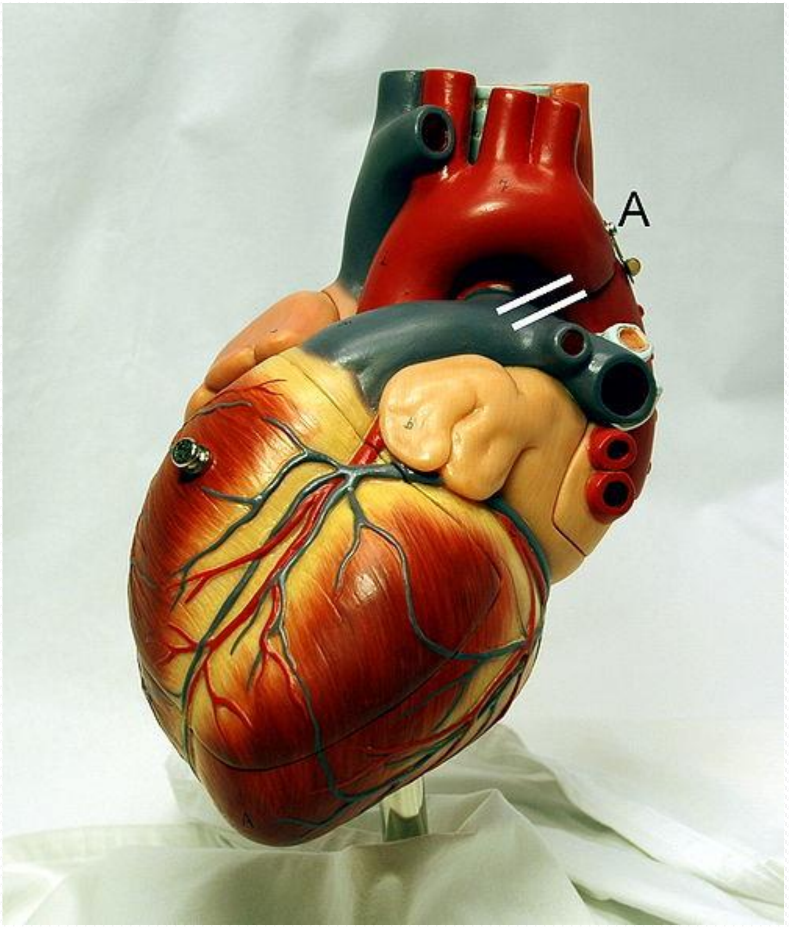
بسم الله الرحمن الرحيم

السلام عليكم ورحمة الله وبركاته

Cardiovascular System Block
Cardiac Cycle- 1
(Physiology)

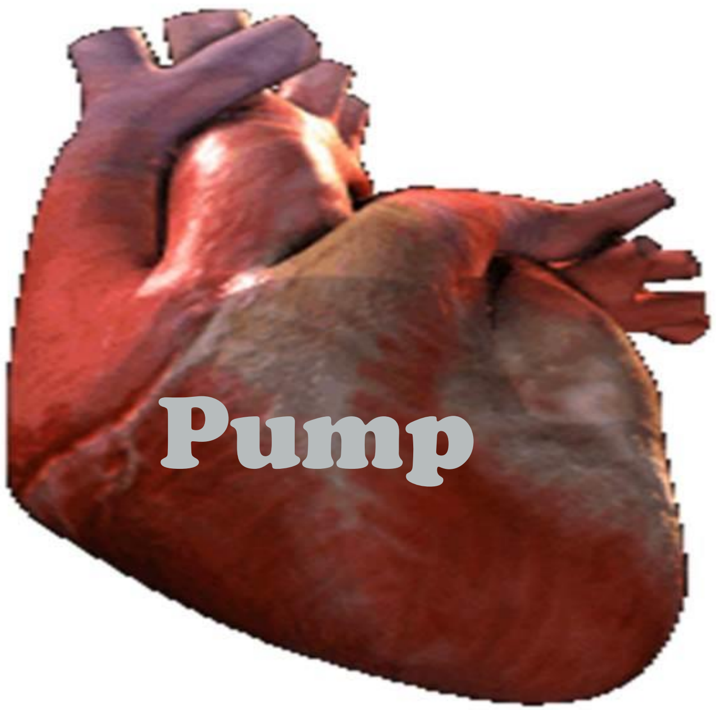


Dr. Hayam Gad
MBBS, MSc, PhD
Associate Professor Of Physiology
College of Medicine, KSU

Learning Objectives

1. Main Function of the Heart
2. Cardiac Cycle Time
3. Phases of the Cardiac Cycle
4. ventricular Volume during Cardiac cycle

