Cardiovascular system

Introduction

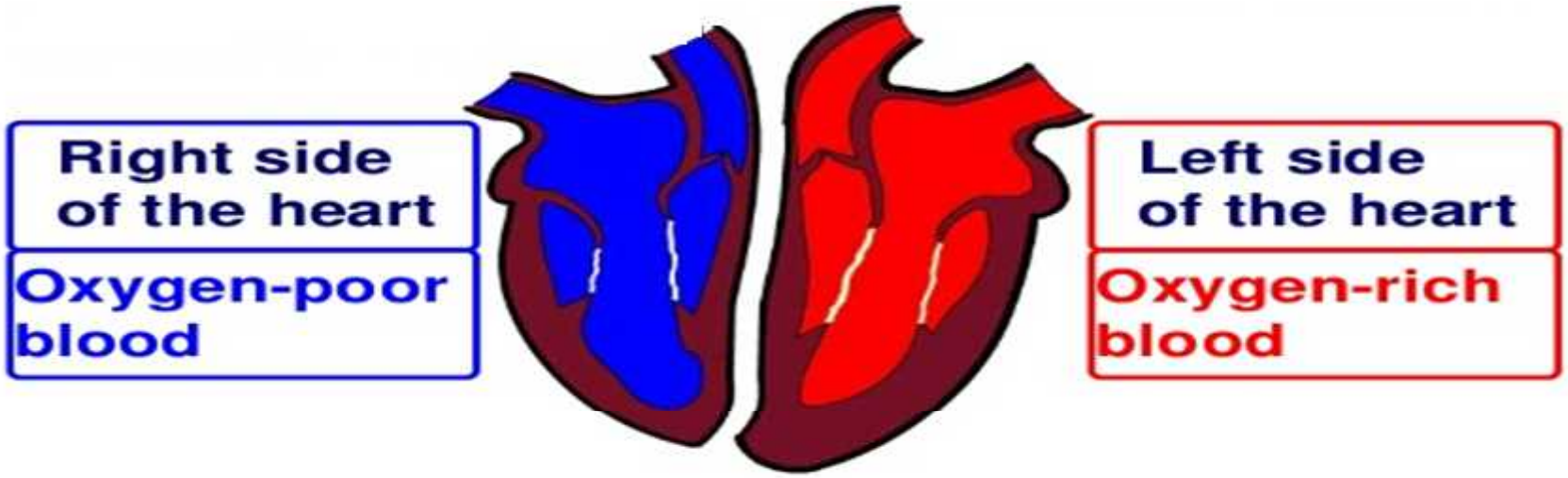
The cardiovascular system includes

the *Heart* , which serves as a **pump** for the blood,

the *blood vessels* , which **transport** blood throughout the body.

<u>continuous, closed circuit</u>, meaning that the blood is found only in the heart and blood vessels.

The heart actually consists of two separate pumps;



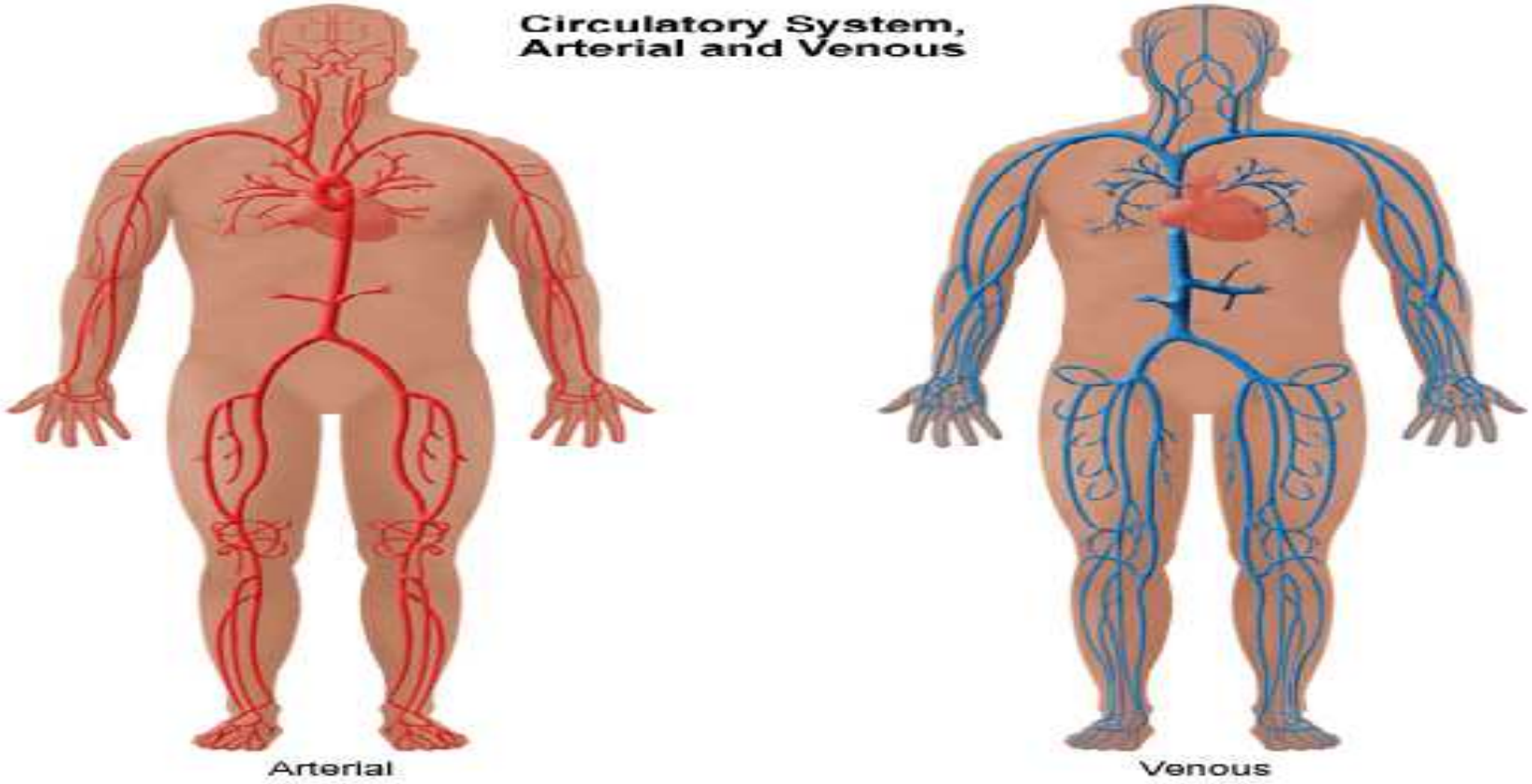
The right side

gas exchange, uptake of oxygen and elimination of carbon dioxide

The left side

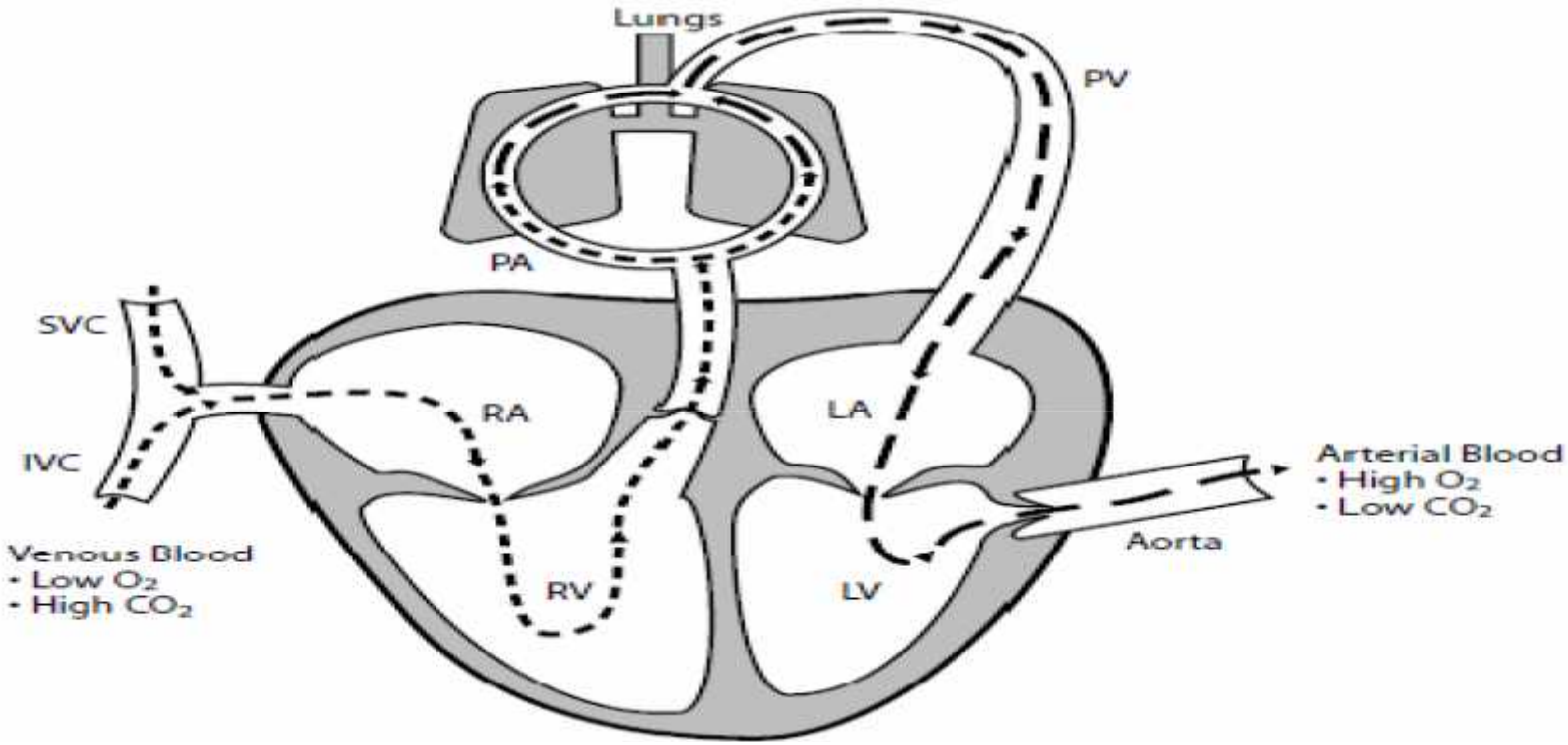
oxygen and nutrients are delivered to the tissues to sustain their activities and carbon dioxide and other metabolic waste products are removed from the tissues.

The heart consists of two Vascular systems



the *arterial system* , arteries and arterioles, *capillaries* ,
the *venous system* , veins and venules,

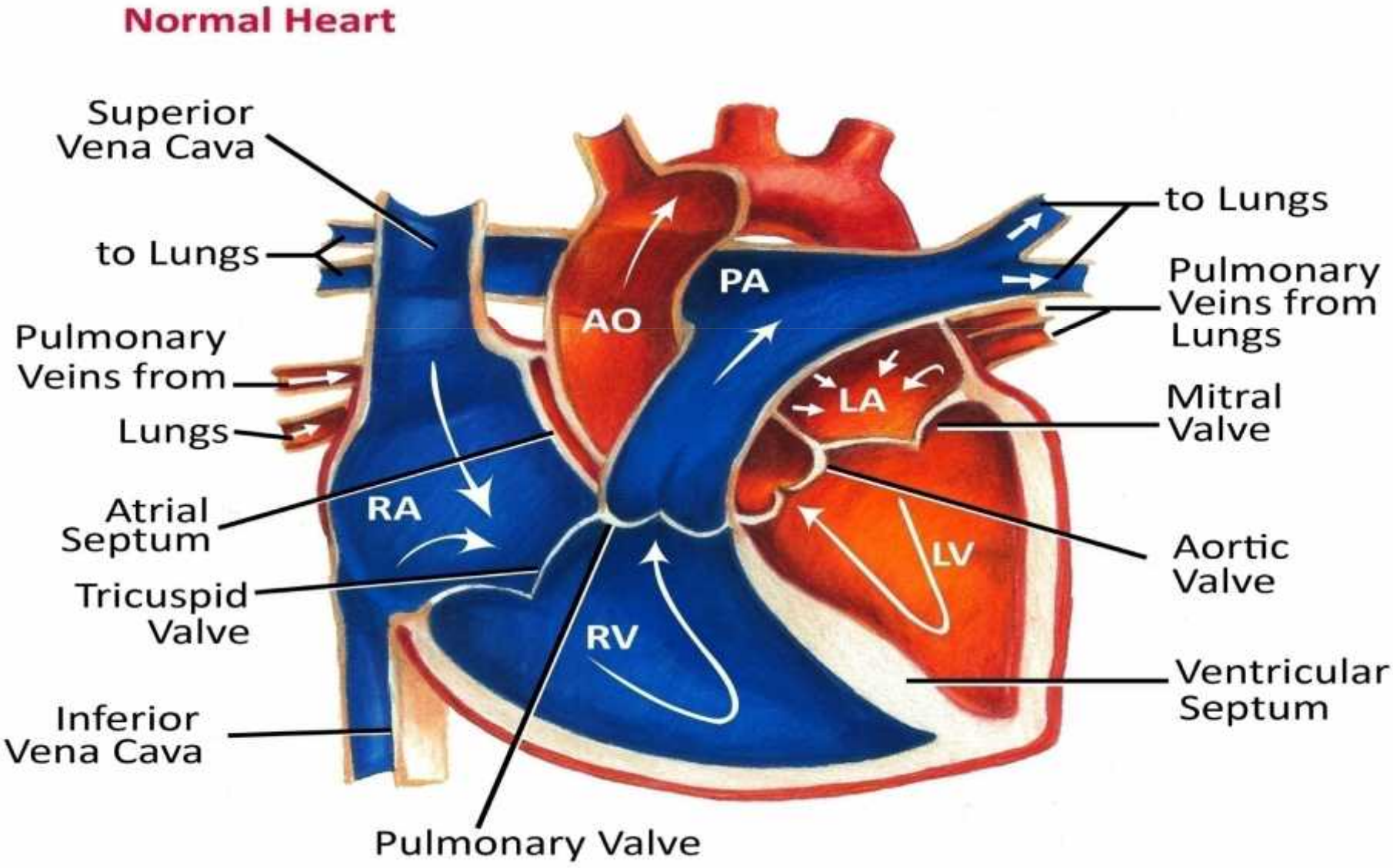
The route of blood flow through the heart



