L:12cm x W:8cm x T:6cm)
- Weight
  - male: 300-350 grams
  - Female: 250-300 grams
- Well-trained athlete (specializing in aerobic sports) can be larger than this.
- Cardiac muscle responds to exercise in a manner similar to skeletal muscle-increase protein myofilaments individual cells size (not increase in numbers). –HYPERTROPHY-
- Not always a result in exercise, can be from pathologies such as HCM.

Hypertrophic Cardiomyopathy -HCM-



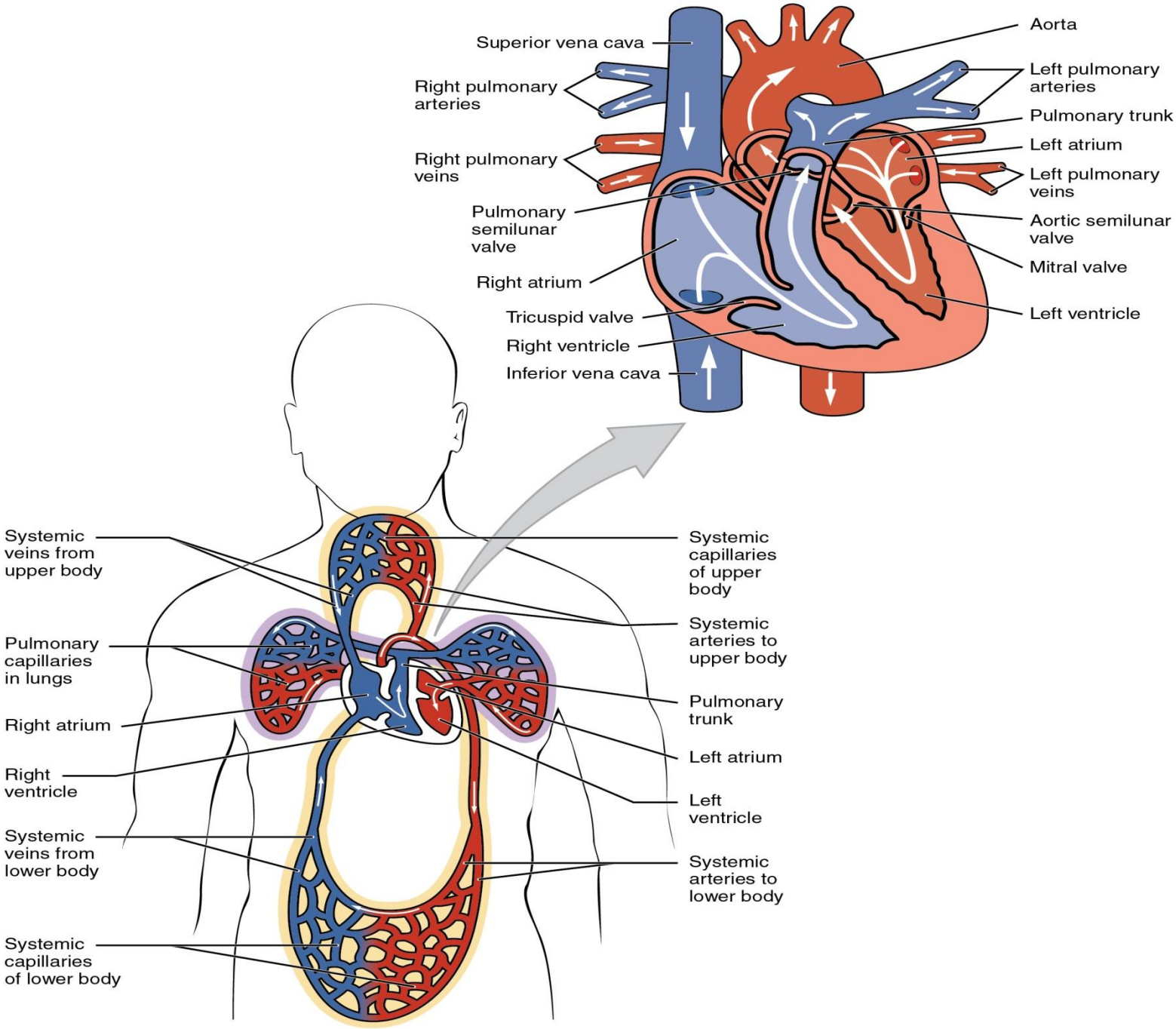




- Cause is UNKNOWN (idiopathic)
- Often undiagnosed
- Can cause sudden death in healthy young people.

Main Chambers

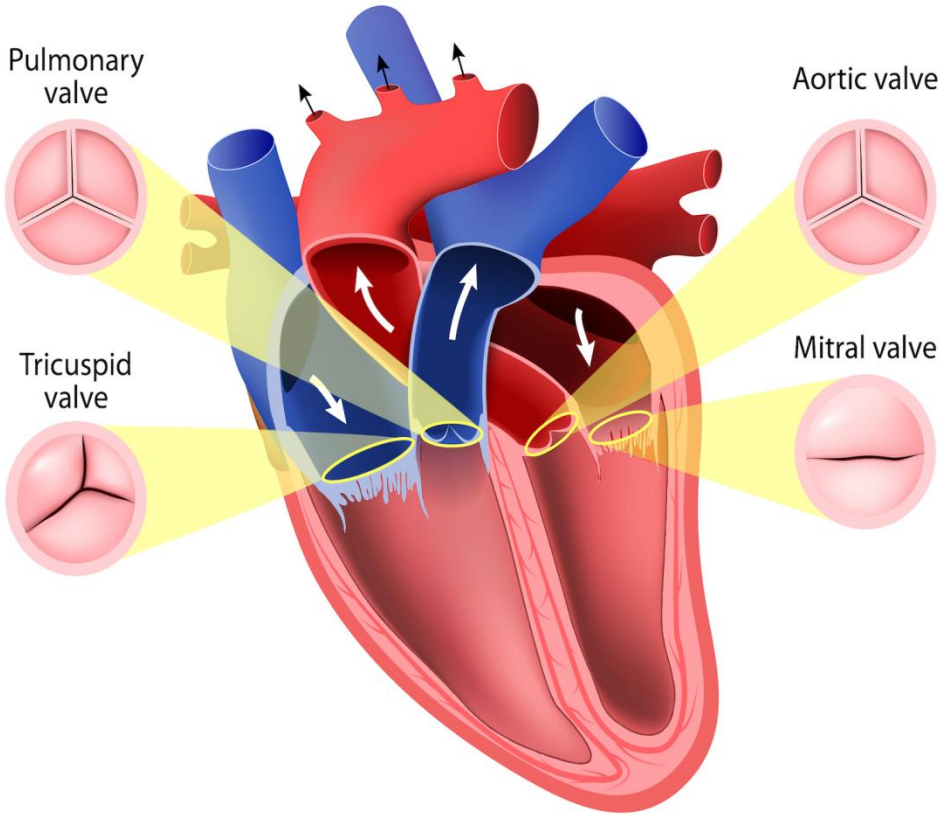
- Consists of four chambers:
  - 2 atrium (upper chamber):
    - Right atrium (RA)
    - Left atrium (LA)
  - 2 ventricle (lower chamber):
    - Right ventricle (RV)
    - Left ventricle (LV)


Superior vena cava
Right pulmonary arteries
Right pulmonary veins
Pulmonary semilunar valve
Right atrium
Tricuspid valve
Right ventricle
Inferior vena cava
Aorta
Left pulmonary arteries
Pulmonary trunk
Left atrium
Left pulmonary veins
Aortic semilunar valve
Mitral valve
Left ventricle
Systemic veins from upper body
Pulmonary capillaries in lungs
Right atrium
Right ventricle
Systemic veins from lower body
Systemic capillaries of lower body
Systemic capillaries of upper body
Systemic arteries to upper body
Pulmonary trunk
Left atrium
Left ventricle
Systemic arteries to lower body

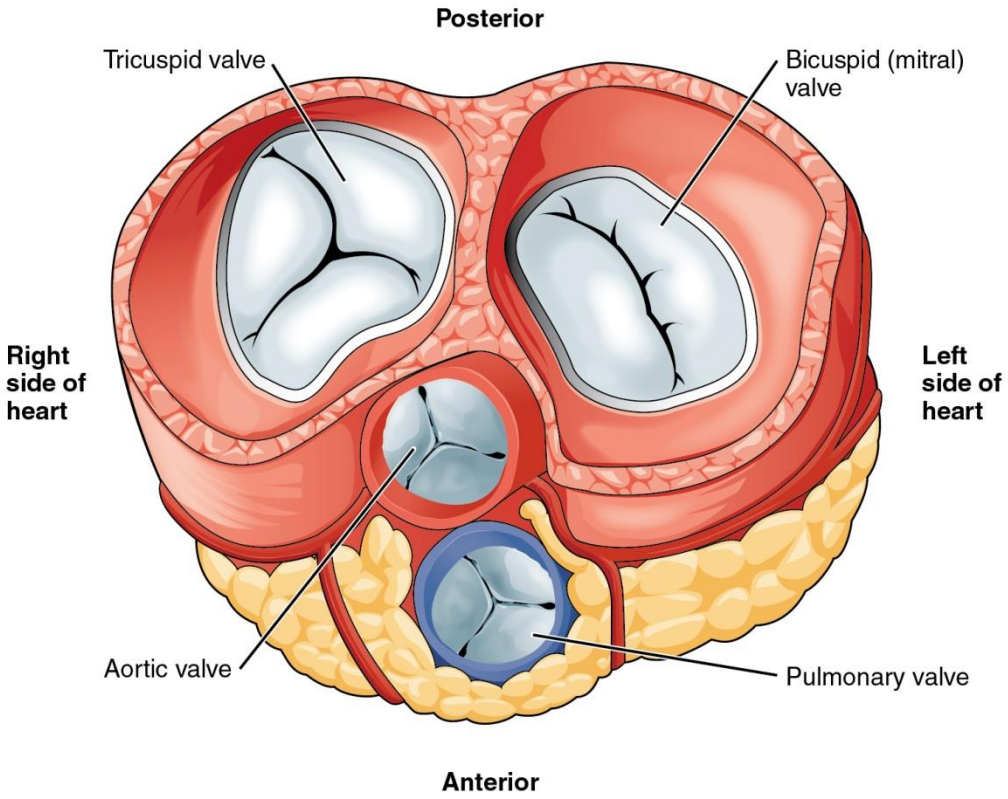
Valves

- Has **four** valves, which separate its chambers.
- One valve lies between each atrium and ventricle (**atrioventricular valve**)
- One valve rests at the exit of each ventricle (**semilunar valve**).

