# The Cardiovascular System

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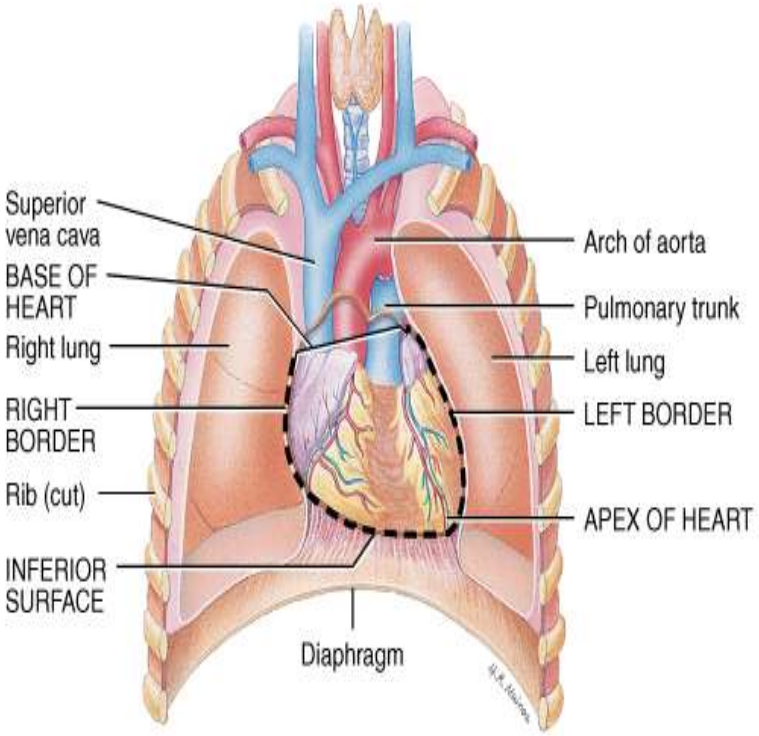
# THE HEART

- The Heart is part of the cardiovascular system.
- Heart is the central pump and the blood vessels
- **Function:-** To supply oxygen, nutrients and other essential substances to the tissues of the body and to remove metabolic end products from the tissues.

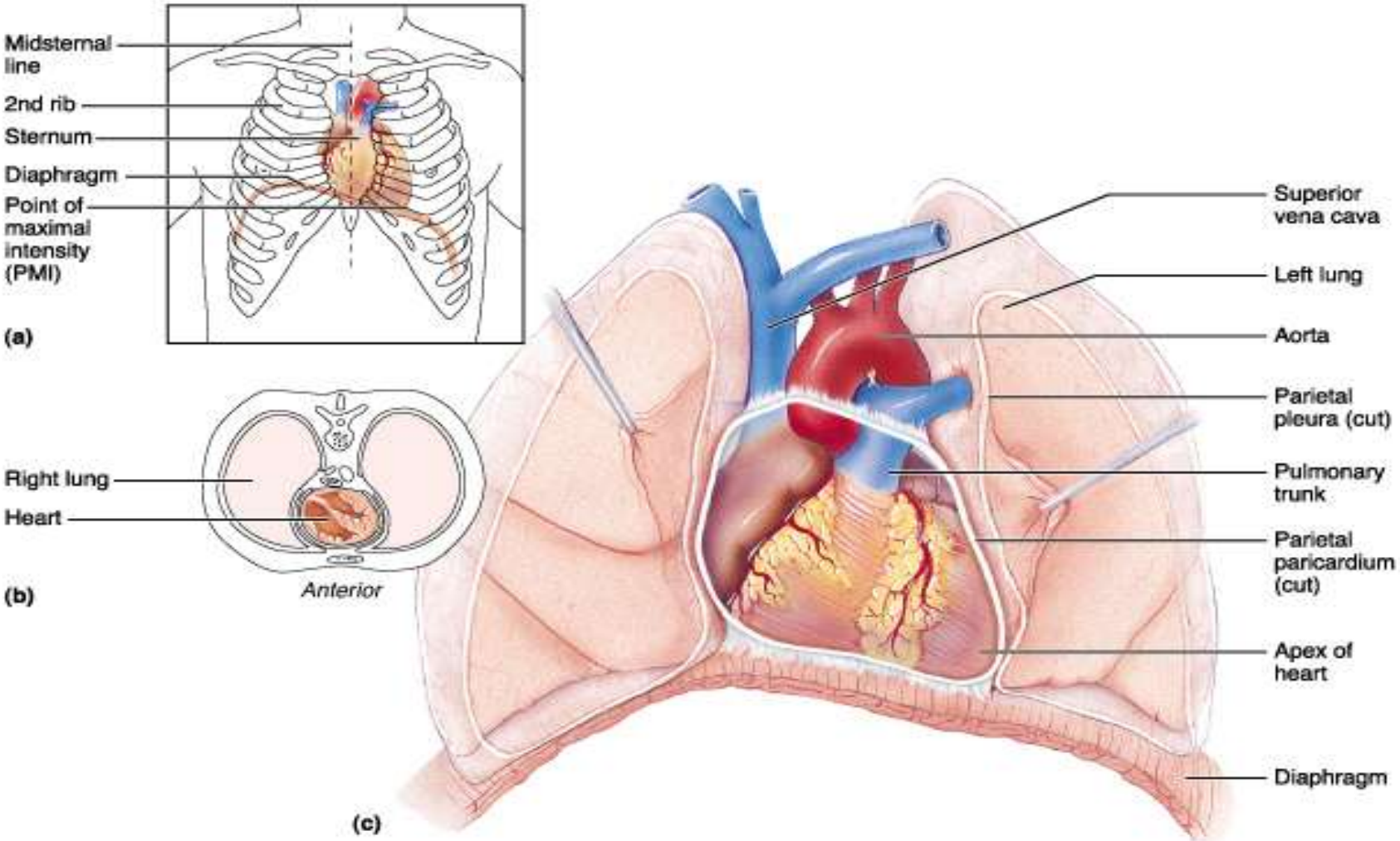
**LOCATION OF HEART:-**

- Heart is located in the ***mediastinum*** area from the sternum to the vertebral column and between the lungs.
  - **Apex** - directed anteriorly, inferiorly and to the left
  - **Base** - directed posteriorly, superiorly and to the right
  - **Anterior surface** - deep to the sternum and ribs
  - **Inferior surface** - rests on the diaphragm
  - **Right border** - faces right lung
  - **Left border (pulmonary border)** - faces left lung

# ANATOMY OF HEART




- Cone shaped hollow muscular organ
- The heart is located in the thoracic cavity between the lungs. This area is called the **mediastinum**.
- The base of the cone-shaped heart is uppermost, behind the sternum, and the great vessels enter or leave here. The apex (tip) of the heart points downward and is just above the diaphragm to the left of the midline.
- The heart is slightly left side of the body.


Midsternal line
2nd rib
Sternum
Diaphragm
Point of maximal intensity (PMI)
(a)
Right lung
Heart
(b)
Anterior
Superior vena cava
Left lung
Aorta
Parietal pleura (cut)
Pulmonary trunk
Parietal pericardium (cut)
Apex of heart
Diaphragm
(c)

# Structure of Heart

Mainly composed of three layers of tissues

**A) PERICADIUM**

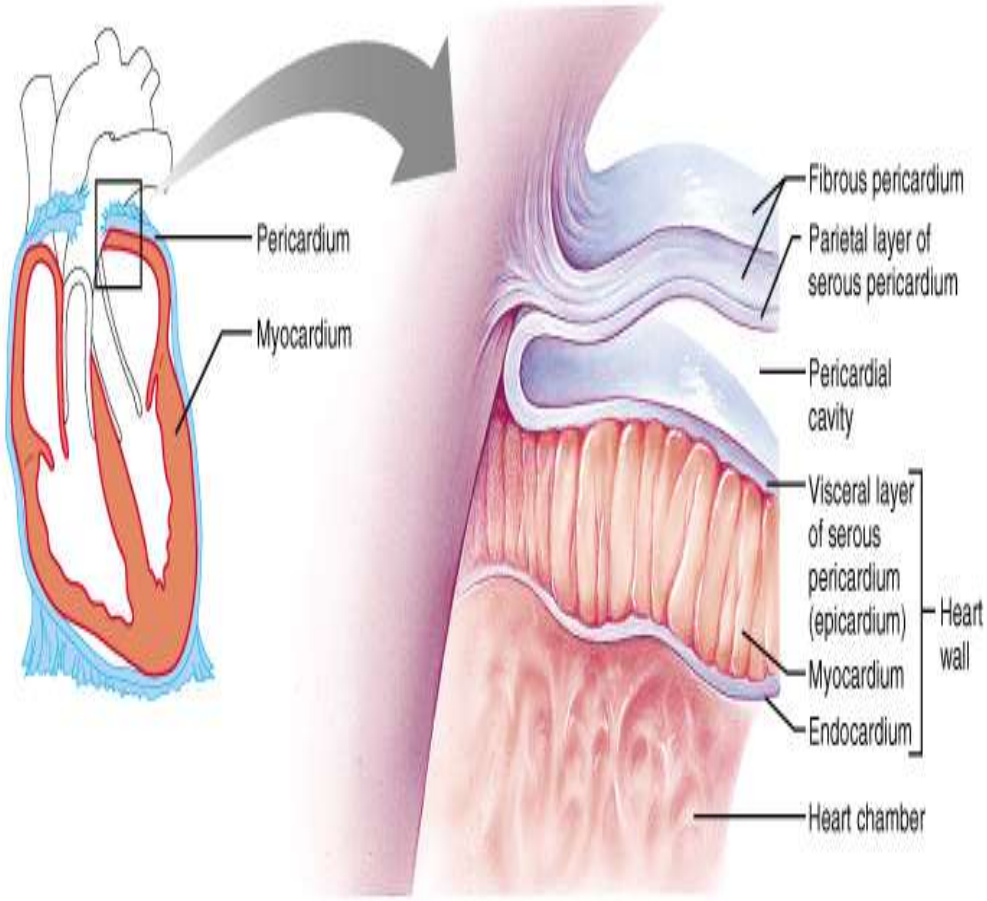
**B) MYOCADIUM**

**C) ENDOCADIUM**

The heart is enclosed in a double walled sac called the pericardium.

The superficial

layer is the fibrous pericardium, and the deep layer is the serous pericardium.



# PERICARDIUM

The Fibrous Pericardium Is Composed Of Dense Irregular Connective Tissue.