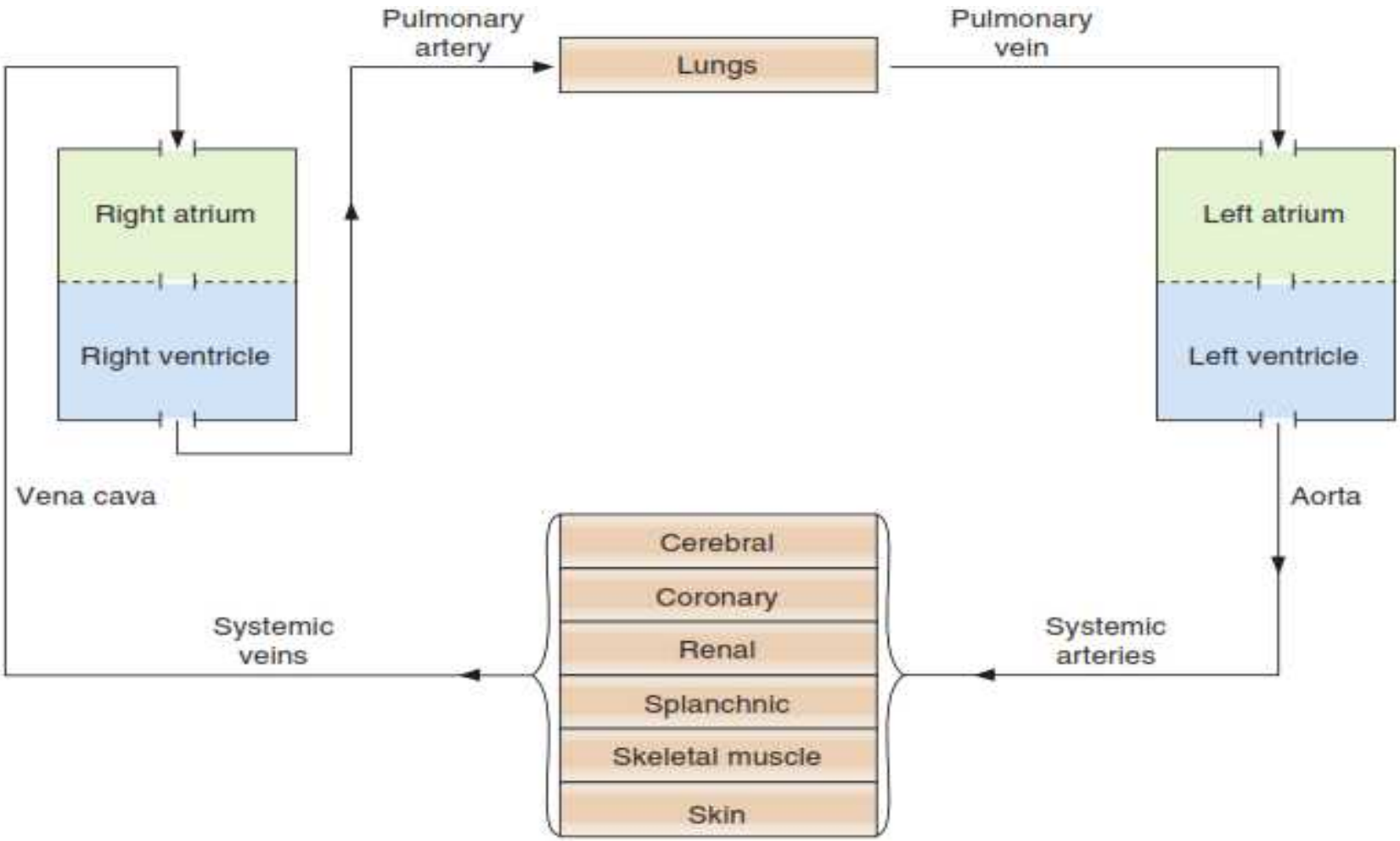
The heart is composed of :

- **Receiving chambers**
- **Delivery chambers**
- **Valves**

The route of blood flow through the heart



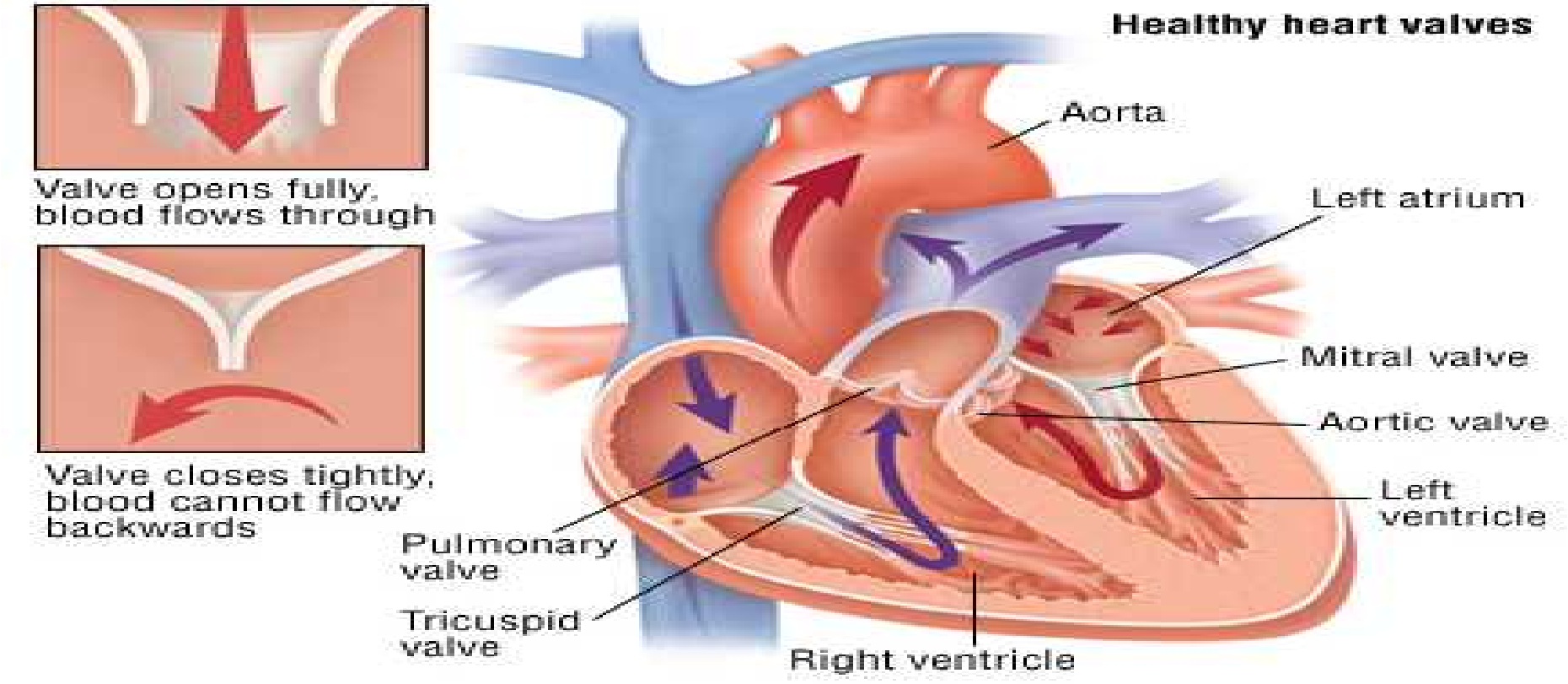
The route of blood flow through the heart



In summary,

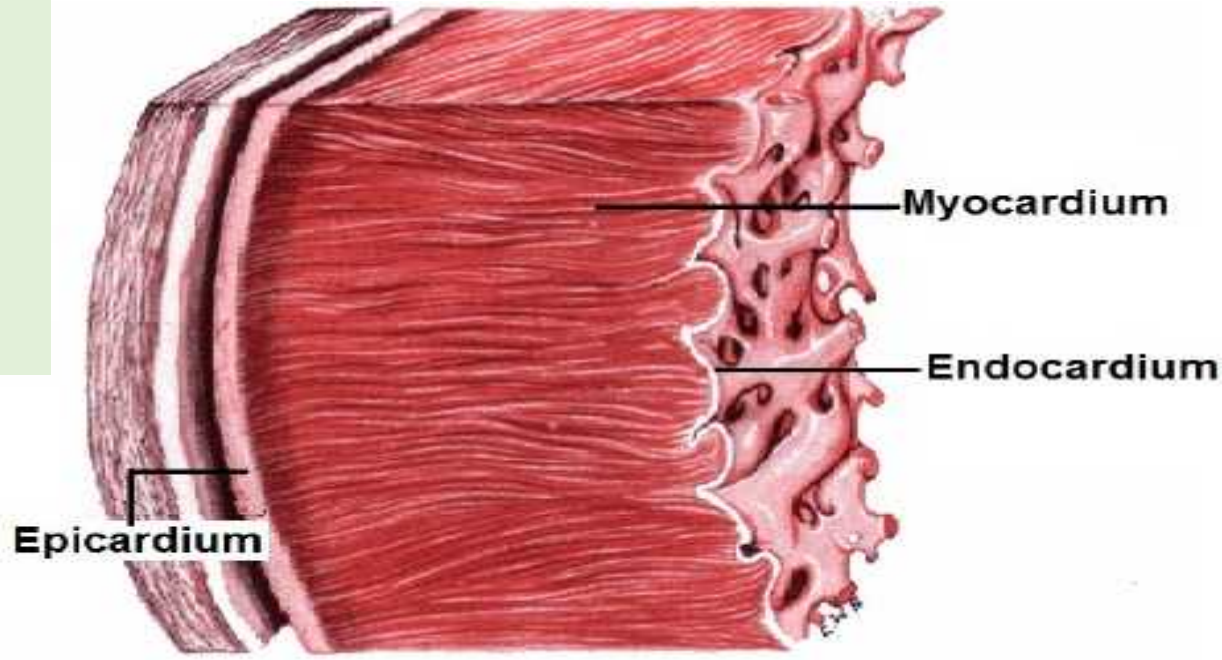
- **the heart is a single organ consisting of two pumps;**
- the right heart delivers blood to the lungs and the left heart delivers blood to the rest of the body**.**
- **Both pumps work simultaneously.** The atria fill with blood and then contract at the same time and the ventricles fill with blood and then contract at the same time.
- **Contraction of the atria occurs prior to contraction of the ventricles in order to ensure proper filling of the ventricles with blood.**

Heart valves;



- Atrioventricular (AV) valves
- Semilunar valves
- **There are no valves between the venae cavae or the pulmonary veins and the atria into which they deliver blood.**

Heart Wall



3 layers:

- Epicardium: outer wall joined with pericardium
- Myocardium: the actual cardiac muscle that contracts
- Endocardium: lines heart chambers & vessels

Myocardium; is the muscular layer of the heart. This is the thickest layer; Thickness is related to the amount of work that a given chamber must perform when pumping blood.