VALVE	NUMBER OF FLAPS/CUSPS	LOCATION	PREVENT BACKFLOW OF BLOOD
Atrioventricular valves	3 (right), 2 (left)		From the ventricles into the atria
Tricuspid valve	3	between the right atrium and right ventricle.	
Bicuspid or mitral valve	2	between the left atrium and left ventricle.	
Semilunar valves	3 (half-moon shaped) flaps		into the ventricle
Pulmonary semilunar valve	3 (half-moon shaped) flaps	at the opening between the right ventricle and the pulmonary trunk	
Aortic semilunar valve	3 (half-moon shaped) flaps	at the opening between the left ventricle and the aorta	

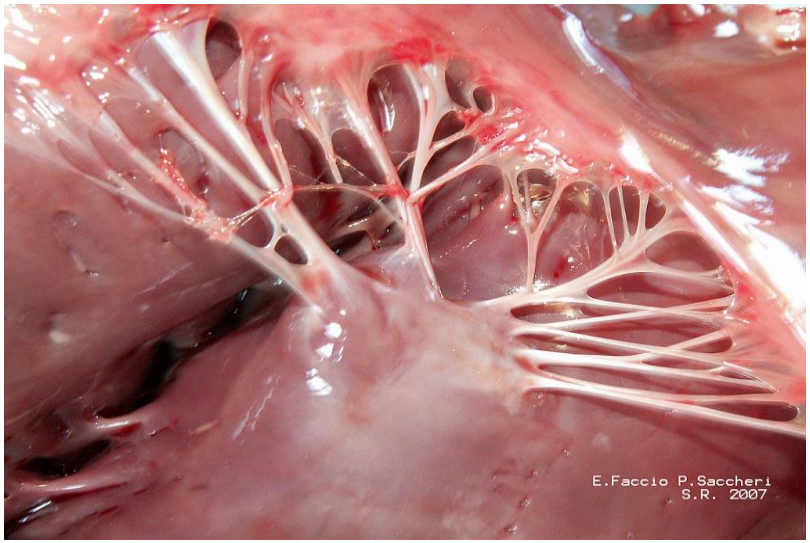


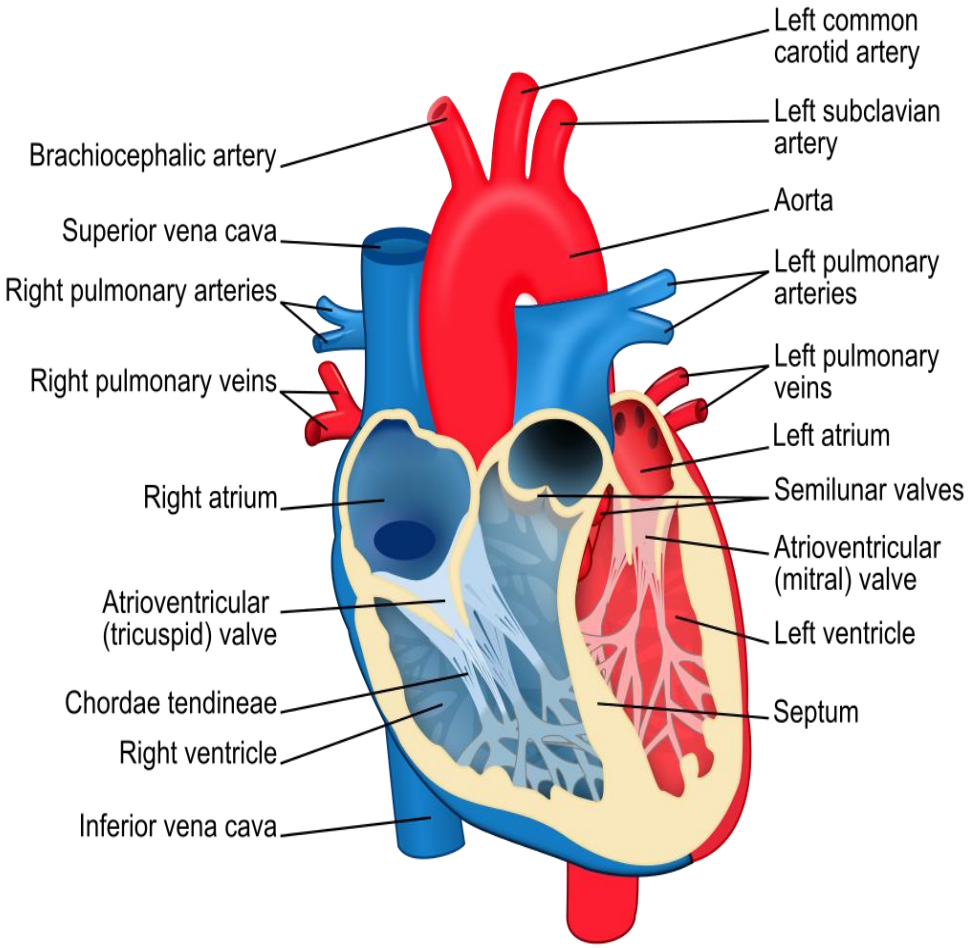
- With the atria and major vessels removed, all four valves are clearly visible.



Other Structure Valve-related

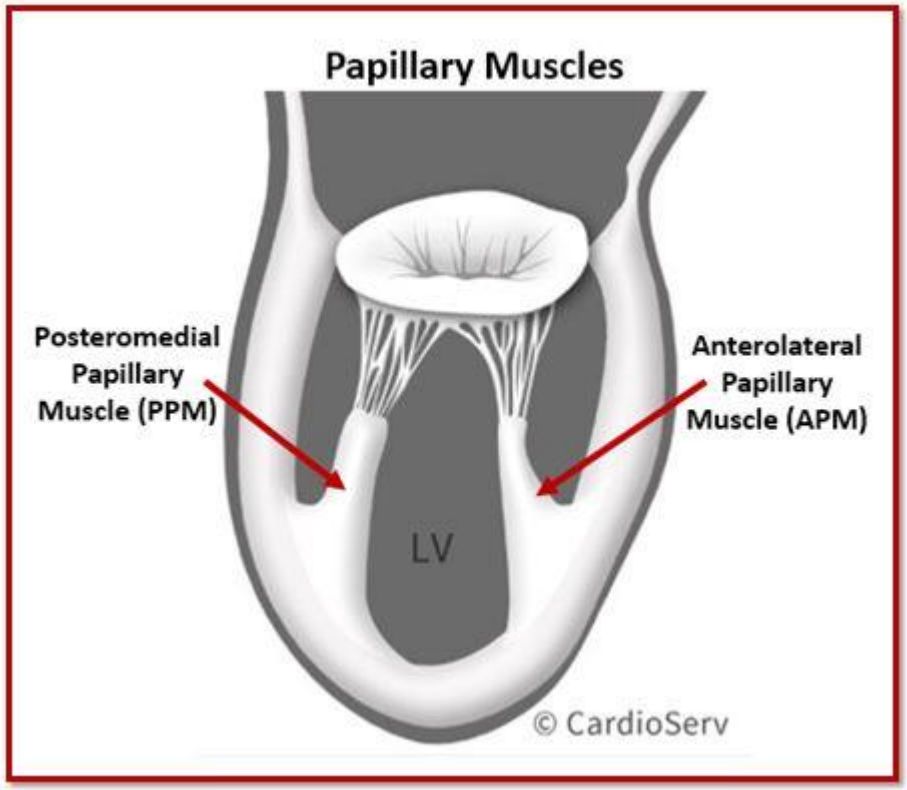
- ***Chordae tendineae***
  - Known as Heart Strings
  - Inelastic cords of fibrous connective tissue
  - Connect papillary muscle to the atrioventricular valve.