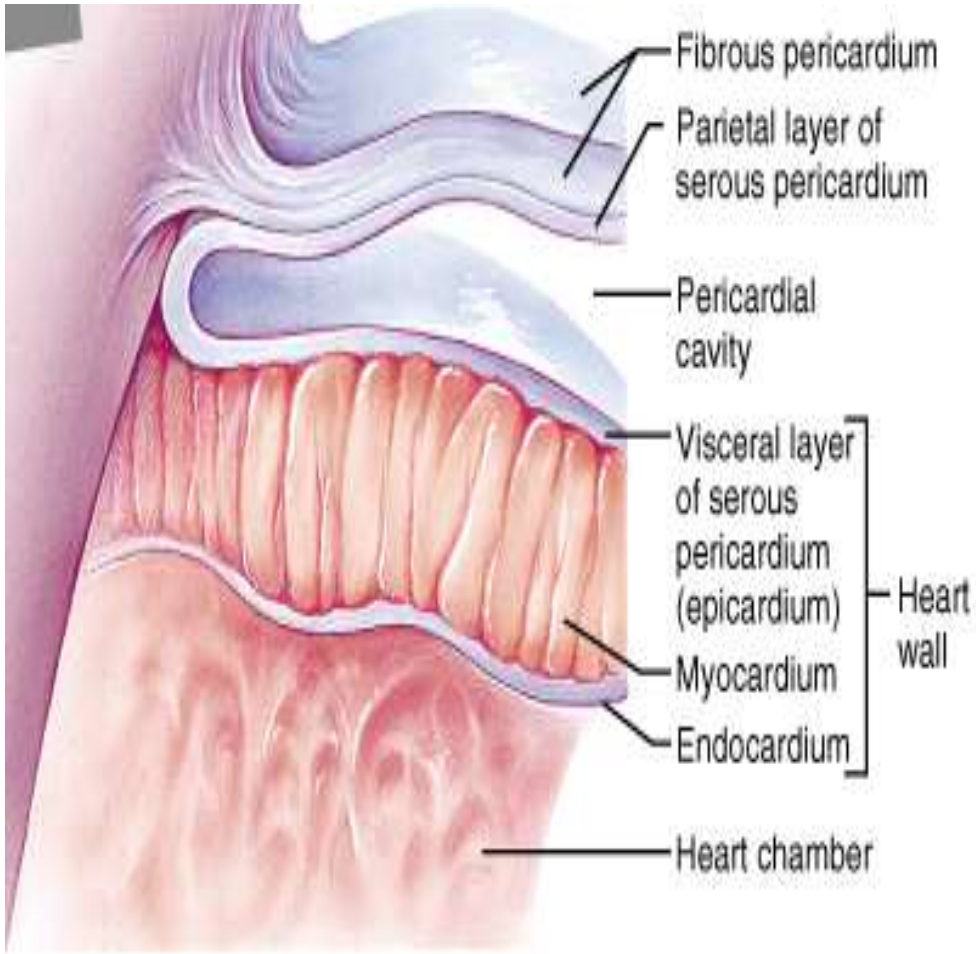
# PERICARDIUM

Functions Of The Fibrous Pericardium

1. Protects The Heart.
2. Anchors The Heart Within The Thorax.
3. Prevents Overfilling Of The Heart.

# PERICARDIUM

The serous pericardium, a thin slippery serous membrane, is composed of two layers, the parietal layer and the visceral layer or epicardium.

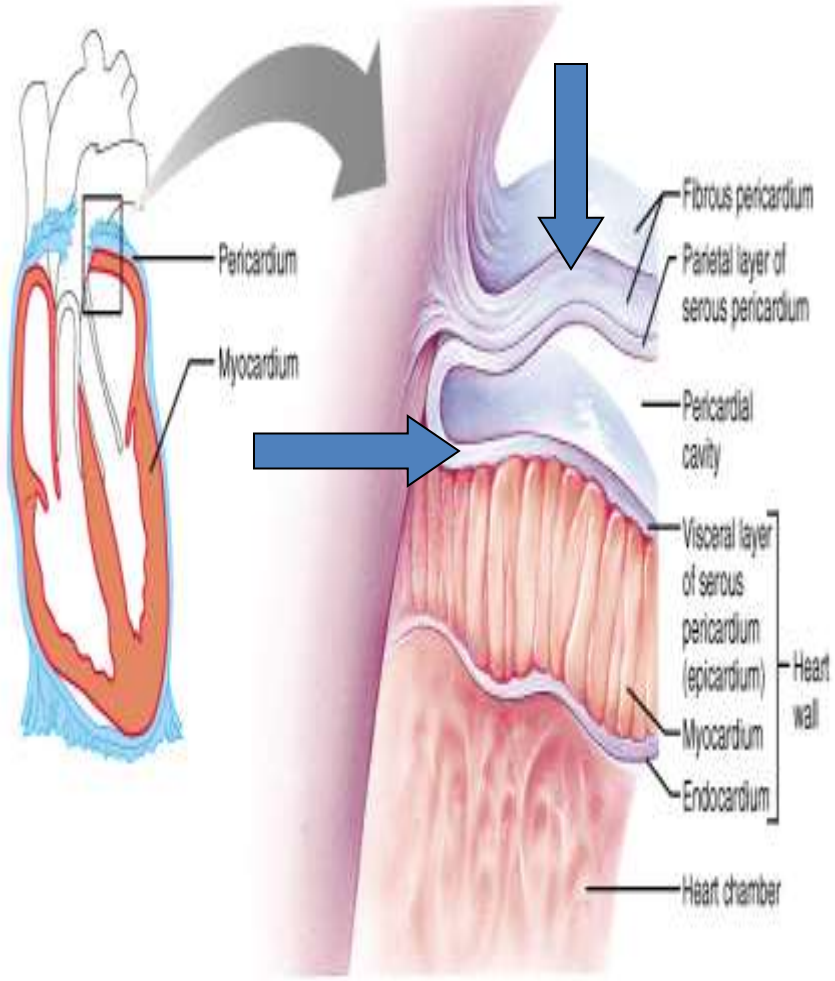


# PERICARDIUM

The parietal layer lines the inner surface of the fibrous pericardium.

The visceral layer or epicardium forms the outer layer of the heart.

Between the two layers is the pericardial cavity. This cavity contains a film of serous fluid.



- **epicardium** (visceral pericardium)
  > thin & transparent
- **myocardium** (cardiac muscle tissue)
  > striated muscle fibers
- **endocardium** (smooth endothelial tissue)

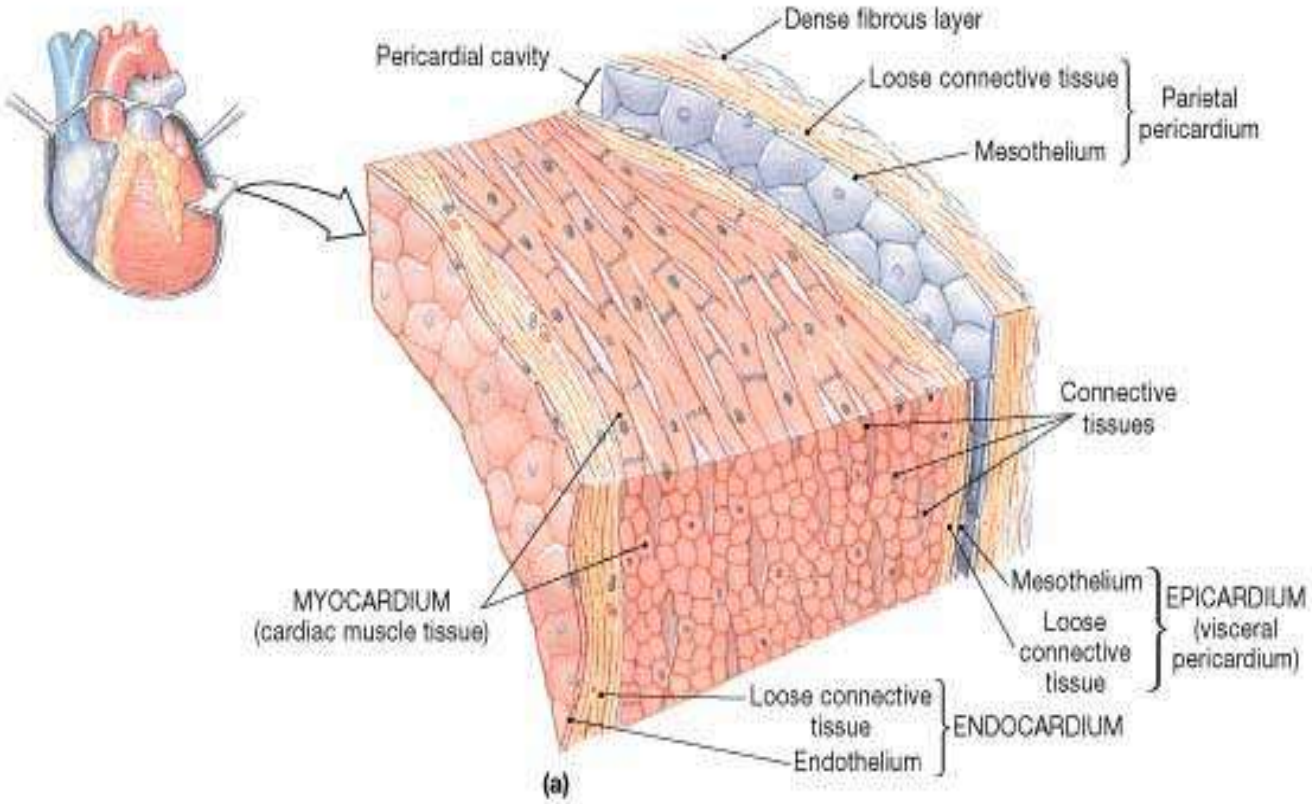
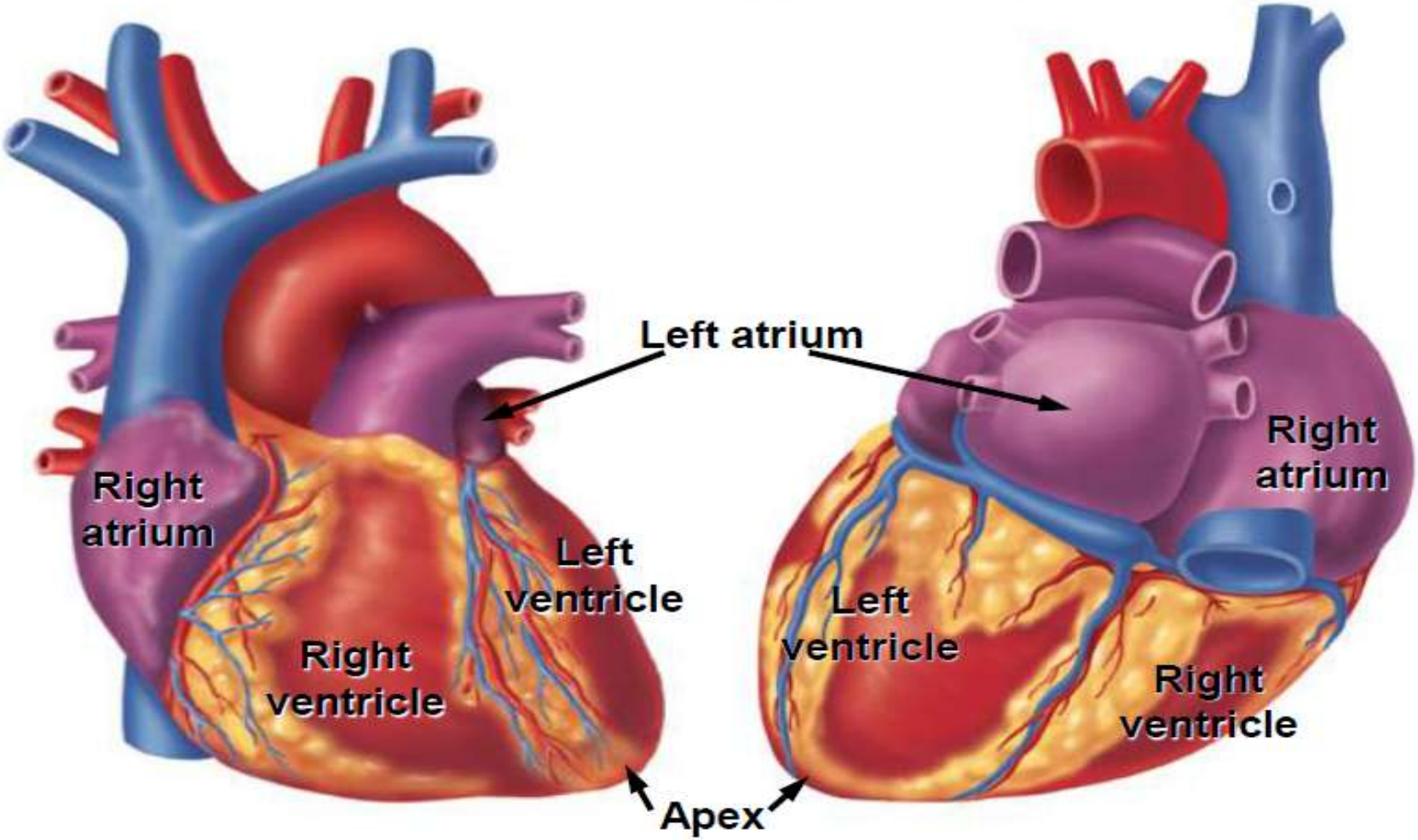