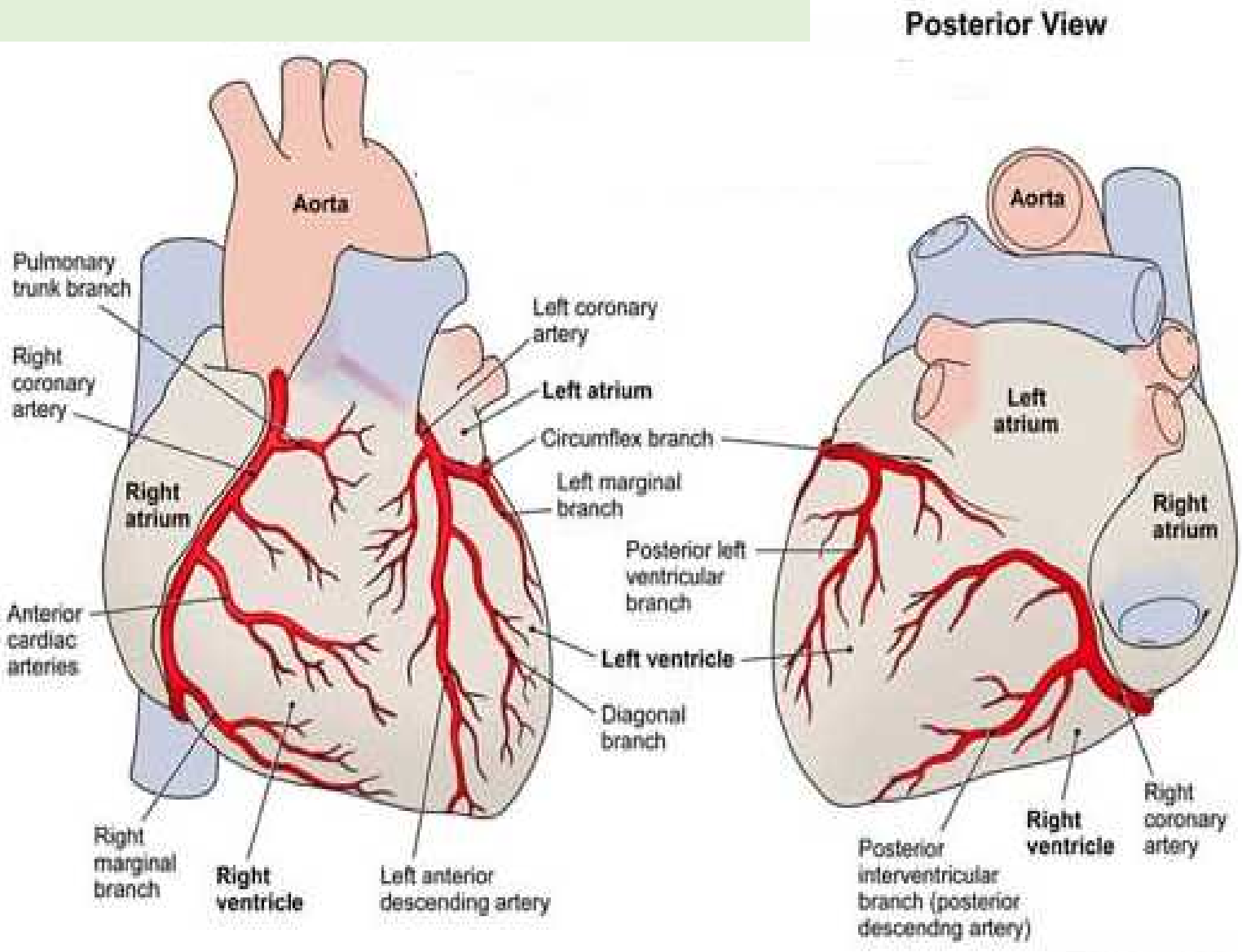
Heart Wall

- Under normal resting conditions, between heart beats, the pressure in the **pulmonary artery is approximately 8 mmHg** and pressure in the **aorta is approximately 80 mmHg**.

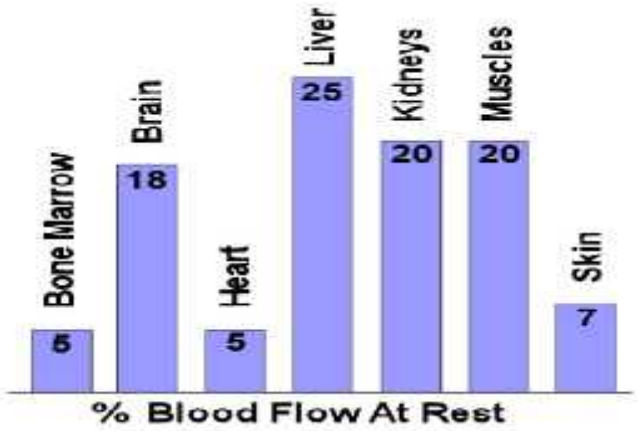
- Therefore, in order to eject blood into the pulmonary artery, the right ventricle must generate a pressure greater than 8 mmHg and, in order to eject blood into the aorta, the left ventricle must generate a pressure greater than 80 mmHg.

- Because **the left ventricle** performs significantly more work, **its wall is much thicker than that of the right ventricle.**

Cardiac arteries



Heart muscle ischemia

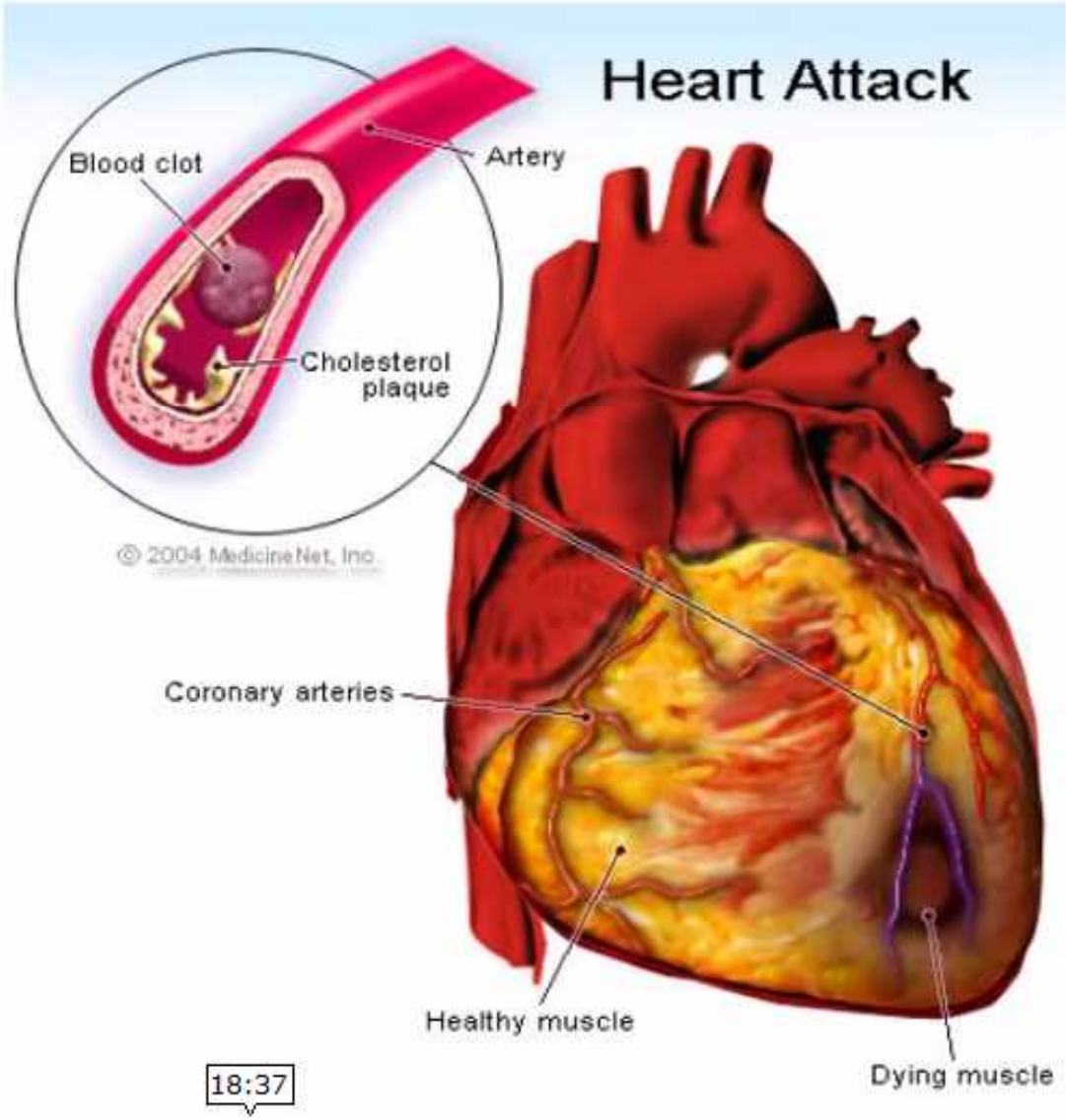


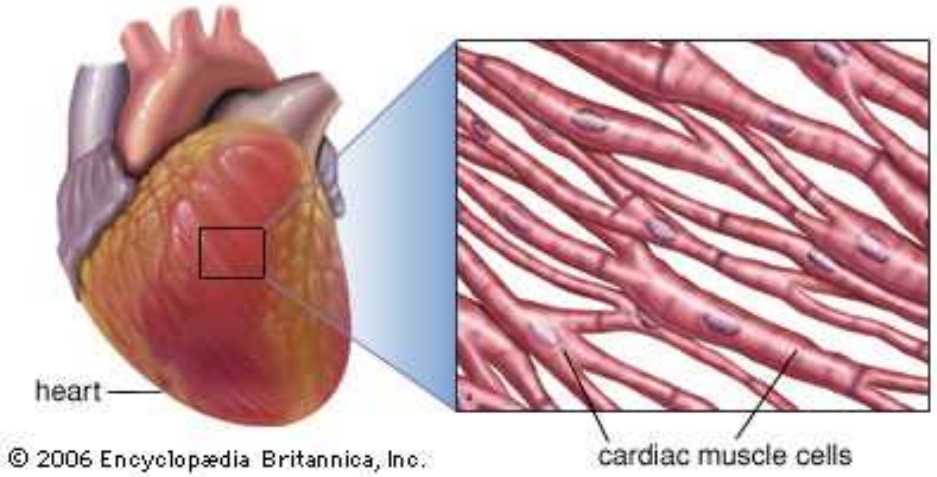
Circulation* (% of Resting Cardiac Output)	Local Metabolic Control	Vasoactive Metabolites	Sympathetic Control	Mechanical Effects
Coronary (5%)	Most important mechanism	Hypoxia Adenosine	Least important mechanism	Mechanical compression during systole
Cerebral (15%)	Most important mechanism	CO_2 H^+	Least important mechanism	Increases in intracranial pressure decrease cerebral blood flow
Muscle (20%)	Most important mechanism during exercise	Lactate K^+ Adenosine	Most important mechanism at rest (α_1 receptor causes vasoconstriction; β_2 receptor causes vasodilation)	Muscular activity causes temporary decrease in blood flow
Skin (5%)	Least important mechanism		Most important mechanism (temperature regulation)	
Pulmonary† (100%)	Most important mechanism	Hypoxia vasoconstricts	Least important mechanism	Lung inflation

Ischemic heart diseases

- Since coronary arteries **deliver intermittent limited amount of blood to the heart muscle** (5% of total cardiac output at rest) which reduced magnificently at contraction and exercise, any coronary artery disorder or disease can have serious implications by reducing the flow of oxygen and nutrients to the heart muscle (ischemia)
- This can lead to a heart attack and possibly death.
- Atherosclerosis (a buildup of plaque in the inner lining of an artery causing it to narrow or become blocked) is the most common cause of heart disease.

Ischemic heart diseases





Cardiac muscle

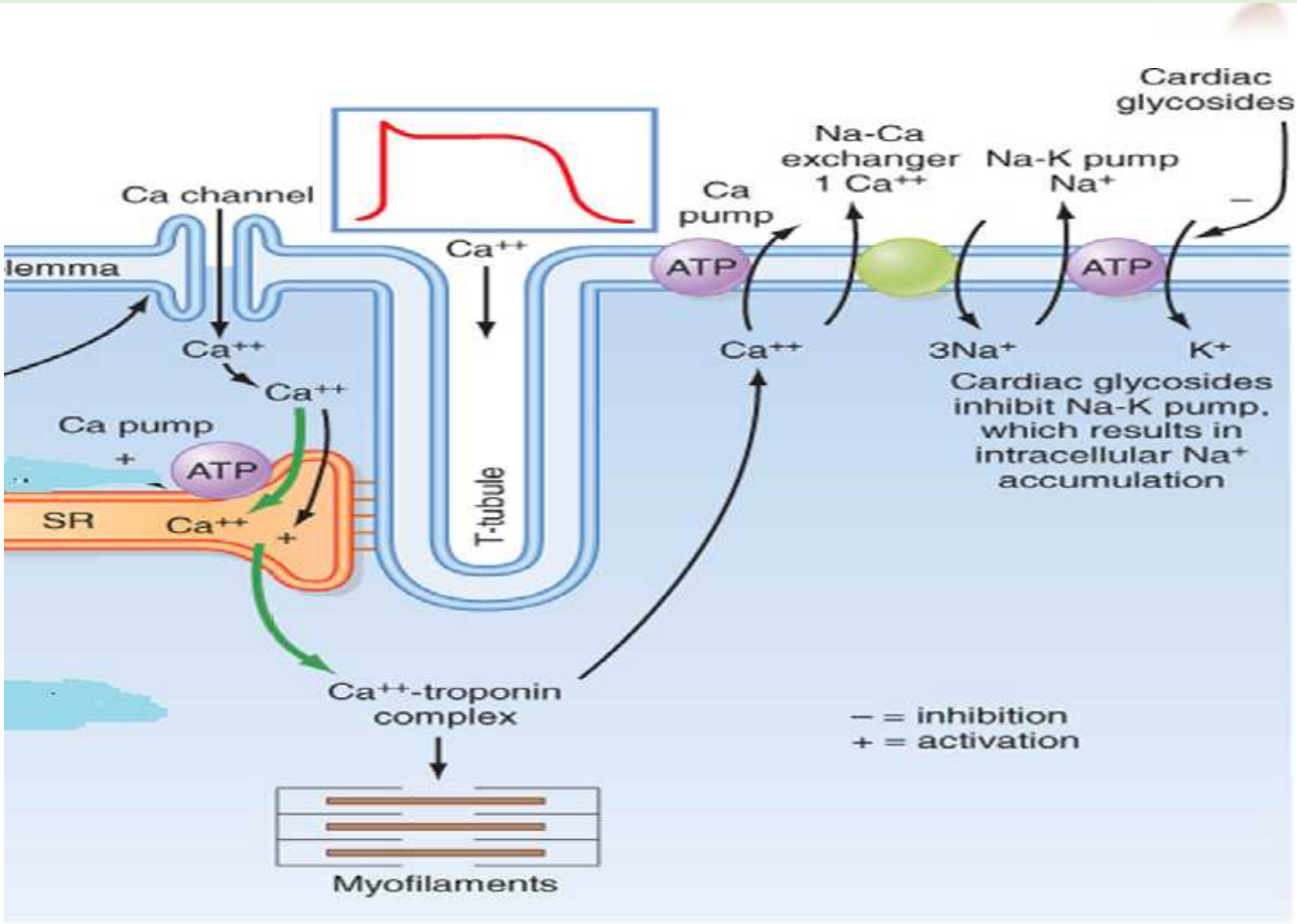
Properties of the cardiac muscle

- **Syncytium.**
- **Automaticity and rhythmicity (Autorhythmicity).**
- **Excitability and conductivity.**
- **Contractility**
  - Systole Contraction period of heart
  - Diastole relaxation period of heart