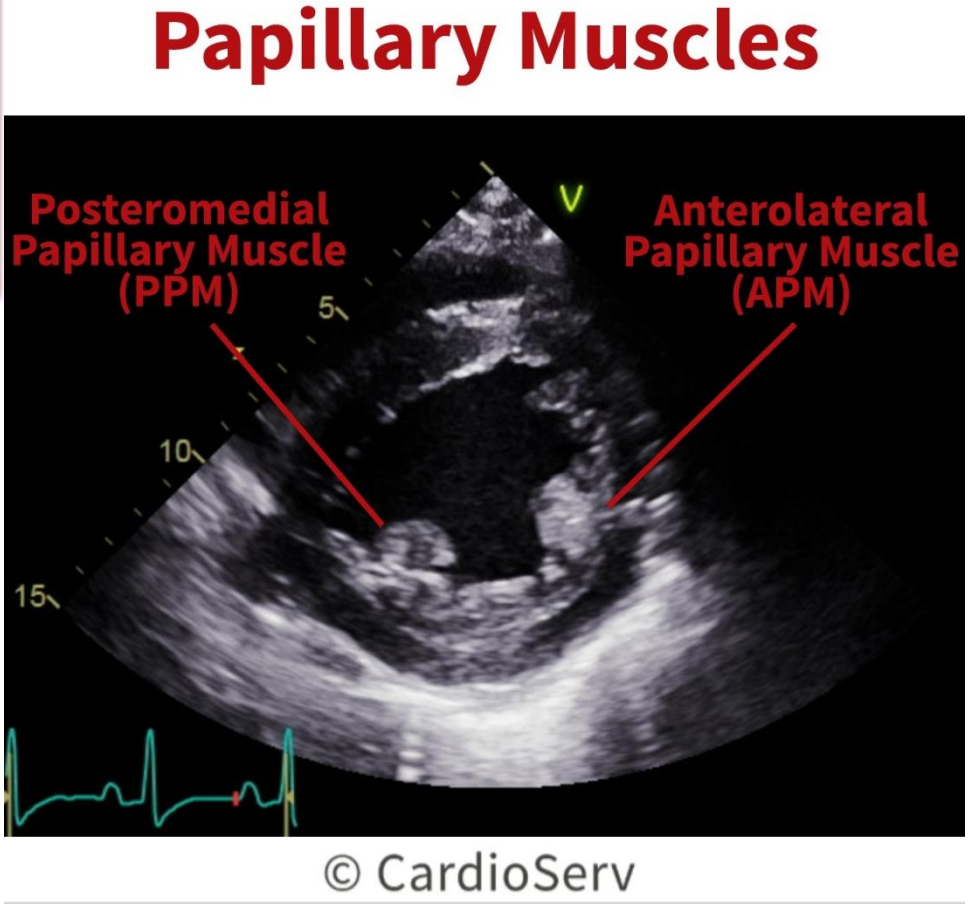


Other Structure Valve-related

- ***Papillary muscle***
  - Attach to the cups of atrioventricular valve via chordae tendineae.
  - Contract to prevent inversion or prolapse of these valves during ventricular systole.
  - Constitute about 10% of total heart mass.
  - Total are five papillary muscle
    - 3 in RV (anterior, posterior and septal)
    - 2 in LV (anterolateral and posteromedial)



- Anterolateral PM:
  - LAD (Diagonal branch)
  - LCX (OM branch)
- Posteromedial PM:
  - RCA (Posterior interventricular artery)

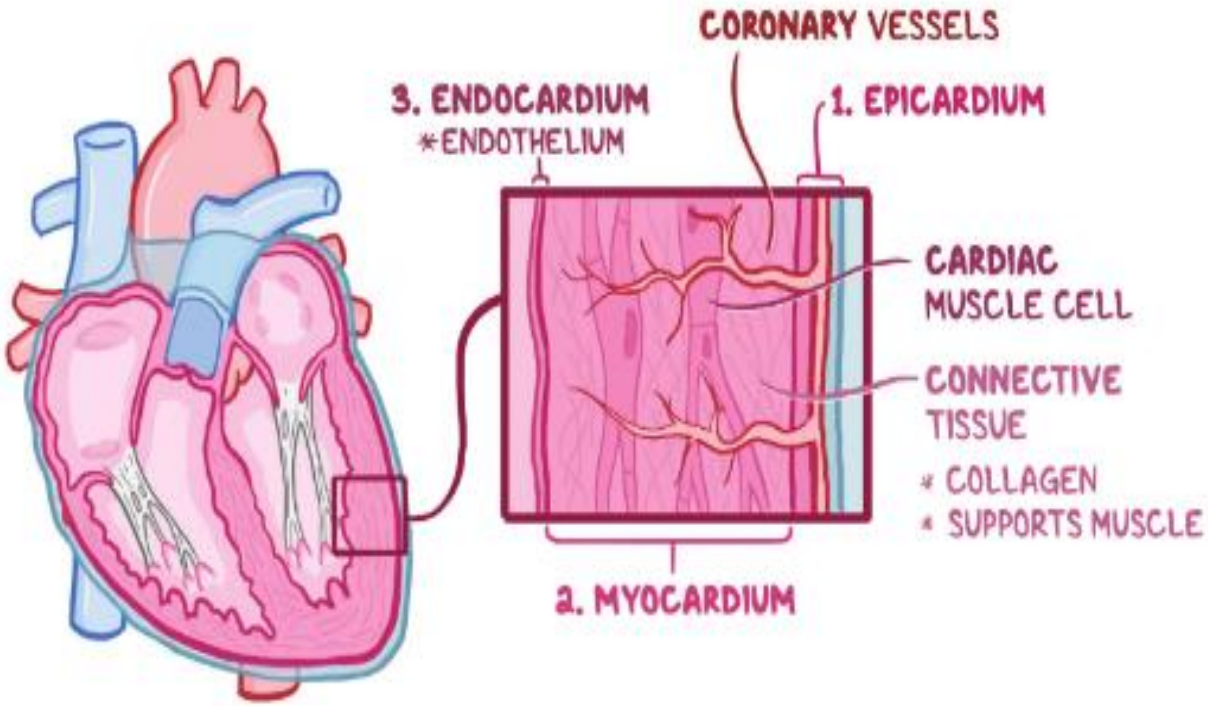


Heart Wall Layers

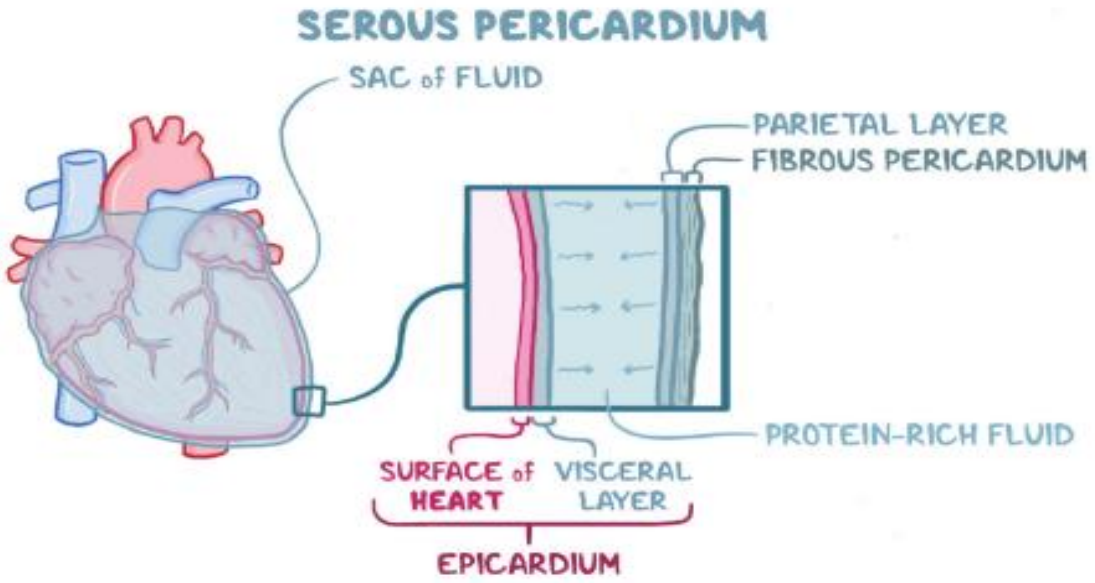
- ***Epicardium***
  - Covers surface, great vessels (aka visceral pericardium)
- ***Myocardium*** (muscular middle layer)
  - Cardiac muscle cells: striated, branching cells with **mitochondria, intercalated disks** for synchronous contraction.
  - Cardiac myocytes: striated, branching cells with **fibrous cardiac skeleton** (support muscle tissue, crisscrossing connective tissue collagen fibers), **coronary vessels** (lie on outside of the heart, penetrate into myocardium)

Heart Wall Layers

- ***Endocardium*** (innermost layer)
  - Made of thin epithelial layer, underlying connective tissue
  - Lines heart chamber and valve
- ***Pericardium*** (double-layered sac surrounding)
  - fibrous pericardium: outer layer, tough fibrous connective tissue anchors heart within mediasternum
  - Serous pericardium: simple squamous epithelium layer
  - Perietal pericardium: lines fibrous pericardium
  - Visceral pericardium: (epicardium) covers outer surface of the heart.
  - Cells of parietal, visceral pericardium secrete protein-rich fluid (pericardial fluid), fills space between layers (lubricant)