**FIGURE 20-7** The Heart Wall. **(a)** A diagrammatic section through the heart wall, showing the relative positions of the epicardium, myocardium, and endocardium.

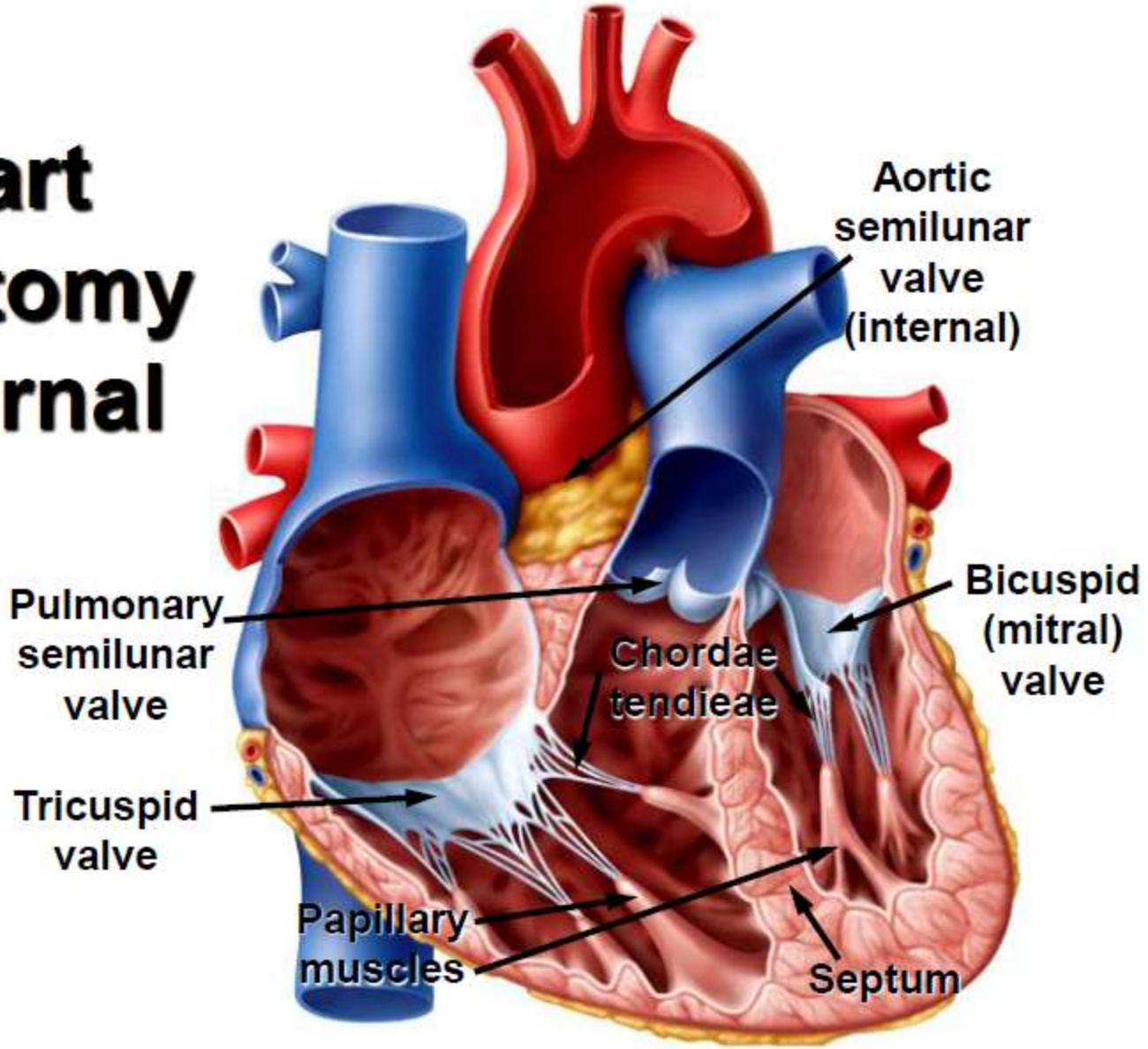
# Anatomy of Internal Heart

- The heart divided into right and left side by a septum
- Each side divided by an AV (atrioventricular) valve an upper chamber, the atrium; an lower chamber ,the ventricular
- The right AV valve (tricuspid valve) has three flaps
- The left AV valve (biscuspid valve or mitral valve ) has two cups or flaps
- The atria are filling chamber and they have thin walls
- The ventricles are emptying chamber and so the thick walled
- The left ventricles pushed the blood through the arteries in whole body ( systemic circulation)
- The right ventricles has to push the blood only in pulmonary circulation of the chest (pulmonary circulation)

# Heart Anatomy - The Chambers



# Heart Anatomy - Internal



# BLOOD FLOW THROUGH THE HEART

# Blood Circulation

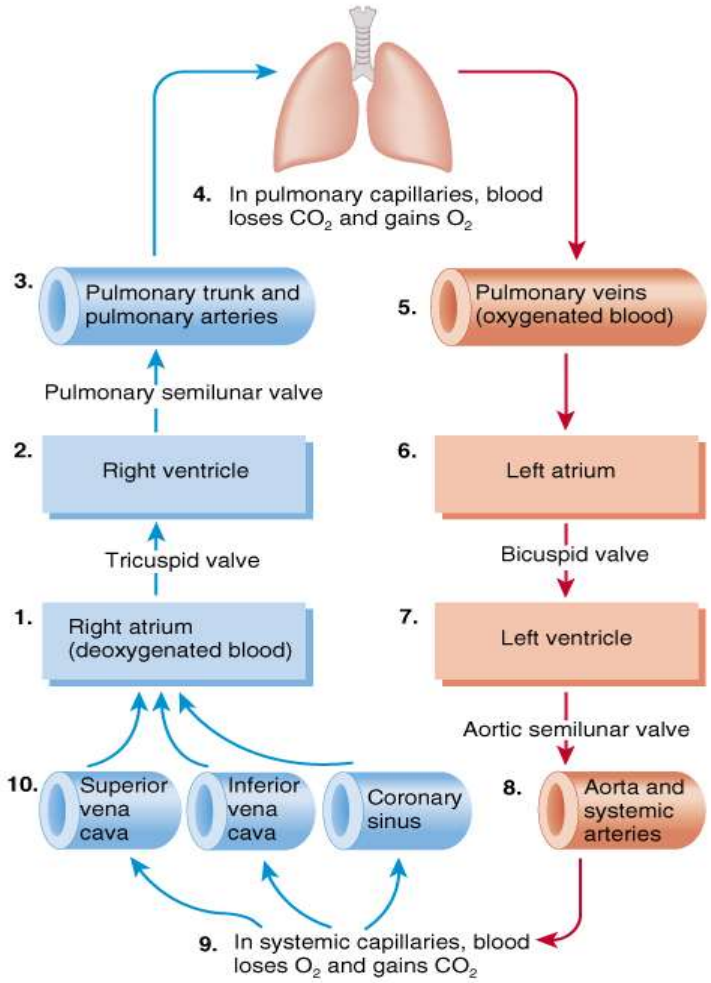
***Systemic circulation***

- Left side of heart pumps blood through body
- Left ventricle pumps oxygenated blood into aorta
- Aorta branches into many arteries that travel to organs
- Arteries branch into many arterioles in tissue
- Arterioles branch into thin-walled capillaries for exchange of gases and nutrients
- Deoxygenated blood begins its return in venules
- Venules merge into veins and return to right atrium

***Pulmonary circulation***

- Right side of heart pumps deoxygenated blood to lungs
- Right ventricle pumps blood to pulmonary trunk
- Pulmonary trunk branches into pulmonary arteries
- Pulmonary arteries carry blood to lungs for exchange of gases
- Oxygenated blood returns to heart in pulmonary veins