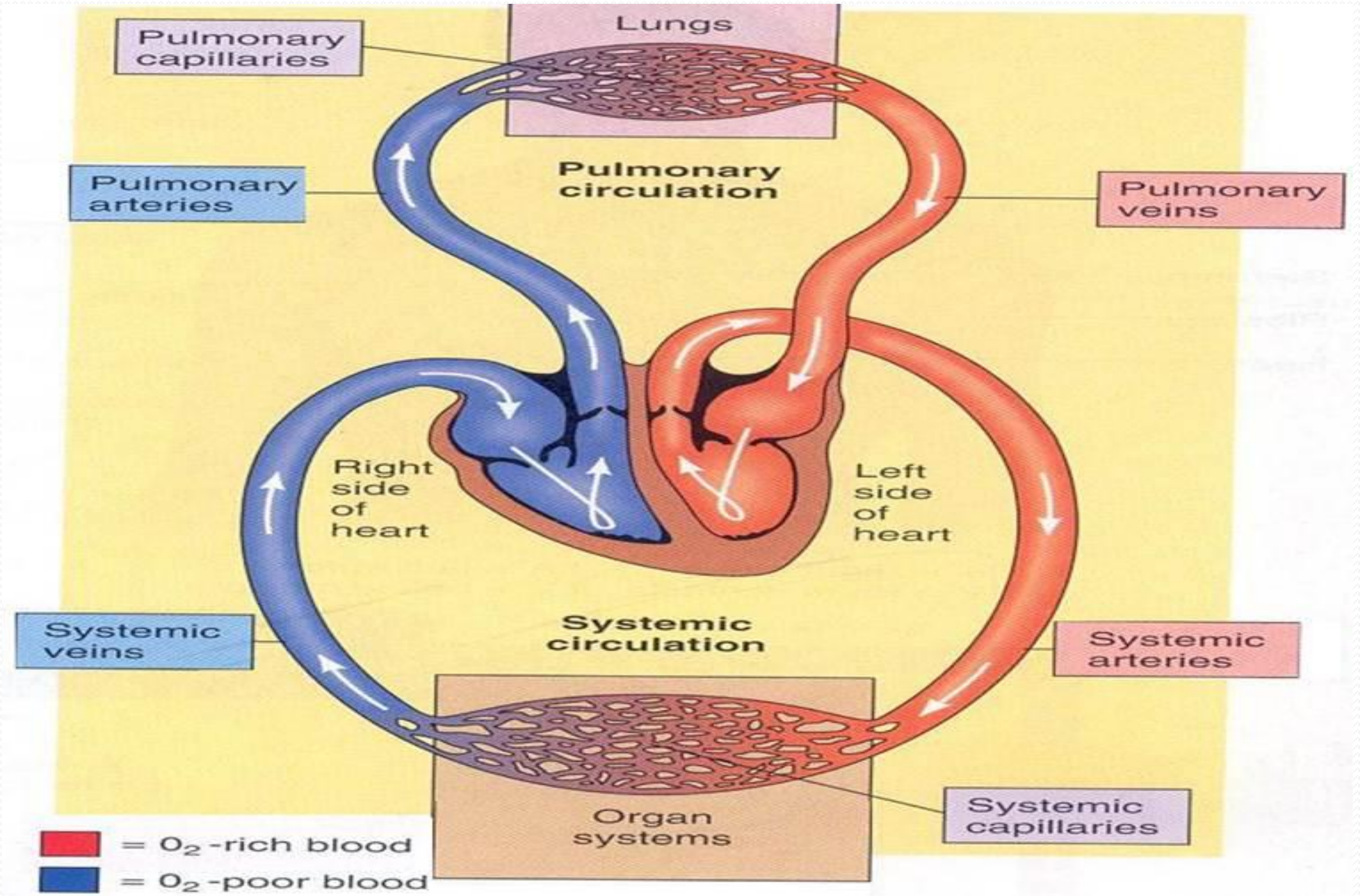
Function of the Heart



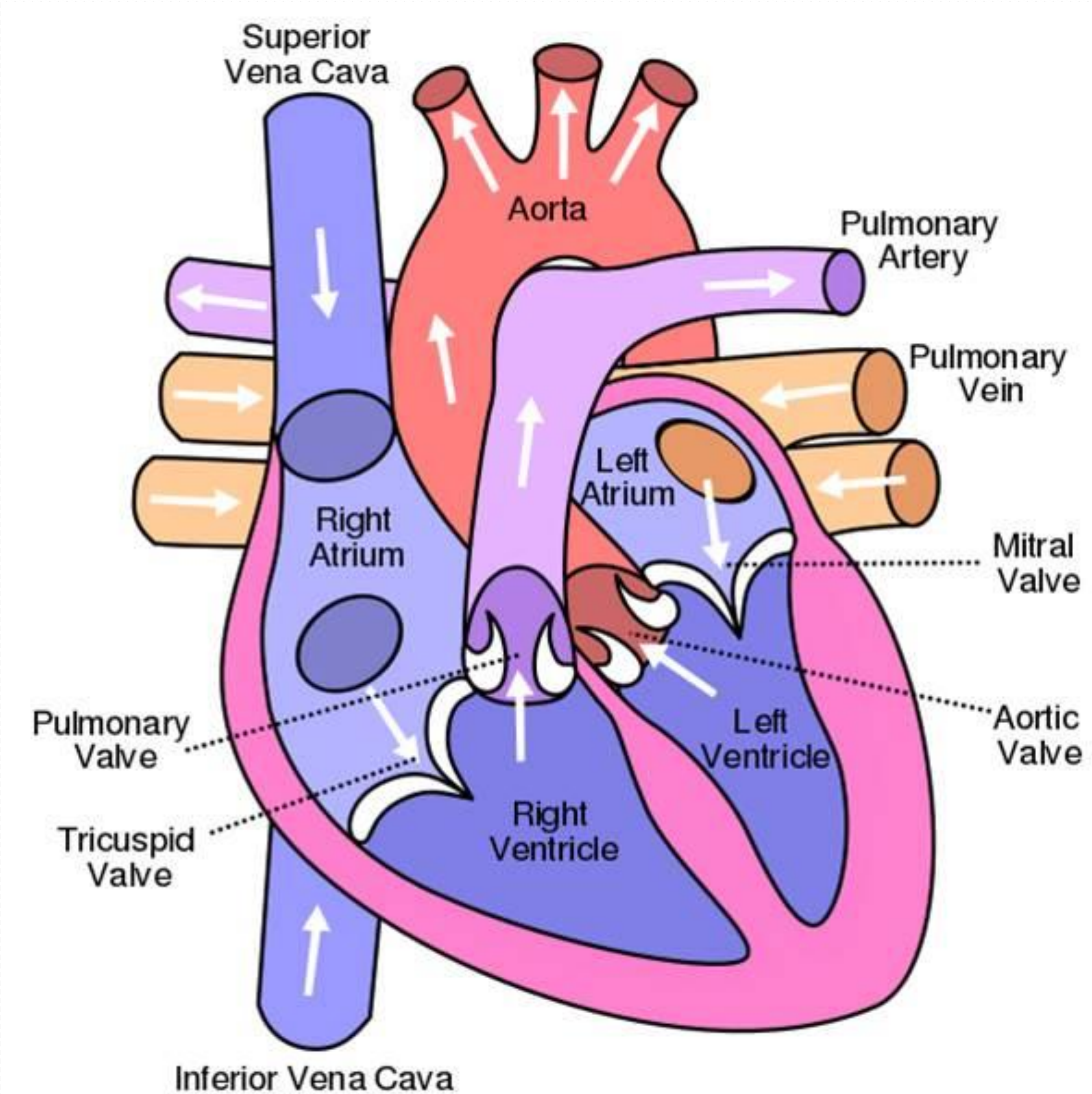
The Heart is a double pump

Heart is a double pump (right & left) that work together.