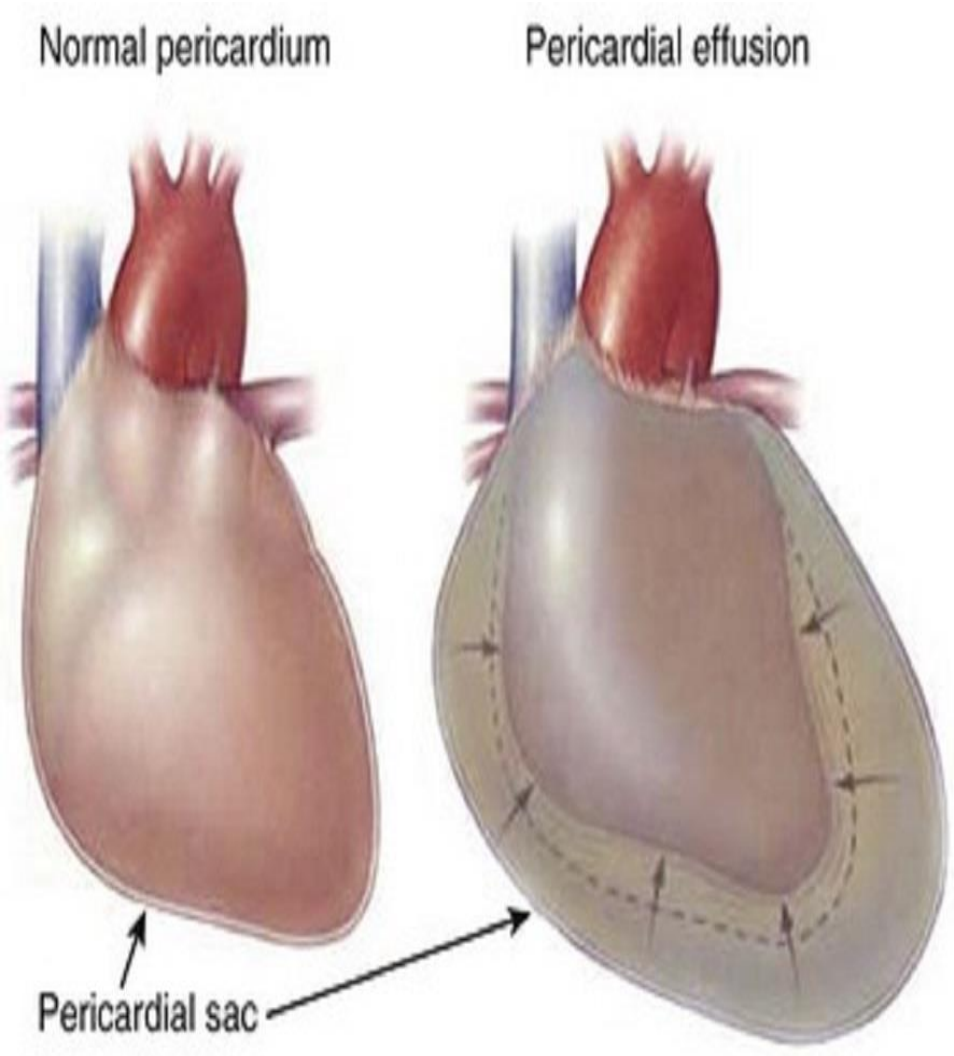


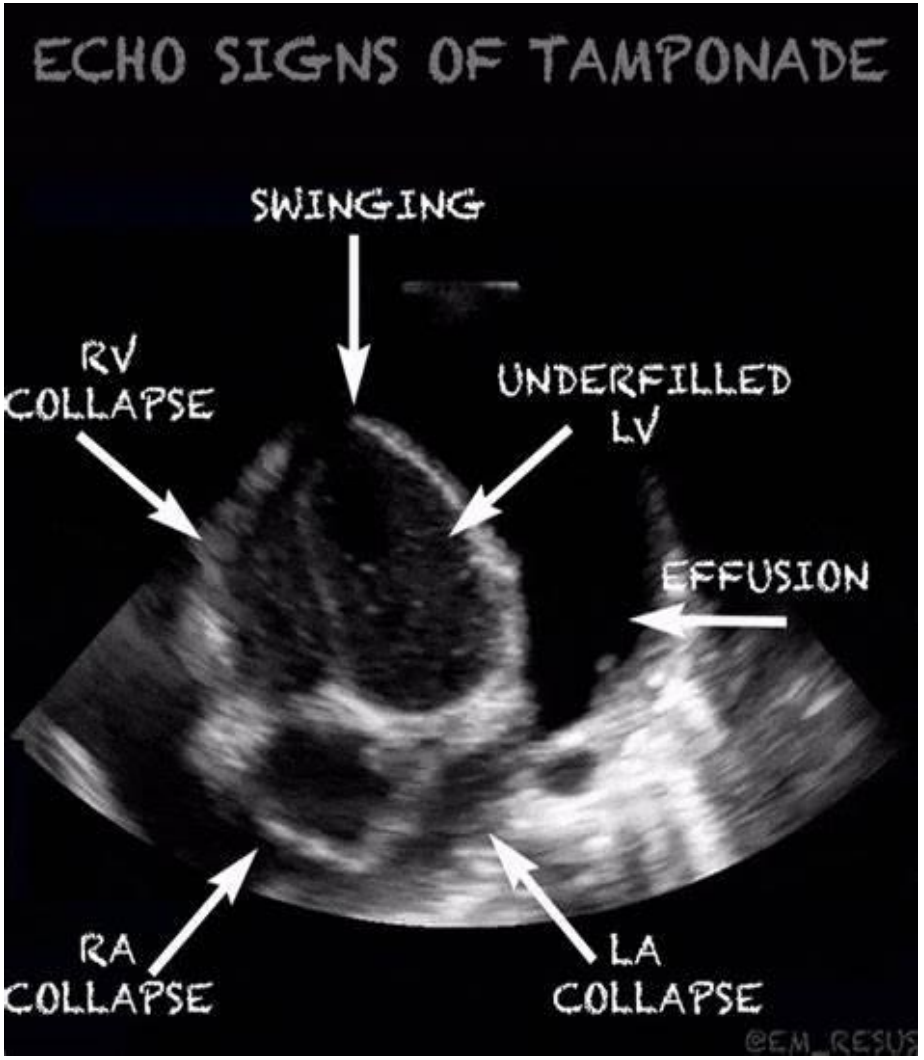
- Heart wall layers, superficial to deep