Myocardial cell criteria

Cardiac muscle	Skeletal muscle
Organized into sarcomeres	Organized into sarcomeres
Sliding-filament mechanism of contraction	Sliding-filament mechanism of contraction
Source of calcium: Sarcoplasmic reticulum	Source of calcium: Sarcoplasmic reticulum
Tranverse tubules	
Resting length of sarcomere *less than* optimal length	Resting length of sarcomere *equal* to optimal length
Gap junctions provide electrical communication between cells, forming a functional syncytium	No gap junctions
Myogenic	Neurogenic
Contraction *modified* by autonomic nervous system	Contraction *elicited* by somatic nervous system

Myocardial cell Contraction

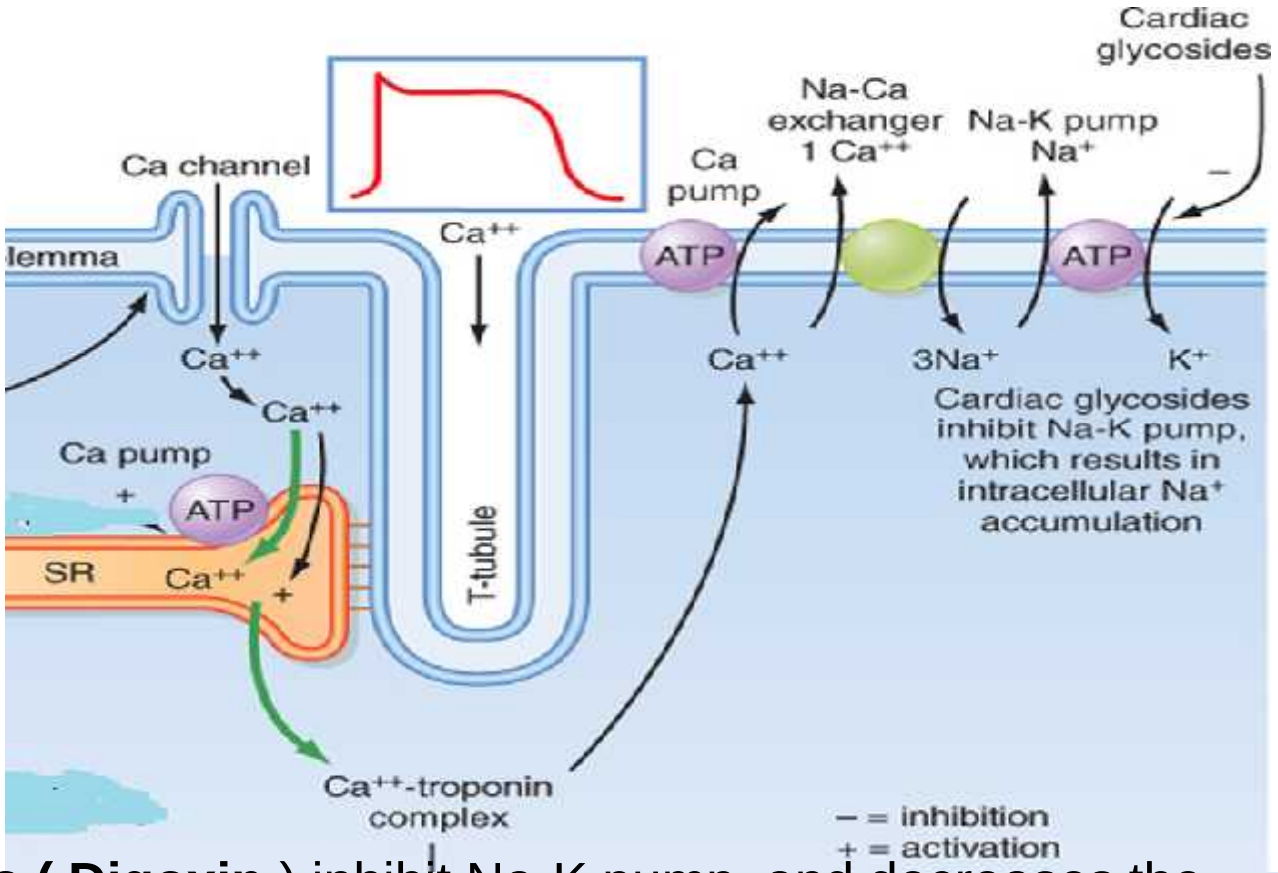


Myocardial cell Contraction

- Unlike skeletal muscle whose only source of calcium is the **sarcoplasmic reticulum**, cardiac muscle also **obtains calcium from the T tubules**, which are filled with extracellular fluid. **This added calcium results in a much stronger contraction.**

EXCITATION-CONTRACTION COUPLING IN THE HEART MUSCLE

1. Action potential enter from adjacent cell
2. L- Ca channel open & Ca enter
3. Ca induce Ca release from SR
4. Ca bind to Troponin to initiate contraction
5. Ca pumped back to SR & exchange with Na to produce relaxation



Note; Cardiac glycosides (Digoxin) inhibit Na-K pump and decreases the hearts ability to pump calcium out of the cardiac cell so we get increased contractility of the heart. This is known as an **increased inotropic effect**. This leads to an increase in cardiac output (greater contractility and duration) in **a failing heart**

Next

Frank–Starling mechanism

- The arrangement of the myofilaments into sarcomeres renders the cardiac muscle subject to **the *length–tension relationship*** .
- **In the heart, the resting sarcomere length is determined by the volume of blood within the ventricle immediately prior to contraction**. This length–tension relationship is described by **the *Frank–Starling mechanism*** ; this concept is important in the **management of heart failure**

Frank–Starling mechanism

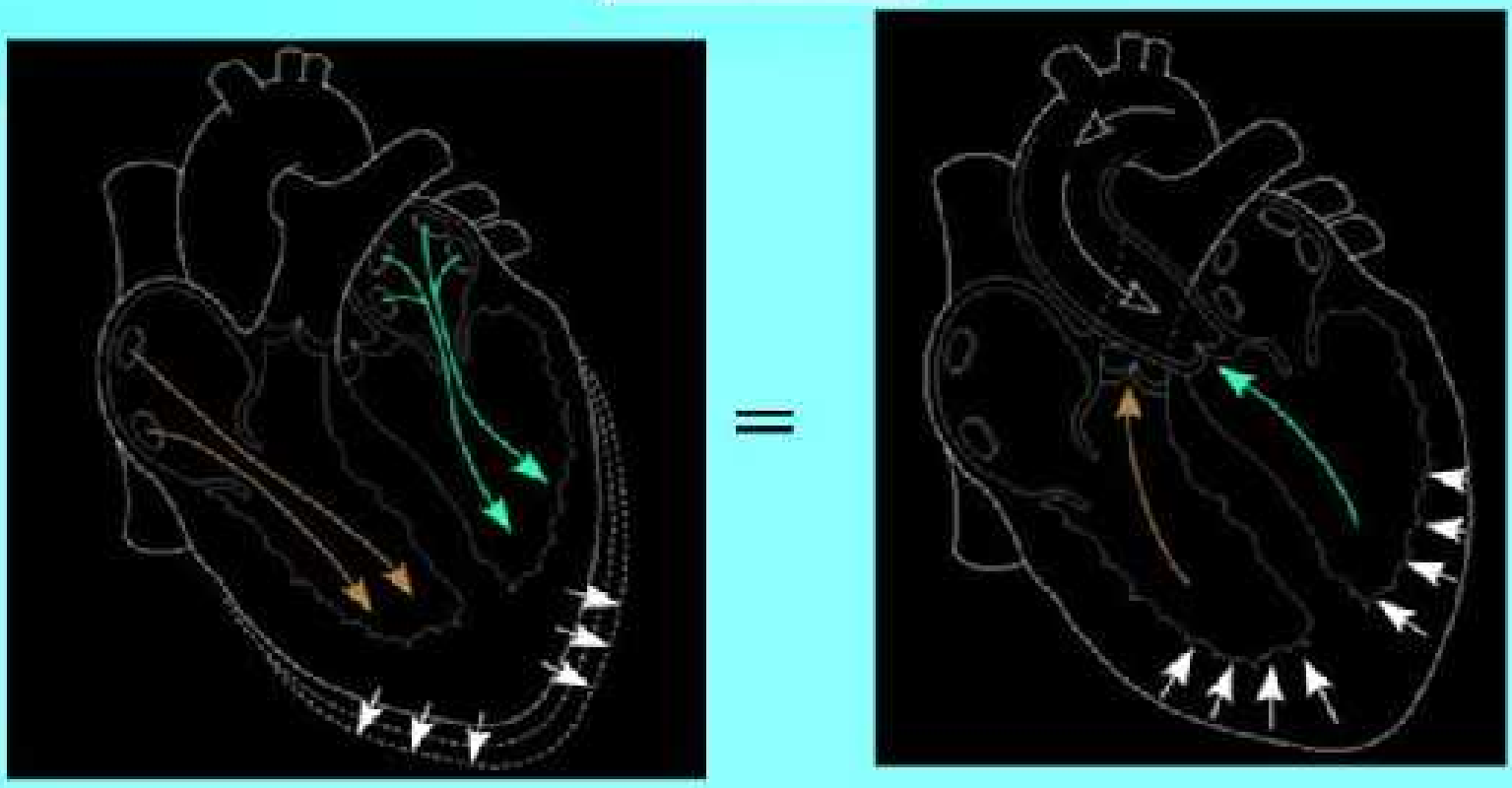
Preload: ***Starling's law*** of the heart

- Preload = volume of blood returning to right side of heart
- *Increased preload causes increased stretch to heart chamber walls and a greater force of contraction*

Afterload: pressure in the aorta that the left ventricle has to overcome to pump blood into the systemic circulation

- Increased systemic blood pressure results in increased afterload

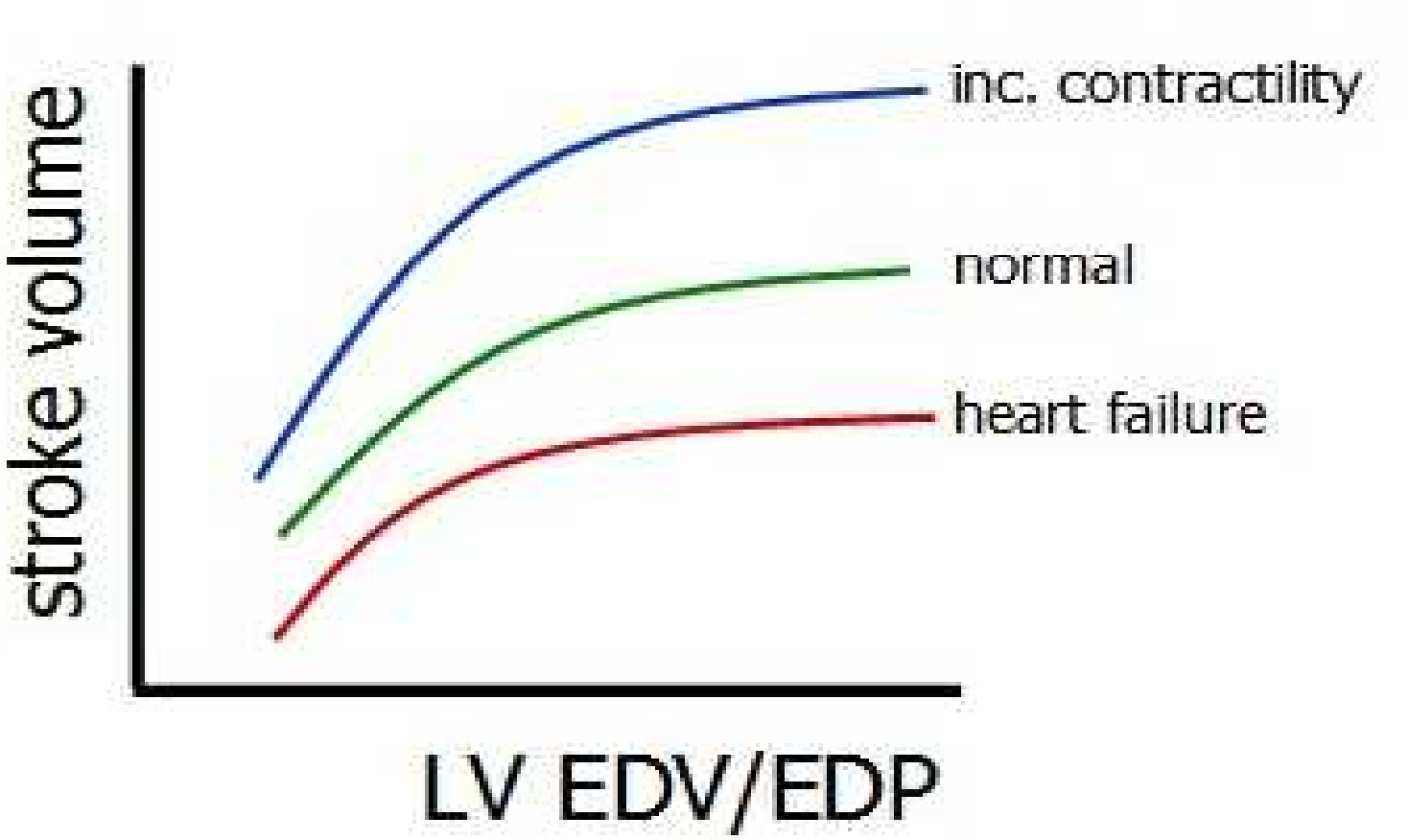
Frank–Starling mechanism



Increased blood volume = increased stretch of myocardium

Increased force to pump blood out.