Systemic & Pulmonary circulation work together



Intracardiac Blood circulation



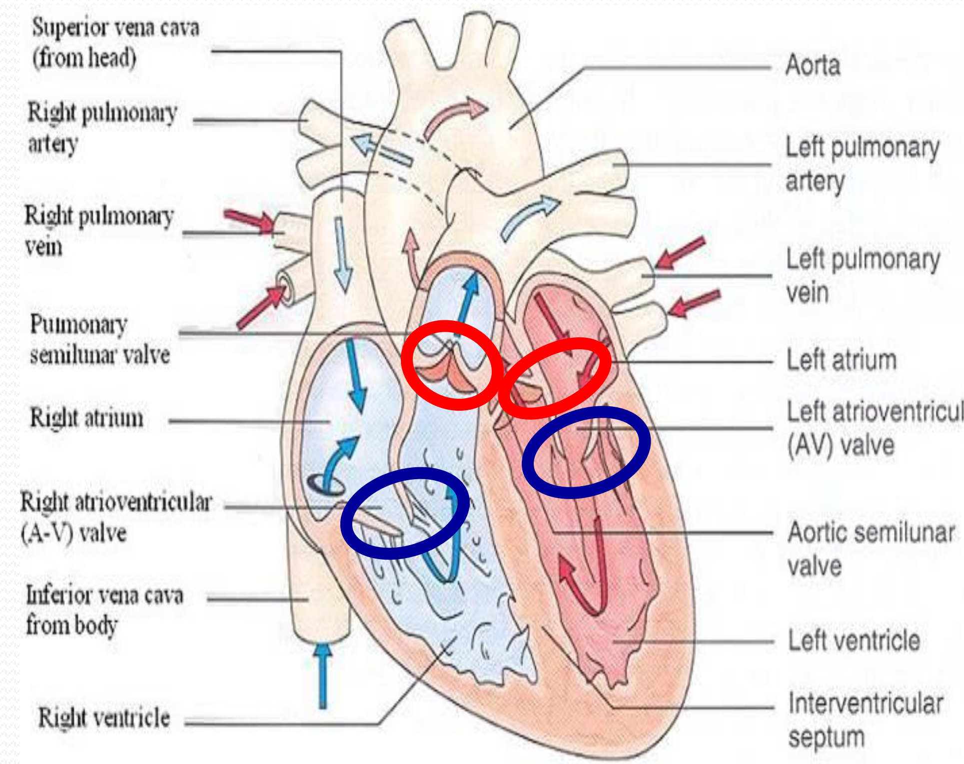
Valves of the heart

Atrioventricular valves:

1. <u>Tricuspid valve</u>: between right atrium & right ventricle.
2. <u>Mitral valve</u>: between left atrium & left ventricle.

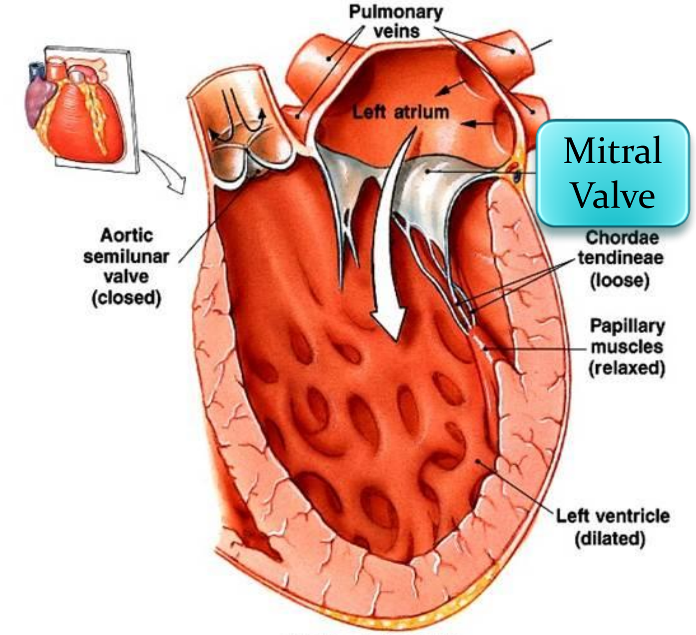
Semilunar valves:

1. Pulmonary valve: between right ventricle & pulmonary artery.
2. Aortic valve: between left ventricle & aorta.

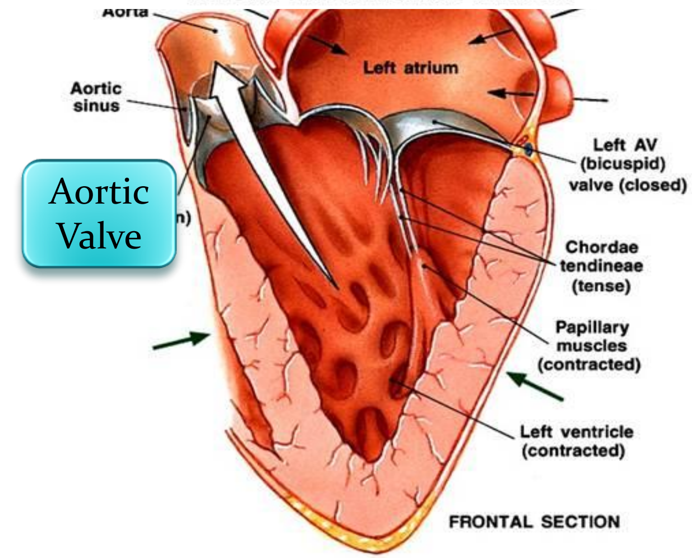


Functions of the Valves

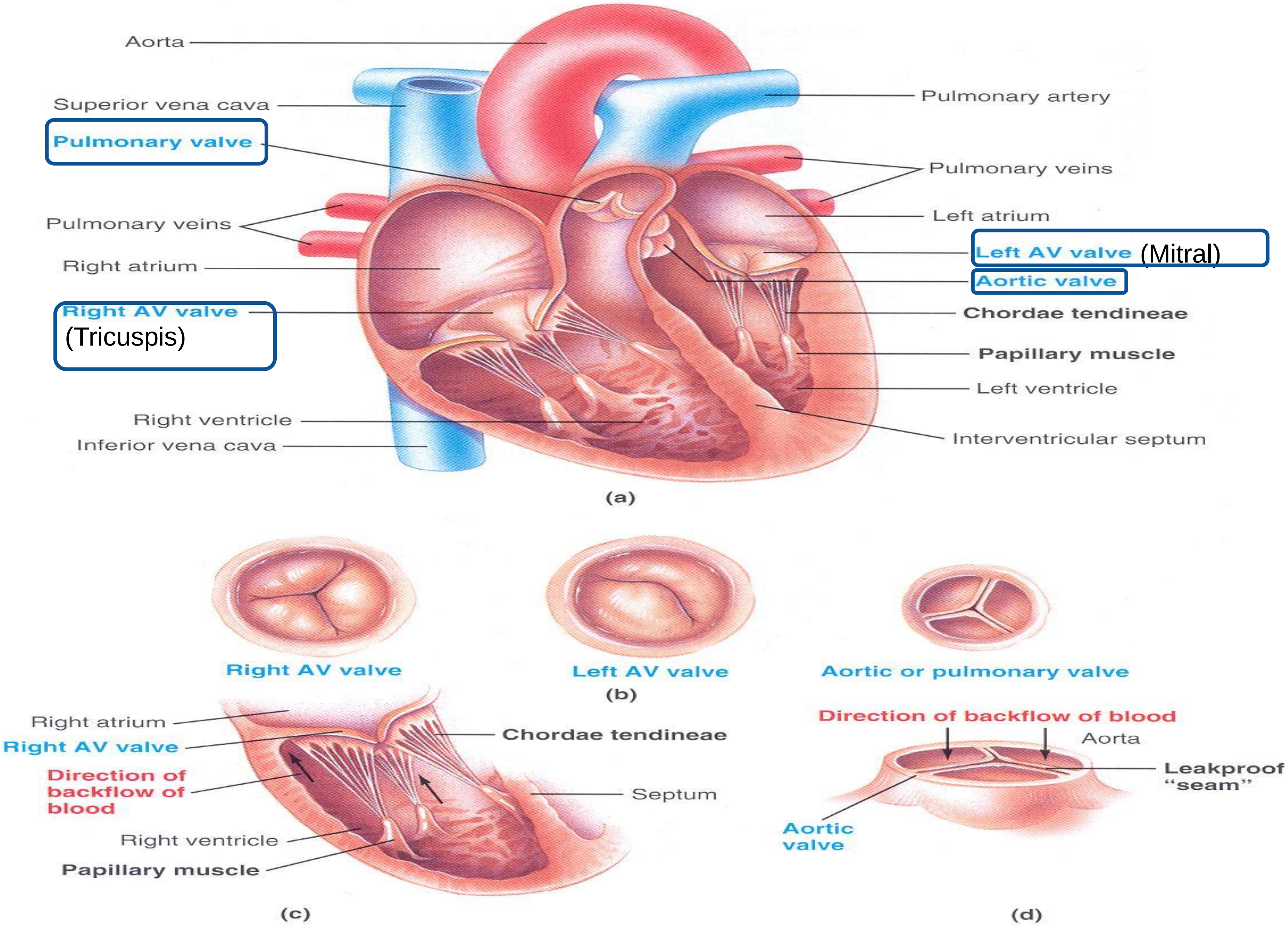
- Valves allow blood to flow in only <u>ONE</u> direction.
- Opening & closure of valves occur as a result of pressure gradient across the valve.
- When A-V valves open, semilunar valves close & vice versa.
- A-V cusps are held by chordae tendinea to muscular projections called "Papillary muscles".