- Layers of pericardium (double-layered sac surrounding the heart

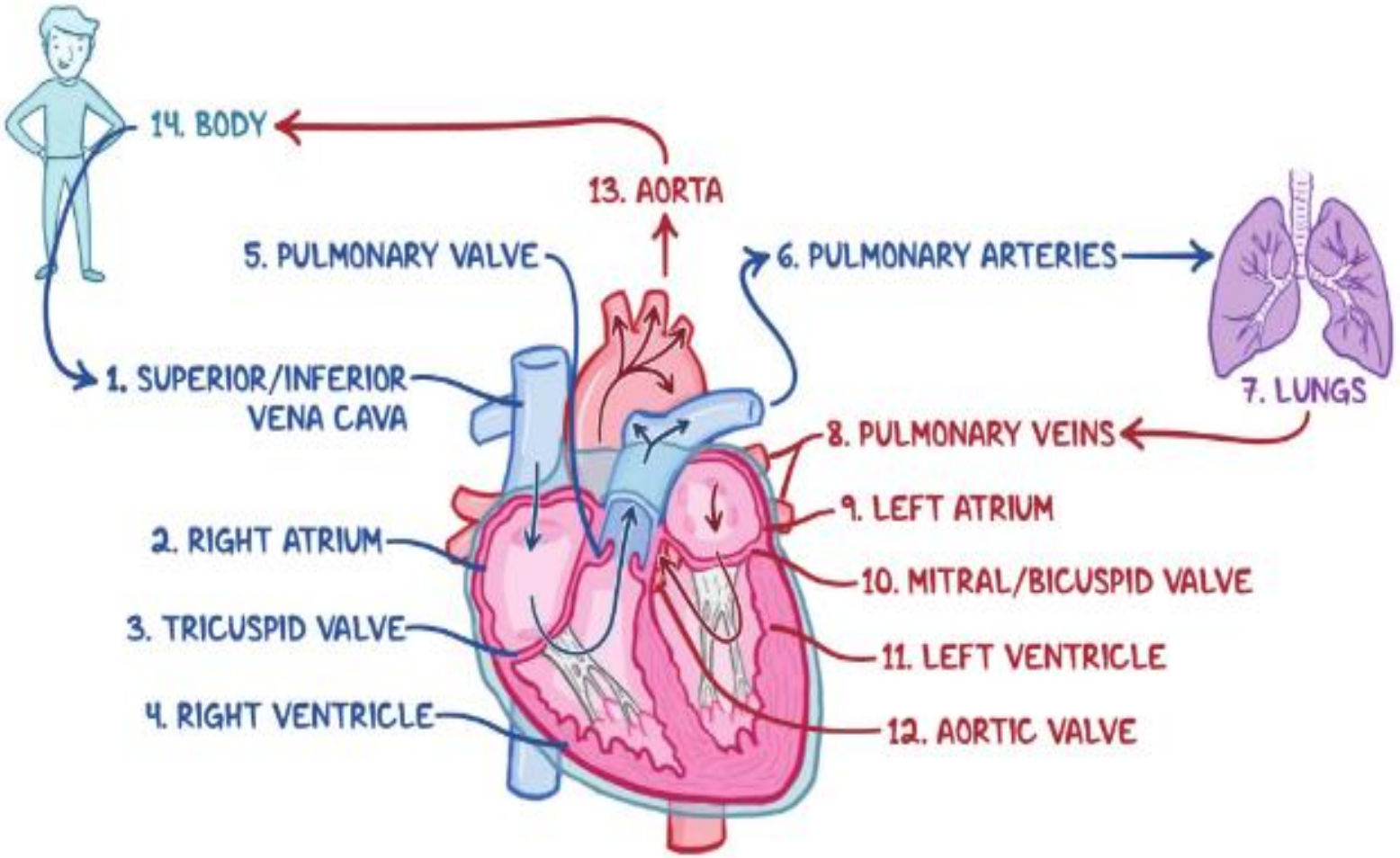
Cardiac Tamponade





Systemic VS Pulmonary Circulation

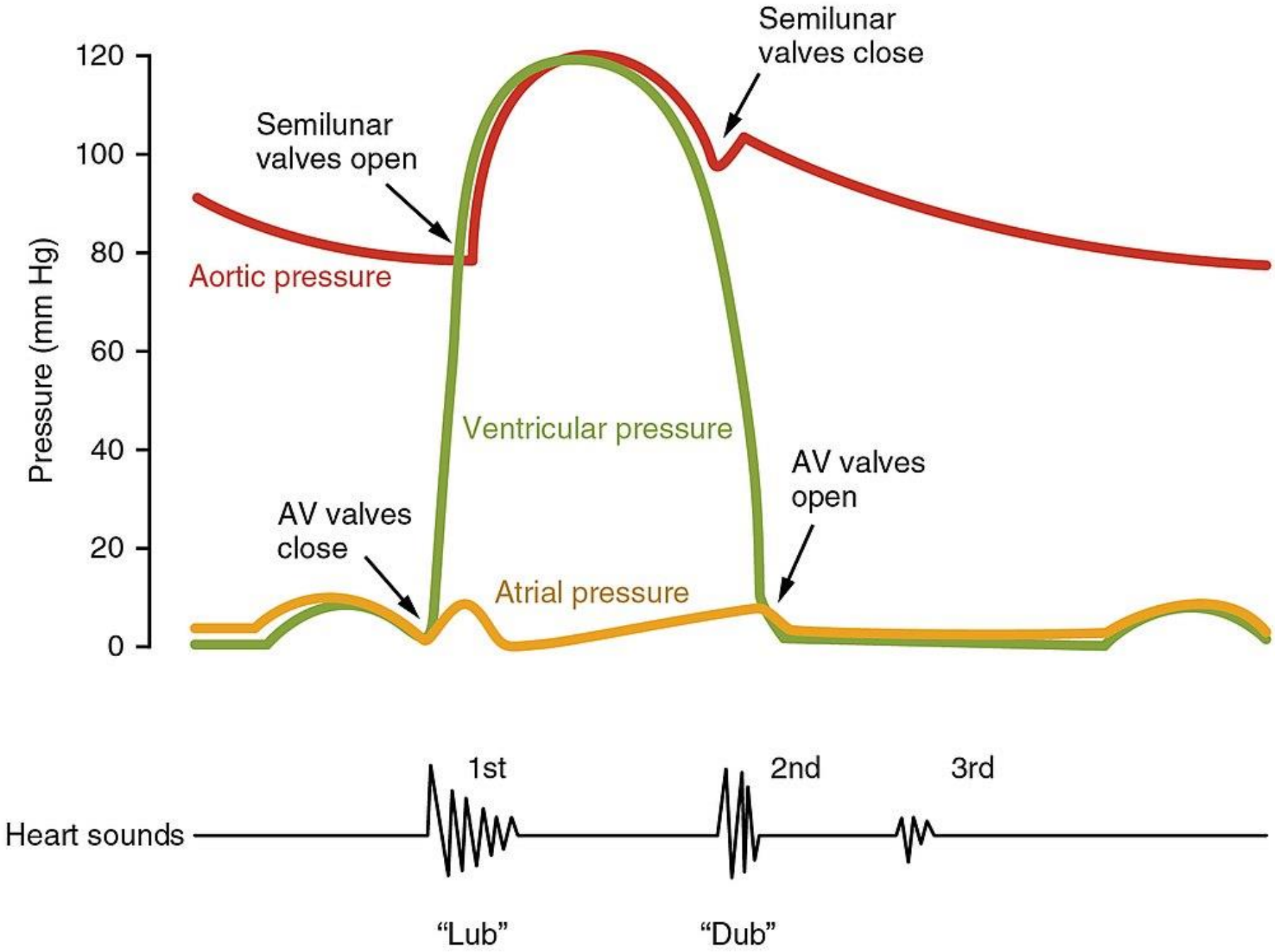
- Pulmonary and systemic circulation both pump same amount of blood.
- Pulmonary circulation:
  - Low pressure system
  - Right side of heart pump deoxygenated blood through pulmonic circulation to collect oxygen
  - RA -> RV -> Pulmonary artery -> lungs.
- Systemic circulation:
  - High pressure system
  - Left side pumps oxygenated blood to systemic circulation
  - Pulmonary veins -> LA -> LV -> Aorta -> body
  - LV 3 times thicker than RV (high systemic circulation resistance)

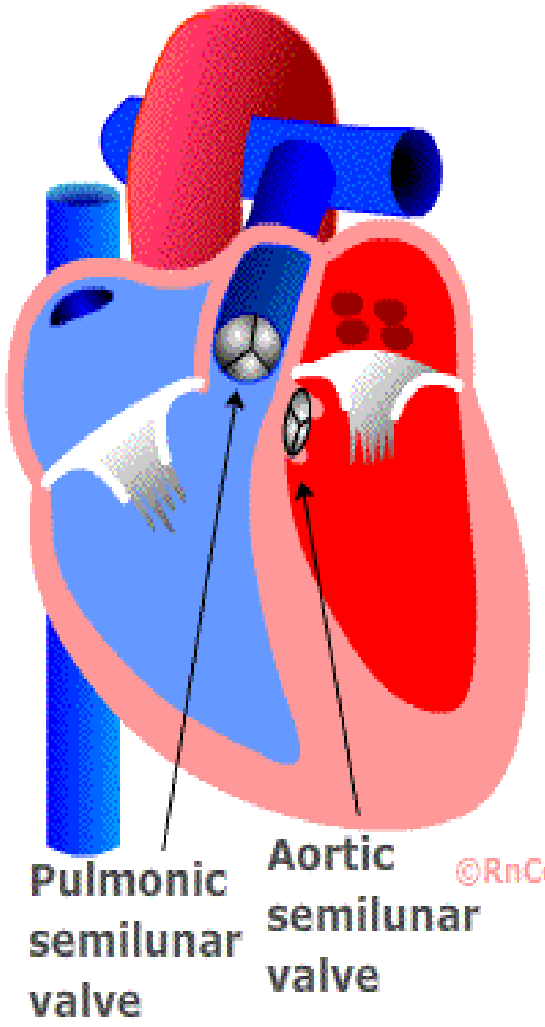


- Blood flow physiology starting with SVC and IVC bringing deoxygenated blood from body to the RA.