Frank–Starling mechanism



Preload and after load

Heart failure

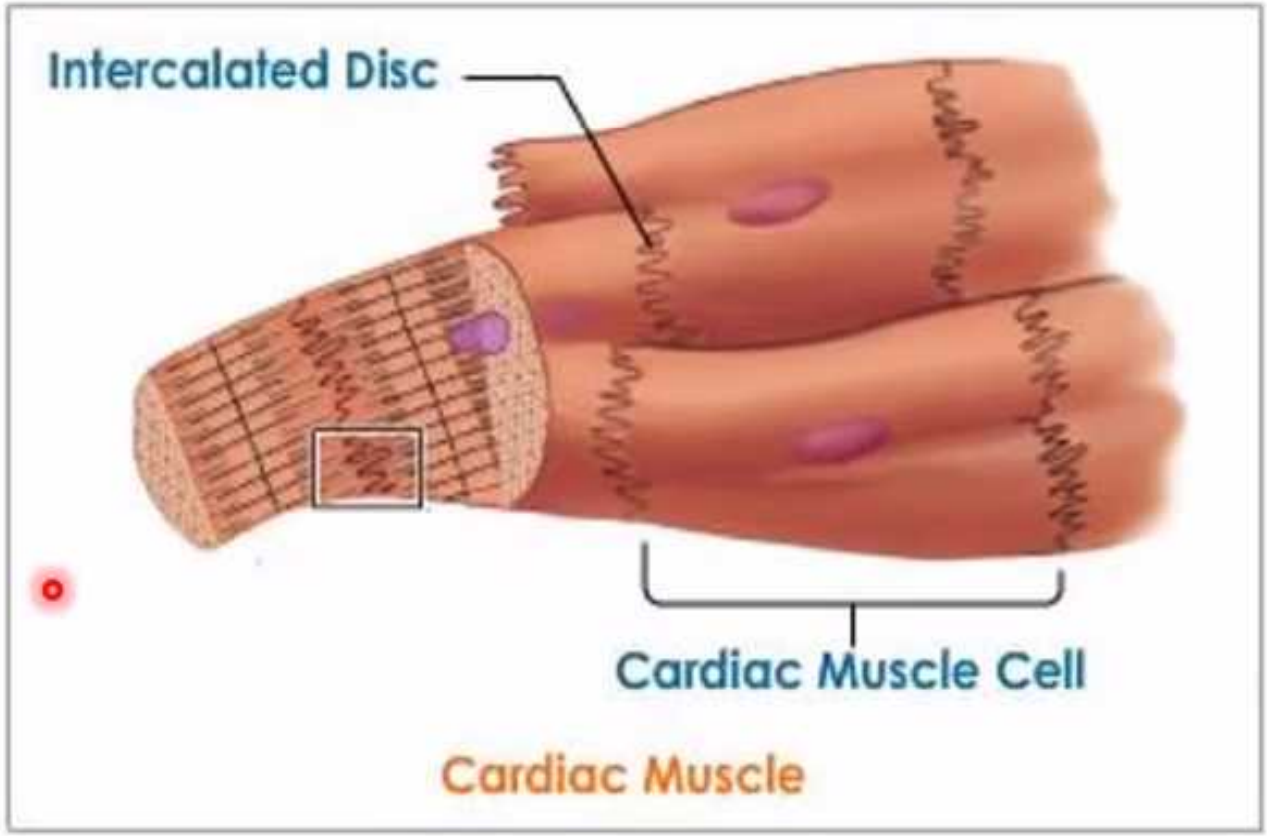
- Heart failure is a clinical syndrome that comprises a constellation of signs and symptoms that occur as a result of **pump failure**, a series of histopathological and structural changes occur in the left ventricular myocardium that lead to progressive decline in left ventricular performance.

- Ultimately, **ventricular remodeling** may result in diminished contractile (systolic) function and reduced stroke volume ; (Heart Failure) , this can be reversed or delayed by some drugs like ACEI or spirinolactone.

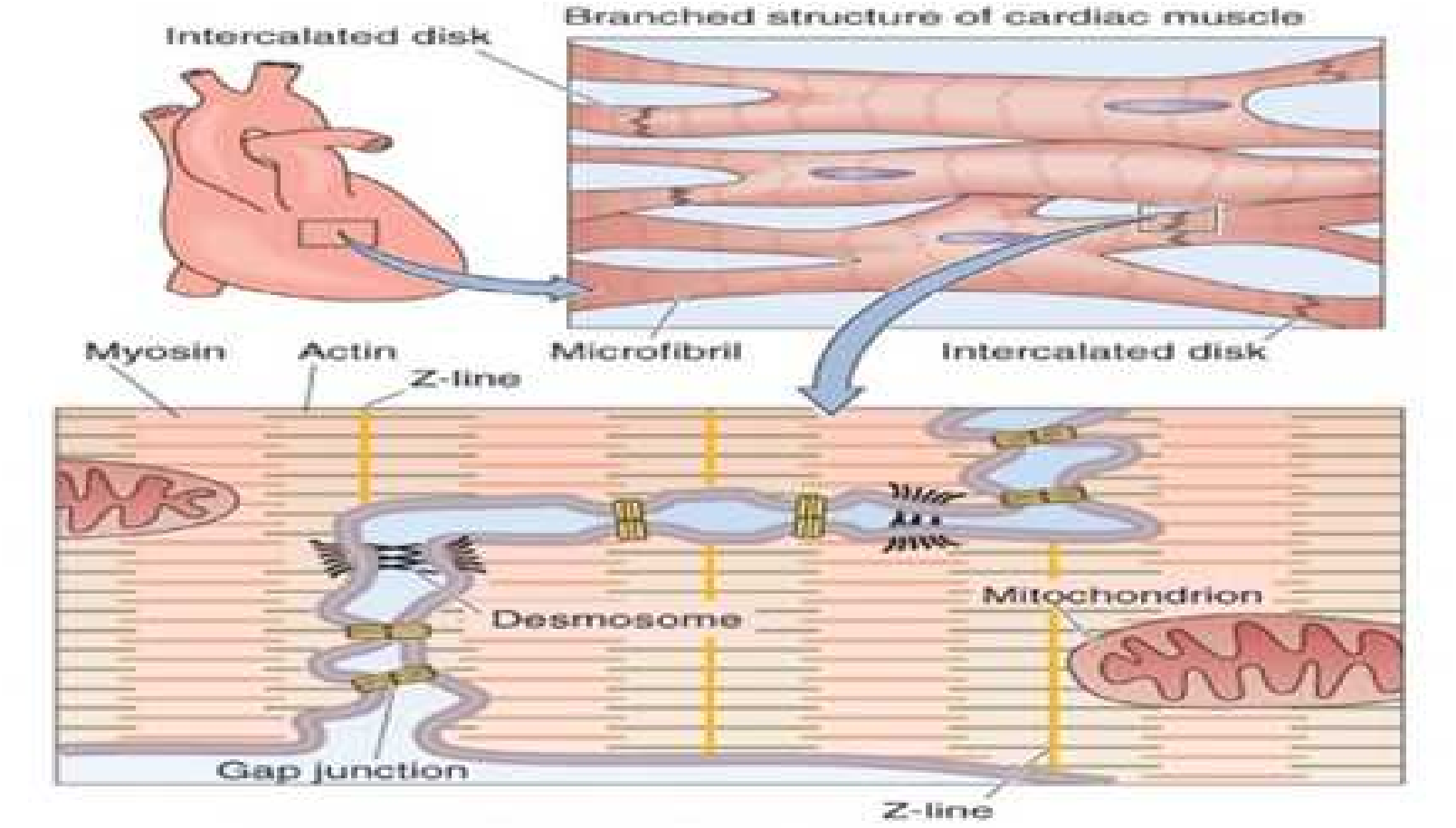
The myocardium is a syncytium

Functional syncytium;

- *atrial syncytium*
- *ventricular syncytium*



The myocardium is a syncytium



The myocardium is a syncytium

Two types of cell-to-cell junctions exist within these discs;

Desmosomes

- structural support
- To counteract mechanical stress that would tend to pull the cells apart.

Gap junctions

- **allow free diffusion of ions.**
- **the electrical impulse, or heart beat, spreads rapidly from one cell to another.**

The myocardium is a syncytium

As a result, the myocardium is a syncytium in which the initiation of a heart beat in one region of the heart results in stimulation and contraction of all cardiac muscle cells at the same time.

The heart is actually composed of two syncytium: **atrial and ventricular.** In each case, but particularly in the ventricles, simultaneous stimulation of all the muscle cells results in a more powerful contraction, facilitating the pumping of blood.

The heart pacemaker

Skeletal muscle is neurogenic and requires stimulation from the somatic nervous system to initiate contraction.

Cardiac muscle, is *myogenic* , or self-excitatory; this muscle spontaneously depolarizes to threshold and generates action potentials without external stimulation.

The heart pacemaker

- The region of the heart with the fastest rate of inherent depolarization initiates the heart beat and determines the heart rhythm. In normal hearts, **in which alot of Na leakage channel are present , those channels are starting pacemaker activity**

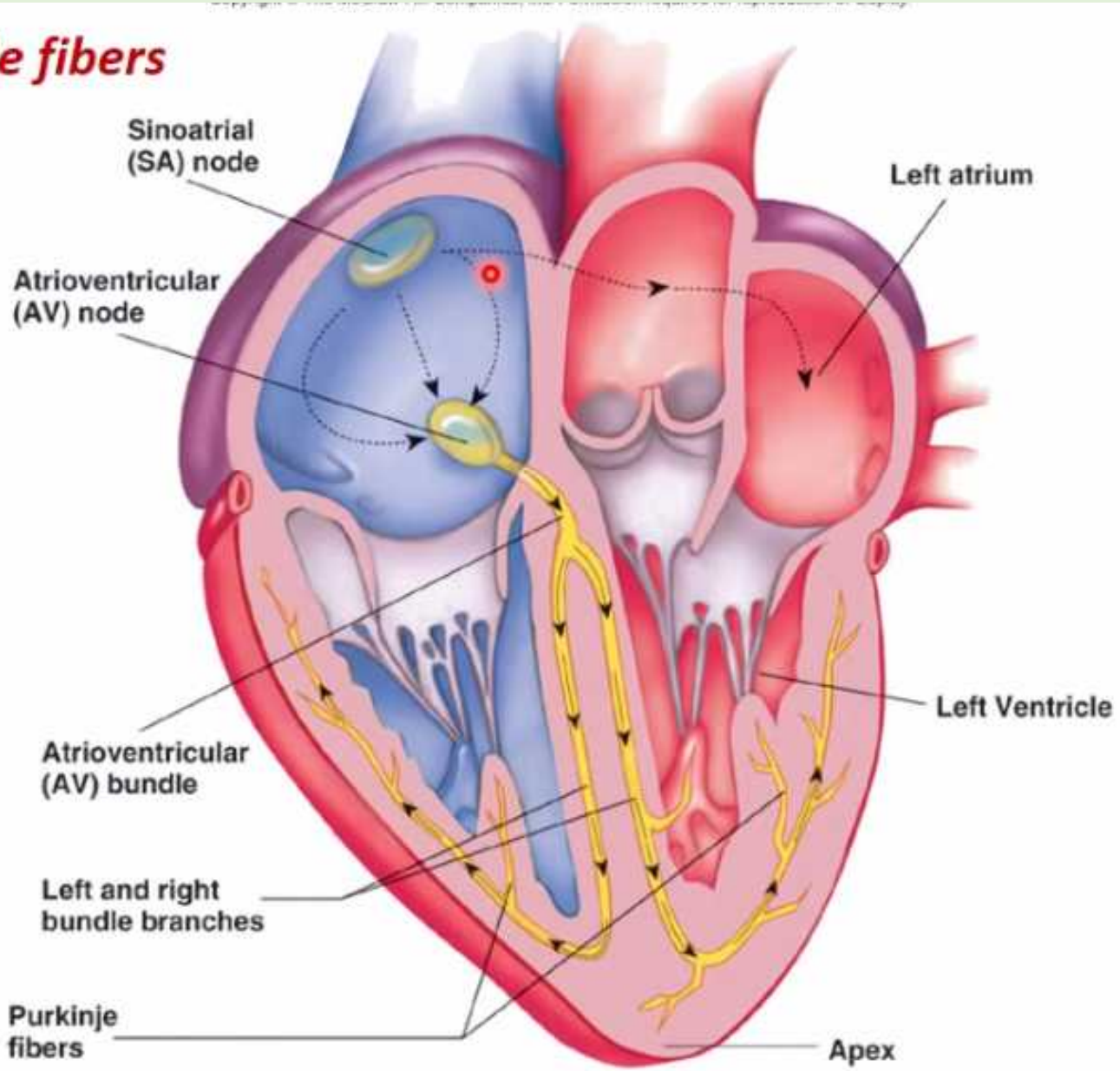
- **this " *pacemaker* " region is the sinoatrial node.**