FRONTAL SECTION THROUGH LEFT ATRIUM AND VENTRICLE



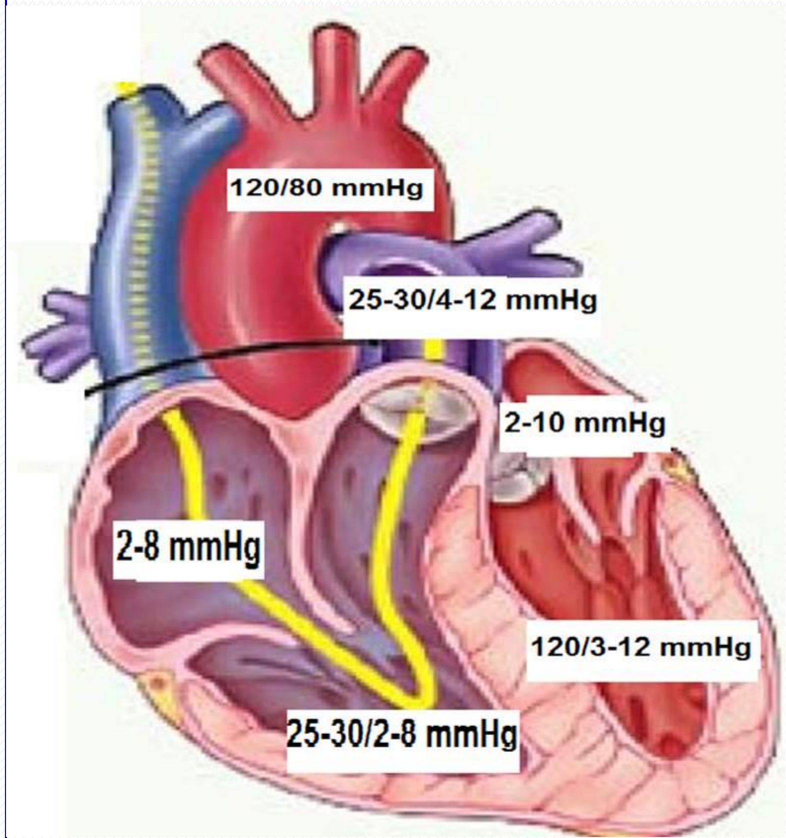
FRONTAL SECTION



Heart valves

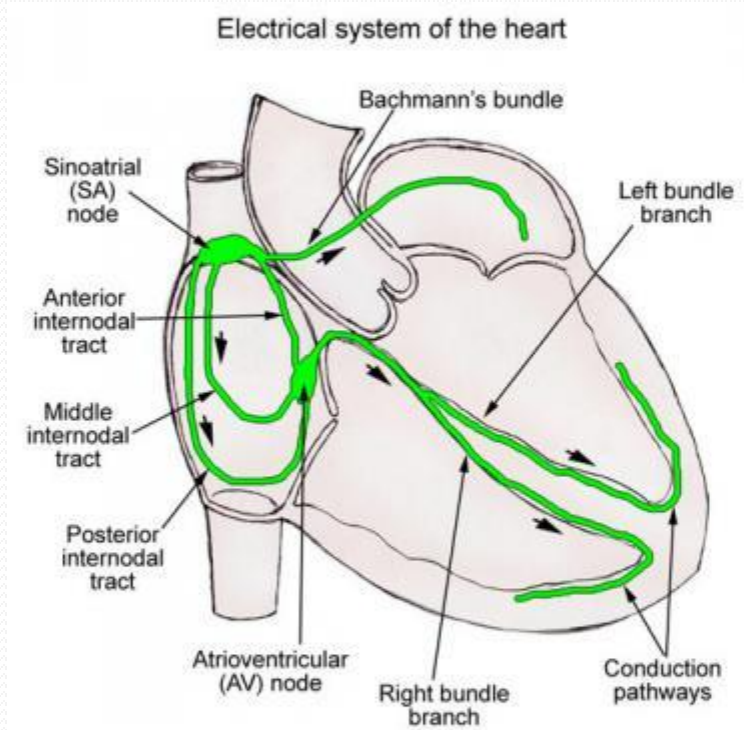
General Principles

- Contraction of the heart generates pressure changes & results in orderly blood movement.
- Blood flows from an area of high pressure to an area of low pressure.
- Events are the same in the right & left sides of the heart, but with lower pressures in the right side.
- Atrial & ventricular systole do not occur at same time, but their relaxation occurs at same time during diastole of whole heart which lasts for 0.4 sec.



The Cardiac Cycle

- Sequence of events that take place in the heart in each beat (from the beginning of one heart beat to beginning of the next one).
- Each cycle is initiated by depolarization of S-A node, followed by contraction of the atria.
- The signal is transmitted to ventricles through A-V node & A-V bundle to cause ventricular contraction.



Cardiac cycle Time

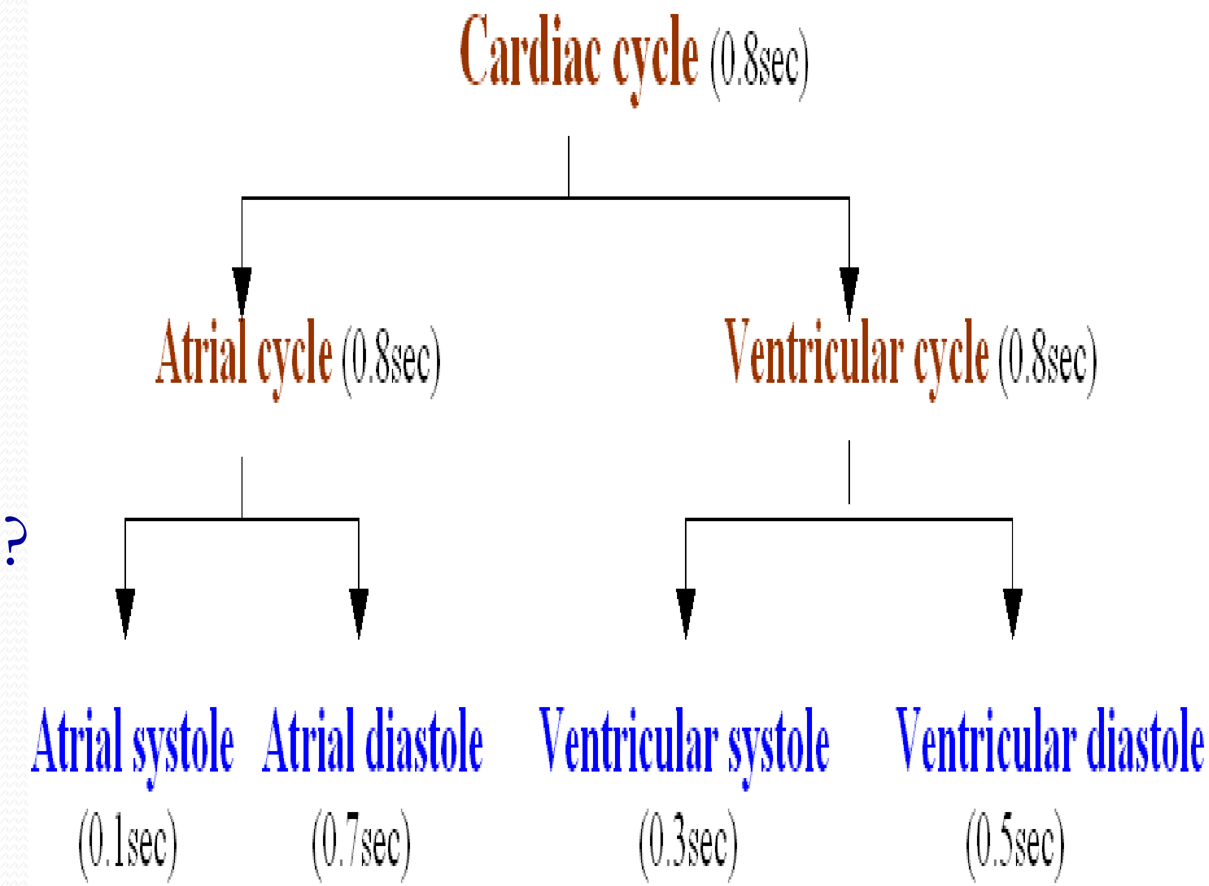
- This is time required for one complete cardiac cycle.
- When heart rate (HR) is 75 beats/min, the time will be 0.8 Sec