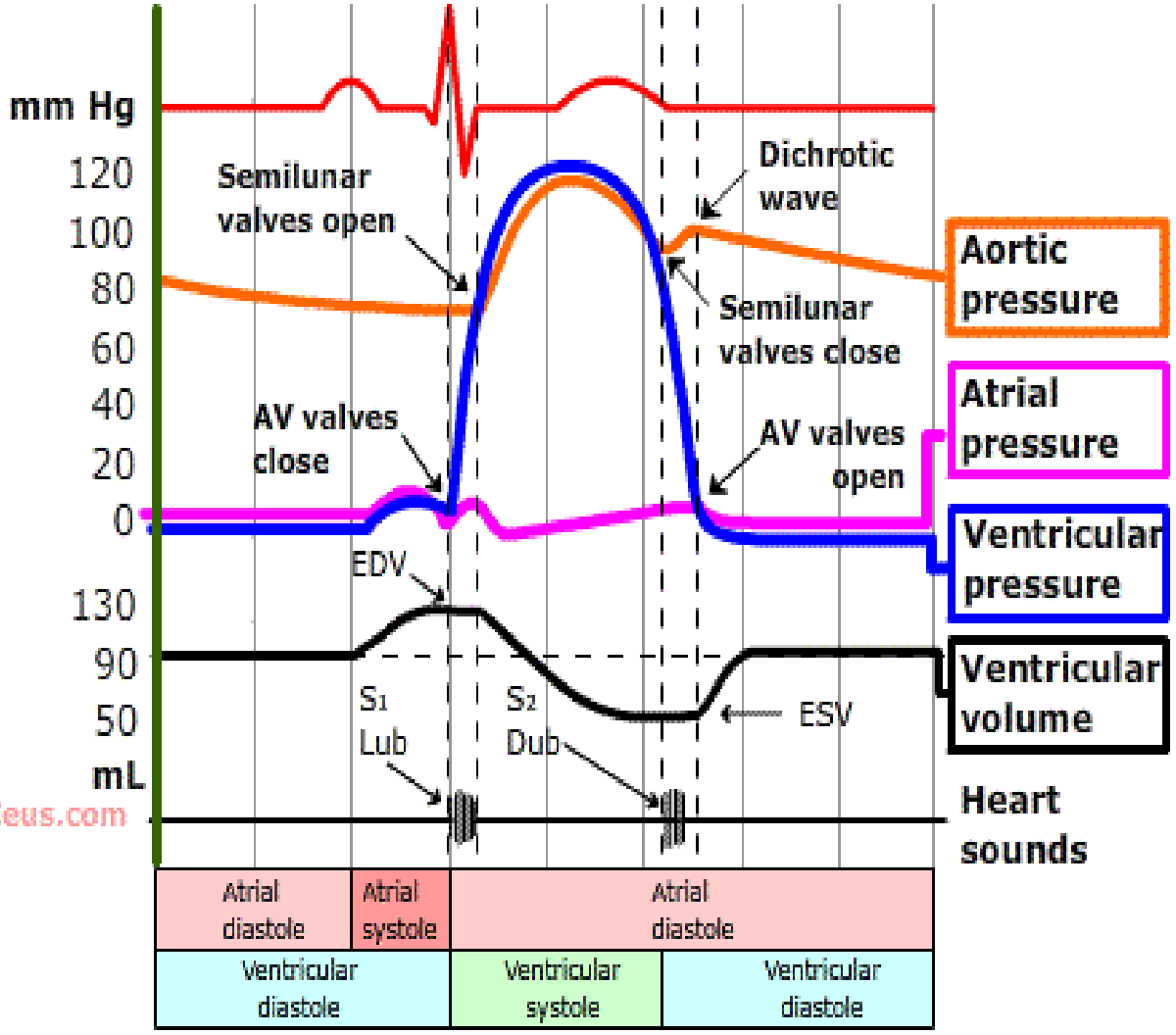
Ventricular Systole VS Diastole

- Systole:
  - Ventricular contraction (atrial relaxation at the same time)
  - Occurs during S1 sound
    - Aortic, pulmonic valves open -> blood pushed into aorta, pulmonary artery
  - Systolic blood pressure
    - Arterial pressure when ventricles squeeze out blood under high pressure
    - Peripheral pulse felt
- Diastole:
  - Ventricular relaxation (atrial contraction at the same time)
  - Occurs during S2 sound
    - Tricuspid, mitral valves open -> blood fills ventricles
  - Diastolic blood pressure
    - Ventricles fill with more blood (lower pressure)


Semilunar valves close
Semilunar valves open
120
100
80
60
40
20
0
Pressure (mm Hg)
Aortic pressure
Ventricular pressure
AV valves open
AV valves close
Atrial pressure
1st
2nd
3rd
Heart sounds
"Lub"
"Dub"



Cardiac Cycle ©RnCeus



Blood Flow Terminology

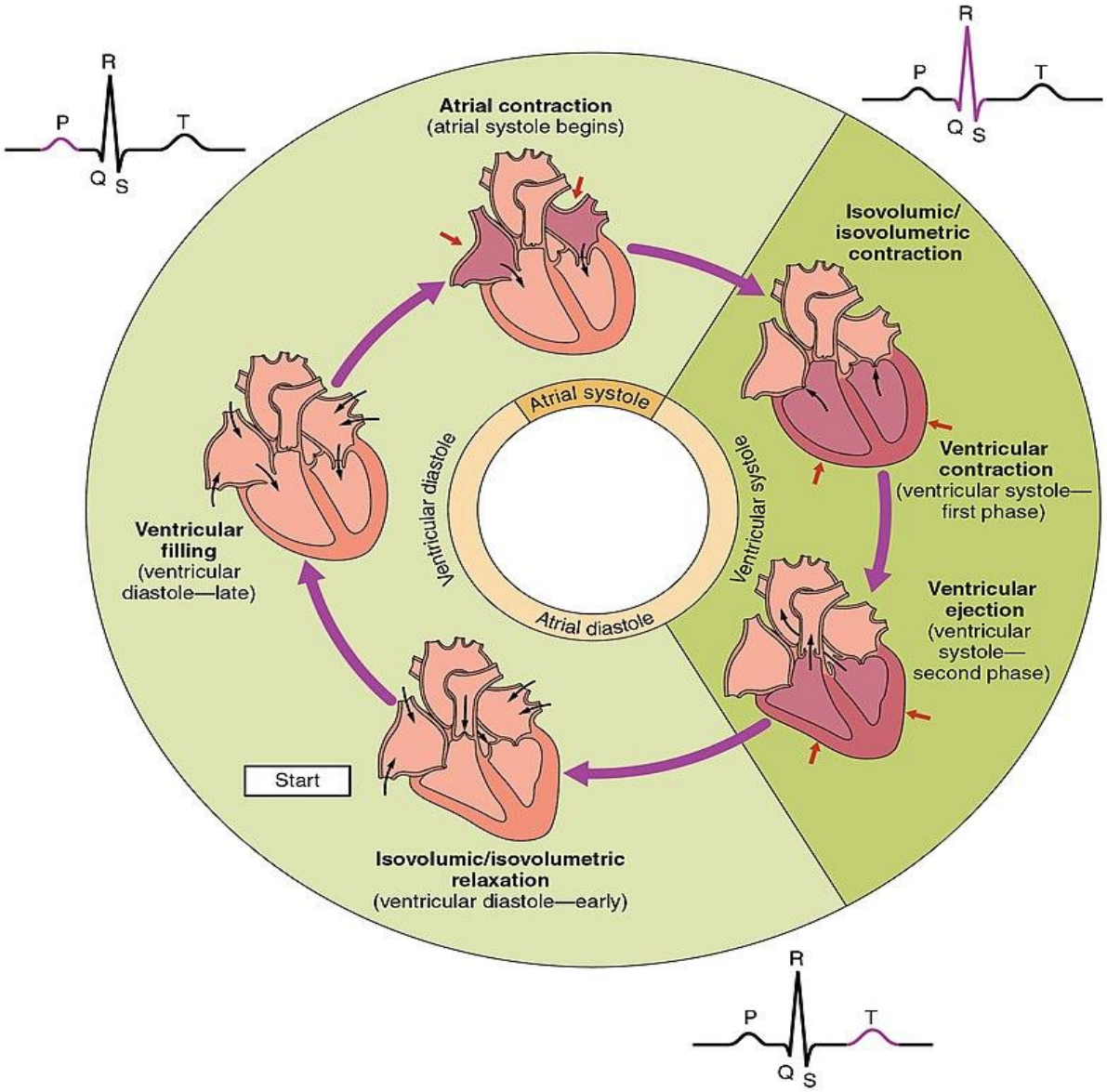
- Preload
  - Amount of blood in LV before contraction
  - Determined by filling pressure (end diastolic pressure)
  - “volume work” of heart
- Afterload
  - Resistance (load) LV needs to push against to eject blood during contraction
  - “tension work” of heart
  - Components include:
    - Amount of blood in systemic circulation
    - Degree of arterial vessel wall constriction (systemic arterial resistance for left side, Pulmonary arterial pressure for right side)
- Frank-Starling mechanism
  - Ventricular contraction strength related to amount of ventricular myocardial stretch
  - Maximum contraction force achieved when myocardial actin, myosin fibers are stretch about 2-2.5 times normal resting length

Blood Flow Terminology

- Stroke volume
  - Blood volume pump by heart per contracion
  - Determined by amount of blood filling ventricle, compliance of ventricular myocardium
  - SV = EDV - ESV
- Cardiac output
  - Blood volume pumped by heart per minute (L/min)
  - CO = SV x heart rate
- Ejection fraction
  - Percentage of blood leaving heart during each contraction
  - EF = SV / EDV x 100
- Venous return
  - Blood-flow from veins back to atrial