# Blood Circulation




## Blood flow

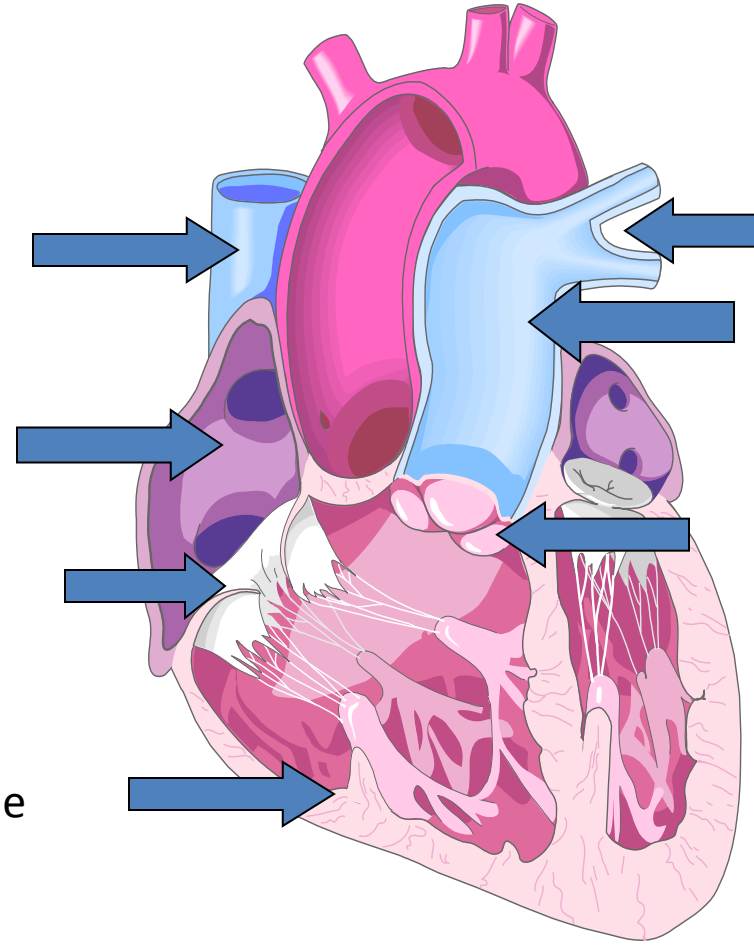
- blue lines = deoxygenated
- red lines = oxygenated

1. Superior Vena Cava

2. Right Atrium

3. Tricuspid Valve

4. Right Ventricle



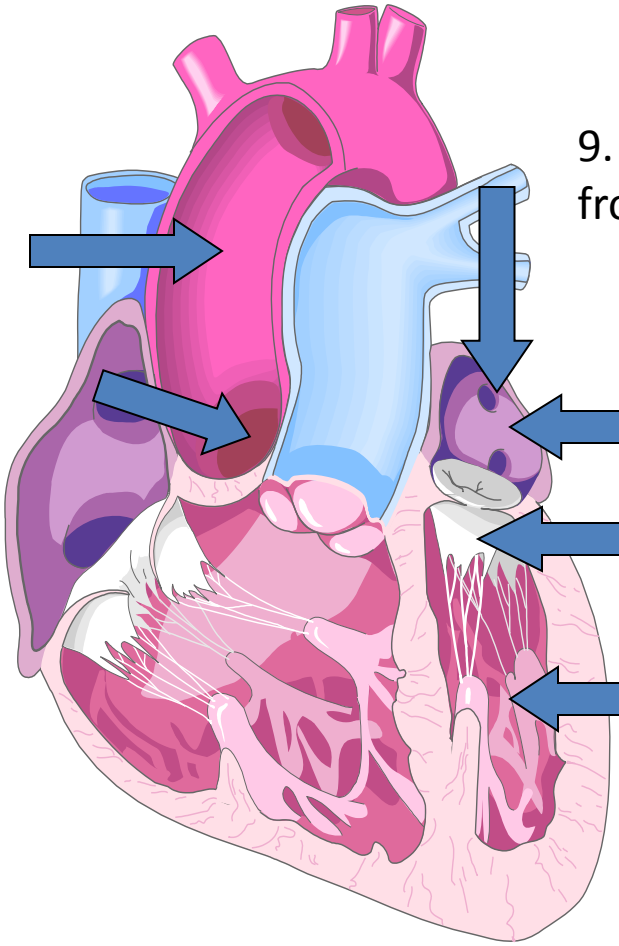
7. To Lungs via Pulmonary Arteries

6. Pulmonary Trunk

5. Pulmonary Semilunar Valve

14. Aorta

13. Aortic Semilunar Valve



9. Pulmonary Veins from the Lungs

10. Left Atrium

11. Bicuspid Valve (Mitral)

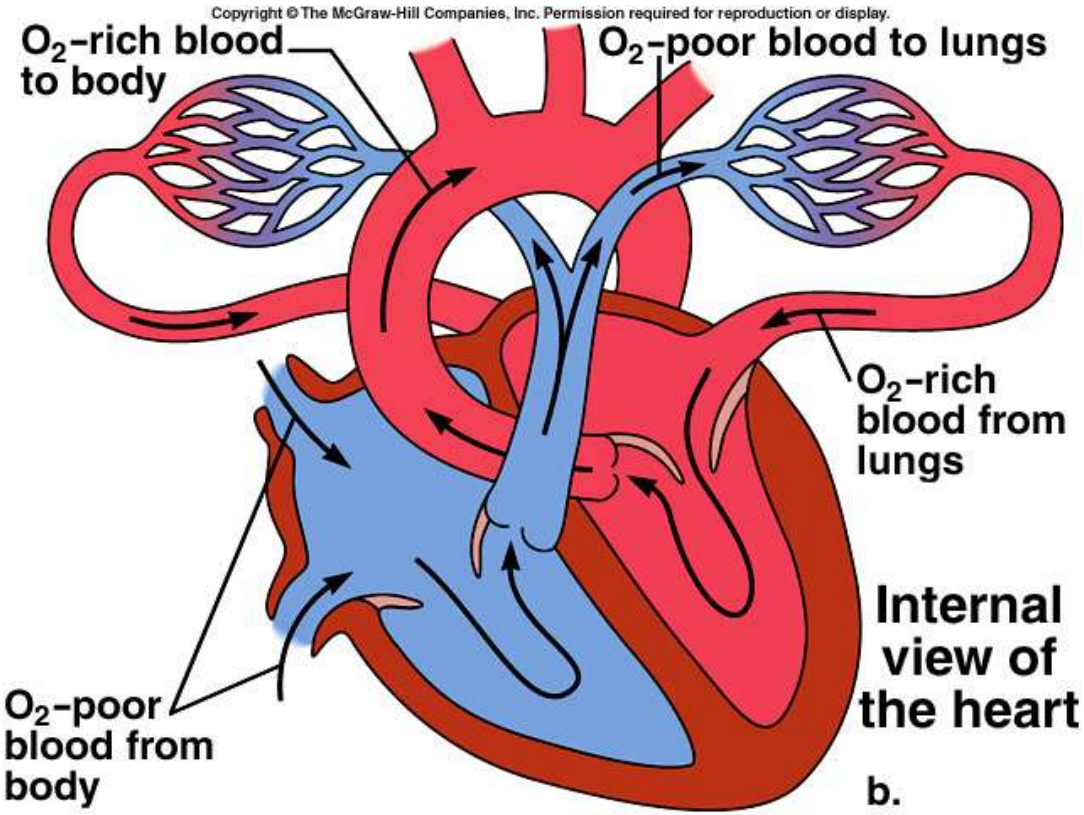
12. Left Ventricle

# Passage of Blood through the Heart

**Body**

SVC/IVC → Right Atrium → (tricuspid valve) → Right Ventricle

(pulmonary semilunar valve)




Pulmonary Arteries

**Lungs**

Pulmonary Veins

Left Atrium

bicuspid (mitral) valve

Left Ventricle

(aortic semilunar valve) → Aorta → **Body**

# PHYSIOLOGY OF THE HEART
# (PROPERTIES OF CARDIAC MUSCLE)

**Electrophysiologic properties (regulates heart rate & rhythm)**

- **Automaticity** – ability of all cardiac cells to initiate an impulse spontaneously & repetitively

- **Excitability** – ability of cardiac cells to respond to stimulus by initiating an impulse (depolarization)

- **Conductivity** – cardiac cells transmit the electrical impulses they receive

- **Contractility** – cardiac cells contract in response to an impulse

-**Rhythmicity** –the ability of a tissue to produce its own impulse regularly is called rhythmicity---

SA node---70-80/minute, AV node –40-60/minute, Atrial muscle—40-6-/minute

**All or none law—** muscle responds to the maximum or it does not give response at all

**Refractory period** muscle does not show any response to a stimulus

a) absolute refractory period (the strength of the stimulus)

b) relative refractory period ( maximum)

**Tonicity**– keeps up certain amount of constant tension on the blood, it contaions

# NUTRITION OF THE CARDIAC MUSCLE

- **ATP (Adenosine Tri-Phosphate) :-** Energy for the heart is obtained from ATP. By glycolysis, and mostly by oxidation of glucose, lactate, pyruvate, ketone bodies, and amino acids. Heart muscles obtain energy from oxidation in presence of oxygen.
- **Oxygen:** Important gaseous nutrition of heart that regulate oxidative process for cardiac energy. Lack of $O_2$ gives rise to partial anoxia which produce pain in heart a painful cry of the hypoxia hungry heart for more $O_2$ (MI).
- **Sodium Ion:** It initiates and maintains the Heart Beat.
- **Calcium Ion:** It strengthens the systole and inhibits the diastole of the heart .With excessive Ca+2 ion, the heart stop in systole.
- **Potassium Ion:** It inhibit the contraction and prolongs the relaxation. Excess potassium ion , the heart stops in diastole.

# JUNCTIONAL TISSUES OF THE HEART

- The heart muscles is conducting system.
- All muscle fibres are interlinked. Atrial impulses cannot be conducted to the ventricles because of its valvular rings. The specialised junctional conducting tissues over come this difficulty.
- Junctional tissues are highly specialised tissues which generate and conduct the cardiac impulses all over the heart.
- They are :
  - The Sino-atrial node (SA node)
  - Atrio-ventricular node (AV Node)
  - Atrio-ventricular bundle (AVB) or Bundle of His
  - Right and Left branches of AVB
  - Purkinjee Fibres (PF)

# PHYSIOLOGY OF THE HEART
# ( HISTOLOGY OF CARDIAC MUSCLE)

- In transverse section the cardiac muscle fibres is shorter and less circular than the skeletal muscle fibres.
- Cardiac muscle fibres have 50-100 μm long and 14 μm in diameter.
- Nucleus is located centrally but some times it contains more than one nucleus.
- One cardiac muscle connected to other with the help of sarcolema is called INTERCOLATED DISCS which contain the desmosomes that hold the two fibres together and gap junction transfer the potential from one fibre to other.