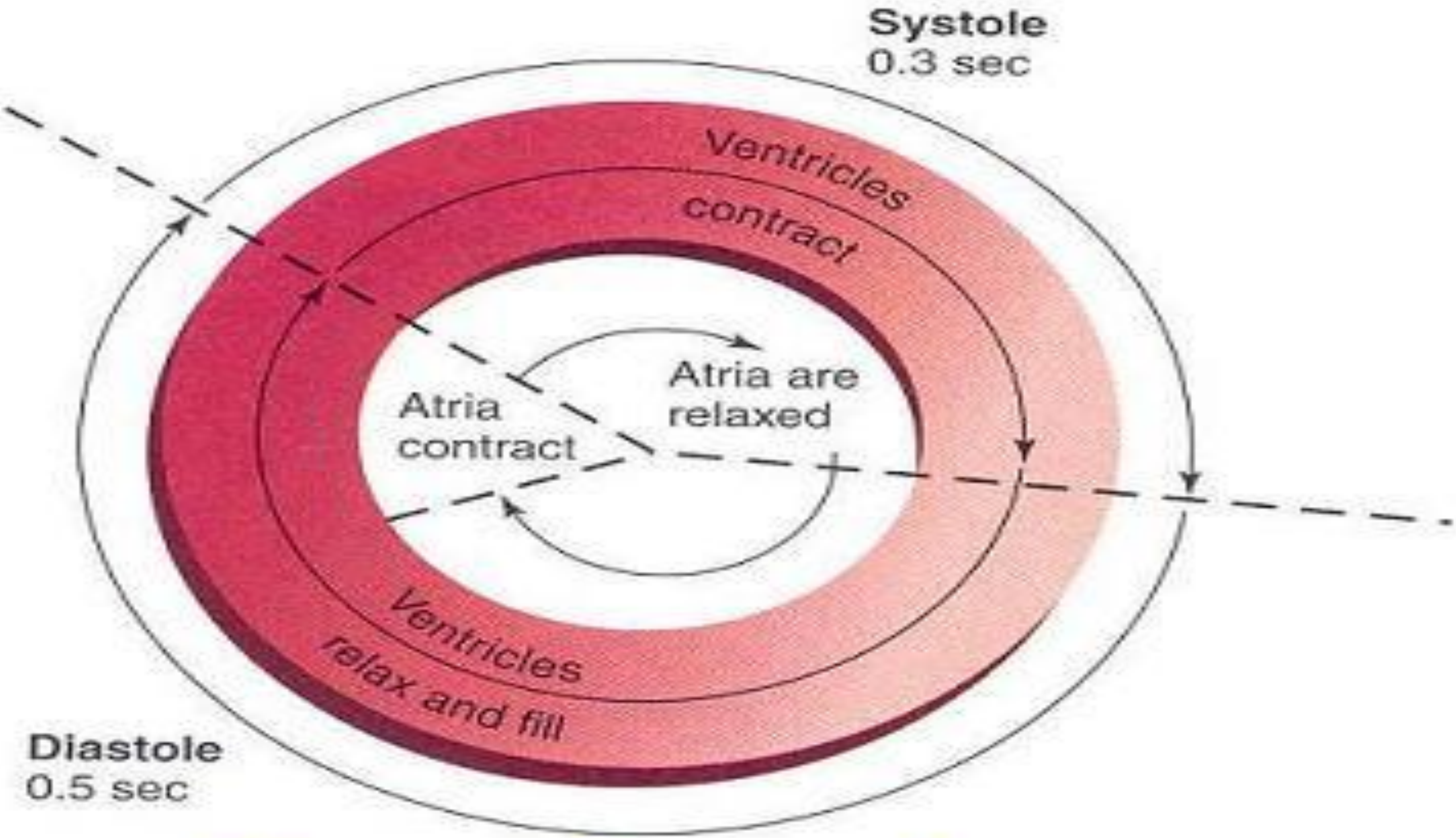
Cardiac cycle time= 60/HR = 60/75= 0.8 Sec.

- The time is inversely proportional to HR.
- Cardiac cycle starts by systole of both atria (0.1 sec), then systole of both ventricles (0.3 sec), then diastole of whole heart (0.4 sec).

Cardiac Cycle Duration

- **Cardiac cycle duration = 0.8 sec (w**hen HR 75 beats/min).
    - Ventricular systole = 0.3 sec
    - Ventricular diastole = 0.5 sec
    - Atrial systole = 0.1 sec
    - Atrial diastole = 0.7 sec
- Normally, diastole is longer > systole
- Importance of long ventricular diastole?
    - Coronary blood flow
    - Ventricular filling





The cardiac cycle

Definitions

- **End-diastolic volume (EDV):**

  Volume of blood in ventricles at the end of diastole = **110-130 mL.**

- **Stroke volume (SV):**

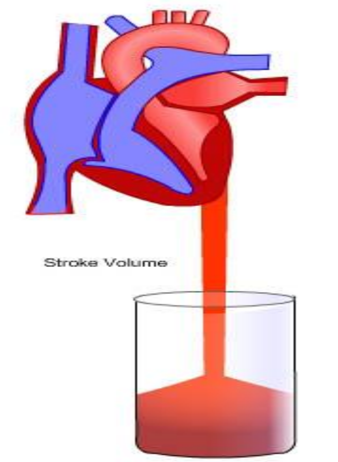
  Amount of blood ejected from ventricles during systole = **70 mL/beat.**