The heart pacemaker

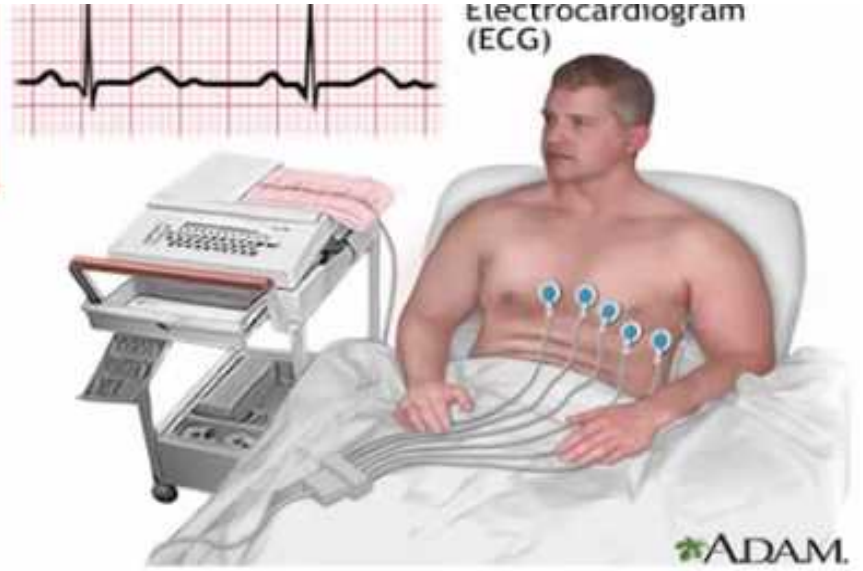
Auto-rhythmic muscle fibers

SA node has property of ***'Autorythmicity'***

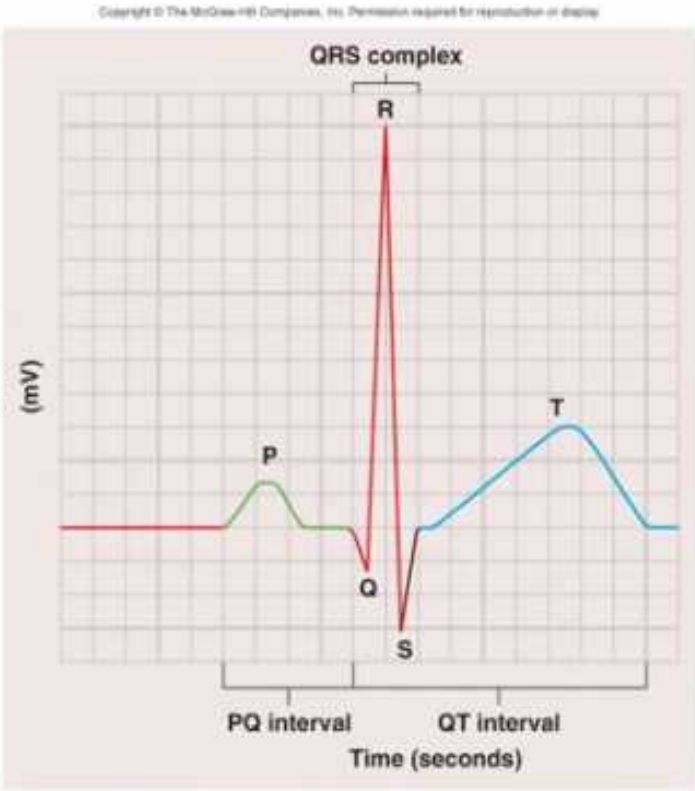
Tachycardia vs. Bradycardia



ECG

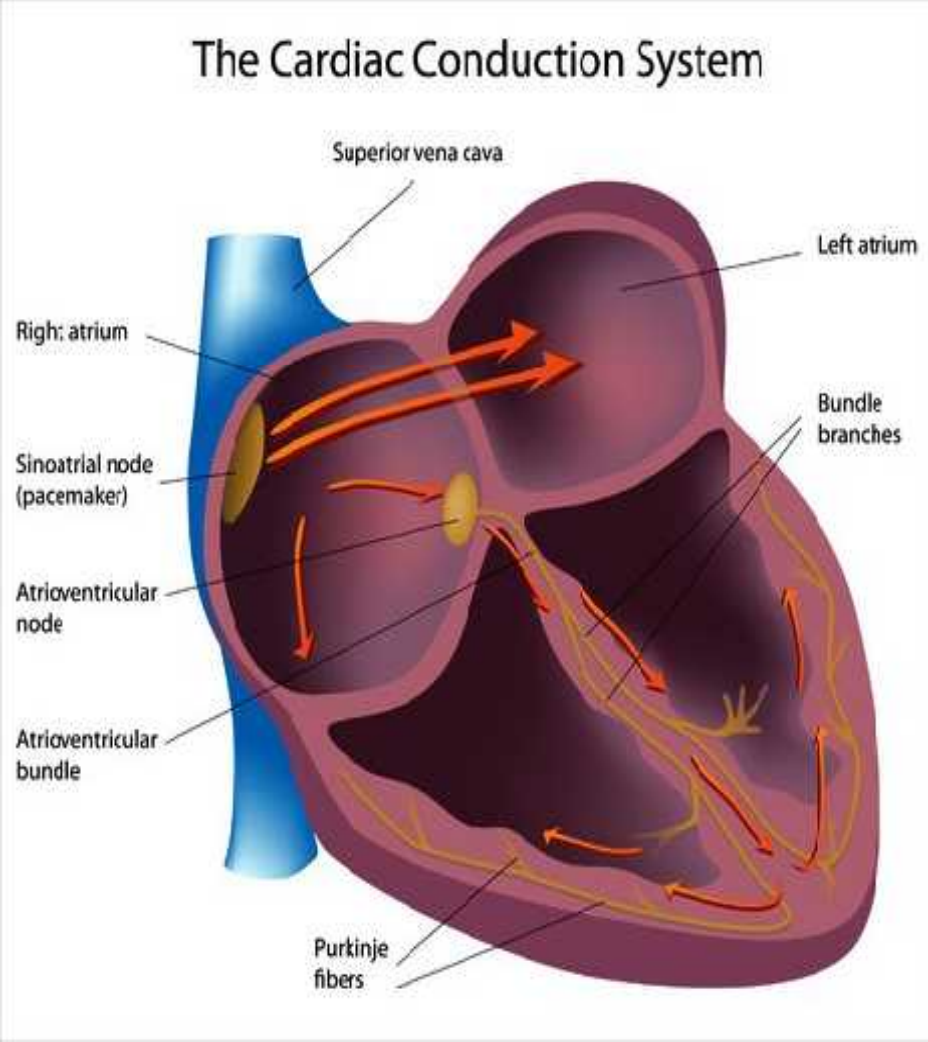


- **P wave**:signals onset of **atrial contraction**
- **QRS complex**: signals onset of **ventricular contraction**.
- **T wave**: repolarization of ventricles; precedes ventricular relaxation



locations of autorhythmic cell regions (superior to inferior);

1. sinoatrial (SA) node
2. atrioventricular (AV) node
3. atrioventricular (AV) bundle
4. right & left bundle branches
5. purkinje fibers

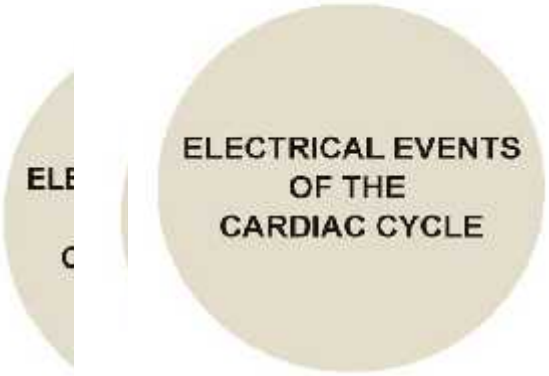


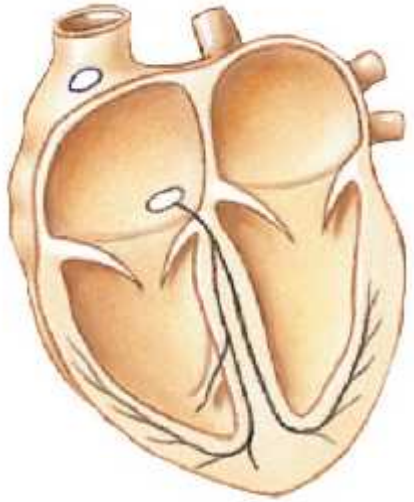
Cardiac cycle:

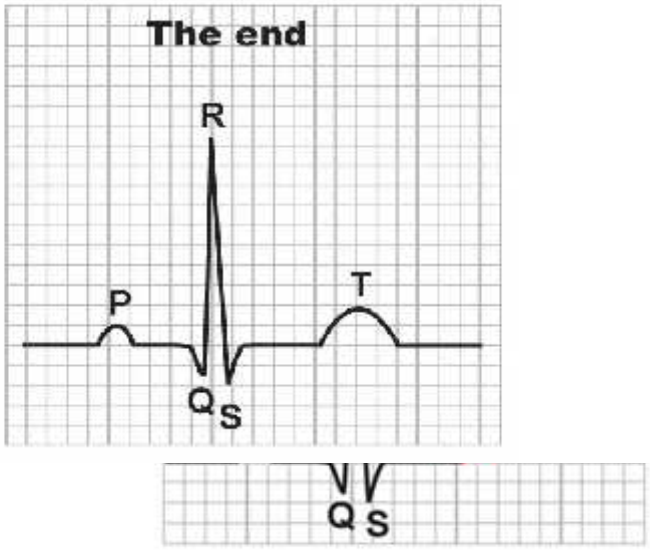
1. The atria contract at the same time (atrial **systole**)
2. The ventricles then contract at the same time (ventricular **systole**)
3. The entire heart then relaxes (**diastole**)
4. When ventricles are in systole, atria are in diastole (passive filling)

Cardiac cycle:

Cardiac cycle is the sequence of events as blood enters the atria leaves the ventricles and then starts over.



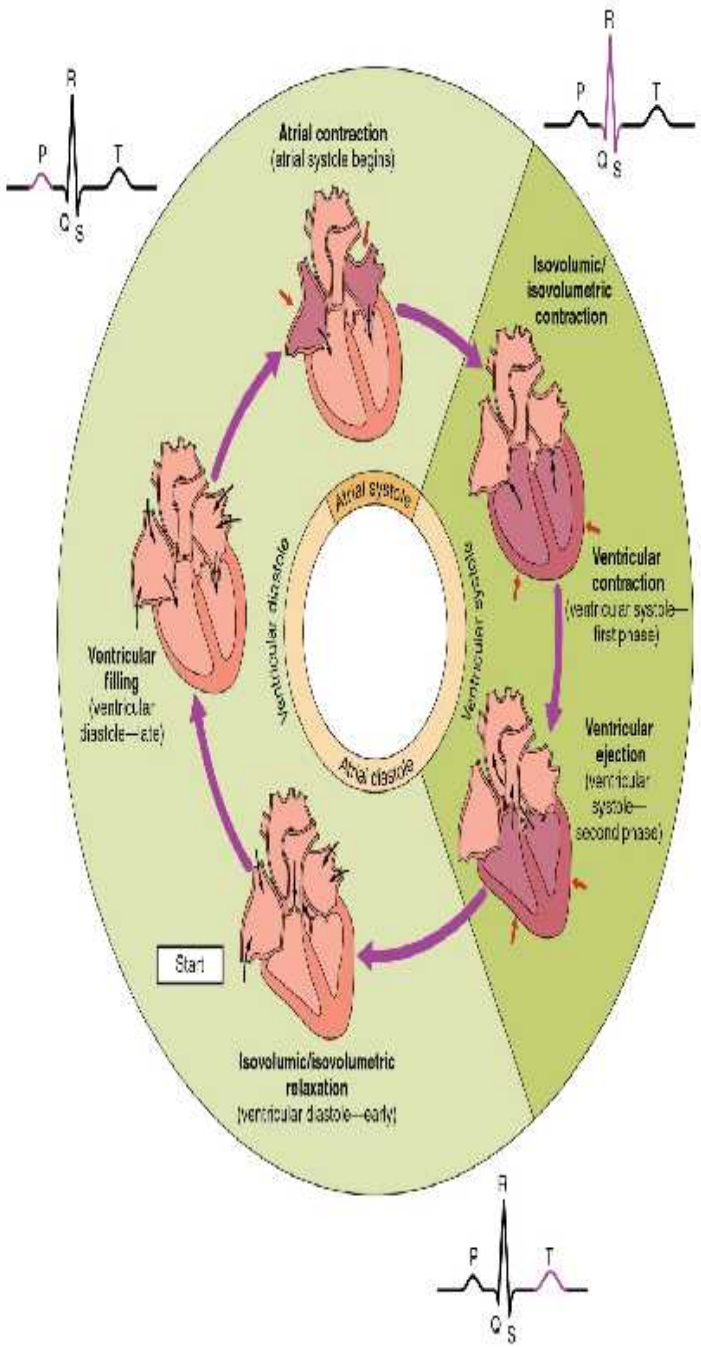




Cardiac cycle:

Phases of the cardiac cycle:

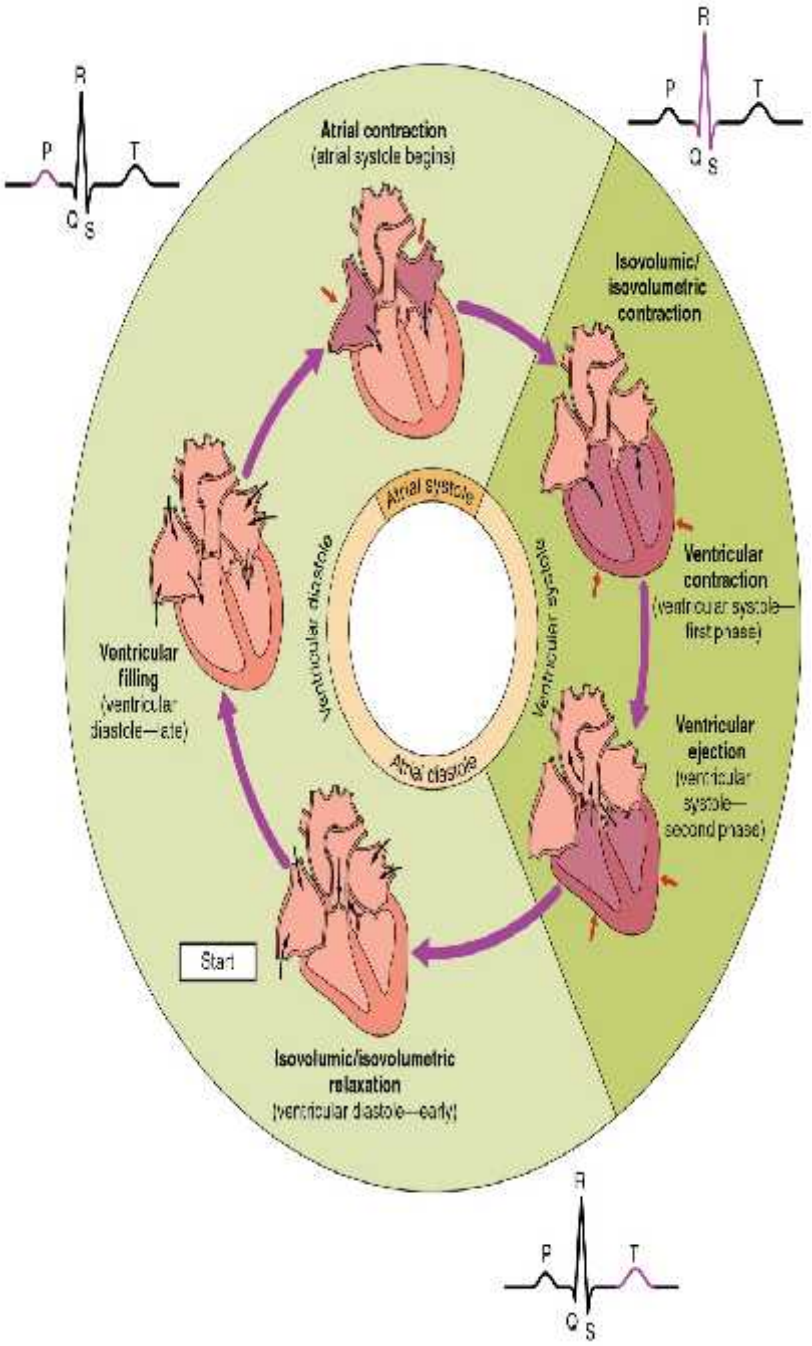
- **atrial systole**
- **ventricular systole**
- **diastole of the whole heart.**



Cardiac cycle*:*

<u>The cardiac events that occur from the beginning of one heart beat to the beginning of the next beat</u>

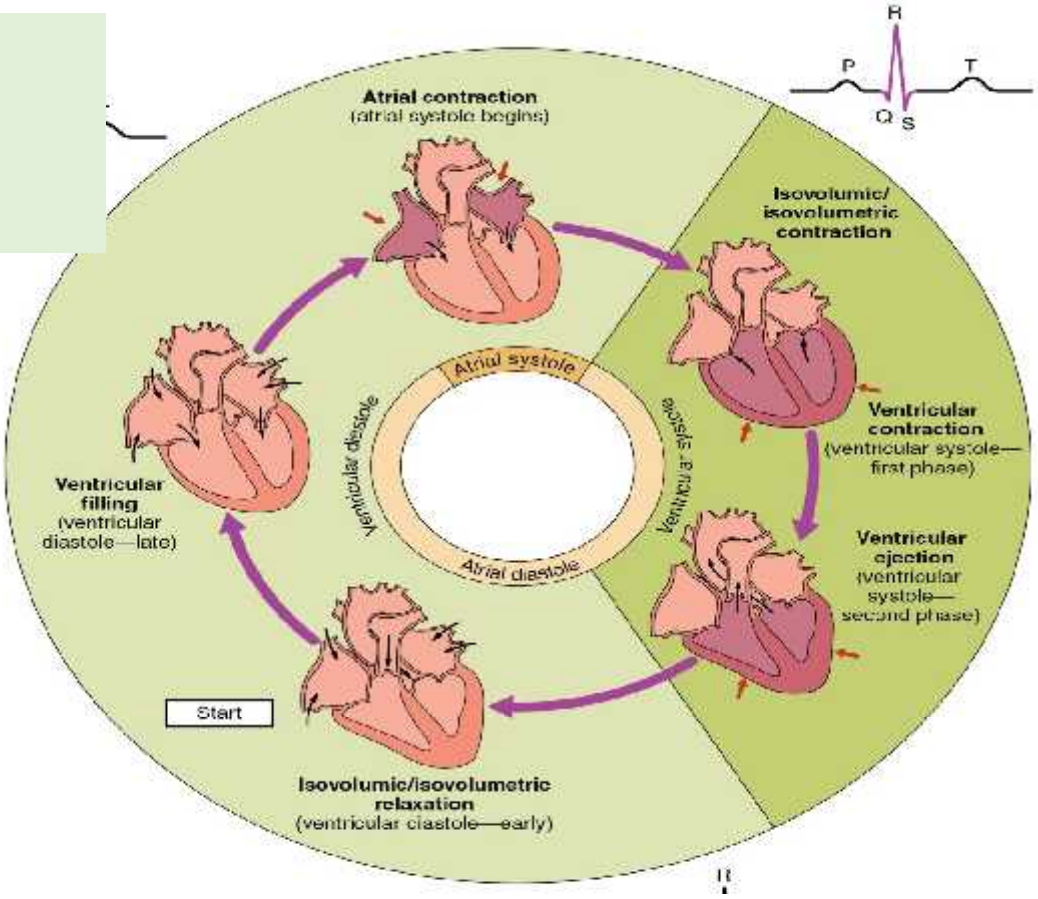
the atria act as *primer pumps* for the ventricles, and the **ventricles** in turn provide the major source of power for **moving blood through the body's vascular system.**



Cardiac cycle:

- **The duration of each cardiac cycle lasts about 0.8 second;**
- **For the Atria**,
- the cycle lasts for about **0.15** second in **systole** and **0.65** second in **diastole**.
- **For the ventricles**
- **The diastole;** a period of ventricular relaxation in which the ventricles fill with blood and it last for about **0.50** second.
- **The systole;** a period of ventricular contraction and blood ejection, lasting about **0.30** second.

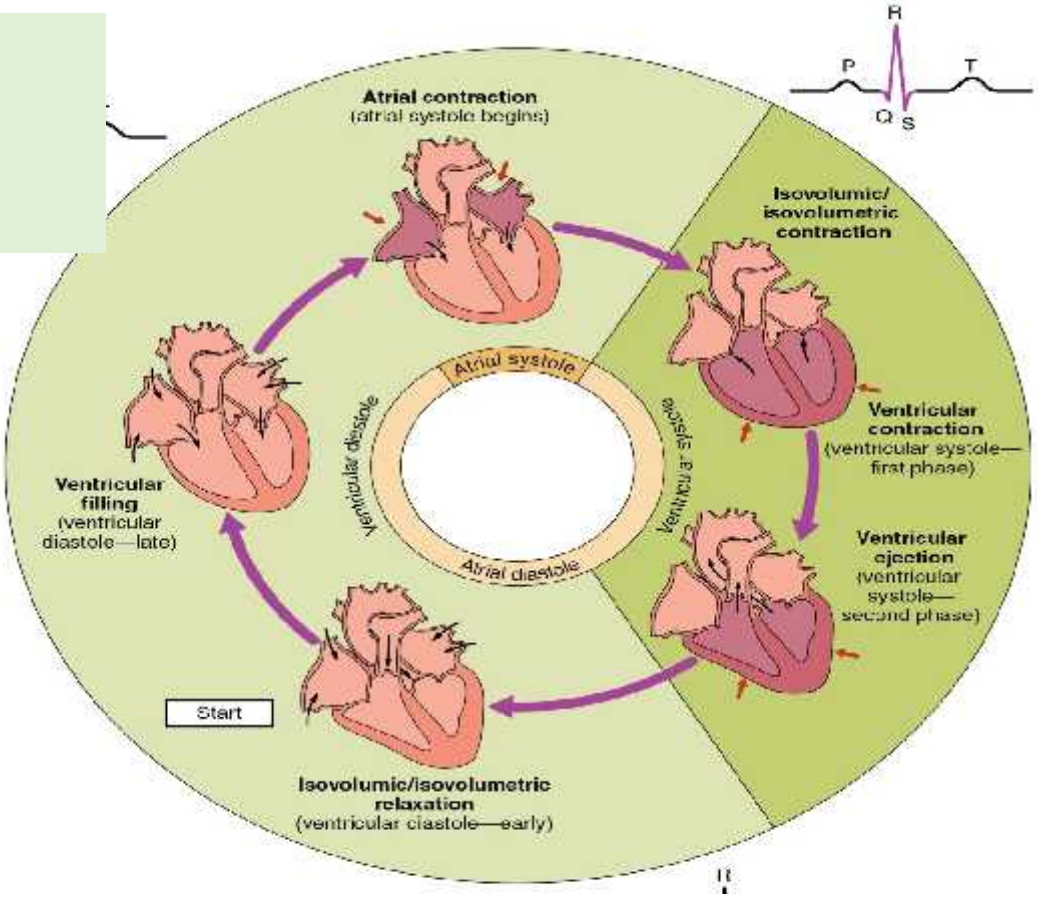
Cardiac cycle:



Atrial systole (atria as a pump): 0.15 sec

- about 75% of the blood in the atria flow directly into the ventricles even before the atrial contraction.
- Then, atrial contraction usually causes an additional 25% filling of the ventricles.

Cardiac cycle:

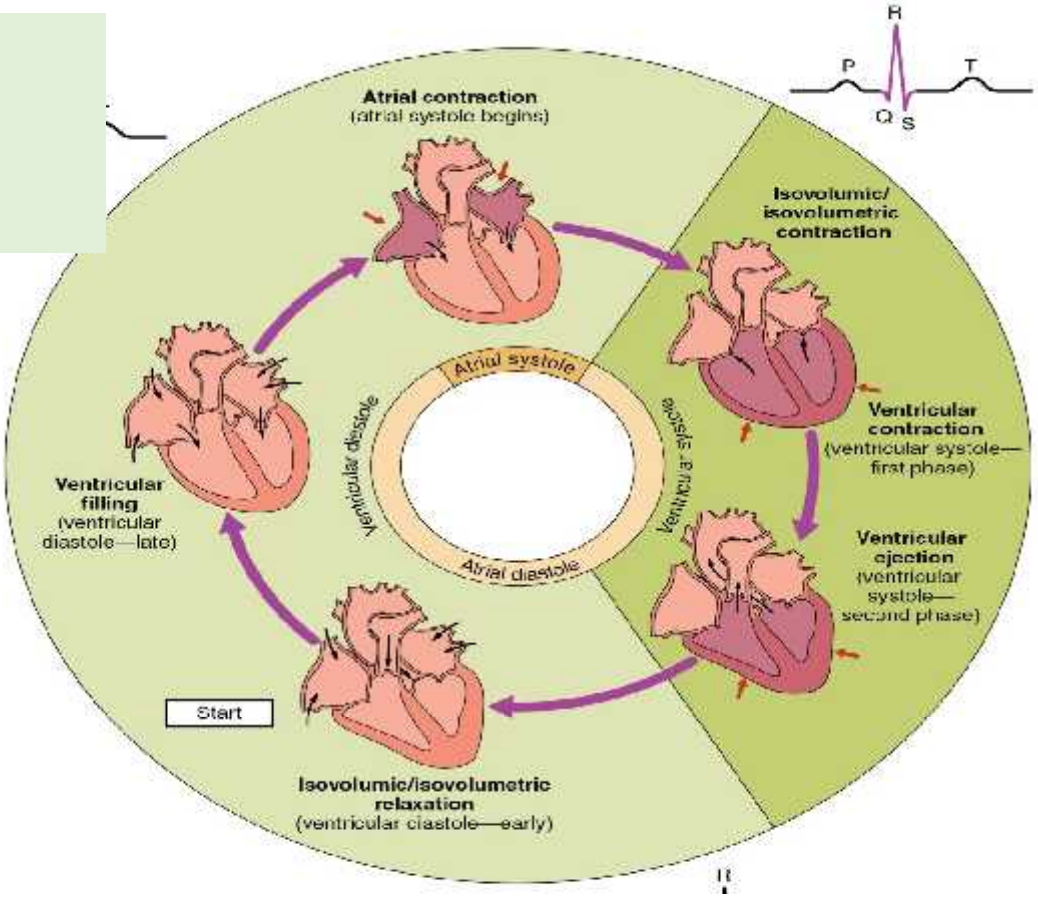


Ventricular cardiac cycle

1- Ventricular filling 0.50 sec

- the AV valves open and allow blood to flow rapidly into the ventricles.