# CARDIAC CONDUCTION PATHWAY

- The heart possesses a specialized electrical system; the cardiac conduction system that leads the electrical signal from atria to the ventricle.
- The heart generates its own beat, and the electrical impulses follow a very specific route throughout the myocardium.
- ***SA node = 1.***
  - Cardiac impulse is initiated from sinoatrial (**SA**) node, located in right atrium wall inferior to the opening of Superior Venacava.
  - SA node dose not have stable resting potential.
  - Repeatly depolarize to threshold potential.
  - Spontaneous depolarization is called pacemaker potential.
  - Due to some stimuli the pacemaker potential reaches the threshold; it triggers the action potential.
  - Each action potential propagate the throughout both atria via intercalated discs.
  - Following action potential atria contract.

***AV node = 2.***

- Then the action potential reaches to the atrioventricular (AV) node.
- In atrial septum, between to atria anterior to the opening of the coronary sinus.
- Transmits signal to bundle of His (atrioventricular bundle).

***AV bundle of His = 3.***

- Site where the action potential conducts from atria to ventricle.
- The signal is transmitted down a rapid conduction pathway, composed of the right and left bundle branches, which are extend through the interventricular septum towards the apex of the heart and to stimulate the right and left ventricle and cause them to contract.

**Purkinje fibers = 4.**

- the bundle branches divide into network of conducting Purkinje fibers just below the endocardium surface.
- It has a long refractive period, so they can block premature depolarization waves from the atria.

# Conduction System of the Heart

- **SA node**: sinoatrial node. The pacemaker.
  - Specialized cardiac muscle cells.
  - Generate spontaneous action potentials *(autorhythmic tissue).*
  - Action potentials pass to atrial muscle cells and to the AV node
- **AV node**: atrioventricular node.
  - Action potentials conducted more slowly here than in any other part of system.
  - Ensures ventricles receive signal to contract after atria have contracted
- **AV bundle**: passes through hole in cardiac skeleton to reach interventricular septum
- **Right and left bundle branches**: extend beneath endocardium to apices of right and left ventricles
- **Purkinje fibers**:
  - Large diameter cardiac muscle cells with few myofibrils.
  - Many gap junctions.
  - Conduct action potential to ventricular muscle cells (myocardium)

# CONDUCTION SYSTEM OF HEART

- **Sinoatrial node (SA node)**

  - pacemaker cells initiate impulses at 60 – 100 beats/min

- **Atrioventricular node (AV node)**

  - located in the junctional area

  - normal delay (allows the atria to contract completely before the ventricles are stimulated to contract)