- **End-systolic volume (ESV):**

  Amount of blood left in ventricles at the end of systole = **40-60 mL.**

- **Ejection fraction (EF):**

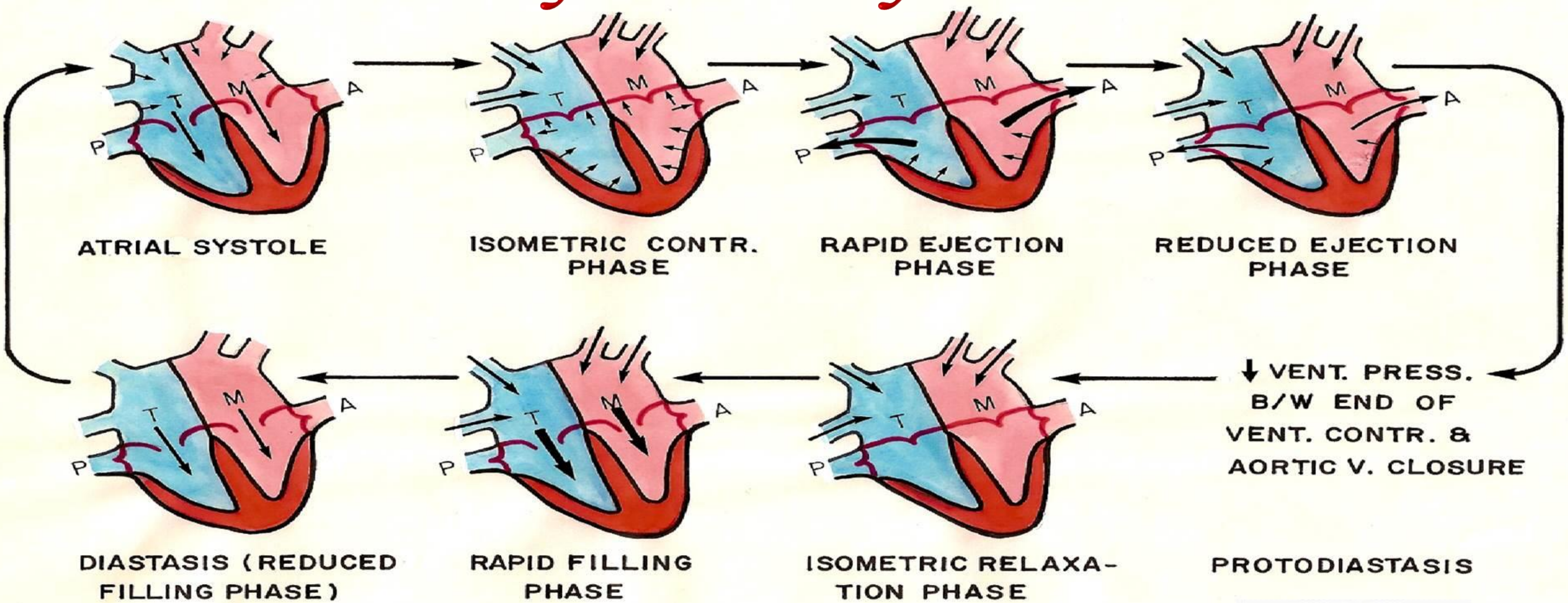
  Fraction of end-diastolic volume that is ejected = **60-65 %.**



Phases of cardiac cycle

- Atrial systole (0.1 sec.)
- Ventricular systole (0.3 sec.)
  - Isovolumic (isovolumetric) contraction phase (0.05 sec.)
  - Maximum ejection phase (0.15 sec.)
  - Reduced ejection phase (0.1 sec)
- Ventricular diastole (0.4)
  - Protodiastolic phase (0.04 sec.)…..????
  - Isovolumic (isovolumetric) relaxation phase (0.06 sec.)
  - Rapid filling phase (0.1 sec.)
  - Reduced filling phase (0.2 sec.)

Phases of Cardiac Cycle: 7 Phases



N.B. ? Considered ‘8’ phases if including 1st phase of diastole

Events in the cardiac Cycle

1. Mechanical events
2. Ventricular volume changes
3. Pressure Changes
4. Heart Sounds
5. Electrical Events (ECG)

1- Atrial Systole:

- It is a phase of atrial contraction, occurs at end of ventricular diastole
- It lasts for ≈ 0.1 sec.
- It is preceded by atrial depolarization.
- Valves: A-V valves open (semilunar valves closed). blood goes from atria to ventricles.
- Ventricular volume: ↑ due to blood passage into ventricle. It reaches the end diastolic volume (EDV) 130 ml.
- Ventricular pressure: First slightly ↑ due to entry of blood from atria. Then ↓ due to dilatation of ventricles. In both cases, it is less than atrial P.
- Atrial pressure: First ↑ due to systole of atria. Then ↓ due to blood passage into ventricles.
- 4^{th} Heart sound heard.

2- Isovolumetric Contraction Phase:

- It occurs at beginning of ventricular systole. It lasts for ≈ 0.04 sec.
- Starts with closure of A-V valves.
- 1st Heart sound heard.
- Semilunar valves: Still closed.
- Ventricle is a closed chamber. It contracts with no changes in volume (isometrically, no shortening)
- Volume in ventricle = EDV
- Ventricular pressure ↑ suddenly
- Aortic valve opens at the end of this phase, when LV exceeds 80mmHg.
- Atrial pressure: ↑ due to doming of cusps of closed A-V valves into atria.

3- Maximum (Rapid) Ejection Phase:

- The ventricles contract isotonically (with shortening) pushing most of blood (75% of ventricular blood) into aorta & pulmonary artery.
- Duration: 0.15 sec.
- Semilunar valves open at beginning of this phase when LV pressure exceeds 80 mmHg.
- AV valves: Still closed.
- Ventricular pressure reaches 120 mmHg in left V .
- Ventricular volume: ↓ sharply due to shortening of ventricular wall and ejection of blood.
- Atrial pressure: First ↓ because when ventricles contract, they pull fibrous AV ring with AV valves downward thus ↓ atrial P.

4- Reduced Ejection Phase:

- The ventricles contract with less shortening than the previous phase and less blood is ejected (end of systole).
- Almost 25% of ventricular blood is ejected, i.e. 25% of SV.
- Duration: 0.1 sec.
- AV valves: Still closed.
- Semilunar valves: Still opened.
- Atrial pressure: Still ↑ gradually due to accumulation of venous blood.
- Ventricular volume: Continue ↓ gradually till it reaches the end systolic volume (60 ml).
- Ventricular pressure: ↓ gradually, as volume of blood leaving ventricles > the decrease in ventricular volume.