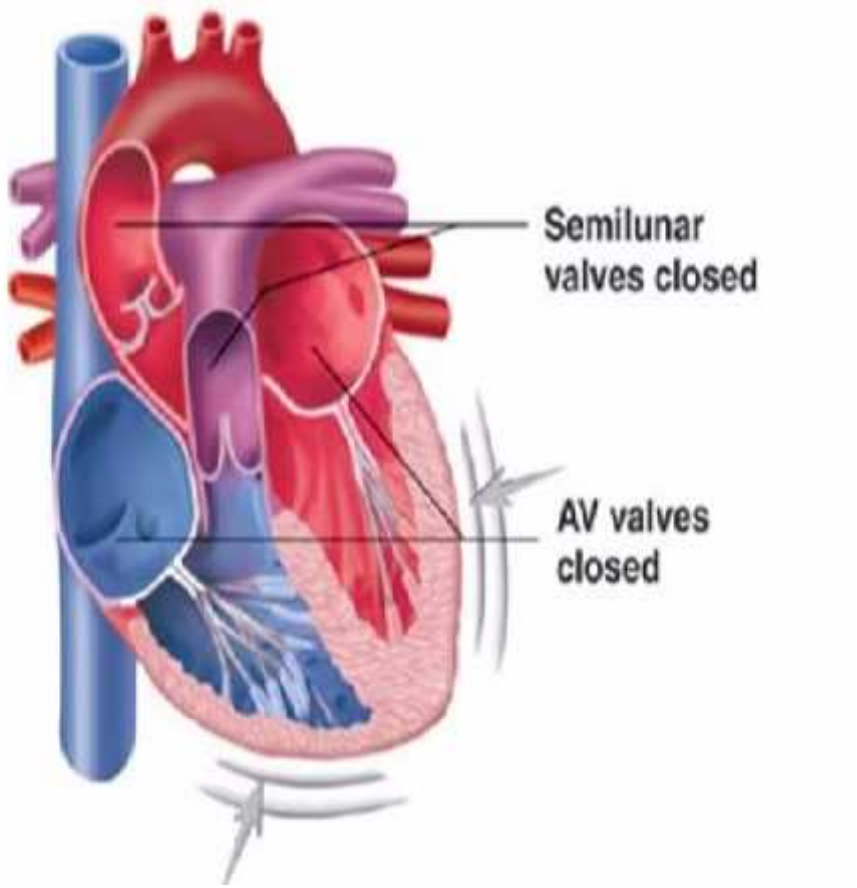
Cardiac cycle:



2-Ventricular systole: 0.30 sec

- **Isovolumic, isometric contraction** (isovolumetric contraction).
- **Ventricular ejection.**

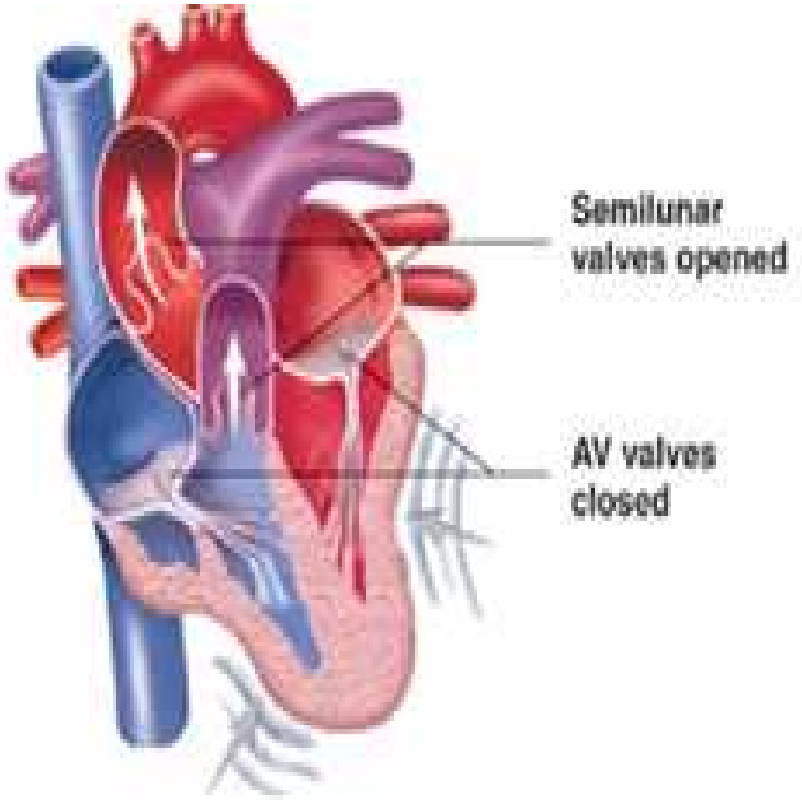
Cardiac cycle:



A-Isovolumetric contraction

- **It is ventricular contraction but without blood ejection (no emptying)**
- means that only the tension is increasing in the ventricular muscle without shortening of the muscle and with no change in blood volume.

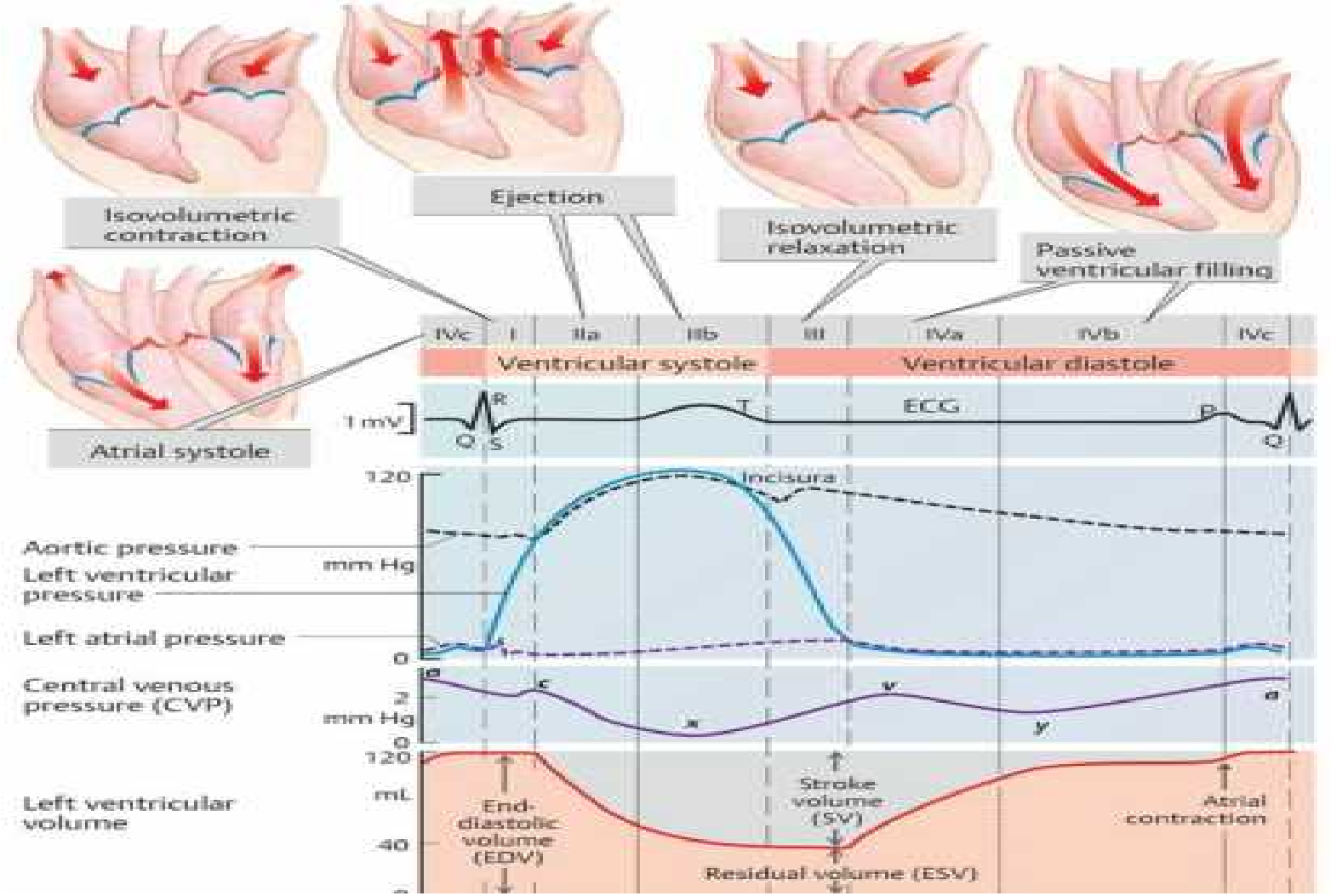
Cardiac cycle:



B-Ventricular ejection

- **The blood ejected from the ventricles into pulmonary trunk and aorta when the ventricular pressure rises and forces the semilunar valves open.**
- **Left ventricular pressure** rises above **80 mmHg. Right ventricular pressure** rises above **8 mmHg.**

Cardiac cycle:



Cardiac cycle regulation

1. The amount of blood pumped at any one time must adjust to the current needs of the body (more is needed during strenuous exercise).

2. The S-A node is innervated by branches of the sympathetic and parasympathetic divisions, so the **CNS (central nervous system) controls heart rate.**

3. ***Sympathetic*** ('fight or flight')
   - increases heart rate and force of contraction
   - increased cardiac output (CO)

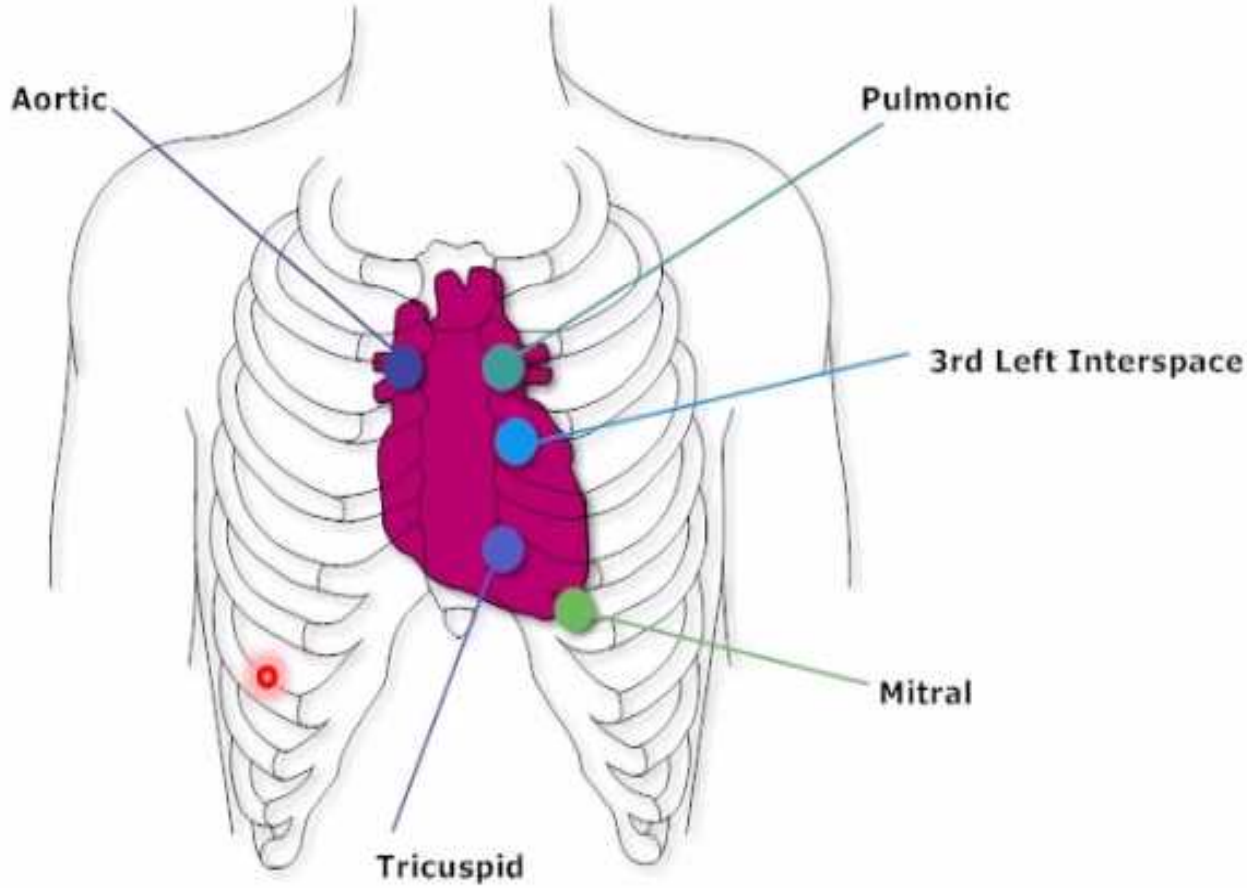
4. ***Parasympathetic*** ('rest & digest')
   - Decrease in heart rate

Heart sound

- **Heart Sounds**
  1. Heart sounds can be described as a ***"lubb-dupp"*** sound.
  2. The first sound **(*lubb*)** occurs as ventricles contract and *A-V valves are closing*.
  3. The second sound **(*dupp*)** occurs as ventricles relax and *aortic and pulmonary valves are closing*.

- **Auscultation** –listening to heart sounds using a stethoscope

Heart sound



Anterior view of torso, heart in ribcage.

Blood pressure

- **Systolic pressure** –arterial blood pressure at maximal ventricular contraction
- **Diastolic pressure-** pressure in arterial system during ventricular relaxation
- **120 mmHg / 80 mmHg** = 'normal' blood pressure = aortic pressures

Cardiac output

CO = 'Cardiac Output';

- amount of blood pumped by the heart per minute

  - **CO = SV x HR**

SV = Stroke volume (blood pumped from the left ventricle during each heart beat)

HR = Heart rate (number of times heart beats per minute)

Thank you