  - 40 – 60 beats/min

- **Bundle of His**

  - located in the interventricular septum

  - Left and Right bundle branches

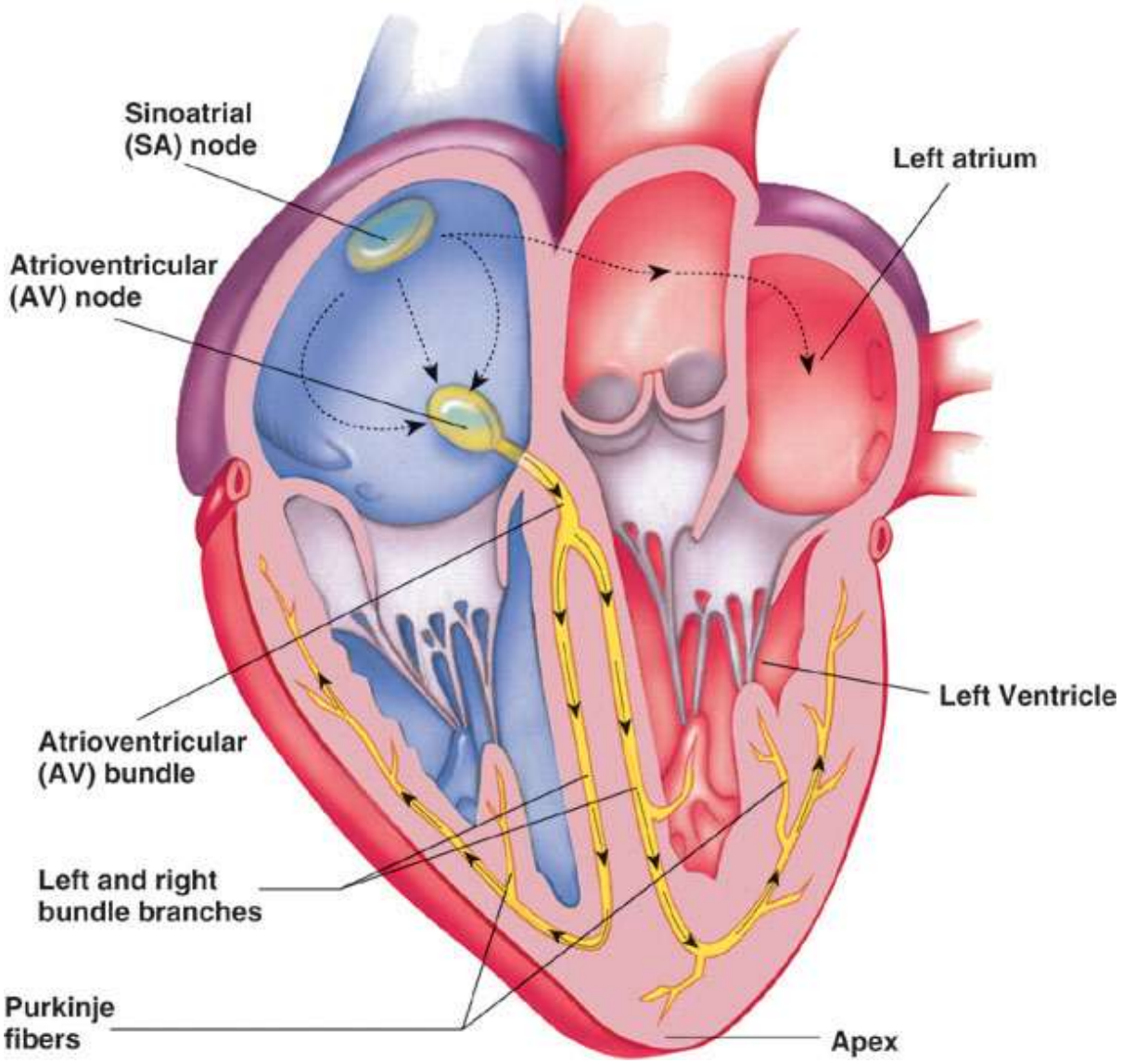
- **Purkinje fibers**

  - terminal branches that carry the impulse to RV & LV

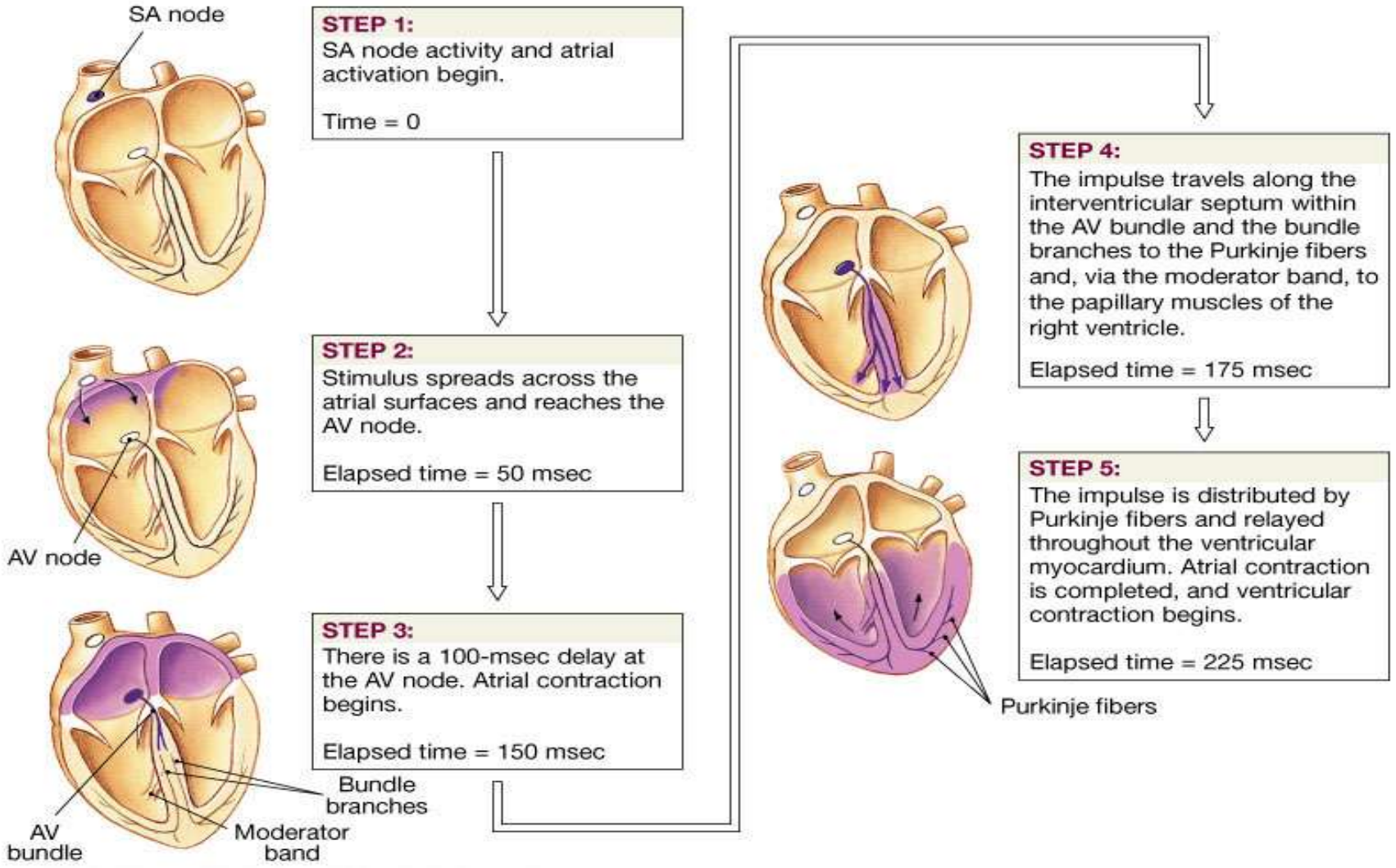
  - 20 – 40 beats/min

# Conducting System of Heart





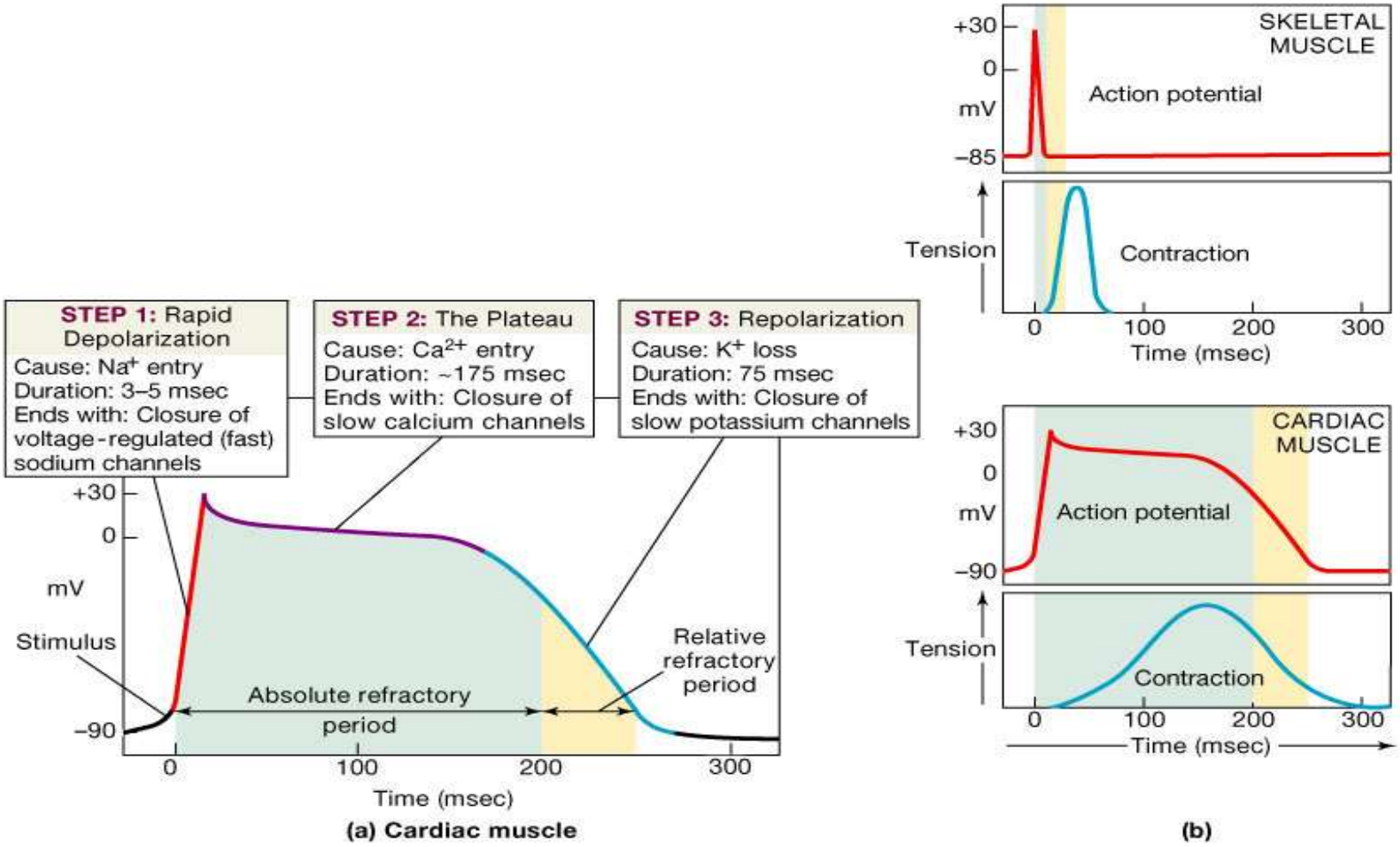
# Impulse Conduction through the Heart



# Differences Between Skeletal and Cardiac Muscle Physiology

- Action Potential
  - Cardiac: Action potentials conducted from cell to cell.
  - Skeletal, action potential conducted along length of single fiber
- Rate of Action Potential Propagation
  - Slow in cardiac muscle because of gap junctions and small diameter of fibers.
  - Faster in skeletal muscle due to larger diameter fibers.
- Calcium release
  - Calcium-induced calcium release (CICR) in cardiac
    - Movement of extracellular $Ca^{2+}$ through plasma membrane and T tubules into sarcoplasm stimulates release of $Ca^{2+}$ from sarcoplasmic reticulum
  - Action potential in T-tubule stimulates $Ca^{++}$ release from sarco-plasmic reticulum

# The Action Potential in Skeletal and Cardiac Muscle



# Depolarization of SA Node

- SA node - no stable resting membrane potential
- Pacemaker potential
  - gradual depolarization *from -60 mV*, slow influx of $Na^+$
- Action potential
  - occurs at threshold of *-40 mV*
  - depolarizing phase *to 0 mV*
    - fast $Ca^{2+}$ channels open, ($Ca^{2+}$ in)
  - repolarizing phase
    - $K^+$ channels open, ($K^+$ out)
    - *at -60 mV* $K^+$ channels close, pacemaker potential starts over
- Each depolarization creates one heartbeat
  - SA node at rest fires at 0.8 sec, about 75 bpm

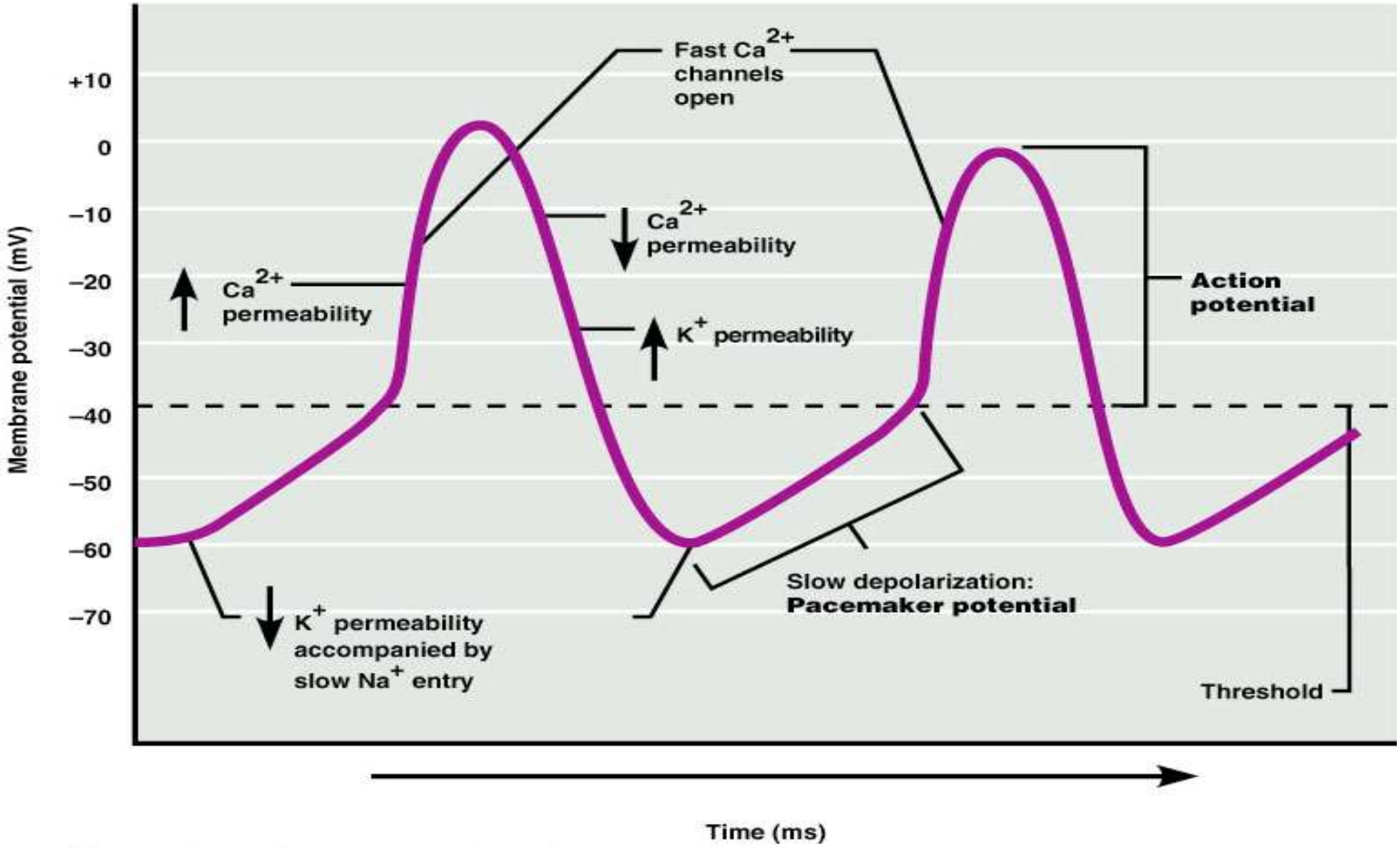
# Electrical Properties of Myocardial Fibers

1. Rising phase of action potential (Depolarization)
    - Due to opening of fast $Na^+$ channels
2. Plateau phase
    - Closure of sodium channels
    - Opening of calcium channels
    - Slight increase in $K^+$ permeability
    - Prevents summation and thus tetanus of cardiac muscle
3. Repolarization phase
    - Calcium channels closed
    - Increased $K^+$ permeability

# Heart Physiology: Intrinsic Conduction System

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

# PACEMAKER AND ACTION POTENTIALS OF THE HEART



# Cardiac cycle:

- It include all the events associated with one heart beat.
- It consist of systole and diastole of atria and same for ventricles.

**Pressure and volume change during cardiac cycle:**

- In each cardiac cycle, the atria and ventricle alternatively contract and relaxed, forcing the blood from the area of the higher pressure to the area of lower pressure.
- There is a change in ECG signals and change in atrial pressure, ventricular pressure, aortic pressure and ventricular pressure during cardiac cycle.
- When heart rate is 75 beats/min, a cardiac cycle lasts 0.8 sec.