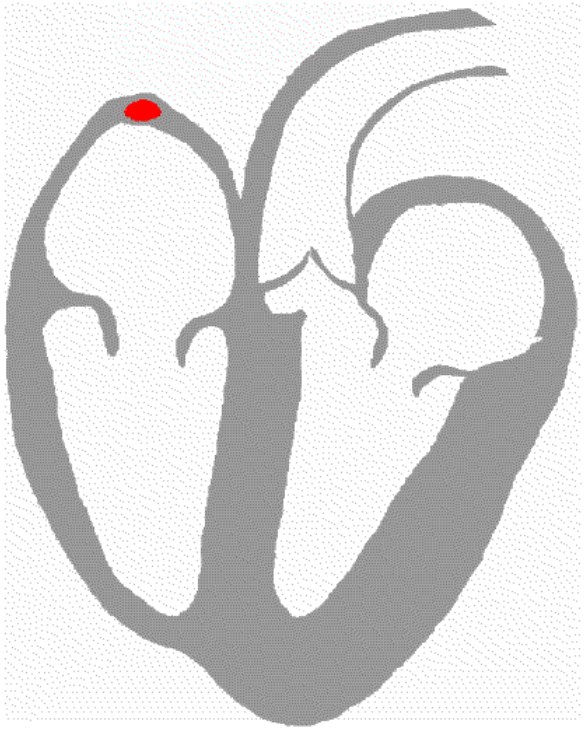
Cardiac Cycle

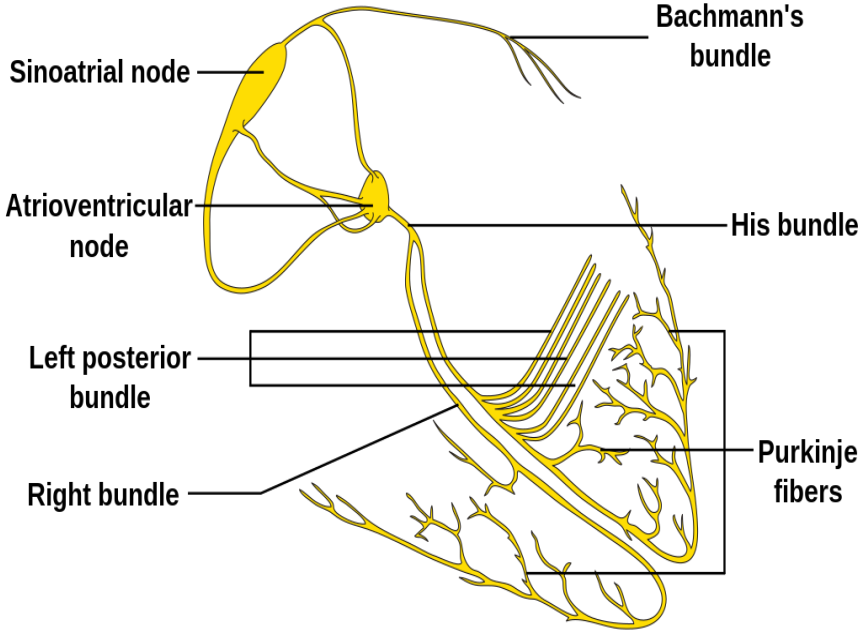
- Sequence of events (contract and relax) every heartbeat.
- Start with ventricle relax (early diastole), blood from at atrial passing through open atrioventricular valve as high pressure (atrial) to low pressure (ventricle) until reached isovolumatric.



Electrical Conduction

- Normal rhythmical heart beat called sinus rhythm
- Established by heart's own pacemaker: sinoatrial node (SA node)
- Travel through the heart muscle causing heart to contract
- Location of SA node: upper part of RA near to junction with SVC.
- Electrical signal generated by SA node travels through the RA in a radial way that is **not completely understood.**
- Travels to LA via Bachmann's bundle causing the left and right atrial muscles contract together.
- Reached atrioventricular node (AV node), boundary between RA and LV.
- Annulus fibrosis is part of cardiac skeleton, tissue within the heart that the electrical signal cannot pass through-forces the signal to pass through the AV node only.
- To Bundle of His the left and right bundle branches through to the ventricles of heart.
- In ventricles, the signal is carried by specialized tissue called Purkinje Fibers, then transmit the electrical charge to the heart muscle.

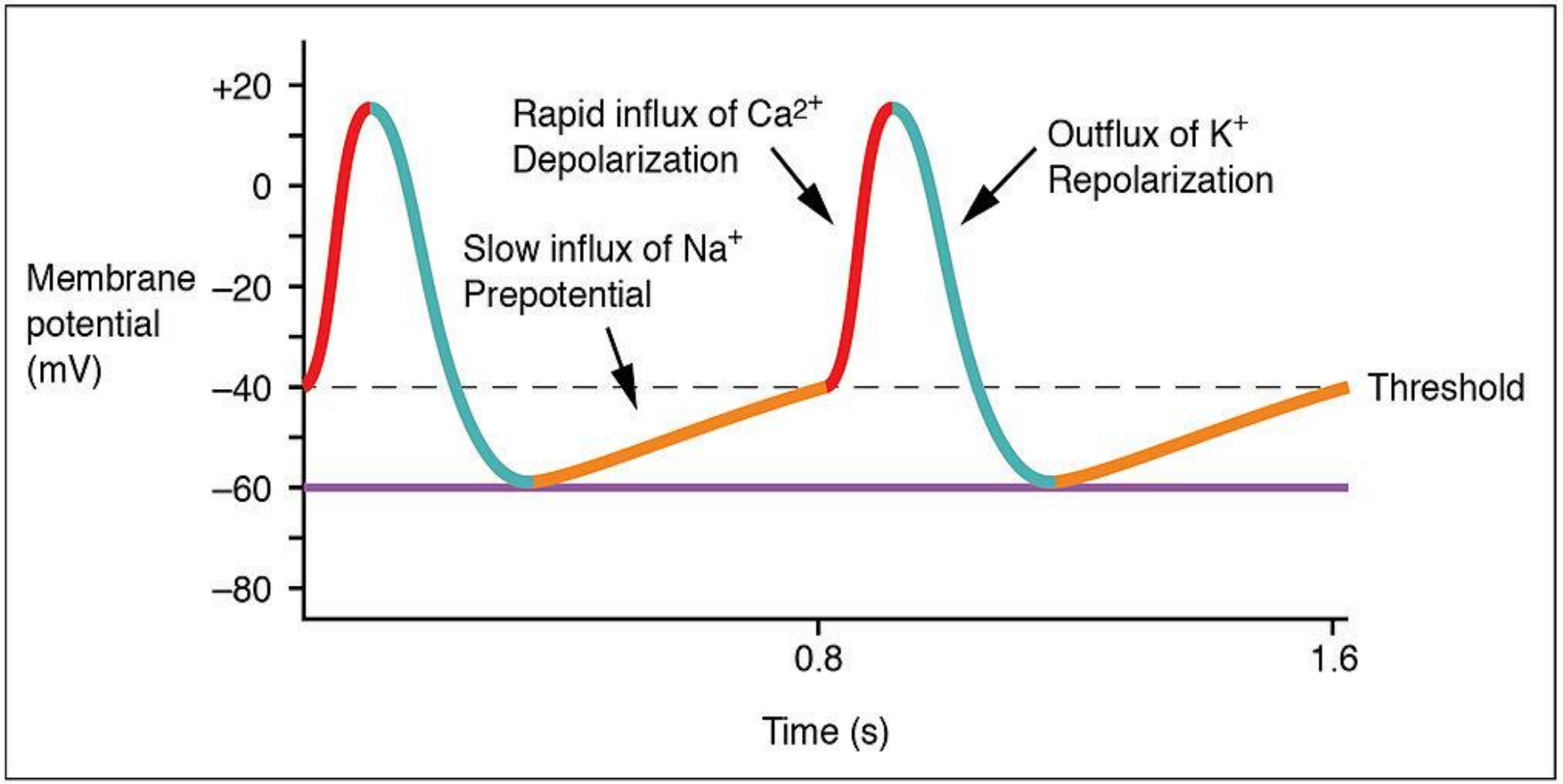



Bachmann's bundle
Sinoatrial node
Atrioventricular node
His bundle
Left posterior bundle
Purkinje fibers
Right bundle

Action Potential and Heart Rate

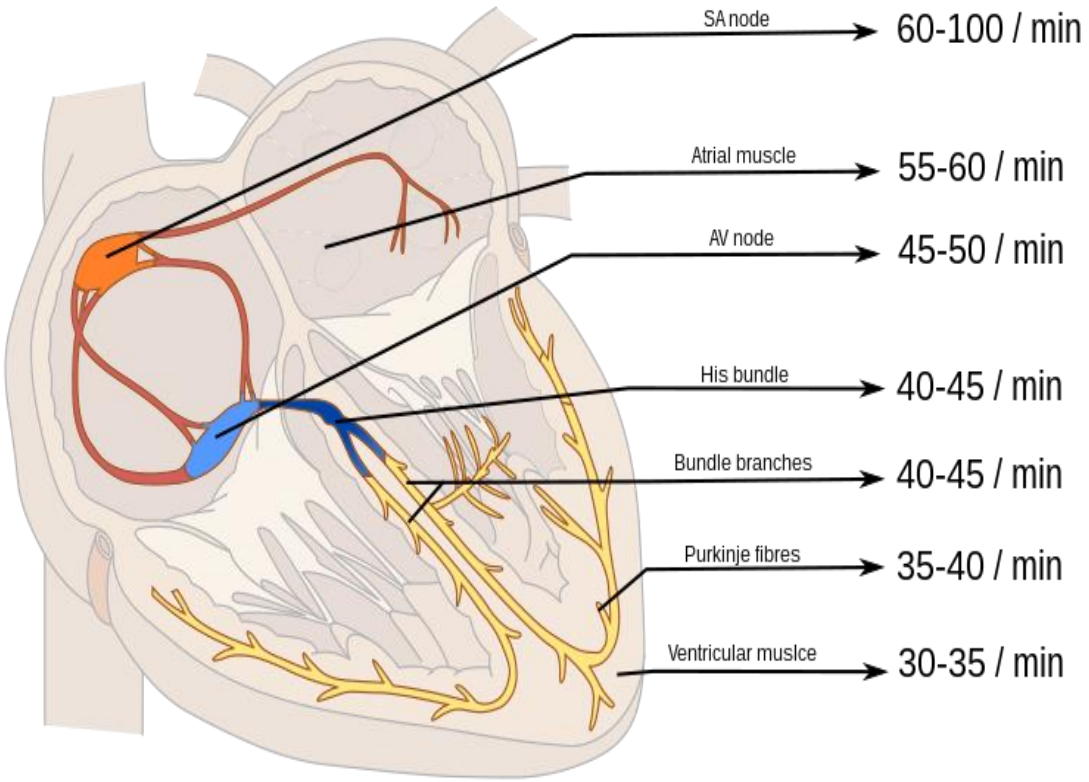
- Action potential created by movement of specific electrolytes into and out of pacemaker cells (SA node), then spread to nearby cells.
- When SA node cells are resting (negative charge inside membranes), a rapid influx of sodium ion cause the membranes charge to become positive: called depolarization, occurs spontaneously (prepotential).
- Once the cells has a sufficiently high charge (threshold), the sodium channels close and calcium ions begin to enter the cells until reached peak.
- Calcium channel then close, potassium channels open allowing potassium ions to leave the cell causing the cells to have negative resting charge: repolarization.
- When membrane potential reaches approximately -60mV, potassium channels close and the process may begin again.