5- Isovolumetric Relaxation Phase:

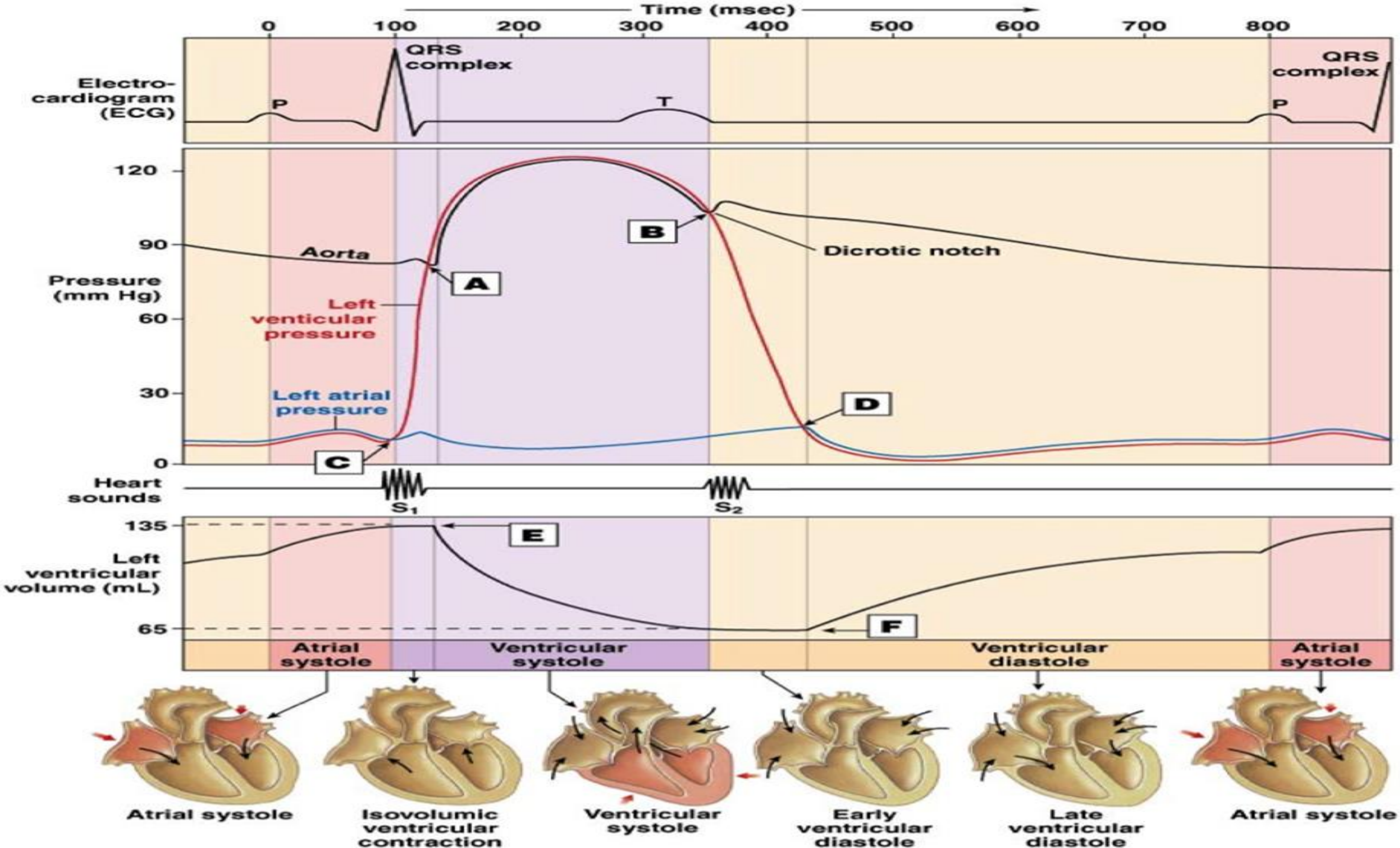
- The ventricles relax without changing their volume. It occurs at the beginning of diastole.
- It lasts for ≈ 0.04 sec.
- Ventricular volume is constant at the ESV (60 ml).
- Semilunar valves: close at the beginning of the phase.
- 2^{nd} Heart sound is heard.
- A-V valves: Still closed.
- Ventricular pressure: ↓ rapidly, because the valves are closed & the relaxation is isometric.
- Atrial pressure: Still ↑ gradually due to accumulation of venous blood.

6- Rapid Filling Phase:

- Atrial pressure > ventricular pressure. A-V valves open.
- ≈ 60-70% of blood passes passively to the ventricles along pressure gradient.
- Duration ≈ 0.1 sec.
- 3rd Heart sound heard due to rush of blood into ventricles and vibration in ventricular wall.
- Semilunar valves: Still closed.
- Atrial pressure: First sudden ↓ due to rush of blood from atria to ventricles. Then gradually ↑ due to entry of venous blood.
- Ventricular volume: ↑ because it is being filled with blood.
- Ventricular pressure: Slightly ↑ but < atrial pressure

7- Reduced Filling Phase (Diastasis):

- Remaining atrial blood flows slowly into ventricles by pressure gradient.
- Duration ≈ 0.2 sec.
- A-V valves still open.
- Semilunar valves: Still closed.
- Atrial pressure: Still ↑ gradually due to continuous venous return.
- Ventricular volume: Still ↑ due to entry of blood into ventricles.
- Ventricular pressure: Slightly ↑ gradually because the increase in volume is less than the entering blood.


Time (msec)
0
100
200
300
400
500
600
700
800
Electro-cardiogram (ECG)
QRS complex
P
T
P
QRS complex
120
90
60
30
0
Pressure (mm Hg)
Aorta
Left venticular pressure
Left atrial pressure
A
B
C
D
Dicrotic notch
Heart sounds
S1
S2
135
65
Left ventricular volume (mL)
E
F
Atrial systole
Ventricular systole
Ventricular diastole
Atrial systole
Atrial systole
Isovolumic ventricular contraction
Ventricular systole
Early ventricular diastole
Late ventricular diastole
Atrial systole

Events in the cardiac Cycle

1. Mechanical events
2. Ventricular volume changes ?
3. Pressure Changes
4. Heart Sounds
5. Electrical Events (ECG)

6- Ventricular Volume Changes

Phases	Ventricular Volume
1- Atrial systole	↑
2- Isometric contraction	Constant
3- Rapid Ejection	↓ rapidly
4- Reduced Ejection	↓ slowly
? Protodiastolic	Constant
5- Isometric Relaxation	Constant
6- Rapid Filling	↑ rapidly
7- Reduced Filling	↑ slowly


Thank You