  Atrial systole

  Ventricular systole

  Relaxation period

**Atrial systole**: last about 0.1 sec, the atria are contracting. At the same time the ventricles are relaxed.

1) Depolarization of SA node cause atrial depolarization, marked by P wave in ECG.
2) It cause atrial systole. As atria contract, they exert the pressure on the blood within, which force the blood through the open AV valve in to the ventricles.
3) Atrial systole contributes a final 25 ml of blood to the volume already in each ventricles (about 105 ml). The end of the atrial systole is the end of ventricular diastole. Thus, each ventricles contains about 130 ml at the end of relaxation period. This is the end diastolic volume.
4) The QRS complex in the ECG markes the onset of ventricular depolarization.

**Venricular systole:** last about 0.3 sec, the ventricle contracting. At the same time the atria relaxed, in the atrial diastole.

5) depolarization cause ventricular systole. As it begins, pressure rise inside the ventricles and pushes blood up against the AV valve, forcing them shut. For about 0.5 sec both valves are closed (AV & SL). This period is isovolumetric contraction.

During this cardiac muscle fibers are contracting and exert force. Thus, muscle contraction is isometric (same length), because of four valves are closed, ventricular volume remains the same (isovolumetric).

6) Continues contraction of the ventricles cause pressure inside the chamber to rise sharply. Left ventricular pressure is about 80 mmHg, the right ventricular pressure is rise above the pressure in pulmonary trunk, the SL valve opens. At this point ejection of the blood from the heart is begins. It is ventricular ejection, is last about 0.25 sec. the pressure in the left ventricle continue to rise about 120 mmHg, where the pressure in the right ventricle climb to about 25-50 mmHg.

7) The left ventricle eject about 70 ml of the blood in to aorta and right ventricle eject the same volume of blood into pulmonary trunk.

The volume remain in each ventricle at the end of systole, about 60 ml, it is end diastolic volume.

Stroke volume: the vol. ejected per beat from each ventricles, SV= EDV- ESV i.e. 130-60=70 ml.

8) The T wave in the ECG marks the onset of ventricular repolarisation.

**Relaxation period**: last for 0.4 sec. the atria and ventricles are both relaxed.

As heart beats are faster and faster the relaxation period are shorter and shorter.

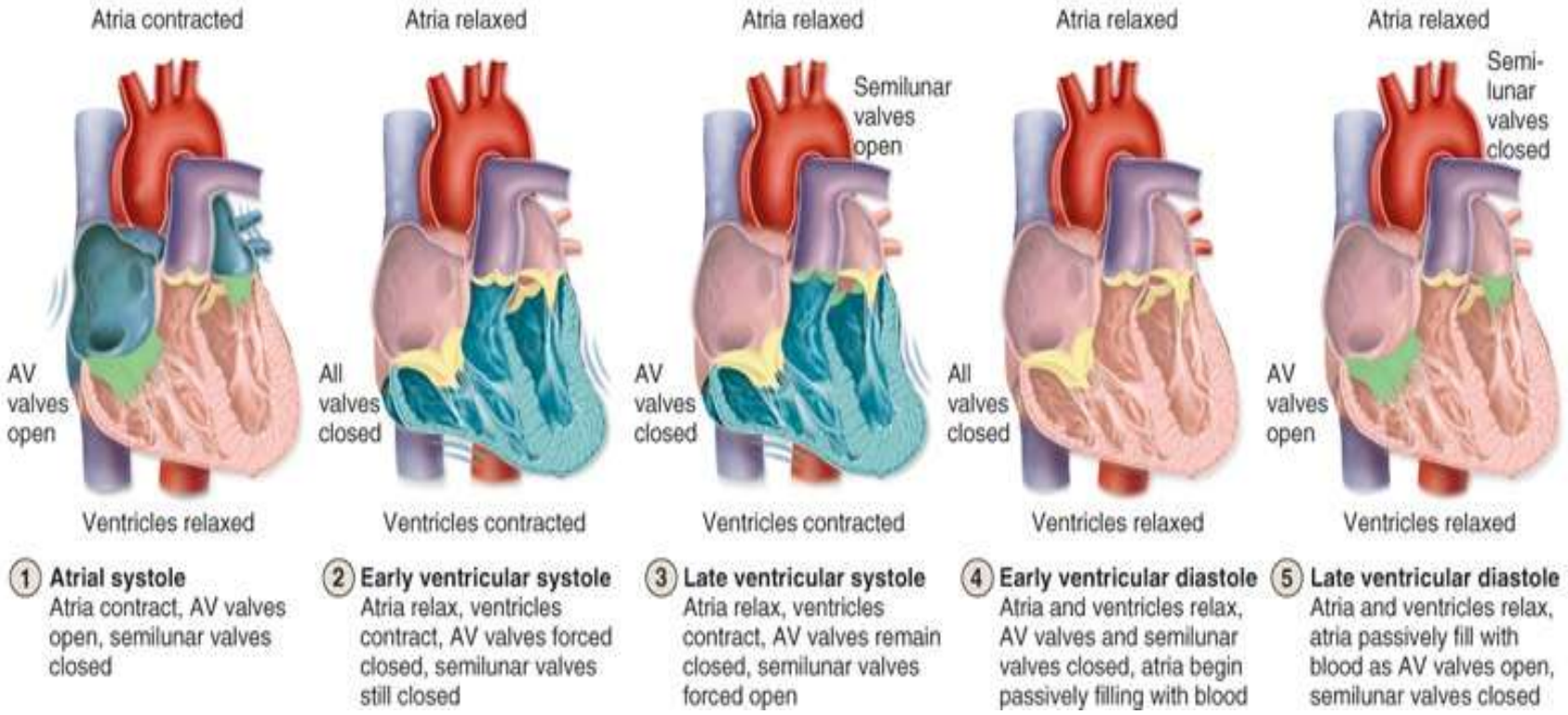
9) Ventricular repolarisation cause ventricular deiastole. As ventricle relaxred, pressure within the chamber falls. The blood in the aorta and pulmonary trunk beings to flow backward toward the regions of lower pressure in the ventricles.

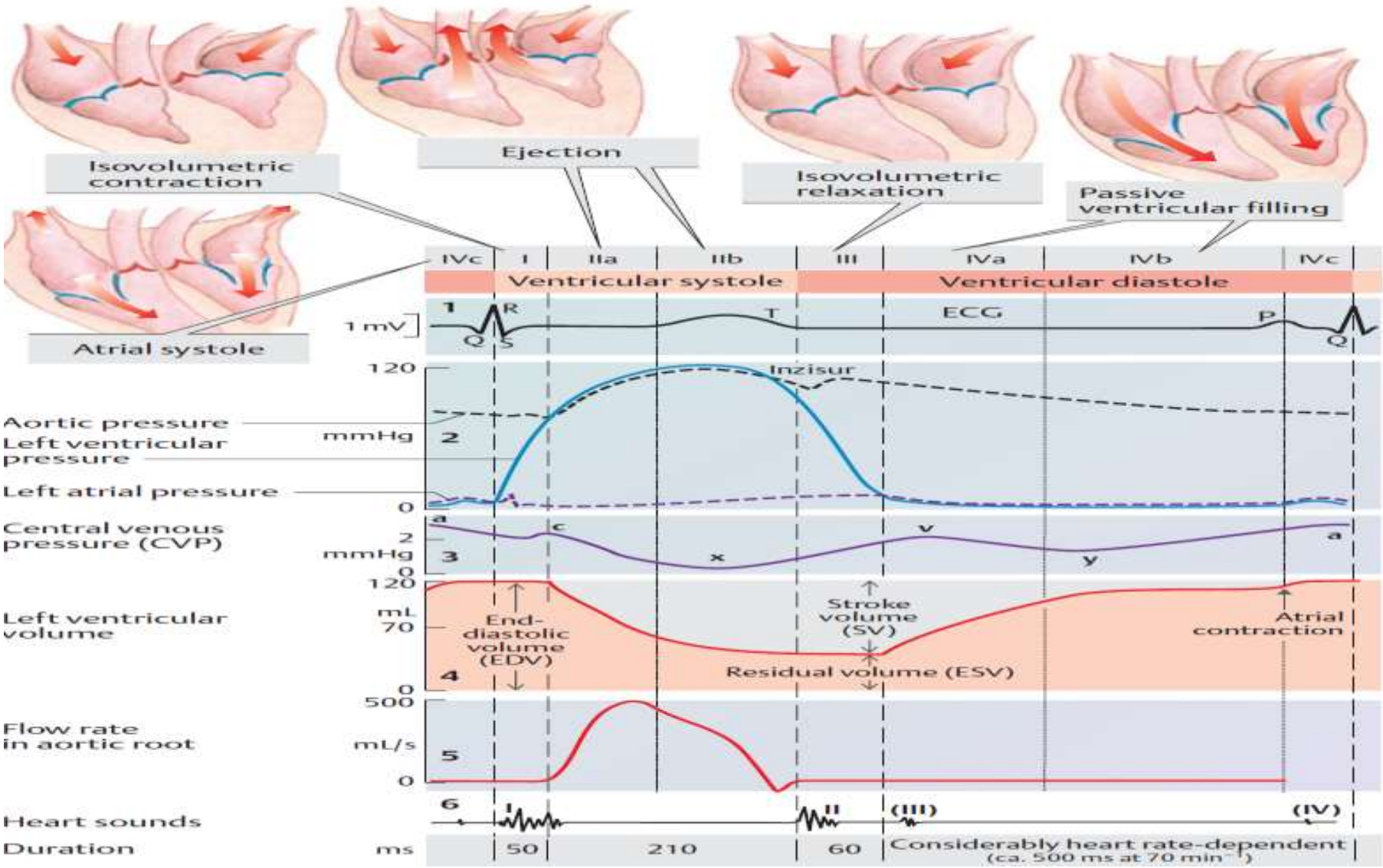
   Backflow blood catches in the valve cups and close the SL valve. After the SL valve closed, there is a brief interval when the ventricular blood volume does not exchange because all four valve are closed. This is the period of **isovolumetric relaxation**.

10) As ventricles continue to relax, the pressure falls quickly. When vetricular pressure drops below atrial pressure , the AV valve open and ventricular filling being. The major part of the ventricular filling is just after the AV valve open.