Pacemaker Action Potential

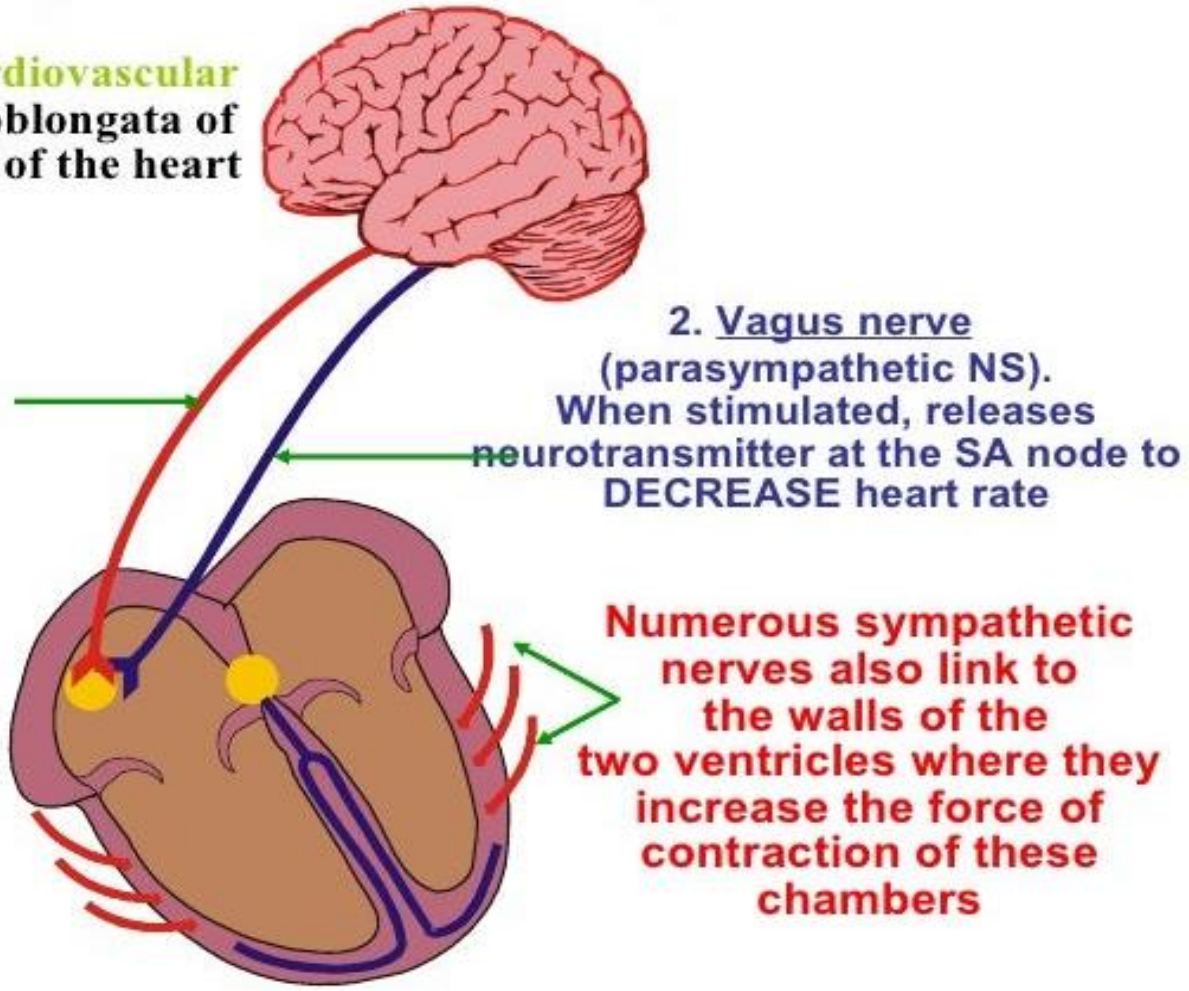


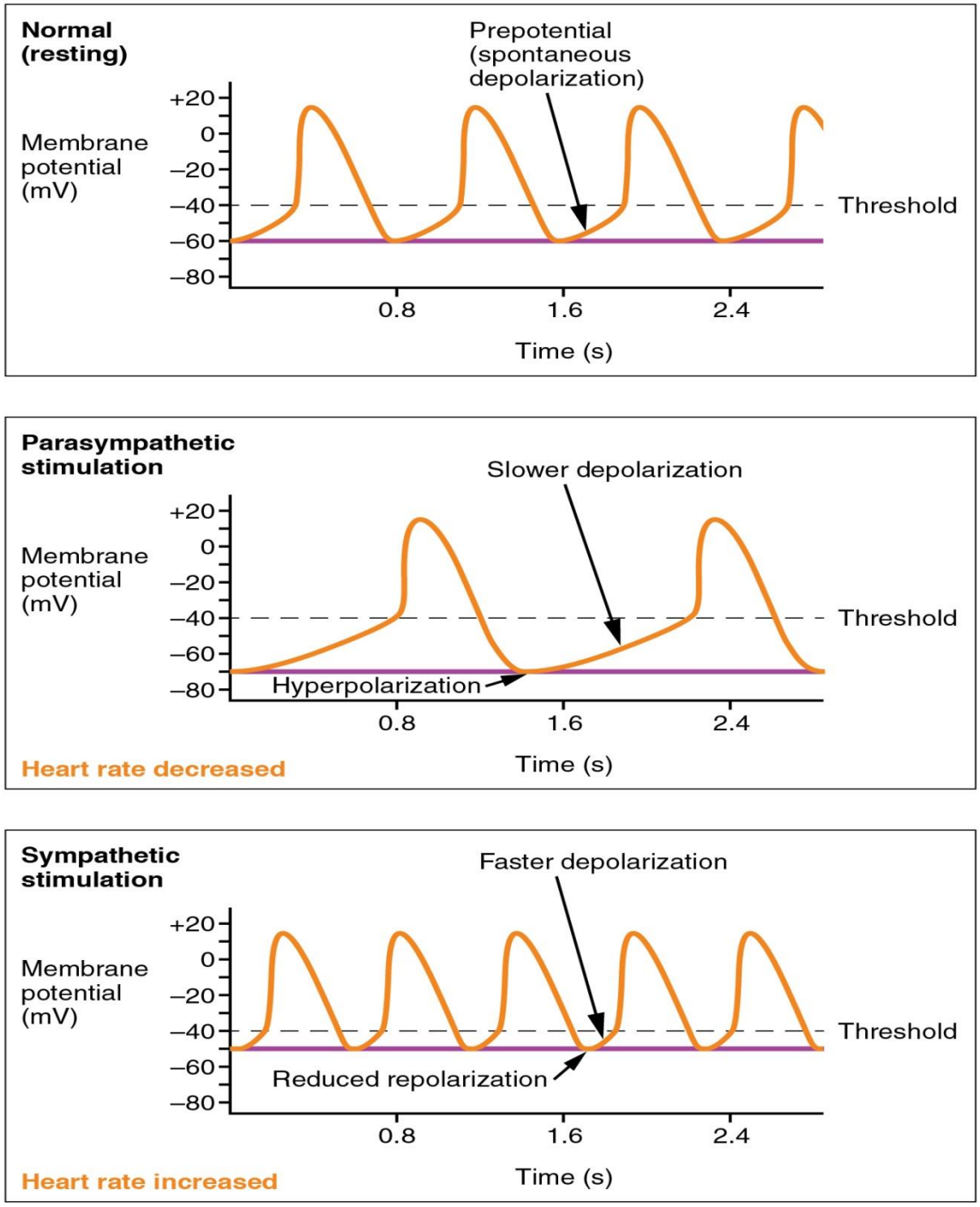
Pacemakers

- The heart has several pacemakers, each fires at its own intrinsic rate



Nervous System Controlling Heart Rate




Normal (resting)
Prepotential (spontaneous depolarization)
Membrane potential (mV)
+20
0
–20
–40
–60
–80
Threshold
0.8
1.6
2.4
Time (s)
Parasympathetic stimulation
Slower depolarization
Hyperpolarization
Heart rate decreased
Sympathetic stimulation
Faster depolarization
Reduced repolarization
Heart rate increased

Other Influences

- Baroreceptors
  - Sensing the stretching of blood vessels
  - Located in the aortic sinus, carotid bodies, vena cava.
- Chemoreceptors
  - Sensing pH of blood
  - Located in the carotid bodies or adjacent to the aorta in the aortic body.
- Exercise and fitness levels
- Age
- Body temperature
- Basal metabolic rate
- Emotional state
- Level of hormones: epinephrine, norephinephrine and thyroid hormones.
- Level of electrolytes: calcium, potassium and sodium
- Dehydration (low blood volume)


THANK YOU