    Blood that has been flowing in to and building up in the atrial during ventricular systol and rush rapidly in to the ventricles.

| Structure \ Phase | Atrial systole | Early ventricular systole ⟷ Late ventricular systole | Early ventricular diastole ⟷ Late ventricular diastole |
|---|---|---|---|
| Atria | Contract | Relax | Relax |
| Ventricles | Relax | Contract | Relax |
| AV valves | Open | Closed | Open |
| Semilunar valves | Closed | Open | Closed |




Isovolumetric contraction
Ejection
Isovolumetric relaxation
Passive ventricular filling
Atrial systole
IVc
I
IIa
IIb
III
IVa
IVb
IVc
Ventricular systole
Ventricular diastole
1 mV
ECG
R
T
P
Q
S
Q
120
Inzisur
Aortic pressure
Left ventricular pressure
mmHg
2
Left atrial pressure
0
Central venous pressure (CVP)
a
c
v
a
2
mmHg
3
x
y
0
120
Left ventricular volume
mL
70
End-diastolic volume (EDV)
Stroke volume (SV)
Atrial contraction
4
Residual volume (ESV)
0
500
Flow rate in aortic root
mL/s
5
0
6
I
II
(III)
(IV)
Heart sounds
Duration
ms
50
210
60
Considerably heart rate-dependent
(ca. 500 ms at 70 min⁻¹)

**The heart sound:**

The **heart sounds** are the noises (sound) generated by the beating heart and the resultant flow of blood through it. This is also called a **heartbeat**. In cardiac auscultation, an examiner uses a stethoscope to listen for these sounds, which provide important information about the condition of the heart.

In addition to these normal sounds, a variety of other sounds may be present including *heart murmurs*

**Murmurs** are abnormal heart sounds that are produced as a result of turbulent blood flow which is sufficient to produce audible noise. This most commonly results from narrowing or leaking of valves or the presence of abnormal passages through which blood flows in or near the heart.

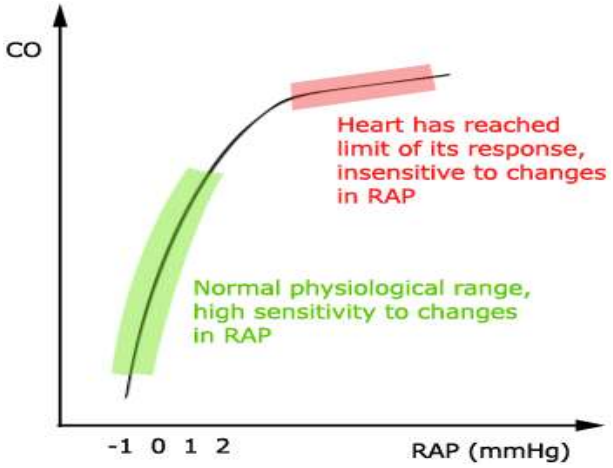
- **Cardiac output** is the amount of blood pumped by a ventricle in 1 minute. A certain level of cardiac output is needed at all times to transport oxygen to tissues and to remove waste products. During exercise, cardiac output must increase to meet the body's need for more oxygen.
- To calculate cardiac output, we must know the pulse rate and how much blood is pumped per beat. **Stroke volume** is the term for the amount of blood pumped by a ventricle per beat; an average resting stroke volume is 60 to 80 mL per beat.
- Cardiac output= stroke volume X pulse (heart rate)

CO = 70 mL/beat X 75 beats/min
= 5250 mL/min
= 5.25 L/min

Cardiac reserve: deference between a person's max. c.o.p. and c.o.p. at the rest.

Frank-Starling law of the heart

- states that the greater the volume of blood entering the heart during diastole (end-diastolic volume), the greater the volume of blood ejected during systolic contraction (stroke volume).
- The preload is proportional to the volume of blood that fills the ventricles at the end of diastolic, the end diastolic volume (EDV).
- Normally, the greater the EDV, more forceful the next contration.



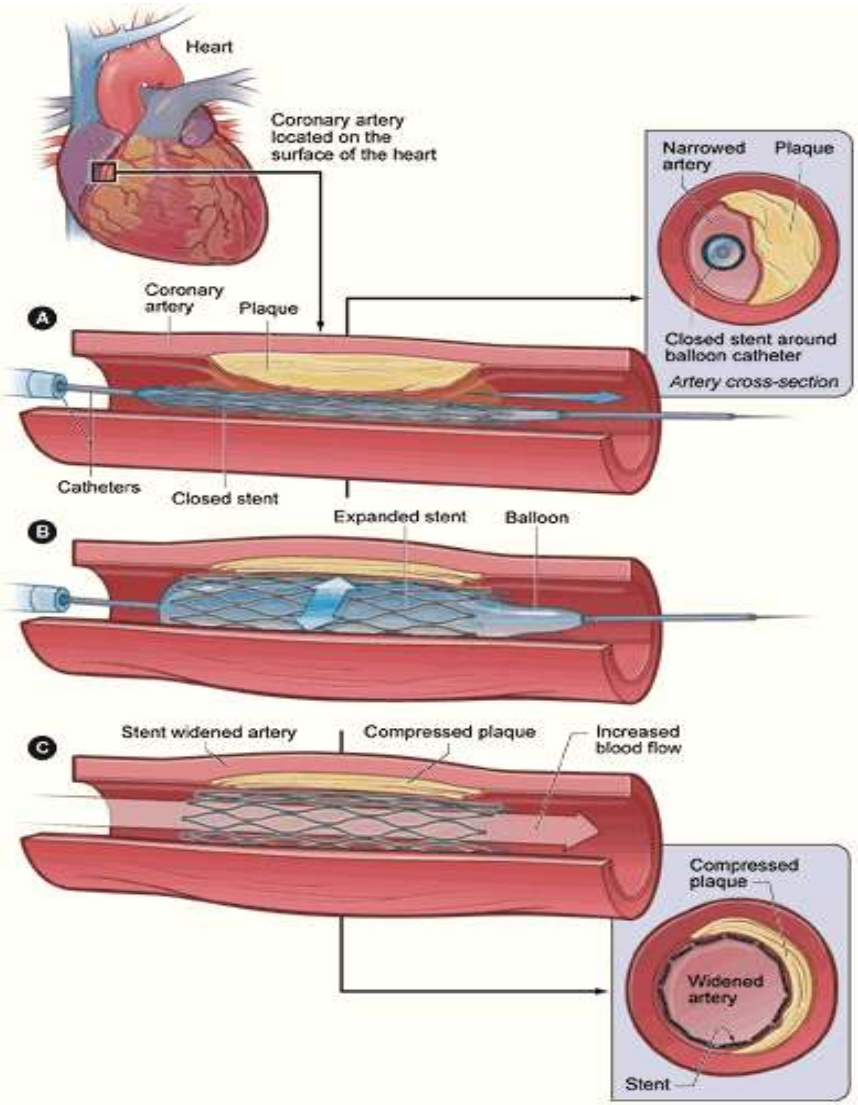
- **Regulation of stroke volume:** A healthy heart will pump out all the blood that entered its chambers during the previous diastole. i.e. more blood is returning to heart during diastole, than more blood is ejected during the next systole.
- Three factor regulate the stroke volume, and volume of the blood.

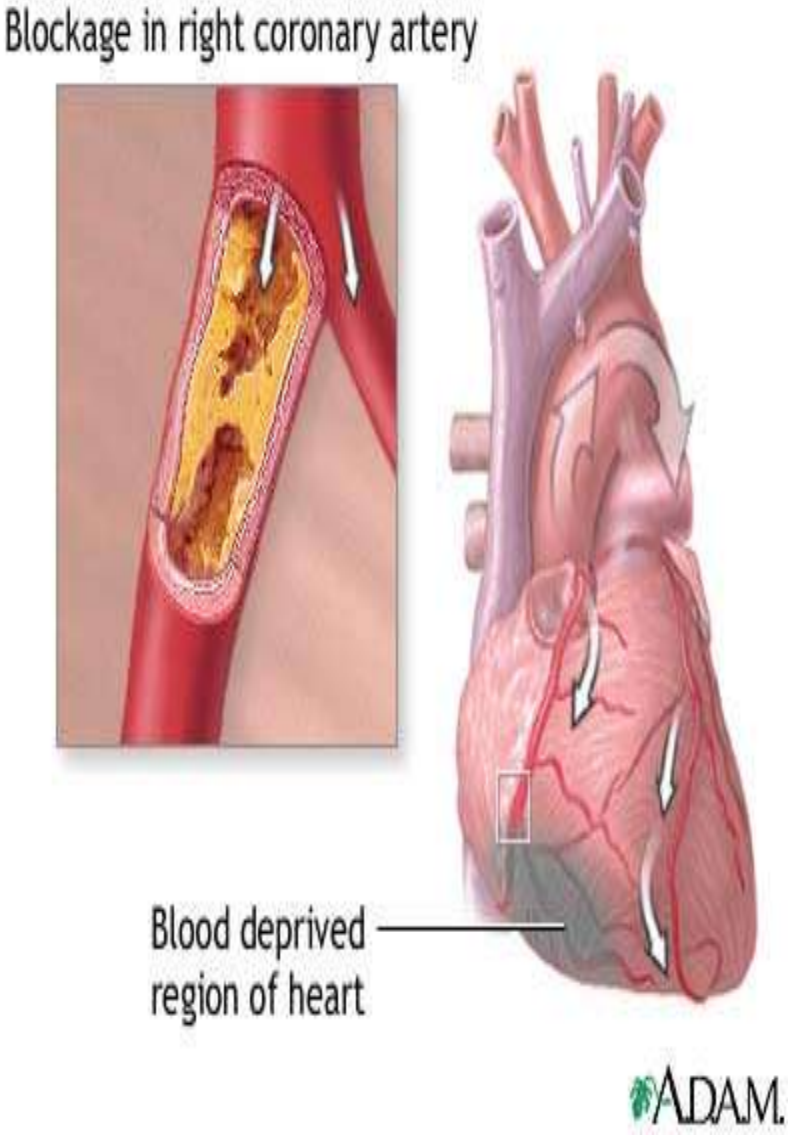
1. Preload: the degree of stretch on the heart before it contract
2. Contractility: the forcefulness of contraction of individual ventricular muscle fibers. That is the strength of contraction at any given preload. The substance that increase the contractility are positive inotropic agent. Those decreased negative inotropic agent.
3. After load: the pressure that must be exceeded before ejection of blood from the ventricles can occur.

# DIFFERENT CARDIAC DISORDERS:

- Heart failure (HF) is a condition in which a problem with the structure or function of the heart impairs its ability to supply sufficient blood flow to meet the body's needs. It should not be confused with cardiac arrest.
- Hypertension
- Arrhythmia
- Coronary artery disease: Athlerosclerosis, Angina pectoris

- Stents and bypass surgery



# Thank you.